Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries

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The developing countries in South and Southeast Asia derive substantial economic, social, and nutritional benefits from their coastal resources and fisheries. The eight countries (namely, Bangladesh, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Vietnam) that participated in the project have a combined population of about 1.7 billion people, or approximately a quarter of the global population. The proportion of the population below the official poverty line in these countries is high, varying between 16% in Malaysia and 51% in Vietnam. Rural poverty is more severe than the national average, ranging from 18% of the rural population in Malaysia to 51% in the Philippines.

Apart from providing livelihood to 11.7 million poor coastal fishers and their families, the coastal fisheries sector in these countries generates food totaling 16.2 million tonnes of fish per year, as well as export revenues of about US $ 4.5 billion annually. Fish represent an important part of the diet in these countries with per capita fish consumption averaging 25 kg per year. In coastal communities, fish makes up as much as 70% of the animal protein intake. The aggregated marine fisheries production (mostly originating from coastal shelves) was 11.1 million tonnes in 1998, representing 11% of the global landings. Fisheries are particularly important in rural, coastal areas where the sector contributes substantially to food security and social stability of the poorest segment of the population.

The Asian Development Bank (ADB) recognizes the importance of the marine and fisheries sector for the food security and improvement of people's living standards in the Asia-Pacific region. ADB attached high priority to the marine and fisheries sector from the very beginning. Starting with its first marine and fisheries project in 1969, ADB has to date extended a total of 58 marine and fisheries projects, amounting to over $1.2 billion, to 21 developing member countries (DMCs). ADB has also provided technical assistance grants amounting to about $40 million for over 90 country-specific project preparation and advisory services, and 20 regional programs.

The coastal fish stocks of several Asian countries, such as Bangladesh, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand, and Vietnam have been severely depleted due mainly to over-fishing, with obvious consequences on the economies of commercial fisheries, income of small scale fishers and fish supply to consumers. Recognizing the problems of degradation of coastal fisheries resources and the resultant adverse impact on coastal communities, many DMC governments have made efforts to improve marine and coastal fisheries resources management and to initiate various programs to improve the social and economic conditions of coastal communities. However, effective marine and fisheries resources management strategies and regulations have not been put into place in many countries due in part to a lack of reliable fisheries resource information and database that are both essential for developing improved coastal fisheries resources management strategies and regulations.

ADB's fisheries policy and investments intend to: (i) support the development of long-term sustainable fisheries resources management; (ii) strengthen capacity building for development and resource management; (iii) build and strengthen the productive capacity, infrastructure, and services; and (iv) encourage regional cooperation. The primary emphasis is on the creation of an appropriate policy and institutional environment, and capacity building to enable the DMCs to optimize the utilization and ensure the sustainable management of fisheries and aquatic resources. ADB seeks to assist the DMCs to develop viable strategies and options for increasing and sustaining fish production to reduce poverty among marginalized

fish farmers and fishers. This workshop exemplifies the kind of regional cooperation and networking that ADB is keen to promote.

At this juncture it is worthwhile to recount the background of ADB's regional technical assistance (RETA No. 5766) under which this workshop has been organized. In 1996 ADB provided a small scale RETA[1] to the WorldFish Center (formerly International Center for Living Aquatic Resources Management - ICLARM) for a "Review of Sustainable Exploitation of Coastal Fish Stocks in Asia". RETA No. 5651 assisted seven DMCs[2] to establish a systematic fisheries resource database as a first step in meeting the fisheries resource management needs and preparing appropriate strategies, action plans and options to rehabilitate degraded coastal fish stocks. ICLARM, in collaboration with the participating national fisheries agencies, conducted the review from March to August 1996. The Technical Adviser's final report identified several key issues and opportunities impacting on coastal fisheries resources and outlined the scope for regional collaborative efforts to catalytically assist the DMCs to improve resource baseline (database) and utilize coastal fish stocks in a sustainable manner. The participating DMCs requested ICLARM and ADB to initiate further regional collaborative efforts by building on the findings and recommendations of the TA. The result was RETA No. 5766, " Sustainable Management of Coastal Fish Stocks in Asia", approved in 1997, to assist DMCs[3], in improving the management and sustainable utilization of their coastal fisheries resources and related ecological systems.

The implementation of the 3-year project began in March 1998 in collaboration with multidisciplinary teams of scientists from the eight developing member countries. We are happy that the RETA has progressed satisfactorily. The main interest of ADB now is to see the translation of the TA outputs into concrete decisions in policy-making and management of marine and fisheries resources. We hope that consultative workshops at national and regional levels under RETA No. 5766 will enable key stakeholders to identify effective strategic directions and formulate action programs for more sustainable management of coastal fisheries.

We at ADB believe that this workshop has provided an excellent opportunity for the participants to share and exchange experience and knowledge on coastal fisheries resource assessment and management. We hope also that the workshop outputs will be the major basis and valuable inputs to the development of national policies and strategies of participating countries, to consolidate and formulate the regional research program, and to establish a regional network to improve the coastal fisheries resources management and arrest the further degradation of coastal fish stocks in Asia.

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[1] RETA No. 5651 for $100,000 approved on 4 December 1995.
[2] Bangladesh, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Vietnam.
[3] Bangladesh, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Vietnam.

Foreword
WorldFish Center

The restoration of coastal fisheries can be a cornerstone to poverty reduction in Asia. Fish and fisheries play a critical role in the lives of the poor in Asia, in terms of nutrition, food security and livelihoods. Fish is a traditional staple in the diet of many Asians, supplying protein, calcium and other nutrients. In some poor rural areas fish contributes up to 70% of the animal protein in people's diets. Fish is consumed in larger quantities in many Asian countries compared to the rest of the world. The annual per capita consumption of fish in Asian countries is over 24 kg, compared to the world average of 15 kg. Asia alone consumed over half of the world's fisheries products in 2000. As the population of Asia continues to increase, so will the demand for fish. In the past 30 years global fish consumption has doubled and the developing countries have increased from 44% to 70% of the global consumption. By 2020 they are predicted to be responsible for 80% of the fish consumption. This increasing demand raises the issue of how will it be met? Where will the fish come from?

Currently, fisheries produce 70% of the fish for consumption. The fish production from aquaculture is expected to increase from the current 30% to over 40% in the next 20 years. However, fisheries production will still need to be maintained in order to meet the growing demand for fish. Asia produces over 40% of world fisheries production. The key question for Asian countries is how to manage their fisheries to ensure food security in the face of increasing demand.

Fisheries also provide a livelihood to an estimated 22 million fishers in Asia and are one of the few employment options for the poorest of the poor, the landless poor. They are also a vital source of income to many women who have a traditional role in the processing and marketing of the catch. These livelihood options and sources of income need to be maintained.

Fisheries are also a vital contributor to the trade and political stability of developing countries. Currently 40% (by value) of the global fish output is traded internationally, and is worth over US$55 billion, of this US$18 billion goes to developing countries. However, ineffective fisheries management is resulting in lost earnings. In 1986 it was estimated that the Philippines was loosing $125 million/year in rent revenues from its fisheries. We, at the WorldFish Center, are also seeing increasing conflicts over fisheries resources. These conflicts often become political issues. As the value of fish increases and the resources become scarce, these conflicts are likely to escalate.

Management of fisheries in Asia is often hampered by a lack of information on the state of the fisheries. There are increasing signs worldwide that fisheries are at a crisis point, but information to critically evaluate their state in developing countries is often limited. The WorldFish Center, since its inception in 1977, has played a major role in developing software tools, methods and approaches in understanding the status of the fisheries and approaches for improved management. Information and communications technology has also played a central role in the project reported in this volume. The foundation of the understanding of the serious decline in the fish stocks of Asia was the Fisheries Resource Information System and Tools (FiRST) database system. The WorldFish Center has played a crucial role in the development of information technology and knowledge management systems in areas related to fish and fisheries. FishBase[1], ReefBase[2] and the Ian R Smith

[1] www.fishbase.org
[2] www.reefbase.org

Memorial Library and Documentation Center[3] are the Center's most developed and well-known databases or information sources. In this project the FiRST database system provided partner countries with tools to facilitate the analysis of historic research survey data. These analyses increase our understanding of the status of fish stocks and a baseline for restoration. The database also played a central role in the integration of socioeconomic and the biophysical data. Moreover, the data compiled can provide useful indicators to guide and assist countries in achieving the World Summit for Sustainable Development, Johannesburg 2002, target of restoring depleted stocks by 2015.

The "Sustainable management of coastal fish stocks in Asia" project builds on previous projects in the region and examined the biological and socioeconomic state of coastal fisheries in the eight participating countries and also reviewed the policy environment. The results demonstrate the drastic decline in coastal fish stocks. This is critical as the coastal areas are the most productive areas of the ocean and the regions on which poor, small scale fishers rely. The declines in fisheries resources documented by the project should raise serious concerns among fishers, other stakeholders and policy makers. The fisheries are clearly on a downward trend that must be reversed. Fisheries management in Asia should take a forward-looking perspective, focusing on the restoration of fisheries in such a manner to benefit the poor people of the region. This project provides the first steps in this direction in the form of the outputs of the national workshops that document the issues and potential interventions to improve fisheries management in the partner countries. We now have the opportunity to build on these and develop and implement fisheries restoration plans.

Fisheries restoration will require a broad range of skills and new approaches to management. The restoration plans for fisheries should be based on holistic "fishery assessments" rather than traditional "stock assessments". Fishery assessments would involve economic, social and biological assessments of the fisheries, potentially using innovative techniques to gather the information required. This approach would maximize the traditional knowledge about the fisheries and overcome difficulties due to the lack of long-term statistical data. The restoration plans should be developed through a co-management approach. The serious declines in the fish stocks suggest that the centralized approach to management has not been successful. Co-management, or a more participatory approach to the development of the restoration plans, may assist in ensuring the effective implementation of the plans. To achieve the necessary management changes will require major national policy shifts in Asian countries.

Finally, we hope that the outputs the "Sustainable management of coastal fish stocks in Asia" project documented in the Proceedings of this workshop, will contribute to increasing the profile of fisheries management in Asia. The results should spur some concrete steps towards the restoration of fisheries in the region and equitable distribution of the benefits. At the WorldFish Center we believe coastal fisheries have a critical role to play in poverty reduction in the Asian region.

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[3] www.worldfishcenter.org/libinfo/libinfo.htm

Preface

In March 1998, the WorldFish Center (formerly ICLARM - International Center for Living Aquatic Resources Management) initiated activities of the Project, "Sustainable Management of Coastal Fish Stocks in Asia" (ADB-RETA No. 5766). The project was undertaken in collaboration with eight countries, viz. Bangladesh, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Viet Nam. The project built on the outcomes of a 1996 regional workshop, "Status and Management of Tropical Coastal Fisheries in Asia" (ADB-RETA No. 5651)[1]. The WorldFish Center, the partner countries and the Asian Development Bank provided funding and support for the project. The project had three main objectives, namely to: (1) strengthen the capabilities of selected institutions in participating DMCs in the area of coastal fisheries assessment and management; (2) develop a database (based largely on extant trawl surveys and related environmental and socioeconomic information) relevant to the management needs of the DMCs; and (3) examine management implications (including strategies and action plans as appropriate) of analyzed results based on data contained in the database and related information.

As part of the project's culminating activities, a workshop called "International Workshop on Management of Tropical Coastal Fisheries in Asia" was organized during 20 - 23 March 2001 in Penang, Malaysia.

The workshop aimed to:
1. Present and review the results of activities (database, resource analysis, socioeconomics, and management planning) under the project, "Sustainable Management of Coastal Fish Stocks in Asia" (ADB-RETA No. 5766);
2. Examine the key issues and opportunities at the national and regional levels for the improved management of coastal (demersal) fisheries in developing Asian countries;
3. Discuss strategies and programs of action (both planned and ongoing) of national/ international agencies towards improving the management of coastal (demersal) fisheries in the region; and
4. Explore follow-up actions and support activities for regional collaboration to enhance national efforts in the area of coastal fisheries management.

To realize these objectives, the workshop program (see Appendix I) was divided into four sessions. A total of 84 delegates participated in the workshop (see Appendix II), of which 48 participants were from the eight national project teams, 18 from other national/ regional fisheries institutions (e.g. ACIAR, BOBP, FAO, MRAG, SEAFDEC, UNDP-GEF, Brunei Darussalam and Taiwan) and 18 from the WorldFish Center. In all, the participants represented a total of 14 countries and 28 agencies.

These Proceedings are based on the papers presented at the workshop as well as the achievements of the project ("Sustainable Management of Coastal Fish Stocks in Asia"), which include:
1. Development of the database called "Fisheries Resource Information System and Tools" (FiRST), which contains resource and socioeconomic data for the marine fisheries sector in South and Southeast Asia, and relevant tools for analysis. The FiRST database is now an important regional repository of information for the sustainable management of coastal fish stocks in developing Asian countries.
2. Documentation of the decline in coastal fishery resources throughout the region and the extent of overfishing in the region. Alarmingly, stocks are down to 5 - 30% of the original unfished levels (or before the expansion of the fisheries) in most countries. The assessments have also shown that the relative abundance of the more valuable fish (such

[1] ICLARM Conf. Proc. 53, 208 p.

as groupers, snappers, sharks and rays) has decreased sharply and that there has been a proportionate increase in smaller, less valuable species (such as cardinal and trigger fish). These results provide a clear picture of the extent of stock rehabilitation required to restore maximum economic value to the fisheries of the region.

3. In consultation with key stakeholders, evaluation of fisheries management in the participating countries, resulting in strategies and action programs that should improve productivity of coastal fish stocks on a sustainable basis. These strategies and action programs define the critical issues and opportunities at the national level, and the regional assistance required to support the national efforts.
4. Improved capabilities in coastal fisheries assessment, planning and management within national institutions. A total of 71 scientists/managers from participating fisheries institutions received training during the project including the participation of more than 250 scientists/policymakers from the 8 countries in the national consultative workshops.

In addition to the documented resource decline, the papers also detail assemblage structure analyses that provide a description of the distribution of fishery resources. The spatial patterns detected in the resources have implications for the spatial fisheries management zones implemented in many of the countries. The delineation of management zones should take into account the spatial patterns in resources in order to manage the overall impact from different fishery sectors. Some papers also describe the next stage of analysis, the production of ecosystem models. These models, while preliminary, have identified key data or research gaps currently limiting the development of fisheries ecosystem modeling in the region. Most importantly, the ecosystem analyses have allowed an initial attempt at modeling the trophic impact of the excess fishing effort, resource degradation and species composition trends noted above.

The Proceedings also includes a workshop synopsis and recommendations for improved management of coastal fish stocks in Asia (see Silvestre et al. this vol.). The declines in fisheries resources documented by the papers within the proceedings should raise serious concern. This project provides some first steps towards addressing these declines. The national workshops conducted documented the issues and potential interventions to improve fisheries management in each country. The Proceedings document the action plans developed by each country and also at the regional level. These strategies and action plans provide the countries and the region with some directions towards the sustainable management of the coastal fisheries. The workshop and the project also initiated a regional network of fisheries assessment and management specialists. It is hoped that this network will continue to provide the participants with support and assistance in dealing with fisheries management issues.

The Proceedings presented here would not have been possible without the assistance of various agencies and colleagues. We particularly wish to acknowledge the funding support provide by ADB and the WorldFish Center, as well as the technical support and cooperation of the participating institutions, namely: Department of Fisheries, Bangladesh Fisheries Research Institute, and University of Chittagong (CTU) - Bangladesh; the Indian Council for Agricultural Research (ICAR) and Central Marine Fisheries Research Institute (CMFRI) - India; Directorate General of Fisheries and the Central Research Institute for Fisheries - Indonesia; the Department of Fisheries (DOF) and Fisheries Research Institute (FRI) - Malaysia; Bureau of Fisheries and Aquatic Resources (BFAR) and the University of the Philippines - Visayas - Philippines; Ministry of Fisheries and Aquatic Resources Development and the National Aquatic Resources Agency - Sri Lanka; Department of Fisheries and the Southern Marine Fisheries Development Center - Thailand; and Ministry of Fisheries and the Research Institute of Marine Fisheries (RIMF) - Vietnam. We also wish to thank the WorldFish Center staff members who participated in the workshop and completed these Proceedings.

The Editors

Role of the Editorial Board

Geronimo T. Silvestre was the Project Leader. He obtained funding for the original proposal, provided overall scientific leadership and management for the project, provided scientific expertise to the population analyses and policy and planning sections, technical directions in the development of the FiRST software and contributed significant technical editing of all the papers.

Len R. Garces played a major role in project implementation, operational management and the production of these Proceedings. He provided scientific expertise in the community and ecosystem analyses and policy and planning section, as well as technical editing of all the papers.

Ilona Stobutzki provided technical editing of all the papers and oversaw the final production of the Proceedings.

Mahfuzuddin Ahmed provided scientific leadership to the socioeconomics section during the project, scientific expertise to the bioeconomic modeling, socioeconomic analysis and policy review and technical editing of the socioeconomic papers.

Rowena Andrea Valmonte-Santos assisted in the implementation and coordination of the socioeconomic analyses and provided technical editing of the socioeconomics papers.

Cesar Z. Luna assisted in the implementation and coordination of the policy reviews and provided scientific expertise and technical editing of the policy papers.

Lualhati Lachica-Alino assisted in the implementation and coordination of the community analyses and provided scientific expertise and technical editing of the community analyses papers.

Patricia Munro provided English editing of all the papers in the Proceedings, as well as compiled the species and geographic indexes.

Villy Christensen provided scientific leadership and expertise to the ecosystem modeling and technical editing of the ecosystem model papers.

Daniel Pauly originated the initial concept of the project, which emphasized the value of historical research surveys to assess the status of fish stocks. He provided scientific expertise to the project and technical directions in the development of the FiRST software, and technical editing of the papers on resource assessment, community analysis and ecosystem modeling.

South and South-East Asian Coastal Fisheries: Their Status and Directions for Improved Management. Conference Synopsis and Recommendations*

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Abstract

As a step to address the problems of coastal fisheries in Asia, the WorldFish Center joined forces with fisheries agencies from eight developing Asian countries (Bangladesh, India, Indonesia, Malaysia, The Philippines, Sri Lanka, Thailand and Vietnam) and the Asian Development Bank, to implement a project entitled "Sustainable Management of Coastal Fish Stocks in Asia" (also known as the "TrawlBase" project). The project was implemented between 1998 and 2001. The main achievements of this partnership were: (a) Development of a database called "Fisheries Resource Information System and Tools" (FiRST), which contains trawl research survey data and socioeconomic information for selected fisheries, and facilitates its analysis; (b) Evaluation of the extent of resource decline and over-fishing, both biological and economic, in the region; (c) Identification of the measures needed to manage coastal fisheries in the participating countries, resulting in draft strategies and action plans; and (d) Strengthening of national capacity in coastal fisheries assessment, planning and management.

The analyses show an alarming decline in coastal fishery resources throughout the

* WorldFish Center Contribution No. 1709

region, with biomasses down to 5 - 30% of levels prior to the expansion of fishing. The relative abundance of the larger, more valuable fish has decreased sharply and that there has been a proportionate increase in smaller, less valuable species. The socioeconomic characteristics of the coastal fisheries, including fleet dynamics and cost efficiency has also been documented. These results provide a clear picture of the extent of stock rehabilitation and management required to restore maximum economic value to the fisheries of the region.

The project has contributed to increasing awareness of key issues and opportunities in coastal fisheries management at the national and regional levels and illustrated the benefits of collaborative efforts in addressing issues of regional concern. It has also highlighted the need and urgency for concerted action at various levels of the institutional hierarchy to successfully resolve fisheries issues. There is a need to foster regional/national collaboration and cooperation among scientists and institutions involved in assessment and management of coastal fisheries. These gains provide the base (and momentum!) for the effective follow-up actions by the countries and international agencies to sustain the benefits derived from coastal fisheries by developing Asian countries.

The directions for follow-up action towards improving the management of coastal fisheries resources presented in this paper were based on the results of a multisectoral consultation conducted in the region. The main goal of fisheries management suggested is the sustainable utilization of coastal fishery resources in South and Southeast Asia, defined with environmental, socioeconomic and institutional objectives. Eight interventions to achieve these objectives are presented. These are grouped into interventions for implementation by the national fisheries institutions in the respective countries and regional support activities. We also urge that the countries must commit to continuous, long-term capacity building and institutional strengthening.

Introduction

Globally, fisheries face the challenge of meeting increasing demand for fish[1] while the abundance of fish stocks is declining. In Asia, as in many parts of the world, capture fisheries are showing signs of being fully exploited or over-fished, with their production leveling off or declining (FAO 2000; Silvestre and Pauly 1997a; Silvestre and Pauly 1997b; Watson and Pauly 2001) . This is a critical issue as fish plays an important role in terms of food security, employment and income in Asian countries. Fish contributes 15 to 54% of the animal protein intake in Asian countries and is a particularly important protein source for poor coastal communities (see Table 1). The global demand for fish is expected to increase 0.5% annually, due to increases in population size and economic development (Delgado et al. 2002). Given this situation effective management and utilization of fish stocks is vital in ensuring long-term sustainability and maximum production from fisheries.

In 1996, the Asian Development Bank (ADB) provided a small scale technical assistance grant (TA)[2] to the WorldFish Center (formerly known as the International Center for Living Aquatic Resources Management - ICLARM), for a "Review of Sustainable Exploitation of Coastal Fish Stocks in Asia". The Center, in collaboration with participating national fisheries agencies from developing member countries (DMCs) of ADB, implemented the study from March to August 1996. This study identified key issues impacting coastal fisheries resources that were common across the region: (i) over-fishing and excessive fishing pressure; (ii) inappropriate exploitation patterns; (ii) post-harvest losses; (iv) large vs. small scale fisheries conflicts; (v) habitat degradation; (vi) a deficit of research and information; and (vii) institutional weaknesses and constraints

[1] Fish is used to refer to all aquatic products, including crustaceans, shellfish, etc.
[2] RETA No. 5651, approved on 4 December 1995 involving ICLARM and seven of the Bank's Developing Member Countries (DMCs), namely: Bangladesh, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Vietnam.

Table 1. Selected statistics for trophical developing countries in South and Southeast Asia.

Country	Population ($x 10^6$)[1] (2001)	Percent under Poverty line[2]	Fisheries employment (million)	Share of fisheries in total employment (%)	Number of Fishers ($x10^3$)[3]	Continental Shelf (0 - 200m depth) ($x 10^3 km^2$)	Total Fisheries Production ($x 10^3 t \cdot year^{-1}$)[4] (2000)	Marine Fisheries Production ($x 10^3 t \cdot year^{-1}$)[5] (2000)	Fishery Exports (US$ x $10^6 year^{-1}$)[6] (2000)	Per Capita Fish Consumption ($kg \cdot year^{-1}$)[7] (2000)
Bangladesh	140.4	36.0	1.55 (1996 - 97)	2.84 (1996 - 97)	1 445	55	1 661	330	371.5	10.9
India	1 025.1	39.7	6.00 (1995)	–	5 959	452	5 684	2 788	1405.2	4.5
Indonesia	214.8	7.2	2.09 (1997)	2.40 (1997)	4 568	2 777	4 858	3 897	1 584.5	19.5
Malaysia	22.6	<2.0	0.08 (1997)	0.91 (1997)	101	374	1 441	1 131	349.1	57.9
Philippines	77.1	14.6	0.99 (1997)	3.55 (1997)	991	178	2 287	1 809	400.3	29.6
Sri Lanka	19.1	6.6	0.12 (1997)	2.06 (1997)	125	27	308	250	134.5	21.1
Thailand	63.6	<2.0	0.61 (1995)	1.87 (1995)	439	86	3 643	2 671	4 367.3	28.7
Vietnam	79.2	17.7	1.40 (1995)	4.03 (1995)	3 030	328	1 961	1 321	1 480.1	19.2
Total	1 641.9	–	12.84		16 658	4 277	21 843	14 197	10 092.5	23.9
World	6 134.1	–	28.50			21 426	130 400	83 663	55 197.3	

Note: [1] **FAO Stat 2001. http://apps.fao.org**
[2] **http://www.developmentgoals.org (proportion of population below $1 a day)**
[3] **APFIC 1998**
[4] **FAO 2000. FishStat + database**
[5] **FAO 2002. FAO Yearbook. Fisheries Statistics - Capture and Aquaculture 2000. Vol 90/1 and 2**
[6] **FAO 2002. FAO Yearbook. Fisheries Statistics - Commodotoes 2000, Vol 91.**
[7] **FAO 2001. Food Balance Sheet database (http://faostat.fao.org/faostat)**

(Silvestre and Pauly 1997c). Collectively these issues have impacted fishery resources, the supply and price of fish to consumers, the income of fishers and the welfare of coastal communities.

The 1996 study documented the existence of management strategies to address these issues in varying degrees among the countries in South and Southeast Asia (Silvestre and Pauly 1997a; Silvestre and Pauly 1997c). However, there were underlying concerns that these interventions (if and when they existed) lacked sufficient scope, resources and information to reverse the interrelated problems. The concern regarding the lack of information referred to ensuring that management has the necessary baselines and understanding of the resource status to develop appropriate strategies.

In the Asian region many countries have conducted resource surveys, most commonly with trawl gear, some starting in the 1920s. However, most of the available trawl surveys had not been sufficiently documented, or analyzed, for their resource management implications (Silvestre and Pauly 1997a). The 1996 study highlighted the need for documentation and retrospective analyses of these surveys to provide baselines for improved resource management. These baselines, combined with related biological and socioeconomic information, can lead to more appropriate strategies to manage and rehabilitate the stocks and sustain the benefits derived from coastal fisheries (Silvestre and Pauly 1997c).

The 1996 study acknowledged that the multiplicity of issues required action on a broad front. Success in reversing or mitigating fisheries issues will depend on institutional capabilities and resources mobilization in the countries. However, most national institutions face considerable technical, manpower and financial constraints. The consensus achieved in 1996 was that there was a need to catalytically assist the countries in the region in identifying, prioritizing and implementing the interventions to address the issues. The 1996 study identified key elements for an expanded regional collaboration. This led to the implementation of the project "Sustainable Management of Coastal Fish Stocks in Asia" or the "TrawlBase" project as it has been referred to in the region. The TrawlBase project was implemented with support from the WorldFish Center, ADB and the eight partner countries, Bangladesh, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Vietnam (Fig. 1).

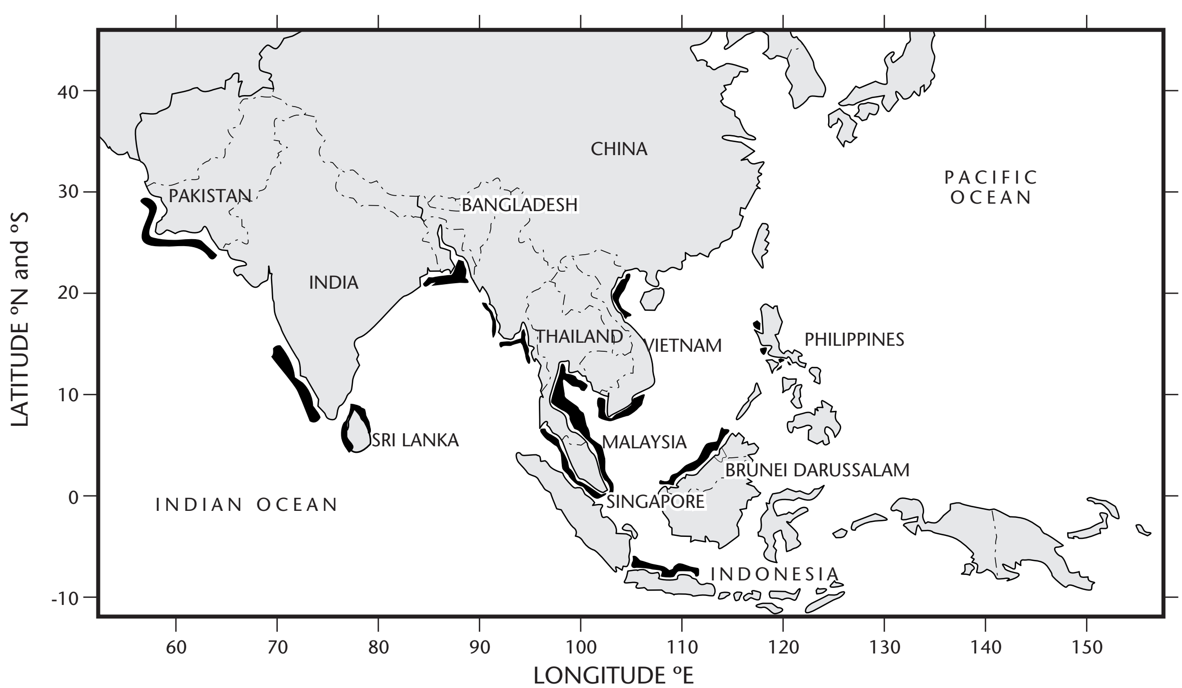

Fig. 1. Geographical coverage of trawl survey data in FiRST (Ver. 2001).

As part of the TrawlBase project's culminating activities, a workshop entitled "International Workshop on Management of Tropical Coastal Fisheries in Asia" was organized during 20 - 23 March 2001 in Penang, Malaysia. The workshop aimed to:

1. review the results of project activities (i.e. database establishment, resource and socioeconomics analyses, and management planning);

2. examine the key issues and opportunities at the national and regional levels for improved management of coastal fisheries in developing Asian countries;

3. discuss strategies and programs of action (both planned and ongoing) of national/international agencies towards improved management of coastal fisheries in the region; and

4. explore follow-up action and support activities for regional collaboration to enhance national efforts in the area of coastal fisheries management.

The technical contributions in this volume were presented at this workshop.

In this synopsis, we present a brief sectoral background of the coastal fisheries in the South and Southeast Asian region and description of the "TrawlBase" project to provide the context. The paper then summarizes the key scientific outputs of the collaborative project, the details of which are provided in the technical contributions. We emphasize the utility of developing a fisheries resource information system and retrospective analysis of the compiled data. The analyses provide a better understanding of the resource condition and a solid basis for management. The host of fisheries management issues identified by the country level contributions in this volume is then summarized to provide a regional perspective.

We then present a strategy to assist the eight countries in addressing the issues identified. The strategy was formulated with substantial inputs from various stakeholders including scientists and resource managers from the eight countries as well as participants of the final project workshop. The primary goal of the strategy is to continue our progress towards sustainable utilization of coastal fishery resources. The focus is on the implementation of the interventions identified. Its specific objectives include: (1) protecting fishery resources and the environment that sustains them; (2) maximizing economic benefits from the utilization of resources; (3) minimizing poverty among artisanal fishers; (4) minimizing resource use conflicts; (5) strengthening national institutional capabilities and linkages; and (6) increasing regional cooperation and collaboration.

Sectoral Background

The study focused on coastal fisheries, from the shoreline to 200 m depth, which exploit the continental shelves, the most productive part of the ocean (Longhurst and Pauly 1987). The eight participating countries have a combined population of about 1.6 billion people, approximately one quarter of the global population (Table 1). The proportion of the population below the official poverty line in these countries is high, varying between 2% in Malaysia and 36% in Bangladesh (Table 1). Poverty in rural areas is more severe than the national average, ranging from 18% of the rural population in Malaysia to 51% in the Philippines.

The fisheries sector is important to these countries in terms of employment, revenue and food security. Fisheries provide a livelihood to about 12 million fishers and their families and export revenues of about US$10 billion annually (Table 1). The sector generates food totaling 16.1 million t of fish•year^{-1} in these countries. Fish is an important part of the diet with per capita fish consumption averaging 24 kg•year^{-1}, while the worldwide average is around 15 kg•year^{-1}. In coastal communities, fish makes up as much as 70% of the animal protein intake. Coastal fisheries are particularly important in rural, coastal areas where the sector contributes substantially to food security and social stability of the poorest segment of the population.

The geographic extent of marine resources varies among the countries. Indonesia has the largest Exclusive Economic Zone (EEZ), while Bangladesh has the smallest (Table 1). The area of EEZ per person, which provides a rough indicator of the amount of marine resources available per capita, is highest in Malaysia and lowest in Bangladesh. The proportion of the EEZ covered by the continental shelf varies from 5 to 72% among the countries. As the continental shelves are the most productive part of the ocean (Longhurst and Pauly 1987), their extent may influence fish production (Chua and Garces 1994).

In 2000 the eight DMCs contributed nearly 22 million t to global fish production (Table 1). Trends in total fish production (Fig. 2) show that the eight countries fall into three groups: high-producing countries, India, Indonesia and Thailand, producing more than 3.5 million t, moderate-producing countries Bangladesh, Malaysia, the Philippines and Vietnam, with production of 1 - 2 million t, and Sri Lanka, which is a nominal fish producer.

Marine fisheries are the most significant to total fish production in these countries contributing 60 to 97% (Table 1) and amounting to 16.1 million t in 2000. In most countries 60 to 85% of the marine production comes from the coastal fisheries, of which demersal species dominate (Abu Talib and Alias 1997; Barut et al. 1997; Eiamsa-ard and Amornchairojkul 1997). Thus, production trends in demersal fish production may be used to infer general trends in the exploitation of coastal fishery resources.

The trends in demersal fish production (Fig. 3) show some differences to the total fish production (Fig. 2). India is clearly the leader in demersal production. From the mid-seventies to the present, India's demersal production has been higher than its nearest rivals by 100 000 t to as much as 400 000 t. A sharp increase in demersal fish production during the early seventies and another sharp increase from the mid-eighties to the early nineties placed India way ahead of the others. Except for a leveling off in production during the nineties, the trend of India's demersal fisheries production largely reflects its total fish production. The Philippines demersal fish production figures were the second highest from the fifties until the end of the eighties, after which Indonesia's production overtook the Philippines production. Demersal production in the Philippines was highly variable from the fifties till the mid-seventies, after which it stayed from 260 000 t to 350 000 t. The relatively constant annual demersal production, since the mid-seventies, contrasts with the steadily increasing total fisheries production during the same period. This suggests that other sources such as aquaculture were responsible for increasing the total production in the Philippines.

Indonesia's demersal production increased gradually from the fifties till the mid-seventies, followed by larger, but still steady, annual increases till the present, mirrored in the increase in total produc-

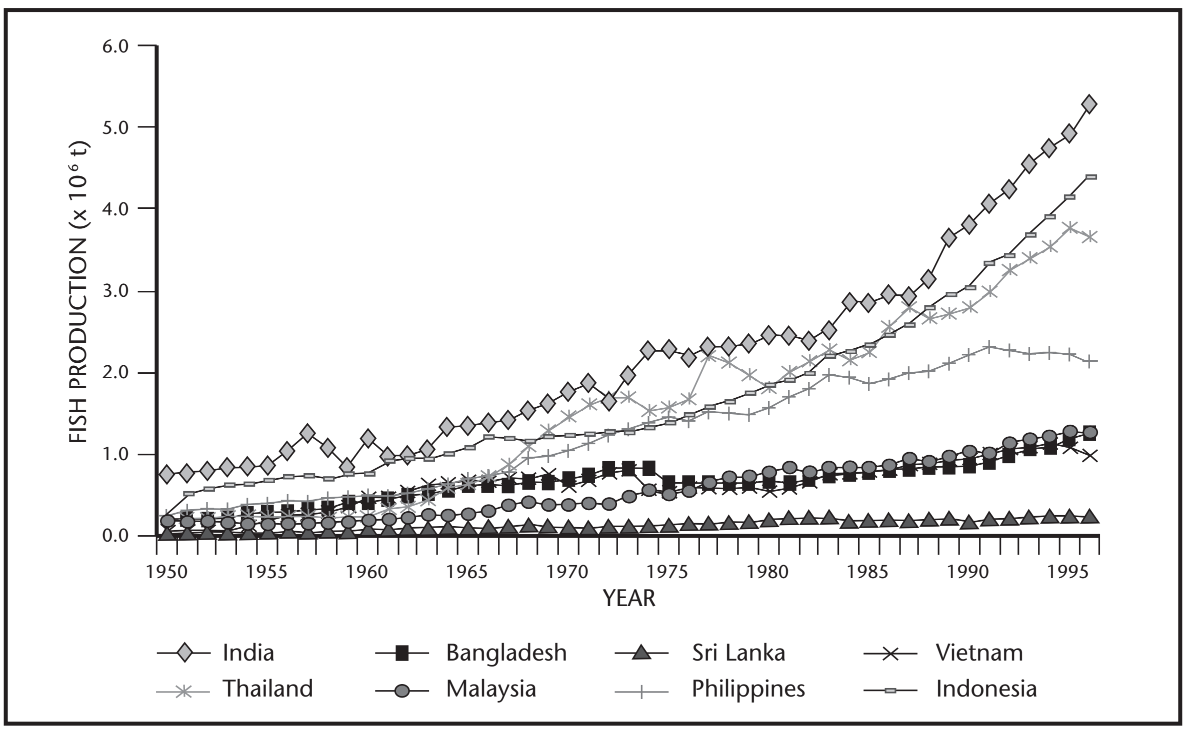

Fig. 2. Trends in fish production in the eight countries, 1950 - 96. Source: FAO 1998.

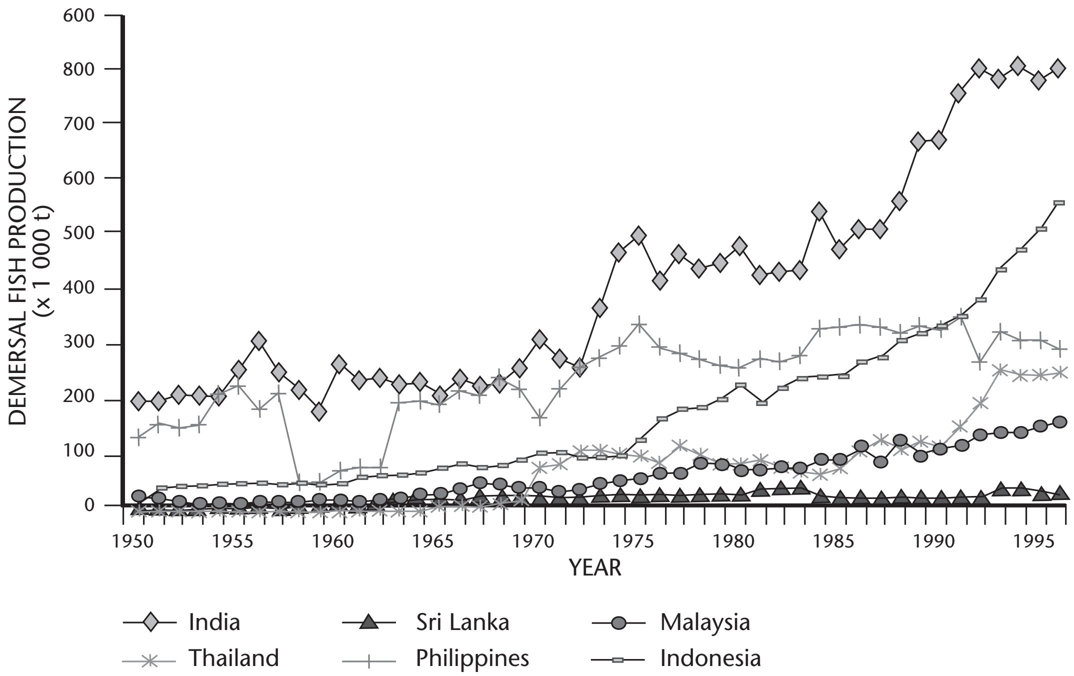

Fig. 3. Trends in demersal fish production in six countries, 1950 - 96. Source: FAO 1998.

tion. Thailand's demersal production is characterized by two periods of sharp increase alternating between years of relatively constant production. The first sharp increase occurred in 1970 while the other happened from 1990 to 1993. This differs markedly from the trend in total production, which displays an accelerated increase, suggesting that increases in total fish production were coming from sources other than demersals. In the case of Malaysia the steady increase in demersals mirrors the trend in overall production. Likewise, Sri Lanka's demersal production remained relatively constant, similar to its total fisheries production.

Capture fisheries in the region are conventionally classified into and managed as artisanal (small scale) and commercial (industrial) sectors. In most of the countries, the small scale fisheries contribute significantly to the fisheries catches as well as accounting for the majority of the gear types in terms of numbers. The catch of the coastal fisheries is generally a highly diverse multispecies one. Approximately 150 fish families occur in the demersal catch from the continental shelf in tropical Asia (Longhurst and Pauly 1987). A wide range of gear is used to exploit the multispecies resource (Silvestre and Pauly 1997a). The gear varies from the relatively simple types such as hand-lines and gillnets using no watercraft or dug-out boats to large trawls and purse seines using boats with powerful inboard engines equipped with Global Positioning Systems (GPS) and sonar. In most fishing grounds in the region, the areas of deployment of the different gear types overlap. For example, demersal trawlers operating close inshore not only compete for the same resources as the small scale fishers, but also often destroy their passive gear (Pauly 1996a). Variations in technological and biological interactions of the coastal fisheries also make assessment and management difficult (Murawski et al. 1991; Pauly and Murphy 1982).

The Sustainable Management of Coastal Fish Stocks Project

Objectives and Scope

The primary objective of the project ("Sustainable Management of Coastal Fish Stocks in Asia" - RETA No. 5766) was to provide partner countries (Bangladesh, India, Indonesia, Malaysia, the Philippines,

Sri Lanka, Thailand and Vietnam) with improved tools and strategies to advance management and sustainable utilization of their coastal fisheries resources and related ecological systems. Specifically, the study aimed to:

i. develop a fisheries resource information system that relates environmental and socioeconomic factors to resource management needs of partner countries;
ii. develop appropriate strategies and action plans to assist partner countries in managing and rehabilitating their coastal fish stocks; and
iii. strengthen the capabilities of partner country institutions in coastal fisheries assessment and management.

Project Components

The project involved collaborative work among multidisciplinary teams from the partner countries and the WorldFish Center, as well as close interactions with managers and policy-makers at the national level, and staff of various regional and international organizations. The project included the following main activities:

a. Fisheries Resource Information System[3]
    i. Development of resource databases within the participating countries (based on trawl research surveys) and their consolidation into a single regional database management system.
    ii. Review and analysis of the compiled data and related information to examine the biological and socioeconomic status of the fisheries resources.

b. Strategies and action plans
    i. Strategic review of the fisheries management situation and programs at the national and regional levels, including resources management trends and opportunities.
    ii. Development of national and regional strategies and action plans.

c. Capacity building
    i. Training at the national level in the use of databases and analytical software tools.
    ii. Training programs in the fields of stock assessment, assemblage and ecological analyses, socioeconomic analyses, and coastal resource management/policy analysis and planning.
    iii. National workshops for data consolidation/generation and consultative planning.
    iv. Regional workshops to consolidate data analysis results and to discuss regional trends, strategies and action programs.

In pursuit of the project objectives, the WorldFish Center organized four working groups (research components), namely: (1) Fisheries resource information system development; (2) Resource assessment (stock assessment, assemblage and ecosystem analyses); (3) Socioeconomics analysis and bioeconomic modeling; and (4) Fisheries management (policy/planning) (Fig. 4). The eight participating countries organized similar national research teams, each with a national team leader. The technical reports presented in this publication are grouped to reflect their contribution to the relevant component.

The WorldFish Center as the Executing Agency was responsible for implementing the project in collaboration with national fisheries agencies in the eight participating countries executing country-specific tasks/activities. The total cost of the project over its three-year implementation period was estimated at US$2.86 million. The Bank approved US$1.4 million (49% of the total cost) to cover part of the cost of services, travel, training, workshops, administrative support and operating expenses. About US$1 million was provided by the WorldFish Center, and the balance of US$460 000 came from the collaborating agencies of participating countries. Full details of the project are described in *http://www.worldfishcenter.org/trawl.*

Key Scientific Outputs

Fisheries Resource Information System and Tools

In South and Southeast Asia, at least 301 trawl surveys covering about 40 000 trawl stations have been carried out since the 1920s (Silvestre and Pauly 1997a). As detailed previously, in 1996 South and Southeast Asia countries agreed on the importance of compiling and analyzing past trawl surveys. A prototype database system and analyti-

[3] A system to organize, store, retrieve and exchange historical and contemporary trawl survey data. The system includes relevant socioeconomic and environmental information, and is linked with complementary analysis, statistical and other database systems to allow comprehensive analyses.

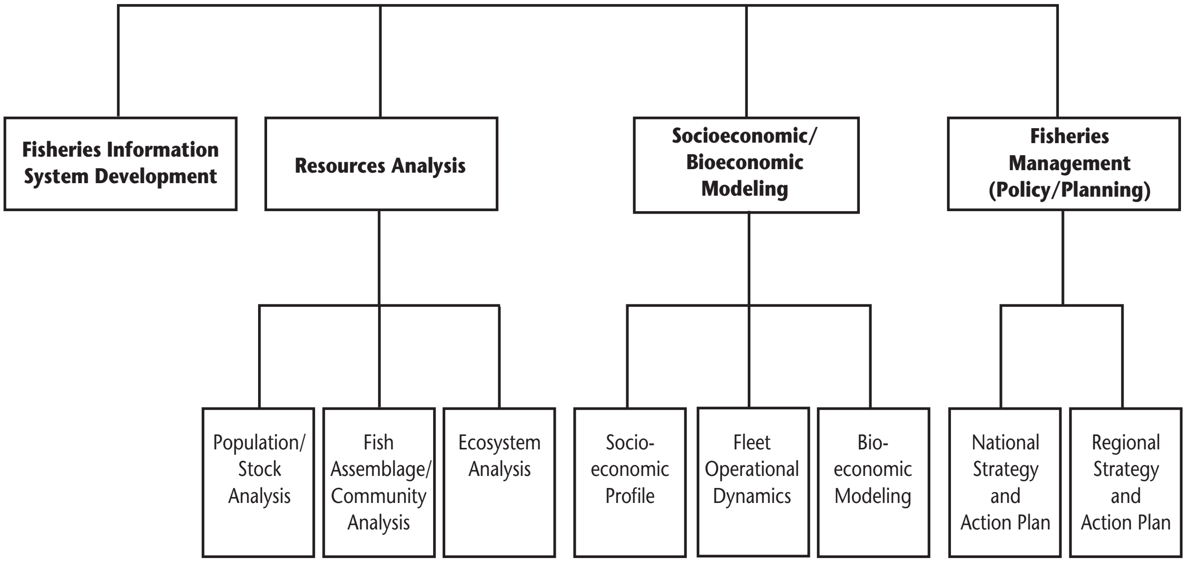

Fig. 4. Multidisciplinary design of the project showing how the four working groups are interrelated.

cal tool for this purpose was evaluated in a workshop in 1996 (Gayanilo et al. 1997). This provided the basis for the Fisheries Resource Information System and Tools (FiRST).

FiRST was developed as a data container of trawl research surveys with the focus on facilitating key analyses to assist management decisions (Gayanilo et al. 2001; Garces and Silvestre this vol.) In order to provide a management focus, the database system includes generic socioeconomic data, as well as catch and effort statistics. Basic analytical routines, such as models to approximate biomasses, have been made an integral part of FiRST. The system also facilitates analyses using external software by data extraction routines.

The FiRST software has been distributed to the participating countries, which have each established national databases. The database system is now becoming an important facility for storing trawl survey information and provided the basis for the analyses documented in these proceedings. The data access protocol agreed upon by the participating countries was that permission must be secured from the particular country for access to country-specific data.

Collectively, the regional database system contains about 20 620 hauls/stations (Table 2) from eight participating DMCs, and published trawl data from Singapore and Myanmar. Fig. 1 gives the geographical distribution of these data. In addition to the trawl survey data, the database includes socioeconomic and related information from the eight participating DMCs. Efforts have been made by all participating countries to encode more trawl survey data for inclusion in FiRST beyond the project's lifespan. Around 19 000 hauls/stations remain for validation/uploading by the countries. Efforts to expand the geographic coverage of the database system as well as to facilitate national data repatriation from international research institutions to the countries will be a priority of the WorldFish Center and the participating countries in the follow-up phase of the project.

Resource Assessment

The historical data available, from the 1920s to the 1990s, provide a basis for retrospective analyses (Table 3) that can assist in clarifying resource status. These analyses can also assist in determining achievable goals for restoration and management of coastal ecosystems that could not be contemplated based on the limited perspective of recent observations alone (Jackson et al. 2001).

The resource analyses undertaken aimed to elaborate the biological status of the coastal fishery resources and establish resource baselines for stock rehabilitation. To achieve this, a review and analysis (at the stock, assemblage and ecosystem level) of each national fisheries resource situation was conducted. Analyses at the stock level focused on biomass decline and exploitation levels of the dominant fish species (Khan et al.; Abu Talib et al. and Kongprom et al. this vol.). Analyses of fish assemblages focused on determining assemblage boundaries, the environmental gradients influencing these, and the implications pertaining to delineation of fishing zones (Mustafa; Pillai et al.; Nurhakim; Alias; Campos and Kongchai et al. this vol.). The ecosystem modeling aimed to develop ecosystem/trophic models for selected areas fisheries (Mustafa; Pillai et al.; Nurhakim; Alias; Garces et al.; Campos and Vibunpant et al. this vol.).

Table 2. The trawl surveys contained in the database system (FiRST ver. 2001) for each country.

Country	No. of Cruises	No. of Stations	Years
Malaysia	177	4 418	1926 - 93
Philippines	125	838	1947 - 95
Thailand	106	5 890	1968 - 95
Singapore	42	925	1969 - 73
Indonesia	2	1 376	1974 - 79
Myanmar	4	375	1979 - 80
Bangladesh	55	1 450	1980 - 88
India	12	613	1994 - 95
Sri Lanka	16	618	1920 - 80
Vietnam	84	4 021	1979 - 88
Pakistan	5	96	1976
TOTAL		20 620	

Overall, the resource analyses illustrate substantive degradation and over-fishing of coastal fish stocks. The stock analyses indicate that catch rates and hence resource biomass have declined to 4 - 44% of original ("baseline") biomass levels in the fishery areas (Table 4) studied. Fig. 5 illustrates the evident decline in biomass in the case of Manila Bay and the Gulf of Thailand up to the early 1980s. In Manila Bay, biomass in 1981 was down to about 31% of prior levels, due to the massive expansion of fishing effort in the late 1940s (Barut et al. this vol.). In the Gulf of Thailand, resource biomass in 1983 was down to 14% of the level in the early 1960s (Kongprom et al. this vol.). Later reference points (mid - 1990s) indicate that biomass in Manila Bay and the Gulf of Thailand had further deteriorated to 8 - 12% of original unexploited biomass levels (Pura et al. 1994; Kongprom et al. this vol.).

Table 3. The geographic and temporal scope of the resource analyses.

Country	Survey Area	Survey Period	Reference
Bangladesh	Inner Bay of Bengal (up to 100 m depth)	1984 - 86	Khan et al. (this vol.)
India	Southwest coast of India	1994 - 96	*
Indonesia	North coast of Central Java (NCCJ)	1979	*
Malaysia	West coast peninsular Malaysia (WCPM) East coast peninsular Malaysia (ECPM) Sabah and Sarawak (SS)	1972, 1981, 1987, 1991 and 1997	Abu Talib et al. (this vol.)
Philippines	San Pedro Bay Samar Sea Manila Bay	1994 - 95 1979 - 80 1992 - 93	Barut et al. (this vol.)
Sri Lanka	Southwest coast of Sri Lanka	1978 - 80	*
Thailand	Gulf of Thailand	1973 - 95	Kongprom et al. (this vol.)
Vietnam	Southwest coast of Vietnam	1993 - 95	*

Note: * Technical reports to the project.

Table 4. The estimates of demersal biomass trends from the resource assessments based on the trawl surveys documented by the TrawlBase project and also from previous studies in the region.

Country/Area	Year	Stock density ($t \cdot km^{-2}$)	Relative density (%)	Source
BRUNEI DARUSSALAM (waters within 0 - 50 m)	1979 - 80 1989 - 90	12.8 11.7	100.0 91.0	Beales et al. (1982) Silvestre et al. (1991)
BANGLADESH Bay of Bengal	1973 1985 - 86	12.3 5.47	100.0 44.0	Khan et al. (this vol.)
INDIA Goa	 1973 - 74 1979 - 80	 161* 95*	 100.0 59.0	 Joseph (1980)
Mangalore	1973 - 74 1979 - 80	141* 94*	100.0 66.7	Joseph (1980)
Cochin	1972 - 73 1979 - 80	217* 126*	100.0 58.1	Joseph (1980)
Madras	1972 - 73 1979 - 80	127* 82*	100.0 64.6	Joseph (1980)
INDONESIA Java Sea	 1977 1998	 3.72 2.20	 100.0 59.1	 Dwiponggo and Badrudin (1978) Aziz et al. (1998)
PHILIPPINES Various areas	 1947 - 49 1993 - 95	 7.88 1.39	 100.0 17.6	 Barut et al. (this vol.)
San Miguel Bay	1947 1980 - 81 1992 - 93	10.60 2.13 1.96	100.0 20.1 18.5	Warfel and Manacop (1950) Vakily (1982) Cinco et al. (1995)
Lingayen Gulf	1949 1979 1987 - 88	92.1* 63.7* 31.8*	100.0 69.2 34.5	Ochavillo et al. (1989)
Manila Bay	1949 - 52 1992 - 93	4.61 0.47	100.0 10.2	Warfel and Manacop (1950) MADECOR [Mandala Agricultural Development Corporation] and National Museum (1995)
MALAYSIA West Coast	 1971/72 1987 1997	 2.44 1.59 0.36	 100.0 65.2 15.6	 Abu Talib et al. (this vol.)
East Coast	1972 1986 1998	5.09 1.93 0.20	100.0 37.9 3.9	Abu Talib et al. (this vol.)
Sarawak	1972 1986 1998	3.90 1.17 1.11	100.0 30.0 28.5	Abu Talib et al. (this vol.)
Sabah	1972 1986 1998	12.52 1.52 0.87	100.0 12.1 6.9	Abu Talib et al. (this vol.)
THAILAND Gulf of Thailand	 1961 1991	 6.70 0.55	 100.0 14.2	 Kongprom et al. (this vol.)

Note: * - in catch rate ($kg \cdot hr^{-1}$).

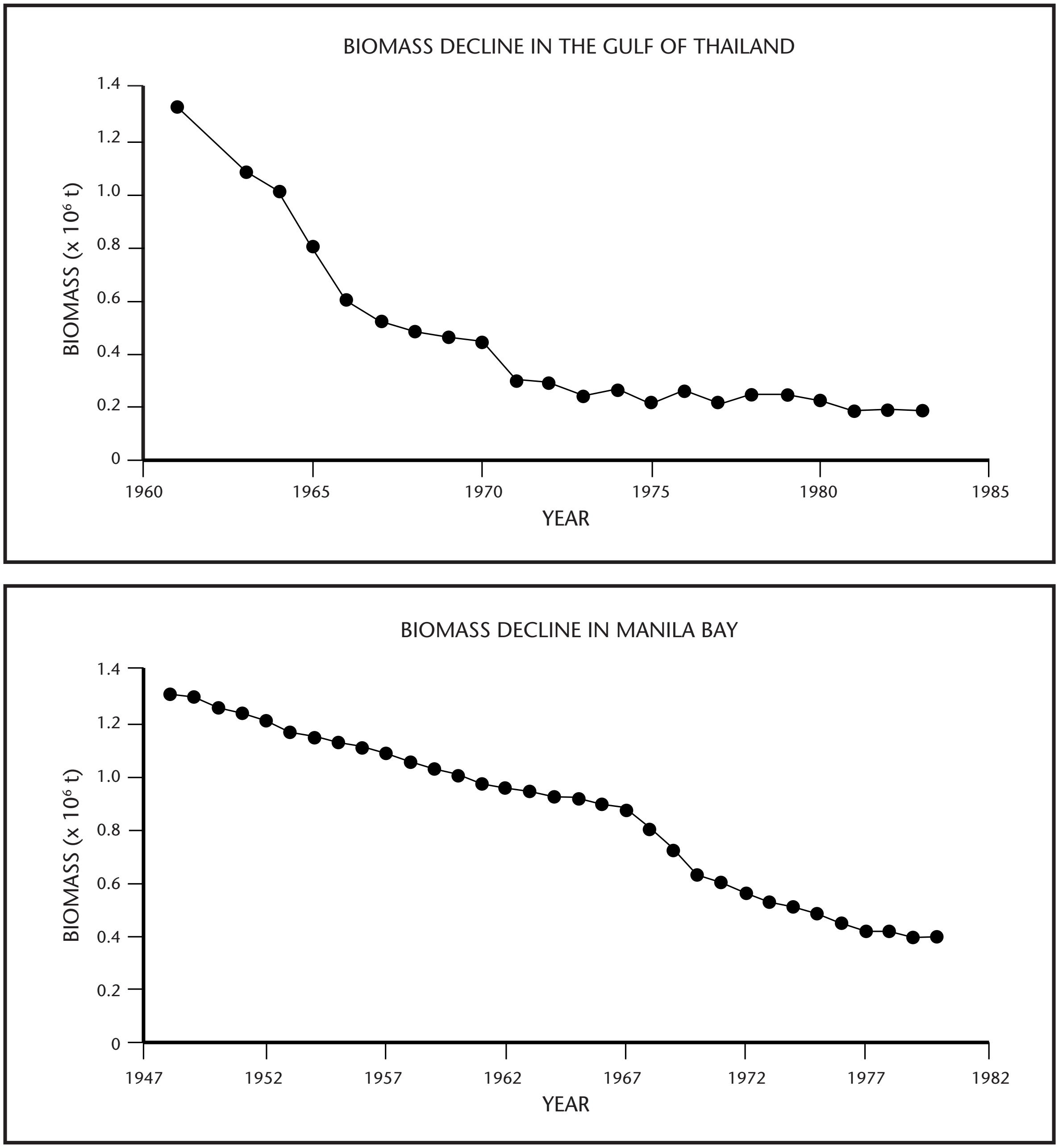

Fig. 5. Illustrative examples of biomass trends in the Gulf of Thailand and Manila Bay, Philippines.

The trends seen in catch per unit of effort (CPUE) from demersal fisheries confirm this decline. The Gulf of Thailand provides a clear example of the regional trends (Fig. 6). While the demersal fish production has increased over time, the CPUE decreases dramatically. The decrease in commercial CPUE has not been as dramatic as that seen in the research surveys. This difference is likely to be due to a range of factors, including the behavior of fishers (e.g. targeting areas of high catch rates) and

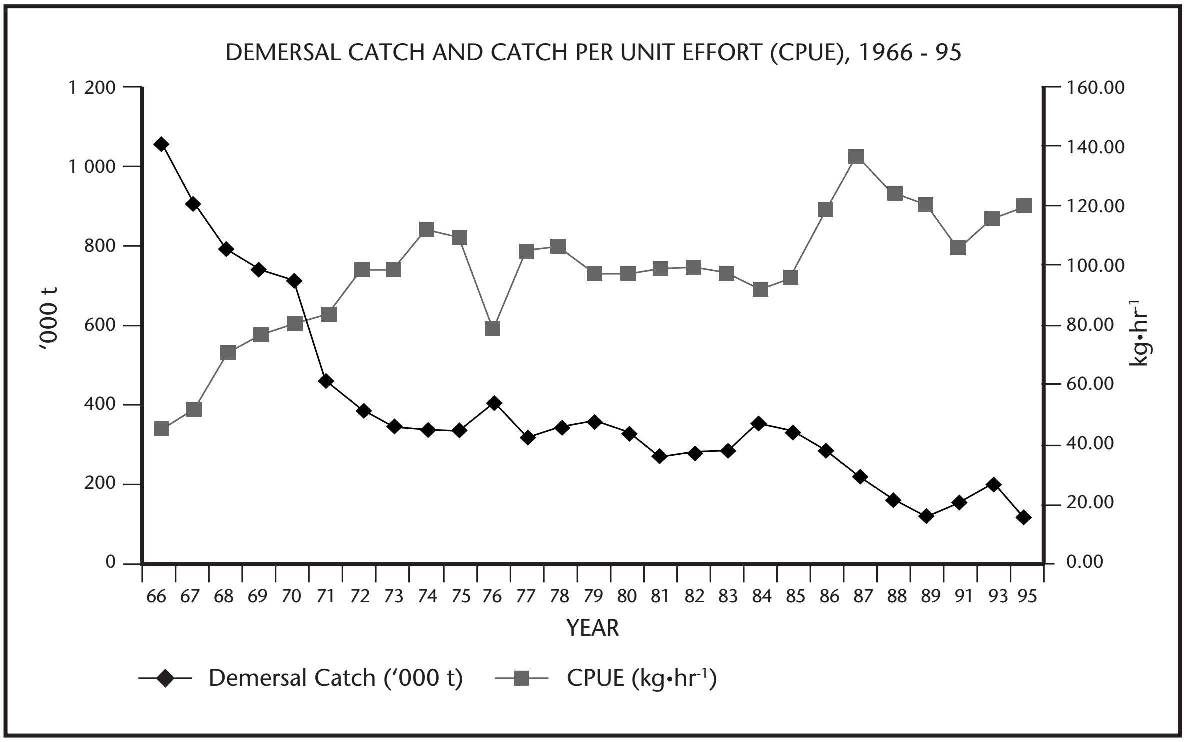

Fig. 6. Trends of catch per unit effort for the fishery exploiting demersal fish in the Gulf of Thailand from 1966 to 1995.

the inability to standardize effort to account for all increases in efficiency (e.g. gear/boat development and use of GPS). This difference highlights the need to have independent resource surveys to assess the status of the resources, and to assist in counteracting the biases seen in commercial fishing data.

The exploitation ratios (E) for species/stocks were calculated and validate the results of the stock analyses. The E values, derived independently from length-based single species assessments, represent the proportion of the fish population that die due to fishing as opposed to total mortality (Beverton and Holt 1966; Pauly 1984b). The distribution of the E values of the species (427 stocks) from South and Southeast Asian regions (Fig. 7) and the overall mean E (~ 0.59) confirm the extent of over-fishing to which the stocks are subjected to. Population analysis models indicate the optimum E range to be 0.30 - 0.50 to maximize biological yield (Gulland 1988; Pauly 1984b). Most of the species exploited in the region show E values above the optimum range. Figure 8 presents the E distribution for 25 species of trawl-caught fish in Brunei Darussalam, a country with limited fishing pressure (Silvestre and Matdanan 1992) Silvestre & Garces in press), compared with E estimates from similar species (119 stocks) in the countries involved in the project. The stocks in Brunei have lower E values, most likely associated with the lower effort. The massive biomass declines and high E values indicate substantive degradation and biological over-fishing of the coastal fish stocks.

The massive declines in resource biomass have led to substantive changes in species composition of the coastal fishery resources. Table 5 illustrates this in the case of the Gulf of Thailand and the Lingayen Gulf in the Philippines. Surveys conducted from the late 1940s to the late 1980s indicate that larger, more valuable species (e.g. groupers, snappers, sharks and rays) high up in the food chain have declined in relative abundance. Comparatively, small species and generalists (e.g. triggerfish, cardinal fish, squids/octopus) lower in the food chain have increased in relative abundance.

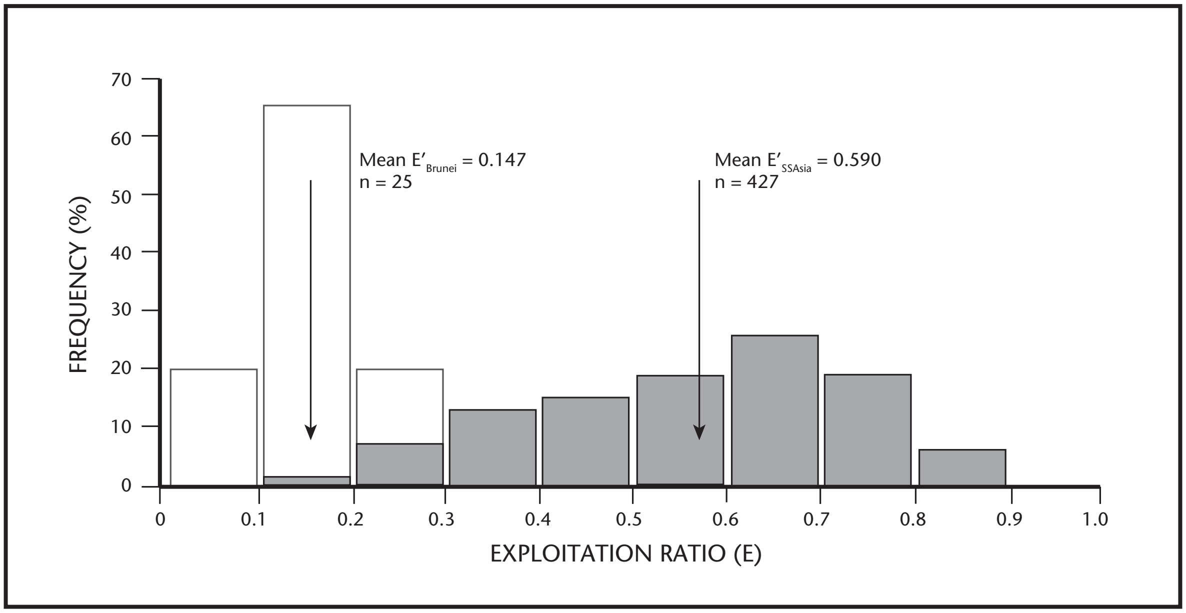

Fig. 7. Distribution of E values for 25 trawl-caught fish in Brunei Darussalam compared with E estimates from the South and Southeast Asian region (grey bars) for similiar species (427 stocks). (Adapted from Silvestre and Garces, in press).

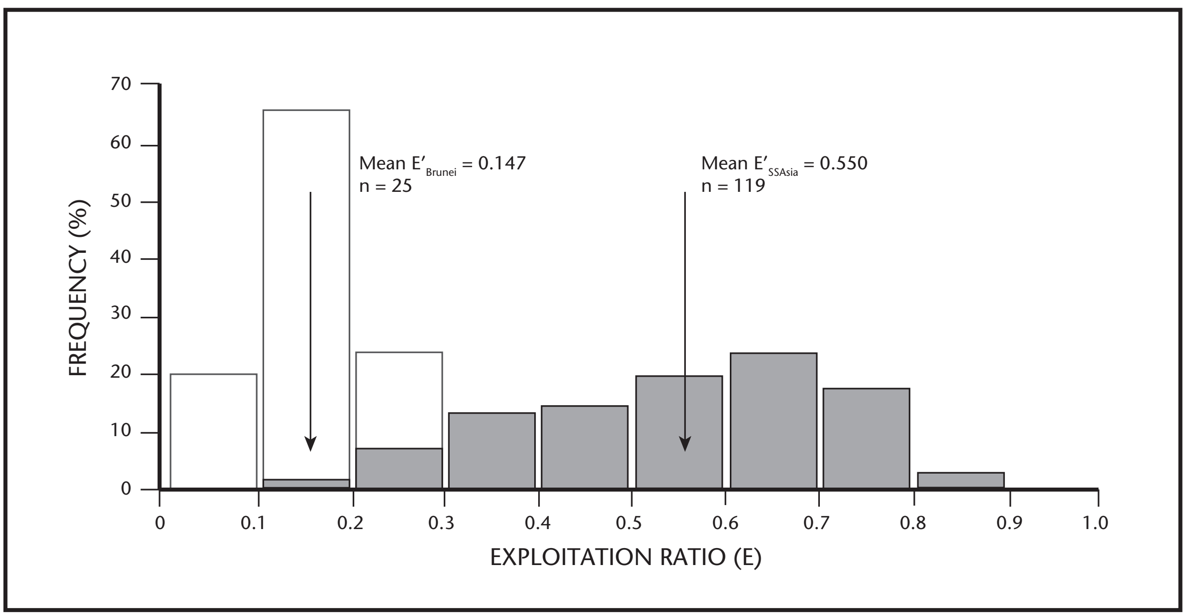

Fig. 8. Distribution of E values for 25 trawl-caught fish in Brunei Darussalam compared with E estimates from the South and Southeast Asian region (grey bars) for similiar species (119 stocks). (Adapted from Silvestre and Garces, in press).

Table 5a. Relative abundance of 10 leading species/taxa during research survey trawls in the Gulf of Thailand.

	1966		1976		1986		1995
Species	**(%)**	**Species**	**(%)**	**Species**	**(%)**	**Species**	**(%)**
Dasyatidae (Rays)	8.15	*Loligo duvauceli*	10.60	*Loligo duvauceli*	10.06	*Leiognathus splendens*	13.06
Nemipterus hexodon	7.39	*Nemipterus hexodon*	5.84	*Priacanthus tayenus*	8.61	*Loligo duvauceli*	9.04
Mullidae	4.97	*Loligo chinensis*	3.83	*Saurida undosquamis*	4.14	*Sphyraena obtusata*	6.96
Nemipterus mesoprion	4.67	*Priacanthus tayenus*	3.80	*Loligo chinensis*	3.59	*Secutor spp.*	5.30
Loligo duvauceli	4.39	*Nemipterus mesoprion*	3.69	*Nemipterus hexodon*	3.48	*Scolopsis taeniopterus*	5.19
Tachysuridae	2.84	*Trichiuridae Lepturus*	3.31	*Priacanthus macracanthus*	2.99	*Saurida undosquamis*	3.96
Priacanthus tayenus	2.54	*Saurida undosquamis*	2.82	*Nemipterus mesoprion*	2.19	Mullidae	3.80
Saurida undosquamis	2.44	Mullidae	2.74	*Scolopsis taeniopterus*	2.05	Siganidae	3.05
Lutjanus lineolatus	1.84	*Loligo sumstrensis*	2.00	Mullidae	1.96	*Loligo chinensis*	3.00
Atule mate	1.73	Gerreidae	1.98	*Loligo sumstrensis*	1.88	*Leiognathus bindus*	2.68

Table 5b. Relative abundance of important families/groups in the Lingayen Gulf, Philippines, 1940s and 1980s.

1940s*		1980s**	
Family/Group	**Relative Abundance (%)**	**Family/Group**	**Relative Abundance (%)**
Leiognathidae	63.0	Leiognathidae	31.4
Synodontidae	7.4	Carangidae	12.9
Pomadasyidae	6.7	Trichiuridae	9.3
Nemipteridae	6.6	Scombridae	6.9
Lutjanidae	3.1	Synodontidae	6.1
Psettooidae	2.5	Mullidae	3.6
Dasyatidae	1.9	Cephalopods	3.5
Lactariidae	1.8	Nemipteridae	3.4
Carangidae	1.4	Engraulidae	2.6
Serranidae	0.9	Apogonidae	2.4
TOTAL	95.3	TOTAL	82.1
Catch rate ($kg \cdot hr^{-1}$)	92.1	Catch rate ($kg \cdot hr^{-1}$)	31.8

Source: Ochavillo et al. 1989.

Table 6. Summary of the major fish assemblages with boundaries observed from community structure analysis.

Tropical Coastal Areas in Asia	Major assemblages			Notes	Source
Indonesia – North coast of Java	Shallow < 20 m	Deep > 20 - 30 m		Spatial analysis based on depth	Nurhakin (this vol.)
Gulf of Thailand	Shallow < 30 m	Deep > 30 m		Spatial analysis based on depth	Khongchai et al. (this vol.)
Philippines – San Pedro Bay	Shallow < 15 - 20 m	Deep > 15 - 20 m		Spatial analysis based on depth	Campos (this vol.)
Philippines – Samar Sea	Shallow < 30 - 40 m	Intermediate 40 - 50 m	Deep > 50 - 60 m	Spatial analysis based on depth	Campos (this vol.)
Malaysia	Shallow/Coastal < 40 m	Intermediate 40 - 90 m	Deep/Offshore > 90 m	Spatial analysis based on depth	Alias (this vol.)
Bangladesh (Bay of Bengal)	Shallow < 90 m	Deep > 90 m		Spatial analysis based on depth	Mustafa (this vol.)
Philippines – Manila Bay	Inner bay	Outer bay		Spatial analysis based on depth	Campos (this vol.)
India – Southwest Coast	Pre-monsoon	Post-monsoon		Temporal analysis	Srinath et al. (this vol.)
India – Southwest Coast	Cochin – Mangalore	Konkan – Goa-Allepey	Wadge bank - Quilon	Based on geographic coverage	Srinath et al. (this vol.)

The assemblage structure analyses undertaken (Table 6) indicate demersal assemblages with boundaries mainly influenced by depth. This is largely consistent with data from the limited number of assemblage/community structure studies conducted previously in the region (Table 7). Fig. 9 gives an illustrative example of results of assemblage analysis work in Malaysia, with the assemblage boundaries evident at around 40 m, 40 - 90 m and > 90 m depth. The assemblage boundaries are comparable with the results of similar analysis in Brunei Darussalam (Fig. 10). The assemblage patterns are associated with a variety of environmental factors. However, it appears that depth, salinity and bottom type are the main structuring factors in the analyses (Mustafa; Pillai et al.; Nurhakim; Alias; Campos; and Kongchai et al. this vol.). Temporal stability of the assemblages requires further in-depth investigation; although it appears from current analyses that the deeper boundaries (40 - 60 m, 80 - 110 m and 180 - 200 m depth) are temporally stable, and the shallower ones (10 - 30 m depth) are seasonally influenced (Campos this vol.).

The critical implication of this spatial structure for fisheries management is the relationship to fisheries management zones (Table 8). The spatial fisheries management measures in the region (e.g. 15 km boundary in the Philippines and fishing zones in Malaysia) are largely inconsistent with the resource assemblage patterns observed (Table 9, see also Alias this vol.). The fisheries management zonation patterns have been determined, primarily, on historical patterns of use and are often aimed to reduce conflicts between gear types or fisheries of different scales (e.g. large scale commercial fisheries *versus* small scale artisanal). The delineation of management zones should also take into account the spatial patterns in resources in order to manage the overall impact from different fishery sectors.

Table 7. Summary of the major assemblages observed from previous community structure studies in tropical Asia.

Region	Major assemblages					Source	Method Used
Pakistan shelf	Shallow shelf zone (coastal stations, relatively stable temperature and oxygen values)	Deeper shelf zone (from about 50 - 80 m, where the environmental conditions change dramatically on a seasonal basis)	Slope zone (average depth 213 m for the September 1983 survey)			Bianchi (1992)	TWINSPAN DCA
Northwest coast of Sumatra	Shallow community (40 m and below)	Deeper community (> 40 m)	Slope stations (average depth 298 m)			Bianchi (1996)	TWINSPAN DCA
Java Sea (including part of southern South China Sea)	Shallow coastal areas (due to the presence of estuaries)	Central and deepest part of the basin (> 30 m depth)				Bianchi et al. (1996)	TWINSPAN DCA
Eastern Gulf of Thailand	< 10 m	10 - 20 m	20 - 30 m	Beyond 30 to 60 m		Chittima and Wannakiat (1992)	Similarity Index ($C\pi$)
Ragay Gulf, Burias Pass, Ticao Pass, north of Samar Sea	Shallow sub - areas	Shallow – coralline sub-areas (hard bottom with rocks or other structures and the presence of sponge communities and coral patches)	Deep sub-areas (> 100 m)			Federizon (1992)	UPGMA TWINSPAN NMDS CA
Sunda continental shelf (off Vietnam, South China Sea)	Winter	Spring	Summer			Kihara and Itosu (1989)	Affinity Index (I)
Indian Ocean coast of Bali to mid-Sumatra	Shallow (< 100 m)	Deep (> 100 m)				McManus (1996)	TWINSPAN DCA
Southwest shelf of Indonesia	Shallow (non-Java)	Shallow (Java)	Deep (non-Sumbawa) 100 - 120 m	Deep (Sumbawa) 100 - 120 m		McManus (1989)	TWINSPAN
Samar Sea, Philippines	Shallow sub-community (< 40 m)	Deep sub-community (> 40 m)				McManus (1986)	TWINSPAN DCA
Northern continental shelf of South China Sea	West of the Taiwan Bank	40 m	40 - 100 m	100 - 200 m	Continental shelf edge	Qui (1990)	Bray-Curtis Measure of Similarity
Gulf of Thailand (southwestern part of South China Sea)	1975 - 83	1970 - 74	1963			Suvapepun (1991)	Spearman's Rank Correlation of Principle Species Groups

Table 8. Spatial delineation of fisheries management zones in Asia based on existing legislation.

Countries	Fishing Zone I	Fishing Zone II	Fishing Zone III	Fishing Zone IV	Legislation	Reference
Bangladesh	Shore to 18.5 m depth • Traditional/artisanal	18.5 to 40 m depth • Industrial/commercial			Marine Fisheries Ordinance, 1983: • Bangladesh fisheries water • Rule 13, Area of fishing	Management of Fisheries, Coastal Resources and Coastal Environment in Bangladesh: Institutional, Legal and Policy Perspectives (unpublished)
Brunei - Darussalam	Shore to 3 nm • Small scale/artisanal	3 to 20 nm • Industrial: trawlers < 350 HP engine and purse seiners < 20 m LOA*	20 to 45 nm • Industrial: trawlers with 350 - 550 HP engine and purse seiners with 20 - 30 m LOA	45 nm to EEZ limit • Industrial: purse seiners > 30 m LOA		SEAFDEC (1999); Silvestre and Matdanan (1992)
Cambodia	Shore to 20 m depth • Coastal: small scale with/without engine (5 to 50 HP engine)	20 m to EEZ limit • Commercial: > 50 HP				SEAFDEC (1999)
India	Northern sector: Shore to 16 m depth, Southern sector: Shore to 32 m depth • Artisanal craft/ traditional gears	Northern sector: 16 to 20 m depth, Southern sector: 32 to 40 m depth • Motorized craft using traditional gear	Northern sector: 20 to 40 m depth, Southern sector: 40 to 70 m depth • small mechanized: vessels < 25 GRT	Deep seas fishing • vessels > 25 GRT and engine > 120 HP	Marine Fisheries Regulation Acts (No. 16 to 22)	Sathiadhas et al. (1995) Vivekanandan et al. (this vol.)
Indonesia	Shore to 3 nm • Small scale: vessels < 5 GT/ 10 HP engine	3 to 7 nm • Small scale: vessels < 25 GT/50 HP engine	7 to 12 nm • Industrial: vessels < 100 GT/200 HP engine	>12 nm • Industrial: vessels > 100 GT/200 HP engine	Agriculture Minister Decree No. 607/ 1976 concerning Fishing Zonation	Purwaka and Sunoto (1999)
Malaysia	5 nm • Traditional: artisanal, owner-operated vessels	5 nm to 12 nm • Commercial: owner-operated trawlers and purse seines of < 40 GT	12 nm to 30 nm • Commercial: trawlers and purse seines of > 40 GT, wholly owned and operated by Malaysian fishers	30 nm to EEZ • Commercial: deep sea fishing vessels > 70 GT	Fisheries Act of 1985	Abu Talib and Alias (1997)
Myanmar	Northern area: shore to 5 nm, Southern area; shore to 10 nm • Coastal: vessels < 30 feet or engine < 12 HP	Outer limit of Zone I to EEZ • Industrial: vessels > 30 feet or engine > 12 HP				SEAFDEC (1999)
Philippines	Shore to 15 km • Municipal: vessels < 3 GT or fishing not requiring the use of fishing vessels	15km to EEZ limit Commercial: Small scale - passive or active gear and vessels 3.1 GT to 20 GT, Medium scale - active gear and vessels 20.1GT to 150 GT, Large scale - active gear and vessels of > 150 GT	–	–	Republic Act 8550 (1998)	Philippines (1998)
Thailand	Shore to 12 nm • Small scale: vessels < 5 GT operating	12 nm to EEZ limit Large scale: vessels > 5 GT	–	–	Fisheries Act of 1997	SEAFDEC (1999)
Vietnam	Northern and Southern areas: shore line to 30 m depth in, Central area: shore to 50 m depth • Small scale:, vessels with no engine or < 40 HP engine	Limit of Zone I to EEZ limit • Large scale: engine > 40 HP	–	–	–	SEAFDEC (1999)

Note: * LOA = overall length

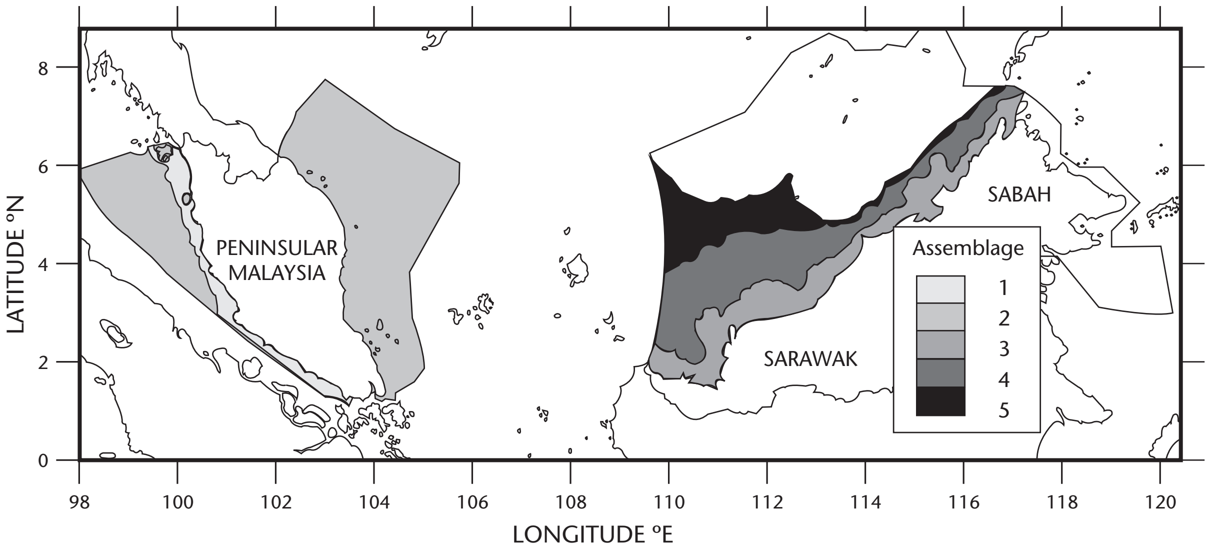

Fig. 9. Spatial delineation of fish assemblages in Malaysia (from Alias, this vol.).

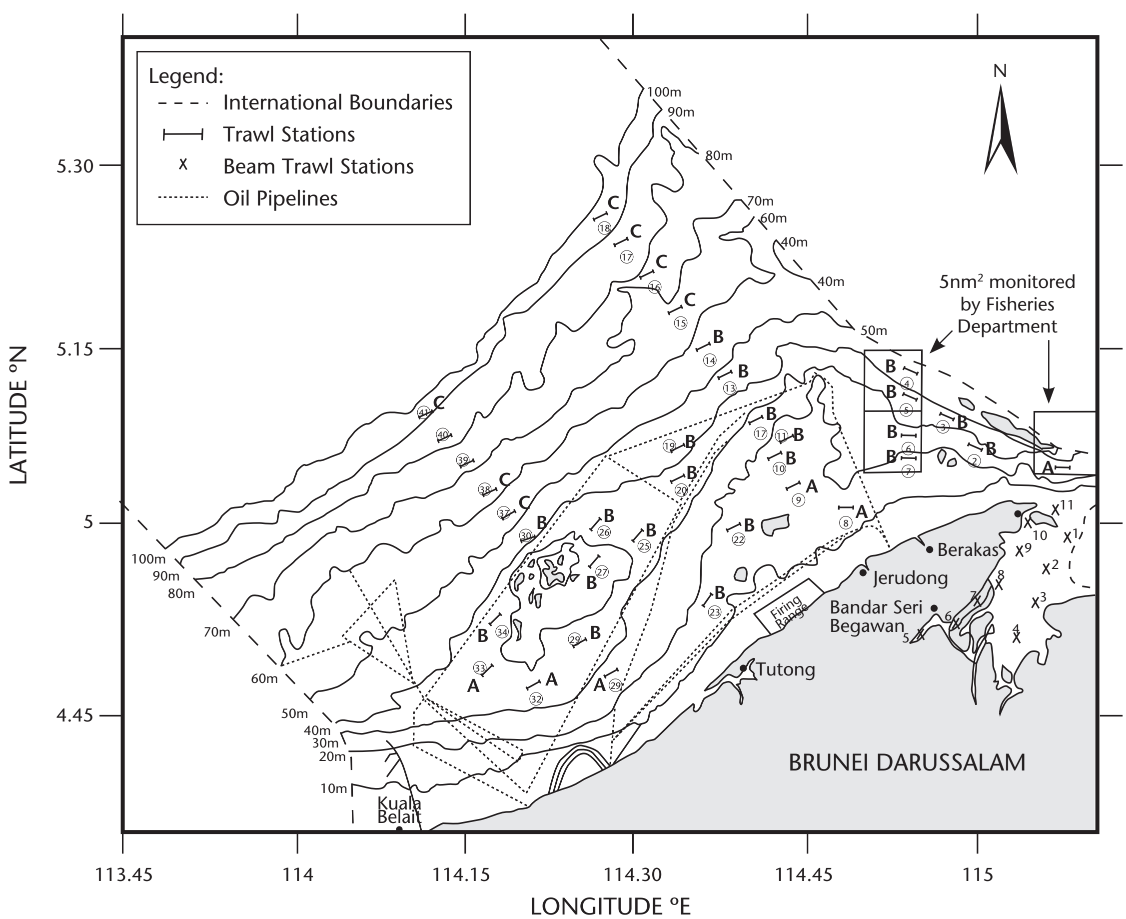

Fig. 10. Spatial distribution of fish assemblages in Brunei Darussalam. Note: A, B, C indicate fish assemblage groups. Source: Silverstre unpublished data.

Preliminary trophic models of coastal fishing systems were constructed for areas within each country (Table 9). These models were intended to assess the available information and provide a foundation for ecosystem-based approaches to fisheries assessment and management of fisheries in the future. Concededly, ecosystem-based approaches to fisheries assessment and management in the region (and worldwide) are still in their initial development stages. Project activities in this area have facilitated interest and the construction of preliminary models. It should be emphasized that the biomass values for the demersal groups were obtained from the compiled trawl research survey data, providing a comparatively robust input.

The production of the ecosystem models has been useful in identifying data or research gaps currently limiting the development of fisheries ecosystem modeling in the region. These include a systematic approach to assigning species to ecological groups, data on diet composition, and determination of system boundaries, among others. As these models are further developed and refined they may be useful in scenario building (i.e. anticipating or modeling the ecosystem impacts of fisheries management measures and decisions). Most importantly, the ecosystem analyses have allowed an initial attempt at modeling the trophic impact of the excess fishing effort, resource degradation and species composition trends noted above (Christensen et al. this vol.).

Overall, the resource analyses have quantified the biological extent of excessive fishing pressure in the focal areas. These results served as key inputs to the situational analysis activities of the project.

Socioeconomic Analysis and Bioeconomic Modeling

The thrust of this component was to assess the socioeconomic and bioeconomic status of the coastal fisheries. The scope of the analyses included socioeconomic profiling of coastal fishing and fisher populations, analysis of fleet operational dynamics, and bioeconomic modeling. The socioeconomic profiling provided an analysis of the importance of coastal fisheries in terms of earnings, employment,

Table 9. Summary information for the Ecopath models constructed for areas in South and Southeast Asia.

Area	Year	No. of Ecological Groups	Mean Trophic Level	Catch* ($t \cdot km^{2} \cdot year^{-1}$)	Reference
BANGLADESH Bay of Bengal (up to 100 m depth)	1985	15	2.70	0.88	Mustafa (this vol.)
INDIA Southwest coast	1994 - 96	11	2.61	13.83	Vivekanandan et al. (this vol.)
INDONESIA North Coast of Central Java	1979	27	3.04	4.67	Subhat (this vol.)
MALAYSIA West coast peninsular Malaysia (up to 120 m)	1987 - 91	15	3.19	5.76	Alias (this vol.)
East coast peninsular Malaysia	1972	15	3.24	2.10	Christensen et al. (this vol.)
West coast Sabah, Malaysia (10 - 60 m depth)	1972	29	3.33	1.33	Garces et al. (this vol.)
Sarawak, Malaysia (10 - 60 m depth)	1972	29	3.38	0.21	Garces et al. (this vol.)
PHILIPPINES San Pedro Bay	1994 - 95	16	3.25	7.24	Campos (this vol.)
THAILAND Gulf of Thailand	1973	40	2.72	2.43	Vibunpant et al. (this vol.)
VIETNAM Southwest coast of Vietnam	1993 - 95	15	3.11	0.36	Christensen et al. (this vol.)

Note: * Estimate catch based on fished groups in the models.

trade and nutrition, and assessed their contribution to the economy. Fleet operational dynamics examined the microeconomic determinants of profitability and effort allocation, and included a description of operations such as costs, revenues and net profits. The bioeconomic modeling focused on assessing the extent of economic over-fishing (i.e. excessive effort that dissipates resource rent for the coastal fishery).

The socioeconomic profiles of the fisheries highlight the importance of the sector to the different countries. The fisheries sector contribution to the Gross Domestic Product (GDP) ranges between 1.3% for India (Immanuel this vol.) and 3.5% for the Philippines (Cruz-Trinidad this vol.). The sector provides employment to as many as 2 million people in Indonesia, 1.55 million in Bangladesh and 1.4 million in Vietnam (Table 1). The share of the fisheries sector in total employment varies between 4% in Vietnam and 1% in Malaysia. For countries such as the Philippines and Thailand, fish is a major export item creating a large positive trade balance (Cruz-Trinidad this vol.; Boonchowong and Dechboon this vol.). For most of the countries net export earnings from fish is considered as an important source of foreign exchange to pay the bills for food imports. For five countries out of the eight, the share of fish export to total agricultural export was more than 20% with the share reaching as high as 56% in Bangladesh in 1995 - 96.

The analyses of costs, earnings and profitability indicate that fishing is still a profitable enterprise in all countries particularly for the owners of commercial fishing vessels (Table 10). However, the ownership of the means of production (i.e. the vessels, gear or license) has substantial influence on the distribution of net profit among fishers. The major concern lies with sustaining the existing socioeconomic structure within the fisheries sector under the present mode of operation and distribution of proceeds from fishing operations. In general, owners of commercial craft and gear earn large sums while artisanal (small scale) fishers hardly earn a living. Commercial fishing fleets employ few crew, providing little opportunity for unemployed or under-employed small scale fishers. Even in the artisanal fishery, proceeds are not evenly distributed among owners of boat-gear and ordinary laborers. These issues have important implications for the sustainable management of coastal resources and sustenance of livelihood of the coastal fishers and their families in the region. It is a common belief that the tendency to over-exploit the coastal resources cannot be avoided until measures are taken to ameliorate the impoverished conditions of the vast majority of fishers.

The bioeconomic modeling, based on surplus production models, largely confirmed the widely accepted view that coastal fishery resources in most Asian countries are suffering from over-fishing,

Table 10. Profitability of fishing operations in selected countries.

Country/ Gear	(US$'000)				Profitability (%)
	Total Investment	Total Revenue	Total Cost	Total Profit	
Malaysia					
Trawl	36 - 50	69 - 80	55 - 64	13 - 16	24 - 25
Purse Seine	25 - 34	71 - 149	56 - 125	15 - 23	18 - 26
Drift nets	5	7.78	533	2.45	46
Thailand					
Small scale	1.8 - 4.4	2.0 - 6.2	1.8 - 5.6	0.19 - 0.59	11 - 22
Beam Trawl	7.7	3.1	2.6	0.47	17
Push net	20.87	5.87	5.7	0.15	2.5
Pair & otter trawl	53 - 97	8 - 15	6 - 13	1.26 - 1.36	9 - 22
Purse Seine	119	15	13	1.98	15
Vietnam					
Single Trawler	33.50	72.13	56.48	15.65	28
Pair Trawler	65.18	79.04	62.99	15.70	25
Purse Seine	41.99	34.48	26.79	7.73	29
Hooks and Lines	13.57	69.76	54.75	15.97	29

both biological and economic. The countries, for which historical data on catch and effort were available, showed a clear trend of declining CPUE. For instance, in the Gulf of Thailand, the CPUE (measured in standard hours) declined to 15.9 kg in the 1990s compared to 231.6 kg in the 1960s (Boonchowong & Dechboon this vol.). Huge rent dissipation and large excess capacity (both labor and capital) were also evident in Thailand (Table 11). These results provided some suggestions for policy measures and sector-specific interventions needed to correct over-fishing and related socioeconomic trends in coastal fisheries in Asia.

Fisheries Management (Policy/Planning)

The objective of the component was to examine the management and policy implications of the analyses. This involved elaboration of the issues outlined in Silvestre and Pauly (1997b), and detailed in the introduction. The process involved strategic action planning at the national and regional levels. This was supported by consultative workshops at the national and regional levels. Key national and regional stakeholders participated in identifying strategic directions and formulating action programs for the sustainable management of coastal fisheries.

National strategic planning activities reviewed and evaluated fisheries management at the country level. Activities within each country included:

a. formation of a National Policy and Planning Group from the planning/policy counterparts seconded by the collaborating institutions;
b. preparation of a National Fisheries Evaluation Guide that provided an assessment framework for marine fisheries in terms of goals, objectives, policies, programs, projects, etc;
c. evaluation of the national fisheries situation and review of fisheries management planning through a series of workshops and consultations (although the review focused on national fisheries plans, it also covered lower level plans such as provincial or municipal plans); and
d. production of a National Fisheries Situation Review and recommendations for Strategies and Action Plans.

From August to October 2000, eight national consultative workshops were conducted by the participating countries. The national workshops reviewed the analyses of the resource analysis and socioeconomic components and the draft "Strategic Review of National Fisheries Situation". The participants developed strategies for improved management of fisheries resources and discussed follow-up activities. The national strategic reviews were revised to incorporate the recommendations from the consultative workshops and form contributions to this volume (Abu Talib et al. Barut et al., Janekitkosol et al.; Purwanto; Rahman et al.; Samaranayake; Son and Vivekanandan et al.).

While the countries share the issue of over-fishing in their coastal fisheries, the complexity and intensity of the issues means that there can be no single strategy that will resolve all issues. Realistically, the eight countries can aim towards moving progressively closer to a state of sustainable exploitation through long-term resource management that repeatedly cycles through planning, implementation and evaluation. This strategic review makes a modest contribution to the planning aspect by analyzing current issues and opportunities and by suggesting management objectives and interventions. A simple planning framework (Fig. 11) was used to structure the presentations and working groups during the March 2001 workshop. The framework provided a logical sequence for discussion, begin-

Table 11. Comparison of the catch, revenues, costs and profits at different levels of effort based on a fixed price model and 1966 - 95 data, Gulf of Thailand.

State of fishery	Effort (Std. hr·10^6)	Catch (t·10^3)	Revenue (Bahts·10^6)	Cost (Bahts·10^6)	Profit (Bahts·10^6)
MSY	28.57	985	6 578	1 992	4 586
MEY	21.75	952	6 359	1 517	4 842
Open Access	62.70	654	4 372	4 372	0
Actual (1995)	56.88	728	4 862	3 966	896

ning with "where are we right now", the issues and opportunities, then progressing to "where do we want to go", the management objectives. Finally, knowing where we want to go, we can propose interventions or means to get there.

Fisheries Management Issues

The issues that commonly occur in the coastal fisheries of South and Southeast Asia are numerous, interrelated (Fig. 12) and have been documented previously to some extent (Chua and Scura 1992; Hotta 1996; SEAFDEC 2001; Silvestre and Pauly 1997a). The national strategic reviews examined the issues in detail for each country (i.e. Rahman et al. - Bangladesh; Vivekanandan et al. - India; Purwanto - Indonesia; Abu Talib et al. - Malaysia; Barut et al. - Philiipines; Samaranayake - Sri Lanka; Janekitkosol et al. - Thailand; and Son - Vietnam). Here we briefly present an overview of the links among the issues and then details of the regional perspective.

The issue of the depleted state of coastal fisheries resources dominates the fisheries sector in South and Southeast Asia. This is due to the cumulative effect of excessive fishing effort, inappropriate exploitation patterns, destructive fishing and habitat degradation or destruction. As fishery resources decline, fishers turn to more efficient ways to fish, thus putting more pressure on the resource and locking the situation into a downward spiral.

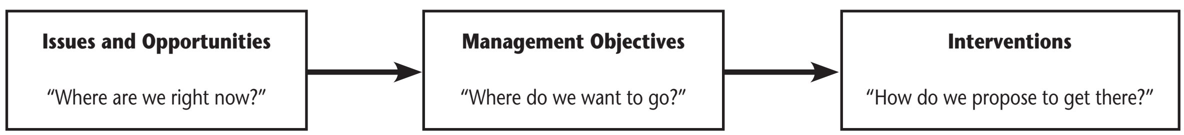

Fig. 11. A simple planning framework suggests a logical sequence for considering issues, opportunities, management objectives and interventions.

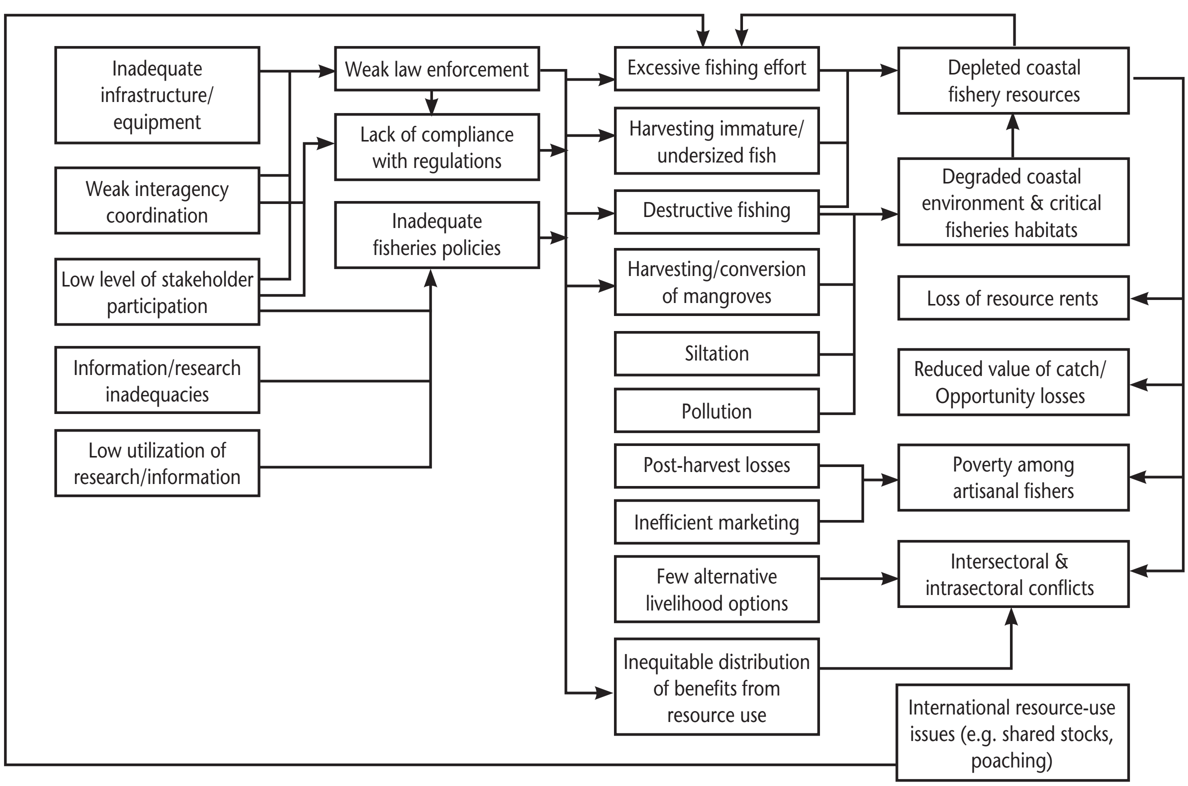

Fig. 12. Coastal fisheries issues in South and Southeast Asia.

The progressive decline of resources has severe social and economic impacts. Declining resources increase competition within and among fisheries and often leads to conflict. Also, the cost of fishing increases, thus reducing profits and resource rents. In addition, poor post-harvest practices reduce the value of catches. Other economic losses result from lost opportunities due to inefficient marketing, harvesting small sized fish and wastage from discards and by-catch. The impacts of the above are most strongly felt by artisanal fishers, the overwhelming majority of fishers in the region. The artisanal fisheries, generally, have few alternative means of livelihood, and have little choice but to adjust to reduced incomes. In addition, artisanal fishers are often engaged in a lopsided competition against commercial fishers. Given such circumstances, it is not surprising that so many artisanal fishers are mired in poverty.

The underlying causes of most resource-use problems can be traced to weak law enforcement and inadequate fisheries policies, which translate to a lack of effective fishing rights or open access to resources and minimal protection for the coastal environment. Weak law enforcement and inadequate policies, in turn, are caused by a number of institutional weaknesses and constraints (Fig. 12).

Excessive Fishing Effort

Over-exploitation of coastal fishery resources has been a regional concern for a significant time, starting in the 1980s (Pauly and Chua 1988; Silvestre and Pauly 1997a). This study quantified the extent of this issue in the eight countries all of which displayed symptoms (Tables 12 and 13) including: high exploitation ratios of species (as in the case of India), decreasing catch rates (e.g. Thailand), and changes in dominant species from high-valued to low-valued species (e.g. Malaysia and Thailand). Some countries display a range of symptoms.

The governments' inability to enforce effective property rights has resulted in open access to resources. This causes in individual fishers to attempt to maximize their fishing effort, resulting in excessive effort. In South and Southeast Asia, as mentioned earlier, other factors that contribute to excessive fishing include poverty or low incomes among artisanal fishers, few alternative livelihood options, and a host of institutional weaknesses and

Table 12. Symptoms of over-exploitation of fisheries in South and Southeast Asia.

Country (Reference)	Symptom
Bangladesh (Rahman et al. this vol.)	Over-exploitation noted in strategic review and during the national workshop. Decline in biomass noted in resource assessment.
India (Vivekanandan et al. this vol.)	Over-exploitation noted in strategic review.
Indonesia (Purwanto this vol.)	In the Java Sea, excess effort is estimated at 428 units of 25 GT trawlers.
Malaysia (Abu Talib et al. this vol.)	Density of demersal resources from 1987 to 1997 reduced by 67% in the west coast and 83% in the east coast of peninsular Malaysia. Changes in dominant species. Landings of small pelagics in the west coast have exceeded the potential yield by about 5 000 t. Landings of prawn have exceeded potential yields.
Philippines (Barut et al. this vol.)	Over-exploitation noted in national workshop. Reductions in biomass of demersal species and changes in species composition of catches.
Sri Lanka (Samaranayake this vol.)	Over-fishing noted in national workshop.
Thailand - Gulf of Thailand (Janekitkosol et al. this vol.)	In trawl fisheries, changes in catch composition of demersal resources towards smaller-sized fish and low- valued species. Trash fish constitute about 60 % of the catch. Average monthly catch rates of research vessels have decreased from 300 $kg{\bullet}hr^{-1}$ in 1961 to 18 $kg{\bullet}hr^{-1}$ in 1998.
Vietnam (Son this vol.)	During 1987 - 99, 3-fold increase in horsepower resulted in only 1.81 times increase in total catch. Increased amount of by-catch and smaller sizes of fish caught by trawl fisheries.

Table 13. Examples of over-exploited fishery resources in South and Southeast Asia.

Country (Reference)	Over-exploited resources
India (Vivekanandan et al. this vol.)	Demersals in the 0 - 50 m depth zone. Pelagics. Cephalopods along the southwest coast.
Indonesia (Purwanto this vol.)	Coastal demersals and small pelagics in the Java Sea.
Malaysia (Abu Talib et al. this vol.)	Demersals off Peninsular Malaysia. Small pelagics on the west coast. Prawns.
Thailand (Janekitkosol et al. this vol.)	Demersals in the Gulf of Thailand. Sardines (*Sardinella* spp.).
Vietnam (Son this vol.)	Most coastal fish resources (exploited at or above sustainable levels). Green mussel and pearl oyster in some areas.

constraints. The increasing fisher population is a major cause of excessive effort in countries such as Bangladesh, India and the Philippines (Rahman et al.; Vivekanandan et al.; Barut et al. this vol.). While this is clearly the case for these countries, high fisher population is not an unequivocal issue in the region. Malaysia actually has a declining fisher population (Abu Talib et al. this vol.). However, reducing the number of fishers alone may not address the excessive effort.

Harvesting Immature/under-sized Fish

Inappropriate exploitation patterns, primarily the harvesting of immature and under-sized fish is considered a serious issue in five countries (Table 14). Small mesh sizes in the cod end of trawls contribute significantly to this problem. In the Gulf of Thailand, where "trash fish" constitute about 60% of the catch, between 18% and 32 % of "trash fish" are juveniles of commercially important species. There is a high demand for "trash fish", which is processed into fishmeal and yet the economic loss is substantial. Juveniles of commercially important species, when sold as "trash fish", fetch about 2 Baht (US$0.05[4]) per kg. If allowed to mature, these species can be sold at 20 to 50 Baht per kg (Janekitkosol et al. this vol.). Malaysia has similar problems with trawls that use small mesh sizes and supply "trash fish" to fishmeal processors (Abu Talib et al. this vol.).

Some artisanal gear also catch immature fish, including: bag nets, beach seines and push nets (Table 14). In Bangladesh, the estuarine-set bag net, which accounts for 30% of the inshore landings, catches mostly juvenile fish (Khan et al. 1997; Rahman et al. this vol.). Inshore push nets specifically target fry and juveniles of cultured species such as shrimp and milkfish. In the Philippines, gathering of milkfish fry is considered traditional and is thus difficult to stop (Ahmed et al. 2001; Smith 1981). Heavy fishing on immature fish can result in growth and recruitment over-fishing (Pauly et al. 1989).

Destructive Fishing

Destructive fishing practices pose serious threats in Indonesia, the Philippines, Thailand, Sri Lanka and Vietnam. Destructive practices include blast fishing, the use of poisons and the use of trawls in reefs and seagrass areas (Table 15). Aside from their visible impacts on reefs and seagrasses, trawls may impact soft-bottom communities, with possible negative consequences on the aquatic food web (Jones 1992; Kaiser et al. 1998; Philippart 1998). Changes in species composition and diversity of the benthos in the Gulf of Thailand have been attributed to trawling (Christensen 1998; Pauly and Chua 1988). In Sri Lanka, destructive fishing occurs even in sites declared as marine protected areas (Samaranayake this vol.).

[4] 1 US$ = 40.20 Baht (2000 average value)

Table 14. Gear that harvest immature/undersized fish in South and Southeast Asia.

Bangladesh	India	Malaysia	Philippines	Thailand
Estuarine bag net Beach seine Push net	Trawl	Trawl Push net	Trawl Push net	Trawl Push net Drag net
Rahman et al. (this vol.)	Vivekanandan et al. (this vol.)	Abu Talib et al. (this vol.)	Barut et al. (this vol.)	Janekitkosol et al. (this vol.)

Table 15. Destructive fishing practices in South and Southeast Asia.

Country (Reference)	Destructive fishing practices
Indonesia (Purwanto this vol.)	Blast fishing and the use of poisons on coral reefs.
Sri Lanka (Samaranayake this vol.)	Existence noted; type of practice not specified.
Thailand (Janekitkosol et al. this vol.)	Use of trawls, push nets and drag-nets in seagrass areas. Blast fishing and the use of bottom-trawlers and drag nets in coral reefs.
Vietnam (Son this vol.)	Blast fishing.

Degradation of Critical Habitats

There is a range of coastal and marine habitats that are critical to maintaining productive fisheries resources. Mangroves trap silt and sediments from the land and stabilize shorelines (Birkeland and Grosenbaugh 1985; Snedaker and Getter 1985). They are often (but not always) crucial to the productivity of nearby fisheries because of their roles as nutrient exporters and providers of nursery areas (Fortes 1989; Paw and Chua 1991). Seagrass beds and estuaries also provide nursery grounds and important habitats for marine species (Fortes 1989). Coral reefs, which are among the most diverse and productive of ecosystems, contain far more resources than their size would suggest (Gomez 1988; White 1987).

In the South and Southeast Asian region, these critical habitats are at risk due to exploitation and coastal development. All countries report substantial losses of mangrove cover (Table 16). Six of the eight countries reported quantitative estimates of the losses, which are staggering in both spatial extent and speed of occurrence. All the countries with significant coral reef areas report widespread deterioration of coral reefs.

Uncontrolled land clearing, logging and development in catchments have lead to the siltation of rivers, waterways and coastal areas. Siltation is a major problem in all countries except India (Table 17). A survey in 1995 of 119 of Malaysian rivers and tributaries reported that 48 were “clean”, 53 were “slightly polluted” and 14 were “polluted”, with silt identified among the major pollutants (Abu Talib this vol.). The impact of siltation on coral reefs and seagrasses is often devastating, as observed in Thailand and the Philippines (Chou 1994; Yap and Gomez 1985).

Aside from siltation there are other types of pollution that are considered significant threats in particular countries (Table 17). With some exceptions, the notes on pollution in the national strategic reviews are mostly general and merely indicate the existence of certain polluting activities. Details on the specific nature, magnitude and extent of pollution are sparse. However, some accounts provide glimpses into the nature of pollution in the region (Talaue-MacManus 1999). For example, the Bangladesh strategic review notes that half of the 900 industrial firms identified as polluting belong to the leather and textile industries (Rahman et al. this vol). In Malaysia (Abu Talib et al. this vol.), a survey of coastal waters around the country indicated that almost all samples had values of lead, copper and cadmium that exceeded proposed standards. Heavy metal content in fish and shellfish, however, did not exceed public health thresholds.

Table 16. Mangrove areas lost and status of coral reefs in South and Southeast Asia.

Characteristics		Countries					
		Bangladesh	India	Indonesia	Sri Lanka	Thailand	Vietnam
Mangrove Areas Lost	Area (km^2)		700	1 760.8	3.3	101.8	2 430
	Percent of original cover	40 - 45% of the two major mangrove species*	50	41	28	75	61
	Period	1959 - 83	1980 - 2000	1982 - 93	1986 - 93	1961 - 96	1950 - 94
	Rate ($km^2 \cdot yr^{-1}$)		35	160.1	0.5	2.9	55.2
Status of Coral Reefs		Limited coral reef areas	Reefs are "destroyed to a large extent"	Some reefs have deteriorated due to exploitation for commercial and tourism purposes, and siltation caused by development projects	Only 2 out of 8 reefs surveyed had live coral cover > 50%	Over 60% of major reefs are in either poor (live-to-dead ratio = 1 : 2) or fair condition (1 : 1); less than 36% are good (2 : 1) or very good (> 3 : 1)	Most nearshore reefs are heavily exploited
		Rahman et al. (this vol.)	Vivekanandan et al. (this vol.)	Purwanto (this vol.)	Samaranayake (this vol.)	Janekitkosol et al. (this vol.)	Son (this vol.)

N.B. * Applies only to Khulna Sunderbans Reserve Forest.
**** Applies only to mangroves around the Gulf of Thailand.**

Table 17. Checklist of siltation and pollution issues in South and Southeast Asia.

Issues	Bangladesh	India	Indonesia	Malaysia	Philippines	Sri Lanka	Thailand	Vietnam
Siltation	✔		✔	✔	✔	✔	✔	✔
Industrial pollution	✔	✔		✔	✔		✔	✔
Agricultural pollution	✔			✔			✔	
Domestic/ sewage pollution	✔			✔			✔	✔
Marine-based oil pollution	✔	✔		✔				
	Rahman et al. (this vol.)	Vivekanandan et al. (this vol.)	Purwanto (this vol.)	Abu Talib et al. (this vol.)	Barut et al. (this vol.)	Samaranayake (this vol.)	Janekitkosol et al. (this vol.)	Son (this vol.)

International Resource-use Issues

All the countries are likely to share their marine resources with other countries. Various countries share the Bay of Bengal, the Andaman Sea, the Gulf of Thailand and the Celebes Sea. Among countries with contiguous EEZs, potential conflicts exist with regard to shared stocks, migratory stocks and unauthorized foreign fishing or poaching. If stocks are shared among countries, their management must be complementary to reduce the potential for over-fishing. The strategic reviews of Bangladesh and Malaysia cite poaching as an issue of concern. Fishing boats transiting other countries' EEZs to get to favored fishing grounds can also be an issue. Sri Lankan fishers must obtain prior approval from India and the Maldives to pass through their EEZs.

Inequitable Distribution of Benefits and Intersectoral and Intrasectoral Conflicts

Increasing competition between artisanal and commercial sectors for limited resources inevitably intensifies into conflicts. In the 1980s violent confrontations between these sectors prompted the Indonesian government to ban trawling (Sarjono 1980). The governments of Bangladesh, India and the Philippines have banned commercial operations in nearshore areas in an attempt to reduce conflict with artisanal fisheries. These areas are usually legally demarcated on the basis of depth or distance from the coastline (Table 18). In such cases conflicts continue when trawlers encroach into these demarcated areas.

Among the countries, Sri Lanka is the one country where the conflict between commercial and artisanal fishing sectors is not a significant issue (Samaramayake this vol.). The Sri Lankan strategic review attributes this to the absence of trawling in Sri Lanka. Intersectoral conflicts in Sri Lanka arise between fishers and other coastal users.

Intrasectoral conflicts occur mostly in the artisanal sector and involve spatial and gear conflicts (Pauly 1996b; Pauly and Chua 1988; Silvestre and Pauly, 1997c). Whether intersectoral or intrasectoral, conflicts essentially occur over rights to resources. As resources dwindle and/or provide lower returns, conflicts are likely to intensify. Governments will face increasing costs of managing these conflicts, unless proactive measures are taken.

Post-harvest Losses

Improper handling of fish onboard vessels and during distribution results in reduced quality and spoilage of the fishery products. About 30% of fish caught in Bangladesh end up spoiled and unfit for human consumption (Rahman et al. this vol.). In Sri Lanka, overall post-harvest losses are estimated at 22 - 25% and in the case of extended fishing, more than 50% of the landings are spoiled (Samanarayake this vol.). Spoiled fish in Thailand is sold as trash fish at greatly reduced values (Janekitkosol et al. this vol.). Lack of skill in handling and lack of facilities are the major causes of post-harvest losses (Alverson et al. 1994).

A related issue is the discarding of by-catch. The extent of this varies among the countries, but it is rarely documented. In Bangladesh, an estimated 30 000 t of by-catch are discarded annually, mostly by shrimp trawlers (Khan et al. 1997; Rahman et al. this vol.). The survival of this discarded by-catch is unknown, as is the impact on fisheries resources and the broader ecosystem.

Table 18. Intersectoral and intrasectoral conflicts in South and Southeast Asia noted during the project. (Abu Talib et al. this vol.; Barut et al. this vol.; Janekitkosol et al. this vol.; Purwanto this vol.; Rahman et al. this vol.; Samaranayake this vol.; Son this vol.; Vivekanandan et al. this vol.)

Conflict	Type	Countries
Intersector conflicts	Commercial vs. artisanal	Bangladesh, India, Indonesia, Malaysia, Philippines, Thailand, Vietnam
	Fishers vs. other coastal users	Sri Lanka
Intrasector conflicts	Conflicts among artisanal fishers from different locations	India
	Gear conflicts	Bangladesh, Thailand
	Intra-municipal conflicts (spatial and other types of conflict)	Philippines

Inefficient Marketing

Outputs of national workshops in the Philippines, Sri Lanka, Thailand stated that inefficient marketing is an issue in those countries (Samaranayake this vol.; Janekitkosol et al. this vol.; Barut et al. this vol.). However, no details were given on the exact nature of the inefficiencies. In India an inefficient distribution system, which includes cold storage and transportation systems, is blamed for the failure to supply fish to the interior parts of the country (Vivekanandan et al. this vol.). In order to address this, there are recommendations to introduce a compulsory licensing system for traders and for the government to supervise the fish auction system.

Inadequate Infrastructure/equipment

Fisheries infrastructure, which includes ports, municipal landings, post-harvest/cold storage facilities, processing facilities and fishing gear repair shops, are deemed inadequate in six countries (Table 19). In addition, related basic infrastructure and amenities such as roads, electricity and freshwater are often inadequate in rural areas. Estimates of the adequacy of fisheries facilities are available in Indonesia (Purwanto this vol.). For the country as a whole, infrastructure can only accommodate about 25% of the marine fishery production. In the western part of Indonesia where fisheries infrastructure can only accommodate 28.4% of production, ports and related facilities are operated at 120% higher than their optimum service capacity.

Inadequate fisheries infrastructure means wastage, decreased value of catches and higher operating costs for fishers. The provision of more infrastructure seems to be the obvious response to this issue. However, the situation is not always as simple and straightforward, particularly in the case of processing facilities. In India only 25% of the capacity of processing plants is currently used due to the lack of raw materials (Vivekanandan et al. this vol.). Similarly, in Bangladesh processing plants currently operate at 13 - 15% of capacity (Rahman et al. this vol.)

Poverty Among Artisanal Fishers

Earnings from fisheries are generally lower than those from other sectors. The average GDP per fisher in Vietnam is about US$160 per year, which places fishers among the country's poorest (Son this vol.). In Thailand, the per capita income and total household income of fishers are lower than national averages (Janekitkosol et al. this vol.). Within the fisheries sector, artisanal fishers as a group earn the lowest income s. In India, while laborers working in mechanized and motorized craft earn annual incomes of US$795 and US$350, respectively, fishers using artisanal craft earn only

Table 19. Checklist of institutional weaknesses and constraints in South and Southeast Asia.

Issues	Bangladesh	India	Indonesia	Malaysia	Philippines	Sri Lanka	Thailand	Vietnam
Inadequate infrastructure facilities/ equipment	✔		✔	✔	✔	✔	✔	
Information and research inadequacies	✔			✔	✔	✔	✔	✔
Inadequate fisheries policies	✔	✔		✔	✔		✔	
Weak law enforcement	✔	✔	✔	✔	✔	✔	✔	
Weak interagency coordination	✔	✔	✔		✔	✔	✔	
	Rahman et al. (this vol.)	Vivekanandan et al. (this vol.)	Purwanto (this vol.)	Abu Talib et al. (this vol.)	Barut et al. (this vol.)	Samaranayake (this vol.)	Janekitkosol et al. (this vol.)	Son (this vol.)

US$200 annually (Vivekanandan this vol.). Likewise, artisanal fishers in Sri Lanka, Thailand, Malaysia, the Philippines, and Indonesia live below poverty thresholds (Samaranayake this vol.; Janekitkosol et al. this vol.; Abu Talib et al. this vol.; Barut et al. this. vol.; Purwanto this vol.).

To completely understand the causes of poverty among artisanal fishers, one must not confine the analysis to the fisheries sector, but must look beyond it. However, it is still instructive to consider at factors within the fisheries sector. The obvious causes of poverty among artisanal fishers include dwindling fishery resources and the highly unequal distribution of the total catch in favor of the commercial sector, at least on a per capita basis (Pauly and Chua, 1988). Also, artisanal fishers are mired in poverty because they have few alternatives to fishing. This is the case in Sri Lanka, Thailand, the Philippines and Indonesia (Samaranayake this vol.; Janekitkosol et al. this vol.; Barut et al. this. vol; Purwanto this vol.).

Other factors are less well-known and may be confined to certain places. Some credit systems may increase the burden on artisanal fishers, as is the case in Bangladesh (Rahman et al. this vol.). In Indonesia a tendency among fishers, not to save, but to increase spending during periods of high catches has been observed (Purwanto this vol.).

Information and Research Inadequacies

In South and Southeast Asia, information needed to set appropriate levels of exploitation is generally insufficient (Silvestre and Pauly 1997c). Such information is available only for some major fisheries. In addition, the information may be outdated or irregularly collected. This project has contributed to ensuring the data available from trawl research surveys are accessible and analysed to assist mana-gement. The inadequacies of information and research are also often associated with low utilization of the research or information available (Silvestre and Pauly 1997c). The lack of or low utilization of data results in a weak basis for the development of fisheries and environmental policies.

Inadequate Fisheries and Environmental Policies

Most of the countries in the region have fisheries and environmental policies, to varying degrees. However, the inadequacy of these policies is clear when the degraded state of the resources is demonstrated. Table 20 contains examples of policy inadequacies identified during the national strategic reviews. For most examples the main factor that led to the inadequacy seems to be the lack of information. In some cases the lack of skill in policy analysis is apparently at the root of the problem, or at least a part of it.

Weak Inter-agency Coordination

Weak inter-agency coordination is noted in most countries in the region (Table 19). This factor can result in contradictory law enforcement or inefficient use of limited resources. For example, in Bangladesh while the Fisheries Department seeks to protect the nursery areas in the Sunderbans mangroves, the Forestry Department allows fishing in those areas (Rahman et al. this vol.). Given the limited resources available in these countries, efficient inter-agency coordination is needed to ensure the effective use of the resources.

Table 20. Examples of policy inadequacies in South and Southeast Asia.

Country	Policy inadequacy	Reference
Bangladesh	Unplanned development of shrimp culture	Rahman et al. (this vol.)
India	Lack of policies for managing particular fisheries	Vivekanandan et al. (this vol.)
Malaysia	No legislation to establish sea grass protected areas	Abu Talib et al. (this vol.)
Thailand	Fishing fees do not reflect value of resource rents Policies that unwittingly increase fishing effort: 1. Fuel subsidies for fishing boats 2. Allowing aliens to work as crews, thus increasing the number of fishers Tax on imported trash fish meal. This has increased demand for local trash fish. Juveniles of commercially important species may comprise up to 32% of local trash fish Subsidy to lower the price of tuna	Janekitkosol et al. (this vol.)

Weak Law Enforcement

In the region insufficient enforcement capabilities result in the proliferation of illegal activities, including: encroachment by commercial fishers into areas reserved for artisanal fishers, destructive fishing, violations of mesh size regulations, operation of unlicensed boats, and violations of regulations in mangrove reserves and marine protected areas. The weak law enforcement is linked to other institutional weaknesses such as the low level of stakeholder participation in management.

Lack of Compliance with Regulations

In South and Southeast Asia, the list of institutional weaknesses and constraints in Table 20 suggests that most problems in fisheries can be traced to the government's failure as a regulator. However, resource users are not without blame. In India, Malaysia, the Philippines and Indonesia, the resistance of fishers to regulatory measures is regarded as a significant constraint (Vivekanandan et al. this vol.; Abu Talib et al. this vol.; Barut et al. this. vol.; Purwanto this vol.). In Sri Lanka, the extent of public participation in resource management is said to be less than desired (Samaranayake this vol.).

Fisheries Management Opportunities

The National Strategic Reviews conducted by the participating countries identified potential management opportunities within each country. Increasing community and stakeholder participation in resource management, the presence of existing laws and regulations, and the potential existence of under-exploited fishery resources offshore were the most frequently identified opportunities.

There is growing evidence that increasing the levels of stakeholder participation in resource management may increase the effectiveness of the management (Berkes et al. 2001). This may be particularly important in situations where a "top-down" approach driven by the centralized government has failed to effectively manage the fisheries. This has been the case in many countries in the region. Increasingly, coastal communities, people's organizations, NGOs and other stakeholder groups in Malaysia and the Philippines are participating actively in the management of coastal resources (Abu Talib et al. this vol.; Barut et al. this vol.). It is hoped that the greater involvement of stakeholders will increase compliance and decrease enforcement costs. A related opportunity is the existence of traditional or indigenous resource management practices. For example, in Sri Lanka there is a rotational system governing the use of beach seines (Samaranayake this vol.). These traditional resource management practices provide a basis and a history for greater involvement of communities in resource management.

All the participating countries have existing laws and regulations that govern fisheries and the marine environment. These establish the right of the government to take lead in resource management. The existing laws and regulations also provide a basis for improvement. In some situations the laws are appropriate; it is the enforcement that is lacking.

All countries except the Philippines report the potential existence of under-exploited offshore stocks. However, this must be assessed rigorously. Economic and technological constraints presently limit access to these offshore resources. Thus, there are calls for governments to assist in overcoming some of these constraints and some governments are actively providing assistance to develop offshore fleets. An example is the suggestion to develop an offshore demersal fleet in Indonesia (Purwanto this vol.). Assuming that the technological and economic constraints can indeed be overcome (and this is debatable in particular cases), one must ask if it is wise to invest in and encourage such efforts without first addressing the inadequacies of a resource management system that failed to prevent the over-fishing of nearshore resources. In general, offshore resources are lower than nearshore (Marten and Polovina 1982; Pauly and Chua 1988), and without proper management may be rapidly depleted (Silvestre and Pauly 1997c). This can been seen in the stock assessment undertaken in Malaysia, where the catch rates and hence biomass, decrease with increasing depth or distance offshore (Abu Talib this vol.). If offshore resources are depleted, it is likely that the offshore vessels will then encroach on nearshore areas.

Fisheries Management Objectives and Interventions

Based on the recommendations from the multisectoral workshop, the objectives of coastal fisheries management in South and Southeast Asia are given in Fig 13. The management objectives relate to the issues documented previously (Fig. 13). In addi-

tion to considering the issues, the objectives were selected to reflect the resource management objectives stated in the national strategic reviews. An earlier version of this goal-objectives tree was presented at the March 2001 workshop and revised on the basis of suggestions from the conference participants, who were mostly from the countries. Thus, the objectives in Figure 14 are intended to represent aspirations of people in the region.

The overarching goal of sustainable utilization of coastal fishery resources is elaborated by environmental, socioeconomic and institutional objectives. The environmental objectives distinguish between fishery resources and the environment that sustains them. This distinction may seem unnecessary, since fishery resources are part of the environment, and therefore a single objective to protect the environment would cover fishery resources as well. However, the intent is to emphasize the need to broaden the scope of traditional fisheries management, to a "whole system" approach. This would acknowledge issues such as water quality, which were previously regarded as outside its scope.

The objective to maximize the economic benefits from the utilization of fishery resources is the single, all-encompassing economic objective. It implicitly incorporates objectives to minimize loss of resource rents and opportunity losses. The other socioeconomic objectives relate to the issues of poverty among artisanal fishers and resource-use conflicts, which are regarded as the most pervasive socioeconomic issues related to fisheries.

Finally, the institutional objectives call for strengthening national institutions at the domestic front and increasing cooperation and collaboration at the international level. These objectives are somewhat more specific than the environmental and socioeconomic objectives. They seem less of a description of "where do we want to go" and relate more to "how do we propose to get there." However, conference participants felt that building institutional capabilities is of such paramount importance that it must be emphasized as a fundamental objective.

To achieve the resource management objectives, the workshop recommended four specific interventions to be implemented by the respective countries and four support activities that would be more cost-effective if implemented at the regional level (Fig. 14). The workshop recognized that capacity building and institutional strengthening are sorely needed to overcome the institutional weaknesses and constraints that prevent the countries from effectively implementing resource management measures. In the countries the areas that should be strengthened vary from several agencies at various levels of government to the entire system for coastal fisheries management. Given the specific needs of each country, a general program of capacity building and institutional strengthening would be of little use. This strategy proposes the establishment of a regional Coastal Fisheries Research and Management Network, which will supply some of the training and information needs of the DMCs. Real capacity building and institutional strengthening, however, will have to be an ongoing, long-term concern.

The interventions are briefly described below.

Interventions for Implementation by Countries (Table 21)

Integrated Coastal Fisheries Management (ICFM)

This would involve the implementation of area- and/or fisheries-specific management plans to reduce or maintain fishing effort at sustainable levels and to protect coastal habitats. ICFM typically begins with interdisciplinary resource and social assessments to obtain an understanding of the resources, the environment, the resource users and the interconnections among these elements. This has commenced within the TrawlBase project, but needs to be undertaken at finer scales within countries, at scales appropriate to the management issues. A key feature of ICFM is stakeholder participation in planning and management to increase compliance with resource management measures. Greater stakeholder participation also creates opportunities for conflict resolution.

Supplemental/Alternative Livelihood for Artisanal Fishers

This program will provide artisanal fishers with skills to seek employment outside the fisheries sector or to engage in small businesses. Since artisanal fishers comprise the overwhelming majority of fishers, providing them with alternative sources of sustenance and income is potentially the most effective way to ease pressure on fish stocks.

System of Aquatic Protected Areas

In aquatic protected areas or marine reserves,

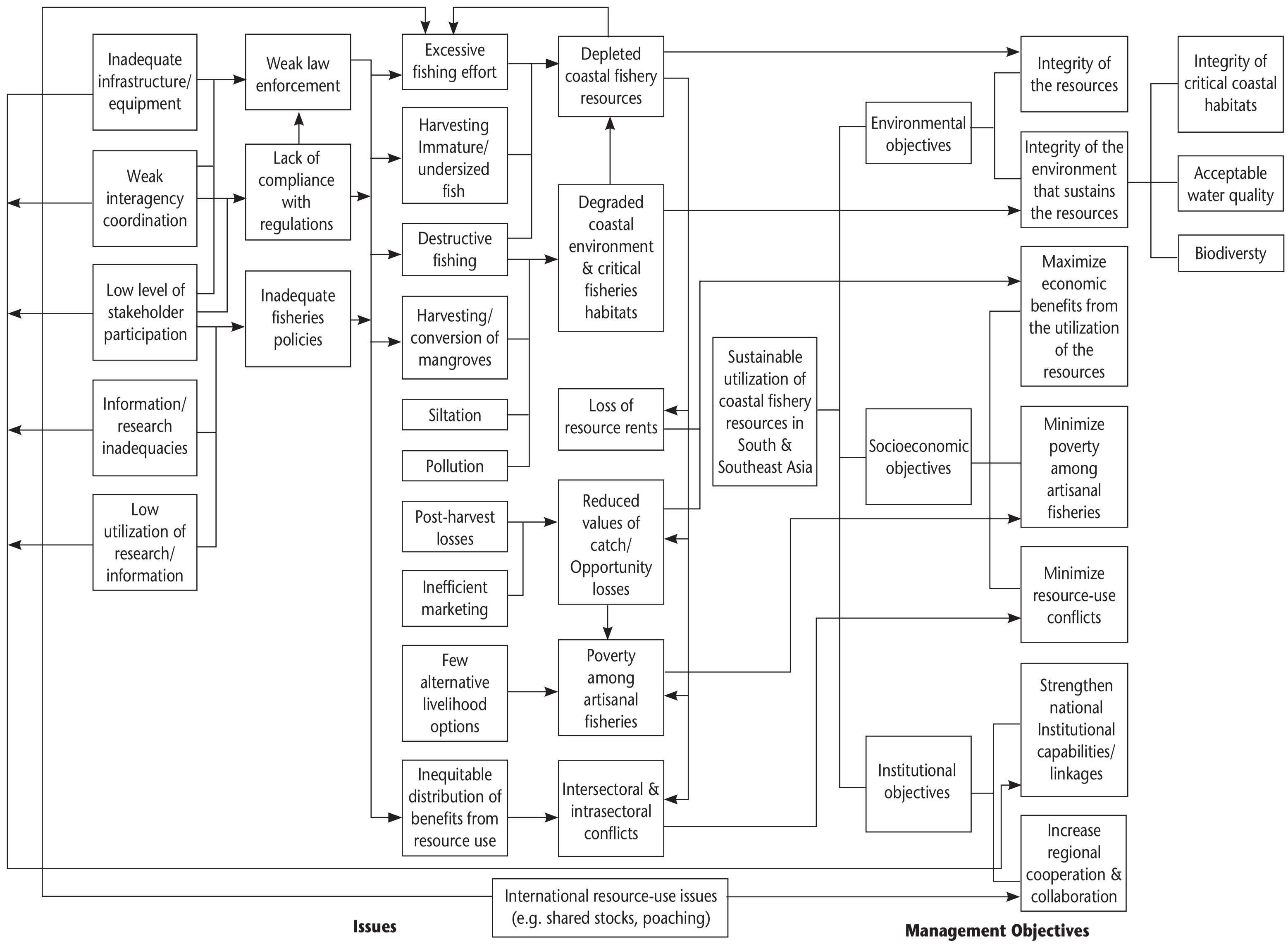

Fig. 13. Coastal fisheries management objectives to address the issues.

Table 21. The objectives pursued and issues addressed by the proposed interventions at the national level.

Intervention	Objective(s) Pursued	Issue(s) Addressed
Integrated Coastal Fisheries Management	Integrity of the resources	Depleted coastal fishery resources, loss of resource rents, excessive fishing effort, harvesting immature/undersized fish, destructive fishing
	Integrity of the environment that sustains the resources (Integrity of critical coastal habitats, biodiversity)	Degraded coastal environment and critical fisheries habitats, harvesting/conversion of mangroves
	Maximize economic benefits from the utilization of the resources	Intersectoral and intrasectoral conflicts, inequitable distribution of benefits from resource use
	Minimize resource-use conflicts	Lack of compliance with regulations, low level of stakeholder participation
Supplemental/Alternative Livelihood for Artisanal Fishers	Minimize poverty among artisanal fishers	Poverty among artisanal fishers, few alternative livelihood options
	Integrity of the resources	Depleted coastal fishery resources, loss of resource rents, excessive fishing effort, harvesting immature/undersized fish, destructive fishing
System of Aquatic Protected Areas	Integrity of the resources	Depleted coastal fishery resources, harvesting immature/undersized fish, destructive fishing
	Integrity of the environment that sustains the resources (Integrity of critical coastal habitats, biodiversity)	Degraded coastal environment and critical fisheries habitats, harvesting/conversion of mangroves
Minimizing By-catch and Post-harvest Losses	Maximize economic benefits from the utilization of the resources	Opportunity losses, post-harvest losses
Capacity building and institutional strengthening*	Strengthen national institutional capabilities/ linkages	Weak law enforcement, inadequate fisheries policies, inadequate infrastructure/equipment, information/research inadequacies, low utilization of research/information

Note: * Capacity building and institutional strengthening are suggested as a general recommendation. No specific activities have been specified.

human activities such as fishing may be strictly controlled or prohibited altogether to allow the replenishment and rehabilitation of fish stocks and other aquatic organisms. An aquatic protected area may be designed to achieve a variety of conservation objectives, including reducing fishing mortality, optimizing fishing patterns or spatio-temporal distribution of fishing effort, conserving biodiversity, protecting endangered species, and rehabilitating habitats or ecosystems. A system of aquatic protected areas should be planned from a national perspective to ensure the protection of the species or habitats that are most vulnerable and/or environmentally valuable.

Minimizing By-catch and Post-harvest Losses

This will involve: (1) extension work and training to improve fish handling; (2) education campaigns on minimizing by-catch; and (3) product development research on using by-catch as raw material.

Regional Support Activities (see Fig. 14)

Coastal Fisheries Research and Management Network

A regional network will provide information, training and advisory support to assist the countries in implementing the above interventions and other

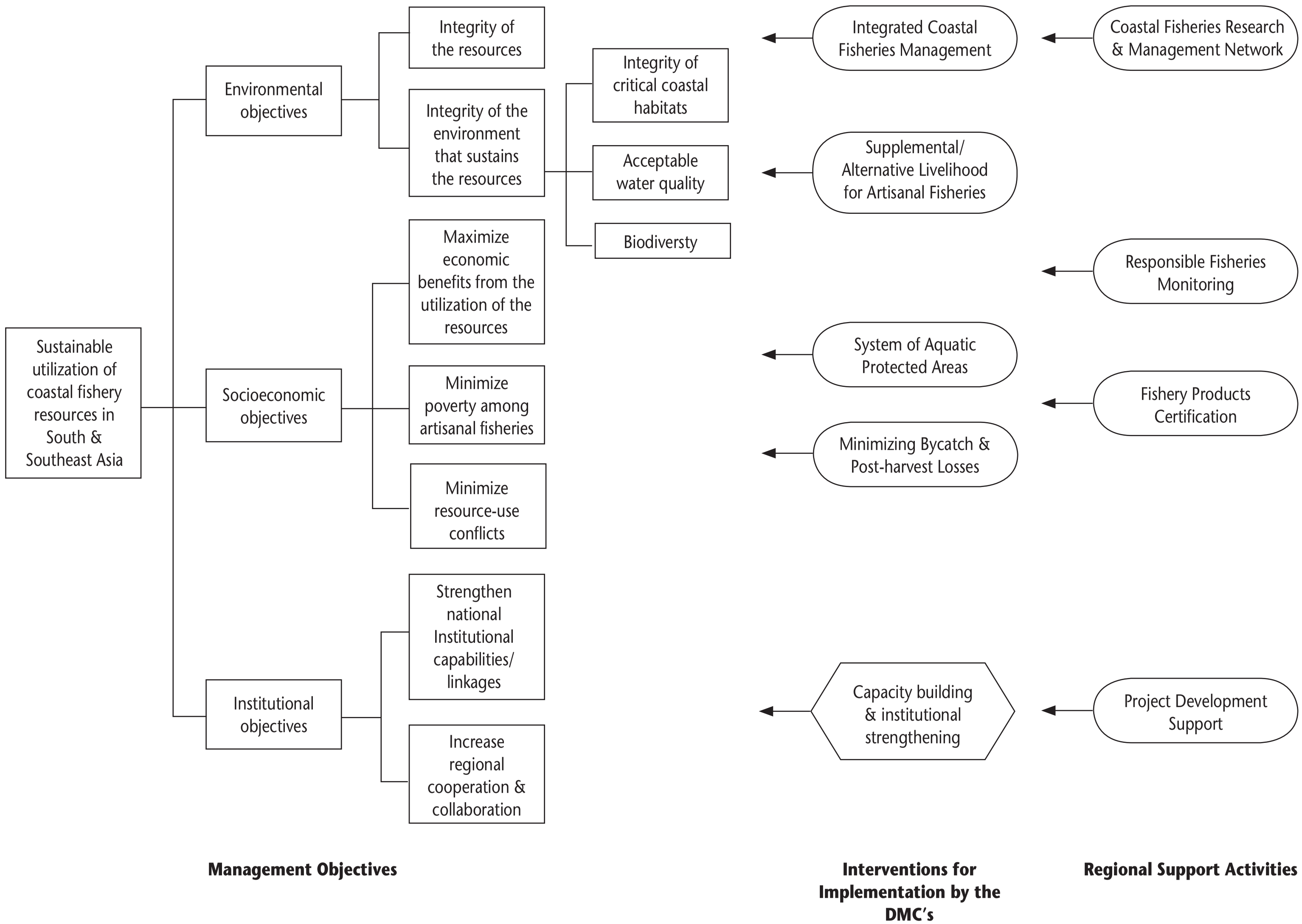

Fig. 14. The interventions to achieve the objectives.

action programs toward responsible fisheries. The network will promote research collaboration and institutional exchanges, thus supporting the capacity building efforts of countries. It would also facilitate the elaboration, implementation and review of regional and national agendas for responsible fisheries.

Responsible Fisheries Monitoring Network or Program

This program will establish an independent system of monitoring and reporting on compliance with principles, standards, norms and guidelines of responsible fisheries. It will involve the development of an objective, independent, credible set of indicators and monitoring tools, which will be used to increase public awareness of the performance of national fisheries towards responsible fisheries.

Fishery Products Certification Program

This program will establish an independent, non-governmental certification system on responsibly produced fishery products (e.g. Marine Stewardship Council certification, "dolphin-friendly" tuna and "turtle-friendly" shrimp).

Project Development Support

The strategic reviews prepared by the National Project Teams contain three major elements, namely, (1) an analysis of the issues; (2) recommendations; and (3) project proposal summaries intended to translate the more important recommendations into projects worthy of funding. All strategic reviews contain a thorough analysis of issues and appropriate recommendations. Unfortunately, the project proposal summaries comprise the weakest section in most strategic reviews. In some cases the set of projects address the more important issues inadequately. In other cases the quality of individual projects could be substantially improved. Some countries only require small grants to allow team members or local experts to properly develop and package projects. Others require technical assistance in order to develop projects to address the issues identified.

The Scope of the Interventions: Achieving A Balance Between Comprehensiveness and Practicality

The four national and the four regional interventions together comprise a comprehensive program that will address almost all resource management objectives and issues. There are reasons why the interventions will not address or only partly address certain issues and objectives.

There is no intervention that deals specifically with water quality, siltation and pollution. Integrated Coastal Fisheries Management can partly address these issues. Yet the real solution to these issues lies in controlling human activities in the catchments and minimizing externalities from other sectors such as forestry, agriculture and industry. When the interactions among these other sectors and fisheries must be taken into account, ICFM can be subsumed under a larger Integrated Coastal Area Management Program or an Integrated Coastal Area and River Basin Management Program (UNEP 2000).

This strategy focuses on activities that are closer to the fisheries domain because those who will lead its implementation are likely to come from fisheries organizations. It is also practical to start with a few, focused activities, which can be expanded later as experience is gained and when the need arises.

From Recommendations to Action

The interventions proposed by this strategy will help realize many provisions in the Code of Conduct for Responsible Fisheries and in Agenda 21 of the UN Conference on Environment and Development. Thus, the strategy deserves the support of the countries and the international community.

The first step to implement the strategy is to organize a Project Development Support group consisting of persons who are knowledgeable about the proposed interventions and the institutional aspects of their implementation. This group will work with the countries to develop the interventions into projects, which will be submitted to funding agencies. The WorldFish Center, having worked with the countries, would be a suitable base for the Project Development Support group.

Next, an international meeting or a series of such meetings should be organized to establish the Coastal Fisheries Research and Management Network, the Fishery Products Certification Program, and the Responsible Fisheries Monitoring Network/ Program. The participants of the meeting should include high-level representatives from the countries and from international organizations that are active in coastal fisheries management in the region, such as the WorldFish Center, Food and Agriculture Organization (FAO) - Asia-Pacific Commission (APFIC), Southeast Asian Fisheries Development Center (SEAFDEC), and the World Wildlife Fund. Thus, resource management activities can proceed simultaneously at national and regional levels.

Summary and Conclusion

The result of over-fishing in South and Southeast Asia is that coastal fish stocks have been severely depleted. Resources have been fished down to 5 - 30% of their unexploited levels. Such declines have increased poverty among coastal fishers who are already among the poorest of the poor in developing Asian countries. Over-fishing has also reduced the contribution of coastal fisheries to employment, export revenue, food security and rural social stability in these nations. The trends (resource decline, increasing poverty and impaired contribution to national development) are expected to worsen as coastal populations increase, unless remedial action is undertaken.

Measures to reduce poverty among coastal fishers and fishing communities cannot be divorced from the need to address the downward spiral in coastal fisheries resources. As recognized at the 2002 World Summit on Sustainable Development (WSSD), the restoration and improved management of stocks is urgently required to reduce poverty among fishers and sustain the contribution of coastal fisheries to the economies of developing countries. Owing to the technical, personnel and financial constraints faced by many Asian countries, however, the rehabilitation and improved management efforts needed to rebuild fish stocks to more productive levels will depend on catalytic interventions to identify and implement the measures. Sustaining the gains over the long-term will also depend on increasing national capacity in coastal fisheries assessment, rehabilitation, planning, management and policy reform.

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An Overview of the Fisheries Resource Information System and Tools (FiRST) Version 2001: A Database Management System for Storing and Analyzing Trawl Survey Data[1*]

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Abstract

Demersal trawl surveys have been used for assessments of fisheries potential and monitoring the status of fish stocks in many countries in South and Southeast Asia. This paper presents the development of a database system, the "Fisheries Resource Information System and Tools" (FiRST), from a regional collaborative effort between eight countries and the WorldFish Center. The effort has collated about 21 000 hauls/stations from research trawl surveys across the South and Southeast Asian region.

FiRST (ver. 2001) was designed as a data management system (to organize, store, retrieve and exchange) for extant trawl surveys. In addition, the database system includes an analytical routine to approximate biomasses and generic socioeconomic data, as well as catch and effort statistics for coastal fisheries. Analytical modules from other software needed for data analyses have also been made accessible via the database system.

This paper also presents some examples of the utility of retrospective analysis of trawl survey data in establishing resource baselines and improving understanding of the biology and exploitation status of coastal fishery resources. The database system is now an important regional repository of information for management of coastal fish stocks in developing Asian countries. FiRST is envisioned to provide solid foundations for the formulation of appropriate fisheries management strategies and action plans at the national and regional level.

[1] This paper was also presented at the International Symposium on Oceanographic and Information Management with special attention to biological data. 25 - 27 November 2002, Brussels, Belgium.
[*] WorldFish Center Contribution No. 1710

Introduction

Resource surveys (e.g. experimental trawl fishing) have been conducted since the early 1900s principally to identify productive fishing grounds and determine the abundance and distribution of fisheries resources. Demersal trawl surveys have been suggested to represent the most straightforward way of finding how much and what kinds of fish occur in a given area (Pauly 1996). In South and Southeast Asia, at least 301 trawl surveys have been carried out in the region between the 1920s to 1990s; they have covered an approximate of 40 000 trawl stations (Silvestre and Pauly 1997). Retrospective analysis of these data would clarify underlying causes and rates of ecological change, and also demonstrate achievable goals for restoration and management of coastal ecosystems that can not be derived from the limited perspective of recent observations.

In July 1996, a Workshop on "Sustainable Exploitation of Coastal Fish Stocks in Asia" was organized by the WorldFish Center (formerly ICLARM - the World Fish Center) with participation of seven countries in Asia. A consensus was achieved on the usefulness of compiling and analyzing past trawl surveys in establishing benchmarks for stock rehabilitation, supplementing existing statistical baselines and improving management directions and strategies (Silvestre and Pauly 1997). A prototype database and analytic tool for this purpose was presented and evaluated during the Workshop using available data from surveys in South and Southeast Asia (Gayanilo et al. 1997).

From 1998 to 2001, the prototype database and analytic tool was further improved and developed by the WorldFish Center with assistance from the Asian Development Bank (ADB). With participation of eight countries namely, Bangladesh, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam, the FiRST software was developed to serve as a database system for extant trawl surveys. The database system also provides access to analytic modules from other software for proper data analyses.

The project - "Sustainable Management of Coastal Fish Stocks in Asia (ADB-RETA No. 5766)" - aimed to: (1) strengthen the capabilities of selected institutions in participating Developing Member Countries (DMCs) in the area of coastal fisheries assessment and management; (2) develop a database (based largely on extant trawl surveys and related environmental and socioeconomic information) relevant to the management needs of the DMCs; and (3) examine management implications (including strategies and action plans as appropriate) of analyses of results based on data contained in the database and related information (Silvestre et al. 2000). This project is commonly referred to throughout the Asian region as the "TrawlBase" project. Full details of the project components and activities are described in *http://www.worldfishcenter.org/trawl.*

The WorldFish Center has given priority to the development of databases for use in management of aquatic resources such as FishBase - a global encyclopedia of fishes (Froese and Pauly 2000), and ReefBase - a global database of status and threats to coral reefs (Vergara et al. 2000). FiRST has been developed and designed to complement these global databases and also to provide fisheries managers with information on the status of fish stocks and options for restoring production of coastal fisheries resources.

This paper presents the main features of the FiRST (ver. 2001) software and highlights key results from retrospective analysis of trawl survey data. The analyses provide evidence of the resource situation (i.e. biological extent of excessive fishing).

The Fisheries Resource Information System and Tools (FiRST)

FiRST (ver. 2001) is a Microsoft Access-based database system principally designed as data container (to organize, store, retrieve and exchange) from trawl surveys. Basic analytical routines such as models to approximate biomasses have also been developed and made an integral part of FiRST. The detailed technical description and documentation of the database system is given by (Gayanilo et al. 2001).

The following minimum configuration is required for the system to work:

- Microsoft Windows 95 or 98
- At least 64 MB RAM
- A 1024 x 768 high resolution monitor; and
- At least 5MB free-space in the Windows directory and another 12 MB for the destination address.

The database system contains nine interrelated main tables as illustrated in Fig. 1; their contents and functions are described in Table 1. The general features of the forms (or user interface) used in FiRST are similar to the standard features of commercially available Windows-based programs. The main form in the database system is the catch form (Fig. 2), which contains catch data in a given fishing station. The information includes the taxon (or scientific name), total catch (in kg), sample weight (in g), and sample count or number of sample specimens recorded. Scientific names and species codes (e.g. ISSCAAP[2] or NANSIS[3]) can be encoded directly, or selected from a list constructed from previous entries. The database system is also configured to check the valid scientific names using FishBase.

The catch data is linked to the station form, which contains information on geographic location of each trawl haul/station (see Fig. 3). Hence, using a mapping routine and geographic information system (GIS), the spatial distribution of a given species /taxa can be generated from the database.

Other important forms in the database system are gear details and trawler forms. The gear details form records technical details of the gear used in the trawl survey while the trawler form records the technical specifications of the vessel used for the survey. These forms also allow the storage of the scanned image of the gear or trawler. Fig. 4 for example, shows the scanned images with technical specifications of the gear used in the trawl survey. The headline width, although not a required input, is necessary to estimate biomass using the swept-area method. In the absence of the headline width as input, FiRST (ver. 2001) assumes the value to be 50% of the length of the headrope (Pauly 1980). Similarly, the scanned image with technical specification of the research vessel (or fishing boat) can be stored in the trawler form.

Data access protocols in FiRST (ver. 2001) have been established based on recommendations and consultations with various partners (mostly government agencies mandated for fisheries management) under the TrawlBase Project. The FiRST software has been distributed to the eight participating countries of the project and copies of the software can be obtained upon request from the WorldFish Center. The data access classification in FiRST (ver. 2001) is as follows (Gayanilo et al. 2001): (1) Restricted - only users with proper authorization; (2) Conditional accessible - data which are older than five years, unless otherwise indicated by the national database coordinator; and (3) Fully Accessible - data with no restrictions as to their distribution and use. The trawl data contained in FiRST can be obtained from the country and permission must be secured with the particular country for data access of country-specific data (see*http://www.worldfishcenter.org/trawl* for contact details of the partners).

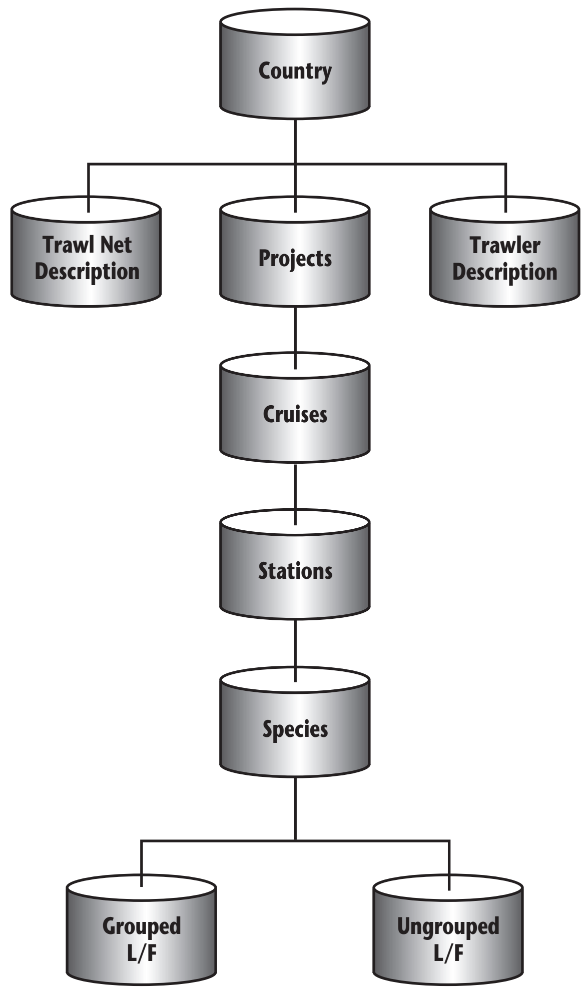


Fig. 1. Schematic representation of the main tables in FiRST (ver. 2001) and their relationships. (Note: L/F means length frequency).

[2] ISSCAAP - International Standard Statistical Classification of Aquatic Animal and plants.
[3] NANSIS is a software for fishery survey data logging and analysis developed by FAO.

Table 1. Main tables of FiRST (ver. 2001), their contents and functions (adapted from Gayanilo et al. (2001)).

Name	Function
Country	Contains information taken from the country table of FishBase 99. The information is static, i.e. it changes only as FishBase changes. A supporting table is attached to this table for remarks about the country.
Trawl Net Description	Contains basic information about the trawl/experimental gear(s) used in the project(s), particularly parameters required to estimate the area swept by the gear.
Trawler Description	Contains basic technical details of the vessel(s) used in the project(s).
Project	Lists all projects undertaken in the country and describes them (e.g. project objectives, collaborating institutions, implementing agencies, etc.).
Cruise	Contains information describing a particular cruise in a project using a specific trawler and trawl net.
Station	Contains other station-related parameters such as geographic location and geophysical condition of the station and trawling period.
Species	Records the catches (in number and weight) by species/taxa. The biomass and catch per unit effort (CPUE) fields in the table are not filled in by the user but by FiRST when the biomass estimation routine is activated.
Grouped L/F	Records frequencies grouped in length classes. The headers, defining the class size, unit used and lower limit of the smallest length group, are stored in the Species table.
Ungrouped L/F	Contains individual length measurements.

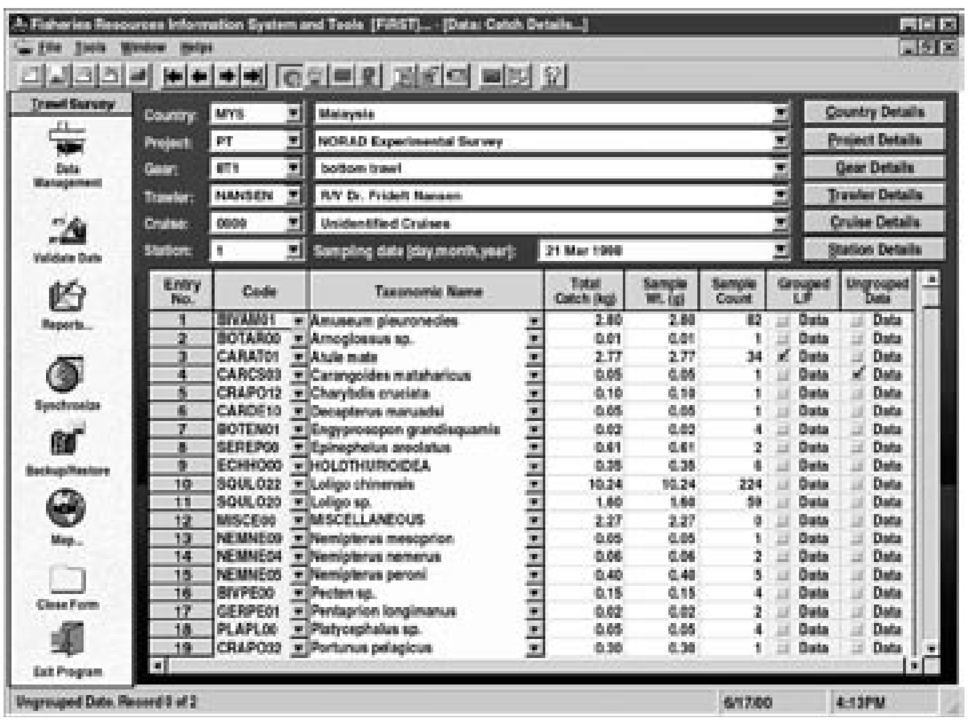


Fig. 2. The catch form of FiRST (ver. 2001). Note that the last two columns indicate presence of related data.

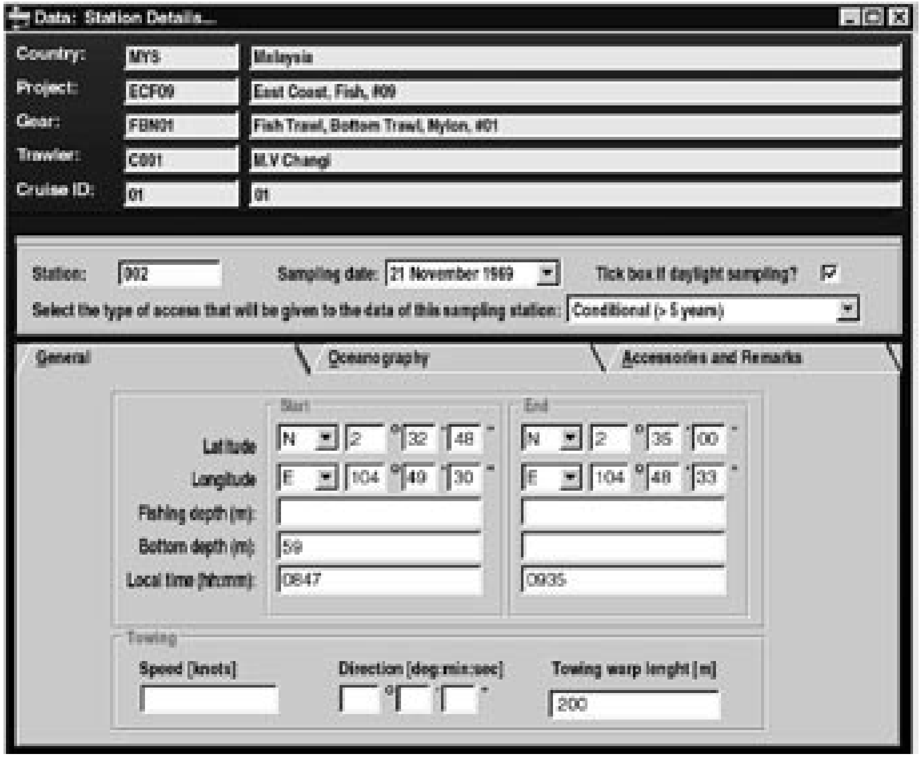


Fig. 3. The station form of FiRST (ver. 2001) to record station-related information.

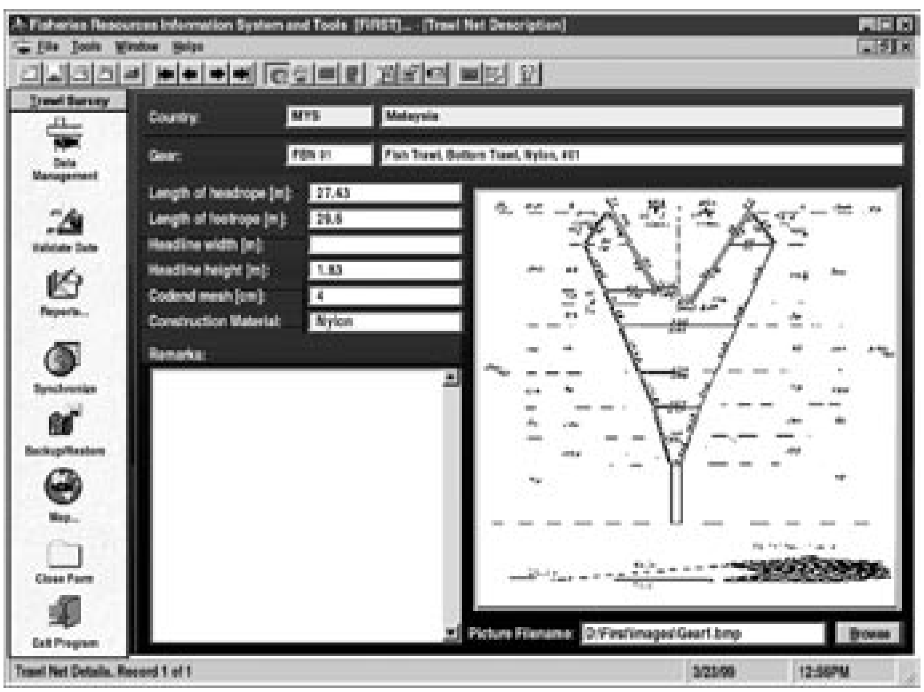
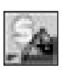


Fig. 4. The gear details form in FiRST (ver. 2001). Note that a scanned picture of the gear used for the trawl survey can be stored.

Basic analytical routines, such as models to approximate biomasses, have been developed and made an integral part of FiRST (ver. 2001). Analytical modules from other software needed for data analyses have been made accessible via the database system (Table 2). These include, among others, FiSAT (Gayanilo et al. 1996) for fish population dynamics and fish stock assessment and Ecopath with Ecosim (Christensen et al., 2000) for ecosystem modeling. To facilitate the use of these external softwares, modules have been developed to allow the saving of data in the required format.

Table 2. Available analytical modules in FiRST (version 2001).

Icon	Title	Description
	Map...	Activates the mapping routine.
	Biomass...	Activates the mapping routine.
	Population Dynamics	Links to modules on fish population dynamics and stock assessment which are yet to be developed.
	Community Analysis	Links to modules on fish assemblage analysis which are yet to be developed.
	Ecosystem Modeling	Links to modules on ecosystem modeling which are yet to be developed.
	Bioeconomics	This function is for modules on bioeconomics.

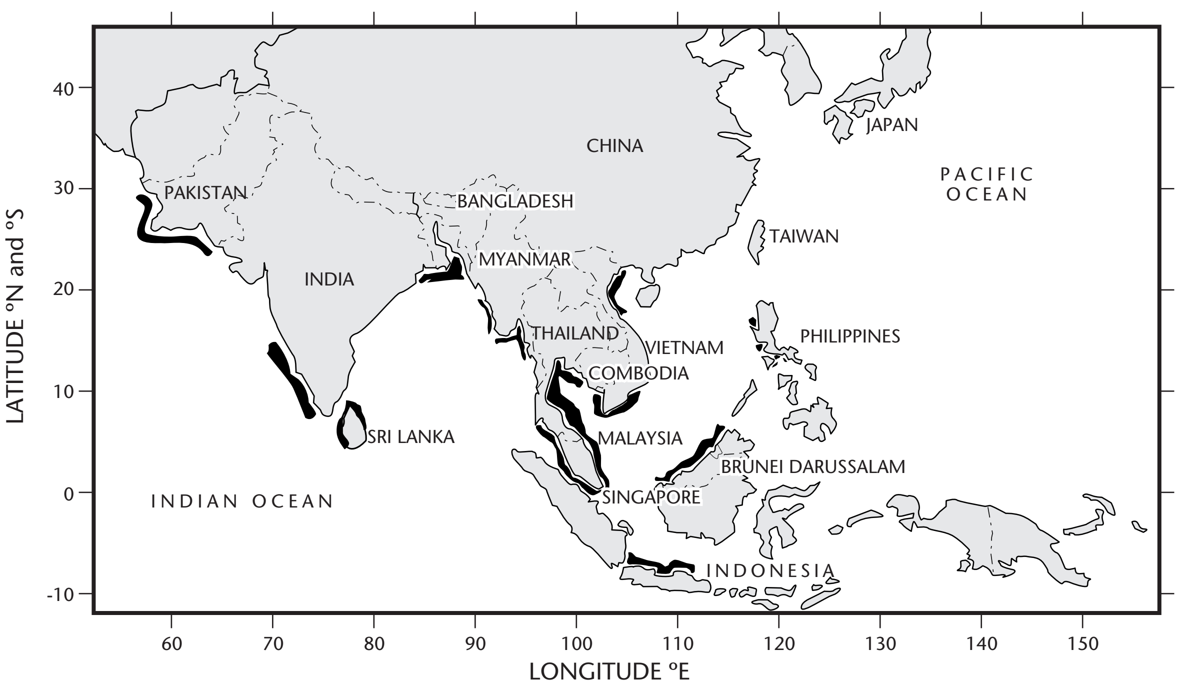


Fig. 5. Geographical coverage of trawl survey data in FiRST (ver. 2001).

Collectively, the database system contains about 20 620 hauls/stations from eight participating countries and published trawl data from Singapore, Myanmar and Pakistan. Fig. 5 shows the geographical distribution of these data and Table 3 gives a list of the distribution of the trawl data contained in FiRST (ver. 2001). In addition to the trawl survey data, the FiRST 2001 release also includes socio-economic and related information from the eight participating countries (Table 4).

Table 3. List of trawl surveys contained in the database system (FiRST ver. 2001).

Country	Survey Areas	Name of Project/Survey	No. of Cruises	No. of Stations	Year
Malaysia	East Coast of Peninsular Malaysia	East Coast, #01	13	341	1926
	East Coast of Peninsular Malaysia	East Coast, #02	9	262	1927
	East Coast of Peninsular Malaysia	East Coast, #04	4	153	1967
	East Coast of Peninsular Malaysia	East Coast, #07	6	148	1972
	East Coast of Peninsular Malaysia	East Coast, #09	37	822	1969 - 73
	East Coast of Peninsular Malaysia	East Coast, #11	4	85	1981 - 85
	East Coast of Peninsular Malaysia	East Coast, #13	6	130	1984
	East Coast of Peninsular Malaysia	East Coast, #16	5	114	1986
	East Coast of Peninsular Malaysia	East Coast, #19	5	186	1991
	West Coast of Peninsular Malaysia	West Coast, #01	3	64	1926
	West Coast of Peninsular Malaysia	West Coast, #02	13	303	1927
	West Coast of Peninsular Malaysia	West Coast, #05	4	121	1971
	West Coast of Peninsular Malaysia	West Coast, #06	4	79	1972
	West Coast of Peninsular Malaysia	West Coast, #07	4	105	1973
	West Coast of Peninsular Malaysia	West Coast, #08	4	93	1974
	West Coast of Peninsular Malaysia	West Coast, #11	4	103	1980
	West Coast of Peninsular Malaysia	West Coast, #12	4	192	1981
	West Coast of Peninsular Malaysia	West Coast, #13	3	44	1984
	West Coast of Peninsular Malaysia	West Coast, #15	1	50	1987
	West Coast of Peninsular Malaysia	West Coast, #16	4	52	1988
	West Coast of Peninsular Malaysia	West Coast, #18	5	61	1990 - 91
	West Coast of Peninsular Malaysia	West Coast, #19	4	32	1992 - 93
	Sabah - Sarawak Waters	Sabah, Sarawak #01	3	87	1927
	Sabah - Sarawak Waters	Sabah, Sarawak #07	10	300	1972
	Sabah - Sarawak Waters	Sabah, Sarawak #11	6	134	1981
	Sabah - Sarawak Waters	Sabah, Sarawak #12	3	141	1986
	Sabah - Sarawak Waters	Sabah, Sarawak #14	1	17	1986
	Sabah - Sarawak Waters	Sabah, Sarawak #15	12	96	1989 - 93
		ALL Malaysia Surveys	177	4 418	
Philippines	Malampaya, Palawan	Assessment of the Fisheries	14	60	1975,1979
	Philippine Waters	Otter trawl explorations	24	157	1947 - 49
	Samar	Samar Sea Trawl Survey	11	300	1980
	San Miguel Bay	San Miguel Bay	22	64	1992 - 93
	Ragay Gulf	REA of Ragay Gulf	1	62	1994 - 95
	San Pedro Bay	San Pedro Bay	17	158	1994, 1995
	Manila Bay	Manila Bay	36	37	1992, 1993
		ALL Philippine Surveys	125	838	
Thailand	Gulf of Thailand	Bottom trawl survey	106	5 890	1968 - 76
Singapore	Mostly offshore	M/V Changi survey	42	925	1969 - 73
Indonesia	Western Indonesia	RV Mutiara survey	2	1 376	1974 - 79
Myanmar	Myanmar waters	Surveys on the Marine Fisheries	4	375	1979 - 80

Table 3. List of trawl surveys contained in the database system (FiRST ver. 2001). (continued)

Country	Survey Areas	Name of Project/Survey	No. of Cruises	No. of Stations	Year
Bangladesh	EEZ of Bangladesh	Bottom trawl survey (fish)	32	1 021	1984 - 87
		Acoustic survey (bottom & pelagic)	12	324	1988
		Marine Fisheries survey	7	90	1980
		Shrimp trawl survey	4	15	
		ALL Bangladesh Surveys	55	1 450	
India	Southwest coast of India	Experimental fishing	12	613	1994 - 95
Sri Lanka	Waters around Sri Lanka	Fish Resource Survey in Sri Lanka	13	393	1920, 1921
		Resource Survey (RV F. Nansen)	3	225	1978 - 80
		ALL Sri Lanka Surveys	16	618	
Vietnam	Vietnamese Sea Waters	Fishery Survey in Vietnam	78	3 894	1979 - 82
	Southwest Sea Waters	Fishery Survey in Vietnam	4	127	1993 - 95
		ALL Vietnam Surveys	84	4 021	
Pakistan	Pakistan waters area in Pakistan	Records on survey area in Pakistan	5	96	1976
	TOTAL (ALL countries)			20 620	

Table 4. Summary of the standard workbooks and worksheets as provided by FiRST (ver. 2001) to store socioeconomic and related information.

Workbook	Worksheet	Description
Socioeconomic Profile	A.1	Fishery production and value by fishery sector
	A.2.1	Gross national product (GNP), gross domestic product (GDP) and gross value added (GVA)
	A.2.2	Income and employment indicators by sector
	A.2.3	Volume and value of fish exports and imports
	A.2.4a	Food balance sheet of fish and fishery products in live weight and fish contribution to protein supply
	A.2.4b	Household expenditure by food item
	A.2.5	Projected production and demand for fish
Fleet Operation Dynamics	B.1a	Number of vessels and characteristics
	B.1b	Other indicators of fishing operation
	B.2a	Productivity efficiency indicators
	B.2b	Estimated production function by type of fishing gear
	B.3.1	Investment costs by major assets
	B.3.2a	Monthly fixed costs
	B.3.2b	Monthly variable costs
	B.3.3	Costs, earnings and profitability
	B.3.4	Share system, mode and frequency of payment
	B.3.5	Capital intensity and cost effectiveness indicators
	B.4	Amount and proportion of discards/ bycatch by type of gear
	B.5a	Catch composition by type of gear
	B.5b	Price of fish by type of species
Bioeconomic Modeling	C.1	Catch and effort data
	C.2	Catch and effort data by type of gear

Some Illustrative Examples of the Results of the Analysis

Results of the resource analyses conducted under the TrawlBase project illustrate substantive degradation and over-fishing of coastal fish stocks in the areas covered by the studies. The analyses indicate that catch rates, and hence resource biomass, have declined to about 5 to 30% of original ("baseline") biomass levels in these areas (see *http://www.worldfishcenter.org/trawl*). Table 5 gives some illustrative examples on decline in total biomass in Asian fishing areas. The compiled population parameters from length-based assessments indicate that E (exploitation ratios) values of more abundant species are above the optimum levels (i.e. 0.3 - 0.5), and thus confirm the trends in biomass decline from the trawl surveys (Silvestre and Garces In press).

There are also indications of undesirable changes in relative abundance of species/taxa in the trawl survey catches. For example, the abundance of more valuable species (such as groupers, snappers, sharks and rays) has decreased sharply while smaller, less valuable species have increased in numbers (i.e. cardinal and trigger fishes).

The results of analyses of trawl survey data using software for community and ecological studies (e.g. TWINSPAN, CANOCO) also showed assemblage boundaries at about 50 m and 100 m depth. This type of information will be useful for policy recommendations in designing or revising zonation schemes for fisheries management.

Table 5. Some estimates of the declines in demersal biomass from trawl surveys in Asian countries (adapted from Garces et al. (2001))

Country Area	Year	Stock Density ($t \cdot km^2$)	Relative Density (%)	Source
PHILIPPINES				
San Miguel Bay	1947	10.60	100.00	Warfel and Manacop (1950)
	1980 - 81	2.13	20.10	Vakily (1982)
	1992 - 93	1.96	18.50	Cinco et al. (1995)
Manila Bay	1949 - 52	4.61	100.00	Warfel and Manacop (1950)
	1992 - 93	0.47	10.20	MADECOR (Mandala Agricultural Development Corporation) and National Museum (1995)
INDONESIA				
Java Sea	1977	3.72	100.00	Naamin (2001)
	1998	2.20	59.10	
MALAYSIA				
West Coast	1971 - 72	2.44	100.00	Abu Talib et al. (this volume)
	1997	0.36	15.06	
East Coast	1972	5.09	100.00	Abu Talib et al. (this volume)
	1998	0.20	3.90	
Sarawak	1972	3.90	100.00	Abu Talib et al. (this volume)
	1998	1.11	28.50	
Sabah	1972	12.52	100.00	Abu Talib et al. (this volume)
	1998	0.87	6.90	
THAILAND				
Gulf of Thailand	1961	6.70	100.00	Kongprom et al. (this volume)
	1991	0.55	14.20	

Conclusion

FiRST currently contains nearly 21 000 stations from eight countries in South and Southeast Asia. This has allowed retrospective analyses of trawl data, providing insights into the extent of over-fishing and the tremendous decline in demersal biomass (i.e. 4 to 60% of original un-fished levels). FiRST is now an important regional repository of information for sustainable management of coastal fish stocks in eight Asian countries. The development of FiRST provides a solid basis for countries to formulate and implement improved policies for fisheries management.

The FiRST (version 2001) software is distributed by the WorldFish Center. Access to country-specific data contained in FiRST requires permission from relevant government institutions in the participating countries. There are plans for further enhancement of the FiRST database through expanded geographic and temporal coverage. The analysis modules, such as models to approximate fish biomasses and mapping routines, can also be developed further.

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Fisheries Impact on the South China Sea Large Marine Ecosystem: A Preliminary Analysis using Spatially-Explicit Methodology*

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Abstract

A multiple regression model is derived, based on biomass estimates in 16 mass-balance food web (Ecopath) models, which explains 68 % of the variation in the data at hand, and shows that the abundance of fish with trophic levels of 3.0 or more in the South China Sea area had declined, by 2000, to less than half its value in 1960. This is worrisome, as this generalizes to the entire region declining trends observed in local areas within the South China Sea. Moreover this estimate is almost surely too conservative, given the method we used. This declining trend is compatible however with the fishing 'down marine food webs', reported from well studied parts of the South China Sea, notably the Gulf of Thailand, where the mean trophic levels of landings have declined, indicating gradual replacement in the underlying ecosystems of large, long lived, high-trophic level fishes by small, short-lived, low trophic level species often described as 'trashfish'. The only exception to these trends is Brunei, whose offshore oilrigs have led to regulations precluding trawling across much of the shelf, thus in effect creating a marine reserve. We conclude by pointing out that marine reserves are indeed one approach that will have to be used if the present declining trends are to be reversed, along with a rollback of excessive fishing effort.

Introduction

Fisheries impact not only on the stocks they exploit, but also the ecosystems in which the stocks are embedded (Gislason et al. 2000; Hall 1998). This is particularly true for demersal trawl fisheries, which

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are non-selective and also impact on the habitat on which the fish depend. Indeed, contrary to a still widely spread perception, fisheries are causing the major impact on marine ecosystems, far outweighing effects such as pollution and environmental changes. This is particularly true in Southeast Asia where regime shifts such as are observed in the North Pacific do not appear to occur, and hence where fisheries operate in an almost pure 'experimental' setting (Christensen 1998; Pauly and Chuenpagdee 2003).

We investigate here the impact of fisheries on the South China Sea system using a subset of the data collected and models constructed during the ADB-RETA 5766 project (Sustainable Management of Coastal Fish Stocks in Asia), and a spatially-explicit methodology developed for analyzing fisheries impact on marine ecosystems (Christensen et al. 2003).

Materials and Methods

Materials

Table 1 summarizes the major characteristics of the mass-balance food web (Ecopath) models, used here as starting point for this analysis.

The spatially explicit primary production data used here originated as SeaWiFS data, as processed by the European Union's Joint Research Center, in Ispra, Italy (Hoepffner et al. unpublished data), based on a model that incorporates estimated chlorophyll, photosynthetically active radiation, and sea surface temperature patterns (Behrenfeld and Falkowski 1997). The data are average values for 1998.

Depth information by ½ by ½ degrees of latitude/longitude was obtained from the ETOPO5 data-set available on the U.S. National Geophysical Data Center's Global Relief Data CD *(www.ngdc.noaa.gov/products/ngdc_products.html)*.

Table 1. Overview of ecosystem models used for estimating abundance patterns of fish biomasses around the South China Sea.

Area covered	Year(s)	Spatial cells	Functional groups	Reference
Gulf of Thailand	1963, 1973, 1980	45	29, 40, 29	Christensen (1998), Vibunpant et al. (this vol)
Peninsular Malaysia, west coast	1970, 1990	48	15	Alias M. (this vol.)
Peninsular Malaysia, east coast	1972	63	15	see Annex A (this paper)
Sabah	1972	17	29	Garces et al. (this vol.)
Sarawak	1972	81	29	Garces et al. (this vol.)
Central Java, north coast	1979	15	27	Nurhakim (this vol.)
Deep South China Sea (50 - 200 m)	1980	160	13	Pauly and Christensen (1993)
Ocean part, South China Sea (> 200 m)	1980	509	10	Pauly and Christensen (1993)
Vietnam, coast (< 50 m)	1980	44	13	Pauly and Christensen (1993)
Brunei Darussalam	1989	19	13	Silvestre et al. (1993)
San Miguel Bay, Philippines	1993	1	16	Bundy (1997); Bundy and Pauly (2001)
San Pedro Bay, Philippines	1994	8	16	Campos (this vol.)
Vietnam, southwest	1994	63	15	see Annex B (this paper)

Methods

The methodology we have used to predict the biomass of fish in the South China Sea draws on a combination of ecosystem modeling, information from hydrographic databases, statistical analysis, and GIS modeling (Christensen et al. 2003). The mapping of biomass changes was performed using a series of steps as follows:

1. The 16 models of Table 1 were re-expressed on a spatial basis (again using ½ by ½ degree cells, corresponding to 30 by 30 miles at the Equator) using the spatial model Ecospace, with particular attention to the rapid decline in biomass of demersal fish with depth that is known to occur in South East Asia (Pauly 1989). For each of the spatial models, the cells were distributed between habitats based on depth only. The following depth strata were used for all models: (1) < 10 m, (2) 11 - 50 m, (3) 51 - 100 m, (4) 101 - 200 m, (5) 201 - 1000 m, and (6) > 1000 m. These yielded estimates of biomass by Ecopath functional groups for each of the spatial cells covered by each model, which ranged from 1 to 509 cells (see Table 1).

2. The biomass of different functional fish-groups were re-expressed as a single value representing all fish with a trophic level of 3.0 or higher, (excluding, however the unexploited meso- and bathypelagics and deep-sea benthic fish in the model representing the deepest, central part of the South China Sea; see Table 1).

3. Regression analyses were performed using multiple linear regression in S-Plus 6. We used the software's additive and variance stabilizing transformation, (AVAS) to decide how individual variables are best transformed to obtain linearity.

4. A multiple regression was identified which predicted the fish biomass based on the year for which the biomass was estimated (expressed as log (year - 1959)), primary production in each half-degree cell (log transform), and the mean depth of each cell (log transform). To prevent the records from models covering large areas from overwhelming those from other models, each of the records was weighted in the regression analysis by the inverse of the square root of the number of non-land cells in the model to which it belonged. As data material we extracted 1 158 records based on the ½ by ½ degree spatial cells of the 16 ecosystem models in Table 1. Each of the records included estimates of fish biomass (trophic level ≥ 3.0), depth, primary production, and year of the model.

5. Following a first run of regression in Step 4, and an examination of the residuals, it was clear that the biomass values for the 1989 Brunei-model where higher than the model predicted. This is expected as fishing is very limited in Brunei, due to offshore oil rigs which fishing vessels may not approach (Cruz-Trinidad et al. 1997; Pauly et al. 1997). Thus a dummy variable was used to indicate whether a cell belonged to the EEZ of Brunei or not.

6. Using the regression the biomass for each cell represented was predicted and plotted for 1960 and 2000, representing the extremes for the period covered.

Results and Discussion

Based on the data in Table 2, we conclude that the multiple regression we derived is adequate in that it explains the major part of the variance in the dataset (R^2 = 0.68), and the partial regression coefficients (slopes) all have the expected signs. The t-values in Table 2 indicate the internal 'ranking' of the parameters, i.e. they identify those that matter most (or where the probability of exceeding the t-value by chance is smallest). However, due to covariation between variables the 'rankings' should be treated with extreme caution. We note that the highest t-value is associated with the depth parameter, followed by the year, then primary production. The intercept is estimated least reliably, which is the reason why we abstain from presenting absolute biomass estimates obtained through the multiple regression.

Table 2. Parameter estimates and associated test statistics for multiple linear regression to predict the biomass (log, g·m^{-2}) for fishes (TL > 3.0) in the South China Sea during the period from early 1960s to late 1990s. The variables are arranged by t-value (value relative to standard error, given) corresponding to adjusted partial slopes (Blalock 1972). All parameters are highly significant.

Variable (Unit)	Value	Std. error	t-value	Pr(>|t|)	Transformation
Depth (m)	-0.293	0.013	-22.7	0.000 000 0	Logarithmic
Year (year - 1959)	-0.760	0.043	17.6	0.000 000 0	Logarithmic
Brunei (0 or 1)	1.167	0.132	8.84	0.000 000 0	None
Primary production (gC•m^{-2}•year^{-1})	0.407	0.073	5.61	0.000 000 0	Logarithmic
(Intercept)	2.045	0.438	4.68	0.000 003 3	–

Figure 1 shows the transformation required to obtain linearity in the models. Based on this, log transformations were deemed suitable for all parameters apart from the dummy variable identifying the Brunei-variable. Further, Figure 2 shows the distribution of predicted versus observed values. There is no obvious pattern suggesting the model failed to linearize, or to include a key variable.

Figure 3 contrasts the maps of biomass distribution from the multiple regression model for 1960 against that for 2000. The high fish concentrations originally occurring in the Malacca Strait, the Gulf of Thailand, along the northern coast of Kalimantan and in other productive areas around the South China Sea, had completely disappeared by 2000, with the exception of the waters off Brunei, where fishing is forbidden around offshore oil rigs, a theme to which we return below. As estimated by the multiple regression and illustrated in Figure 3, fish biomass has strongly declined over the last 40 years, with present biomass generally less than half their values in 1960. This decline is most probably underestimated, as the catch per unit of effort of research trawlers in the Gulf of Thailand decreased from over 400 kg·hour^{-1} in 1961 to around 30 kg·hour^{-1} in the 1990s (Eiamsa-ard and Amornchairojkul 1997; Pauly 1979), with similar declines reported elsewhere.

This underestimation is a feature of the approach used here, which leads to conservative estimates. A similar conservative result was obtained in an earlier application of the above methodology to the North Atlantic, where individual species have declined far more sharply than estimated by the multiple regression used for biomass prediction (Christensen et al. 2003).

We also note that the decline of trawlable biomass documented here accompanied strong changes in species composition, noted by various authors as early as the 1960s (Pauly 1979; Pope 1979), a feature that can be straightforwardly reproduced by simulation modelling.

Figure 4 illustrates this through the example of the Gulf of Thailand, whose catches have stagnated since the 1970s, in spite of a massive increase in fishing effort, and a strong decline in the mean trophic level of the catch. These changes imply the loss (or at least disproportional decline) of large, long-lived high-trophic level species in the system, and their partial replacement with small short-lived, low trophic level species, used as duck and fish feed in the case of the Gulf of Thailand (Pauly and Chuenpagdee 2003).

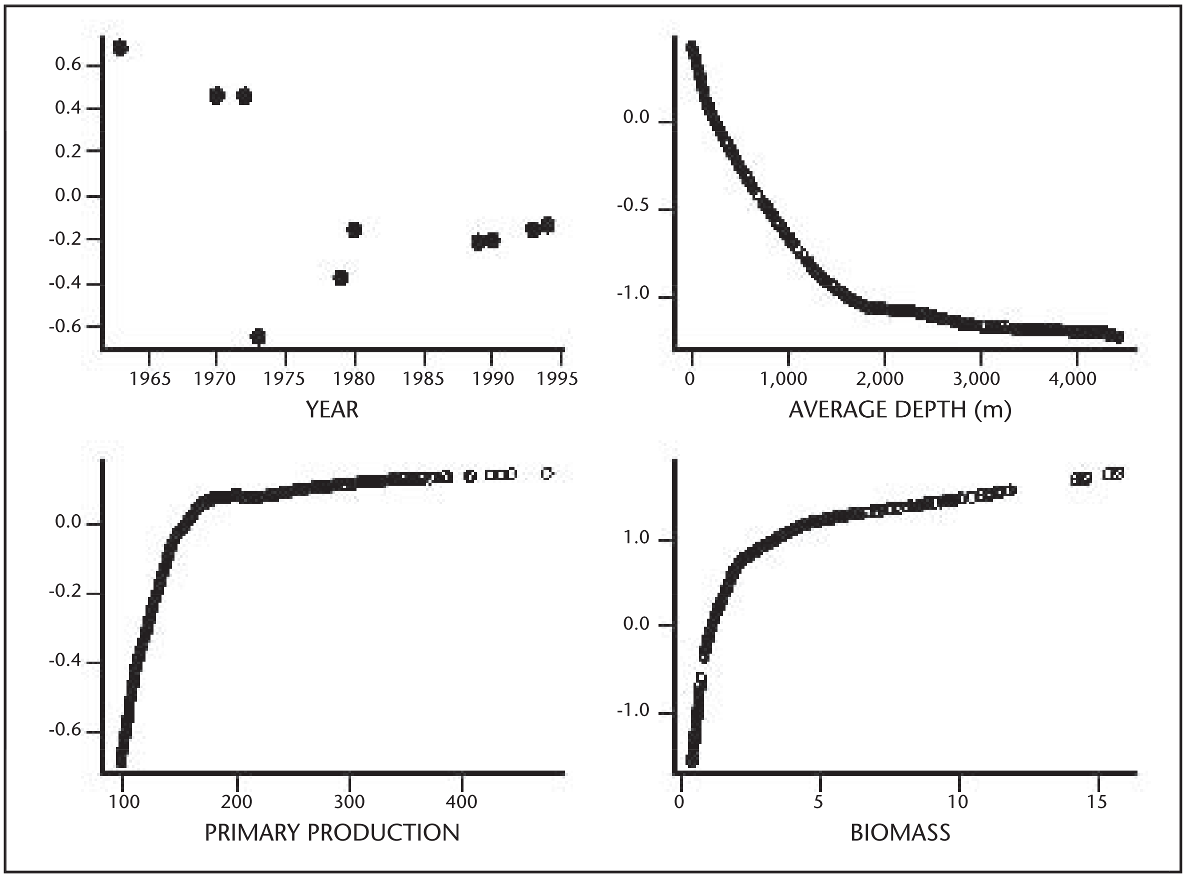

Fig. 1. AVAS transformations indicating how parameters (X-axis) should be transformed (Y-axis indicate biomass, linear scale) to linearize the individual parameters while considering their joint effects. These results indicate that logarithmic transformations are reasonable for year, depth, and primary production.

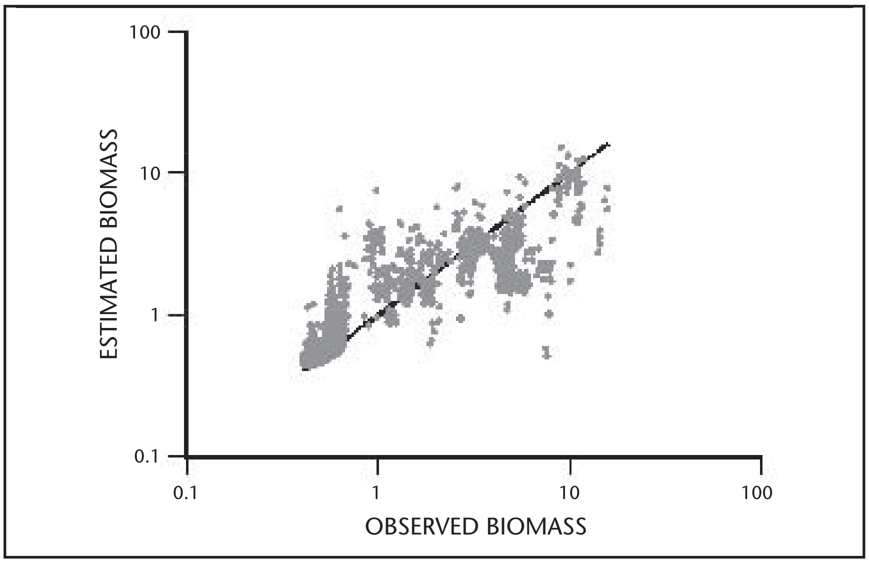

Fig. 2. Plot of predicted versus observed biomass ($g{\cdot}m^{-2}$). The predicted values are from the regression in Table 2, the 'observed' values from the spatialization of Ecopath models described in the Methods section.

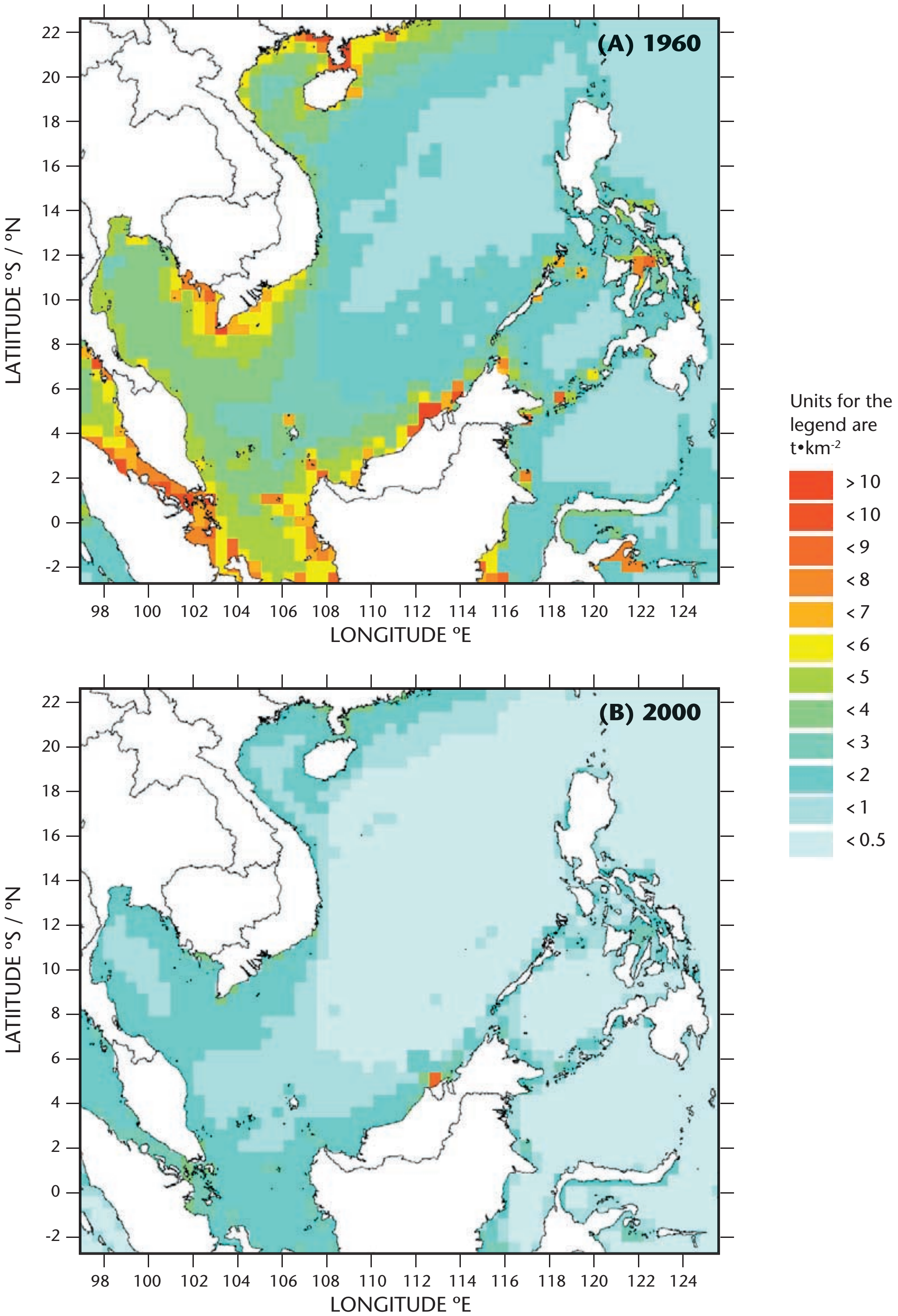

Fig. 3. Biomass distributions for fishes (trophic level ≥ 3.0) in the South China Sea large marine ecosystem in (A) 1960, and (B) 2000. The distributions are predicted from linear regressions based on log-transforms of depth, year, and primary production. Note that the high coastal concentrations in the early period have nearly completely disappeared - except for the Exclusive Economic Zone of Brunei.

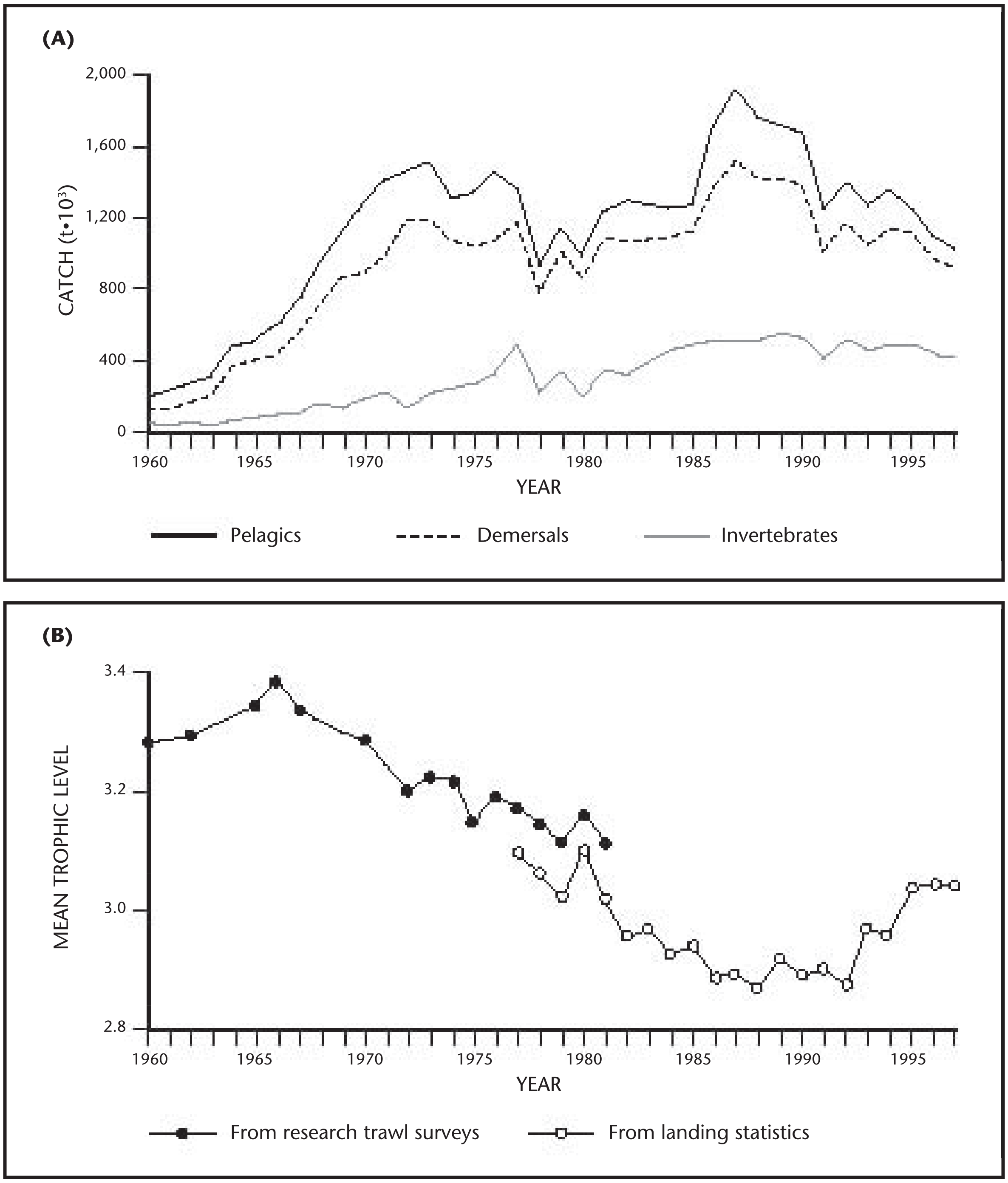

Fig. 4. Impact of fishing on the Gulf of Thailand ecosystem, an example of trends in the South China Sea:

(A) Catches, by major species groups (excluding tuna and other large pelagics). Note stagnation and decline of demersal catches, following their rapid increase in the 1960s and 1970s. Also note increasing contribution of small and medium pelagics, and overall decline in the 1990s.

(B) Trophic level (TL) trends in the catch of research trawlers (reflecting relative abundances in the ecosystems), and in the total landings (both series excluding large pelagics). Lower TL's in 1977 to 1997 series are due to inclusion of small pelagics and other low-TL organisms caught by gear other than trawl (adapted from Pauly and Chuenpagdee 2003)

The methodology deployed here thus diagnoses the same problems for the South China Sea that occur throughout the world, notably a complete absence of sustainability (Pauly et al. 2002). Indeed, if present trends are not reversed, fisheries are heading for a collapse of their underlying resource base, and of the ecosystems on which the fisheries depends (Pauly et al. 2002). At the same time, this study gives a pointer toward an important component of a solution for the over-fishing problem in South East Asia as well as elsewhere, through the example of Brunei - the only country in the region that has a significant part of its shelf effectively closed to fishing due to the presence of offshore oil rigs, around which fishing is not permitted. This has limited the Brunei trawl fishery to a small area near Muara, the only industrial port. While the small exploited area near Muara exhibits the same signs of over-fishing as the rest of South East Asia (Pauly 1989), a significant part of the biomass on the rest of the Brunei shelf has been retained, thus allowing for export of larvae and other live stages to adjacent areas, and the maintenance of functioning ecosystems.

It is hard to conceive how the depleted demersal stocks of the other areas of the South China Sea could be replenished without closing areas to fishing, or at least to trawling. The 1980 trawling ban in Indonesia might be instructive here as well (Sardjono 1980), though it is quite evident that the gain that could have been realized through the closure has been quickly dissipated, at least in the Java Sea by an enormous expansion of small scale fisheries and of an industrial pelagic fishery.

Thus, we cannot but reiterate that capping, and ultimately reducing fishing effort, including that of small scale fisheries is the only long term solution to halting, and reversing the worrying trends described here.

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Annex A.

Notes on the construction of the Ecopath model for the east coast of Peninsular Malaysia (1970).

In constructing the 1970 Ecopath model, the 1990 mass-balance trophic model constructed for the coastal fisheries ecosystem of the west coast of Peninsular Malaysia (see Alias, this vol.) was used. The ecosystem is partitioned into 15 trophic groups with biomasses for selected groups (e.g. large zoobenthos feeders) obtained from research (trawl) surveys conducted in the area in 1970. Biomass values were calculated using stock density estimates from Talib et al. (this vol.) ~ 5.092 5 t•km^2, and species composition from the trawl surveys (Jothy et al. 1975).

Total landings for each species/group were obtained from catch statistics of the Department of Fisheries for 1970. The 1970 P/B (=Z) values of the all-fished groups were calculated using the following equations:

$$Z_{70} = [\, Z_{90}\,(F_{70} + M)\,] \,/\, (F_{90} + M) \qquad \text{(Eqn. 1)}$$

where: Z_{90} is the 1990 total mortality values, F_{90} the estimated fishing mortality (1990); F_{70} the estimated fishing mortality (1970); M is the natural mortality and was assumed to be the same in 1970 and 1990. F_{70} was estimated:

$$F_{70} = (F_{90} \times C_{70}) \,/\, C_{90} \qquad \text{(Eqn. 2)}$$

where: F_{70} is the fishing mortality (1970); F_{90} is the estimated fishing mortality (1990); C_{70} is the total catch for the species/group in 1970; and C_{90} is the total catch for the species/group in 1990.

Table A1 presents the basic input and output parameter values used in modeling the coastal fisheries ecosystem off the west coast of Peninsular Malaysia.

Table A1. Basic input and output (in parenthesis) parameter values used in modeling the coastal fisheries ecosystem off the west coast of Peninsular Malaysia.

Ecological group	Biomass (t•km^{-2})	P/B (year^{-1})	Q/B (year^{-1})	EE	Catch (t•km^{-2}•year^{-1})
Mammals	0.02	0.05	30.00	(0.00)	–
Large predators	(0.02)	2.86	7.30	(0.69)	0.02
Large pelagics	(0.17)	3.93	9.55	0.95	0.17
Medium pelagics	(0.15)	2.43	10.00	0.95	0.05
Large zoobenthos feeders	0.25	3.90	7.85	0.95	0.02
Intermediate predators	(0.78)	7.49	15.00	(0.12)	0.42
Small demersal species	2.54	(0.21)	23.74	0.95	0.43
Small pelagics	(0.62)	3.75	12.9	0.95	0.86
Crustaceans (excl. plankton)	(6.55)	5.11	21.81	0.95	0.07
Misc. invertebrates	(5.96)	5.51	11.02	0.95	–
Squids	(4.40)	4.10	10.51	0.95	0.05
Turtles	0.02	1.50	3.50	(0.00)	–
Zooplankton	(2.66)	67.00	280.00	0.95	0.03
Aquatic plants	(14.08)	71.15	–	0.50	–
Detritus	100.0	–	–	(0.38)	–

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = Ecotrophic efficiency.

Annex B.
Notes on the construction of the Ecopath model for the southwest coast of Vietnam (1994).

The primary source of quantitative information (i.e. biomass) in determining the input data for the model were obtained from results of the trawl surveys conducted in southwest Vietnam between 1993 to 1995. Other sources of information on the study area include (Khoi et al. 1995) for plankton studies, and (Chung and Ho 1995) for zoobenthos fauna. Only the biomasses estimated from the trawl surveys in southwest Vietnam were used as input values for demersal groups i.e. demersal predators, Leiognathids and other small demersals. Biomass values for zoobenthos were taken from results of a zoobenthos study in the seawaters of Vietnam (Chung and Ho 1995).

The food web model consists of 15 functional groups, i.e. 13 consumer groups, a producer (phytoplankton) group and a detritus group (see Table B1). The species composition and biomass data from the trawl surveys were used to determine the ecological groups. The aggregation process for this model was performed based on similarities in habitat, body size, growth and mortality rates and diet composition, after the method proscribed by (Christensen and Pauly 1996; Pauly and Christensen 1993). Such information (notably for fish) was mainly obtained from the FishBase database (www.fishbase.org). Table B2 summarizes the basic input and output parameter values used in modeling the coastal fisheries of southwest Vietnam.

Table B1. Species composition for the 15 functional groups of the southwest Vietnam Ecopath model[a]

Ecological Groups	Species/taxa included
Large predators	Sharks (Carcharinidae), Scombridae
Tuna	Scombridae (*Scomberomorus* spp., *Auxis* spp., *Euthynnus* spp., *Thunnus* spp.)
Medium pelagics (except Tuna)	Carangidae, Trichiuridae, Stromateidae
Small pelagics	Clupeidae and Engraulidae
Other pelagics	Carangidae, Caesionidae, Scombridae (*Rastrelliger* spp.)
Cephalopods	Includes squids (*Loligo* spp.), cuttlefish (*Sepia* spp.) and octopus (*Octopus* spp.)
Demersal predators	Apogonidae, Ariidae, Cepolidae, Cynoglossidae, Drepanidae, Fistularidae, Gobiidae, Holocentridae, Meneidae, Monocanthidae, Nemipteridae, Muraenidae, Ostraciidae, Paralichthyidae, Pegasidae, Platycephalidae, Plotosidae, Polynemidae, Priacanthidae, Rhinobathidae, Sciaenidae, Syngnathidae, Synodontidae, Tetraodontidae, Lethrinidae, Serranidae, Scorpaeinidae
Reef fish	Chaetodontidae, Labridae, Pomacentridae
Leiognathids	*Gazza minuta, Leiognathus* spp., and *Secutor* spp.
Other small demersals	Bothidae, Cynoglossidae, Gerreidae, Haemulidae, Mullidae, Nemipteridae, Psettodidae, Siganidae, Sillaginidae, Soleidae, Sparidae, Teraponidae Sciaenidae
Crustaceans (crabs & shrimps)	Portunidae, Palinuridae, Scyllaridae, Penaeidae
Zoobenthos	Crustacea, Polychaeta, Coelenterata Echinodermata, Porifera (Chung and Ho 1995)
Zooplankton	Copepoda, Chaetognatha (Khoi et al. 1995)
Phytoplankton	
Detritus	Comprised of particulate and dissolved organic matter

[a] Fish groups are only listed as families, complete species list can be found in the species composition of trawl surveys (Thouc and Dat 2000).

Table B2. Basic input and output (in parenthesis) parameter values used in modeling the coastal fisheries ecosystem off the southwest coast of Vietnam.

Ecological group	Biomass ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Catch ($t \cdot km^{-2} \cdot year^{-1}$)
Large predators	(0.01)	1.20	15.00	0.50	0.003
Tuna	(0.02)	0.80	(4.00)	0.95	0.004
Medium pelagics	(0.05)	1.50	(7.50)	0.95	0.015
Small pelagics	(0.21)	3.35	17.60	0.95	0.025
Other pelagics	(0.12)	3.00	(12.00)	0.90	0.048
Cephalopods	(0.08)	3.10	16.00	0.95	0.000
Demersal predators	1.21	3.00	12.00	(0.27)	0.151
Reef fish	(0.10)	2.00	12.00	0.70	0.021
Leiognathids	0.49	3.00	17.50	(0.60)	0.061
Other small demersals	0.21	(3.70)	18.50	(0.70)	0.026
Crustaceans	(2.85)	4.00	21.90	0.95	0.003
Zoobenthos	20.00	6.57	27.40	(0.64)	–
Zooplankton	(4.26)	50.00	200.00	0.90	–
Phytoplankton	(6.87)	120.00	–	0.90	–
Detritus	120.00	–	–	0.53	–

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = Ecotrophic efficiency.

Status of the Demersal Fishery Resources of Bangladesh

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Abstract

The present study makes use of the fisheries survey data collected during the period 1984 - 87 by the multi-purpose research vessel RV Anusandhani in the waters of Bangladesh, Bay of Bengal. The data consists of twelve survey cruises directed at the shrimp resources (1985 - 87) and nineteen survey cruises directed at the demersal fish resources (1984 - 86).

The biomasses for shrimp and demersal fish during the survey period were estimated, along with a detailed analysis of biomass distribution by depth zone and catch rates for important species of shrimp and demersal fish species. The demersal fish and shrimp biomass during the survey period was estimated as 176 160 t and 857 t, respectively. The levels of biomass when compared with 1973 estimates indicate a tremendous decline, by about 90% for shrimps and 30% for demersal fish.

Population parameters for four species of shrimps (for both males and females) as well as for eight demersal fish species were also estimated. The parameter estimates were validated using available growth and mortality parameter values from the literature, and were in turn used to estimate the mean exploitation rate (E) of demersal fish and shrimp species comprising the trawl catch. Mean E values for shrimp species is at 0.61 and 0.57 for demersal fish species, indicating over-exploitation of demersal resources in the Bay of Bengal.

Exploratory analysis using surplus production modeling of catch and effort data shows that the maximum sustainable yield (MSY) level for shrimp resources is around 3 500 t, corresponding to a maximum effort level of approximately 6 480 fishing days. Similar analysis for demersal fish catches gave poor correlations between catch rates and fishing effort.

Introduction

The 200 nm Exclusive Economic Zone (EEZ) of Bangladesh encloses an area of about 166 000 km^2 while the length of its coastline from the southeast border to the southwest border is approximately 710 km. The continental shelf, covering an area of 66 440 km^2, is relatively shallow with about 36% (24 000 km^2) less than 10 m deep (Table 1). The shelf area down to about 150 m depth appears to

be very even, although some areas with obstacles hazardous to trawling have been observed. The continental edge is found at depths between 160 to 180 m.

The continental slope is very abrupt making demersal trawling operations impractical, particularly in waters deeper than 180 m (Khan et al. 1997). The continental shelf within the 50 m depth zone contains significant fish resources, however, factors such as salinity, dissolved oxygen and water temperature tend to limit the distribution of fish to a narrow belt, so that the effective fishing area is reduced to about 14 000 km^2. The marine shrimp grounds are further restricted to only about 700 km^2 (Rahman 1992). The major species groups targeted by trawls in the coastal waters of Bangladesh are the penaeid prawns and several species of demersal fish.

Table 1. Depth distribution of shelf areas of Bangladesh waters.

Depth Zone (m)	Area (km^2)	%
Up to 10	24 000	36
10 - 24	8 400	13
25 - 49	4 800	7
50 - 74	5 580	8
75 - 99	13 410	20
100 - 199	10 250	16
TOTAL	66 440	100

The annual marine fish production of Bangladesh in 1996 - 97 was about 274 704 t, about 95% (261 140 t) of which was contributed by coastal (artisanal) fisheries. The annual trends in fish production during 1990 - 99 are given in Table 2. There was an increase in the total marine production from 241 538 t in 1990 - 91 to about 291 900 t in 1998 - 99. Marine shrimp landings during this period almost doubled and the catches were mostly from artisanal gear.

Since 1958 several resource surveys have been conducted in Bangladesh, particularly to assess the status of the demersal fish resources. Results of these surveys showed great variation in the estimates of demersal fish stock ranging from 55 000 t to 373 000 t. Significant work has been carried out by Khan et al. (1983); Lamboeuf (1987); Penn (1982); Saetre (1981); West (1973). Amongst them, Lamboeuf (1987) estimated the standing stock of demersal fish at 157 000 t within the 10 to 100 m depth zone, and about 188 000 t within the 10 - 200 m depth area. These estimates are based on 17 cruises covering 581 stations in the Bangladesh waters of the Bay of Bengal. Although the trawl surveys do not cover the same number of cruises as that of Lamboeuf (1987); Saetre (1981) estimated the standing stock of demersal fish at 160 000 t, while Khan et al. (1983) estimated it at 152 000 t.

Previous surveys have been conducted principally to estimate the resource potential of fish stocks. The most comprehensive of these (mainly trawling) were the ones under the UNSF/PAK-22 Project conducted from 1968 - 71 by the Bangladesh Fisheries Development Corporation (BFDC), in collaboration with Food and Agriculture Organization (FAO). The project covered an area of 26 000 km^2 and resulted in the identification and charting of four major commercial fishing grounds. These are South Patches (3 662 km^2), Southwest of South Patches (2 538 km^2), Middle Ground (4 600 km^2) and "Swatch of No Ground" (3 800 km^2) (Fig. 1).

Until the beginning of 1984, trawl survey cruises were conducted by foreign government agencies and a few international organizations for the purpose of demersal fish stock assessment. During the period from 1984 to 1987, the research vessel RV Anusandhani was placed under the operational control of the FAO/UNDP Project BGD/80/025. Foreign marine scientists worked on board the vessel along with counterparts from the Department of Fisheries, Bangladesh. The surveys were carried out to provide biological information and reliable assessments of major fish stocks in order to implement rational fisheries management schemes and well-defined policies.

This study aims to provide an overview of the status of demersal fish stocks in the waters of Bangladesh, Bay of Bengal. Biomass levels of commercially important species of fish and shrimps from the trawl surveys carried out using RV Anusandhani from 1984 - 87 are presented. It also infers the extent of over-fishing of the demersal resources by comparing the biomass and CPUE levels with earlier estimates. The growth and mortality parameters of some fish and shrimp species are also used to estimate the current level of exploitation.

Table 2. Fishery production of Bangladesh (1990 - 99).

Year	Total fish Production (t) (Inland + Marine)	Total Marine Production (t) (Fish + Shrimp)	Industrial Production (t) (Fish + Shrimp)	Artisanal Production (t) (Fish + Shrimp)	Marine Shrimp Production (t) (Trawl + Artisanal)	Marine Fish Production (t) (Trawl + Artisanal)
1990 - 91	895 935	241 538	8 760	232 778	17 633	223 905
1991 - 92	952 079	245 474	9 623	235 851	20 042	225 432
1992 - 93	1 020 654	250 492	12 227	238 265	23 975	226 517
1993 - 94	1 090 610	253 044	12 454	240 590	21 519	231 525
1994 - 95	1 172 868	264 650	11 715	252 935	20 360	244 287
1995 - 96	1 257 940	269 702	11 959	257 743	26 353	243 349
1996 - 97	1 306 739	274 704	13 564	261 140	24 818	249 886
1997 - 98	1 473 673	283 673	15 673	268 000	* 25 318	* 258 355
1998 - 99	1 598 900	291 900	15 900	276 000	* 26 020	* 265 880

Source: Banik and Humayun (1999); Department of Fisheries (DOF) (1999).
Note: * Approximate values

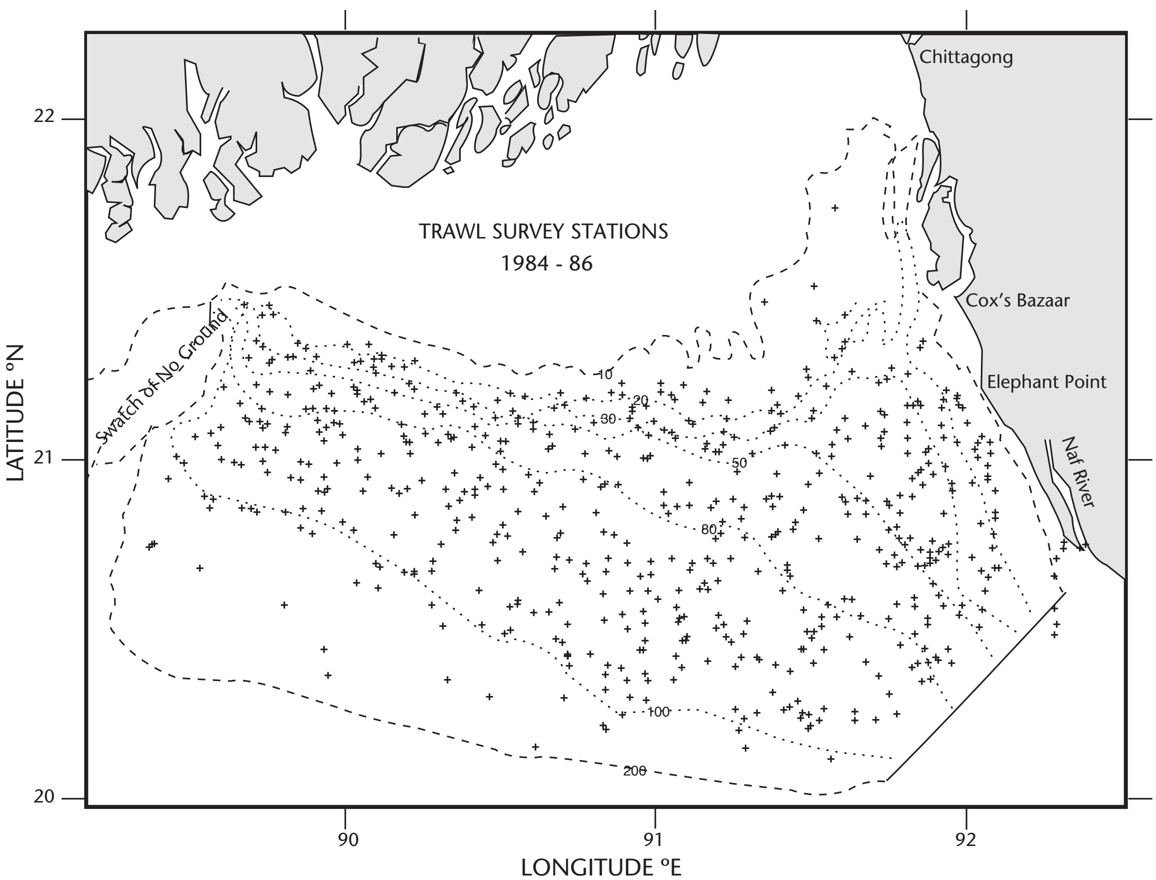

Fig. 1. The coastal waters of Bangladesh, Bay of Bengal and the trawl survey stations (1984 - 86) used for biomass estimation.

Materials and Methods

Estimation of Demersal Biomass

Data collected within the 10 - 100 m depth zone by RV Anusandhani in the Bay of Bengal off Bangladesh from September 1984 to October 1987 were used in the estimation of biomass of the demersal resources. RV Anusandhani is a multipurpose research vessel constructed in Japan in 1979 and designed mainly for stern trawling. The vessel has an overall length (LOA) of 32.4 m and a displacement of 221 GRT.

Fish trawling was conducted using a high opening Engel trawl with a cod-end mesh size of 32 mm and a head-rope length of 57.7 m. For shrimp trawling, a total of four nets were used. On each side of the vessel, twin shrimp nets of the same dimensions were operated from outriggers. Each had a head rope measuring 15.2 m in length while the ground rope was 18.6 m long. The total length of the net from the tip of the wing to the tip of the cod-end was 16.6 m. Detailed specifications of the research vessel and trawl nets are given in Lamboeuf (1987).

A total of 31 cruises were carried during the survey period (Table 3). Twelve (12) of these cruises were shrimp surveys while the remaining nineteen (19) were fish surveys. Fig. 1 shows an outline of the survey area indicating the location of trawling stations.

The survey area was limited towards the north and the east by the 10 m depth contour, as trawling and navigation in shallower waters were impossible due to the presence of artisanal fishers. The southern limit was originally set at the 200 m depth zone, but then only a few stations were actually undertaken beyond 120 m. A line drawn at 45º from the southern end of St. Martin's island towards Myanmar was taken as the limit of the survey area in the southeast. In the west, the limit was the eastern edge of the "Swatch of No Ground" fishing area.

On board catch sampling followed the procedures given in Pauly (1983). The catch was sorted and classified to species level whenever possible and separately weighed to the nearest 0.25 kg. In the event that a catch in a particular trawl haul exceeded 500 kg, a sub-sample was taken and the results were later raised to the value for the total catch. For large fish (whose number was usually

Table 3. List of RV Anusandhani trawl survey cruises (1984 - 87).

Cruise No.	Duration	Survey Type	Valid hauls
1	15 - 25 September 1984	Fish	42
2	3 - 13 October 1984	Fish	45
3	20 - 30 October 1984	Fish	43
4	9 - 19 November 1984	Fish	44
5	27 November - 5 December 1984	Fish	40
6	13 - 20 December 1984	Fish	41
7	24 - 28 December 1984	Fish	–
8	6 - 16 January 1985	Fish	46
9	31 January - 24 February 1985	Fish	49
10	17 - 24 February 1985	Fish	44
12	19 - 24 May 1985	Fish	13
13	12 - 17 July 1985	Fish	13
14	21 - 24 August 1985	Shrimp/Fish	7
15	28 September - 6 October 1985	Fish	29
16	22 - 31 December 1985	Shrimp	35
17	21 - 30 November 1985	Shrimp	26
18	7 - 18 December 1985	Shrimp	32
19	10 - 18 January 1986	Shrimp	27
20	25 January-4 February 1986	Fish	41
21	12 - 22 February 1986	Shrimp	34
22	2 - 11 March 1986	Fish	31
23	18 - 28 March 1986	Shrimp	32
24	2 - 11 April 1986	Fish	22
25	22 April - 1 May 1986	Shrimp	22
26	12 - 21 May 1986	Fish	25
27	1 - 4 June 1986	Fish	7
28	1 - 5 July 1986	Shrimp	9
29	November 1986	Shrimp	N/A
30	2 - 4 December 1986	Fish	26
31	15 - 21 December 1986	Shrimp	N/A
32	January 1987	Shrimp	N/A

Note: N/A = Not available.

less than 20 individuals) the actual number was recorded along with the total weight in order to calculate the average weight of an individual. If the number was greater, samples were usually taken for length frequency measurements; these samples were weighed and used to calculate the average weight.

Density and biomass estimates were obtained using the swept area method. The number of huals in each depth stratum is given in Table 4. For fish trawling, the following inputs were used: the distance between trawl wing tips was 18 m, the average trawlingdistance was 1.3 nm (1.5 miles). For shrimp trawling, the distance between trawl wing tips was 60.8 m (15.2 m x 4), the average trawling distance was about 3 nm and the escapement factor was 50%. Average catch rates were calculated for each stratum. Multiplication with the corresponding stratum area gives the total stratum biomass while the overall biomass was obtained by the summation of each individual stratum biomass.

Estimation of Population Parameters

For the abundant species in the catch, samples of 50 to 200 individuals were randomly selected for length frequency measurements. Total lengths (TL) were measured in cm. Total length of shrimp samples was measured from the tip of the rostrum to the posterior edge of the telson. No length measurements were made for the sea catfish (Family *Ariidae*) and the jewfish (Family *Sciaenidae*) because of inconsistent taxonomic identification of the species.

Length frequency data for four shrimp (*Penaeus monodon, P. semisulcatus, P. merguiensis* and *Metapenaeus monoceros*) and eight demersal fish species (*Saurida tumbil, Upeneus sulphureus, Nemipterus japonicus, Lepturacanthus savala, Pomadasys hasta, Pampus argenteus, P. chinensis* and *Ilisha filigera*) were re-analyzed to obtain the growth parameters L_∞ (asymptotic length) and k (growth constant) of the von Bertalanffy growth formula (VBGF). All the length frequency data were pooled and re-entered using the FiSAT software. To estimate population parameters the ELEFAN I routine (incorporated in FiSAT) was used. The same data were used for the estimation of total mortality (Z), natural mortality (M), and fishing mortality (F), as well as their exploitation ratios. Total mortality was estimated using the length converted catch curve method incorporated as a separate routine in FiSAT. The natural mortality coefficient (M) was estimated using Pauly's empirical formula (Pauly 1980) and the fishing mortality coefficient (F) was derived by subtracting M from Z. The exploitation ratio (E) was then computed as the ratio of F and Z.

Preliminary Surplus Production Modeling

The annual shrimp catch and fishing effort of commercial trawlers from 1981 to 1998 and the annual fish catch and fishing effort of commercial trawlers from 1986 to 2000 were used to estimate the Maximum Sustainable Yield (MSY). The surplus production models described by (Schaefer, 1954 and Fox 1970) were used in the estimation of MSY. The data used for the modeling were taken from trawl catch statistics compiled by the Department of Fisheries.

Table 4. The number of shrimp and fish trawls used in the analyses, by year and depth zone.

Depth zone (m)	Area (km²)	Shrimp trawl			Fish trawl		
		1985	1986	1987	1984	1985	1986
10 - 20	6 861	3	8	9	29	24	7
21 - 50	6 769	22	78	28	48	55	47
51 - 80	5 395	37	49	31	58	44	42
81 - 100	12 315	11	17	1	109	83	45
TOTAL	31 340	73	152	69	244	206	141

[*] The number of hauls in each depth stratum is given in Table 4.

Results and Discussion

Catch per unit effort (CPUE)

The mean catch rates and estimated biomass for shrimps and demersal fish per cruise are given in Tables 5a and 5b respectively. The highest catch rate (mean CPUE) of 16.23 kg•hr^{-1} (corresponding to an estimated shrimp biomass of 3 009 t) was recorded from cruise 14 and the lowest catch rate of 0.22 kg•hr^{-1} (with an estimated biomass of 41 t) was from cruise 23. For demersal fish surveys, cruise 13 had the highest mean catch rate of 630 kg•hr^{-1}, for an estimated demersal fish biomass of 394 597 t. In contrast, cruise 06 had the lowest mean catch rate of only 162.52 kg•hr^{-1}, corresponding to an estimated biomass of only 102 790 t.

Tables 6a and 6b are the overall species composition (by weight and percentage) of shrimp and demersal fish catches (from mean CPUE) for each survey year, respectively. For shrimps, the 1987 survey recorded the highest CPUE at 6.2 kg•hr^{-1} while the lowest was during 1986 at 3.1 kg•hr^{-1}. During shrimp trawling, the perennial component of the catches was the brown shrimp (*Metapenaeus monocerus*), which usually accounted for 38% to 52% of the total shrimp catch. The 1985 fish survey recorded the highest CPUE at 148.1 kg•hr^{-1} while 1984 had the lowest at 127.5 kg•hr^{-1}. Groups with high abundance in trawl catches are the croakers, goatfishes, threadfin breams and hairtails.

Table 5a. Mean catch rate and estimated biomass of shrimp (1985 - 87).

Cruise No.	Mean Catch Rate (kg·hr^{-1})	Biomass (t)
14	16.23	3 009
16	1.68	312
17	4.50	834
18	7.47	1 386
19	6.69	1240
21	3.05	565
23	0.22	41
25	8.54	1 584
28	3.83	710
29	12.35	2 291
31	6.12	1 134
32	7.30	1 355

Table 5b. Mean catch-rate and estimated biomass for fish (1984 - 86).

Cruise No.	Mean Catch Rate (kg·hr^{-1})	Biomass (t)
01	301.28	188 708
02	239.58	150 065
03	203.22	127 303
04	287.96	180 370
05	265.68	166 415
06	162.52	101 790
08	241.20	151 077
09	286.45	179 698
10	165.78	103 838
12	362.70	227 173
13	630.00	394 597
14	380.68	238 447
15	588.96	368 892
16	283.02	177 268
20	206.46	129 312
22	265.84	166 510
24	239.74	150 164
26	285.52	178 842
30	312.22	195 561

Biomass Estimates

Shrimp Biomass

The estimated biomass for penaeid shrimps within the 10 to 100 m depth zone amounts to 1.055 t using a catchability coefficient of 0.5 (Table 7). The most abundant species was the brown shrimp (*Metapenaeus monoceros*), whose estimated biomass of 551 t accounts for more than half of the total penaied shrimp biomass. Next in abundance was the pink shrimp (*Parapenaeopsis stylifera*), which had an estimated biomass of 211 t (20%) and the giant tiger shrimp (*Penaeus monodon*) whose abundance was estimated at 74 t (7%). The highest concentration of *M. monoceros* was found at the 81 to 100 m depth zone, for *P. monodon* it was at the 51 to 80 m depth zone, while for *P. stylifera* it was at the 10 to 20 m depth zone.

Table 6a. Species composition of shrimp trawl catches (1985 - 87).

Species	Year							
	1985		1986		1987		1985 - 87	
	CPUE ($kg{\cdot}hr^{-1}$)	%	CPUE ($kg{\cdot}hr^{-1}$)	%	CPUE ($kg{\cdot}hr^{-1}$)	%	CPUE ($kg{\cdot}hr^{-1}$)	%
Penaeus monodon	0.40	7.03	0.34	10.93	0.50	8.03	0.40	8.66
Penaeus merguiensis	0.08	1.41	0.02	0.64	–	–	0.03	0.65
Penaeus semisulcatus	0.04	0.70	0.05	1.61	0.31	4.98	0.09	1.95
Metapenaeus monoceros	2.97	52.20	1.32	42.44	2.37	38.04	1.94	41.99
Metapenaeus spinulatus	0.09	1.58	–	–	–	–	0.01	0.22
Parapenaeopsis stylifera	1.14	20.04	0.14	4.50	0.43	6.90	0.34	7.36
Penaeus indicus	–	–	0.04	1.29	0.06	0.96	0.04	0.87
Metapenaeus brevicornis	–	–	0.20	6.43	0.17	2.73	0.13	2.80
Other shrimps	0.97	17.05	1.00	32.16	2.39	38.36	1.64	35.50
TOTAL	5.69	100.00	3.11	100.00	6.23	100.00	4.62	100.00

Table 6b. Species composition of demersal fish catches (1984 - 86).

Species	Year							
	1984		1985		1986		1984 - 86	
	CPUE ($kg{\cdot}hr^{-1}$)	%	CPUE ($kg{\cdot}hr^{-1}$)	%	CPUE ($kg{\cdot}hr^{-1}$)	%	CPUE ($kg{\cdot}hr^{-1}$)	%
Saurida tumbil	0.78	0.61	2.44	1.65	1.16	0.83	1.26	0.90
Upeneus sulphureus	3.60	2.82	2.36	1.59	2.69	1.92	2.86	2.03
Lepturacanthus savala	3.97	3.11	2.31	1.56	4.21	3.00	3.07	2.18
Nemipterus japonicus	1.54	1.21	1.71	1.15	9.45	6.74	2.49	1.77
Pomadasys hasta	1.88	1.47	0.84	0.57	0.86	0.61	1.22	0.87
Pampus argenteus	1.21	0.95	0.49	0.33	0.80	0.57	0.74	0.53
Pampus chinensis	0.33	0.26	0.14	0.09	0.21	0.15	0.20	0.14
Johnius argentatus	4.12	3.23	0.31	0.21	–	–	0.98	0.70
Harpadon nehereus	0.84	0.66	1.15	0.78	–	–	0.63	0.45
Ilisha filigera	0.70	0.55	0.39	0.26	1.11	0.79	0.62	0.44
Arridae spp.	2.74	2.15	0.49	0.33	–	–	0.80	0.57
Sciaenidae spp.	1.04	0.82	5.71	3.85	3.54	2.53	2.41	1.71
Other fish	104.75	82.16	129.80	87.63	116.18	82.86	123.34	87.71
TOTAL	127.50	100.00	148.14	100.00	140.21	100.00	140.62	100.00

The estimated biomass for penaeid shrimps in 1986 was 577 t for the same catchability coefficient (Table 7). Again, the most abundant species was *M. monoceros* whose biomass of 245 t was roughly 42% of the overall shrimp biomass. *Penaeus monodon* followed at 63 t, equivalent to 11%. Another brown shrimp (*Metapenaeus brevicornis*) came next, whose 37 t amounted to 6% and then the pink shrimp. *P. stylifera* contributed 26 t or roughly 5% of the total biomass. The most abundant concentration of *M. monoceros* was found at the 51 to 80 m depth zone. *P. monodon* had its highest concentration in the 21 to 50 m depth zone while *M. brevicornis* and *P. stylifera* were highest in the 10 to 20 m depth zone.

The estimated shrimp biomass for 1987 was 1 153 t (Table 7). *M. monoceros* contributed 439 t or 38% to the total shrimp biomass while *P. monodon* and *P. stylifera* contributed 93 t (8%) and 79 t (7%), respectively. *M. brevicornis* contributed 32 t or roughly 3% of the total shrimp biomass. *M. monoceros* and *P. monodon* were most abundant in the 21 to 50 m depth zone while *M. brevicornis* and *P. stylifera* were abundant in the 10 to 20 m depth zone.

Analyzing the combined data for the three sampling years (1985 - 87), the average penaeid shrimp biomass amounted to 857 t within the 10 to 100 m depth zone. The highest biomass was in the 21 to 50 m depth zone, followed by the 51 to 80 m depth zone. The biomass levels at 10 to 20 m and in the 81 to 100 m depth zones are almost identical at 173 t and 177 t respectively (Table 7). However, the 81 to 100 m depth zone covers a much larger area.

Based on earlier surveys conducted to estimate standing stock of shrimps in the Bay of Bengal, Bangladesh, the estimates varied from 1 000 t to 11 000 t (Mustafa et al. 1987; Penn 1983; Van Zalinge 1986; West 1973; White and Khan 1985). Penn (1983) and Rashid (1983) reported almost the same standing stock of shrimp at 3 000 t (average), while estimates made by White and Khan (1985) were slightly higher at 3 300 t (average). The shrimp biomass estimated from the trawl surveys has shown a tremendous (about 90%) decline from about 11 000 t in 1973 to only about 857 t in 1985 - 87. However, there are disparities in the number of sampling stations, survey area and differences in collection time, as most trawling operations for the period under the study were done during the daytime.

Demersal Fish Biomass

The estimated biomass for demersal fish within the 10 to 100 m depth zone using a catchability coefficient of 1.0 amounted to 159 725 t in 1984 (Table 8). The highest estimated biomass of 59 746 t was obtained from the 10 to 20 m depth zone. This was followed by the 21 to 50 m depth zone with an estimated biomass of 41 282 t. *Johnius argentatus* recorded the highest biomass from both the 10 to 20 m and 21 to 50 m depth zones, amounting to 3 220 t and 1 944 t, respectively. The sea catfish (Ariidae) was the next most abundant species in the 10 to 20 m depth zone with 2 878 t, while in the 21 to 50 m depth zone it was the hairtail (*Lepturacanthus savala)* with 1 038 t. In the 51 to 80 m depth zone, the most abundant species was the goatfish (*Upeneus sulphureus)* with 1 983 t, followed by *L. savala* with 1 277 t. At the 81 to 100 m depth zone, the most abundant species was *Nemipterus japonicus* (Japanese threadfin bream) with 1 517 t, followed by *U. sulphureus* (1 375 t).

During the trawl survey in 1985, the biomass for demersal fish within the 10 to 100 m depth zone for the same catchability coefficient was estimated at 185 581 t (Table 8). As in 1984, the 10 to 20 m depth zone had the highest estimated biomass at 61 055 t, which is almost one-third of the total fish biomass, followed by the 21 to 50 m depth zone whose estimated biomass was 56 163 t. The sea catfish (Ariidae) had the highest estimated abundance in both the 10 to 20 m and 21 to 50 m depth zones, amounting to 4 835 t and 2 131 t respectively. The bombay duck (*Harpadon nehereus*) was the next most abundant species in the 10 to20 m depth zone with 748 t, while in the 21 to 50 m depth zone, the second most abundant species was the hairtail, *L. savala*. *Upeneus sulphureus* was again the most abundant species in the 51 to 80 m depth zone with 1 380 t followed by the Japanese threadfin bream, *N. japonicus* with 1 113 t. In the 81 to 100 m depth zone, *N. japonicus* had the highest estimated biomass at 800 t, followed again by *L. savala* with 394 t.

The demersal fish biomass within the 10 to 100 m depth zone in 1986 was estimated to be 175 648 t (Table 8). Unlike in the two previous years (1984 and 1985), the 51 to 80 m depth zone now had the highest biomass with 53 742 t followed by the 21 to 50 m depth zone whose estimated biomass stood at 49 577 t. The most abundant species in the 10 to 20 m depth zone was the hairtail, *L. savala*

Table 7. Biomass distribution of shrimps by depth zone estimated from the trawl surveys, Table 4 shows the area of each depth zone and the number of hauls.

Depth zone (m)	1985			1986			1987			1985 - 87		
	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)
10 - 20	5.21	30.80	211	1.36	8.03	55	7.01	41.50	285	4.26	25.18	173
21 - 50	6.37	37.71	255	5.27	31.16	211	18.95	112.11	759	7.84	46.40	314
51 - 80	7.52	44.47	240	6.43	38.05	205	3.50	20.73	112	6.06	35.85	193
81 - 100	4.78	28.27	348	1.45	8.55	105				2.43	14.36	177
TOTAL	5.69	33.65	1 055	3.11	18.40	577	6.23	36.87	1 155	4.62	27.35	857

Table 8. Biomass distribution of demersal fish by depth zone estimated from the trawl surveys, Table 4 shows the area of each depth zone and the number of hauls.

Depth zone (m)	1984			1985			1986			1984 - 86		
	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)	Mean catch rate (kg·h⁻¹)	Mean density (kg·km⁻²)	Biomass (t)
10 - 20	435.72	8 708.10	59 746	445.26	8 898.81	61 055	286.26	5 361.24	36 783	411.52	8 224.39	56 428
21 - 50	305.14	6 098.63	41 282	145.16	8 297.11	56 163	366.46	7 324.17	46 577	360.40	7 202.86	48 756
51 - 80	198.92	3 975.63	21 449	319.60	6 387.65	34 461	498.42	9 961.38	53 742	302.84	6 052.32	32 652
81 - 100	151.34	3 024.59	37 248	137.74	2 752.92	33 902	144.42	2 886.34	35 545	155.70	3 111.94	38 324
TOTAL	255.00	5 096.51	159 725	296.28	5 921.55	185 581	280.42	5 604.59	175 648	281.24	5 620.92	176 160

with 2 702 t, followed by the sea catfish (Ariidae) with biomass of 2 586 t. For the depth zone (21 to 50 m), *U. sulphureus* was the most abundant at 2 622 t, followed by *L. savala* at 1 874 t. For the 51 to 80 m depth zone and 81 to 100 m depth zones, the Japanese threadfin bream (*N. japonicus*) exhibited the highest abundance at 3 239 t and 8 130 t, respectively. *U. sulphureus* was the second most abundant species in the 51 to 80 m depth zone with 717 t while in the 81 to 100 m depth zone, the sea catfish (Ariidae) was the second most abundant species with 1 286 t.

Analysis of the combined demersal trawling data for the three sampling years (1984 - 86) gives an estimated fish biomass of 176 160 t (Table 8). Biomass was highest in the 10 to 20 m depth zone and it decreased subsequently (in deeper strata). It is worth noting that within such a short period of time as three years, a very drastic change in demersal fish catch composition can occur. A good example would be the species *J. argentatus*, which was the most abundant species in 1984. It showed a huge decrease in abundance the following year (1985) and then a year later (1986) it was no longer within the list of most abundant species. Other species have emerged as the most abundant replacing the over-exploited ones. Although the results may not be conclusive, such absences (or "disappearances") could be an indication of biological over-fishing. Similar to the biomass trends exhibited by the shrimp resources, the demersal fish biomass also declined by about 30% from 260 000 t in 1973 to 176 000 t in 1984 - 86 (Fig. 2).

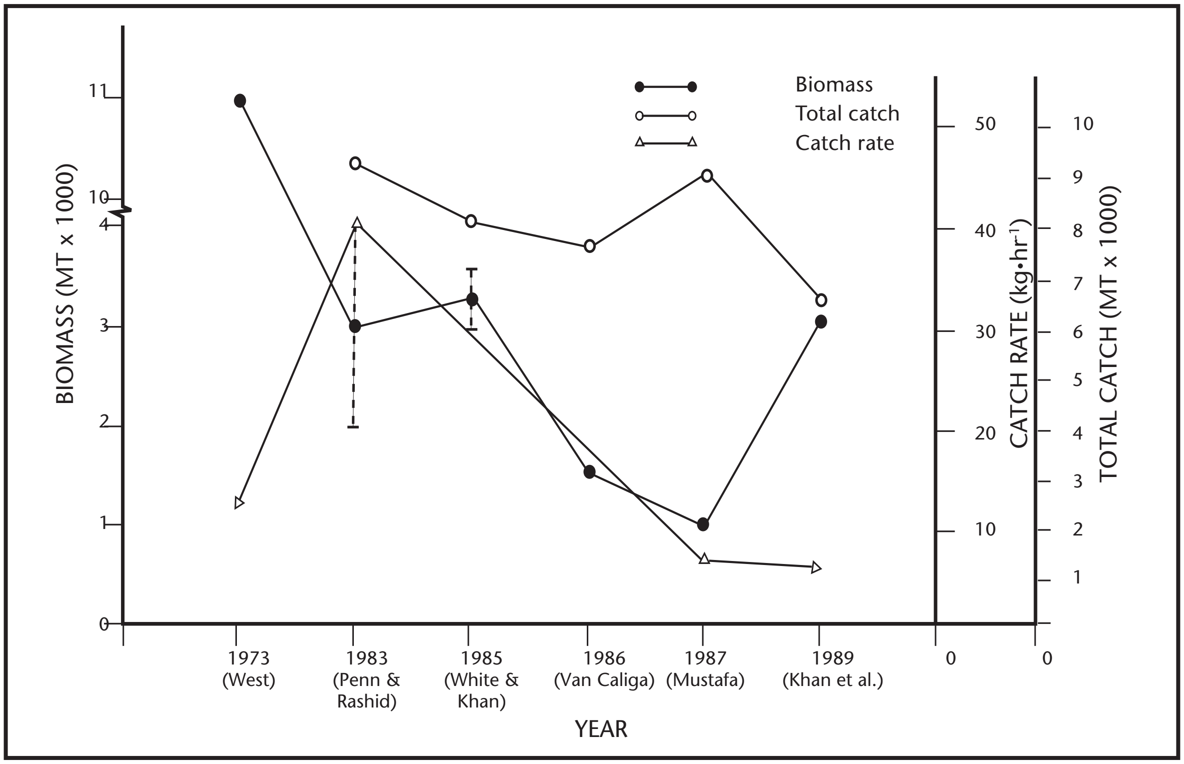

Fig. 2. Yearly biomass, catch rate and total catch of shrimp.

Growth and Mortality Parameters

Aside from looking at standing stock (or biomass), another indicator of the status of the fisheries is the rate of exploitation of targeted (or even untargeted) species. Knowledge of their growth and mortality parameters is essential in establishing whether the stock (or species) is optimally exploited or not. The parameters derived from the present study are presented in Table 9.

Results of the length-frequency analysis for both male and female *P. monodon* resemble the population and mortality parameters estimated by Khan et al. (1994) using data collected during the period 1988 - 89. For *P. semisulcatus*, there was a considerable difference between the asymptotic lengths for males and females, utilizing the same procedure, although similar fishing pressure on *P. semisulcatus* applied to the results of Mustafa (1999).

The male and female populations of the banana shrimp (*P. merguiensis),* were studied separately. Results show that the estimated parameters for females are higher than for males. The E values were estimated to be 0.68 and 0.47 for males and for females, respectively. The estimated growth parameters for the brown shrimp (*M. monoceros)* were similar to the results observed by Khan et al., (1994). The exploitation ratios were 0.58 and 0.47 for males and females, respectively. These estimates bear some resemblance to the results found by Mustafa (1989).

The growth parameters for the lizardfish (*S. tumbil*) estimated using ELEFAN I were similar to the estimates made by Mustafa and Khan, (1988). The present estimates of total (Z), natural (M) and fishing (F) mortalities, as well as the exploitation ratio (E) were also similar to the results found by Mustafa and Khan, (1988). For the goatfish (*U. sulphureus)*, the present growth estimates resemble the results of the study by Mustafa (1993a) while estimates of mortality and exploitation ratios closely resemble the results observed by Mustafa (1999). The growth estimates computed for the Japanese threadfin bream (*N. japonicus)*, were similar to those estimated by Khan and Mustafa (1989). The rates of total (Z), natural (M) and fishing (F) mortalities of *N. japonicus* were also similar to the estimates of Khan and Mustafa (1989) although the exploitation (E) value was a little higher.

Table 9. Growth and mortality parameters for selected trawl-caught demersal fish and shrimp species in Bangladesh waters (1984 - 87) (M = male, F = female).

Species	Asymptotic Length (cm) (L_∞)	Growth Constant (k)	Mortality Rate (Annual)			Exploitation Rate (E)	M/K	$Lc/_\infty$	Probability of Capture		Spawning Time	
			Natural (M)	Fishing (F)	Total (Z)				L_{50}	L_{75}	Winter Cohort	Summer Cohort
A. SHRIMP												
Penaeus monodon (M)	29.0	1.29	2.13	5.93	8.06	0.74	1.65	0.71	20.57	21.51	February	September
P. monodon (F)	32.5	1.2	1.97	2.68	4.65	0.58	1.64	0.69	22.54	23.82	February	September
P. semisulcatus (M)	24.7	1.36	2.31	5.41	7.72	0.70	1.69	0.63	15.47	16.29	January	August
P. semisulcatus (F)	25.6	1.28	2.19	3.81	6.00	0.63	1.71	0.77	19.69	20.76	January	September
P. merguiensis (M)	17.92	1.235	2.37	5.01	7.38	0.68	1.92	0.80	14.36	15.13	January	June
P. merguiensis (F)	22.10	1.299	2.31	2.03	4.34	0.47	1.78	0.80	17.69	18.59	February	July
Metapenaeus monoceros (M)	17.50	1.40	2.59	3.52	6.11	0.58	1.85	0.54	9.37	10.15	April	October
M. monoceros (F)	18.0	1.32	2.47	2.17	4.64	0.47	1.87	0.62	11.23	12.06	April	October
B. FISH												
Saurida tumbil	40.70	0.635	1.22	0.71	1.93	0.37	1.92	0.49	19.96	21.27	–	June
Upeneus sulphureus	22.40	1.40	2.41	4.71	7.12	0.66	1.72	0.41	9.12	9.92	–	May
Nemipterus japonicus	26.50	1.04	1.90	1.96	3.86	0.51	1.83	0.38	10.19	11.16	–	June
Lepturacanthus savala	105.35	0.68	0.98	1.05	2.03	0.52	1.44	0.26	27.91	32.68	February	–
Pomadasys hasta	57.0	0.40	0.82	0.67	1.49	0.45	2.05	0.77	44.16	46.19	–	May
Pampus argenteus	28.0	0.63	1.35	1.38	2.73	0.51	2.14	0.81	22.61	23.60	–	August
P. chinensis	38.0	0.70	1.32	2.17	3.49	0.62	1.88	0.66	25.25	26.07	January	–
Ilisha filigera	41.10	0.63	1.21	0.71	1.92	0.37	1.92	0.39	15.91	16.92	–	June

For the ribbonfish (*L. savala)* the L_∞ and k values were similar to those reported by Khan et al., (1994) using length frequency data collected during 1988 - 89. The mortality estimates, however, were similar to those estimated by Mustafa (1999), although the exploitation ratio was lower. Estimates of growth parameters for the white grunter (*P. hasta)*, were almost the same as the estimated values derived by Mustafa and Azadi (1995). The mortality estimates as well the exploitation rates of the present study, however, were similar to those reported by Mustafa (1999).

For the silver pomfret (*P. argenteus)*, the estimated values of L_∞ and k were the same as the values reported by Mustafa (1993b), utilizing length frequency data collected in 1986. Though estimated instantaneous rates of total, natural and fishing mortalities for *P. argenteus* do not resemble any of those reported by other authors, the exploitation ratio was similar to the derived estimate of Khan et al., (1997). The estimated growth parameters of the Chinese pomfret (*P. chinensis)* show close similarity with the results observed by Mustafa (1999), but the estimated values of total, natural and fishing mortalities of *P. chinensis* were all higher than those reported by Mustafa (1999), together with the exploitation ratio. The estimated L_∞ value for the big-eye Ilisha, *Ilisha filigera* (L_∞ = 41.1 cm) was bigger than that derived by Mustafa (1999) although the value of k (0.63 year^{-1}) was lower. The mortality rates obtained were lower, including the exploitation ratio as compared to the values reported by Mustafa, (1999).

The ratio of exploited species compared to under-exploited species differs in the present study compared to literature values for the same region. The disparity could be explained by the different computation procedures, or differences in computational adjustments such as correction for gear selectivity. Since the derived parameters were not subjected to the same computational procedures, the exploitation rates in their present form cannot be used forcomparing prevailing conditions during their respective periods. Nevertheless, it is evident that since the preferred (or targeted) species are shrimps, their exploitation rates on the average are much higher than those of the demersal fish. Since the rate of exploitation (E) is the ratio of fishing mortality to total mortality, it follows that those species with high E values are the same species exhibiting high fishing mortality values.

Tables 10 and 11 give the compiled growth and mortality parameters for shrimps and demersal fish respectively. The E value based on the compiled parameters for shrimps is 0.61 (Fig. 3) while for demersal fish it is 0.57 (Fig. 4), both above the optimal exploitation value of 0.50; thus indicating that the demersal resources in the study area are over-exploited and confirming the declining trend in demersal biomass noted earlier.

Surplus Production Models

The annual shrimp catch and fishing effort of trawlers from 1981 to 1998 and the annual fish catch and fishing effort of trawlers from 1986 to 2000 are shown in Tables 12a and 12b. During the last one and a half decades, the total effort of the shrimp trawl fishery was within the range of around 5 000 - 6 000 standard fishing days, producing 3 500 - 6 000 t of shrimps. Earlier reports estimated the MSY for penaeid shrimps at 7 000 t with optimum effort at around 7 000 - 8 000 standard fishing days. However, Mustafa and Khan (1993) on the basis of surplus production models, estimated the MSY for shrimps to be within 4 100 to 4 300 t at effort levels of 8 500 to 11 000 fishing days. Nonetheless, recent statistics yield a different set of estimated values for MSY and optimum effort.

The surplus production models of Schaefer (1954) and Fox (1970) were used to estimate the MSY for shrimps using the catch and effort data presented in Table 12a. These data were taken from trawl catch statistics compiled by the Department of Fisheries. The MSY value for penaeid shrimps using the Schaefer model was 3 566 t corresponding to an optimum effort level (f_{msy}) of 6 483 standard fishing days. Using the Fox model, the MSY for shrimps was estimated to be 3 474 t at an optimum effort level of 6 456 fishing days. Three data points corresponding to the years 1981-82, 1983-84 and 1984-85 were not included in the computation for MSY and f_{msy} values since the estimated effort values during those years were considered unreliable by Mustafa and Khan, (1993). The correlation coefficients were 0.30 and 0.269 for the Schaefer and Fox models, respectively. Similar analysis undertaken for demersal fish catches exhibited extremely poor correlation between catch rates and effort values. This was probably due to error estimates in the discarded by-catch, so the results were not considered.

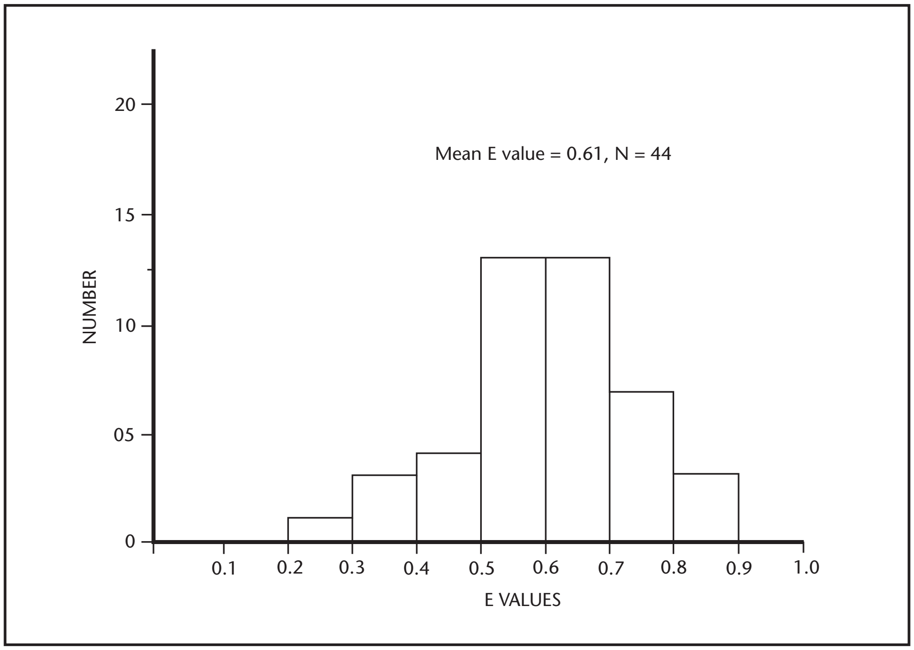

Fig. 3. Distribution of compiled E values of different shrimp species.

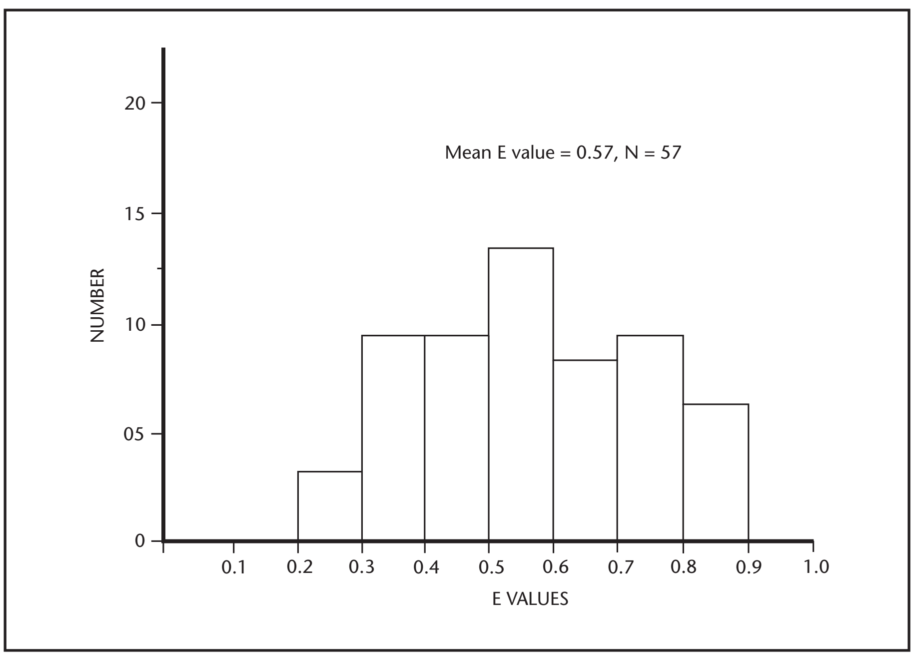

Fig. 4. Distribution of compiled E values of different fish species.

Table 10. Compilation of growth and mortality parameters, from previous studies of some marine shrimp species exploited by the trawl fishery in Bangladesh (M = male, F = female).

Species	Asymptotic Length (cm) (L_∞)	Growth Constant (k)	Mortality Rate (Annual)			Exploitation Rate (E)	M/K	Lc/L_∞	L_{75}	References
			Natural (M)	Fishing (F)	Total (Z)					
Penaeus monodon (M)	30.50	1.14	1.94	4.89	6.83	0.71	1.70	0.57	17.5	Mustafa and Khan (1989)
P. monodon (F)	31.50	1.35	2.14	3.58	5.72	0.62	1.59	0.50	15.7	-do-
P. monodon (M)	30.10	1.00	1.89	3.15	5.04	0.63	1.89	0.64	19.38	Khan et al. (1989)
P.monodon (F)	31.30	1.21	2.00	6.38	8.38	0.76	1.65	0.78	24.51	-do-
P. monodon (M)	28.80	1.20	2.03	5.86	7.89	0.74	1.69	0.61	17.50	Khan et al. (1994)
P.monodon (F)	30.50	1.70	2.50	3.28	5.78	0.57	1.47	0.51	15.70	-do-
P. monodon (M)	30.00	0.94	1.72	3.33	5.05	0.66	1.83	–	–	Mustafa (1999)
P.monodon (F)	32.10	0.97	1.72	2.13	3.85	0.55	1.77	–	–	-do-
P. semisulcatus (M)	23.50	0.80	1.73	3.47	5.20	0.67	2.16	–	–	Mustafa (1999)
P.semisulcatus (F)	27.00	0.90	1.72	2.98	4.70	0.63	1.91	–	–	-do-
Metapenaeus monoceros (M)	16.20	1.40	2.64	4.90	7.54	0.65	1.89	0.66	10.68	Khan et al. (1989)
M. monoceros (F)	19.60	1.45	2.56	5.10	7.66	0.67	1.77	0.59	11.64	-do-
M. monoceros (M)	15.70	1.60	2.91	2.98	5.89	0.51	1.82	0.76	11.93	Mustafa (1989)
M. monoceros (F)	18.50	1.65	2.84	1.68	4.52	0.37	1.72	0.79	14.63	-do-
M. monoceros (M)	18.00	1.40	2.80	2.41	5.21	0.54	2.00	0.49	8.90	Khan et al. (1994)
M. monoceros (F)	18.60	1.60	2.70	3.58	6.28	0.55	1.69	0.51	9.50	-do-
M. monoceros (M)	16.50	1.50	2.75	3.68	6.43	0.57	1.83	–	–	Mustafa (1999)
M. monoceros (F)	19.40	1.52	2.65	3.94	6.59	0.60	1.74	–	–	-do-

Table 11. Compilation of growth and mortality parameters from previous studies of some demersal fish species exploited by the trawl fishery in Bangladesh.

Species	Asymptotic Length (cm) (L_∞)	Growth Constant (k)	Mortality Rate (Annual)			Exploitation Rate (E)	M/K	L_c/L_∞	L_{75}	References
			Natural (M)	Fishing (F)	Total (Z)					
Saurida tumbil	39.0	0.64	1.66	0.88	2.54	0.35	2.59	0.46	18.02	Mustafa and Khan (1988)
S. tumbil	41.8	0.95	1.57	1.42	2.99	0.47	1.65	–	–	Mustafa (1999)
Upeneus sulphureus	20.87	1.45	2.40	9.10	11.50	0.79	1.66	–	–	Khan et al. (1987)
U. sulphureus	20.35	1.23	2.28	6.36	8.64	0.74	1.85	0.52	10.61	Khan et al. (1989)
U. sulphureus	22.0	1.10	2.07	9.45	11.52	0.82	1.88	0.50	11.07	Mustafa (1993a)
U. sulphureus	22.70	0.98	1.91	3.86	5.77	0.67	1.95	–	–	Mustafa (1999)
Nemipterus japonicus	24.16	1.06	1.97	1.08	3.75	0.47	1.86	–	–	Khan and Mustafa (1989)
N. japonicus	26.50	0.60	1.32	3.93	5.25	0.83	2.20	–	–	Humayun et al. (1989)
N. japonicus	24.50	0.94	0.78	0.55	1.33	0.41	0.83	–	–	Mustafa (1994)
N. japonicus	25.60	0.94	1.79	2.58	4.37	0.59	1.90	–	–	Mustafa (1999)
N. japonicus	27.20	0.92	1.74	0.51	2.25	0.23	1.89	–	–	Ashraful (1998)
Lepturacanthus savala	105.0	0.85	1.33	0.73	2.06	0.35	1.56	0.38	40.05	Khan et al. (1994)
L. savala	106.50	0.80	1.08	0.81	1.89	0.43	1.35	–	–	Ashraful (1998)
L. savala	108.00	0.75	1.04	1.54	2.58	0.60	1.39	–	–	Mustafa (1999)
Pomadasys hasta	54.83	0.39	0.77	0.78	1.55	0.51	1.97	–	–	Khan et al. (1985)
P. hasta	56.90	0.38	0.79	0.82	1.61	0.51	2.08	–	–	Mustafa and Azadi (1995)
Pampus argenteus	28.00	0.63	1.35	0.28	1.63	0.17	2.14	–	–	Mustafa (1993b)
P. argenteus	30.50	1.66	2.35	2.90	5.25	0.55	1.42	–	–	Khan et al. (1997)
P. argenteus	29.80	0.53	1.18	0.79	1.97	0.40	2.23	–	–	Mustafa (1999)
P. chinensis	38.10	0.67	1.29	0.83	2.12	0.39	1.92	–	–	Mustafa (1999)
Ilisha filigera	32.50	0.90	1.63	1.25	2.86	0.44	1.81	–	–	Ashraful (1998)
I. filigera	35.00	0.75	1.42	1.95	3.37	0.58	1.89	–	–	Mustafa (1999)

Table 12a. Annual shrimp catch and fishing effort of trawlers (1981 - 98).

Year	Standard effort (days)	Shrimp catch (t)	Catch per unit effort (kg·day^{-1})
1981 - 82	3 782	1 697	449
1982 - 83	7 024	3 120	444
1983 - 84	9 662	5 461	565
1984 - 85	8 159	5 518	676
1985 - 86	6 444	4 034	626
1986 - 87	6 928	4 488	648
1987 - 88	6 583	3 523	535
1988 - 89	6 945	4 893	705
1989 - 90	5 546	3 134	565
1990 - 91	4 499	3 430	762
1991 - 92	6 122	2 902	474
1992 - 93	7 065	4 188	593
1993 - 94	7 169	3 480	485
1994 - 95	6 761	2 416	357
1995 - 96	7 394	3 588	485
1996 - 97	7 107	3 536	497
1997 - 98	7 491	2 444	326

These results for shrimp catches indicate that the current levels of exploitation are not sustainable and that the fishing effort exerted should be decreased by at least 13.5% to attain sustainability. The 1987 - 88 fishing effort level is the one very close to the optimum level needed to attain MSY. Moreover, considering that only 45 - 49 trawlers were operating during the period of study (1984 - 87) and there are 69 trawlers currently operating, it is suggested that the present fleet should not be increased by the addition of new vessels, so that the proper and rational management of marine fishery resources in Bangladesh can be implemented.

Table 12b. Annual fish catch and fishing effort of trawlers (1986 - 2000).

Year	Standard effort (days)	Fish catch (t)	Catch per unit effort (kg·day^{-1})
1986 - 87	432	1 433	3 318
1987 - 88	846	1 535	1 814
1988 - 89	606	973	1 605
1989 - 90	792	2 105	2 658
1990 - 91	5 116	5 067	990
1991 - 92	900	1 868	2 075
1992 - 93	1 312	6 121	2 119
1993 - 94	1 018	2 723	2 675
1994 - 95	1 083	4 404	4 067
1995 - 96	1 146	4 568	3 986
1996 - 97	1 325	5 793	4 373
1997 - 98	1 485	7 515	5 060
1998 - 99	1 709	1 299	760
1999 - 00	2 014	2 987	1 187

Summary and Conclusion

On the basis of data collected from 1984 - 87 the estimated demersal fish biomass was 176 160 t which was in close proximity to the value presented by Lamboeuf (1987) i.e. 157 000 t (on average). The estimated penaeid shrimp biomass was only 857 t and is much lower than the estimate made by Khan et al. (1989) i.e. 3 100 t. The current estimate is limited by the area covered by the study and the sample size.

The present study reveals that the majority of the penaeid shrimps have been over-fished, except for the females of *P. merguiensis* and *M. monoceros*, whose exploitation ratios were lower than the optimum level. For the demersal fish species only three out of eight species examined did not exceed the optimum level of exploitation. Combining the

estimated E values from the present study with those reported by other authors, the average value is beyond the optimum level of exploitation.

The number of trawling vessels operating in Bangladesh since the period of study (1984 - 87) has increased considerably. From 49 shrimp and fish trawlers combined, the present number now stands at 69 trawling vessels. Therefore, it can be safely assumed that other species of fish and shrimps are now over-exploited. So no additional trawlers should be allowed to operate if proper and sound management of the marine fishery resources is to be implemented.

Another matter that needs serious consideration is the discarding of trash fish in the sea. It is a well-known fact in the industry that fish of lower price (mostly fresh fish) are thrown into the sea by trawler operators in order to maximize storage of commercially important fish and shrimps on board. As per Marine Fisheries Ordinance 1983, each shrimp trawler is required to bring 30% of its total catch of white fish to the shore, but operators are not complying. This provision should be strictly enforced. The utilization of mother vessels for collecting the trash fish from trawlers at sea (as discussed in a forum by the Ministry of Fisheries and Livestock and the Directorate of Fisheries) should be looked into.

There is a government order regarding the cessation of fishing operations by trawlers from mid-January to mid-February in order to enable the spawners to breed in the open sea. This order should be applied.

Allowing the irrational development of marine fisheries has resulted in the decline of fish and shrimp stocks. It is a common occurrence that a single stock of fish or shrimp is harvested by a number of different fisheries at different stages of their life cycle. Hence over-fishing in one fishery has affected the others. A classic example is the push net fishery for post larvae of the tiger shrimp (*P. monodon*) and the estuarine set bag net (ESBN) and beach seine fisheries for their juveniles. These methods have been identified as destructive. These fisheries restrict recruitment to the industrial fishery, and result in the lowering of catch rates and overall production. To reverse this alarming situation, particularly for the penaeid shrimp larvae inhabiting the coastal and estuarine waters, fishing gear destructive to shrimp and fish larvae must be banned.

The push net fishery is not only the means of livelihood for the particular community concerned. Some fishers and villagers operate these nets periodically as an alternative source of income. In contrast, a number of coastal fisherfolk largely depend on ESBN and beach seines for their livelihood. An alternative solution might be gradual withdrawal from this fishery and subsequent engagement in other income generating activities. Awareness and motivation amongst the fishers regarding the harmful effects of the gear concerned is lacking.

The day is not far-off when artisanal fishers will hardly catch anything. Therefore, proper conservation and management of the resources are essential. This situation warrants research on the sustainability of resources and biological studies on the stocks (stock assessment). Detailed accounts of fishing activities and the gear operating therein are also crucial for fishery managers. The generation of information would then translate into management plans and actions supportive and beneficial to the fisheries.

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Status of Demersal Fishery Resources of Malaysia

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Abstract

Research trawl surveys have been conducted in four areas of Malaysian waters (west and east coast of Peninsular Malaysia, and waters off the coast of Sarawak and off the west coast of Sabah) since 1970. Selected surveys (1972 - 98) were used to examine the status of demersal fishery resources in each area, focusing on catch rate and biomass trends, population parameters and the exploitation rates of dominant species. Annual fishery catch and effort data for Peninsular Malaysia (1971 - 96) and Sarawak (1969 - 96) were used to assess the maximum sustainable yield (MSY) and fishing effort to achieve optimum level (f_{MSY}). The results indicate over-exploitation of the demersal resources, severe depletion and excess effort in the fisheries. The catch rates have declined up to 96% in some regions, while biomass estimates are down to 6% of the virgin stock biomass. Most of the dominant species have exploitation ratios over 0.40. Analysis of the standardized fishing effort and yield using the Fox model indicates that the 1996 effort is 135 - 200% of the level needed to harvest MSY. The levels of reduction of catch and of exploitation vary among the four areas and with depth, but most show over-exploitation and severe reductions.

Introduction

Fisheries are an important sector in the Malaysian economy. Besides providing the main source of protein, the sector provides employment to about 80 000 fishers (Department of Fisheries (DOF) 1969 - 96). With the implementation of the Malaysian Exclusive Economic Zone (EEZ) in 1981, fishing grounds were extended beyond traditional areas. The total Malaysian EEZ area is 548 800 km^2, of which 45% (250 000 km^2) is off Sarawak and Sabah.

The Malaysian EEZ is generally divided into four areas, namely the west and east coast of Peninsular Malaysia, and the waters off the coast of Sarawak and off Sabah. Since the early 1970s the waters of Malaysia have been sub-divided for research survey purposes (Figs. 1 and 2). The west coast of Peninsular Malaysia was divided into six sub-areas (Fig. 1) (Mohammed Shaari et al. 1976b; Mohammed Shaari et al. 1976a): Sub-area I is between the islands of Langkawi and Penang, Sub-area II is between Penang and Pangkor Island, Sub-area III is between Pangkor Island and Bemam River, Sub-area IV is between Bemam River and Sepang river-mouth, Sub-area V is between the Bemam river-mouth and Kesang river-mouth and Sub-area VI covers the area between Kesang river-mouth and the southernmost part of Johore.

The four sub-areas on the east coast of Peninsular Malaysia (Fig. 1) have been fixed since surveys in

1970 (Pathansali et al. 1974): Sub-area I covers the entire coast of Kelantan and the northern third of Terengganu, Sub-area II covers the southern two-thirds of Terengganu state, Sub-area III covers the entire coast of Pahang state and Sub-area IV covers the entire coast of Johore.

The survey areas off the state of Sarawak, west coast of Sabah and the Federal Territory of Labuan (Fig. 2) have been divided into six sub-areas (Sub-areas I - III are in Sarawak waters, IV - VI in Labuan and Sabah) since the first survey conducted in 1972 (Mohammed Shaari et al. 1976a): Sub-area I stretches from Tanjung (Tg.) Dato to Tg. Sirik, Sub-area II is from Tg. Sirik to Tg. Kidurong, Sub-area III is from Tg. Kidurong to Kuala Baram, Sub-area IV covers the entire coast of Brunei Darussalam including the Federal Territory of Labuan, Sub-area V is from north of Labuan to Kota Kinabalu and Sub-area VI is north of Kota Kinabalu to Marudu Bay.

The waters of the west coast of Peninsular Malaysia seldom exceed 120 m depth. Physically, the sub-strate of the Straits of Malacca shows a gradual downward slope from both the coastline of East Sumatra and the west coast of Peninsular Malaysia

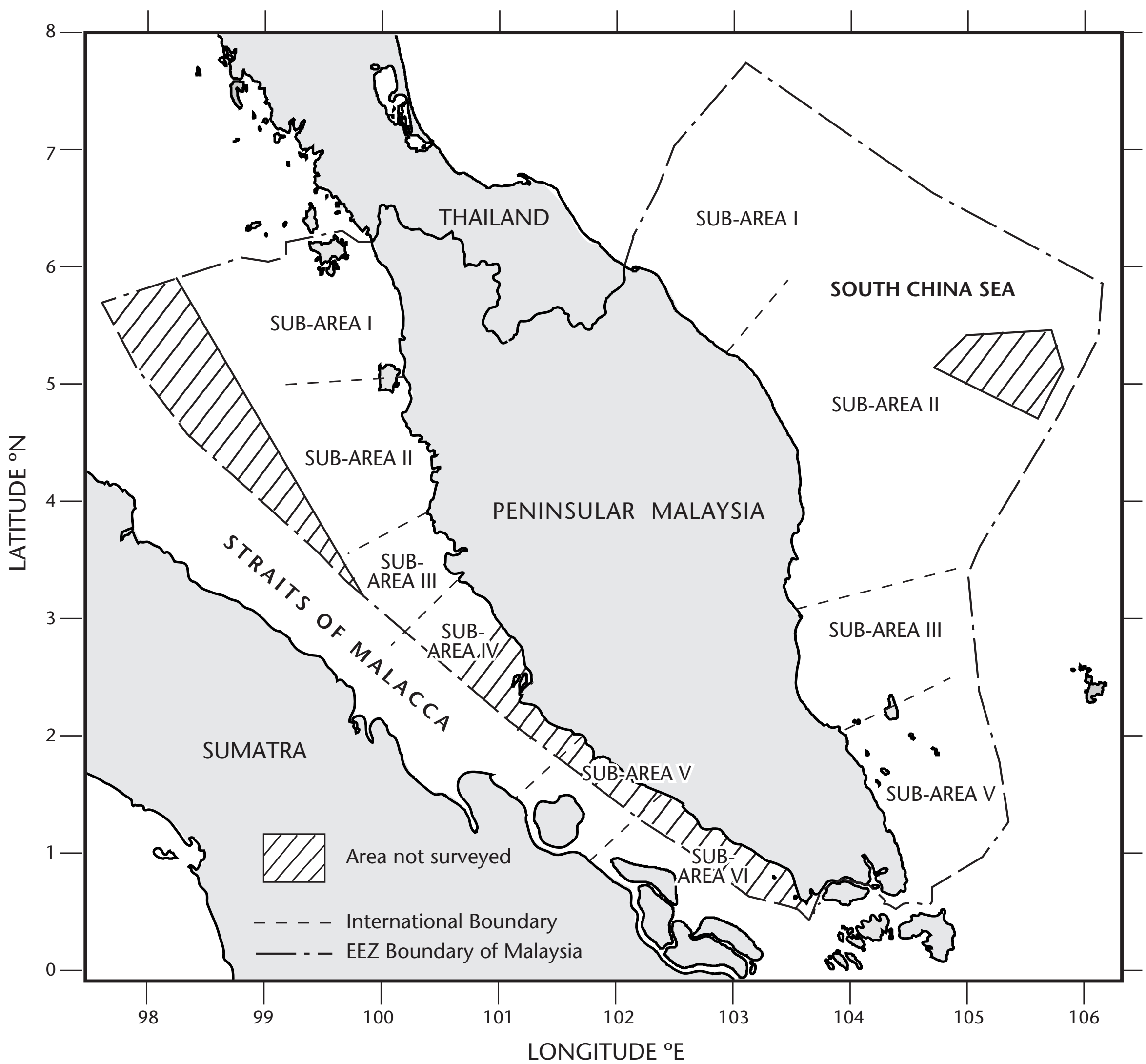

Fig. 1. Peninsular Malaysia showing the six sub-areas off the west coast and four sub-areas off the east coast.

(Liong 1974). The area can be divided into two parts by the 30 m isobath near One Fathom Bank in the middle of Sub-area IV (Fig. 1), where the bottom topography shows an increase in depth both toward the Andaman Sea in the north and the South China Sea in the south. The depth increase toward the north is however far greater and the deepest part is at the northern tip of Sub-area I (Fig. 1). Earlier surveys show a gradual transition in substrate from mud in the north to mixtures of mud/sand in Sub-areas I to IV which are suitable for trawling (Mohammed Shaari et al. 1974). Untrawlable (i.e. rocky) and uneven ground was reported for the entire Sub-area V, hence the absence of commercial trawling operations in the area.

Untrawlable ground was also reported on the northern part of Sub-area VI but not the southern part, which was predominantly muddy (Mohammed Shaari et al. 1976b).

The waters off the east coast of Peninsular Malaysia have a relatively flat topography and depths less than 100 m. The four Sub-areas (Fig. 1), though suitable for trawling, have minor patches with hard and soft corals in Sub-area II and mud-clay

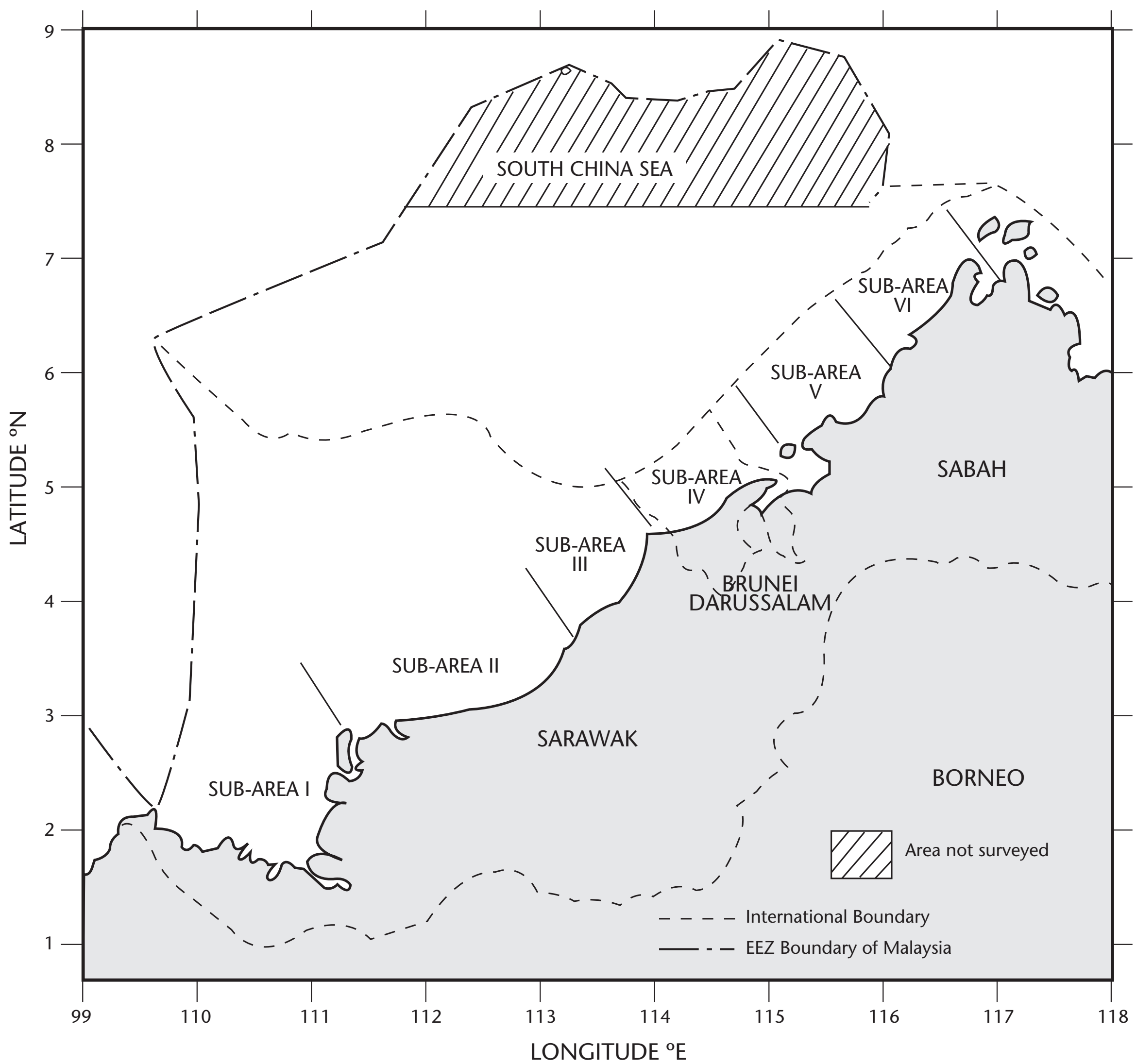

Fig. 2. The Sarawak and Sabah states showing the six sub-areas. Sub-areas I, II and III are off the coast of Sarawak and Sub-area IV, V and VI are off the coast of Sabah.

sediments in Sub-area IV (Pathansali et al. 1974). The continental shelf off Sarawak (Fig. 2) extends up to 220 nm at its furthest point north of Tg. Po in Sub-area II and its narrowest point is at 30 nm north of Tg. Baram in Sub-area III. The continental shelf extends 200 m, after which depth quickly drops to 1 000 m over a mean distance of 2.5 nm. From Sub-area IV off Brunei Darussalam waters to Kudat (on the northern tip of the west coast of Sabah) in Sub-area VI, the continental shelf extends only 30 nm from the shoreline.

Some important habitats found in Malaysian coastal waters are coral reefs, and mangroves. There is little reef along the peninsular mainland, with most of the fringing reefs occurring around offshore islands. The islands off the west coast have less extensive reefs compared to those off the east coast due to turbid conditions and muddy substrate. Along the west coast of Peninsular Malaysia, coral reefs are mainly found near Sembilan and Pangkor Island in Sub-area III, Langkawi and Payar Island in Sub-area I and off the coast near Port Dickson in Sub-area V. Redang and Perhentian Islands in Sub-area II and the area around Tioman Island in Sub-area IV are the two main reef areas off the east coast of Peninsular Malaysia. The fringing reefs off Sarawak and Sabah occur mainly along the islands off the west coast of Sabah. The continental shelf off Sarawak, especially in Sub-area II has scattered reefs and rough grounds. In Sub-areas V and VI on the west coast of Sabah, reefs and rough grounds are very extensive almost forming barrier reefs parallel to the coast. It is estimated that reefs and rough grounds comprise about 50% of the continental shelf in these Sub-areas. Mangroves are abundant in the sheltered waters off the west coast off Peninsular Malaysia and in Sub-areas I, III and VI off Sarawak and Sabah. On the east coast of Peninsular Malaysia, mangroves are found in patches within sheltered estuaries in a number of rivers.

The west coast of Peninsular Malaysia is traditionally the largest producer of marine fish in Malaysia. In 1996, this area produced 519 500 t valued at RM1 797 million (US$714.24million*) (or 46% of the total marine fish landings in the country). About 60% of the landings came from the trawl fishery, particularly from Sub-areas I, II, III and IV, which contributed 97% of total trawl landings. The east coast of Peninsular Malaysia is second in terms of total landings, contributing about 26% or 288 200 t valued at RM642 million. Landings from Sabah and Labuan totaled 218 300 t, valued at RM582 million. The trawl is second to traditional gear in catching marine fish in this area. Landings by trawlers stood at only 74 800 t. Although Sarawak has the widest fishing area, its contribution is only about 9% of the total national marine fish landings. Production in this area for 1996 was 100 700 t, valued at RM582 million, about 48% of which was landed by trawlers (Department of Fisheries (DOF) 1969 - 96).

Trawl surveys have been conducted both in traditional fishing grounds and within the Malaysian EEZ to determine demersal fish biomass, exploitation levels and species composition. Since the first survey in 1967, a total of 18 and 15 demersal surveys were conducted off the west and east coast of Peninsular Malaysia, respectively. A total of 13 surveys have been conducted off the coast of Sarawak and the west coast of Sabah since 1972. The initial aim of the surveys was to locate suitable trawling grounds and determine the size of demersal resources for development of the trawl fishery. Since 1970, surveys have been regularly conducted using local research vessels for the purpose of monitoring the status of the resources. Several foreign research vessels have also conducted demersal surveys in Malaysian waters. The RV Dharanat (Isarankura 1971), RV Fridtjof Nansen (Aglen et al. 1981) and RV Rastrelliger (Anon. 1988) have conducted surveys on the west coast of Peninsular Malaysia. On the east coast of Peninsular Malaysia, foreign vessels that have conducted surveys include RV Manihine (Ommanney 1961), RV Pramong II (Anon. 1967), RV Fridtjof Nansen (Aglen et al. 1981), MV Seafdec (SEAFDEC 1983) and RV Rastrelliger (Anon. 1988).

Two types of trawl survey have been conducted, coastal and offshore surveys. Coastal surveys cover the area from the coast to 5 nm offshore and waters 10 to 60 m deep. Offshore surveys cover the outer areas starting either from 12 nm, 30 nm or from the limit of the territorial area up to 100 fathoms (185 m) deep. The 1926 and 1927 surveys, using ST Tongkol, do not fall into either category since they were exploratory in nature (Birtwistle and Green 1927). The coastal surveys adhering to "standard procedures" were initiated in 1970 off the west coast (Mohammed Shaari et al., 1974), in 1967 off the east coast (Anon. 1967) and in 1972 off Sar-

* 1 US$ = RM2.51596 (1996)

awak and west coast of Sabah (Mohammed Shaari et al. 1976a). To date, there have been 14 coastal surveys completed off the west coast, 12 off the east coast of Peninsular Malaysia and 9 off Sarawak and west coast of Sabah. The first countrywide offshore survey was conducted in 1986 - 87 (Anon. 1988), while the second was conducted in 1997 - 98 (Anon. 2000). This report presents the results of assessments using the trawl survey data gathered during research surveys off Peninsular Malaysia, Sarawak and the west coast of Sabah. For each area, five to six surveys (including the two offshore surveys) were selected and analyzed.

Materials and Methods

Fishing Vessel and Gear Specifications

The first systematic trawl survey to monitor the status of demersal fish resources was conducted in 1967. Since then, several research vessels have been used to conduct coastal and offshore surveys in different study areas (Table 1). The vessel used for the first coastal survey off the east coast of Peninsular Malaysia in 1967 was RV Pramong II - a 23 m (LOA) wooden stern trawler (Appendix A). The vessel was owned by the Department of Fisheries, Thailand and was used under the Thai-Malaysian-German joint trawling project (Anon. 1967). The first research vessel owned by the Department of Fisheries that conducted a coastal survey was KK Jenahak, a wooden stern trawler (Pathansali et al. 1974, Appendix A). This vessel was used for coastal surveys in Peninsular Malaysia from 1970 until 1981. Within the same period, another research vessel KK Merah, also a wooden stern trawler was used for coastal surveys in Sarawak and Sabah (Lam et al. 1975, Appendix A). In 1983, KK Mersuji, a fiberglass-reinforced plastic (FRP) stern trawler replaced KK Jenahak in conducting coastal surveys in Peninsular Malaysia (Ahmad Adnan 1998, Appendix A). In 1987 KK Manchong, another FRP stern trawler replaced KK Merah (Rumpet 1994). However, KK Manchong was deployed for both coastal and offshore surveys off Peninsular Malaysia, Sarawak and Sabah as she was suitable for both purposes.

The first offshore demersal survey was conducted in 1986 - 87 using the vessel RV Rastrelliger. This vessel was owned by the Food and Agriculture Organization (FAO) of the United Nations and was chartered by the survey's executing agency on behalf of the Government of Malaysia. The second offshore survey carried out in 1997 - 98 utilized the KK Manchong. The specifications of the survey vessels and their principal equipment are given in Appendix A.

Table 1. Research vessel and method of sampling used during selected surveys in Malaysian waters, 1967 - 98. Coastal sampling covers 10 - 60 m depth, offshore sampling covers 18 - 185 m depth.

Research Vessel	Sampling Method	Survey Area	Survey Year (Selected surveys)
RV Pramong II	Systematic random (coastal)	East coast, P.M.*	1967
KK Jenahak	Systematic random (coastal)	West coast, P.M. East coast, P. M. Sarawak & Sabah	1981 1972, 1981 1972
KK Merah	Systematic random (coastal)	West coast, P.M Sarawak & Sabah	1972 1972, 1981
RV Rastrelliger	Stratified random (offshore)	West coast, P. M. East coast, P. M Sarawak & Sabah	1987 1986 1986
KK Mersuji	Systematic random (coastal)	West coast, P. M East coast, P. M.	1991 1991
KK Manchong	Stratified random (offshore)	West coast, P. M. East coast, P. M. Sarawak West coast Sabah	1997 1998 1989/92/93, 1998 1993, 1998

Note: see also Appendix C - H. * P.M. = Peninsular Malaysia.

The trawl used for the surveys was a standard German otter trawl (Anon. 1967). The net was made of nylon with cod-end mesh size of 40 mm. The exceptions were the net used by RV Rastrelliger, whose cod-end mesh size was 50 mm (Anon. 1988) and the net used by KK Manchong, which was made of polyethylene, with a cod-end mesh size of 38 mm (Rumpet 1994). Details of the fishing gear used during the surveys are given in Appendix B.

Trawl Sampling Stations

West coast of Peninsular Malaysia

Three coastal surveys were selected for this area, those conducted in 1971 - 72, 1981 and 1991, in Sub-areas I and II. The sampling stations were located 5 to 60 nm from the coastline, in 10 to 60 m depth (Appendix C). Sampling stations were selected using a systematic random technique where the number of stations in each grid of 10 x 10 nm was randomly fixed. Trawling speed was 2.8 knots during the 1971 - 72 and 1981 surveys, and 3.0 knots during the 1991 survey. Fishing was conducted during daylight with each trawl one hour in duration.

The two offshore surveys were included in the analysis (1987 and 1997). The area surveyed in 1987 extended seaward from the 30 nm boundary (roughly overlapping with the 55 m or 30 fathom depth contour) to the offshore limits of the territorial boundary (up to 12 nm from shore). The survey covered all of Sub-areas I, II, III and IV. The second offshore survey covered a wider area, from 12 nm offshore to the offshore limits of the territorial boundary. However, for the purpose of this analysis, only offshore survey data from Sub-areas I and II were used. The stations for both surveys were selected using stratified random sampling. Each sub-area was divided into three depth strata; Stratum 1 was 18 to 55 m (10 - 30 fathoms), Stratum 2 was 56 to 91 m (> 30 - 50 fathoms), and Stratum 3 was 92 to 185 m (> 50 - 100 fathoms). Within each depth stratum, trawl stations were randomly selected so that in each grid of 15 x 15 nm, one fishing station was covered. Fishing operations were conducted during daytime and were one hour in duration. Towing speed was fixed at 3.5 knots in 1987 and 4.0 knots during the second survey.

Details of the total area covered by each trawl survey and the distribution of sampling stations by sub-area are given in Table 2(a). The distribution of sampling stations for the surveys is shown in Appendix C.

East coast of Peninsular Malaysia

Four coastal and two offshore surveys were selected for analysis, covering the area from the Thai-Malaysian border in the north to the Malaysian-Singapore border in the south. The area covered by these surveys extended from 12 nm from the shore up to the 200 nm EEZ, 10 to 90 m water depth. The coastal surveys were conducted in 1967, 1972, 1981 and 1991, the offshore surveys in 1986 and 1998. Sampling stations were selected using the stratified random technique. Each Sub-area had only two depth strata, i.e. 18 to 55 m and 56 to 91 m. Survey procedures were similar to those used off the west coast.

Table 2(b) gives details of the area covered by the surveys and the distribution of sampling stations by sub-area. The distribution of the sampling stations for the surveys is shown in Appendix D.

Sarawak

The three coastal surveys selected for this study were those conducted in 1972, 1981 and 1989/92/93. These surveys covered the area from the shoreline of Sarawak up to 80 nm from the coast. The survey in 1989/92/93 was done in three stages. The first stage carried out in 1989 covered Sub-area I, the second stage in 1992 covered Sub-area II, and the final stage in 1993 covered Sub-area III. The sampling stations were selected using a systematic random technique and were located in areas with depths of 10 to 60 m. The trawling speed was 2.8 knots for the 1972 and 1981 surveys and 3.5 knots for the 1989/92/93 survey. All fishing operations were done during daylight with trawl durations of one hour. The offshore surveys were conducted in 1986 and 1998. Both covered the same area, from the territorial limit (roughly between 12 to 25 nm offshore) up to the 185 m (100 fathom) depth contour.

The total area covered by each survey and the distribution of the sampling stations by sub-area are given in Table 2(c). The distribution of sampling stations for the surveys is shown in Appendix E.

West Coast of Sabah

The 1972 coastal survey was selected for analysis. The survey covered coastal waters up to 50 m deep and stations were determined using the systematic random technique. Trawling speed was 2.8 knots over the standard one hour towing duration and all fishing operations were done during daylight. The offshore surveys were conducted in 1986, 1993 and in 1998. All three surveys covered the same area, 12 nm offshore up to the 185 m depth contour. Trawling speed was 3.5 knots during the 1987 and 1993 survey and 4.0 knots during the 1998 survey.

The total area covered by the surveys and the distribution of sampling stations by Sub-area are given in Table 2(d) and illustrated in Appendix F.

Table 2. Total survey area and number of sampling stations during the coastal and offshore surveys off the (a) west coast of Peninsular Malaysia, (b) East coast of Peninsular Malaysia, (c) Sarawak and (d) west coast of Sabah. The Sub-areas are shown in Figs. 1 and 2.

(a) West coast of Peninsular Malaysia: total survey area is the area between 5 nm from the shoreline to the offshore limit of the territorial waters.

			Stations (No.)				
Survey Area	**Survey Strata**	**Area (km²)**	**Dec. 1971**	**Oct. 1981**	**Jan. 1987**	**Jan. 1991**	**Sept. 1997**
Sub-area I	I.1 (5nm - 55m)	6 187	46	41	2	25	4
	I.2 (56 - 91m)	6 252	–	–	10	11	8
	I.3 (92 - 185m)	3 853	–	–	10	–	4
	TOTAL	16 292	46	41	22	36	16
Sub-area II	II.1 (18 - 55m)	5 508	51	36	–	18	4
	II.2 (56 - 91m)	10 449	–	–	18	4	14
	TOTAL	15 957	51	36	18	22	18
Total survey area		32 249	97	77	40	58	34

(b) East coast of Peninsular Malaysia: total survey area is the area between 5 nm from the shoreline to the limit of the EEZ.

			Stations (No.)					
Survey Area	**Survey Strata**	**Area (km²)**	**March 1967**	**Aug. 1972***	**June 1981**	**Oct. 1986***	**Aug. 1991***	**Apr. 1998**
Sub-area I	I.1 (5nm - 55m)	19 832	29	48	22	24	26	22
	I.2 (56m - EEZ)	10 100	–	–	–	10	–	13
	TOTAL	29 932	29	48	22	34	26	35
Sub-area II	II.1 (5nm - 55m)	9 243	48	24	16	–	25	1
	II.2 (56m - EEZ)	52 857	–	–	–	65	–	61
	TOTAL	62 100	48	24	16	65	25	62
Sub-area III	III.1 (5nm - 55m)	10 312	45	35	21	2	8	3
	III.2 (56m - EEZ)	7 408	–	–	–	9	–	10
	TOTAL	17 720	45	35	21	11	8	13
Sub-area IV	IV.1 (5nm - 55m)	10 503	28	37	19	–	3	4
	IV.2 (56m - EEZ)	3 104	–	–	–	4	–	4
	TOTAL	13 607	28	37	19	4	3	8
Total survey area		123 359	150	144	78	114	62	118

Note: * Pre-Northeast Monsoon.

(c) Sarawak: total survey area is the area between the shoreline to the 185 m isobath.

Survey Area	Survey Strata	Area (km²)	Stations (No.)						
			April 1972	May 1981	April 1986	Aug. 1989*	April 1992	March 1993	Sept. 1998*
Sub-area I	I.1 (0 - 55m)	22 467	56	51	14	30	–	–	11
	I.2 (56 - 91m)	10 166	13	–	13	13	–	–	13
	I.3 (92 - 185m)	892	–	–	1	–	–	–	1
	TOTAL	33 525	69	51	28	43	–	–	25
Sub-area II	II.1 (0 - 55m)	21 030	54	39	18	–	11	–	16
	II.2 (56 - 91m)	16 417	–	–	21	–	18	–	20
	II.3 (92 - 185m)	22 909	–	–	28	–	–	–	30
	TOTAL	60 356	54	39	67	-	29	-	66
**Sub-area III	III.1 (0 - 55m)	11 242	47	30	3	-	-	3	6
	III.2 (56 - 91m)	11 765	7	-	15	-	-	13	11
	III.3 (92 - 185m)	15 556	-	-	16	-	-	-	19
	TOTAL	38 563	54	30	34	-	-	16	36
Total survey area		132 444	177	120	129	43	29	16	127

Note: * Pre-Northeast Monsoon.
**** Inclusive of southern portion of Sub-area IV which is off the coast of Sarawak.**

(d) West coast of Sabah: total survey area is area between the shoreline to the185 m isobath.

Survey Area	Survey Strata	Area (sq. km²)	Stations (No.)			
			April 1972	April 1986	May 1993	Oct. 1998*
**Sub-area V	V.1 (0 - 55m)	11 558	36	2	4	4
	V.2 (56 - 91m)	2 881	–	4	6	6
	V.3 (92 - 185m)	1 872	–	3	1	1
	TOTAL	16 311	36	9	11	11
Sub-area VI	VI.1 (0 - 55m)	8 652	59	2	13	13
	VI.2 (56 - 91m)	3 642	–	4	7	7
	VI.3 (92 - 185m)	2 334	–	2	3	3
	TOTAL	14 628.76	59	8	23	23
Total survey area		30 939	95	17	34	34

Note: * Pre-Northeast Monsoon.
**** Inclusive of northern portion of Sub-area IV which is off the coast of Sabah.**

On Board Catch Sampling Procedure

Once the catch was landed on board, large-sized fish as well as dangerous and poisonous species were separated for later identification and recording. Poisonous but non-commercial specimens were counted and disposed. The remaining portion of the catch was evenly distributed into boxes with a 50 kg capacity, to estimate the weight of the catch. One out of every five boxes (20% of the catch) was selected as a sub-sample for further sorting. If the total catch per haul was less than 100 kg, the whole catch was sampled. All sub-samples were grossed-up to estimate the total catch per haul.

In the sub-sample, genuine trash species (i.e. non-commercial species) were sorted, weighed, counted and later discarded. All commercial species, irrespective of size, were weighed and individual lengths measured on board or placed in labeled plastic bags for further work in the laboratory. Length measurements (dorsal extreme length) by 0.5 cm class (except for some larger species where 1.0 cm intervals were used) were recorded by station for dominant species. For fishes with filaments on their caudal fins, the total length was measured from the tip of the snout to the tip of the caudal lobe without the filament.

Catch-per-unit Effort by Area and Year

Data from coastal and offshore surveys were grouped together by Sub-area and depth stratum. The shallowest depth stratum, covering the area 5 nm from the coast up to 55 m depth, is mostly investigated during coastal surveys. Offshore surveys normally cover areas in depth stratum 2 (56 to 91 m) and 3 (92 to 185 m). However, a few stations during some of the offshore surveys were located in depth stratum 1. To investigate trends in mean catch rate over the study period, the cod-end mesh size was also standardized. The standard cod-end mesh size used for the west and east coast of Peninsular Malaysia was 40 mm, while that for Sarawak and the west coast of Sabah was 38 mm.

Stock Density and Biomass Estimates

The swept area method was used to estimate demersal stock density (D) and biomass (B) using the NAN-SIS software (Strömme, 1992). The equations used for the calculation were:

$$D = (C/f)/(a \cdot x_1)$$
$$B = ((C/f) \cdot A)/(a \cdot x_1)$$
$$a = t \cdot v \cdot h \cdot x_2$$

where

- C/f = catch-per-unit effort or CPUE ($kg \cdot hr^{-1}$)
- A = total survey area
- a = area swept by the trawl in time t
- x_1 = proportion of fish in path of the gear that escapes from the net (0.5 in Southeast Asian waters)
- t = time spent trawling
- v = trawling speed
- h = length of head-rope
- x_2 = effective head-rope length (0.5 in Southeast Asian waters).

Pelagic fish species were excluded from the calculations because (1) their pelagic nature affects their availability to the demersal trawl, and (2) they tend to show schooling behavior and thus are not uniformly distributed.

Length Frequency Data Analysis

Length frequency data for selected species and surveys were analyzed using FiSAT (FAO-ICLARM Stock Assessment Tools) (Gayanilo et al. 1996) to estimate growth parameters, mortalities and exploitation rates. Length frequency data from surveys conducted in 1997 off the west coast of Peninsular Malaysia and in 1998 off the east coast of Peninsular Malaysia, Sarawak and west coast of Sabah were used to estimate growth and mortality parameters. For the west coast of Peninsular Malaysia and Sabah where the surveys were completed within one month, the data were grouped as a single length-frequency distribution for that month. This was then repeated as sample data for the same month in the following year, making two months of sample data over two years for analysis using the FiSAT software. The length-frequency data collected during the 1998 survey off the east coast of Peninsular Malaysia and Sarawak were plotted as a time series over three months. These were then repeated for the following year and the set used as input for FiSAT analysis. The value of L_∞ (estimated from the Powell-Wetherall plot was used as an input to the ELEFAN I program. The seasonal oscillation level (C) and minimum growth period or winter period (WP) were not considered in the analyses. Similarly, no attempt was made to estimate the value of t_0 (the age of fish at zero length).

Using the growth parameters (L_∞ and K) obtained from the above procedure, total mortality (Z) was estimated using length-converted catch curves.

The Z estimation is based on pooling of percent samples from all or part of the length frequency data. The aim here is to simulate a steady-state population. Selection of points included in the estimation of Z were made by taking the points to the right of the highest point in the catch curve.

The estimate of Z was split into its fishing mortality (F) and natural mortality (M) components. The estimate of M for each species was calculated using Pauly's equation (Pauly 1980; Pauly 1984a; Pauly 1984b)

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.463 \log_{10} T$$

Where T is the mean habitat temperature (°C) of the fish (Pauly 1983). The mean (surface) temperature used in this study was 27.9° C for waters off the west coast of Peninsular Malaysia and 29.0° C for waters off the east coast of Peninsular Malaysia, Sarawak and West Sabah. Subtracting the estimate of M from Z gives an estimate of fishing mortality F. The exploitation rate (E) for each species was estimated by dividing F with Z.

The parameters a and b of the length-weight relationship (of the form $W = aL^b$) were estimated through base-10 logarithmic transformation of the length-weight data pairs and ordinary least-squares linear regression (Sparre and Venema 1992; Sparre et al. 1989). The goodness of fit index was determined using the correlation coefficient.

Analysis of Demersal Yield and Effort

The fishery catch data for demersal fishes (including trash fish and cephalopods) from 1971 to 1996 for the west and east coast of Peninsular Malaysia and from 1969 to 1996 for Sarawak (as compiled by the Department of Fisheries) were used in the analyses. In the case of Sabah, the annual Fisheries Statistics provide catches of demersal fishes by type of gear aggregated for the whole state. Analysis for Sabah was not possible as the research surveys were only conducted off the west coast.

The CPUE of research vessels used during surveys off the west and east coast of Peninsular Malaysia were standardized into the CPUE of KK Jenahak. The CPUE of KK Manchong was used as standard for surveys done in Sarawak. The size of the trawl head-rope and towing speed were two factors considered in converting the CPUE of other research vessels into CPUE of the standard vessel. The annual fishing effort was calculated based on the linear change of CPUE for the selected surveys by area. A weighted running average was used for approximating equilibrium fishing effort. The following formula was used:

$$f_{wt} = \frac{Kf_t + (K - 1)f_{t-1} + (K - 2)f_{t-2}}{K + (K - 1) + (K - 2)}$$

where f_{wt} = weighted average effort in year t,
f_t = actual effort in year t,
K = number of years (3) included in weighted average calculation.

The maximum sustainable yield (MSY) and F_{MSY} for demersal fishes (including trash fish and cephalopods) was estimated by fitting the time series data of annual catch (Y) and annual fishing effort (f_{wt}) using the Fox model (Fox 1970). The model assumes that catch-per-unit effort (Y/f_{wt}) declines exponentially as the effort (f_{wt}) increases.

Results and Discussion

Catch-per-unit Effort by Area and Year

Mean catch rate by depth stratum and Sub-area for the four study areas is given in Appendix G and H, and key results are illustrated in Figs. 3 to 6. These indicate a general trend of decline in resource abundance across the four areas. Geometric means provide a better estimate of average catch rate from trawl surveys. These were the values used for the detailed area analyses below.

West coast of Peninsular Malaysia

There has been a prominent reduction in mean catch rate of demersal fish in depth stratum 1 since 1971 - 72, especially when only coastal surveys are compared. The offshore surveys in 1987 and 1997 do not show such a similar trend, due to the limited number of sampling hauls (Fig. 7).

Mean catch rate in the coastal area of Sub-area I was reduced from 74.5 $kg{\bullet}hr^{-1}$ in 1971 - 72 to only 22.7 $kg{\bullet}hr^{-1}$ in 1991 and further down to 18.6 $kg{\bullet}hr^{-1}$ in 1997 (Appendix H). This is a reduction of 75% over the period considered. The 101.8 $kg{\bullet}hr^{-1}$ recorded in 1987 cannot be accepted since this was derived from only two sampling stations. In Sub-area II, the mean catch rate of 67.2 $kg{\bullet}hr^{-1}$ in 1971 - 72 was reduced to 21.00 $kg{\bullet}hr^{-1}$ by 1991. The higher value recorded in 1997 at 29.1 $kg{\bullet}hr^{-1}$ is misleading due to the limited sampling stations. This indicates that during the period between 1991 - 72 and 1991, resource abundance was reduced by 69%.

Offshore areas deeper than 55 m have been surveyed three times since 1987. In Sub-area I, catch rate for the stratum with depths of 56 to 91 m was reduced from 116.7 $kg{\bullet}hr^{-1}$ in 1987 to 33.3 $kg{\bullet}hr^{-1}$ in 1997. This is a 72% reduction in catch rate over a ten-year period. The decline for the same depth stratum in Sub-area II was more drastic, from 184.8 $kg{\bullet}hr^{-1}$ in 1987 to 47.1 $kg{\bullet}hr^{-1}$ in 1991 and to 33.6 $kg{\bullet}hr^{-1}$ in 1997, or a reduction of 82%. However, for the deepest stratum (92 to 185 m), which only exists in Sub-area I, the reduction was only 24% over a period of ten years. This may indicate less fishing activities in this area.

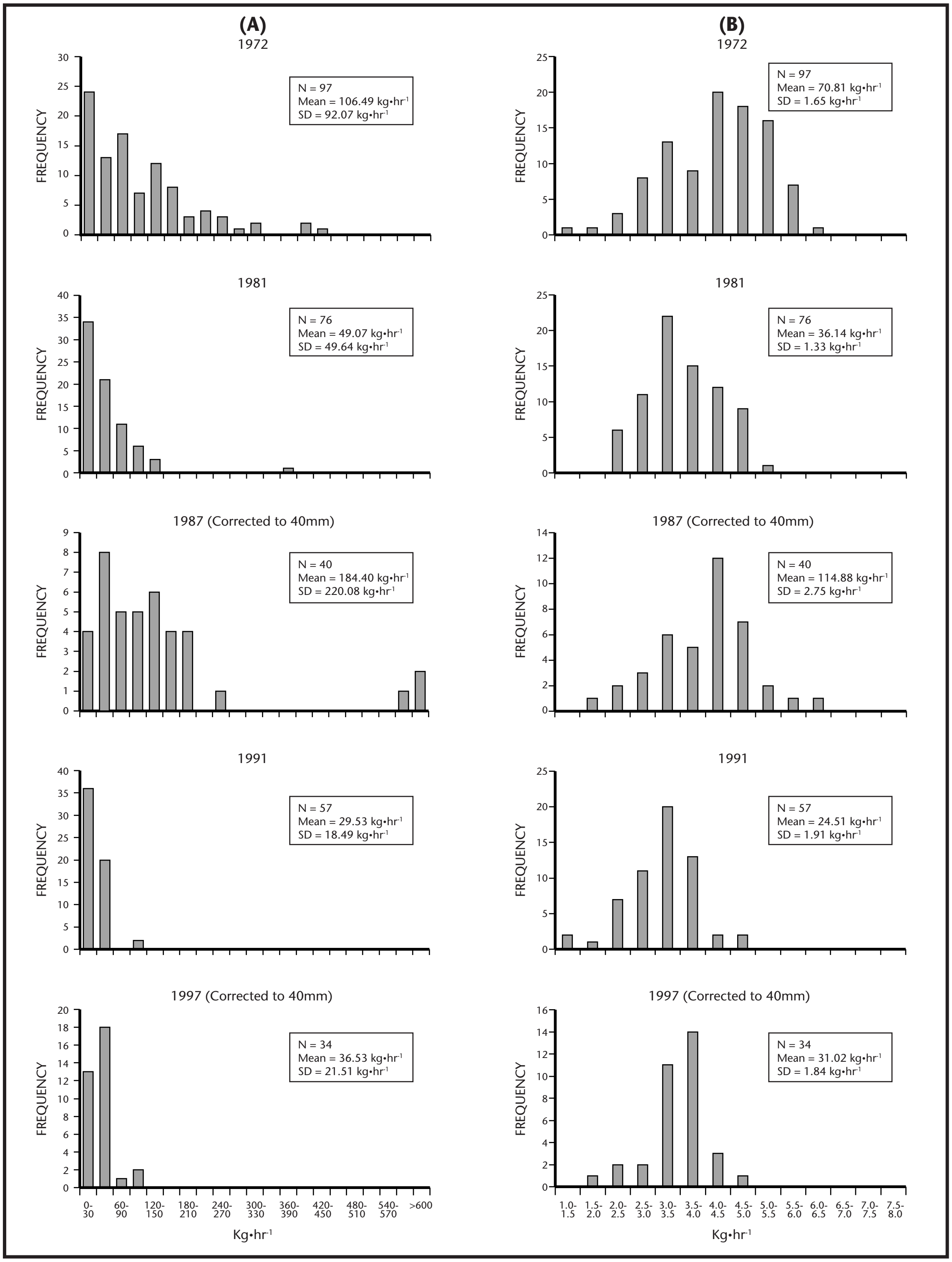

Fig. 3. Frequency distribution of CPUE (A) and log-transformed CPUE (B) from selected trawl surveys in Sub-area I and II off the west coast of Peninsular Malaysia from 1971 to 1997.

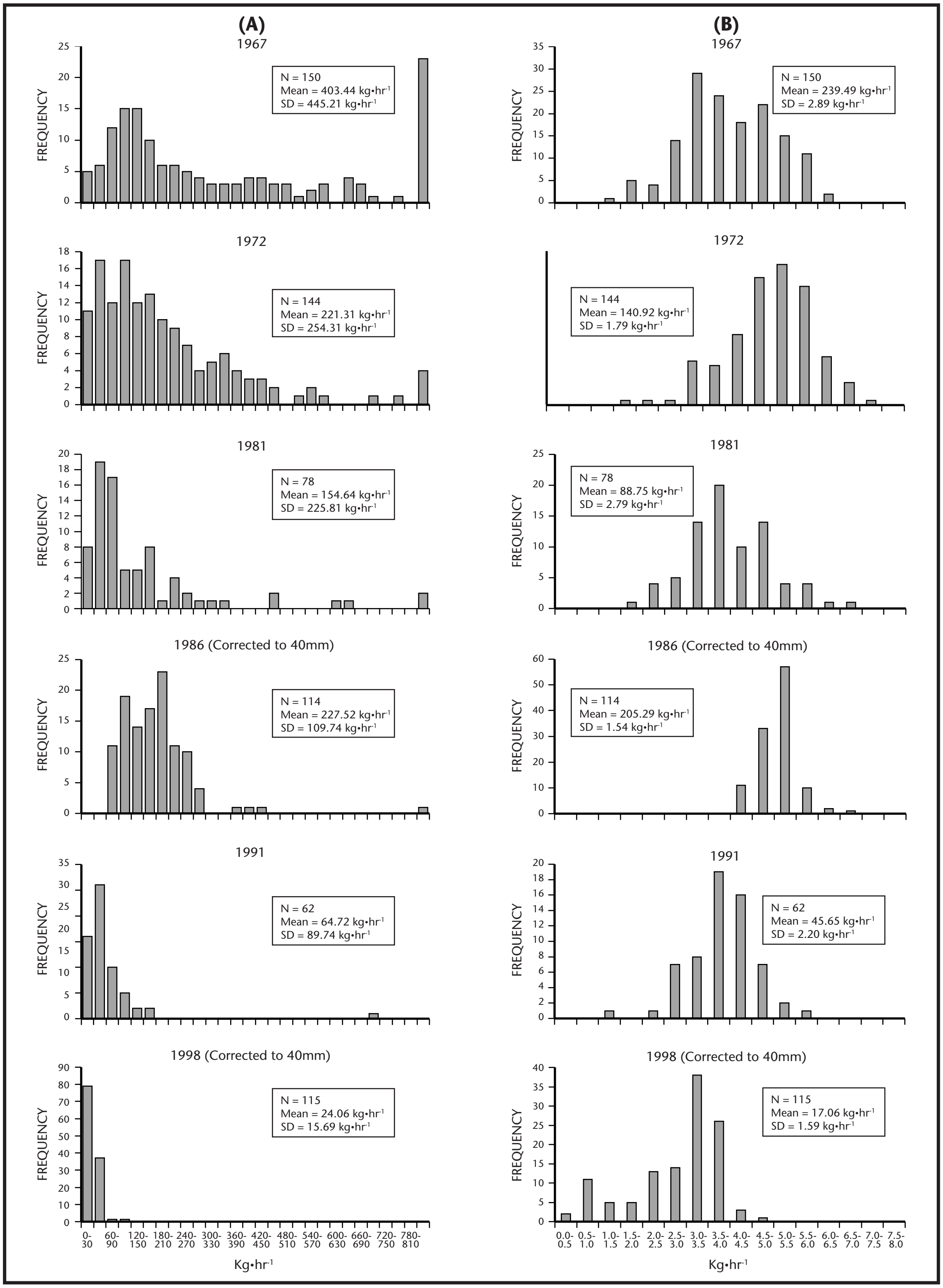

Fig. 4. Frequency distribution of CPUE (A) and log-transformed CPUE (B) from selected trawl surveys off the east coast of Peninsular Malaysia from 1967 to 1998.

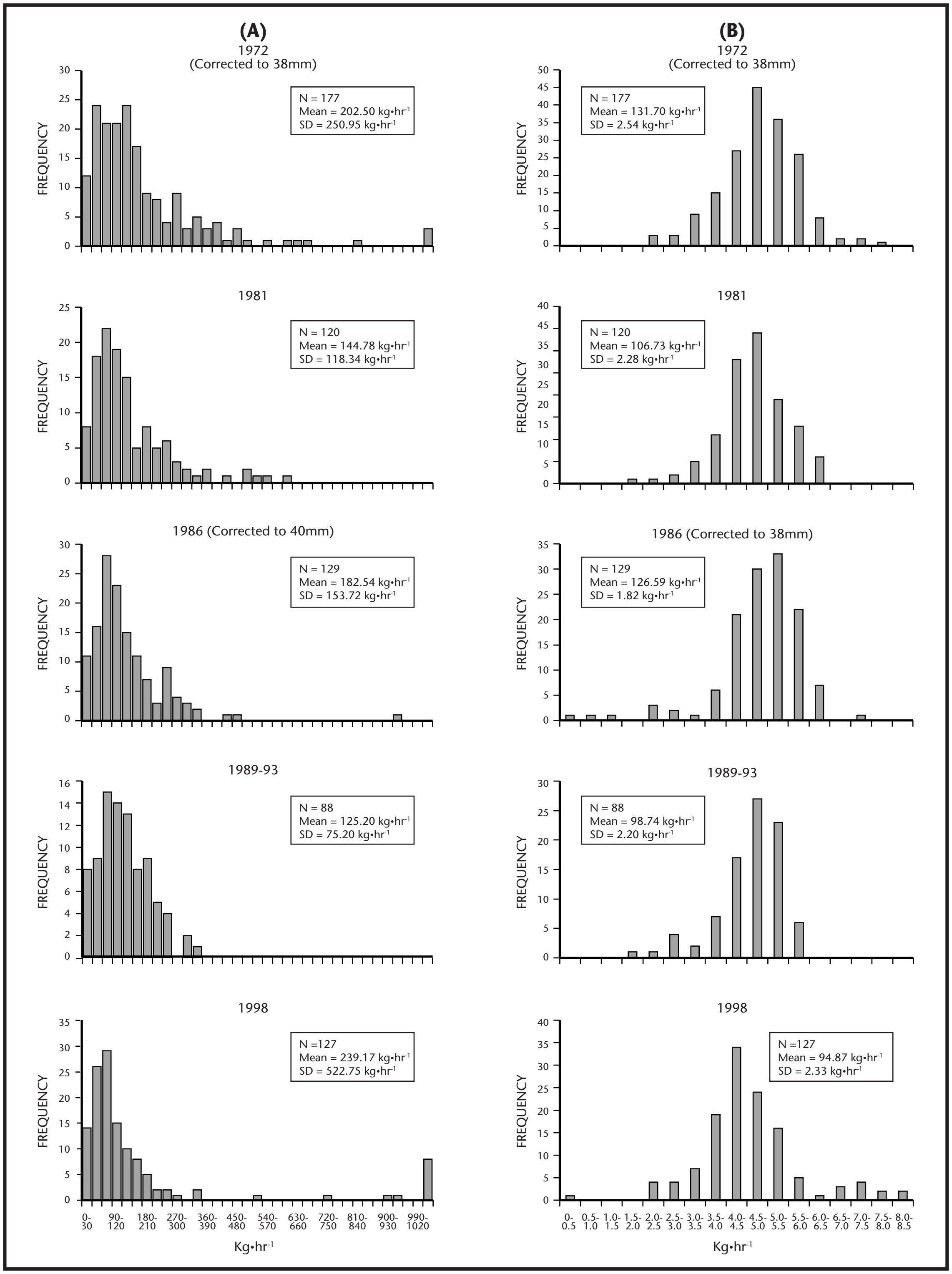

Fig. 5. Frequency distribution of CPUE (A) and log-transformed CPUE (B) from selected trawl surveys off the coast of Sarawak from 1972 to 1998.

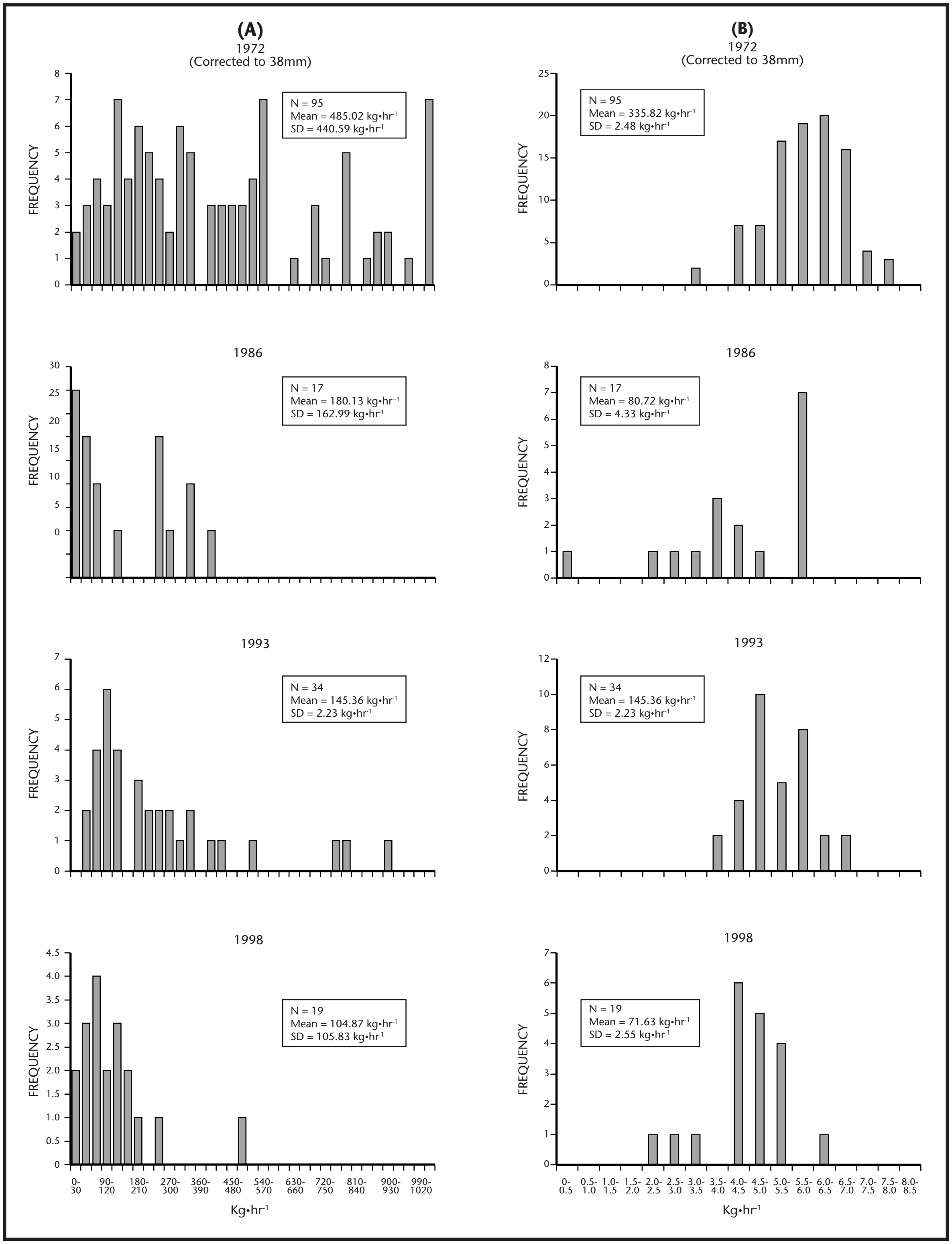

Fig. 6. Frequency distribution of CPUE (A) and log-transformed CPUE (B) from trawl surveys off the west coast of Sabah from 1972 to 1998.

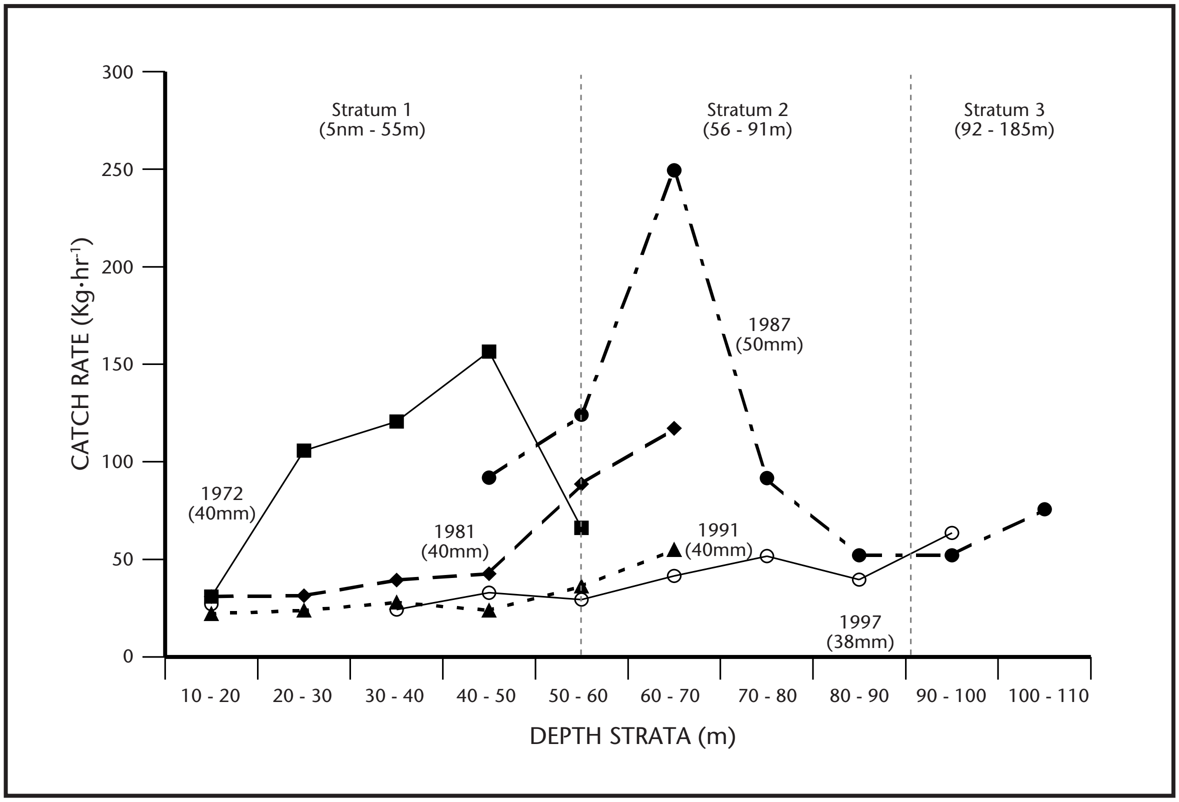

Fig. 7. Demersal fish abundance in (kg·hr^{-1}) by depth in Sub-area I and II off the west coast of Peninsular Malaysia during the trawl surveys from 1971 to 1997.

The coastal area of Sub-area I was more productive than those in Sub-area II. This is evident in all surveys except for the last survey in 1997. The most productive fishing grounds were located between Langkawi and Penang Island, as reported earlier by (Mohammed Shaari et al. 1974). The current catch rate in Sub-area I is lower than Sub-area II as the former has been, and currently is, heavily fished. The results reflect the high resource decline in both the areas. (Mohammed Shaari and Chai 1976) estimated a 30% reduction of the resource in Sub-area I and II by 1974. This is consistent with the sharp decline of abundance noted in the coastal area from results of the five surveys compared here (Figs. 3 and 7)

East coast of Peninsular Malaysia

Fig. 8 shows the catch rates (by 10 m depth interval) for the surveys included in the study. Overall, higher catch rates were recorded at depths of 20 to 40 min Stratum I. There is a continuous decline in catch rates over the survey period.

(Pathansali et al. 1974) noted the marked effect of the monsoons on abundance, distribution and species composition in this area. The surveys, therefore, were normally carried out during the interval between monsoons (August to October) to minimize such seasonal variability. However, surveys in 1967, 1981 and 1997 were conducted during the post-northeast monsoon period, while surveys in 1972, 1986 and 1991 were carried out during the pre-northeast monsoon period (Appendix H(b)).

The coastal area under depth stratum 1 (except for Sub-area II and IV) was covered during the six selected surveys. Sub-area II and IV was also not covered during the offshore survey in 1986. The offshore area in depth stratum 2 was only investigated during the offshore surveys in 1986 and 1997. Results of the analysis are therefore discussed by Sub-area rather than considering the whole area.

In Sub-area, I there was a clear decline of catch rate from 1967 to 1997 for the coastal area and from 1986 to 1997 for the offshore area. There are variations between high values recorded from pre-northeast monsoon surveys and low values from the post-northeast monsoon surveys. The reduction in catch rate for the coastal area (depth stratum 1) and offshore area (depth stratum 2) was 90% and 87%, respectively (Appendix H). The decline in catch rate was also observed for Sub-area II, Catch rate in 1997 was only 11% of that recorded in 1967. In Sub-area III, the catch rates fluctuated with no clear indication of monsoon effect. Both depth strata were heavily exploited with the 1997 catch rate only 5% of that in 1967. Sub-area IV is the poorest area in terms of demersal fish abundance. The decrease in catch rate in the coastal area was 96% over the 1967 - 97 period. Over-exploitation has also taken place in the offshore area as evidenced by the sudden drop in catch rate from 266.6 $kg \cdot hr^{-1}$ in 1986 to only 7.7 $kg \cdot hr^{-1}$ in 1997.

Sarawak

Catch rate by 10-m depth interval is shown in Fig. 9. In the Sarawak area, on the whole the declining trend in catch rate was only evident in depth stratum 1. There was no clear trend in depth stratum 2 and in depth stratum 3 the catch rate obtained in 1998 was higher than in 1986. The high catch rate obtained in this depth stratum during 1998 was probably due to sampling in rough (coral and uneven) grounds where high concentrations of fish are normally found.

The three coastal surveys and the offshore survey in 1986 were all conducted during the post-northeast monsoon (Appendix H). The only pre-northeast monsoon survey was the one conducted in September 1998. During the offshore surveys in 1986 and 1998, all three depth strata in the 3 Sub-areas were covered even though they were done during different monsoon periods. The coastal surveys on the other hand covered only depth stratum 1 and 2 in the three sub-areas. Results indicate a reduction of catch rate in coastal areas (stratum 1) of Sub-area I, II and III of about 64%, 48% and 26%, respectively. For depth stratum 2 the reduction was 40% while an increase in catch rate was noted for depth stratum 3, particularly in Sub-area II and III.

West coast of Sabah

Catch rate by 10-m depth interval is shown in Fig. 10. Declining catch rate was pronounced in the coastal area during the 1972 - 98 period. In the deeper strata, no clear trend was observed. The high catch rate obtained in Stratum 3 in 1993 was probably due also to sampling in rough (coral and uneven) ground.

The first demersal fish survey in 1972 was confined to the coastal area. The 1986 and 1998 surveys were offshore surveys covering the area from the reef barrier, about 12 nm from the coastline. The survey in 1993 covered both the coastal and offshore grounds in the two Sub-areas. As in Sarawak, all surveys were carried out during the post-northeast monsoon season, except for the survey in 1998, which was done in October, or pre-monsoon. Drastic declines in catch rates were recorded in depth stratum I of both Sub-areas (Appendix H). Catch rates obtained in the most recent survey were only 12% and 18% of those obtained during the 1972 survey in Sub-areas V and VI respectively. However, catch rates in depth stratum 2 and 3 of Sub-area V were higher than those recorded during the first offshore survey in 1986. Mean catch rate in the offshore strata in Sub-area VI showed a slight decrease (Appendix H).

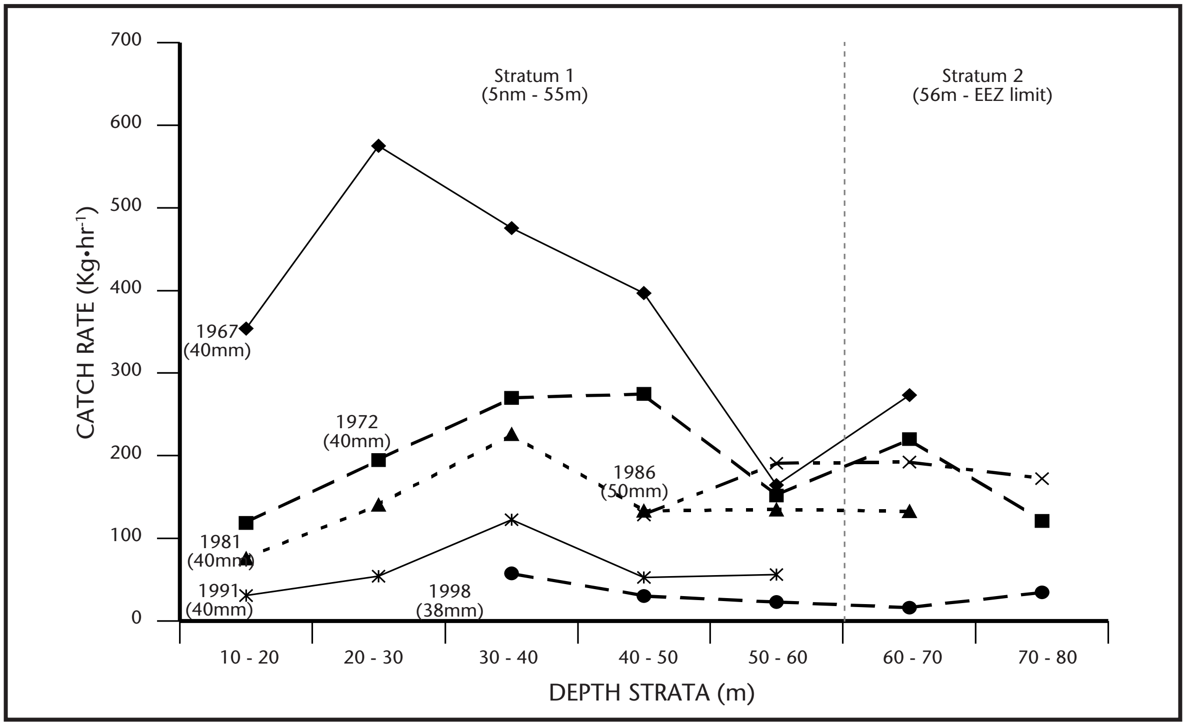

Fig. 8. Demersal fish abundance in (kg·hr^{-1}) depth strata off the east coast of Peninsular Malaysia during the trawl surveys from 1967 to 1998.

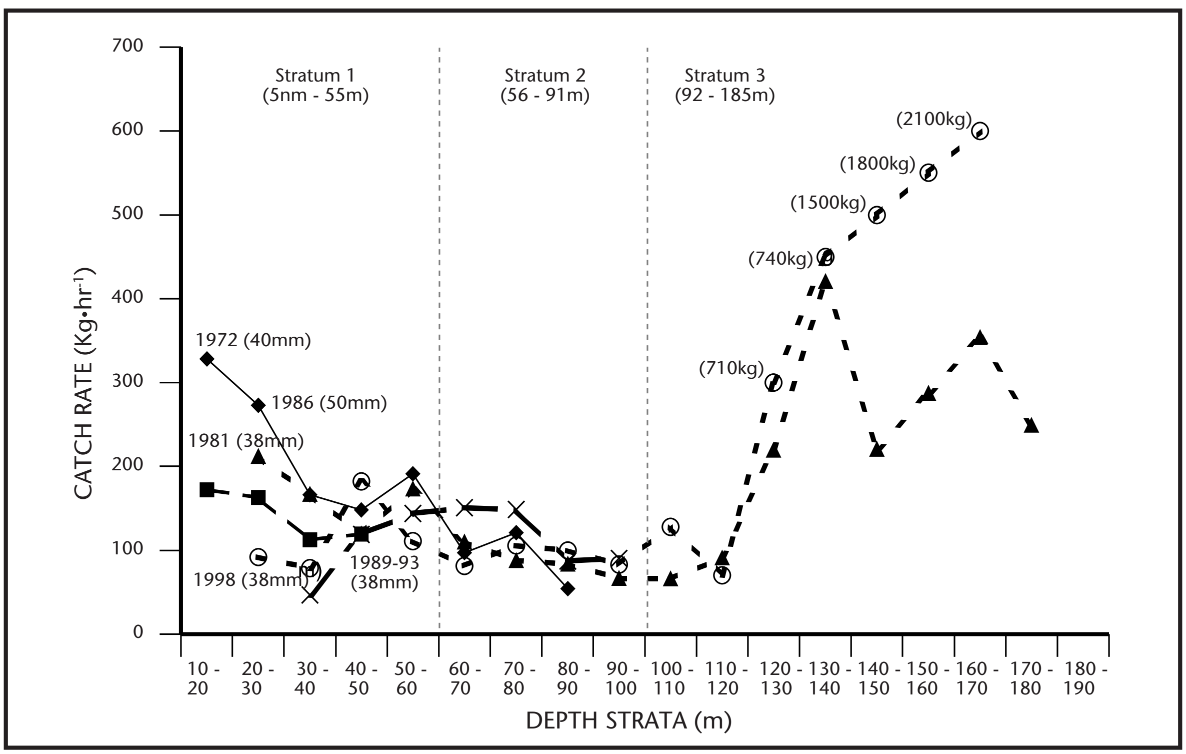

Fig. 9. Demersal fish abundance in (kg·hr^{-1}) by water depth off the coast of Sarawak during the trawl surveys from 1972 to 1998.

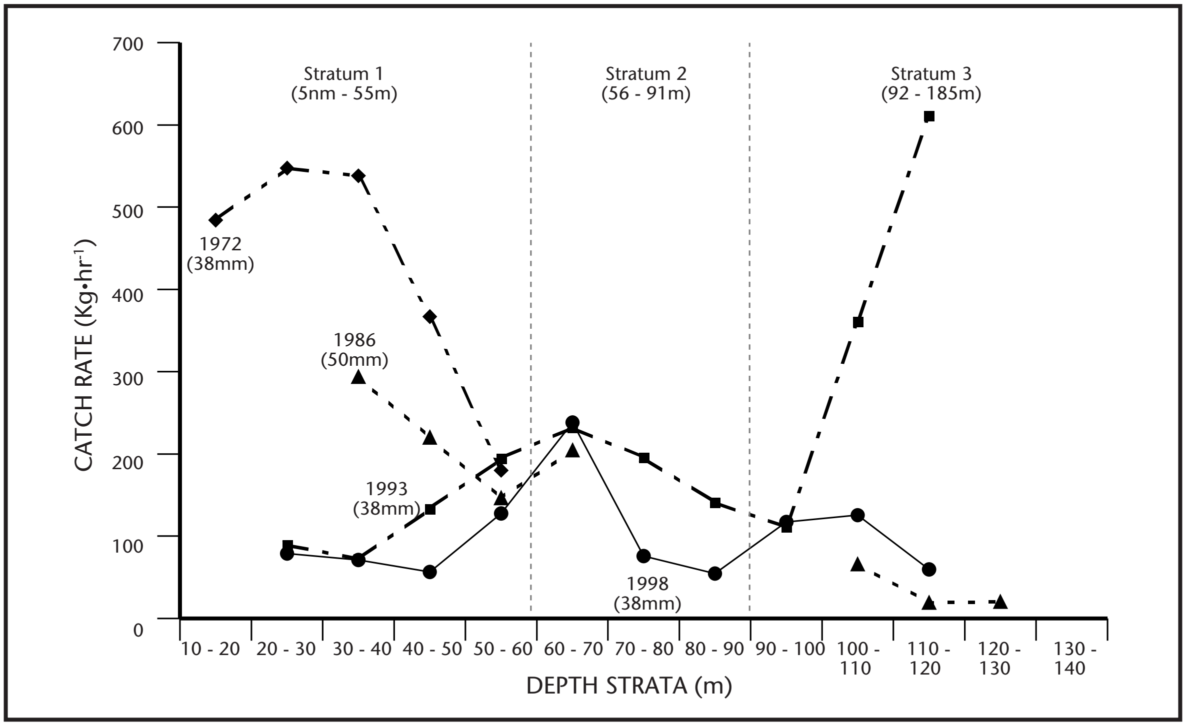

Fig. 10. Demersal fish abundance in (kg·hr^{-1}) by water depth off the west coast of Sabah during the trawl surveys from 1972 to 1998.

Stock Density and Biomass

West coast of Peninsular Malaysia

Appendix I details the estimates of stock density and biomass by depth stratum for Sub-area I and II off the west coast of Peninsular Malaysia. Changes over the study period are illustrated in Fig. 11. The 50% reduction level in density for the coastal area of Sub-area I and II was reached around 1981 - 82. In depth stratum 2, the 50% reduction in density and biomass for both Sub-areas occurred around 1993, only six years after introduction of deep-sea fishing.

Reduction in biomass of demersal fish can be very rapid especially in coastal areas. The estimated density in 1997 in the coastal area of Sub-area I and II was only 8% and 14%, respectively, of the value in 1971-72 (Mohammed Shaari et al. 1974). If the density of 3.59 t·km^{-2} for Southeast Asia given by (Tiews 1966) is taken as unexploited (or virgin) density, then the 1997 density of 0.35 t·km^{-2} for the study area represents only 9.8% of the virgin stock level. This indicates decimation of demersal fish resources in the area, compared to levels prescribed by surplus production models (Fox 1970; Schaefer 1954).

East coast of Peninsular Malaysia

Estimates of stock density and biomass are detailed in Appendix J and illustrated in Fig. 12. The density of demersal fish in 1998 showed a decline of more than 95% in coastal waters of all four Sub-areas. The same degree of reduction was observed in offshore areas of Sub-area III and IV. Stock density declined by 83% and 91% over the 1986 - 98 period in the offshore areas of Sub-areas I and II, respectively. If the density of 3.59 t·km^{-2} for Southeast Asia given by (Tiews 1966) is taken as unexploited density, the 1998 estimate for the whole study area of 0.20 t·km^{-2} represents only 6% of the virgin stock level. The east coast of Peninsular Malaysia shows greater exploitation and resource decline than the west coast.

Sarawak

Estimates of density and biomass by depth stratum for the three Sub-areas are given in Appendix K and illustrated in Fig. 13. Reduction in demersal stock density was observed in coastal waters of all three Sub-areas. Stock density was either gradually decreasing or increasing in the offshore areas.

West coast of Sabah

A substantive reduction in density and biomass was observed in coastal waters of Sub-area V and VI (Appendix L and Fig. 14). The 1998 densities in offshore areas are higher than estimated values from the first offshore survey in 1986, but this maybe an artifact of the limited number of stations and high catch rate variability typical of trawl surveys.

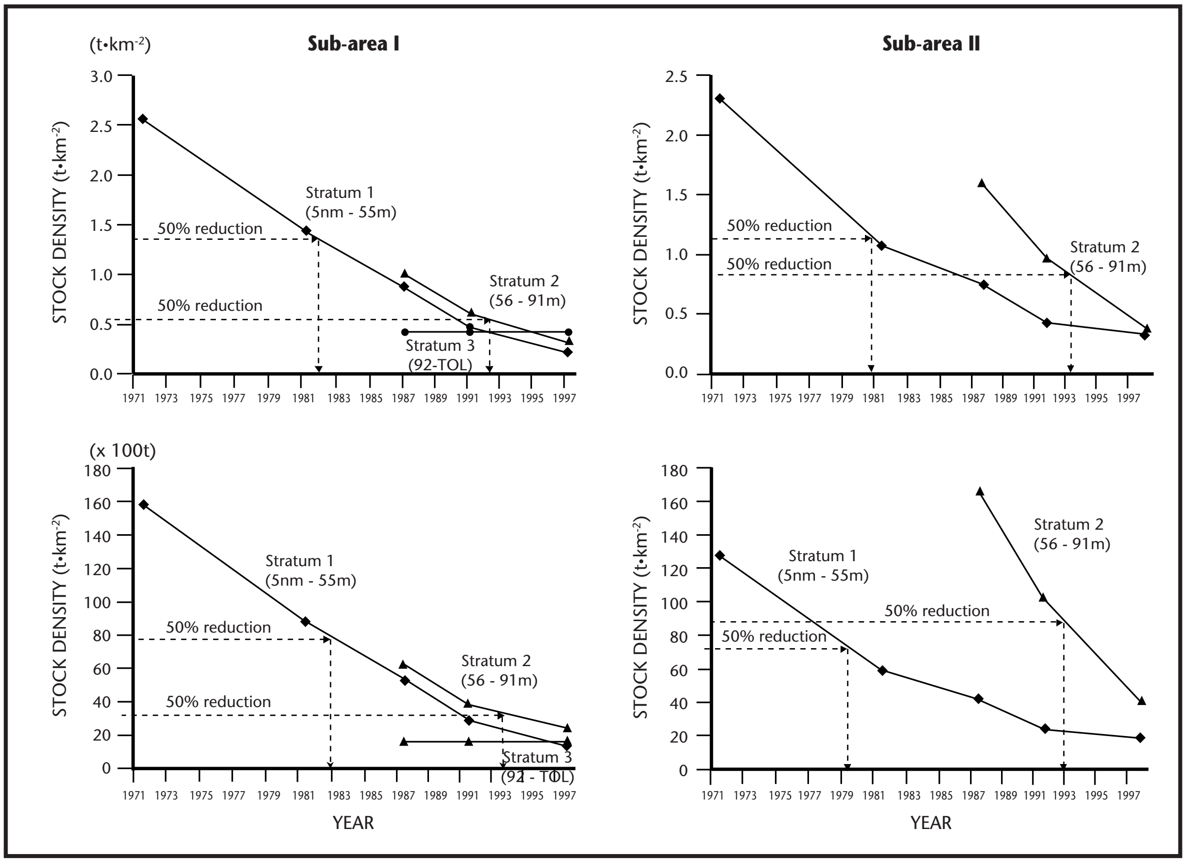

Fig. 11. Estimates of stock density (t·km^{-2}) and biomass (t) of demersal fish in Sub-area I and II off the west coast of Peninsular Malaysia obtained from surveys conducted from 1971 to 1997.

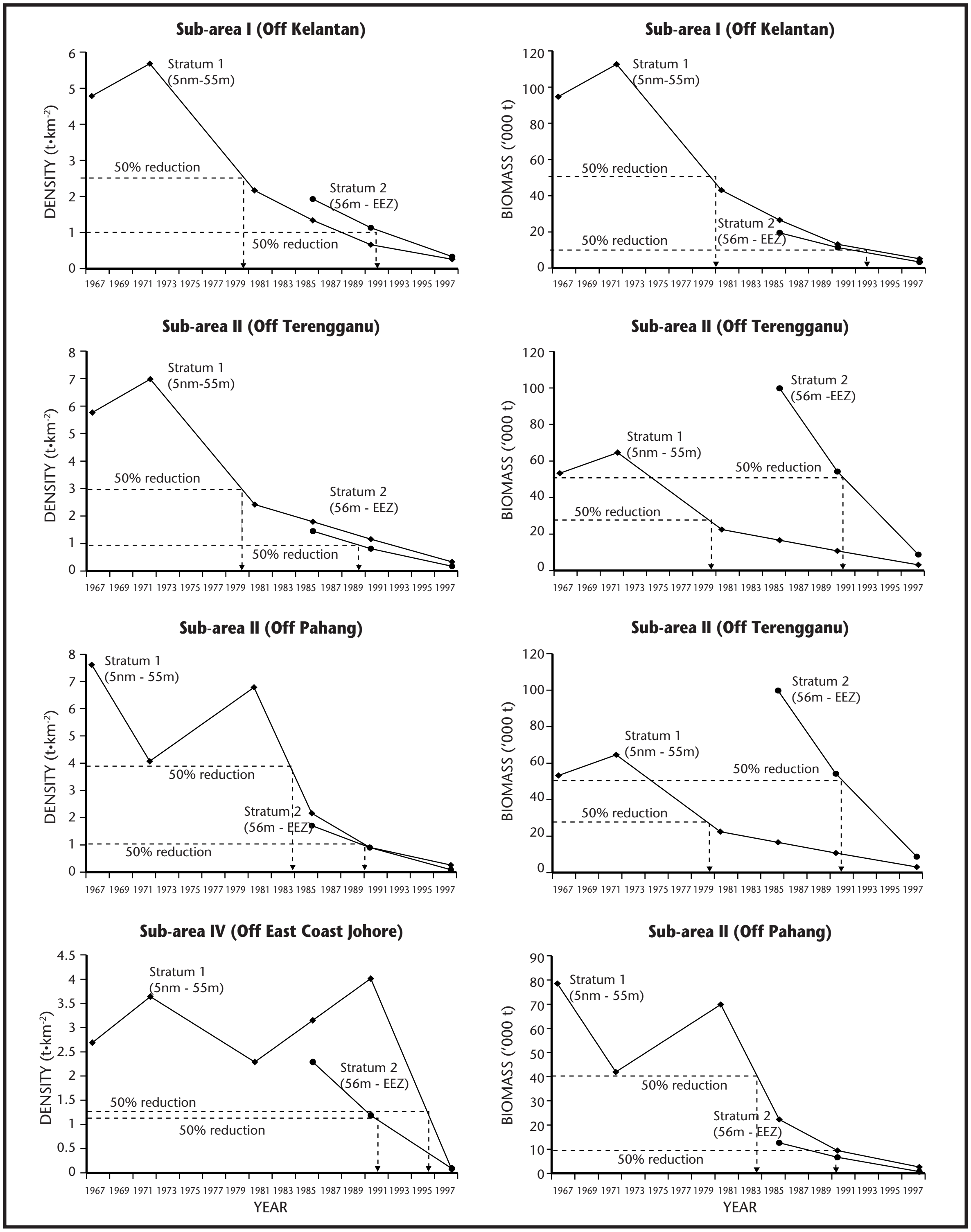

Fig. 12. Estimates of stock density ($t \cdot km^{-2}$) and biomass (t) of demersal fish off the east coast of Peninsular Malaysia obtained from surveys conducted from 1967 to 1998.

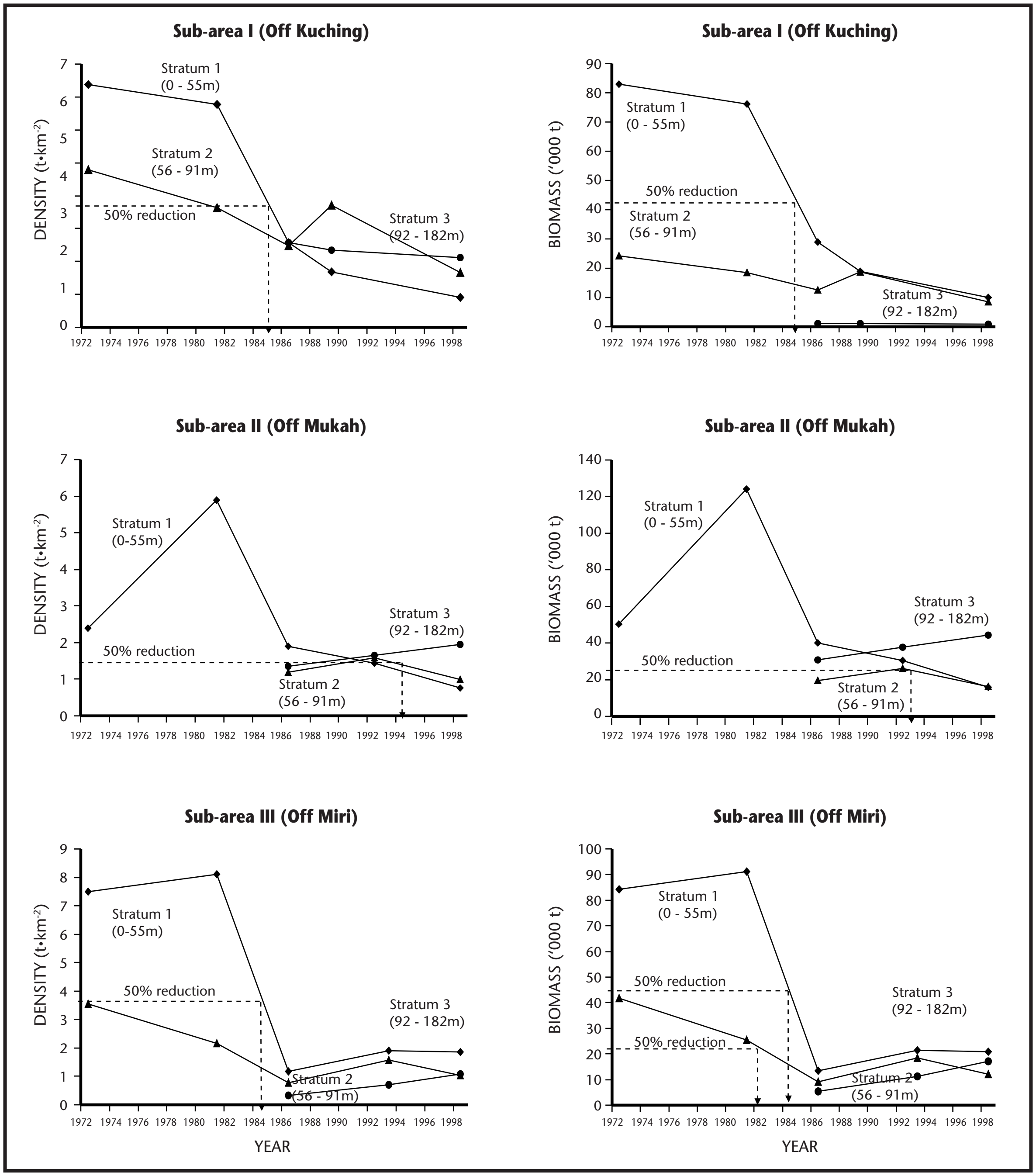

Fig. 13. Estimates of stock density (t·km^{-2}) and biomass (t) of demersal fish off the coast of Sarawak obtained from surveys conducted from 1972 to 1998.

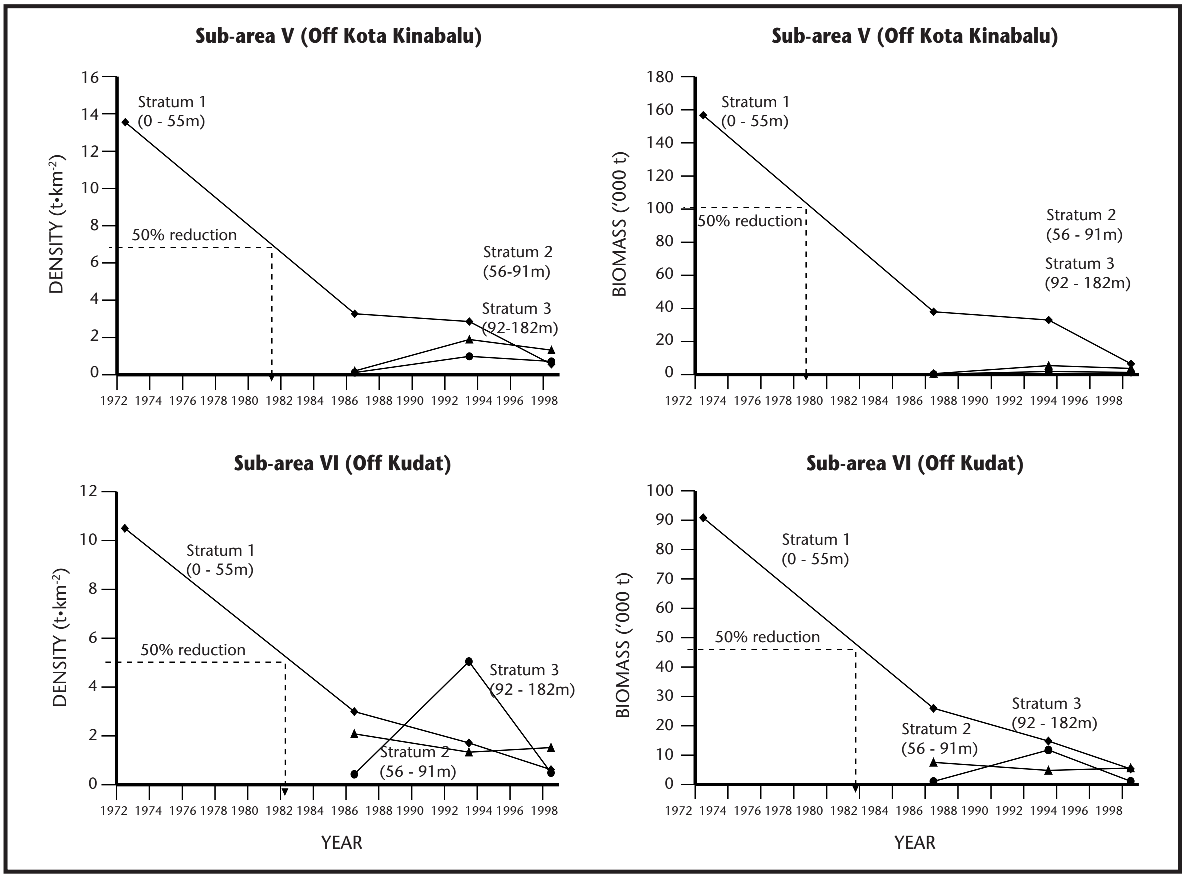

Fig. 14. Estimates of stock density (t·km^{-2}) and biomass (t) of demersal fish off the west coast of Sabah obtained from surveys conducted from 1972 to 1998.

Growth and Mortality Parameters

West coast of Peninsular Malaysia

Estimates of growth parameters (L_∞ and K) obtained using the FiSAT software for all 15 demersal fishes and three cephalopods are given in Table 3. These species represent 48% of demersal abundance in the area. The M/K values for most species are between 1.5 and 2.5, which are acceptable values for most tropical species (Beverton and Holt 1959). The only exception is *Upeneus luzonius* with an M/K value of 2.64.

The mortality rates (Z, M and F) for the 18 species are also given in Table 3. The fishing mortality rate (F) ranges from 0.59 to 7.16. The F value for 13 species were higher than 1.50. Only five species exhibit F below 1.50 : *Nemipterus delagoae (N. bipunctatus*), Saurida tumbil, Siganus oramin (S. canaliculatus*), Upeneus luzonius and Loligo sighalensis*. These species, except *Saurida tumbil*, are rarely seen in the market.

The exploitation ratio (E) for the species varies from 0.27 (*Nemipterus delagoae*) to 0.77 (*Upeneus sulphureus*). Only 2 of the 18 species have E values below 0.40. Fig. 15 shows the distribution of the E values. The mean E for all the species (including cephalopods) was 0.62 and the weighted mean E was also 0.62. The high exploitation ratios are indicative of the heavy fishing pressure off the west coast Peninsular Malaysia.

* Valid name in FishBase

East coast of Peninsular Malaysia

Estimates of growth, mortality and exploitation parameters for 31 species caught off the east coast of Peninsular Malaysia are given in Table 4. These species constitute 33% of the total catch during the survey. Fishing mortality (F) ranges from 0.81 in *Pentaprion longimanus* to 6.0 in *Sphyraena obfusafa*. The F estimates for 17 demersals and four cephalopods were greater than 1.50 The exploitation ratio varies from 0.34 (Brachypleura novaezeelandiae) to 0.82 (Priacanthus macracanthus) The mean E for all species (including cephalopod) was estimated at 0.57 and the weighted mean E value was slightly higher at 0.59 (Fig. 16). These high E values indicate heavy fishing pressure (and overfishing) on the demersal resources off the east coast of Peninsular Malaysia.

Sarawak

Estimates of growth, mortality and exploitation parameters for 28 species caught off Sarawak are presented in Table 5. The 26 demersal fish and 2 cephalopod species represent 76% of the total catch during the survey. Values of M/K for the species are within the normal range of 1.5 to 2.5, except for 3 fish species *(Lutjanus linoelatus, Thamnaconus hypargyneus* and *Upeneus taeniopterus)*. Fishing mortality varies from 0.12 (*Nemipterus nemurus*) to 6.63 (*Carangoides malabaricus*). Fishing mortality for 18 demersal fishes (69% of the total) was higher than 1.50.

The exploitation ratios range from 0.10 in *Nemipterus nemurus* to 0.82 in *Carangoides malabaricus* and *Pentaprion longimanus.* Only two species *(Nemipterus nemurus* and *Priacanthus tayenus)* have E less than 0.40 but thirteen have E values beyond 0.50. The mean E for all species (including cephalopods) was 0.60 and the weighted mean E was slightly higher at 0.61 (Fig. 17). These E values indicate very heavy fishing pressure on most species comprising the bulk of demersal resources off Sarawak.

West coast of Sabah

The parameter estimates for 10 demersal and 1 cephalopod species are summarized in Table 6. These species comprise 58% of the total catch obtained during the survey. The M/K values for all species are within the range of 1.5 to 2.5. Nine of the 11 species have F greater than 1.50. The exploitation ratio varies from 0.44 *(Saurida tumbil)* to 0.76 *(Upeneus bensasi)*. The mean E for all species (including cephalopods) is 0.60 and the weighted mean E is also 0.60 (Fig. 18).

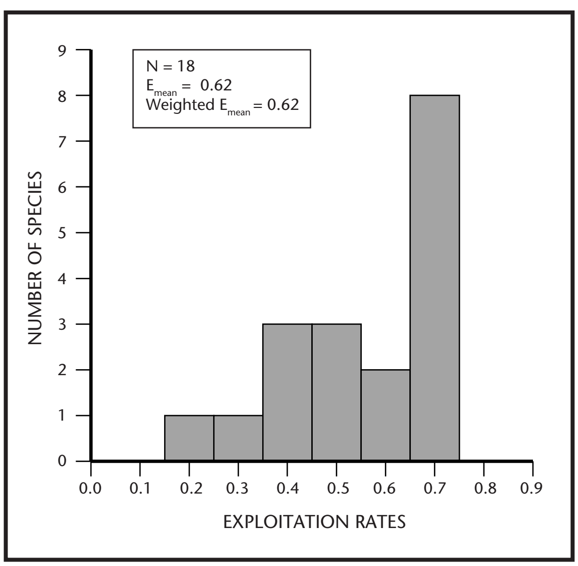

Fig. 15. Distribution of exploitation ratio (E) of 18 demersal species obtained during the 1997 survey off the west coast of Peninsular Malaysia.

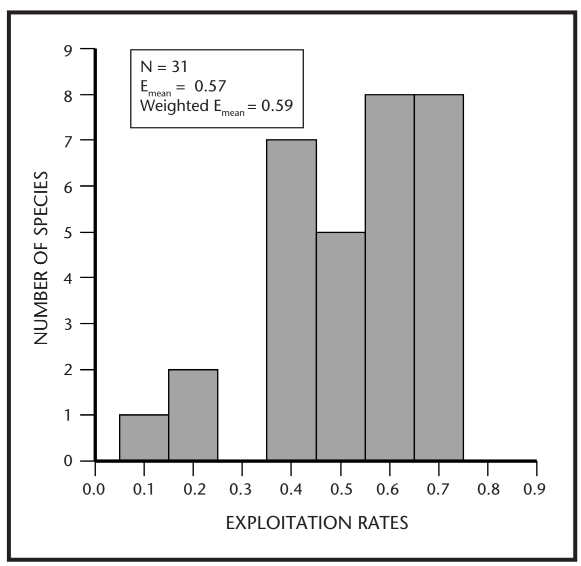

Fig. 16. Distribution of exploitation ratio (E) of 31 demersal species obtained during the 1998 survey off the east coast of Peninsular Malaysia.

Table 3. Growth, mortality and exploitation parameters of demersal species estimated using the 1997 survey data obtained off the west coast of Peninsular Malaysia. Terms are defined in the methods section.

Species	Sample size (n)	Growth parameters				Mortality parameters			M/K	Exploit Ratio (E = F/Z)
		$W = aL^b$		L_∞	K	Z	M	F		
		a	b	(cm)	(yr^{-1})	(yr^{-1})	(yr^{-1})	(yr^{-1})		
Demersal fish:										
Leiognathus splendens	124	0.028	2.73	19.0	0.85	7.16	1.87	5.29	2.20	0.74
*Nemipterus delagoae (N. bipunctatus)**	321	0.014	2.92	30.0	0.80	2.18	1.59	0.59	1.99	0.27
Nemipterus japonicus	1 061	0.029	2.73	34.8	0.85	3.76	1.58	2.18	1.86	0.58
Pennahia macropthalmus	552	0.010	3.12	30.0	1.30	7.76	2.18	5.58	1.68	0.72
Pentaprion longimanus	421	N/A	N/A	20.0	0.80	7.13	1.78	5.35	2.23	0.75
Priacanthus macracanthus	1 181	0.048	2.56	37.0	1.30	8.45	2.06	6.39	1.58	0.76
Priacanthus tayenus	1 930	0.027	2.72	23.0	0.55	3.85	1.34	2.51	2.44	0.65
Saurida longimanus	1 463	0.005	2.97	30.0	1.00	5.14	1.84	3.30	1.84	0.64
Saurida tumbil	863	0.002	3.34	46.0	1.30	3.40	1.93	1.47	1.48	0.43
Saurida undosquamis	4 956	0.004	3.15	34.0	1.20	4.25	2.00	2.25	1.67	0.53
Siganus oramin	257	N/A	N/A	23.0	0.60	2.60	1.42	1.18	2.37	0.45
Trichiurus lepturus	1 307	0.0002	3.26	70.0	0.85	2.94	1.30	1.64	1.53	0.56
*Upeneus bensasi (U. japonicus)**	1 073	0.008	3.14	25.0	0.55	5.40	1.31	4.09	2.38	0.76
Upeneus luzonius	255	N/A	N/A	19.0	0.50	2.22	1.32	0.90	2.64	0.41
Upeneus sulphureus	1 295	N/A	N/A	21.0	0.60	6.28	1.45	4.83	2.42	0.77
Cephalopods:										
Loligo chinensis	891	N/A	N/A	38.0	1.00	5.94	1.72	4.22	1.72	0.71
Loligo duvaucelli	3 419	N/A	N/A	23.0	1.30	9.51	2.35	7.16	1.81	0.75
Loligo sighalensis	1 755	N/A	N/A	42.0	1.40	3.00	2.08	0.92	1.49	0.31

Note: * Valid name in FishBase. N/A = Not available.

Table 4. Growth, mortality and exploitation parameters of demersal species estimated using the 1998 survey data obtained off the east coast of Peninsular Malaysia. Terms are defined in the methods section.

Species	Sample size (n)	Growth parameters				Mortality parameters			M/K	Exploit Ratio (E = F/Z)
		$W = aL^b$		L_∞	K	Z	M	F		
		a	b	(cm)	(yr^{-1})	(yr^{-1})	(yr^{-1})	(yr^{-1})		
Demersal fish:										
Brachypleura novaezeelandiae	1 714	0.001	2.96	21.9	0.71	2.43	1.61	0.82	2.27	0.34
Carangoides malabaricus	834	0.041	2.67	28.7	0.88	3.76	1.72	2.04	1.95	0.54
Lutjanus lineolatus (L. lutjanus)*	637	0.010	3.08	27.6	0.54	3.79	1.24	2.55	2.30	0.67
Nemipterus balinensoides	1 148	0.018	2.81	23.8	0.46	4.08	1.17	2.91	2.54	0.71
Nemipterus bathybius	156	0.025	2.77	29.4	0.41	3.04	1.03	2.01	2.51	0.66
Nemipterus marginatus	2 429	0.015	2.98	30.1	0.52	3.42	1.21	2.21	2.33	0.65
Nemipterus nematophorus	1 954	0.013	3.01	35.0	0.34	1.69	0.86	0.83	2.53	0.49
Nemipterus nemurus	1 690	0.012	3.03	31.5	0.71	3.17	1.45	1.72	2.04	0.54
Nemipterus peronii	647	N/A	N/A	34.1	0.60	2.67	1.25	1.42	2.08	0.47
Nemipterus tambuloides	1 472	0.017	2.87	33.0	0.61	2.48	1.30	1.18	2.13	0.48
Nemipterus thosaporni	4 917	0.015	2.95	34.0	0.36	2.18	0.91	1.27	2.53	0.58
Parupeneus pleurospilus (P. heptacanthus)*	527	0.011	3.08	35.2	0.92	3.18	1.64	1.54	1.78	0.48
Pentaprion longimanus	5 021	0.009	3.19	22.5	0.46	1.99	1.18	0.81	2.57	0.41
Priacanthus macracanthus	4 825	0.023	2.82	39.0	0.56	6.60	1.17	5.43	2.09	0.82
Priacanthus tayenus	1 529	0.033	2.66	31.4	0.78	2.46	1.55	0.91	1.99	0.37
Saurida longimanus	4 615	0.003	3.20	37.9	0.35	1.93	0.87	1.06	2.49	0.55
Saurida tumbil	1 390	0.002	3.36	62.6	0.80	2.62	1.54	1.08	1.93	0.79
Saurida undosquamis	5 263	0.006	3.05	40.5	0.98	5.05	1.67	3.38	1.70	0.67
Sphyraena jello	439	0.004	3.11	41.0	1.52	4.55	2.19	2.36	1.44	0.52
Sphyraena obtusata	581	0.007	2.87	54.6	0.96	7.52	1.52	6.00	1.58	0.80
Synodus hoshinonis	3 489	0.005	3.12	25.8	0.58	3.47	1.33	2.14	2.29	0.62
Trichiurus lepturus	564	0.001	3.08	109.0	0.78	2.71	1.08	1.63	1.38	0.60
Upeneus bensasi (U. japonicus)*	2 904	0.013	2.94	23.4	0.86	4.15	1.79	2.36	2.08	0.57
Upeneus moluccensis	235	0.012	3.01	39.5	0.32	3.60	0.81	2.79	2.53	0.77
Upeneus sulphureus	1 952	0.010	3.10	19.4	0.56	2.74	1.40	1.34	2.50	0.49
Xiphocheilus typus	549	N/A	N/A	17.8	0.76	4.98	1.75	3.23	2.30	0.65

Table 4. Growth, mortality and exploitation parameters of demersal species estimated using the 1998 survey data obtained off the east coast of Peninsular Malaysia. Terms are defined in the methods section. (continued)

Species	Sample size (n)	Growth parameters				Mortality parameters			M/K	Exploit Ratio (E = F/Z)
		W = aL^b		L_∞	K	Z	M	F		
		a	b	(cm)	(yr^{-1})	(yr^{-1})	(yr^{-1})	(yr^{-1})		
Cephalopods:										
Loligo chinensis	7 587	N/A	N/A	42.0	0.96	4.51	1.61	2.90	1.68	0.64
Loligo duvaucelli	500	N/A	N/A	23.2	0.85	4.68	1.75	2.93	2.06	0.59
Loligo singhalensis	3 819	N/A	N/A	23.2	0.80	5.06	1.69	3.37	2.11	0.67
Loligo tagoi	454	N/A	N/A	9.2	0.95	6.16	2.44	3.72	2.57	0.60
Sepia aculeate	104	N/A	N/A	17.0	0.45	2.13	1.25	0.88	2.78	0.41

Note: * Valid name in FishBase. N/A = Not available.

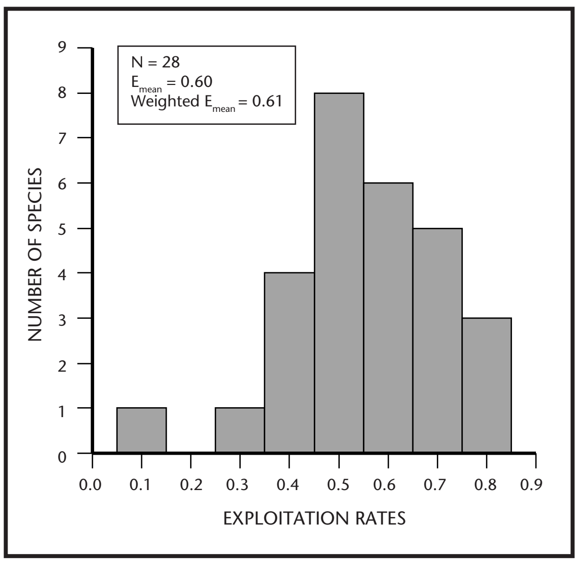

Fig. 17. Distribution of exploitation ratio (E) of 28 demersal species obtained during the 1998 survey off the coast of Sarawak.

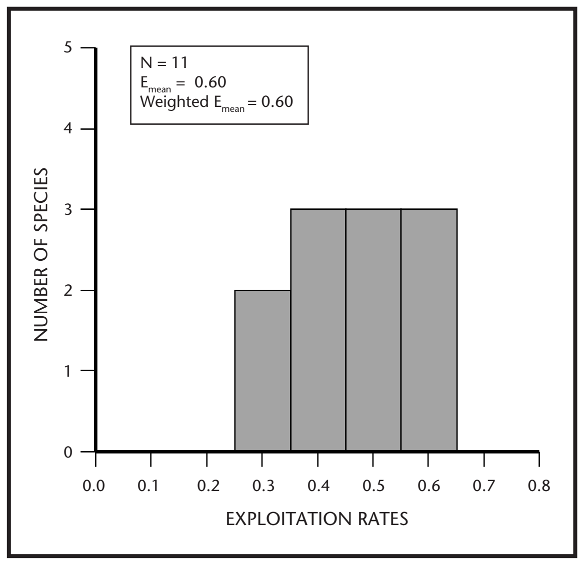

Fig. 18. Distribution of exploitation ratio (E) of 11 demersal species obtained during the 1998 survey off the west coast of Sabah.

Table 5. Growth, mortality and exploitation parameters of demersal species estimated using the 1998 survey data obtained off the coast of Sarawak. Terms are defined in the methods section.

Species	Sample size (n)	Growth parameters				Mortality parameters			M/K	Exploit Ratio (E = F/Z)
		W = aL^b		L_∞	K	Z	M	F		
		a	b	(cm)	(yr^{-1})	(yr^{-1})	(yr^{-1})	(yr^{-1})		
Demersal fish:										
Carangoides equula	680	0.090	2.44	30.5	0.40	2.38	1.01	1.37	2.53	0.58
Carangoides malabaricus	646	0.019	2.92	38.1	0.78	8.11	1.48	6.63	1.90	0.82
Leiognathus bindus	867	N/A	N/A	13.0	0.74	8.38	1.91	6.47	2.58	0.77
Leiognathus lineolatus	1 046	N/A	N/A	17.0	0.77	4.31	1.82	2.49	2.36	0.58
*Lutjanus lineolatus (L. lutjanus)**	565	N/A	N/A	22.5	0.33	1.69	0.97	0.72	2.94	0.43
Lutjanus lutjanus	416	N/A	N/A	32.0	0.89	5.20	1.68	3.52	1.89	0.68
Nemipterus bathybius	2 826	0.015	2.96	33.5	0.82	4.13	1.57	2.56	1.91	0.63
Nemipterus marginatus	1 160	0.010	3.12	29.2	0.60	3.21	1.33	1.88	2.22	0.59
Nemipterus mesoprion	595	N/A	N/A	27.5	0.41	3.86	1.05	2.81	2.56	0.73
Nemipterus nematophorous	1 030	0.015	2.97	35.0	0.92	5.15	1.67	3.48	1.82	0.68
Nemipterus nemurus	1 138	0.013	2.98	28.0	0.45	1.23	1.11	0.12	2.47	0.10
Nemipterus peronii	590	0.011	3.04	31.5	0.49	2.02	1.14	0.88	2.33	0.44
Nemipterus tambuloides	498	N/A	N/A	35.0	0.74	3.06	1.45	1.61	1.96	0.53
Nemipterus virgatus	392	0.018	2.74	32.4	0.76	3.60	1.51	2.09	1.99	0.58
Pentaprion longimanus	1 574	N/A	N/A	28.5	0.51	6.55	1.20	5.35	2.35	0.82
Priacanthus macracanthus	2 904	0.021	2.83	42.0	0.71	6.10	1.34	4.72	1.89	0.78
Priacanthus tayenus	779	0.017	2.90	32.0	0.68	2.15	1.41	0.74	2.07	0.34
Psenopsis anomala	292	N/A	N/A	28.0	0.54	6.50	1.26	5.24	2.33	0.81
Saurida tumbil	3 654	0.003	3.29	63.5	0.44	2.75	0.87	1.88	1.98	0.68
Saurida undosquamis	1 415	0.005	3.04	55.5	0.41	3.00	0.87	2.13	2.12	0.71
Scolopsis taeniopterus	516	N/A	N/A	30.5	0.47	2.74	1.12	1.62	2.38	0.59
Thamnaconus hypargyreus	716	N/A	N/A	18.0	0.47	4.40	1.30	3.10	2.77	0.70
*Upeneus bensasi (U.japonicus)**	2 292	0.010	3.04	29.0	0.58	2.53	1.30	1.23	2.24	0.49
Upeneus moluccensis	2 014	0.006	3.27	25.3	0.57	2.54	1.34	1.20	2.35	0.47
Upneus sulphureus	1 091	0.005	3.39	22.0	0.65	4.88	1.52	3.36	2.34	0.69
Upeneus taeniopterus	198	N/A	N/A	22.5	0.42	2.57	1.13	1.44	2.69	0.56
Cephalopods:										
Loligo chinensis	1 682	N/A	N/A	35.5	0.54	2.45	1.18	1.27	2.19	0.52
Loligo duvaucelli	670	N/A	N/A	31.0	0.51	3.38	1.18	2.20	2.31	0.65

Note: * Valid name in FishBase. N/A = Not available.

Table 6. Growth, mortality and exploitation parameters of demersal species estimated using the 1998 survey data obtained off the coast of Sabah. Terms are defined in the methods.

Species	Sample size (n)	Growth parameters				Mortality parameters			M/K	Exploit Ratio (E = F/Z)
		$W = aL^b$		L_∞	K	Z	M	F		
		a	b	(cm)	(yr^{-1})	(yr^{-1})	(yr^{-1})	(yr^{-1})		
Demersal fish:										
Carangoides equula	138	0.016	3.01	22.0	0.80	3.59	1.74	1.85	2.18	0.52
Nemipterus bathybius	538	0.026	2.73	32.0	0.80	5.25	1.57	3.68	1.96	0.70
*Nemipterus bleekeri (N. bipunctatus)**	267	0.005	3.31	31.0	0.75	3.27	1.51	1.76	2.01	0.54
Nemipterus nemurus	193	0.013	2.99	31.0	0.80	3.01	1.58	1.43	1.98	0.48
Pentaprion longimanus	300	N.A.	N/A	28.0	1.30	6.41	2.23	4.18	1.72	0.65
Priacanthus macracanthus	192	0.009	3.13	31.0	0.75	4.93	1.51	3.42	2.01	0.69
Priacanthus tayenus	148	0.019	2.90	32.0	0.55	3.06	1.22	1.84	2.22	0.60
Saurida tumbil	267	0.011	2.89	36.0	0.95	3.03	1.69	1.34	1.78	0.44
Saurida undosquamis	359	0.004	3.14	42.0	1.20	3.95	1.89	2.06	1.58	0.52
*Upeneus bensasi (U. japonicus)**	505	0.016	2.91	24.0	0.80	7.11	1.70	5.41	2.13	0.76
Cephalopods:										
Loligo chinensis	615	N/A	N/A	37.0	0.80	5.26	1.50	3.76	1.88	0.71

Note: * Valid name in FishBase. N/A = Not available.

Demersal Yield and Effort

West coast of Peninsular Malaysia

For the west coast of Peninsular Malaysia, calculation of MSY and f_{MSY} for demersal fishes based on 26 years of landings data and the CPUE of the research vessel KK Jenahak is given in Appendix M. The trends in demersal catch and catch-per-unit effort are illustrated in Figs. 19 a and b, respectively. The estimate of MSY is about 273 000 t obtained at 7.06 x 10^6 towing hours of KK Jenahak, the vessel taken as standard. The results indicate that the MSY level of the demersal resources was reached around 1994. The 1996 landings of about 305 000 t were 11 % above the MSY value. The 1996 effort, of about 9.55 x 10^6 towing hours, is 35% more than the f_{MSY} level. This indicates that the fisheries off the west coast are over-exploiting the demersal fish resources.

East coast of Peninsular Malaysia

The catch and effort time series for the demersal fisheries is given in Appendix N and illustrated in Figs. 20 a and b. There appears to be a discontinuity in the rate of decline in CPUE around the mid-1980s (Fig. 20b), with a slower decline during 1986 - 96 compared to 1971 - 85. This can be due to a number of reasons (including technological improvements and expansion to deeper areas) that require further investigation. The immediate implication is that the effort time series requires more vigorous standardization prior to use in Fox modeling. The data and results are documented here for purposes of future follow-up. The MSY and f_{MSY} values given in Appendix 14, therefore should not be used, pending the results of the follow-up studies.

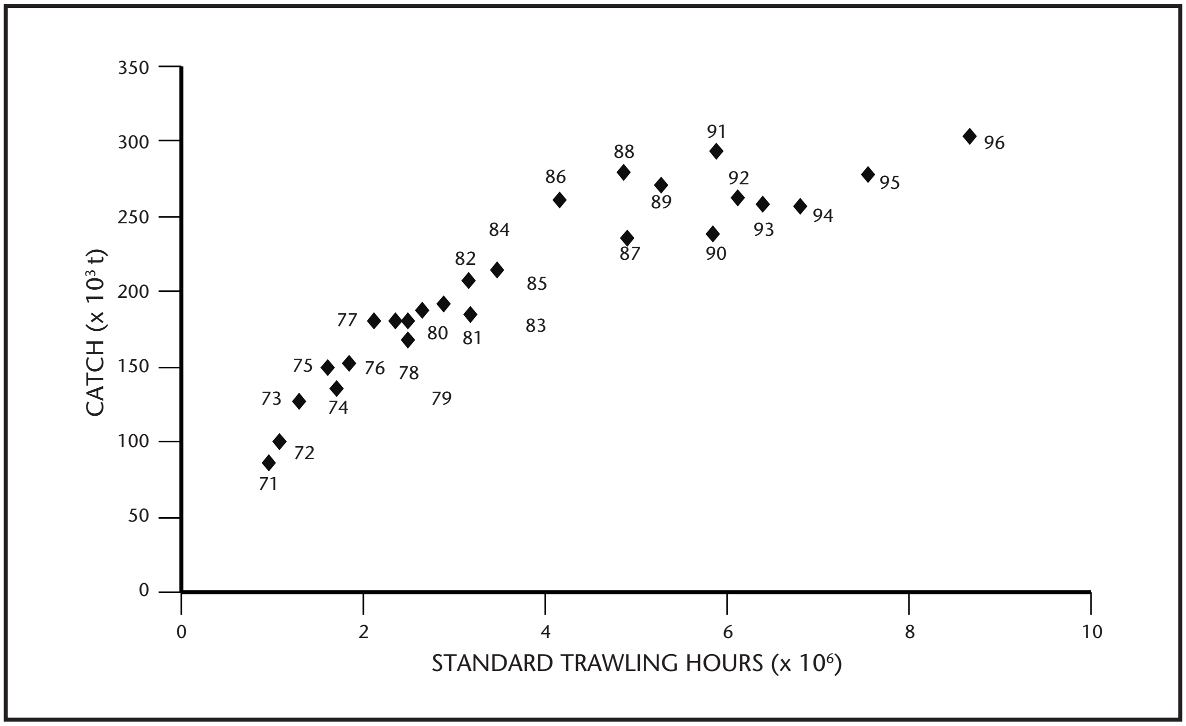

Fig. 19a. Catch and effort for the fisheries exploiting demersal resources off the West coast of Peninsular Malaysia from 1971 to 1996.

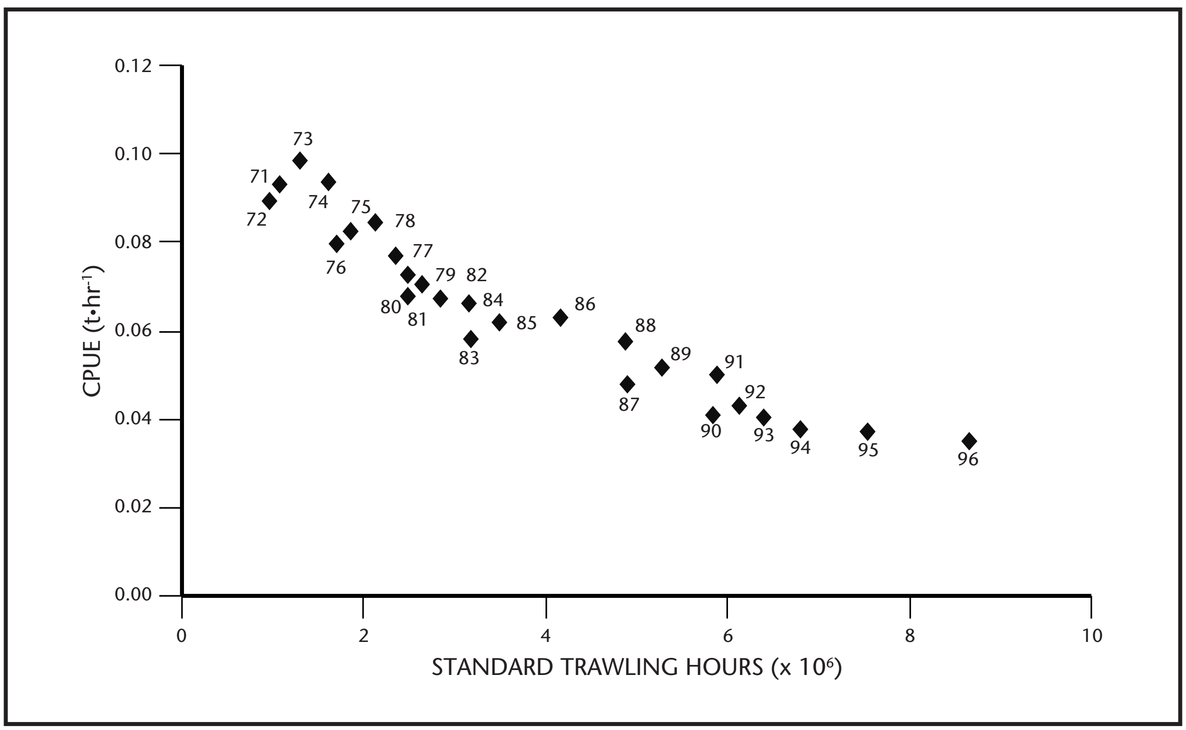

Fig. 19b. Catch-per-unit effort (CPUE) for the fisheries exploiting demersal resources off the West coast of Peninsular Malaysia from 1971 to 1996.

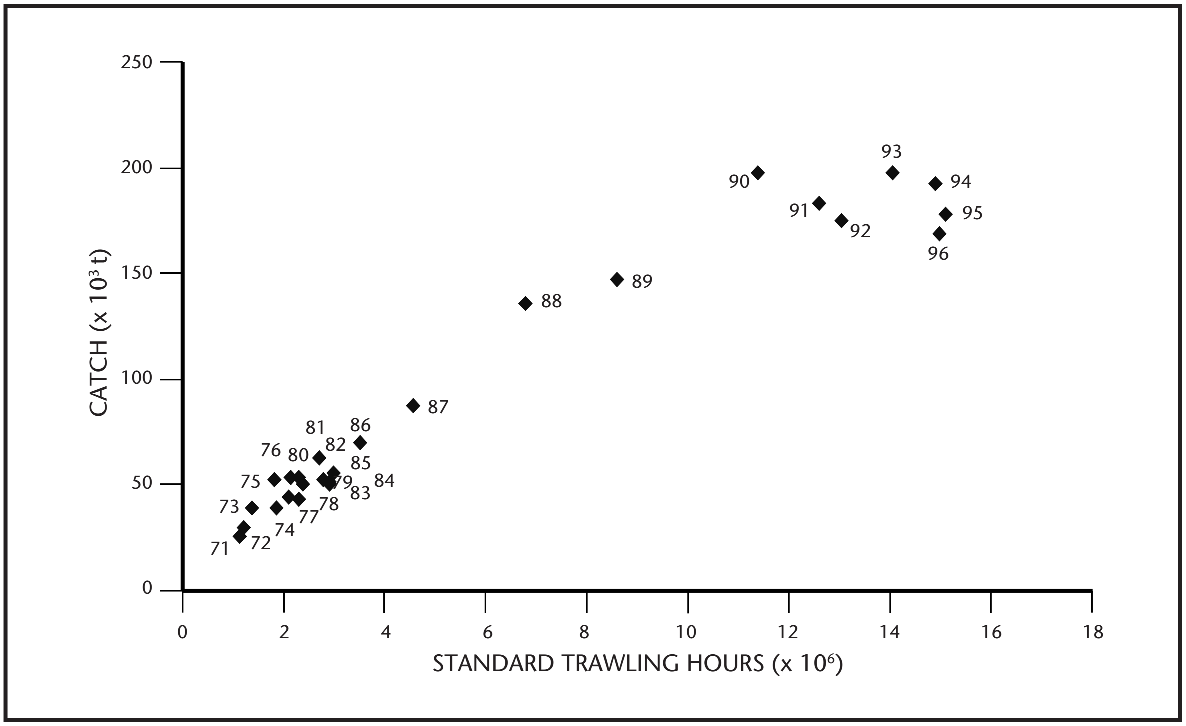

Fig. 20a. Catch and effort for the fisheries exploiting demersal resources off the East coast of Peninsular Malaysia from 1971 to 1996.

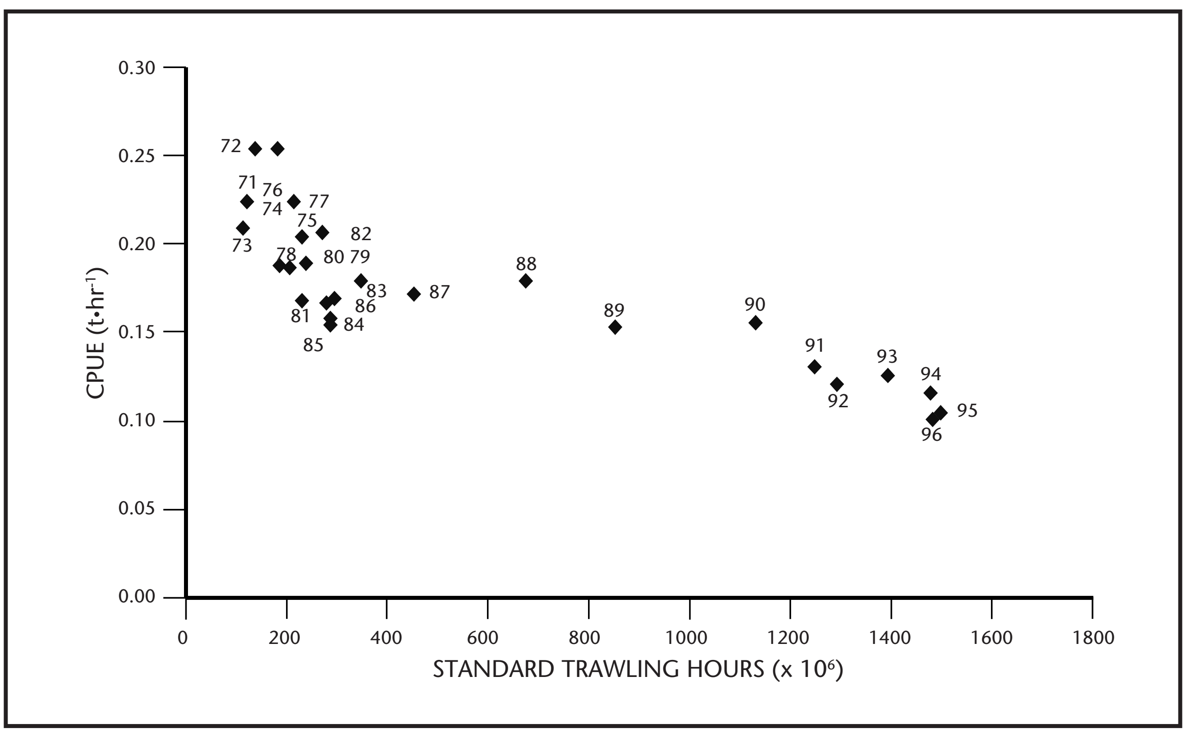

Fig. 20b. Catch-per-unit effort for the fisheries exploiting demersal resources off the East coast of Peninsular Malaysia from 1971 to 1996.

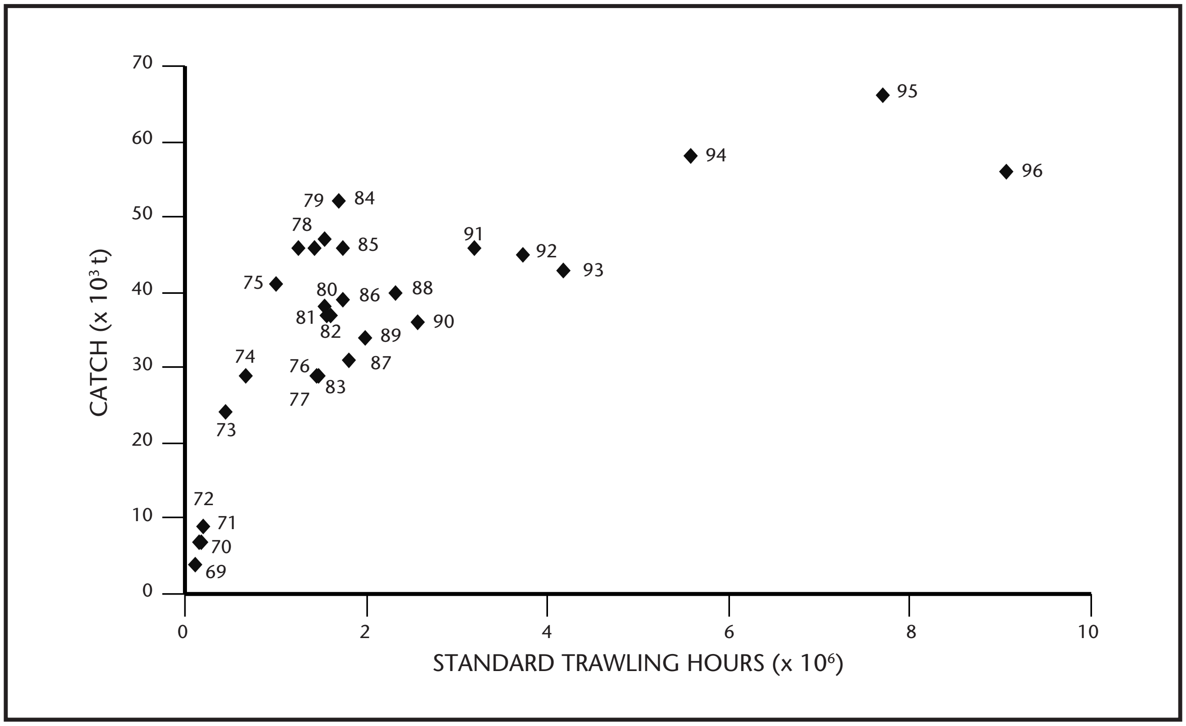

Fig. 21a. Catch and effort for the fisheries exploiting demersal resources off Sarawak from 1969 to 1996.

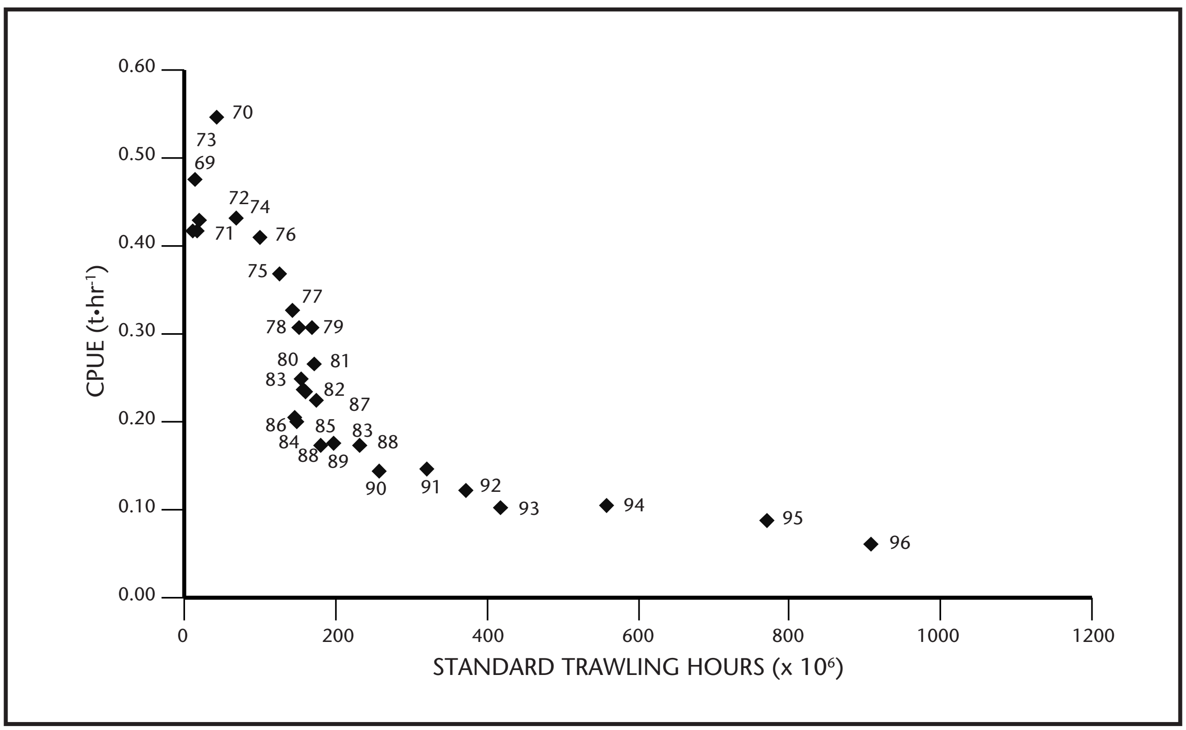

Fig. 21b. Catch-per-unit effort (CPUE) for the fisheries exploiting demersal resources off Sarawak from 1969 to 1996.

Sarawak

Most of the catch in Sarawak comes from coastal areas less than 91 m deep, or within 30 nm of the coastline. Statistics show that in 1986 there were 732 licensed trawlers in Sarawak, 70% below 20 gross tons or GT, 82% with engines below 99 HP, r and 99% less than 25 m long. The number decreased to 506 in 1996, around 50% of which were below 20 GRT and only 5% above 70 GRT. In Sarawak, even fishing vessels above 70 GRT are allowed to operate within 30 nm from the coastline. Hence the catch is mostly from the coastal area less than 100 m deep. Based on this, calculation of MSY and f_{MSY} only included data for strata 1 and 2 (areas less than 91 m deep). Only CPUE from research vessels obtained in these two depth strata were used.

The 28-year catch and effort time series used in estimating MSY and f_{MSY} is given in Appendix O and illustrated in Figs. 21 a and b. The MSY and f_{MSY} value obtained was about 60 000 t and 0.42 million towing hours, respectively. It appears that the f_{MSY} level was reached around 1993 in the coastal area of Sarawak and by 1996 the fishing effort may have been twice the level necessary to harvest MSY.

Conclusion

The first trawl survey conducted during 1926 - 27 by S/T Tongkol attempted to assess the demersal fish resources in order to introduce trawling. However, the unfavorable results obtained did not lead to any serious development of trawling until the late 1960s. The first monitoring survey was initiated off the east coast of Peninsular Malaysia under a bilateral agreement with the Federal Republic of Germany in 1967. Since then a total of 13 surveys have been carried out in this area. Similar surveys were also carried out off the northern part of the west coast of Peninsular Malaysia, Sarawak and the west coast of Sabah. To date, a total of 14 surveys have been conducted off the west coast of Peninsular Malaysia and 9 surveys off Sarawak and Sabah. Analysis of data from selected surveys for these four study areas provides major conclusions that are summarized below.

West coast of Peninsular Malaysia

- The average catch rate in 1997 of demersal fish in coastal waters of Sub-area I and II was only 25% and 30% respectively, of the values obtained in 1971 - 72. The 1997 average catch rate in offshore areas from 56 to 91 m depth (stratum 2) was only 28% in Sub-area I and 18% in Sub-area II as compared to values in 1987. The catch rate in the deeper offshore areas from 91 to 185 m (Stratum 3) in Sub-area I had also decreased.The 1997 catch rate was about 76% of the value obtained in 1987.
- Demersal stock density in coastal waters of Sub-areas I and II were only 8% and 14%, respectively, of the estimated values in 1971 - 72. Density in stratum 2 in Sub-area I and Sub-area II was 38% and 25% respectively, of the values estimated in 1987. The density in stratum 3 of Sub-area I was similar to the density obtained in 1987.
- Length-based analyses of 15 demersal fish and 3 cephalopod species give a mean E value of 0.62 confirming over-exploitation of the resources. These selected species comprise 48% of the demersal fish caught during the survey in 1997.
- The calculated MSY and f_{MSY}. were 273 000 t and 7.06 x 10^6 standard towing hours respectively. The 1997 catch and effort values indicate that the demersal resources were already over-exploited then.

East coast of Peninsular Malaysia

- Reduction of mean catch rate in the coastal area (depth stratum 1) since 1967 is 91% in Sub-area I, 89% in Sub-area II, 95% in Sub-area III and 96% in Sub-area IV. The offshore area (depth stratum 2) is also heavily exploited. The 1997 catch rate was only 13%, 7% 4% and 3% in Sub-area I, II, III and IV respectively, of the values obtained in 1987.
- In 1998, stock density of demersal fish in coastal waters was only 5% of the 1967 level and off shore stock density was 5 - 10% of the 1986 level.
- Length-based studies of 24 demersal fish and 4 cephalopod species (comprising 33% of the catch during the 1998 survey) provide a mean exploitation ratio of 0.58, thus confirming over-exploitation.

Sarawak

- The coastal area showed reductions in average catch rate of 64%, 48% and 26% in Sub-area I, II and III respectively, over the period 1972 to 1998. However, both offshore depth strata show either a slight reduction or increase in average catch rate of demersal fish.
- The coastal demersal stock density obtained in the latest (1998) survey was only 23% to 32% of the value recorded in 1972. The offshore area of Sub-area I and II still has 60% to 85% of the density obtained in 1986, while the offshore area of Sub-area III indicates some increase.
- Length-based studies of 26 demersal fish and 2 cephalopod species (comprising over 50% of total catch during the 1998 survey) provide a mean exploitation ratio of 0.62 and confirm the over-exploitation in coastal areas.
- The MSY estimate for the coastal area is about 60 000 t at a f_{MSY} of about 0.42 million towing hours. Results indicate that there is over-exploitation of the demersal fish resources in the coastal area off Sarawak.

West coast of Sabah

- The average catch rate obtained in the latest (1998) survey in the coastal area was only 12% and 18% of those recorded in the first survey in 1972 in Sub-area V and Sub-area VI, respectively.
- The 1998 demersal stock density in the offshore areas was higher than the densities obtained in the 1986 survey. Coastal demersal stock density was only 4 to 6% of the values recorded in 1972.
- Length-based studies of 10 demersal fishes and 1 cephalopod species (comprising 45% of total catch during the 1998 survey) provide a mean exploitation ratio of 0.60 and confirms over-exploitation in the coastal area.

Acknowledgement

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Appendix A. Specifications of the research vessels used for demersal resource surveys in Malaysian waters, 1967 - 98.

Specification	RV Pramong II	KK Jenahak	KK Merah	RV Rastrelliger	KK Mersuji	KK Manchong
Owner	DoF, Thai*	DoF**	DoF**	FAO***	DoF**	DoF**
Type	Wood	Wood	Wood	Steel	FRP****	FRP****
Length overall (m)	23	23.23	23	46.4	23.25	27.50
Breadth moulded (m)	–	–	5.7	9.01	5.80	6.40
Depth moulded (m)	–	–	–	5.09	2.35	3.00
Designed Draft (m)	–	–	–	–	1.95	2.20
Gross Tonnage	76	80.2	73.5	390.94	97.03	150
Speed on trials (knots)	–	–	–	12.2	11.1	12.48
Towing Speed (knots)	2.5	2.8	2.8	3.5	3.0	4.0
Main engine:						
Make	Cumming	M.W.M	Caterpillar	Wichmann	Yanmar	Yanmar
Type	–	Diesel	Diesel	8 ACAT	500ps	Diesel
Horse power (bhp)	320	325	365	1320	550	900
RPM	–	900	1800	–	900	–
Deck Machinery:						
Main Fishing Winch	–	–	–	Brattvaag	–	Awakumi
Net hauler	–	–	–	Triplex	–	Awakumi
Net Drum	–	–	–	Brattvaag	–	–
Navigation equipment:						
Radar	–	–	–	Decca	Furuno	Furuno
Sounder	Atlas	Atlas	–	Simrad	Furuno	Furuno
Sonar	–	–	–	Simrad	–	Furuno
Satellite Navigator	–	–	–	Furuno	JRCJLE	Furuno
Capacities:						
Fishroom/Fishhold	14 t	20 t	–	200 m^3	9.62 m^3	28 m^3
Fresh water	–	–	–	46 m^3	11.52 m^3	14 m^3
Accomodation:						
Officers	–	4	–	12	6	6
Crew	–	10	–	16	12	16

Note: * DoF, Thai - Department of Fisheries, Thailand.
** DoF - Department of Fisheries, Malaysia.
*** FAO - Food & Agriculture Organization.
**** FRP - Reinforced-Fiberglass Plastic.

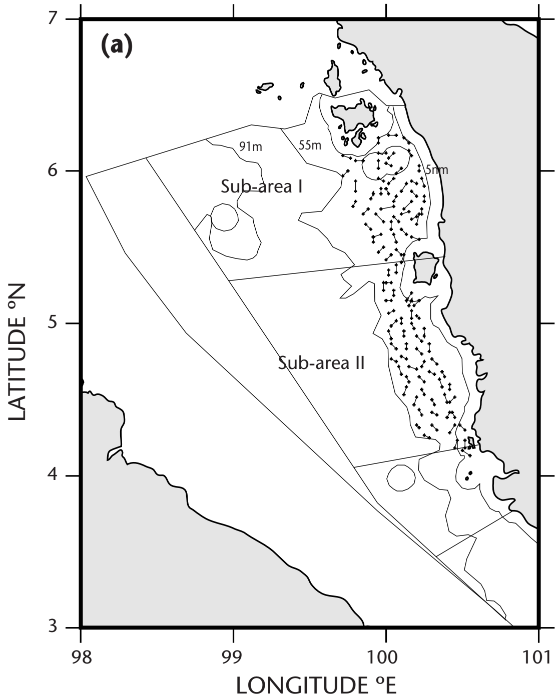
Appendix B. Specifications of the trawl net and otter-board used by research vessels during the surveys conducted in Malaysian waters, 1967 - 98.

Specification	Pramong II	KK Jenahak	KK Merah	RV Rastrelliger	KK Mersuji	KK Manchong
Trawl Net:						
Design	*SGOT	SGOT	SGOT	HLEBT**	SGOT	SGOT
Type	Nylon	Nylon	Nylon/PE	Nylon	Nylon	PE
Circumference (m)	23.5	23.5	23.5	112.6	23.52	40.50
Length of head-rope (m)	39.5	22.4	22.4/16.3	71.9	34.8	47.10
Length of foot-rope (m)	48.0	29.6	29.6/19.9	80.5	–	55.50
Cod-end length (m)	10.0	10.0	10.0/10.0	12	10.0	11.40
Cod-end mesh (mm)	40.0	40	40/38.1	50	40	38
Effect. Horizontal Opening (m)	17.0	20	20	26	20	19
Effect. Vertical Opening (m)	3.5	–	–	6	–	2.3
Sinkers	Iron chain	Iron chain	Iron chain	Rubber disc & Iron chain	Tire Disc	Tire Disc
Otter Board:						
Net length (m)	47.7	–	–	79.5	–	69.75
Material	Wood	Wood	Wood	Steel	Wood	Steel
Size (m x m x cm)	2 x 1 x 2	–	–	3 x 1.8	2.5 x 1.1	–
Total weight (kg)	–	–	–	1 000	250	350
Type	Rectangular	Rectangular	Rectangular	Polyvalent	Rectangular	Polyvalent
Wire warp ratio (Depth: wire rope out)						
Soft ground	1 : 5	–	–	–	–	–
Hard ground	1 : 6	–	–	–	–	–
Shallow area (< 50m)	–	1 : 5	1 : 5	–	1 : 5	1 : 5
Deep area (> 50m)	–	1 : 3	1 : 4	–	1 : 4	1 : 4

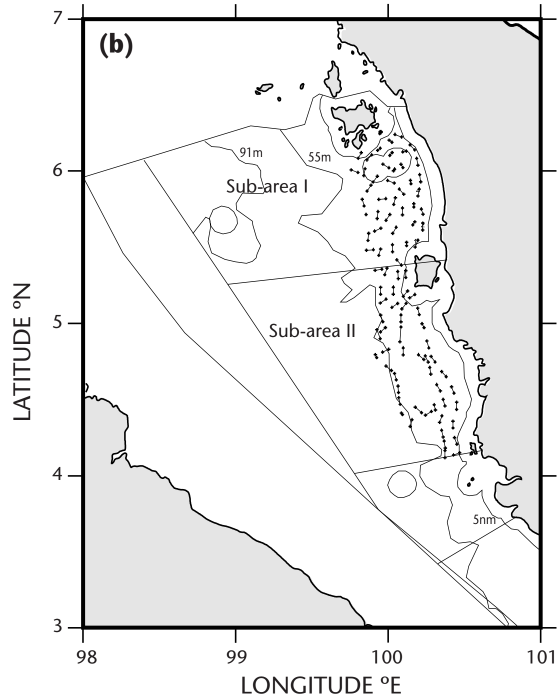
Note: * SGOT - Standard German Otter-Trawl.
**** HLEBT - High Lift Engel Balloon Trawl.**

Appendix C. Distribution of sampling stations during the demersal resource surveys in Sub-areas I and II off the west coast of Peninsular Malaysia: (a) 1971 - 72 - KK Merah, (b) 1981 - KK Jenahak, (c) 1987 - RV Rastrelliger, (d) 1990 - 91 - KK Mersuji and (e) 1997 - KK Manchong.

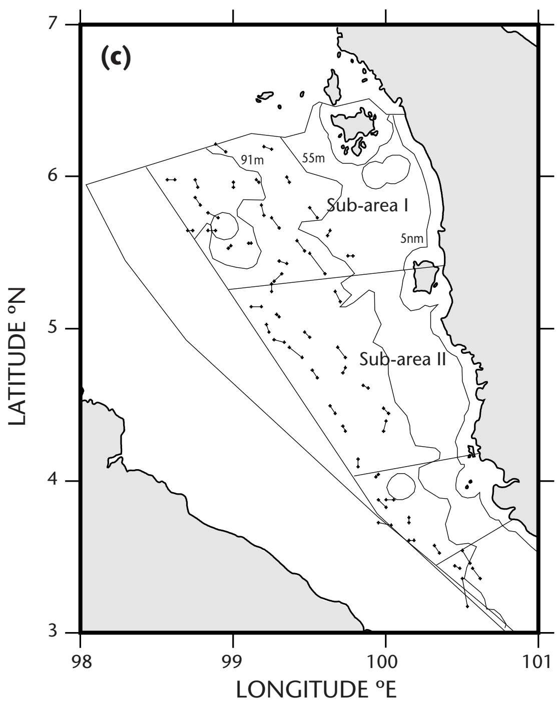
(a) 1971 - 72 - KK Merah.



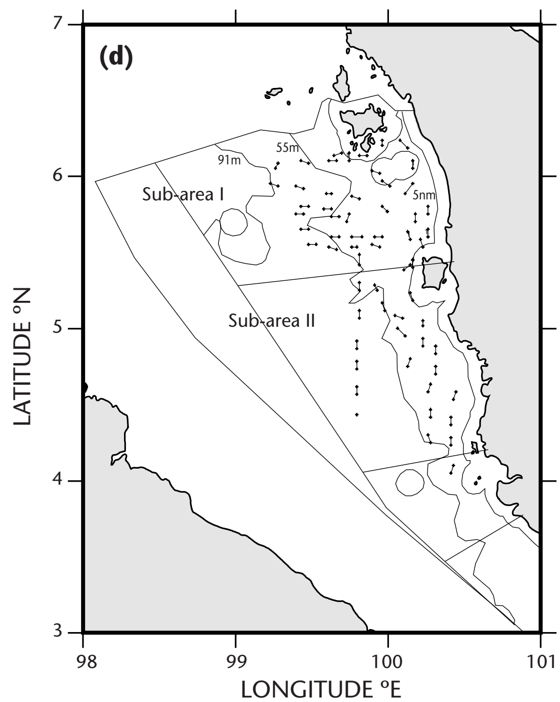
(b) 1981 - KK Jenahak.



(c) 1987 - RV Rastrelliger.

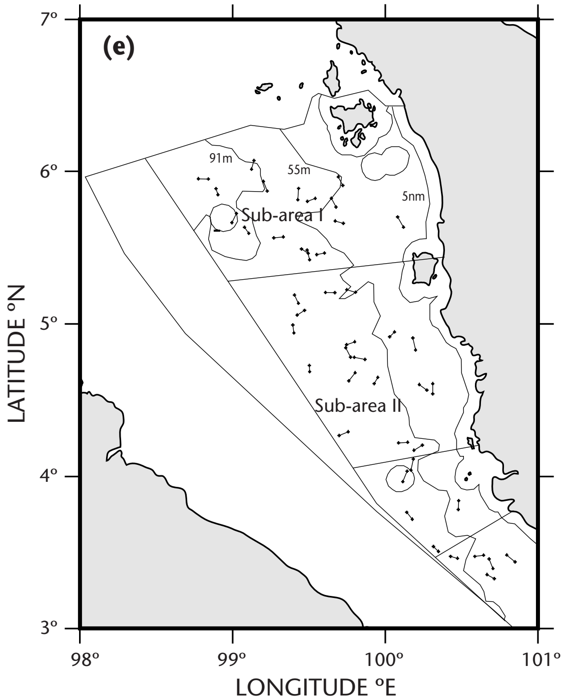


(d) 1990 - 91 - KK Mersuji.



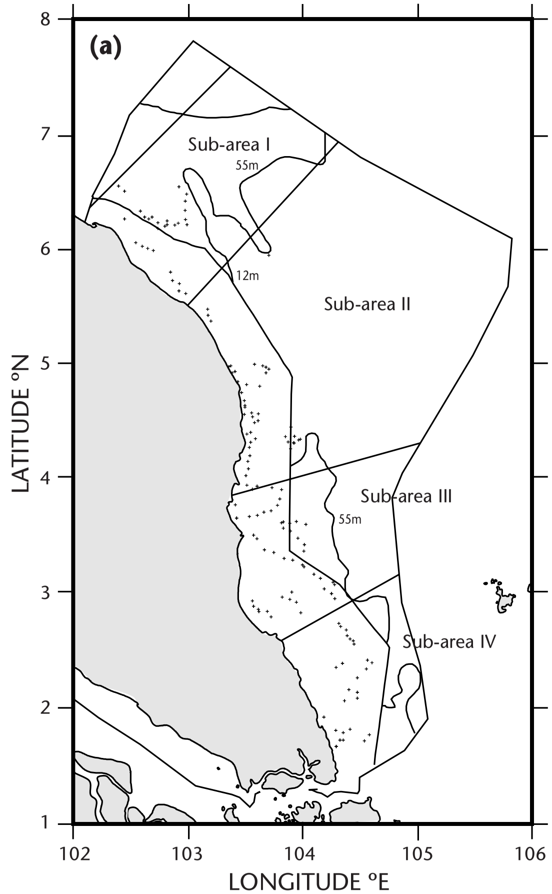
Appendix C. Distribution of sampling stations during the demersal resource surveys in Sub-areas I and II off the west coast of Peninsular Malaysia. (continued)

(e) 1997 - KK Manchong.

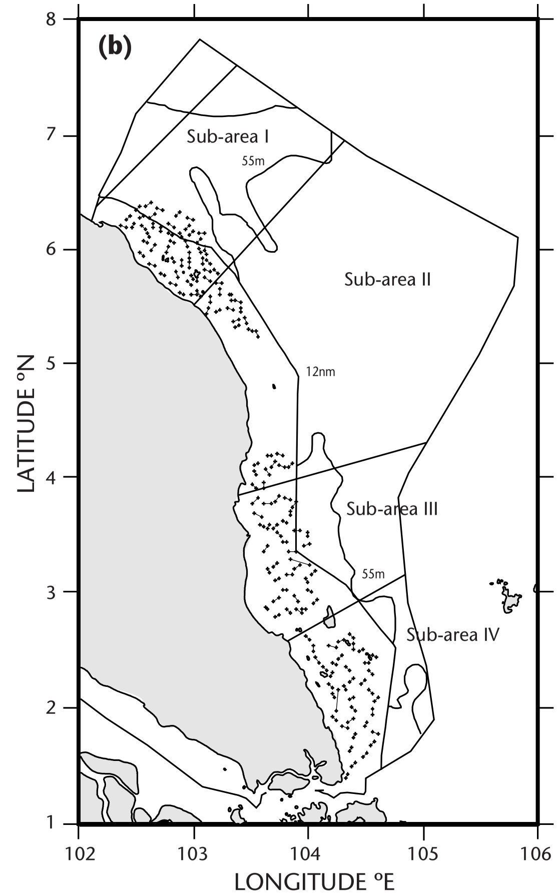


Appendix D. Distribution of sampling stations during the demersal resource surveys off the east coast of Peninsular Malaysia: (a) 1969 - Pramong II, (b) 1972 - KK Jenahak and (c) 1981 - KK Jenahak, (d) 1986 - RV Rastrelliger and (e) 1991 - KK Mersuji.

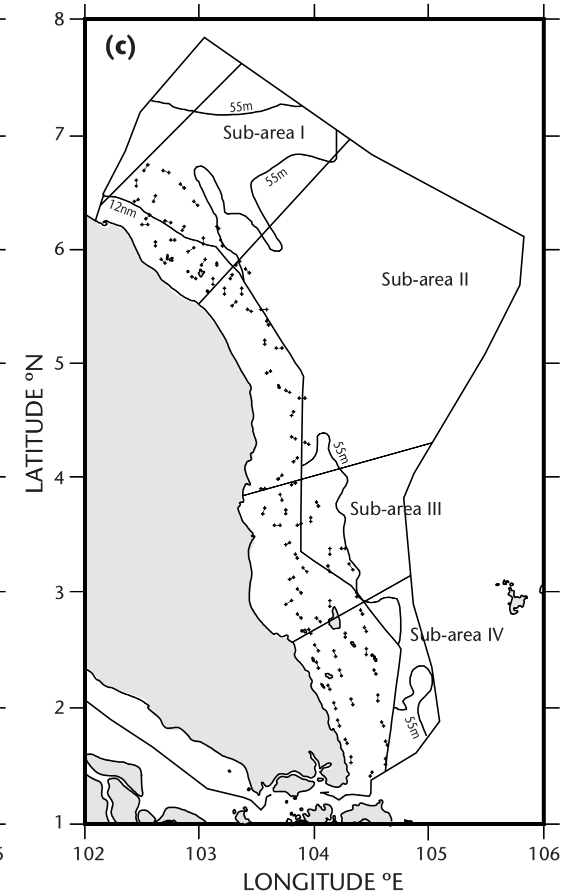
(a) 1969 - Pramong II.



(b) 1972 - KK Jenahak.

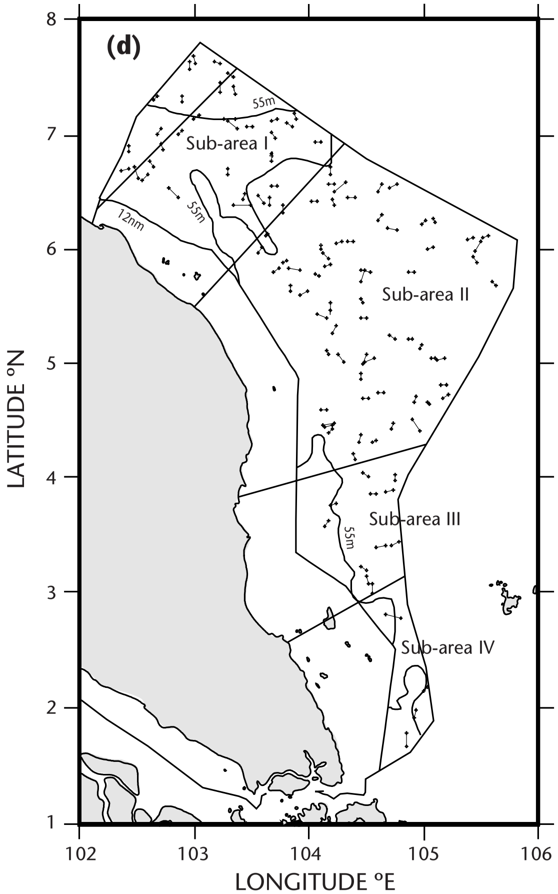


(c) 1981 - KK Jenahak.

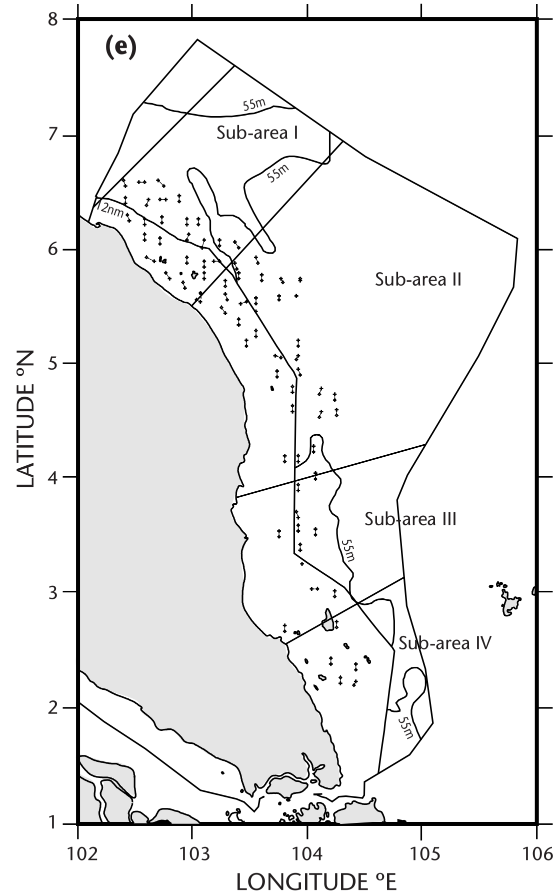


Appendix D. Distribution of sampling stations during the demersal resource surveys off the east coast of Peninsular Malaysia: (a) 1969 - Pramong II, (b) 1972 - KK Jenahak and (c) 1981 - KK Jenahak, (d) 1986 - RV Rastrelliger and (e) 1991 - KK Mersuji. (continued)

(d) 1986 - RV Rastrelliger.

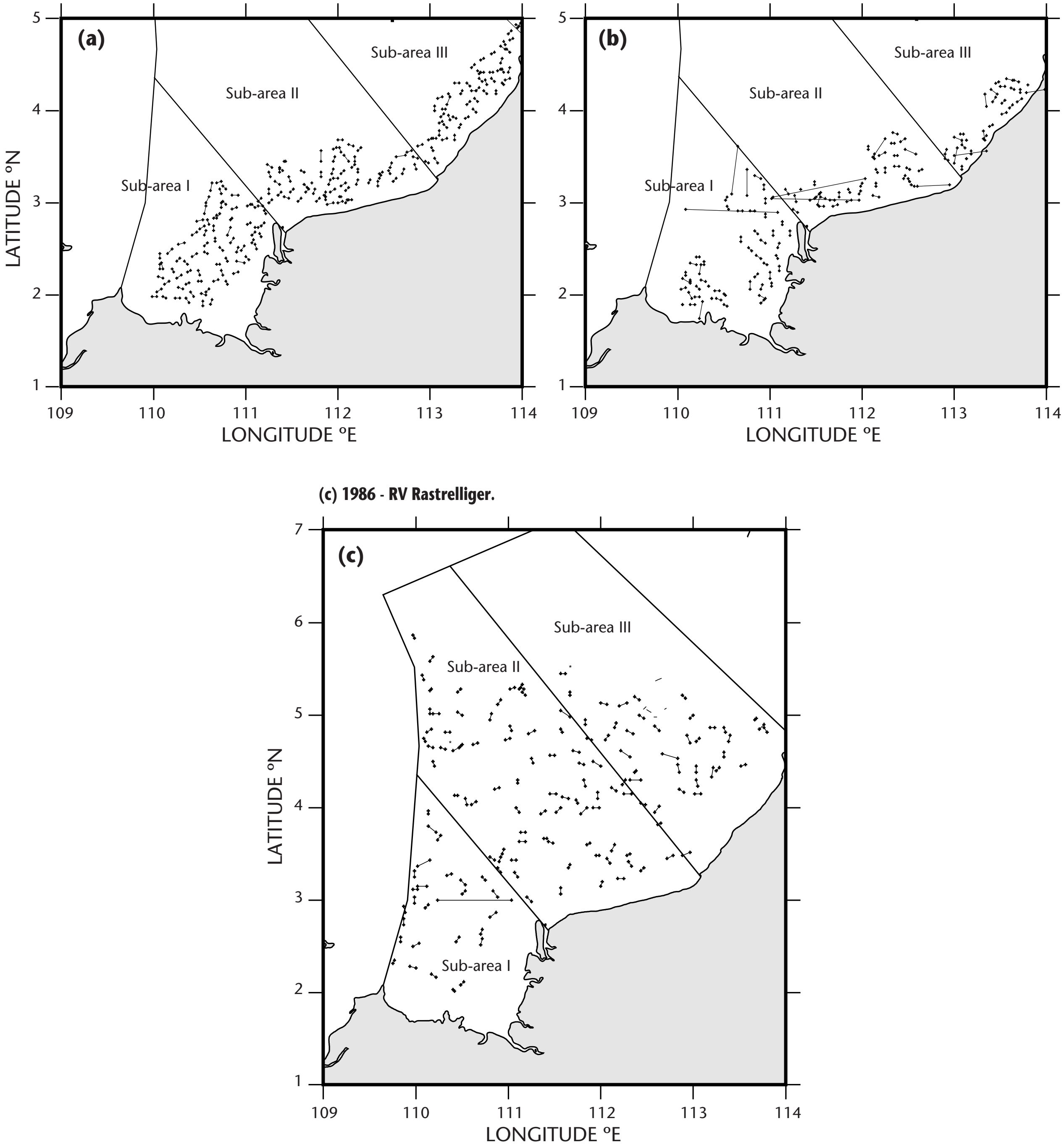


(e) 1991 - KK Mersuji.



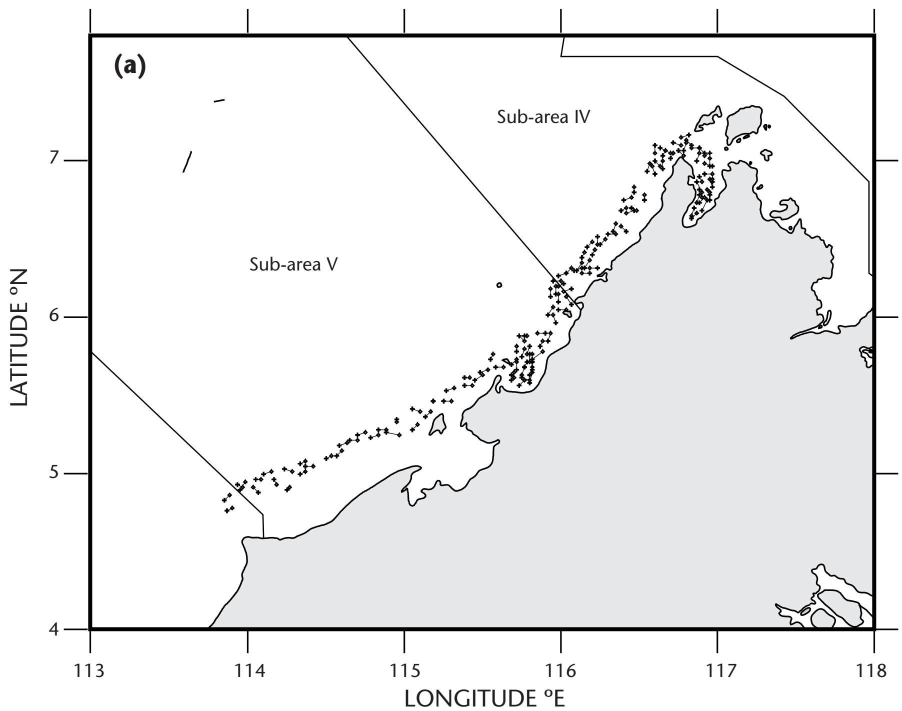
Appendix E. Distribution of sampling stations during the surveys off the coast of Sarawak: (a) 1972 - KK Jenahak/KK Merah, (b) 1981 - KK Merah and (c) 1986 - RV Rastrelliger.

(a) 1972 - KK Jenahak/KK Merah. **(b) 1981 - KK Merah.** **(c) 1986 - RV Rastrelliger.**

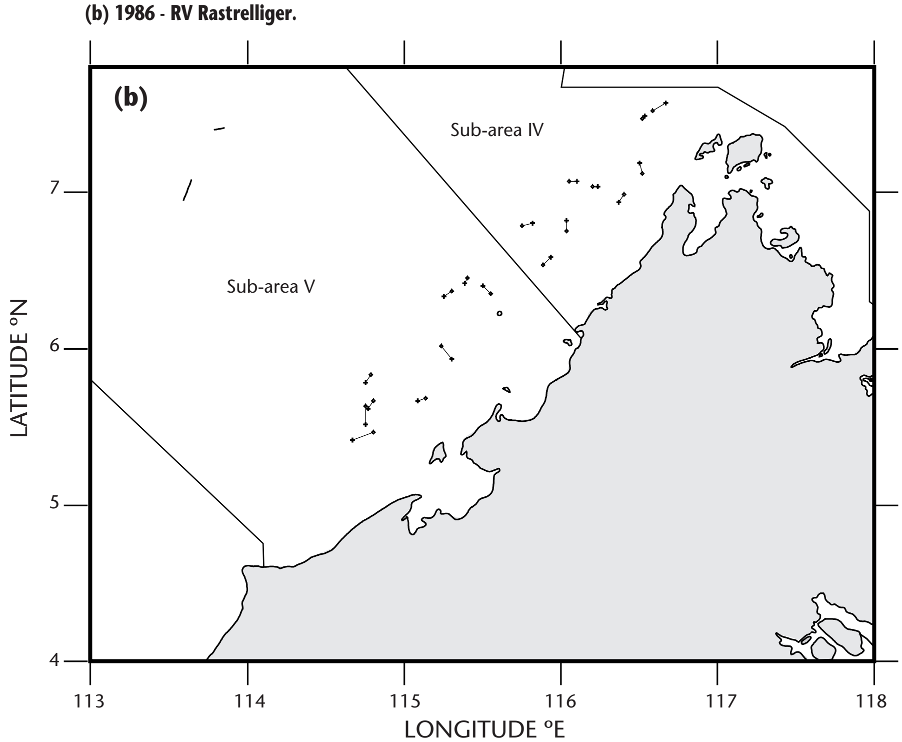


Appendix F. Distribution of sampling stations during the demersal resource surveys off the west coast of Sabah: (a) 1972 - KK Jenahak/KK Merah and (b) 1986 - RV Rastrelliger.

(a) 1972 - KK Jenahak/KK Merah.



(b) 1986 - RV Rastrelliger.



Appendix G. Mean CPUE ($kg \cdot hr^{-1}$) by sub-area and by year off the (a) west coast of Peninsular Malaysia, (b) east coast of Peninsular Malaysia, (c) Sarawak and (d) west coast of Sabah.

(a) West coast of Peninsular Malaysia.

Sub-area	1971		1981		1987*		1991*		1997*	
	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD
I.1	112.9	89.9	55.6	59.6	114.9	60.2	28.4	12.0	22.8	15.7
I.2	–	–	–	–	190.3	223.5	38.9	31.3	34.9	11.4
I.3	–	–	–	–	65.5	42.7	–	–	52.5	46.9
II.1	100.7	94.5	41.9	35.0	–	–	25.3	13.2	30.4	11.2
II.2	–	–	–	–	228.5	188.2	47.4	6.5	38.6	21.6
All	106.5	92.1	49.1	49.6	184.4	220.1	29.5	18.5	36.5	21.5

Note: * The catch rate was corrected to the rate for cod-end mesh size of 40 mm.

(b) East coast of Peninsular Malaysia.

Sub-area	1967		1972		1981		1986*		1991		1998*	
	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD	$Kg \cdot hr^{-1}$	SD
I.1	312.6	312.6	222.1	185.1	85.5	62.2	166.2	47.1	39.4	24.0	28.5	17.8
I.2	–	–	–	–	–	–	319.7	305.0	–	–	33.3	13.8
II.1	439.7	441.3	360.1	468.4	111.0	99.1	–	–	66.8	39.2	30.7	–
II.2	–	–	–	–	–	–	235.2	71.6	–	–	21.3	15.0
III.1	-546.7	-534.0	-187.8	-151.2	328.4	372.2	252.8	20.1	49.1	23.2	30.1	22.2
III.2	–	–	–	–	–	–	208.7	48.4	–	–	17.9	17.4
IV.1	189.3	313.5	161.8	186.4	79.3	52.0	–	–	307.9	346.2	6.1	–
IV.2	–	–	–	–	–	–	268.6	30.4	–	–	24.2	30.2
All	403.4	445.2	221.3	254.3	154.6	225.8	227.5	109.7	64.7	89.7	24.0	15.6

Note: * The catch rate was corrected to the rate for cod-end mesh size of 40 mm.

Appendix G. Mean CPUE (kg·hr^{-1}) by sub-area and by year off the (a) west coast of Peninsular Malaysia, (b) east coast of Peninsular Malaysia, (c) Sarawak, and (d) west coast of Sabah. (continued)

(c) Sarawak.

	1972*		1981		1986*		1989/92/93		1997*	
Sub-area	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD
I.1	135.1	85.8	96.5	83.6	178.1	105.5	88.0	65.8	59.0	38.7
I.2	81.0	41.0	–	–	157.1	66.3	152.9	71.3	86.3	55.8
I.3	–	–	–	–	150.2	–	–	–	92.6	-
II.1	224.2	296.0	159.5	118.5	253.5	125.5	144.5	99.6	146.5	224.3
II.2	–	–	–	–	173.9	92.9	139.3	58.3	90.4	30.8
II.3	–	–	–	–	230.0	244.6			531.8	873.4
III.1	301.7	329.7	207.7	136.7	173.6	150.2	165.8	94.8	169.0	56.9
III.2	134.7	88.2	–	–	138.4	94.2	138.2	72.9	105.1	53.9
III.3	–	–	–	–	100.7	150.5	–	–	328.3	639.5
All	202.5	251.0	144.8	118.3	176.2	116.0	125.2	75.2	239.2	522.8

Note: * The catch rate was corrected to the rate for cod-end mesh size of 38 mm.

(d) West coast of Sabah.

	1972*		1986*		1991		1998	
Sub-area	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD
V.1	496.4	6.0	386.3	74.0	298.5	286.3	71.4	51.9
V.2	–	–	63.4	77.5	173.5	124.7	196.0	241.4
V.3	–	–	34.2	47.6	–	–	203.1	32.2
VI.1	478.1	504.2	349.9	19.7	164.3	129.1	56.4	23.3
VI.2	–	–	283.3	146.8	146.8	131.5	147.9	73.8
VI.3	–	–	50.4	0.4	464.5	326.8	70.0	78.7
All	485.0	440.6	180.1	163.0	202.0	186.3	104.9	105.8

Note: * The catch rate was corrected to the rate for cod-end mesh size of 38 mm.

Appendix H. Mean CPUE (kg·hr^{-1}) obtained from log-normal frequency distribution by sub-areas and by year off the (a) west coast of Peninsular Malaysia, (b) east coast of Peninsular Malaysia, (c) Sarawak and (d) west coast of Sabah.

(a) West coast of Peninsular Malaysia.

Sub-area	1971		1981		1987*		1991		1997*	
	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD
I.1	74.5	2.9	41.5	2.1	101.8	2.0	22.7	1.7	18.6	2.2
I.2	–	–	–	–	1116.7	4.0	29.4	2.2	33.3	1.4
I.3	–	–	–	–	49.2	2.2	–	–	36.2	3.0
II.1	67.2	2.6	31.0	2.2	–	–	21.0	2.1	29.1	1.8
II.2	–	–	–	–	184.8	1.7	47.1	1.2	33.6	1.8
All	70.6	15.2	36.1	3.8	114.9	15.6	24.5	1.9	31.0	1.8

Note: * The catch rate was corrected to the rate for cod-end mesh size of 40 mm.

(b) East coast of Peninsular Malaysia.

Sub-area	1967		1972@		1981		1986*@		1991		1998*@	
	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD
I.1	218.3	2.5	165.0	2.2	63.0	2.5	156.3	1.4	32.0	2.0	22.3	2.0
I.2	–	–	–	–	–	–	224.5	2.2	–	–	28.8	1.6
II.1	263.3	3.0	202.7	3.3	70.4	3.0	–	–	56.1	1.9	29.2	–
II.2	–	–	–	–	–	–	219.9	1.5	–	–	14.4	2.6
III.1	348.1	1.7	118.1	3.3	196.8	2.8	252.2	1.1	44.1	1.7	22.3	2.6
III.2	–	–	–	–	–	–	199.5	1.4	–	–	8.1	4.5
IV.1	122.9	2.2	105.7	2.1	66.5	1.8	–	–	193.7	3.3	5.8	–
IV.2	–	–	–	–	–	–	266.6	1.2	–	–	7.7	6.6
All	239.5	18.0	140.9	1.8	88.8	2.8	205.3	1.5	45.7	2.2	17.1	1.6

Note: * The catch rate was corrected to the rate for cod-end mesh size of 40 mm.
@ Pre-Northeast Monsoon.

Appendix H. Mean CPUE (kg·hr^{-1}) obtained from log-normal frequency distribution by sub-areas and by year off the (a) west coast of Peninsular Malaysia, (b) east coast of Peninsular Malaysia, (c) Sarawak and (d) west coast of Sabah. (continued)

(c) Sarawak.

Sub-area	1972*		1981		1986*		1989/92/93		1998@	
	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD
I.1	107.2	2.2	71.7	2.3	150.5	1.8	64.1	2.4	38.9	3.5
I.2	69.5	1.9	–	–	144.4	1.6	141.3	1.5	72.7	1.8
I.3	–	–	–	–	150.2	–	–	–	92.6	–
II.1	126.8	3.0	124.8	2.1	222.0	1.7	109.9	2.5	66.2	3.8
II.2	–	–	–	–	138.8	2.3	121.3	1.9	85.9	1.4
II.3	–	–	–	–	156.7	2.4	–	–	169.3	4.5
III.1	217.6	2.2	171.2	1.9	137.2	2.3	145.9	1.9	161.0	1.4
III.2	103.1	2.4	–	–	89.9	3.9	120.1	1.8	90.1	1.9
III.3	–	–	–	–	39.9	4.9	–	–	95.3	4.9
All	131.7	2.5	106.7	2.3	119.3	1.8	98.7	2.2	94.9	2.3

Note: * The catch rate was corrected to the rate for cod-end mesh size of 38 mm.
@ Pre-Northeast Monsoon.

(d) West coast of Sabah.

Sub-area	1972*		1986*		1991		1998	
	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD	Kg·hr^{-1}	SD
V.1	393.8	2.1	382.7	1.2	217.3	2.4	48.7	3.2
V.2	–	–	24.7	6.8	144.1	1.9	115.0	3.4
V.3	–	–	14.5	5.3	–	–	63.2	1.6
VI.1	304.8	2.7	349.6	1.1	131.1	1.9	54.0	1.5
VI.2	–	–	242.2	2.1	101.9	2.6	133.9	1.7
VI.3	–	–	50.4	1.0	384.3	2.2	42.5	4.6
All	335.8	2.5	80.7	4.3	145.4	2.2	71.6	2.6

Note: * The catch rate was corrected to the rate for cod-end mesh size of 38mm.
@ Pre-Northeast Monsoon.

Appendix I. Demersal biomass by year and depth stratum in Sub-area I and II off the west coast of Peninsular Malaysia.

Year	Vessel/ mesh-size	Sub-area	Stratum[1]	No. of Stn.	Area (km^2)	Catch rate [2] $kg \cdot hr^{-1}$	Stock Density ($t \cdot km^{-2}$)	Biomass (t)
1971 - 72	KK Merah (40 mm)	I	1	46	6 187	74.47	2.56	15 866
		II	1	51	5 507	67.21	2.31	12 747
1981	KK Jenahak (40 mm)	I	1	41	6 187	41.45	1.43	8 831
		II	1	36	5 507	31.03	1.07	5 885
1987	RV Rastrelliger (corrected to 40mm)	I	1	2	6 187	101.79	0.87	5 405
			2	10	6 251	116.68	1.00	6 260
			3	10	3 852	49.24	0.42	1 628
		I	All strata	22	16 291	89.24	0.61	9 981
		II	2	18	10 449	184.81	1.59	16 574
1991	KK Mersuji (40 mm)	I	1	25	6 187	22.66	0.47	2 900
			2	11	6 251	29.41	0.61	3 803
		II	1	18	5 507	20.98	0.43	2 390
			2	4	10 449	47.07	0.97	10 175
		II	All strata	22	15 957	34.03	0.70	11 232
1997	KK Manchong (corrected to 40 mm)	I	1	4	6 187	18.57	0.21	1 317
			2	8	6 251	33.33	0.38	2 388
			3	4	3 852	36.22	0.42	1 599
		I	All strata	16	16 291	29.37	0.34	5 774
		II	1	4	5 507	29.12	0.33	1 838
			2	14	10 449	33.59	0.39	4 024
		II	All strata	18	15 957	31.36	0.36	6 037
		I - II	All area	34	32 248	30.17	0.35	11 739

Note: [1] Stratum 1 = 5 nm - 55 m; Stratum 2 = 56 - 91 m; Stratum 3 = 92 - Territorial Water Limit.

[2] Estimates are from log-transformed catch-per-unit effort.

Appendix J. Demersal fish biomass by year and depth stratum off the east coast of Peninsular Malaysia.

Year	Vessel/ mesh-size	Sub-area	Stratum[1]	No. of Stn.	Area (km²)	Catch rate [2] kg·hr⁻¹	Stock Density (t·km⁻²)	Biomass (t)
1967	Pramong II (40 mm)	I	1	29	19 832	218.33	4.78	94 702
		II	1	48	9 243	263.29	5.76	53 226
		III	1	45	10 312	348.09	7.61	78 51
		IV	1	28	10 502	122.86	2.69	28 222
1972	Jenahak (40 mm)	I	1	48	19 832	165.03	5.68	112 705
		II	1	24	9 243	202.69	6.98	64 514
		III	1	35	10 312	118.12	4.07	41 946
		IV	1	37	10 502	105.70	3.64	38 229
1981	Jenahak (40 mm)	I	1	22	19 832	2.17	63.02	43 038
		II	1	16	9 243	70.42	2.42	22 414
		III	1	21	10 312	196.78	6.78	69 879
		IV	1	19	10 502	66.47	2.29	24 040
1986	Rastrellier (corrected to 40 mm)	I	1	24	19 832	156.25	1.34	26 595
			2	10	10 100	224.51	1.93	19 462
		I/	All	34	29 932	190.38	1.63	48 908
		II	1	–	9 243	–	–	–
			2	65	52 856	219.86	1.89	99 741
		II	All	65	62 099	–	2.16	–
		III	1	2	10 312	252.19	1.71	22 320
			2	9	7 407	199.49	1.94	12 683
		III	All	11	17 720	225.84	–	34 716
		IV	1	–	10 502	–	2.29	–
			2	4	3 104	266.64	–	
		IV	All	4	13 607	–	–	–
		I - IV	All Area	114	123 359	–	–	–
1991	Mersuji (40 mm)	I	1	26	19 832	32.02	0.66	13 137
		II	1	25	9 243	56.09	1.16	10 725
		III	1	8	10 312	44.12	0.91	9 412
		IV	1	3	10 502	193.71	4.01	42 090
1998	Manchong (corrected to 40 mm)	I	1	22	19 832	22.30	0.26	5 069
			2	13	10 100	28.81	0.33	3 336
		I	All	35	29 932	25.56	0.29	8 769
		II	1	1	9 243	29.21	0.33	3 095
			2	61	52 856	14.42	0.17	8 738
		II	All	62	62 099	21.82	0.25	15 530
		III	1	3	10 312	22.32	0.26	2 638
			2	10	7 407	8.07	0.09	684
		III	All	13	17 720	15.19	0.17	3 086
		IV	1	4	10 502	5.82	0.07	701
			2	4	3 104	7.70	0.09	273
		IV	All	8	13 607	6.76	0.08	1 054
		I - IV	All Area	118	123 359	17.33	0.20	24 509

Note: [1] Stratum 1 = 5 nm - 55 m; Stratum 2 = 56 - EEZ Limit.
[2] Estimates are from log-transformed catch-per-unit-effort.

Appendix K. Demersal fish biomass by year and depth stratum off the coast of Sarawak, Malaysia.

Year	Vessel/mesh-size	Sub-area	Stratum[1]	No. of Stn.	Area (km^2)	Catch rate [2] $kg \cdot hr^{-1}$	Stock Density ($t \cdot km^{-2}$)	Biomass (t)
1972	Jenahak (Corrected to 38 mm)	I	1	56	22 467	107.21	3.69	82 945
			2	13	10 166	69.45	2.39	24 313
		II	1	54	21 029	126.8	2.39	50 294
		III	1	47	11 242	217.61	7.49	84 245
			2	7	11 764	103.13	3.55	41 781
1981	Merah (38 mm)	I	1	51	22 467	71.74	3.39	76 274
		II	1	39	21 029	124.75	5.90	124 150
		III	1	30	11 242	171.2	8.10	91 081
1986	Rastrelliger (corrected to 38 mm)	I	1	14	22 467	150.49	1.29	29 018
			2	13	10 166	144.42	1.24	12 601
			3	1	892	150.18	1.29	1 150
		I	All	28	33 525	148.36	1.27	42 689
			1	18	21 029	221.9	1.90	40 060
		II	2	21	16 417	138.815	1.19	19 558
			3	28	22 908	156.73	1.35	30 816
		II	All	67	60 355	172.50	1.48	89 355
		III	1	3	11 242	137.23	1.18	13 241
			2	15	11 764	89.94	0.77	9 081
			3	16	15 555	39.98	0.34	5 337
		III	Al	34	38 562	89.05	0.76	29 472
		I - III	All Area	129	132 444	136.64	1.17	155 318
1989	Manchong (38 mm)	I	1	30	22 467	64.12	0.84	18 874
			2	13	10 166	141.25	1.85	18 813
1989 -		II	1	11	21 029	109.95	1.44	30 294
92			2	18	16 417	121.34	1.59	26 099
		III	1	3	11 242	145.93	1.91	21 494
1993			2	13	11 764	120.05	1.57	18 504
1998	Manchong (38 mm)	I	1	11	22 467	38.92	0.45	10 024
			2	13	10 166	72.73	0.83	8 476
			3	1	892	92.57	1.06	946
		I	All	25	33 525	68.07	0.78	26 163
			1	16	21 029	66.19	0.76	15 957
		II	2	20	16 417	85.93	0.99	16 172
			3	30	22 908	169.29	1.94	44 460
		II	All	66	60 355	107.14	1.23	74 130
		III	1	6	11 242	160.99	1.85	20 748
			2	11	11 764	90.13	1.03	12 156
			3	19	15 555	95.33	1.09	17 000
		III	All	36	38 562	115.48	1.32	51 053
		I - III	All Area	127	132 444	96.90	1.11	147 124

Note: [1] Stratum 1 = 5 nm - 55 m; Stratum 2 = 56 - 91 m; Stratum 3 = 92 - Territorial Water Limit.
[2] Estimates are from log-transformed catch-per-unit-effort.

Appendix L. Demersal fish biomass by year and depth stratum off the west coast of Sabah.

Year	Vessel/mesh-size	Sub-area	Stratum[1]	No. of Stn.	Area (km^2)	Catch rate [2] $kg \cdot hr^{-1}$	Stock Density ($t \cdot km^{-2}$)	Biomass (t)
1972	Jenahak	IV	1	6	11 557	393.75	13.56	156 716
	(Corrected to 38 mm)	V	1	59	8 652	304.75	10.49	90 797
1986	Rastrelliger	IV	1	2	11 557	382.69	3.28	37 962
	(Corrected to 38 mm)		2	4	2 881	24.71	0.21	611
			3	3	1 874	14.50	0.12	233
		IV/	All	9	16 313	140.63	1.2	19 691
		V	1	2	8 652	349.59	3.00	25 959
			2	4	3 641	242.23	2.08	7 570
			3	2	2 334	50.39	0.43	1 009
		V	All	8	14 627	214.07	1.84	26 875
		IV - V	All Area	17	30 941	177.35	1.52	47 097
1993	Manchong (38 mm)	IV	1	4	11 557	217.3	2.85	2 905
			2	6	2 881	144.14	1.89	5 440
			3	1	1 874	75.68	0.99	1 858
		IV/	All	11	16 313	145.71	1.91	31 142
		V	1	13	8 652	131.11	1.72	14 862
			2	7	3 641	101.98	1.34	4 865
			3	3	2 334	384.33	5.04	11 753
		V	All	23	14 627	205.81	2.7	39 442
		IV - V	All Area	34	30 941	175.76	2.31	46 673
1998	Manchong (38 mm)	IV	1	4	11 557	48.65	0.56	6 446
			2	6	2 881	114.98	1.32	3 797
			3	1	1 874	63.19	0.72	1 357
		IV/	All	11	16 313	75.61	0.87	14 139
		V	1	13	8 652	53.99	0.62	5 355
			2	7	3 641	133.87	1.53	5 588
			3	3	2 334	42.48	0.49	1 136
		V	All	23	14 627	115.17	0.88	12 875
		IV - V	All Area	34	30 941	76.19	0.87	20 233

Note: [1] Stratum 1 = 0 - 55 m; Stratum 2 = 56 - 91 m; Stratum 3 = 92 - Territorial Water Limit.
[2] Estimates are from log-transformed catch-per-unit effort.

Appendix M. Annual demersal catch, CPUE of the research vessel KK Jenahak and estimated total effort off the west coast of Peninsular Malaysia.

Year	Demersal catch (t)	CPUE * KK Jenahak ($t \cdot hr^{-1}$)	Estimated Total effort ($t \cdot hr^{-1}$)	Weighted average Total effort ($t \cdot hr^{-1}$)
1971	86 514	0.089 4	967 718	967 718
1972	100 405	0.087 1	1 152 755	1 078 740
1973	127 351	0.084 8	1 501 780	1 296 428
1974	150 342	0.082 5	1 822 327	1 603 883
1975	135 944	0.080 2	1 695 062	1 705 270
1976	152 597	0.077 9	1 958 883	1 848 183
1977	180 007	0.075 6	2 381 044	2 125 993
1978	181 658	0.083 3	2 478 281	2 359 302
1979	180 813	0.071 0	2 546 661	2 496 265
1980	168 873	0.068 7	2 458 122	2 490 995
1981	187 661	0.066 4	2 826 221	2 656 928
1982	192 449	0.064 1	3 002 324	2 852 923
1983	208 168	0.061 8	3 368 414	3 156 019
1984	185 298	0.059 5	3 114 254	3 180 319
1985	215 500	0.057 2	3 767 482	3 483 228
1986	261 212	0.054 9	4 757 959	4 153 849
1987	279 749	0.052 6	5 318 422	4 873 111
1988	235 168	0.050 3	4 675 308	4 903 455
1989	271 876	0.048 0	5 664 083	5 276 881
1990	294 931	0.045 7	6 453 632	5 894 062
1991	239 023	0.043 4	5 507 442	5 848 946
1992	263 985	0.041 1	6 422 992	6 122 915
1993	258 878	0.038 8	6 672 113	6 394 961
1994	257 318	0.036 5	7 049 808	6 819 440
1995	278 976	0.034 2	8 157 192	7 540 551
1996	304 668	0.031 9	9 550 721	8 669 393

Note: * Values calculated from linear relationship obtained from changes in catch rate over time during the surveys conducted in 1971, 1981, 1987, 1991 and 1997 in Sub-areas I and II off the west coast of Peninsular Malaysia.

$\ln (c/f_{wt}) = -2.250\,3 - 1.42E - 07 f_{wt}$ $r^2 = 0.945\,5$

Fox Model : MSY = 273 374 t

$f_{MSY} = 7.06 \times 10^6$ towing hours of KK Jenahak

Appendix N. Annual demersal catch, CPUE off the research vessel KK Jenahak and estimated total effort off the east coast of Peninsular Malaysia.

Year	Demersal catch (t)	CPUE * KK Jenahak ($t \cdot hr^{-1}$)	Estimated Total effort ($t \cdot hr^{-1}$)	Weighted average Total effort ($t \cdot hr^{-1}$)
1971	30 534	0.224 3	136 130	136 130
1972	26 418	0.219 4	120 410	126 698
1973	39 158	0.214 5	182 555	154 103
1974	52 019	0.209 6	248 182	205 011
1975	39 540	0.204 7	193 161	209 734
1976	54 099	0.199 8	270 766	241 134
1977	44 133	0.194 9	226 439	235 668
1978	53 336	0.190 0	280 716	260 965
1979	50 727	0.185 1	274 052	268 338
1980	43 457	0.180 2	241 160	258 717
1981	63 061	0.175 3	359 734	305 929
1982	52 480	0.170 4	307 981	314 095
1983	56 736	0.165 5	342 816	334 024
1984	51 398	0.160 6	320 041	325 623
1985	50 069	0.155 7	321 574	324 603
1986	70 693	0.150 8	468 786	394 925
1987	87 892	0.145 9	602 413	511 064
1988	136 269	0.141 0	966 447	762 159
1989	147 691	0.136 1	1 085 165	965 134
1990	198 307	0.131 2	1 511 486	1 278 539
1991	183 962	0.126 3	1 456 548	1 412 964
1992	175 980	0.121 4	1 449 588	1 462 224
1993	198 084	0.116 5	1 700 292	1 576 100
1994	192 702	0.111 6	1 726 720	1 671 722
1995	178 109	0.106 7	1 669 250	1 693 580
1996	169 660	0.101 8	1 666 601	1 677 504

Note: * Values calculated from linear relationship obtained from changes in catch rate over time during the surveys conducted in 1967, 1972, 1981, 1986 and 1991 off the east coast of Peninsular Malaysia.

$n\ (c/f_{wt}) = -1.5316 - 3.85E - 07f_{wt}$ $\quad r^2 = 0.7835$

Fox Model : MSY = 206 412 t

$f_{MSY} = 2.59 \times 10^6$ towing hours of KK Jenahak

Appendix O. Annual demersal catch, CPUE of the research vessel KK Manchong and estimated total effort off the coast of Sarawak.

Year	Demersal catch (t)	CPUE * KK Jenahak ($t \cdot hr^{-1}$)	Estimated Total effort ($t \cdot hr^{-1}$)	Weighted average Total effort ($t \cdot hr^{-1}$)
1969	4 757	0.417 3	11 399	11 399
1970	7 403	0.404 0	18 324	15 554
1971	7 126	0.390 7	18 239	17 127
1972	9 132	0.377 4	24 197	21 232
1973	24 483	0.364 1	67 243	44 727
1974	29 726	0.350 8	84 738	68 816
1975	41 134	0.337 5	121 879	100 393
1976	46 396	0.324 2	143 109	126 304
1977	46 870	0.310 9	150 756	143 394
1978	47 392	0.297 6	159 247	153 727
1979	52 487	0.284 3	184 618	170 517
1980	46 256	0.271 0	170 686	173 424
1981	37 315	0.257 7	144 800	160 065
1982	38 749	0.244 4	158 547	155 988
1983	37 138	0.231 1	160 701	157 333
1984	29 880	0.217 8	137 190	148 587
1985	29 778	0.204 5	145 614	145 321
1986	39 248	0.191 2	205 272	174 039
1987	31 072	0.177 9	174 660	180 023
1988	34 796	0.164 6	211 397	198 131
1989	40 092	0.151 3	264 983	232 067
1990	36 943	0.138 0	267 703	257 412
1991	46 669	0.124 7	374 250	320 523
1992	45 212	0.111 4	405 853	372 294
1993	43 078	0.098 1	439 123	417 221
1994	58 460	0.084 8	689 387	558 710
1995	66790	0.071 5	934 126	770 046
1996	56 053	0.058 2	963 110	907 828

Note: * Values calculated from linear relationship obtained from changes in catch rate over time during the surveys conducted in 1972, 1981, 1986, 1989 - 93 and 1998 in areas less than 91 m depth off the coast of Sarawak.

$\ln (c/f_{wt}) = -0.9566 - 2.36E - 06f_{wt}$ $r^2 = 0.7993$

Fox Model : MSY = 59 878 t

$f_{MSY} = 0.423 \times 10^6$ towing hours of KK Manchong

Status of Demersal Fishery Resources in the Gulf of Thailand

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Abstract

Data from trawl surveys (1961 - 95) and annual production statistics (1971 - 95) were used to examine the status of demersal fishery resources in the Gulf of Thailand. Analyses were focused on biomass trends, population parameters and exploitation rates of dominant species, and assessment of excess capacity from fishing effort and yield estimates. The results indicate by 1995, the trawlable biomass in the Gulf had declined to only about 8.2% of the biomass level in 1961. The substantial decline is true for major components (demersal fish and trash fish) and species groups (*Nemipterus* spp., *Priacanthus* spp., *Saurida* spp. and squids) comprising trawlable biomass. Estimates of exploitation rate (E) for 23 species indicate that most (particularly demersals) are over-fished. By 1995, 21 of the species had E values of 0.79 and higher. Analyses of standardized fishing effort and yield using the Fox model indicate that the 1995 fishing effort was about twice the level needed to harvest the maximum sustainable yield. Overall, the results illustrate that the resources are severely over-exploited. The excess demersal fishing effort is estimated to be about 50% of the number of registered boats in 1995.

Introduction

The demersal resources in the Gulf of Thailand have been subjected to increasing exploitation since the introduction of trawling in 1960. The rapid increase in trawling capacity has resulted in the decline of the resources and operations have become less profitable (Demersal Fish Working Group (DFWG), 1995; Isarankura and Kuhmorgen 1966). Since the introduction of trawling, the Department of Fisheries (DOF), Thailand has conducted systematic trawl surveys to monitor the status of the resources and levels of exploitation. The DOF research vessel *Pramong 2*, later supplemented by *Pramong 9*, were used to conduct the routine surveys. The size and design of these vessels were similar to commercial boats operating in the area. The surveys have provided reliable information on the status of the resources through time and are deemed important for their proper management (Isarankura 1971; Tiews 1965).

The catch-per-unit effort (CPUE) from the trawl surveys has been reported to have declined from 298 kg·hr^{-1} in 1961 to around 20 kg·hr^{-1} in the early 1990s (Department of Fisheries (DOF) 1999). Various studies of the demersal, pelagic and invertebrate resources in the Gulf of Thailand (Boonyubol and Pramokchutima 1982; Chullasorn, 1998; Demersal Fish Working Group (DFWG) 1995; Hong-

skul 1972; Pelagic Fish Working Group (PFWG) 1995; Supongpan 1988; Supongpan 1993; Supongpan 1996; Vibhasiri, 1987) indicate over-exploitation problems. Catch composition changes toward smaller and less valuable species have been noted. Lately, fishing gear using light lures and nets with smaller mesh sizes have been deployed by fishers in efforts to increase catches. Light luring techniques, however, tend to catch juveniles and so have aggravated over-fishing and conflicts among fishers. While DOF (under the Ministry of Agriculture and Co-operatives) has issued several laws and regulations to improve management of the fisheries, excess fishing capacity and illegal fishing activities still persist.

This study attempts to provide an update on the status of the demersal fishery resources in the Gulf of Thailand. It infers the extent of over-fishing of the resources by looking at (1) the trends in biomass from the trawl surveys, (2) the population parameters and exploitation rates of dominant species, and (3) the available catch and effort time series from the commercial fisheries.

Materials and Methods

Biomass Estimation

Data collected by *Pramong* 2 and *Pramong 9* for the years 1961 to 1995 were used for the estimation of biomass of trawlable resources in the Gulf of Thailand. *Pramong* 2 is a wooden stern trawler with a displacement of 79 gross tons (GRT). It has an overall length (LOA) of 24.5 m and a breadth of 5.2 m. It is fitted with a 320 HP diesel engine with remote control system. *Pramong 9* is also a wooden stern trawler with a displacement of 85 GRT. It has an LOA of 25.2 m, a breadth of 5.95 m and a 412 HP engine.

Both research vessels used the German otter trawl. The net was nylon with a total length of 47.7 m, wing width of 17 m, and a height of 3.5 m. Mesh size ranged from 16 cm at the wing to 4 cm at the cod-end. Surveys since 1981 have used a cod-end cover of 2.5 cm (Eiamsa-ard and Amornchairojkul, 1997). The length of ground and head rope was 48 and 39 m, respectively. The otter boards were made of hard wood with edges covered by steel (Eiamsa-ard et al., 1977).

The Gulf of Thailand (Fig. 1) is situated from 6º to 13º30' North latitude and 99º to 104º East longitude and has a total seabed area of 304 000 km^2. It is relatively shallow, with a mean depth of about 58 m (the deepest being 85 m) (Supongpan, 1996). For the trawl surveys, the Gulf of Thailand was divided into 9 areas (Area 1 to 9), each area further divided into grids of 30 nm x 30 nm. The sampling scheme involved 80 trawl hauls in each area (one hour per haul), totaling 720 hauls in one year. This sampling scheme was used from 1963 to 1976. As the abundance of commercially important demersal species was very low beyond the 50 m depth contour, the surveys were largely limited to the 10 - 50 m depth range (Isarankura, 1971).

Pramong 9 was commissioned in 1977 to conduct the surveys together with *Pramong 2*. During the first sampling month, *Pramong 2* was deployed in Areas 1 to 4 while *Pramong 9* was simultaneously deployed in Areas 5 to 9. In the next sampling month, vessel deployment was reversed (and so on for the rest of the year). From 1977 onwards, the scheme was changed to grid areas of 15 nm x 15 nm (Fig. 1). As a result, more substantial information on catch, effort, fish biology, and species size distribution was collected. Because of the oil crisis in 1973 and subsequent budgetary shortfalls, the number of hauls in each area was reduced to 60, so that the total number of hauls per year was reduced to 540.

During the surveys, trawling was conducted only during daylight hours. The position, trawling depth, engine speed, vessel velocity and time of operation was recorded for each haul. Trawling speed was maintained at 2.5 knots as much as possible. Places not suitable for trawling (e.g. rough bottom, with obstructions) were marked and their positions noted for future reference.

The catch for each haul was classified into food or trash fish, and then identified to the lowest taxonomic level possible (species or genera). A balance was used to weigh samples. Sea snakes, sea urchins and other poisonous species were separated from the catch and discarded after recording.

Biomass (B) was estimated via the swept area method, using the formula given by (Sparre and Venema, 1992) as follows:

$$B = \frac{\overline{CPUE}}{a*X_1} * A$$

where,
A (total area) = 101 384 km^2
a (swept area) = 0.090 29 km^2,
X_1 (proportion of fishes in the path of the trawl retained by it) = 0.5 .

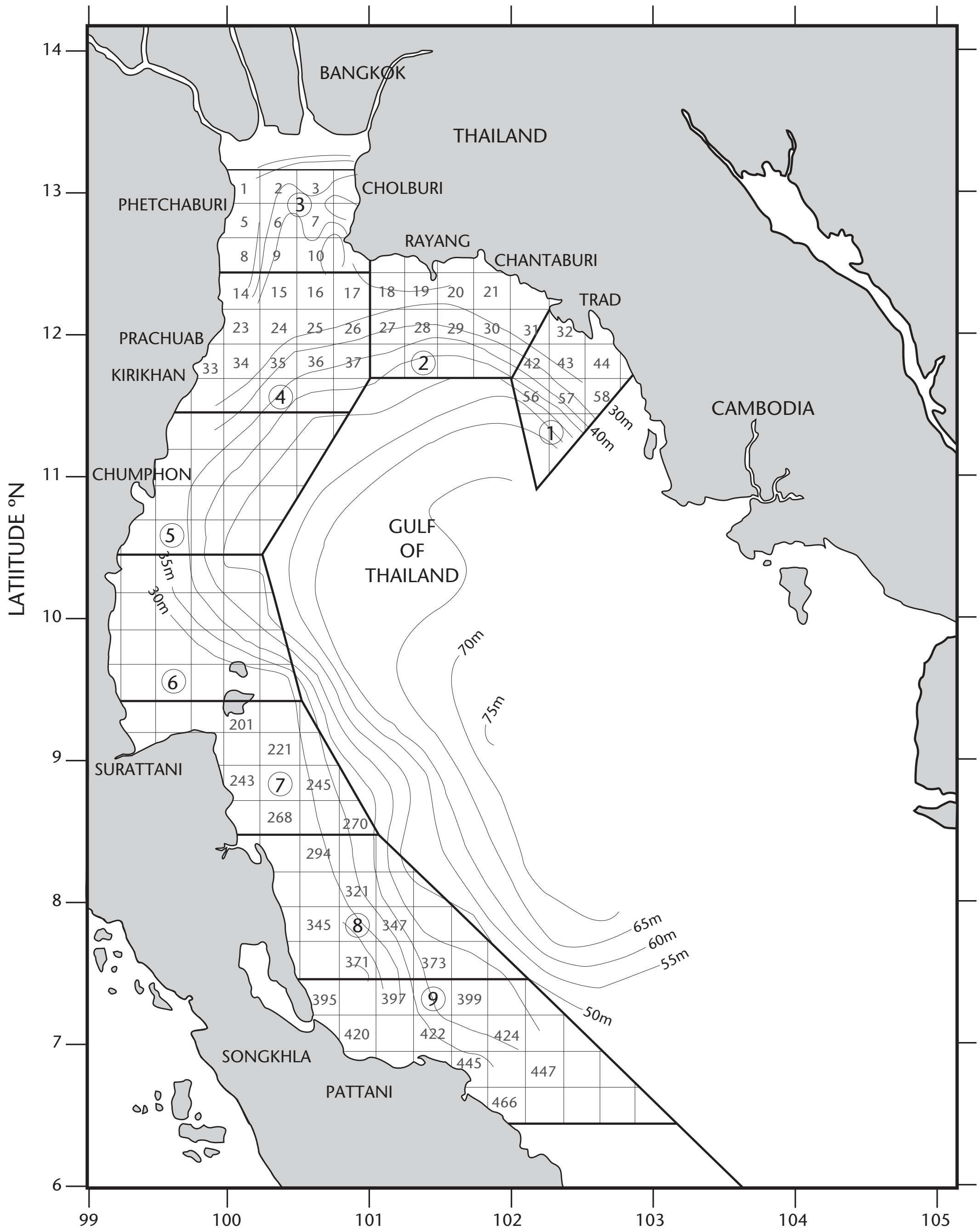

Fig. 1. The Gulf of Thailand showing depth contours, the 9 survey areas and trawl sampling grids.

The swept area was estimated from the equation:

$a = t*v*h*X_2$

where,

t (time spent trawling) = 1 hr,

v (trawling speed) = 2.5 knots

(multiplied by 1.853 2 to convert to km•hr^{-1}).

h (length of trawl head rope) = 39 m,

X_2 (effective width of the trawl relative to its head rope) = 0.5.

The mean catch-per-unit effort ($\overline{CPUE}$) was calculated as the arithmetic mean of catches from hauls in a given survey year (excluding extremely high values). Although geometric means are better measures of central tendency for trawl survey data, it was not possible to retrieve some of the primary catch (per haul) data, particularly for the earlier surveys. Survey reports giving only arithmetic mean catch rates were used in these instances, therefore arithmetic means were used for consistency of the biomass time series. Interpolation (between years for which estimates were available) was done for a limited number of years when no survey was conducted.

Estimation of Population Parameters and Exploitation Rates

Size frequency data of commercially important species have been collected during the trawl surveys since the early 1980s. Total length was measured using 1 cm length intervals. Punch cards (with scale) were used to record the measurements. The 10 most abundant economically-important species were usually chosen for generation of size distribution data.

Population parameters of nine species (*Rastrelliger kanagurta, Atule mate, Scolopsis taeniopterus, Lutjanus lineolatus, Nemipterus nematophorus, Nemipterus peronii, Epinephelus sexfasciatus, Sepia recurvirostra* and *Sepia aculeata*) were estimated in this study from size frequency data collected during various years. These parameters include:

1. coefficients (a and b) of the length-weight relationship;
2. growth parameters (L_∞ and K) of the von Bertalanffy equation;
3. gear selection parameters ($L_{25\%}$, $L_{50\%}$, $L_{75\%}$); and
4. natural mortality coefficient (M).

The FiSAT (FAO - ICLARM Stock Assessment Tools) software (Gayanilo and Pauly 1997) was used to obtain the parameters. The value of M was estimated using the empirical equation of (Pauly 1980) as incorporated in FiSAT. Apart from the nine species mentioned above, population parameters for 14 other species were obtained from the literature.

For each of the 23 species included in the study, the fishing mortality (F) was estimated by dividing yield (Y) with biomass (B) estimates for the species (i.e. F = Y/B). The Y values were obtained from annual production statistics (Department of Fisheries (DOF), 1971 - 96a) while the B values were estimated from trawl surveys conducted during the 1971 - 1995 period. Total mortality (Z) was calculated by the addition of M and F (i.e. Z = M+F) and exploitation rate (E) estimated by dividing F by Z (i.e. E = F/Z). For each of the 23 species therefore the annual E estimate is given for the 1971 - 95 period.

Fishing Effort and Yield

Annual production or yield (Y) by species or species group during the period 1971 - 95 was taken from statistical records of the Department of Fisheries (Department of Fisheries (DOF) 1971 - 96a). The total number of registered trawlers (sum of otter trawlers, pair trawlers, beam trawlers, and push net units) and other fishing vessels from 1971 - 95 are also given in the annual statistics of the Department of Fisheries (Department of Fisheries (DOF) 1971 - 96b). Generation of a composite annual effort index to match the annual production figures however is difficult given the challenge of standardization across the various types of gear used in the Gulf of Thailand. To estimate annual effort (f), annual production was divided by the annual mean CPUE from the trawl surveys. The resulting f estimate is expressed in standard trawling hours with the survey vessel as standard.

The maximum sustainable yield or MSY (total and for major species groups) and fishing effort corresponding to MSY (f_{MSY}) were estimated using the Fox model. The annual Y and f series for the 1971 - 95 period were utilized following the procedure described by (Sparre and Venema, 1992), viz.:

$$\frac{Y_i}{f_i} = e^{c+dfi}$$

$$MSY = -\frac{1}{d} e^{c-1}$$

$$f_{MSY} = -\frac{1}{d}$$

where *c* and *d* are constants derived via regression, and Y_i and f_i refer to yield and fishing effort respectively for year i.

Results and Discussion

Biomass Trends

Fig. 2 shows the estimates of total trawlable biomass in the Gulf of Thailand (0 - 50 m depth) between 1961 and 1995. Trawlable biomass declined from about 680 000 t in 1961 to about 56 000 t in 1995 (i.e. down to 8.2% of the 1961 level). Separation of trawl survey catches into major species groups began only in 1966. Fig. 2 also shows the substantial decline in biomass of the demersal fish and trash fish components of trawlable biomass. Fig. 3 illustrates the biomass estimates for four major species groups (*Nemipterus* spp., *Priacanthus* spp., *Saurida* spp. and squids) comprising trawl survey catches. All groups show the same downward trend over the period 1966 - 95.

Relative indices of total number of trawlers, catch and biomass (based on available data) during the period 1961 - 95 are illustrated in Figs. 4 - 6. As noted earlier, the trash fish, demersal fish and total

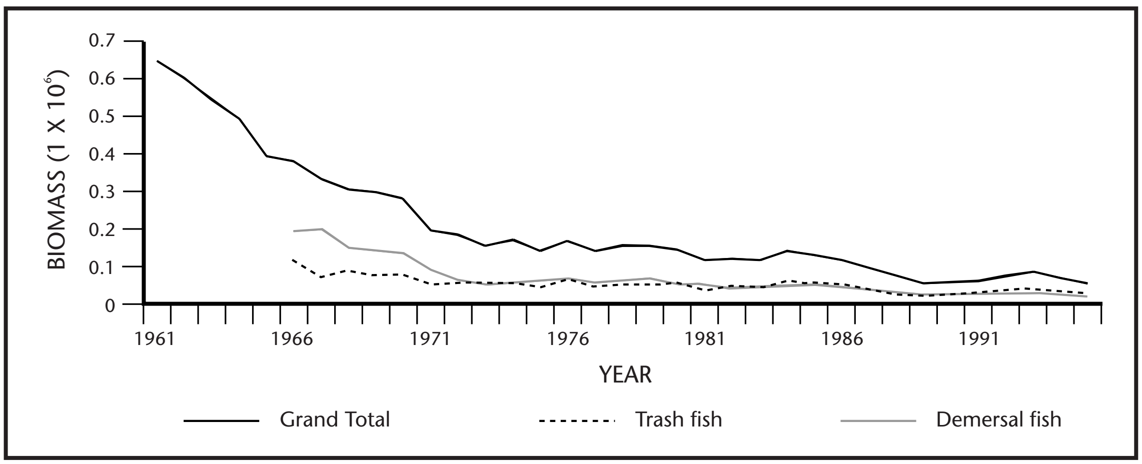

Fig. 2. Total trawlable trash fish and demersal fish biomass in the Gulf of Thailand, 1961 - 95.

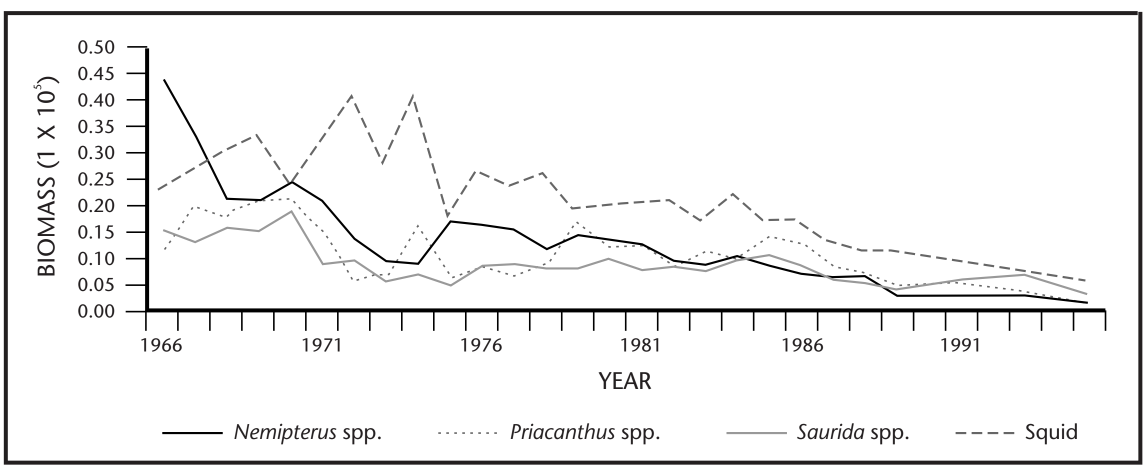

Fig. 3. Biomass of *Nemipterus* spp, *Priacanthus* spp, *Saurida* spp. and squid in the Gulf of Thailand ,1966 - 95.

trawlable biomass estimated from trawl surveys have declined tremendously. The relative number of trawlers and total production generally correspond well (i.e. increases in number of trawlers generally result in increases in total production and vice-versa). During 1985 - 95 however this relationship was reversed, with production increases corresponding to decreases in number of trawlers. Increased production has been attributed to larger trawlers extending their operations to deeper waters while small-sized boats continued fishing in shallow coastal waters (Demersal Fish Working Group (DFWG) 1995). Pair trawlers also expanded their operations into deeper areas and previously untrawlable zones in the middle part of the Gulf by adjusting their riggings (Department of Fisheries (DOF) 1999). Moreover, purse seiners increased their fishing efficiency by reducing their mesh size from 4.7 cm to 3.5 - 3.8 cm, equipping their vessels with fish finders, and by the development of light luring techniques (Department of Fisheries (DOF) 1999; Pelagic Fish Working Group (PFWG) 1995).

Adjustments in the operation of trawlers led to increases in demersal fish catch during 1985 - 95 (Fig. 6), as the trash fish catch declined and then stabilized from its highest level in 1987 (Fig. 5). All these adjustments were undertaken by the trawl fleet as the biomass of demersal fish and trash fish by 1995 had declined to about 7% and 15% respectively, of their 1966 levels. The production

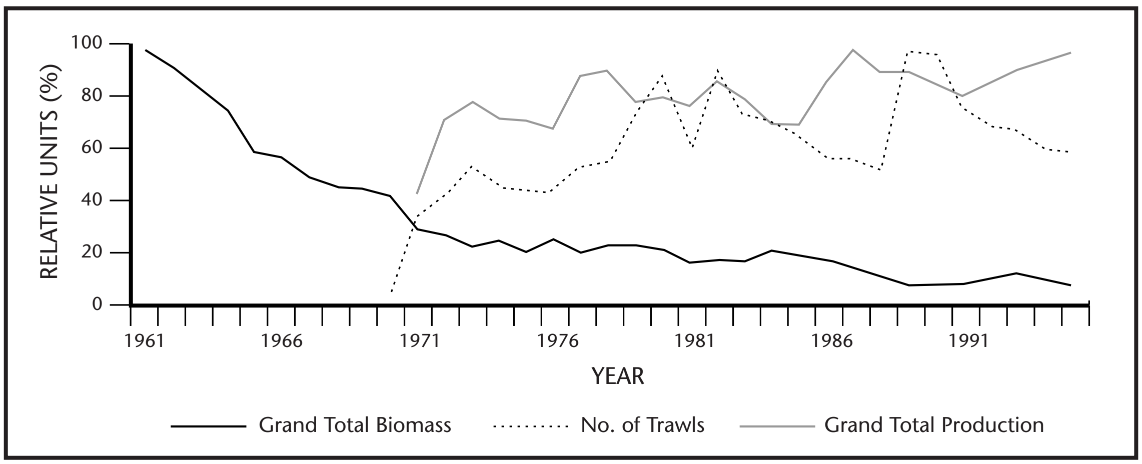

Fig. 4. Relative indices of trawlable biomass, number of trawlers and total production in the Gulf of Thailand, 1961 - 95. Trawl gear are otter board trawl, pair trawl, beam trawl and push net.

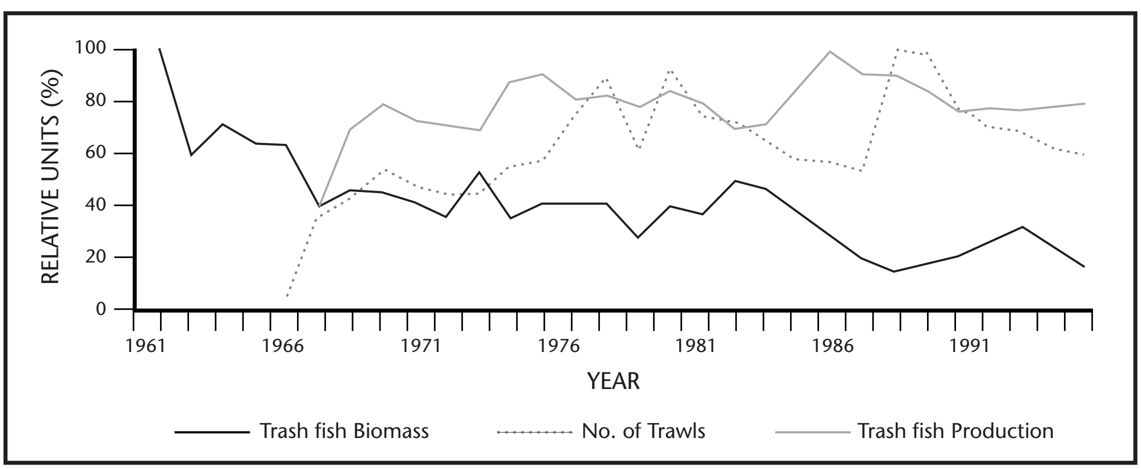

Fig. 5. Relative indices of trash fish biomass, number of trawlers and trash fish production in the Gulf of Thailand, 1966 - 95.

of *Nemipterus* spp., *Priacanthus* spp. and *Saurida* spp. (which are main components of the demersal fish catch) increased substantially after 1985. These groups are mostly used to make *surimi* (artificial crabmeat) because of their good flesh, taste and colour. In recent years, fishers have sorted out more rigorously small-sized individuals of *Nemipterus* spp., *Priacanthus* spp. and *Saurida* spp. from trash fish for making *surimi*. This is partly the reason why demersal fish production increased while trash fish production declined between 1985 and 1995. (Fig. 5 and 6).

Fig. 7 gives the relative indices of squid production, biomass and total number of trawlers for the 1966 - 95 period. At the beginning of the squid fishery, fishers used trawls as the major gear for catching squids. Since 1982, fishing gear using light luring techniques have been gradually expanded. More squid catches come from light luring fishing techniques than trawling (Supongpan 1996). Squid production has fluctuated considerably, but exhibits a general trend of decline since reaching a maximum in 1977. Estimates of squid biomass from trawl surveys had declined by 1995, to only about 14% of the maximum level reported in 1974. Table 1 presents the species composition changes from trawl survey catches in the Gulf of Thailand. There is a noticeable increase in the contribution of squids (*Loligo duvauceli*) from 1966 to 1986 and a decreasing trend in the contribution of threadfin breams (*Nemipterus hexodon*) in

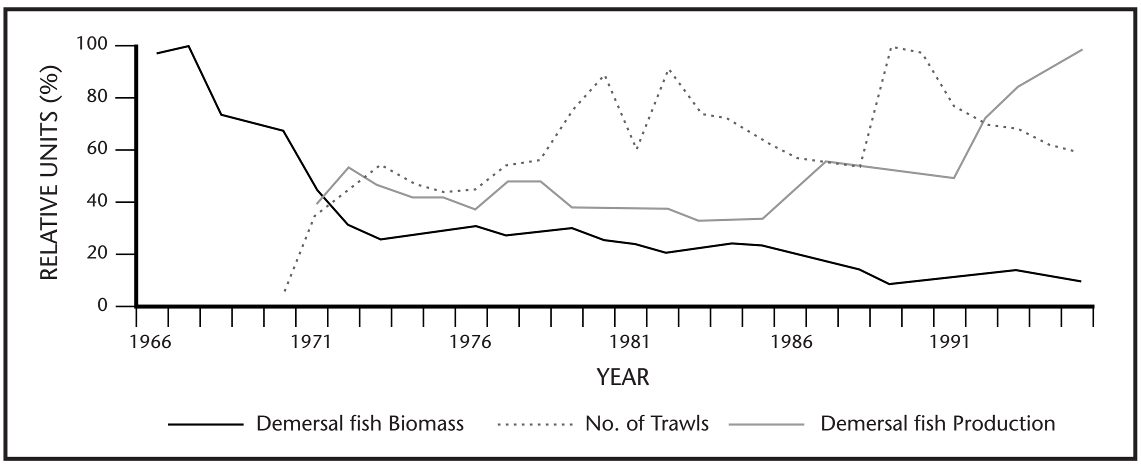

Fig. 6. Relative indices of demersal fish biomass, demersal fish production and number of trawlers in the Gulf of Thailand, 1966 - 95.

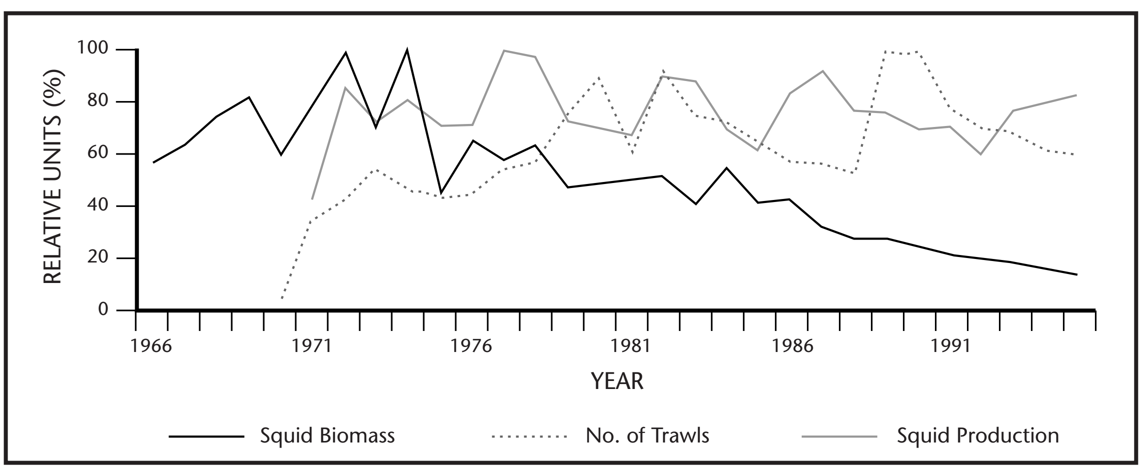

Fig. 7. Relative indices of squid biomass, squid production and number of trawlers in the Gulf of Thailand, 1966 - 95.

Table 1. The change over time of 10 leading species composition caught by RV in the Gulf of Thailand (Source: Supongpan 2001)

Species	1966 %	Species	1976 %	Species	1986 %	Species	1995 %
Dasyatidae (Rays)	8.15	*Loligo duvauceli*	10.60	*Loligo duvauceli*	10.06	*Leiognathus splendens*	13.06
Nemipterus hexodon	7.39	*Nemipterus hexodon*	5.84	*Priacanthus tayenus*	8.61	*Loligo duvauceli*	9.04
Mullidae	4.97	*Loligo chinensis*	3.83	*Saurida undosquamis*	4.14	*Sphyraena obtusata*	6.96
Nemipterus mesoprion	4.67	*Priacanthus tayenus*	3.80	*Loligo chinensis*	3.59	*Secutor spp.*	5.30
Loligo duvauceli	4.39	*Nemipterus mesoprion*	3.69	*Nemipterus hexodon*	3.48	*Scolopsis taeniopterus*	5.19
Tachysuridae	2.84	*Trichiuridae Lepturus*	3.31	*Priacanthus macracanthus*	2.99	*Saurida undosquamis*	3.96
Priacanthus tayenus	2.54	*Saurida undosquamis*	2.82	*Nemipterus mesoprion*	2.19	Mullidae	3.80
Saurida undosquamis	2.44	Mullidae	2.74	*Scolopsis taeniopterus*	2.05	Siganidae	3.05
Lutjanus lineolatus	1.84	*Loligo sumstrensis*	2.00	Mullidae	1.95	*Loligo chinensis*	3.00
Atule mate	1.73	Gerreidae	1.98	*Loligo sumstrensis*	1.88	*Leiognathus bindus*	2.68

the same period. Dasyatidae (rays) were most abundant 1966 trawl survey catches but has disappeared from the top ten in the more recent years, and in 1995, the most abundant species were the pony fishes. These trends are consistent with documented species composition changes due to effects of overfishing in other fishing areas in Southeast Asia (Silvestre 1990; Silvestre et al. 1995)

Population Parameters and Exploitation Rates

Table 2 gives a summary of the population parameters for the 23 species included in the study. Parameters for nine of the species were estimated using the FiSAT software and length distribution data from trawl surveys between 1980 and 1989. Parameters for the 14 other species were obtained from previous studies conducted in the Gulf of Thailand. The 23 species together accounted for about 30% of the total trawlable biomass and about 50% of 'good fish' biomass (pelagic fish, demersal fish and invertebrates combined minus trash fish) during the 1995 trawl survey. The species exhibit relatively high rates of growth (K = 0.46 - 3.72) and natural mortality (M = 1.09 - 4.67).

Table 3 gives the annual exploitation rate (E) calculated for the 23 species from 1971 to 1995. E values for some species were only available for a few years (e.g. *Megalaspis cordyla, Loligo chinensis* and *Epinephelus sexfasciatus* during the years 1988 - 95). Pelagic fishes like *Scolopsis taeniopterus* and *Megalaspis cordyla*, which are not fully vulne-rable to trawl gear, had relatively low E values for most of the period considered. The E values for the rest of the species were initially low, but had increased to very high E values (0.79 - 0.98) by 1995. Some demersal species, particularly *Priacanthus tayenus, Saurida elongata, Saurida undosqamis, Nemipterus hexodon* and *Nemipterus peronii*, had E values close to the 0.9 level. The exploitation rates and biomass declines noted above indicate that the fishery resources, particularly the demersals, were over-exploited.

Fishing Effort and Yield

Estimates of total production in the Gulf of Thailand from 1971 to 1996 are given in Table 4. From 1971 to 1984, the production statistics did not include the contribution of smallscale fishing gear (fish gillnets, mackerel gillnets, squid light luring fishing gear, shrimp gillnet, squid trap, crab gill-nets and fish trap). Only statistics on the production of 11 important types of gear were available. To estimate total production for 1971 - 84, the production of the 11 important gear was adjusted by 15%, the average difference representing small scale production for the period 1985 - 93.

The time series of production (yield) and fishing effort (expressed in trawling hours) from 1971 to 1995 were used to estimate MSY and f_{MSY}. The

Table 2. Population parameters of 23 marine species in the Gulf of Thailand. Where the source is this study, the years in brackets refer to the data from those years. Parameters are defined in the methods section.

Species	a	b	L_∞ (cm)	W_∞ (g)	K (yr^{-1})	$L_{25\%}$ (cm)	$L_{50\%}$ (cm)	$L_{75\%}$ (cm)	M (yr^{-1})	References
Rastrelliger brachysoma	0.006	3.21	22.0	113	3.72				4.67	Demersal Fish Working Group (DFWG) 1995
Rastrelliger kanagurta			28.0		1.30				2.19	This study (1988, 1989)
Scomberomorus commerson	0.013	2.88	110.0	10046	1.19				1.41	Cheunpan (1988)
Selar crumenopthalmus	0.171	2.90	28.4	281	2.40				3.26	Isara (1993)
Atule mate			31.0		1.40	10.6	12.4	14.2	2.24	This study (1980)
*Megalaspis cordyla**	0.014	2.98	28.8	320	2.40				3.25	Noopeth and Podapol (1983)
Selaroides leptolepis	0.004	3.31	19.2	76	1.54				2.72	Noopeth (1984)
Scolopsis taeniopterus	0.027	2.76	31.0		1.04	8.1	9.6	11.0	1.84	This study (1989)
Saurida undosqamis	0.004	3.18	40.6		1.80				2.45	Boonvanich (1991)
Saurida elongata	0.007	3.05	46.1		1.94				2.48	Boonvanich (1991)
Trichiurus lepturus			95.5		1.18				1.46	Dhamniyom (1993)
Lutjanus lineolatus			23.0		1.50	4.1	4.7	5.3	2.55	This study (1988) Demersal Fish Working Group (DFWG) 1995
Priacanthus tayenus	0.018	2.95	31.0		1.90				2.73	Isara (1991) Demersal Fish Working Group (DFWG) 1995
Nemipterus hexodon	0.018	2.91	31.8		1.74				2.56	Isara (1991)
	0.002(T)	2.93(T)	19.5							
Nemipterus mesoprion	0.078(E)	3.10(E)	15.5		0.97				2.00	Isara (1991)
Nemipterus nematophorus			27.0		0.57	5.1	5.4	5.7	1.29	This study (1988)
	0.012(T)	2.99(T)								
Nemipterus peronii	0.020(E)	3.00(E)	31.0		1.60	7.1	8.5	9.9	2.44	This study (1989)
Epinephelus sexfasciatus			33.0		0.48	6.0	7.2	8.4	1.09	This study (1988)
Loligo duvauceli	0.374	2.00	26.6	266	0.86				1.70	Supongpan (1988)
Loligo chinensis	0.421	2.00	40.9	704	0.46				1.00	Supongpan (1988)
Sepia recurvirostra			15.0		1.2	5.9	6.9	7.8	2.48	This study (1988)
Sepia aculenta			21.0		1.3	5.2	5.9	6.7	2.38	This study (1988)
Portunus pelagicus	< 0.001	3.48	23.0		2.84				3.87	Bannasopit et al. (1980)

Note: * *Megalaspis cordyla;* L_∞ is in fork length.

Table 3. Estimate of exploitation ratio for 23 species in the Gulf of Thailand during the period 1971 - 95.

Species	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1991	1993	1994	1995
Atul mate	0.14	0.29	0.42	0.18	0.39	0.47	0.32	0.34	0.34	0.35	0.53	0.48	0.44	0.48	0.54	0.52	0.55	0.72	0.73	0.74		0.93	0.83
Epinephelus sexfasciatus												0.23	0.21	0.26	0.42	0.47	0.70	0.65	0.81	0.76	0.91	0.98	0.96
Loligo chinensis	0.37	0.48	0.53	0.47	0.63	0.54	0.65	0.63	0.62	0.61	0.59	0.65	0.70	0.58	0.61	0.68	0.76	0.75	0.75	0.78	0.81	0.94	0.87
Loligo duvauceli	0.26	0.35	0.40	0.34	0.50	0.41	0.52	0.50	0.49	0.48	0.46	0.53	0.57	0.45	0.48	0.56	0.65	0.64	0.64	0.67	0.73	0.92	0.79
Lutanus lineolatus	0.30	0.53	0.40	0.47	0.48	0.32	0.44	0.53	0.38	0.51	0.49	0.32	0.33	0.17	0.35	0.44	0.49	0.46	0.68	0.81	0.91	0.92	0.86
Megalaspis cordyla					0.07	0.09	0.04	0.10	0.09	0.13	0.19	0.21	0.17	0.03	0.08	0.19	0.23	0.32	0.39	0.31	0.64	0.98	0.39
Nemipterus nematophorus	0.31	0.52	0.56	0.58	0.43	0.39	0.46	0.56	0.48	0.44	0.50	0.54	0.53	0.47	0.57	0.72	0.80	0.75	0.89	0.90	0.94		0.98
Nemipterus hexodon	0.18	0.34	0.40	0.40	0.28	0.25	0.30	0.39	0.31	0.29	0.33	0.37	0.36	0.31	0.40	0.56	0.65	0.61	0.82	0.84	0.88	0.77	0.97
Nemipterus mesoprion	0.22	0.40	0.46	0.46	0.33	0.30	0.35	0.45	0.37	0.35	0.38	0.43	0.42	0.37	0.46	0.62	0.71	0.67	0.86	0.87	0.93	0.81	0.96
Nemipterus peronii	0.19	0.35	0.41	0.41	0.29	0.26	0.31	0.41	0.32	0.30	0.34	0.38	0.37	0.32	0.40	0.57	0.65	0.63	0.83	0.84	0.95	0.75	0.92
Portunus pelagicus	0.57	0.49	0.71	0.68	0.71	0.76	0.80	0.77	0.58	0.63	0.71	0.82	0.79	0.79	0.78	0.76	0.87	0.81	0.80	0.83	0.78	0.69	0.85
Priacanthus tayenus	0.19	0.47	0.35	0.20	0.43	0.30	0.46	0.33	0.15	0.23	0.20	0.26	0.24	0.24	0.21	0.31	0.50	0.52	0.61	0.63	0.82	0.81	0.95
Rastrelliger brachysoma	0.63	0.84	0.81	0.90	0.89	0.85	0.85	0.78	0.58	0.80	0.80	0.71	0.77	0.84	0.79	0.80	0.86	0.74	0.96	0.95	0.72	0.77	0.95
Rastrelliger kanagurta		0.54	0.66	0.75	0.61	0.49	0.52	0.58	0.53	0.58	0.60	0.52	0.61	0.49	0.50	0.57	0.62	0.81	0.90	0.92	0.75	0.95	0.94
Saurida elongata	0.31	0.38	0.45	0.37	0.45	0.31	0.34	0.37	0.32	0.28	0.28	0.27	0.31	0.26	0.24	0.38	0.53	0.55	0.63	0.58	0.73	0.70	0.87
Saurida undosquamis	0.31	0.38	0.46	0.37	0.46	0.31	0.34	0.37	0.33	0.28	0.28	0.27	0.32	0.27	0.24	0.38	0.53	0.56	0.64	0.59	0.72	0.79	0.89
Scolopsis taeniopterus	0.26	0.30	0.39	0.42	0.40	0.38	0.43	0.02	0.14	0.06	0.06	0.12	0.02	0.08	0.03	0.05	0.19	0.20	0.17	0.09	0.02		0.02
Scomberomorus commerson					0.62	0.71	0.78	0.75	0.67	0.68	0.82	0.69	0.79	0.81	0.74	0.84	0.83	0.87	0.85	0.75	0.77	0.95	0.87
Selar crumenopthalmus												0.09	0.17	0.02		0.06	0.39	0.72	0.77	0.72	0.37	0.97	0.89
Selaroides leptolepis	0.12	0.25	0.38	0.16	0.35	0.42	0.28	0.30	0.30	0.31	0.49	0.44	0.40	0.45	0.50	0.47	0.50	0.69	0.68	0.72		0.31	0.80
Sepia aculenta	0.41	0.50	0.59	0.46	0.58	0.56	0.64	0.64	0.61	0.64	0.66	0.83	0.86	0.87	0.84	0.89	0.88	0.87	0.94	0.96	0.91	0.88	0.94
Sepia recurvirostra	0.40	0.49	0.58	0.45	0.57	0.55	0.63	0.63	0.61	0.64	0.65	0.82	0.85	0.87	0.83	0.89	0.88	0.87	0.94	0.96	0.93	0.96	0.91
Trichiurus lepturus	0.44	0.43	0.49	0.56	0.3	0.41	0.58	0.62	0.35	0.74	0.82	0.59	0.51	0.56	0.57	0.59	0.38	0.83	0.79	0.73	0.65	0.96	0.95

Table 4. Estimate of total production (t) of fisheries resources in the Gulf of Thailand during the period 1971 - 96. The 11 important gear types are: otter board trawl, pair trawl, beam trawl, push net, three purse seines (Light luring, Thai, Green), anchovy purse seine, mackerel encircling gillnet, king mackerel gillnet, bamboo stake trap.

Year	Total production (t) *	Production of 11 Important gear types (t)**
1971	(654 292)	568 950
1972	(1 056 089)	918 339
1973	(1 218 594)	1 059 647
1974	(1 177 448)	1 023 868
1975	(1 194 858)	1 039 007
1976	(1 296 552)	1 127 437
1977	(1 782 937)	1 550 380
1978	(1 698 755)	1 477 179
1979	(1 488 949)	1 294 739
1980	(1 448 611)	1 259 662
1981	(1 498 983)	1 303 464
1982	(1 574 134)	1 368 813
1983	(1 632 510)	1 419 574
1984	(1 567 496)	1 363 040
1985	1 744 683	1 426 789
1986	1 951 404	1 638 495
1987	2 174 942	1 800 560
1988	2 001 645	1 690 483
1989	1 963 657	1 696 719
1990	1 923 433	1 671 565
1991	1 820 687	1 559 808
1992	2 082 528	1 759 824
1993	1 929 672	1 724 251
1994	1 996 542	
1995	2 318 053	
1996	1 903 555	

Note: * Data for 1971 - 84 were estimated by adding 15% (average from 1985 - 93) to the production of the 11 important gear types.

estimates were made for all types of fish (total production including pelagics), trash fish, pelagic fish and various demersal groupings. Table 5 gives a summary of the estimates derived in this study together with the results obtained by other studies for comparison purposes. Figs. 8 to 10 illustrate the trend of yield and effort for total (all fishes and invertebrates), trash fish, and demersal plus trash fish group in the Gulf of Thailand. The results indicate that the 1995 level of fishing effort is about twice the effort necessary to harvest MSY, and indicate that the demersal and other fishery resources are severely over-fished.

It is noted that the MSY and f_{MSY} estimates from other works are different from those given in this study. This is due to a number of reasons, namely: (1) the use of production data only for the 11 important types of fishing gear, thus excluding the smallscale fisheries production; (2) differences in the definition of demersal groups; (3) the use of a longer time series in this study compared to previous works; and (4) the use of research vessel as fishing effort standard in this study compared to commercial boat categories as standard. However, the trends noted by this and other studies, as well as conclusions that the resources are over-fished, are consistent.

Conclusion

Numerous studies have been conducted and regulations have been issued to help resolve the problem of resource over-exploitation and conflicts among fishers in the Gulf of Thailand. The 3rd National Seminar organized by the Department of Fisheries, Fisheries Society of Thailand and Fish Marketing Organization was held in April 1999 specifically to find out the needs of the fishers and how to improve management of the marine resources (Department of Fisheries (DOF) 1999). Trawl fishing was one of the main topics and recommendations were made to enforce a ban on push nets and enlarge the cod-end mesh size of shrimp and fish trawls (to 2.5 cm and 3.0 cm, respectively). The present study clearly shows that the demersal and other fishery resources in the Gulf are severely over-fished. Reduction of excess fishing capacity, particularly in the trawl fisheries, requires urgent management attention.

Table 5. Summary of MSY and f_{MSY} estimates for the Gulf of Thailand.

Group	MSY (t)	f_{MSY}* (x 10^6 hr)	Years	References
Total (All species groups and all gear; including smallscale fisheries)	2 159 049	64.25	1971 - 95	Fox Model (This study)
Trash fish (including small scale fisheries)	818 722	61.76	1971 - 95	Fox Model (This study)
Pelagic fish (including smallscale fisheries)	624 318	295.55	1971 - 95	Fox Model (This study)
Demersal fish (All gear, including small scale fisheries)	196 953	19.99	1971 - 95	Fox Model (This study)
Demersal fish (11 major gear**, excluding small scale fisheries)	136 300	10.1	1971 - 91	Demersal Fish Working Group (DFWG) 1995
Demersal group (Demersal fish and trashfish combined; including small scale fisheries)	970 905	35.65	1971 - 95	Fox Model (This study)
	944 632	23.3***	1973 - 97	Fox Model (Boonchuwong and Dechboon this vol.)
	1 036 428	23.9***	1973 - 97	Schaefer model FAO (2001)
Demersal group (Demersal fish, trash fish and invertebrates combined; excluding small scale fisheries)	884 202	28.6	1972 - 89	Fox Model Boonvanich (1993)

Note: * refers to standard research vessel units unless specified otherwise.
**** refers to otter board trawl, pair trawl, beam trawl, push net, three purse seines (Light luring, Thai, Green), anchovy purse seine, mackerel encircling gillnet, king mackerel gillnet, bamboo stake trap.**
***** refers to standard commercial boat units.**

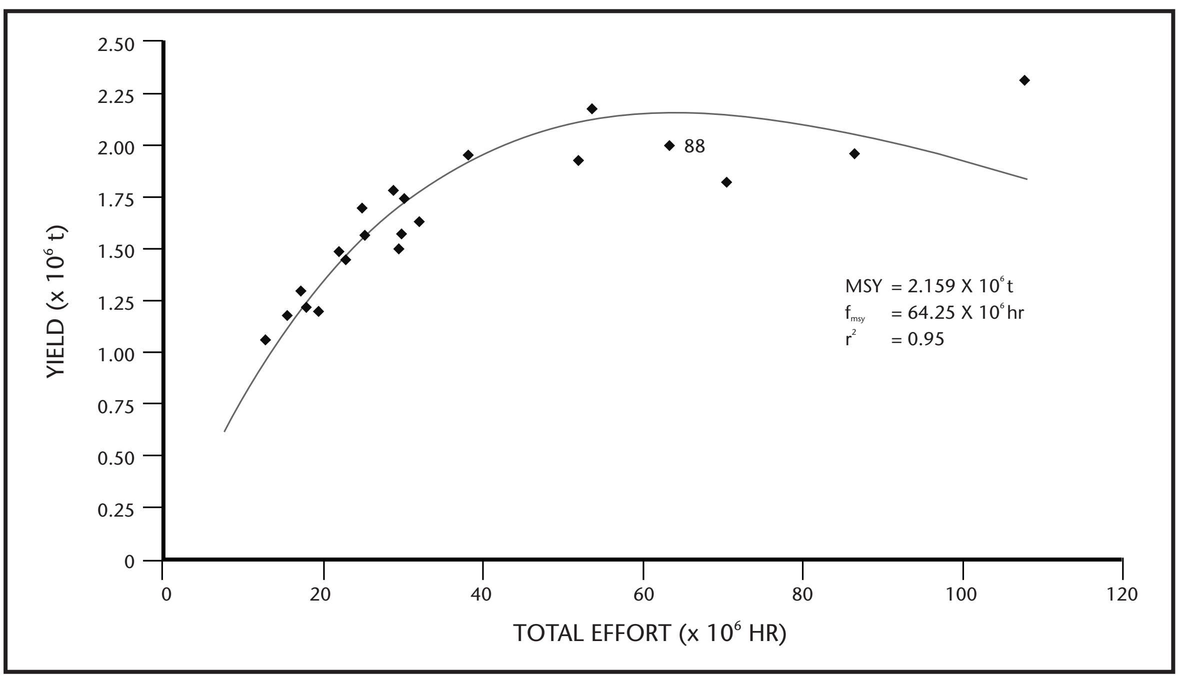

Fig. 8. Total yield and fishing effort in the Gulf of Thailand fisheries.

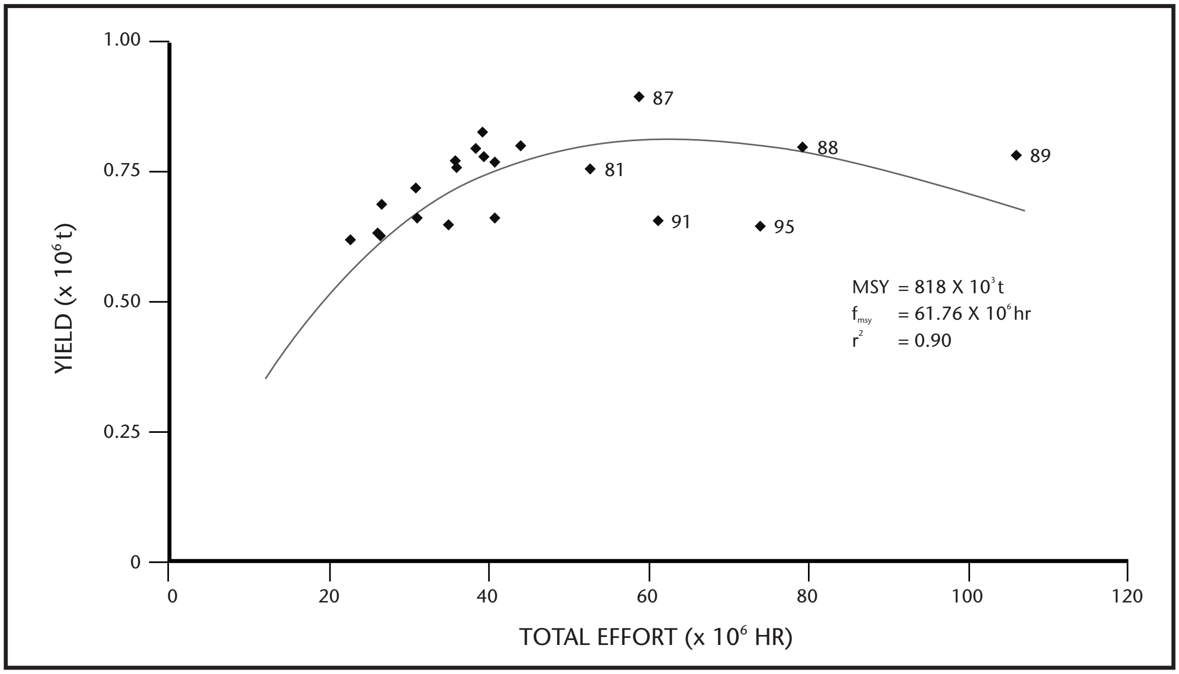

Fig. 9. Trash fish yield and effort in the Gulf of Thailand.

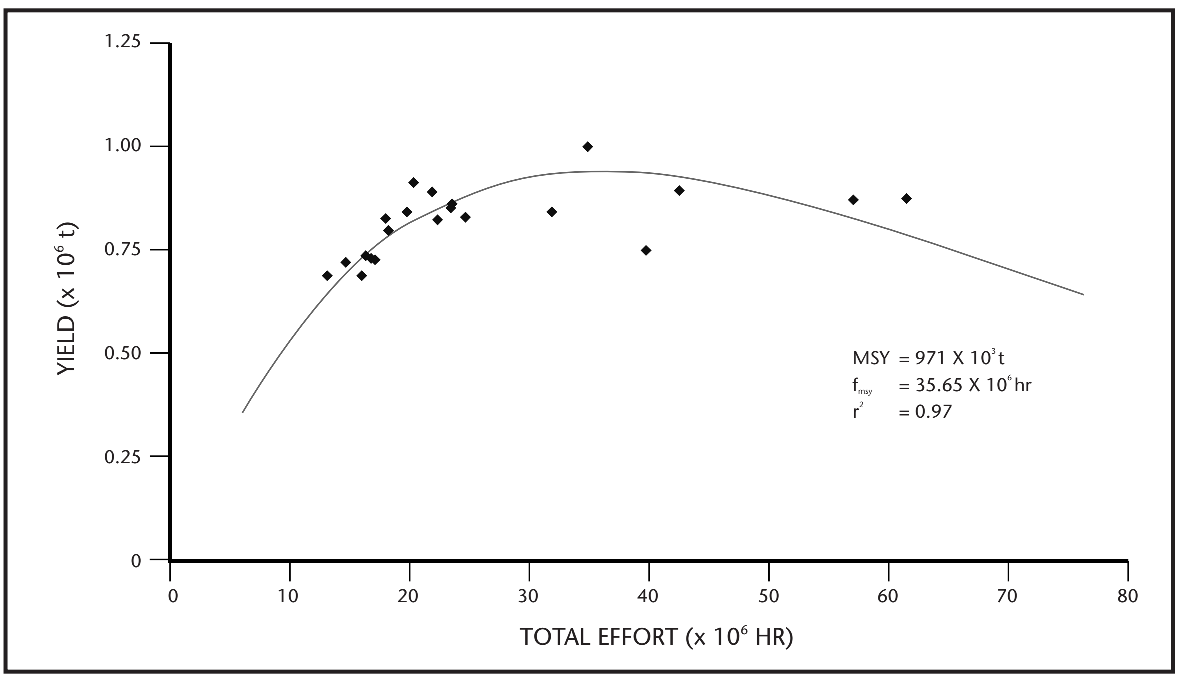

Fig. 10. Demersal fish plus trash fish yield and fishing effort in tbe Gulf of Thailand.

It is known that trash fish production figures taken from the statistical records emanate from both demersal and pelagic fishing gear. Their actual proportions, however, have not been established. This requires research attention in the effort to reduce capacity and improve management of the resources.

The excess demersal fishing effort is estimated to be about 50% of the number of registered boats in 1995. The excess number of fishing boats totals 2 506 units, which can be broken down into 1 024 medium otter board trawlers, 1 309 large otter board trawlers, 1 081 pair trawlers, and 167 push nets. The excess fishing effort should be eliminated from the fishery and new entrants effectively banned.

A ban on push nets would lower excess fishing effort by about 3%. A ban on both push nets and pair trawlers would result in the lowering of excess fishing effort by about 22%. The reduction of pair trawls and push nets should receive first priority as they operate near-shore and catch valuable small sized fish that only goes into fish meal factories. They also sometimes operate within 3 km from the coast which is illegal.

Other suggestions to improve management of the demersal resources include:

1. Studies to examine the appropriate cod-end mesh size for both fish and shrimp trawls, including examination of the economic loss (or gain) for affected fishers.

2. The areas within 3 km from the coast in the Gulf of Thailand and Andaman Sea are protected areas, to protect nursery grounds for fish eggs, larvae and juvenile fishes. The existing protected area should be enlarged to 3 nm and the enforcement of fishery laws must be strengthened.

3. Studies should be conducted into alternative fishery-related activities for those who will be affected by (proposed) management measures and regulations.

4. Financial assistance must be provided for fishers who want to change to non-destructive fishing gear/practices like fish gillnet, as well as for those who are willing to go into other forms of livelihood.

5. In places where communities are already organized, community-based fisheries co-management programs must be established so that the local fishers can take care of their own resources.

6. Awareness and education programs should be established and sustained over the long term.

7. Government service officers should exert every effort to make fishers appreciate the importance of responsible fishing.

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Preliminary Analysis of the Demersal Fish Assemblages in the Bangladesh waters of the Bay of Bengal

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Abstract

This paper presents the results of analyses of the demersal fish assemblages in Bangladesh waters of the Bay of Bengal. Catch data from three trawl survey cruises from January to February 1985 covering 135 stations were utilized for community structure analysis using TWINSPAN and DCA techniques. Both techniques separated the deepwater stations (> 90 m) from the shallow areas (< 90 m). The shallow regions had the most species and the dominant ones included *Nemipterus japonicus, Lepturacanthus savala, Pennahia* spp., *Pentaprion longimanus, Upeneus* spp., *Arius* spp., *Pomadasys maculatus, Thryssa brevirostris, Leiognathus bindus, Rastrelliger kanagurta, Leiognathus* spp. and *Upeneus sulphureus.* Dominant species in deeper regions were *Priacanthus hamrur, Priacanthus* spp., *Johinus* spp., *Saurida elongata* and *Nemipterus* spp.

Introduction

The fishery sector in Bangladesh plays a vital role in meeting the protein demand, employment opportunity and foreign exchange earnings of the country. Bangladesh declared its 200 nautical mile (nm) Exclusive Economic Zone (EEZ) in 1974, and as a result an area of more than 166 000 km^2 is now under the economic jurisdiction of the country for exploration, exploitation, conservation and management of its fisheries resources.

The continental shelf (between 0 to 200 m depth) of Bangladesh is relatively wide, covering about 66 400 km^2, of which 24 000 km^2 is less than 10 m depth (Chowdhury et al. 1979; Rashid 1983; Shahidullah 1986; White and Khan 1985). The average depth of the Bay of Bengal within Bangladesh territorial limits is about 10 m (Mahmood 1977). There are four major fishing grounds in the bay (i.e. South Patches, South of South Patches, Middling and Swatch of No Ground). The "South Patches" and "Southwest of South Patches" cover the most extensive area (i.e. 6 200 km^2) of the major fishing grounds (Shahidullah 1983).

Limited information about the intensity of fishing pressure and the status of exploitation of the coastal resources of Bangladesh is available (Chowdhury et al. 1979; Hussain et al. 1972; Khan et al. 1989; Khan et al. 1983; Mustafa 1994; Mustafa 1999; Mustafa and Khan 1993; Mustafa et al. 1987; Mustafa et al. 1996; Rashid 1983). However, several resource surveys have been carried out in Bangladesh waters and these reported that the fisheries resources were still abundant (Hussain et al. 1972; Khan et al. 1989; Khan et al. 1983; Lamboeuf 1987; Mustafa and Khan 1993; Mustafa et al. 1987;

Mustafa et al. 1996; Rashid 1983; White and Khan 1985).

A multi-species, multi-gear fishery exploits the traditional fishing grounds in Bangladesh waters. Among the capture fisheries activities trawl fishing is the most effective and profitable gear, with two types of trawl gear operating. These are the pair boom trawl for shrimp (in this paper referred to as "shrimp trawler") and stern trawl for fish (referred to as "fish trawler"). At present there are 41 shrimp trawlers and 15 fish trawlers operating in the trawlable grounds off Bangladesh. Research surveys (Lamboeuf 1987; Mustafa and Khan 1993; Mustafa et al. 1987) provide an indication of the catch composition of the shrimp and fish trawls, with 58 fish and shrimp taxa recorded (Table 1). A number of species dominated the fish trawl catch. As expected, catch composition from shrimp trawls consisted mainly of shrimp species.

The present study looked at the distribution pattern of demersal species assemblages based on the research trawl surveys. Specifically the study aimed to describe; (1) the composition of the species assemblages; (2) the delineation of assemblage boundaries or potential fishing zones; and (3) the relationship of the assemblages to environmental parameters.

Material and Methods

Trawl Surveys

The Bangladesh Marine Fisheries Survey Management and Development Project conducted an exploratory demersal fishing survey in the offshore waters of the Bay of Bengal between September 1984 and December 1986 (Table 2, see also Khan et al. this vol.). The survey area extended from the 10 m depth contour in the north and east to the 200 m depth contour in the south. A line drawn at 45°(from the southern tip of St. Martin Island was considered to approximate the Bangladesh/Burmese marine border in the southeast. The area in the west portion of the survey area extended to the Bangladesh/Indian marine border, but in practice no trawling was conducted west of the eastern edge of the "Swatch of No Ground" (Fig 1.).

Different sampling methodologies were applied by the different surveys in the waters within the Bangladesh EEZ. These included blocked designed surveys, line, random and stratified random surveys. The present study only utilized data obtained from surveys using stratified random sampling, where the position of the sampling stations was randomly selected within depth strata. Five depth strata were applied, 10 - 20 m, 20 - 50 m, 50 - 80 m, 80 - 100 m and 100 - 200 m. However, only four depth strata were sampled for most of the surveys, as the 100 - 200 m depth zone was composed of strips of deeper zones that were difficult to trawl. A total of 626 trawl stations were surveyed using the random stratified sampling technique (Table 3). The depth zone between 80 and 100 m had the highest number of stations occupied while the depth zone > 100 m comprised few sampling stations. Table 4 shows the distribution of trawl stations across sampling seasons and years.

The survey vessel (R.V. Anusandhani) is a 32.4 m multipurpose research vessel, principally designed for stern trawling, constructed in Japan in 1979 and used for resource surveys since 1983. The trawl net used was an Engel high-opening fish trawl with a cod-end mesh size of 32 mm. The distance between the wings was estimated to be 2.5m as measured by the net-sounder and the footrope was equipped with a 30 cm diameter rubber float. The technical specifications of the vessel and trawl gear are described in (Lamboeuf 1987).

All hauls were 30 minute duration, time started when the net reached the bottom and ended as soon as hauling commenced as determined by the net-sounder. If trawl fishing was disrupted within 15 minutes of dragging, the haul was considered invalid and the results were discarded. The procedures used in the surveys followed (Pauly 1983). The catch was sorted to species level whenever possible, and then taxa weighed to the nearest 0.25 kg. When a catch exceeded 500 kg, it was divided into two equal portions and one was sorted and the final results then doubled.

Table 1. Percentage catch composition of shrimp and fish trawls using R.V. Anusandhani (Mustafa 1999).

Taxa		Shrimp trawl	Fish trawl
Croakers, Jewfishes	Sciaenidae	16.36	11.58
Threadfin bream	Nemipteridae	14.07	10.16
Trash fish		12.62	6.27
Catfish	Aridae	8.00	12.21
Lizardfish	Synodontidae	5.75	4.37
Jacks, Scads	Carangidae	5.61	4.76
Goatfish	Mullidae	4.41	4.84
Shrimps		3.69	1.82
Rays		3.11	3.64
Bombay duck	Harpadon nehereus	2.67	1.47
Grunter	Terapontidae	2.16	2.44
Cuttlefish, squids	Cephalopodae	2.08	1.54
Scalts		1.92	0.00
Silver biddis	Gerreidae	1.88	1.71
Ponyfish	Leiognathidae	1.87	3.58
Sardines, Shads	Clupeidae	1.79	3.43
Crustaceans		1.25	0.42
Tongue sole	Cynoglossidae	1.09	0.19
Bullseyes	Priacanthidae	1.04	2.31
Sharks		1.01	0.84
Tripoid fishes	Triacanthidae	0.90	0.98
Hairtails	Trichiuridae	0.88	4.42
Indian halibuts	Psettodidae	0.69	0.15
Shark and Rays		0.60	0.32
Drift fishes	Centrolophidae	0.60	0.81
Pike conger	Muraenesocidae	0.54	0.21
Mackerels/Tuna	Scombridae	0.40	5.99

Taxa		Shrimp trawl	Fish trawl
Barracuda	Sphyrnidae	0.35	0.82
Pomfrets	Bramidae	0.31	1.95
Pufferfish	Tetraodontidae	0.30	0.25
Threadfins	Polynemidae	0.25	0.29
Sicklefish	Drepaenidae	0.23	0.21
Snappers	Lutjanidae	0.22	1.20
False trevallies	Lactariidae	0.20	0.68
Cardinal fish	Apogonidae	0.19	0.28
Lefteye flounders	Bothidae	0.13	0.08
Groupers	Serranidae	0.13	0.15
Cornet fish	Aulostomidae	0.11	0.14
Anchovies	Engraulidae	0.11	1.67
Spade fish	Ephippidae	0.10	0.10
Tenpounders	Elopidae	0.09	0.26
Mixed fish		0.08	0.18
Seabreams	Sparidae	0.06	0.14
Therapons	Teraponidae	0.05	0.29
Cobias	Rachycentridae	0.05	0.05
Sillaginidae		0.02	0.02
Wolf-herring	Chirocentridae	0.01	0.22
Tiggerfish	Diadontidae	0.01	0.02
Moonfish	Monodactylidae	0.00	0.40
Sharksuckers	Echeneidae	0.00	0.01
Scorpionfish	Scorpaenidae	0.00	0.05
Grey mullets	Mugilidae	0.00	0.01
Flying fish	Exocoetidae	0.00	0.04
Flatheads	Platycephalidae	0.00	0.01

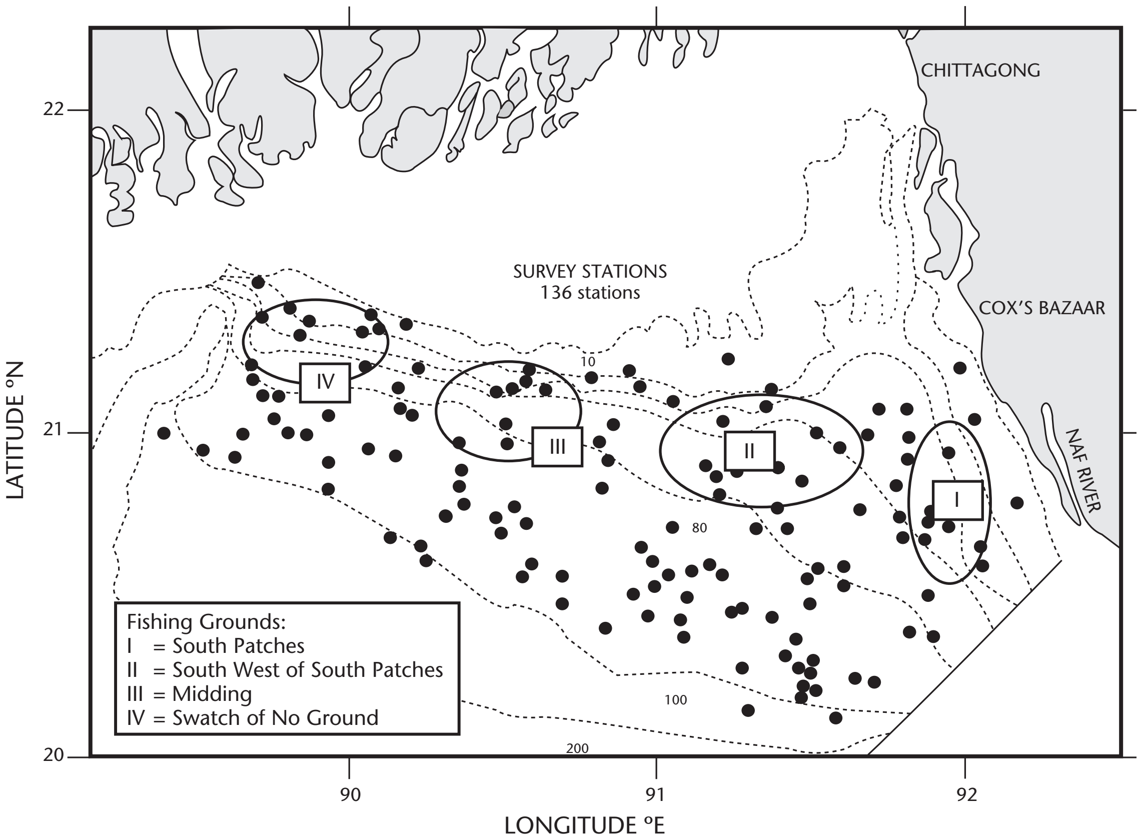

Fig. 1. Map of the survey areas within the Bangladesh EEZ, indicating the trawl fishing stations.

Data Analysis

Catch composition data were collected from the Marine Fisheries Survey Management Unit, Agrabad, Chittagong. Survey cruises were conducted by R.V. Anusandhani from January to February 1985 for this study. A total of 3 fish trawl cruises were utilized comprising 135 stations (Table 4) to examine the spatial distribution of the species assemblages using multivariate techniques.

Following the analysis of the demersal assemblages on the coast of several tropical areas, viz, the Pacific coast of Central America (Bianchi 1991), Angola (Bianchi 1992a) and Congo-Gabon (Bianchi 1992b), Detrended Correspondence Analysis (DCA) (Gauch 1982) and Two-way Indicator Species Analysis (TWIA) (Hill 1979) were used in this study.

TWIA (Hill 1979) is a classification technique implemented by the program TWINSPAN, while DCA (Hill and Gauch 1980) is an ordination method included in the program package of CANOCO. TWIA is a divisive clustering method that classifies sites and species and produces a sorted species-by-station table, showing hierarchical classification in a binary notation. Input data were catches from trawl surveys, i.e. stations vs. species matrices containing catches in terms of weight per standard haul of each species. Since expressing abundance on relatively crude scales retains much of the quantitative information, the original abundance values are re-scaled in TWINSPAN by defining "pseudospecies" cut levels (Hill, 1979). Five abundance cut levels were used to define pseudospecies corresponding to classes with lower limits set at 0, 2, 5, 10 and 20 kg. As recommended (Hill 1979), the class limits were set to suit the observed range of the catches without over-weighting the effect of dominance. The catch of individual species in surveys varied between 0 and 999 kg.

Table 2. Fish trawl cruises from September 1984 to December 1986.

Cruise No.	Data/Duration	Valid Hauls
1	15 - 25 September 1984	42
2	03 - 13 October 1984	45
3	20 - 30 October 1984	43
4	09 - 19 November 1984	44
5	27 November - 05 December 1984	40
6	13 - 20 December 1984	41
8*	06 - 16 January 1985	46
9*	31 January - 11 February 1985	49
10*	17 - 24 February 1985	40
12	19 - 24 May 1985	13
13	12 - 17 July 1985	13
14	21 - 24 August 1985	1
15	28 September - 06 October 1985	15
16	22 - 31 December 1985	35
20	25 January - 04 February 1986	41
22	02 - 11 March 1986	31
24	02 - 11 April 1986	22
26	12 - 21 May 1986	25
27	1- 4 June 1986	7
30	02 - 04 December & 15 - 21 December 1986	26

Note: * cruises covered in the analysis for this study

Table 3. The distribution of trawl stations by depth, from the trawl surveys conducted by RV Anusandhani (1984 - 86), Cruise No. refers to Table 2.

Cruise No.	Number of stations by depth zone (m)				
	10 - 20	20 - 50	50 - 80	80 -100	>100
1	10	10	7	15	0
2	2	7	13	21	2
3	6	9	9	17	2
4	3	6	10	24	1
5	6	7	8	16	3
6	2	9	11	16	3
8	7	8	8	19	4
9	6	10	10	19	4
10	0	8	3	29	0
12	3	4	3	3	0
13	4	8	1	0	0
14	0	1	0	0	0
15	0	6	7	2	0
16	4	8	5	11	7
20	2	10	9	16	4
22	3	14	7	6	1
24	0	4	5	7	6
26	2	14	10	6	0
27	0	4	3	0	0
30	0	5	12	9	0
TOTAL	60	152	141	236	37

Table 4. Depth distributions of trawl stations of the surveys conducted by the R.V. Anusandhani in 1985.

Cruise No.	Data/Duration	Valid stations by depth zone (M)					Total
		10 - 20	20 - 50	50 - 80	80 - 100	> 100	
8	06 - 16 January	7	8	8	19	4	46
9	31 January - 11 February	6	10	10	19	4	49
10	17 - 24 February	0	8	3	29	0	40
	TOTAL	13	26	21	67	8	135

DCA is an ordination method based on the abundance values of the species. The program CANOCO was used to run DCA, the input was catches in terms of weight, and detrending by second order polynomials was applied. All species were given equal weight in the analysis. The method does not assume linear relationships between species abundance and environmental variables and thus is considered particularly useful in ecological studies (Ter Braak 1990). Both TWINSPAN and DCA are based on correspondence analysis hence it is possible to compare the results directly. (Bianchi 1991) has discussed the detailed methods and their suitability to this type of study.

The DCA analysis enables the relationship between the patterns observed and environmental variables to be examined. In the current analysis the Spearman rank correlations between the station scores on the DCA Axes and depth were examined.

Results and Discussion

The classification results from TWINSPAN show the clusters of stations among the 135 fish trawl stations from the survey during 1985 (Fig 1). The first division separated the major shallow water stations (A) from the deep area stations (B). The geographical distribution of the stations between the two groups is shown in Fig. 2.

The DCA results in which data for 135 stations were included, showed similar patterns to those revealed by TWINSPAN output, but DCA provides information on variation in several dimensions. The eigenvalues of the four axis in DCA were 0.859, 0.727, 0.702 and 0.539 respectively. Eigenvalues are measures of importance of the corresponding axis, and typically values above 0.5 reflect good separation of the stations along that axis (Jongman et al. 1987). Thus all four axes in this

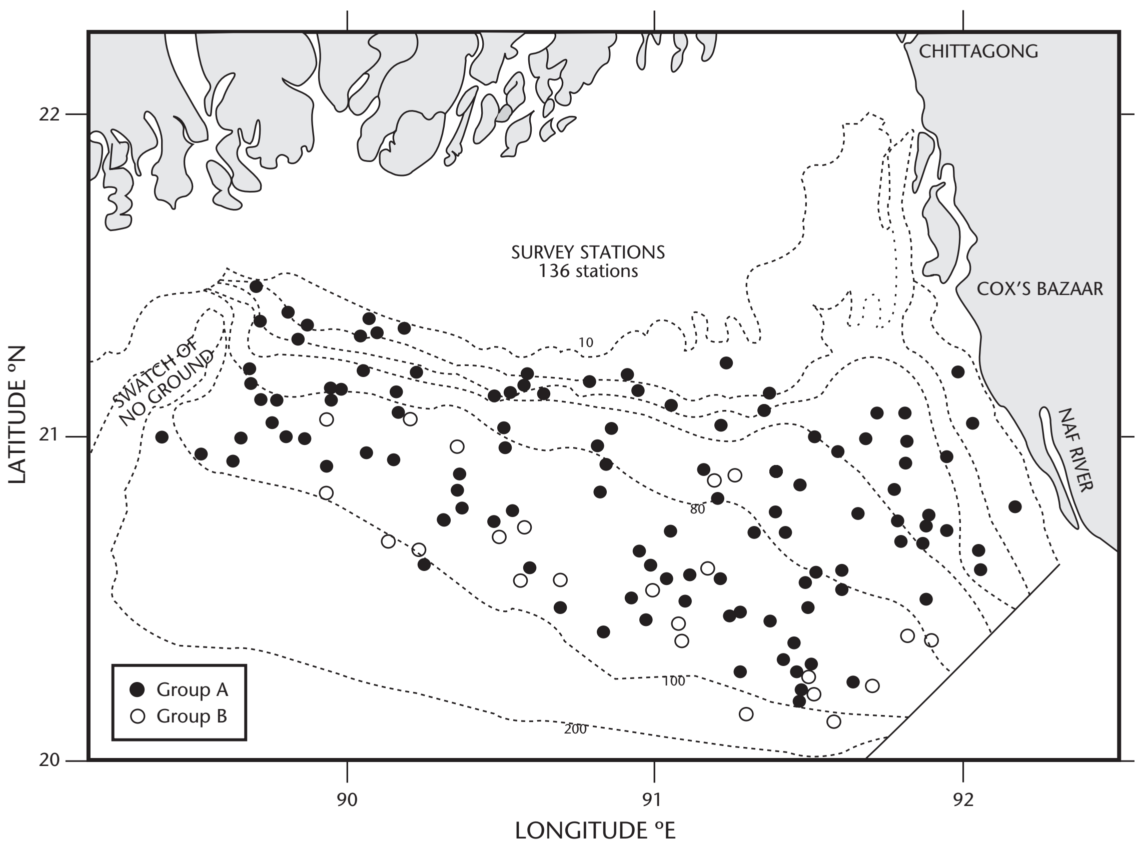

Fig. 2. Spatial distribution of trawl stations based on the classification analysis using TWINSPAN .

analysis were likely to reveal ecologically significant information. The DCA plot in Fig 3. shows the distribution of TWINSPAN groups stations according to their scores on Axis-1 and Axis-2. Axis-1 represented essentially a depth gradient (Spearman rank order correlation of station scores on Axis-1 and depth). For DCA plot station clusters were grouped as A and B, based on the TWINSPAN analysis. Group A stations are associated with shallow water areas less than 90 m in depth, while Group B stations belong to deeper areas more than 90 m in depth. However other environmental factors, e.g. salinity may also affect spatial distribution patterns, this may explain the overlap of station distribution between 80 to 100 m depth (see Fig. 2).

The DCA plot for 74 species is shown in Fig. 3. Species forming clusters were grouped as A and B. In the DCA plot, major species within group A include *Nemipterus japonicus*, *Lepturacanthus savala*, *Pennahia* spp., *Pentaprion longimanus*, *Upeneus* spp., *Arius* spp., *Pomadasys maculatus*, *Triacathus brevirostris*, *Leiognathus bindus*, *Rastrelliger kanagurta*, *Leiognathus spp.* and *Upeneus sulphureus*. Species within group B were *Penaedae*, *Priacanthus hamrus*, *Priacanthus* spp., *Johinus* spp., *Saurida elongata* and *Nemipterus* spp. Species distributions within groups (A and B) and their percentage composition are presented in Table 5. Further analysis of the data needs to be undertaken to determine the environment factors that influence these species assemblages.

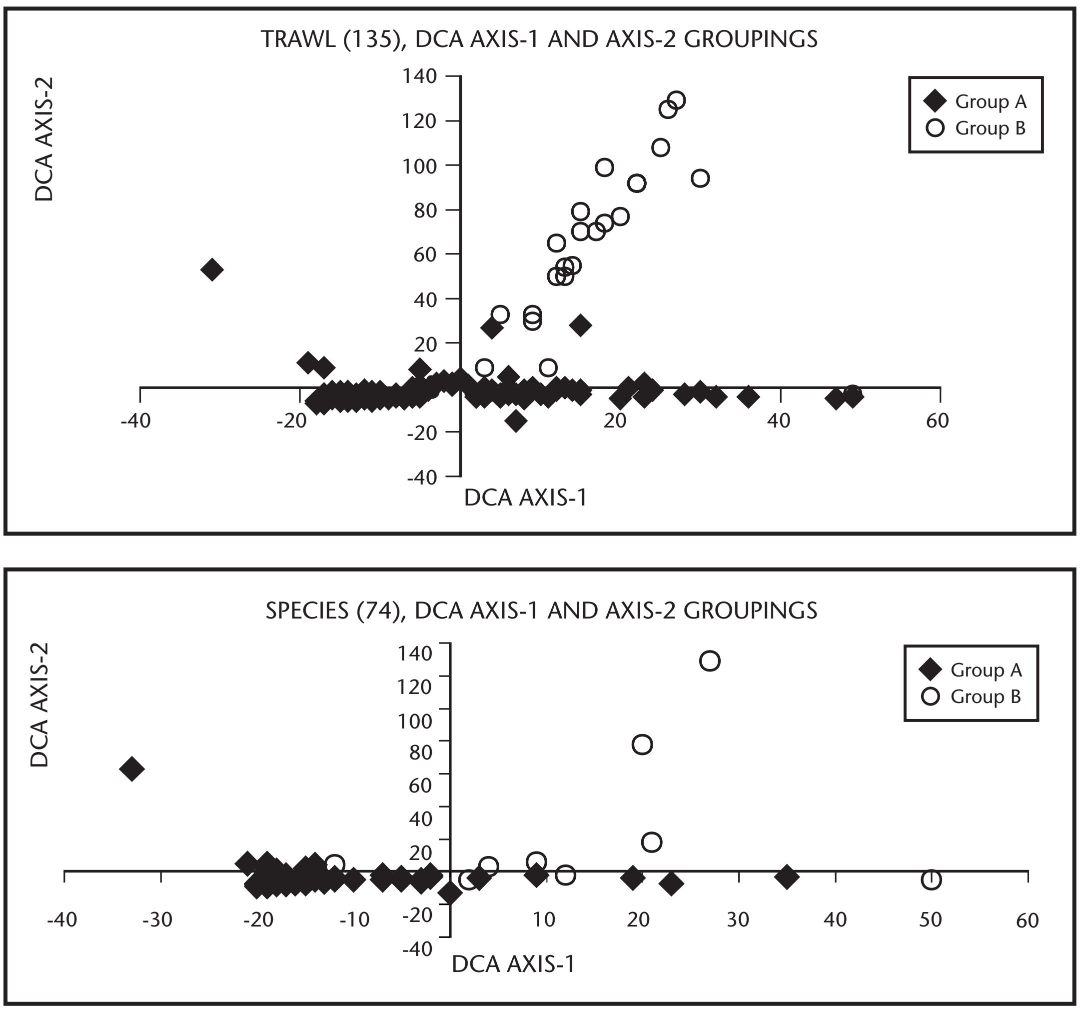

Fig. 3. Ordination plots generated from DCA of 135 stations and 74 species from three survey cruises, the Group A and B are from the TWINSPAN analysis (see fig. 2.).

Table 5. Relative abundance (%) of the dominant taxa within the groups identified by the TWINSPAN and DCA ordination of 135 trawl stations in the Bay of Bengal.

Group A				Group B			
Group A1		Group A2		Group B1		Group B2	
Taxa	%	Taxa	%	Taxa	%	Taxa	%
Nemipterus japonicus	5.79	*Arius* spp.	12.07	*Priacanthus hamrur*	1.50	*Nemipterus* spp.	19.58
Trash fish	4.76	*Pomadasys maculatus*	3.88	Penaedae	1.26	*Johnious* spp.	4.34
Lepturacanthus savala	2.70	*Rastrelliger kanagurta*	2.61	Other crustaceans	0.89	*Priacanthus* spp.	2.69
Rays	0.85	*Triacathidus brevirostris*	2.54	*Decapterus kurroides*	0.25	*Saurida elongata*	1.59
Sciaenidae	0.79	*Upeneus sulphureus*	2.38			*Saurida undusquamis*	0.93
Apogon spp.	0.29	*Pennahia* spp.	2.08			*Parakuhlia macrophtalmus*	0.38
Decapterus spp.	0.24	*Upeneus* spp.	2.08				
Crabs	0.21	*Pentaprion longimanus*	1.97				
Cynoglossus spp.	0.19	*Leiognathus* spp.	1.51				
Argyrops spinifer	0.16	*Setipinna taty*	0.99				
Arioma indica	0.10	*Decapterus maruadsi*	0.98				
Decapterus macrosoma	0.07	*Sphyraena forsteri*	0.88				
Muraenesox spp.	0.07	*Parastromateus niger*	0.87				
Rastelliger spp.	0.04	Cuttlefish	0.85				
		Pampus argenteus	0.79				
		Metapeneaus monoceros	0.78				
		Pomadasys hasta	0.75				
		Tetradontidae	0.73				
		Megalaspis cordyla	0.69				
		Ilisha megaloptera	0.61				
		Terapon jarbua	0.55				
		Protonibea spp.	0.43				
		Atropus atropus	0.43				
		Lutjanus johni	0.41				
		Triacanthus spp.	0.41				

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Demersal Fish Assemblages of the Southwest Coast of India

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Abstract

Demersal surveys from the southwest coast of India were analyzed to determine the general pattern of distribution of demersal species assemblages in the area. Seasonality is pronounced, indicating three major periods, pre-monsoon, monsoon and post-monsoon. Each of the periods is characterized by different oceanographic circulation patterns that mainly determine the pattern of distribution of species assemblages. Spatial analysis confirmed that the Wadge Bank has the highest potential for producing good quality fish. Region-wise analysis of data indicated that maximum effort and highest landings are from the known grounds along the southwest coast, although certain northern areas were also found to be fairly productive.

Introduction

Marine fisheries production in India increased from 0.5 to 2.7 million t between 1950 and 1997. Landings along the Indian coast from 1970 to 1997 provide insights on the distribution and abundance of the major fish stocks. The dominant species groups of marine landings throughout India during this period were: oil sardine, penaeid prawns, croakers, Bombay duck, carangids, lesser sardines, ribbonfishes and non-penaeid prawns (Table 1). The Indian coast is subdivided into six major coastal zones, namely northwest (NWCZ), southwest (SWCZ), southeast (SECZ), northeast (NECZ), Lakshadweep Island (LAKCZ) and Andaman and Nicobar Islands (ANCZ) (Fig. 1).

Table 1. Relative abundance (%) by species group in landings along the Indian coast (1970 - 97).

Taxa	Common Name	NWCZ	SWCZ	SECZ	NECZ	LAKCZ	ANCZ	India
Setipinna spp.	Anchovies	0	0	0.1	2.2	0	0	0.1
Bregmaceros mcclellandii	Unicorn cod	0.2	0	0	0	0	0	0.1
Lobsters	–	0.2	0.02	0.1	0	0	0.02	0.1
Exocoetidae	Flying fishes	0	0.01	0.7	0	0.6	0	0.2
Sillaginidae	Mullets	0.4	0.04	0.3	0.08	0	4.4	0.2

Table 1. Relative abundance (%) by species group in landings along the Indian coast (1970 - 97) (continued).

Taxa	Common Name	NWCZ	SWCZ	SECZ	NECZ	LAKCZ	ANCZ	India
Eels	–	1	0.01	0.2	0.5	0	0	0.4
Sphyraenidae	Barracudas	0.1	0.4	0.8	0.05	0.3	3.5	0.4
Polynemidae	Threadfins	0.4	0.03	0.6	0.8	0	0.8	0.5
Lactarius lactarius	Whitefish	1	0.5	0.4	0.08	0	0	0.6
Mullidae	Goatfish	0.3	1.1	1.3	0.3	0.9	0	0.8
Synodontidae	Lizard fish	0.6	1.4	1	0.2	0	0	1
Crabs	–	0.7	0.7	2.8	0.5	0	0.5	1.2
Dasyatidae	Rays	0.9	0.5	3	1.4	0.6	0.6	1.3
Hilsa spp.	Shad	1.1	0.05	1.3	13.8	0	0.2	1.4
Thryssa spp.	Thryssa	0.9	1.1	2.4	0.8	0	4.5	1.4
Scombridae	Tunas	0.8	2.1	1	0.2	69.9	3.2	1.5
Platycephalidae	Flatfishes	1.2	2.8	0.7	0.4	0	0	1.6
Coilia spp.	Grenadier anchovies	4.4	0.01	0.4	3.2	0	0	1.7
Scombridae	Seerfishes	1.8	1.4	2.4	2.8	1.4	3	1.8
Sharks	–	2.9	0.9	2.5	2.8	4.5	2.6	2.1
Cephalopods	–	3	2.5	1.4	0.2	0.4	0.3	2.2
Other perches	–	1.1	2.1	4.2	1.1	3.8	8.6	2.3
Bramidae	Pomfrets	3.9	0.6	1.3	8.1	0	1.3	2.3
Ariidae	Catfishes	3.4	2.3	2.3	8.1	0	2.1	3
Stomatopods	–	2.4	5.7	0.4	0.6	0	0	3
Galaxiidae	Whitebaits	0.2	5.1	4.8	0.9	0	5.5	3.2
Nemipteridae	Threadfin breams	2.1	5.1	2.4	0.3	0	0	3.2
Gerridae	Silverbellies	0.2	1.6	10.4	1	0.4	6.2	3.2
Trichiuridae	Ribbonfishes	6.3	2.6	4.3	4.1	0	1.6	4.3
Non-penaeid prawns	–	12	0.07	0.7	2.6	0	0	4.3
Clupeidae	Lesser sardines	0.4	4.1	11.3	3.7	0	12.5	4.6
Carangidae	Trevally	1.9	7.9	4.8	1.7	1.4	6	4.8
Harpadon nehereus	Bombayduck	16.2	0	0.2	7.2	0	0	5.8
Sciaenidae	Croakers	10.7	2.3	5.1	15.5	0	1.1	6.4
Scombridae	Mackerel	1.6	13.7	4.7	0.8	0	3	6.8
Penaeidae	Penaeid prawns	9.3	8.7	5.9	4.5	0	1.1	8
Sardinella longiceps	Oil sardine	0.3	22	4.1	0.07	0	0	9.2

Note: NWCZ = northwest, SWCZ = southwest, SECZ = southeast, NECZ = northeast, LAKCZ = Lakshadweep Island and ANCZ = Andaman and Nicobar Islands.

The NWCZ extends from 16° N to 24° N comprising the maritime states of Gujarat and Maharashtra and the union territory of Daman and Diu. The length of the coastline is about 2 350 km and the area of the continental shelf is around 27 600 km^2. The annual average landings from 1970 to 1997 were 563 240 t, which contributed 33% of the mean total landing in India during the period. The NWCZ is characterized by the abundance of Bombay-duck, non-penaeid prawns and croakers, which together constituted 39% of landings in the area (Table 1). In addition to these species groups, eels, *Coilia* spp., ribbonfishes, whitefish, mullets, unicorn cod, penaeid prawns, spiny lobsters and cephalopods also contributed significantly to the landings in the NWCZ.

The SWCZ extends from 8° N to 16° N, comprising the maritime states of Goa, Karnataka and Kerala. The length of the coastline is about 990 km and the area of the continental shelf is roughly 75 400 km^2. The annual average landing from 1970 to 1997 was 629 780 t, which contributed 37% to the overall mean landing in India during the period. The SWCZ is characterized by the abundance of oil sardine, Indian mackerel and penaeid prawns, which together constituted 45% of the total landings in this area (Table 1). In addition to these species groups, the whitebaits, lizardfishes, threadfin breams, carangids, flatfishes and stomatopods also contributed fairly high quantities to landings in the SWCZ.

The SECZ extends from 8° N to 19° N, comprising the maritime states of Tamil Nadu and Andhra Pradesh besides the union territory of Pondicherry. The length of the coast is about 2 020 km and the area of the continental shelf is about 73 500 km^2. The annual average landing from 1970 to 1997 was 408 930 t, which contributed 24% to the total mean landing in India during this period. The SECZ is characterized by the abundance of lesser sardines, silverbellies and penaeid prawns, which together contributed 27% to landings in this zone (Table 1). In addition to these species groups, rays, *Thryssa* spp., flyingfishes, major perches, goatfishes and crabs contributed significantly to the landings.

The NECZ extends from 19° N to 22° N, comprising the maritime states of Orissa and West Bengal. The length of the coast is about 640 km. and the area of the continental shelf is about 40 600 km^2. The annual average landing from 1970 to 1997 was 83 650 t, which contributed 5% of the overall mean landings in India. The NECZ is characterized by the abundance of croakers, *Hilsa* spp. and catfishes, which together constituted 38% of the landings in this zone (Table 1). In addition to these groups, sharks, threadfins, pomfrets and seerfishes contributed a fairly high percentage to the landings.

The LAKCZ in the Arabian Sea extends from 8.5° N to 12° N and has a continental shelf area of 4 340 km^2. The annual average landing from 1970 to 1997 was 4 400 t, which contributed 0.3% to the overall mean landings in India. This coastal zone is characterized by the abundance of various species of tuna (70% of the landings). In addition to tunas, sharks and major perches contributed significantly to landings in this zone.

The A&N coastal zone in the Bay of Bengal extends from 7.5° N to 15° N and has a continental shelf area of 35 000 km^2. The annual average landing from 1970 to 1997 was 9 900 t, which contributed 0.6% to the total mean landing in India. This coastal zone is characterized by the abundance of lesser sardines, perches and silverbellies, which together contributed 28% to the overall mean landing in this zone.

Analyses of demersal species assemblages were focused within the continental shelf of the SWCZ . Specifically, the study aims to investigate the: (1) composition of species assemblages, (2) delineation of assemblage boundaries, and (3) environmental factors which explain the assemblage pattern.

Materials and Methods

Of the six coastal zones off the Indian subcontinent, the study focused on the continental shelf in the SWCZ. Trawl data were collected by a stern trawler (28.8 m LOA) using a bottom trawl with otter doors. Fish biology for the major species was done in each survey. Environmental data were collected in the zone using the facilities of a modern fisheries oceanographic research vessel.

The location of sampling stations between Cape Comorin in the south (7°N) and Ratnagiri in the north (17°N) is given in Fig 2. Each 1° square was subdivided into 36 equal squares of about 10 nm x 10 nm. Average trawl effort per 10 minute fishing squares was calculated irrespective of the number of hauls. The survey was conducted in trawlable

areas. Station gaps identified could be due to areas not suitable for trawling either because of rocky substratum or shallow depths.

The surveys were done in a 12-month period divided into three major predetermined seasons viz. pre-monsoon (February-May), monsoon (June-September) and post-monsoon (October-January). A total of 161 fishing squares were included in this study. The station numbers assigned for each fishing square during the three monsoon periods are given in Table 2. Average catch of the total number of hauls per fishing square was calculated. Two 28.8 m - LOA stern trawlers, M/V M.F.V. Samudrika, owned by the Integrated Fisheries Project, Cochin, Ministry of Agriculture, Government of India, were used in the surveys from April 1994 to March 1996.

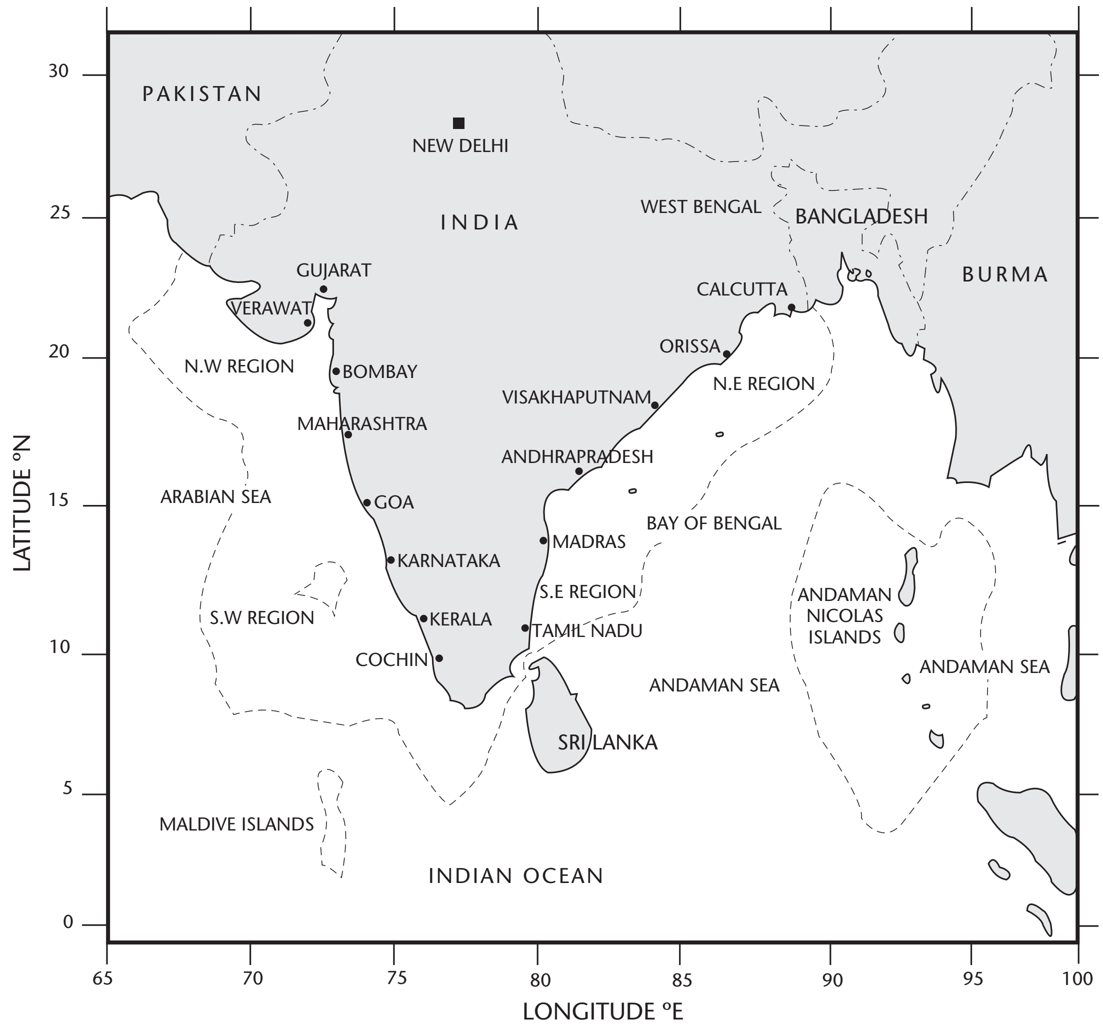

Fig. 1. Map illustrating the geographic delineation of the coastal waters of India.

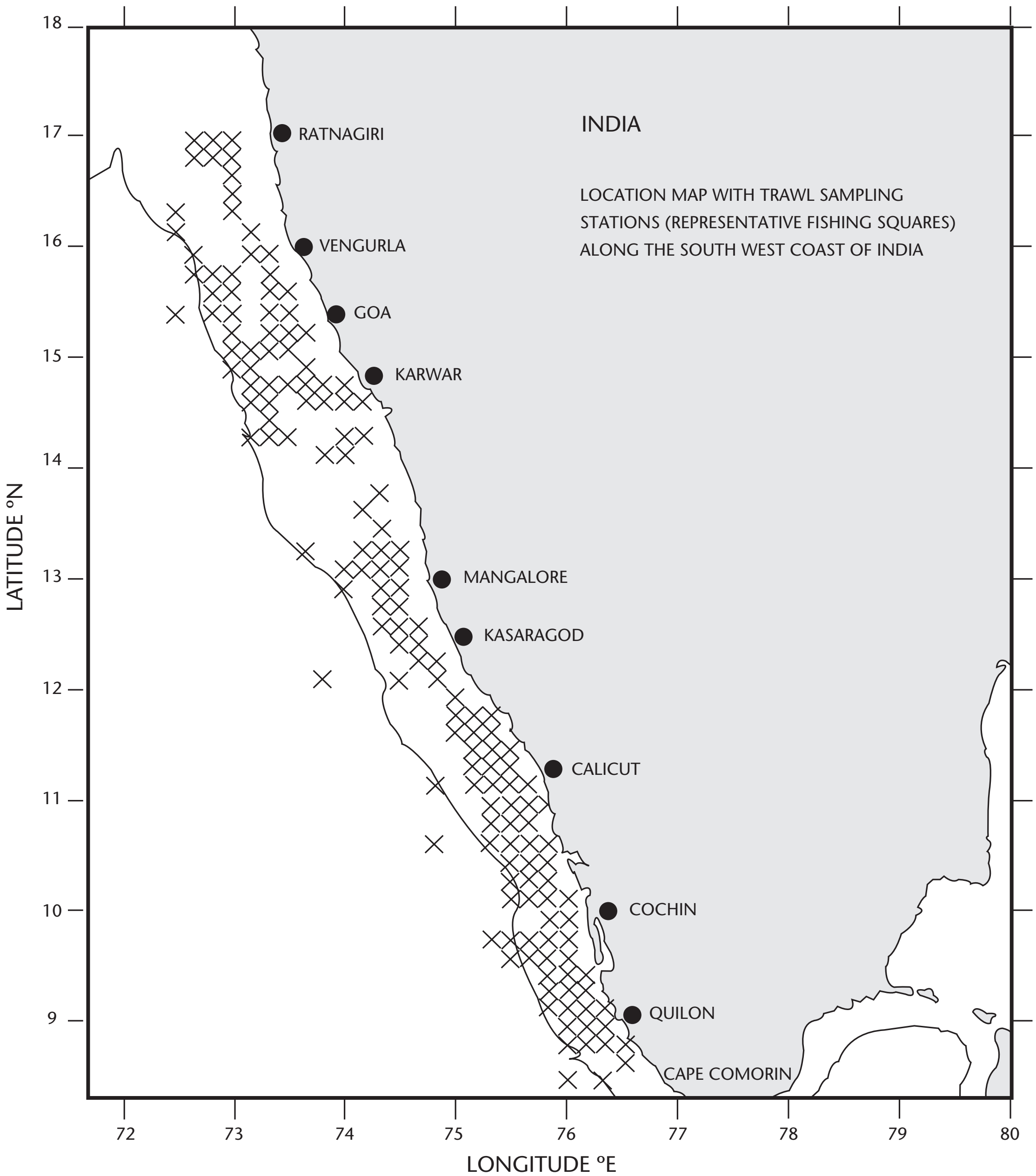

Fig. 2. Sampling squares along the Southwest coast of India (between Cape Comorin and Ratnagiri) used in this study.

Table 2. List of fishing squares and the corresponding station numbers used in the analysis.

Pre-monsoon (February - May)		Monsoon (June - September)		Post-Monsoon (October - January)	
Fishing square	**Station**	**Fishing square**	**Station**	**Fishing square**	**Station**
7 - 76/6E	24	7 - 77/5B	14	7 - 77/1A	38
7 - 77/4C	25	7 - 77/5D	15	7 - 77/4D	39
7 - 77/5A	26	7 - 77/5E	16	7 - 77/5A	40
7 - 77/5B	27	7 - 77/6A	17	7 - 77/5B	41
7 - 77/5C	28	7 - 77/6C	18	7 - 77/5C	42
7 - 77/5D	29	7 - 77/6D	19	7 - 77/5D	43
7 - 77/5E	30	7 - 77/6E	20	7 - 77/5E	44
7 - 77/5F	31	7 - 77/6F	21	7 - 77/5F	45
7 - 77/6B	32	7 - 78/6F	22	7 - 77/6B	46
7 - 77/6C	33	8 - 76/5C	23	7 - 77/6C	47
7 - 77/6D	34	8 - 76/6A	24	7 - 77/6D	48
7 - 77/6E	35	8 - 76/6B	25	7 - 77/6E	49
7 - 78/5F	36	8 - 76/6C	26	8 - 76/6C	50
8 - 75/6F	37	8 - 77/1A	27	8 - 76/6F	51
8 - 76/5A	38	8 - 77/1E	28	8 - 77/1B	52
8 - 77/1B	39	8 - 77/1F	29	8 - 77/1E	53
8 - 77/2B	40	8 - 77/6F	30	9 - 75/2F	54
9 - 75/4F	41	8 - 78/1A	31	9 - 75/5A	55
9 - 75/5A	42	9 - 75/3F	32	9 - 75/5F	56
9 - 75/5F	43	9 - 75/4E	33	9 - 75/6A	57
9 - 75/6F	44	9 - 75/4F	34	9 - 76/1B	58
9 - 76/3A	45	9 - 75/5E	35	9 - 76/2B	59
9 - 76/4A	46	9 - 75/5F	36	9 - 76/3A	60
9 - 76/5A	47	9 - 76/1A	37	9 - 76/3B	61
9 - 76/6A	48	9 - 76/1B	38	9 - 76/4A	62
9 - 76/6F	49	9 - 76/2A	39	9 - 76/5A	63
10 - 75/1E	1	9 - 76/2B	40	9 - 76/6A	64
10 - 75/1F	2	9 - 76/2F	41	9 - 76/6F	65
10 - 75/2F	3	9 - 76/3A	42	10 - 75/2F	1
10 - 75/6D	4	9 - 76/3F	43	10 - 75/6D	2
10 - 75/6F	5	9 - 76/4A	44	11 - 75/2C	3
10 - 76/1A	6	9 - 76/5A	45	11 - 75/2D	4
11 - 75/3C	7	9 - 76/6B	46	11 - 75/5B	5

Table 2. List of fishing squares and the corresponding station numbers used in the analysis. (continued)

Pre-monsoon (February - May)		Monsoon (June - September)		Post-Monsoon (October - January)	
Fishing square	**Station**	**Fishing square**	**Station**	**Fishing square**	**Station**
11 - 75/3D	8	10 - 75/1F	1	11 - 75/6A	6
11 - 75/4B	9	10 - 75/2E	2	12 - 74/1F	7
11 - 75/6A	10	10 - 75/3D	3	12 - 74/2E	8
12 - 74/2D	11	10 - 75/3E	4	12 - 74/2F	9
12 - 74/2E	12	10 - 75/3F	5	12 - 74/5E	10
12 - 74/2F	13	10 - 75/4D	6	12 - 74/6D	11
12 - 74/4E	14	10 - 75/4E	7	13 - 74/1D	12
12 - 74/6A	15	10 - 75/5D	8	13 - 74/2D	13
13 - 74/2B	16	10 - 75/6D	9	13 - 74/4C	14
13 - 74/2C	17	10 - 75/6E	10	14 - 73/2C	15
14 - 73/3C	18	11 - 75/1B	11	14 - 73/2D	16
14 - 73/4C	19	11 - 75/1C	12	14 - 73/3C	17
14 - 73/5B	20	13 - 73/3F	13	14 - 73/4A	18
15 - 72/3F	21			14 - 73/4C	19
15 - 72/4F	22			14 - 73/4E	20
15 - 72/5F	23			14 - 73/4F	21
				14 - 73/5C	22
				14 - 73/5E	23
				14 - 73/5F	24
				14 - 73/6B	25
				14 - 73/6E	26
				14 - 74/1B	27
				14 - 74/2A	28
				14 - 74/5A	29
				15 - 73/1E	30
				15 - 73/2E	31
				15 - 73/3D	32
				15 - 73/4C	33
				15 - 73/4D	34
				15 - 73/5C	35
				15 - 73/6B	36
				15 - 73/6D	37

Cluster analysis was carried out using **T**wo-**W**ay **IN**dicator Species ANalysis **(TWINSPAN)** for classification of stations based on the relative abundance of species. **D**etrended **C**orrespondence **A**nalysis **(DCA)** using the CANOCO program was used to verify the results of TWINSPAN. Both analyses were based on correspondence analysis, thus it is possible to directly compare their results. The data collected during the pre-monsoon, monsoon and post-monsoon seasons were analyzed separately to reduce variability due to seasonality of the catch.

Results

During the two-year period (1994 - 96) the trawler *M.F.V. Samudrika* made 22 voyages in 414 days on the southwest coast. A total of 749 hauls were made in 1 533.5 hours of trawling and 206.21 t of catch were landed at an average catch rate of 134.44 kg•hr^{-1}. In the first year of operation (1994 - 95) the vessel made 10 voyages in 191 days and hauled up to 114.56 t in 766.10 hours at an average catch rate of 188.69 kg•hr^{-1}. In the following year (1995 - 96), the vessel was at sea for 223 days on 12 voyages. The vessel spent about 767 hours fishing and landed 91.65 t at an average catch rate of 119.43 kg•hr^{-1}.

Catch Composition

Total catch landings were segregated into 22 major groups and their relative abundance calculated. Threadfin breams dominated the catch of 22.5% of the overall landings. This species group is composed of *Nemipterus mesoprion, N. japonicus* and *N. delagoae.* Of these, *N. delagoae* was caught mainly in the Wadge Bank, whereas the other two were found mixed with the bulk of the SWCZ landings. The period June to August was the peak time for this species group, though stray catches were observed from November to March from the 40 - 81 m depth zone.

Next in abundance to the threadfin breams were *Decapterus* spp. (round scads) forming 15.7% of landings, with highest abundance in the months of May and September-October. Generally three species were observed, namely, *Decapterus russelli, D. macrosoma* and *D. kurroides.* As they are usually shoaling species, more than 5 to 6 t were encountered in a single haul along the southwest coast.

Bulls eye or *Priacanthus* spp., an emerging unconventional resource, formed 7.7% of the overall landings. Commonly observed only in the months of March-April and August, these species were observed almost throughout the year during this survey. Bulls eye in demersal landings was previously quite rare. They were also abundant towards the north of Calicut in April.

Perches comprised about 12.3% of the overall landings. Serranids, lutjanids and lethrinids landings from the Wadge Bank area were grouped under three species groups; rock-cods, snappers and breams respectively.

The percentage of cephalopods was about 5.2% of the total landings, including squids and cuttlefishes. The most commonly found species in the catch were *Loligo duvauceli* (squid) and *Sepia pharaonis* and *S. aculeata* (cuttlefish). Their occurrence at a commercially valuable size was recorded during the months of August-September.

Elasmobranchs, shark, rays and skates, formed the next abundant group (6.7%). Among these, the abundance of rays was higher (4%) than sharks and skates. Though these species were caught almost throughout the year, their maximum abundance was observed in the months of August and May.

A sizeable percentage (5.2%) was contributed by the ribbonfishes, which were most abundant during the monsoon periods (i.e. June to September). Two commonly observed species in the catch were *Trichiurus lepturus* and *Lepturacanthus savala.* The percentage occurrence of Indian mackerel was about 5.1% of the overall landings during this period. Though Indian mackerel occur almost throughout the year, the most abundant months were in April-May and September-November within the 40 m-depth zone. Barracudas formed about 1.5% of the total catch and were not obtained in the months of June-July. Their most abundant period was August to November and February to May. The commonly found species of barracuda were *Sphyraena jello, S. barracuda* and *S .obtusata.* Horse mackerel was found throughout the year except in the months of June-July, constituting about 1.6% of the overall catch.

In the present study, only about 0.2% of the total catch was contributed by the catfishes, in the

months of January-February. A substantial reduction in catfish landings was conspicuous, indicating an overall decline of the resource. Better landings for this group were reported in the past from this region.

Seasonal and Spatial Distribution

In tropical waters, it is difficult to demarcate sharply any season of commercial availability of fisheries resources, as the resources are dynamic. Exploratory analyses of trawl catch data were done in this study to provide information on the distribution pattern of species assemblages in the area. The grouping of stations by monsoon period is due to the observed variation of species groups in these periods, and is based on the preliminary analysis of catch composition.

Pre-monsoon

The station-clusters based on the two techniques used in the analysis, i.e. TWINSPAN and DCA, indicated the existence of two major classifications of areas, which had sub-areas within them (Table 5 and Fig. 3, see also Appendix I).

In general sub-area A_{11} was characterized by the predominance of *Priacanthus* spp. mainly off the area between Cochin and Mangalore. This fish group formed 63% of the total landings in this period. Horse mackerel and barracudas also seemed to show affinity to the area during this season. The Indian mackerel and squids seemed to occur in all regions, thus they are classified as ubiquitous species. The sub-areas A_{12}, A_{21} and A_{22} are characterized by species of scads. The sub-areas A_{21} and A_{22} were sampled mainly at stations from the Konkan-Goa region.

Area B was dominated by species of *Lobotes*, perches, croakers, mackerel and rays. The catfishes were observed in almost all the stations. Most of the stations were in the Wadge Bank area. Relative abundance of each station-cluster is summarized in Table 6.

Monsoon

During this season there were two major groupings observed evident in the result of TWINSPAN and DCA (Table 7 and Fig. 4). Area B is characterized by the absence of sharks, rays, ribbonfish, croakers, pomfrets, perches etc., which are dominant in A. Squids and cuttlefish were observed in both but relatively higher in area B. Threadfin breams and *Priacanthus* spp. were not reported in A during this period. Area A stations were in the Wadge and Quilon banks while area B mainly consists of stations in the Alleppey and Cochin regions. The relative abundance of each species taxa by station-cluster is presented in Table 8.

Table 5. Stations-clusters generated from TWINSPAN (February-May).

Group	Sub-group	Region	Stations
A	A_{11} and A_{12}	Cochin - Mangalore	23, 22, 18, 11, 16, 17, 8, 6, 7, 9, 19, 13, 14, 2, 10, 20, 21, 15, 4, 12, 1
	A_{21} and A_{22}	Konkan - Goa - Allppey	43, 46, 47, 31, 36, 45, 41, 38, 42, 49, 44, 37, 3, 5, 48
B	B_{11} and B_{12}	Wadge bank - Quilon	24, 39, 30, 33, 35, 40, 29, 34
	B_{21} and B_{22}	Wadge bank - Quilon	26, 27, 48, 25, 32

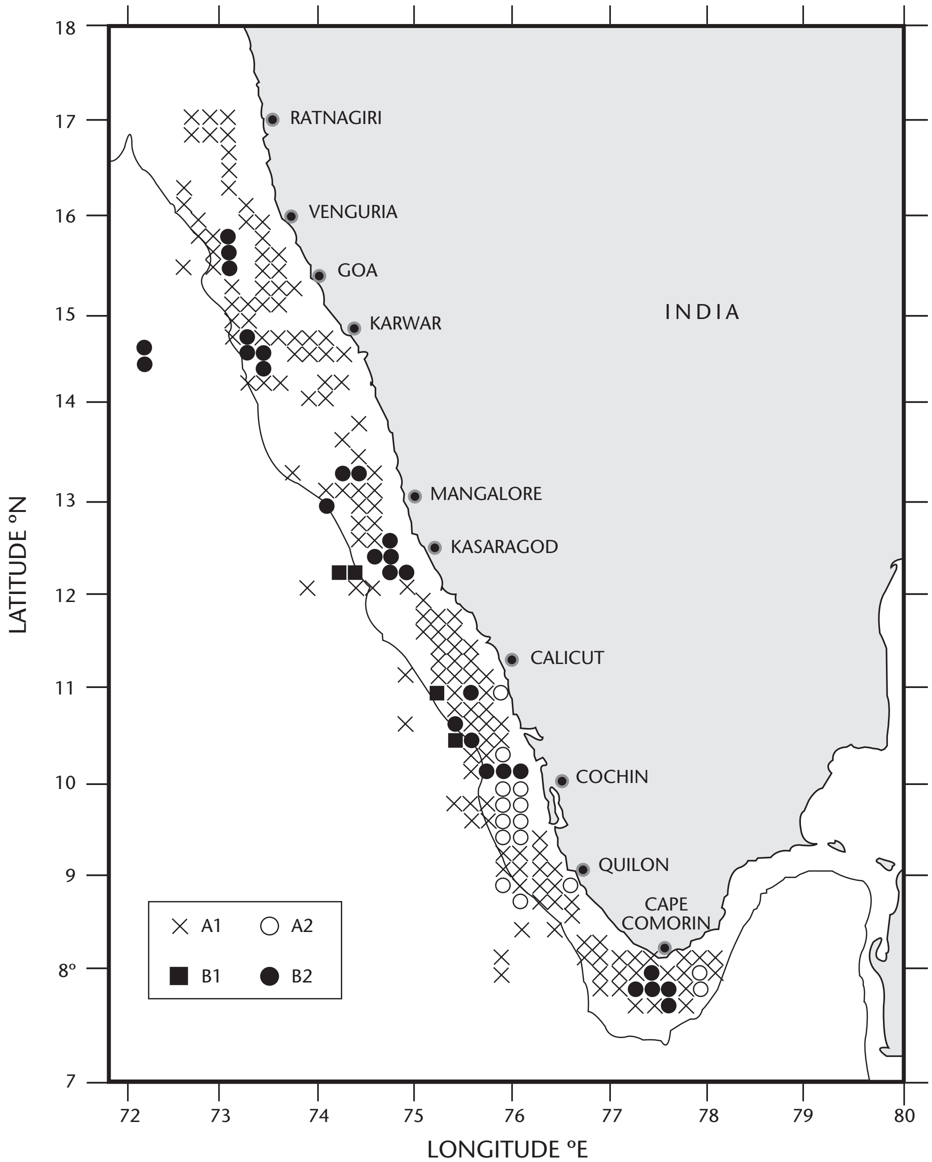

Fig. 3. Spatial distribution of sampling square based on the classification analysis using TWINSPAN during the pre-monsoon season.

Table 6. Relative abundance (%) of the species groups by station-cluster during the pre-monsoon period.

Species/Taxa	Station-Groups							
	A				B			
	A_{11}	A_{12}	A_{21}	A_{22}	B_{11}	B_{12}	B_{21}	B_{22}
Barracuda (Sphyraenidae)	6.46	0.56	0.49	0.00	0.00	0.24	0.00	0.00
Caranx spp.	0.00	0.00	0.05	0.00	0.55	0.32	0.00	0.00
Catfish (Ariidae)	12.11	0.01	0.24	0.16	2.50	2.06	0.01	0.00
Chirocentrus spp.	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Horse mackerel (Carangidae)	0.00	0.73	0.22	0.28	0.00	0.00	0.00	0.00
Indian mackerel *(Rastrelliger kanagurta)*	0.00	1.44	10.17	14.24	5.55	3.74	0.04	0.00
Lizard fishes (Synodontiade)	0.00	0.00	2.59	0.00	0.00	0.00	0.00	0.00
Lobotes spp.	0.00	0.01	1.30	0.00	50.65	53.81	0.37	0.00
Lobster	0.00	0.00	0.00	0.81	0.00	0.00	0.00	0.00
Perch	0.00	0.00	0.00	0.00	0.00	1.14	75.08	77.88
Pomfrets (Bramidae)	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00
Priacanthus spp.	62.81	19.89	2.31	0.00	0.00	0.00	0.00	0.00
Rays (Dasyatidae)	0.00	0.22	3.62	3.29	19.75	19.12	8.10	0.00
Ribbonfishes (Trichiuridae)	9.86	0.08	0.21	0.00	0.00	0.00	0.00	0.00
Scads (Carangidae)	0.00	75.93	77.81	80.97	0.00	0.00	0.00	0.00
Croakers (Sciaenidae)	0.00	0.01	0.26	0.00	14.56	15.13	15.01	22.12
Seerfishes (Scombridae)	8.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sharks	0.00	0.00	0.00	0.25	5.55	3.70	1.39	0.00
Silverbellies (Gerridae)	0.00	0.02	0.41	0.00	0.00	0.00	0.00	0.00
Soles (Soleidae)	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Squids	0.00	0.76	0.26	0.00	0.89	0.74	0.01	0.00
Threadfin breams (Nemipteridae)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00

Table 7. Stations-clusters generated from TWINSPAN (June-September).

Groups	Sub-group	Region	Stations
A		Wadge bank - Quilon	24, 27, 28, 29, 30, 31, 14, 15, 16, 17, 18, 19, 20, 21, 22
B	B_1, B_{21} and B_{22}	Aleppey - Cochin	25, 32, 34, 35, 36, 37, 38, 39, 40, 42, 43, 44, 45, 1, 2, 4, 5, 6, 7, 9, 11, 12, 23, 26, 33, 41, 46, 3, 10, 8, 13

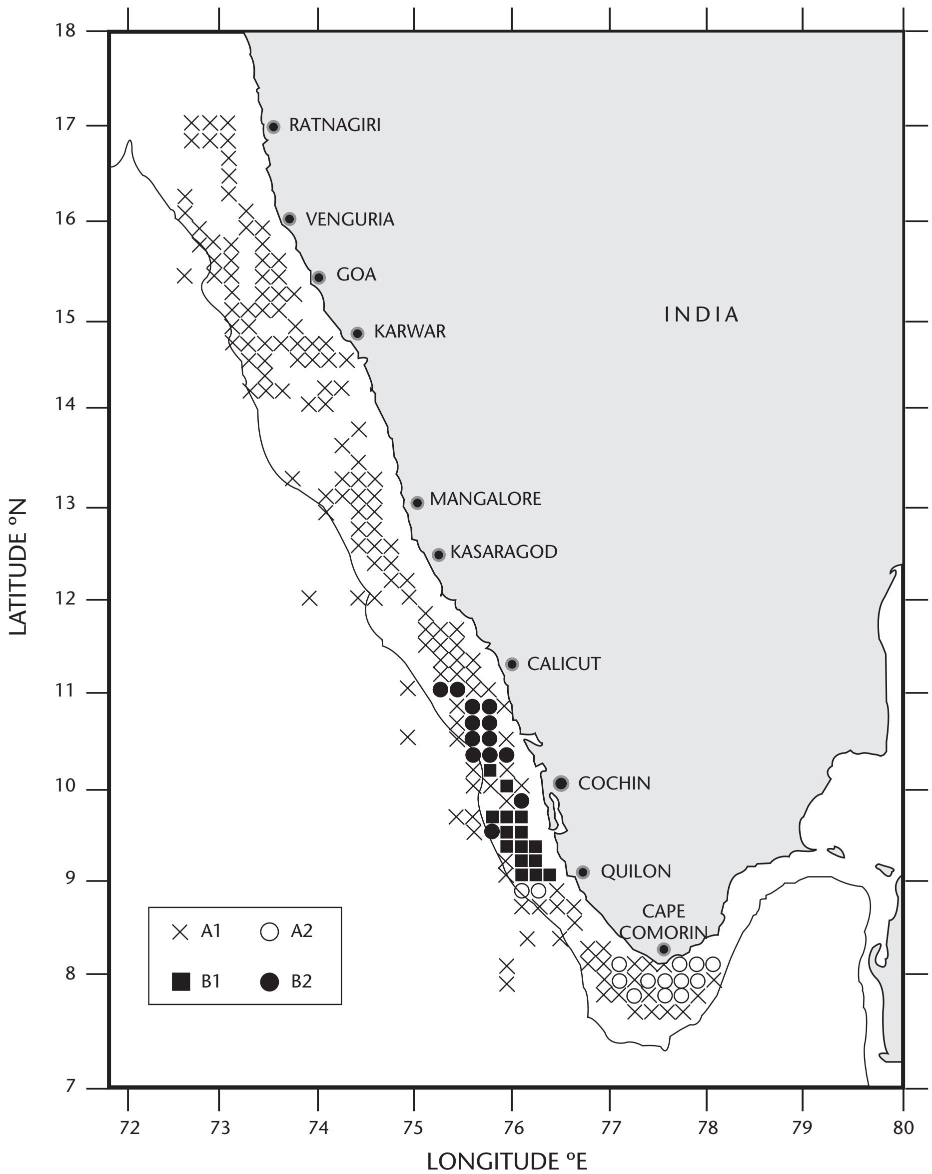

Fig. 4. Spatial distribution of sampling square based on the classification analysis using TWINSPAN during the monsoon season.

Table 8. Relative abundance (%) of the species assemblages formed during the monsoon period.

Species/Taxa	Station-Groups			
	A		B	
	A	B_1	B_{21}	B_{22}
Barracuda (Sphyraenidae)	1.5	1.31	0.00	0.00
Caranx spp.	5.47	0.00	0.00	0.00
Catfishes (Ariidae)	0.04	0.02	0.00	0.00
Cuttlefishes	0.63	0.58	0.94	0.23
Horse mackerel (Scombridae)	0.00	0.08	0.00	0.00
Lizardfishes (Synodontidae)	0.04	0.00	1.41	1.21
Lobotes spp.	25.7	0.00	0.00	0.00
Miscellaneous	3.76	0.30	0.46	0.18
Perch	12.31	0.00	0.00	0.00
Pomfrets (Bramidae)	0.14	0.00	0.00	0.00
Priacanthus spp.	0.98	18.63	8.59	7.55
Rays (Dasyatidae)	20.44	0.00	0.00	0.00
Ribbonfishes (Trichiuridae)	1.55	0.00	0.00	0.00
Sardines (Clupeidae)	0.00	0.13	0.00	0.00
Scads (Carangidae)	0.10	1.91	32.46	14.41
Croakers (Sciaenidae)	19.40	0.07	0.10	0.00
Scomberoides spp.	0.01	0.00	0.00	0.00
Sharks	1.14	0.00	0.00	0.00
Silverbellies (Gerridae)	0.36	0.00	0.00	0.00
Soles (Soleidae)	0.02	0.00	0.00	0.00
Squids	6.42	12.35	0.00	0.00
Threadfin breams (Nemipteridae)	0.00	64.61	56.05	76.42

Post-monsoon

During this season DCA station-clusters indicated two major groupings with some embedded clusters revealed by TWINSPAN (Table 9 and Fig. 5). There seems to be a more or less homogeneous mixture of species during this period. Sub-area A_1 is characterized by the abundance of *Caranx* spp. followed by seerfish, pomfrets, horsemackerel and *Priacanthus* spp. This station-group is mainly found in the Konkan region (northern part of SW coast). Ribbonfishes and Indian mackerel dominate the sub-area A_2 with stations found in Quilon Bank to North Kanara region (Table 10). The sub-area B_1, which is in the Konkan region is characterized by the dominance of threadfin breams, scads and *Priacanthus* spp. Most of the stations in this sub-area are deep-water stations with depths ranging from 100 - 180 m. Sub-area B_2 is exclusively found in the Wadge Bank area characterized by the abundance of perches and seerfishes.

Table 9. Station-clusters generated from TWINSPAN (October-January).

Groups	Sub-group	Region	Stations
A	A_1	Goa	8, 13, 20, 28, 29, 30, 31, 32
	A_2	Cochin - Malabar	51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 14, 15, 16, 22, 24, 25, 27, 33, 34, 35, 36, 38
B	B_1	Konkan	17, 18, 19, 21, 23, 26, 37
	B_2	Wadge bank - Quilon	39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50

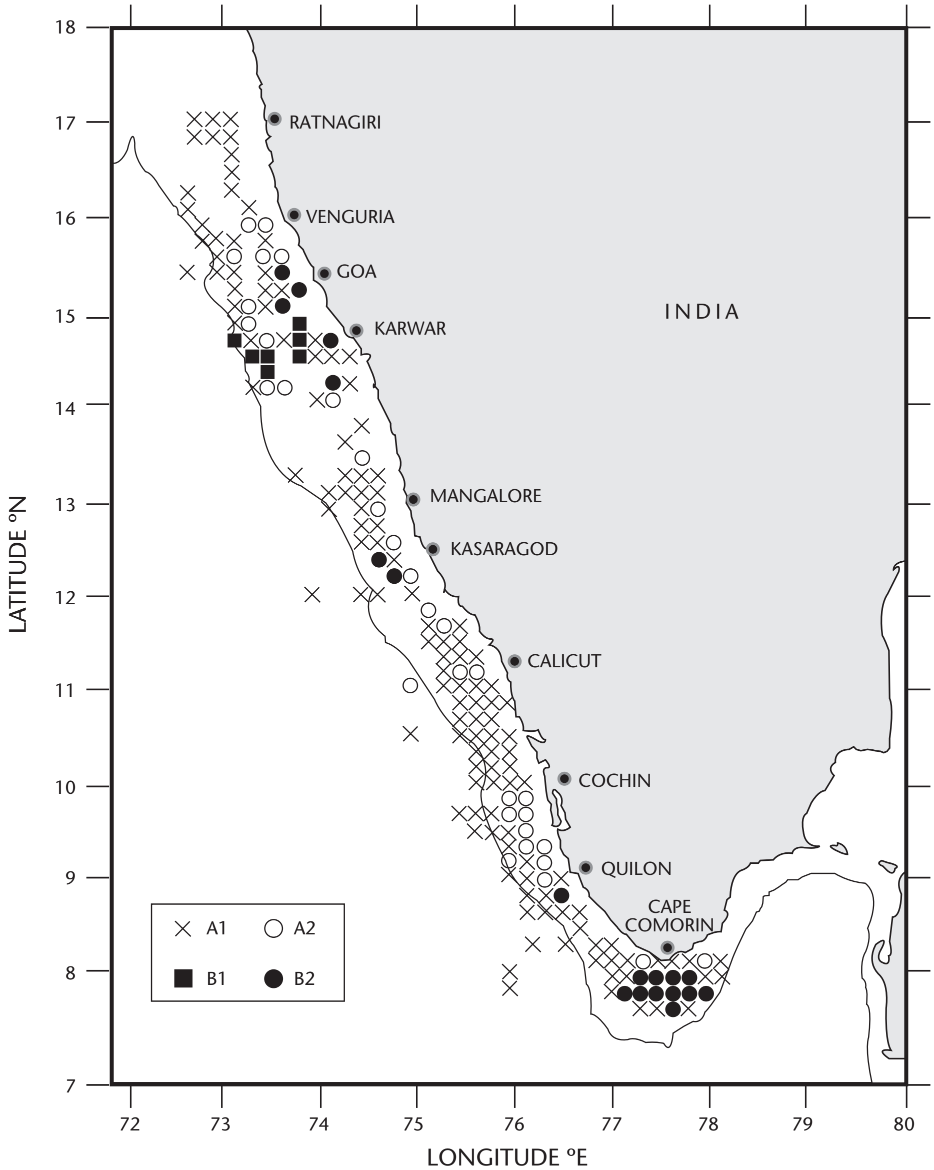

Fig. 5. Spatial distribution of sampling square based on the classification analysis using TWINSPAN during the post-monsoon season.

Table 10. Relative abundance (%) of the species assemblages formed during the post-monsoon period.

Species/Taxa	Station-Groups			
	A		B	
	A_1	A_2	B_1	B_2
Barracuda (Sphyraenidae)	0.00	4.14	1.31	1.53
Caranx spp.	61.80	1.61	0.00	0.07
Catfishes (Ariidae)	0.00	0.45	0.00	0.00
Chirocentrus spp.	3.34	2.44	0.00	0.00
Cuttlefishes	0.00	0.70	1.79	0.11
Eels	0.00	0.13	0.00	0.00
Horse mackerel (Scombridae)	4.10	6.45	0.07	0.00
Indian mackerel *(Rastrelliger kanagurta)*	0.00	22.18	0.00	0.00
Lizardfishes (Synodontidae)	0.00	0.13	0.13	0.00
Lobotes spp.	0.00	0.00	0.22	0.00
Miscellaneous	0.00	1.27	0.00	0.02
Perch	0.00	2.30	0.17	63.52
Pomfrets (Bramidae)	7.84	3.16	0.07	0.00
Priacanthus spp.	4.15	0.56	12.35	2.14
Rays (Dasyatidae)	0.00	5.12	0.00	6.49
Ribbonfishes (Trichiuridae)	0.00	36.81	0.53	0.00
Sardines (Clupeidae)	0.00	0.79	0.00	0.19
Scads (Carangidae)	0.00	0.00	12.17	0.00
Croakers (Sciaenidae)	0.00	0.00	0.00	21.98
Seerfishes (Scombridae)	16.63	0.64	0.07	0.00
Sharks	2.14	5.07	0.00	1.53
Silverbellies (Gerridae)	0.00	0.73	0.00	0.00
Squids	0.00	5.33	0.18	2.42
Threadfin breams (Nemipteridae)	0.00	0.00	70.96	0.00

Discussion

The southwest coast of the Indian continent is mainly characterized by three major monsoon periods. The months of February to May are classified as the "pre-monsoon period" which is commonly known as the winter to summer season. Months of June to September are the "monsoon period" or the southwest monsoon season, and the months of October to January are the "post monsoon period" or the northeast monsoon season. Each of the periods is characterized by different oceanographic circulation patterns that mainly determine the pattern of distribution of species assemblages on the southwest coast of India.

During the southwest monsoon (May-October) there is a southerly flow observed along the west coast spread over the entire shelf region. At the time of the change from the southwest monsoon to the winter season, a northerly current is established off the shelf. Adjacent to and on the seaward side of the northerly flow, a southerly current is present, but is limited to the southerly regions. From winter to summer (February-April) the northerly current vanishes and the circulation breaks up into eddies. The southerly current persists in summer though it is limited to a narrow belt. Once again during the southwest monsoon period this narrow southerly stream spreads over the entire shelf. In general along the west coast, the current during the winter season appears to be stronger than the southwest monsoon current. During the northeast monsoon period (October-January) the surface current reverses its direction and turns northerly.

The stronger current during the winter season ("pre-monsoon") is associated with the relatively gradual increase in catch rate as compared to the other monsoon periods. The presence of a large concentration of threadfin breams, round scads, bullseyes and cephalopods in the landings in the west coasts and the relatively fast increasing catch rate were observed during the southwest monsoon season ("monsoon") associated with the weaker current system. The reversal of current during the northeast monsoon season ("post-monsoon) was observed to be evident in the relatively more productive multi-species population of the Wadge Bank.

The spatial analysis confirmed that the Wadge Bank is potentially the best ground for quality fish such as perches. The area has been intensively fished by various agencies.

In the Alleppey-Cochin area, the resources were mainly threadfin breams and round scads within the 41 - 80 m depth range, while mackerel was reported from 0 - 40 m area. June-July and August showed better landings for threadfin bream, while *Decapterus* spp. (round scads) were more abundant in the month of May and September-October. There is increasing interest in the fishing industry for squids and cuttlefish due to greater export demand. This group, which formed less than 1% of the total landings earlier, is now found to represent over 6.6%. The region between latitude 8ºN and 11º N and within 80 m depth, in September–October periods yielded progressive catches of cephalopods.

Towards the northern latitudes along the Karnataka, Konkan, Goa, Maharashtra and Sourashtra coasts high potential for demersal resources were reported earlier (Bapat et al. 1972; Joseph 1980). Exploratory survey results of Fishery Survey of India confirmed the above findings. Moderate landings of pomfret, seerfish, ribbonfish and golden anchovy recorded in the area were distinct from the landings of southwest coast. Under-size threadfin breams and bullseye reported from Karnataka and Goa region indicate the need to explore the migration pattern of these varieties towards higher latitudes.

On the whole an analysis of region-wise data indicated that the maximum effort and highest landings are from the known grounds along the southwest coast although certain northern areas were also found to be fairly productive. It is observed that there is an inverse relationship between the fishing effort and catches; wherever there was a high catch rate, the intensity of fishing was found to be less. An increased effort in the commercially known fishing grounds produced only lesser yields, as evidenced in Quilon ground and Wadge Bank area.

During the past two decades several attempts have been made to assess the potential of the EEZ based on the commercial fisheries landings, and the estimates were found to vary widely. The generally accepted estimate for the demersal finfish resources of the EEZ beyond 50 m is around 1.7 million t as against the current yield of 0.5 million t. So there is further scope for enhancing the production from this area. According to recent estimates marine production in India has already reached its full potential yield, and 90% of this is landed from the area less than 50 m depth. This is the same area that the research surveys were conducted in.

Studies on the effect and influence of oceanographic parameters on the distribution and abundance of fish groups along the SW coast of India are comparatively limited, but the works of (Longhurst and Wooster 1990; Madhupratap et al. 1994; Murthy 1965; Murthy 1992; Murthy 1993; Murthy 1995; Murthy and Edlman 1970; Pillai 1982; Pillai 1991; Pillai 1996; Pillai et al. 1998a) are worth mentioning in this context. Studies made by (Murthy et al. 1990) on board FORV *Sagar Sampada* revealed a tremendous contrast among three regions viz. Gulf of Mannar, Wadge Bank and Quilon (07º to 09º N Lat. and 75º 28' to 78º 43' E Long.) in respect of oceanographic conditions. During the peak of the SW monsoon season (July-August) both seawater temperature and salinity of Quilon Bank waters were comparatively low, whereas Wadge Bank waters were moderate in water temperature but high in salinity. The Gulf of Mannar waters were found to be moderate in respect of salinity but warmer with thermal inversions in the middle region of the water column. The bottom water temperature, rather than salinity appeared to be the reason for the species variations in the trawl catches in the region. Nemipterids were not present in the Gulf of Mannar where the bottom temperatures were comparatively high. Barracudas were absent in both the Wadge Bank and Quilon Bank where the bottom waters were comparatively cooler. Nemipterids constituted a good monsoon fishery off Cochin where the process of upwelling resulted in comparatively cooler bottom waters with lower dissolved oxygen concentrations. Probably the concentration of nemipterids on the Quilon Bank and Wadge Bank areas are due to the extended effect of upwelling southwards down to Wadge Bank because of favourable southerly currents.

(Suseelan et al. 1990), based on observations carried out onboard FORV *Sagar Sampada* observed a noteworthy feature along the southwest coast of India with regard to the occurrence of the coastal prawn *Parapenaeopsis stylifera* (Karikkadi prawn), in varying densities in the offshore waters up to 53 m depth during the southwest monsoon period (June and July) almost as a continuous belt between Quilon and Goa. This species is basically

a coastal species inhabiting areas within the 30 m depth contour. Experimental shrimp trawling off Cochin established that during June-July *P. stylifera* migrates in large numbers to the offshore areas up to about 60 m depth as a result of upwelling. Nemipterids exhibit a shoreward (deep water to shallow water) as well as alongshore (southerly along the west coast) migration following the movement of cold, high saline, oxygen deficient upwelling waters during the SW monsoon season (Pillai et al. 1998b). The *Priacanthus* spp. (bulls eye) also take advantage of the shoreward movement of the upwelling water and reach comparatively shallower areas of the shelf during the Southwest monsoon season.

Summary and Conclusion

The southwest coast of the Indian continent is mainly characterized by three major monsoon periods (i.e. winter to summer, southwest monsoon and northeast monsoon). Each of the periods are characterized by different oceanographic circulation patterns that mainly determine the pattern of distribution of species assemblages on the southwest coast of India.

Spatial analysis confirmed that the Wadge Bank was potentially the best ground for quality fish such as perch. In the shallower region of the area (30 - 50 m) balistids have become predominant. In the Alleppey-Cochin area, threadfin breams and round scads dominated the depths within 41 - 80 m while mackerel was reported from 0 - 40 m. Towards the northern latitudes along Karnataka, Konkan, Goa, Maharashtra and Sourashtra coasts high potential for demersal resources were observed.

Region-wise analysis of data indicated that maximum effort and highest landings are from the known grounds along the southwest although certain northern areas were also found to be fairly productive. Increased effort in the commercially known fishing grounds produced only lesser yields as evidenced in the Quilon ground and Wadge Bank area.

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Appendix I. TWINSPAN and DCA results for the pre-monsoon, monsoon and post-monsoon seasons.
a. TWINSPAN classification of fishing squares during the pre-monsoon.

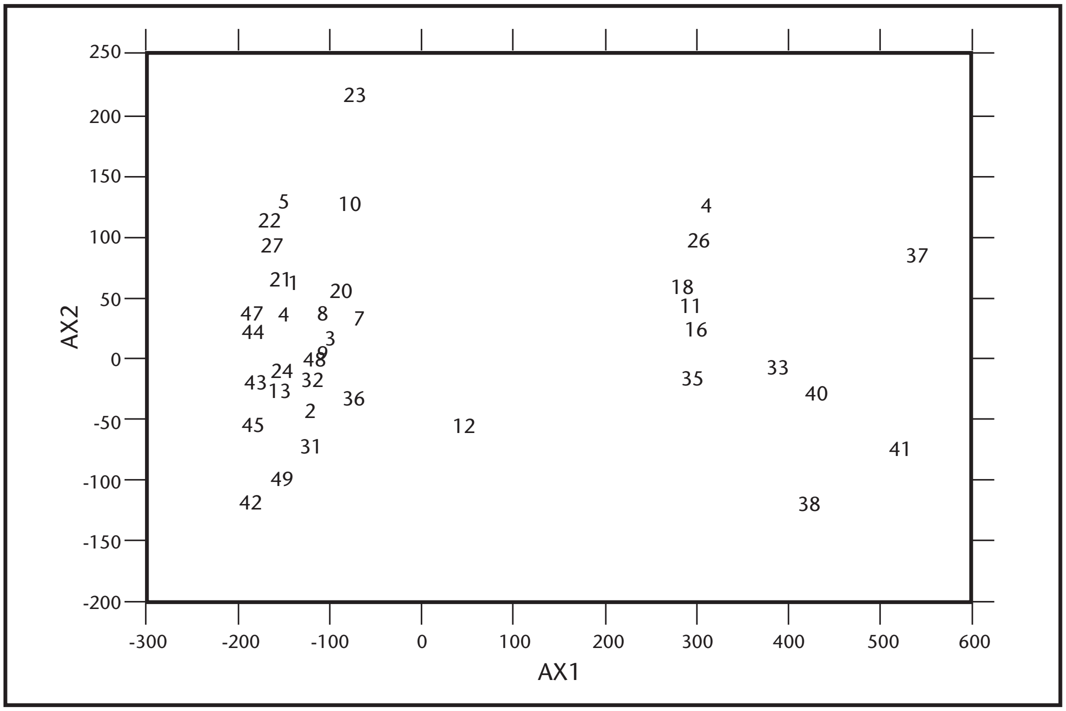
	Fishing Squares by Station-Group							
Clusters	A_{11}	A_{12}	A_{21}	A_{22}	B_{11}	B_{12}	B_{21}	B_{22}
Resource	**2 2 2 3**	**1 1 2 2 1 1 1 1 1 1 1 1 2 8 9 0 1 4 9 1 2 3 5 6 7 1 6 0 4 7 8**	**4 4 4 3 3 4 3 6 7 1 6 5**	**3 4 4 4 4 3 4 8 1 2 9 4 7 3 5 8**	**2 3 4 9**	**3 3 3 4 2 3 0 3 5 0 9 4**	**2 2 2 6 7 8**	**2 3 5 2**
Wolfherring	– –	– – – – – – – – – – – – – – – – – – –	– 1 – – – –	– – – – – – – – –	– –	– – – – – –	– – –	– –
Lizardfishes	– –	– – – – – – – – – – – – – – – – – – –	– 1 – 2 2 2	– – – – – – – – –	– –	– – – – – –	– – –	– –
Lobsters	– –	– – – – – – – – – – – – – – – – – – –	– – – – – –	– – – – – 2 – – –	– –	– – – – – –	– – –	– –
Silverbellies	– –	– – – – – – – – – – – – – – – – 1 – –	1 1 1 – – –	– – – – – – – – –	– –	– – – – – –	– – –	– –
Scads	– –	1 1 1 2 1 3 1 3 4 5 3 3 3 1 1 1 1 1 1	5 4 5 5 4 5	5 5 5 5 5 4 1 1 4	– –	– – – – – –	– – –	– –
Ribbonfish	2 2	1 1 1 1 2 – – – – – – – – – 1 – – – –	– – 1 – – –	– – – – – – – – –	– –	– – – – – –	– – –	– –
Seerfish	2 2	– – – – – – – – – – – – – – – – – – –	– – – – – –	– – – – – – – – –	– –	– – – – – –	– – –	– –
Horse Mackerel	– –	1 1 1 2 1 1 1 1 1 1 1 2 2 1 2 1 1 1 2	1 1 1 – – –	– – – – – – – – 2	– –	– – – – – –	– – –	– –
Pomfrets	– –	– – – – – – – 1 1 1 2 – – 2 2 2 1 – –	– – – – – –	– – – – – – – – –	– –	– – – – – –	– – –	– –
Priacathids	4 4	– 5 5 4 5 4 2 3 2 2 3 3 3 2 – 2 2 3 3	1 2 1 – – –	– – – – – – – – –	– –	– – – – – –	– – –	– –
Threadfin breams	– –	– – – – – 1 1 – – – – – – – – – – – –	– – – – – –	– – – – – – – – –	– –	– – – – – –	– – –	– –
Barracuda	2 2	– – – – – 1 1 1 1 1 1 1 1 1 1 1 1 2 2	– 1 1 1 1 –	– – – – – – – – –	– –	– – – – 1 1	– – –	– –
Indian mackerel	– –	2 1 1 1 1 2 2 2 2 1 2 2 2 2 2 3 1 2 2	1 1 2 1 1 –	– 2 – 2 2 3 2 1 2	2 2	1 1 1 1 1 1	– – 1	– –
Squids	– –	1 1 2 1 1 1 1 2 1 1 1 2 2 1 1 1 2 1 2	– 1 1 – – 1	– – – – – – – – –	1 1	1 1 1 1 1 1	– – –	– –
Cuttlefish	1 2	1 – – – – – – – – – – – – – – – – – –	1 1 1 1 1 1	– – – – 1 – – – –	1 1	1 1 1 1 1 1	– – –	– –
Rays	– –	– – – – – – – – – – – – – 1 1 – 5 3 5	– 2 1 1 1 2	– – – – 2 – 3 2 2	2 2	2 2 2 2 2 2	2 2 2	– –
Sharks	– –	– – – – – – – – – – – – – – – – – – –	– – – – – –	– – – – 1 – – – –	2 2	1 1 1 1 1 1	2 1 1	– –
Perches	– –	– – – – – – – – – – – – – – – – – – –	– – – – – –	– – – – – – – – –	– –	– – – – 1 –	4 4 4	4 5
Croakers	– –	– – – – – 1 – – – – – – – – – – – – –	– – – 1 1 –	– – – – – – – – –	2 2	2 2 2 2 2 2	2 2 2	3 2

b. TWINSPAN classification of fishing squares during monsoon.

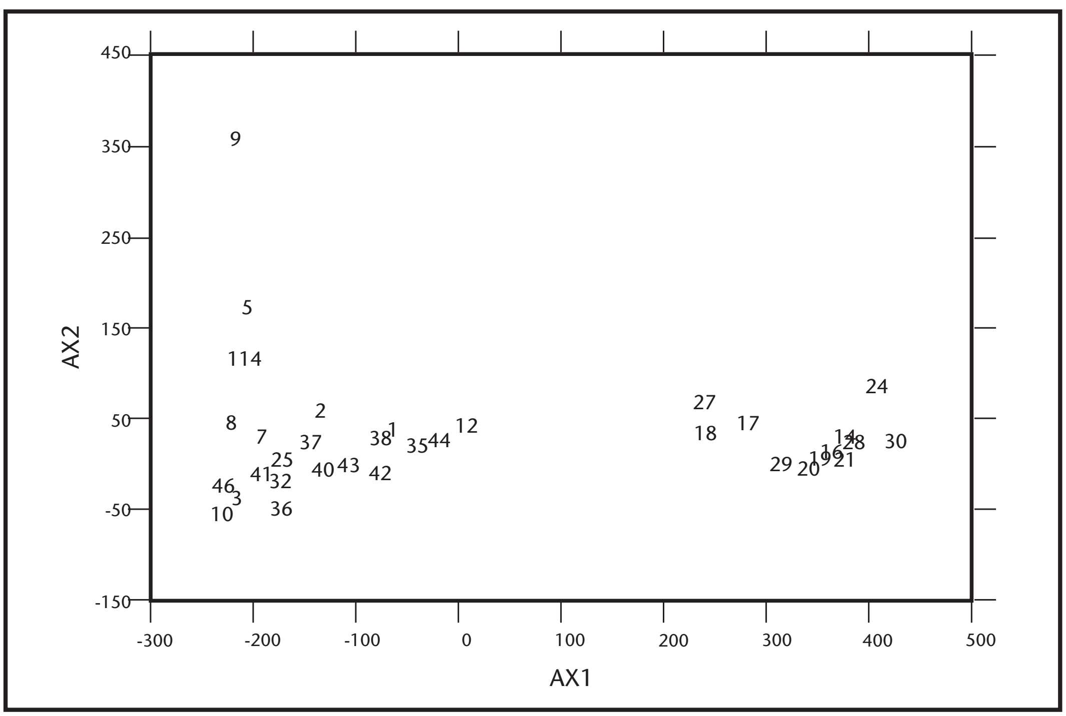
	Fishing Squares			
Clusters	**A**	**B_1**	**B_{21}**	**B_{22}**
Resource	**2 3 3 1 1 2 2 2 2 1 1 2 1 1 2** **4 0 1 6 9 1 2 0 9 4 5 8 7 8 7**	**4 4 3 4 4 3 4 2 3 3 3 3 3** **2 1 4 5 5 2 3 8 0 5 4 7 2 6 9**	**1 1** **9 4 5 1 6 7 2**	**1 1 2 2 3 4 4** **8 0 3 3 6 3 6 3 1**
Croakers	5 2 2 2 2 2 2 2 2 2 2 2 3 2 2	– – – 1 1 1 – – – – – – – – –	– 1 – – – – –	– – – – – – – – –
Sharks	– 2 2 – 1 1 1 1 1 – – 2 – – –	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Caranx spp	– – – 2 2 2 2 1 2 2 2 2 2 – 2	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Lobotes spp	– – – 3 3 2 2 2 2 3 3 3 2 3 2	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Rays	– 3 3 2 2 2 2 2 2 2 2 2 2 2 2	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Ribbonfishes	– – – 1 – 1 2 1 1 – – – – 1 1	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Soles	– – – – – 1 – – – – – – – – –	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Pomfrets	– – – 1 – 1 – 1 – – – – – – –	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Seerfishes	– – – – – – – 1 – – – – – – –	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Silverbellies	– – – – 1 1 – 1 – – – – – – –	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Perches	– 3 3 – 2 3 2 2 2 – – – – – –	– – – – – – – – – – – – – – –	– – – – – – –	– – – – – – – – –
Miscellaneous	– – – 2 2 2 2 1 1 – – – – – –	– – – 2 – – – 1 – 1 – 1 1 – –	– – – – 1 2 –	– – – – – – – – –
Catfishes	– – – – – – – – – – – – – 1 1	– – – – – 2 – – – – – – – – –	– – – – – – –	– – – – – – – – –
Barracuda	– – – – 2 – – 2 2 – – – – – –	– – 2 2 2 3 2 1 1 2 1 2 – – 1	– – – – – – –	– – – – – – – – –
Squids	– – 2 1 1 1 1 1 1 1 2 1 2 2 2	1 4 4 4 4 2 3 4 3 1 2 2 2 2 2	– – – – – – –	– – – – – – – – –
Cuttlefish	– – – – 1 1 – 1 – 1 1 – 1 – 1	1 – 2 – 2 1 – – – 1 1 1 – – –	1 1 1 – 1 1 –	– – – – – – – – –
Horse mackerel	– – – – – – – – – – – – – – –	– – – – – – – 1 1 – 1 – – – –	– – – – – – –	– – – – – – – – –
Priacanthus	– – – – 1 1 1 1 1 – – – 2 2 2	5 3 2 2 1 – 2 2 2 2 2 3 3 2 3	1 2 2 2 2 2 2	2 – – – – – –2 3
Sardines	– – – – – – – – – – – – – – –	– – – – – – – – – – – – – 2 –	– – – – – – –	– – – – – – – – –
Scads	– – – – – – – – – – – – – – 2	– – – – – – – 1 1 2 – 2 – – –	5 3 3 3 2 2 2	2 – – – – – 2 – –
Threadfin breams	– – – – – – – – – – – – – – –	– – – – 2 3 3 2 3 4 4 3 4 4 4	2 3 3 4 4 4 4	5 5 5 5 5 5 5 5 4
Lizardfishes	– – – – – – – – – – – – 1 – –	– – – – – – – – – – – – – – –	1 1 – 1 1 – 1	1 – – – – – – – –

c. TWINSPAN classification of fishing squares during post-monsoon.

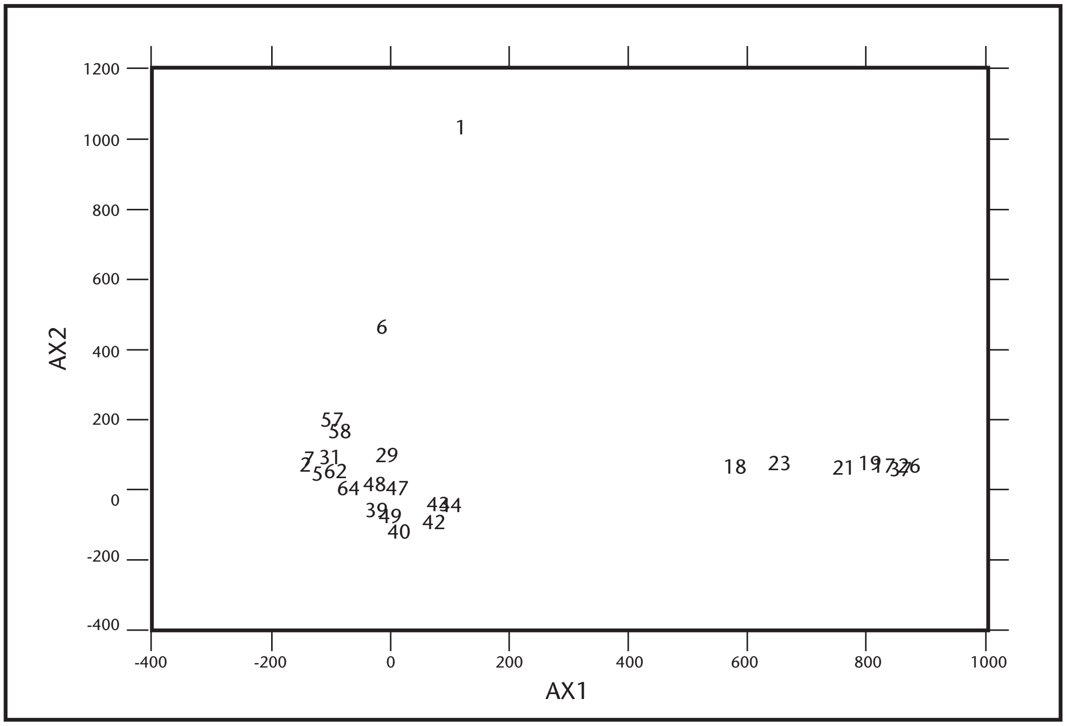
	Fishing Squares			
Clusters	**A**	**B_1**	**B_{21}**	**B_{22}**
Resource	**2 333122** **98201308**	**66 1255 126333556562556656 2311311** **12234562267273468597105758634945301**	**2311212** **67793811**	**3444445444445** **92346940157806**
Caranx spp.	25534244	– 2 – – – – – – – – 2 1 2 2 – – – – – – – – 2 2 1 1 1 2 – 1 – 1 1 1 1 1 1	– – – – – – – –	– – 1 – – – – – – – – – – –
Pomfrets	– – 222 – 12	– – – – 2 1 – – 2 – – – 2 –2 2 2 2 2 2 – – 1 – – 1 2 – 1 – – – – – – – –	– 1 – – – – – –	– – – – – – – – – – – – – –
Seerfishes	22 – 33422	– – – 2– –22– – 1 2 2– 222 – – – – – – – – 1 – – – – 1 1– – – – –	– 1 – – – – – –	– – – – – – – – – – – – – –
Wolf herring	21 – – – – – –	2 1 2 2 2 2 2 2 2 2 2 2 2 1 1– – – – – – 1 2 – – – 1 1 – 1 – – – – – – – –	– – – – – – – –	– – – – – – – – – – – – – –
Horse mackerel	– – – – – 222	1 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2– 2 2 2 2 1 2 – 1 2 2 2 2 2 2 2 2 2	– 1 – – – – – –	– – – – – – – – – – – – – –
Miscellaneous	– – – – – – – –	– – 2 2 2 3 2 2 2 2 2 2 1 1 – – – 1 1 1 1 – – – – 1 1– 1 – – – – – – – –	– – – – – – – –	– – – – – – – – – – – 1 – –
Ribbonfishes	– – – – – – – –	3 2 2 2 2 2 2 3 3 2 2 2 3 2 2 2 3 4 4 3– – 4 2 2 3 3 – 3332 – – 2 – –	– 1 – – – – – –	– – – – – – – – – – – – – –
Catfishes	– – – – – – – –	– – – – – – – – – – – 1 1– – – – – – – – – 1 – – – – – 1 – – 2 2 2 2– 2	– – – – – – – –	– – – – – – – – – – – – – –
Mackerel	– – – – – – – –	2 2 2 2 2 2 2 2 2 2 2 3 2 2 – 2 – 2 2 2 3 3 2 2 2 2 2 2 2 3 3 3 3 3 3 4 4–	– – – – – – – –	– – – – – – – – – – – – – –
Eels	– – – – – – – –	– 1 – – – – – 1– – – – – –	– – – – – – – –	– – – – – – – – – – – – – –
Silverbellies	– – – – – – – –	– – – – – – – – – – – – – 2– – – – – – – – – – – 1 1 2 1– 2 1 – – – – – –	– – – – – – – –	– – – – – – – – – – – – – –
Barracuda	– – – – – – – –	– – – – – – – – – – – 1 1– – – – 2 2 2 – – 1– 1 1 2 2 1 1 2 1 1 1 1 1 2–	– – – 2 – – –	– – – – – – – – – – – – – –
Squids	– – – – – – – –	2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 1 1 1 2– 2 1 2 1 1 1 1 1 2 2 2 2 2 2 2–	1 – – – – –	–1 – 1 1 1 1 2 1 1– 2 1–
Sardines	– – – – – – – –	– – – – – – – – – – – – 1– – – – – – – 2 2 1 1– 1 1– – – – – – – – – – – –	– – – – – – –	– – – – – – – – – – 1 2 – 3
Sharks	2 – – – – – – –	2 1– – – – – – – – 2 – 1– – – – – 1 – 1 2 1 2 4 2 1– 1– – – – – – – – – –	– – – – – – –	1 – 1 – 1 1 – – 1 1– 2 2 2
Lizardfishes	– – – – – – – –	– 1– – – – – – – – – – – – 2 2 2– 1	– 1 1 1 1 –	– – – – – – – – – – – – – –
Cuttlefish	– – – – – – – –	– 2 2 1 1 2– – – – – – – – – 1 1	1 1 1 1 1 5	– – – – – – – – – – 2 – – 2
Scads	– – – – – – – –	– 2 1	– – – 3 3 –	– – – – – – – – – – – – – –
Lobotes spp.	– – – – – – – –	– –	– – – 1 1 –	– – – – – – – – – – – – – –
Threadfin breams	– – – – – – – –	– 5 5	5 5 4 2 3 –	– – – – – – – – – – – – – –
Priacanthus	2 – – – 2 – – –	– 1– – – – – – – – – – 1– – – – – – – – – – – – 2– – – – – – – – – – – 1 1	2 2 2 3 2 –	– 2 3 3– – – – – – – – – –
Perches	– – – – – – – –	– –	– 1 1 – 1 –	2 4 3 3 4 4 4 5 5 4 4 3 3–
Rays	– 1 – – – – – –	2 2– – – 3– – – – – – – – – – – – – – 2 2 – – 1 1 2– 2 1 – – – – – – 1 – –	– – – – – – –	4– 2 2 2 2 2– – – 2– 2–
Croakers	– – – – – – – –	– –	– – – – – – –	2 3 2 2 2 2 2 2– 2 2 2 2–



d. Premonsoon ordination of stations (DCA results).



e. Monsoon ordination of the stations (DCA results).



f. Postmonsoon ordination of the stations (DCA results).

Analysis of Demersal Assemblages off the North Coast of Central Java, Indonesia

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Nurhakim S. 2003. Analysis of demersal assemblages off the north coast of Central Java, Indonesia, p. 187 - 206. *In* G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings 67, 1 120 p.

Abstract

Trawl survey data collected by the RV Mutiara 4 in 1979 off the north coast of Central Java (Indonesia) were used to examine the composition and distribution of species assemblages in the area. Classification (TWINSPAN) and ordination (DCA) techniques commonly used in community structure analysis were utilized during the study. The results indicate the existence of "shallow" and "deep" assemblages with a boundary at around 20 - 30 m depth (varying with the monsoon season). There is some consistency in the assemblages between the seasons.

Introduction

The waters off the north coast of Central Java (Fig. 1) are exploited not only by traditional fishers but also by commercial shrimp trawlers. Trawling started to increase in 1970 when shrimp trawlers expanded their fishing grounds from the Malacca Straits and Southern Java. In 1980, a Presidential Decree banned the operation of trawlers. Most of the trawlers converted to purse seining which developed rapidly in the Java Sea. Traditional fishers, with operations limited to near the coast (< 80 km), continued to exploit the demersal and shrimp species using traditional fishing gear. The presence of a fishing port and other facilities along the north coast of central Java are conducive to the concentration of traditional fishers in this area.

Intensive trawl surveys were conducted from 1974 to 1979 by the Indonesian-German Demersal Fisheries Project. After the ban on trawl operations in 1980, irregular surveys were done by the Research Institute for Marine Fisheries. (Bianchi et al. 1996) examined the demersal fish assemblages of the Java Sea using the 1974 - 76 survey data. Their results show that the Java Sea has at least three demersal assemblages: one assemblage in the central and one in the deep part of the basin (> 30 m), and the shallow coastal assemblage.

This paper analyzes data from trawl surveys conducted off the north coast of central Java Sea in 1979 using methods commonly used in community structure analysis. It aims to investigate the distribution of demersal assemblages and their species composition.

Materials and Methods

This study focused on waters off the north coast of central Java Sea (Fig. 1). Data were collected using the wooden stern trawler RV Mutiara 4 (24.52 m LOA, 100 GT, 286 HP). The trawl used was the "Thailand trawl" with headline and footrope length of 35 m and 42.2 m respectively. The cod-end mesh size was 40 mm with a 22 mm cod-end insert net. Average trawling speed was 5.4 km•hr^{-1} and the vertical net opening was estimated at 2 m. Most

of the hauls lasted one hour and were made during daylight hours (from 0500 H to 1800 H).

A total of 144 hauls were made during the 6 cruises conducted in the area in 1979 (Table 1). Catches were sorted up to species level for “food” fish (economically important) species and to families for “trash” fish. Environmental data (i.e. sea temperature, turbidity, depth) were collected for each haul.

The data from the 144 stations were grouped into seasons based on current understanding of monsoon seasonality in the study area. This process resulted in 3 temporal station groupings, namely: (1) West Monsoon (18 stations sampled in January and February); (2) Intermonsoon I (71 stations in April and May); and (3) Intermonsoon II (55 stations in September and October). No data are available for the East Monsoon season given the absence of cruises during June to August 1979. Each monsoon season is characterized by different environmental conditions, thus analysis was done separately by season.

The station-species/group matrices for each of the three temporal groups were analyzed using Two-Way Indicators Species Analysis, or TWINSPAN (Hill 1979), and Detrended Correspondence Analysis (DCA) using the CANOCO software (Ter Braak 1988). There was no data transformation done prior to analysis using TWINSPAN and CANOCO.

Table 1. RV Mutiara 4 cruises in waters off the north coast of Central Java in 1979.

Cruise No.	Date	No. of Stations
01/79	12 - 13 January	7
03/79	19 - 20 February	11
04/79	26 - 30 April	27
05/79	10 - 24 May	44
09/79	9 - 10 September	11
11/79	12 - 18 October	44
TOTAL	12 Jan - 18 Oct	144

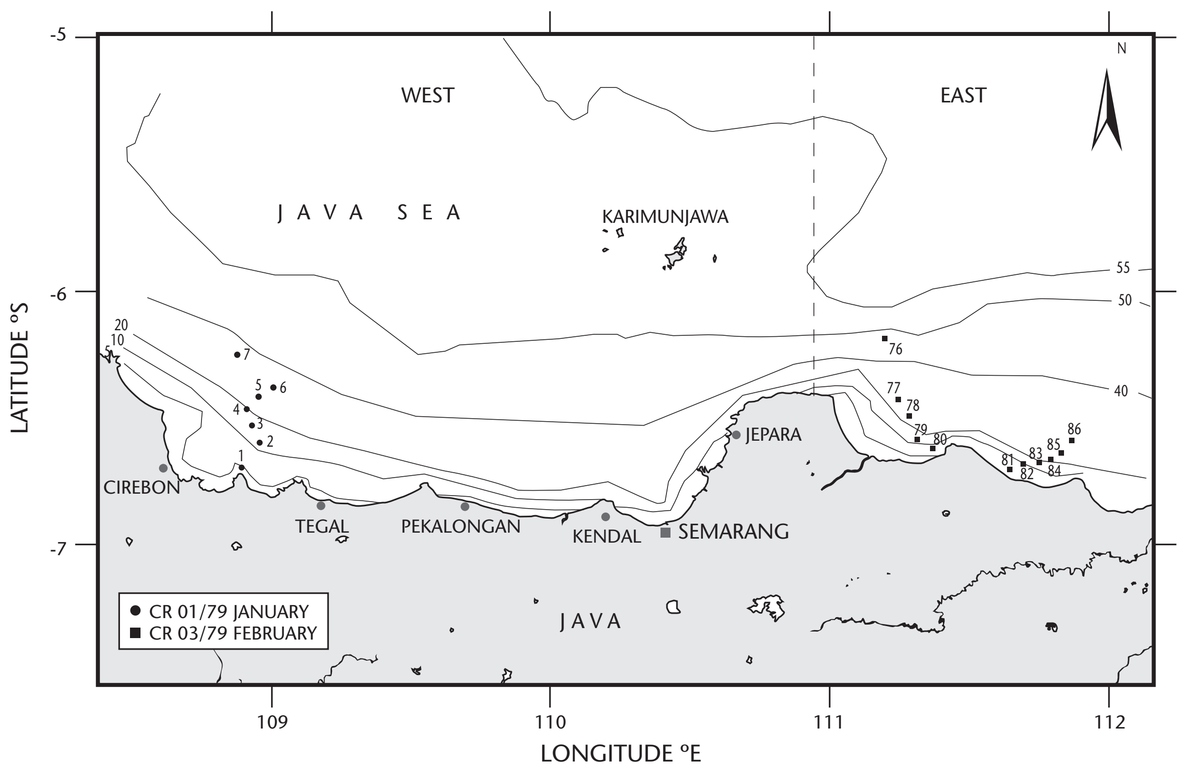

Fig. 1. Map of waters off the north coast of Central Java.

Results and Discussion

The two-way table generated from TWINSPAN and the ordination plot from DCA for the January and February (west monsoon period) trawl stations is given in Table 2 and Fig. 2 respectively. Two groups of stations were evident, each with a characteristic species composition. The first group (Table 2, Group A) consists of eleven stations, characterized by areas with depths of more than 20 m while the second group (Table 2, Group B) consists of seven stations associated with the shallow/coastal waters (< 20 m) (Fig. 3).

There are notable differences in species composition between the shallow and deep-water stations (Table 2). The taxa in species cluster 1a include, among others, of *Lutjanus sanguineus*, *Pomadasys argyreus*, *Pomadasys hasta*, *Scolopsis* spp. and *Abalistes stelaris*. These were observed to be absent in shallow water stations. Taxa in species cluster 2d consisting of Sciaenidae, Muraenidae and *Anodontostoma* spp. which were absent in deep water stations. Some taxa (e.g. species cluster 1d) species cluster such as *Priacanthus* spp., *Pentaprion longimanus,* Sphyraenidae, *Arius thalassinus* and *Nemipterus japonicus* were relatively more abundant in deep compared to shallow water stations.

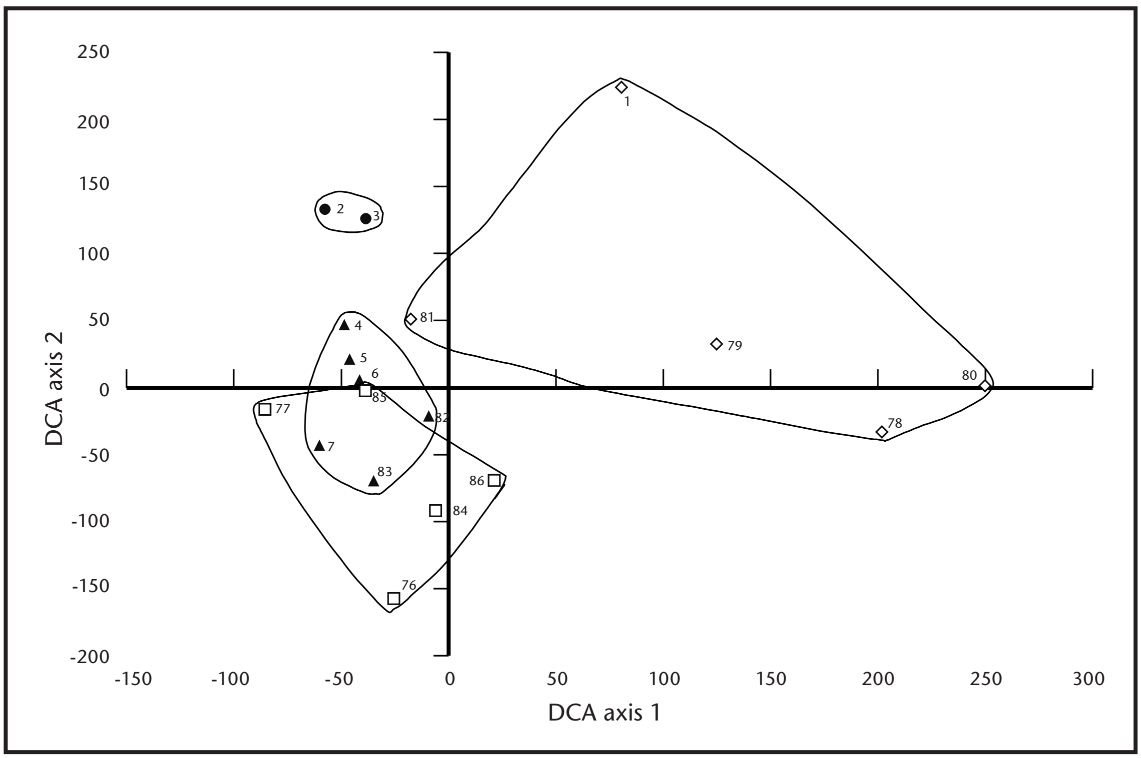

Fig. 2. Ordination plot from DCA of the stations fished during the west monsoon period (January - February 1979).

Table 2. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the west monsoon period (January - February 1979).

	Group A (20 - 30m)											Group B (< 20m)								
	76	77	84	85	86	4	5	6	7	82	83	78	79	80	1	81	2	3		
34 Other Lutjanidae	–	1	–	–	–	–	–	–	3	2	2	–	–	–	–	–	–	–	0 0 0 0 0	
36 *Pomadasys hasta*	–	–	1	–	–	–	1	–	–	2	2	–	–	–	–	–	–	–	0 0 0 0 0	
49 Drepaneidae	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	0 0 0 0 0	
41 Snakes	2	–	1	–	–	2	–	–	–	1	1	–	–	–	–	–	–	–	0 0 0 0 1	Spp cluster 1a
44 *Abalistes stellaris*	1	–	–	–	1	–	–	2	2	–	–	–	–	–	–	–	–	–	0 0 0 0 1	
60 Serranidae	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	0 0 0 1 0 0	
48 Other sharks	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0 0 0 1 0 1	
58 Pentaponidae	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0 0 0 1 0 1	
59 *Nemipterus marginatus*	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0 0 0 1 0 1	
64 *Upeneus bensasi**	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0 0 0 1 0 1	
20 *Lutjanus sanguineus*	2	4	1	1	–	2	–	–	2	1	2	–	–	–	–	–	–	–	0 0 0 1 1 0	
42 *Pomadasys argyreus*	1	2	1	–	–	–	1	2	1	–	–	–	–	–	–	–	–	–	0 0 0 1 1 0	
53 Other Pomadasyidae	1	2	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–	0 0 0 1 1 0	
54 *Carcharhinus sealei*	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	0 0 0 1 1 1	
57 *Scolopsis* spp.	1	–	1	1	–	–	–	–	1	–	1	–	–	–	–	–	–	–	0 0 0 1 1 1	
4 *Priacanthus* spp.	5	5	5	5	4	1	1	3	3	2	4	2	1	–	–	–	–	1	0 0 1 0	
26 Other Nemipteridae	2	3	1	–	1	1	1	1	1	–	2	–	–	–	–	1	–	1	0 0 1 0	
29 *Atule* spp.	1	–	3	1	2	–	1	–	–	1	1	–	–	–	–	1	–	–	0 0 1 0	
37 Other invertebrates	1	1	1	1	1	1	1	–	–	–	1	–	–	–	–	–	–	1	0 0 1 0	
14 *Pentaprion longimanus*	5	3	1	1	1	1	3	3	4	1	–	1	1	–	–	–	–	–	0 0 1 1 0	Spp cluster 1b
45 Heterosomata	1	1	1	1	1	1	1	1	1	1	–	–	–	1	–	–	–	–	0 0 1 1 0	
11 Sphyraenidae	1	2	3	2	2	2	1	4	4	4	4	1	–	–	–	2	–	–	0 0 1 1 1	
25 *Arius thalassinus*	1	1	1	1	–	1	2	1	1	2	2	2	–	–	–	–	–	–	0 0 1 1 1	
33 *Nemipterus japonicus*	1	1	1	1	1	1	1	2	2	1	2	1	1	–	–	–	–	1	0 0 1 1 1	
7 *Upeneus sulphareus*	4	5	5	3	4	1	3	3	4	–	1	1	1	3	–	2	1	1	0 1 0 0	
16 *Selar spp.*	–	3	3	2	1	–	1	–	4	–	1	3	–	–	–	1	–	1	0 1 0 0	
22 Synodontidae	2	3	1	1	2	–	1	1	2	–	1	1	–	1	–	2	–	1	0 1 0 0	
43 *Rachycentridae canadus*	–	–	2	–	–	–	1	–	–	–	1	–	–	–	–	1	–	–	0 1 0 1 0	
47 Lobster	1	–	–	2	–	–	–	–	–	–	1	–	–	1	–	1	–	–	0 1 0 1 1	Spp cluster 1c
50 Other rays	–	–	2	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	0 1 0 1 1	
55 *Leiognathus equulus*	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	0 1 0 1 1	
56 Polynemidae	–	1	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	0 1 0 1 1	

Table 2. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the west monsoon period (January-February 1979). (continued)

	Group A (20 - 30m)											Group B (< 20m)								
	76	77	84	85	86	4	5	6	7	82	83	78	79	80	1	81	2	3		
10 Trichiuridae	1	3	3	5	2	1	2	2	2	2	1	2	4	1	3	2	–	–	0 1 1 0 0 0	
30 Other food fish	1	2	1	1	1	–	–	–	3	1	–	1	1	1	1	1	–	–	0 1 1 0 0 0	
51 *Leiognathus bindus*	1	1	1	1	–	–	–	–	1	1	–	1	1	–	–	1	–	–	0 1 1 0 0 0	
6 Other Carangidae	2	4	5	3	2	3	3	3	2	4	4	2	3	3	1	3	1	2	0 1 1 0 0 1	Spp cluster 1d
19 *Selaroides leptolepis*	1	–	3	1	1	–	–	–	1	4	2	1	1	1	–	3	–	1	0 1 1 0 0 1	
39 Cuttles	1	2	–	–	1	–	1	1	1	1	1	–	1	1	1	–	–	1	0 1 1 0 0 1	
1 *Leiognathus splendens*	–	5	4	5	1	5	5	5	5	5	4	–	1	2	–	5	5	5	0 1 1 0 1	
27 Theraponidae	1	1	–	–	3	1	1	1	–	1	–	–	1	–	–	1	1	2	0 1 1 0 1	
32 Chirocentridae	–	–	–	2	–	–	1	1	–	3	1	–	1	1	–	–	1	–	0 1 1 1	
17 *Scomberomorus* spp.	2	–	–	–	1	3	2	2	2	3	1	2	1	1	1	1	1	2	1 0 0	
23 Dasyatidae	1	–	3	–	1	–	1	1	–	1	1	–	–	4	–	–	–	–	1 0 0	Spp cluster 2a
31 Formionidae	1	–	1	1	1	3	2	1	–	–	–	1	1	1	1	1	–	–	1 0 0	
9 Squids	3	3	2	3	2	1	2	2	1	2	–	2	4	5	1	2	1	2	1 0 1 0	
28 Stromatidae	–	–	2	1	1	1	2	–	–	1	–	–	–	1	2	1	1	–	1 0 1 0	
3 Other Leiognathidae	2	3	1	2	1	4	5	5	5	1	1	2	3	1	2	3	5	4	1 0 1 1 0	
5 Trash fish	2	3	3	3	1	1	2	2	2	5	4	1	3	3	1	5	3	2	1 0 1 1 0	Spp cluster 2b
35 Lactaridae	–	2	–	1	1	1	1	1	1	1	–	1	1	1	–	1	1	1	1 0 1 1 0	
18 *Dussumieria acuta*	–	–	1	1	–	1	5	1	1	–	–	2	2	1	1	–	1	1	1 0 1 1 1	
63 Shrimps	1	–	–	–	–	1	–	–	1	1	–	1	–	1	1	–	–	–	1 0 1 1 1	
8 *Alectis indicus*	2	1	1	4	3	1	1	3	1	2	1	4	3	5	1	3	1	1	1 1 0 0	
46 Crabs	–	1	–	1	1	–	–	–	–	–	–	1	1	1	1	–	–	–	1 1 0 0	
2 *Rastrelliger* spp.	1	–	2	2	2	1	1	1	1	2	1	3	4	5	–	2	2	4	1 1 0 1 0	
12 *Sardinella* spp.	–	–	1	3	1	1	1	1	1	1	1	5	2	4	1	1	1	–	1 1 0 1 0	Spp cluster 2c
38 *Illisha* spp.	–	–	–	1	–	1	–	–	–	–	–	–	–	–	3	–	1	1	1 1 0 1 0	
13 Other Ariidae	1	–	–	–	–	4	1	2	2	1	1	–	–	4	4	3	2	–	1 1 0 1 1	
21 *Stolephorus* spp.	–	–	–	1	1	–	1	4	1	1	–	1	1	3	2	1	1	1	1 1 0 1 1	
61 Other Mullidae	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	1 1 0 1 1	
24 Sciaenidae	–	1	–	–	–	–	–	–	–	–	–	1	1	1	2	4	–	–	1 1 1 0	
40 Other Engraulidae	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2	2	–	–	1 1 1 0	
52 Muraenesocidae	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	1 1 1 0	Spp cluster 2d
65 Other Gerreidae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1 1 1 0	
15 *Anadonstoma* spp.	–	–	–	–	–	1	–	–	1	–	–	–	–	–	1	1	5	5	1 1 1 1	
62 *Decapterus* spp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1 1 1 1	
	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1		
	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0	1	1		
	0	0	1	1	1	0	0	0	0	1	1	0	0	0	1	1				

(*U. japonicus)**
***valid name in FishBase 2000**

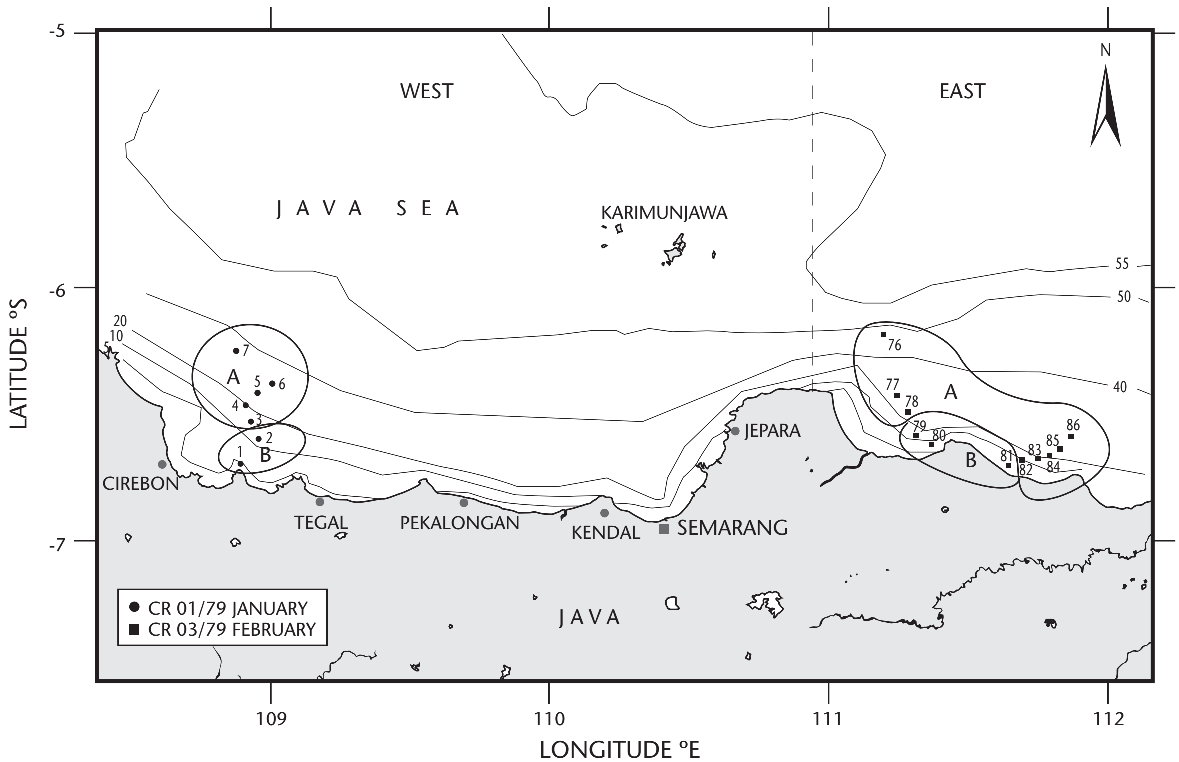

Fig. 3. Trawl stations off the north coast of Central Java in January and February 1979 showing station clusters derived using TWINSPAN and DCA.

In contrast, taxa belonging to species cluster 2c were more abundant in the shallower stations than the deeper ones. Its appears that taxa in species cluster 1c, 1d, 2a and 2b have almost the same abundance in both shallow and deep water stations. However, abundance of taxa in species cluster 1d and 2b was higher than those in species cluster 1c and 2a (e.g. *Leiognathus splendens* and squid) (Table 2).

During the intermonsoon I period (April and May 1979), 65 stations were included in the analysis. Two main station clusters were formed. The first cluster included stations with depth of less than 25 m, and the second cluster included stations in depths of 25 to 45 m (see Table 3, Figs. 4 and 5).

The species/groups in species cluster 1a, 1b and 1c preferred shallow waters below 25 m. Species/groups in species cluster 1a were abundant at depths < 20 m, but rare at stations with depths greater than 20 m. Species/groups in species cluster 2 preferred the deep stations (Table 3). Lactaridae, *Scomberomorus* spp., *Rastrelliger* spp., squid and *Leiognathus splendens* which belong to species cluster 1d were abundant both in shallow and deep stations; they are ubiquitous species/groups.

In species cluster 2, *Upeneus sulphureus*, *Stolephorus* spp. and *Pentaprion longimanus* were more abundant at 35 to 45 m deep stations. Serranidae, *Charcharinus sealea*, Pentapodidae, *Abalistes stelaris* and *Nemipterus margiatus* were observed to be absent at shallow water stations (< 25 m depth).

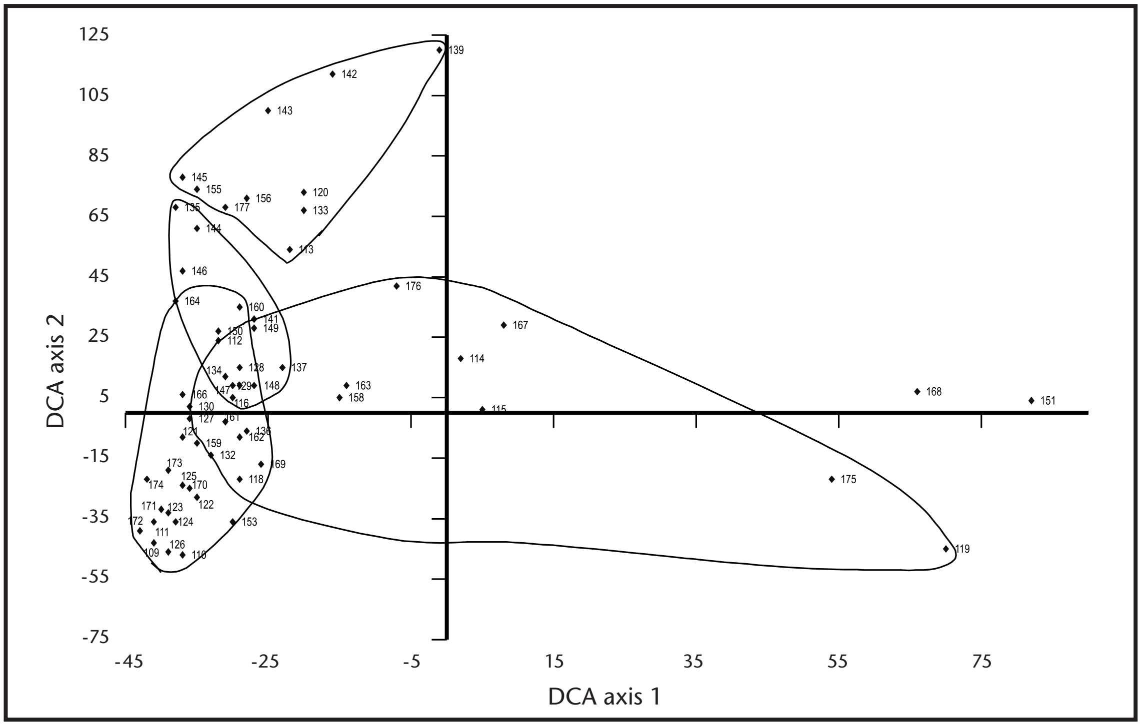

Fig. 4. Ordination plot from DCA of the stations fished during the intermonsoon I period (April - May 1979).

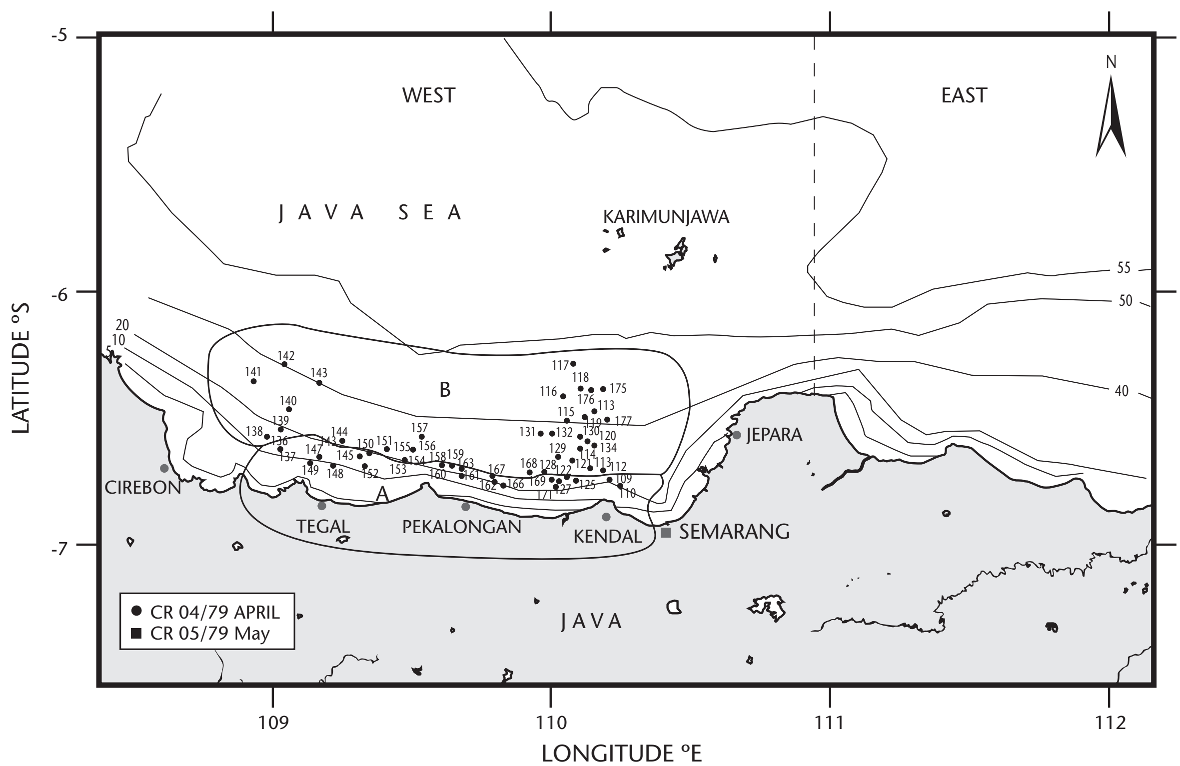

Fig. 5. Location of the trawl stations off the north coast of Central Java in April and May 1979 showing station derived using TWINSPAN and DCA.

Table 3. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the intermonsoon I period (April-May 1979).

	Group A		Group B			
	20<25m	<20m	25<35m	35-45m		
	147 150 135 137 146 148 149 153	110 111 124 125 126 109 121 122 123 168 169 170 173 163 164 171 159 172 174 160 161 162	131 138 152 144 145 177 120 139 142 143 140 141 151 113 127 128 134 155 156 167 168 136	112 116 114 129 130 132 115 118 133 175 176 119 158		
14 *Leiognathus equulus*	– – 2 – – 1 – 1	5 3 1 1 5 4 2 4 4 1 4 3 3 4 5 5 1 3 1 1 3 4	– – 2 1 – – – – – – – – – 1 2 – – – 1 1 1 –	– – – 1 – – – – – – – – –	0 0 0	
20 Polynemidae	– – – – – – – –	3 4 1 1 – 1 1 – – – 1 – 2 2 – 3 1 – – 5 1 –	– – 1 – – – – – – – – – – – – – – – – – – –	1 – – – – – – – – – – – –	0 0 0	Spp cluster 1a
8 Drepaneidae	– – – – – – – –	– 1 – – 1 – – – – – 1 – 1 – – 1 – – – – – –	– – – – – – – – – – – 1 – – – – – – – – – –	– – – – – – – – – – – – –	0 0 0	
7 Other Clupidae	– – – – – – – –	– – – – – – – – – – – – 1 – – – – 1 – 1 1 –	– –	– – – – – – – – – – – – –	0 0 0	
7 *Anadonstoma* spp.	3 4 2 1 3 3 1 1	3 5 4 5 4 5 5 2 3 5 4 2 5 3 3 5 4 5 5 5 3 4	– – 1 3 1 1 2 1 1 1 1 1 3 1 1 1 2 1 1 2 4 1	– 1 2 3 3 1 1 1 1 1 1 1 1	0 0 1	
28 Stromatidae	– – 2 2 – 1 – 5	3 3 1 2 5 1 2 3 2 – 4 2 3 4 5 5 5 6 4 2 5 5	2 – 2 1 – 1 1 – – – – 1 – 1 1 1 2 2 – 1 – –	– 2 2 2 2 2 2 2 1 – 1 2 3	0 0 1	Spp cluster 1b
21 *Pomadasys hasta*	1 1 – – – – – –	3 2 1 2 1 – – 1 – – – 1 – 1 – – 1 1 1 5 1 1	– – 1 – 1 – 1 1 – – – – – 1 1 – – – – 1 2 –	1 – – – – – – – – – – – –	0 0 1	
9 Other Engraulidae	1 1 – 1 1 1 1 1	3 1 1 – 1 1 – 1 1 1 1 1 1 3 3 2 3 1 4 2 2 1	– – – – – 1 1 1 – – – 1 – – 1 – – 1 1 1 – –	1 – – – – – – – – – – 1 1	0 0 1	
7 *Illisha spp.*	1 1 1 – – – 1 –	– – – – – 1 – – – – 1 – 1 – 1 1 – 1 1 – – –	– – – – – – – – 1 1 – 1 – – – – – 1 – – – 1	– – – – – – – – – – – – –	0 1 0 0 0	
5 *Alectis indicus*	3 4 4 5 3 5 4 5	5 3 4 5 4 4 1 2 4 3 5 3 5 3 3 5 3 3 1 5 4 4	1 5 1 4 4 1 1 2 1 1 1 2 2 1 1 3 – 3 3 4 1 2	2 2 2 1 3 1 2 2 1 2 4 2 4	0 1 0 0 1 0	
7 *Sardinella* spp.	2 1 3 4 1 3 3 1	2 2 3 4 4 3 1 1 3 2 3 1 1 2 4 2 1 2 1 3 2 1	1 3 1 1 1 1 1 2 1 1 1 1 1 1 1 1 – 1 1 1 1 1	4 1 1 1 1 1 1 – – – 1 – 1	0 1 0 0 1 0	Spp cluster 1c
33 Trash fish	1 1 4 1 – – – 1	2 2 1 2 1 2 3 2 3 4 3 4 2 2 2 1 2 2 2 4 3 5	– 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 2 2 2 3 –	1 2 1 1 1 1 1 2 1 1 1 1 1	0 1 0 0 1 1	
2 Dasyatidae	5 – – – – – – –	1 – – – 3 3 – – – 4 – 5 4 – – – 3 – 4 5 1 –	– 1 4 1 1 4 – 1 1 1 1 1 – – – 1 – – – – – –	– 1 1 – – – 1 – – 1 1 1 –	0 1 0 0 1 1	
32 Other food fish	– 1 1 2 1 – – 1	3 3 – 2 1 2 1 1 1 – – 1 2 – – 1 2 2 1 2 – 1	1 1 – – – 1 1 1 – – 1 1 – 1 1 1 – 1 1 1 1 1	2 1 – 1 1 1 – – – 1 – 1 –	0 1 0 0 1 1	
14 Other Leiognathidae	– – 1 – – – – –	3 5 1 2 5 4 3 1 1 1 2 3 1 3 2 3 2 1 2 4 4 4	– 1 1 1 – 1 – 1 – 1 1 1 1 1 2 1 – 1 2 1 3 –	1 1 1 1 1 1 – 1 – 1 1 1 2	0 1 0 1	
2 Other rays	– – – – – – – –	3 4 3 – – – – – – – – – – – – – – – – – – 4	– – – – – 3 – – – – – – – – – – – – – – – –	– – – – – – – – – 5 – – –	0 1 0 1	
13 Lactaridae	1 1 1 1 1 1 1 –	1 3 1 1 3 4 1 2 1 1 2 1 1 2 2 2 4 1 1 4 2 2	1 – 1 1 – 1 1 1 – – 1 1 1 1 1 1 1 1 2 1 1 –	1 1 1 1 1 1 1 2 1 1 1 2 3	0 1 1 0	
21 Other Pomadasyidae	– – – – – – – –	3 3 1 – 1 2 – – – – – – – 1 – – – – – – – –	– – – – – – – – – 1 – – – – – – 1 – – 1 – –	– – – – 1 – – – – 2 2 – –	0 1 1 0	Spp cluster 1d
11 Other Gerreidae	– – – – – – – –	– 2 1 – – – – – – – – – – 1 – – – 1 1 – – –	– – – – – – – – – – – – – 1 1 – – – – – – –	– – – – – – 1 – – – – – 1	0 1 1 0	
25 *Scomberomorus* spp.	4 4 3 2 1 1 1 2	– 1 2 2 1 1 3 2 2 2 4 2 1 4 3 2 3 1 1 1 2 3	2 1 2 3 1 2 2 – – – 1 3 2 1 – 2 2 2 2 2 2 1	– 3 2 2 3 2 1 2 1 1 1 2 4	0 1 1 1 0 0	
40 Snakes	1 1 – – – 1 – –	1 – – – 1 1 1 1 2 1 – 2 – – 1 3 – – – – – –1	– – – – 1 – 2 – – 2 – – 1 – – – – – – – – –	– 1 – – 1 – 1 1 – – – 2 –	0 1 1 1 0 0	
25 *Rastrelliger spp*	2 5 5 1 5 1 2 4	3 4 5 3 2 3 4 2 4 1 5 3 5 5 5 5 5 – 2 5 2 2	1 1 2 5 5 5 3 1 2 3 1 2 – 3 1 3 3 5 4 1 5 1	4 3 4 3 5 2 6 – 1 4 5 2 –	0 1 1 1 0 1	
5 Other Carangidae	1 1 1 4 1 1 1 1	2 2 3 2 5 2 4 3 4 3 3 3 1 4 3 4 3 3 1 5 5 5	1 3 3 1 1 3 2 1 1 2 1 1 1 4 1 3 2 3 2 3 3 1	3 4 3 3 3 2 5 2 2 4 3 2 2	0 1 1 1 0 1	
34 Squids	1 1 2 2 1 1 1 1	1 1 2 3 3 1 2 2 3 2 1 2 2 4 4 3 3 3 2 4 4 3	2 2 1 2 1 1 3 4 1 3 4 2 1 3 2 2 2 4 5 3 – –	1 2 3 2 2 4 2 2 2 2 2 2 2	0 1 1 1 0 1	

Table 3. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the intermonsoon I period (April-May 1979). (continued)

	Group A		Group B			
	20<25m	<20m	25<35m	35-45m		
	147 150 135 137 146 148 149 153	110 111 124 125 126 109 121 122 123 168 169 170 173 163 164 171 159 172 174 160 161 162	131 138 152 144 145 177 120 139 142 143 140 141 151 113 127 128 134 155 156 167 168 136	112 116 114 129 130 132 115 118 133 175 176 119 158		
3 Other Ariidae	3 3 1 2 1 1 1 2	5 4 – – 1 3 4 4 2 – 3 5 2 2 – 3 3 – – 4 1 3	1 1 1 1 – – 1 – – – 1 1 1 4 – 3 2 1 1 1 3 4	1 3 1 2 4 – – 2 1 2 2 4 5	0 1 1 1 0 1	
27 Sphyraenidae	1 – 1 – – – – –	4 4 1 – 1 1 2 2 – 1 1 2 – 3 3 1 2 – 1 4 5 4	– 3 1 1 – 1 2 1 – – – – – 2 1 1 1 1 1 1 2 –	2 1 1 2 2 1 1 1 1 1 2 1 3	0 1 1 1 0 1	
30 Theraponidae	– – – – 1 – – 1	2 – 1 2 4 1 2 1 2 2 1 1 – 1 1 1 1 – 1 4 2 4	– 1 1 1 1 – 1 – 1 – 1 – 1 1 1 1 1 1 1 2 1 –	1 1 1 1 – 1 1 1 1 – 1 1 2	0 1 1 1 0 1	
5 *Megalaspis cordyla*	– – – – – – – –	– – 1 1 1 1 1 3 1 – – – – – – – – – – – – –	– – – – – – 1 – – – – – – 2 1 1 1 – – – – –	1 1 – 2 1 – – – – – – – –	0 1 1 1 0 1	
24 Sciaenidae	– – – – – 1 – –	2 1 – – 3 1 – – – – 1 1 1 1 2 1 1 1 1 1 1 1	– – – – – 1 – – – – – 1 1 1 – 1 1 1 – 1 – 1	1 – 1 – 1 1 – – 1 1 1 – –	0 1 1 1 0 1	Spp cluster 1d
14 *Leioguathus splendens*	– – 2 – – – – –	5 5 5 5 5 5 5 5 5 – 5 5 5 5 4 5 5 5 4 – 4 3	1 – 3 – – 2 1 – 1 – 1 3 – 1 2 3 4 1 4 1 3 –	4 5 5 3 4 4 5 5 2 5 4 5 4	0 1 1 1 1 0	
31 Trichiuridae	3 2 – 1 1 1 – 5	– 1 5 5 5 – 1 4 5 – 5 5 1 1 1 5 2 1 – 2 1 2	2 – 3 1 1 1 1 1 1 1 – 1 1 1 1 3 1 1 1 1 1 1	1 3 3 5 5 3 2 1 1 1 3 2	0 1 1 1 1 0	
7 *Dusssumieria acuta*	1 1 1 1 1 1 – 1	1 2 – 1 1 1 1 2 – – 3 2 2 3 3 3 – 2 1 1 4 2	1 – 1 1 – 1 – – – – – 1 1 1 1 1 1 1 – – 1 –	2 4 2 2 1 – 2 2 1 1 2 1 1	0 1 1 1 1 0	
14 *Leiognathus bindus*	– – 1 – – – – –	1 – – – 1 1 – 1 1 – 1 1 1 1 1 1 1 1 1 1 1 1	– 1 – – – – – – – – 1 – – – – 2 1 – – 1 – 1 –	– 1 1 1 – 1 – 1 1 1 1 1 1	0 1 1 1 1 0	
6 Chirocentridae	– – – – – – – –	– – 1 – 1 1 – 1 – – – – 1 1 – 1 1 1 1 – 1 2	– – – – – – – – – – – – – 1 – 1 – 1 – – – 1	– 1 – – – – 1 1 1 – 2 1 –	0 1 1 1 1 1	
9 *Stolephorus* spp.	– 1 – – – – – –	– 1 1 1 1 1 1 1 1 1 1 1 1 2 3 1 2 1 1 1 3 1	– 1 – – – 1 1 – – 1 – 1 – 1 1 1 1 1 1 1 1 –	3 4 4 4 4 2 1 2 1 1 1 1 1 2	1 0 0	Spp cluster 2a
23 *Rachvcentridae canadus*	– – – – – – – –	– – – – – – – – – – – – – 3 – – – – – – – –	– – – 1 – 1 – – – – – – – – – – – – – 1 2 – –	– – – – – – – – – – – – –	1 0 0	
16 *Upeneus sulphureus*	– – – 1 1 1 1 –	– 1 – – – 1 1 1 – 1 1 1 1 1 2 1 3 1 1 5 2 3	1 1 1 1 – 1 1 – 1 – 1 1 1 1 1 1 1 1 2 1 2 –	3 4 1 1 1 1 2 2 1 2 3 1 3	1 0 1	
11 *Pentaprion longimauus*	– 1 – – – – – –	1 – 1 1 2 1 1 1 1 – 1 1 1 1 – 1 3 1 1 4 2 3	1 – – – – 1 1 1 1 1 1 1 1 1 1 1 1 1 3 1 1 –	2 4 2 1 1 2 2 3 2 4 2 2 2	1 0 1	Spp cluster 2b
3 *Arius thalassinus*	– – – – – – – –	2 – 1 – – 2 1 – – – – 1 – – – – – – 1 – 1 – 4	– – – 1 – – 1 1 – – – – – – 1 – – 1 – – – 2 –	2 1 1 1 – 1 1 2 – 2 1 – –	1 0 1	
29 Synodontidae	– 1 – 1 1 1 1 1	– – – – – 1 2 1 – – 1 – – 1 – – 1 – 1 2 1 1	– – 1 1 1 1 1 – – 1 – – 1 1 1 1 1 1 1 1 1 –	1 1 1 1 1 1 – – – 1 1 1 1	1 0 1	
37 Crabs	1 1 – – 1 – 1 –	– 1 – – 1 – 1 – 1 – 1 1 1 – – – – – – – 1 – –	– – – – 1 1 3 1 – – – – – 1 – 1 1 – – 1 1 –	– 1 – – – 1 – – – – – – – 1	1 1 0	
1 Other sharks	– – 1 – – – – –	– –	– – – – – – 4 – – – – – – – – – – – – – – – –	– – – – – – – – – – – – –	1 1 0	Spp cluster 2c
5 *Atule* spp.	– – – – 1 – – –	– – – – 1 – – 1 – – – – – – – – – – – – – –	– 1 – 1 1 – – 1 – 1 – – – 1 1 – – – – – – – –	– – 1 – – – – – – – – – –	1 1 0	
10 Formionidae	1 1 1 – 1 1 – –	– 1 – 1 – 1 – 1 1 – – – – 2 – – 1 – – – – – –	1 1 1 1 1 – 1 1 2 2 1 – 1 1 – 1 2 1 3 1 – –	1 2 1 – – – 1 1 – 1 1 – 1	1 1 1 0 0	
35 Cuttles	– – 1 1 1 – – –	1 – 1 – 1 – 2 – – – 2 – – 1 – – – – – – – – –	– – 1 – – – 1 – 1 – 1 – 1 1 – 1 1 1 1 – 1 –	– – 1 – – – – – – 1 – – – –	1 1 1 0 0	
18 *Nemipterus japonicus*	– – – – – – – –	– – – – 1 1 1 – 1 1 1 1 – 1 – – – – – – 1 1 –	1 – – – – – 1 1 1 – 1 1 – 1 – 1 – 1 1 – 1 –	– 1 2 – – – 2 – – 3 1 4 1	1 1 1 0 0	Spp cluster 2d
38 Lobster	– – – – – – – –	– – – – – – – – 1 – – – – – – – – – – – – – –	– –	2 – 3 2 2 2 2 3 2 3 2 3 3	1 1 1 0 0	
15 *Lutjanus sanguineus*	– – – – – – – –	– – – – – – – – 1 – – 2 1 – – – – – 1 – – 1 – 1	5 – – – – – – – – – – 1 – – – – 1 – – – 2 1 –	– 1 – 1 1 – 1 – – 3 2 1 2	1 1 1 0 1	

Table 3. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the intermonsoon I period (April-May 1979). (continued)

	Group A		Group B			
	20<25m	<20m	25<35m	35-45m		
	147 150 135 137 146 148 149 153	110 111 124 125 126 109 121 122 123 168 169 170 173 163 164 171 159 172 174 160 161 162	131 138 152 144 145 177 120 139 142 143 140 141 151 113 127 128 134 155 156 167 168 136	112 116 114 129 130 132 115 118 133 175 176 119 158		
5 *Selar* spp.	– 1 – 1 – – – –	– – – 1 – 1 1 2 – – 1 1 – – – – – – – 4 2 –	1 1 1 – – 1 3 1 5 3 1 1 1 4 – 1 1 – 3 2 3 –	2 – 3 2 2 2 2 3 2 3 2 3 3	1 1 1 0 1	
5 *Selaroides leptolepis*	– – – 1 – – – –	– – – – – 1 – – 1 – – – – – – – 1 – – 3 1 1	2 1 1 1 1 1 – 1 – 1 1 1 1 1 1 – – – 1 – – –	– 1 – 1 1 – 1 – – 3 2 1 2	1 1 1 0 1	
21 *Pomadasys argyreus*	– – 2 – – – – –	– – – – – – – – – – – 1 – – – – – – – – – –	– – – – – – – – – – – – – – – – – – – 1 1 –	– 1 – – – 1 1 1 1 1 1 1 –	1 1 1 0 1	
15 Other Lutjanidae	– – – – – – – 2	– – – – 1 – – – – – – – – 3 – – – – – – – –	5 5 5 – – – 1 1 – – – – 2 1 – – – – 1 – 4 –	1 1 1 1 – – – – – 2 1 1 1	1 1 1 1 0 0	
26 Serranidae	– – – – – – – –	– –	– – – – – 1 1 1 1 – 4 – – – – – – – – – – –	– 1 – – 1 – – – 1 – 1 – –	1 1 1 1 0 0	
39 Other invertebrates	– – – – – – – –	– –	– – – – – 1 1 1 1 1 1 1 1 1 – – 1 – – – 1 –	– – 1 – 1 1 – – 1 1 1 – –	1 1 1 1 0 0	
18 Other Nemipteridae	– – – – – – – –	– – – – – – 1 – – – – – – – – – – – – 1 – –	1 1 1 1 – – 1 1 1 1 1 1 1 1 – – – – – 1 1 –	1 1 1 1 1 1 1 1 1 1 1 1 –	1 1 1 1 0 1	Spp cluster 2d
1 *Carcharbinus sealei*	– – – – – – – –	– –	– – – – – 3 – – – – – – – – – – – – – – – –	– 2 – – – – – – – – – – –	1 1 1 1 0 1	
16 Other Mullidae	– – – – – – – –	– –	– – – – – – – 1 – – – – – – – – – – – – – –	– – – – – – 1 – – – – – –	1 1 1 1 0 1	
22 *Priancanthus* spp.	– – – – – – – –	– – – – – 1 1 1 – – – – – – – – – – – 1 1 –	1 1 – – – – 1 1 1 – 1 1 – 1 – 1 1 – 1 – 1 –	1 2 2 2 1 3 1 2 1 1 2 2 1	1 1 1 1 1 0	
19 Pentapodidae	– – – – – – – –	– –	2 – – – – 1 – 1 – – – – – – – – – – – – – –	– – – – – – – 1 – 1 1 – –	1 1 1 1 1 0	
4 *Abalistes stellaris*	– – – – – – – –	– –	– – – – – – – – – – – 1 – – – – – – – – 1 –	– – – – 1 – – – 1 1 – – –	1 1 1 1 1 0	
36 Shrimps	– – – – – – – –	– –	– – – – – – – – – – – – – – – – – 1 – – – –	– – – – – 1 – – – – 1 – –	1 1 1 1 1 0	
18 *Scolopsis spp*	– – – – – – – –	– –	– – – – – – – 1 – – – – – – – – – – – – – –	– 1 – – – – 1 1 1 1 1 – –	1 1 1 1 1 1	
12 Heterosomata	– – – – – – – –	– –	– 1 –	– 1 1 – – 1 – – 1 – 1 – –	1 1 1 1 1 1	
42 Sponges	– – – – – – – –	– –	– –	– – – – – – 2 1 – – – – –	1 1 1 1 1 1	
18 *Nemipterus marginatus*	– – – – – – – –	– –	– –	– – – – – – – – – 1 – – –	1 1 1 1 1 1	
	0 0 0 0 0 0 0 0	0000000000000000000000	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1		
	0 0 0 0 0 0 0 0	1111111111111111111111	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1		
	0 0 1 1 1 1 1 1	0000000000000000000111	0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0 0 0 0 0 0 1 1 1 1 1 1 1		
	0 1 1 1 1 1	0011111111111111111	0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0 1 1 1 1 1 0 0 0 0 0 1 1		
	0 0 0 0 1	000000000000111111	0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1	0 1 1 1 1 0 0 0 1 1		
		000111111111000111	0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 1			

A total of 49 stations were finally included in the analysis for the intermonsoon II period (September and October 1979). Two major groups of stations were observed (Table 4, Figs. 6 and 7). One group was associated with shallow water stations (0 - 30 m) and the other group was associated with stations of more than 30 m depth. Some species in species cluster 1a, such as *Gazza minuta, Arius maculatus, Leiognathus equulus*, *Ilisha* spp., *Arius caelatus, Pomadasys hasta,* Drepanidae, and Polynemidae were abundant in shallow stations. Some species in species cluster 2d such as *Abalistes stelaris, Atule* spp. *Lutjanus sanguineus, Scolopsis* spp. and *Nemipterus nemurus* were found mainly in deep stations.

Taxa which belong to species cluster 1d, 2a and 2b were found to have the same abundance in shallow and deep water stations (e.g., *Leiognathus splendens, Priacantus* spp., *Sphyraena* spp.). These ubiquitous species/groups dominate catches in the study area. Species/groups that were abundant in shallow water stations (and rare in deep waters) include Dasyatidae, *Alectis indicus*, Sciaenidae, *Sardinella* spp., *Anadontostoma* spp. *Stolephorus* spp. Lactaridae, Stromatidae, *Thryssa* spp. and *Leiognathus brevirostris* (species cluster 1b). Species/groups which belong to species cluster 2c, such as *Priacanthus tayenus, Nemipterus mesoprion, Atropus atropus, Upeneus sulphureus, Pentaprion longimanus, Selaroides leptolepis, Selar* spp. and *Leiognathus bindus* were more abundant in deep than in shallow stations. A summary of the most important species/groups comprising the shallow and deep assemblages during the three time periods considered here is given in Table 5 and 6. The species clusters were observed to be similar across seasons (i.e. there is consistency in taxa associated with the shallow versus deep stations).

The scope of the present study was limited by data constraints. These include the design of the trawl survey in 1979, the sorting and identification of catches, and availability of relevant environmental data. Best use of the data was attempted despite these constraints and has produced some insight into the species assemblages in the region. The results indicate the existence of shallow and deep and shallow assemblages with a boundary at around 20 - 30 m depth. This is consistent with the findings of (Bianchi et al. 1996).

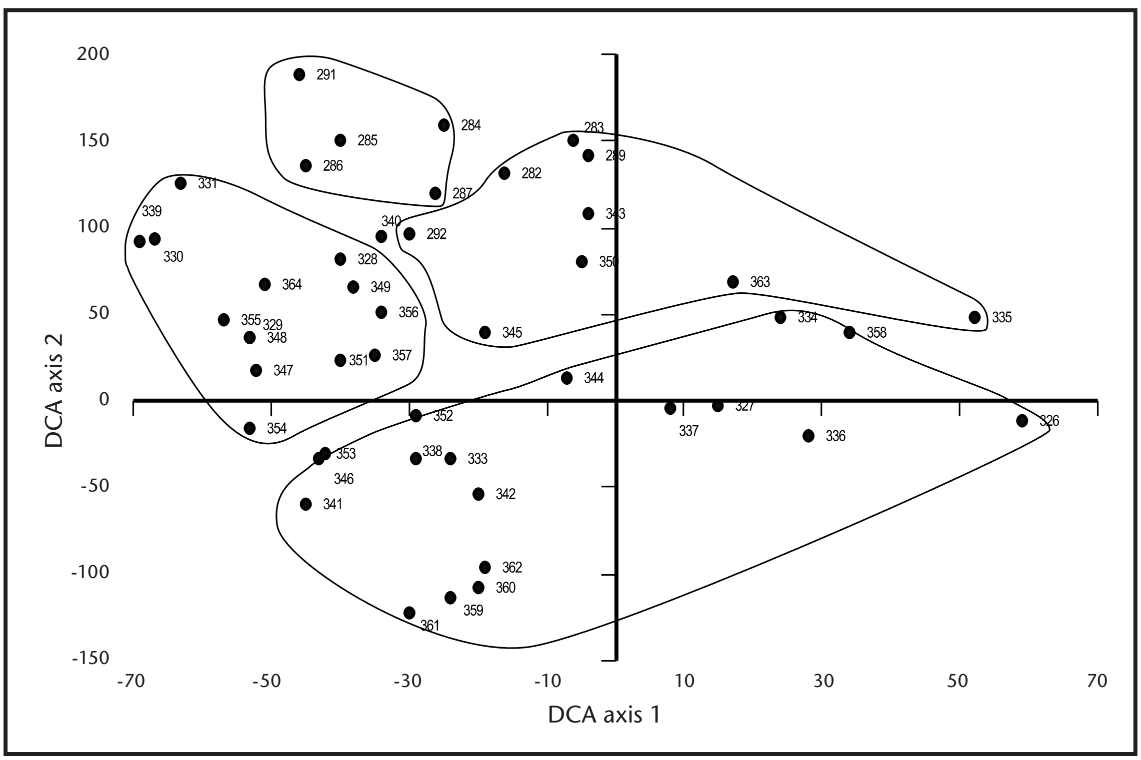

Fig. 6. Ordination plot from DCA of the stations fished during the intermonsoon II period (September - October 1979).

Table 4. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the intermonsoon II period (September-October 1979).

	Group A (< 30m)	Group B (> 30m)		
	346 360 361 362 334 336 337 359 343 326 327 333 336 341 347 354 353 344 346 351 352 290 336 383 364 282 283 288 289 292	328 357 350 358 365 339 340 348 349 355 356 329 330 331 284 287 285 286 291		
14 *Gazza minuta*	– 4 1 – – 1 – 1 1 1 – 1 1 1 – 1 – – 1 – – – – – – – – – – –	– – – – – – – 1 – – – – – – – – – – –	0 0 0 0	
3 *Arius maculatus*	– – 1 – – – – – 2 1 – 2 1 – – – – – – – – – – – – – – – – –	– – – – – – – – – – – – – – – – – – –	0 0 0 0	
3 Other Ariidae	– – – – – – – – 1 – – – 1 1 – – – 1 – – – – – – – – – – – –	– – – – – – – – – – – – – – – – – – –	0 0 0 0	
7 Other Clupidae	– 2 –	– – – – – – – – – – – – – – – – – – –	0 0 0 0	Spp cluster 1a
8 Drepanidae	1 – – – 2 – – 2 – – – 1 – – – – – – 1 1 – 5 2 1 1 – 1 – – –	– – – – – – – – – – – – – – – – – – –	0 0 0 1 0	
14 *Leiognathus equulus*	1 – 2 – 2 2 2 3 4 4 – 1 – – – – 1 1 1 1 1 1 – – 2 – – – – –	– – – – – – – – – – – – – – 1 – – – –	0 0 0 1 1 0	
20 Polynemidae	– – – 1 – – 1 – 1 4 2 – 1 – – – – 1 – 1 – – 2 – – – – – – –	– – – – – – – – – – – – – – – – – – –	0 0 0 1 1 0	
7 *Illisha* spp.	– 2 – 1 1 – – – – – 1 1 – – – – – – – 1 – – 1 – – – – – – –	– – – – – – – – – – – – – – – – – – –	0 0 0 1 1 0	
3 *Arius caelatus*	1 1 2 1 – 4 2 2 – 5 4 – 1 – – – 1 – – 1 – 5 2 1 1 – – 4 1 –	– – – – – – – – – – – – – – – – – – –	0 0 0 1 1 1	
21 *Pomadasys hasta*	2 4 4 3 4 2 1 3 3 3 3 1 1 1 1 – 1 4 1 2 1 – 5 2 3 – 2 – – 3	– – – – – – – – – – – – – – – – – – –	0 0 0 1 1 1	
2 Other Rays	– – – – – – – – – – 5 – – – – – – 4 – – – – – – – – – – – –	– – – – – – – – – – – – – – – – – – –	0 0 0 1 1 1	
2 Dasyatidae	4 1 4 4 2 4 1 1 4 1 – 2 2 1 – – 2 5 5 5 – 2 4 4 4 2 4 5 2 –	– – – – 1 1 1 2 – – – 2 2 1 1 – 5 – 4	0 0 1 0	
5 *Alectis indicus*	– – – – 1 1 1 3 – 1 1 – – – – – – 1 – – – 1 – – 1 4 3 2 4 3	– – 1 – – 1 – – – – – – – – 2 1 – – 1	0 0 1 0	
23 *Rachycentridae canadus*	– – – – – 1 1 – 1 1 – – – – – – – – – – – – – – 1 – 1 1 – 1	– – – – – 1 – – – – – 1 – – – – – – –	0 0 1 0	
6 Chirocentridae	– – 1 – – 1 – – – – – – – – – – – – 1 1 – – – – – – – – – –	1 – – – – – – – – – – – – – – – – – –	0 0 1 0	
14 Other Leiognathidae	5 4 2 4 2 1 3 2 2 4 5 1 2 2 1 3 3 1 1 1 1 2 2 4 2 4 1 2 2 3	– 1 1 1 1 1 1 1 1 1 1 2 – – 1 1 2 1 1	0 0 1 1 0	
24 Sciaenidae	3 2 3 1 2 3 4 2 3 1 3 1 – – 1 1 6 1 1 1 1 1 3 3 1 1 1 2 1 2	– 3 1 1 – 1 – – 1 – – – 1 1 1 3 – – –	0 0 1 1 0	Spp cluster 1b
7 *Sardinella* spp.	2 – 2 2 2 2 1 1 3 3 2 1 1 1 4 2 1 1 1 2 1 1 1 – 1 1 1 1 3 1	1 1 1 1 1 – 1 1 1 1 – – – – 1 1 – – 1	0 0 1 1 0	
11 Other Gerreidae	1 – 2 2 2 2 – 1 1 1 – – – – – – – 2 1 – – – 1 1 1 1 1 – – –	– – 1 – – – – – – – – – – – 1 – – – –	0 0 1 1 0	
7 *Anadonstoma* spp.	1 – 1 2 1 1 1 2 3 3 2 2 2 4 3 4 1 – – – – 1 2 3 1 2 – 1 1 –	1 1 1 1 1 – – 1 3 1 – – – – – – – – –	0 0 1 1 1 0	
9 *Stolephorus* spp.	– 2 1 5 1 1 1 1 1 2 4 2 2 1 1 3 2 – – – – 1 1 – 1 – 1 – 1 3	1 – – – – – – 1 1 1 1 1 – 1 – 1 1 – –	0 0 1 1 1 0	
13 Lactaridae	– 1 1 2 1 1 2 1 1 2 2 1 1 1 1 2 1 – 1 1 1 – 1 – – 1 1 – 1 1	1 – – – 1 – – – – 1 1 – – – – 1 1 – –	0 0 1 1 1 0	
28 Stromateidae	2 1 2 2 3 3 1 2 4 5 2 3 4 1 – 3 1 – 1 1 1 – 2 3 1 – 1 1 2 –	– 2 – – – – 1 2 – – 2 1 – – 1 1 1 – –	0 0 1 1 1 1	
9 *Thryssa* spp.	– 2 1 2 – 1 3 – 3 2 2 – 1 1 1 – 4 1 – 1 – – 1 1 1 – – – 1 –	– – – – 1 – 1 – – – – 1 – – – 1 – – –	0 0 1 1 1 1	
4 *Leiognathus bevirostris*	– 4 3 3 1 2 2 2 1 1 – 1 1 1 1 1 1 1 1 1 1 – 3 1 1 – – – – –	– – 1 1 1 1 – – – – – – – – – – – – –	0 0 1 1 1 1	
21 *Nemipterus* spp.	1 – – – 1 1 – 1 4 2 – – – 1 – – – 1 1 – – – – – – 1 – 1 – – –	– – – – – – 1 – – – – – – – – 1 – – – –	0 0 1 1 1 1	
5 *Alepes* spp.	3 2 2 2 2 2 2 1 4 1 2 1 3 5 5 5 5 2 1 2 3 – 1 1 1 – – – – –	2 1 1 1 1 1 – 1 2 3 2 2 1 – – – – – –	0 1 0	
3 *Osteogeneosis milit*	1 – – – 3 1 2 – 2 4 1 2 3 1 – – 2 – 1 – – – 1 – 1 – 1 – 1 –	3 3 – 1 – – – – – – – – – – 1 – – – –	0 1 0	Spp cluster 1c
14 *Secutor insidiator*	1 3 2 – 1 1 1 1 – 1 2 – – 1 1 3 – 1 – – 1 – 1 – – – – – – –	1 – – – – – – 1 1 1 2 1 – – – – – – – –	0 1 0	
5 *Carangoides* spp.	– – – – – – – – 1 2 1 1 1 – – – – – – – – – – – – – – – – – –	2 – – – – – – – – – – – – – – – – – –	0 1 0	
14 *Leiognathus splendens*	5 5 5 5 – 5 5 4 5 5 5 5 5 4 1 5 4 1 5 1 1 – 1 5 2 1 – 1 1 –	1 2 1 2 1 1 2 5 4 5 4 5 – – 1 – 1 1 –	0 1 1 0	

Table 4. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the intermonsoon II period (September - October 1979). (continued)

	Group A (< 30m)	Group B (> 30m)		
	346 360 361 362 334 336 337 359 343 326 327 333 336 341 347 354 353 344 346 351 352 290 336 383 364 282 283 288 289 292	328 357 350 358 365 339 340 348 349 355 356 329 330 331 284 287 285 286 291		
7 *Dussumieria acuta*	4 3 2 1 2 3 3 2 3 2 3 3 2 2 4 3 1 1 1 1 – 1 1 1 1 – 1 1 3 4	2 1 – – – – 1 2 4 1 5 1 – – – 2 – – –	0 1 1 0	
5 *Megalaspis cordyla*	1 2 1 – – 2 4 1 1 – – – 2 2 2 2 3 – 1 1 1 1 1 – 1 1 1 1 1 3	1 1 1 – – – – 1 1 – – 1 1 – 5 – – – –	0 1 1 0	
30 Theraponidae	2 2 1 – 1 2 2 2 2 1 1 1 1 2 3 1 1 1 2 1 1 1 1– 1 – 1 3 1 1	1 1 1 1 1 1 1 1 1 1 – 1 1 1 2 – 2 – –	0 1 1 0	
33 Trash fish	4 5 3 3 4 3 3 4 3 – 1 2 3 3 2 2 4 2 3 3 2 3 4 – 2 3 4 3 3 3	2 2 2 2 2 2 2 1 2 2 1 3 3 1 5 3 3 5 3	0 1 1 1 0 0	Spp cluster 1d
22 *Priacanthus* spp.	3 5 5 5 3 3 3 2 4 1 3 1 3 5 5 5 5 3 2 3 3 1 2 1 2 1 1 1 1 3	2 1 2 1 1 1 1 3 3 4 2 3 2 1 2 1 2 3 4	0 1 1 1 0 0	
27 Sphyraenidae	1 – 1 1 1 4 1 1 4 1 – 2 – 2 2 – 3 1 2 1 1 1 1 – 1 2 2 1 1 1	1 2 1 1 1 1 2 2 3 1 – 2 1 – 2 1 1 3 –	0 1 1 1 0 0	
32 Other food fish	1 5 5 5 2 2 2 1 1 1 2 1 1 – 1 – – 2 2 1 1 1 2 – 1 1 1 1 1 –	– – 1 – 1 1 1 3 2 3 – 3 2 1 1 1 1 1 1	0 1 1 1 0 1	
25 *Scoberomorus* spp.	2 2 1 – 2 2 2 1 1 – – 2 1 2 2 1 3 1 2 1 1 1 2 1 – – – – 2 2	1 2 1 1 1 1 2 2 1 1 3 2 – 1 1 – 2 – –	0 1 1 1 0 1	
16 *Nemipterus lolu*	– – – – – – – – – – – – – – – – – 1 – – – – – – – 1 – – – – –	– – – – – – – – 1 – – – – – – – – – – – –	0 1 1 1 1 1	
5 Other Carangidae	– – – – – 1 1 – 1 – 3 1 1 1 1 – 1 2 1 1 – 1 – – – 3 3 2 3 2	2 – – 1 1 1 – – – – – – – – – 5 3 2 1 3	1 0 0 0	
37 Crabs	– – – 1 – 1 1 – – – – – – 2 1 – – 1 1 1 – – – – – 1 1 1 1 1	– 1 1 – 1 – – – – – – – – 1 – 1 1 –1 1	1 0 0 0	
25 *Rastrelliger* spp.	– – – 1 – 2 1 – – 5 4 – – 2 4 3 4 – – 2 2 1 1 3 1 5 2 1 3 2	1 2 3 – 1 1 1 1 3 3 3 2 2 1 5 3 1 – –	1 0 0 1	Spp cluster 2a
34 Squids	2 – 1 – 2 1 1 1 – 1 2 1 2 1 1 – 1 1 1 1 1 1 1 2 1 1 1 1 2 4	1 1 1 1 1 2 1 1 1 1 – 1 1 – 2 – 1 3	1 0 0 1	
5 *Caranx* spp.	– – – – 1 1 1 2 2 – – 3 3 1 2 1 – 1 2 1 – – – 2 1 – – – – –	– 1 1 1 1 3 1 2 2 1 1 2 – 1 – – – – –	1 0 0 1	
39 Other invertebrates	– – – – – 1 1 1 1 1 – 1 2 1 2 – 1 1 1 1 1 – – – – – – – 1 –	1 1 1 1 1 1 1 1 – 1 – 1 – 1 1 1 – 1	1 0 1 0	
10 Formionidae	– 2 3 – – 1– – – – – – 1 1 – 1 – – – 1 1 – – – – – 1 – 1 1	1 1 – – – – 1 1 – 1 2 1 1 – 2 1 1 – –	1 0 1 1 0 0	
3 *Arius thalassinus*	– – 2 – 1 – – 2 1 2 4 3 1 1 3 – – – – 1 – – 2 – – 1 2 1 3 2	2 2 1 – – 1 1 2 1 – – 4 1 – 4 1 1 1 2	1 0 1 1 0 1	
35 Cuttles	– – – – 1 1 – – 1 – – 1 2 1 2 1 1 1 1 1 1 1 1 – 1 2 2 1 1 1	1 – 1 1 1 – 1 1 1 – 1 1 1 1 2 1 1 1 2	1 0 1 1 0 1	
12 Heterosomata	1 1 – – – 1 – 1 – – 1 1 1 1 1 3 – – 1 1 – – 1 1 1 2 1 1 1 1	1 – 1 1 1 1 1 1 1 – 1 1 1 1 1 1 1 2 1	1 0 1 1 0 1	Spp cluster 2b
31 Trichiuridae	– – – 1 – – 1 – 1 1 1 1 1 1 1 – – 1 – 1 1 – – – – – 1 1 1 3	1 1 – – – 1 1 – – 1 1 1 1 1 1 1 2 1 –	1 0 1 1 0 1	
36 Shrimps	– – – – – – – – – – – – – 1 1 – 1 – 1 1 1 – – – – 1 – 1 1 1	1 1 1 – 1 – – – – – 1 1 1 – – 2 1 1 –	1 0 1 1 0 1	
18 *Nemipterus japonicus*	– – – – 1 1 1 2 1 1 3 1 1 1 1 1 – 1 1 1 1 – – – 1 1 1 – 1 –	1 1 1 1 1 1 1 1 1 1 1 2 2 1 1 1 3 4 –	1 0 1 1 1	
29 Synodontidae	1 – – – 1 1 1 1 2 1 1 1 1 1 1 1 – 1 1 1 – – 1 1 1 3 1 1 2 2	1 1 – 1 1 1 1 1 1 1 1 1 1 – 2 2 2 2 2	1 0 1 1 1	
3 *Arius* spp.	– 2 –	– – – – – – – – – – – – – – – – 2 – –	1 0 1 1 1	
3 *Arius venosus*	– – – – – – – – – 4 – – 3 3 – 3 – – – – – – – – – – – – – –	– 1 – 1 3 1 – 2 1 – 2 – 2 – – – – – –	1 1 0 0 0	
5 *Seriolina nigrofasciata*	– – – – – – – – – – – 1 – 1 1 2 – – 1 1 – – – – – – – – – –	– 1 1 1 1 – – 1 – – – – 1 – – – – – –	1 1 0 0 0	
18 *Nemipterus hexodon*	– – – – – 1 1 – 1 1 – – 1 1 – 1 – – 1 1 – – – – 1 – – – – –	1 1 1 1 1 1 1 – 1 – – 1 1 1 – – – – –	1 1 0 0 0	
1 *Carcharhinus scalei*	– – – – 1 – – – – – – – 1 – – – 1 – – – – – – – – – – – – – –	3 – – – – – – – – – – – – – – – – – 2	1 1 0 0 1 0	
22 Other Pomadasyidae	– – – – – – – – 1 – – 1 2 1 2 2 1 – 1 1 1 – – – – – – – – –	2 2 1 1 1 5 3 3 3 4 5 4 5 2 – – – – –	1 1 0 0 1 1	
22 *Priacanthus layenus*	– – – – – – – – – – – 2 2 1 1 1 – – 1 – – – – – – – – – – – –	2 1 1 1 2 1 2 2 2 – – 3 3 1 – – – – –	1 1 0 0 1 1	
18 *Nemipterus mesoprion*	– – – – – 1 – – 1 – – – 1 1 – 1 – – 1 1 – – – – – – – – – – –	1 1 1 1 1 1 1 1 1 1 1 2 1 1 – – – – –	1 1 0 0 1 1	
14 *Leiognathus elongatus*	– – – – 1 –	1 – – – – – – – – – – – 1 – – – – – –	1 1 0 0 1 1	Spp cluster 2c
40 Snakes	– – – 2 – – – 1 – – – – – – 2 – – – 2 – 3 – – – – – – – – –	1 2 2 – – 2 – 1 – – – 2 2 – – – – 2 –	1 1 0 1 0 0	
5 *Atropus atropus*	– – – – – – – – – – – – 1 1 – 1 – 1 1 1 1 – 1 – 1 – – – – –	1 1 – 1 1 2 1 1 3 1 1 – 1 1 – – – – –	1 1 0 1 0 0	

Table 4. Two-way table of stations versus species/groups generated from TWINSPAN for data collected during the intermonsoon II period (September-October 1979). (continued)

	Group A (< 30m)	Group B (> 30m)		
	346 360 361 362 334 336 337 359 343 326 327 333 336 341 347 354 353 344 346 351 352 290 336 383 364 282 283 288 289 292	328 357 350 358 365 339 340 348 349 355 356 329 330 331 284 287 285 286 291		
16 Other Mullidae	– – – – – – – – – – – – – – – – – 1 1 1 1 – – – – – – 1 – –	– – 1 – – 1 – 1 1 – – 1 1 – 1 – – 1 –	1 1 0 1 0 0	
16 *Upeneus sulphureus*	1 1 1 – – – – – 11 – 1 3 1 2 4 – – 1 1 – – – – – – 1 – 1 1 4	1 2 1 – 4 4 4 4 4 2 2 5 4 – 1 1 5 2 –	1 1 0 1 0 1	
11 *Pentaprion longimanus*	– 1 – – – 1 1 1 – – – 1 3 – 1 4 – – 1 1 – – – – – – 1 – 1 1	1 1 1 1 1 4 3 4 4 2 2 5 4 2 1 1 3 3 3	1 1 0 1 0 1	
5 *Decapterus spp.*	– – – 1 –	– – – – – – – – – 1 – – 1 – – – – – –	1 1 0 1 0 1	
5 *Selaroides leptolepis*	1 – – – – – – – – – 1 2 1 1 – 1 1 1 1 – – – 1 – 2 1 – – 2	– 1 1 1 1 – 1 1 1 1 2 3 1 2 4 1 3 1 4	1 1 0 1 1	
5 *Selar spp.*	– – – – – – – – – – – 1 1 – 2 – 4 1 1 – – – – – 1 1 – – – –	2 – – 1 – – 3 2 1 2 1 1 1 1 2 2 4 1 1	1 1 0 1 1	
14 *Leiognathus bindus*	1 – – – – – – 1 – – – 1 1 – – 5 – – – – – – – – 1 – – – – –	2 1 1 – 2 1 – 1 1 1 1 2 1 – 1 – 4 1 –	1 1 0 1 1	
21 *Pomadasys argyreus*	1 – – – – – 1 1 – – 1 – 1 1 1 – – – 1 1 – – – – – 1 – 1 1 –	– – – 1 – 1 – 1 1 1 1 2 2 – – 1 1 2 –	1 1 0 1 1	
4 *Abalistes stellaris*	– – – – – – – – – – – – – – – – – -– – – – – – – – – 1 – – 1	– – – – 1 1 1 1 1 – – – – – 1 – 1 1 1	1 1 1 0 0	
5 *Atule spp.*	– – – – – – – – – – – – – – – 1 – – – – – – – – – – – – – –	– – – 1 – 1 1 – 1 – – – – – 2 – – – –	1 1 1 0 0	
17 Muraenesocidae	– –	– – – 1 – – – – – – – – – – – – – – –	1 1 1 0 0	
16 *Upeneus bensasi*	– –	– – – – – – – – – – – – – – – – – – 3	1 1 1 0 1 0	
16 *Nemipterus marginatus*	– –	– – – – – 1 – – – – – - 1 1 – – 1 – 2	1 1 1 0 1 0	
42 Sponges	– –	– – – – – 1 – – – – – 1 2 – – – – – –	1 1 1 0 1 0	
18 *Nemipterus peronii*	– –	– – – – – – – – – – – - – – – – – – 1	1 1 1 0 1 0	Spp cluster 2d
15 *Lutjanus sanguineus*	– – – – – 1 – 1 1 – – – – – – – – – 1 – – – – – – – – – – –	– – – – – 1 1 5 3 3 3 2 – 2 – – 4 4 –	1 1 1 0 1 1	
18 *Scolopsis spp.*	– – – – – – – – – – – – – – – – – 1 1 – – – – – – – – – – –	– – 1 – – 1 – 1 1 – 1 1 1 1 1 – 1 1 1	1 1 1 0 1 1	
15 Other Lutjanidae	– – – – – 1 – 1 – 1 –	– – – – – – – 1 – 1 – – – 1 1 – 1 1 1	1 1 1 1 0	
38 Lobster	– – – – – – – – 1 – – – – – – – – – – – – – – – – – 1 1 – 1	– – – – – 1 1 – – – – – – – 1 1 1 1 1	1 1 1 1 0	
18 Other Nemipteridae	– 1 – – 1 –	– – – – – – – – – – – – 1 1 1 – 3 3 4	1 1 1 1 1	
18 *Nemipterus nemurus*	– 1 –	– – – – – – – – – – – – – – 1 1 1 1 1	1 1 1 1 1	
19 Pentapodidac	– 1 – – –	– – – – – – – – – – – – 1 1 – – 1 – 1	1 1 1 1 1	
	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		
	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1		
	0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1	0 0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 1 1 1		
	0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 1 0 0 0 0 1 1 1 1 0 0 0 0 1	0 0 1 1 1 1 1 1 0 0 0 0 1 1 1		
	0 0 0 0 0 1 1 0 0 0 0 1	0 0 0 1 1		
	0 0 0 0 1			

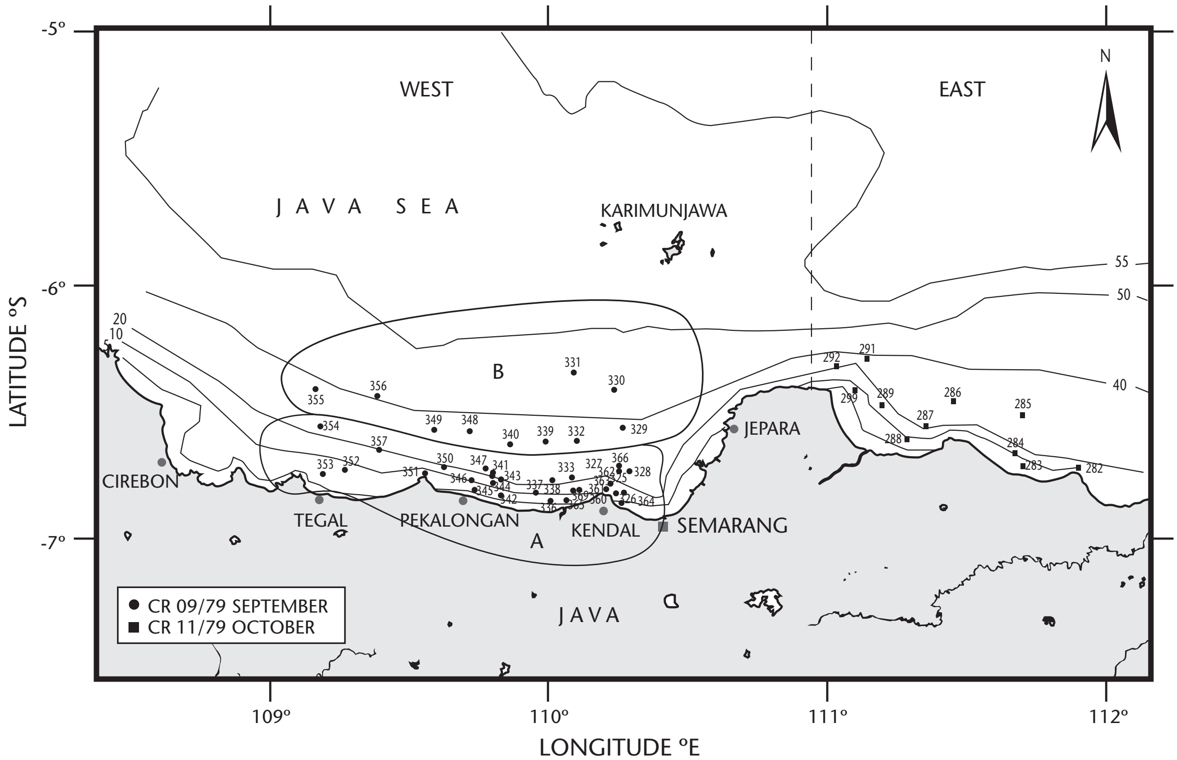

Fig. 7. Trawl stations off the north coast of Central Java in September and November 1979 showing station clusters derived using TWINSPAN and DCA.

Table 5. Catch rate and relative abundance of the 30 most important taxa comprising the shallow and deep assemblages during the west monsoon and intermonsoon I period.

West Monsoon					
Shallow			Deep		
Taxa	$kg \cdot h^{-1}$	%	Taxa	$kg \cdot h^{-1}$	%
Leiognathus splendens	29.8	20.2	*Leiognathus splendens*	80.0	39.0
Rastrelliger spp.	25.1	17.1	*Priacanthus* spp.	15.2	7.4
Alectis indicus	11.0	7.5	Other Leiognathidae	10.7	5.2
Sardinella spp.	10.0	6.8	*Upeneus sulphureus*	10.3	5.0
Anadontostoma spp.	9.2	6.2	Other carangidae	9.7	4.7
Other Leiognathidae	8.9	6.1	Trash Fish	9.1	4.4
Squids	7.8	533	Sphyraenidae	7.4	3.6
Trash Fish	7.5	5.1	*Pentrapion longimanus*	6.2	3.0
Other Ariidae	6.2	4.2	Trichiuridae	4.7	2.3
Trichiuridae	5.0	3.4	*Alectis indicus*	4.1	2.0
Other Carangidae	4.0	2.7	Squids	3.7	1.8
Scianidae	2.5	1.7	*Selar* spp.	3.0	1.4
Stolephorus spp.	2.3	1.6	*Lutjanus sanguineus*	2.6	1.3
Upeneus sulphureus	1.6	1.1	*Dussumieria acuta*	2.6	1.3
Scomberomorus spp.	1.6	1.1	*Scomberomorus* spp.	2.5	1.2
Dasyatidae	1.4	1.0	Other Ariidae	2.4	1.2
Selaroides leptolepsis	1.2	0.8	*Selaroides leptolepsis*	2.4	1.2
Selar spp.	1.1	0.8	Synodontidae	1.9	0.9
Dussumieria acuta	1.1	0.7	*Rastrelliger* spp.	1.8	0.9
Other Engraulidae	1.0	0.7	Other Nemipteridae	1.5	0.7
Ilisha spp.	1.0	0.7	*Atule* spp.	1.4	0.7
Theraponidae	0.9	0.6	*Arius thalassinus*	1.3	0.6
Stromateidae	0.8	0.5	Dasyatidae	1.3	0.6
Lactaridae	0.6	0.4	Other Food Fish	1.2	0.6
Priacanthus spp.	0.6	0.4	*Stolephorus* spp.	1.1	0.6
Formionidae	0.5	0.4	Other Lutjanidae	1.1	0.5
Arius thalassinus	0.5	0.3	*Nemipterus japonicus*	1.1	0.5
Muraenesocidae	0.5	0.3	Chirocentridae	1.0	0.5
Sphyraenidae	0.5	0.3	*Pomadasys hasta*	1.0	0.5
Others	2.3	1.6	*Sardinella* spp.	1.0	0.5
			Others	11.3	6.1

Table 5. Catch rate and relative abundance of the 30 most important taxa comprising the shallow and deep assemblages during the west monsoon and intermonsoon I period. (continued)

Intermonsoon II					
Shallow			Deep		
Taxa	$kg \cdot h^{-1}$	%	Taxa	$kg \cdot h^{-1}$	%
Leiognathus splendens	59.8	21.7	*Rastrelliger* spp.	15.7	15.9
Trichiuridae	27.3	9.9	*Leiognathus splendens*	10.3	10.4
Anadontostoma spp.	26.2	9.5	*Alectis indicus*	8.5	8.6
Rastrelliger spp.	21.9	7.9	Trichiuridae	6.8	6.8
Stromateidae	16.5	6.0	Other Lutjanidae	4.7	4.7
Alectis indicus	15.4	5.6	Other Carangidae	4.6	4.7
Leiognathus equulus	11.2	4.0	Squids	4.4	4.4
Other Carangidae	10.1	3.7	*Lutjanus sanguineus*	4.3	4.4
Other Leiognathidae	8.7	3.1	Stromateidae	3.4	3.4
Other Ariidae	6.8	2.5	Other Ariidae	3.4	3.4
Trash Fish	6.2	2.3	*Scomberomorus* spp.	3.2	3.3
Squids	5.8	2.1	*Selar* spp.	3.1	3.2
Dasyatidae	5.8	2.1	*Anadontostoma* spp.	2.4	2.4
Sphyraenidae	5.3	1.9	*Sardinella* spp.	1.9	2.0
Sardinella spp.	5.2	1.9	Other Rays	1.9	1.9
Scomberomorus spp.	4.0	1.5	*Pentrapion longimanus*	1.8	1.8
Lactaridae	3.9	1.4	*Stolephorus* spp.	1.5	1.5
Theraponidae	3.6	1.3	*Upeneus sulphureus*	1.5	1.5
Polynemidae	3.2	1.1	Formionidae	1.4	1.5
Dussumieria acuta	3.1	1.1	Trash Fish	1.3	1.3
Upeneus sulphureus	2.9	1.1	Dasyatidae	1.2	1.2
Pomadasys hasta	2.8	1.0	Sphyraenidae	1.1	1.1
Other Food Fish	2.5	0.9	*Priacanthus* spp.	1.0	1.0
Other Engraulidae	2.4	0.9	*Dussumieria acuta*	0.9	0.9
Pentrapion longimanus	1.8	0.7	Lactaridae	0.8	0.8
Other Rays	1.8	0.6	Cuttles	0.7	0.7
Stolephorus spp.	1.4	0.5	other Leiognathidae	0.6	0.6
Selar spp.	1.3	0.5	*Arius thalassinus*	0.5	0.5
Snakes	1.0	0.4	Theraponidae	0.5	0.5
Arius thalassinus	1.0	0.4	*Selaroides leptolepsis*	0.4	0.4
Others	6.5	2.3	Others	5.1	5.1

Table 6. Catch rate and relative abundance of the 30 most important species/groups comprising the shallow and deep assemblages during the intermonsoon II period.

Deep			Shallow		
Species/Group	**kg·h^{-1}**	**%**	**Species/Group**	**kg·h^{-1}**	**%**
Leiognathus splendens	12.88	10.53	*Leiognathus splendens*	55.84	30.98
Priacanthus spp.	11.47	9.38	Dasyatidae	9.67	5.36
Priacanthus macracanthus	8.45	6.91	*Alepes* spp.	9.36	5.19
Upeneus sulphureus	8.26	6.75	*Arius caelatus*	8.30	4.60
Pentrapion longimanus	7.11	5.81	Other Food Fish	8.07	4.48
Trash Fish	6.52	5.33	Trash Fish	7.86	4.36
Rastrelliger spp.	4.30	3.51	Sciaenidae	7.39	4.10
Lutjanus sanguineus	4.23	3.46	Other Leiognathidae	6.04	3.35
Dasyatidae	3.91	3.19	*Pomadasys hasta*	4.91	2.72
Other Leiognathidae	3.42	2.80	*Rastrelliger* spp.	4.82	2.68
Arius thalassinus	3.38	2.76	Stromateidae	3.94	2.19
Dussumieria acuta	3.30	2.69	*Dussumieria acuta*	3.61	2.00
Other Carangidae	2.54	2.07	*Anadontostoma* spp.	3.14	1.74
Selaroides leptolepis	2.32	1.90	*Sardinella* spp.	2.58	1.43
Nemipterus japonicus	2.32	1.90	Sphyraenidae	2.19	1.22
Megalaspis cordyla	1.95	1.59	*Scomberomorus* spp.	1.96	1.09
Selar spp.	1.94	1.58	*Megalaspis cordyla*	1.94	1.08
Other Food Fish	1.84	1.50	*Stolephorus* spp.	1.89	1.05
Sphyraenidae	1.79	1.46	*Leiognathus equulus*	1.80	1.00
Priacanthus tayenus	1.41	1.15	*Alectis indicus*	1.75	0.97
Squids	1.39	1.13	*Leiognathus brevirostris*	1.72	0.95
Other Nemipteridae	1.36	1.11	*Thryssa* spp.	1.66	0.92
Leiognathus bindus	1.27	1.04	Theraponidae	1.61	0.89
Scomberomorus spp.	1.27	1.04	*Upeneus sulphureus*	1.58	0.87
Alepes spp.	1.26	1.03	Drepanidae	1.46	0.81
Synodontidae	1.19	0.97	*Arius thalassinus*	1.45	0.80
Scianidae	1.17	0.96	*Osteogeneosis milit*	1.42	0.79
Other Rays	1.10	0.90	Squids	1.42	0.79
Arius venosus	1.06	0.87	Other Carangidae	1.27	0.70
Snakes	0.90	0.74	*Priacanthus* spp.	1.19	0.66
Others	16.72	13.60	Others	18.07	10.03

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Preliminary Analysis of Demersal Fish Assemblages in Malaysian Waters

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Abstract

Spatial and temporal variations of the demersal fisheries resources of Malaysia were studied using multivariate analysis of their abundance (biomass) from research trawl surveys in relation to geographical and environmental parameters. TWINSPAN results indicate that the demersal resources of Malaysia can be geographically divided into five major species assemblages. Two assemblages are in Peninsular Malaysia and three assemblages are in Sabah and Sarawak waters. In general the demersal resources can be grouped into three types: assemblages associated with coastal/mangrove communities, with the offshore (deepwater) ecosystem and an intermediate assemblage. The coastal assemblage is found in shallow coastal waters, less than 40 m depth, while the offshore assemblage is beyond the 90 m depth range. The intermediate assemblages occur between 40 to 90 m depth. Intermediate assemblages were observed in the entire peninsula of Malaysia. A coastal assemblage was also found on the West Coast of Peninsular Malaysia. The Sabah and Sarawak waters were characterized by all three types of demersal assemblages. Salinity and temperature were noted as the environmental parameters that influence the delineation of the species assemblages geographically. In terms of temporal variation, two periods in relation to the monsoon were recognized, the pre-monsoon period and the post-monsoon period, separated from each other in July.

Introduction

The marine waters of Malaysia are generally grouped into three areas, namely: (1) West Coast of Peninsular Malaysia (WCPM); (2) East Coast of Peninsular Malaysia (ECPM); and (3) Sabah and Sarawak Coast (Fig. 1). These areas include parts of the Straits of Malacca, South China Sea, Sulu Sea and Sulawesi Sea. In 1996, the total landings from marine capture fisheries of Malaysia were about 1.1 million t, with a value of RM 3.6 billion *(US$1.431 billion) (Department of Fisheries (DOF) 1969 - 96). The WCPM contributed about half the landings, while the ECPM and the Sabah and Sarawak Coast each contributed about a quarter of landings. The trawl is considered the most important fishing gear, contributing about 55% of the total marine landings. About 65% of the demersal fish landings are trawl-caught.

The fisheries resources of Malaysia show area variations that are not yet fully understood. This is despite the number of demersal research (trawl) surveys in the three areas since the 1930s. The trawl

* 1 US$ = RM2.51596 (1996)

survey data are under-utilized, and knowledge of demersal assemblages is lacking.

This paper represents a first attempt to explore the distribution of demersal fish assemblages in the three areas surrounding Malaysia using classification techniques. The analysis utilizing extant trawl survey data aims to provide explanations and insights into the spatial and temporal variation of demersal species assemblages, as well as the potential factors that explain the causes of such variations.

Materials and Methods

Trawl Survey Data

Trawl surveys conducted in 1972, 1981, 1987, 1991 and 1997 from the three marine areas (Fig. 1) were used for this study. Demersal trawl surveys in Malaysia consist of coastal and offshore surveys. The coastal waters are subdivided into three zones based on distance from the coastline, namely: Zone A (0 - 5 nm), Zone B (5 - 12 nm), and Zone C (12 - 30 nm). The offshore waters (Zone D) are those beyond 30 nm up to the Exclusive Economic Zone (EEZ) boundary (see Fig. 1). The trawl surveys in 1972, 1981, and 1991 were coastal surveys while those conducted in 1987 and 1997 were offshore/EEZ surveys.

Two different sampling designs were employed during the surveys (i.e. grid sampling for the coastal surveys, and random stratified sampling for the offshore/EEZ surveys). In the grid sampling, the position of the trawl sampling station was normally at the center of a small grid (usually 10 x 10 nm). The survey area was divided into grids without any stratification and practically all the grids were visited. In the offshore surveys, the study area was first geographically divided into sub-areas, which were then further divided into depth strata. A three-depth strata system was normally applied (20 - 60 m, 60 - 100 m and 100 - 200 m) following the methodology outlined by Mackett 1973. The offshore surveys involved grid sizes of 15 x 15 nm.

The surveys were carried out using a bottom trawl. Each trawl haul lasted one hour at a constant trawling speed of 5.4 km·hr^{-1} and 7.2 km·hr^{-1} for the coastal and offshore surveys respectively. The catch from each haul was sorted and identified to Species Level (when possible), weighed and recorded. Identification to Species Level was done only for the more recent surveys (i.e. 1987, 1991 and 1997). In earlier surveys, taxonomic identification were done to the Family Level.

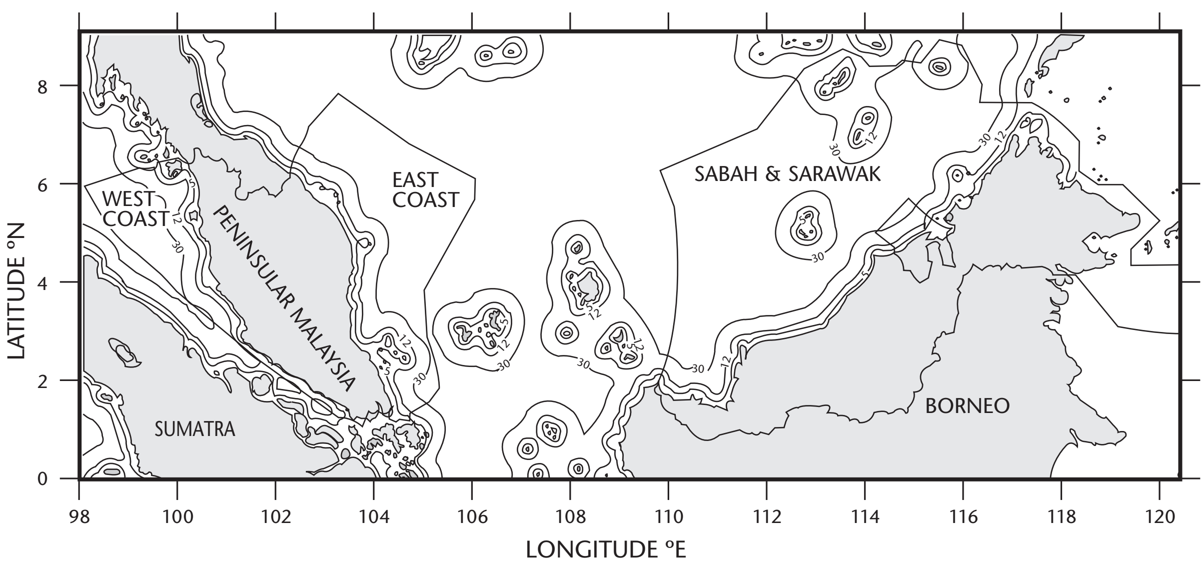

Fig. 1. Geographical boundaries of the three major coastal marine areas of Malaysia. Spatial and legal boundaries of Malaysia. Delineation of fishing area by distance from the coastline. (Zone A: 0 - 5 nm; Zone B: 5 - 12 nm; Zone C: 12 - 30 nm; Zone D: > 30 nm).

The research vessel K.K. Jehanak (85 GRT, 325 HP and 23 m LOA) and similar boats (Penyeledik I and II) were used for the coastal surveys in 1972, 1981 and 1991. For the offshore/EEZ surveys, R.V. Rastrelliger (390 GRT, 1320 HP and 46 m LOA) was used in 1987, and K.K. Manchong (150 GRT, 900 HP and 27 m LOA) in 1997. The locations of the trawl sampling stations during the surveys are illustrated in Appendix 1.

For the coastal surveys, a nylon trawl net with 40 mm cod-end mesh size and a head-rope length of 22.4 m was used. The head-rope length was increased to 34.8 m in the 1991 survey. The effective trawl net opening used in calculation of stock density was half the head-rope length. For the offshore survey in 1987, the trawl net used was made of nylon with a cod-end mesh size of 50 mm and a head-rope length of 79.5 m. Using sonar equipment, the effective trawl opening was calculated to be 26 m. For the 1997 offshore survey, the trawl net was made of polyethylene with a cod-end mesh size of 38 mm and ahead-rope length of 47.1 m. Using sonar, the trawl opening was calculated to be 19 m. For standardization purposes, the stock density for all surveys (coastal and offshore) were corrected to 40 mm mesh size and a value of 0.6 was used as a catchability factor.

Data Analyses

The **T**wo-**W**ay **IN**dicator **S**pecies **AN**alysis (TWINSPAN) software (Hill 1979) was used for classification analysis using the trawl survey data. To analyze the trawl survey data in a single run, a data compression method based on grid area was applied. Species were grouped to Family Level due to inconsistency in species identification over all five surveys. Using this method, station data belonging to the same grid area in one survey period were averaged for each family. This procedure resulted in a reduction in the number of samples (stations) from 1598 stations to 251 stations for a single run analysis using the TWINSPAN software. In addition, the species density values were transformed from $kg{\cdot}nm^{-2}$ to $kg{\cdot}nm^{-2}$ ($x\ 10^2$) to make the data suitable for analysis. Using the compressed data, the following analysis steps were then undertaken to obtain the spatial assemblages in the study areas:

1. Overall analysis - TWINSPAN run using the compressed data matrix consisting of 251 stations (20 x 20 nm grids square), resulting in two main groups (coastal and offshore).

2. Sub-group analysis - separate TWINSPAN runs for the coastal group and offshore group, resulting in five distinct assemblages. For each subgroup analysis, the grid square size was reduced to 10 x 10 nm to achieve higher resolution.

3. Mapping of clustered stations and validation of groups based on environmental parameters (salinity, depth).

4. Final delineation of assemblages.

To explore seasonal variations in the fish assemblages, two assemblages with a comprehensive coverage of months in a year were used (i.e. Assemblage 2 - the ECPM waters, and Assemblage 4 - Sabah/Sarawak area). The data used for this analysis was also analyzed using TWINSPAN and the same data was utilized for sub-group analysis.

Results and Discussion

Spatial Analysis

In the overall analysis of the 251 grids (stations) two distinct groups were found, coastal and offshore assemblages. The sub-group analysis for coastal assemblages yielded two groups, Peninsular and Sabah/Sarawak. In comparison, the analysis of the offshore assemblages separated the groups into west coast, east coast and Sabah/Sarawak area. Overall, the TWINSPAN results indicate that the demersal fish resources of Malaysia can be geographically divided into five major assemblages (see Fig. 2). The delineation was based on salinity and temperature or at the depth contour of 40 m (the WCPM and Sabah-Sarawak areas) and 90 m (Sabah-Sarawak). With salinity and temperature as the main factor, the demersal resources can be grouped into three assemblage types: assemblages associated with coastal / mangrove communities, offshore (deepwater) ecosystem assemblages, and intermediate assemblages. The coastal assemblage is found in shallow coastal waters less than 40 m deep, while the offshore assemblage is beyond the 90 m depth range. The intermediate assemblages are observed between 40 to 90 m.

Fig. 3 shows the sub-group mapping analysis and delineation of the clustered stations for assemblages 1 and 2. The clustered stations from the TWINSPAN analysis of the coastal data of Peninsular Malaysia are overlaid on the clustered stations

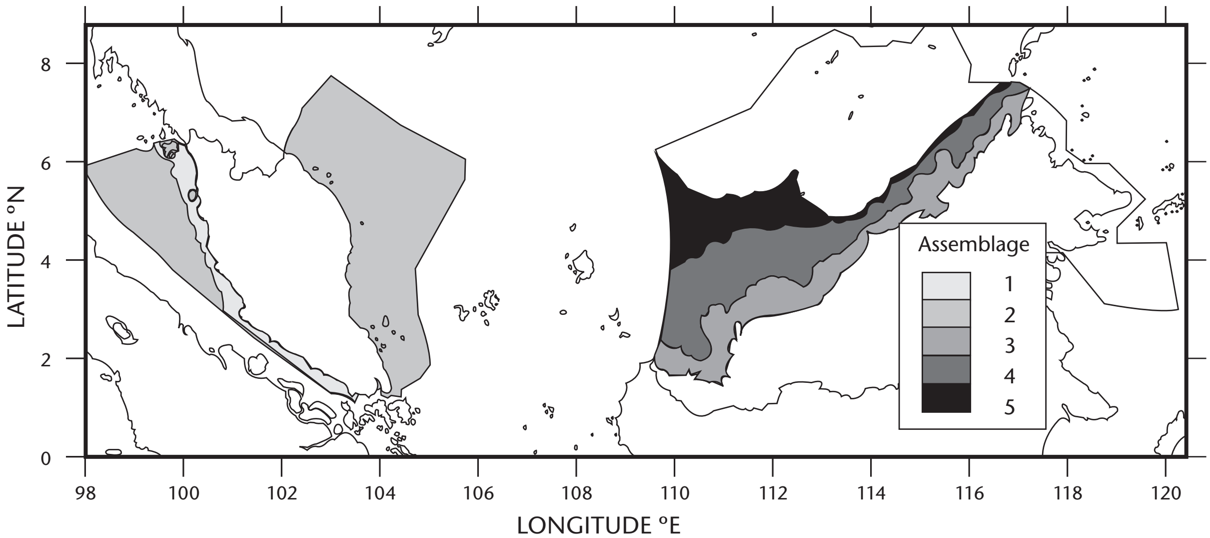

Fig. 2. Geographical delineation of major fish assemblages in Malaysia.

obtained from the analysis of the offshore data of Peninsular Malaysia. The map shows that the assemblages obtained from the coastal and offshore data on the ECPM are actually only one assemblage (Assemblage 2). On the other hand, the analysis on the WCPM showed two distinct assemblages that were delineated at a depth of about 40 m. Overall, two assemblages (Assemblage 1 and Assemblage 2) can be recognized in Peninsular Malaysian waters.

Similarly, Sabah and Sarawak waters can be divided into three distinct assemblages (Fig. 4). Assemblage 3 is situated close to the shore and is delineated from Assemblage 4 at about the 40 m depth contour. Assemblage 5 is located offshore and delineated from the Assemblage 4 at about 90 m depth. Assemblage 4 is the intermediate assemblage and is situated between 40 to 90 m depth.

Table 1 presents the species composition of the assemblages. It is evident that miscellaneous fish, mostly small-sized or trash fish and Leiognathids (slipmouths), are predominant in the coastal areas (i.e. Assemblages 1, 2a, 3 and 4), while Monacanthids (filefishes) are dominant in the offshore areas and along the East Coast of Malaysia.

The generalized fish assemblage structure covering the demersal resources in Malaysia based on the TWINSPAN results are summarized in Fig. 6. The assemblages are geographically (spatially) delineated by depth. Shallow coastal waters, less than 40 m depth, where the coastal assemblages are found, the offshore assemblages are beyond 90 m depth range, and intermediate assemblages are observed between 40 to 90 m depth. Salinity and temperature are also perceived to influence the distribution of fish communities. However, further research and data analyses is needed to confirm their specific effects on the fish assemblages.

Table 1. Percentage of abundance and species composition of the five major assemblages of demersal resources in Malaysia.

Assemblage 1		Assemblage 2a		Assemblage 2b		Assemblage 3		Assemblage 4		Assemblage 5	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Miscellaneous	10.98	Leiognathidae	9.73	*Monocanthus* spp.	8.83	Miscellaneous	32.17	Miscellaneous	31.60	*Thamnaconus hypargyreus*	62.68
Leiognathidae	9.73	Miscellaneous	8.70	Miscellaneous	8.65	Mullidae	9.40	Mullidae	8.23	Miscellaneous	7.81
Rastrelliger kanagurta	9.39	Mullidae	5.93	*Nemipterus* spp.	8.07	Leiognathidae	7.72	*Nemipterus* spp.	5.88	*Saurida* spp.	3.40
Loliginidae	8.82	*Priacanthus* spp.	4.78	Sciaenidae	7.45	Carangidae	4.36	Dasyatidae (rays)	4.82	*Priacanthus* spp.	3.08
Leiognathus splendens	4.10	Nemipteridae	4.26	Leiognathidae	5.98	Dasyatidae (rays)	4.18	Synodontidae	3.50	*Priacanthus macracanthus*	2.25
Mullidae	3.72	*Nemipterus* spp.	3.71	*Priacanthus* spp.	4.48	*Nemipterus* spp.	3.10	Clupeidae	3.47	*Decapterus kurroides*	2.05
Carangidae	3.54	Gerreidae	3.14	*Paramonacanthus* spp.	4.32	Ariidae	3.09	Ariidae	3.40	*Nemipterus* spp.	1.70
Dussumieria hasselti	3.38	Loliginidae	3.02	Mullidae	3.62	Clupeidae	2.66	Carangidae	2.12	*Saurida tumbil*	1.55
Anodontostoma chacunda	3.06	*Trichiurus haulmela*	2.75	Loliginidae	2.92	*Anodontostoma chacunda*	2.61	*Abalistes stellatus*	1.73	*Neocentropogon aeglefinis*	1.44
Trichiurus spp.	2.46	*Lutjanus argentimaculatus*	2.51	*Pentaprion* spp.	2.77	Sciaenidae	2.38	Sharks	1.51	*Nemipterus bathybius*	1.38
Secutor insidiator	2.34	*Loligo* spp.	2.43	Carangidae	2.43	Sharks	2.31	*Pomadasys* spp.	1.43	*Diodon* spp.	1.00
Pampus argenteus	2.01	Synodontidae	2.17	*Scolopsis* spp.	1.72	*Pomadasys* spp.	2.30	Lutjanidae	1.26		
Sciaenidae	1.97	Carangidae	2.13	Dasyatidae (rays)	1.68	Gerreidae	2.15	*Pentaprion longimanus*	1.26		
Triacanthus brevirostris	1.75	*Leiognathus* spp.	2.06	Ariidae	1.63	Synodontidae	2.02	Loliginidae	1.24		
Pennahia macropthalmus	1.68	*Pentaprion longimanus*	1.97	*Selaroides leptolepis*	1.51	Lutjanidae	1.87	Leiognathidae	1.12		
Synodontidae	1.61	*Saurida undosquamis*	1.84	Synodontidae	1.47	Pomadasyidae	1.22				
Chirocentrus dorab	1.53	*Abalistes stellatus*	1.43	*Pentapodus* spp.	1.39	Loliginidae	1.07				
Triacanthus spp.	1.43	*Lagocephalus* spp.	1.36	*Loligo* spp.	1.32						
Clupeidae	1.41	Dasyatidae (rays)	1.32	*Lagocephalus* spp.	1.17						
Nemipterus spp.	1.41	*Pentaprion* spp.	1.22	*Terapon* spp.	1.00						
Ariidae	1.19	*Saurida* spp.	1.17								
Pomadasys spp.	1.12	*Atule mate*	1.10								
Loligo spp.	1.02	*Upeneus sulphureus*	1.01								
Priacanthus spp.	1.00										

Note: 1 - West Coast (coastal), 2a - West Coast (offshore), 2b - East Coast (whole area), 3 - Sabah/Sarawak (coastal), 4 - Sabah/Sarawak (shallow-offshore), 5 - Sabah/Sarawak (deep-offshore).

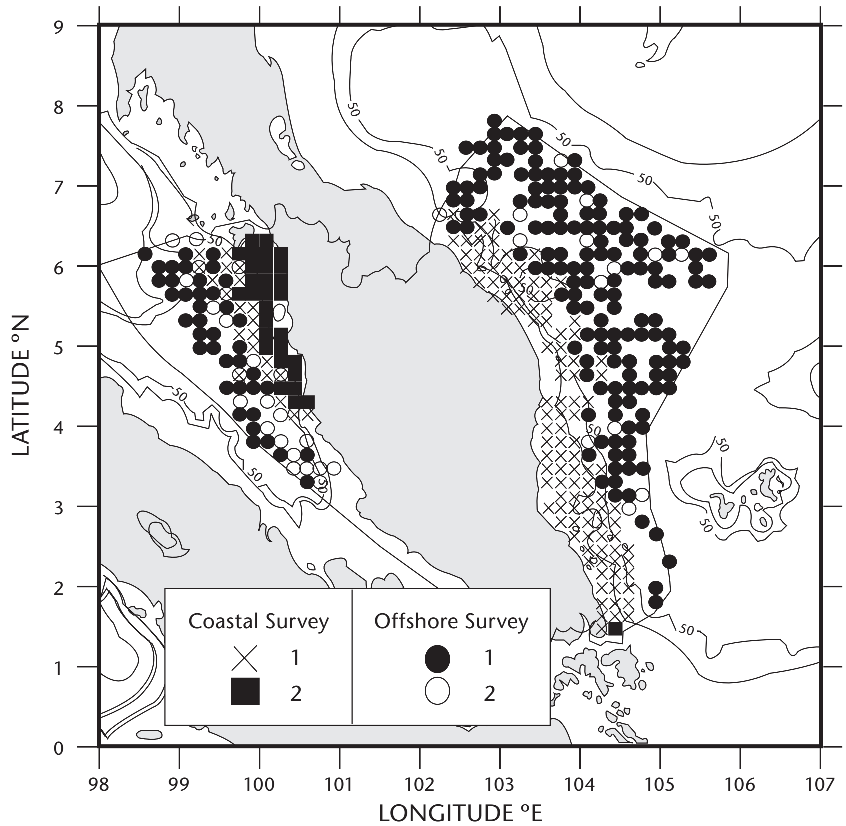

Fig. 3. Delineation of fish assemblages 1 and 2 off the west and east coasts of Peninsular Malaysia.

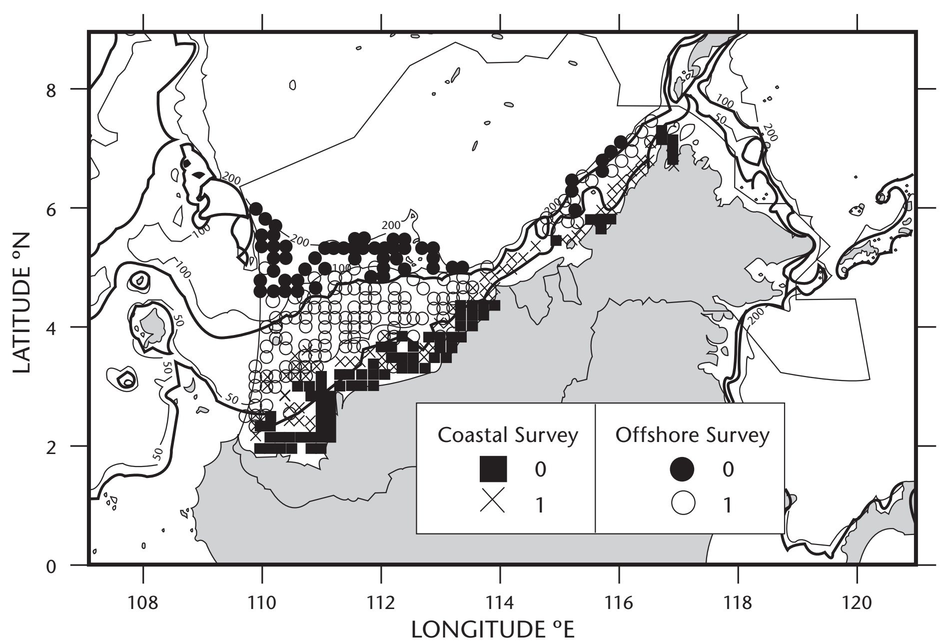

Fig. 4. Delineation of fish assemblages 3, 4 and 5 in Sabah and Sarawak waters, Malaysia.

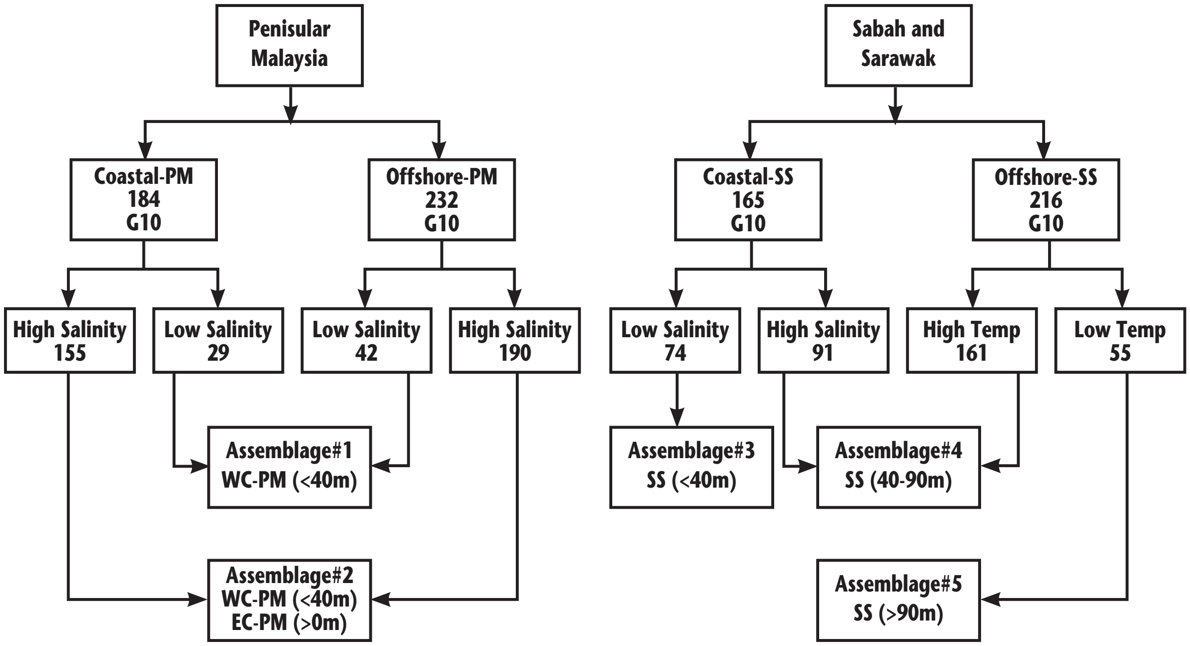

Fig. 5. Generalized classifications of the major fish assemblages in Malaysia.

Exploratory Temporal Analysis

Seasonal variations on the fish abundance were examined using Assemblage 2 (the east coast waters) and Assemblage 4 (Sabah/Sarawak area). In general, two seasonal periods were apparent. Both assemblages showed that the fish communities were differentiated by two temporal phases, the pre-monsoon season (June to November) and the post-monsoon season (March to June). Table 2 gives a summary of species/taxa that are abundant during the pre-monsoon and post-monsoon seasons.

Figs. 6 and 7 show the seasonal variations in terms of average fish density from the coastal and the offshore surveys respectively. The offshore surveys indicate that the ECPM has a relatively higher density of demersal fish during the pre-monsoon season as compared to the post-monsoon. Unlike on the ECPM, seasonal variation has little effect on the abundance and distribution of the demersal resources in Sabah-Sarawak waters. Moreover, consistent with general ecological principles, higher fish densities were obtained in coastal areas as compared to the offshore areas.

Table 2. List of abundant taxa during the post- and pre-monsoon seasons for the ECPM and Sabah/Sarawak waters.

East Coast		Sabah/Sarawak	
Post-monsoon	**Pre-monsoon**	**Post-monsoon**	**Pre-monsoon**
Tricanthidae	Lobsters	Sphyraenidae	Serranidae
Theraponidae	Lethrinidae	Lactariidae	Scombridae
Engraulidae	Balistidae	Labridae	Menidae
Tetraodontidae	Monacanthidae	Crustaceans	Lobsters
Sparidae	Lutjanidae	Soleidae	Lethrinidae
Pomacentridae	Sphyraenidae	Leiognathidae	Balistidae
Platicidae	Nemipteridae	Gerreidae	Trash fish
Megalopidae	Mmullidae	Siganidae	Psettodidae
Istiophoridae	Trichiuridae	Platycephalidae	Nemipteridae
Soleidae	Synodonthidae	Bivalves	Cephalopoda
Psettodidae	Serranidae	Shrimps	Carangidae
Pomadasyidae	Gerreidae	Rays	Plotosidae
Menidae	Plotosidae	Muraenesocidae	Ephipiidae
Caesionidae	Carangidae	Cynoglossidae	Clupeidae
Sharks	Sillaginidae	Bothidae	Chaetodontidae
Leiognathidae	Cephalopoda	Tricanthidae	Priacanthidae
Ariidae	Bothidae	Crabs	Centrolophidae
Muraenesocidae	Crustaceans	Caesionidae	Sciaenidae
Ariommidae	Crabs	Mullidae	Engraulidae
	Siganidae	Ariommidae	Theraponidae
	Platycephalidae		Chirocentridae
	Scombridae		Ariidae
	Rays		Tetraodontidae
	Trashfish		Sharks
	Shrimps		Drepanidae
	Achycentridae		Sparidae
	Labridae		Rachycentridae
	Bivalves		Pomacentridae
	Polynemidae		Lutjanidae
	Cynoglossidae		Stromateidae
	Sciaenidae		Batrachoididae
	Clupeidae		Sillaginidae
	Batrachoididae		Pomadasyidae
			Platacidae

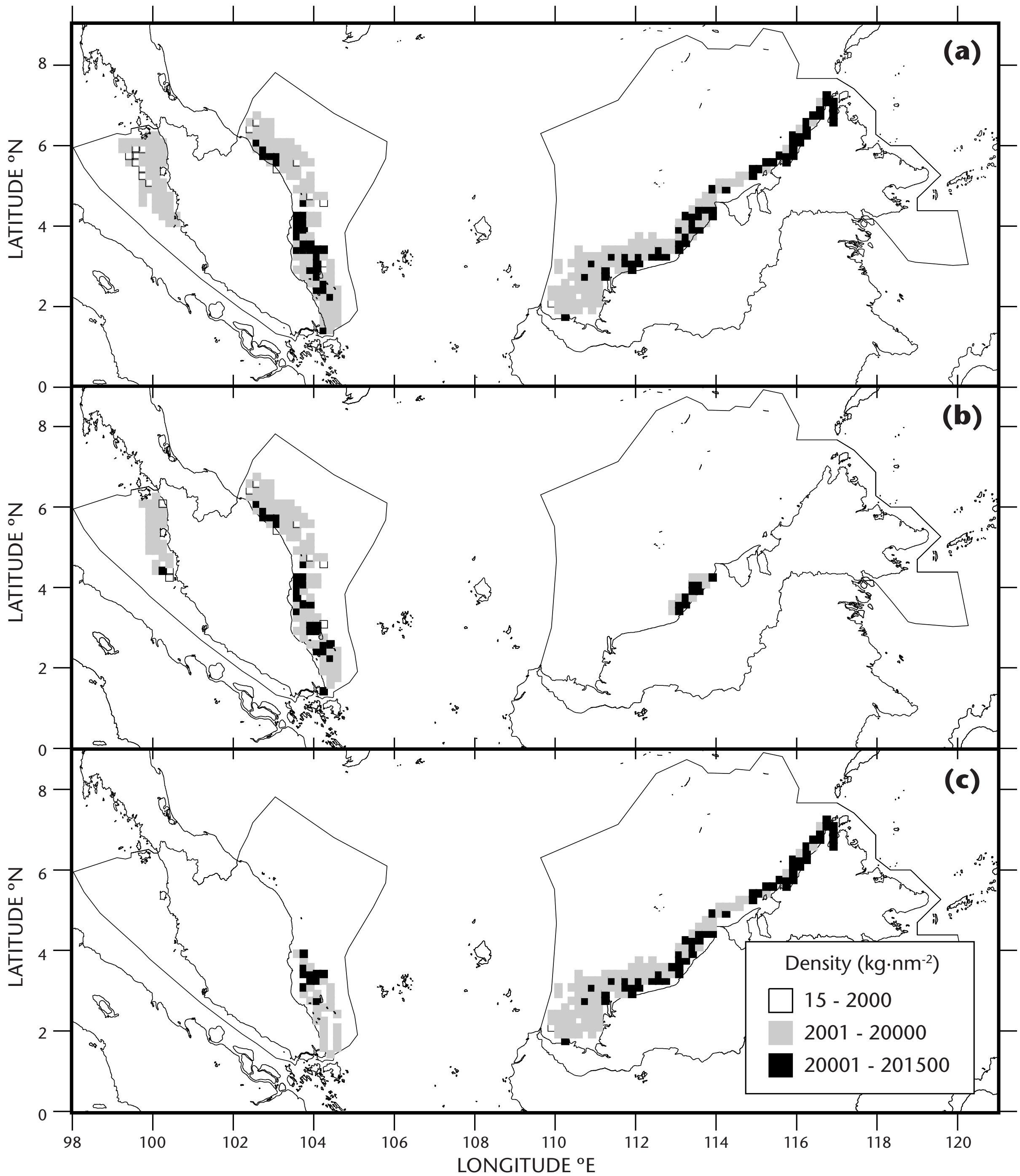

Fig. 6. Seasonal variation on the average fish density from the coastal surveys in Malaysia (a - average; b - pre-monsoon; c - post monsoon).

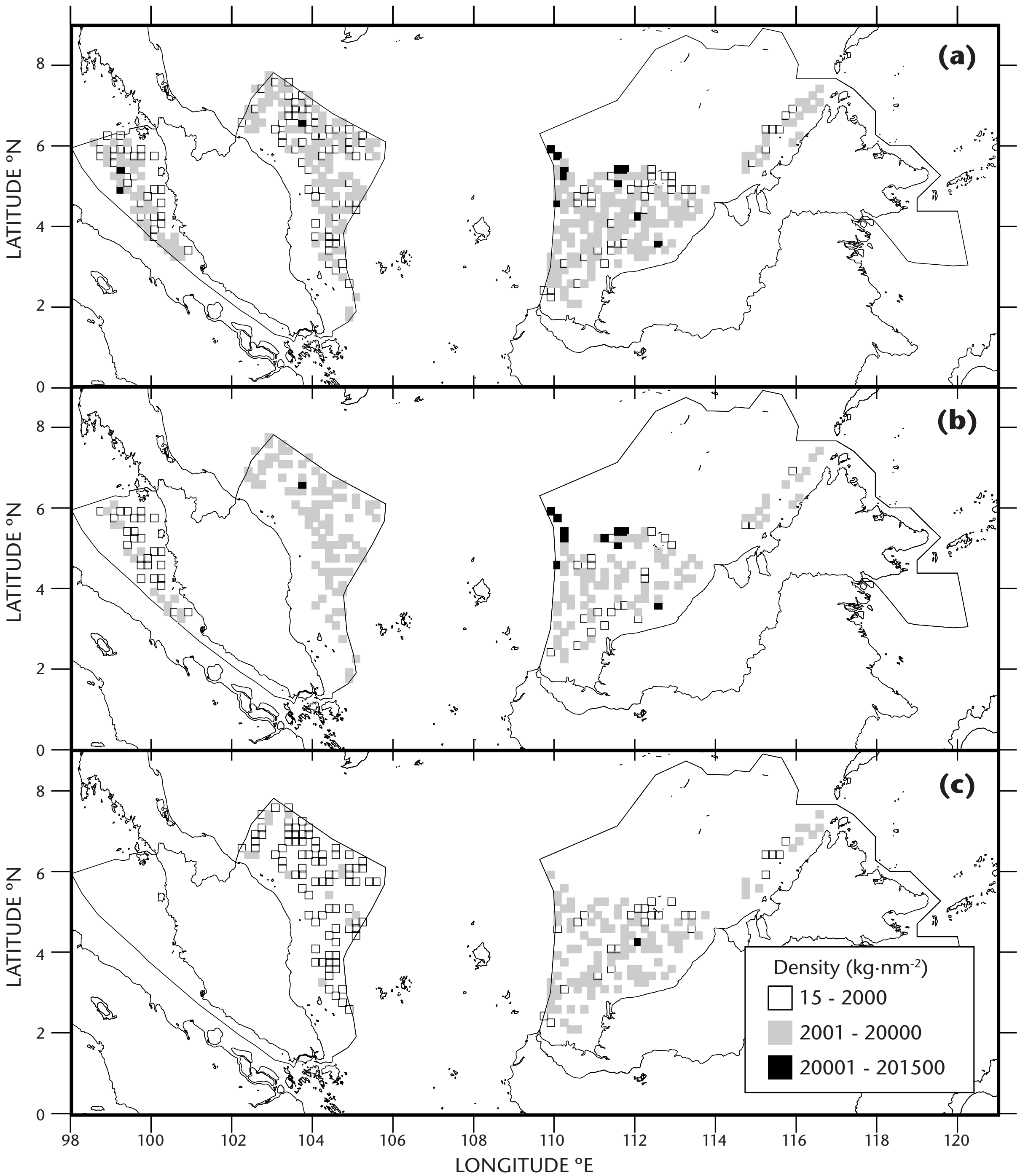

Fig. 7. Seasonal variation in average fish density from offshore surveys in Malaysia (a - average; b - pre-monsoon; c - post-monsoon).

Summary and Conclusion

Stock Boundary Delineation and Species Composition

The coastal assemblages off the WCPM and Sabah-Sarawak waters were similar. The coastal assemblages were separated at a depth of about 40 m. The main species were prawn and other mangrove-related fish species, caught mostly by prawn trawlers. The coastal assemblages have a relation to the mangrove areas, suggested by the fact that there was no such assemblage on the ECPM. On the east coast there are high salinity waters starting from the coastline. Mangroves are not present on the ECPM except in the southern part.

The offshore assemblage was separated into two; the shallower assemblage (between 40 – 90 m), and the deeper assemblage (> 90 m). The ECPM has the shallow offshore assemblage. For the WCPM and the Sabah and Sarawak waters, this assemblage is found immediately next to the coastal assemblage. The main component of this assemblage is the commercial demersal fish species, caught mostly by the fish trawlers. The deeper offshore assemblage can only be found in the Sabah and Sarawak waters, and is delineated at depths beyond 90 m. The main component of this fish assemblage is the low-value demersal fish species.

Implication on Research and Management

At present, the management of the fisheries rsources using various gear in Malaysia is based on the zoning system, that is, on the distance from the coastline (Fig. 2). This legally-binding zoning system allocates Zone A (0 – 5 nm) to traditional fisheries. Zones B, C and D are allocated to commercial fisheries. Zone B (5 – 12 nm) is for commercial fisheries with boats not larger than 40 GRT, Zone C (12 – 30 nm) is for commercial boats with 40 to 70 GRT, and Zone D is for boats greater than 70 GRT. With better information on fish assemblages, the management could be further improved. For example, mangrove communities in waters less than 40 m, on the west coast and in Sabah/Sarawak waters, need a special management strategy. These should be treated differently from the non-mangrove coastal communities found on the ECPM.

A more detailed analysis of the trawl survey data should be carried out to determine the spatial and temporal distribution of the demersal fish assemblages in the country. The results of the detailed analysis will be very useful for the review and possible revision of the zoning system.

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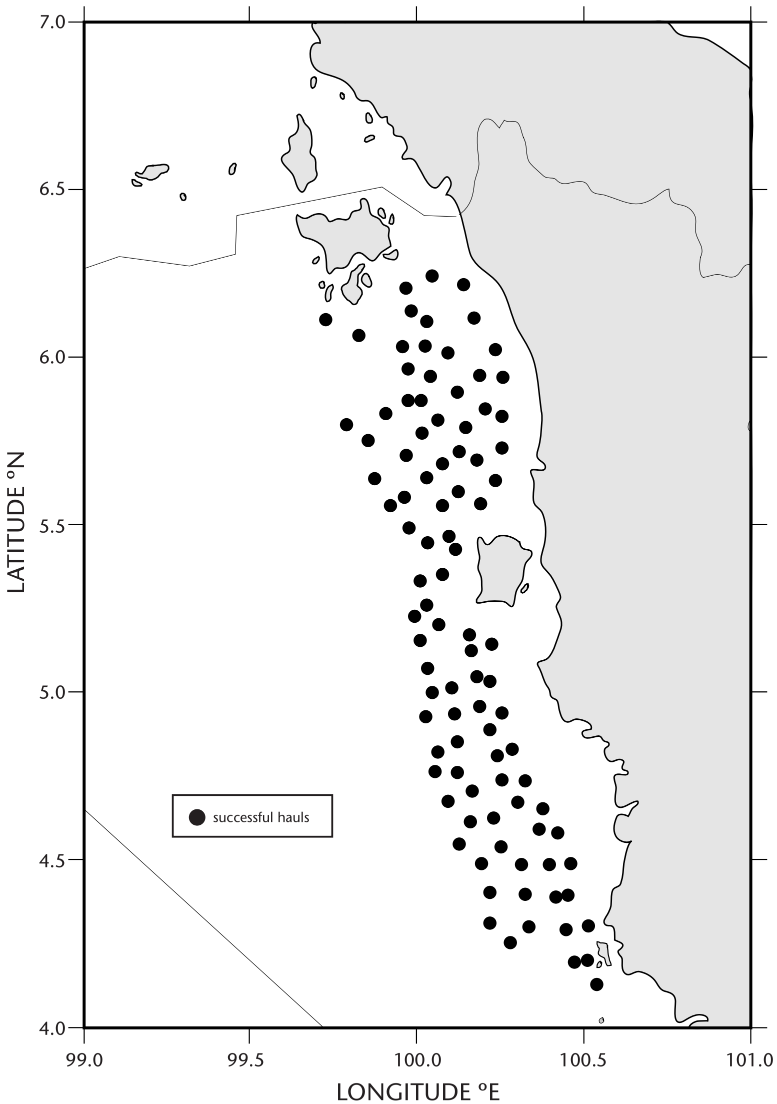
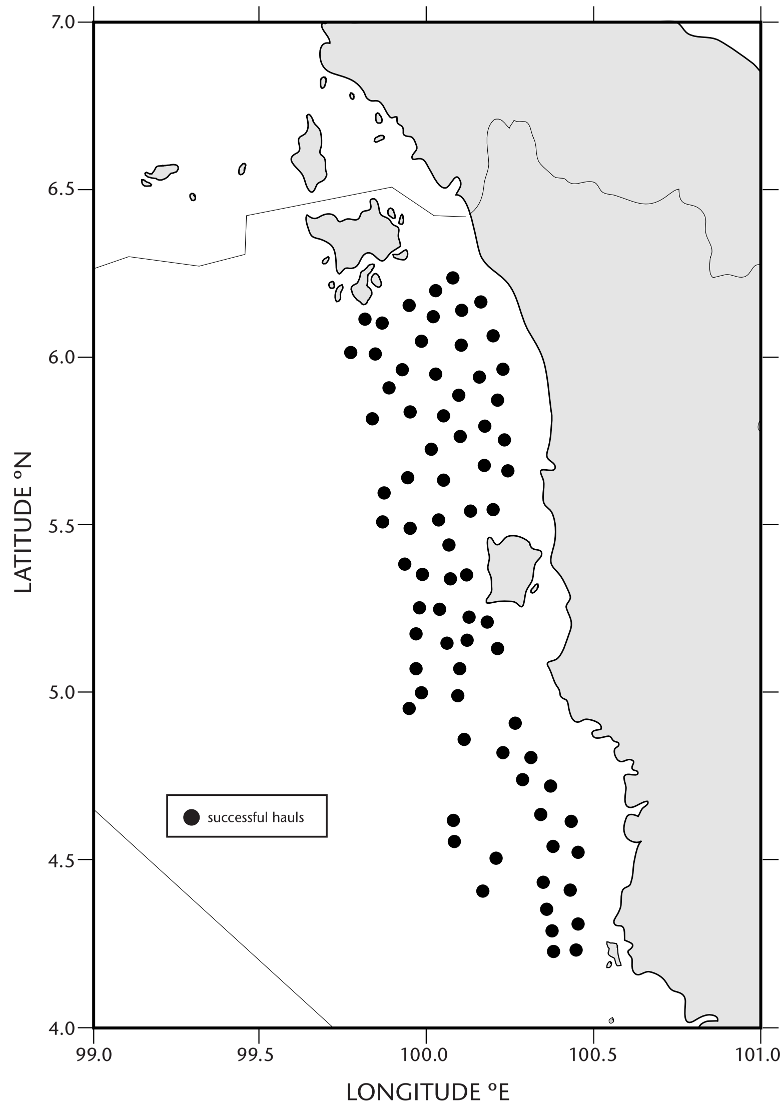
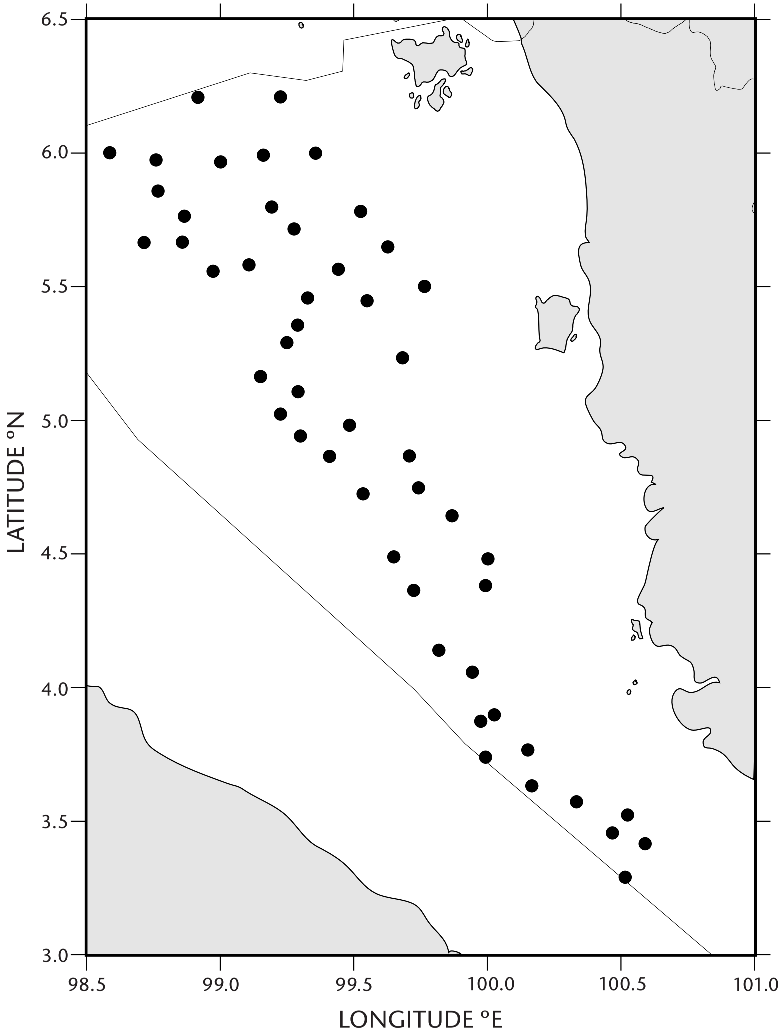


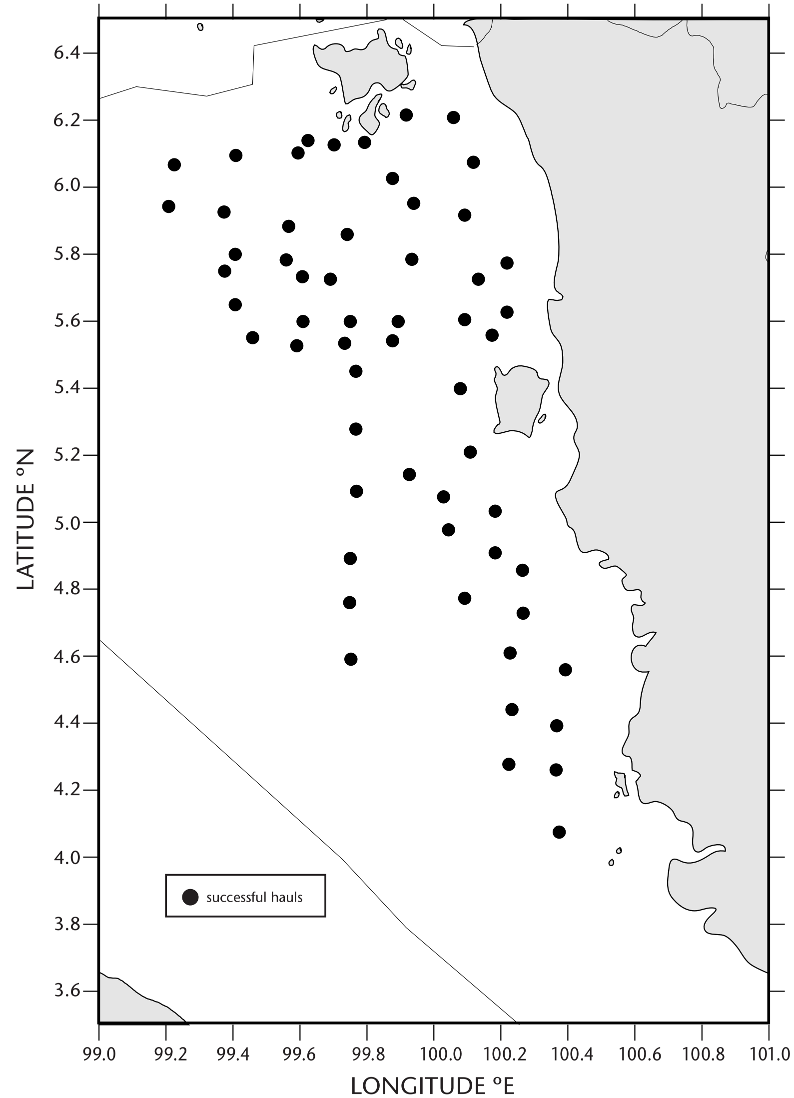
Appendix Fig. 1. Trawl sampling stations during the coastal survey on the WCPM in 1972.



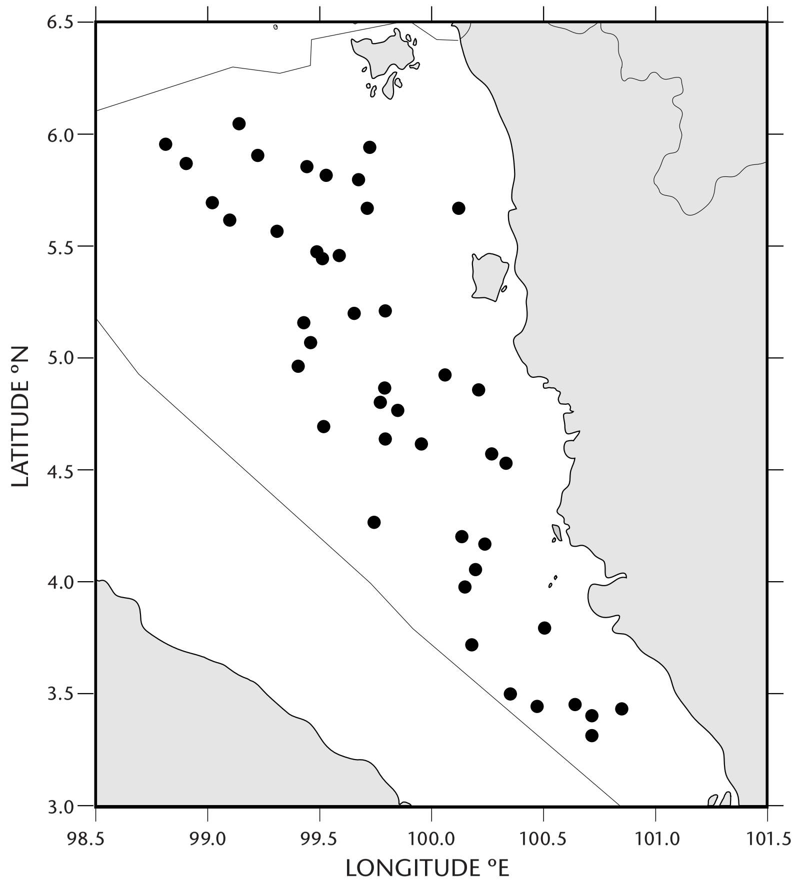
Appendix Fig. 2. Trawl sampling stations during the coastal survey on the WCPM in 1981.



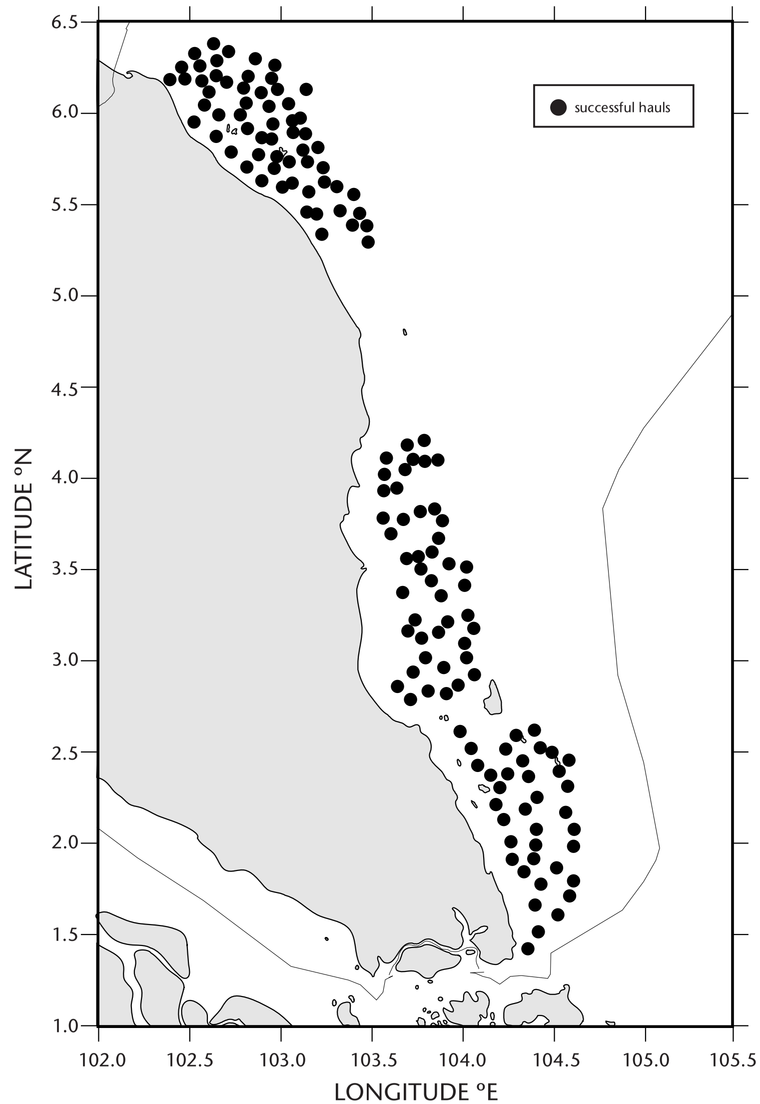
Appendix Fig. 3. Trawl sampling stations during the offshore/EEZ survey on the WCPM in 1987.



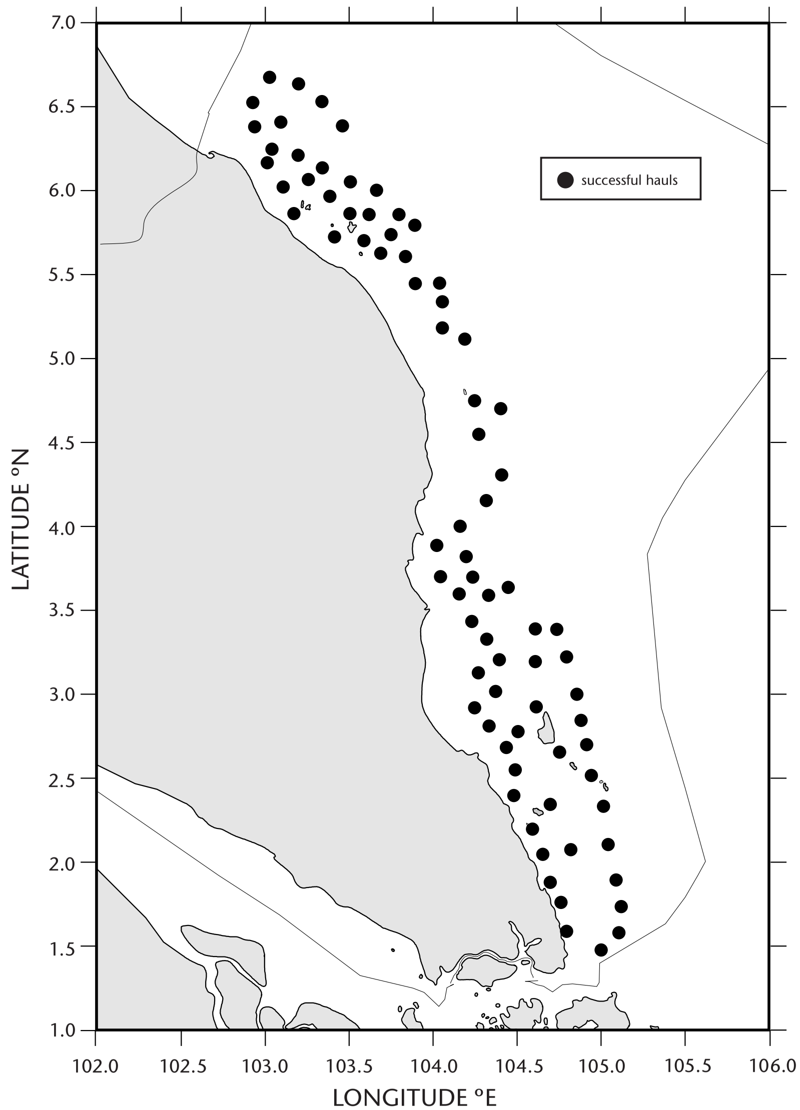
Appendix Fig. 4. Trawl sampling stations during the coastal survey on the WCPM in 1991.



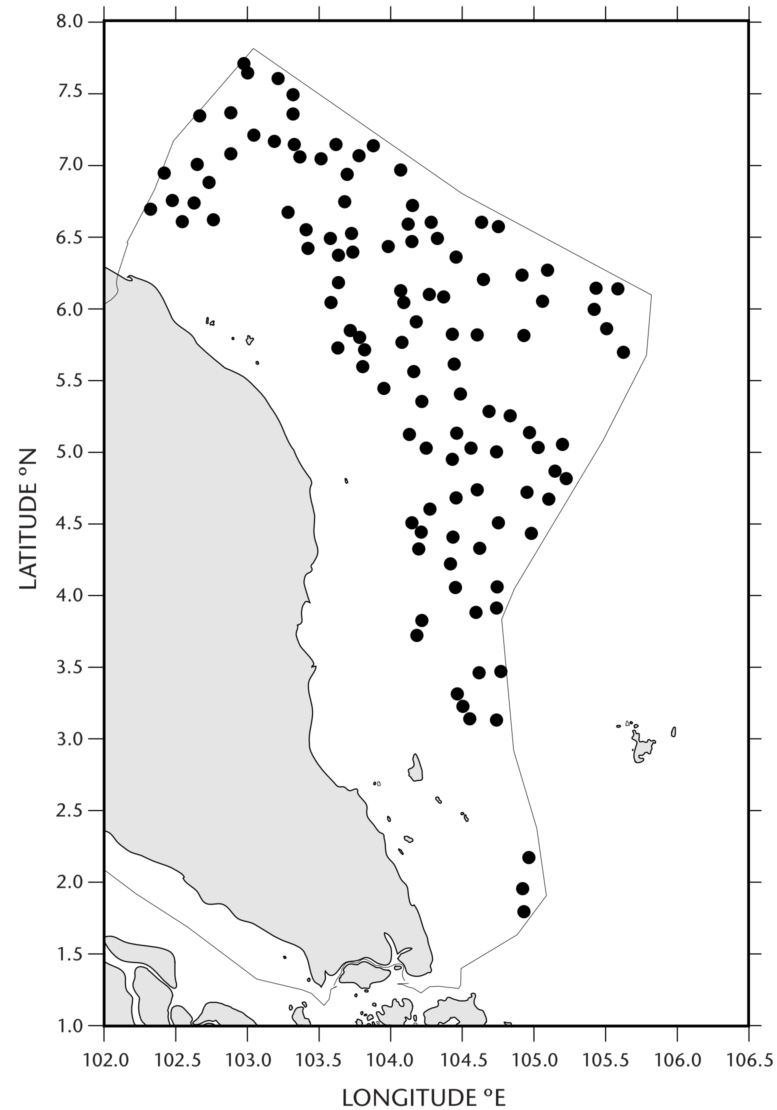
Appendix Fig. 5. Trawl sampling stations during the offshore/EEZ survey on the WCPM in 1997.



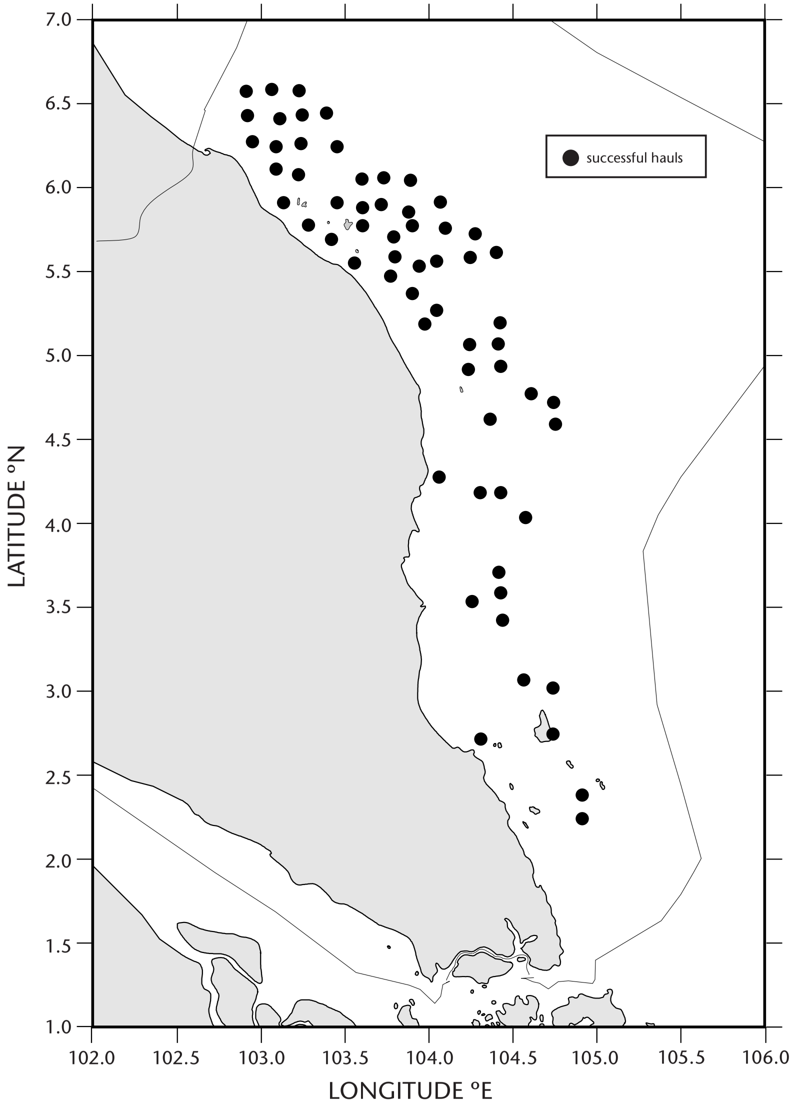
Appendix Fig. 6. Trawl sampling stations during the coastal survey on the ECPM in 1972.



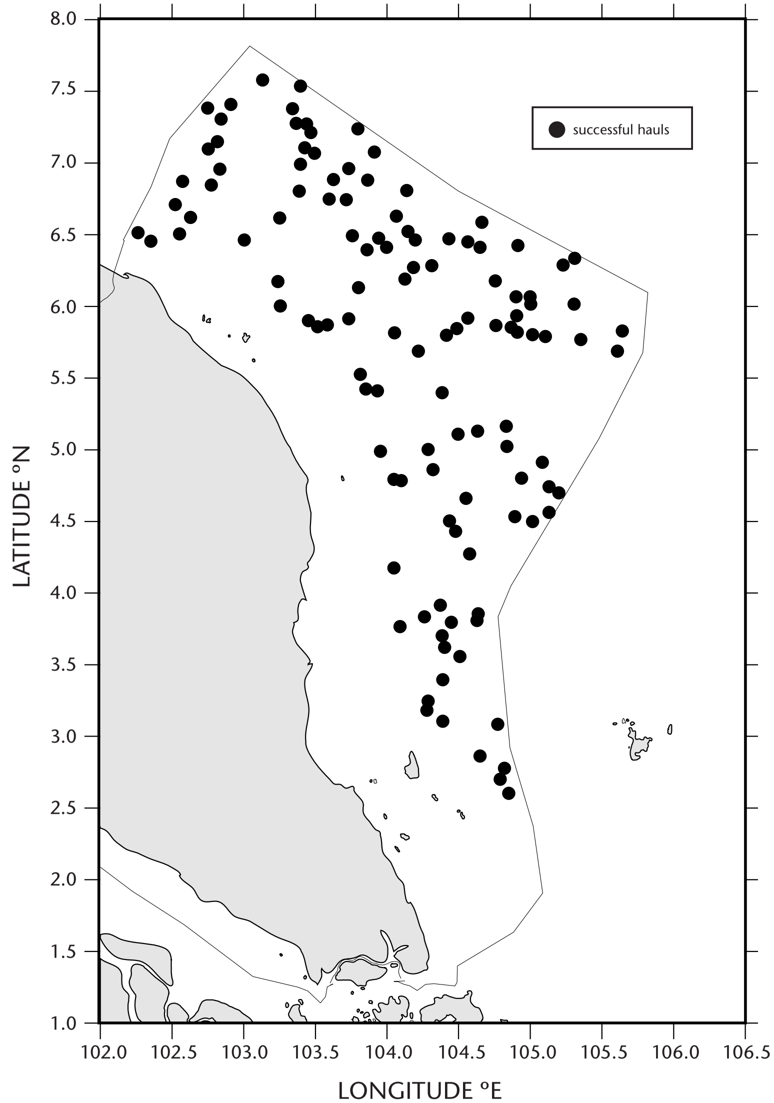
Appendix Fig. 7. Trawl sampling stations during the coastal survey on the ECPM in 1981.



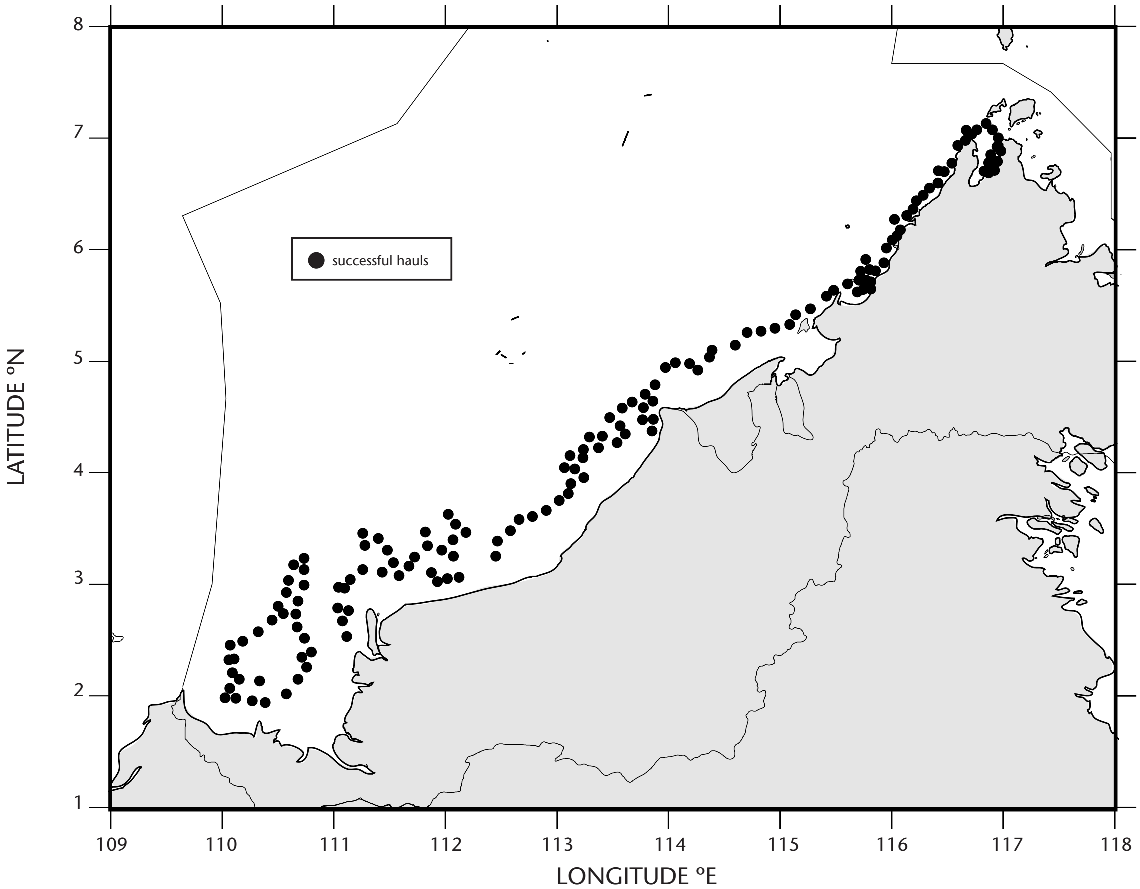
Appendix Fig. 8. Trawl sampling stations during the offshore/EEZ survey on the ECPM in 1987.



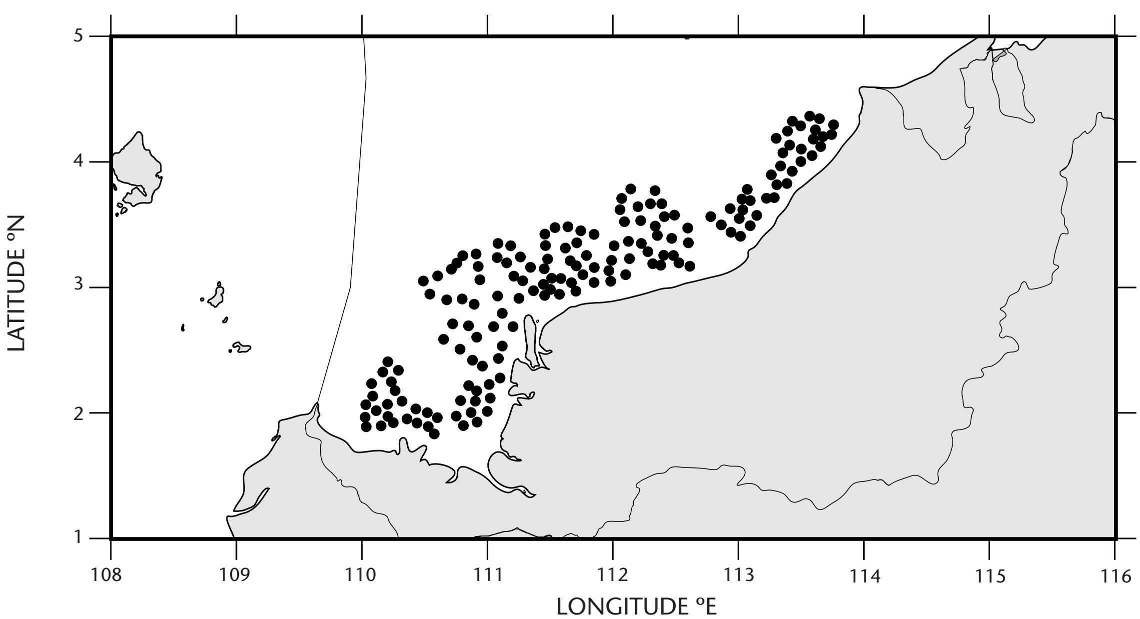
Appendix Fig. 9. Trawl sampling stations during the coastal survey on the ECPM in 1991.



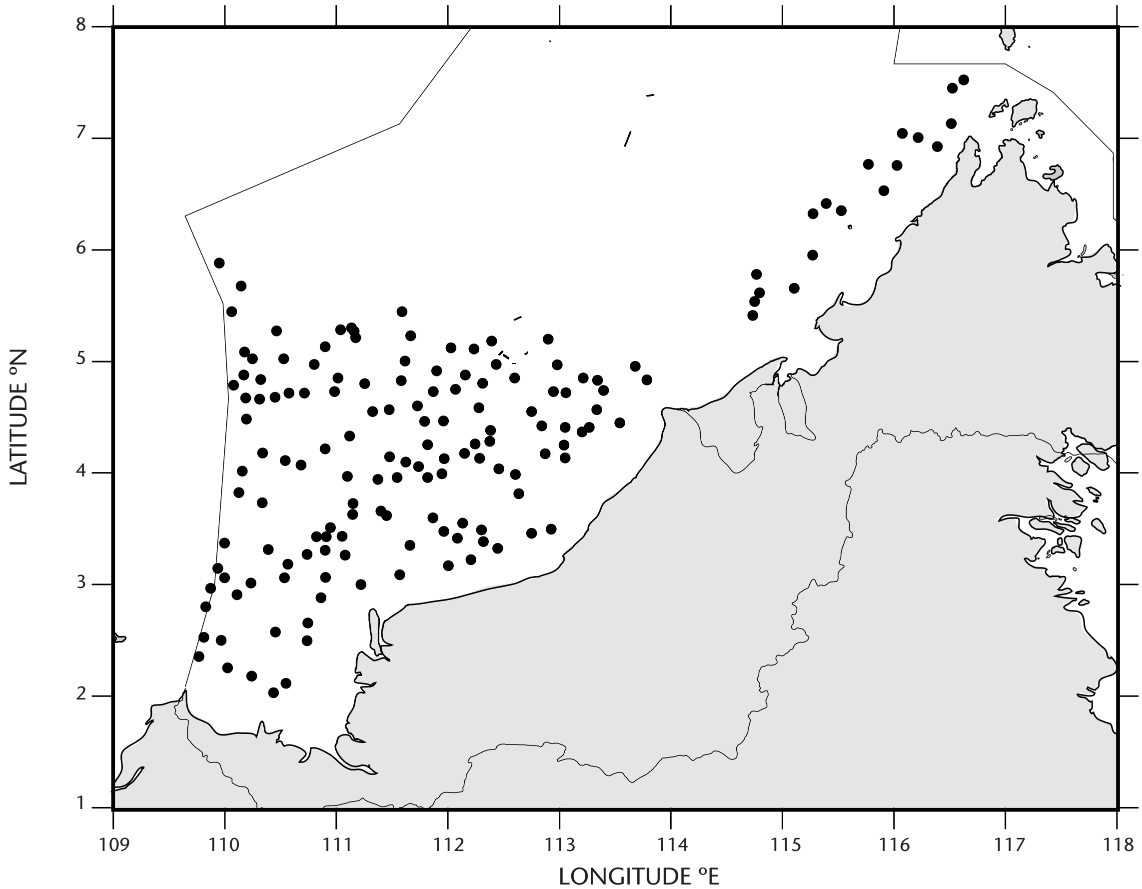
Appendix Fig. 10. Trawl sampling stations during the offshore/EEZ survey on the ECPM in 1997.



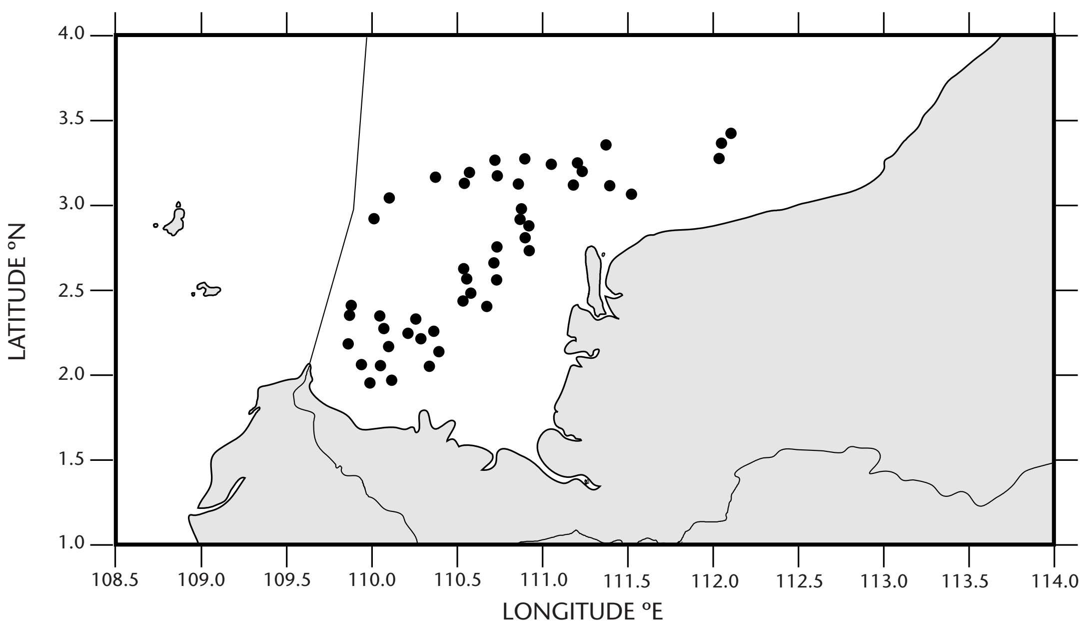
Appendix Fig. 11. Trawl sampling stations during the Sabah-Sarawak coastal survey in 1972.



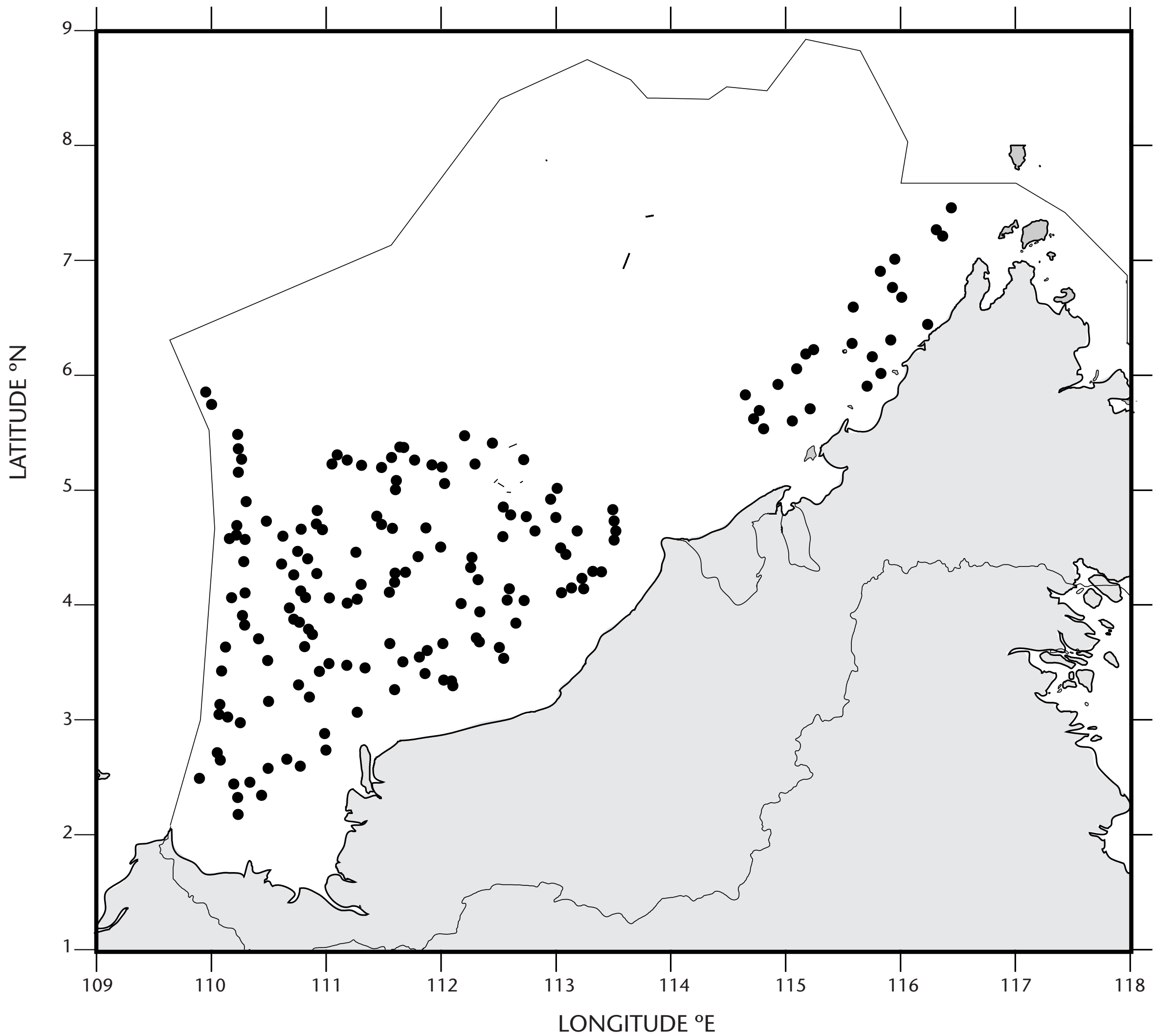
Appendix Fig. 12. Trawl sampling stations during the Sabah-Sarawak coastal survey in 1981.



Appendix Fig. 13. Trawl sampling stations during the Sabah-Sarawak offshore/EEZ survey in 1987.



Appendix Fig. 14. Trawl sampling stations during the Sabah-Sarawak coastal survey in 1991.



Appendix Fig. 15. Trawl sampling stations during the Sabah-Sarawak offshore/EEZ survey in 1997.

Analysis of Demersal Fish Assemblages in Selected Philippine Fishing Grounds

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Campos, W.L. 2003. Analysis of demersal fish assemblages in selected Philippine fishing grounds, p. 227 - 248. *In* G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings 67, 1 120 p.

Abstract

This paper presents the results of analyses of demersal fish assemblages in various fishing grounds in the Philippines. Data from exploratory trawl surveys conducted in 1947 - 49 show that the 24 fishing grounds covered by the survey can be arranged along a gradient of substrate type (i.e. relative coral cover and sediment characteristics). These may be used to determine the species commonly caught in these grounds. A trend of increasing catch rates with decreasing water depth and increasing proportion of mud in the substrate was noted. Data from more recent systematic surveys in Samar Sea (1979 - 80), San Pedro Bay (1994 - 95) and Manila Bay (1992 - 93) were analyzed to examine spatio-temporal patterns in fish assemblages. In all 3 areas, the fish community was characterized by a large number of ubiquitous species, with Leiognathids comprising at least 28% of the total catch. In terms of habitat relations, depth was the primary factor in Samar Sea and San Pedro Bay, where transitions in fish assemblage composition were recognizable at certain depth ranges. In Manila Bay, however, species composition appears to be more related to location (inner versus outer portions of the bay).

Analysis of data from five locations (Manila Bay, Tayabas Bay, Sorsogon Bay, Samar Sea and San Pedro Bay) extending from the western to the eastern portions of the country showed similar seasonality, with fish assemblage composition varying slightly during the monsoon season.

Introduction

This paper summarizes analyses of data from selected trawl surveys conducted in the Philippines. The trawl data sources include (1) exploratory surveys (1947 - 49) in 24 fishing grounds around the country; (2) systematic trawl surveys in Samar Sea (1979 - 80), San Pedro Bay (1994 - 95) and Manila Bay (1992 - 93); and (3) quasi-systematic surveys for demersal biomass in Tayabas Bay (1994 - 95) and Sorsogon Bay (1994 - 95). Data were analyzed to: identify assemblages of trawl-caught organisms; examine how these are distributed in space and time within the surveyed areas; and determine if the different areas surveyed showed similar patterns. This information, in turn, can help in the delineation of assemblage boundaries and fishing zones applicable to various fishing grounds in the country.

Historical (1947 - 49) data were analyzed to examine the broad pattern of demersal fish assemblages in the country prior to the expansion of the trawl

fishery in the mid-1970s. This provides insight into possible changes in the composition of demersal resources since that period, and whether such changes are indicative of ecosystem overfishing as reported in other heavily-fished areas.

Materials and Methods

The initial task of the study was to determine the distribution of demersal assemblages in space and time. Because the surveys had different objectives, there are differences in content and resolution of their information. For example, the exploratory surveys did very limited sampling in each fishing ground. The quasi-systematic surveys consisted of monthly sampling, but because fixed trawl stations were not used, this precluded spatial distribution analyses. Only the systematic surveys (with fixed sampling time intervals and trawl stations) allowed analyses across space and time. It was therefore not possible to employ a standard set of analyses for all the surveys. The general approach in data analyses is described in this section, while analytic details are given in separate sections dealing with the different data sets.

Data from the exploratory surveys were used to characterize the 24 fishing grounds with respect to species group composition and apparent habitat characteristics. Data from the systematic and quasi-systematic surveys were then analyzed to examine potential temporal patterns, and to see if similar patterns occur in different areas of the country. Lastly, data from the systematic trawl surveys were examined for extensive spatial analyses and for comparison between seasons.

Temporal Distribution

The objective here was to determine if any of the areas examined showed seasonality in species composition of the catch (e.g. seasonal differences in species caught in an area or relative abundance of the species). To do this, seasons or time slices (i.e. month groupings) within a year were determined by clustering months based on monthly species abundances (i.e. all stations combined). The resulting seasons then served as the time slices within which spatial distributions were further examined.

Spatial Distribution

The spatial distribution of demersal assemblages was examined at 2 levels: at the annual or within year level, and at the seasonal level. An annual characterization of species assemblages and habitats within each survey area was done by combining all monthly species abundance data for each station and then performing the cluster analysis. At the seasonal level, species abundance data for months in the time slice were combined for each station. The stations were then clustered to show the distribution of habitats within the area.

Internal Analysis

Cluster Analysis

All cluster analyses were executed using **T**wo-**W**ay **IN**dicator **SP**ecies **AN**alysis (TWINSPAN) (Hill, 1979), which produced two-way tables in which the row (species) arrangement corresponds to the species clusters (species assemblages) and the column (sample = station or month) arrangement corresponds to the sample clusters (i.e. stations form habitats, months form seasons). Dendrograms were constructed using the information contained in the output files of the software. These provide a visual presentation of the similarity or dissimilarity between the formed clusters. Ordinations were conducted as a way to verify the clusters formed (see below). Where necessary, a frequency of occurrence of 5 - 10% was used as criteria to limit the number of species included in the analysis. Because of apparent reading errors in the software, all data were first transformed (natural logarithms) and pseudospecies cut levels were then determined from a frequency table of the transformed data.

Ordination Analysis

Ordination of samples (stations or months) in "species space" and "sample space" was performed using Detrended Correspondence Analysis (DCA) in the CANOCO program (Ter Braak 1988). Ordination is a method of plotting samples on a coordinate system representing gradients in species abundance (species space) or plotting species along axes representing station (i.e. habitat) or month (i.e. season) preferences (sample space). These plots reveal how distinct (or indistinct) the TWINSPAN-generated clusters were from each other, or how effective the clustering method was.

External Analysis

External analysis refers to the technique of relating community data to habitat information that is

normally not included, and thus external to, the typical samples-by-species data matrix. For the systematic and quasi-systematic trawl surveys, only depth could be extracted (when not recorded) as the habitat factor available for the various stations. It was only with the exploratory surveys that any useful habitat (fishing ground) information other than depth could be extracted, and thus sensibly subjected to external analyses.

Exploratory Trawl Surveys (1947 - 49)

Exploratory trawl fishing in different areas of the country was conducted as part of the Philippine Fishery Program from September 1947 to July 1949 (Warfel and Manacorp 1950). Twenty four areas were surveyed in an effort to explore potential trawling grounds in the country (Fig. 1). Generally, fishing grounds were surveyed only once during the two-year period (Table 1). Two vessels equipped with trawl nets that differed primarily in the length of head and foot ropes were used during the surveys. A total of 228 tows were attempted, 70% of which were successful. The rest were aborted because of underwater obstructions. In 16 of the 24 areas surveyed, at least 3 tows were made.

The semi-processed data are available in (Warfel and Manacorp 1950) as catch per hour of trawling (all tows in an area combined). Although the catch information in several fishing grounds reflects only 1 or 2 tows, all 24 fishing grounds were used in the analysis in an effort to maximize the use of the data. Catches were listed by families in kg•hr^{-1} units. In addition to catch data, information on total (surface) area, average depth, and general bottom characteristics were also reported (Table 1). Substrate information was based on observations recorded in the various fishing grounds during the surveys.

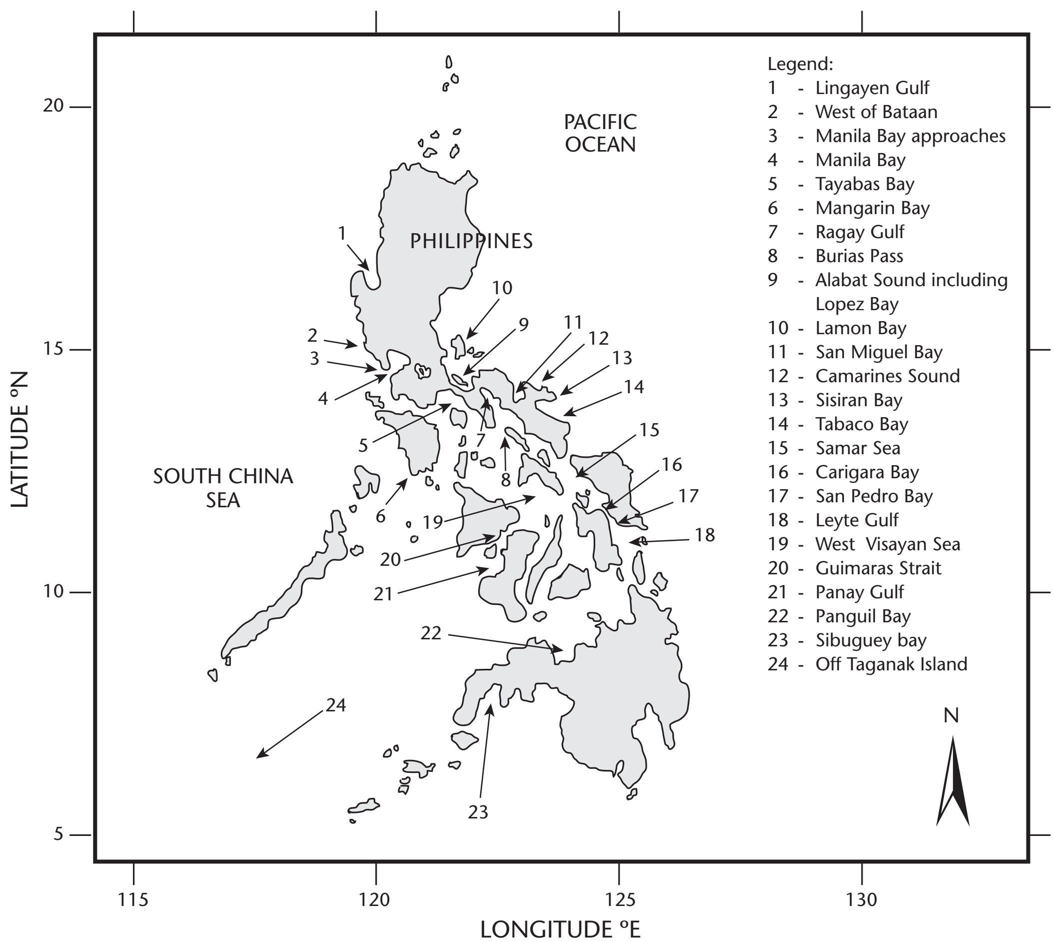


Fig. 1. Locations of the 24 fishing grounds covered during exploratory trawl surveys in 1947 - 49 (Warfel Manacop 1950).

Table 1. Catch and related data for the 24 fishing grounds covered during exploratory trawl surveys from 1947 to 1949 (Warfel and Manacorp 1950).

Area	Fishing ground	Survey dates	Surface area (km^2)	Average depth (m)	Mud & sand[a]	Coral cover[b]	CPUE ($kg \cdot hr^{-1}$)
1.	Lingayen Gulf	Feb - April 1949	1 482	45.8	2	1	67.7
2.	West of Bataan	Oct.1947, Oct. 1948	390	45.8	3	2	11.4
3.	Manila Bay approaches	Oct. to Nov. 1947	520	64.1	3	1	44.1
4.	Manila Bay	Sept. & Nov. 1947	1 352	27.5	2	4	33.6
5.	Tayabas Bay	Nov. 1948	910	64.1	1	5	59.5
6.	Mangarin Bay	Sept. 1948	26	366.0	2	4	40.5
7.	Ragay Gulf	Nov. 1948	1 820	164.7	2	1.5	66.4
8.	Burias Pass	Nov. 1948	520	82.4	1	4	80.0
9.	Lopez Bay	Jul. 1948	481	40.3	1	4	71.8
10.	Lamon Bay	Jul. 1948	2 080	69.5	1	5	136.4
11.	San Miguel Bay	Jul. 1948	520	12.8	1	0	289.1
12.	Camarines Sound	Jul. 1948	4 680	54.9	2	5	59.5
13.	Sisiran Bay	Jul. 1948	52	9.2	1	5	219.1
14.	Tabaco Bay	Jun. 1948	130	73.2	1	4	12.3
15.	Samar Sea	Aug. 1949	780	27.5	2	0	41.8
16.	Carigara Bay	Aug. 1949	520	45.8	2	0	177.3
17.	San Pedro Bay	Aug. 1949	286	14.6	2	4	67.3
18.	Leyte Gulf	Aug. 1949	27	69.5	2	1	27.7
19.	West Visayan Sea	Sept. 1948	650	27.5	1	5	279.5
20.	Guimaras Strait	Aug. and Dec.1948	2 080	18.3	1	4	236.4
21.	Panay Gulf	Jan. and Aug. 1948	520	32.9	1	4	198.5
22.	Panguil Bay	Jul. 1948	377	36.6	1	0	17.7
23.	Sibuguey Bay	Oct. 1949	1 560	32.9	2	4	50.0
24.	Off Taganak Island	Sept. 1949	5 200	36.6	2	5	19.1

Note: [a] **Mud & sand scale: 1 = muddy, 2 = mud-sand, 3 = sand-mud, 4 = sand**
[b] **Coral cover scale: 1 = patchy heads, 2 = scattered corals, 3 = numerous heads, 4 = large coral heads, 5 = fringing reefs & numerous heads**

Fishing grounds were first clustered based on catch abundance of 26 species groups (families) using TWINSPAN. The resulting clusters (species groups and fishing grounds) were then analyzed using Canonical Correspondence Analysis (CCA) in CANOCO and Discriminant Analysis (DA) in STATISTICA, in an attempt to examine habitat relations (external analysis).

Systematic & Quasi-systematic Surveys

These included data from surveys involving fixed stations sampled over regular time intervals (Samar Sea, Manila Bay and San Pedro Bay) and data from surveys involving only randomly-chosen trawling sites sampled monthly to determine stock biomass (Tayabas Bay and Sorsogan Bay). Information pertinent to the systematic trawl survey areas and their respective sampling schemes are shown in Table 2. The location of the surveyed areas are shown in Fig. 2.

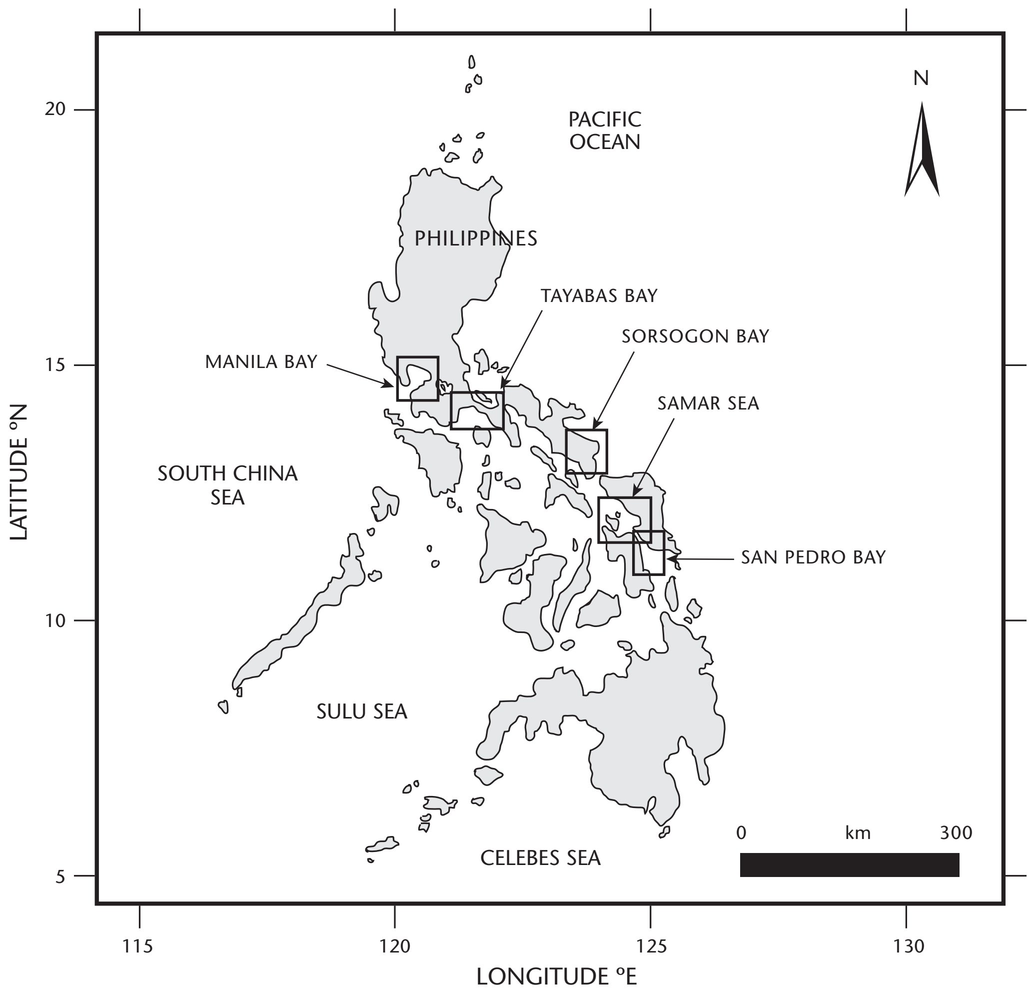


Fig. 2. Locations of areas covered by systematic and quasi-systematic trawl surveys used in the study.

Table 2. Information on systematic trawl survey areas and sampling schemes.

	Samar Sea	San Pedro Bay	Manila Bay	Sorsogon Bay	Tayabas Bay
Surface area (km²)	3 049	625	1 782	256	1 800[d]
Coordinates North Latitude East Longitude	 12° 00′ 00″ 124° 40′ 00″	 11° 05′ 30″ to 11° 17′ 30″ 125° 00′ 00″ to 125° 14′ 00″	 14° 15′ 00″ to 14° 50′ 00″ 120° 30′ 00″ to 121° 00″ 00′	 12° 51′ 00″ to 12° 58.5′ 00″ 123° 51′ 00″ to 124° 03′ 00″	 13° 15′ 00″ to 14° 00′ 00″ 121° 18′ 00″ to 122° 30′ 00″
Sampling period No. of Stations No. of Months	Mar 79 - May 80 28 11[a]	Jun 94 - May 95 13[b] 12	Nov 92 - Oct 93 16 6	Apr 94 - Jan 95 10[c] 10	Oct 94 - Jun 95 8 9
Fishing vessel	TRV Albacore	F/B Tristan Dos & F/B Roselle	Commercial fishing boat	Mini-trawler	Commercial fishing boat
Type	Steel Hull	With outriggers	With outriggers	With outriggers	With outriggers
Overall length (m)	31.60	15.20 / 17.80	13.50	6.0	–
Breadth (m)	7.00	1.50 / 1.82	1.20		–
Depth (m)	3.20	1.45 / 1.10	1.48	0.5	–
Engine	600 HP	185 HP / 145 HP	Fuzo 4DR5	16HP Gasoline	–
Sampling gear	High opening bottom trawl	Two-seamed net	Otter trawl	Two-seamed net	–
Head-rope (m)	48.80	28.00 / 26.00	15.40	6.0	14.0[e]
Ground-rope (m)	55.0		15.52	6.8	–
Cod-end mesh size (mm)	200	200 / 200	220	117	–
Reference	Armada et al. (1983)	Armada (1996)	MADECOR (Mandala Agricultural Development Corporation) and National Museum (1995)	Cinco and Perez (1996)	Resources Combines Incorporated (1997)

Note: [a] **Survey suspended from Oct 79 to Jan 80**
[b] **3 out of original 16 stations with incomplete data**
[c] **Not all stations were sampled regularly. In some months, hauls at some unspecified stations were unsuccessful.**
[d] **Surface area of the bay estimated from nautical chart and includes a large portion (~ 30%) with depths > 200m**
[e] **Head-rope estimated from raising factors used in deriving biomass estimates from CPUE (kg·h^{-1}) estimates.**

For the systematic trawl surveys, both spatial and temporal distributions of species and samples were analyzed. For samples, station clusters reflect (spatial) habitats, while month clusters (temporal-annual) reflect seasons of the species clusters (species assemblages) formed. To examine seasonality in the distribution of species and habitats (temporal-seasonal), spatial analyses were also conducted within each time slice formed in the temporal annual analyses.

In the case of quasi-systematic surveys, only temporal analyses could be done, since sampling stations were randomly chosen in each sampling period. This allowed a comparison of seasons (i.e. formed by month clusters based on temporal species occurrences and abundances) among different areas of the country.

Results

Exploratory Trawl Survey (1947 - 49)

The two-way table formed by the resulting clusters of families and fishing grounds is shown in Fig. 3. The families formed 2 broad groups. One is uncommon or even absent in (the first 2 groups of) fishing grounds, where the substrate is a mixture of mud and sand, with low to moderate coral cover. The other broad group is relatively common in these grounds, and includes typical soft-bottom demersal families, such as Sciaenidae, Gerreidae, Synodontidae, Psettodidae and Nemipteridae. Species clusters 4 and 5 were most frequently recorded in fishing grounds with sandy substrate and coral cover ranging from low to high. These include common reef groups such as Sphyraenidae, Pomadasyidae, Serranidae and Lutjanidae.

Figure 4 shows the clustering of fishing grounds superimposed on a map of the country. Figs. 5a and b show the CCA plots of the fishing ground and species group clusters formed by the cluster analyses, while Fig. 5c shows the plot of environmental factors in the same ordination space. Figure 6 shows the 24 areas in environmental space, based on canonical roots resulting from discriminant analysis. The results of the latter, while not allowing direct correlations with habitat factors, are nevertheless consistent with those suggested by the clusters and by the CCA. It thus appears that the 24 areas can be arranged in gradients reflecting their substrate make-up (i.e. relative coral cover and sediment characteristics), which in turn somewhat determines the kind of species commonly caught in them. These characteristics however do not discount the importance of other factors such as water depth. Catch rate ($kg \cdot hr^{-1}$) was negatively correlated with both average water depth (-0.48, $p < 0.05$) and mud/sand substrate (-0.51, $p < 0.05$), and reflects an underlying trend of increasing catch rates in areas with shallower and more muddy bottoms. This is also consistent with the distribution of the more abundant families in the catches (e.g. Leiognathidae, Mullidae).

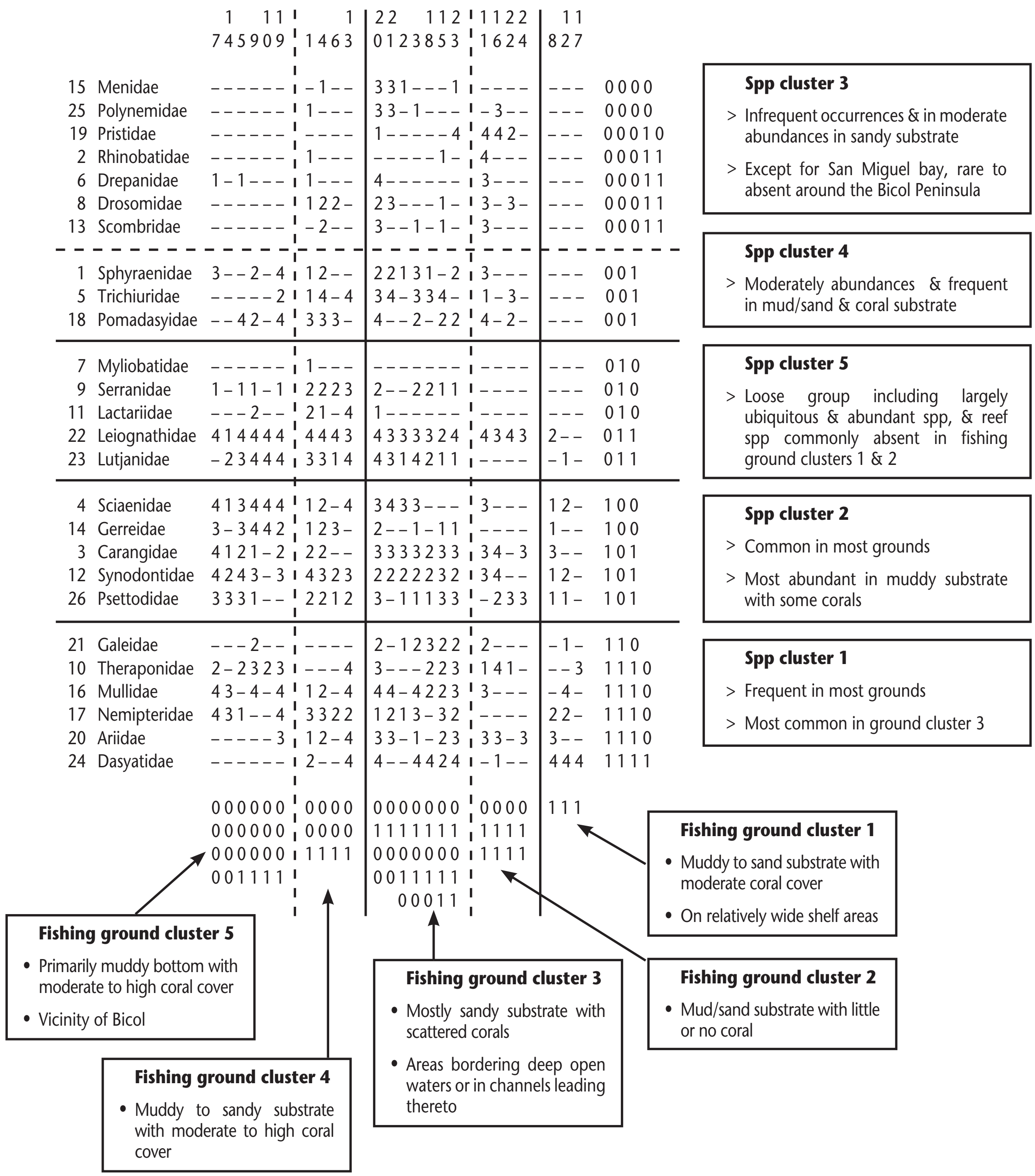


Fig. 3. Two-way table of TWINSPAN results for data from 24 fishing grounds (26 species groups) around the Philippines.

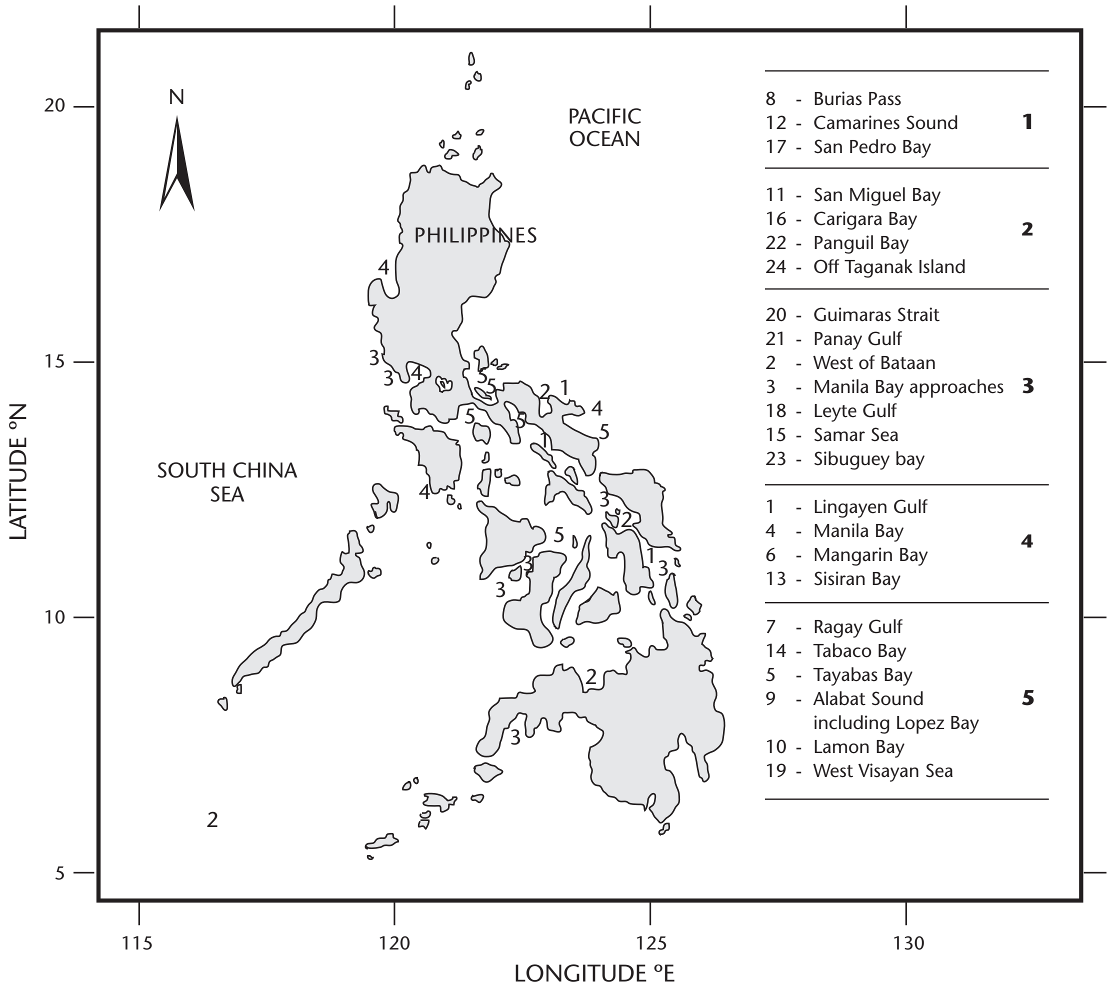


Fig. 4. Map showing the location of fishing ground clusters formed in the analyses of data from Warfel and Manacop (1950).

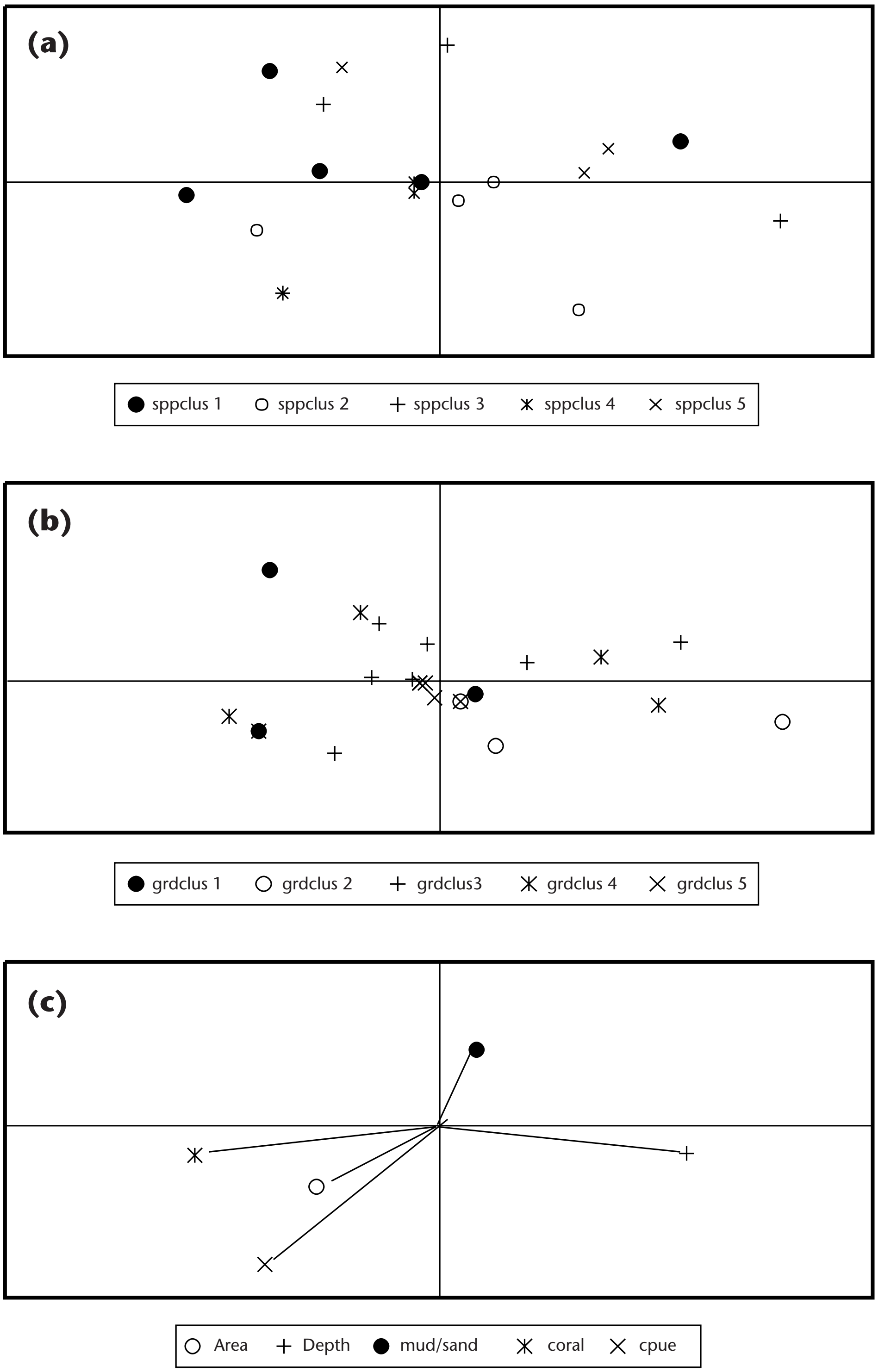


Fig. 5. (a) CCA plot of fishing ground clusters, (b) species group clusters, and (c) environmental factors for the 24 areas sampled during the exploratory surveys in 1947 - 49. The x and y axes are CCA Axes 1 and 2, respectively. In (a) and (b), the various symbols refer to the different species group or fishing ground clusters formed by the cluster analysis.

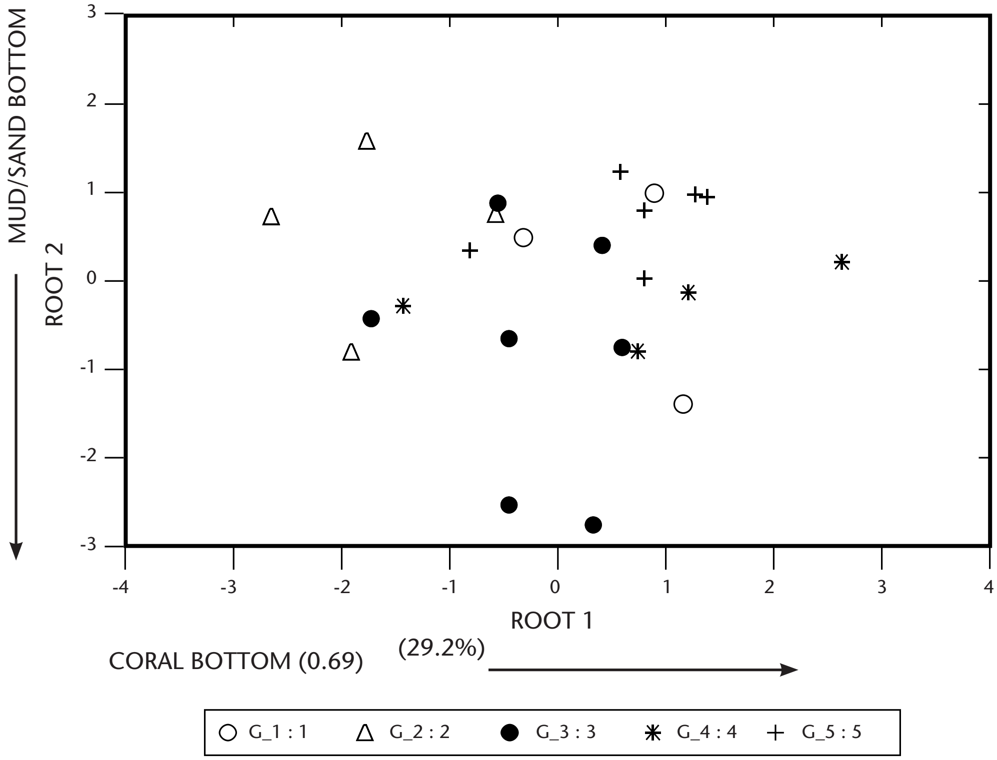


Fig. 6. Plot of 24 fishing grounds (cluster membership shown in legend at lower right of figure) in environmental space (i.e. canonical roots derived by discriminant analysis). Percentages refer to portion of total variation in the data accounted for by each root. Roots are defined by variables showing the highest correlations (in parentheses) with them.

Systematic and Quasi-systematic Trawl Surveys

Generally, the demersal resources in Manila Bay, San Pedro Bay and Samar Sea are characterized by a large number of ubiquitous species that occur in varying abundances across the different habitats in the areas surveyed. In all three areas leiognathids comprised at least 28% of the total trawl catches, and together with squid (*Loligo* spp) comprised up to 59% of the total catch (Tables 3 - 5).

In terms of habitat relations, depth appears to be the primary factor in San Pedro Bay and Samar Sea. In San Pedro Bay, catch species composition shows a transition at depths of 15 - 20 m (Figs. 7 & 8). This depth range transition is also consistent throughout the year. Temporal analysis of the data showed the following grouping of months: June - July, August - November, and December - May; roughly corresponding to the monsoon and inter-monsoon seasons. The spatial distributions of station clusters during the SW monsoon and inter-monsoon seasons show little variation from the overall annual pattern (Fig. 8), particularly the transition in species assemblage distribution at the 15 - 20 m depth range.

Similarly, demersal assemblage composition in Samar Sea shows a transition at the 30 - 40 m depth range, and again at the depths of 50 - 60 m, with further differences in composition between inner

(southern) and outer (northern) stations in deeper areas (Figs. 9 & 10). As in San Pedro Bay, the results of the temporal analysis again closely paralleled the monsoon and inter-monsoon seasons; April - June, July - October, and February - June. Spatial analysis within each season showed close similarities with the overall annual pattern, with the depth range transition in species assemblages remaining constant all year round but also with some intensification of the inner-outer differences in station clustering towards and during the southwest monsoon season.

Manila Bay shows a different pattern, since changes in species composition appear to be more related to location (i.e. inner or outer portions) than to depth (Figs. 11 & 12). In both inner and outer portions there are also qualitative differences in species composition between the western and eastern halves of the bay (Fig. 12). Again, similar to the previous two areas, this general annual pattern is shown throughout the year, although some seasonal differences in the delimitation of inner and outer portions of the bay are evident. Whether such variations are the result of factors like local hydrography, bay topography, watershed characteristics or fishing effort distribution is not known, but it would be interesting to investigate further. The temporal pattern in Manila Bay shows a clear correspondence with the Northeast (November - March) and Southwest (May - September) monsoon seasons.

In all of the above three areas, seasonality or within-year differences in species distribution and composition reflect the monsoon and inter-monsoon systems. This is also shown in the results of the temporal analysis of data from Sorsogon Bay and Tayabas Bay (Figs. 13 & 14). In Sorsogon Bay, the grouping of months are April - July, August - November, and December - February. In Tayabas Bay, the transition months June, October and December grouped together, while the regular monsoons were formed by the remaining months. The question of possible differences in the effects of the monsoon systems on the distribution of demersal resources in different portions of the country (e.g. South China Sea coast, interisland waters and Pacific coast) still remains. This may be addressed when sufficient data for the different regions become available.

Table 3. Most abundant trawl-caught species in Samar Sea, 1979 - 80.

Species	% of total catch
Leiognathus bindus	25.30
Loligo sp.	5.93
Pentaprion longimanus	5.93
Saurida undosquamis	4.70
Saurida tumbil	3.60
Upeneus sulphureus	3.10
Nemipterus nematophorus	3.10
Leiognathus splendens	2.84
Rastrelliger brachysoma	2.74
Decapterus macrosoma	2.63
Apogon spp.	2.30
Sepia sp.	2.27
Leiognathus equulus	2.22
*Trichiurus haumela (T. lepturus)**	2.22
Rastrelliger kanagurta	2.01
*Sphoeroides lunaris (Lagocephalus lunaris)**	1.95
Priacanthus macracanthus	1.76
Priacanthus tayenus	1.73
Fistularia spp.	1.70
Stolephorus indicus	1.31

* Valid name in Fish Base

Table 4. Most abundant trawl-caught species in San Pedro Bay, 1994 - 95.

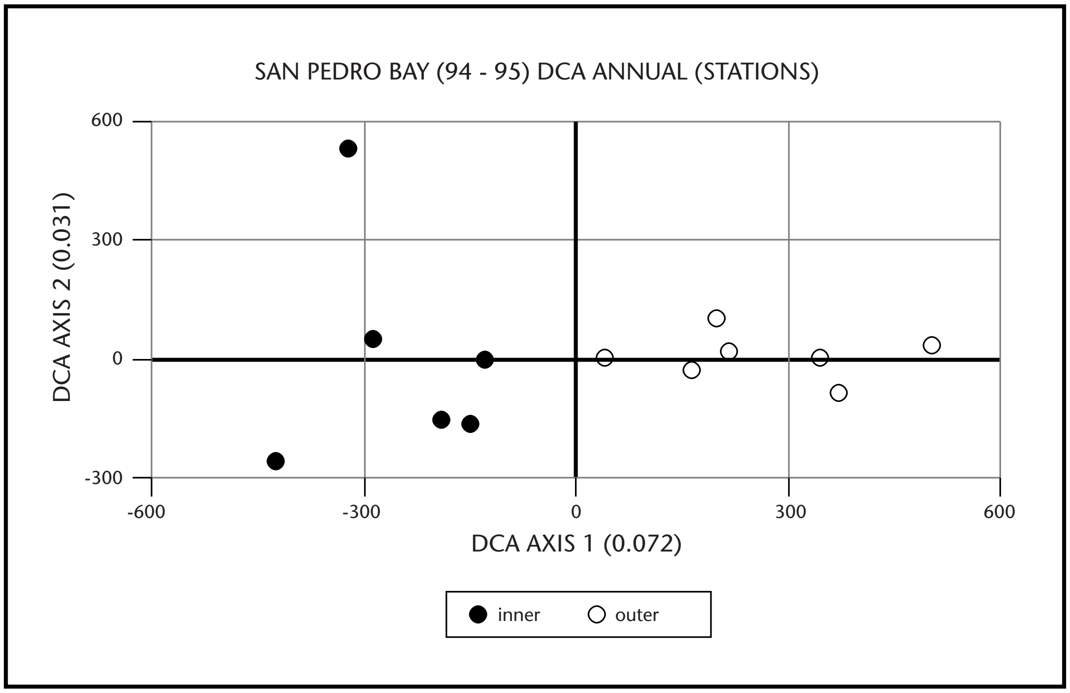
Species	% of total catch
Leiognathus splendens	26.18
Leiognathus bindus	17.43
Gazza minuta	6.54
Secutor ruconius	4.51
Leiognathus equulus	3.64
Dussumieria acuta	3.01
Loligo sp.	2.39
*Gerres abbreviatus (G. erythrourus)**	2.21
Nemipterus hexodon	2.18
Saurida tumbil	2.02
Leiognathus leuciscus	1.93
*Trichiurius haumela (T. lepturus)**	1.86
Apogonidae	1.58
Secutor insidiator	1.49
Selariodes leptolepis	1.30
*Stolephorus commersoni (S. commersonii)**	1.21
Holothuridae	0.99
Pentaprion longimanus	0.97
Sardinella gibbosa	0.78
Scolopsis taeniopterus	0.75

* Valid name in Fish Base

Table 5. Most abundant trawl-caught fishes in Manila Bay, 1992 - 93.

Species	% of total catch
Loligo sp.	22.70
Secutor insidiator	12.61
Leiognathus bindus	10.31
Gazza minuta	5.38
*Trichiurus haumela (T. lepturus)**	3.25
Thryssa setirostris	2.49
*Stolephorus bataviensis (S. waitei)**	2.37
Gerres filamentosus	2.29
Atule mate	2.24
Stolephorus indicus	2.06
Valamugil seheli	2.04
Apogon sp.	1.98
Pelates quadrilineatus	1.89
Upeneus tragula	1.65
Stolephorus commersonii	1.61
Stolephorus sp.	1.54
Sardinella fimbriata	1.51
*Caranx malabaricus (Carangoides malabaricus)**	1.41
*Pennahia macrophthalmus (P. anea)**	1.32
Arothron stellatus	1.22

* Valid name in Fish Base



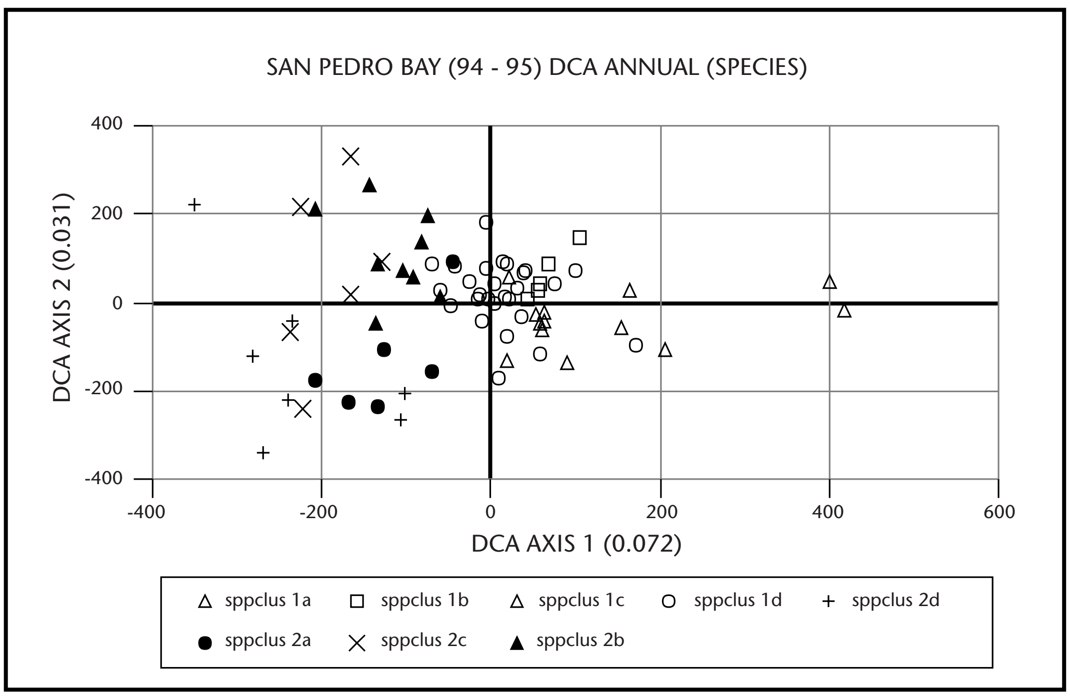


Fig. 7. Ordination of stations (above) and species (below) in the spatial analysis of San Pedro Bay data.

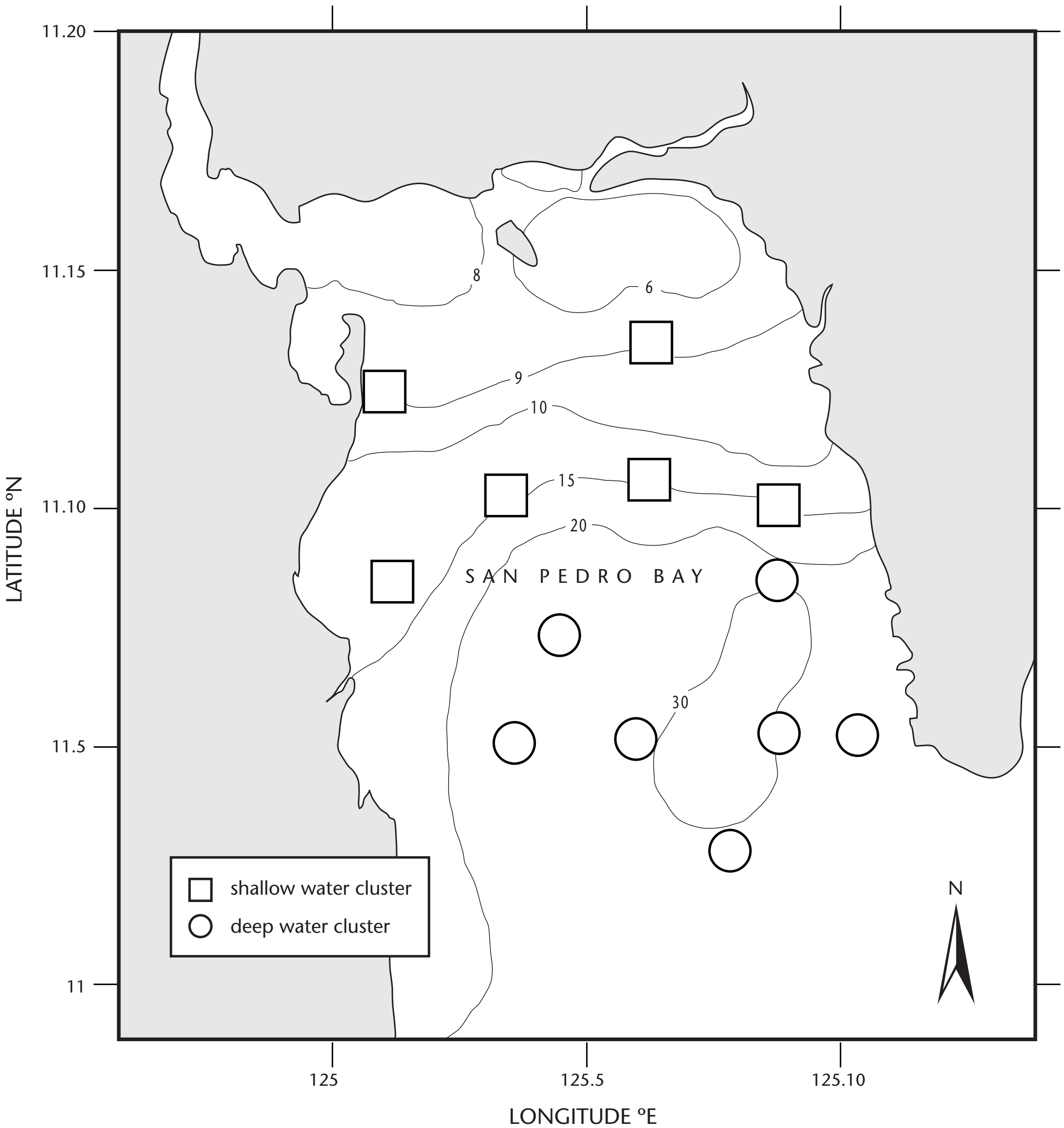


Fig. 8. Map of station cluster locations in San Pedro Bay based on the annual spatial analysis. Isobaths are in meters.

Outer Deep | Inner Deep | Outer Shallow | Inner Shallow

			Outer Deep	Inner Deep	Outer Shallow	Inner Shallow	
			11 1 112	122222	12 2	12 11	
			13890567490	281567	52344	283176	
4	Brac	spp	33332122322	322112	–1–1–	––––––	000
47	Trig		54111111344	442234	–1––1	––––––	000
22	Nemi	nem	55544445444	544244	23343	–22––1	001
25	Pria	mac	54443355444	442223	32–41	–1–––2	001
28	Pter	spp	2223–212232	332333	–1322	1–––2–	001
50	Urab	spp	33212222112	431223	3–111	11––––	001
2	Alut	mon	22–1221–122	333334	32113	–1––13	010
8	Deca	mac	53343222223	242444	21–32	133–25	01100
11	Fist	spp	44443444444	453344	33333	332–22	01100
10	Epin	sex	2223–333333	342334	31332	–22113	01101
23	Pent	lon	54554433444	554555	45445	333122	01101
34	Saur	und	45554455555	444334	44443	442333	01101
51	Uras	hel	2133–333222	332222	3233–	211–12	01101
9	Elat	spp	––1–3323122	13221	33232	111113	011100
26	Pria	tay	44333444444	344344	44444	224233	011100
35	Scol	tae	2–332224212	–22433	33334	123122	011100
43	Sphy	lan	31–43311–12	231122	12224	2121––	011100
3	Apog	spp	44443444444	444444	44443	443344	011101
7	Cham	spp	3232–222222	222122	23232	221221	011101
13	Leio	bin	65555555455	555655	45555	544343	011101
17	Loli	spp	54443444444	454544	54545	554555	011101
18	Natn	sp	21121111122	211122	11131	111222	011101
19	Nemi	bat	–133–222212	–33333	23222	3231–2	011101
21	Nemi	jap	43333333433	333223	43432	433444	011101
24	Plat	spp	33121222212	4–1121	12222	231332	011101
27	Pset	eru	322–22–1222	31332	––222	33212–	011101
29	Rast	bra	24334353344	344444	45444	335334	011101
30	Rast	kan	33423432545	2–1343	42453	443343	011101
32	Sard	sam	2231–232222	122333	23212	233343	011101
33	Saur	tum	45544445444	444444	44444	444444	011101
39	Sepi	spp	44442444444	444434	44453	444344	011101
40	Seri	nig	4234–323222	332312	13332	222311	011101
41	Spho	lun	44442444444	443333	43443	343444	011101
45	Stol	ind	32233434334	423344	44442	433344	011101
46	Tric	hau	34332333332	415225	54353	432443	011101
48	Upen	sul	444–2444444	544454	34444	444443	011101
5	Cara	mal	2122–312–21	332332	23323	121232	01111
31	Rept	3	3211–1–2333	31323	33113	132133	0111
36	Scom	com	–––2–313132	–13442	33333	343433	1000
37	Sela	mat	–4–––432222	–22432	33344	333132	1000
38	Sela	lep	–2–3–321333	133433	34434	444433	1000
49	Upen	sun	11–2–322232	343323	33233	233333	1000
20	Nemi	hex	11332122111	23–333	33323	333333	1001
42	Sphy	jel	32–1––––312	333–44	2–222	323333	1001
44	Sphy	obt	21––211221–	412223	23–34	223322	1001
1	Alep	dje	–––––23–112	1–3332	32452	234432	101
15	Leio	leu	431––2112––	3–1332	43434	432423	101
6	Cara	arm	11–––222211	–12221	22332	333332	11
12	Gerr	kap	–1–––1111–1	–1––––	32342	233434	11
14	Leio	equ	–––––––11–2	2222–2	44454	444544	11
16	Leio	spl	–––––––11––	–1––––	43553	354545	11
			00000000000	000000	11111	111111	
			00000000000	111111	00000	111111	
			00111111111	001111	00111	000001	
			000111111			00011	
			000111				

Fig. 9. Two-way table output for annual spatial analysis of Samar Sea data.

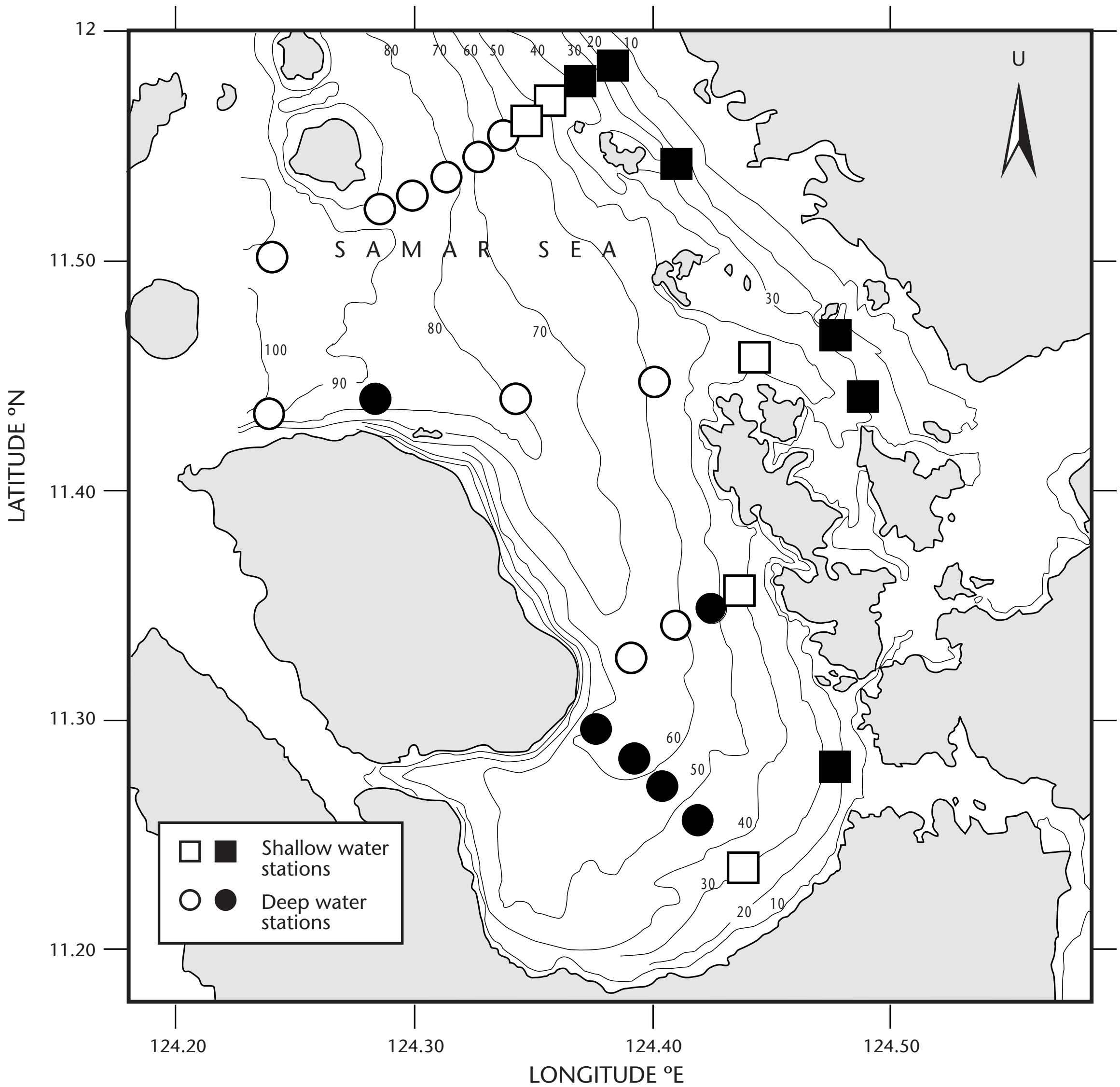


Fig. 10. Map of station cluster locations in Samar Sea for the entire study period, March 1979 - May 1980 (annual spatial analysis). Isobaths are in meters.

		Inner		Outer		
		111			1111	
		012	578961	234	3456	
3	Mugicep	244	–––––2	–––	–––1	000
14	Scomcom	––1	–12232	–––	1–––	000
16	Eleutet	334	–33211	–––	–––1	000
32	Stolbat	556	265537	–––	––––	000
27	Sciaenid	614	2–662–	–––	1–12	0010
28	Stoltri	444	66656–	––6	3–––	0010
37	Stolcom	677	544645	35–	2–––	00110
39	Pennmac	456	343442	–1–	2–44	00110
43	Sillsih	433	431343	131	–––2	00110
44	Thryset	654	464454	–46	1–1–	00110
23	Nemanas	445	–432––	–––	––32	00111
25	Valaseh	466	22–2–2	222	––––	00111
17	Stolepho	756	–––5–7	64–	––––	010
18	Therjar	122	––11–2	–21	–––1	010
22	Lagoine	333	2––213	–2–	–4–1	010
35	Leiospl	444	1–––33	344	–––2	010
34	Alepmel	222	–41232	322	–––2	01100
46	Sardfim	447	244324	343	–––4	01100
48	Atulmat	443	353451	–23	2144	01100
54	Gerrfil	655	454444	243	––44	01100
36	Pelaqua	231	222241	–21	–136	011010
50	Caramal	334	442343	244	134–	011010
51	Penaeus	444	343344	133	3–43	011010
2	Megacyp	–1–	–1–2––	–1–	––2–	011011
42	Nemijap	2––	232343	–13	2–34	011011
45	Upensul	122	13–353	332	––43	011011
55	Trichau	432	444645	255	4255	011011
56	Secinsi	644	476567	777	1464	011011
57	Loligos	655	666766	566	5466	011011
9	Rastkan	2––	331–––	–21	––1–	0111
11	Gobiidae	–12	22––3–	––1	1–2–	0111
12	Platycep	–11	–3111–	–––	–2–2	0111
6	Valamugi	–12	––––22	–22	––––	1000
7	Caraarm	–––	––2222	–42	––––	1000
26	Scatarg	–––	2–1–12	132	–––1	10010
38	Leioequ	11–	221–24	344	–––2	10010
10	Sphyfor	–1–	–––124	122	–4––	10011
20	Caradin	–––	–31211	–3–	–13–	10011
49	Gazzmin	244	442464	464	2434	10011
53	Apogons	233	543356	236	5655	10011
19	Sphyjel	––2	1112–2	–––	–234	1010
21	Alecind	2––	2–211–	–2–	2–32	1010
31	Squilla	––2	2–1–53	–22	2343	1010
8	Pomamac	–2–	––––21	–12	––12	1011
29	Sphybar	322	–221––	22–	–132	1011
47	Crabs	142	111111	111	3332	1011
33	Stolind	–––	–6–––6	254	––46	11000
40	Selalep	–––	–4–14–	453	2–42	11000
41	Leioleu	21–	232342	653	–334	11000
1	Aleccil	11–	1–––––	–3–	––2–	11001
24	Tetraodo	11–	–211–1	223	–2–2	11001
30	Saurtum	–1–	11–––2	332	––3–	11001
52	Leiobin	–2–	5–2342	–67	5776	1101
4	Pentlon	–––	––––––	––1	–424	111
5	Pomacent	–––	––––––	3––	–4––	111
13	Priatay	–––	–––––1	233	2–2–	111
15	Upentra	–––	––––––	21–	–62–	111
		000	000000	111	1111	
		000	111111	000	1111	
			000001			
			00001			

Spp cluster 1a

More common and abundant in inner stations

Spp cluster 1b

No clear spatial distribution pattern; Includes ubiquitous species

Spp cluster 2a

Low to moderately abudant species with slight preference for outer stations

Spp cluster 2b

Low to moderately abudant species with somewhat stronger preference for outer stations

Fig. 11 Two-way table output from TWINSPAN showing station and species clusters for the annual spatial analysis of Manila Bay trawl data (1992 - 93).

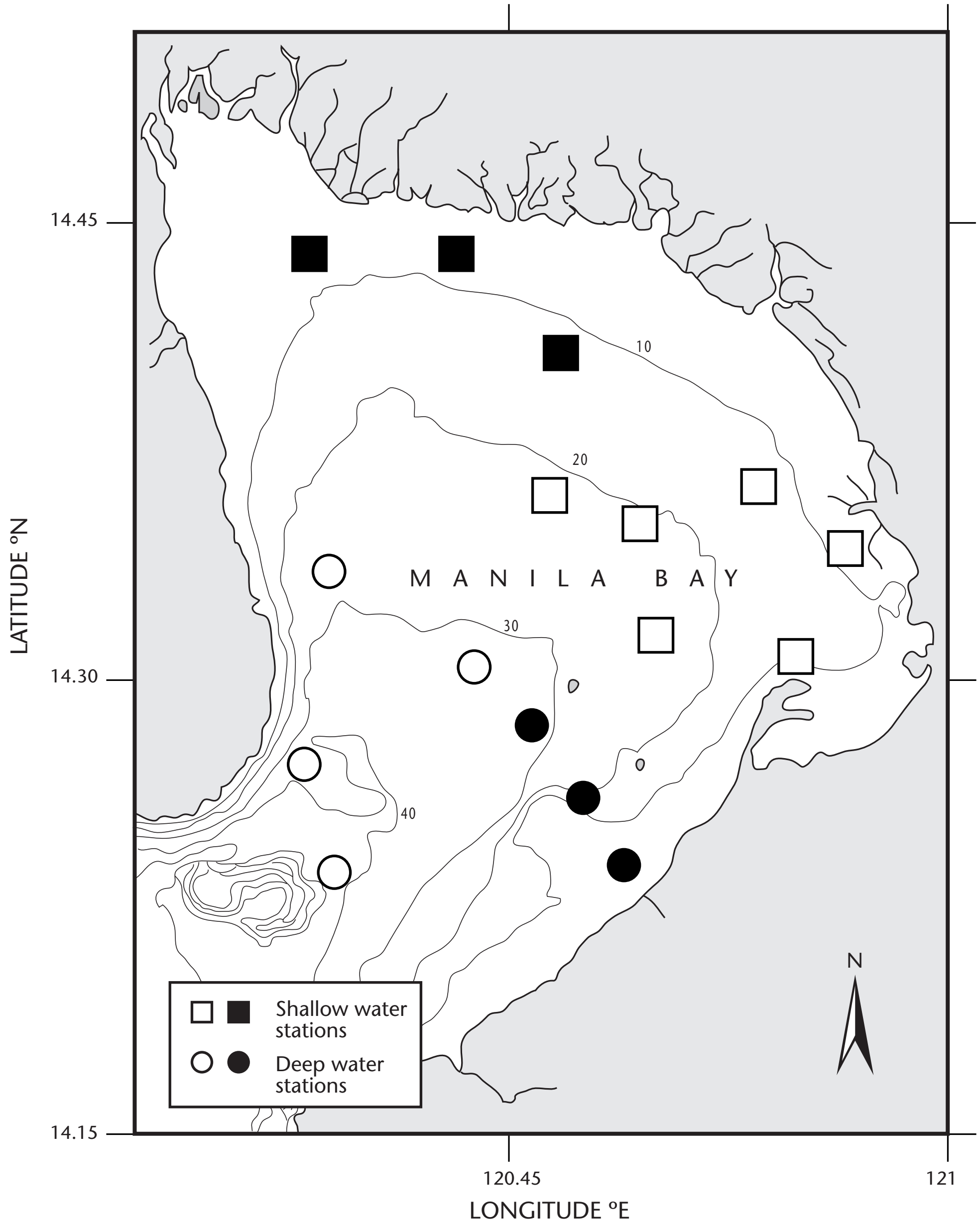


Fig. 12. Map showing location of station clusters formed in the annual spatial analysis of Manila Bay data (September 1992 to October 1993).

		8 9	4 5 6 7	1 2 3		
7	Crabs(s)	3 3	– – – –	– – –	0 0 0 0	Present only during Northeastern monsoon months
18	Shrimp	3 –	– – – –	– – –	0 0 0 0	
34	Cynoglos	2 –	– – – –	– – –	0 0 0 0	
40	Saurida	3 –	– – – 1	– – –	0 0 0 0	
53	Charybdi	– 3	– – – –	– – –	0 0 0 0	
38	Soleahu	– 2	– – – 1	– – –	0 0 0 1 0 0	Moderately abundant during both Northeastern & Southwest monsoon months, but with higher abundances
41	Octopus	2 –	1 – – –	– – –	0 0 0 1 0 0	
48	Therapon	– 2	– 1 – –	– – –	0 0 0 1 0 0	
17	Shrimp (	– 4	1 1 – 2	– – –	0 0 0 1 0 1	
21	Goby sp.	4 4	3 2 3 2	– – –	0 0 0 1 0 1	
26	Gerress	2 3	– – – 3	– – –	0 0 0 1 0 1	
12	Sillago	3 4	– – 2 –	– – 1	0 0 0 1 1	
15	Seasnake	– –	2 – – –	– – –	0 0 1 0	Absent during transition months (Apr - Jul), but no clear pattern for the rest of the year. Includes uncommon and ubiquitous apecies
19	Sphyraen	– –	– – 1 –	– – –	0 0 1 0	
22	Goby sp.	– –	1 – – –	– – –	0 0 1 0	
23	Goby sp.	– –	1 – – –	– – –	0 0 1 0	
32	Bukawil	– –	– 1 – –	– – –	0 0 1 0	
45	Lagoceph	– –	– – 2 –	– – –	0 0 1 0	
50	Therapon	– –	– – 2 –	– – –	0 0 1 0	
51	Upeneus	– –	1 – – –	– – –	0 0 1 0	
2	Apogonq	4 4	4 4 4 4	4 – –	0 0 1 1	
46	Leiognat	4 3	3 4 4 4	– 1 1	0 0 1 1	
20	Triacant	2 –	– – – 1	– – 1	0 1 0 0	
43	Platycep	3 3	– 1 1 –	1 1 –	0 1 0 0	
49	Therapon	3 –	– 1 – –	– 1 –	0 1 0 0	
13	Seacucu	– 4	3 – 3 –	– – 3	0 1 0 1 0	Species with moderate to high abundances and common throughout the year
28	Platycep	3 2	3 3 3 3	2 3 –	0 1 0 1 0	
11	Portunus	4 4	3 3 4 3	3 3 4	0 1 0 1 1 0	
16	Secutor	2 2	3 1 3 –	– 1 3	0 1 0 1 1 0	
31	Brachyrh	3 3	4 3 3 3	2 3 4	0 1 0 1 1 0	
39	Scorpaen	2 2	1 – 2 2	1 1 2	0 1 0 1 1 0	
8	Pseudorh	3 3	– – 1 3	3 1 –	0 1 0 1 1 1	
6	Tetraodo	– –	– 3 – 2	3 – –	0 1 1	Species with low abundances and present during the Southwest and trasition months
9	Pseudorh	– –	2 2 2 3	– 2 3	0 1 1	
25	Gerress	– –	– 2 2 –	– – 1	0 1 1	
37	Solea sp	– –	– – 2 2	1 – –	0 1 1	
14	Seas nake	3 2	2 – 2 –	– 3 2	1 0	Species rarely occurring during the Northeastern months and most common during transition months
36	Sepia sp	– 3	– 1 – 1	– 1 2	1 0	
5	Loligos	– –	3 2 2 –	4 3 3	1 1 0	
27	Platycep	– –	1 – – 1	– – 2	1 1 0	
30	Sillago	– –	1 2 – 2	2 2 –	1 1 0	
55	Cyno glos	– –	– – – 1	– 1 1	1 1 0	
1	Alectis	– –	– – – –	– – 1	1 1 1	Species present only during transition months
3	Apogonq	– –	– – – –	– 4 4	1 1 1	
4	Gobiidae	– –	– – – –	4 4 2	1 1 1	
10	Pseudorh	– –	– – – –	– 1 –	1 1 1	
24	Gobiidae	– –	– – – –	3 3 –	1 1 1	
29	Penaeus	– –	– – – –	2 3 2	1 1 1	
33	Cynoglos	– –	– – – –	2 – –	1 1 1	
35	Squilla	– –	– – – –	– – 2	1 1 1	
42	Platycep	– –	– – – –	1 – –	1 1 1	
44	Platycep	– –	– – – –	1 – –	1 1 1	
47	Leiognat	– –	– – – –	1 – –	1 1 1	
52	Penaeus	– –	– – – –	1 – –	1 1 1	
		0 0	0 0 0 0	1 1 1		
		0 0	1 1 1 1			

Northeastern monsoon months

Southwest monsoon months

Transition months (Apr - Jul)

Fig. 13. Two way table output for temporal analysis of Sorsogon trawl data. Sampling was monthly April (1) to January (9) (no sampling in May).

		8 4 5 6 2 7	1 3 9	
13	Red Snap	– 3 3 2 1 –	– – –	0 0 0
19	Thick-li	– 2 2 – 1 3	– – –	0 0 0
22	Trumpetf	– 1 – 1 – –	– – –	0 0 0
15	Redbull	– 3 2 3 1 2	1 1 –	0 0 1
20	Groupers	3 2 – – – –	– – 1	0 0 1
21	Blackpo	– 1 – 2 2 1	– 1 –	0 0 1
7	Lizardfi	3 4 3 3 2 3	1 2 –	0 1 0
11	Threadfi	3 2 3 2 4 3	1 1 1	0 1 0
17	Whitings	2 1 1 3 1 2	– 1 1	0 1 0
16	Imperial	1 2 3 2 – –	1 2 –	0 1 1 0 0
6	Barracud	– 4 1 3 1 3	3 3 1	0 1 1 0 1 0
1	Slipmout	4 4 4 4 4 4	4 4 4	0 1 1 0 1 1
2	Goatfish	4 4 4 4 4 4	3 4 4	0 1 1 0 1 1
3	Carangid	4 4 3 4 3 4	3 4 4	0 1 1 0 1 1
4	Mojarras	4 3 4 3 2 3	2 2 3	0 1 1 0 1 1
5	Anchovie	4 4 2 3 3 3	2 2 –	0 1 1 0 1 1
10	Monocle	2 3 3 3 – 3	2 1 3	0 1 1 0 1 1
12	Four-lin	2 3 2 2 2 2	1 2 2	0 1 1 0 1 1
26	Crabs	1 1 1 1 1 1	1 1 1	0 1 1 0 1 1
8	Hairtail	– 2 – 2 2 4	3 2 –	0 1 1 1
9	Sardines	3 2 2 2 3 2	3 – 2	0 1 1 1
14	Mackerel	2 2 – 1 2 3	1 – 2	0 1 1 1
23	Squids	3 3 3 3 3 3	3 4 4	1 0
29	Scallops	3 2 1 1 2 1	1 4 3	1 0
24	Cuttlefi	– 1 1 1 2 1	1 4 –	1 1 0
27	Mantiss	– – 1 – 1 1	– 4 1	1 1 0
18	Fusilier	– – – – – 1	2 – 3	1 1 1
25	Octopus	– – – – – –	– – 1	1 1 1
28	Penaeid	– – – – – –	– – 1	1 1 1
		0 0 0 0 0 0	1 1 1	
		0 1 1 1 1 1		
		0 0 0 1 1		

Species rare during transition months (Oct, Dec & Jun)

Species occurring all year round in comparable abundances. Includes species with high and low abundances

Species most abundant during transition months

Transition months

Northeastern monsoon months

Fig. 14. Two way table output for temporal analysis of Tayabas Bay data. Sampling was monthly from October (1) to June (9).

Conclusion

The 24 fishing grounds in the exploratory surveys in 1947 - 49 can be arranged in gradients reflecting their substrate make-up (i.e. relative coral cover and sediment characteristics). Catch rate ($kg \cdot hr^{-1}$) was negatively correlated with both average water depth (-0.48, $p < 0.05$) and mud/sand substrate (-0.51, $p < 0.05$), and reflects an underlying trend of increasing catch rates in areas with shallower and more muddy bottoms. This is also consistent with the distribution of the more abundant families in the catches (e.g. Leiognathidae, Mullidae).

Depth appears to be the primary factor that determines the station clusters in Samar Sea and San Pedro Bay. In San Pedro Bay, catch species composition shows a consistent transition at depths of 15 - 20 m throughout the year. Similarly, Samar Sea shows a transition at the 30 - 40 m depth range, and again at the depths of 50 - 60 m, with further differences in composition between inner (southern) and outer (northern) stations. Manila Bay shows a different pattern; changes in species composition appear to be more related to location (i.e. inner or outer portions) than to depth. Differences in demersal assemblages were observed throughout the year in both inner and outer portions, and between the western and eastern halves of the bay seasonality or within-year differences in species assemblages reflecting the monsoon systems were also evident in Sorsogon Bay and Tayabas Bay.

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Preliminary Analysis of Demersal Fish Assemblages in Coastal Waters of the Gulf of Thailand

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Abstract

The 1995 trawl data of the research vessels Pramong 2 and 9 in the Gulf of Thailand were analyzed using TWINSPAN and DCA. Four main station clusters were identified related to geographic location and depth. Two clusters are associated with shallow water areas and the other two clusters are found in deeper areas with water depths > 30 m. Temporal analysis indicates clustering of monthly data into wet and dry seasons. Examination of species abundance data indicates that the seasonality may not be very pronounced. However, this may be due to the degree of disaggregation used in sorting the trawl survey samples.

Introduction

There is much evidence indicating over-exploitation of marine resources in the Gulf of Thailand. The evidence includes the results of trawl monitoring surveys using RV Pramong #2 and #9. A declining trend in catch-per-unit effort (CPUE, kg•hr^{-1}) has been observed: from 172 kg•hr^{-1} in 1966 to about 40kg•hr^{-1} in 1989 (Eiamsa-ard and Amornchairojkul 1997). The decline continues up to the present time. The same trend has been observed in the commercial trawl fisheries operating in the Gulf. The species and sizes captured reflect the very small cod-end mesh size used by trawlers, resulting in a high percentage of trash fish (about 40 - 50%) in the catch. In addition, approximately 40 - 60% of the trash fish consists of young, economically-important food fish (Isara 1996; Supongpan and Kongmuag 1981). The young economically important food fish caught averaged total length from 3.5 to 4.5 cm (Isara 1996).

The fishing mortality index also showed a slight increase from 1961 to 1986, and increased tremendously from 1987 onwards (FAO 1996a). The number of registered trawlers in Thailand increased from 2 601 in 1970 to 12 639 in 1989 (Department of Fisheries 1995a). The excess fishing effort is estimated to be about 60% of the number of registered trawlers (FAO 1996b). Since 1990, registered

trawlers have not exceed 10 000 units due to a policy of allowing no new entry and termination of registration of old units. However frequent requests to re-open registration for illegal trawlers have resulted in poor compliance with the policy. In addition, trash fish requirements of fishmeal plants are about 1.75 million t annually. The Gulf supplies about 52% of this demand, with sardine catches and imported dried trash fish making up the rest (Department of Fisheries, 1995b). Trash fish demand is one of the main reasons for continuing over-exploitation of the Gulf.

This paper presents results of analyses of data from trawl surveys conducted in the Gulf of Thailand in 1995 using methods commonly used for community structure analysis. The study aims to determine the (1) composition of species assemblages; and (2) environmental parameters which help explain the assemblage patterns observed.

Materials and Methods

The Gulf of Thailand (Fig. 1) is situated from 6º N to 13º30' N latitude and 99ºE to 104º E longitudes. It has a seabed area of 304 000 km^2 and is relatively shallow, with a mean depth of 58 m and maximum depth of 85 m. Fishing activities occur throughout the area (Supongpan 1996). The Gulf is delineated into 9 statistical areas. Each area is divided into grids measuring 30 nm^2. Sampling was set to 80 trawl hauls (each lasting 1 hr) in each area, or a total of 720 hauls for the 9 areas in one year. Routine surveys using this sampling scheme was started in 1963 and continued up to 1976. The abundance of commercially important demersal species in the Gulf of Thailand has been found to be very low beyond 50 m depth while depths of less than 10 m yield very high quantities of trash fish (Isarankura 1971). The surveys therefore were carried out mainly within the 10 to 50 m depth range. Sampling was stratified by depth: 10 - 19 m, 20 - 30 m, 31 - 44 m and more than 44 m.

The R.V. Pramong 9 and R.V. Pramong 2 were used for monthly sampling from 1977. In a sampling month, the R.V. Pramong 2 was used in Areas I to IV while R.V. Pramong 9 was used in Areas V to IX. This deployment was reversed in the next sampling month. In 1977, depth stratification was discarded although the grid area was reduced to 15 x 15 nm^2. Information on the catch, species caught, biological data and size distribution of important species were collected routinely. The number of hauls in each area has varied; currently the number of hauls is about 60 hauls per area, with a total of about 540 hauls per year for the 9 statistical areas.

R.V. Pramong 2 is a 320 HP wooden stern trawler of 79.13 gross tons (GT) and 24.5 m length overall. On the other hand, R.V. Pramong 9 is a 415 HP wooden stern trawler of 84.89 GT and 25.25 m length. Both research vessels use the same German trawl net with otter boards. The trawl net is made of nylon and has a total length of 47.7 m, wing width of 17 m, and a height of 3.5 m. The mesh sizes decrease from 16 cm stretched mesh at the wing to 4 cm at the cod-end. The ground rope and head rope is 48 and 39 m, respectively. The otter boards are made of hard wood covered with steel at their edges (Eiamsa-ard and Amornchairojkul 1997; Eiamsa-ard et al. 1977). Due to differences in size and power of the research vessels, the fishing efficiency of the two vessels was experimentally standardized in 1977 (Eiamsa-ard et al. 1977).

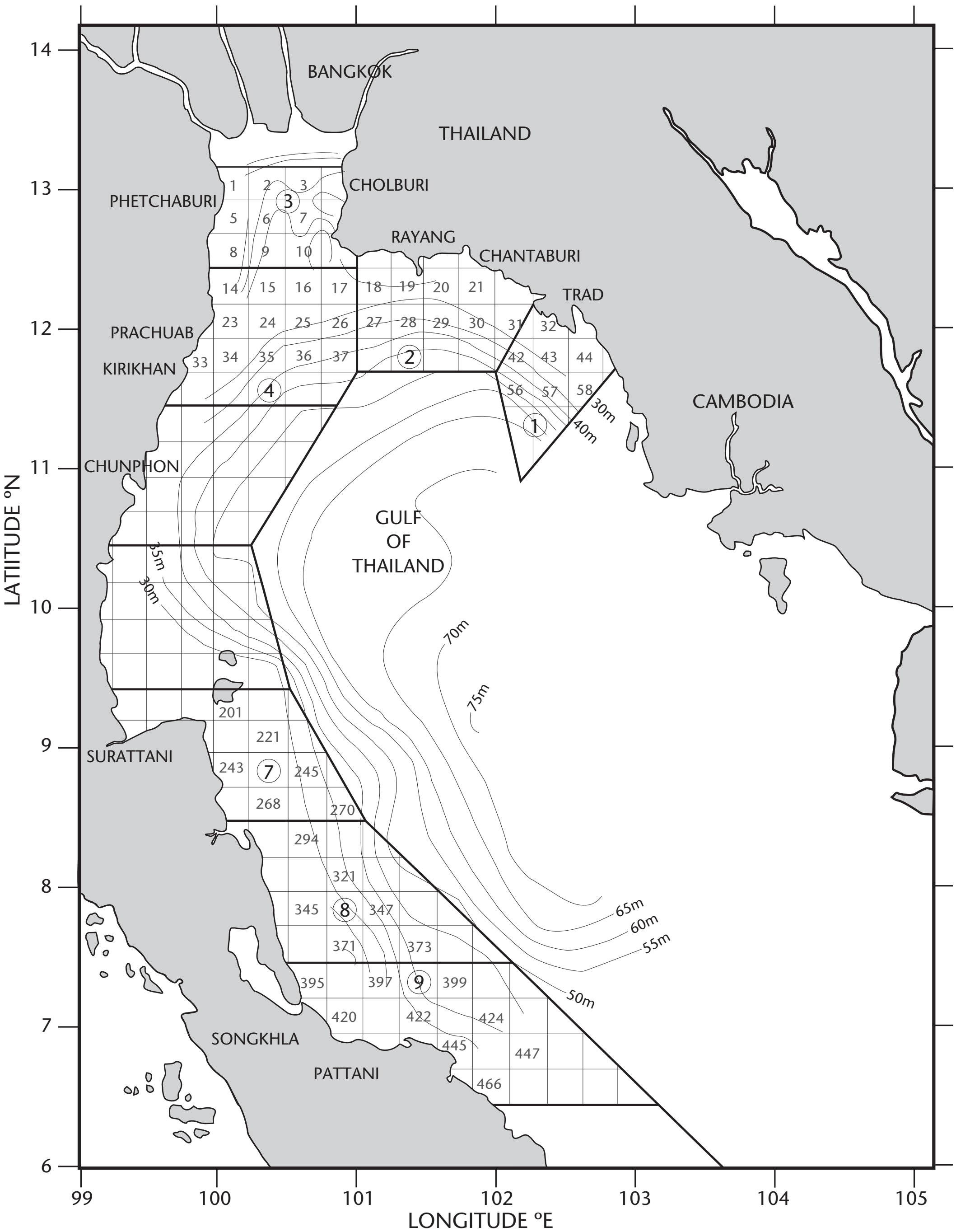

Fig. 1. Grid stations and depth contours in the Gulf of Thailand used in the study. Circled numbers indicate statistical areas.

Data collected by RV Pramong 2 and 9 in 1995 were used in this study. Data from a total of 59 fixed stations or grids numbered in Fig. 1 each measuring 225 nm^2 (15 x15 nm) were used. Data for areas 5 and 6 were not available. CPUE data for 8 months (January, March, June, July, August, September, October and December) were available to estimate mean biomass for each month using the swept area method. The analysis steps undertaken during the course of this study are illustrated in Fig. 2. CPUE values by statistical grid were utilized to estimate biomass. Biomass was estimated using the swept area method (Sparre and Venema 1992) as follows:

$$B = \frac{CPUE}{a \cdot X_1} \cdot A$$

where A is the station or grid area (= $(15 \cdot 1.853\,2)^2$ km^2),
a is swept area (= 0.090 29 km^2), and
X_1 is the proportion of fish in the path of the gear retained in the net (= 0.5).

The swept area was estimated from the equation:

$$a = t \cdot v \cdot h \cdot X_2$$

where t is the time spent trawling (= 1 hr),
v is velocity of trawling (= 2.5 knot),

h is the length of head-rope (= 39 m), and
X_2 is the ratio representing the effective head-rope length (= 0.5).

The resulting swept area (a) is 0.090 29 km^2.

CPUE (kg•hr^{-1}) was recorded to species level whenever possible. A total number of 175 species or groups were recorded across the grids covered by the study. After deleting species of less than 0.1% relative abundance, a total of 90 species or groups and 59 stations were used in the analyses. Mean biomass by grid or station was used in **T**wo-**W**ay **IN**dicator **SP**ecies **AN**alysis (TWINSPAN) (Hill, 1979) and Detrended Correspondence Analysis (DCA) using the CANOCO program (Ter Braak, 1988). Classification diagrams were drawn to show the species and sites assemblages. Outliers were deleted in the process of analyses.

An attempt to use the biomass data and environmental parameters in the southern part of the Gulf (areas 7, 8 and 9) in external analysis was made (by plotting the first DCA axis scores vs. environmental parameters). Chemical and physical parameters were collected specific to the same time and grid. Environmental parameters assembled were depth, bottom type, temperature, salinity, pH, dissolved oxygen, total suspended solids, nitrates, nitrites, ammonia and phosphate during the months of July, September and October 1995. A summary of the bottom type data is illustrated in Fig. 3. Due to the limited spatial and temporal coverage of the environmental data, the external analysis was discontinued.

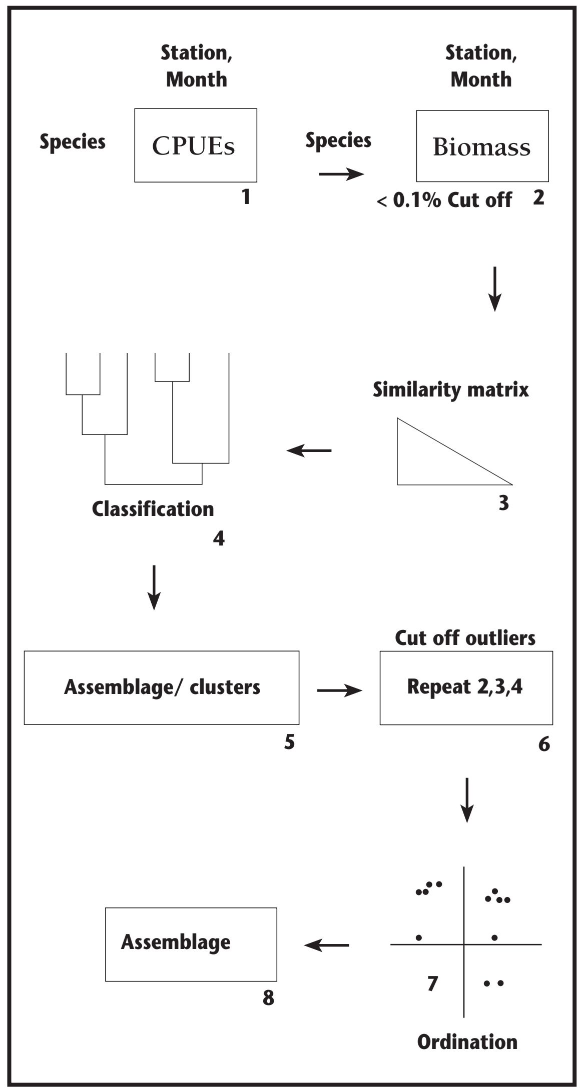

Fig. 2. Graphical representation of the stages of analysis made in this study.

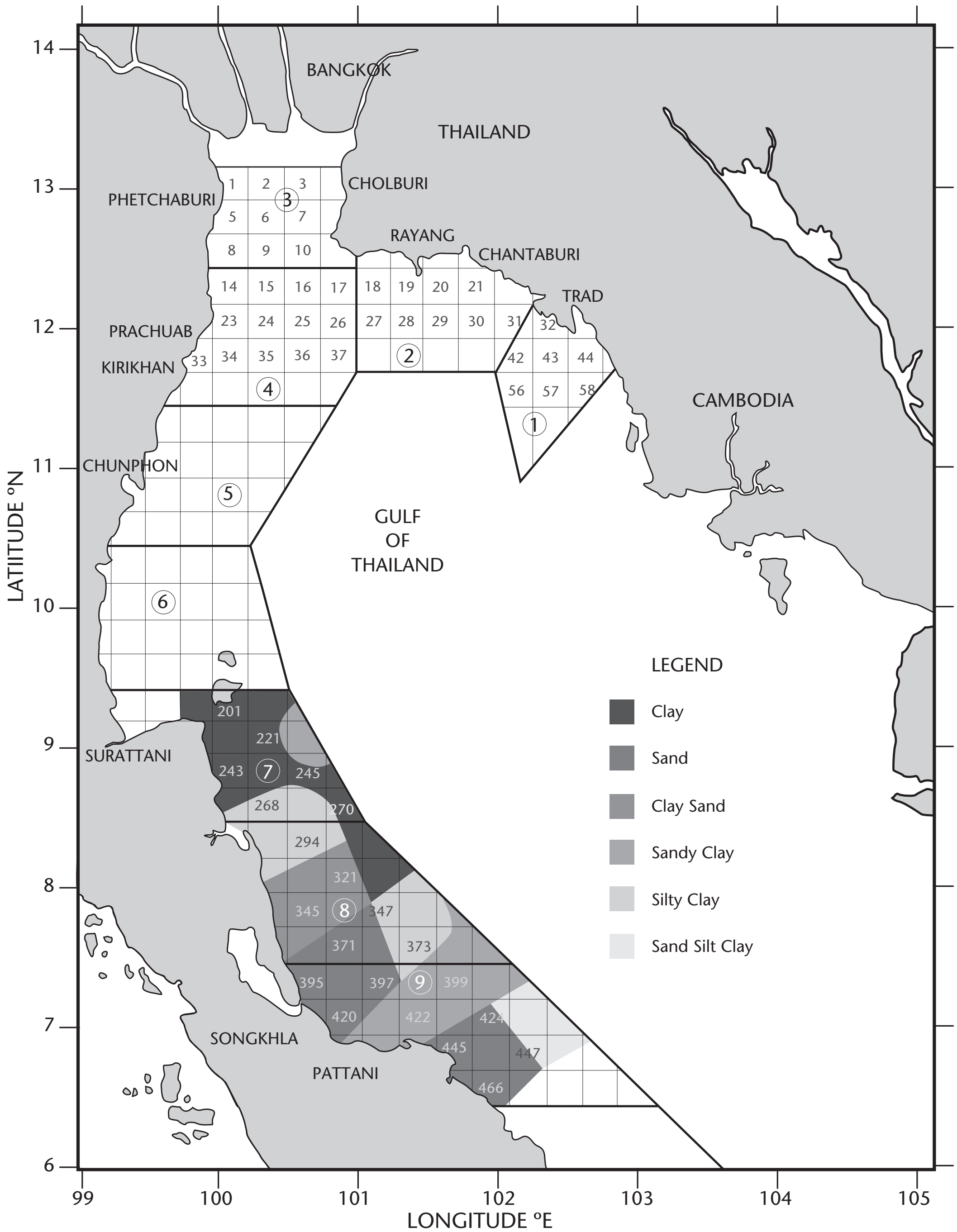

Fig. 3. Bottom types in the southern Gulf of Thailand, 1995.

Results and Discussion

Species Composition

A total of 175 species/groups from the 59 trawl grids/stations were caught by RV Pramong 2 and 9 in 1995. Data for species/groups which formed less than 0.1% of the total biomass were deleted, resulting into 90 species/groups retained for the analysis (Table 1). The most abundant groups were Leiognathidae (slipmouths), squids, Synodontidae, Sphyraenidae, miscellaneous trash fish, all Nemipteridae, *Priacanthus* spp., Mullidae, Carangidae and *Siganus* spp.. Leiognathids were dominant comprising over 20% of catches, and this included *Leiognathus elongatus, Leiognathus splendens, Leiognathus bindus* and *Leiognathus leniolatus.* In 1995, Leiognathidae was classified as food fish compared to previous work which grouped them as trash fish. Trash fish comprised about 40 - 50% of the total catch (Marine Fisheries Division 1997).

Two stations (016 and 033) were deleted because these were identified as outliers. Station 016 and 033 catches comprised 38 and 47 species/groups, respectively. The most abundant species/group in station 016 was Sphyraenidae (including *Sphyraena obtusata*), which accounted for about 84% of the biomass. At station 033, the most abundant group was miscellaneous trash fish which made up 82% of the biomass. One group heavily dominated these two outlier stations. The use of large categories (such as miscellaneous trash fish) gives the opportunity to dump species that are difficult to identify into this category. This issue has been noted in other studies (Bianchi et al. 1996). This can lead to inconsistencies between different stations of a given survey.

Table 1. CPUE (kg·hr^{-1}) and biomass (t) of 90 species/groups in the Gulf of Thailand, 1995.

Taxa	CPUE (kg·hr^{-1})	Biomass (t)	Taxa	CPUE (kg·hr^{-1})	Biomass (t)
Leiognathidae	277.1	3 496	Bothidae	7.0	134
Squids	154. 6	2 550	*Atule mate*	8.0	131
Leiognathus elongatus	103.6	1 702	Serranidae	7.5	125
Leiognathus splendens	126.6	1 491	*Alepes melanoptera*	7.0	118
Miscellaneous trash	124.0	1 478	*Charybdis ferriatus*	6.5	108
Synodontidae	84.4	1 405	*Scomberomorus commerson*	6.0	101
Sphyraenidae	70.4	1 194	*Leiognathus* spp.	12.1	101
Sphyraena obtusata	62.9	1 075	*Lutjanus vitta*	5.1	93
Scolopsis spp.	59.8	1 013	Miscellaneous crabs	5.9	92
Scolopsis taeniopterus	59.7	1 013	Fistulariidae	6.2	91
Saurida undosquamis	45.9	770	*Encrasicholina* spp.	6.2	90
Mullidae	41.4	659	Sciaenidae	6.3	87
Carangidae	36.9	564	*Sepia recurvirostris*	5.1	84
Loligo duvauceli	33.4	556	Trichiuridae	4.3	71
Leiognathus bindus	31.9	538	*Caranx malabaricus (Carangoides malabaricus*)*	4.3	71
Siganidae	34.0	527	*Rastrelliger kanagurta*	4.0	65
Nemipteridae	30.1	505	*Sepia lycidas*	3.9	64

Table 1. CPUE (kg·hr^{-1}) and biomass (t) of 90 species/groups in the Gulf of Thailand, 1995. (continued)

Taxa	CPUE (kg·hr^{-1})	Biomass (t)	Taxa	CPUE (kg·hr^{-1})	Biomass (t)
Priacanthidae	28.6	482	*Chirocentrus dorab*	3.9	62
Secutor spp.	51.3	455	*Megalaspis cordyla*	3.9	62
Cuttlefishes	23.9	412	*Sepia pharaonis*	3.7	60
Lutjanus lutjanus	24.4	402	Muraenesocidae	3.5	59
Amusium pleuronectes	23.3	390	Lutjanidae	3.5	59
Crabs	23.2	380	*Loligo chinensis*	4.2	52
Saurida elongata	22.3	365	*Pentaprion longimanus*	3.1	52
Lutjanidae	18.4	318	Clupeidae	3.8	52
Priacanthus tayenus	18.8	315	*Secutor ruconius*	2.6	51
Crabs (trash)	19.8	296	*Anodontostoma chacunda*	3.1	50
Loligo sumatrensis	17.6	291	Dorosomatinae	3.1	50
Saurida isarankurai	15.3	254	*Trichiurus lepturus*	3.0	49
Nemipterus mesoprion	14.9	246	*Selaroides leptolepis*	3.4	48
Sepioteuthis lessoniana	12.7	209	*Sphyraena jello*	2.7	47
Nemipterus hexodon	12.3	208	*Alepes kalla (A. djedaba*)*	5.1	47
Apogonidae	11.3	184	*Plectorhinchus pictus*	2.8	46
Lutjanus johni (L. johnii)*	11.1	176	Pleuronectidae	2.9	46
Leiognathus lineolatus	10.3	173	*Scomberomorus* spp.	3.4	43
Tetraodontidae	11.0	171	*Selar crumenopthalmus*	2.5	42
Portunus pelagicus	10.2	168	*Nemipterus peronii*	2.3	38
Priacanthus macracanthus	9.9	166	Cynoglossidae	1.8	38
Platycephalidae	9.8	163	Pentapodidae	2.3	38
Scombridae	10.18	157	*Sepia brevimana*	2.3	37
Balistidae	12.0	157	*Gazza minuta*	2.1	34
Octopus spp.	9.6	150	*Parastromateus niger*	2.	34
Rastrelliger spp.	9.0	149	*Rastrelliger brachysoma*	1.8	33
Sepia aculeata	7.9	147	*Secutor insidiator*	1.9	32
Mantis shrimps	9.2	147	Rays	2.2	32

Note: * valid name in Fishbase.

Spatial Analysis

The resulting station groupings using TWINSPAN are illustrated in Figs. 4 and 5. The DCA results are summarized in Fig. 6. Trawl stations are clustered into 4 groups, viz. Group A, B, C and D.

Group A includes 3 stations (stations 032, 044 and 058) located in the near-shore area at Ao Trad, Trad Province in the eastern part of the Gulf (Fig. 6). This group is in shallow areas with water depths less than 30 m (Fig. 1). The abundant species/groups in these stations are Leiognathidae (five groups/species), crabs, Synodontidae, miscellaneous crabs, carrangids and squid (Table 2). Pelagic crabs and mud crabs are also abundant in this group.

Group B includes 16 stations located near-shore in the inner and southern parts of the Gulf. This group is in water depths less than 30 m. The abundant species/groups in this cluster are miscellaneous trash fish, Leiognathidae, squid, two species of *Leiognathus*, two species of *Scolopsis*, cuttlefishes, Siganidae and crab (Table 2).

Group C includes 23 stations located in deeper areas in the inner and eastern part of the Gulf. This group is found in depths of about 30 m. The most abundant species/groups in this cluster are Sphyraenidae, squid, Synodontidae, Leiognathidae, *Scolopsis* spp. and Mullidae (Table 2).

Group D includes 15 stations located in deeper areas in the southern Gulf and two stations in the inner Gulf. This group is found in depths of more than 30 m. The most abundant species/groups are Leiognathidae, squid, Siganidae, Synodontidae, *Lutjanus* spp., *Priacanthus* spp., carrangid and *Nemipterus* spp. (Table 2).

It was observed that squid was distributed widely, but more abundant in deeper water. Crabs were found abundant only in Group A and B, in shallow areas. *Scolopsis* spp. was found only in the shallow water of upper and southern parts of the Gulf. Synodontidae was abundant in Groups A, C and D. In general, differences in abundance were related to geographic location. Considering the depth contour in Fig. 1 and the station groupings in Fig. 6, the four station groups indicate clustering by geographic zone and depth.

Group	Trawl grids/stations
A	032,044,058
B	001,002,003,005,006,008,014,023 201,221,243,268,294,345,395,420
C	018,021,007,009,010,015,017,024,025,026,035,036 042,043,056,057,019,020,027,028,029,030,031
D	034,037,245,270,321,347,371,373,397,399,422,424,445,447,466

Fig. 4. Classification diagram of station clusters in the Gulf of Thailand based on trawl survey data collected in 1995.

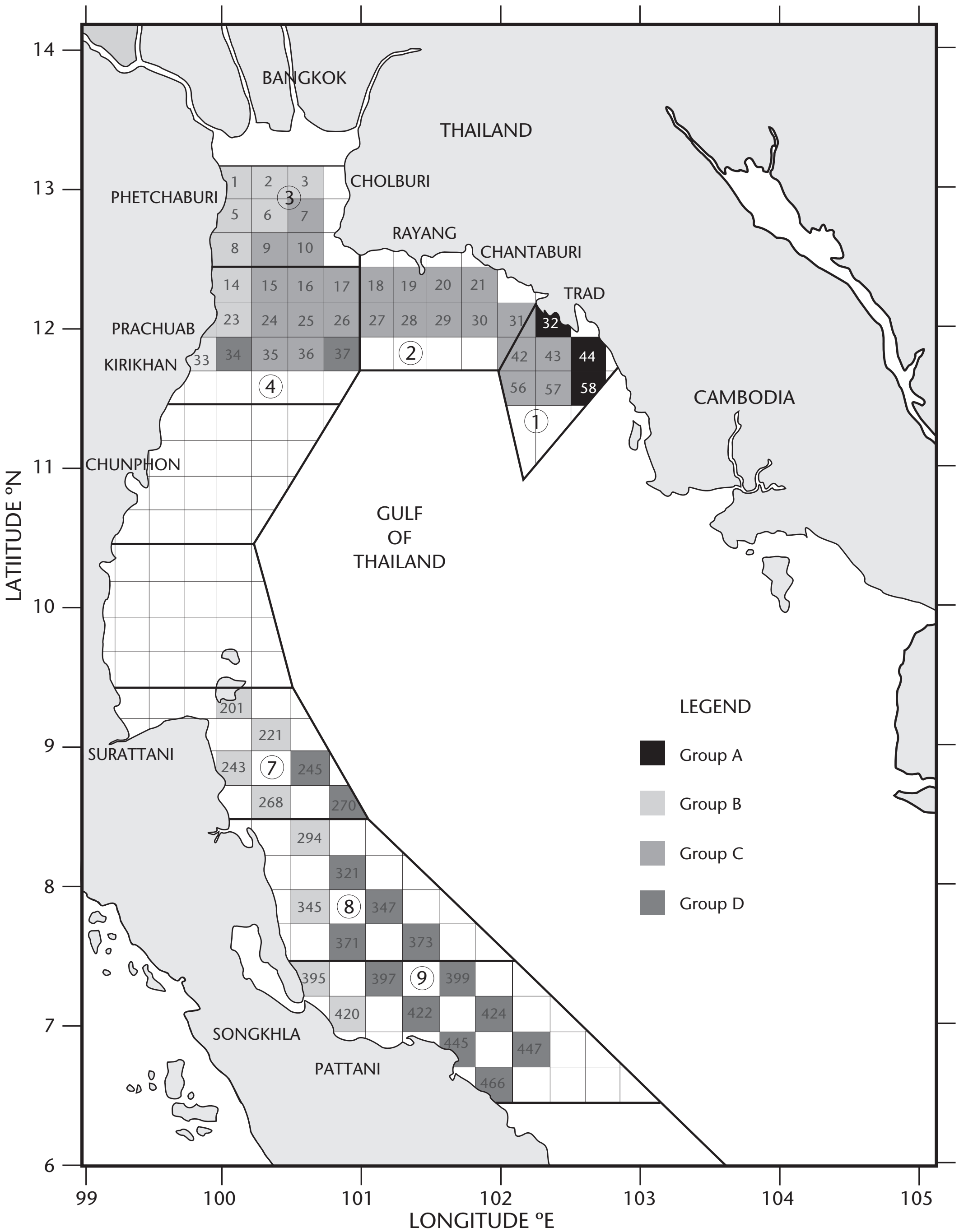

Fig. 5. Trawl grid/station groupings in the Gulf of Thailand based on 1995 research survey data.

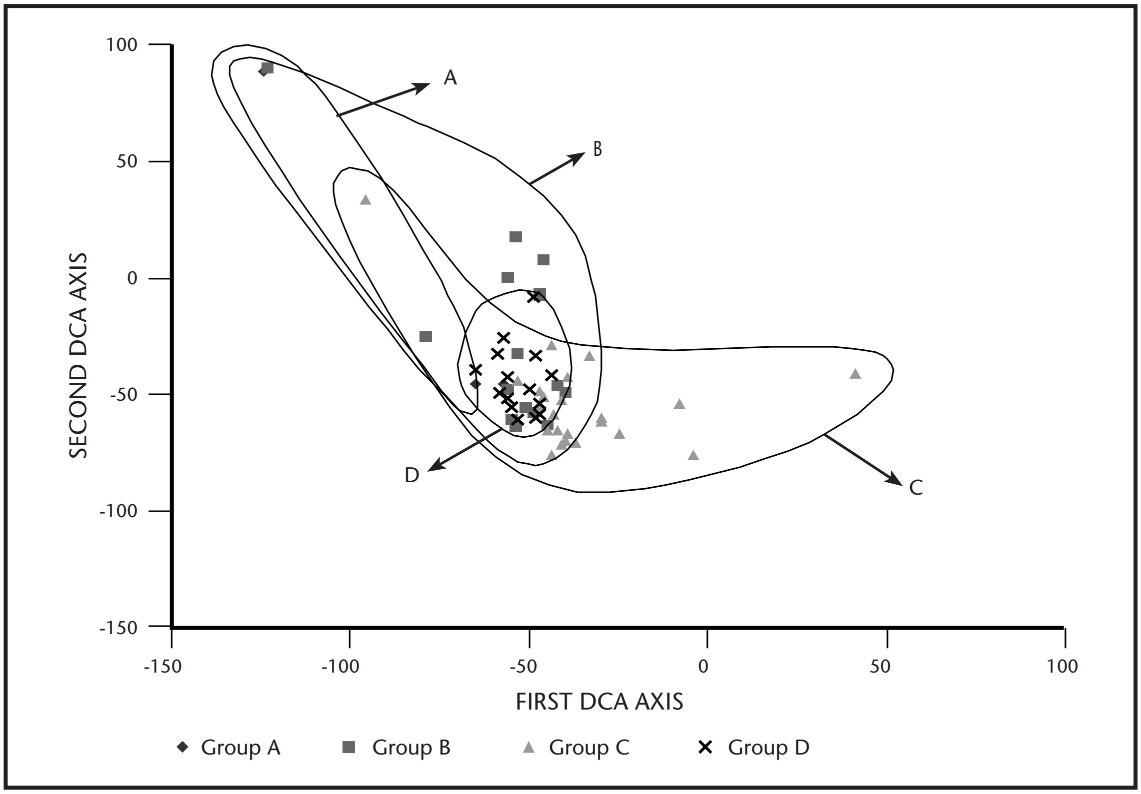

Figure 6. DCA plots showing the station assemblages.

Table 2. Biomass (t) and relative abundance (%) of the top ten species/group in each station-cluster resulting from spatial analysis.

Group A			Group B		
Species/Group	**Biomass (t)**	**%**	**Taxa**	**Biomass (t)**	**%**
Leiognathidae	1 051.0	31.51	Miscellaneous trashfish	1 212.5	16.85
Leiognathus splendens	501.7	15.04	Leiognathidae	937.7	13.03
Secutor spp.	402.7	12.07	Squids	799.9	11.12
Balistidae	108.7	3.26	*Leiognathus splendens*	774.4	10.76
Leiognathus spp.	100.1	3.00	*Leiognathus elongatus*	620.2	8.62
Crabs	94.6	2.84	*Scolopsis* spp.	169.5	2.36
Synodontidae	88.8	2.66	*Scolopsis taeniopterus*	168.8	2.35
Miscellaneous crabs	87.3	2.62	Cuttlefishes	160.1	2.23
Carangidae	84.0	2.52	Siganidae	111.6	1.55
Squids	79.1	2.37	Crabs (trash)	103.9	1.44

Table 2. Biomass (t) and relative abundance (%) of the top ten species/group in each station-cluster resulting from spatial analysis. (continued)

Group C			Group D		
Species/Group	**Biomass (t)**	**%**	**Taxa**	**Biomass (t)**	**%**
Sphyraenidae	1 137.9	8.95	Leiognathidae	761.6	10.31
Sphyraena obtusata	1 074.4	8.45	Squids	643.6	8.71
Squids	1 027.4	8.08	*Leiognathus elongatus*	389.2	5.27
Synodontidae	882.7	6.95	Siganidae	371.9	5.03
Leiognathidae	746.0	5.87	Synodontidae	347.9	4.71
Scolopsis spp.	658.2	5.18	*Lutjanus lutjanus*	335.5	4.54
Scolopsis taeniopterus	658.2	5.18	Priacanthidae	313.0	4.24
Leiognathus elongatus	652.1	5.13	*Leiognathus bindus*	289.9	3.92
Saurida undosquamis	583.1	4.59	Carangidae	264.7	3.58
Mullidae	489.7	3.85	Nemipteridae	250.1	3.39

Temporal Analysis

The average biomass by month was computed and used in the temporal analysis. Two temporal groups were identified: Group A comprising September and October; and Group B comprising January, March, June, July, August and December. In September and October, rainfall in the Gulf of Thailand is high compared to other months. In 1995, very heavy rainfall (about 500 - 2 600 mm) occurred during October (Department of Meteorology, 1995). It appears that Group A is associated with the wet season, and Group B with the dry season. The species appearing in both groups were almost the same but with different relative abundances (Table 3). The observed relative abundances are not very different however, suggesting that seasonal variability may not be pronounced. This may be due to the level of disaggregation used in sorting the survey catch into species/groups. Demersal fish and trashfish were the major components accounting for 18.4% and 17.8% of the biomasses of group A and B respectively. Squid appeared in both groups (5 - 6% of the total biomass). Sphyraenidae and *Sphyraena obtusata* were the only ones, which showed large differences in biomass between wet and dry seasons. In Group A (September and October), Sphyraenidae and *Sphyraena obtusata* amounted to about 12% of biomass whereas they were very low in abundance in Group B. Trashfish and *Leiognathus spendens* were abundant in the dry season. Species occurring in Group B were common throughout the year (Table 3). The DCA output is given in Fig. 7. It is suggested that further analysis should be completed with environmental data including biological information to explain these temporal differences in biomass estimates.

Table 3. Biomass (t) and relative abundance (%) of the top ten species/group in each station-cluster resulting from spatial analysis.

Group A			Group B		
Species/Group	**Biomass (t)**	**%**	**Taxa**	**Biomass (t)**	**%**
Demersal fishes	273	18.39	Trash groups	345	17.82
Trash groups	128	8.61	Demersal fishes	222	11.45
Cephalopods	110	7.38	Leiognathidae	174	8.97
Sphyraenidae	90	6.04	Cephalopods	124	6.42
Sphyreana obtusata	88	5.93	Misc. trash	115	5.93
Squids	86	5.81	*Leiognathus splendens*	104	5.37
Leiognathidae	80	5.39	Squids	92	4.75
Leiognathus elongatus	60	4.01	*Leiognathus elongatus*	58	2.99
Scolopsis taeniopterus	41	2.75	Synodontidae	57	2.96
Synodontidae	37	2.51	Pelagic fishes	49	2.53
Pelagic fishes	33	2.22	Saurida undosquamis	31	1.62
Secutor spp.	31	2.10	Mullidae	29	1.51
Mullidae	23	1.55	*Scolopsis taeniopterus*	29	1.51
Siganidae	23	1.53	*Leiognathus brevirostris*	25	1.31
Saurida undosquamis	22	1.47	*Loligo duvauceli*	24	1.24
Leiognathus splendens	18	1.24	Carangidae	23	1.17
Loligo duvauceli	16	1.08	*Lutjanus lutjanus*	22	1.13
Shells	15	1.04	Priacanthidae	22	1.12
Amusium pleuronectes	15	1.01	Nemipteridae	20	1.01
Nemipteridae	15	0.98	Crabs	19	0.97
Carangidae	14	0.92	Crabs (trash)	17	0.85
Cuttlefish	13	0.85	Siganidae	16	0.80
Priacanthidae	12	0.79	*Saurida elongata*	16	0.79
Loligo sumatrensis	11	0.71	Cuttlefish	15	0.77
Lutjanidae	10	0.70	*Priacanthus tayenus*	15	0.77

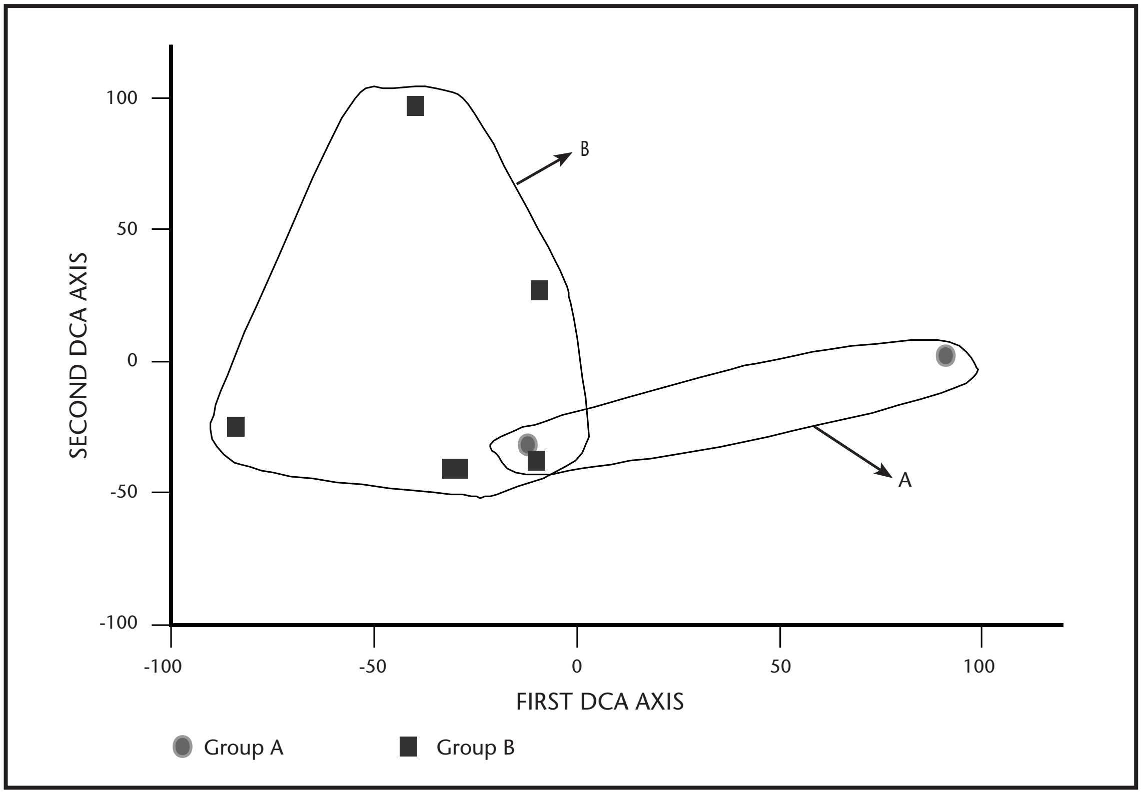

Fig. 7. DCA plots showing temporal groupings of assemblages.

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Trophic Model of the Coastal Ecosystem in the waters of Bangladesh, Bay of Bengal

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Mustafa, M.G. 2003. Trophic model of the coastal ecosystem in the waters of Bangladesh, Bay of Bengal, p. 263 - 280. *In* G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) Assessment, Management and Future Directions of Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings 67, 1 120 p.

Abstract

A trophic model of the coastal ecosystem in the waters of Bangladesh, Bay of Bengal (from the shoreline to 150 m depth) is presented. The model consists of 15 ecological groups. The biomasses of the groups (particularly the demersal species) were estimated from demersal trawl surveys conducted in the area between 1984 and 1986. The model estimated that the average trophic level of the trawl fishery catch was 2.7 in these years.

Introduction

Fisheries are important to the economy and food security in Bangladesh. They account for 4 - 5% of the Gross Domestic Product, 8 - 10% of export earnings and 70 - 80% of the animal protein intake in the country. About 12 million people are directly or indirectly associated with various fishery activities (Mazid 1998).

Bangladesh marine fisheries primarily target shrimp and finfish in the Bay of Bengal. A range of gears are used from small craft in the coastal waters, including drifting gillnet, fixed gillnet, set bag net, trammel net, and hook and line. There are also about 70 large trawlers fishing for shrimps and finfishes further offshore, between 30 m and 80 m depth.

The drift gillnets, targeting diadromous *Hilsha* spp., dominate the inshore areas, operating almost year-round. Fixed gillnets also target *Hilsha* spp., but only for a few months at river mouths. There are two types of set bag nets. Larger ones operate in the coastal areas (8 m - 10 m) while smaller ones are deployed in the estuarine and riverine areas. Hook and line fishing is seasonal, usually during the calmer winter months. These fishers target croakers, catfishes, groupers, skates, rays and sharks. The seine netters operate very near to shore and target small fish.

The trawlers mainly target larger shrimps *(Penaeus monodon, P. semisulcatus, P. merguiensis and P. indicus)*. However, small shrimps *(Metapenaeus monoceros, M. brevicornis, M. spinulatus, M. brevirostris, Metapenaeopsis toluensis*, *Parapeneopsis stylifera* and *Solenocera indica)* and finfishes also contribute to the catch.

The demersal shrimps and finfishes are economically important resources in the waters off Bangladesh and surveys have been carried out, by both national and international agencies, to assess the resources (Mohiuddin et al. 1980). From these surveys estimates of standing stock and potential yield have been made (Chowdhury et al. 1979; Karim 1978; Khan et al. 1989; Khan et al. 1983; Lamboeuf 1987; Mustafa et al. 1987; Mustafa et al. 1996; West 1973). There have also been studies of the population dynamics of different fish and

shrimps based on analysis of length-frequency data (Khan and Mustafa 1989; Khan et al. 1985; Khan et al. 1987; Khan et al. 1986; Mustafa 1989; Mustafa 1993; Mustafa 1994a; Mustafa 1994b; Mustafa 1995; Mustafa 1996; Mustafa 1999; Mustafa and Khan 1988; Mustafa and Khan 1993; Mustafa and Azadi 1995; Mustafa et al. 1989; Mustafa et al. 1995; Mustafa et al. 1998; Quddus et al. 1994). However, information on fishing effort and sustainable stock levels is limited. There are reports of declining availability of the target shrimp species in the offshore trawl catch (Van Zalinge 1986). The total shrimp production increased from 1 697 t in 1981 - 82 to 5 518 t in 1984 - 85. It thereafter declined to around 3 000 t in 1989 - 90 (Mustafa and Khan 1993). Finfish landings increased from 1 300 t in 1978 - 79 to 7 400 t in 1985 - 86 and have fluctuated since then. About 50 - 65% of the finfish caught are being discarded at sea as by-catch (Shahidhullah 1986).

To date the emphasis has been on single-species assessment and ecosystem modeling of the coastal waters of Bangladesh has not been done. However, there is widespread recognition of the need to move toward ecosystem-based approaches in fisheries management. For conservation and sustainable exploitation of the fisheries, scientific management incorporating ecosystem considerations is important. However, proper management and utilization of fishery resources in developing countries are generally inhibited by lack of appropriate information about the ecosystem components. Quantitative assessment of trophic interactions has important implications to understanding and managing multispecies fisheries in the Bay of Bengal. The availability of ecosystem modeling software enables a first attempt at analysis of the coastal fisheries ecosystem off Bangladesh.

Hence, a study of the ecosystem and fisheries interaction in the Bay of Bengal is of high interest. This study aims to construct a trophic model of the coastal fisheries off Bangladesh as a first step in this direction.

Material and Methods

The Study Area

In 1974 Bangladesh declared an EEZ (Exclusive Economic Zone) reaching 200 nm (322 km) offshore, with an average depth of 10 m (Mahmood 1977) As a result about 166 000 km^2 of the Bay of Bengal is now under the jurisdiction of the country for exploration, exploitation, conservation and management (see Table 1 for a depth profile). The average depth of the Bay of Bengal within Bangladesh territorial limits is about 10 m (Mahmood 1977).

Table 1. The area of the depth zones within the Exclusive Economic Zone of Bangladesh, up to 200 m (Khan et al. 1997).

Depth (m)	Area (km^2)
< 10	24,000
10 - 24	8,400
25 - 49	4,800
50 - 74	5,580
75 - 99	13,410
100 - 200	10,250
Total Continental Shelf	66,440
Total EEZ	166,000

The oceanography of the Bay of Bengal is dominated by three main factors: (i) wind direction; (ii) precipitation; and (iii) river discharges, all impacting on fish distribution and abundance. Surface currents in this region run clockwise from January to July and counter clockwise from August to December, consistent with the direction of the monsoon winds (Lamboeuf 1987). Three main rivers (the Ganges, Brahmaputra and Meghna) drain vast areas of the Himalayas, India and Bangladesh and discharge into the Bay of Bengal. The rivers render the surface waters of the northern part of the Bay almost riverine during the post-monsoon months (September and October); the lowest salinity (10.5 ppt) is observed during this time (Mustafa and Prova Dey 1994). In comparison, near-estuarine conditions prevail from January to June. The highest salinity (936 ppt) is reported in March (Mustafa and Prova Dey 1994). Strong salinity gradients exist from March to July and September to October, with hyper-saline conditions occurring from October to July. Thus, sea surface temperatures (SST) are highest in September (24.8º C) and lowest in January and February (24.1º C) (Mustafa and Prova Dey 1994).

Important fish families that contribute 56 - 76% of total demersal biomass are Ariidae (12%), Sciaenidae (10%), Nemipteridae (9%), Trichiuridae, Carangidae, Scombridae, Mullidae, Leiognathidae, Synodontidae and Clupeidae (Lamboeuf 1987). Rays, sharks, cuttlefish and squids are particularly abundant in the commercial trawl catch. Among penaeid shrimps, *Penaeus monodon, P. semisulcatus, Metapenaeus monoceros, Parapenaeopsis stylifera, P. sculptilis* and *Solenocera indica* are the major species caught. The brown shrimp *M. monoceros* accounts for about 56% of the total shrimp catch. Tiger shrimp *P. monodon* is the main targeted species because of its high price and export value, but a 17% decline between 1980 - 81 and 1990 - 91 has been reported by Mustafa and Khan (1993). Boats operate mainly in near-shore areas. Fixed gill nets also target *Hilsha* spp. but only for a few months at river mouths. There are two types of set bag nets. Larger ones operate in the coastal areas with average depth of 8 to 10 m and smaller ones are deployed in the estuarine areas as well as in a river where tidal effect is high. Trawlers operate in a deeper part of the Bay of Bengal. The shrimp and fish trawlers were imported from Thailand, Japan and some European countries. In 2000, 41 shrimp trawlers and 15 fish trawlers were operating in the off-shore trawling grounds. Hook and line fishing is seasonal, usually during winter months when the sea is calmer. Most of the fishers target croakers, catfishes, groupers, skates, rays, and sharks. Most of the seines operate very near to shore and target small fishes.

The Survey Area and Trawl Stations

Fig. 1 shows the trawl survey area and survey trawl stations used as the source of data for this study. The survey area is bounded in the north and east by the 10 m depth contour, as trawling in shallow waters was not possible due to the presence of

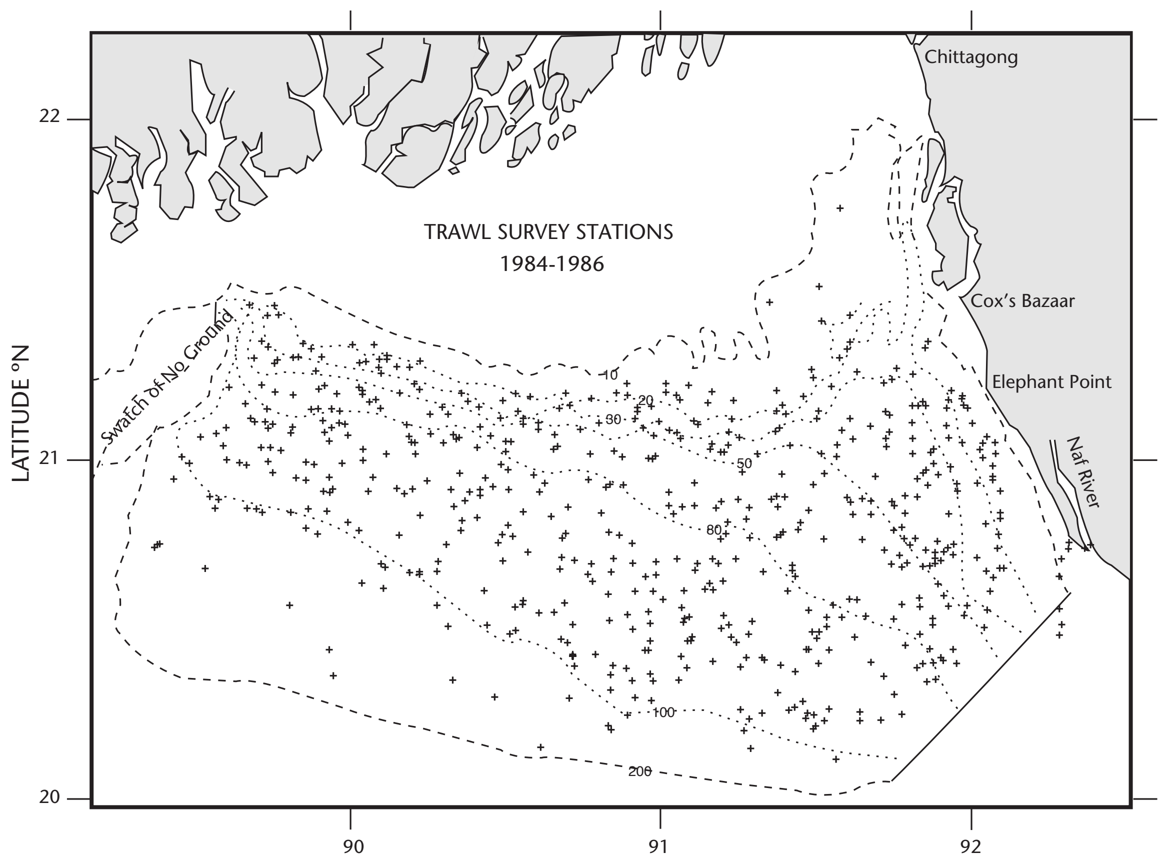

Fig. 1. The coastal waters of Bangladesh, Bay of Bengal, that are covered by the ecosystem model and the trawl survey stations (1984 to 1986) used for biomass estimation.

artisanal fishing gears. To the south, the boundary was set at the 200 m depth contour. In the south-east, a line drawn at 45º (from the southern end of St. Martin islands was taken as the limit of the survey area towards Burma. In the west the survey was limited to the eastern edge of the area known as “Swatch of No Ground” (described in Khan et al. this vol.). Fifty trawl stations were selected randomly prior to each cruise covering the entire survey area.

The surveys were conducted between September 1984 and December 1986 by the Marine Fisheries Survey Management Unit, Agrabad, Chittagong. The survey vessel used was the R.V. Anusandhani, a 32.4 m “multipurpose” research vessel principally designed for stern trawling. The trawl gear used was an Engel high-opening fish/shrimp bottom trawl with a cod-end mesh size of 32.0 mm. Detailed specification of the survey vessel and gear, and details of the operations are given in Khan et al. (this vol.). However, a summary is provided in Table 2.

Table 2. Summary of research survey hauls used for constructing the ecosystem model.

Cruise No.	Date/Duration	Valid hauls	Depth zone (m)				
			10 - 20	20 - 50	50 - 80	80 - 100	> 100
1	15 - 25 Sep. 1984	42	10	10	7	15	0
2	03 - 13 Oct. 1984	45	2	7	13	21	2
3	20 - 30 Oct. 1984	43	6	9	9	17	2
4	09 - 19 Nov. 1984	44	3	6	10	24	1
5	27 Nov. - 05 Dec. 1984	40	6	7	8	16	3
6	13 - 20 Dec. 1984	41	2	9	11	16	3
8	06 - 16 Jan. 1985	46	7	8	8	19	4
9	31 Jan. - 24 Feb. 1985	49	6	10	10	19	4
10	17 - 24 Feb. 1985	44	0	8	7	29	0
12	19 - 24 May 1985	13	3	4	3	3	0
13	12 - 17 Jul. 1985	13	4	8	1	0	0
14	21 - 24 Aug. 1985	3	0	3	0	0	0
15	28 Sep. - 6 Oct. 1985	12	0	3	7	2	0
16	22 - 31 Dec. 1985	35	4	8	5	11	7
20	25 Jan. - 4 Feb. 1986	41	2	10	9	16	7
22	02 - 11 Mar. 1986	31	3	14	7	6	1
24	02 - 11 Apr. 1986	22	0	4	5	7	6
26	12 - 21 May1986	25	2	14	10	6	0
27	1 - 4 Jun. 1986	7	0	4	3	0	0
30	2 - 4, 15 - 21 Dec. 1986	26	0	5	12	9	0
	TOTAL	629	60	151	145	236	37

The Ecopath Model

The Ecopath software (Christensen et al. 2000; Pauly et al. 2000) was used to build a (trophic) model of the Bangladesh waters of the Bay of Bengal. As described in Christensen and Pauly (1992a and 1992b), the Ecopath model stems from the work of Polovina (1984b; 1985; Polovina and Ow 1983). The basic equation of Ecopath is,

$$B_i * (P/B_i) * EE_i - \sum_{j=1}^{n} B_j * (Q/B_j) * DC_{ji} - EX_i = 0 \quad (1)$$

where, B_i is the biomass of group i; P/B_i is the production/biomass ratio of group i, which under steady-state conditions, is equal to the instantaneous coefficient of total mortality, Z (Allen 1971); EE_i is the ecotrophic efficiency of group ; B_j is the biomass of predator j; Q/B_j is the consumption/biomass ratio for predator j; DC_{ji} is the fraction of group i in the diet of predator j; and EX_i is the sum of fisheries catches of i plus emigration to adjacent ecosystems.

Basically the approach is to model an ecosystem using a system of simultaneous linear equations (one for each group i in the system).

Ecological Groupings

The Ecopath model includes a total of 15 ecological groups (Table 3). Of these, 12 groups are exploited and the 3 remaining groups are zooplankton, phytoplankton and detritus.

Table 3. The ecological groups used in the Ecopath analysis of the coastal waters of Bangladesh, Bay of Bengal. The taxa contributing to each group is shown and their percentage by weight contribution to the trawl survey catches.

Group No.	Ecological group	Taxa	% of total catch weight	% in group
1	Sharks	Carcharhinidae	0.22	24.48
		Carcharhinus spp.	0.66	72.67
		Sphyrna spp .	0.02	1.65
		Sphyrna blochii	0.01	1.10
		Rhizoprionodon spp .	< 0.01	0.11
2	Medium pelagics	Scombridae	< 0.01	0.03
		Scomberomorus spp .	< 0.01	0.01
		Scomberomurus guttatus	0.19	1.66
		S. commerson	0.17	1.42
		S. commersoni	0.03	0.29
		Rastrelliger spp.	0.60	5.11
		Rastrelliger kanagurta	4.66	39.60
		Rastrelliger brachysoma	0.31	2.62
		Rastrelliger faughni	0.03	0.24
		Sarda orientalis	0.01	0.10
		Euthunnus affinis	0.04	0.32
		Sphyraena spp.	0.19	1.64
		Sphyraena obtusata	0.03	0.22
		Sphyraena forsteri	0.54	4.59
		Carangidae	0.03	0.23
		Atropus spp.	< 0.01	0.04
		Atropus atropus	0.75	6.35
		Megalaspis cordyla	0.95	8.10
		Decapterus spp.	0.17	1.44
		Decapterus maruadsi	1.56	13.23
		Decapterus macrosoma	0.01	0.09
		Decapterus kurroides	0.13	1.10
		Carangoides spp.	0.07	0.62
		Carangoides malabaricus	0.12	1.04
		Carangoides seriolina	< 0.01	< 0.01
		Alectis spp.	0.01	0.08

Table 3. The ecological groups used in the Ecopath analysis of the coastal waters of Bangladesh, Bay of Bengel. The taxa contributing to each group is shown and their percentage by weight contribution to the trawl survey catches. (continued)

Group No.	Ecological group	Taxa	% of total catch weight	% in group
2 (cont'd)	Medium pelagics	*Alepes melanoptera*	0.05	0.43
		Caranx spp.	0.02	0.13
		Selar spp.	0.26	2.24
		Selar boops	0.14	1.16
		Selar crumenophtalmus	< 0.01	0.03
		Parastromateus niger	0.44	3.73
3	Medium mesopelagics	Trichiuridae	< 0.01	0.03
		Trichiurus lepturus	0.05	0.72
		Lepturacanthus savala	4.93	68.47
		Pampus argenteus	1.87	25.94
		Pampus chinensis	0.34	4.77
4	Medium demersals	*Pomadasys* spp.	< 0.01	0.01
		Pomadasys hasta	1.24	4.96
		Pomadasys maculatus	1.25	5.00
		Polynemus indicus	0.04	0.15
		Polynemus paradiseus	0.06	0.23
		Polynemus sextarius	0.07	0.27
		Eleutheronema spp.	< 0.01	0.02
		Eleutheronema tetradactylum	< 0.01	0.04
		Lutjanus spp.	0.36	1.44
		Lutjanus johni	0.63	2.50
		Lutjanus malabaricus	0.16	0.64
		Lutjanus sanguineus	0.03	0.11
		Arius spp.	11.58	46.28
		Sciaenidae	2.55	10.18
		Johnius spp.	1.48	5.92
		Johnius argenteus	3.30	13.17
		Otolithes spp	0.96	3.82
		Otolithes brauritus	0.01	0.06
		Otolithes maculatus	0.19	0.77
		Protonibea spp.	0.12	0.46
		Protonibea diacanthus	0.18	0.72
		Pennahia spp.	0.50	1.98
		Pennahia macrophtalmus	0.22	0.86
		Chrysochir spp.	0.04	0.14
		Chrysochir aureus	0.02	0.07
		Otolithoides spp.	0.05	0.20
5	Small demersals	*Nemipterus* spp.	4.71	17.24
		Nemipterus japonicus	7.71	28.23
		Saurida spp.	1.28	4.67
		Saurida tumbil	2.17	7.95
		Saurida undosquamis	0.63	2.30
		Saurida elongata	0.47	1.73
		Upeneus spp.	1.17	4.29
		Upeneus sulphureus	3.96	14.50
		Upeneus moluccensis	0.04	0.15
		Priacanthus spp.	1.24	4.52
		Priacanthus hamrur	0.64	2.35
		Priacanthus maculatus	0.07	0.26
		Harpodon nehereus	0.80	2.93
		Cynoglossus cynoglossus	0.19	0.67

Table 3. The ecological groups used in the Ecopath analysis of the coastal waters of Bangladesh, Bay of Bengel. The taxa contributing to each group is shown and their percentage by weight contribution to the trawl survey catches. (continued)

Group No.	Ecological group	Taxa	% of total catch weight	% in group
5 (cont'd)	Small demersals	*Tetradontidae*	0.25	0.93
		Lagocephalus spp.	0.02	0.07
		Tricanthus spp *Tricanthus*	0.29	1.06
		Brevirostris	0.77	2.81
		Sparidae	< 0.01	< 0.01
		Agryrops spp.	0.02	0.07
		Agryrops spinifer	0.12	0.44
		Lactarius spp.	< 0.01	< 0.01
		Lactarius lactarius	0.37	1.37
		Serranidae	< 0.05	< 0.01
		Epinephelus spp.	0.17	0.62
		Apogonidae	< 0.01	0.02
		Apogon spp.	0.19	0.70
		Apogon novemfasciatus	< 0.01	< 0.01
		Platycephalidae	0.01	0.05
6	Small mesopelagics	Leiognathidae	0.02	0.60
		Leiognathus spp.	3.81	98.91
		Leiognathus bindus	< 0.01	0.05
		Leiognathus equulus	0.02	0.44
7	Small pelagics	Clupeidae	0.21	2.86
		Dussumeria spp.	< 0.01	0.10
		Dussumeria acuta	0.13	1.75
		Hilsa spp.	0.05	0.72
		Hilsa toli	0.05	0.71
		Hilsa kelee	0.10	1.35
		Ilisha spp.	0.32	4.30
		Ilisha filigera	1.36	18.17
		Raconda russeliana	0.85	11.30
		Sardinella spp.	0.01	0.16
		Stolephorus spp.	0.06	0.83
		Stolephorus heterolobus	0.01	0.17
		Stolephorus tri	0.05	0.60
		Stolephorus taty	0.80	10.73
		Thryssa spp.	0.30	4.06
		Thryssa setirostris	0.19	2.55
		Coilia spp.	0.10	1.26
		Coilia neglecta	< 0.01	0.01
		Coilia ramcarati	< 0.01	0.05
		Coilia dussumieri	0.15	1.95
		Mene maculata	0.33	4.45
		Therapon jarbua	0.21	2.83
		Therapon oxythymelus	0.03	0.41
		Therapon theraps	< 0.01	0.05
		Fistularia villosa	0.13	1.67
		Ephippus spp.	0.04	0.57
		Ephippus orbis	0.08	1.06
		Mugil spp.	< 0.01	0.11
		Liza subvirides	< 0.01	< 0.01
		Exocoetus spp.	0.05	0.65
		Elops machnata	0.16	2.15
		Gerres spp.	0.55	7.37
		Gerres filamentosus	0.28	3.71
		P. longimanus	0.84	11.26

Table 3. The ecological groups used in the Ecopath analysis of the coastal waters of Bangladesh, Bay of Bengel. The taxa contributing to each group is shown and their percentage by weight contribution to the trawl survey catches. (continued)

Group No.	Ecological group	Taxa	% of total catch weight	% in group
8	Small discards	discards	4.95	100
9	Rays	Rays and Skates	3.91	100
10	Penaeidae	*Penaeus* spp.	1.35	71.71
		Penaeus monodon	0.07	3.60
		Penaeus inducus	< 0.01	0.04
		Penaeus semisulcatus	< 0.01	0.11
		Penaeus japonicus	< 0.01	0.21
		Penaeus merguiensis	< 0.01	0.26
		Metapenaeus monoceros	0.41	21.87
		Metapenaeus spinulatus	< 0.01	8.31
		Metapenaeus affinis	< 0.01	0.01
		Metapenaeus brevicornis	< 0.01	0.03
		Metapenaeopsis toluensis	< 0.01	0.32
		Parapenaeopsis spp.	0.05	2.49
		Parapenaeopsis stylifera	< 0.01	0.04
		Parapenaeopsis sculptilis	0.05	2.59
		Solenocera indica	< 0.01	0.21
		Mixed shrimps	< 0.01	0.01
11	Other Crustaceans	Crabs	0.07	16.52
		Lobsters	0.16	35.27
		Other crustaceans	0.22	48.21
12	Cephalopoda	Cuttlefish and Squids	1.66	100
13	Zooplankton	Zooplankton	–	–
14	Phytoplankton	Phytoplankton	–	–
15	Detritus	Detritus	–	–

Model Parameterization (Sources of Input Parameters)

The trawl survey catch data (Table 3) were used to calculate biomass inputs except for the groups Penaeidae, other crustaceans and Cephalopoda, where biomass was estimated from shrimp cruise catch data (described in Khan et al. this vol.).

Biomass for each group was estimated using the "swept area" method. In order to reduce the variance, geometric rather than arithmetic means were employed (Pauly 1984). An escapement factor of 50% was used for the calculation of biomass. The average trawling speed was 3.0 knots. Biomass results given in this report refer to a trawl with an 18 m horizontal opening measured between trawl wing-tips; the distance covered by the trawl in 30 min is 1.5 nm, which gives an area swept by the net of about 0.05 km^2.

Table 4 shows the growth and mortality parameters for the species used to estimate P/B. In some groups (i.e. Penaeidae, other crustaceans and Cephalopoda), P/B ratios were adjusted to give EE values less than 1 and to make the respiration estimate positive. The consumption/biomass (Q/B) ratio was obtained for fish groups using the empirical formula of (Palomares and Pauly 1989). Consumption/biomass ratios for non-fish groups were taken from (Pauly et al. 1993).

A limited amount of work has been done in the study area on the diet composition of fish (Mansur et al. 1998; Mazid 1998; Mustafa and Mansura 1994). Many studies are qualitative in nature and

Table 4. Estimates of growth and mortality parameters for representative species

Ecological group	Species	L_∞ (cm)	K (year^{-1})	M (year^{-1})	F (year^{-1})	Z (year^{-1})	Source
Medium pelagics	*Parastromateus niger*	41.0	0.59	1.16	1.26	2.42	Mustafa (1999)
	Megalaspis cordyla	38.5	0.54	1.11	1.17	2.28	– do –
	Rastrelliger kanagurta	27.4	0.90	1.71	3.21	4.92	– do –
	Megalaspis cordyla	37.9	0.58	1.17	0.58	1.75	Ashraful (1998)
Medium mesopelagics	*Lepturacanthus savala*	108.0	0.75	1.04	1.54	2.58	Ashraful (1998)
	Pampus argenteus	29.8	0.53	1.18	0.79	1.97	– do –
	Pampus chinensis	38.1	0.67	1.29	0.83	2.12	– do –
	Lepturacanthus savala	106.5	0.80	1.08	0.81	1.89	Ashraful (1998)
	Lepturacanthus savala	105.0	0.85	1.33	0.73	2.06	Mustafa and Khan (1993)
Medium demersals	*Pomadasys hasta*	58.8	0.52	0.97	0.72	1.69	Mustafa and Khan (1993)
	Johnius argentatus	50.0	0.72	1.25	5.63	6.88	Shahanaz (1996)
	Johnius argentatus	46.1	0.86	1.44	0.58	2.02	Ashraful (1998)
	Pomadasys hasta	56.9	0.38	0.79	0.81	1.60	Mustafa and Azadi (1995)
Small pelagics	*Ilisha filigera*	35.0	0.75	1.42	1.95	3.37	Mustafa (1999)
	Coilia dussumeri	16.8	1.30	2.49	2.30	4.79	Amin (1997)
	Ilisha filigera	32.5	0.90	1.63	1.25	2.86	Ashraful (1998)
Penaeidae	*Penaeusmonodon* (male)	30.0	0.94	1.72	3.33	5.05	Mustafa (1999)
	Penaeusmonodon (female)	32.1	0.97	1.72	2.13	3.85	– do –
	Penaeus semisulcatus (male)	23.5	.80	1.73	3.47	5.20	– do –
	Penaeus semesulcatus (female)	27.0	.90	1.72	2.98	4.70	– do –
	Metapenaeu monoceros (male)	16.5	1.50	2.75	3.68	6.43	– do–
	Metapenaeus monoceros (female)	19.4	1.52	2.65	3.94	6.59	– do–
	Parapenaeopsis sculptilis	16.8	1.25	2.43	2.93	5.36	Amin (1997)
	Exopalaemon styliferus	11.21	2.20	3.94	4.57	8.51	– do –
	Penaeus monodon (male)	28.8	1.20	2.03	5.86	7.90	Mustafa and Khan (1993)
	Penaeus monodon (female)	30.5	1.70	2.51	3.28	5.80	– do –
	Metapenaeus monoceros (male)	18.0	1.40	2.89	3.41	6.30	– do –
	Metapenaeus monoceros (female)	18.6	1.60	2.77	3.53	6.30	– do –
	Lysmata ensirostris	7.3	2.2	8.44	0.92	9.36	Aysha (1997)
	Palaemon stylifera	10.5	1.45	3.00	1.49	4.44	Mustafa et al. (1995)
Benthopelagic	*Ariomma indica*	22.0	1.12	2.10	3.43	5.53	Humayun et al. (1988)

fish are often lumped together as a single diet item. In cases where local diet compositions were not available, data from the literature summarized in FishBase were used.

Ecotrophic efficiency (EE) expresses the fraction of the total production consumed by predators or caught by a fishery. It usually ranges from 0.7 to 0.9 (Polovina 1984a; Polovina 1984b; Ricker 1969). In Ecopath, EE must either be entered (when biomass, P/B, or Q/B is unknown) or is estimated by the program (when biomass, P/B and Q/B are entered). The fraction (1-EE) is the proportion of the production directed towards the detritus box, from which it may be exported out of the system. The program estimated EE for all groups except phytoplankton.

Table 5 gives estimates of biomass, catch and the instantaneous rate of fishing mortality (F) for the different groups. In most cases, biomass estimates from the demersal trawl survey during 1984 - 86 were used. Biomass estimate for penaeid shrimps based on the swept area method is probably an underestimate. There is no published data on biomass of zooplankton, phytoplankton and detritus for the study area. Input data for zooplankton were obtained from (Silvestre et al. 1993).

Table 5. Biomass (t), catches (t·year^{-1}) and instantaneous rate of fishing mortality (F; year^{-1}) for species groups in the Bangladesh waters of the Bay of Bengal.

Ecological group	Biomass (t)	Catches (t·year^{-1})	F (year^{-1})
Sharks	1713	949	0.55
Medium pelagics	22118	1360	0.06
Medium mesopelagics	13528	708	0.05
Medium demersals	47000	10538	0.22
Small demersals	51352	990	0.02
Small mesopelagics	7240	932	0.13
Small pelagics	14070	3724	0.27
Small discards	9308	11105	1.19
Rays	7353	809	0.11
Penaeidae	8014	3759	0.47
Other crustaceans	4771	863	0.18
Cephalopoda	5833	1286	0.22
TOTAL	188,000	37,023	

Results and Discussion

Table 6 gives input and output estimates of biomass, production/biomass (P/B), consumption/biomass (Q/B) ratio, and ecotrophic efficiency (EE) for the different groups for the Bay of Bengal. The P/B ratio is dependent on the estimates of F and M. The Q/B ratios for the finfishes (Groups 2 - 8, Table 3) based on the empirical formula of (Palomares and Pauly 1989) are comparable to those given by (Pauly 1989) for a number of tropical species. Estimates of ecotrophic efficiencies were high for most groups. It is reasonable to assume that most of the production in an exploited ecosystem will be predated upon or fished, except perhaps for the top predators. There is a certain amount of predation on these groups by skipjacks and sharks, which were not in the model so therefore not counted.

Table 7 shows the diet matrix for the different groups used in the model. Food and feeding studies carried out in the Bay have been largely qualitative requiring substantive resort to the literature and educated guesswork to convert values to quantitative estimates of diet composition. In most cases only minor adjustments were necessary to satisfy mass-balance constraints in the analysis.

Figure 2 shows trophic linkages of the coastal fisheries ecosystem in the Bangladesh waters of the Bay of Bengal. The small demersal, medium demersal, medium pelagic and small pelagic groups dominate the fish biomass. The major prey in the system are the small mesopelagic, small discards, penaeidae, cephalopoda and other crustaceans with consumption rates of 30.0, 18.0, 55.0, 22.4 and 15.5 t·km^{-2}·year^{-1}, respectively. The trawl fishery in the years modeled is found to operate at a trophic level of 2.7.

Figure 3 presents mixed trophic impacts of the groups included in the Bay of Bengal ecosystem model. The mixed trophic impacts (Christensen and Pauly 1992a; Christensen and Pauly 1992b) suggest that fishing has an indirect positive impact on medium pelagics, medium demersals, and rays. However, fishing negatively impacts sharks, small mesopelagics, small pelagics and cephalopods, as they are the preferred targets of existing fisheries. The figure also shows: positive impacts of sharks on medium mesopelagics, small demersals, small mesopelagics and small pelagics; negative impacts of medium pelagics, and small and medium mesopelagics; and positive impacts of medium demersals on small discards and other crustaceans.

Table 8 presents respiration, assimilation and other important component parameters by group. Details of the calculation procedure for these parameters were described by Christensen and Pauly (1992a).

Detritus, generated mainly by phyto- and zooplankton, is one of the important groups in the ecosystem and major energy flows connect it to other groups. Table 9 presents flow to detritus (t·km^{-2}·year^{-1}) from different groups. Table 10 presents the total mortality in its components, fishing, predation and other kinds of mortality. Other crustaceans, cephalopods, Penaeidae, and small mesopelagics show high predation mortality, while sharks as top predators have lower predation mortality, as may be expected. The penaeidae, medium demersals and small discards showed higher fishing mortality, due to demersal trawling in the fishing grounds. Table 10 presents the consumption by predation, export, flow to detritus, respiration and throughput for the different trophic levels.

Table 6. Basic input and output (in parenthesis) for the Ecopath model of the coastal waters of Bangladesh, Bay of Bengal. P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = Ecotrophic efficency.

Ecological group	Biomass ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE ($year^{-1}$)
Large sharks	0.42	2.37	12.00	(0.03)
Medium pelagics	0.53	4.00	12.00	(0.96)
Medium mesopelagics	0.33	3.20	10.00	(0.93)
Medium demersals	1.13	2.20	6.00	(0.96)
Small demersals	1.23	3.10	8.00	(0.93)
Small mesopelagics	0.25	9.00	120.00	(0.95)
Small pelagics	0.35	2.20	10.00	(0.96)
Small discards	0.30	6.30	60.00	(0.95)
Rays	0.18	2.20	12.00	(0.94)
Penaedae	0.22	17.20	250.00	(0.95)
Other crustaceans	0.12	60.00	130.00	(0.97)
Cephalopoda	0.14	11.50	160.00	(0.12)
Zooplankton	10.00	35.00	150.00	(0.06)
Phytoplankton	13.00	(134.27)	–	0.80
Detritus	120.00	–	–	(0.17)

Table 7. Diet composition of the consumers in the trophic model of the coastal waters of Bangladesh, Bay of Bengal. Values represent the proportion (by weight or volume) each prey contributes to the diet of the predator. The numbers in the first row refer to the predator number (same as prey numbers given in first column).

	Predator												
Prey	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. Large sharks													
2. Medium pelagics	0.40												
3. Medium mesopelagics	0.07	0.06							0.10				
4. Medium demersals	0.27			0.11									
5. Small demersals	0.13			0.33				0.01	0.10				
7. Small pelagics									0.30				
9. Rays	0.07												
10. Penaeidae				0.11	0.12						0.10		
11. Other crustaceans			0.20		0.17				0.09	0.05	0.10		
12. Cephalopoda				0.07	0.08				0.10				
13. Zooplankton		0.50	0.50	0.08	0.15	0.50	0.50	0.28		0.15		0.30	
14. Phytoplankton		0.31	0.30	0.09	0.24	0.40	0.40	0.28		0.40			0.90
15. Detritus				0.11	0.12	0.10	0.10	0.43		0.40	0.80	0.70	0.10
16. TOTAL	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

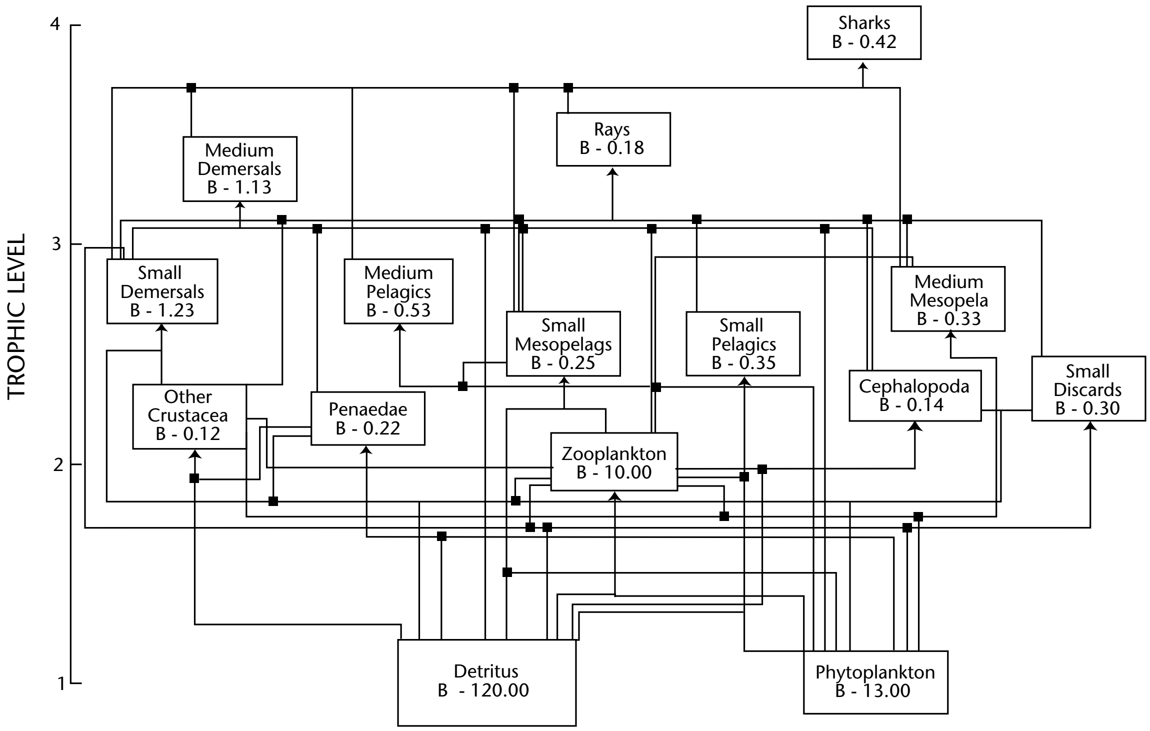

Fig. 2. Trophic model of the coastal waters of Bangladesh, Bay of Bengal. Only predator-prey links with flows of 0.1 t·km^{-2}·year^{-1} or more are included. Groups are arranged after trophic levels on the Y-axis, and box size is a function of group biomass (indicated in t·km^{-2})

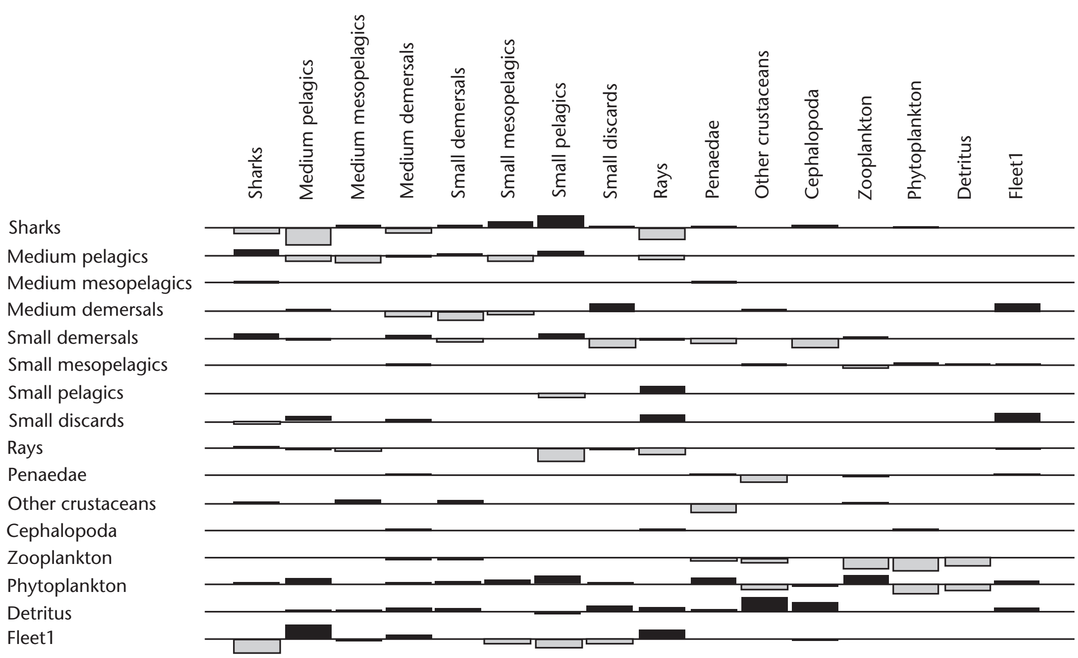

Fig. 3. Mixed trophic impacts in the Ecopath model of the coastal fisheries ecosystem in Bangladesh waters of the Bay of Bengal. The graph shows the direct or indirect trophic impacts the groups to the left (rows) have on the groups mentioned above (columns). Positive impacts are shown above and negative impacts below the baseline. The impacts are relative but comparable between the groups.

Table 8. Respiration, assimilation and other parameters by group.

Ecological group	Respiration ($t \cdot km^{-2} \cdot year^{-1}$)	Assimilation ($t \cdot km^{-2} \cdot year^{-1}$)	Respiration/ Assimilation	Production/ Respiration	Respiration/ Biomass
Large Sharks	2.03	3.02	0.67	0.49	4.83
Medium pelagics	2.98	5.11	0.58	0.71	5.60
Medium mesopelagics	1.56	2.60	0.60	0.67	4.80
Medium demersals	2.94	5.42	0.54	0.85	2.60
Small demersals	4.07	7.90	0.52	0.94	3.30
Small mesopelagics	21.75	24.00	0.91	0.10	87.00
Small pelagics	2.03	2.80	0.73	0.38	5.80
Small discards	12.51	14.40	0.87	0.15	41.70
Rays	1.31	1.70	0.77	0.30	7.40
Penaeidae	51.21	55.00	0.93	0.07	232.80
Other crustaceans	5.24	12.37	0.42	1.36	44.00
Cephalopoda	16.31	17.92	0.91	0.10	116.00
Zooplankton	850	1200	0.71	0.41	85.00

Table 9. Omnivory index, efficiency and flow to detritus of each ecological group.

Ecological group	Omnivory index	Net efficiency	Flow to detritus ($t \cdot km^{-2} \cdot year^{-1}$)
Large sharks	0.15	0.33	2.98
Medium pelagics	0.18	0.42	1.34
Medium mesopelagics	0.24	0.40	0.72
Medium demersals	0.46	0.46	1.45
Small demersals	0.31	0.48	2.26
Small mesopelagics	0.00	0.09	6.12
Small pelagics	0.00	0.28	0.73
Small discards	0.02	0.13	3.67
Rays	0.03	0.23	0.45
Penaeidae	0.07	0.07	0.21
Other crustaceans	0.21	0.58	3.45
Cephalopoda	0.00	0.09	4.53
Zooplankton	0.00	0.29	606.49

Table 10. Components of the total mortality for the groups in the ecosystem. (All are instantaneous rates, expressed on an annual basis).

Ecological group	Total mortality (P/B=Z)	Fishing mortality (F)	Predation Mortality (M2)	Other mortality (M0)
Large sharks	2.37	0.08	0.00	2.29
Medium pelagics	4.00	0.06	3.79	0.15
Medium mesopelagics	3.20	0.06	2.92	0.22
Medium demersals	2.20	0.27	1.85	0.08
Small demersals	3.10	0.19	2.68	0.23
Small mesopelagics	9.00	0.13	8.38	0.49
Small pelagics	2.20	0.28	1.84	0.08
Small discards	6.30	0.68	5.39	0.23
Rays	2.20	0.19	1.90	0.11
Penaeidae	17.20	0.41	15.82	0.96
Other crustaceans	60.00	0.00	57.02	2.98
Cephalopoda	11.50	0.29	10.87	0.33
Zooplankton	35.00	0.00	4.35	30.65

Table 11. Total energy flow distribution by trophic level in the coastal ecosystem in the Bangladesh waters of the Bay of Bengal. All flows are in t·km^{-2}·year^{-1}.

Trophic level	Consumed by predators	Export	Flow to detritus	Respiration	Throughput
VI	0.00	0.00	0.00	0.00	0.00
V	0.00	0.00	0.02	0.03	0.04
IV	0.04	0.01	0.37	0.59	1.02
III	1.02	0.10	2.07	3.74	6.93
II	6.93	0.33	11.95	35.42	54.63
I	54.63	0.44	930.23	624.17	1 609.46
TOTAL	1 609.46	1 080.65	349.09	0.00	3 039.21

Conclusion

Ecopath was used to produce an ecosystem view of the coastal resources in the waters of Bangladesh, Bay of Bengal. It was especially useful with regard to estimating biomasses and trophic levels and produced results which are consistent with existing understanding of the resources. The present analysis is only a first step toward ecosystem analysis and management, but is also a necessary step to evaluate where additional information is required to reach a level where the analysis becomes sufficiently robust. Much more work is required, however, to obtain the necessary ecological and economical parameters for more effective modeling and evaluation of management options.

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Trophic Model of the Coastal Fisheries Ecosystem of the Southwest Coast of India

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Abstract

The Ecopath approach and software were used to construct a trophic model of the coastal fisheries ecosystem of the southwest (SW) coast of India. The model consisted of 11 ecological groups and used estimated landings from all areas along the southwest coast (based on the sample surveys conducted by Coastal Marine Fisheries Research Institute for the years 1994, 1995 and 1996). The trophic model suggests high catch levels, particularly for the large and medium predators, demersal feeders and detritivores. The biomass estimates in the trophic model were comparable to the biomass estimates from trawl surveys based on the swept area method for the southwest coast.

Introduction

There are numerous studies on the population dynamics of individual species of commercially important fishes and invertebrates of the Indian coast (Devaraj et al. 1994; Fernandez and Devaraj 1996; Vivekanandan and James 1986) with few extensions to multispecies cases (Murty et al. 1992). Pertinent models have been developed in applied ecology involving energy, nutrient and trophodynamics for temperate ecosystems (Andersen and Ursin 1977; Laevastu and Larkins 1981; Walsh 1981). Most of the earlier models are very data-demanding and therefore, not suitable for tropical fisheries where information is limited. (Polovina 1984) developed a relatively simple mass-balance trophic box model known as Ecopath, which provides a methodology for constructing models of trophic interactions in aquatic ecosystems. The model involves partitioning of the ecosystem into species/groups and, given a set of parameters as inputs, provides estimates of mean annual biomass, annual biomass production and annual biomass consumption for each species/group. These groups are defined based on similarity of life history parameters, physical habitat and diet. This approach was expanded upon by (Christensen and Pauly 1992; Christensen and Pauly 1993; Christensen et al. 2000; Pauly et al. 2000; Walters et al. 1997; Walters et al. 1999). Considering the need to gain insight into the functioning of the multispecies Indian fishery resources, this approach is particularly relevant considering that little work has been published on Indian coastal ecosystems.

The Study Area

The southwest coast of India was selected for the eco-system analysis because fish population and

community structure analyses had been made in this area (see Srinath et al. this vol.). The southwest ecosystem extends from 8º N to 16º N comprising the maritime states of Kerala, Karnataka and Goa (Fig.1), covering a continental shelf area of 75 390 km^2. The environment of the southwest coast is influenced by monsoon and can be categorized into 3 seasons, *viz.,* monsoon or rainy season (June-September), post-monsoon (October-January) and pre-monsoon (February-May). The characteristics of the marine environment during the 3 seasons have been well studied and documented (Pillai et al. 1997).

Oceanographic Characteristics

During the monsoon, the southerly current spreads over the entire continental shelf. Isolines of water temperature, salinity, dissolved oxygen (DO), and density rise to the surface due to upwelling and occupy the area between the southerly current and the coast. Consequently, dense and cool water with low DO occupies the surface near the coast. During the post-monsoon period (October-January), there is a strong current with northerly flow. On the seaward side of the flow, there is a southerly flow, but only in the southern region of the southwest coast. During this period, the low salinity equatorial waters are advected northwards, causing sinking of high salinity Arabian water below the equatorial waters between 10º and 12º N latitude. During the pre-monsoon period (February-May), the northerly current disappears and the southerly flow is restricted to a narrow belt.

During the monsoon, the thermocline reaches the surface and the average sea surface temperature is around 24º C. During the post-monsoon period, the thermocline descends from the surface (October-November), and reaches deep waters (December-February). During the pre-monsoon, the thermocline remains deep, and the average surface water temperature increases to about 30º C.

During the monsoon, the mean sea surface salinity is relatively low (32.5 ppt) due to river runoff and the salinity maximum (35 ppt) occurs at 30 - 50 m depth. During the post-monsoon, the sea surface salinity is 33 ppt in the southernmost sector of the southwest coast off Cape Comorin and increases northwards up to Karwar (about 35 ppt). During the pre-monsoon period, as the temperature is high, the salinity also remains high in the entire shelf with mean surface salinity of 36 ppt. Oxygen-deficient water starts penetrating the shelf by May, and covers the entire bottom by June-July. By August, the oxycline becomes shallow and reaches the surface where it remains till September-October. It has been observed that the oxycline remains for a longer duration in the northern sector (Karwar: 6 months) than in the southern sector (Quilon: 2 months). However, the DO level is higher in the northern sector as the intensity of upwelling is low. During November-April, the shelf water is well aerated and the mean DO is 4.5 to 5.0 $ml \cdot L^{-1}$. Due to upwelling during the southwest monsoon, the southwest coast is characterized by a high level of nutrients such as phosphate, nitrate and silicate in the surface waters. The nitrate content in the surface waters is very high (3 to 4 µM) compared to < 1µM during the other months, which results in high productivity of 660 mg $C \cdot m^{-2} \cdot day^{-1}$ compared to 200 mg $C \cdot m^{-2} \cdot day^{-1}$ during the other months. The plankton biomass is significantly higher (0.9 to 1.2 $ml \cdot m^{-3}$) compared to < 0.5 $ml \cdot m^{-3}$ during the other months. The rate of primary production in the neritic waters, for instance, is as high as 1 g C $\cdot m^{-2} \cdot day^{-1}$ during upwelling off Cochin compared to only 0.1 g $C \cdot m^{-2} \cdot day^{-1}$ during the other seasons. The phytoplankton production along the southwest coast shows a strong north-south gradation, (Fig. 2). The production increases from 0.1 g $C \cdot m^{-2} \cdot day^{-1}$ off Goa to > 1 g $C \cdot m^{-2} \cdot day^{-1}$ off Cochin (Pant 1992).

In general, the southwest coast is rich in phytoplankton and zooplankton biomass compared to the other Indian coastal waters, see Figure 3. The secondary production along the southwest coast ranges from 10 to 57 mg $C \cdot m^{-2} \cdot day^{-1}$ with an average of 20 mg $C \cdot m^{-2} \cdot day^{-1}$ (Mathew et al. 1990) During upwelling, the minimum zooplankton biomass is > 1 $ml \cdot m^{-3}$ and at times attains up to 12 $ml \cdot m^{-3}$.

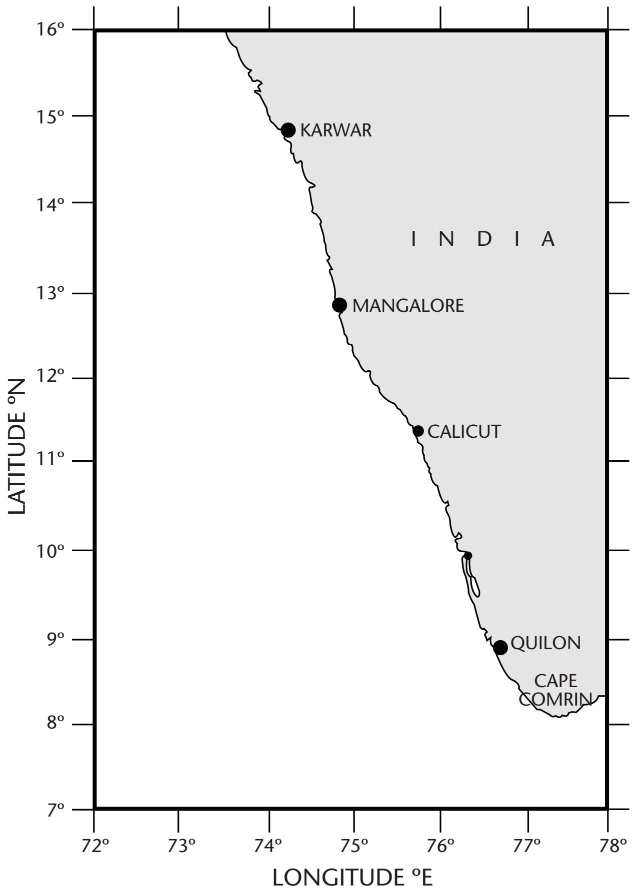

Fig. 1. Study area: the southwest coast of India.

Fig. 3. Primary productivity along the coasts of India during June-August 1998 showing high productivity along the southwestern coast. Scale and source are the same as Fig. 2.

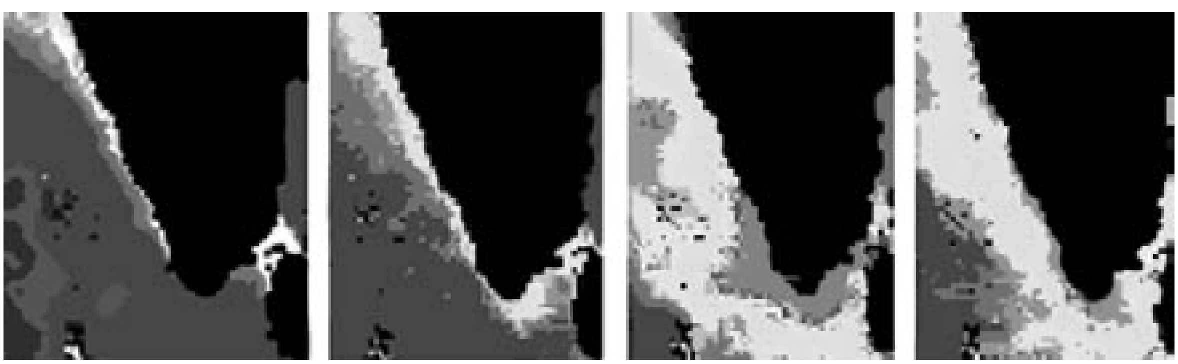

Fig. 2. Primary productivity along the southwest coast of India. The pictures cover 3-months periods starting from December 1997 through November 1998. The scale ranges from 0 (gray) to 150 (white) g C·m^{-2}·month^{-1}. Based on satellite data made available courtesy of the Marine Environment Unit, Space Applications Institute, of the Joint Research Centre of the European Union.

Fisheries

The fishing grounds along the southwest coast are quite extensive and very productive. The sea bottom is generally muddy and sandy. Most of the area is suitable for trawling barring the southern sector, which is characterized by coral and rocky grounds. The 50 m depth contour is at a distance of about 25 km from the coast in the southern sector (off Kerala) and at about 40 km from the coast in the northern sector (off Karnataka and Goa). The width of the continental shelf from the shore varies from about 65 km off Kerala to about 90 km off Karnataka and Goa.

The annual average fish landings along the southwest coast was 630 000 t during 1970 - 97 (see Pillai et al. this vol.), or 37% of total Indian landings. The southwest coast ecosystem is characterized by the abundance of oil sardine, Indian mackerel and penaeid prawns, which together contribute 45% of the landings. In addition to these groups, whitebaits, lizardfishes, threadfin breams, carangids, flatfishes and stomatopods also contribute a high percentage to the landings.

A variety of craft and gear combinations are being used by the commercial fishing sector along the southwest coast (Table 1). Among the mechanized vessels, trawlers are the most common, followed by gillnetters. Of the various traditional crafts, catamarans are prevalent only in the southern sector, while dugout canoes and plank-built boats are prevalent along the entire coast. Gillnets and boat-seines of various dimensions are the most common gears for the artisanal craft. In Kerala alone, 15 types of boat-seines and 26 types of gillnets of various mesh sizes are employed depending upon the fish target resources, which range from species with small body size such as whitebaits to large bodied groups such as rays.

Annual average fish catches along the southwest coast increased from 0.19 million t in 1950 to 0.80 million t in 1997 (Devaraj et al. 1997). The increase was largely due to research and development efforts by different organizations. Motorization of indigenous craft started in Kerala in the early 1980s, and became instantly popular. Consequently, most of the indigenous craft have been fitted with outboard motor and fishing with non-motorized craft has become rare.

Table 1. Major fishing vessel and gear types used along the southwest coast of India.

	Vessel	Vessel Length (m)	Gear	Mesh size (mm)
Mechanized	Trawler	12 - 16	Trawl	15 (codend)
	Gillnetter+	7 - 10	Drift gillnet	70 - 130
	Purse-seiner+	11 - 14	Purse-seine	8 - 10 & 20 - 30
Motorized/	Catamaran	5 - 10	Boatseine*	5 - 20
Artisanal	Dugout canoe	4 - 10	Ringseine*	5 - 15
	Plank built boat	6 - 14	Drift gillnet*	60 - 110
			Bottom set gillnet*	20 - 260
			Other gillnets*	5 - 100
			Hook and line*	
			Mini trawl*	10 - 15 (codend)
			Dragnet*	12
			Stake net*	8 - 10
			Shore seine	8 - 10

Note: + mechanization employed for propulsion only * operated from any of the 3 motorized/artisanal craft

Mechanization was introduced in the late 1950s and currently, there are about 14 000 mechanized vessels along the southwest coast, most of which are trawlers. Purse seine operation started experimentally in 1957 and was commercialized in the 1960s. There were about 700 purse seiners in the 1980s, but the number declined in the 1990s. At present there are only about 350 purse seiners operating along the southwest coast. The introduction of mechanized fishing vessels and modern gear occurred through 1951 - 60. The increase in the use of synthetic gear materials since 1960, introduction of purse seines in the 1960s, motorization of artisanal crafts in the 1980s, and the substantial growth in the mechanized and motorized crafts since 1985 are the major reasons for the significant increase in production.

However, the technological developments in craft and gear are becoming counterproductive. There is evidence that several fish stocks along the southwest coast are overexploited, and declining (Devaraj et al. 1997). Hence, implementation of appropriate management measures is imperative.

In India, the maritime state governments are responsible for formulation and implementation of fisheries management measures. At present, the three maritime states in the southwest coast (*viz.* Kerala, Karnataka and Goa) observe closed fishing season for the mechanized vessels for a period of 45 to 60 days during the southwest monsoon (June-September). Also, mechanized vessels are banned from fishing within 5 km from the shore. However, the effectiveness of these restrictive management measures on the sustainability of the resources has not been demonstrated. These management measures, on the other hand, have resulted in inter and intra sectoral conflicts. Management measures, which are effective for sustainability of resources and are acceptable to all stakeholders need to be developed.

Materials and Methods

Ecopath Model

The Ecopath approach stems from work of (Polovina 1984; Polovina and Ow 1983). It is a trophic modeling approach and is based on the assumption of mass balance, i.e.

Production = fishing mortality + predation mortality + other mortalities + migration + biomass accumulation. (1)

In addition, it is based on the following relationship:

Consumption = production + unassimilated food + respiration. (2)

The Ecopath master equation takes in the following form (Christensen and Pauly 1993): (3)

$$B_i \frac{P_i}{B_i} - \sum_j B_j \frac{Q_j}{B_j} DC_{ij} - B_i \frac{P_i}{B_i}(1 - EE_i) - EX_i = 0$$

where: B_i = biomass of i; P/B = production/biomass ratio, which is equal to the instantaneous rate of total mortality (Z) under steady state conditions (Allen, 1971); EE_i = ecotrophic efficiency of i; B_j = biomass of predator j; Q_j/B_j = consumption/biomass ratio of predator j; DC_{ij} = fraction of prey i by weight in the average diet of predator j; EX_i = sum of fisheries catches of i plus net migration to adjacent ecosystems.

Ecological Groupings

The ecosystem along the southwest coast was categorized into 11 ecological groups based on feeding habit and the ecological niche of the component species/groups. The compositions of these groups are summarized in Table 2.

Landings and Biomass

The research trawler *M.F.V. Samudrika*, used had a codend mesh size of 35 mm and fished in waters more than 25 m depth off the southwest coast of India. Consequently, the crustaceans were not well-represented in the catches. Moreover, the survey did not consider pelagic resources (which are abundant along the southwest coast). Hence, biomass estimates based on the trawl survey data were not used as input parameters and the biomass values were obtained as outputs from Ecopath. For the present analysis, estimated landings from all gears operated by commercial vessels along the southwest coast (based on the sample survey conducted by CMFRI for the years 1994, 1995 and 1996) were used as inputs.

Table 2. The ecological groupings used for the Ecopath analysis of fishery resources along the southwest coast of India.

Group	Taxa
Large predators	Sharks, seerfishes, tunas, billfishes
Medium predators	Catfishes, lizardfish, snappers, pigface breams, ribbonfishes, barracudas, cephalopods
Large zoobenthic feeders	Skates, rays, eels, Indian halibut
Demersal feeders	Threadfin breams, other perches, goatfishes, threadfins, croakers, silverbellies, whitefish, pomfrets, flounders, soles, stomatopods
Mesopelagic feeders	Wolf herring, half beaks, full beaks, horse mackerel, leather jackets, other carangids
Molluscan feeders	Crabs, lobsters
Plankton feeders	Oil sardine, other sardines, hilsa shad, other shads, Coilia spp., *Stolephorus* spp., *Thryssa* spp., Indian mackerel, other clupeids, scads, gastropods
Zooplankton	
Phytoplankton	
Detritivores	Mullets, penaeid prawns, non-penaeid prawns
Detritus	

Production/biomass (P/B) and Consumption/biomass (Q/B) Ratios

The P/B ratio for each ecological group was obtained from Z estimates for representative species under each category occurring along the southwest coast, as consolidated in Appendix III (this vol.). The annual P/B ratios for phytoplankton and zooplankton were set at 70 and 40, respectively, and the EE's at 0.75 (Polovina 1984).

The Q/B for each ecological group was estimated following the empirical equation suggested by (Pauly et al. 1990):

$$Q/B = 10^{6.37} \cdot 0.0313^{Tk} \cdot W_{\infty}^{-0.168} \cdot 1.38^{Pf} \cdot 1.87^{Hd} \qquad (4)$$

where:

Tk = 1000/(T° + 273) = 3.333;

T° = average annual sea surface temperature (27°C);

W_{∞} = asymptotic weight (g) of the species which contributed maximum to the biomass;

Pf = 1 for large predators and zooplankton feeders and 0 for other feeding types; and

Hd = 0 for carnivores and 1 for herbivores and detritivores.

Diet Composition

Though there are studies on the diet composition of numerous species in Indian waters, many of these studies have over-aggregated the diet, and items are only mentioned as "fish", "crustaceans", etc. For the present analysis, wherever diet composition was not available, the general habitat characteristics of the group and information available in FishBase (see http://www.fishbase.org) were used to characterize the diet composition.

Ecotrophic Efficiency

It was assumed that the EE for different ecological groups ranged from 0.65 to 0.95 and a conservative value of 0.75 was assumed for phytoplankton, following (Mendoza 1993).

Assimilation in all the ecological groups (except zooplankton) was considered as 80% of consumption, which is the default value in the Ecopath software. For zooplankton an assimilation rate of 60% was used as this results in a more realistic respiration/biomass ratio for this herbivorous group (V. Christensen pers. comm.)

Primary Production

Phytoplankton primary production has been estimated along the southwest coast by several researchers. The average production in the neritic waters is estimated to be 0.5 g C•m^{-2}•day^{-1} (Pant 1992). A conversion factor of 0.06 g C = 1 g wet weight (Walsh 1981) was employed for transformation. Average total primary production for the ecosystem was estimated as 3042 t•km^{2}•year^{-1}.

Model Parameterization

Large Predators

The large predators include sharks, seerfishes, tuna and billfishes. The dominant species of shark along the SW coast are the large-sized *Carcharhinus* spp. and *Rhizoprionodon acutus* and the smaller *Scoliodon laticaudus*. As the carcharhinids contributed most of the biomass, the asymptotic weight of a medium-sized species, *C. dussumieri* (15 kg) (Compagno 1984) was considered as representative of the sharks. The total mortality (Z) reported for the most abundant species *S. laticaudus* (1.45; Devadoss 1998) was used as the P/B value. The major species of seerfishes and tunas and their representative W, Pf and Hd values are given in Table 3. The diet of the large predators was considered to consist mostly of plankton feeders (0.6) such as the clupeids (Table 4), which is the most abundant group along the southwest coast. The minor diet components were medium predators (0.2) such as the lizardfish, sea breams and cephalopods; young ones of their own group (0.1); large zoobenthic feeders (0.1) such as the perches; and a small quantity (0.01) of zooplankton, ingested along with other prey. It was also considered that import (0.08) would have occurred in the form of migration, especially of the tuna such as *Thunnus tonggol* from other ecosystems and the sharks such as *Carcharhinus* spp. from the offshore into the inshore fishing grounds. There is evidence that the seerfish, *Scomberomorus commerson*, undertakes coastal migration (Devaraj et al. 1997). The Q/B and P/B values for this group were estimated as 7.307 year^{-1} and 2.231 year^{-1}, respectively for the large predators (Table 5).

Table 3. Estimated annual landings and selected input parameters for species within the ecological groups (Table 2) for the Ecopath analysis covering the southwest coast of India.

		Landings (t)			Input parameters				
Group	Taxa	1994	1995	1996	W_∞(g)	Pf	Hd	Q/B	P/B
Large predators	Sharks	4 966	4 386	3 319	15 000	1	0	6.22	1.45
	Seerfishes	714	683	1 028					
	Scomberomorus commerson	8 644	9 009	6 621	7 500	1	0	6.99	
	Scomberomorus guttatus	617	479	635	6 000	1	0	7.26	4.08
	Euthynnus affinis	7 169	8 515	6 982	2 000	1	0	8.73	1.52
	Auxis spp.	8 802	3 139	9 700	1 500	1	0	9.16	2.20
	Thunnus tonggol	236	176	255	5 000	1	0	7.48	1.47
	Other tunas	601	933	1 655	10 000	1	0	6.66	
	Billfishes	169	173	436	10 000	1	0	6.66	1.50
Medium predators	Catfishes	779	2 510	783	8 000	0	0	5.01	3.00
	Lizard fishes	14 671	15 568	14 369	700	1	0	10.41	3.00
	Snappers	226	81	349	8 000	0	0	5.01	3.00
	Pig-face breams	446	445	676	6 000	0	0	5.26	3.00
	Ribbon fishes	25 273	7 619	27 270	1 250	0	0	6.84	3.40
	Barracudas	3 613	6 322	5 424	5 500	0	0	5.34	3.00
	Cephalopods	47 577	53 102	41 209	2 000	0	0	6.33	2.50
Large zoobenthic feeders	Skates	156	309	354	10 000	1	0	6.66	1.00
	Rays	2 438	1 731	2 042	15 000	1	0	6.22	1.00
	Eels	185	424	504	5 000	1	0	7.48	1.00
	Rock cods	4 242	6 652	8 470	10 000	0	0	4.83	1.00
	Halibut	343	437	584	3 500	0	0	5.76	1.00

Table 3. Estimated annual landings and selected input parameters for species within the ecological groups (Table 2) for the Ecopath analysis covering the southwest coast of India. (continued)

Group	Taxa	Landings (t)			Input parameters				
		1994	1995	1996	W_∞(g)	Pf	Hd	Q/B	P/B
Demersal feeders	Threadfin breams	49 390	35 132	60 650	450	0	0	8.13	3.50
	Other perches	18 448	16 380	16 128	1 000	0	0	7.11	3.50
	Goatfishes	416	179	106	200	0	0	9.31	3.50
	Threadfins	90	16	2	1 000	0	0	7.11	3.50
	Croakers	22 210	14 998	22 606	600	0	0	7.74	4.00
	Silverbellies	7 118	5 732	6 537	25	0	0	13.21	6.00
	Big-jawed jumper	2 341	1 794	3 012	200	0	0	9.31	5.00
	Black pomfret	5 564	4 564	3 829	2 000	0	0	6.33	4.20
	Silver pomfret	1 370	980	1 643	2 000	0	0	6.33	4.20
	Chinese pomfret	870	25	26	1 750	0	0	6.47	4.20
	Flounders	109	136	14	1 500	0	0	6.64	4.00
	Soles	28 792	17 141	22 606	500	0	0	7.98	5.00
	Stomatopods	69 373	34 487	29 858	100	0	0	10.46	5.00
Mesopelagic feeders	Wolf herring	2 433	1 632	2 011	3 500	0	0	5.76	2.00
	Half beaks & full beaks	728	3 928	734	800	1	0	10.18	2.00
	Horse mackerel	7 777	10 062	5 298	700	0	0	7.55	2.85
	Leather jackets	757	1570	869	500	0	0	7.98	2.50
	Other carangids	23 763	22 861	26 767	1 000	0	0	7.11	3.08
Molluscan feeders	Lobsters	447	97	112	2 000	0	0	6.33	1.20
	Crabs	6 691	3 086	3 086	750	0	0	7.46	4.50
Plankton feeders	Oil sardine	3 187	18 137	38 815	150	1	0	13.49	2.23
	Other sardines	23 129	54 923	13 851	200	1	0	12.85	5.00
	Hilsa shad	159	186	50	450	1	0	11.21	1.71
	Other shads	213	290	7	500	1	0	11.02	1.71
	Coilia	368	220	8	50	1	0	16.22	2.70
	Stolephorus	42 439	48 624	34 426	20	1	0	18.92	3.07
	Thryssa	12 777	10 184	9 127	150	1	0	13.49	3.07
	Other clupeids	17 663	14 613	23 940	200	1	0	12.85	3.00
	Scads	40 996	93 025	53 892	250	1	0	12.38	3.88
	Indian mackerel	147 165	105 103	204 282	400	1	0	11.44	4.50
	Gastropods	1 334	471	2 112	300	0	0	8.70	2.00
Zooplankton	Mullets	733	758	343	500	0	1	15.09	
	Penaeid prawns	82 906	52 830	56 489	70	0	1	20.99	10.00
	Non-penaeid prawns	278	182	137	10	0	1	29.11	12.00
	Miscellaneous	25 593	14 866	14 060					
	TOTAL	779 494	711 908	792 095					

Note:
W = asymptotic weight of the species which contributed maximum to the biomass, Pf = 1 for large predators and zooplankton feeders and 0 for other feeding types, Hd = 1 for herbivores and detritivores and 0 for carnivores, Q/B = Consumption/Biomass ratio (year^{-1}), P/B = Production/ Biomass ratio (year^{-1}).

Table 4. Diet composition input for the ecological groups of the Ecopath model of the southwest waters of India. This was assumed to be constant for all years.

Prey	Predator								
	1	2	3	4	5	6	7	8	10
1. Large predators	0.01	–	–	–	–	–	–	–	–
2. Medium predator	0.20	0.01	–	–	–	–	–	–	–
3. Large zoobenthic feeders	0.10	0.02	0.01	–	–	–	–	–	–
4. Demersal feeder	–	0.04	0.15	0.01	–	–	–	–	–
5. Mesopelagic feeders	–	0.03	0.10	0.15	0.01	–	–	–	–
6. Mollusc feeders	–	–	–	–	–	0.010	–	–	–
7. Plankton feeders	0.60	0.75	0.70	0.75	0.80	0.75	0.05	–	–
8. Zooplankton	0.01	0.15	0.04	0.04	0.14	0.19	0.04	0.05	–
9. Phytoplankton	–	–	–	–	–	–	0.90	0.95	–
10. Detritivores	–	–	0.00	0.05	0.05	0.05	0.01	–	–
11. Detritus	–	–	–	–	–	–	–	–	1.00
Import	0.08	–	–	–	–	–	–	–	–
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 5. Estimated annual average consumption/biomass (Q/B) and production/biomass (P/B) of ecological groups along the southwest coast of India during 1994 - 96.

Ecological group	Q/B ($year^{-1}$)	P/B ($year^{-1}$)
Large predators	7.31	2.23
Medium predators	6.83	2.99
Large zoobenthic feeders	6.19	1.00
Demersal feeders	8.16	4.28
Mesopelagic feeders	8.34	2.41
Molluscan feeders	6.89	2.85
Plankton feeders	13.23	2.74
Zooplankton	133.30	40.00
Phytoplankton		70.00
Detritivores	21.73	11.00

Medium Predators

The medium predators include the lizardfish *Saurida tumbil,* major perches such as snappers *(Lutjanus* spp.*),* pig-face breams (*Lethrinus* spp.*),* ribbonfishes (*Trichiurus* spp., *Lepturacanthus savala*), barracudas (*Sphyraena* spp.) and cephalopods (*Sepia pharaonis, Sepia elliptica, Sepiella inermis,* etc.). The annual average Q/B and P/B values estimated were 6.827 and 2.986, respectively.

Large Zoobenthic Feeders

The large zoobenthic feeders include skates, rays, eels, groupers (*Epinephelus* spp.) and Indian halibut (*Psettodes erumei*). The annual Q/B and P/B were 6.19 and 1.0, respectively (Table 5). Though this group is a major predator on demersal feeders such as threadfin breams and croakers, available information suggests that plankton feeders such as the Indian mackerel, which descend to the bottom and contribute to the trawl catches, constitute the major part of the diet (0.7).

Demersal Feeders

The demersal fish groups such as the threadfin breams, croakers, silverbellies and pomfrets constitute this group. The Q/B and P/B values for the group are given in Table 5. The demersal feeders consume large quantities of plankton feeders (0.75), mesopelagic feeders (0.15) and detritivores (0.05).

Mesopelagic Feeders

This ecological group includes the carangids such as *Caranx* spp., *Alepes* spp., *Selar* spp., *Chorinemus*, the horse mackerel *Megalaspis cordyla,* the wolf herring *Chirocentrus* spp, half beaks and full beaks. They feed mainly on the plankton feeders (0.80), zooplankton (0.14) and detritivores (0.05). The annual Q/B and P/B were 8.336 and 2.405, respectively.

Molluscan Feeders

The crabs *Portunus* spp. and *Charybdis* spp. and the spiny lobsters *Panulirus* spp. feed primarily (0.75) on bivalves such as the mussels and clams. The annual Q/B and P/B ratios were 6.892 and 2.850, respectively.

Plankton Feeders

The plankton feeders are mostly small pelagics such as the clupeids *Sardinella* spp., *Stolephorus* spp. and *Thryssa* spp.; the scads *Decapterus* spp. and the Indian mackerel *Rastrelliger kanagurta* contribute the maximum biomass to the southwest ecosystem. The information on the diet composition of the small pelagics has been reviewed by (Devaraj et al. 1997). The lesser sardines *Sardinella fimbriata* and *Stolephorus devisi* feed primarily on phyto-plankton whereas *S. gibbosa* and *S. bataviensis* (*S. waitei* in FishBase 2000) feed mainly on zooplankton.

Ontogenetic changes in the feeding habits are also observed in several species. The oil sardine *S. longiceps,* for instance, feeds on diatoms and microalgae when it is a postlarva, on zooplankton when it is a juvenile, and once again on diatoms after becoming adult. The mackerel *R. kanagurta* feeds on zooplankton when it is a juvenile, and on phytoplankton after becoming adult. Thus it is difficult to categorize such species as exclusive phytoplankton feeders or zooplankton feeders. Nevertheless, it is considered that phytoplankton and zooplankton constitute a major share (0.94) in the diet of this ecological group, and the juveniles of the plankton feeders themselves contribute the rest.

The total mortality coefficient values (Z) available for several species of the plankton feeders along the SW coast were collected, and the average Z was used as the P/B of each species/group. The estimated annual Q/B and P/B values for this ecological group were 13.233 and 2.739, respectively.

Detritivores

The penaeid and non-penaeid prawns and the mullids are categorized as the detritus feeders. The detritivores feed almost exclusively on detritus (1.0). The Z values of several penaeid (10.0) and non-penaeid (12.0) prawns are very high (Table 3) as they are preyed upon by several ecological groups. Moreover, the penaeid prawns are a target group for the commercial fisheries. The annual Q/B and P/B values of this ecological group were estimated as 21.733 and 11.0, respectively (Table 5).

Zooplankton

This group includes mostly copepods and fish larvae. Following (Polovina, 1984), the P/B value was set at 40 $year^{-1}$ and the diet vector based essentially on phytoplankton (0.95) and on cannibalism to a lesser extent (0.05). The zooplankton biomass was estimated as 10 $t{\cdot}km^{-2}$.

Phytoplankton

The annual P/B was set at 70 (Polovina, 1984) and the estimated biomass was 129.87 $t{\cdot}km^{-2}$.

Detritus

There was no available information regarding the detritus component along the southwest coast. The detritus biomass of 426 $t{\cdot}km^{-2}$ was estimated by employing the following empirical relationship suggested by (Pauly et al. 1993):

$$\text{Log } D = 0.954 \log PP + 0.863 \log E - 2.41 \qquad (5)$$

where:

D = detrital biomass in g $C{\cdot}m^{-2}$;

PP = primary production (182 g $C{\cdot}m^{-2}{\cdot}year^{-1}$ for the southwest coast; after (Pant 1992), and

E = the euphotic layer depth (40 m).

Results and Discussion

The trophic model as devised using Ecopath for the southwest coast of India is presented in Fig. 4. The estimated parameters for the trophic model are summarized thus: 1994 in Table 6, 1995 in Table 7 and 1996 in Table 8. Most of the fish biomass and production is within the domain of plankton feeders, i.e. the small pelagic fishes (Table 9). Among the demersal resources, most of the biomass and production are associated with the detritus and detritivores.

Figure 5 illustrates the impact of each ecological group on the other ecological groups during 1994, as obtained through mixed impact analysis. The phytoplankton and plankton feeders are impacted by a large number of ecological groups. It is interesting that the fishery has a positive impact on large zoobenthos feeders and mesopelagic feeders. This is because this fishery, even though it has a direct negative impact on these groups, also has an indirect positive impact, by removing predators on the groups, (notably large and medium predators in the case of the large zoobenthos feeders).

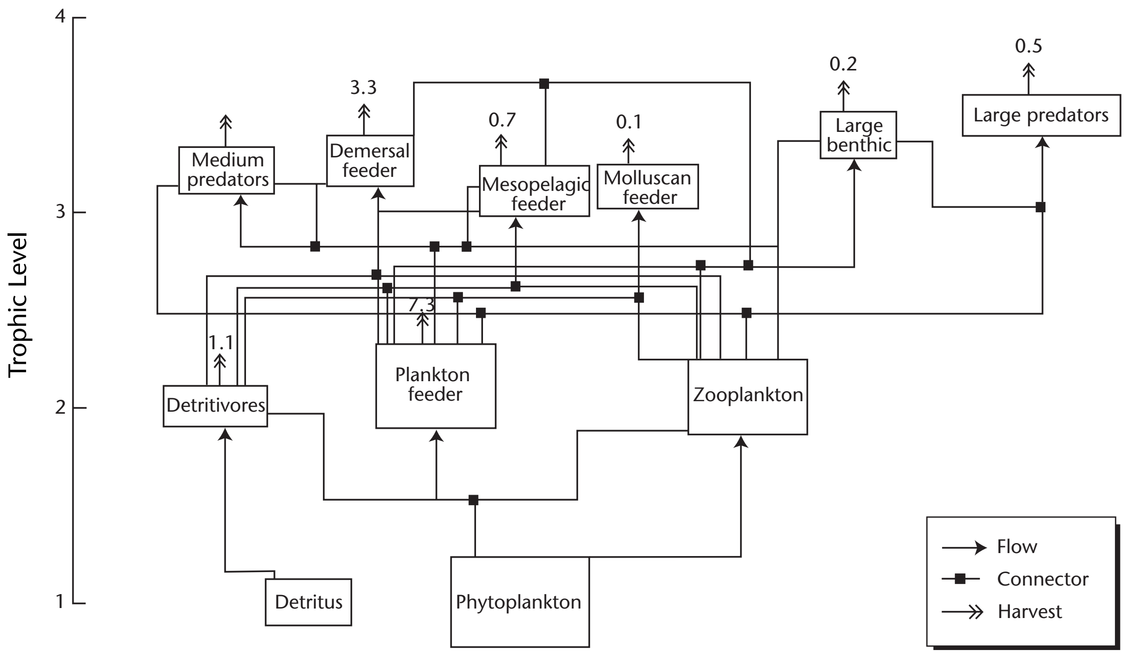

Fig. 4. Flowchart showing the trophic interactions in the ecosystem model of the southwest coast of India.

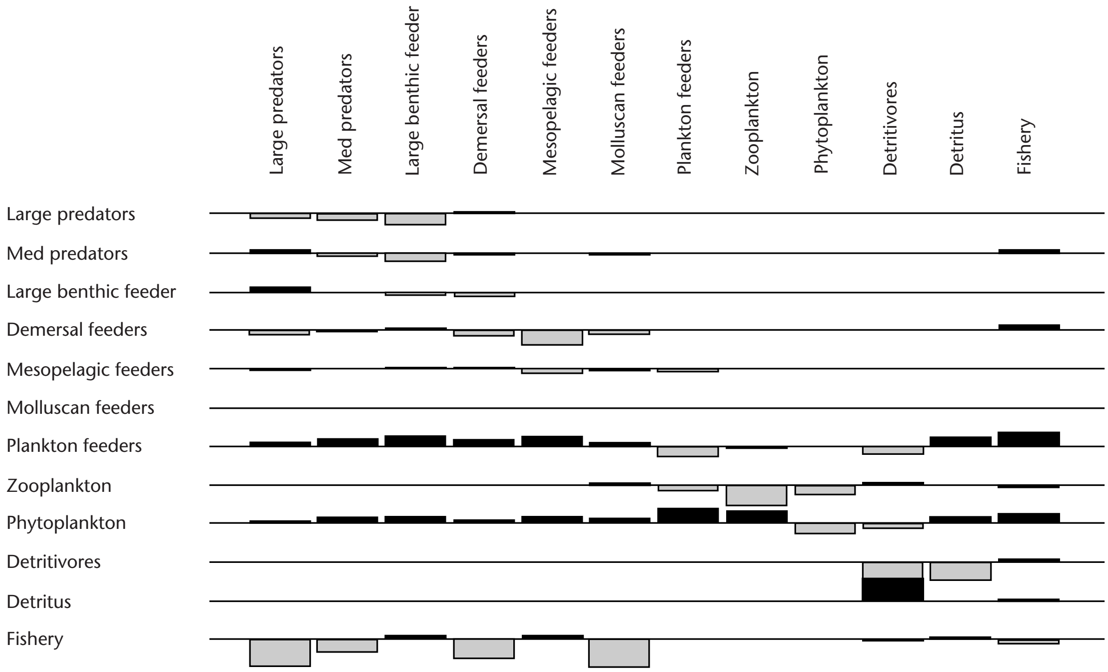

Fig. 5. Mixed trophic impact in the 1994 ecosystem model for the southwest coast of India. The graph shows the impact that each of the groups on the left (rows) is predicted to have on each of the groups on top (columns). Positive impacts are shown above the baseline, and negative below it. The impacts are relative but comparable between groups.

Table 6. Basic input and output parameters (in parentheses) for the Ecopath model of the southwest waters of India for the year 1994.

Ecological group	Biomass (t·km^{-2})	P/B	Q/B	EE	Catch (t·km^{-2} ·year^{-1})	Trophic Level	Flow to Detritus	Net Efficiency	Respiration (t·km^{-2}·year^{-1})	Assimilation (t·km^{-2}·year^{-1})
Large predators	(0.44)	2.23	7.31	0.65	0.61	(3.50)	(0.99)	(0.38)	(0.002)	(0.003)
Medium predator	(1.12)	2.99	6.83	0.75	1.78	(3.21)	(2.36)	(0.55)	(0.003)	(0.006)
Large zoobenthic. feeders	(0.35)	2.50	6.19	0.85	0.24	(3.39)	(0.56)	(0.51)	(0.001)	(0.002)
Demersal feeder	(1.18)	4.28	9.50	0.80	3.30	(3.26)	(3.25)	(0.56)	(0.004)	(0.009)
Mesopelagic feeders	(0.85)	4.00	8.34	0.85	0.71	(3.10)	(1.94)	(0.60)	(0.002)	(0.006)
Mollusc feeders	(0.05)	2.85	6.89	0.80	0.10	(3.10)	(0.09)	(0.52)	(0.000)	(0.000)
Plankton feeders	(14.64)	3.00	15.00	0.95	7.25	(2.11)	(46.12)	(0.25)	(0.132)	(0.176)
Zooplankton	10.00	40.00	133.30	0.19	0.00	(2.05)	(0.00)	(0.50)	(6.609)	(5.575)
Phytoplankton	(129.87)	70.00	–	0.75	0.00	(1.00)	(0.00)	–	(0.00)	(0.000)
Detritivores	(0.37)	12.00	60.00	0.95	1.13	(2.00)	(4.70)	(0.25)	(0.01)	(0.018)
Detritus	1.00	–	–	(0.37)	0.00	(1.00)	–	–	(0.00)	(0.000)

Note: P/B = Production/Biomass ratio (year^{-1}), Q/B = Consumption/Biomass ratio (year^{-1}), EE = Ecotrophic efficiency.

Table 7. Basic input and output parameters (in parentheses) for the Ecopath model of the southwest waters of India for the year 1995.

Ecological group	Biomass ($t \cdot km^{-2}$)	P/B	Q/B	EE	Catch ($t \cdot km^{-2} \cdot year^{-1}$)	Trophic Level	Flow to Detritus	Net Efficiency	Respiration ($t \cdot km^{-2} \cdot year^{-1}$)	Assimilation ($t \cdot km^{-2} \cdot year^{-1}$)
Large predators	(0.40)	2.23	7.31	0.65	0.55	(3.50)	(0.89)	(0.38)	(0.001)	(0.002)
Medium predator	(1.05)	2.99	6.83	0.75	1.70	(3.21)	(2.22)	(0.55)	(0.003)	(0.006)
Large zoobenthic. feeders	(0.30)	2.50	6.19	0.85	0.19	(3.39)	(0.49)	(0.51)	(0.001)	(0.001)
Demersal feeder	(0.96)	4.28	9.50	0.80	2.61	(3.26)	(2.63)	(0.56)	(0.003)	(0.007)
Mesopelagic feeders	(0.77)	4.00	8.34	0.85	0.80	(3.10)	(1.75)	(0.60)	(0.002)	(0.005)
Mollusc feeders	(0.03)	2.85	6.89	0.80	0.06	(3.10)	(0.06)	(0.52)	(0.000)	(0.000)
Plankton feeders	(13.04)	3.00	15.00	0.95	6.86	(2.11)	(41.10)	(0.25)	(0.117)	(0.157)
Zooplankton	10.00	40.00	–	0.90	0.00	(2.05)	(0.00)	(0.50)	(6.634)	(5.595)
Phytoplankton	(129.91)	70.00	0.00	0.75	0.00	(1.00)	(0.00)	–	(0.000)	(0.000)
Detritivores	(0.33)	12.00	60.00	0.95	1.07	(2.00)	(4.21)	(0.25)	(0.012)	(0.016)
Detritus	1.00	(0.37)	–	–	0.00	(1.00)	–	–	(0.000)	(0.000)

Note: P/B = Production/Biomass ratio ($year^{-1}$), Q/B = Consumption/Biomass ratio ($year^{-1}$), EE = Ecotrophic efficiency.

Table 8. Basic input and output parameters (in parentheses) for the Ecopath model of the southwest waters of India for the year 1996.

Ecological group	Biomass ($t \cdot km^{-2}$)	P/B	Q/B	EE	Catch ($t \cdot km^{-2} \cdot year^{-1}$)	Trophic Level	Flow to Detritus	Net Efficiency	Respiration ($t \cdot km^{-2} \cdot year^{-1}$)	Assimilation ($t \cdot km^{-2} \cdot year^{-1}$)
Large predators	(0.44)	2.23	7.31	0.65	0.61	(3.50)	(0.99)	(0.38)	(0.002)	(0.003)
Medium predator	(1.12)	2.99	6.83	0.75	1.78	(3.21)	(2.36)	(0.55)	(0.003)	(0.006)
Large zoobenthic. feeders	(0.35)	2.50	6.19	0.85	0.24	(3.39)	(0.56)	(0.51)	(0.001)	(0.002)
Demersal feeder	(1.18)	4.28	9.50	0.80	3.30	(3.26)	(3.25)	(0.56)	(0.004)	(0.009)
Mesopelagic feeders	(0.85)	4.00	8.34	0.85	0.71	(3.10)	(1.94)	(0.60)	(0.002)	(0.006)
Mollusc feeders	(0.05)	2.85	6.89	0.80	0.10	(3.10)	(0.090)	(0.52)	(0.000)	(0.000)
Plankton feeders	(14.64)	3.00	15.00	0.95	7.25	(2.11)	(46.12)	(0.25)	(0.132)	(0.176)
Zooplankton	10.00	40.00	–	0.90	0.00	(2.05)	(0.00)	(0.07)	(6.609)	(5.575)
Phytoplankton	(129.87)	70.00	0.00	0.75	0.00	(1.00)	(0.00)	–	(0.000)	(0.000)
Detritivores	(0.37)	12.00	60.00	0.95	1.13	(2.00)	(4.70)	(0.25)	(0.013)	(0.018)
Detritus	1.00	(0.37)	–	–	0.00	(1.00)	–	–	(0.000)	(0.000)

Note: P/B = Production/Biomass ratio ($year^{-1}$), Q/B = Consumption/Biomass ratio ($year^{-1}$), EE = Ecotrophic efficiency.

Table 9. Comparison of average reported catch from commercial vessels and biomass estimates from the Ecopath model during 1994 - 96 along the southwest coast of India.

Group Name	Catch ($t \cdot year^{-1}$)	Catch ($t \cdot km^{-2} \cdot year^{-1}$)	Biomass ($t \cdot km^{-2}$)
Large predators	30 83	0.60	0.44
Medium predators	91 63	1.78	1.12
Large zoobenthic feeders	9 85	0.19	0.35
Demersal feeders	172 48	3.35	1.18
Mesopelagic feeders	37 97	0.74	0.85
Molluscan feeders	5 30	0.10	0.05
Plankton feeders	346 57	6.74	14.64
Detritivores	66 55	1.29	0.37
TOTAL	761 17	14.80	19.00

Some of the results of the trophic models for the years 1994 to 1996 can be summarized as follows:

- The total system throughputs were 14 083, 14 078 and 14 083 $t \cdot km^{-2} \cdot year^{-1}$ (see Table 10) for the years 1994, 1995 and 1996, respectively. The throughputs were higher than that (7 621 $t \cdot km^{-2} \cdot year^{-1}$) reported for the northeastern (NE) Venezuela shelf ecosystem (Mendoza, 1993);
- The ecosystem off the southwest coast of India has very high net primary production (9 091 $t \cdot km^{-2} \cdot year^{-1}$ during 1996) and consequently high detritus biomass (426 $t \cdot km^{-2}$) compared to the detritus biomass (135 $t \cdot km^{-2}$) off northeastern Venezuela.
- However, the total biomass (excluding detritus) was only marginally higher off the southwest coast of India (158.9 $t \cdot km^{-2}$) than that off the northeastern coast of Venezuela (122.1 $t \cdot km^{-2}$).
- The biomass of commercially exploited fishery resources was estimated as 19.0 $t \cdot km^{-2}$ off the southwest coast of India (Table 9). The gross efficiency (total catch/primary production) was 0.0017.

Mean Trophic Level

Ecopath estimates the mean trophic level of the exploited fishery from the diet composition by placing primary producers and detritus on trophic level 1 and the consumer groups on trophic levels estimated as the weighted average trophic level of their prey groups plus one (Christensen and Pauly 1992). The mean trophic levels of commercial catches along the southwest coast were estimated as 2.61, 2.59, and 2.61 during 1994, 1995 and 1996, respectively. Comparatively, the trophic level of catches in the Gulf of Thailand ecosystem is reported to have declined from 3.12 in 1963 to 3.01 in 1980 (Christensen 1998). This difference appears to be due to the greater abundance and catches of pelagics low in the food chain off the southwest coast of India.

The present analysis has to be viewed as a preliminary approximation of the fisheries ecosystem off the southwest coast of India. Inadequacies of the present analysis could be classified under the following categories: (i) data inadequacy; (ii) categorization of ecological groups; and (iii) incomplete analysis.

a. Data Inadequacy: The tropical ecosystem is complex and inhabited by numerous species with diverse biological characteristics. For instance, there are 15 species of sardines, 24 species of whitebaits, 15 species of hilsa and other shads, 10 species of *Thryssa* and 40 species of other clupeids, which contribute to the ecological group of plankton feeders (Devaraj et al. 1997). It may be difficult to estimate the required input parameters such as W_∞, Q/B, P/B and diet composition of all the species in an ecosystem to estimate the biomass of that ecological group. Hence, several assumptions and compromises had to be made in completing the model.

b. There are several default values in Ecopath, the reliability of which should be tested for each ecological group in different ecosystems. For instance, the assimilation efficiency will be different for large predators and for detritivores. Hence, it is crucial for future work to examine the impact of changes to the default parameter settings on the outputs.

Categorization of Ecological Groups

a. Maximum body size (W_∞ or L_∞) of individual species in each ecological group varies so much that categorization of fishes into ecological group is subject to individual bias. For instance, the as-

ymptotic weight of the bullet tuna *(Auxis rochei)* is only 5 kg whereas that of the migratory yellowfin tuna *(Thunnus albacares)* is 170 kg. Hence, it is possible that the small coastal tunas *Euthynnus affinis, Auxis thazard)* and *A. rochei* should be categorized as medium predators, rather than be included with other tunas as large predators, as has been done in the present analysis.

b. Ontogenetic shifts in feeding habits also could greatly influence the categorization. The thread fin bream *Nemipterus japonicus,* for instance, feeds primarily on detritus when young but preys upon small demersal fishes when adult (Vivekanandan, unpublished data). A reverse feeding pattern is observed for the lizardfish, *Saurida tumbil.* The Ecosim module of the Eco path Software incorporates ontogenetic shifts by modeling adult and juveniles separately; Ecosim analysis will however have to await further studies.

Incomplete Analysis

a. Predators on fishes such as marine mammals, reptiles and birds have not been included due to lack of data. For the same reason, invertebrates such as jellyfishes and starfishes, which are abundant and prey on small fishes, and holothurians, which play a significant role in detrital turnover, have been left out.

b. The contribution of benthic biota to biomass flow could not be accounted for. As the detrital biomass is large along the southwest coast, the benthic biomass consisting of meiofauna (body size < 0.5 mm) and macrofauna (> 0.5mm) is also expected to be high. (Parulekar 1985) estimated that the biomass varies from 0.1 to 601 $g \cdot m^{-2}$ with an average of 38.5 $g \cdot m^{-2}$, and concluded that the benthic biota play a significant role in demersal fish production.

Table 10. Biomass flows in the southwest Indian coast ecosystem.

Index	1994	1995	1996
Sum of all consumption ($t \cdot km^{-2} \cdot year^{-1}$):	7 242.62	7 237.22	7 242.62
Sum of all exports ($t \cdot km^{-2} \cdot year^{-1}$):	15.12	13.84	15.12
Sum of all respiratory flows ($t \cdot km^{-2} \cdot year^{-1}$):	6 765.70	6 773.36	6 765.70
Sum of all flows into detritus ($t \cdot km^{-2} \cdot year^{-1}$):	60.01	53.34	60.01
Total system throughput ($t \cdot km^{-2} \cdot year^{-1}$):	14 083.44	14 077.76	14 083.44
Sum of all production ($t \cdot km^{-2} \cdot year^{-1}$):	9 553.07	9 548.86	9 553.07
Mean trophic level:	3.61	3.59	3.61
Gross efficiency (catch/net primary production):	< 0.01	< 0.01	< 0.01
Calculated total net primary production ($t \cdot km^{-2} \cdot year^{-1}$):	9 090.89	9 093.68	9 090.89
Total primary production/total respiration:	1.34	1.34	1.34
Net system production ($t \cdot km^{-2} \cdot year^{-1}$):	2 325.19	2 320.32	2 325.19
Total primary production/total biomass:	57.22	57.99	57.22
Total biomass/total throughput (year):	0.01	0.01	0.01
Total biomass (excluding detritus) ($t \cdot km^{-2}$):	158.87	156.80	158.87
Total catches ($t \cdot km^{-2} \cdot year^{-1}$):	15.12	13.84	15.12
Connectance Index:	0.36	0.36	0.36
System Omnivory Index:	0.10	0.109	0.10

c. Diverse habitats such as coral reefs provide shelter for unique fishes, which feed on coral polyps. Information is not available on these biologically rich ecosystems, which is a habitat for diverse ecological groups. The southern part of the present study area is rocky with coral reefs. The biomass in this habitat along with the associated fauna and flora has not been included in the biomass budget.

d. Another shortcoming is that imports and exports (barring the catches) are not known. Biomass estimates for species/groups from adjacent ecosystems may be necessary. In the present analysis, import was set only for large predators (8% of diet), assuming that interactions with adjacent ecosystems are very low.

Summary

Nevertheless, the Ecopath biomass estimates are comparable to the biomass estimates based on the swept area method for the southwest coast (Matthew et al. 1990). In the trawl survey, penaeid prawns (detritivores), spiny lobsters and crabs (molluscan feeders) and plankton feeders (clupeids) were not well represented in the catch. The biomass of the remaining resources was estimated at 3.71 t•km^{-2} during 1994 - 96. In the Ecopath analysis, the estimated total biomass was 19.0 t•km^{-2}, and the biomass of the ecological groups represented in the trawl survey was 3.94 t•km^{-2}. Hence, the biomass of the top 5 ecological groups (large and medium predators, large zoobenthos feeders, demersal feeders and mesopelagic feeders) estimated by employing the two different methods (namely, Ecopath and swept area) are very close to each other.

Ecopath is a powerful tool not only for understanding ecosystem functioning but also for fisheries management. The present analysis suggests that the annual average catches have exceeded estimated biomass in the case of the large and medium predators, demersal feeders and detritivores (Table 9). It appears that there is scope for increasing the catch of large zoobenthic feeders, mesopelagic feeders such as the carangids, and plankton feeders such as sardines, shads, whitebaits, *Thryssa* spp. and other clupeids and scads. Gear employed for exploitation of demersal resources, particularly bottom trawl, is probably in excess. The trawlable biomass appears to be overexploited and a reduction in trawl effort may be necessary to sustain the trawl fisheries along the southwest coast of India. On the other hand, there appears room for increasing gear employed for the exploitation of pelagic resources considering the abundance of plankton feeders. However, as the present analysis has limitations, further research and consolidation of available data are required to improve the model, refine the analysis and enhance the accuracy of the results.

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Marine Fisheries Resources of the North Coast of Central Java, Indonesia: An Ecosystem Analysis

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Abstract

A trophic model of the marine fisheries resources of the north coast of Central Java, Indonesia was constructed using the Ecopath with Ecosim software and data from a trawl survey conducted in the area in 1979. The model consists of 27 ecological groups with a mean trophic level of 3.04. The exploited fishery was then a moderately mature and relatively stable system. The impact of the fishery at the time was low to moderate in comparison with the fisheries in other systems and notably in later time periods.

Introduction

The Sunda shelf of Southeast Asian waters is one of the most extensive continental shelves in the world, covering some 1 850 000 km^2 with most of the area shallower than 100 m depth. Mud, muddy sand, and sand are the predominant bottom sediment, and several large areas were, before the onset of trawling, densely covered by giant cup sponges. Exploitation of the demersal resources has a long history (Butcher 1996), but the intensity of exploitation has not spread uniformly over the whole area, causing several areas to be overexploited, especially on the north coast of Java (Martosubroto 1996). Most fishers exploit nearshore areas using traditional fishing gears. However, trawlers began operating near the coast in the early 1970s, soon leading to conflicts and concerns about the resource situation. In the 1980s, all trawl operations in Western Indonesia were banned, and most trawlers on the north coast of Java were converted to purse seiners. Purse seine effort then developed rapidly, while the demersal fishes and shrimps were largely left for traditional fishers to exploit.

Stock assessments indicate that the demersal resources along the north coast of Java are overexploited (Dwiponggo et al. 1986), implying the need for management. Owing to the complexity of the fisheries and the resources management, using ecosystem approaches are required. Although problems remain in adopting an ecosystem-based approach in the area, the Ecopath with Ecosim software which include time- and spatial-dynamic simulation models, may be used as a tool to study fisheries resources in an ecosystem context and for exploring management options (Christensen et al. 2000; Pauly et al. 2000).

Materials and Methods

Study Area and Data Sources

This study is based on the Ecopath with Ecosim mass-balance trophic modeling approach and describes the fisheries resources along the north coast of Central Java (Fig. 1).

Data and information used to build the ecosystem

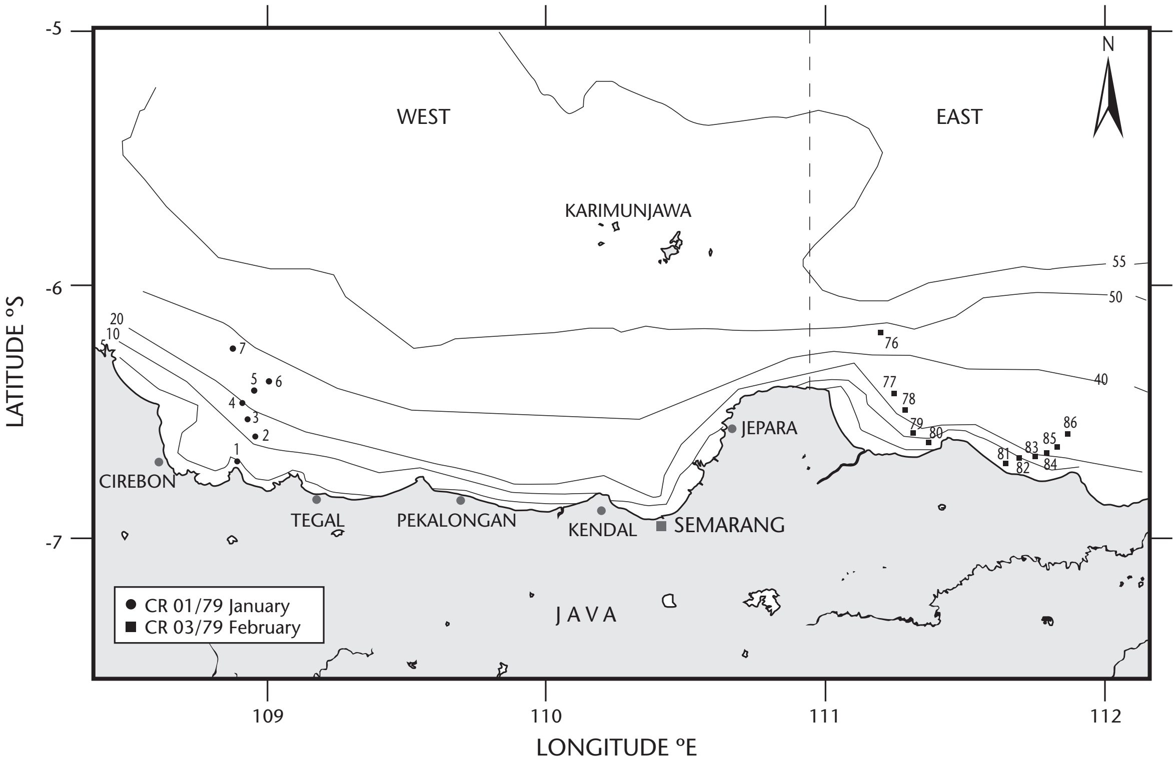

Fig. 1. Map of the Java Sea showing the bathymetry and areas covered by the trawl surveys in 1979.

model involved both published and unpublished reports (hard-to-access). To build the Ecopath model, data from within the actual study area (*viz.* the Java Sea) were used. The primary source for this purpose was the trawl survey of the *R/V Mutiara IV*, along the north coast of Central Java in 1979, as well as various surveys conducted by the oceanographic institute LON-LIPI from 1977 to 1979 in the area (Pauly and Martosubroto 1996).

Landing data from the Java Sea were obtained from the Directorate General of Fisheries (DGF) for the year 1979. Unless otherwise specified, information on diet composition was obtained from FishBase (www.fishbase.org). Information on diet composition for non-fish groups was derived from various models documented in Christensen and Pauly (1993) and Pauly and Christensen (1993).

Cross checking compilations of species records from the study area was conducted, (based on Buchary 1999; Dwiponggo et al. 1986; Losse and Dwiponggo 1977; Martosubroto and Pauly 1976; Pauly and Martosubroto 1996), and DGF landings statistics.

Attributes of non-fish species from the north coast of Central Java Sea were adapted from (Buchary 1999), who relied on both direct and indirect sources. Direct sources included: (1) periodic oceanographic surveys conducted in the study area from the 1970s to 1980s by the oceanographic institute LON-LIPI, (2) DGF fisheries statistics (Dwiponggo 1987), (3) research articles of the *Snellius II* Expedition, (which covers mainly the eastern part of Indonesia, but also the eastern tip of the Java Sea), and (4) other literature about the study area. Indirect sources included: (1) literature covering neighbouring areas, and (2) Ecopath models of neighbouring ecosystems. Most notable among these were: the Gulf of Thailand model (Christensen 1998) the South China Sea models (Pauly and Christensen 1993), the Brunei coast model (Silvestre et al. 1993), the Bolinao reef (Philippines) model (Aliño et al. 1993; Pauly et al. 1993), and to a much lesser extent the Caribbean coral reef model of (Opitz 1996).

Data Analysis and Model Parameterization

Where several data sets were available, input

parameters for the functional groups were calculated as arithmetic mean, without weighing. The aggregation process into ecological groups was performed based on similarities in habitat, body size, growth and mortality rates and diet composition, after the method described by Christensen and Pauly (1996).

Fish were allocated into functional groups first by habitat preferences, then by body size. Size ranges were specified so that fish with an average or maximum body length of less than 40 cm were considered "small". Fish with an average or maximum body length between 40 and 60 cm were considered "medium"; those that were greater than 60 cm were considered "large". For some species groups, the allocation process was quite straightforward because of their significant contribution to landings, (e.g. clupeoids, *Decapterus* spp.) and/or in the trawl surveys, (e.g. leiognathids). These therefore formed individual functional groups.

Some groups other than fish, however, presented problems. For instance, the marine mammal species proved difficult to handle. Based on a literature search, the following marine mammals were reported to occur in the Java Sea: dugongs, resident dolphins, and transient whales (Buchary 1999; Jefferson et al. 1993; Klinowska 1991; Rice 1989; Tas'an and Leatherwood 1984; White 1983). In the process of data analysis and model parameterization, a number of modifications were found necessary to balance the model and are described below:

1. As an endangered species that receives very little attention in Indonesia, the population of dugong in the Java Sea is probably very small, though actual counts of this species in the study area do not exist. However, an account was made of the dugong's distribution, based on unstructured interviews with local people throughout its suspected distribution range, conducted from the late 1960s to the late 1970s (Buchary 1999; Nishiwaki et al. 1979). Assuming that these data provide a relative index of abundance, an estimation of dugong biomass in the Java Sea was obtained which was so low (less than 0.0001 $t \cdot km^{-2}$) that it has no bearing on the trophic dynamics of the ecosystem. Hence, this group was not included in the model.

2. Dolphins in the Java Sea are considered to be resident (Buchary 1999; Tas'an and Leatherwood 1984). Whales, however, are transient in the system (Buchary 1999; Jefferson et al. 1993; Klinowska 1991; Rice 1989), migrating from the Indian Ocean, through the Java Sea and then to the Pacific Ocean during the winter to breed, and returning during the summer, mainly to feed. Thus, dolphins and whales were initially separated into two functional groups. While balancing the model, however, unrealistic values for the transient whales were obtained, (e.g. respiration exceeded assimilation). The problem was resolved by aggregating these two groups into a single marine mammal group.

Other taxa identified but not accommodated in the model were marine turtles and marine birds, even though their existence in the Java Sea is a matter of record. Marine turtles in the Java Sea (Buchary 1999; White 1983) include the hawksbill turtle (*Eretmochelys imbricata*), and to a lesser extent the green turtle (*Chelonia mydas*). No population estimates are presently available for either species in the study area, but both are considered to be endangered (Buchary 1999; Groombridge 1982). Hence, their population was assumed too small to incorporate into the model. A similar rationale was followed for marine birds, based on the following evidence. White (1983) and Buchary (1999) noted that there are 131 species of marine birds recorded in Indonesia. The majority of them are shorebirds and vagrant waders, which occur in coastal mudflats, marshes and mangroves. Additionally, oceanic seabirds usually form colonies on smaller islands away from the presence of humans. True marine birds are rare in the Java Sea. Consequently, this group was not included in the model.

To perform efficiently, and be both ecologically and biologically realistic, an Ecopath model should have at least a dozen functional groups (Christensen and Pauly 1996). There is no upper limit on how many groups can be accommodated, but existing models typically include 25 - 35 groups. The present model falls within this range with 27 functional groups (Table 1).

Table 1. Composition of the 27 ecological groups used for modeling the fisheries resources of the north coast of Central Java model.

Ecological group	Taxa
Benthic producers	Marine algae (epilithic algae, endolithic algae, reef turf algae, benthic fleshly algae, macroalgae, and benthic algae) and spermatophytes (sea grass)
Phytoplankton	Dominated by diatoms (*Bacteriatrum* spp., *Biddulphia* spp., *Bacillaria* spp., *Chaetoceros* spp., *Coscinodiscus* spp., *Ditylum* spp., *Eucampia* spp., *Hemiaulus* spp., *Hemidiscus* spp., *Lauderia* spp., *Leptocylindricus* spp., *Nitzschia* spp., *Rhizosolenia* spp., *Skeletonema* spp., *Streptotheca* spp., *Thalassiothrix* spp. *Thalassionema* spp. and dinoflagellates (*Ceratium* spp., *Dinophysis* spp., and *Peridinium* spp.)
Small herbivorous zooplankton (Small herb. Zoopl.)	Copepods, ostracods, bivalve larvae, cirripedia larvae, cladocerans, echinoderm larvae, larvacea, other mollusc larvae
Large herbivorous zooplankton (Lg. Herb. Zoopl)	Mysids, sergestids, euphausiids, amphipods, luciferidae, and other decapod larvae
Carnivorous zooplankton	Chaetognaths (*Sagitta* spp.), annelids and ichthyoplankton
Jellyfishes	All medusoid form of cnidarians (hydrozoa and scyphozoa only); although scyphozoa medusae dominate
Benthic infauna	Includes all burrowing benthos ≤ 1.0 mm, viz., polychaetes, molluscs, echinoderms, crustaceans, sipunculids, and benthic stage larvae of other larger organisms
Structure-associated fish (SAF)	Includes all fish that are ecologically dependent (directly and/or indirectly) on living bottom structure (LBS, see group 10) to complete their life cycle. For this model, it includes fish of the families Balistidae, demersal Carangidae, Lethrinidae, Lutjanidae, Pentapodidae, Platacidae, Polynemidae, Sparidae, Sphyraenidae, Scaridae, Acanthuridae, and Tetraodontidae
Macrozoobenthos	This group includes all larger (size > 1.0 mm) molluscs and echinoderms, such as conch, oyster, scallops, clams, cockles, mussels, sea urchins, sea cucumbers, and sea stars.
Living bottom structure (LBS)	All biogenic organisms that live on and/or are attached to the sea floor, such as sponges (notably giant cup sponges, *viz. Poterion nautilus*, *P. neptuni*, and *P. amphitritae*), gorgonians (sea fans and sea whips), soft coral, sea pens, sea anemones, etc.
Juvenile penaeid shrimp (Juv. Pen. Shrimp)	Includes all juvenile shrimps, not just penaeid shrimps. However, parameterization of this group is based on the juveniles of *Penaeus* spp. and *Metapenaeus* spp.
Large pelagic predators - juvenile (Lg. Pel. Pred. J)	Juveniles of the families Chirocentridae, large Scombridae, and Trichiuridae
Adult penaeid shrimps (Ad. Pen. Shrimps)	Includes all adult shrimps, but data refer only to *Penaeus* spp. and *Metapenaeus* spp.
Miscellaneous pelagics (Misc. pelagics)	Belonidae, Carangidae, Harpodontidae, Hemirhamphidae, Lactaridae, Mobulidae, Scianidae (*Kathala axillaris*), and Scombridae (*Auxis sp.*)
Leiognathids	*Gazza minuta*, *Leiognathus* spp., and *Secutor* spp.
Crabs and Lobsters	Portunidae, Palinuridae, Scyllaridae, etc.
Cephalopods	Includes squids (*Loligo* spp.), cuttlefish (*Sepia* spp.) and octopus (*Octopus* spp.)
Decapterus spp.	*Decapterus macrosoma, D. maruadsi and D. russelli*
Rastrelliger spp.	*Rastrelliger brachysoma* and *R. kanagurta*
Clupeoids	Clupeidae and Engraulidae

Table 1. Composition of the 27 ecological groups used for modeling the fisheries resources of the north coast of Central Java model. (continued).

Ecological group	**Taxa**
Small demersals	Apogonidae, Ariidae, Ariommatidae, Caesionidae, Cynoglossidae, Dactylopteridae, Drepanidae, Ephippidae, Gerridae, Haemulidae, Holocentridae, Kurtidae, Menidae, Mullidae, Nemipteridae, Priacanthidae, Serranidae, Siganidae, Sillaginidae, Stromatidae, Synodontidae, Teraponidae and Sciaenidae
Large demersal predators - juvenile (Lg. Dem. Pred. J)	Juveniles of the families Ariidae (*Arius thalassinus*), Carcharhinidae, Muraenesocidae, Serrandae (*Epinephelus lanceolatus*), Sphyrnidae, Stegostomidae, Pristidae, Rhinidae, and Rhinobatidae
Demersal rays	Dasyatidae and Myliobatidae
Large pelagic predators - adult (Lg. Dem. Pred. A)	Chirocentridae, large Scombridae and Trichiuridae
Large demersal predators - adult (Lg. Dem. Pred. A.)	Ariidae (*Arius thalassinus*), Carcharhinidae, Muraenesocidae, Serranidae (*Ephinephelus lanceolatus*), Sphyrnidae, Stegostomidae, Pristidae, Rhinidae and Rhinobatidae
Marine mammals	Comprised of resident dolphins *viz.*, Bottlenose dolphins (*Tursiops* spp.), Spinner dolphins (*Stenella longirostris*), Irrawady dolphins (*Orcaella brevirostris*), finless porpoises (*Neophocaena phocaenoides*), and Indo-Pacific humpbacked dolphins (*Sousa chinensis*); and transient whales, *viz.*, sperm whales (*Physeter catodon*), Bryde's whales (*Balaenoptera edenii*), and minke whales (*B. autorostrata*)
Detritus	Particulate and dissolved organic matter

Results and Discussion

Basic Model Results

Final input and output parameters of the model are presented in Table 2 while Table 3 gives the final diet composition matrix; Figure 2 illustrates the Ecopath model derived for the north coast of Central Java (1979).

The north coast of Central Java ecosystem spans about four trophic levels, with cetaceans and the fishery acting as top predators. The distribution of functional groups among trophic level is relatively equal between low trophic levels (< 2.5) and intermediate trophic levels (2.5 - 3.5). There are 11 groups at low trophic levels, and 12 groups at intermediate trophic level. The remaining five groups have trophic levels greater than 3.5. The relatively high number of groups located at similar trophic levels indicates a situation where strong competition for resources occurs. In such circumstances, the direct impact of a fishery is likely to be amplified throughout the entire system, by direct and indirect interactions.

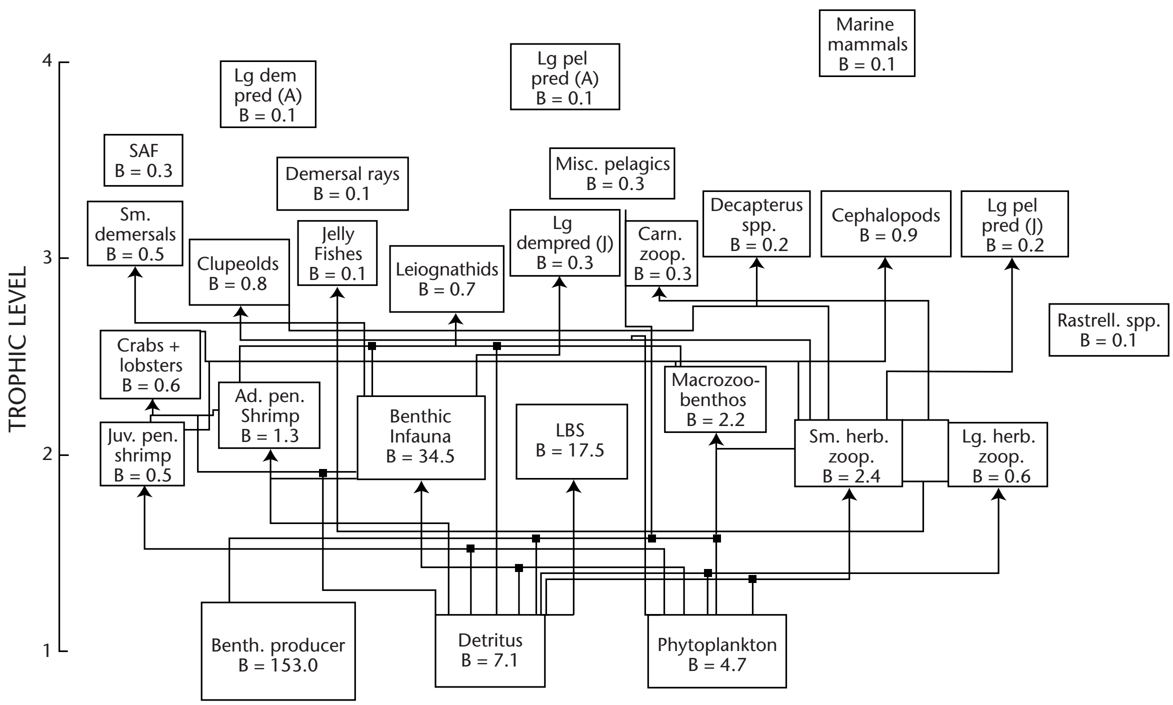

Fig. 2. Ecopath model of the north coast of Central Java (1979). Only flows exceeding 1 t·km^{-2}·year^{-1} are represented. The groups are arranged by trophic level, and the box size is a function of the biomass of the groups (in 1 t·km^{-2}).

Table 2. Parameter inputs and outputs (in parentheses) of the Ecopath model for the north coast of Central Java 1979.

Ecological Groups	Biomass ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	GE	Landings ($t \cdot km^{-2} \cdot year^{-1}$)	Flow to detritus ($t \cdot km^{-2} \cdot year^{-1}$)	Trophic level	Omnivory index	R/A ($year^{-1}$)	R/B ($year^{-1}$)
Benthic producers	153.00	11.86	–	< (0.01)	–	0	1 813.15	1.0	0	–	–
Phytoplankton	(4.68)	135.00	–	0.95	–	0	31.60	1.0	0	–	–
Small herb. Zoopl.	2.43	60.22	220.00	(0.46)	0.46	0	29.59	2.0	0	(0.54)	(71.78)
Lg. Herb. Zoopl.	0.56	20.00	70.00	(0.92)	0.48	0.02	16.62	2.0	0	(0.52)	(22.00)
Carn. Zoopl.	0.31	42.58	135.05	(0.21)	0.40	0	18.84	3.0	0	(0.61)	(65.46)
Jelly fishes	0.10	5.01	25.05	(0.53)	0.25	0.05	0.74	3.0	0	(0.75)	(15.03)
Benthic infauna	34.48	6.57	27.40	(0.43)	0.30	0	318.95	2.1	0.09	(0.70)	(15.35)
SAF	0.32	(3.81)	7.63	(0.30)	0.62	0.03	1.33	3.5	0.24	(0.38)	(2.29)
Macrozoobenthos	(2.21)	3.00	12.50	0.75	0.30	0.01	7.18	2.3	0.35	(0.70)	(7.00)
LBS	(17.48)	0.10	0.50	0.95	0.25	0.26	1.84	2.1	0.09	(0.75)	(0.30)
Juv.pen.shrimp	(0.47)	13.00	70.00	0.95	0.23	0.02	6.92	2.0	0	(0.77)	(43.00)
Lg.pel.pred.(J)	(0.19)	(4.73)	15.75	0.95	0.38	0.71	0.65	3.2	0.14	(0.62)	(7.88)
Ad.pen.shrimps	(1.27)	5.000	28.94	0.95	0.22	0.10	7.67	2.2	0.19	(0.78)	(18.16)
Misc.pelagic	(0.30)	(2.91)	14.57	0.95	0.25	0.43	0.92	3.5	0.48	(0.75)	(8.74)
Leiognathids	0.71	(3.52)	15.59	(0.28)	0.28	0.20	4.03	2.9	0.24	(0.75)	(8.95)
Crabs and Lobster	(0.63)	4.00	21.90	0.95	0.23	0.00	2.87	2.5	0.31	(0.77)	(13.52)
Cephalopods	(0.90)	3.10	20.32	0.95	0.19	0.05	3.77	3.2	0.11	(0.81)	(13.15)
Decapterus spp.	(0.24)	(3.73)	13.89	0.95	0.34	0.63	0.71	3.2	0.57	(0.66)	(7.38)
Rastrelliger spp.	(0.12)	(4.43)	14.16	0.95	0.34	0.39	0.37	2.6	0.23	(0.63)	(7.08)
Clupeoids	(0.81)	6.20	15.75	0.95	0.49	0.71	2.82	2.9	0.10	(0.51)	(6.40)
Small demersals	0.50	3.25	15.24	(0.98)	0.27	0.39	1.54	3.1	0.17	(0.73)	(8.94)
Lg.dem.pred.(J)	(0.32)	3.254	15.2	0.95	0.27	0.39	1.02	3.1	0.18	(0.73)	(8.94)
Demersal rays	(0.09)	(0.17)	9.10	0.95	0.02	0.01	0.16	3.4	0.10	(0.98)	(7.11)
Lg.pel.pred (A)	(0.09)	(2.28)	11.39	0.95	0.25	0.18	0.21	4.0	0.12	(0.75)	(6.88)
Lg.dem.pred (A)	(0.07)	(3.50)	7.49	(0.26)	0.58	0.07	0.30	3.9	0.20	(0.42)	(2.49)
Marine mammals	0.14	0.04	15.36	(0.09)	0.00	0.01	0.43	4.1	0.05	(0.10)	(12.24)
Detritus	17.14	–	–	(0.372)	–	0	0.00	1.0	0.26	–	–

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = Ecotrophic efficiency, GE = Gross efficiency, Q/B = , R/A = Respiration/assimilation ratio, R/B = Respiration/Biomass ratio.

Table 3. Diet composition matrix for functional groups in the Java Sea in the mid-1970's. Values represent the proportion (on a weight or volume basis) each prey contributes to the diet of the predator.

Prey	Predator																						
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1. Benthic producers	–	–	–	–	–	0.01	0.15	0.10	–	–	<0.01	–	–	–	–	–	–	<0.01	0.02	–	–	–	–	–
2. Phytoplankton	0.70	0.70	–	–	0.17	–	0.29	0.04	0.80	–	–	0.10	0.01	–	–	0.23	0.37	0.08	–	0.07	–	–	–	–
3. Small herb. Zoopl.	–	–	0.80	–	–	–	0.14	0.04	–	0.77	0.02	0.11	0.01	–	0.540	0.32	0.58	0.85	0.05	0.14	–	–	–	–
4. Lg. Herb. Zoopl.	–	–	0.20	0.60	–	0.02	0.01	0.01	–	<0.01	<0.01	0.04	0.01	–	0.010	0.03	0.01	<0.01	0.01	<0.01	–	–	–	<0.01
5. Carn. Zoopl.	–	–	–	0.40	–	0.01	0.07	–	–	0.02	-	0.03	0.01	–	–	–	–	0.02	0.02	–	–	–	–	–
6. Jelly fishes	–	–	–	–	–	–	–	–	–	–	–	0.04	–	–	–	–	–	<0.01	–	-	-	–	-	-
7. Benthic infauna	–	-	-	-	0.08	0.07	-	-	-	–	0.17	0.05	0.45	0.15	0.020	-	-	0.02	0.51	0.56	0.15	-	<0.01	-
8. SAF	–	–	–	–	–	<0.01	–	–	–	–	–	0.03	–	–	–	–	–	–	–	0.02	–	0.04	0.12	-
9. Macrozoobenthos	–	–	–	–	–	0.11	–	–	–	–	–	0.07	0.10	0.05	0.060	–	–	–	0.10	0.05	0.50	–	0.14	–
10. LBS	–	–	–	–	–	0.07	0.01	–	–	–	0.01	–	<0.01	0.01	–	–	–	–	0.02	–	<0.01	–	–	–
11. Juv.pen.shrimp	–	–	–	–	–	0.06	–	–	–	0.03	–	0.03	0.01	0.10	0.150	0.01	0.05	0.03	0.06	0.05	–	–	–	–
12. Lg. pel. pred.(J)	–	–	–	–	–	–	–	–	–	–	–	<0.01	–	–	–	–	–	–	<0.01	–	–	0.03	<0.01	0.02
13. Ad.pen.shrimps	–	–	–	–	–	0.07	–	–	–	–	–	0.10	0.20	0.10	0.030	–	–	–	0.08	0.05	0.10	0.13	0.15	0.02
14. Misc. pelagics	–	–	–	–	–	–	–	–	–	–	–	>0.01	–	–	–	–	–	–	<0.01	–	–	0.15	–	0.09
15. Leiognathids	–	–	–	–	–	0.01	–	–	–	–	–	0.08	–	–	0.001	0.01	–	–	<0.01	<0.01	<0.01	0.02	0.01	0.01
16. Crabs+Lobster	–	–	–	–	–	0.11	–	–	–	–	–	<0.01	–	–	0.100	–	–	–	0.02	–	0.10	<0.01	0.05	–
17. Cephalopods	–	–	–	–	–	0.02	–	–	–	–	–	0.08	–	–	0.040	–	–	–	0.02	0.05	0.05	0.10	0.09	0.41
18. *Decapterus* spp.	–	–	–	–	–	–	–	–	–	–	–	0.03	–	–	–	–	–	–	–	–	–	<0.01	–	0.04
19. *Rastrelliger* spp.	–	–	–	–	–	–	–	–	–	-	–	–	–	–	–	–	–	–	0.01	–	–	<0.01	–	0.04
20. Clupeoids	–	–	–	–	–	–	–	–	–	0.18	–	0.12	–	–	0.028	0.40	–	–	0.02	–	–	0.47	<0.01	0.27
21. Small demersals	–	–	–	–	–	0.13	–	–	–	–	–	0.05	<0.01	–	0.010	–	–	–	0.01	–	0.10	–	0.21	0.10
22. Lg.dem.pred	–	–	–	–	–	0.17	–	–	–	–	–	–	–	–	0. 001	–	–	–	–	–	–	0.05	217	–
23. Demersal rays	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	–
24. Lg.pel.pred (A)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	<0.01
25. Lg.dem.pred (A)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–									
26. Marine mammals	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.01	–
27. Detritus	0.30	0.30	–	–	0.75	0.01	0.34	0.80	0.20	–	0.08	0.02	0.20	0.59	0.010	–	–	–	0.05	–	–	–	–	–

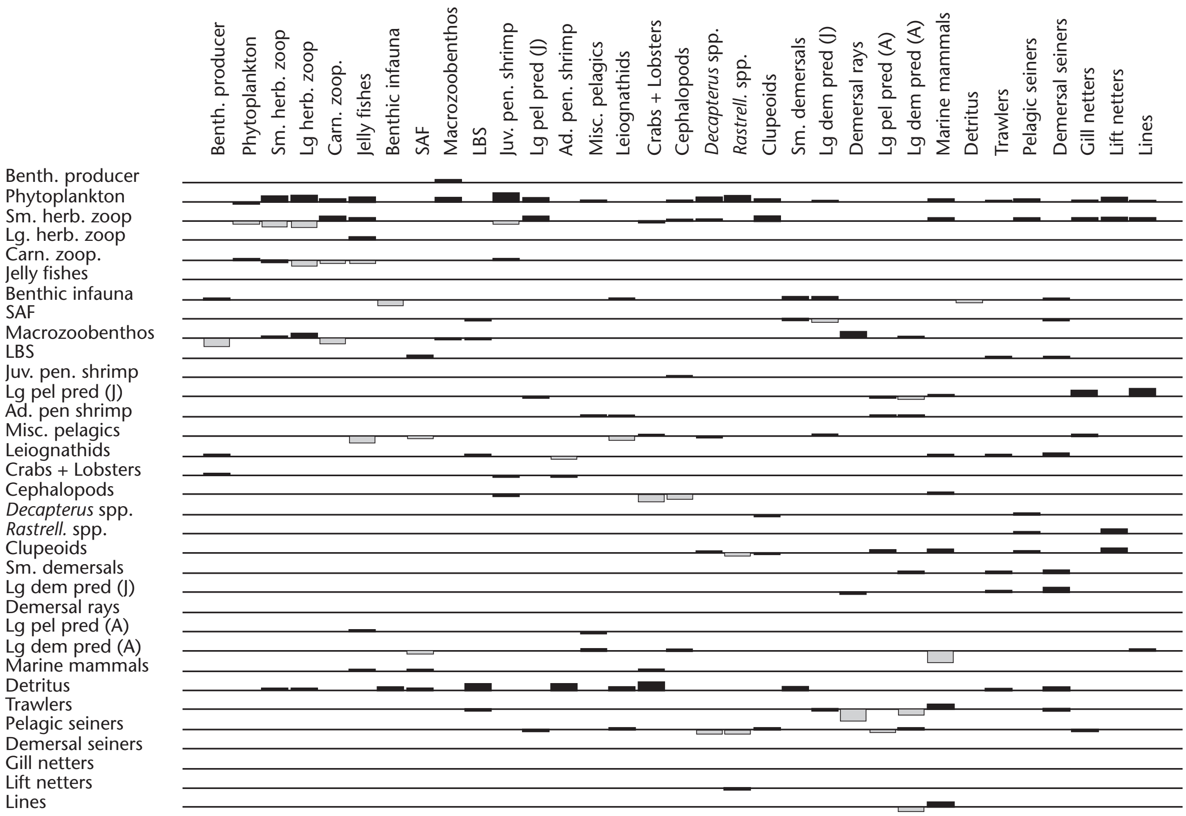

Fig. 3. Mixed trophic impacts in the 1979 model of the north coast of Central Java ecosystem. The graph shows the direct or indirect trophic impacts the groups to the left (rows) have on the groups mentioned above (columns). Positive impacts are shown above the baseline, and negative below. The impacts are relative but comparable between groups.

Trophic Impact Assessment

Figure 3 presents the trophic interactions of the ecosystem under study. All functional groups appear to respond negatively to an increase in their own biomass. This is due to an increase within group competition for food resources.

Trawlers and pelagic seiners were the two fleets that showed the most impact on the ecosystem. The fishery was positively affected mostly by lower and intermediate trophic levels, as indicated by the positive impact of phytoplankton, small herbivorous zooplankton, *Rastrelliger* spp., and clupeoids on many fisheries. The fishery exhibits the largest positive increases from increases in primary productivity and zooplankton biomass.

As indicated earlier, the fishery and the cetacean group have similar trophic levels (i.e. 4.1), hence, competition is clearly a possibility. The trophic impact routine confirms this, although the effect appears slight. An increase in marine mammal biomass slightly decreased the fishery (i.e. -0.02, -0.05, -0.01, -0.05 for trawl, pelagic seiners, demersal seiners, gillnets, liftnets and line respectively), while an increase in fishing effort produced a variable impact on the marine mammals (i.e. -0.07 to 0.001) depending on the fishing gear used.

Maturity of the Java Sea Ecosystem

A system for describing the maturity of an ecosystem was first described by Odum (1969). Ulanowicz (1986) developed this further to include a new interpretation of ecosystem growth and development, using concepts mainly drawn from thermodynamics and information theory. Key concepts that are parts of Odum's and Ulanowicz's theories are available as Ecopath routines (Christensen and

Pauly 1992a; Christensen and Pauly 1992b). These routines were used (Christensen 1994; Christensen 1995) to compare the maturity and stability levels of 41 aquatic ecosystems represented by Ecopath models. A comparison between the north coast of Central Java ecosystem, and these 41 aquatic systems, can provide a relative assessment of the maturity of the north coast of Central Java system, and perhaps elucidate possible responses to perturbation.

Table 4 presents the summary statistics, while Table 5 and Table 6 list network flow indices and transfer efficiencies, respectively, for the north coast of Central Java model in 1979.

Table 4. Summary statistics of the Ecopath model for the north coast of Central Java (1979).

Property (units)	**Value**
Sum of all consumption ($t \cdot km^{-2} \cdot year^{-1}$):	1 756
Sum of all exports ($t \cdot km^{-2} \cdot year^{-1}$):	1 596
Sum of all respiratory flows ($t \cdot km^{-2} \cdot year^{-1}$):	851
Sum of all flows into detritus ($t \cdot km^{-2} \cdot year^{-1}$):	2 538
Total system throughput ($t \cdot km^{-2} \cdot year^{-1}$):	6 745
Sum of all production ($t \cdot km^{-2} \cdot year^{-1}$):	2 891
Mean trophic level of the catch:	3.04
Gross efficiency (catch/net primary production):	0.0019
Calculated total net primary production ($t \cdot km^{-2} \cdot year^{-1}$):	24 502
Total primary production/total respiration (P_p/R):	2.87
Net system production ($t \cdot km^{-2} \cdot year^{-1}$):	1 598
Total primary production/total biomass (P_p/R) ($year^{-1}$):	11.0
Total biomass/total throughput (year):	0.03
Total biomass (excluding detritus) ($t \cdot km^{-2}$):	222
Total catches ($t \cdot km^{-2} \cdot year^{-1}$):	4.67
Connectance Index:	0.284
System Omnivory Index:	0.138

In 1979, the north coast of Central Java was moderately dependent on detritus (Table 6); half of the flows originated from detritus. Odum (1969) stated that as ecosystems mature, they should become more dependent on detrital flows and less on flows from primary producers.

Odum (1969) indicated that the ratio between total primary production and total respiration (P_p/R) is a functional index of the relative maturity of an ecosystem. This ratio would approach 1 as systems mature. In their comparative study of 41 aquatic ecosystems, Christensen and Pauly (1993) found that the bulk of P_p/R ratios were in the range between 0.8 and 3.2, although the extreme values were < 0.8 and > 6.4. The P_p/R ratio of the north coast of Central Java in 1979 was 2.9 (Table 4).

Christensen and Pauly (1993) indicated that ecosystems with very high P_p/R ratio usually will either present problems in model parameterization (especially problems with quantification of assimilation rates, and hence indirectly of respiration), or bacterial activity will have been omitted from the model. In the first case, usually the ratio between total export and system throughput exceeds 0.3 (Christensen and Pauly 1993). In the north coast of Central Java system, this ratio was 0.24 (Table 4). Hence, problems of model parameterization are not likely to be the cause, which lead us to the second case, i.e. omission of bacterial activity. In this study, bacterial activity was not included, which in this case over estimates the P_p/R ratio. The north coast of Central Java ecosystem acts as a detrital sink for adjacent land, from which the run-off (i.e. suspended and particulate solids) comes primarily from agriculture sources. This provides an explanation for the high P_p/R value obtained for this model.

Buchary (1999) notes that the ratio between total system productivity and total system biomass (P/B) is high in developing systems and low in mature systems. Christensen and Pauly (1993) ranked the P/B ratios of 41 aquatic ecosystems according to the maturity ranking of Odum (1969). Compared to these 41 aquatic systems, the Java Sea, having a total P/B of 7.18 $year^{-1}$ (Table 4), is at an intermediate level of maturity.

Another measure of maturity is cycling, which is assumed to increase as systems mature (Odum 1969). Finn (1976) quantified this using an index now called Finn's Cycling Index (FCI), which expresses the percentages of the total throughput

Table 5. Network flow indices of the north coast of Central Java as computed by Ecopath.

Source	Ascendency		Overhead		Capacity	
	Flowbits	%	Flowbits	%	Flowbits	%
Import	0	0.0	0.0	0.0	0.0	0.0
Internal flow	4 986	21.1	10 983	46.6	15 970	67.7
Export	2 233	9.5	1 149	4.9	3 383	14.3
Respiration	1 689	7.2	2 538	10.8	4 227	17.9
Totals	8 909	37.8	14 671	62.2	23 581	100.0
Finn's Cycling Index	8.58 (% of total throughput)					
Finn's Mean path length	2.753					

Table 6. Transfer efficiencies (TE) and flows at each discrete trophic level in the north coast of Central Java model.

Trophic Level	TE (%)	Outflows			Inflows
		Consumption by predators ($t \cdot km^{-2} \cdot year^{-1}$)	Consumption by fisheries ($t \cdot km^{-2} \cdot year^{-1}$)	Sum of all outflows ($t \cdot km^{-2} \cdot year^{-1}$)	Throughput ($t \cdot km^{-2} \cdot year^{-1}$)
II	11.9	183.52	0.89	184.41	1 549.77
III	13.0	21.04	2.83	23.87	183.52
IV	14.5	2.19	0.86	3.05	21.04
V	13.6	0.20	0.08	0.28	2.19
VI	12.3	0.02	< 0.01	0.02	0.20
VII	6.25	< 0.01	< 0.01	< 0.01	0.02

Proportion of total flow from: Detritus = 0.53; Primary producers = 0.47.

actually recycled in the system. As maturity *sensu* (Odum 1969) was shown to be related with stability sensu (Christensen and Pauly 1993; Rutledge et al. 1976) it was demonstrated that when FCI is plotted against system overhead for a large number of ecosystems, they provide a parabolic correlation; The apex or inflections are moving away from stability. When the FCI (8.58%, Table 5) and the system overhead (62.2%, Table 5) of the north coast of Central Java are plotted in the parabolic relation of Christensen and Pauly (1993), it indicates the north coast of Central Java as a relatively stable ecosystem. The north coast of Central Java ecosystem is less stable than the Gulf of Thailand and the Brunei coast, but more stable than the Gulf of Mexico continental shelf and Monterey Bay.

Christensen and Pauly (1993) also plotted the FCI of 41 aquatic ecosystems against their total primary production/total respiration (P_p/R) ratios, and indicated that P_p/R ratio moves toward unity and FCI increases as ecosystems mature. When the north coast of Central Java's indices of FCI (8.58%, Table 5) and P_p/R (2.87, Table 4) are plotted onto this correlation (Christensen and Pauly 1993, Figure 8), the Java Sea is placed at an intermediate level of maturity.

In terms of the correlation between FCI (8.58%, Table 5) and mean path length (2.75, Table 5), the north coast of Central Java fell within the intermediate range of maturity among all the ecosystem models described in Christensen and Pauly (1993, Figure 9).

As stated by Buchary (1999): "Following Lindeman (1942) definition of trophic transfer efficiencies (TE) and using a method to calculate TE described in Christensen and Pauly (1992a). Christensen and Pauly (1993) calculated TE for all 41 aquatic ecosystem models and plotted them all against their respective discrete trophic levels. Average TE by trophic levels were as follows: 10% for the herbivores/detritivores, 11% for the next trophic level, and lower efficiency (7.5 - 9.0%) on the higher trophic levels. The overall mean TE was 9.2%". The TE of the north coast of Central Java in1979 was almost similar (Table 6).

In summary, the north coast of Central Java ecosystem model in 1979 behaves as can be expected from a tropical shelf system. Furthermore, it can be regarded as moderately mature and relatively stable. The impact of the fishery was low to moderate in comparison with the fisheries of other systems. Therefore, it is anticipated that the Java Sea ecosystem should be moderately resilient to perturbation.

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Trophic Model of the Coastal Fisheries Ecosystem of the West Coast of Peninsular Malaysia

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Abstract

A preliminary mass-balance trophic model was constructed for the coastal fisheries ecosystem of the West Coast of Peninsular Malaysia (0 - 120 m depth). The ecosystem was partitioned into 15 trophic groups, and biomasses for selected groups were obtained from research (trawl) surveys conducted in the area in 1987 and 1991. Trophic interactions of the groups are presented. The network analysis indicates that fishing fleets for demersal fishes and prawns have a major direct or indirect impact on most high-trophic level groups in the ecosystem.

Introduction

The fisheries ecosystem of the West Coast of Peninsular Malaysia, (WCPM); between 98° to 104° E longtitude, and 1° to 7° N latitude) from the coastline to the EEZ border (20 - 120 m depth) was studied (Fig. 1). Fish landings from the area contributed about 50% of total landings in the country. The total marine area is about 20 400 nm^2, including about 263 nm^2 of islands in the north. The Langkawi group of islands is the largest with a total land area of about 140 nm^2. Apart from mangroves, some of these islands adjoin unique coral reefs. Pulau Payar, an island gazetted as a marine park, is one of the most diverse coral reef ecosystem in Malaysia. The sheltered waters of the west coast, which have muddy substrate are trawled year round.

Based on analyses of demersal community structure (Alias, this vol.), the waters of the WCPM can be divided into two main assemblages (coastal, < 40-m; offshore, > 40-m). The mangrove-related communities are found all along the coast, in waters of up to 40 m depth. The commercially most important species group in this community comprise of prawns. Small-sized fishes including slipmouth (Leiognathidae) are also predominant in the coastal areas.

Off the WCPM, the waters within the EEZ rarely exceed 120 m, the deepest part being at the northern tip of the Straits of Malacca. In general, WCPM is shallow, with a huge mud flat area (< 10 m) running northwest from the central part of the coast (Fig. 1).

In the Straits of Malacca, currents generally flow in a northwestern direction throughout the year. Tidal action is not appreciable beyond a distance of about 8 miles off the northern coast of Sumatra and about 40 miles off the northeast coast. During the northeast monsoon period (October-April), its current flow is a branch of the southward monsoon current in the South China Sea, which rounds the extremity of the Malay peninsula and passes into the strait. During the southwest monsoon period (May-September), part of the water which flows westward in the Java Sea and northwestward through the Karimata Strait towards the South China Sea also passes directly into the Malacca Strait (Hydrographic Department. Admiralty 1964).

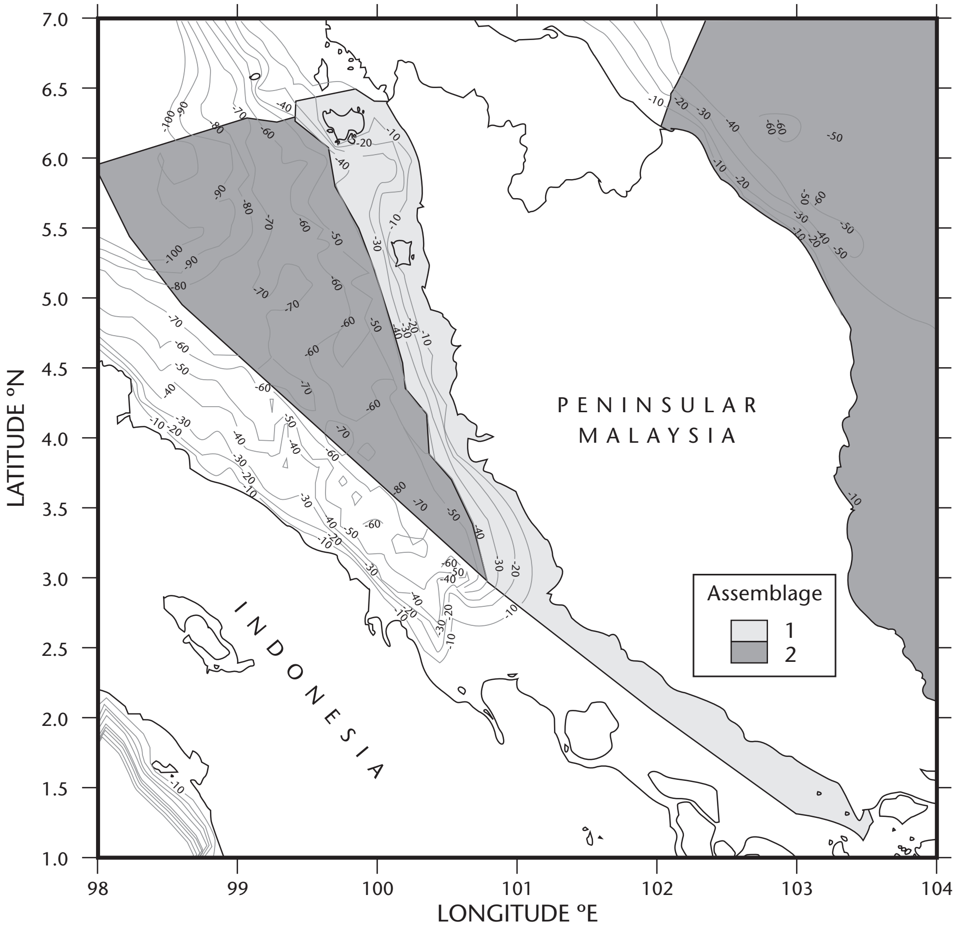

Fig. 1. Map of the West Coast of Peninsular Malaysia WCPM showing delineation of fishing area by fish assemblage. Isobaths are in meters.

Currents exceeding the rate of one knot may be experienced throughout the year in the strait. When the currents are most constant (December - February), only about 17% of all observed rates exceed one knot in northwesterly directions.

Studies of primary productivity were conducted only off the East Coast of Peninsular Malaysia and in waters off Sarawak. Average surface concentration of chlorophyll *a* in waters off the East Coast of Peninsular Malaysia is 0.08 mg•m^{-3}, and the average value is 0.208 mg•m^{-3} (Raihan and Ichikawa 1986). Similarly low concentrations of chlorophyll *a* are observed in Sarawak waters, ranging between 0.049 to 0.150 mg•m^{-3} throughout the water column (Lokman et al. 1988). On the East Coast, the density of particulate organic carbon from the sea surfaced to 50 m depth ranged from 3.9 to 6.0 gC•m^{-2} (Ichikawa 1986), and from 3.7 to 6.0 gC•m^{-2} in Sarawak waters (Ichikawa and Law 1988).

The WCPM ecosystem comprises four main habitats: mangrove mud flats, seagrass beds, coral reefs, and muddy-sandy bottoms. The mangrove areas are in the state of Perak (40 000 ha), Johor (25 600 ha), Selangor (22 500 ha) and Kedah (9 000 ha) (Choo et al. 1994). The Larut Matang mangroves in Perak were reported to be the largest mangrove forest in Peninsular Malaysia and possibly the best managed mangrove forest in the world (Gong et al. 1980). There have been numerous studies showing the linkage of mangroves to fishery resources (Malaysian Coastal Resources Study Team (MCRST), 1992).

The coral reef areas of the WCPM are found around islands located to the north of Kedah (Payar Islands) and off Perak (Sembilan Islands). There are also small isolated fringing reefs occurring along the mainland coast. There are at least five large seagrass beds off the WCPM (Kushairi 1992). Five species of seagrass are found in shallow waters between 0.2 and 1.8 m, namely: *Halophila ovalis, H. uninervis, H. pinifolia, H. minor* and *Enhalus acoroides*.

Beyond 40 m, the seabed is generally muddy with small spots of sandy bottom. These constitute a different habitat altogether with a different faunal assemblage, also targeted by trawl fishery.

The fishery of the WCPM is multispecies and multigear. There are about twelve main fishing gears used, catching a multitude of fish and invertebrate species. Trawls are the main type of fishing gear, accounting for about 60% of total WCPM landings.

The fishery resources on the WCPM are being overharvested. Statistics show that landings in 1996 were 460 302 t, but abundance trends from resource surveys indicate that the resources have declined to only 25% of the original levels (Talib et al. this vol.). Steps have been taken to sustain the WCPM fishery and access is now closed to new entrants to the sector. The focus is now to exploit resources in the EEZ waters off Sarawak.

Previous work on multispecies fisheries and marine ecosystems in Malaysia include a study of the East Coast of Peninsular Malaysia, based on an early version of the Ecopath model (Liew and Chan 1987), while (Alias, 1994) presented multispecies surplus production models for the WCPM based on analysis of catch and effort data on 30 different groups of species. However, analyses at the ecosystem level have so far not been conducted in the WCPM.

Materials and Methods

The Ecopath Model

The master equations of the Ecopath model of (Polovina, 1984) as modified by (Christensen and Pauly, 1992), assumed that the system is in mass-balance, where input for a given group *i* equals output, i.e.

Consumption (*i*) = production (*i*) + unassimilated food (*i*) + respiration (i) (1)

In addition, the production of group i in the system can in its simplest form be expressed as:

Production (*i*) = predation mortality (*i*) + catches (*i*) + other mortality (*i*) (2)

where the predation mortality terms are used to link the predator and prey species. Equation (2) can also be expressed as:

$$P_i - M2_i - P_i\ (1- EE_i) - EX_i = 0 \qquad (3)$$

where P_i is the production of (*i*), $M2_i$ is the total predation mortality of (*i*), EE_i is the ecotrophic efficiency of (*i*) or the proportion of the production that is either exported or predated upon, $(1 - EE_i)$ is the "other mortality", and EX_i is the export or catch of (*i*).

Equation (3) can be re-expressed as:

$$B_i * PB_i - \sum_{j=1}^{n} B_j * QB_j * DC_{ji} - PB_i * B_i (1 - EE_i) - EX_i = 0 \qquad (4)$$

where B_i is the biomass of (i), PB_i is the production/biomass ratio, QB_j is the consumption/biomass ratio and DC_{ji} is the fraction of prey (i) in the average diet of predator (j).

From the first four parameters B_i, PB_i, EE_i and QB_j, one may be unknown, to be estimated when the balancing routine is run. The DC_{ji} and EX_i are always required for all groups.

Later versions of the Ecopath model are more dynamic, with the non-predation losses (Eq. 2) broken up into migration, biomass accumulation and other mortality. Equation (2) becomes:

Production = fishing mortality + predation mortality + migration + biomass accumulation + other mortality (5)

Ecological Groups

Table 1 presents the ecological groups used for the construction of the Ecopath model of the WCPM. Appendices A & B show the list of species from (FAO 1997) as well as the species in the WCPM.

To model the ecosystem, all species therein need to be grouped according to their trophic characters. Then, the biomass and the catch of each trophic group need to be provided. Trophic grouping used by (Pauly and Christensen 1993) for modeling the South China Sea was used, with some modification to fit the WCPM ecosystem, such as the diadromous fishes, mammals and turtles. The mammals and turtles were included in the system although information on these groups is incomplete.

Table 1. Ecological groups used in the Ecopath modeling of the waters off the West coast of Peninsular Malaysia.

Ecological group	Taxa
Benthic producers	Brown, red and green seaweeds Other algae Misc. aquatic plants
Crustacean (excl. plankton)	Crabs Spiny and Slipper lobster Banana prawn, Giant tiger prawn, Greasy-back prawn/Pink prawn, Rainbow prawn, Red prawn, Sand prawn, Sharp-rostrum prawn, Small white prawn, Yellow shrimp Misc. marine crustaceans
Intermediate predators	Barramundi (Giant seaperch), Bombay-duck, Catfish eel, Croakers/Jewfish, Emperors/Scavengers, False trevally, Fusilier, Goatfish, Grouper, Grunter, Lizard fish, Mangrove snapper, Marine catfish, Mojarras/Silver biddies, Monocle bream, Parrotfish, Pony fishes/Slipmouth, Rabbitfish/Spinefeet, Red snapper, Russell's snapper, Sharp-toothed bass, Sillago whitings, Snapper, Spadefish, Spotted sicklefish, Sweetlips, Threadfin bream, Triggerfish, Misc. demersal commercial fishesBlack kingfish/Cobia, Leatherskin/Queenfish, Rainbow runner, Threadfin, Dorab wolf-herring Mixed fish (mainly demersal)
Large pelagics	Frigate tuna, Kawakawa, Longtail tuna, Sailfish/Marlin Spanish mackerel/King mackerel
Large predators	Conger eel Barracuda Shark
Large zoobenthos feeders	Ray
Mammals	Dolphins, Porpoises, Dugong
Medium pelagics	Amberjack, Black pomfret, Chinese silver pomfret, Golden trevally, Horse mackerel/Trevally, Silver pomfret, Small pomfret, Misc. pelagic commercial fishes Largehead hairtail
Misc. invertebrates	Abalones, winkles, conchs, etc. Rock oyster/Flat oyster Brown mussel Scallops, pectens, etc. Blood cockle, Other clams, Undulate venus Misc. marine mollusks Sea-squirts and other tunicates Horseshoe crabs and other arachnoids Sea cucumbers Jellyfish Pearls, mother-of-pearl, shells, etc. Corals Sponges

Table 1. Ecological groups used in the Ecopath modeling of the waters off the West coast of Peninsular Malaysia. (continued)

Ecological group	Taxa
Small demersal prey species	Chacunda gizzard shad, Longtail shad, Shad, Slender shad Elongate ilisha Flatfish, Tonguefish/ tongue sole Misc. demersal trash fishes Trash fish (mainly demersal)
Small pelagics	Bigeye scad, Hardtail scad/Torpedo scad, Mullet, Round scad, Selar scad, Yellowstripe scad Anchovy, Fringescale sardinella, Indo-Pacific tarpon, Rainbow sardine Indian mackerel/Short mackerel Misc. pelagic trash fishes
Squids and cuttlefishes	Common squid, Cuttlefish, Octopus
Turtles	Green turtles
Zooplankton	Sergestid shrimp

Table 2. Basic input parameter values used in modeling the coastal fisheries ecosystem off the West coast of Peninsular Malaysia.

Ecological group	Biomass ($t{\cdot}km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Catch ($t{\cdot}km^{2}{\cdot}year^{-1}$)
Mammals	0.02	0.05	30.00	–	–
Large predators	0.02	2.86	7.30	–	0.03
Large pelagics	–	3.93	9.55	0.95	0.67
Medium pelagics	–	2.43	10.00	0.95	0.13
Large zoobenthos feeders	–	3.90	7.85	0.95	0.07
Intermediate predators	0.03	7.49	15.00	–	3.23
Small demersal species	–	10.00	23.74	0.95	0.14
Small pelagics	–	3.75	12.9	0.95	0.13
Crustaceans (excl. plankton)	–	5.11	21.81	0.95	0.82
Misc. invertebrates	–	5.51	11.02	0.95	0.06
Squids	–	4.10	10.51	0.95	0.29
Turtles	0.02	1.50	3.50		–
Zooplankton	–	67.00	280.00	0.95	0.19
Aquatic plants	–	71.15	–	0.50	–
Detritus	100.00	–	–	–	–

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = Ecotrophic efficiency.

Model Parameterization

To describe the west coast fisheries ecosystem, parameters are required for the Ecopath software. Table 2 gives a summary of the basic input parameters used in the construction of the Ecopath model for the study area.

Biomass Estimates

Most biomasses were estimated from the catch rate of demersal trawl surveys using the swept area-method (see Appendix A). Two different types of demersal survey were conducted in the area, i.e. the coastal and offshore surveys, both conducted in different areas and years. To determine the biomass for the total area, information from the offshore and coastal survey was combined. The closest gap in time pertains to the 1987 offshore survey and the 1991 coastal survey. In this study, the ecosystem was modeled based on the 1991 scenario. The composition of the offshore demersal assemblage in 1987 was assumed to be similar to 1991. However, the 1987 demersal biomass values were reduced by 26% before they were combined with the 1991 biomass of the coastal demersal stocks due to differences in the survey period. The reduction was based on the trend of decline for the period 1987 - 91 (see Talib et al. this vol.).

Estimated biomass should be corrected for varying catchability coefficient; a value of 0.5 is commonly used for trawl surveys in South East Asian waters (Pauly 1984) and this was used here for the estimation of demersal fish biomass in deeper waters. For pelagic species, this value should be much lower due to the gear being inefficient in catching pelagics. In this study, it is assumed that the catchability of pelagic species is half of those for demersal species, i.e. 0.25. The deeper assemblage can be sampled best using a fish trawl as the sampling gear. However, a prawn trawl best samples the shallower assemblage. As the coastal demersal fish survey can only cover the area from 5 m depth and above, the biomass in less than 5 m depth could not be determined. In this study, the initial biomasses for the shallow areas were corrected by assuming catchability equal to that of pelagics.

The Ecopath model was used to estimate the biomass of other groups, such as marine mammals and reptiles. As some of the biomasses estimated via the swept-area method were likely to be underestimates, it was decided to estimate these based on ecosystem demand (i.e. as outputs of Ecopath) and compare these estimates to those from the swept-area method.

Production to Biomass Ratios (P/B)

P/B ratio estimates were mostly obtained from total mortality estimates (Z) derived using length-based methods (Chee and others, 1998). For the crustacean, large pelagics and zooplankton groups, the P/B values were adopted from Silvestre et al. (1993) (see Appendix A). Assuming that biomass for these groups were underestimated, the biomass values were adjusted such that fishing mortality (F) is equivalent to Z minus natural mortality (M).

Consumption to Biomass Ratio (Q/B)

For initial parameterization, Q/B values were estimated from the average of values obtained from the literature (Appendix B), except for the zooplankton group, where the value from Silvestre et al. (1993) was used. The Q/B for mammals was assumed to be similar to that of large predatory fishes.

Diet Composition

The diet composition (Table 3) was estimated based on the work of Liew and Chan (1987) and Silvestre et al. (1993). The diet composition for mammals and turtles was based on the researchers' general knowledge about the groups and their eating habits.

Catches

Landings were obtained from statistics (DOF 1992), even though the exact location of capture could not be established (Appendix C). However, information on distance from shore is implicit in the type of fishing gear used. Legally, all gears are allocated a fishing area. The main task was to reclassify the landings by various fishing gears to landings by fishing area, so that landings as well as biomass from any fishing area could be calculated. This reclassification process involved three steps, i.e. classification of fishing area, classification of fishing gears, and classification of resources/species:

Area Classification. The fishing area has been legally classified into four zones based on distance from shoreline. Zone A is from the shoreline to 5 nm, Zone B is from 5 to 12 nm, Zone C is from 12 to 30 nm, and Zone D is from 30 nm onward.

Zone A is allocated solely for traditional small-scale fishing gears. The zoning system was established after introduction of commercial fishery and was intended to reduce conflict between traditional and commercial fishers. The zoning system does not seem to be based on any scientific study and criteria used for the boundary delineation are unclear. Alias (this vol.) reported two main species assemblages off the West Coast of Peninsular Malaysia. The first assemblage occurs over the shallow area (0 - 40m) roughly matching Zones A and B, and the second assemblage occurs over a deeper area (> 40m) roughly matching Zones C and D.

Fishing Gear Classification. From cluster analysis of the catches of various fishing gears in species space, the fishing gears can be classified into five main groups (Table 4). Information on their areas of operation and species assemblages fished is also given in Table 4.

Species Classification. A 'miscellaneous fishes' category is commonly used in landing statistics and research (trawl) surveys. It includes both demersal and pelagic fishes. From an ecological perspective, these fishes are very different in terms of feeding behavior and diet composition, although they are usually all assigned to the ISSCAAP (Group 39). Difficulties arise during the trophic grouping of species, but especially so for this group. Here the task was to reclassify this group properly. For the trawl survey data, the "miscellaneous fishes" were broken down to species level and then assigned to the appropriate group. For the landings data, the miscellaneous group and "trash fish" were assigned to groups according to the type of gear that caught them. For example, "trash fish" landings of the trawl were assigned to the demersal fishes group because most of the catch was demersals. For the purse seine, the "trash fish" was assigned to the pelagic group as most of the catch is pelagics.

Table 3. Diet composition of the 15 ecological groups used in the analysis - the predator numbers correspond to the prey numbers.

	Predator												
Prey	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. Mammals													
2. Large predators	0.03												
3. Large pelagics	0.66												
4. Medium pelagics		0.10	0.10	0.04									
5. Large zoobenthos feeders		0.01	0.01										
6. Intermediate predators	0.01	0.34	0.34	0.82		0.01		0.05					
7. Small demersal species		0.01	0.01	0.00		0.01							
8. Small pelagics	0.30	0.50	0.50	0.04		0.01		0.01					
9. Crust. (excl. plankton)				0.09	0.68	0.54	0.06	0.05	0.09	0.05	0.08	0.10	
10. Misc. invertebrates					0.17	0.26	0.06		0.13	0.05	0.06	0.10	
11. Squids		0.05	0.05	0.01	0.15	0.15			0.10		0.02		
12. Turles													
13. Zooplankton						0.01	0.88	0.70	0.08	0.30	0.10		0.10
14. Aquatic plants								0.19	0.03	0.10	0.10	0.80	0.65
15. Detritus						0.01			0.58	0.50	0.64		0.25
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 4. Classification of fishing gears into five main groups. The zone of operation refers to the management zones and the assemblage refers to Figure 1.

Fishing Gear Group	Main Target Species	Fishing Gear	Zone of Operation	Assemblage	Distance range from shore (miles)	Average depth range (m)
1	Anchovy	Anchovy purse seine	A	1	0 - 5	0 - 20
2	Pelagic fishes	Fish purse seine	B C D	1 2 2	5 - 12 12 - 30 30 - EEZ	20 - 40 40 - 60 60 - 100
3	Demersal fishes and prawns	Trawlers, drift nets, hooks & lines and portable traps	B C D	1 2 2	5 - 12 12 - 30 30 - EEZ	20 - 40 40 - 60 60 - 100
4	Prawn	Other seine nets, bag nets, barrier nets, push nets & other traditional nets	A	1	0 - 5	0 - 20
5	Shellfishes	Shellfishes collection	A	1	0 - 5	0 - 20

Fish Prices

The wholesale value of fish was obtained from the annual statistics (DOF 1992). The price of fish was grouped into six main groups. Table 5 below gives a summary of the wholesale value of fish in 1991. All prices are in the Malaysian currency, RM. The exchange rate in 1991 was RM2.50 to US$1.00.

Table 5. Wholesale value (in Malaysian Ringgit, RM) of fish by category in 1991.

Group	Sub-group	Type of Catch	Price ($RM \cdot kg^{-1}$)
Fish	Grade 1	Pomfrets, threadfins, spanish mackerels, wolf herrings and grouper	8.27
Fish	Grade 2	Mangrove snappers, longtail shads, shads, red snappers, sweetlips, horse mackerels and giant seaperch	1.33
Fish	Grade 3	Other fish species including anchovies, squids, crabs and jellyfishes.	2.00
Prawn		All types of prawn	5.02
Trash fishes		Trash Fish	0.30
Shellfish		All types of shellfishes	1.08

Results and Discussion

Trends in Commercial and Research Trawl Survey Catches

Fig. 2 shows the trend in stock density of fishes from trawl surveys in coastal and offshore areas from 1971 to 1997 off the WCPM.

In terms of surplus production models, the abundance that generates maximum sustainable yield (MSY) is 50% of the unexploited stock. The present biomass level on the west coast is estimated as 10 - 15% (Talib et al. paper no.6). Fig. 3 shows the trend in catches for the whole area from 1969 to 1996; catches have reached about 500 000 t. This trend suggests that the fisheries have been expanding geographically, an issue not pursued here.

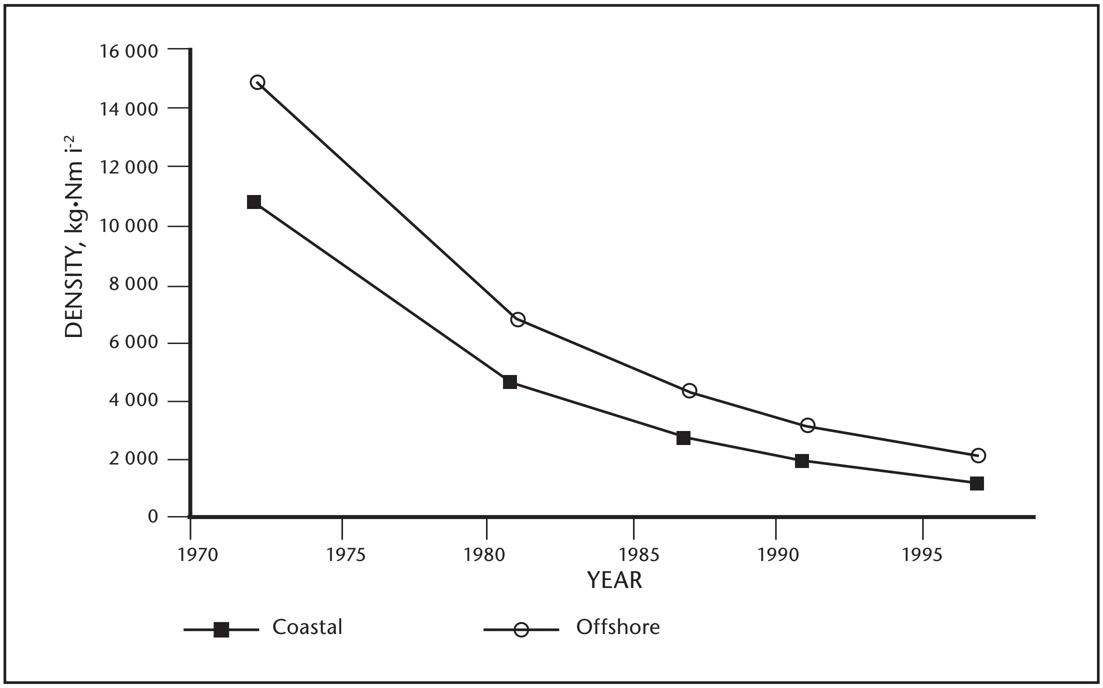

Fig. 2. Total density of fish from research vessel surveys in coastal (1) and off-shore (2) waters off the West Coast Peninsular of Malaysia (WCPM).

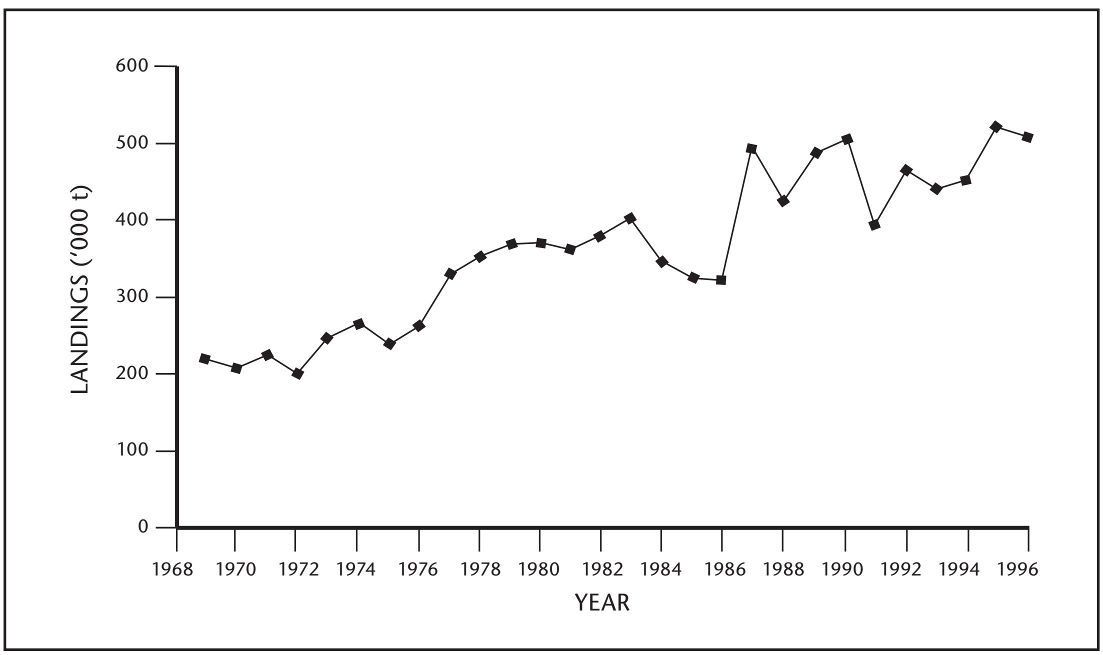

Fig. 3. Total annual landings from the West Coast of Peninsular Malaysia, 1968 - 96.

Trophic Model for the West Coast of Peninsular Malaysia

The model presented below is very preliminary, and will have to be refined before it can be used to provide a basis for the policy exploration that can be performed via Ecopath with Ecosim Software. Ecopath produces a variety of outputs, of interest not just for fisheries management but also for ecological purposes. It is not feasible to reproduce all of these here, but a few may be highlighted. Table 6 presents the biomasses that were input into the model or calculated by Ecopath to ensure mass-balance. Overall, Ecopath requires considerably higher biomass than was estimated by the research trawl surveys especially for the invertebrates and small pelagic groups. Still, some biomasses seem lower than expected (e.g. large predators), which may be due to the overestimation of the P/B ratios.

Figure 4 presents a flowchart of the trophic interactions in the ecosystem. The estimated mean trophic level of the fisheries catch is about 3.2. Fig. 5 documents the impact any of the groups or fishing fleets in the model has on all other groups or fishing fleets through resource competition or direct predation. From this it can be concluded that the fleet fishing for demersals and prawns has a major negative impact on many groups (particularly large zoobenthos feeders and large predators).

This basic Ecopath model can serve as the basis for further analysis of the fisheries and ecosystem, using temporal and spatial dynamic simulation. To give an indication on the sort of analyses that may be carried out through the use of the Ecopath with Ecosim model software (Christensen et al. 2000; Pauly et al. 2000; Walter et al. 1997), a few preliminary runs using Ecosim were conducted.

Table 6. Comparison of biomass ($t \cdot km^{-2}$) estimates as obtained from trawl surveys and the Ecopath model. Values in parenthesis are input assumption. Note that Ecopath estimates are considerably higher for groups with low catchability to the trawl survey gear.

Ecological group	Biomass trawl survey	Biomass Ecopath	Survey/Ecopath Biomass ratio
Large predators	0.02	(0.02)	1.00
Large pelagics	< 0.01	0.14	0.05
Medium pelagics	0.13	0.14	0.92
Large zoobenthos feeders	0.03	(0.03)	1.00
Intermediate predators	0.56	0.71	0.79
Small demersal species	0.01	0.02	0.55
Small pelagics	0.06	0.66	< 0.01
Crust. (excl. plankton)	0.01	3.98	< 0.01
Miscellaneous invertebrates	0.02	3.32	< 0.01
Squids, cuttlefishes	0.14	2.80	0.05

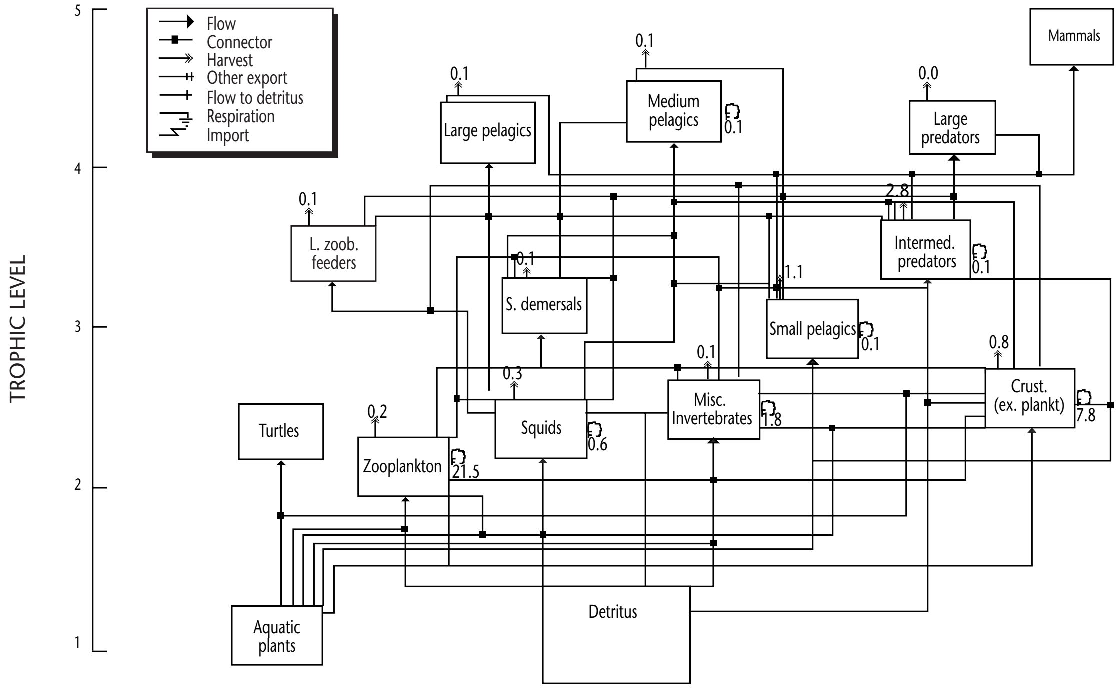

Fig. 4. Flow chart of trophic interactions along the West Coast of Peninsular Malaysia. The model includes 15 groups and five fisheries (not shown), and the groups are arranged on the flow chart by their trophic levels as estimated by Ecopath.

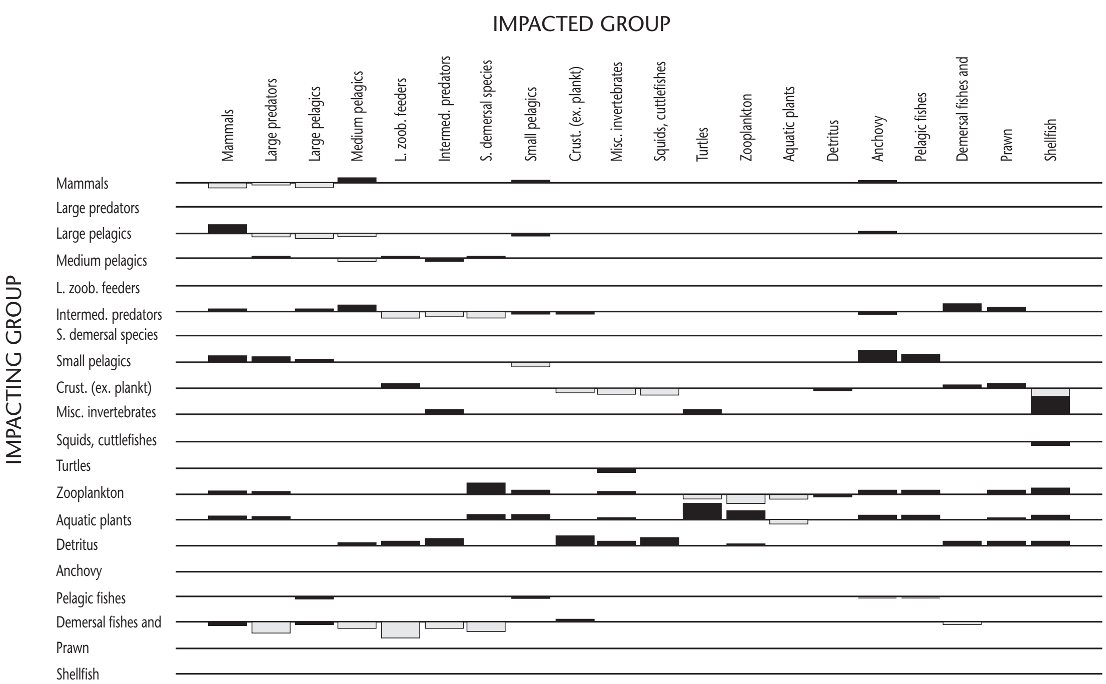

Fig. 5. Mixed trophic impact in the Ecopath model of the West Coast of Peninsular Malaysia. The graph shows the impact the groups to the left (rows) have on the groups mentioned above (columns). Positive impacts are shown above the baseline, and negative below. The impacts are relative but comparable between groups. The last five rows refer to fishing fleets.

The simulations in Table 7 indicate that if overall fishing effort in the WCPM ecosystem was lowered (to 20% of the level in the Ecopath model for 1991) the impact on catches would be limited. Most fleets would catch the same amount. Only the "anchovy" fleet targeting small pelagics would be severely (negatively) impacted. The simulations also indicate that only the anchovy fleet, due to removal of larger fishes preying on small pelagics, would gain from increased fishing, while the other fleet would either maintain their catches or suffer slight decreases.

Ecopath with Ecosim also includes routines for optimization of fishing effort based on various constraints. It can be used to identify the fleet configuration which maximizes (1) net economic value (rent of the fishery), (2) social value (employment), (3) the rebuilding of specific stocks (mandated rebuilding) or (4) ecosystem structure (high biomass of long-lived ecosystem groups). Running the optimization routine with default parameter settings in Ecosim and with an assumption that the costs of fishing amounted to 95% of the value of the fishery (for each of the five fleets included in the analysis), gives the results summarized in Table 8.

Table 7. Results from a preliminary time-dynamic simulation using Ecosim for the West Coast of Peninsular Malaysia ecosystem. The table presents the catches (as % of their 1991 level) that would result from lowering fishing effort to 20% of the 1991 baseline level, compared with the catches resulting from a doubling of the baseline effort.

	Catch (as % of 1991 baseline)	
Fleet	**20% effort**	**200% effort**
Anchovy	22	172
Pelagic fishes	109	87
Demersal fishes and prawns	101	99
Prawn	100	101
Shellfish	100	100

This indicates that considerable economic benefit (more than a doubling of the rent) could be obtained by scaling down the effort of the anchovy, pelagic and demersal fleets, while maintaining the prawn and shellfish fleet effort. However this would come at a price of 30% lower employment in the sector. The results are however very dependent on the assumptions made about the cost of fishing and employment by sector – assumptions about which we have little information at present – in addition to the uncertainty associated with the underlying Ecopath parameters. We do, however, believe that this type of analysis is of direct relevance to future management of the fisheries. It also draws attention to the additional research and data needed to conduct such analyses.

Conclusion

There is a vast amount of information available about aquatic ecosystems and resources, and any attempt to model marine ecosystems should benefit from this. Here this is done through analysis of catch and survey information, combined with extensive literature searches. A major source of information is the FishBase database (www.fishbase.org), which includes a specific search routine for Ecopath modeling. This can be used to extract published information that may be available for fishes occurring in a given area. It should be clear, however, that published information should always be supplemented by local knowledge or research inputs. For the West Coast of Peninsular Malaysia, the main gaps in knowledge with regards to the Ecopath model relates to aspects of food and feeding. At present, with the lack of such information, the ecosystem analysis relies heavily on information from other areas. This information, although from similar ecosystems, is probably less reliable than if local information were obtained.

Table 8. Results from optimization of economic rent of the fisheries of the West Coast of Peninsular Malaysia. Estimates are presented relative to the effort in the 1991 Ecopath model. (See text.)

Economic rent (%)	Employment (%)	Anchovy fleet effort (%)	Pelagic fleet effort (%)	Demersal fleet effort (%)	Prawn fleet effort (%)	Shellfish fleet effort (%)
263	71	63	67	55	99	101

Another possible improvement is to refine the ecosystem model through more detailed spatial analysis. For example, the whole area could be broken down into two separate areas, the coastal and offshore areas. However, the total number of boxes (trophic groups) would have to be increased accordingly so that the system would reflect the real interaction between species, area and size. This can only be done reliably based on information from each area, especially on the diet composition of the various groups. However, with more information about spatial ecosystem dynamics, it would become possible to construct spatial dynamic models using the Ecospace module of Ecopath with Ecosim (Walter et al. 1999).

Thus, we conclude that in order for management issues to be addressed confidently using simulation modeling, it is necessary to obtain more information on diet composition, as well as on the changes in fishing effort over time, and about bioeconomic aspects of the fishing fleets, notably of the cost of fishing.

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Appendix A. Landings (from catch statistics), biomass (from trawl surveys), Production/Biomass ratio (P/B) and Consumption/Biomass (Q/B) of marine aquatic animals and plants used in modeling the West Coast of Peninsular Malaysia fisheries ecosystem 1991.

	Landings ($t \cdot km^{-2} \cdot year^{-1}$)			Biomass ($t \cdot km^{-2}$)			P/B[a] ($year^{-1}$)			Q/B[b] ($year^{-1}$)
Assemblage	**Coastal**	**Offshore**	**Both**	**Coastal**	**Offshore**	**Both**	**Coastal**	**Offshore**	**Both**	
Area, km^2	**231 76.2**	**466 76.3**	**698 52.5**	**231 76.2**	**466 76.3**	**698 52.5**	**231 76.2**	**466 76.3**	**698 52.5**	**69 852.5**
Ecological Group										
Crustacean (excl. plankton)	2.45	0.01	0.82	0.72	<0.01	0.24	5.11	5.11	5.11	21.81
Intermediate predators	5.82	1.95	3.23	0.49	0.59	0.56	13.61	4.98	7.49	11.06
Large pelagics	1.23	0.40	0.67	0.55	0.18	0.30	3.93	3.93	3.93	9.55
Large predators	0.05	0.02	0.03	0.03	0.02	0.02	3.38	2.55	2.86	7.30
Small demersal prey species	0.36	0.04	0.14	0.03	<0.01	0.01	13.39	13.76	13.45	23.74
Small pelagics	0.20	0.09	0.13	0.09	0.05	0.06	4.07	3.49	3.75	12.90
Squids and cuttlefishes	0.47	0.20	0.3	0.23	0.10	0.14	4.11	4.09	4.10	10.51
Zooplankton	0.55	0.00	0.18	2.16	0.86	1.29	67.00	67.00	67.00	280.00[b]
TOTAL	11.70	2.80	5.75	4.49	1.97	2.80	–	–	–	–

Note: [a] P/B values from (Silvestre et al. 1993)
[b] Q/B values estimated from Appendix B.

Appendix B. Consumption/biomass ratio (Q/B) obtained from selected references.

Ecological group	**Taxa**	**Q/B ($year^{-1}$)**	**Sources**
Crustacean (excl. plankton)	Crabs	8.50	De La Cruz-Aguero (1993)
	Banana prawn	37.90	Arreguin-Sanchez et al. (1993)
	Shrimps	19.00	De La Cruz-Aguero (1993)
		28.94	Pauly et al. (1993)
	Misc. marine crustaceans	28.00	Aliño et al. (1993)
Intermediate predators	Bombay duck, Lizard fish	4.27	Pauly et al. (1993)
		8.30	Arreguin-Sanchez et al. (1993)
	Catfish eel	10.00	Arreguin-Sanchez et al. (1993)
	Catfishes	10.00	De La Cruz-Aguero (1993)
	Grouper	2.04	Pauly et al. (1993)
		4.00	Aliño et al. (1993)
		4.60	Arreguin-Sanchez et al. (1993)
	Mangrove snapper	4.89	Pauly et al. (1993)
	Marine catfish	10.00	Arreguin-Sanchez et al. (1993)
	Mojarras/Silver biddies	15.30	Arreguin-Sanchez et al. (1993)
	Parrotfish	28.00	Aliño et al. (1993)
	Rabbitfish/Spinefeet	47.92	Pauly et al. (1993)
	Red snapper	4.40	Arreguin-Sanchez et al. (1993)
	Snappers	4.70	De La Cruz-Aguero (1993)
	Wrasse, hogfish	7.55	Aliño et al. (1993)

Appendix B. Consumption/biomas ratio (Q/B) obtained from selected references. (continued)

Ecological group	Taxa	Q/B (year^{-1})	Sources
Large pelagics	Spanish mackerel/ King mackerel	8.90 10.20	Vega-Cendejas et al. (1993) Arreguin-Sanchez et al. (1993)
Large predators	Conger eel, Moray eel Barracuda Large sharks Shark	6.50 10.00 4.90 7.80	Aliño et al. (1993) Arreguin-Sanchez et al. (1993) Opitz (1993) Arreguin-Sanchez et al. (1993)
Large zoobenthos feeders	Large rays Rays	4.90 10.80	Opitz (1993) De La Cruz-Aguero (1993)
Medium pelagics	Amberjack Jacks	10.00 10.00	Arreguin-Sanchez et al. (1993) De La Cruz-Aguero (1993)
Misc. invertebrates	Misc. marine molluscs See cucumbers nei Sea-urchins	5.60 8.30 8.60 3.83 22.25 3.58 25.00	Aliño et al. (1993) Arreguin-Sanchez et al. (1993) Vega-Cendejas et al. (1993) Pauly et al. (1993) Aliño et al. (1993) Pauly et al. (1993) Aliño et al. (1993)
Small demersal prey species	Flatfish Flatfishes Tonguefish/tongue sole Cardinalfishes Damselfishes Drums and croakers Gobies Mojarras	9.10 9.10 9.10 28.29 19.39 54.70 10.00 12.30 70.09 15.30	Arreguin-Sanchez et al. (1993) De La Cruz-Aguero (1993) Arreguin-Sanchez et al. (1993) Pauly et al. (1993) Aliño et al. (1993) Aliño et al. (1993) De La Cruz-Aguero (1993) De La Cruz-Aguero (1993) Aliño et al. (1993) De La Cruz-Aguero (1993)
Small pelagics	Mullets Needlefishes Anchovy Fringescale sardinella Herrings Chub mackerels	12.30 7.20 19.70 11.70 11.70 14.82	De La Cruz-Aguero (1993) De La Cruz-Aguero (1993) Arreguin-Sanchez et al. (1993) Arreguin-Sanchez et al. (1993) De La Cruz-Aguero (1993) Pauly et al. (1993)
Squids and cuttlefishes	Common squid Octopus Squids	8.30 8.60 7.30 11.70 16.64	Arreguin-Sanchez et al. (1993) Vega-Cendejas et al. (1993) Pauly et al. (1993) Opitz (1993) Pauly et al. (1993)
Turtles	Green turtles	3.50	Polovina (1984)
Zooplankton	Zooplankton Sergestid shrimp Zooplankton	120 24.60 119.70 133.33	De La Cruz-Aguero (1993) Arreguin-Sanchez et al. (1993) Arreguin-Sanchez et al. (1993) Aliño et al. (1993)

Appendix C. Annual landings (t) by type of fish from the West Coast of Peninsular Malaysia.

Code No	Common Name	Local Name	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	91	92	93	94	95	96	97	98
			Year																											
24	1Chacunda Gizzard Shad	Kebasi	558	611	495	676	754	527	888	640	636	1760	966	1249	1175	1362	1538	1555	3018	3354	2472	2195	2364	3140	3171	2435	2633	2842	2609	2776
24	2 Shad, Elongate Ilisha	Puput	310	444	704	886	691	677	440	617	565	729	562	857	429	716	1071	1508	3563	3105	3520	4620	4432	4950	4802	5522	6225	7468	6363	11497
24	3 Shad	Terubuk	2	13	15	–	–	0	4	35	14	18	12	0	12	15	13	2	6	22	1		49	41	1	0	45	17	30	107
25	1 Barramundi (=Giant Seaperch)	Siakap	–	–	–	–	–	–	36	71	317	126	299	205	44	98	143	80	123	112	66	50	34	48	30	61	73	89	82	72
31	3 Tongue Soles	Lidah/ Sebelah	403	430	532	502	611	866	1262	2509	2189	3028	2969	2799	2538	2902	2004	2808	3224	2927	3541	1701	1459	2249	1960	2387	2735	3053	2918	2834
33	1 Parrot Fishes	Bayan	–	–	–	–	–	–	1	6	5	2	–	–	–	–	–	–	29	13	1	2	–	1	–	0	3	10	8	13
33	2 Goatfishes	Biji Nangka	633	667	399	410	506	1610	1745	2110	2324	1899	596	593	404	300	336	322	596	583	1323	1345	2570	2633	2148	2523	1958	2139	1435	983
33	3 Spotted Sicklefish	Daun Baharu	92	52	62	284	282	221	232	215	129	146	84	43	20	18	65	120	53	318	303	269	94	92	158	87	67	82	90	140
33	4 Fusilie	Delah	2		8	37		81	31	37	2	232	22	38	75	29	116	28	62	98	19	35	11	5	6	51	5	23	57	35
33	5 Catfishes	Duri	4117	3860	3036	3266	2964	2223	1791	2582	2358	3033	2863	2434	2448	2658	3173	3063	2694	3274	2621	3326	3749	3656	3404	3393	4285	5265	5131	5839
33	6 Spinefoot	Dengkis		11	7	7	4	128	2	17	13	1	21	35	17	5	103	26	89	371	143	212	107	193	203	173	134	106	91	96
33	7 Croakers	Gelama	3546	2729	2443	2896	3791	4263	4375	6958	8435	6321	6116	5387	5029	6825	7576	8485	10271	–	9354	9111	7084	8257	8072	10260	10631	11070	11590	13305
33	8 Silver Grunt	Gerut	489	546	508	750	572	721	718	989	884	1663	1346	988	1334	1190	869	735	893	794	794	790	734	560	489	456	501	475	354	647
33	9 John's Snapper	Jenahak	727	413	479	752	790	589	558	537	771	1127	1585	958	725	778	1444	727	926	1213	847	914	643	567	497	619	496	434	451	484
33	10 Grunter/Sweetlips	Kaci	–	–	–	2	1	26	34	171	82	569	647	147	124	162	20	95	62	109	136	155	60	64	56	68	139	57	43	26
33	11 Grouper	Kerapu	1019	906	985	1371	1231	900	860	991	1156	1662	3504	1631	152	1823	1894	1619	1454	1583	2101	2811	1829	1996	2154	2391	2166	1765	1593	1629
33	13 Threadfin Breams	Kerisi	1688	1077	799	823	953	1072	842	991	2681	4919	5577	5321	5524	6649	5333	6209	3908	3486	9302	7765	8527	12231	10197	9240	10886	9272	13291	10458
33	13 Crimson Jobfish	Kerisi Bali	–	–	–	–	–	–	–	–	13	–	486	420	141	170	421	448	272	449	501	743	656	521	446	488	474	426	320	190
33	14 Pony Fishes	Kikek	321	162	193	304	108	354	448	194	556	229	341	260	130	258	190	412	345	507	649	570	347	51	96	84	164	85	95	158
33	15 Daggertooth Pike Conger	Malong	622	672	688	602	666	786	904	1803	1419	2013	2176	1990	1698	2286	1589	1972	1433	1497	2379	2027	1612	1506	1468	1505	1635	1733	1751	2550
33	16 Red Snapper	Merah	3797	3247	2976	3185	2393	1259	907	1084	1163	1861	3136	1819	1447	1491	2546	1087	917	1253	1825	2091	1437	1609	1125	648	614	615	337	318
33	17 Greater Lizardfish	Mengkerong	–	530	201	341	567	1339	1667	1187	3472	5649	2017	1342	1204	1562	1337	1058	884	1255	3268	2605	2849	3826	4143	3702	4521	5469	5945	7114
33	18 Bigeye Snapper	Remong	–	–	–	–	–	1	0	56	524	11	84	162	115	172	74	76	150	188	436	494	248	508	446	181	286	234	138	127
33	19 Eel Catfish	Semilang	596	452	278	200	131	191	216	330	411	664	636	777	941	1366	1466	820	850	1615	819	582	826	1294	707	700	916	915	1086	861
33	20 False Trevally	Shrumbu	441	176	187	274	70	23	34	115	26	11	–	–	0	0	0	–	–	–	4	–	–	–	251	207	1202	112	25	3

Appendix C. Annual landings (t) by type of fish from the West Coast of Peninsular Malaysia. (continued)

			Year																											
Code No	Common Name	Local Name	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	91	92	93	94	95	96	97	98
33	21 Silver Sillago	Bulus	–	–	–	–	–	331	180	286	436	257	84	278	276	404	573	448	353	386	302	215	349	773	781	1167	1178	1195	1050	902
33	22 Monocle Bream	Pasir	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36	121	68	24	19	37	16	21	3	1	2	1
34	1 Barracuda	Alu-Alu	428	212	304	375	389	636	791	975	651	3299	1158	1345	933	1084	1091	950	862	979	1125	1488	1460	1504	1249	1334	1036	895	816	875
34	2 Cobia	Aruan Tasek	10	4		6	6	47	161	297	222	198	109	223	137	223	100	85	66	140	162	114	112	117	119	164	131	122	70	83
34	3 Pomfret	Bawal	2331	2450	1813	1764	1633	1997	2104	2005	2533	2897	3885	3720	3819	4006	5701	3242	4265	4811	4771	4897	3868	5138	4071	4884	4631	5841	6748	6167
34	4 Mullet	Belanak	2882	1865	1461	702	382	495	432	513	376	913	1476	2877	4185	4494	3385	2662	4363	4550	1928	1830	1675	2070	1663	1391	1481	1641	3182	3465
34	5 Trevally	Cermin	277	223	278	546	473	253	395	586	110	320	361	213	66	195	182	175	129	343	773	467	520	202	277	327	244	222	381	246
34	6 Torpedo Scad	Cincaru	6015	6865	6115	3223	4678	7836	3475	5597	3263	7644	9244	8224	3746	4896	10460	12407	4340	3787	3887	4764	3841	3061	4644	4459	4724	9670	13164	8523
34	7 Silvermouth Trevally	Demudok	–	–	–	–	–	236	258	256	30	27	763	1071	622	619	1086	930	787	1167	2176	2426	1791	1998	1552	1064	771	594	666	556
34	8 Blackhand Paradise Fish	Kurau	949	837	469	643	609	637	701	1005	1386	1757	941	1193	1676	1871	1920	1144	778	857	734	866	804	857	954	1129	1272	1265	1200	1459
34	9 Scads	Pelata/Selar	1399	956	842	1457	884	520	728	1274	1687	4900	3459	4335	3236	3516	3915	4390	3254	3192	7641	6860	4615	4405	2868	2848	3844	5811	7045	5825
34	10 Yellowstrip Scad	Selar Kuning	28	20	67	134	168	210	448	862	884	3048	2283	1179	2546	2186	2228	2840	1242	1929	2331	2576	2966	3041	2749	2709	2946	3726	2947	3662
34	11 Shortfin Scad	Selayang	3578	3681	2309	1814	4849	7021	5332	3695	6398	6025	6599	7459	8194	9408	11358	10275	4209	5334	13612	10882	13609	15558	6641	6969	10507	9979	10392	8748
34	12 Rainbow Runner	Pisang-Pisang	–	–	–	–	–	26	111	1151	360	324	359	321	177	89	56	86	1	90	606	56	183	188	507	232	262	479	470	262
34	13 Leatherskin	Talang	191	69	58	48	54	349	55	55	126	62	157	502	461	640	485	597	726	513	487	628	546	442	528	449	579	564	324	471
35	1 Anchovies	Bilis	18874	22098	22647	15654	20281	10369	9719	10072	11653	14882	34270	28113	27357	33425	27410	19799	13955	13166	17175	25325	26223	25469	14891	28260	12802	11982	13729	13791
35	2 Dorab Wolf-Herring	Parang	3220	3327	3520	3034	3189	3281	3009	3700	4047	4861	3200	2553	3161	3360	3558	2625	2868	3338	4301	3159	2802	2326	2554	2850	2449	2307	1902	1893
35	3 Sardines	Tamban	2547	3504	3003	2080	3770	5776	4060	10217	9833	5240	4867	6831	5244	6297	7619	5281	3403	3135	6959	6326	4020	5004	5733	5521	5023	3853	3541	4503
35	4 Indo-Pacific Tarpon	Bulan	–	–	–	–	–	–	15	4	3	90	–	–	–	–	–	2	9	16	4	6	4	–	2	1	7	8	7	6
36	1 Tuna	Aya	1333	2492	1740	1992	1002	1590	2590	1712	2344	3190	2024	4701	2632	1713	2680	3075	4551	4036	6719	5035	3666	4626	5051	8194	5460	2939	3727	6178
36	2 Marlin	Mersuji	22	49	53	43	202	208	–	–	0	–	44	70	49	76	120	73	138	93	6	–	–	–	1	0	0	2	3	0
37	1 Short Mackerel	Kembong	57310	29122	33953	9762	21693	12313	9987	12414	19570	23803	34153	51800	45027	54719	62594	68966	58503	31581	56193	40059	42986	55285	35380	46066	36104	63771	101003	73781
37	2 Spanish Markerel	Tenggiri	2987	3607	4340	4015	3435	3985	3169	3269	4338	4728	5376	4869	5151	6694	5170	3138	3970	5703	7623	4933	3813	4255	4608	5665	4411	5222	3767	3886
37	3 Largehead Hairtail	Timah	793	676	410	586	1166	1619	1221	2344	2563	2291	1439	2607	1529	829	767	1266	2180	1694	3084	5066	2087	1598	1961	6243	4123	2862	2899	2759
38	1 Rays	Pari	1697	1921	1932	1522	1638	1258	1543	2343	2638	3097	3205	3256	2456	2767	3063	3167	2921	3623	4672	6126	4391	4672	4601	5430	5608	5104	4670	5011
38	2 Sharks	Yu	996	849	743	957	946	778	872	1800	2142	2229	1644	1420	1003	1068	628	979	972	1080	906	1359	1015	759	776	769	694	769	962	970
39	1 Trash Fish	Ikan Baja	39968	43989	58779	68010	94829	118632	103920	100610	135324	123892	123511	124103	135192	117175	122368	89281	97386	111323	188121	145510	179365	192576	141794	151448	156841	160560	186274	171087
39	2 Mixed Fish	Ikan Campur	10686	8765	9136	8559	10668	8692	8718	7484	5993	7316	7553	4947	4020	6766	8140	9772	8546	7600	10694	9984	10628	15605	13741	9394	9417	9942	13394	14479
39	3 Starry Triggerfish	Jebong	–	–	–	–	–	–	58	18	348	206	279	304	200	168	511	536	343	260	747	1511	793	1433	1916	1164	1571	501	546	721
42	1 Crab	Ketam	2477	1679	1482	1300	1841	1739	2200	3120	3864	3914	3254	2877	2997	4193	4085	3610	3275	3578	3156	2989	3652	3505	3231	3892	3703	3751	4226	3900
45	1 Lobster	Udang Karang	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–	15	42	64	38	177	31	57	31	24	27	33	20	15
45	2 Big Prawn	Udang Besar	–	–	–	–	–	–	–	–	–	–	6397	5578	4047	5061	5120	–	–	–	–	–	–	–	–	–	–	–	–	–

Appendix C. Annual landings (t) by type of fish from the West Coast of Peninsular Malaysia. (continued)

			Year																											
Code No	Common Name	Local Name	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	91	92	93	94	95	96	97	98
45	3 Medium Prawn	Udang Sedang	–	–	–	–	–	–	–	–	–	–	21747	16581	14250	14576	16064	–	–	–	–	–	–	–	–	–	–	–	–	–
45	4 Small Prawn	Udang Kecil	–	–	–	–	–	–	–	–	–	–	28540	28922	27224	32896	29337	–	–	–	–	–	–	–	–	–	–	–	–	–
45	5 Banana Prawn	Udang Putih	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6210	6781	6796	5236	2830	3522	3800	3320	–	–	–	6573	8019
45	6 Greasyback Prawn	Udang Minyakv	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11279	12630	14917	16108	17002	18487	18550	18390	–	–	–	11177	11079
45	7 Pink Prawn	Udang Merah Ros	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5874	8224	5935	2690	356	301	1276	1390	–	–	–	3774	2859
45	8 Rainbow Prawn	Udang Kulit Keras	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3941	2754	1762	2567	2237	2487	2935	2977	–	–	–	2755	2553
45	9 Tiger Prawn	Udang Harimau	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	551	384	368	330	244	228	112	–	–	–	119	204
45	10 Other Prawn	Lain-lain Udang	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11526	13086	15812	25953	31292	–	–	27668	–	–	–	23356	24913
45	11 Other Prawn/ Sergestid Prawn	Lain-lain Udang/ Udang Baring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48419	45335	–	85642	55591	47116	–	–
45	12 Penaeid Prawn	Udang Penaeid	30148	40981	46703	36962	45575	48647	37967	43581	50987	63017	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
45	13 Sergestid Shrimp	Udang Baring	6866	5392	4886	16072	6000	7501	9137	8181	10615	10672	7131	9299	13267	5074	9895	12139	9807	8997	9214	13009			12737	0	17310	16864	14449	17399
45	14 Lobsters/Penaeid Prawn	Udang Karang/ Penaeid	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
45	15 Penaeid Prawn/ Seregestid Shrimp	Udang Penaeid/ Baring	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
45	16 Giant Freshwater Prawn	Udang Galah	–	41	63	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
56	1 Shell	Siput	619	673	743	383	252	68	5000	653	2099	499	1186	2121	2231	7353	5830	4333	2620	818	20467	1529	782	4475	1161	7730	18424	8696	15275	17772
57	1 Octopus	Sotong Kereta	–	–	–	–	–	–	–	–	–	–	379	444	347	413	216	168	136	115	244	209	386	505	202	466	223	304	476	663
57	2 Bobfins Squid	Sotong Katak	–	–	–	–	–	–	–	–	–	–	3613	2631	1947	1741	2175	2171	1871	3178	4324	2918	4169	5132	4632	7105	6283	5785	7143	8052
57	3 Squid	Sotong Biasa	–	–	–	–	–	–	–	–	–	–	8379	5848	6681	7148	7095	6073	6127	7448	11842	10896	16138	14760	15260	18515	12041	11186	14205	14676
57	4 Cephalopods	Sotong Kereta/Katak/ Biasa	1365	2119	1746	1526	2104	4010	5311	8616	11583	11778	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
76	1 Jellyfish	Obor-Obor	–	–	–	–	–	–	–	–	2890	123	–	132	1323	4664	3695	260	12	900	3423	7509	30844	6916	3131	3299	2001	984	2556	3849
	TOTAL		219359	205464	224590	200737	249801	267917	241662	262940	331441	355172	369114	372404	364514	384642	403998	347742	327124	324047	499862	430188	489334	510471	401900	474006	446516	460302	546818	518525

A Trophic Model of the Coastal Fisheries Ecosystem off the West Coast of Sabah and Sarawak, Malaysia*

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Abstract

A mass-balance steady-state trophic model of the coastal fisheries ecosystem off the West Coasts of Sabah and Sarawak, Malaysia (10 - 60 m depth) was constructed using the Ecopath software. The ecosystem models were partitioned into 29 ecological/trophic groups. The input values (e.g. biomasses) for selected groups were obtained from the research (trawl) surveys conducted in the area in 1972. The estimated mean trophic level of the fisheries catch for both models is about 3.3. The biomass values obtained from Ecopath when compared with the estimates of the fishery catch indicate a low level of exploitation of coastal fisheries resources in 1972.

Introduction

Fisheries catches from marine waters off Sabah and Sarawak contributed about 18% (200 933 t) and 9% (101 130 t) of the total marine fish landing of Malaysia in 1999, respectively (Department of Fisheries (DOF) 1999). About 59% of the catch is contributed by small scale (traditional) fisheries, and demersal fish constitute 39% of the catch in Sarawak (Talib et al., this vol.) On the other hand, both commercial and small scale fisheries play an equal role in Sabah and demersal fish constitute about 47% of the total landings.

A total of 13 research (trawl) surveys have been conducted off the coast of Sarawak and the West Coast of Sabah since 1972. The surveys were principally conducted to locate suitable grounds for trawling operations and subsequently to determine the abundance of demersal resources for the development of the trawl fishery (Talib et al. paper no 6).

The results of the trawl surveys in 1972 showed catch rates ranging from 149 to 261 $kg{\cdot}hr^{-1}$ from Sarawak coastal waters while relatively higher catch rates were obtained from the West Coast of Sabah, ranging from 476 to 576 $kg{\cdot}hr^{-1}$ (Latiff et al. 1976). The estimated demersal stock density ranged from 2.39 to 7.49 $t{\cdot}km^{-2}$ in Sarawak waters and 10.49 to 13.56 $t{\cdot}km^{-2}$ in Sabah. Based on the catch rates obtained in 1998, the trawl surveys in the Sarawak waters recorded a reduction of the average catch rate between 26% to 60%, while in Sabah reductions of between 82% to 88% were seen (Talib et al. paper no 6).

* WorldFish Center Contribution No. 1712

The Ecopath with Ecosim (EwE) software (Christensen et al. 2000), developed by the WorldFish Centre and the University of British Columbia, was used to construct a trophic model of the coastal fisheries resources off Sabah and Sarawak. Biomass estimates from trawl surveys in 1972, particularly the demersal species/groups, were utilized in the construction of the ecosystem models (Pauly 1996, noted that demersal trawl surveys represent the most straightforward way of finding how many and what kind of fish appears in a given area).

The Ecopath models when used with time series information (e.g. catch data or CPUE) in the Ecosim routine of the EwE software permit evaluation of the effects of changes in the ecosystem (such as a change in the fishery, artificial enhancement of recruitment and any other measurable change such as nutrient loading or pollution) to be accurately simulated and the outcome predicted (Christensen 1998; Supongpan et al. this vol.). Hence, the trophic models constructed can be used for future temporal and/or spatial analysis. The models can also be utilized to understand the ecosystem effects on the decline in biomass of most demersal resources in the area.

Materials and Methods

Study Area

The continental shelf off Sarawak has an area of about 125 000 km^2, of which 97 000 km^2 is trawlable[a] (see Fig. 1). The continental shelf (located between latitude 1º 30' N to 7º 07' N and longitude 109º 38' E to 114º 05' E) extends up to 220 m at its furthest point north of Tanjong Po in the south and its narrowest point at 30 nautical miles north of Tanjong Baram in the north. Beyond the 200 m isobath in this area, the depths drop to 1 000 m over a mean distance of 2.5 nautical miles.

The fisheries resources of Sarawak are such that major fishing effort is on muddy areas, mostly in the nearshore waters. In 1998, coastal demersal fish was reported as being overfished, while offshore demersal was being lightly exploited. Landing of marine fish by gear in 2000 was dominated by trawl nets, i.e. 70% of total gears.

The coastline of Sabah is about 1 600 km (from the boundary of Brunei Darusalam waters to Kudat on the northern tip of Sabah), and surrounded by the South China Sea and the Palawan Thrust on the northwest, the Celebes Sea on the southeast and the Sulu Sea on the east. The west coast is generally rocky and sandy, while mangrove swamps dominate the east coast. The continental shelf area (located between latitude 4º 50' N to 8º 24' N and longitude 112º 30' E to 117º 00' E) for the west coast of Sabah is roughly 28 000 km^2, with approximately 14 000 km^2 is trawlable[b].

The marine capture fisheries can be categorized into two sub-sectors, i.e. deep-sea fisheries and coastal fisheries. Deep-sea fishing contributes to roughly 30% of the total marine landings in Sabah, mostly pelagic fishes. Deep-sea resources are estimated to be about 140 000 t, of which roughly 11 000 t are demersal fish[c]. Most of the fishing activities however are concentrated within 30 nm from shore (categorized as coastal fisheries), with trawling being the main activity (mostly for prawns and finfishes).

The marine waters in the study area are influenced by monsoon patterns. Based on a recent study, the primary production during the southwest monsoon period varied between 0.13 to 0.88 $gC \cdot m^{-2} \cdot day^{-1}$ particularly in the coastal areas, and production rates were observed to be highest in waters off Brunei Darussalam and Sabah (SEAFDEC, 2000). Moreover, the total calculated biomass for chlorophyll ***a*** from a survey area of 243 000 km^2 was in the order of 1 870 and 2 070 t.

Trawl Survey

A total of 13 surveys have been conducted off the coast of Sarawak and the West Coast of Sabah since 1972 employing research vessels (Talib et al. paper no 6). In 1972, the trawl survey in the coastal waters off Sabah and Sarawak was conducted from 29 March to 1 May 1972. The survey area off the West Coast of Sabah covered about 20 209 km^2 while about 76 668 km^2 was surveyed off the coast of Sawarak waters (see Fig. 1). A total of 268 trawl stations/hauls were conducted between 10 - 60 m depth (see Fig. 2). Of this, 92 hauls were conducted off the West Coast of Sabah and 176 in Sarawak

[a] www.tracc.00server.com/Fisheries/desstructive_fishing/sarawak_trawl_fisheries.html
[b] www.tracc.00server.com/Fisheries/desstructive_fishing/fisheries_sabah.html
[c] www.iczm.sabah.gov.my/Reports/Coastal%20Profile%20Sabah/ch11/11-FISHERIES.html

waters. Detailed descriptions of the survey and fishing operations are presented in (Latiff et al., 1976). The trawl surveys were carried out using two research stern trawlers, namely, KK Jehanak (Penyelidik I) and KK Merah (Penyelidik II). The research vessels have an overall length (LOA) of 23 m and a displacement of 85 GT. The vessels were powered by 325 hp and 365 hp diesel engines, respectively. The trawl gear used was a standard German type otter trawl with cod-end mesh size of 40 mm. At each fishing station, trawling was conducted for about 1 hour with a towing speed of 2.8 knots. Fishing was conducted only during day-time hours (between 6 am to 6 pm).

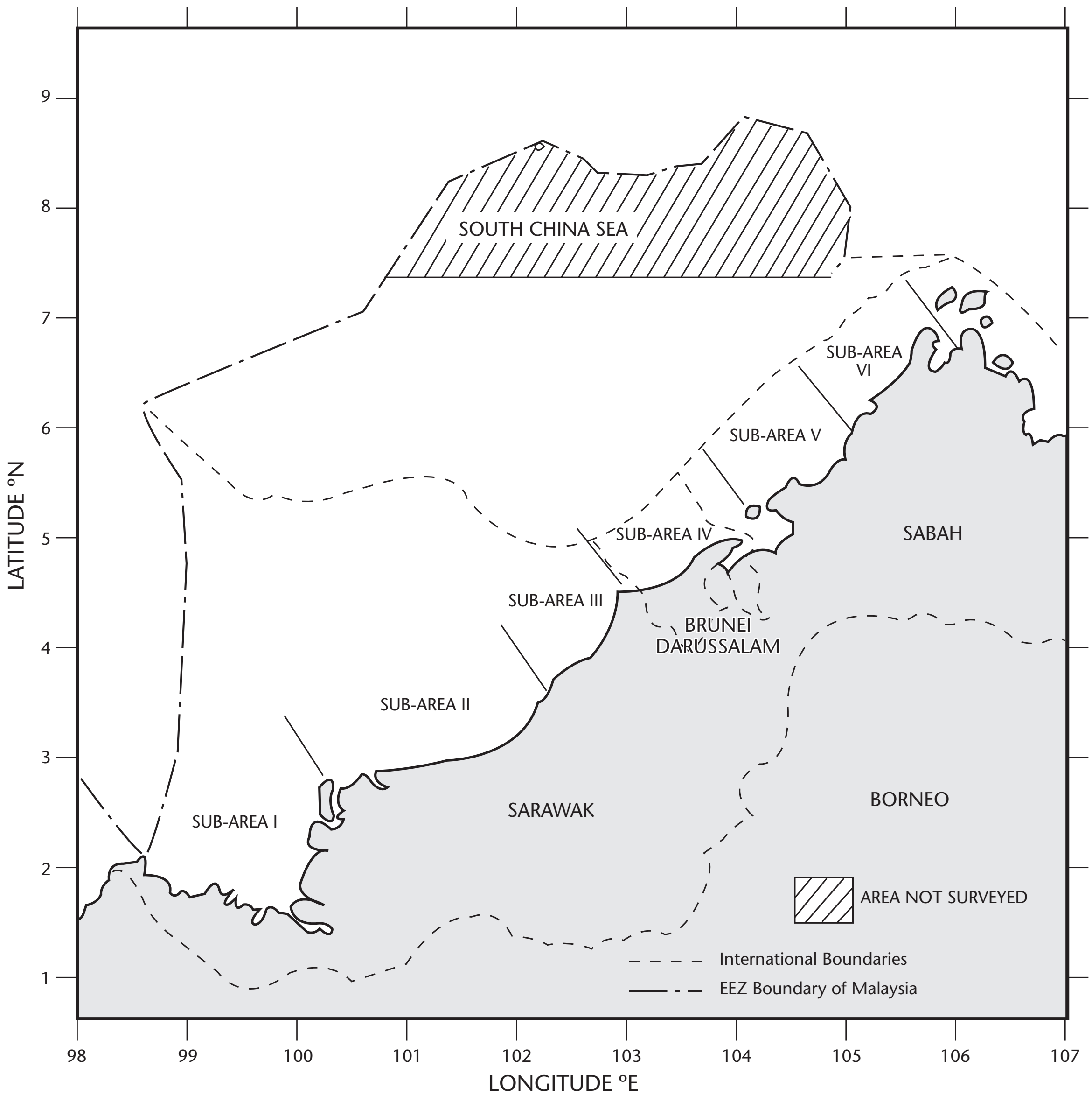

Fig. 1. Map of Sarawak and Sabah states showing the six sub-areas: Sub-areas I, II and III off the coast of Sarawak and Sub-areas IV, V and VI off the coast of Sabah.

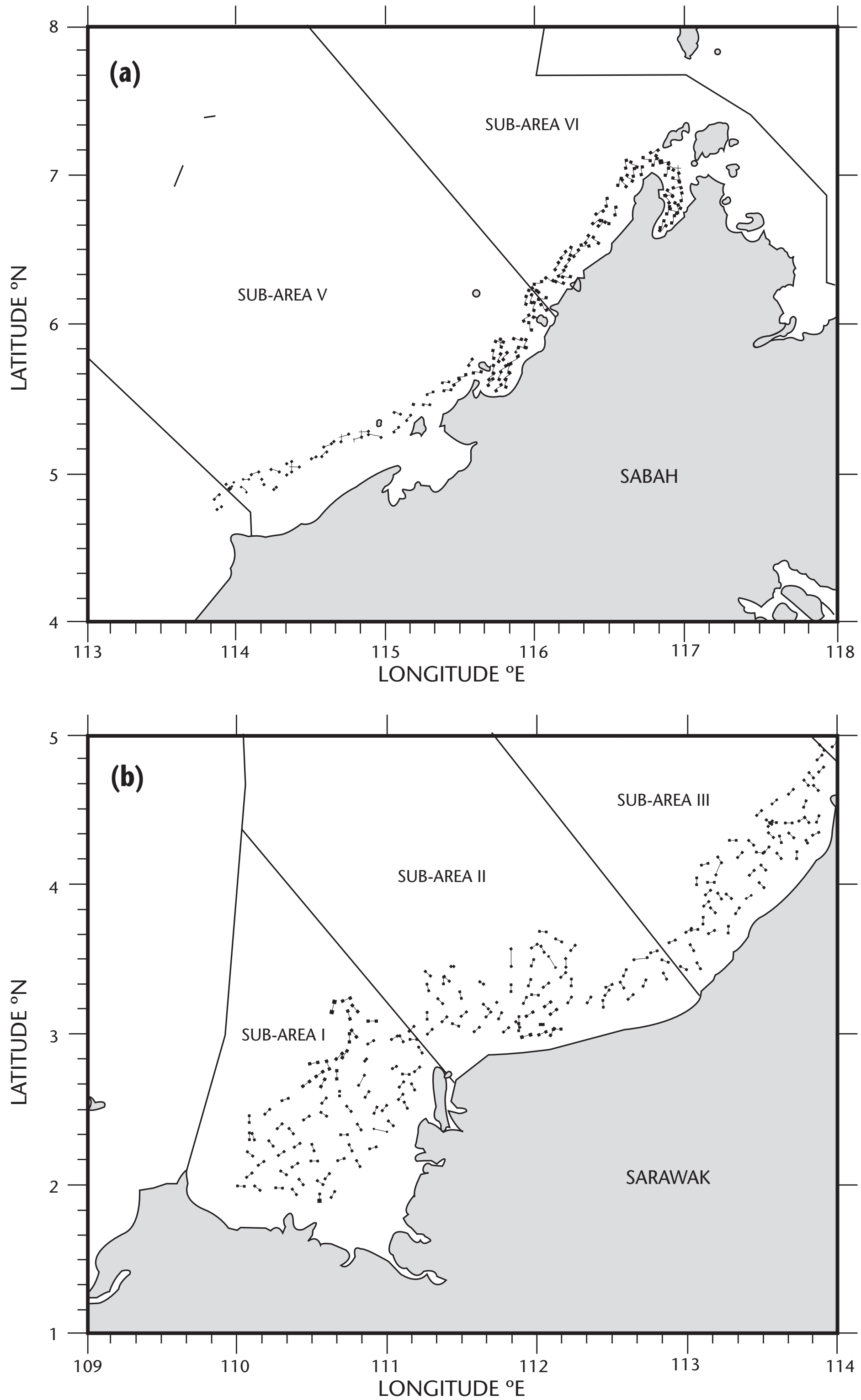

Fig. 2. Distributions of sampling stations during the 1972 surveys off the coast of Sabah (a) and Sarawak (b) using K.K. JENAHAK/K.K. MERAH.

Modeling Approach

The trophic model for Sabah and Sarawak was constructed using the Ecopath with Ecosim (EwE) software following the approach described in Christensen et al. (2000). Ecopath has been used to model a wide variety of aquatic ecosystems (Christensen and Pauly 1993). It is also used to analyze trophic interactions and state variables (biomasses) derived from quantitative steady state models of aquatic systems (Christensen and Pauly 1992a; Christensen and Pauly 1992b).

Ecopath combines the method described by (Polovina 1984) for estimation of biomass and food consumption of the various elements (species or groups of species) of an aquatic ecosystem with an approach by (Ulanowicz 1986) for analysis of flows between the elements of ecosystems.

The basic assumption of Ecopath is that the ecosystem being analyzed is in steady-state, which means that the flows in and out of each component (box) must be balanced over the time period studied. This assumption results in a system of biomass budget using a set of simultaneous linear equations (one for each group *i*) expressed as:

Production by (*i*) - all predation on (*i*) -
non predation losses of (*i*) - export of (*i*) = 0

Another way of expressing the basic equation is:

$$P_i - B_i \cdot M2_i - P_i (1-EE_i) - EX_i = 0 \qquad (1)$$

where P_i = the production of i; B_i = the biomass of *i*; $M2_i$ = the predation mortality of *i*; EE_i = the ecotrophic efficiency of *i*, that is part of the production that is either passed up the trophic level or exported; 1- EE_i = 'other mortality'; and EX_i = the export of *i*.

A predator group is connected to its prey groups by its consumption (QB*i*). Thus equation (1) can be re-expressed as:

$$B_i \cdot PB_i \cdot EE_i - \sum B_j \cdot QB_j \cdot DC_{ji} - EX_i = 0 \qquad (2)$$

where PB_i is the production/biomass ratio, QB_j is the consumption/biomass ratio of the predator (*j*), and Diet Composition (DC*ji*) is the fraction of prey (*i*) in the diet of predator (*j*).

Parameterization of the model calls for input of three of the following four parameters: B, P/B, Q/B and other mortality, for all groups of living organisms discerned in the model (Christensen and Pauly 1992a; Christensen et al. 2000). The fourth parameter is then calculated using a set of linear equations so as to ensure mass balance. For example, for any group (*i*), Ecotrophic Efficiency (EE) can be estimated if biomass (B) and production/biomass (PB) are known along with consumption/biomass (QB) and diet composition (DC) of all its predators. Input of fishery catches is also required. By using Ecopath with Ecosim software, all parameters are normalized to unit surface area using wet weights and expressing rates on an annual basis (Christensen et al. 2000).

Defining the Model Components

The model consisted of 29 ecological groups, i.e. 26 consumer groups, 2 producer (phytoplankton/algae) groups and a detritus group. The taxonomic composition of the groups is listed in Table 1 (see also Appendix A). The species composition and biomass data from the trawl surveys in 1972 and catch/landing data were used to assign the species/groups to the ecological groups. The aggregation process for this model was performed based on similarities in habitat, body size, growth and mortality rates and diet composition (Bundy and Pauly 2001). Such information (notably for fish) was mainly obtained from the FishBase database (Froese and Pauly 2000). Taxonomic groups with notable changes in abundance e.g. Lutjanidae, Balistidae (Silvestre 1990) were hence assigned to separate ecological groups for more detailed analysis using time series data. For some fish species (e.g. Leiognathidae, Nemipteridae), they were assigned to a separate ecological group because of their significant contribution to the fish catch as well as their relative abundance during the trawl survey.

Table 1. Taxonomic composition of the 29 ecological groups of the Sabah and Sarawak model.

Ecological Group	Representative Taxa
Large Predators	Carcharhinidae, Istiophoridae
Tuna	Scombridae (Tuna)
Large zoobenthos feeders	Dasyatidae, Rachycentridae
Intermediate predators	Ariidae, Centropomidae, Chirocentridae, Muraenesocidae, Plectorhynchidae, Plotosidae, Polynemidae, Pomadasyidae, Sphyraenidae, Trichiuridae
Lutjanids	Lutjanidae,
Serranids	Serranidae
Carangids	Carangidae (excluding trevally and scads)
Flatfishes/Soles	Psettodidae
Sciaenids	Sciaenidae
Small pelagics	Caesionidae, Carangidae (trevally), Carangidae (Scads), Hemiramphidae, Scombridae (mackerel)
Engraulids/Clupeids	Clupeidae, Engraulidae
Squids	Squids, Cephalopods
Demersal zoobenthos feeders	Bothidae, Centriscidae, Drepanidae, Formionidae, Gerridae, Lethtrinidae, Mugilidae, Scatophagidae, Siganidae, Sillaginidae, Stromatidae , Synodontidae, Theraponidae, Trash fish
Leiognathids	Leiognathidae
Mullids	Mullidae
Nemipterids	Nemipteridae
Balistids	Balistidae
Lactarids	Lactariidae
Reef Associated Fish	Scaridae, Labridae
Octopus/Sepia	Squids, Octopus
Crabs/Lobsters	Crabs, Lobsters
Shrimps	Penaeus spp.
Ecological group	Representative taxa
Small crustaceans	Sergestid shrimps, juvenile Penaeidae
Macrobenthos	Clams, Mollusc
Meiobenthos	–
Zooplankton	–
Macrobenthic algae	–
Phytoplankton	–
Detritus	–

Model Parameterization

Biomass

The biomass of the demersal fish groups was obtained from the trawl surveys conducted in the coastal waters off Sabah and Sarawak in 1972 (Latiff et al. 1976). Biomass (B) was estimated using the "swept-area" method (Pauly 1984) with the following formula:

$$B = \frac{C/f \cdot A}{a \cdot x_1}$$

where B = biomass, C/f = mean cpue, A = total survey area, a = swept area, and x_1 = proportion of fish in path of gear retained in net (0.5 in Southeast Asian waters).

The swept area is defined by:

$$a = t \cdot v \cdot h \cdot x_2$$

where t = time spent in trawling, v = trawling velocity, h = length of trawl's headrope, and x_2 = fraction of area swept over length of headrope (0.5 in Southeast Asian waters).

The biomass values from the trawl surveys (particularly for the demersal species/taxa) were used as input data and also as the basis for aggregation of the species according to ecological groups (see Table 1).

Other Parameters

Values for most of the other input parameters were taken from the existing Ecopath models e.g. Brunei Darussalam coastal waters (Silvestre et al. 1993) and East Coast Malaysia (Liew and Chan 1987). Various published models on marine systems in (Christensen and Pauly 1993) were also used as reference. Estimates of total mortality (Z) (Silvestre et al. 1993) for representative species of the various fish groups were used as first approximations of the P/B ratios. P/B ratios for the invertebrate and consumer groups were based on turnover rates reported in the literature Christensen and Pauly (1993). Input parameters for phytoplankton and detritus were derived from Silvestre et al. (1993). The basic input parameters are summarized in Table 2.

Fishery Catch

Catch data for the various species/groups were taken from (Ministry of Agriculture and Fisheries (MAF) 1972). In 1972, the total fish catch was estimated at 1.328 $t \cdot km^{-2} \cdot yr^{-1}$ and 0.211 $t \cdot km^{-2} \cdot yr^{-1}$ for Sabah and Sarawak, respectively. It is interesting to note that demersal zoobenthos feeders, intermediate predators and shrimps are the main groups that provide substantial contribution to fish catch in the study areas (see Table 2 a and b). To arrive at these values, the total landings reported in the annual statistics in 1972 were divided by the total area of the coastal waters covered by the model.

Diet Composition

Data for diet compositions were taken from gut content studies in FishBase (http://www.fishbase.org) and from published Ecopath models (Liew and Chan 1987; Silvestre et al. 1993). Other references used include: (Abitia-Cardenas et al. 1999; Blaber et al. 1990; de Lestang et al. 2000; Platell and Potter 2001; Salini et al. 1994; Velasco et al. 2001). The diet composition data used for model construction is given in Table 3.

Table 2a. Basic input parameters used in constructing the Ecopath model for Sarawak.

Ecological Group	Biomass ($t \cdot km^{-2} \cdot year^{-1}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Catch ($t \cdot km^{-2} \cdot year^{-1}$)
Large predators	0.11	–	9.50	0.50	0.010
Tuna	–	2.00	11.64	0.50	0.011
Large zoobenthos feeders	0.16	0.40	6.50	–	0.006
Intermediate predators	–	1.74	8.70	0.95	0.027
Lutjanids	0.19	–	8.70	0.95	0.002
Serranids	–	1.74	8.70	0.95	0.002
Carangids	–	2.07	8.70	0.95	0.004
Flatfishes/Soles	–	0.85	8.70	0.95	0.001
Sciaenids	0.08	–	8.70	0.95	0.009
Small pelagics	–	2.37	7.90	0.95	0.004
Engraulids/Clupeids	–	2.70	7.90	0.95	0.015
Squids	–	2.05	7.90	0.95	0.004
Demersal zoobenthos feeders	–	2.15	10.75	0.95	0.061
Leiognathids	0.85	–	10.75	0.95	0.006
Mullids	0.44	–	10.75	0.95	0.003
Nemipterids	0.16	–	10.75	0.95	0.001
Balistids	–	2.15	10.75	0.95	0.000
Lactarids	–	2.15	10.75	0.95	0.000
Reef associated fish	–	1.50	7.55	0.95	0.000
Octopus/Sepia	–	3.00	12.50	0.95	0.004
Crabs/Lobsters	–	4.00	21.90	0.95	0.002
Shrimps	–	4.00	21.90	0.95	0.034
Small Crustaceans	–	62.00	310.00	0.95	0.001
Macrobenthos	–	6.80	27.40	0.95	0.000
Meiobenthos	–	10.00	50.00	0.95	0.000
Zooplankton	–	67.00	280.00	0.95	0.000
Macrobenthic flora	–	15.35	–	0.03	0.000
Phytoplankton	–	71.20	–	.0500	0.000
Detritus	120.00	–	–	–	0.000

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = ecotrophic efficiency.

Table 2b. Basic input parameters used in constructing the Ecopath model for Sabah.

Ecological Group	Biomass ($t \cdot km^{-2} \cdot year^{-1}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Catch ($t \cdot km^{-2} \cdot year^{-1}$)
Large predators	0.23	–	9.50	0.50	0.06
Tuna	–	2.00	11.64	0.50	0.03
Large zoobenthos feeders	0.15	0.40	6.50	–	0.03
Intermediate predators	–	1.74	8.70	0.95	0.17
Lutjanids	0.05	–	8.70	0.95	0.01
Serranids	–	1.74	8.70	0.95	0.01
Carangids	–	2.07	8.70	0.95	0.02
Flatfishes/Soles	–	0.85	8.70	0.95	0.05
Sciaenids	0.31	–	8.70	0.95	0.06
Small pelagics	–	2.37	7.90	0.95	0.02
Engraulids/Clupeids	–	2.70	7.90	0.95	0.09
Squids	–	2.05	7.90	0.95	0.02
Demersal zoobenthos feeders	–	2.15	10.75	0.95	0.38
Leiognathids	1.99	–	10.75	0.95	0.08
Mullids	1.26	–	10.75	0.95	0.02
Nemipterids	0.57	–	10.75	0.95	< 0.01
Balistids	–	2.15	10.75	0.95	< 0.01
Lactarids	–	2.15	10.75	0.95	< 0.01
Reef associated fish	–	1.50	7.55	0.95	< 0.01
Octopus/Sepia	–	3.00	12.50	0.95	0.02
Crabs/Lobsters	–	4.00	21.90	0.95	0.01
Shrimps	–	4.00	21.90	0.95	0.22
Small Crustaceans	–	62.00	310.00	0.95	< 0.01
Macrobenthos	–	6.80	27.40	0.95	< 0.01
Meiobenthos	–	10.00	50.00	0.95	0.00
Zooplankton	–	67.00	280.00	0.95	0.00
Macrobenthos flora	–	15.35	–	0.03	0.00
Phytoplankton	–	71.20	–	0.50	0.00
Detritus	120.00	–	–	–	0.00

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = ecotrophic efficiency.

Table 3. The diet composition of the ecological groups used in the Ecopath analysis. The Predator numbers correspond to the prey numbers.

	Predator																									
Prey	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
1. Large predators	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2. Tuna	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3. Large zoobenthos feeders	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4. International predators	0.20	0.22	–	0.01	–	–	0.01	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5. Lutjanids	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6. Serranids	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7. Carangids	0.10	0.11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8. Flatfishes/Soles	0.02	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9. Sciaenids	0.10	–	–	–	–	–	–	–	0.02	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10. Small pelagics	0.20	0.11	–	0.05	0.05	0.05	0.05	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11. Engraulids/Clupeids	0.10	0.22	–	0.10	–	0.05	0.05	–	0.03	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12. Squids	0.10	0.11	–	0.05	–	–	0.05	0.05	–	–	–	–	–	–	–	0.02	–	–	–	–	–	–	–	–	–	–
13. Demersal zoobenthos feeder	0.04	0.11	–	0.13	0.30	0.20	0.15	0.15	0.05	0.01	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
14. Leiognathids	0.02	–	–	0.05	0.05	0.05	0.10	0.05	–	0.10	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
15. Mullids	0.02	–	–	0.05	0.05	0.10	0.10	0.05	–	0.01	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
16. Nemipterids	0.02	–	–	0.05	0.05	0.10	0.10	0.05	–	0.01	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
17. Balistids	0.02	–	–	0.02	0.05	0.10	0.10	–	–	–	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
18. Lactarids	0.02	–	–	0.05	0.05	0.05	0.10	0.05	–	0.01	–	–	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
19. Reef associated fish	0.02	–	–	0.01	0.05	0.10	0.02	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20. Octopus/Sepia	0.02	–	0.10	–	0.05	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.02	–	–	–	–	–	–
21. Crabs/Lobsters	–	0.03	0.05	0.02	0.15	0.10	0.10	–	0.10	0.04	–	–	–	–	–	–	0.05	–	–	0.01	0.01	–	–	–	–	–
22. Shrimps	–	0.06	0.20	0.15	0.10	0.05	0.05	–	0.15	0.05	0.15	0.15	–	–	–	0.06	0.05	–	–	–	0.04	0.01	–	–	–	–
23. Small crustaceans	–	0.02	0.15	0.05	0.02	–	–	0.10	0.20	0.05	0.20	0.15	0.15	0.15	0.15	0.15	0.20	0.15	–	0.10	0.04	0.30	–	–	–	–
24. Macrobenthos	–	–	0.40	0.20	0.02	0.05	0.02	0.25	0.30	0.10	0.10	0.10	0.25	0.46	0.45	0.45	0.30	0.45	–	0.10	0.38	0.20	–	–	–	–
25. Meiobenthos	–	–	0.05	0.01	0.01	–	–	0.15	0.05	–	–	–	0.30	0.05	0.05	0.05	0.10	0.05	–	0.07	0.13	0.05	–	0.30	–	–
26. Zooplankton	–	–	–	–	–	–	–	–	0.05	0.50	0.40	0.44	0.20	0.24	0.20	0.20	0.20	0.24	0.10	0.10	0.03	–	0.40	0.10	0.05	0.05
27. Macrobenthic flora	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.60	–	0.02	–	–	0.10	–	–
28. Phytoplankton	–	–	–	–	–	–	–	–	–	0.20	0.10	0.10	–	0.05	0.10	–	–	0.05	0.30	0.10	–	0.05	0.50	0.05	0.05	0.70
29. Detritus	–	–	0.05	–	–	–	–	0.10	0.04	–	0.05	0.05	0.04	0.05	0.05	0.06	0.10	0.06	–	0.50	0.35	0.39	0.10	0.45	0.90	0.25
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Results and Discussion

Trophic Model

The basic estimates of the Ecopath model for the coastal fisheries off Sarawak are presented in Table 4a; Table 4b presents the parameters estimated for the trophic model of the West Coast of Sabah. The biomass values obtained from Ecopath when compared with estimates of fishery catches given in Table 2 (a & b) imply a relatively low exploitation level of fishery resources in 1972. Under the assumption of steady state conditions, estimates of total mortality (Z) are reasonable estimates of turnover rates (P/B ratios). However, these values should be compared with independent fisheries assessments to confirm the estimates.

Fig. 3 presents a mixed trophic impact analysis for the Sarawak ecosystem. This analysis quantifies all direct and indirect trophic impacts (be it through predation or competition), and can be seen both as a sensitivity analysis (what groups are important), and as a measure of the groups and the fishing fleets relating to trophic importance. The figure also indicates that fishing fleets target mainly intermediate predators, carangids, demersal species groups (flatfishes/soles, sciaenids), small pelagics including engraulids/clupeids, and shrimps. The fleets have also shown negative impacts on large predators, tuna, large zoobenthos feeders, lutjanids and serranids since the fisheries are exploiting their prey.

It is interesting to note that a relatively higher phytoplankton biomass has been estimated for the Sabah Ecopath model compared to the Sarawak model. This trend is consistent with the generalization from the oceanographic study (SEAFDEC 2000) in the area, wherein relatively higher primary productivity values were obtained from the coastal waters off Sabah and Brunei Darussalam as compared to Sarawak waters. Primary production levels have an influence on fish abundance as well as biomass of fisheries resources in the study area.

Table 4a. Input and output parameters (in parenthesis) of the Ecopath model for Sarawak, 1972.

Ecological Group	Trophic level	Biomass ($t \cdot km^{-2} \cdot year^{-1}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Production/ Consumption
Large predators	4.4	(0.12)	0.26	(9.50)	(0.50)	0.03
Tuna	4.4	0.01	(2.00)	(11.64)	(0.50)	0.17
Large zoobenthos feeders	3.4	(0.16)	(0.40)	(6.50)	0.10	0.06
Intermediate predators	3.9	0.08	(1.74)	(8.70)	(0.95)	0.20
Lutjanids	4.0	(0.19)	0.01	(8.70)	(0.95)	< 0.01
Serranids	4.0	< 0.01	(1.74)	(8.70)	(0.95)	0.20
Carangids	4.1	0.06	(2.07)	(8.70)	(0.95)	0.24
Flatfishes/Soles	3.5	0.06	(0.85)	(8.70)	(0.95)	0.10
Sciaenids	3.5	(0.08)	1.76	(8.70)	(0.95)	0.20
Small pelagics	3.5	0.17	(2.37)	(7.90)	(0.95)	0.30
Engraulids/Clupeids	3.1	0.13	(2.70)	(7.90)	(0.95)	0.34
Squids	3.1	0.13	(2.05)	(7.90)	(0.95)	0.26
Demersal zoobenthos feeders	3.2	0.47	(2.15)	(10.75)	(0.95)	0.20
Leiognathids	3.2	(0.85)	0.36	(10.75)	(0.95)	0.03
Mullids	3.1	(0.44)	0.67	(10.75)	(0.95)	0.06
Nemipterids	3.3	(0.16)	1.92	(10.75)	(0.95)	0.18
Balistids	3.2	0.11	(2.15)	(10.75)	(0.95)	0.20
Lactarids	3.2	0.14	(2.15)	(10.75)	(0.95)	0.20
Reef associated fish	2.1	0.11	(1.50)	(7.55)	(0.95)	0.20
Octopus/Sepia	2.5	0.09	(3.00)	(12.50)	(0.95)	0.24
Crabs/Lobster	2.9	0.16	(4.00)	(21.90)	(0.95)	0.18
Shrimps	2.8	0.36	(4.00)	(21.90)	(0.95)	0.18
Small Crustaceans	2.4	0.12	(62.00)	(310 .90)	(0.95)	0.20
Macrobenthos	2.4	2.09	(6.80)	(27.40)	(0.95)	0.25
Meiobenthos	2.1	2.19	(10.00)	(50.00)	(0.95)	0.20
Zooplankton	2.1	0.66	(67.00)	(280.00)	(0.95)	0.24
Macrobenthic flora	1.0	13.64	(15.35)	–	(0.03)	–
Phytoplankton	1.0	4.45	(71.20)	–	(0.50)	–
Detritus	1.0	(120.00)	–	–	0.40	–

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = ecotrophic efficiency.

Table 4b. Input and output parameters (in parenthesis) of the Ecopath model for Sabah, 1972.

Ecological Group	Trophic level	Biomass ($t \cdot km^{-2} \cdot year^{-1}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Production/ Consumption
Large predators	4.4	(0.23)	0.55	(9.50)	(0.50)	0.06
Tuna	4.4	0.03	(2.00)	(11.64)	(0.50)	0.17
Large zoobenthos feeders	3.4	(0.15)	(0.40)	(6.50)	0.48	0.06
Intermediate predators	3.9	0.25	(1.74)	(8.70)	(0.95)	0.20
Lutjanids	4.0	(0.05)	0.22	(8.70)	(0.95)	0.03
Serranids	4.0	0.01	(1.74)	(8.70)	(0.95)	0.20
Carangids	4.1	0.14	(2.07)	(8.70)	(0.95)	0.24
Flatfishes/Soles	3.5	0.19	(0.85)	(8.70)	(0.95)	0.10
Sciaenids	3.5	(0.31)	1.13	(8.70)	(0.95)	0.13
Small pelagics	3.0	0.32	(2.37)	(7.90)	(0.95)	0.30
Engraulids/Clupeids	3.1	0.34	(2.70)	(7.90)	(0.95)	0.34
Squids	3.1	0.34	(2.05)	(7.90)	(0.95)	0.26
Demersal zoobenthos feeders	3.2	0.80	(2.15)	(10.75)	(0.95)	0.20
Leiognathids	3.2	(1.99)	0.30	(10.75)	(0.95)	0.03
Mullids	3.1	(1.26)	0.43	(10.75)	(0.95)	0.04
Nemipterids	3.3	(0.57)	0.94	(10.75)	(0.95)	0.09
Balistids	3.2	0.16	(2.15)	(10.75)	(0.95)	0.20
Lactarids	3.2	0.24	(2.15)	(10.75)	(0.95)	0.20
Reef associated fish	2.1	0.13	(1.50)	(7.55)	(0.95)	0.20
Octopus/Sepia	2.5	0.10	(3.00)	(12.50)	(0.95)	0.24
Crabs/Lobster	2.9	0.22	(4.00)	(21.90)	(0.95)	0.18
Shrimps	2.8	0.79	(4.00)	(21.90)	(0.95)	0.18
Small Crustaceans	2.4	0.27	(62.00)	(310 .00)	(0.95)	0.20
Macrobenthos	2.4	4.75	(6.80)	(27.40)	(0.95)	0.25
Meiobenthos	2.1	4.85	(10.00)	(50.00)	(0.95)	0.20
Zooplankton	2.1	1.50	(67.00)	(280.00)	(0.95)	0.24
Macrobenthic flora	1.0	29.76	(15.35)	–	(0.03)	–
Phytoplankton	1.0	10.06	(71.20)	–	(0.50)	–
Detritus	1.0	(120.00)	–	–	–	–

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = ecotrophic efficiency.

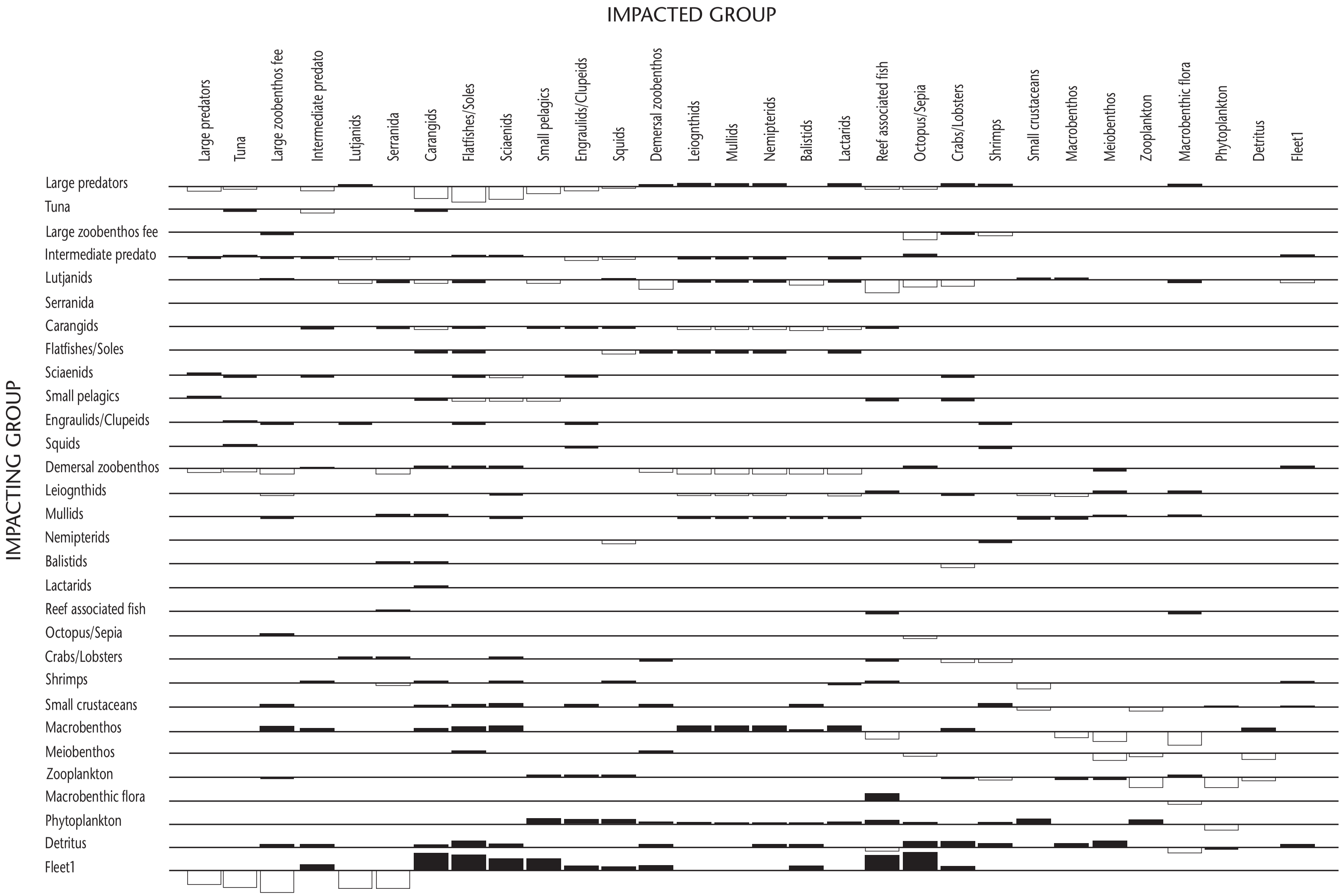

Fig. 3. Mixed trophic impacts in the Sarawak Ecopath model. The graph shows the direct or indirect trophic impacts the groups to the left (rows) have on the groups mentioned above (columns). Positive impacts are shown above the baseline, and negative below. The impacts are relative but comparable between groups.

The summary statistics of the trophic models for Sabah and Sarawak are presented in Table 5. Total throughput is estimated at 3 152 t•km^{-2}•year^{-1} for the trophic model for Sabah and 14 14 t•km^{-2} •year^{-1} for Sarawak. Mean trophic level of the fishery is 3.33 and 3.38, respectively. Biomass estimates for the various trophic levels (excluding detritus) for Sabah is 59.8 t•km^{-2}, and 27.2 t•km^{-2} for Sarawak. The relatively higher biomass in Sabah waters may justify the relatively higher fishery catches (see Table 2) compared to Sarawak. In addition, the sum of all production is also relatively higher in Sabah than Sarawak. It is interesting to note that the 1972 levels in biomass and production in these areas are comparable to the values obtained from the Ecopath model for Brunei Darussalam coastal fisheries (Silvestre et al. 1993), in which the ecosystem was considered as a system under a low level of fishing.

Other derived parameters indicate that the coastal ecosystem in the study areas is in a stage of development. These include: (1) a P/R ratio greater than 1; (2) relatively high net system production (Sabah: 605 t•km^{-2} and Sarawak: 273 t•km^{-2}); and (3) P/B ratio greater than 1. Moreover, these indicators may suggest that the system has been under a moderate level of exploitation. Generally this situation can drive development of the system back to earlier stages (Odum 1971).

Table 5. Summary of ecosystem parameter values for Ecopath models.

Parameter	Sabah	Sarawak
Sum of all consumption (t•km^{-2}•year^{-1})	972.4	434.6
Sum of all exports (t•km^{-2}•year^{-1})	605.5	273.0
Sum of all respiratory flows (t•km^{-2}•year^{-1})	567.7	253.4
Sum of all flows into detritus (t•km^{-2}•year^{-1})	1 006.4	453.3
Total system throughput (t•km^{-2}•year^{-1})	3 152.0	1 414.0
Sum of all production (t•km^{-2}•year^{-1})	1 383.0	616.0
Calculated total net primary production (t•km^{-2}•year^{-1})	1 173.2	536.4
Net system production (t•km^{-2}•year^{-1})	605.5	273.0
Total primary production/total respiration	2.07	2.08
Total primary production/total biomass (year^{-1})	19.62	19.37
Total biomass/total throughput (year)	)0.02	0.02
Total biomass (excluding detritus) (t•km^{-2})	59.8	27.2
Mean trophic level of the fisheries catch	3.33	3.38
Total catches (t•km^{-2}•year^{-1})	1.32	0.21
Gross efficiency (catch/net primary production)	0.0011	0.0004
Connectance Index	0.27	0.27
System Omnivory Index	0.22	0.22

It is suggested that these Ecopath models be utilized with time series information (e.g. catch data or CPUE) and that estimates (e.g. biomasses) be evaluated from fishery-independent surveys. As highlighted earlier, the Ecosim routine of the EwE software permits evaluation of the effects of changes in the ecosystem (such as a change in the fishery and any other measurable change such as nutrient loading or pollution) to be accurately simulated and the outcome predicted. In addition, the models can be used for temporal analysis and in understanding the declines in biomass and the associated changes in species composition due to the increased intensity of fishing from 1972 to the present.

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Appendix A. Taxonomic composition of the 29 ecological groups of the Sabah and Sarawak Ecopath models.

Ecological Group	Local name	English name	Family
Large Predators	Yu	Grey reef shark	Carcharhinidae
	Mersuji	Black marlin	Istiophoridae
Tuna	Aya/Tongkol	Longtail tuna	Scombridae
	Tenggiri	Indo-Pacific Spanish mackerel/Spotted Spanish mackerel	Scombridae
Large zoobenthos feeders	Pari	Pale-edged ray	Dasyatidae
	Aruan tasik	Black kingfish	Rachycentridae
Intermediate predators	Siakap	Barramundi/Giant seaperch	*Lates Calcarifes*
	Duri/Pulutan	Engraved catfish	Ariidae
	Duri/Jahan	Giant catfish	Ariidae
	Pedukang	Sea catfish	Ariidae
	Malong	Dagger tooth pike conger/Silver conger eel	Muraenesocidae
	Kaci	Painted sweetlips	Plectorhynchidae
	Semilang	Canine catfish eel	Plotosidae
	Kurau	Fourfinger threadfin	Polynemidae
	Ikan bulu	Blackhand paradise fish	Polynemidae
	Parang	Dorab wolf-herring	Chirocentridae
	Timah	Hairtail	Trichiuridae
	Gerut-gerut	Lined silver grunter	Pomadasyidae
	Alu-alu	Banded barracuda/Slender sea pike	Sphyraenidae
Lutjanids	Merah	Malabar red snapper	Lutjanidae
	Jenahak	John's snapper/Giant snapper	Lutjanidae
	Kerisi bali	Sharptooth snapper	Lutjanidae
	Remong	Bigeye snapper	Lutjanidae
Serranids	Kerapu	Six-banded grouper	Serranidae
Carangids	Bulan	Indo-Pacific tarpon	Carangidae
	Cermin	Horse mackerel/Malabar cavalla	Carangidae
	Cincaru	Hardtail scad	Carangidae
	Demudok	Blue trevally	Carangidae
	Jamah	Bigeye trevally	Carangidae
	Pisang-pisang	Rainbow runner	Carangidae
	Selunsong	Trevally	Carangidae
	Talang	Queenfish/Slender leatherskin	Carangidae

Appendix A. Taxonomic composition of the 29 ecological groups of the Sabah and Sarawak Ecopath models. (continued)

Ecological Group	Local name	English name	Family
Flatfishes/Soles	Lidah/Sebelah	Tongue soles	Psettodidae
Sciaenids	Gelama Panjang/Terusan	Sin croaker Croaker	Sciaenidae Sciaenidae
Small pelagics	Delah Pelata/Selar Selar kuning Selayang Jolong-jolong Kembong	Fusilier Herring trevally Yellowbanded scad Round scad Halfbeak Short bodied mackerel	Caesionidae Carangidae Carangidae Carangidae Hemiramphidae Scombridae
Engraulids/Clupeids	Kebasi Puput Terubuk Empirit Tamban Bilis Bulu ayam Impirang	Chacunda gizzard shad Slender shad/Elongate illisha Toli shad Longtail shad Fringescale sardinella Shorthead anchovy Grenadier anchovy Scaly hairfin anchovy	Clupeidae Clupeidae Clupeidae Clupeidae Clupeidae Engraulidae Engraulidae Engraulidae
Squids	Sotong biasa Sotong kereta/katak/ biasa	Squid Cephalopods	
Demersal zoobenthos feeders	Daun baharu Dengkis Bulus Mengkerong Lumi Sebelah Kerong-kerong Pelandok Belanak Bawal/Kilat Dueh/Bawal putih Dueh/Bawal hitam Dueh/Bawal tambak Kitang Ikan baja Ikan campur Kekapas/Kapas Kering/Lidi	Spotted sicklefish Rabbitfish Silver whiting Greater lizardfish Bombay duck Malayan flounder Large scale therapon Emperor Large scale mullet Pomfret Silver pomfret Black pomfret Chinese pomfret Spotted scad Trash fish Mixed fish Mojarra (long-rayed) Razorfish	Drepanidae Siganidae Sillaginidae Synodontidae Synodontidae Bothidae Theraponidae Lethrinidae Mugilidae Stromatidae Stromatidae Formionidae Stromatidae Scatophagidae Trash fish Mixed fish Gerridae Centriscidae
Leiognathids	Kikek Ikan baja	Common ponyfish Trash fish (~20%)	Leiognathidae Trash fish
Mullids	Biji nangka	Goatfishes	Mullidae
Nemipterids	Kerisi Pasir	Japanese threadfin breams Monocle bream	Nemipteridae Nemipteridae
Balistids	Jebong	Stary triggerfish	Balistidae
Lactarids	Shrumbu	False trevally	Lactariidae

Appendix A. Taxonomic composition of the 29 ecological groups of the Sabah and Sarawak Ecopath models. (continued)

Ecological Group	Local name	English name	Family
Reef Associated Fish	Bayan/Perenchong Pelayak	Parrot fish Ornate wrasse	Scaridae Labridae
Octpus/Sepia	Sotong kereta Sotong katak	Octopus Bobfins squid	– –
Crabs/Lobsters	Ketam Ketam suri Ketam laut Udang karang	Crab Crab Crab Lobster	– – –
Shrimps	Udang besar Udang sedang Udang kecil Uidang putih Udang minyak Udang merah ros Udang kulit keras Udang harimau	Big prawn Medium prawn Small prawn Banana prawn Greasyback prawn Pink prawn Rainbow prawn Tiger prawn	– – – – – –
Small crustaceans	Lain-lain udang/ Udang baring Udang penaeid/ baring	Other prawn/Sergesiid prawn Penaeid prawn/Sergesiid prawn	– –
Macrobenthos	Siput Kerang Tokoyong Ambai Ramin Lokan	Shell Clams Mollusc Mollusc Mollusc Mollusc	
Meiobenthos	–	–	–
Zooplankton	–	–	–
Macrobenthic algae	–	–	–
Phytoplankton	–	–	–
Detritus	–	–	–

An Ecosystem Model of San Pedro Bay, Leyte, Philippines: Initial Parameter Estimates

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Abstract

A mass-balance model of the trophic structure of San Pedro Bay, Leyte Province, Philippines was constructed using the Ecopath modeling software. The model is composed of 16 ecological groups (13 consumer, 2 producers, 1 detritus groups). The input parameters were obtained from the resource assessments studies conducted in 1994 - 95 and the biomass of Leiognathidae, an important group of small demersal fishes was estimated from trawl survey data using the swept-area method. The model indicated that the average trophic level of the fishery catches is 3.25.

Introduction

San Pedro Bay is located in the central Philippines (Fig. 1), with coordinates 125º 00' to 125º 14' N latitude and 11º 05' 30" to 11º 17' 30" E longitude. The bay is bounded on the west by the island of Leyte and on the east by the island of Samar. It has an average depth of about 20 m, with a maximum recorded depth of 36.6 m and an area of approximately 625 km^2 (Armada 1996). The bottom consists primarily of sandy/muddy substrate, with reefs and seagrass beds distributed along much of the coast.

Ecosystem models using the Ecopath software have been presented from several coastal areas in the Philippines, notably Lingayen Gulf (Guarin 1991), San Miguel Bay (Bundy and Pauly 2001; Palomares et al. 1994), Lagonoy Gulf (Garces et al. 1995), Soarsogon Bay (Cinco 1995), and the Bolinao reef ecosystem (Aliño et al. 1993). This paper aims to contribute to this valuable database by analyzing the fisheries resources of San Pedro Bay using the Ecopath with Ecosim software. Various sources of information, particularly the results of the resource assessments in San Pedro Bay in 1994 - 95 were available for this (Armada 1996; Babaran et al. 1997; Batang 1996; Villoso 1996).

Materials and Methods

Modeling Approach

The ecosystem model of San Pedro Bay, Philippines was constructed using the Ecopath with Ecosim (EwE) software following the approach described in (Christensen et al. 2000). Ecopath is a trophic modeling approach that has been used to model a wide variety of aquatic ecosystems (Christensen and Pauly 1993). The method is also used to analyze trophic interactions and state variables (biomasses) derived from quantitative steady state models of aquatic systems (Christensen and Pauly 1992a; Christensen and Pauly 1992b).

Ecopath combines an approach by (Polovina 1984)

for estimation of biomass and food consumption of the various elements (species or groups of species) of an aquatic ecosystem with that of (Ulanowicz 1986) for analysis of flows between the elements of ecosystems. The approach and parameterization is described in detail in Garces et al. (this volume).

Data Sources

The main source of quantitative information used in determining input parameters for the Ecopath model was the results of the Resource and Ecological Assessment Investigations of San Pedro Bay in 1994 - 95, spearheaded by the Institute of Marine Fisheries and Oceanology (College of Fisheries, University of the Philippines in the Visayas). These include reports of (Armada 1996; Babaran et al. 1997; Batang 1996; Villoso 1996) and others. The trawl and fisheries surveys conducted by (Armada 1996), in particular, provided most of the information used in the analyses. The systematic trawl survey, covering 16 stations with monthly sampling, was conducted from June 1994 to May 1995. A total of 192 species of fishes and invertebrates were recorded during the survey, with 9 species of small fishes of the Leiognathi-didae family comprising more than 60% of the total catch.

Other sources of information for deriving many of the input parameters include (Armada 1996) (Aliño et al. 1993) and also include other papers in (Christensen and Pauly 1993; Opitz 1996).

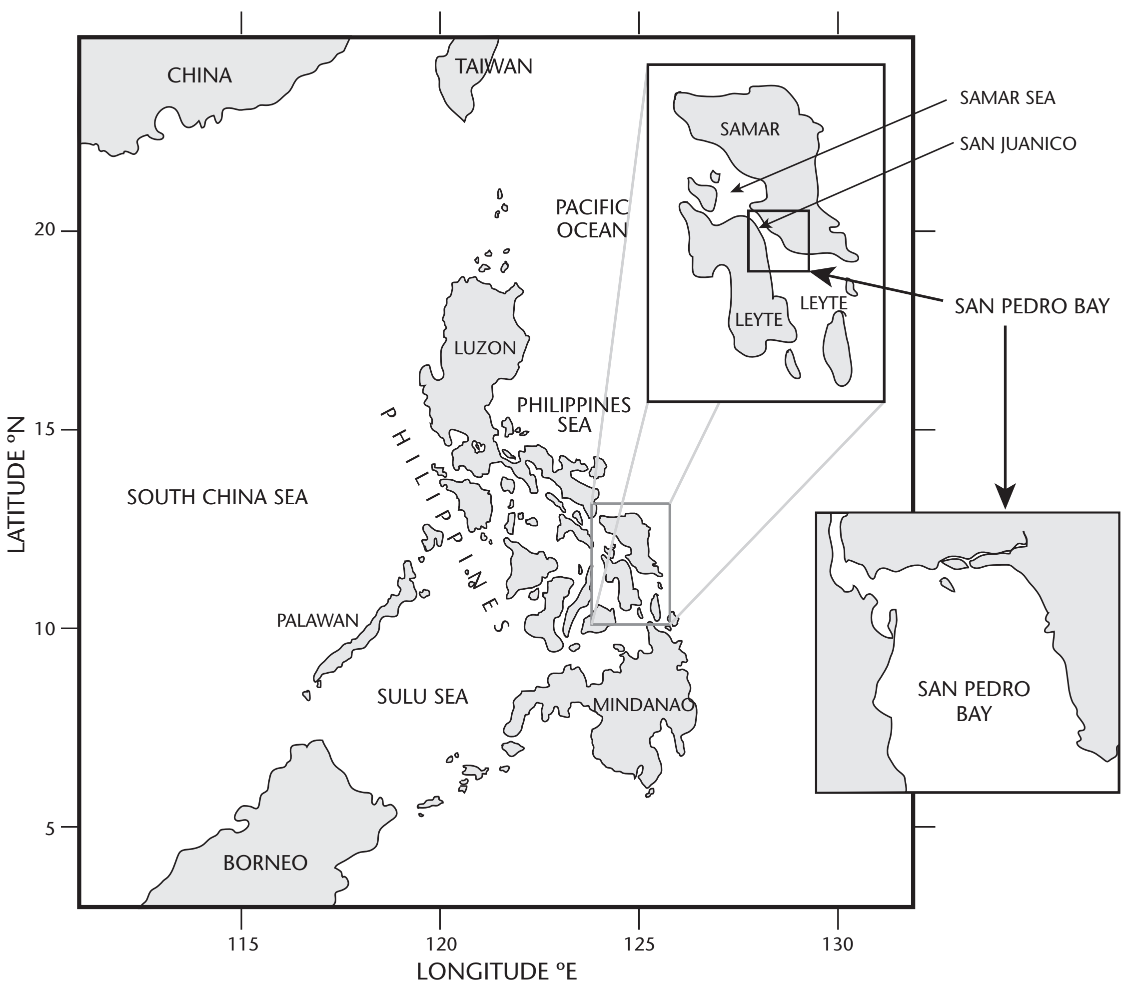

Fig. 1. Map of San Pedro Bay, Leyte, Philippines.

Ecological Groupings

A total of 13 consumer (fishes and invertebrates), 2 producer and 1 detritus groups were used in the analysis. The taxonomic composition of the ecological groups is given in Table 1.

Model Parameters

Biomass

The abundance or density information for most of the groups used in the analyses were either of limited reliability, (e.g. pelagic species caught by trawls), or in a form not readily convertible to biomass, (e.g. numbers without the corresponding species or size information), therefore only two biomass estimates were provided as input into the Ecopath model. These were for Leiognathids and for phytoplankton. The basic input parameters are shown in Table 2.

Using average CPUE values of the trawl survey, average demersal trawlable biomass was estimated at 2.4 $t{\bullet}km^{-2}$, using a catch efficiency of 70% for trawls (Armada 1996), with Leiognathids comprising over 60% of this. The biomass for this group was estimated at approximately 1.5 $t{\bullet}km^{-2}$. For phytoplankton, (Babaran et al. 1997) report a year-round mean chlorophyll *a* concentration of 0.153 $mg{\bullet}l^{-1}$ (n = 9 monthly values, s.d. = 0.121). This is equivalent to a water column concentration of 0.153 $g{\bullet}m^{-2}$. To convert this to the standard unit of measurement used in the model (wet weight in $t{\cdot}km^{-2} = g{\cdot}m^{-2}$), conversion factors reported in the literature were used. A factor of 25 was used to convert g chl *a* to g C (Parsons et al. 1984), while the factors 2.5 and 5 were used to convert g C to g dry weight, then to g wet weight, respectively (Browder 1993). Phytoplankton biomass was thus approximately 48 $t{\bullet}km^{-2}$.

Some biomass information for seagrasses is available from (Batang 1996), but no useful information is available for macroalgae in the bay. Furthermore, the estimated area coverage (in ha) of the major bottom communities, i.e. reefs and seagrass beds (Villoso 1996) appears to be too small to allow meaningful estimates of macrophyte biomass.

Table 1. Taxonomic composition of groups used in the analysis.

Ecological group	Representation taxa
Sharks	Elasmobranchs
Pelagic medium predator	*Auxis* spp, Carangidae, Scombridae, Sphyraenidae, Belonidae
Demersal medium predator	Serranidae, Lutjanidae, Lethrinidae, Pomadasyidae, Sciaenidae
Pelagic small predator	Caesionidae, Carangidae, Hemiramphidae
Demersal small predator	Synodontidae, Acanthuridae, Nemipteridae, flatfish, reef associated fish, Teraponidae
Demersal Small omnivores	Mullidae, Gerreidae, reef associated fish
Ponyfish	Leiognathidae
Squid	Squid, cuttlefish & octopus
Pelagic planktivore	Clupeidae, Engraulidae
Macroepifauna	Macrocrustaceans, echinoderms, etc.
Benthic infauna	Polychaetes, mollusks, etc.
Zooplankton	
Demersal herbivores	Siganidae
Phytoplankton	
Macrophytes	Seagrasses & seaweeds
Detritus	

Table 2. Basic input parameter values used in the analysis.

Ecological group	Biomas ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Catch ($t \cdot km^{-2} \cdot year^{-1}$)
Sharks		1.0	4.0	0.75	0.14
Pelagic medium predator		3.5	10.0	0.50	0.35
Demersal medium predator		3.5	12.5	0.80	0.58
Pelagic small predator		3.5	17.5	0.80	0.61
Demersal small predator		4.0	15.0	0.90	1.47
Demersal small omnivores		4.0	15.0	0.90	0.62
Ponyfish	1.5	4.0	17.5	0.90	1.16
Squid		3.0	15.0	0.80	0.31
Pelagic planktivore		3.5	20.0	0.95	0.73
Macroepifauna		2.5	24.0	0.95	0.83
Benthic infauna		5.0	20.0	0.95	0.07
Zooplankton		35.0	150.0	0.95	–
Demersal herbivores		2.0	10.0	0.95	0.37
Phytoplankton	48.0	140.0		0.80	–
Marcophytes		15.0		0.50	–
Detritus					

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomas ratio, EE = ecotrophic efficiency.

Other Input Parameters

Values for most of the other input parameters were taken from different sources, including description of other ecosystem models in (Christensen and Pauly 1993). Estimates of total mortalities (Z) for representatives of the various fish groups were used as first approximations of the P/B ratios, while P/B ratios for the invertebrate and other consumer groups were based on turnover rates reported in the literature (Christensen and Pauly 1993). Turnover rates for seagrasses and macroalgae were taken from (Aliño et al. 1993). Initial estimates for phytoplankton were derived using mean primary production rates for Pacific shelf areas (= 0.52 g $C \cdot m^{-2} \cdot day^{-1}$; Mann 1982), the relevant conversion factors mentioned above, and the phytoplankton biomass estimate for the study area was 48 $g \cdot m^{-2}$ wet weight.

Consumption rates (Q/B; $year^{-1}$) were computed based on assumed gross efficiency rates ranging from 0.2 to 0.3 (Aliño et al. 1993). Initial EE values were all assumed. A range of 0.90 to 0.95 was assumed for groups 5 to 14, since it is believed that production in these groups is consumed (via predation and fishery harvest) almost entirely within the system. Slightly lower EE values were assumed for groups capable of more mobility, (e.g. pelagics and large demersal predators). A few initial runs were conducted to balance the model. The basic input parameters shown in Table 2 are those that lead to a balanced model.

Fishery Catch

Catch data for the various groups used in the analyses were taken from (Armada 1996). Total catch for the various gear types employed in the bay collectively amount to an annual average of 7.24 t•km^{-2}•year^{-1}.

Diet Composition

Data for diet compositions were taken from unpublished gut content studies, FishBase (Froese and Pauly 2000), and from reports in the literature (Aliño et al. 1993; Opitz 1996; Silvestre et al. 1993); the diet composition data used are given in Table 3.

Table 3. Diet composition of the 13 ecological groups used in the Ecopath analysis. Predator numbers refer to the prey numbers. See Table 1 for definition of groups.

	Predator												
Prey	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Sharks	0.050	0.001	–	–	–	–	–	–	–	–	–	–	–
2 Pelagic medium predator	0.325	0.150	0.010	0.010	–	–	–	0.010	–	–	–	–	–
3 Demersal medium predator	0.075	0.140	0.030	0.028	–	–	–	–	–	–	–	–	–
4 Pelagic small predator	0.100	0.180	0.050	0.050	–	–	–	0.010	–	–	–	–	–
5 Demersal small predator	0.075	0.050	0.072	0.010	0.012	–	–	0.005	–	–	–	–	–
6 Demersal small omnivores	0.075	0.050	0.062	0.010	0.013	0.005	–	0.005	–	–	–	–	–
7 Ponyfish	0.100	0.030	0.035	0.020	0.053	0.042	0.050	0.005	–	–	–	–	–
8 Squid	0.075	0.020	0.025	0.056	0.010	0.010	0.008	0.020	–	–	–	–	–
9 Pelagic planktivore	0.050	0.212	0.038	0.250	–	–	–	0.060	–	–	–	–	–
10 Macroepifauna	0.050	–	0.300	0.046	0.362	0.352	0.049	0.300	–	–	–	–	0.094
11 Benthic infauna	–	–	0.263	0.205	0.250	0.300	0.383	0.160	–	0.375	0.050	–	0.094
12 Zooplankton	–	0.167	0.075	0.230	0.300	0.167	0.410	0.400	0.650	0.050	0.175	0.200	0.072
13 Demersal herbivores	–	–	0.010	0.005	–	–	0.005	–	–	–	–	–	0.010
14 Phytoplankton	–	–	–	0.080	–	–	0.048	–	0.200	–	0.025	0.700	0.014
15 Marcophytes	–	–	–	–	–	0.044	–	–	–	–	–	–	0.684
16 Detritus	0.025	–	0.030	–	–	0.080	0.047	0.025	0.150	0.575	0.750	0.100	0.032

Results and Discussion

Trophic Model

Figure 2 presents the trophic structure of the coastal fisheries of San Pedro Bay as defined here.

The basic estimates are shown in Table 4, while a summary of the estimated ecosystem parameter values are presented in Table 5. Figure 3 presents a mixed trophic impact analysis for the ecosystem, i.e. it quantifies all direct and indirect trophic impacts (predation, competition or fishing), and also can be seen as a sensitivity analysis.

The biomass estimates for the small pelagic groups are rather close to the initial estimate for Leiognathids, the dominant group among demersal fishes. Pelagic small predators (1.24) and squid (1.01) have biomass estimates slightly less than the dominant group, while the estimate for pelagic planktivores (2.68 t•km^{-2}), is about 80% higher than that for Leiognathids.

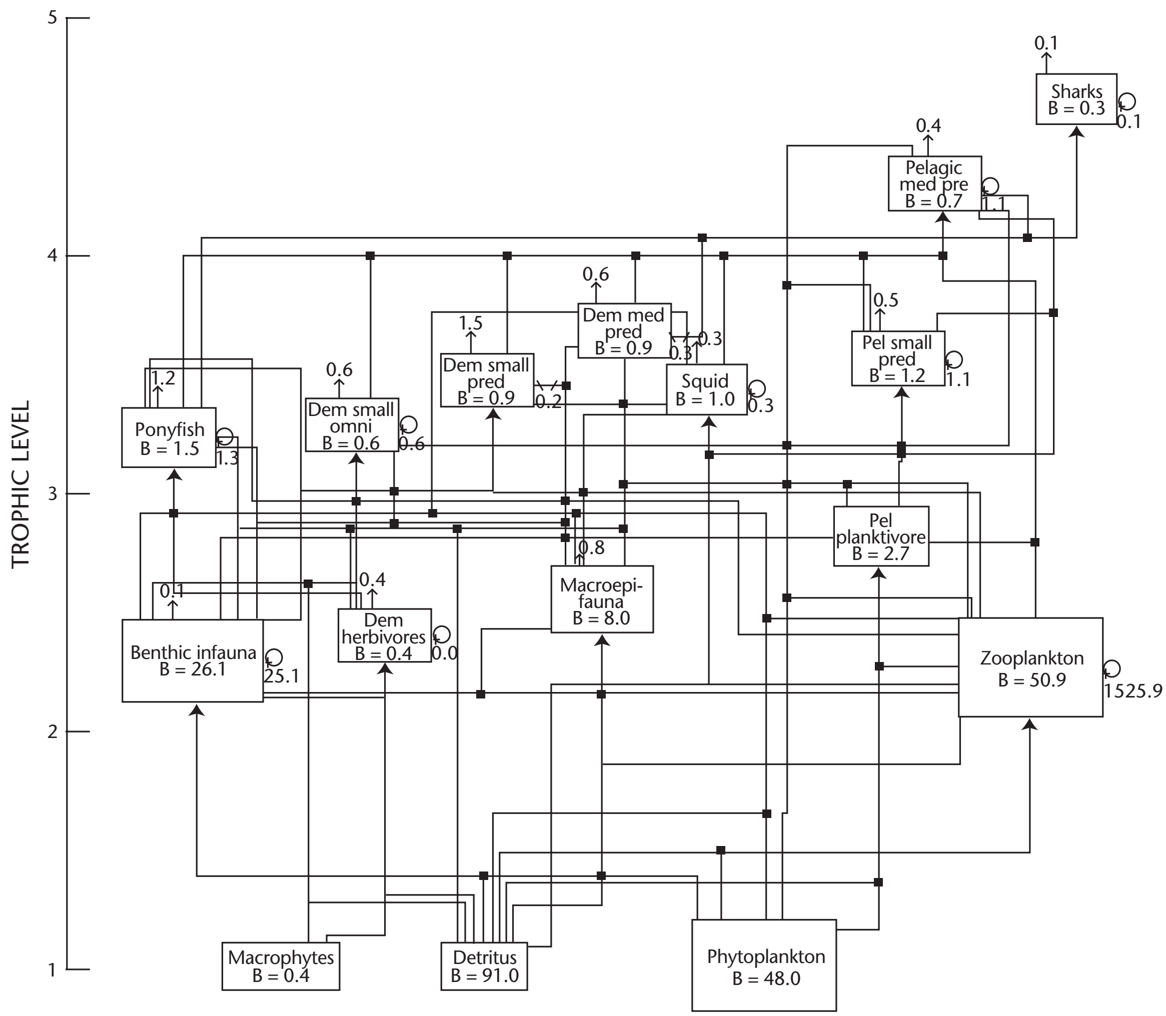

Fig. 2. Flow chart of the food web of San Pedro Bay, Philippines. Only flows exceeding 0.1 t·km^{-2}·year^{-1} are shown. The groups are arranged by trophic level on the Y-axis, and the size of the boxes is a function of the group biomass.

Table 4. Parameter inputs and outputs (in parentheses) from the Ecopath analysis.

Ecological group	Biomas ($t{\cdot}km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	Annual landing ($t{\cdot}km^{-2}{\cdot}year^{-1}$)	Tropic Level	Omnivory Index
Sharks	(0.27)	1.0	4.0	0.75	0.14	(4.6)	(0.48)
Pelagic medium predators	(0.73)	3.5	10.0	0.89	0.35	(4.3)	(0.41)
Demersal medium predators	(0.88)	3.5	12.5	0.85	0.58	(3.7)	(0.33)
Pelagic small predators	(1.24)	3.5	17.5	0.88	0.61	(3.5)	(0.42)
Demersal small predators	(0.86)	4.0	15.0	0.92	1.47	(3.5)	(0.08)
Demersal small omnivores	(0.60)	4.0	15.0	0.95	0.62	(3.3)	(0.28)
Ponyfish	1.50	4.0	17.5	0.79	1.16	(3.2)	(0.21)
Squid	(1.01)	3.0	15.0	0.91	0.31	(3.4)	(0.16)
Pelagic planktivore	(2.68)	3.5	20.0	0.97	0.72	(2.8)	(0.36)
Macroepifauna	(8.01)	2.5	24.0	0.96	0.83	(2.5)	(0.40)
Benthic infauna	(26.14)	5.0	20.0	0.95	0.07	(2.3)	(0.28)
Zooplankton	(50.86)	35.0	150.0	0.95	0.0	(2.2)	(0.25)
Demersal herbivores	(0.38)	2.0	10.0	1.00	0.37	(2.4)	(0.37)
Phytoplankton	(48.00)	140.0	(0.0)	0.80	0.0	(1.0)	(0.0)
Marcophytes	(0.40)	15.0	(0.0)	0.50	0.0	(1.0)	(0.0)
Detritus	0	–	–	(0.41)	0.0	(1.0)	(0.41)

Note: P/B = Production/Biomass ratio, Q/B = Consumption/Biomass ratio, EE = Ecotrophic efficiency.

Table 5. Summary of ecosystem parameter values.

Parameter	Value
Sum of all consumption:	8 519.19
Sum of all exports:	1 879.81
Sum of all respiratory flows:	4 846.14
Sum of all flows into detritus:	3 150.90
Total system throughput:	18 396.03
Sum of all production:	8 695.16
Calculated total net primary production:	6 725.94
Net system production:	1 879.81

Parameter	Value
Total primary production/total respiration:	1.39
Total primary production/total biomass:	46.81
Total biomass/total throughput:	0.008
Total biomass (excluding detritus):	143.67
Total catches:	7.24
Gross efficiency (catch/net p.p.):	0.0011
Connectance Index:	0.45
System Omnivory Index:	0.29

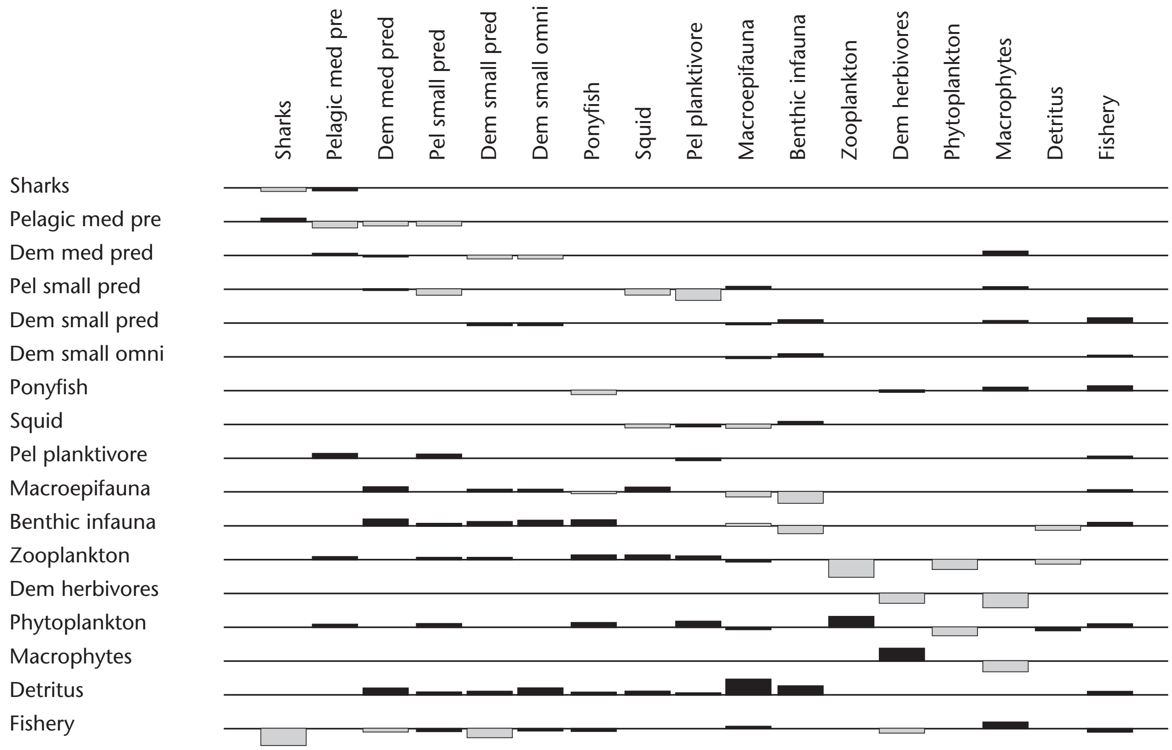

Fig. 3. Mixed trophic impacts in Pedro Bay ecosystem, Philippines. The graph shows the direct or indirect trophic impacts the groups to the left (rows) have on the groups mentioned above (columns). Positive impacts are shown above the baseline, and negative below. The impacts are relative but comparable between groups.

Under the steady state assumption, estimates of total mortality (Z) are reasonable estimates of turnover rates (P/B ratios). Almost all stock assessment results for the Philippines (Armada 1994; Armada 1996; Armada et al. 1983; Federizon 1993; Silvestre et al. 1991; Silvestre et al. 1987; Silvestre et al. 1994) show high total mortality (Z) estimates for the fish groups, reflecting heavy exploitation of the various fishing grounds. Productive ecosystems are able to maintain high energy flows (productivity) with fast turnover rates, even if biomass levels are quite low. The P/B ratios used in the present analyses are consistent with the assessment of (Armada 1996) that the annual total catch from the bay amounts to three (3) times the estimated biomass. Compared with other investigations, however, biomass estimates for San Pedro Bay are comparable to those in less exploited coastal areas in the region, (e.g. Brunei Darussalam, (Silvestre et al. 1993). It appears that San Pedro Bay still maintains a high fishery potential (using biomass as an indicator of harvestable amount) in spite of what appears to be heavy fishing pressure (Armada 1996). This is similarly suggested by the mortality coefficients (Table 6) computed using data on food consumption, assumed ecotrophic efficiencies, harvested amounts, and employed turnover rates. Except for groups 1 (sharks), 5 (demersal small predators) and 13 (demersal herbivores), derived exploitation rates are generally below 0.25%, which is not consistent with a conclusion of heavy exploitation. This indicates that the assumption of steady state conditions may be unrealistic for San Pedro Bay.

Ecosystem Characteristics

A summary of the statistics are presented in Table 5. Total throughput is estimated at 18 396 t•km^{-2}•year^{-1}. Biomass estimates for the various trophic levels are shown in Table 7, with a total value of 144 t•km^{-2} (excluding detritus). Hence the total amount of (potential) energy that passes through the system (consumption plus exports) is about 128 times the estimated biomass of the living components, a value very close to the P/B ratio derived by the model for the phytoplankton. Using the empirical

Table 6. Instantaneous mortality coefficients (year^{-1}) computed for the various groups. (Z refers to total mortality which, under steady state conditions, is approximated by production/biomass ratio; F refers to fishing mortality and is based on fishery harvest estimates; E is the exploitation rate which is equal to F/Z; M2 and M0 refer to components of natural mortality due to predation and other causes, respectively).

Ecological group	Z	F	E	M0	M2
Sharks	1.0	0.52	0.52	0.25	0.23
Pelagic medium predators	3.5	0.48	0.14	0.38	2.64
Demersal medium predators	3.5	0.66	0.19	0.54	2.30
Pelagic small predators	3.5	0.49	0.14	0.42	2.59
Demersal small predators	4.0	1.72	0.43	0.31	1.97
Demersal small omnivores	4.0	1.04	0.26	0.21	2.75
Ponyfish	4.0	0.77	0.19	0.84	2.39
Squid	3.0	0.31	0.10	0.27	2.42
Pelagic planktivore	3.5	0.27	0.08	0.12	3.11
Macroepifauna	2.5	0.10	0.04	0.11	2.29
Benthic infauna	5.0	0	0	0.25	4.75
Zooplankton	35.0	0	0	1.75	33.25
Demersal herbivores	2.0	0.97	0.49	0	1.03
Phytoplankton	140.0	0	0	28.00	112.00
Marcophytes	15.0	0	0	7.50	7.50

formula of (Pauly et al. 1993), biomass of detritus is estimated at about 259 t•km^{-2}, about 1.8 times the total biomass estimated for all living components. Interestingly, only 27% of the total throughput originates from detritus, while the rest is derived primarily from phytoplankton production (Table 8). The latter is consistent with the resulting high biomass estimates of pelagic groups.

Other derived parameters are indicative of an ecosystem in a stage of development, and therefore inconsistent with steady-state (mature) conditions (Odum 1971). These include a relatively high P/R ratio (1.39), relatively high net system production

Table 7. Biomass estimates per trophic level.

Trophic Level	Biomass (t·km^{-2})
Level I	48.40
Level II	78.52
Level III	13.90
Level IV	2.45
Level V	0.36
Level VI	0.04
Level VII	< 0.01

Table 8. Flow estimates (total consumption, exports, flows to detritus, and respiration) originating from detritus and primary producers. Units are $t \cdot km^{-2} \cdot year^{-1}$.

Flow	Detritus	Primary producers	Combined
Total consumption	1 402	5 555	6 957
Export	1 876	3	1 879
Flow to detritus	342	2 808	3 150
Respiration	931	3 914	4 846
Throughput	4 553	12 281	16 834
% contribution to total throughput	27.0	73.0	

($1\ 880\ t \cdot km^{-2} \cdot year^{-1}$) or export in comparison with other coastal areas, low biomass to throughput ratio (0.008), high respiration to biomass ratio (33.7), relatively low omnivory index (0.29), and high overhead from internal flow (57.4% of total capacity). These indicators are consistent with a system where moderate (or tolerable) exploitation generally drives back development to earlier stages (Odum 1971).

While the results of the modelling effort are only preliminary, valuable insights are provided. Of special interest is the high system throughput to biomass ratio (128 $year^{-1}$), which reflects the high model-derived turnover rate for phytoplankton (140 $year^{-1}$). This suggests that the system is essentially phytoplankton-based. San Pedro Bay lies in the interior of the larger Leyte Gulf, which opens into the Pacific Ocean, and is linked to the Samar Sea further north via the San Juanico Strait between the islands of Leyte and Samar. It is thus likely that a considerable amount of water is exchanged between these two much larger bodies of water through the bay. As such, considerable inputs and exports (immigration and emigration) can be expected, particularly from pelagic groups. This is consistent with the estimated large net export of the bay. Hence, the derived high phytoplankton turnover rate reflects the magnitude of water exchange (input and export) passing through the bay. It is therefore possible that the apparent lower fishery catches of pelagic groups in San Pedro Bay may be due to movement, in and out of the area.

Fisheries Management Implications

The major interesting result from the analyses is that San Pedro Bay does not appear to be as heavily exploited, as the employed P/B ratios (= Z) would imply. In comparison to other trawl fishing grounds in the country, (Armada 1996) showed that current extraction rates in San Pedro Bay (3 times existing biomass) are lower than those in other traditional fishing grounds such as Manila Bay and San Miguel Bays and Lingayen Gulf. The results also indicate that the fisheries potential for pelagic species groups might be higher than currently considered. However, it should be clear that increased fishing will lead to increased 'fishing down the food web' and that catch will be increasingly dominated by less valuable low trophic level species and variability, sending a warning that increased fishing effort may be problematic.

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Trophic Model of the Coastal Fisheries Ecosystem in the Gulf of Thailand

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Abstract

The biomass of 40 ecological groups, the diet composition of prey and predators, production/biomass (P/B) and consumption/biomass (Q/B) ratios, and catches were used as basic input to parameterize an Ecopath model of the Gulf of Thailand. Following construction of a mass-balance ecosystem model, a time-dynamic simulation model (Ecosim) was used to simulate the impact of change in fishing effort. This was done using time series data to validate the historic fisheries development in the Gulf of Thailand prior to using the model for forward-looking simulations. The time series data used in the analyses were catch and effort data from research vessel trawl surveys and landings data for six groups of fishing gear operating in the Gulf during the period 1973 to 1993. The fish market price and fixed and variable costs of each fleet (as well as profit) were also used as input for the time-series simulations using Ecosim. The results depict changes in biomass and trophic interactions in time (Ecosim) and space (Ecospace). The model was also used to investigate management options or measures for the fisheries of the Gulf of Thailand. Recommendations for future studies using Ecopath with Ecosim are also presented.

Introduction

Trawl surveys were conducted by the Marine Fisheries Division to monitor marine resource trends since the introduction of otter board trawling in 1960 (Tiews 1962). From 1960 to 1965, the trawl surveys were done in selected areas for specific purposes. Since 1966, the Gulf of Thailand has been divided into nine areas, Area I to Area IX. About 500 stations or grids were designed, each station representing 225 nm^2 (15•15 nm). The early surveys were conducted by research vessels (Pramong 2 and Pramong 9) on a monthly basis every year. Station numbers of surveys were different in each year. Recently, the number of stations was reduced to about 50 due to the expenses connected with operating research vessels. From the year 1994 onwards, the surveys were conducted every two months, with daytime and night time operations alternating between years. In 1995, data collected by research vessels were daytime operations. In this study, the study area is the coastal area of

the Gulf of Thailand. Survey data collected during 1973 to 1995 are used in the analysis.

The study area is located between 6º N to 13º 30' N latitudes and 99º E to 104º E longitudes with a seabed area of 304 000 km^2 (Fig. 1). The Gulf of Thailand is relatively shallow with a mean depth of about 58 m. The distance from each station to shoreline ranges from 3.5 to 43 nm. The water depth of trawling stations ranges from 14 - 50 m with an average of 30 m. The Gulf of Thailand is affected by two strong monsoon winds, the Northeast Monsoon (October to February) and the Southwest Monsoon (May to October). Monsoon winds and tidal currents create complex water circulation patterns and local upwelling. The flow in the inner Gulf is clockwise during the Northeast monsoon and counterclockwise during the Southwest monsoon. The velocity of water current in 1994 and 1995 was 0.0 - 53.0 cm•s^{-1} with an average of 17.6 cm•s^{-1} (Musikasung et al. 1995). Heavy rainfall occurs during October to December ranging between 182 and 2 613 mm, and during June to August the range was 62 - 357 mm (Department of Meteorology (Thailand), 1995). In 1995, water temperature range was 27.8 - 30.0º C with an average of 29º C. Dissolved oxygen ranged from 4.5 to 6.6 mg•L^{-1}, with an average of 5.8 mg•L^{-1} (Naval Hydrographic Department 1995). Water salinity in the outer part of the Gulf ranges from 31.4 to 32.7 ppt, it is lower in the inner part due to freshwater inflow.

There are numerous nutrient-rich rivers which run into the Gulf of Thailand, notably, the: Chao Phraya, Tachin, Bangpakong and Mae Khlong rivers in the inner Gulf. Other rivers in the Eastern and Southern Gulf are Walu in Trad; Rayong river, Phetchaburi river, Lang Suan river in Chumphon; Tapi in Surat Thani; and Songkhla, Pattani and Kolok river in Narathiwas. An advantage for fisheries development in the Gulf (especially trawl fisheries) is the shallow continental shelf with a mean water depth of 45 m, and that the bottom substrate consists of loose mud, soft mud, sandy mud, muddy sand and sand (Naval Hydrographic Department 1995; Shepard et al. 1949).

The Gulf of Thailand functions as a two-layered shallow estuary with lower-salinity surface water flowing out of the Gulf, while high-salinity and colder water entering from the South China Sea. In the Gulf of Thailand, as elsewhere, primary production is high in coastal areas near river mouths, and decreases with depth and distance from the shoreline. In 1995, chlorophyll-a ranged from 0.77 to 13.42 mg•l^{-1}, with an average of 5.2 mg•l^{-1} nearshore. The offshore water 2 km from the shoreline had 1.63 mg•L^{-1} chlorophyll-a (Musikasung et al. 1995). Average primary production is 2.49 gC•m^{-2} •day^{-1} in the inner gulf and 2.96 gC•m^{-2}•day^{-1} offshore. The concentration of phosphate in the inner gulf ranged from 1.02 to 1.59 mg-at N•l^{-1} from 1984 to 1989. Nitrate concentration ranged from 9.15 mg-at N•l^{-1} in 1984 to 24.86 mg-at N•l^{-1} in 1989 (Suvapepun 1991).

In 1996, total marine landings from the Gulf amounted to 1.904 million t or about 70% of the country's total production from marine capture fisheries. Landings consisted of 33.1% pelagic fish, 12.4% demersal fish, 31.7% trashfish*, 5.4% shrimps, 6.1% squids and cuttlefish and 11.4% others. The value of each category accounted for 28.0%, 14.3%, 5.9%, 16.1%, 21.3%, and 14.4% respectively (Department of Fisheries (Thailand) 1999a). The number of registered fishing gears in Thailand in 1996 was 17 950, which consisted of 6 840 otter board trawl (38.1%), 2 179 shrimp gill net (12.1%), 1 843 pair trawl (10.3 %), 1 747 squid cast net (9.7%), 1 482 crab gill net (8.3%), 1 327 purse seine (7.4%), 872 fish gill net (4.9%), 722 push net (4.0%), 289 beam trawl (1.6%) and 649 others (3.6%) (Department of Fisheries (Thailand) 1999b).

Trawl surveys in the Gulf of Thailand showed a decreasing trend in CPUE from 1966 to 1995. In 1966, the CPUE was 172.9 kg•hr^{-1}. A sharp decline occurred from 1966 to 1975 with CPUE going down to 61.5 kg•hr^{-1}. From 1975 to 1983, the rate of decrease slowed with the CPUE going down to about 50 kg•hr^{-1}; and slightly increased in 1984 to 62.1 kg•hr^{-1}. Thereafter, the CPUE continuously declined and reached a minimum of 21.5 kg•hr^{-1} by 1995.

A number of ministerial laws and regulations have been issued in response to the marine resources situation in the Gulf of Thailand, this include Department of Fisheries (Thailand) 1997:

* Trashfish is used to include fishes with little value in the fresh fish market. It includes juveniles or undersized individuals of "economically valuable" species, as well as fishes not prefered for human consumption.

- Prohibition of motorized trawl and push net fishing within 3 km of the shoreline was issued on July 29, 1972;
- Prohibition of coral and coral reef fishing was issued on January 10, 1978;
- Prohibition of squid fishing using light attraction with mesh sizes of less than 3.2 cm was issued on November 5, 1981;
- Prohibition of landing any berried crabs *(Scylla serrata, Portunus pelagicus, Charybdis ferriatus)* was issued on July 11, 1983;
- Prohibition of fishing all species of marine turtles including their eggs was issued on March 13, 1989;
- Prohibition of purse seine fishing with light attraction and with mesh size of less than 2.5 cm was issued on November 14, 1991;
- Prohibition of any fishing using light attraction with mesh size less than 2.5 cm was issued on March 15, 1966. Anchovy fishing boats with sizes (LOA) of less than 16 m as well as lift net and 'drop net' were exempted from the regulation;
- Requirement that shrimp trawls should install and use Turtle Excluding Device for fishing was announced on September 16, 1996;
- Prohibition of motorized push net fishing in Pattani Gulf and the coastal area of Pattani Province was issued on February 26, 1998;
- Prohibition of ''drop net' and lift net with light targeting anchovy in the area of Songkhla Province was issued on July 28, 1998 (Songkhla Provincial Office 1998).

Exemption from these regulations can be granted only to activities involving scientific research upon approval of the Director-General of the Department of Fisheries.

The objectives of this study are to use Ecopath with Ecosim to depict changes in biomass and trophic interactions over time (Ecosim) and space (Ecospace), as well as to simulate the likely impacts of the following management directions:

1. Effect of a push-net fishery ban;

2. Effect of a stop to fishing of four juvenile fish groups and trashfish;

3. Effect of a stop to fishing of four juvenile fish groups combined with push-net fishery ban;

4. Optimization of fishing effort considering the impacts on fish community structure and yields.

5. Preferred effort levels for fishing fleets incorporating economic, social and ecosystem considerations.

Materials and Methods

Basic Model Parameterization

A total of 40 ecological groups were used to model the coastal fisheries ecosystem in the Gulf of Thailand. The groups are given in Table 1 along with the basic input parameters for the model. The catch-per-unit of effort (CPUE in $kg \cdot hr^{-1}$) from trawl surveys (using the research vessels Pramong 2 and Pramong 9) in the Gulf of Thailand for 1973 to 1995 were used to estimate biomass. Only day light hauls were included, and the trawl stations are indicated as numbers in Fig. 1. The biomass (B) was estimated using the swept area method Sparre and Venema 1992, viz:

$$B = \frac{\overline{CPUE}}{a \cdot X_1} \cdot A \qquad (1)$$

where:
$\overline{CPUE}$ is mean CPUE ($kg \cdot hr^{-1}$); A is the total areas (101 384 km^2); a is the area swept by the trawl per hr (0.09029 km^2); and X_1 is the proportion of fish in path of the gear retained by the net (0.5).

The swept area was estimated from the equation:

$$a = t \cdot v \cdot h \cdot X_2 \qquad (2)$$

where:
t is the time spent trawling (= 1 hr); v is the trawling velocity (= 2.5 knots); h is the head rope length of the trawl (= 39 m); and X_2 is the effective width of the trawl relative to the headrope length (= 0.5).

The intake of food by species or group of species was estimated from an empirical equation for estimation of consumption to biomass ratio (Q/B; $year^{-1}$) for finfishes (Palomares and Pauly 1989):

$$Q/B = 3.06 \cdot W_{\infty}^{-0.2018} \cdot T_c^{0.6121} \cdot A_r^{0.5156} \cdot 3.53^{Hd} \qquad (3)$$

where:
T_c is the mean habitat temperature (in this study equal to 29º C); W_∞ is the asymptotic weight of the fishes (maximum weight of fish in adjacent countries obtained from FishBase were used in case no W_∞ was available); A_r is the aspect ratio of the caudal fin of the species/group; and H_d is the food type (0 for carnivores and 1 for herbivores and detritivores).

The aspect ratio of 26 species (Appendix A) of fish was measured by projecting a line along the horizontal axis of the fish body and taking measurements at right angle to the line (Pauly 1989; Sambilay 1990). Specimens were collected at the Songkhla landing place in December 1998. The aspect ratio is defined as:

$$A = h^2 / s \qquad (4)$$

where:
h is the height; and s is the surface area of the caudal fin.

In cases where the aspect ratio is unavailable, Q/B was estimated from:

$$Q/B = 10^{6.37} \cdot 0.0313^{TK} \cdot W_\infty^{-0.168} \cdot 1.38^{Pf} \cdot 1.89^{Hd} \qquad (5)$$

Where:
W_∞ and H_d are as defined above; T_k is the mean annual habitat temperature (in the Gulf of Thailand, T_k = 1,000/(29 + 273.1)); and P_f is 1 for apex and pelagic predators and zooplankton feeders, and 0 for other feeding types.

Table 1. Basic parameters (defined in the Methods section) for the Ecopath model of the Gulf of Thailand, 1973. Values in parenthesis are estimated by Ecopath to fit mass-balance constraints.

Ecological group	Biomass. ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	P/Q	Biom.acc. ($t \cdot km^{-2} \cdot year^{-1}$)
Rastrelliger spp.	(0.187)	3.00	–	0.95	0.25	0
Scomberomorus spp.	0.016	(0.07)	(0.35)	0.95	0.20	-0.003
Carangidae	0.083	(1.34)	(5.37)	0.95	0.25	-0.007
Pomfret	0.008	(0.88)	(4.418)	0.95	0.20	0.001
Small pelagic fish	(0.452)	3.00	–	0.95	0.25	0
False trevally	(0.003)	2.00	–	0.95	0.20	0
Large piscivores	0.054	1.20	–	(0.68)	0.20	-0.001
Sciaenidae	(0.031)	1.50	–	0.95	0.20	0
Saurida spp.	0.054	2.00	–	(0.44)	0.20	0.012
Lutianidae	0.016	0.80	–	(0.54)	0.20	-0.004
Plectorhynchidae	(0.008)	0.80	–	0.95	0.20	0
Priacanthus spp.	0.071	2.00	–	(0.30)	0.20	0
Sillago spp.	(0.111)	2.00	–	0.95	0.20	0.086

Table 1. Basic parameters (defined in the Methods section) for the Ecopath model of the Gulf of Thailand, 1973. Values in parenthesis are estimated by Ecopath to fit mass-balance constraints. (continued)

Ecological group	Biomass. ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	P/Q	Biom.acc. ($t \cdot km^{-2} \cdot year^{-1}$)
Nemipterus spp.	0.093	2.50	–	(0.66)	0.25	-0.004
Ariidae	0.018	2.00	–	(0.68)	0.20	-0.006
Rays	0.048	0.50	–	(0.26)	0.20	-0.01
Sharks	0.013	0.50	–	(0.57)	0.20	-0.005
Cephalopod	0.344	2.00	–	(0.82)	0.25	-0.1
Shrimps	(0.232)	5.00	–	0.95	0.25	0
Crab, Lobster	(3.520)	3.00	–	0.95	0.25	0
Trashfish	0.524	4.00	–	(0.88)	0.25	-0.045
Small demersal fish	(0.158)	3.00	–	0.95	0.25	0
Medium demersal piscivore	0.024	2.00	–	(0.47)	0.20	0
Medium demersal benthivore	0.092	2.00	–	(0.59)	0.20	-0.042
Shellfish	(0.169)	3.00	–	0.95	0.20	0
Jellyfish	2.000	5.00	–	(0.00)	0.25	0
Sea cucumber	1.000	4.50	–	(0.00)	0.20	0
Seaweeds	1.000	15.00	–	(0.00)	–	0
Coastal tuna	(0.019)	0.80	–	0.95	0.20	0
Sergestid shrimp	(0.051)	10.00	–	0.95	0.25	0
Mammals	0.100	0.05	30.00	(0.00)	–	0
Pony fishes	(0.066)	3.50	–	0.95	0.25	0
Benthos	33.000	5.00	–	(0.65)	0.20	0
Zooplankton	17.300	40.00	–	(0.20)	0.25	0
Juvenile small pelagics	(0.073)	4.00	–	0.95	0.25	0
Juvenile *Caranx* spp.	(0.025)	4.00	–	0.95	0.25	0
Juvenile *Saurida* spp.	(0.018)	4.00	–	0.95	0.25	0
Juvenile *Nemipterus* spp.	(0.022)	4.00	–	0.95	0.25	0
Phytoplankton	30.000	200.00	–	(0.44)	–	0
Detritus	10 000	–	–	(0.17)	–	0

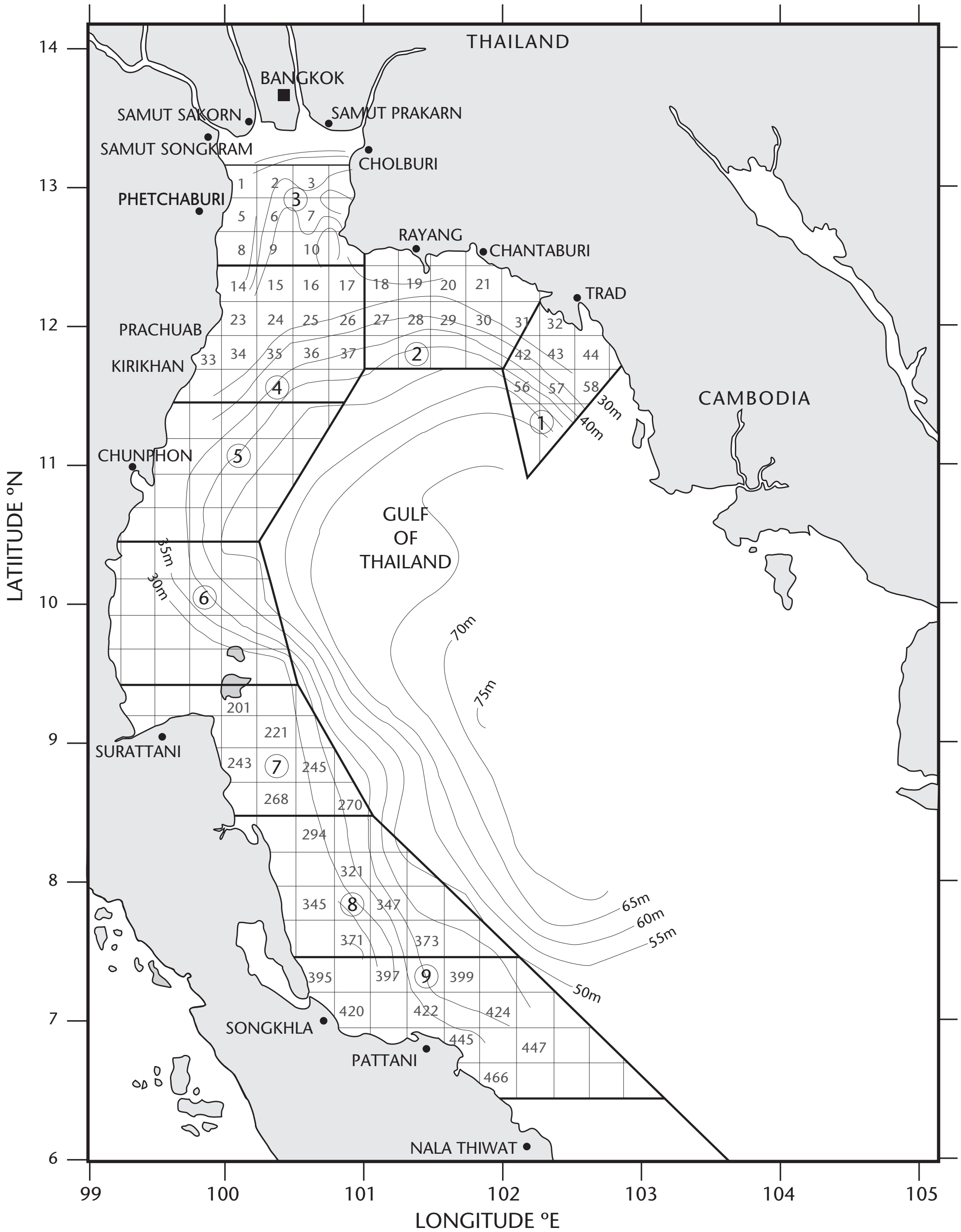

Fig. 1. Map of the Gulf of Thailand covered by the ecosystem model. Numbers indicate trawl stations which were used for biomass estimation.

Annual catch in the Gulf of Thailand from 1973 were taken from statistical data of the Department of Fisheries and regrouped into 40 ecological groups (Table 2). Diet composition for each group was obtained from available literature and is summarized in Table 3.

Table 2. Catch (t·km⁻²·year⁻¹) from Thai waters of the Gulf of Thailand (1973). ("other gear": shrimp gillnet, fish gillnet, swimming crab gillnet & trap).

Ecological group	Otter board trawl	Pair trawl	Beam trawl	Pushnet	Purse seine	Other gear	Total
Rastrelliger spp.	0.016	0.033	0	0	0.070	0.047	0.166
Scomberomorus spp.	0	0.001	0	0	0	0	0.001
Carangidae	0.006	0.008	0	0	0.008	0	0.022
Pomfret	0.002	0.001	0	0	0	0	0.003
Small pelagic fish	0	0	0	0.015	0.069	0.029	0.113
False trevally	0.001	0	0	0	0	0	0.001
Large piscivores	0.013	0.005	0	0	0	0	0.018
Sciaenidae	0.024	0.014	0.001	0.001	0	0	0.040
Saurida spp.	0.025	0.007	0	0	0	0	0.032
Lutjanidae	0.009	0	0	0	0	0	0.009
Plectorhynchidae	0.003	0	0	0	0	0	0.003
Priacanthus spp.	0.022	0.007	0	0	0	0	0.029
Sillago spp.	0.001	0.002	0	0	0	0	0.003
Nemipterus spp.	0.027	0.007	0	0	0	0	0.034
Ariidae	0.012	0.003	0	0	0	0	0.015
Rays	0.011	0.002	0	0	0	0	0.013
Sharks	0.007	0.001	0	0	0	0	0.008
Cephalopod	0.062	0.087	0.001	0.001	0	0	0.151
Shrimps	0.076	0	0.011	0.023	0	0.108	0.218
Crab, Lobster	0.016	0.088	0.001	0.004	0	0	0.109
Trashfish	0.553	0.114	0.007	0.02	0	0	0.694
Small demersal fish	0	0.038	0.001	0.003	0	0	0.042
Medium Demersal piscivore	0	0.001	0	0	0	0	0.001
Medium Demersal benthivore	0.006	0.001	0	0	0	0	0.007
Shellfish	0	0	0	0	0	0.426	0.426
Coastal tuna	0	0	0	0	0.011	0	0.011
Sergestid shrimp	0	0	0.001	0.004	0	0.036	0.041
Juvenile small pelagics	0.011	0.085	0	0	0	0	0.096
Juvenile *Caranx* spp.	0.008	0.017	0	0.001	0	0	0.026
Juvenile *Saurida* spp.	0.026	0.017	0	0	0	0	0.043
Juvenile *Nemipterus* spp.	0.054	0.004	0	0	0	0	0.058
TOTAL	0.991	0.543	0.023	0.072	0.158	0.646	2.433

Table 3. Diet compositions for the Ecopath model of the Gulf of Thailand (1973), the predator numbers refer to the Prey numbers.

Prey	Predator																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	29	30	31	32	33	34
1 *Rastrelliger* spp.	–	0.2	0.1	–	–	–	0.2	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	0.12	–	0.1	–	–	–
2 *Scomberomorus* spp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3 Carangidae	–	0.2	–	–	–	–	0.1	–	–	0.1	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	0.14	–	0	–	–	–
4 Pomfret	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	0.02	–	–	–	–	–
5 Small pelagic fish	–	0.1	0.2	0.1	–	0	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.2	–	0.4	–	–	–
6 False trevally	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.05	–	–	–	–	–
7 Large piscivores	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	0.01	–	–	–	–	–
8 Sciaenidae	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9 *Saurida* spp.	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10 Lutjanidae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11 Plectorhynchidae	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	-0	–	–	–	–	–
12 *Priacanthus* spp.	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–
13 *Sillago* spp.	–	–	–	0	–	–	0	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	0.06	–	–	–	–	–
14 *Nemipterus* spp.	–	–	–	0	–	–	0.1	–	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	0.07	–	–	–	–	–
15 Ariidae	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	0	–	–	–	–	–	0	–	–	–	–	–	–	–	–
16 Rays	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17 Sharks	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18 Cephalopod	–	0.1	–	–	–	–	0.1	–	0.2	0.1	–	–	–	–	–	–	–	0	–	–	–	–	0	–	–	0.05	–	0.1	–	–	–
19 Shrimps	–	0.1	0.1	0.1	–	–	–	0.15	–	0.1	0.1	0	0	0	0.1	0.1	0.1	0.1	–	–	–	0	0.1	0.1	–	–	–	–	–	–	–
20 Crab, Lobster	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	–	0.01	–	–	–	0	–
21 Trashfish	–	0.05	0.2	0.2	–	–	0.1	0.15	0.3	0.3	–	0	–	–	–	–	0.1	0.1	–	–	–	–	0.2	0	–	–	–	0.2	–	–	–
22 Small demersal fish	–	0.05	0.1	0.2	–	–	0.1	0.1	0.2	0.1	–	–	–	–	–	–	0.1	–	–	–	–	–	0.3	–	–	0.05	–	0.1	–	–	–
23 Medium demersal piscivore	–	–	–	–	–	–	0.2	–	–	0.1	–	–	–	–	–	–	0.2	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–

Table 3. Diet compositions for the Ecopath model of the Gulf of Thailand (1973), the predator numbers refer to the Prey numbers. (continued)

Prey	Predator																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	29	30	31	32	33	34
24 Medium demersal benthivore	–	–	–	–	–	–	0.1	–	0.2	–	–	–	–	–	–	–	0.1	–	–	–	–	–	0.2	–	–	0.03	–	–	–	–	–
25 Shellfish	–	–	–	–	–	–	–	–	–	–	0.1	–	–	–	0.1	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–
26 Jellyfish	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27 Sea cucumber	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28 Seaweeds	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29 Coastal tuna	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30 Sergestid shrimp	–	–	–	–	–	0	–	0.1	–	0.1	–	–	–	–	0.1	–	–	0.1	–	–	–	0	–	–	–	–	–	–	–	–	–
31 Mammals	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–
32 Ponyfishes	–	–	0.1	–	–	–	–	0.1	0.1	–	–	0	–	–	–	–	–	0	–	–	–	–	0	0	–	–	–	–	–	–	–
33 Benthos	–	–	0.1	0.2	–	–	–	0.2	0.1	0.1	0.8	0	1	1	0.8	0.8	0.1	–	0	1	0.3	0	0.1	0.8	–	–	0	0.2	0	0.1	-
34 Zooplankton	0.9	0.1	0.2	0.2	1	0	–	–	–	–	–	0	–	0	–	–	–	0.6	0	–	0.3	0	–	–	0	–	0	0.1	0	0.1	–
35 Juvenile small pelagics	0.1	0.03	–	–	–	0	–	0.03	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	0.02	–	–	–	–	–
36 Juvenile *Caranx* spp.	–	0.03	–	–	–	0	–	0.03	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	0.02	–	–	–	–	–
37 Juvenile *Saurida* spp.	–	0.03	–	–	–	–	–	0.03	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	0.02	–	–	–	–	–
38 Juvenile *Nemipterus* spp.	–	0.03	–	–	–	–	–	0.03	–	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–	0.02	–	–	–	–	–
39 Phytoplankton	0.1	–	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.3	–	–	–	1	–	–	–	–	0.2	1
40 Detritus	–	–	–	–	–	–	–	0.1	–	–	0.1	–	–	0	–	0.1	–	–	1	1	0.3	–	–	0	–	–	1	–	0	0.6	0

Estimates of primary production were obtained from (Lursinsap 1980; Lursinsap 1982) (Lursinsap and Taocharlee, 1989). The factor of 7.47 (Cushing, 1973) was used to convert gram carbon to wet weight. Hence, 1 gC•m^{-2}•day^{-1} of primary production corresponds to (7.47* 365*10 000)/ 1 000 t•km^{-2}•year^{-1} of production.

The percentage contribution of four juvenile fish groups to trashfish catch from otter board trawls, pair trawls and purse seines are given in Table 4.

Table 4. Percentage contribution of juvenile ecological groups in catches of trash fish of each fleet.

Juvenile Ecological Groups	Fishing Fleet		
	Otter board trawl	Pair trawl	Pushnet
Juvenile small pelagics	1.5	23.7	0.6
Juvenile *Caranx* spp.	1.1	4.6	5.0
Juvenile *Saurida* spp.	3.4	4.8	0.1
Juvenile *Nemipterus* spp.	7.2	1.0	0.1

Economic Data

The market price of each group was estimated from landed prices during the year 1997 (Department of Fisheries (Thailand), 1998). The value was estimated as the mean price for all sizes of the most abundant species comprising the group (Table 5). The cost and revenue structure for fishing fleets/gears operating in the Gulf of Thailand were estimated for the modeling exercise (Table 6). Fixed cost includes institutional costs such as fishery research, management and administrative cost, and enforcement cost. Fixed cost was estimated from expenditures of the Department of Fisheries for the year 1998. Fishing cost is categorized into effort-related cost and sailing-related cost. Sailing-related cost consist of gasoline and lubricant, while the effort-related cost includes all variable costs. Estimates of fishing cost were obtained from the 1998 surveys conducted by the Fishery Economic Division, Department of Fisheries. Total revenue and the profit of each fleet was estimated by using the catch data based of 1993 and 1995 of the surveys of the Fishery Economic Division of the Department of Fisheries.

Investigating Impact of Multi-fleet Harvesting Strategies

The investigations were made using the 'Fishing Policy Search' option of the Ecosim module of Ecopath (Christensen et al. 2000) for a description of this optimization routine. As Ecosim simulations are very sensitive to the assumption of top-down versus bottom-up control, the simulations were run with varying vulnerability settings. The vulnerability setting regulates how prey in a given predator-prey interaction changes between being vulnerable and non-vulnerable to the predator (Walters et al. 1997; Walters et al. 2000). The rationale for this is that at a given moment in time, not all prey biomass are vulnerable to predators. Predator-prey relationships in nature are often limited by behavioural and physical mechanisms, such as schooling behaviour and diel verticalmigration patterns in clupeid fish, or spatial refuges used by many reef fish that considerably limit exposure to predation. The model is designed so that users can specify the type of trophic control in the food web. For low predator biomass or high exchange rate (v_{ij}), the functional relationship approximates a mass-action flow implying a strong top-down effect. For high consumer biomass or low exchange rates, the functional relationship approaches a donor-controlled (bottom-up) flow rate. In this study, the v_{ij} values were fixed at 0.2, 0.3 and 0.5 in each strategy to test the trophic control hypotheses. A discount rate of 4% was used in all simulations. Five different strategies were studied using the Ecosim optimization routine, four of which are summarized in Table 7.

Table 5. Fish group price (Baht/kg) by fishing fleet, 1997*.

Ecological groups	Otter board trawl	Pair trawl	Beam trawl	Push net	Purse seine	Other gear
Rastrelliger spp.	22.43	22.43	22.43	22.43	27.77	30.00
Scomberomorus spp.	67.64	67.64	67.64	67.64	55.88	72.70
Carangidae	15.46	15.46	15.46	15.46	17.21	0
Pomfret	103.47	103.47	103.47	103.47	0	151.99
Small pelagic fish	15.94	15.94	15.94	15.94	7.50	7.50
False trevally	80.00	80.00	80.00	80.00	35.00	0
Large piscivores	25.00	25.00	25.00	25.00	0	0
Scieanidae	17.50	17.50	17.50	17.50	0	0
Saurida spp.	10.90	10.90	10.90	10.90	0	0
Lutianidae	54.70	54.70	54.70	54.70	0	0
Plectorhynchidae	54.70	54.70	54.70	54.70	0	0
Priacanthus spp.	10.67	10.67	10.67	10.67	0	0
Sillago spp.	30.00	30.00	30.00	30.00	0	60.00
Nemipterus spp.	13.59	13.59	13.59	13.59	0	0
Ariidae	30.00	30.00	30.00	30.00	0	0
Rays	12.86	12.86	12.86	12.86	0	30.00
Sharks	17.00	17.00	17.00	17.00	0	20.00
Cephalopod	56.22	56.22	56.22	56.22	40.00	70.00
Shrimps	72.08	72.08	72.08	72.08	0	198.17
Crab, Lobster	44.06	44.06	44.06	44.06	0	70.00
Trashfish	2.55	2.55	2.55	2.55	0	4.00
Small demersal fish	17.00	17.00	17.00	17.00	0	0
Mededium Demersal piscivore	19.06	19.06	19.06	19.06	0	0
Medium Demersal benthivore	29.70	29.70	29.70	29.70	0	0
Shellfish	7.98	7.98	7.98	7.98	0	0
Jellyfish	1.83	1.83	1.83	1.83	0	4.00
Sea cucumber	17.00	17.00	17.00	17.00	0	25.00
Seaweeds	7.50	7.50	7.50	7.50	0	10.00
Coastal tuna	21.00	21.00	21.00	21.00	26.00	0
Sergestid shrimp	14.85	14.85	14.85	14.85	0	15.00
Ponyfishes	2.55	2.55	2.55	2.55	0	5.00
Juvenile small pelagics	2.55	2.55	2.55	2.55	5.00	5.00
Juvenile *Caranx* spp.	2.55	2.55	2.55	2.55	0	0
Juvenile *Saurida* spp.	2.55	2.55	2.55	2.55	0	0
Juvenile *Nemipterus* spp.	2.55	2.55	2.55	2.55	0	0

*** Source of data: Fishery Economic Division, Department of Fisheries (Thailand) 1998.**

Table 6. Catch and revenue structure by fishing fleet used as input for modelling.

Fleet	Fixed cost (%)	Effort related cost (%)	Sailing related cost (%)	Profit (%)
Otter board trawl	1.2	49.2	35.4	14.2
Pair trawl	0.7	43.1	27.7	28.6
Beam trawl	0	57.3	39.9	2.8
Pushnet	0.7	30.5	66.7	2.1
Purse seine	1.1	42.1	26.9	29.9
Other gears	1.4	56.5	40.7	1.4

Table 7. Summary of strategies examined using the Ecosim routine for optimization of fishing effort.

Strategy	Net economic value	Social value	Eco-system value	Vulner-ability
1. Economic consideration	1	0.0001	0.0001	0.2 0.3 0.5
2. Social consideration	0.0001	1	0.0001	0.2 0.3 0.5
3. Ecological consideration	0.0001	0.0001	1	0.2 0.3 0.5
4. Weighted compromise	1	1	1	0.2 0.3 0.5

Results and Discussion

Ecopath Model Results

The Ecopath model developed here is fairly detailed, but an overview of the groups included and their biomasses and trophic levels can be obtained from the simplified flowchart given in Figure 2. The figure indicates a predominance of groups feeding around trophic level 3, i.e. first order carnivores. This may be indicative of a severely exploited system, where top predator biomasses are minimal, and where the system is dominated by small-sized, fast-growing prey fishes and invertebrates. The predominance of low-trophic level groups in the system is also apparent when examining the biomass by trophic level as estimated from network analysis (Table 8). Overall, this supports the notion that the system has been severely modified through removal of top predators.

Table 8. Biomass by trophic level in the Gulf of Thailand 1973 model.

Trophic level	Biomass ($t \cdot km^{-2} \cdot year^{-1}$)
VI	0.003
V	0.048
IV	0.565
III	8.787
II	50.595

Figure 3 shows a mixed trophic impact analysis for the Gulf of Thailand (1973) ecosystem model. The analysis shows that the bottom trawls have major impact on a large number of groups. Interestingly, bottom trawls even have a positive impact on Carangidae and Pomfrets even though the gear catches them both. Such 'beneficial predation' (as it is termed technically) is caused by bottom trawls favoring groups by negatively impacting their predators and competitors. Sharks show the same form of beneficial predation with Carangidae and Pomfrets.

Time Series Fitting Using Ecosim

In order to use the Ecosim model for policy exploration it is desirable to study how well the model can replicate events in an ecosystem. For the present study this was done by using time series data for relative effort over time (Table 9) to force the Ecosim simulations. This being done, the simulations are studied for correspondence between predicted biomasses over time, and observed biomasses based on trawl survey CPUE. The correspondence is then sought to be improved via the process detailed in Christensen et al. (2000). The end result is a fit as shown in Figure 4.

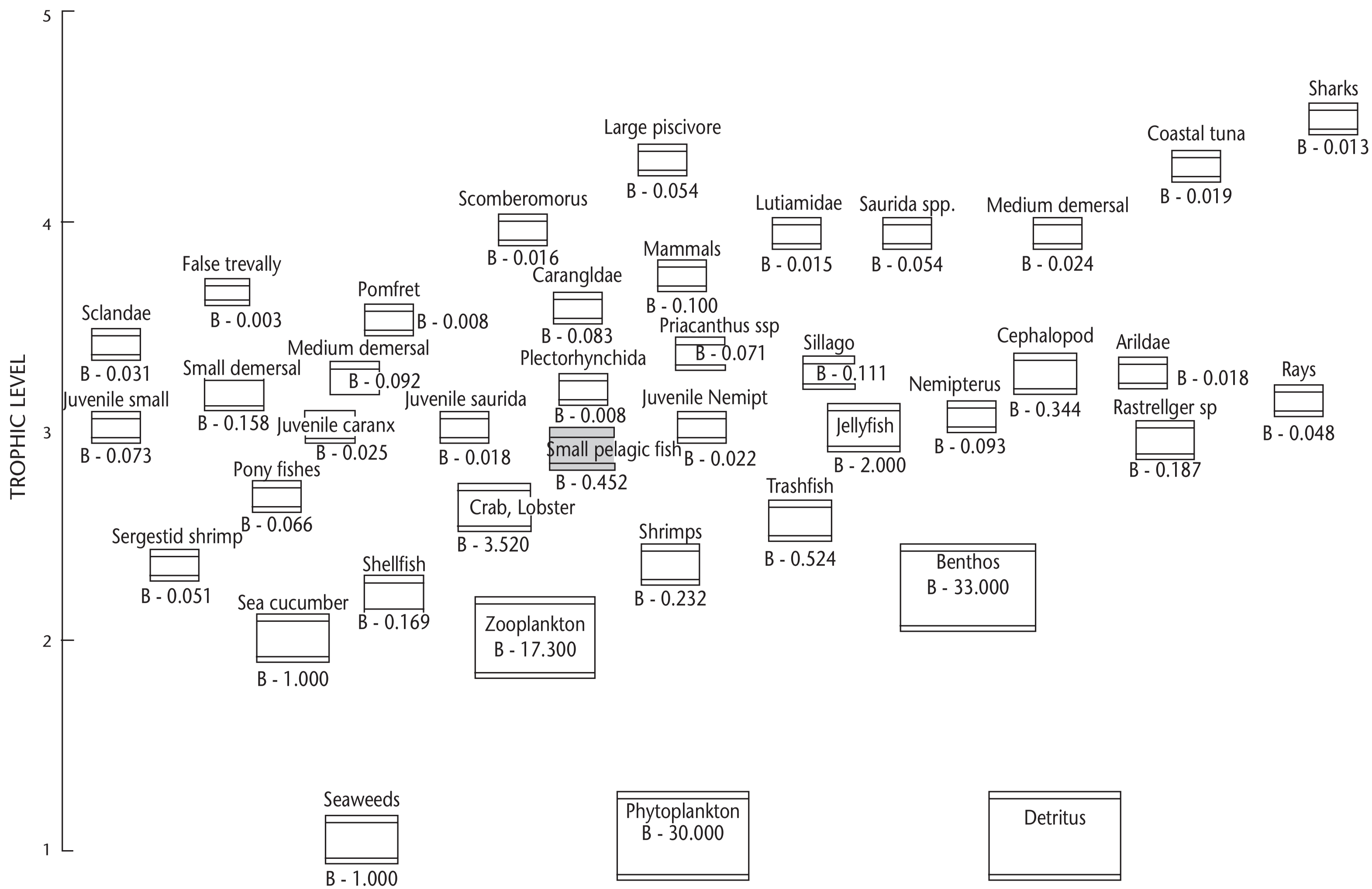

Fig. 2. Ecological groups included in the Gulf of Thailand ecosystem model. The groups are arranged by trophic level on the Y-axis, and the box size is a function of biomass (B).

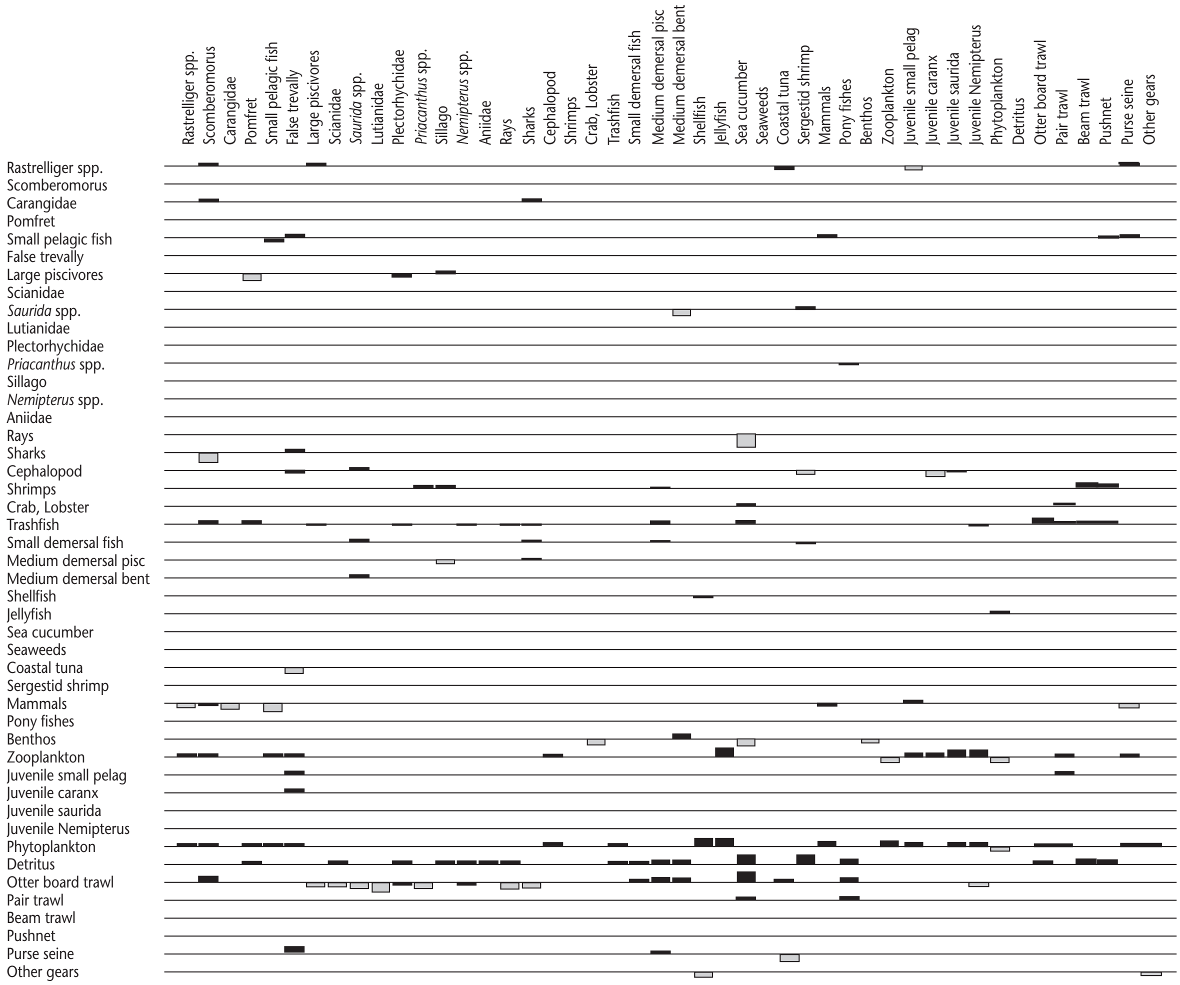

Fig. 3. Mixed trophic impact showing the impacting (rows) and impacted groups (columns). Positive impacts are shown above the baseline, and negative below. The impacts are relative, but comparable between groups.

Table 9. Relative effort time series data for "forcing" Ecosim simulations.

Year	Otter trawl	Pair trawl	Beam trawl	Push-net	Purse-seine	Other gear
1973	1	1	1	1	1	1
1974	1.00	1.00	1.00	1.00	1.00	1.00
1975	0.81	0.82	0.50	0.81	1.04	1.03
1976	0.95	1.14	0.59	0.93	1.13	1.06
1977	0.78	0.92	0.61	0.73	1.20	1.09
1978	1.28	1.39	1.69	1.35	1.32	1.13
1979	1.19	1.11	1.01	1.02	0.97	1.16
1980	1.05	0.98	0.73	1.19	1.08	1.19
1981	1.19	1.87	2.10	1.68	1.09	1.23
1982	1.43	1.09	3.51	1.94	1.23	1.27
1983	1.45	1.10	2.74	4.54	1.22	1.30
1984	1.49	1.17	1.76	1.51	1.22	1.34
1985	1.00	0.94	0.44	0.84	1.55	1.38
1986	1.12	1.00	0.21	0.61	1.70	1.43
1987	1.57	1.40	0.11	0.67	1.91	1.47
1988	2.35	1.88	0.05	1.18	1.77	1.51
1989	2.73	2.57	0.08	0.95	1.92	1.56
1990	3.64	2.98	0.13	1.39	2.09	1.60
1991	3.32	2.36	0.10	1.41	2.25	1.65
1992	3.10	1.83	0.13	1.89	1.70	1.70
1993	2.60	1.87	0.07	1.62	1.64	1.75

Fisheries Status in 1973 Compared to 1993

Results from Ecosim simulations based on the fitted time series (1973 - 1993) show that the total catches of 1.454 t•km^{-2} in 1973 was shared by otter board trawl (36.24%), pair trawl (28.8%), beam trawl (1.51 %), pushnet (5.16%), purse seine (10.2 %) and "other gear" (18.1%) (Table 10). The percentage catches in 1993 by otter board trawl increased to about 41% and the catches by pair trawl, beam trawl, pushnet and purse seine were less than that in 1973 while only "other gears" slightly increased (Table 10 and 11). Comparing 1973 and 1993, it is obvious that the catch, catch value or revenue, and cost were lower in 1973 than in 1993 but the profit of all fleets were higher. It is estimated that the profit of all fleets in the gulf decreased over time. Finally, considerable profit would be lost if the fisheries of the Gulf of Thailand keeps growing in the absence of appropriate regulations.

Simulations of Management Measures/ directions

Effect of Pushnet Fishery Ban

The effect of a pushnet fishery ban was simulated using Ecosim by conducting simulations including and excluding fishing effort by the pushnet fleet. The results are given in Table 12. The catch, revenue, cost and profit of the six fishing fleets in 2000 (with a ban of pushnets) were not very different from those in 1993. Only otter board trawl could gain a little more catch and revenue but lesser profit than the year 1993. The push net fishery ban has no effect on the fisheries situation.

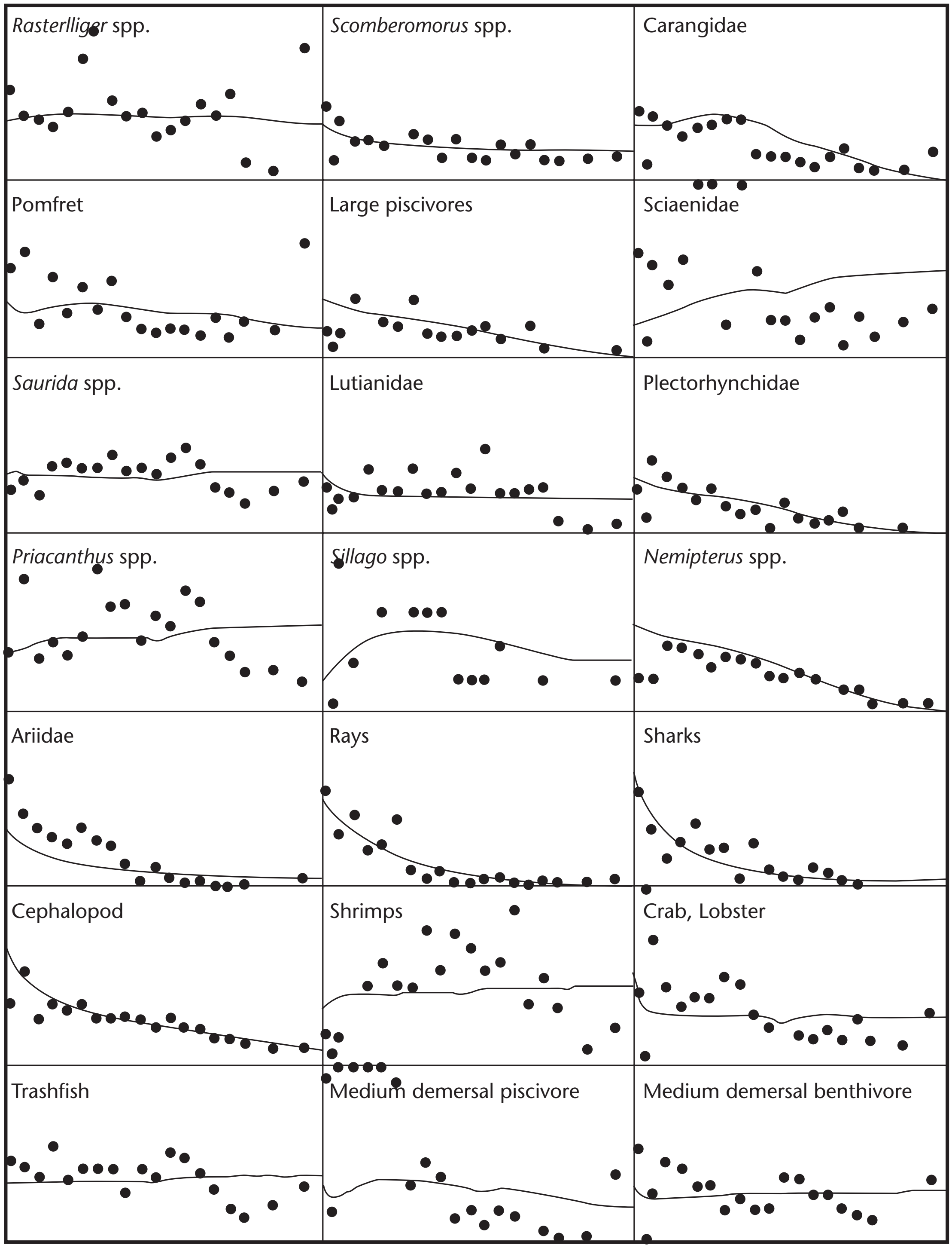

Fig. 4. Time series fit from Ecosim simulation over the period 1973 - 1993. The dots are biomass estimates based on trawl survey CPUE, while the lines shows biomass trends predicted by Ecosim.

Table 10. The fishery status in 1973.

Fishing Fleet	Catch (10^3 Baht·km^{-2})	Revenue (10^3 Baht·km^{-2})	Cost (10^3 Baht·km^{-2})	Profit (10^3 Baht·km^{-2})
Otter board trawl	0.527	10.266	13.661	-3.395
Pair trawl	0.419	6.643	10.716	-4.073
Beam trawl	0.022	1.106	0.865	0.241
Pushnet	0.075	2.738	2.082	0.656
Purse seine	0.148	2.474	2.610	-0.136
Other gear	0.263	29.278	21.210	8.068
TOTAL	1.454	52.505	51.140	1.365

Table 11. The fishery status in 1993.

Fishing Fleet	Catch (10^3 Baht·km^{-2})	Revenue (10^3 Baht·km^{-2})	Cost (10^3 Baht·km^{-2})	Profit (10^3 Baht·km^{-2})
Otter board trawl	0.971	21.348	31.138	-9.790
Pair trawl	0.620	10.781	14.431	-3.650
Beam trawl	0.002	0.086	0.084	0.002
Pushnet	0.097	3.573	3.341	0.232
Purse seine	0.231	3.732	3.442	0.290
Other gear	0.449	48.415	44.225	4.190
TOTAL	2.370	87.936	96.660	-8.724

Table 12. Ecosim results incorporating "Pushnet fishery ban from 1993 up to 2000".

Fishing Fleet	Catch (10^3 Baht·km^{-2})	Revenue (10^3 Baht·km^{-2})	Cost (10^3 Baht·km^{-2})	Profit (10^3 Baht·km^{-2})
Otter board trawl	1.027	22.103	32.693	-10.590
Pair trawl	0.632	10.860	18.195	-7.335
Beam trawl	0.002	0.089	0.078	0.011
Pushnet	0	0	0	0
Purse seine	0.235	3.7690	4.425	-0.656
Other gear	0.459	50.151	40.349	9.802
TOTAL	2.354	86.972	95.74	-8.768

No Fishing of Four Juvenile Fish Groups and Trashfish

The effect of "no fishing of four juvenile groups and trashfish group" was observed through Ecosim simulations for the year 1993 through 2000 (Table 13). It is apparent that catches are lesser in all fleets whilst revenues are higher with lower costs. The costs are almost the same as the fisheries in 1993. Overall, the fisheries can gain more profits especially the otter board trawlers. This is because the fisheries are catching higher price, big-sized fish by enlarging the cod-end mesh size of trawlers since trawlers are catching a high percentage of juvenile fishes and trashfish. In this case, however, there may be implementation difficulties. Trashfish demand to supply fishmeal for aquaculture and fowl rearing remains strong. Importing trashfish and using the sardine catches to fill the trashfish demand of fishmeal factories may be one of the viable solutions.

No Fishing of Four Juvenile Groups Combined with Pushnet Fishery Ban

The effects of "no fishing of four juvenile groups and pushnet fishery ban" from 1993 to 2000 were simulated by Ecosim (Table 14). Results show slightly smaller catch and higher profit overall of the fisheries as compared to the "no fishering of juvenile fish and trashfish" scenario. Other gears gains much more profit relatively than the other five fleets/gears making 2.679 thousand Baht•km^{-2} by catching only 0.44 t•km^{-2}. The pair trawl fleet still has minus profit as in all other cases. This case gives the highest profit at 7.734 thousand Baht•km^{-2} with a total catch of 8.4 t•km^{-2}.

Table 13. Ecosim results incorporating "no fishing of four juvenile groups and trashfish group".

Fishing Fleet	Catch (10^3 Baht·km^{-2})	Revenue (10^3 Baht·km^{-2})	Cost (10^3 Baht·km^{-2})	Profit (10^3 Baht·km^{-2})
Otter board trawl	6.393	36.711	31.138	5.573
Pair trawl	1.888	14.325	14.431	-0.106
Beam trawl	0.002	0.082	0.084	-0.002
Pushnet	0.133	3.397	3.341	0.056
Purse seine	0.225	3.976	3.442	0.534
Other gear	0.430	45.144	44.225	0.919
TOTAL	9.071	103.634	96.66	6.974

Table 14. Ecosim results incorporating "no fishing of four juvenile groups combined with pushnet fishery ban".

Fishing Fleet	Catch (10^3 Baht·km^{-2})	Revenue (10^3 Baht·km^{-2})	Cost (10^3 Baht·km^{-2})	Profit (10^3 Baht·km^{-2})
Otter board trawl	5.930	36.607	31.828	4.779
Pair trawl	1.800	14.087	14.357	-0.270
Beam trawl	0.003	0.096	0.094	0.002
Pushnet	0	0	0	0
Purse seine	0.227	3.986	3.442	0.544
Other gear	0.440	46.904	44.225	2.679
TOTAL	8.400	101.680	93.946	7.734

Optimization of Fishing Effort

To optimize fishing effort of the fisheries, Ecosim search assuming 10% profit in all fisheries at initial state was run through 2000. Results indicate that the fisheries could catch 2.421 t•km^{-2} with total profit of 4.343 thousand Baht•km^{-2} (Table 15). The best performing fleet was the "other gear", which would give highest profit of 18.641 thousand Baht by catching 0.882 t•km^{-2}.

The optimization of fishing with variable profit as initial state indicates that overall fisheries profit is negative. Pair trawl would give highest negative profit while other gear would give highest profit of 61.763 thousand Baht•km^{-2} by catching 1.772 t•km^{-2}.

Harvesting Strategies Based on Economic, Social and Ecosystem Considerations

Table 16 gives the results of economic optimization with three values of vulnerability: 0.2 (bottom- up control), 0.3 (mixed control), and 0.5 (top-down control). The best economic value is shown at v = 0.3 which gives the net economic value, social value, ecosystem stability and total values 0.6, 1.3, 1.0 and 0.9, respectively. The optimum fishing effort over time was obtained by reducing PT by 20%, reducing beam trawl and pushnet by 50% increasing otter board trawl by about 40%, and increasing purse seine and other gear by about 10% and 100%, respectively.

In the Ecosim optimizations targeting maximum social benefits (i.e. jobs which equates to increasing the value of the catch), the best results obtained were 1.6 for the social factor, with an economic value of 0.5, and an ecosystem stability value of 0.8 (all expressed relative to the 1973-level). The optimum fishing effort over time was obtained by increasing (relative to the 1973 level) beam trawl by 60% and pushnet by 75%, while otter board trawl, purse seine and other gear were reduced by 100%, 20% and 430%, respectively, to serve the social objectives.

The optimization for ecosystem stability did not give consistent results, and needs further work before they can be considered.

The set of simulations seeking to optimize economic, social and ecosystem considerations, simultaneously indicate that best output was obtained using a mixed control setting (v = 0.3). Optimum effort was obtained by increasing pair trawl, beam trawl, pushnet and purse seine by about 20%, 72%, and 98% respectively; while otter beam trawl and "other gear" have to increase by about 32% and 180%, respectively, all compared to the 1973 level.

Table 15. Optimum fishing search results with initial setting of 10% profit for all fleets.

Fishing Fleet	Catch (10^3 Baht·km^{-2})	Revenue (10^3 Baht·km^{-2})	Cost (10^3 Baht·km^{-2})	Profit (10^3 Baht·km^{-2})
Otter board trawl	0.013	0.108	0.301	-0.193
Pair trawl	1.457	17.401	31.283	-13.882
Beam trawl	0.001	0.055	0.046	0.009
Pushnet	0.009	0.277	0.240	0.037
Purse seine	0.119	2.002	2.271	-0.269
Other gear	0.822	98.669	80.028	18.641
TOTAL	2.421	118.511	114.170	4.343

Table 16. Optimum fishing search results with initial setting of variable profit.

Fishing Fleet	Catch (10^3 Baht·km^{-2})	Revenue (10^3 Baht·km^{-2})	Cost (10^3 Baht·km^{-2})	Profit (10^3 Baht·km^{-2})
Otter board trawl	0.013	0.644	0.993	-0.349
Pair trawl	1.752	72.963	169.24	-96.277
Beam trawl	0.01	0.634	0.459	0.175
Pushnet	0.027	1.207	0.868	0.339
Purse seine	0.097	1.174	1.653	-0.479
Other gear	1.772	184.757	122.994	61.763
TOTAL	3.673	261.379	296.21	-34.831

Conclusion

In this study, the time series of effort data for purse seine and other gears were based on an assumed rate of effort increase of 3% per year for the period considered. It would be preferable to use actual rather than assumed data. It is also clear that the software used is still under development, and more experience should be sought before using it for actual management. However, we find the approach very promising, and expect it to be widely used.

Among the estimations and simulations performed using Ecosim, the option of "no fishing for juvenile fish combined with a pushnet fishing ban seems to give highest profit although prawn trawl still had negative profit, losing 0.27 thousand Baht in catching 1.8 t•km^{-2}). "No fishing of the juvenile groups" could be obtained by increasing cod-end mesh sizes, although it is not clear by how much. Before implentation, it would be necessary to conduct some experiments on the effect of increasing the cod-end mesh sizes of shrimp and finfish trawls to 2.5 and 3.0 cm, respectively. The experiments should be conducted using commercial fishing boats, and comparison with results from further simulations using Ecosim.

A pushnet fishery ban has been put in place by the Department of Fisheries since 22 June 2000. The DOF is trying to find the best way for fishers to improve the fishery situation and a public hearing has been held in early July 2000, where the preliminary results from the analysis presented here were discussed. At present, the pushnet fishery ban has been postponed for political reasons.

Further simulations on optimum fishing levels and the impact of current regulation concerning closed season and area (both inshore and offshore) using Ecosim and Ecospace for management purposes should be conducted. Data preparation for further simulation studies should be recommended to concerned parties. It is possible to use Ecopath with Ecosim and Ecospace to simulate the development of the fisheries, resources and ecosystem over time, and to study the implications of various management policies. The decision-makers and/or the researchers should be able to test management strategies through ecosystem simulation studies, using Ecosim to evaluate various options for optimizing fishing effort for the Thai fisheries taking into consideration both economic, social and ecological considerations, with the aim of promoting responsible and sustainable development.

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Appendix A. Aspect ratios of marine fishes in the Gulf of Thailand (1998).

Species	N	Caudal fin height (cm)	Caudal fin surface area (cm^2)	Aspect ratio(A_r) ($h^2 \cdot s^{-1}$)
Atule mate	10	6.53	9.23	4.62
Chirocentrus dorab	6	9.70	21.51	4.37
Pampus niger	10	8.95	17.65	4.54
Rastelliger spp.	10	4.84	5.70	4.11
Scomberomorus commerson	12	10.22	23.80	4.39
Selaroides leptolepis	10	2.91	3.36	2.52
Epinephelus aureolatus	8	6.31	23.73	1.68
Epinephelus sexfasciatus	9	2.53	5.70	1.12
*Lutjanus lineolatus (Lutjanus lutjanus**)*	9	5.09	10.10	2.57
Lutjanus malabaricus	11	7.96	37.46	1.69
Mullidae	6	7.28	12.23	4.33
Nemipterus hexodon	10	5.83	10.44	3.26
Nemipterus mesoprion	10	4.84	6.83	3.43
Nemipterus peronii	10	7.03	11.21	4.41
Priacanthus macracanthus	3	6.43	14.4	2.87
Priacanthus tayenus	10	6.56	14.58	2.90
Platycephalidae	12	3.74	8.01	1.75
Saurida elongata	6	8.13	17.5	3.78
Saurida undosquamis	10	6.70	11.11	4.04
Scolopsis taeniopterus	10	6.15	11.43	3.31
Siganidae	10	4.42	7.04	2.78
Nemipterus tambuloides	10	6.74	11.05	4.11
Rachycentron canadus	7	11.40	45.48	2.86
Epinephelus morrhua	9	5.52	19.34	1.58
Euthynnus affinis	10	9.61	15.07	6.13
Thunnus tonggol	9	10.38	19.98	5.39

Note: ** valid name in FishBase 2000.

A Socioeconomic and Bioeconomic Analysis of Coastal Fisheries of Bangladesh

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Abstract

Bangladesh has an exclusive economic zone (EEZ) of 164 000 km^2 and a continental shelf area of 66 440 km^2. Artisanal (small scale) fisheries extend from the coast to 40 m while industrial (commercial scale) fisheries operate beyond 40 m depth. The coastal fisheries of Bangladesh exploit a complex multi-species resource. There are 18 demersal and pelagic species, seven species of larger pelagic and 10 shrimp species that are commercially important among the fishes exploited. In 1996 - 97, total fish production reached 1.3 million t with 75% from capture fisheries (0.9 million t) and 25% from aquaculture (0.4 million t). Artisanal fishing operations dominated the marine fisheries, contributing 82% of the total fish production.

Information on the gross national product (GNP) and domestic product (GDP) showed that the share of agriculture has been declining over the years. The national income accounting procedure in Bangladesh divides the agriculture sector into crops, livestock, forestry and fisheries. Fisheries contribute to economic development of the country in four ways: (a) helping to achieve high growth rates by creating the necessary value-added; (b) providing employment to a large number of people; (c) adding a large volume of valuable foreign exchange; and (d) providing a cheap source of essential food to lower income people. In 1997 - 98, GNP, GDP and value-added contributions at current prices by the fisheries sector amounted to US$35 716 mil, US$34 062 mil and US$1 808 mil, respectively. Of the total export value of US$1 217 mil, 8.5% (US$104 mil) came from fish and fish products. In terms of food consumption, fish ranks third as the most important food item with a mean per capita consumption of 8.36 kg•year^{-1}.

There are three major fishing fleets in Bangladesh namely, the trawlers, the mechanized boats and the non-mechanized boats. In 1972 - 73, there were 10 trawlers and 200 mechanized boats operating in the fishing grounds of Bangladesh. This expanded to 54 trawlers, 3 317 mechanized boats and 14 014 non-mechanized boats in 1996 - 97. Trawlers were divided into 41 shrimp and 13 fish units while mechanized boats included gillnet, set bag net and long-line gear. Non-mechanized boats are also used for gillnet fishing, set bag net fishing, long-line fishing, trammel net fishing and other gear.

The Schaefer and Fox Models were used to estimate the maximum sustainable yield (MSY) for the fisheries of Bangladesh. Results of these bioeconomic models show

that MSY is estimated to be 4 029 t at MSY effort of 9 317 standard fishing days (SFD) using Schaefer's Model. MSY reached 4 136 t at MSY effort of 11 822 SFD using Fox's Model. The current catch of 2 444 t at an effort of 7 491 SFD indicates over-fishing. If this situation continues, the fishery resources will diminish with time. Precautionary measures should be adopted by the Government to minimize if not totally prevent over-exploitation of the fishery resource in the Bay of Bengal. The Government should enact laws and ensure their enforcement. The present number of large trawlers and boat owners should not be allowed to increase. The trawlers and large boat operators should avoid intrusion into near-shore areas and reduce discards/by-catch problems. Artisanal fishers should abandon destructive fishing gear like estuarine set bag net (ESBN), push nets and current jall that kill small fish. Community-based management should be adopted with initiatives coming from the Government, other international and regional agencies and the stakeholders.

Review of the Status of Fishery Resources

The Coastal Water Area

The exclusive economic zone (EEZ) of Bangladesh spans 166 000 km^2 and the shelf area covers 66 440 km^2. The coastal water is very shallow with depths less than 10 m covering 24 000 km^2. Coastal waters are characterized by a prolonged low saline regime due to river discharges. The shelf area down to about 150 m has been found suitable for smooth trawling with very few obstacles. Artisanal fisheries, which previously extended to 20 m depth, now extend to 40 m. An ordinance of the government of Bangladesh (Ministry of Fisheries [MOF] 1997) regulates fishing by traditional fishers up to 40 m depth. Thus, by implication industrial fisheries are those that operate beyond 40 m depth (Habib 1999).

Fishery Resources

Coastal fisheries of Bangladesh exploit a complex, multi-species resource. Eighteen species of demersal and small pelagic, 7 species of larger pelagic and 10 species of shrimps are commercially important exploited resources. Studies undertaken to examine the development potential and status of the resources give different estimates of trawl-able fish stocks varying from 40 000 - 55 000 t to 260 000 - 370 000 t. The current consensus based on a reassessment of these and related studies is a trawlable standing stock of 150 000 - 160 000 t in the coastal waters. Roughly 53% of the standing stock consists of commercially important demersals and 16% consists of commercially important pelagics. Studies on shrimp conducted between 1973 and 1987 give a standing stock of 1 500 - 9 000 t. More recent work suggests a maximum sustainable yield (MSY) figure of 7 000 - 8000 t of penaeid shrimps (Khan et al. 1997). Available information on pelagic resources puts the standing stock at 90 000 - 160 000 t, based on acoustic survey results.

In 1970, coastal fisheries constituted only 10.6% of the total fishery production, but the proportion of coastal fisheries production increased to 28.2% in 1993. In 1996 this proportion, however, declined to 22% (Ministry of Fisheries [MOF] 1997). It is widely acknowledged that increasing pressure on the coastal resources in Bangladesh has caused a decline in marine fish and shellfish in the Bay of Bengal. Artisanal fisheries landings, which contribute about 95% of the total marine landings, are largely composed of post-larvae and juveniles. This has a damaging effect on the stock. Traditional fishing gear is destructive. The trawl fleet is also causing damage as it catches the parent stock during the peak season and also the post-juveniles. An estimated 80% of the catch is not landed by trawlers but discarded at sea. Efforts at limiting trawl operations to deeper (beyond 40 m) areas have been thwarted by court intervention (injunctions). The provision regarding the closed season (Jan. 15 - Feb. 15) is hardly enforced.

The importance of the fisheries sector in the national economy of Bangladesh can be appreciated from Table 1 and Appendix Table 1. In 1996 - 97, the total fish production in Bangladesh was almost 1.3 million t, of which 0.9 million t came from the capture fishery and 0.4 million t from the culture fishery. Table 1 shows that duting a period of 12 years, the capture fishery accounted for 76% of the total fish caught while the remaining 24% was contributed by the culture fishery. The inland fishery supplied 75% of all fish caught in the country, whereas the share of the marine fishery was 25%. Artisanal or small scale fishing dominated the marine fishery, contributing 82% of the total fish caught. The mean values for the decade are smaller

to the corresponding values of 1996 - 97, thus the volume of fish production increased significantly over the decade.

Contribution of the Fisheries Sector to Economic Growth and Welfare

Introduction

Bangladesh is a developing country where much of the total value-added originates in the agriculture sector. But published data on GDP and components of GDP reveal that the share of agriculture in GDP has been declining over the years since independence. The share of the industrial sector has remained more or less constant. Only the services sector has flourished during the last decade. The national income accounting procedure in Bangladesh divides the agriculture sector into four sub-sectors: crops, livestock, forestry, and fisheries. The fishery is an important sub-sector[1] which contributes to the economic development of Bangladesh in four ways. First, the fisheries sector helps achieve high growth rates by creating the necessary value-added. Second, the fisheries sector provides employment to a large number of people. Third, fish and fish products as an export item fetch a large volume of valuable foreign exchange. Finally, fish and fish products provide a cheap source of essential food nutrients to lower income people. Despite the fisheries sector's strategic importance to economic development, it remains a neglected sector.

Our objective in this section is to evaluate the role of the fisheries sector in the economic development of Bangladesh by examining the performance of the fisheries sector in relation to the performance of other sectors. This can be done separately for each of the four roles of the fisheries sector mentioned earlier. For doing so, we developed some methods of analysis and applied these to the four roles of the fisheries sector. First, we discuss the sources of data and methodology of analysis.

Data and Methodology

Most of the data used in this section are adapted from different issues of the Statistical Yearbook of Bangladesh, Household Expenditure Survey and the Yearbook of Agriculture Statistics of Bangladesh. For additional data, we consulted:

Export From Bangladesh, 1972 - 73 to 1995 - 96. (published by Export Promotion Bureau) and *Fish Catch Statistics of Bangladesh*. (published by Department of Fisheries (DOF).

Most of the variables used in this section are from observations for the period from 1972 to 1998. Values of some variables were not available for the last year and data for marine fisheries and inland fisheries were not recorded separately for the first seven years, 1972 to 1979. Export data for the period 1972 to 1996 were used. National Food Balance data on different kinds of food nutrients were recorded for the period 1982 to 1995. We used both GDP data at constant prices (with 19984 - 85 as the base year) and GDP data at current prices but data on GDP at constant prices, were used for analytical purposes.

Table 1. Volume of fish production (t) in Bangladesh.

	Items	Quantity 1996 - 97 (t)	Mean Quantity 1986 - 97 (t)	Mean Proportion
1.	Capture Fishery	874 604	742 510	75.91
	a. Marine	274 704	243 710	25.10
	i. Large scale	13 564	11 390	1.18
	ii. Small scale	261 140	232 320	23.92
	b. Inland	599 900	498 800	50.82
2.	Culture Fishery	432 135	244 240	24.09
	a. Shrimp Farms	79 020	37 369	3.62
	b. Other Culture	353 115	206 880	20.47
3.	Inland Total	1 032 035	743 040	74.90
4.	Marine Total	274 704	243 710	25.10
5.	TOTAL	1 306 739	986 750	100.00

[1] Very recently, the Government of the People's Republic of Bangladesh decreed the formation of a new Ministry assigning it duties related to fisheries management. Henceforth, we will use the term "fisheries sector" instead of 'fisheries sub-sector'.

In this paper, the services sector has been defined as the sum of the following sub-sectors of GDP: Construction, Power, Gas, Water, Sanitary Services, Transport, Storage, Communication, Trade Services, Housing Services, Public Administration, Defense, Banking, Insurance, Professional and Miscellaneous.

To evaluate the role of the fisheries sector in economic growth and welfare, we used the following methods of analysis: first, we analyzed the relative position of the fisheries sector on the basis of the descriptive statistics (e.g. means) in relation to other sectors. This was done for time series data on both value-added by the sectors and proportions of the sectors in GDP. Second, we calculated annual growth rates of all sectors in GDP using the following formula:

$$\text{Growth Rate of Y} = \frac{(Y_t - Y_{t-1}) * 100}{Y_{t-1}}$$

where

Y_{t-1} = previous value of the variable
Y_t = current value of the variable

Time-series plots of annual growth rates of two or more sectors were drawn in the same figure. Calculated series of growth rates for each variable were marked by wide variations so that making any decision about the growth pattern of the variable in question became extremely difficult.

To overcome the problem of wide fluctuations in the annual growth rates, we applied the econometric technique of non-linear regression to estimate a constant parametric growth rate for each variable. The underlying assumption in estimating such a parametric growth rate is that the variable in question grew exponentially at a constant rate over the sample period. The divergence between annual growth rates and the constant parametric growth rate can be attributed to random disturbances. Such estimated growth rates provide a concrete growth pattern for a variable, as long as the sum of squared differences between annual growth rates and the estimated constant growth rate is sufficiently small and does not exceed predetermined tolerance limits. In the parlance of econometrics, the acceptance of the estimated growth rate is contingent upon having a high R^2 value. The estimate of slope in a linear regression of the logarithm of a variable on a "time" variable is the estimated constant growth rate of the variable in question:

$$\text{Log } \hat{Y} = \hat{\alpha} + \hat{\beta}\text{*time},$$

where a ' ^ ' over a variable or a parameter signifies the estimated value of the variable or parameter in question and $\hat{\beta}$ denotes the estimated growth rate. In econometric estimation, OLS (Ordinary Least Squares) estimates are generally preferred to other estimates. When OLS estimates tend to be biased due to different problems like autocorrelation, heteroscedasticity, etc., we use estimated GLS (Generalized Least Squares). Third, we examined the time-series plots of proportions of each sector in GDP. For better comparison, we drew time series plots of two or more sectors in one figure. Time series plots of proportions illuminate the nature of changes in each sector.

Contribution of the Fisheries Sector to GDP Growth

Estimated annual growth rate in a country is the most widely used criterion of economic development. Each of the sectors and sub-sectors contributes to the growth of a country's GDP. Our goal in this section is to make a comparative evaluation of contributions of different sectors to the GDP growth in Bangladesh.

Descriptive Statistics on Value-added by Sectors

Table 2 presents statistics on GNP, GDP and contributions of different sectors to GDP at both current and constant prices.

Annual Growth Rates of Sectors

More insights into the nature of contributions of different sectors to GDP are given in Table 3. The industry sector attained the second highest annual growth rate of almost 10% in 1997 - 98. The fisheries sector grew at the rate of 9%. Although the mining and quarrying sector had the highest growth rate, the sector was still without much importance accounting for a negligible share of GDP. Both GNP and GDP performed reasonably well during the 1997 - 98 financial year growing at the annual rates of 5.45% and 5.66%, respectively. The agriculture sector had the smallest annual growth rate at 2.94%. Annual growth rates of different sectors during the year 1998 provide a partial view of the growth pattern of GDP; examination of historical annual growth rates over a period of twenty-six years (1973 - 99) may present a better picture.

Table 2. Contribution of the fisheries sector to GDP growth: value-added figures.

Sector	Value in 1997 - 98 (Current Price)		Value in 1997 - 98 (Constant Price)		Mean Value (Constant Price)
	Tk (m)	US$ (m)	Tk (m)	US$ (m)	Tk (m)
GNP	1 623 516	35 716	753 570	29 024	449 660
Per Capita GNP	12 834	282	5 957	229	N/A
GDP	1 548 334	34 062	718 674	27 680	436 650
Per Capita GDP	12 240	269	5 681	219	N/A
Agriculture	443 560	9 758	226 959	8 742	171 710
Industry	148 664	3 270	82 601	3 181	44 730
Mining and Quarrying	492	11	293	11	54
Services	955 618	21 023	408 821	15 746	220 160
Fisheries	82 182	1 808	23 485	905	14 394
Inland Fisheries	71 056	1 563	20 305	782	12 563.5
Marine Fisheries	11 126	245	3 180	123	1 830.5
Agricultural without Fisheries	361 378	7 950	203 474	7 837	157 320

Note: N/A = Not Available.

Table 3. Contribution of the fisheries sector to GDP: percentage shares and growth rates, current for the year 1997- 98.

Sector	Current Share in GDP	Mean Share in GDP	Estimated Growth Rates of Shares	Current Annual Growth Rate	Estimated Constant Growth Rate of Sectors
GNP	–	–	–	5.45	4.45[a]
Per Capita GNP	–	–	–	3.62	2.33[a]
GDP	–	–	–	5.66	4.25[a]
Per Capita GDP	–	–	–	3.82	2.13[a]
Agriculture	31.58	41.11	-1.95[a]	2.94	2.22[a]
Industry	11.49	10.01	1.35[a]	9.55	5.99[a]
Mining and Quarrying	0.04	0.009	12.14[b]	32.00	16.54[a]
Services	56.89	48.86	1.41[a]	6.43	5.59[a]
Fisheries	3.27	3.50	-2.71[a]	8.60	1.95
Inland Fisheries	2.83	3.05	-3.11[b]	8.60	1.55
Marine Fisheries	0.44	0.41	1.76[a]	8.60	6.47[a]
Agricultural without Fisheries	28.31	37.61	-1.92[a]	2.34	2.36[a]
Inland Fisheries in Total Fisheries	N/A	87.26	-0.27	N/A	N/A
Marine Fisheries in Total Fisheries	N/A	12.14	4.50[a]	N/A	N/A

Note: [a] = significant at 1% level; [b] = significant at 5 % level; N/A = Not Available.

Time Series Plots of Annual Growth Rates

Annual growth rates calculated for GNP, GDP, and value-added by all sectors of GDP have been recorded. However, because of its irregular fluctuations, it is difficult to discern any trend and provide analysis based on trends.

Regression Analysis of Constant Growth Rates

Annual growth rates are characterized by widespread fluctuations. It is difficult to discern any systematic pattern from annual growth rates. Constant growth rates estimated with the help of regression analysis can be more helpful in determining the nature of growth patterns of GDP and value-added by the sectors of GDP than the annual growth rates. These growth rates are given in Table 3.

Analysis of Sector Shares

Descriptive Statistics on Proportions

The proportion of each sector in GDP for every year is given in Table 3. The published figures for 1997 - 98 show that the percentage shares of the agriculture, industry, and services sectors in the GDP at constant prices were 31.58%, 11.49% and 56.89%, respectively. The fisheries sector contributed only 3.27% of the GDP in 1997 - 98. It is evident from Table 3 that the services sector with a mean share of 48.86% accounted for most of the value-added in the country. As a contributor to GDP growth, the agriculture sector came second with a mean proportion of 41.11%. The industry sector supplied on the average a meager 10% of the total value-added. The mean share of the fisheries sector in the GDP stood at 3.5%, almost 87% of which was provided by inland fisheries. On the average, approximately 0.41% of the total value-added came from marine fisheries during the sample period. The mining and quarrying sector supplied a negligible proportion of the GDP only 0.009%.

Time Series Plots of Proportions

The following five figures show the proportions of the various sectors in the GDP.

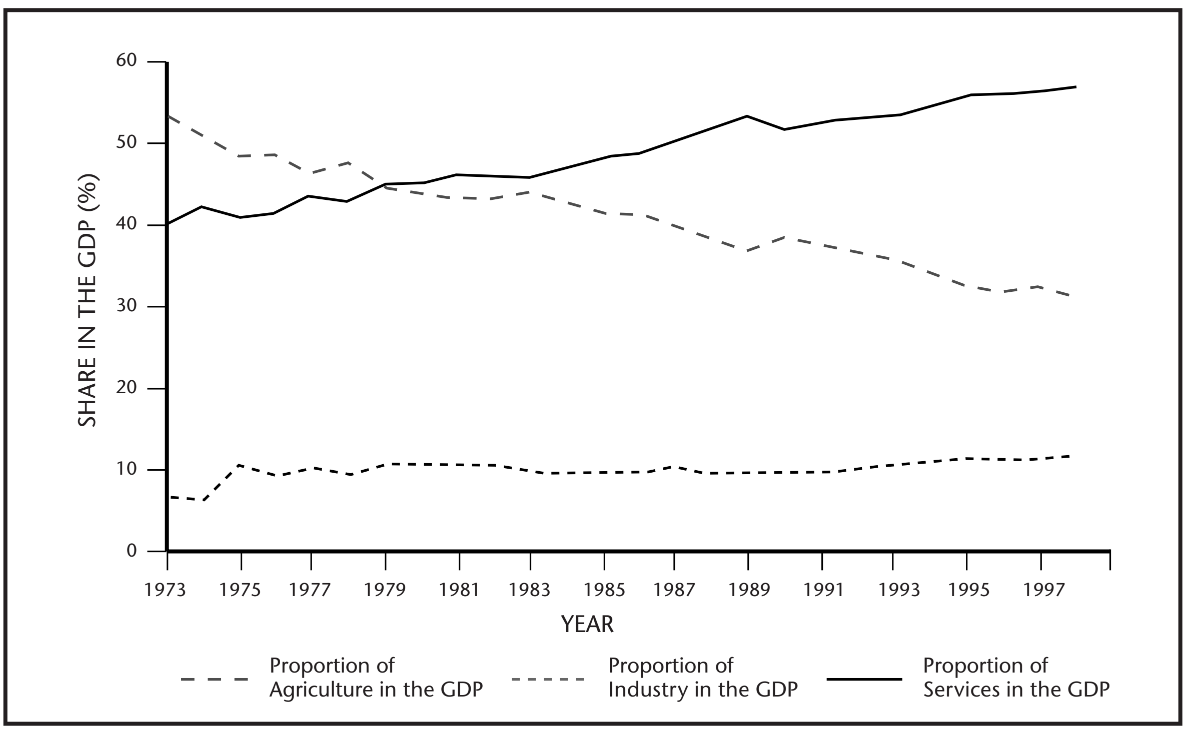

Fig. 1. Proportions of the agriculture, industry and services sectors in the GDP.

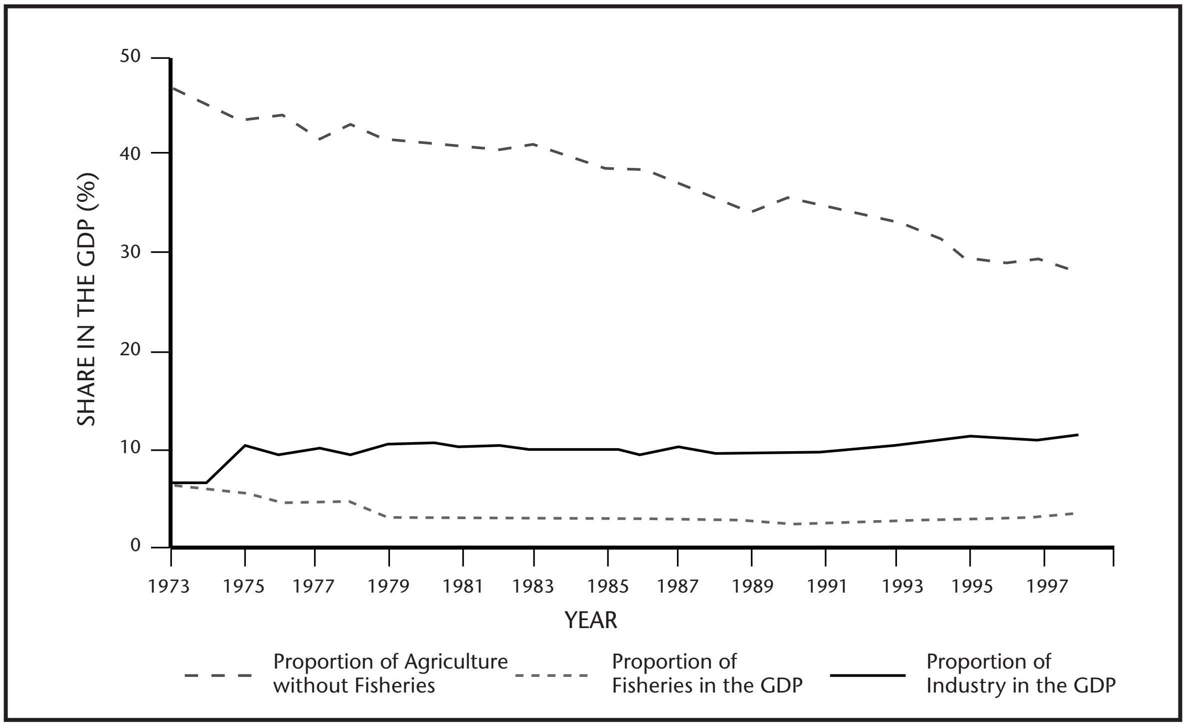

Fig. 2. Proportions of the agriculture sector without fisheries, with fisheries and industry sectors in the GDP.

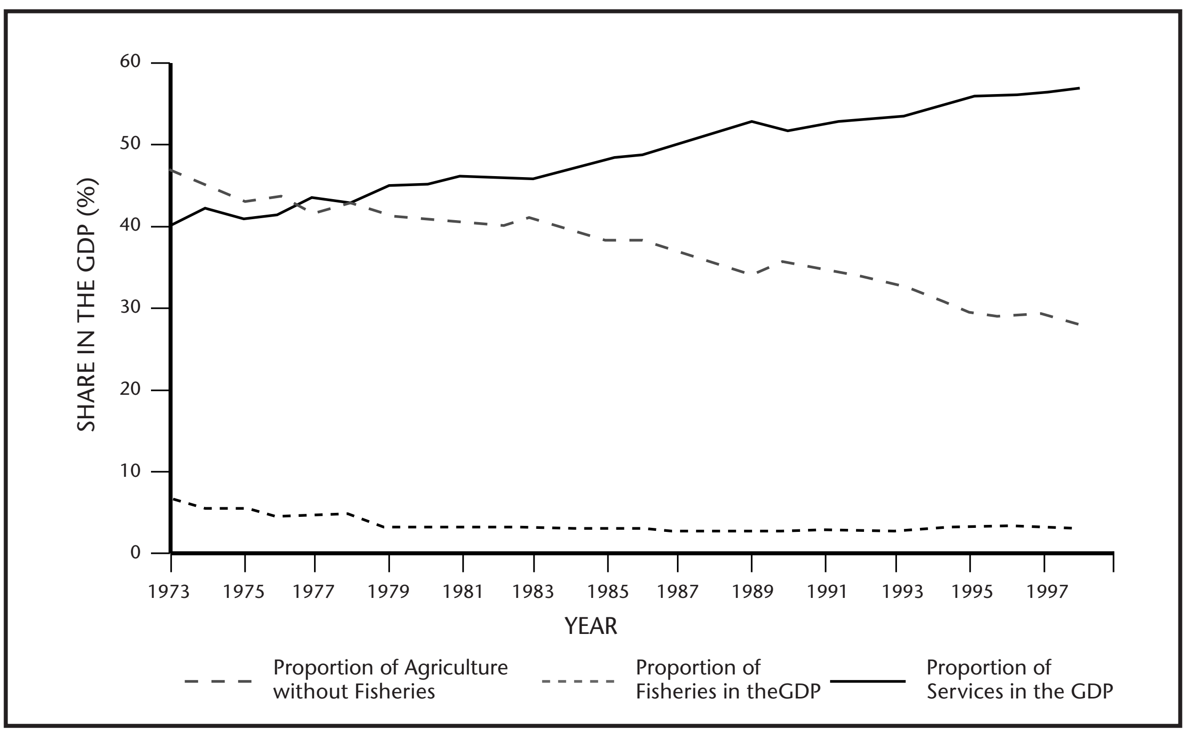

Fig. 3. Proportions of the agriculture without fisheries, with fisheries and services sectors in the GDP.

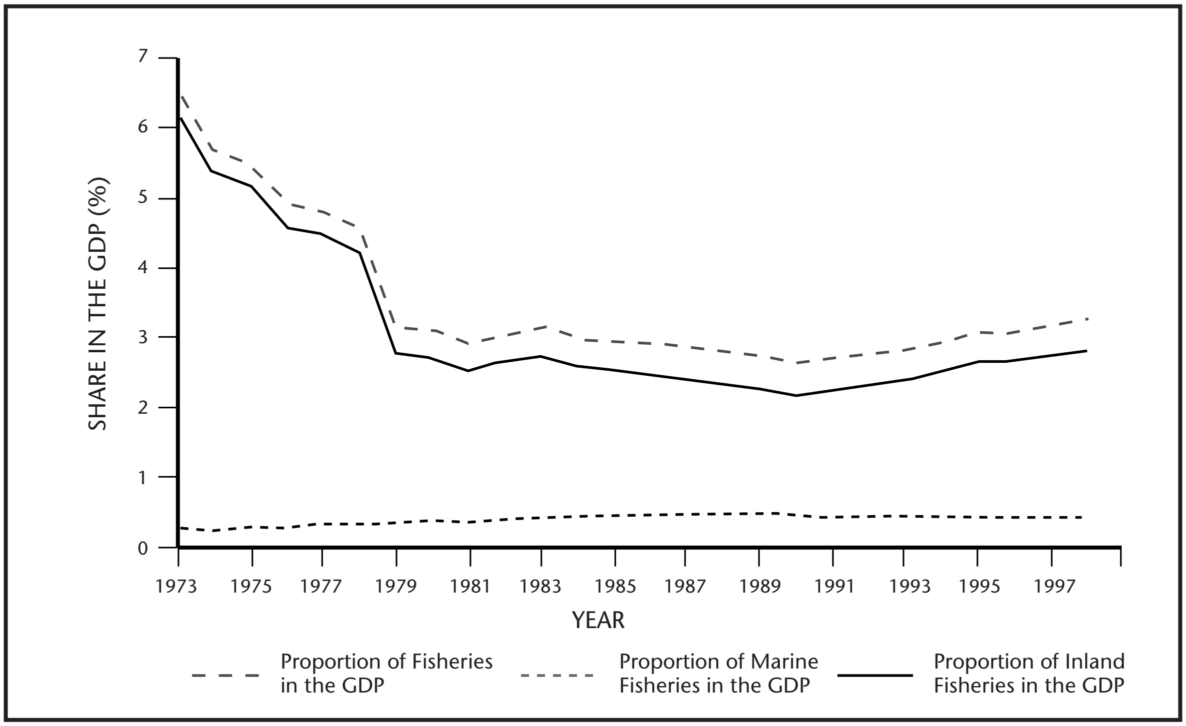

Fig. 4. Proportions of the fisheries, marine fisheries and inland fisheries sectors in the GDP.

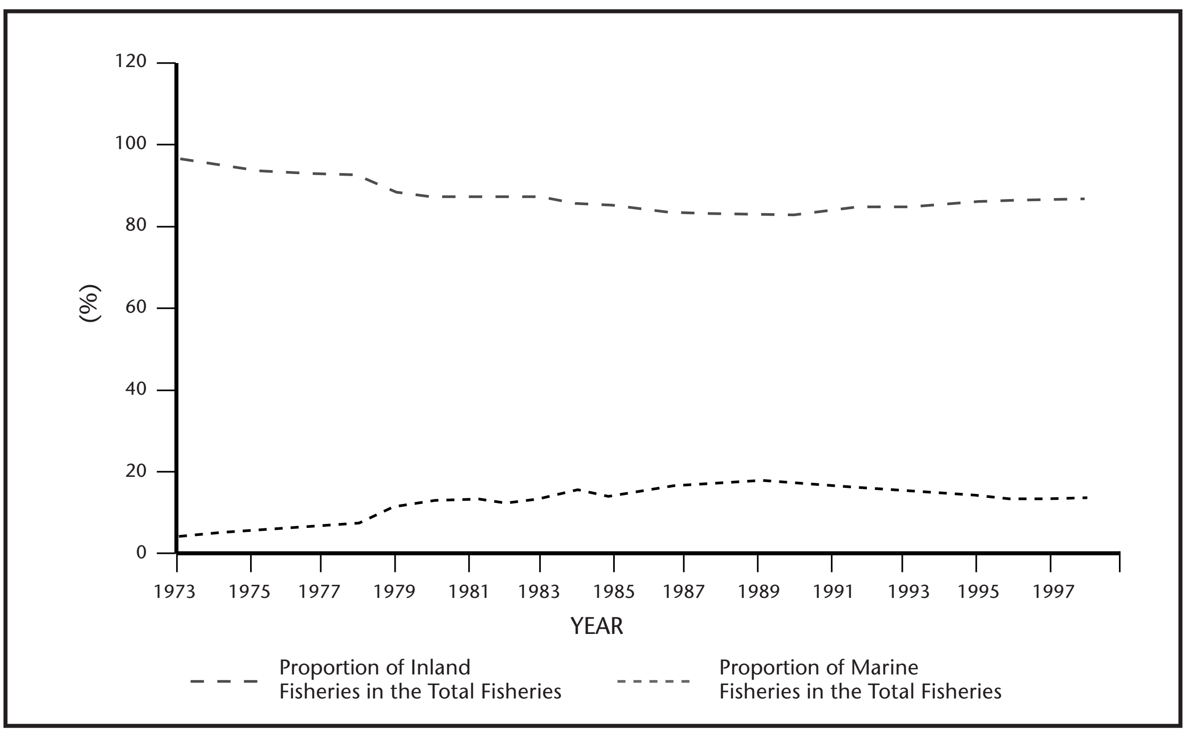

Fig. 5. Proportions of the marine fisheries and inland fisheries in the total fisheries.

Inspection of the time series plots of proportions gives a clear idea of the changing shares of different sectors in the GDP, but it cannot provide the exact measurements of such changes. Regression analysis can be useful for measurements of changes of shares of different sectors over the sample period.

Regression Analysis of Proportions

The estimates of growth rates of proportions were obtained using both the Ordinary Least Squares (OLS) and Generalized Least Squares (GLS) methods. Since most of the OLS regression models had the problem of auto-correlated errors, the analysis of regression results here is based on GLS estimates, which corrects for auto-correlation. Results in Table 3 show negative growth rates for proportions of the agriculture and agriculture without fisheries, with fisheries and inland fisheries sectors, and positive growth rates for the mining and quarrying, industry, marine fisheries and services sectors. In these cases, the estimated coefficients are significantly different from zero at either 5% or 1% levels of significance. In other words, the shares of the agriculture, fisheries and inland fisheries sectors in GDP fell over the sample period.

Mean proportions of the services, agriculture, industry and fisheries sectors in the GDP were 48.86%, 41.11%, 10.01%, and 3.5%, respectively over a period of 26 years. The proportion of the agriculture sector decreased and the proportion of the services sector increased over the sample period. The proportions of the industry and fisheries sectors remained stable. The annual growth rates of the agriculture and agriculture without fisheries sectors fell throughout the sample period, with a few upward fluctuations occasionally occurring. With a few exceptions, the growth rates of the GDP, and of the industry and services sectors were more or less stable. On the average, the growth rates of the services sectors were higher than those of other sectors. The fisheries sector had low growth rates initially, but these growth rates were higher than the growth rates of other sectors at the end of the sample period.

Contribution of the Fishing Industry to Income and Employment

The fisheries sector in Bangladesh provides employment to a large number of people. The artisanal fishers comprise a large section of the total population. Some people are also involved in activities related to fishing such as trading in fresh and dried fish, making fishing gear and crafts, etc.

Data on the total employment level and by sector are available for only a few population census and labor-force survey years. But time series data for the period from 1972 to 1990 on employment levels in the fisheries, marine fisheries and inland fisheries sectors have been recorded elsewhere, and time series observations on nominal wages rate indices by sector are available for the period 1981 - 98.

As in previous sections, descriptive statistics on employment levels have been analyzed. For employment data, two alternative procedures have been applied. Initially, descriptive statistics on employment levels were calculated using the available six observations for all sectors excluding the fisheries sector. For the fisheries sectors, 17 observations were used for calculating the descriptive statistics. Alternatively, interpolated figures were substituted for missing observations to complete the time-series data on employment levels of all sectors of the economy. Data series were interpolated from a trend line estimated for each sector using the available six observations. For each series, we had ultimately 24 observations. The completed time series data were then used in estimating the constant growth rates and calculating descriptive statistics.

Second, we estimated constant growth rates of employment levels with the help of the interpolated data series. Econometric estimates based on six observations are not sufficiently precise, although these estimates are still unbiased.

Third, we calculated real wage rate indices for different sectors of the economy by deflating the nominal wage rate indices by the consumer price index (CPI). Descriptive statistics were not calculated for these real wage rate indices because descriptive statistics on indices are not as interesting as are those on absolute values. Constant growth rates were, however, estimated for these real wage rate indices.

Fourth, we created some pseudo-average productivity of labor series for people employed in different sectors of the economy. To do this for a particular sector, value-added by the sector at constant prices in a particular year was divided by the employment level of the corresponding sector in that year. We then tested for differences in means of average productivity of labor between the sectors.

The seven estimated trend lines using OLS in Table 4 were applied for creating interpolated data series for different sectors:

Table 4. Estimated trend lines of employment levels in Bangladesh.

Sector	Estimated Trend Line	T - Value	Adjusted R^2	d - statistics
Aggregate	$T\hat{E} = 10479000 + 12002000$ Time	4.77	0.81	1.79
Agriculture	$A\hat{E} = 10438000 + 644160$ Time	3.24	0.60	1.87
Manufacturing	$M\hat{E} = -118020 + 169330$ Time	2.99	0.54	1.99
Services	$S\hat{E} = -58536 + 396490$ Time	6.40	0.89	2.02
Inland Fisheries	$IF\hat{E} = 647830 + 1124.4$ Time	1.48	0.63	1.42
Marine Fisheries	$MF\hat{E} = 341530 + 378.06$ Time	0.44	0.92	1.11
Fisheries	$F\hat{E} = 898290 + 4471.4$ Time	1.65	0.67	1.89

Note: $T\hat{E}$ = Total Employment
$A\hat{E}$ = Employment in the Agriculture Sector
$M\hat{E}$ = Employment in the Manufacturing Sector
$S\hat{E}$ = Employment in the Services Sector
$F\hat{E}$ = Employment in the Fisheries Sector
$IF\hat{E}$ = Employment in the Inland Fisheries Sub-Sector
$MF\hat{E}$ = Employment in the Marine Fisheries Sub-Sector

Analysis of Employment Levels

Descriptive Statistics on Employment Levels

Descriptive statistics[3] on employment levels by sector are given in Table 5. The agriculture sector was the biggest employer, providing approximately 69% of all jobs. The services sector, creating 22% of the total employment, was the second biggest employer in Bangladesh. The industry sector accounted for 9% of the total employment level in the country. The mean share of the fisheries sector in the total employment level was approximately 3%. The inland fisheries sub-sector provided approximately 2% and the marine fisheries sub-sector approximately 1% of the total jobs in the country. Table 5 shows that out of a total population of 124.3 million in the country in the 1996 - 97 financial year, 54.6 million people were employed. The agriculture sector provided employment to a maximum of 34.5 million people. The services sector was the second biggest employer with 16 million employees. The numbers of employees were 6.976 million in the industry sector, 1.548 million in the fisheries sector, 0.769 million in the inland fisheries sub-sector, and 0.508 million in the marine fisheries sub-sector in the same year. Total employment in the country averaged almost 37.3 million over a period of 24 years. Average employment levels were 24.8 million in the agriculture sector, 3.64 million in the industry sector, 8.797 million in the services sector and 1.073 million in the fisheries sector. The inland fisheries and marine fisheries sub-sectors employed on the average 6.93 lakh and 3.63 lakh (1 lakh = 100,000) people, respectively.

Regression Analysis of Employment Levels

Estimated constant growth rates of employment levels are shown in Table 5. The regression estimates reveal stagnant levels of employment in the fisheries sector and in its two sub-sectors. The estimated growth rates in these sectors are not significantly different from zero at both the 5% and 1% levels of significance. The total employment level and the employment levels in the agriculture, industry and services sectors increased over a period of 24 years. The total employment level grew at the rate of 3.42% per annum. The sector growth rates of employment levels were 2.75% for the agriculture, 5.08% for the industry and 4.85% for the services sector. These growth rates are statistically significant at a 1% level and the adjusted R^2 values of the corresponding models are very high, ranging between 75%and 92%.

Regression Analysis of Real Wage Rate Indices

Constant growth rates of real wage rate indices were estimated using regression models. The estimated growth rates were statistically significant in four out of five cases. Since the real wage rate index for the services could not be obtained, we used the real wage rate index for construction as a proxy for it. With the exception of the real wage index for construction, real wage rate indices for the economy as a whole and for other sectors of the GDP registered positive growth rates. In other words, the real income of the labor force engaged in these sectors increased during the sample period. The real wage

[3] The analysis of descriptive statistics here is based on size observations.

Table 5. Contribution of the fisheries sector to income and employment.

Sector	Employment Level in 1996 - 97 ('000)	Mean Employment Levels ('000)	Mean Shares of Employment Levels	Growth Rates of Employment Levels	Mean Average Productivity of Labor (APL) (Tk)	Growth Rates of APL	Growth Rates of Real Wage Rate Indices
GDP (Total)	54 597	37 283	–	3.42[a]	10 732.78	0.50	2.25[a]
Agriculture	34 530	24 824	69.17	2.75[a]	6 690.36	-0.69	2.52[a]
Industry	6 976	3 640.2	8.78	5.08[a]	11 511.85	-0.18	2.32[a]
Services	15 959	8 796.5	22.0	4.85[a]	22 177.27	0.45	1.25
Fisheries	15 483	1 072.6	3.22	0.74	13 497.40	4.50[a]	2.28[a]
Inland Fish	768.63	692.7	2.12	0.22	16 637.49	4.46[a]	–
Marine Fish	507.8	362.3	1.06	2.17	5 106.20	5.71[a]	–

Note: [a] = significant at 1% level; [b] = significant at 5 % level. 1 US$ = Tk 42.95 (average 1996 - 97; source: oanda.com)

rate index for construction workers remained constant during the long period of seventeen years (1973 - 90). The real wage rate index for the industrial workers grew at the rate of 2.32% per annum. The general real wage rate index in the country attained a growth rate of 2.25% per annum. The rate of growth of the real wage rate in the agriculture sector was 2.52%. The real wage rate of workers in the fisheries sector increased at the lowest rate of 2.28% per annum.

Analysis of Average Productivity of Labor

Descriptive Statistics on the Average Productivity of Labor (APL)

The descriptive statistics on the average productivity of labor (APL) are given in Table 5. The mean APL over a period of 24 years (1973 - 97) was 10 732.78 taka for the country as a whole (GDP). The highest average value of APL, 22 177.27 taka, originated in the services sector, followed by the inland fisheries sub-sector with an APL of 16 637.49 taka. The marine fisheries sub-sector attained, on the average, the lowest level of average productivity of labor, 5 106.20 taka. Average productivity of labor over a period of 24 years averaged 6 690.36 taka for the agriculture sector, 11 511.85 taka for the industry sector and 13 497.40 taka for the fisheries sector.

Regression Analysis of Average Productivity of Labor (APL)

Table 5 shows that the rates of growth of APL were 4.5% for the fisheries sector, 4.46% for the inland fisheries and 5.71% for the marine fisheries sub-sector. Average productivity of labor did not increase in the agriculture, industry, and services sectors. Moreover, average productivity of labor in the country as reflected by the APL of the GDP remained stagnant over the sample period. The rate of growth of the APL was higher in the marine fisheries sub-sector than in the inland fisheries sub-sector.

T-tests for Difference of Means of Average Productivity of Labor (APL)

Table 6 shows "t" values for tests of differences of means of the APL. It has "t" values for both tests of paired differences in means, and tests of differences in means of independent samples. The mean APL in the fisheries sector was found to be greater than the mean APL in the country as a whole (GDP). The mean APL of the fisheries sector was found to be significantly greater than the mean APL of the agriculture and industry sectors. The mean APL of the fisheries sector was greater than the mean APL of the marine fisheries sub-sector and less than the mean APL of the inland fisheries sub-sector. The mean APL in the fisheries sector was much less than the mean APL in the services sector. Finally, the differences in the sample means of APL of the inland fisheries and marine fisheries sub-sectors were statistically significant. In fact, the mean APL of the inland fisheries sub-sector was much greater than the mean APL of the marine fisheries sub-sector.

Table 6. t Tests For differences of means of average productivity of labor between sectors.

Sectors	t-Value (Independent Samples)	t-Value (Paired Samples)
GDP - Fisheries	-3.58[a]	-3.75[a]
Agriculture-Fisheries	-8.93[a]	-8.72[a]
Industries - Fisheries	-1.84	-2.27[a]
Services - Fisheries	9.68[a]	12.55[a]
Fisheries - Inland Fisheries	-3.21[a]	-19.50[a]
Fisheries - Marine Fisheries	7.64[a]	14.91[a]
Inland Fisheries - Marine Fisheries	11.07[a]	19.21[a]

Note: [a] = significant at 1% level; [b] = significant at 5 % level.

Section Summary: The mean share of the fisheries sector in the total employment level was approximately 3%. The real wage rate of the workers in the fisheries sector increased at the rate of 2.28% per year.

Contribution of the Fisheries Sector to Foreign Exchange Earnings

In this section, we examine the role of the fisheries sector as a supplier of export commodities. Time series data on the export value of different commodities and groups of commodities are available for the period from 1972 to 1996. We collected secondary data on the export value of the following export items: frozen food: shrimps; frozen food: fish, fresh/chilled fish, dried fish, sealed dehydrated fish, shark fins and fish maws, tortoise and turtles, crabs, snails, turtle meat, eggs and fins, sea shell and aquarium fish.

In addition to the total export value of fish, data on the export value of all primary commodities, all manufactured commodities and the total export value for Bangladesh were also used. Fish export is a fraction of the total primary export. The previous techniques of analysis were applied to the export data used in this section. First, descriptive statistics on both absolute values and shares of different commodities and groups of commodities in the total export value were calculated. Second, econometric estimates of the constant growth rates were obtained using both the OLS and GLS methods.

Descriptive Statistics on Export Values

Table 7 shows the descriptive statistics on export values of different commodities and of groups of commodities for the period from 1972 to 1996. The mean proportion of export value of fish to total export value for Bangladesh was 7.20% over the sample period. The proportion of export value of all manufactured commodities in total export value averaged 71.38% during the same period. The mean percentage share of export value of all primary products in total export value was 28.62%. The average total export value over a period of 24 years (1972 - 96) was Tk39 445 million, out of which Tk 3 400.8 million came from fish exports. The average export earnings of all manufactured commodities and all primary commodities were Tk32 034 million and Tk7 411.3 million, respectively.

Table 7. Contribution of the fisheries sector to foreign exchange earnings.

Item	Mean export value (Tk m)	Mean export value (US$ m)	Growth rates of export values	Mean share in total export value	Growth rates of shares
Total Export	39 445	1 217.5	17.31	–	–
Primary Commodities	7 411.3	261.08	11.93	28.62	-5.48[a]
Manufactured	32 034	956.43	19.19	71.38	1.88
Fish	3 400.8	104.36	25.17	7.20	7.80

Note: [a] significant at 1% level; [b] significant at 5 % level.

Regression Analysis of Constant Growth Rates

Constant growth rates for seven variables, including three proportions, were estimated using both GLS and OLS estimation methods. The estimated growth rates of proportions reveal a falling share of all primary commodities and a rising share of fish and all manufactured commodities in total exports. The export value of all commodities and of fish grew over the sample period (1972 - 96). The export value of fish, however, grew at the highest rate of 25.17% per annum. The second highest growth rate of 19.19% was observed for the export value of all manufactured commodities. The growth rate for the total export value was 17.31%, which is much higher than the lowest growth rate of 11.93% per annum obtained for the export value of all primary commodities.

Section Summary: Although fish and fish products had initially a small share in the total export value, this share increased during the period 1972 - 96. Moreover, exports of fish and fish products grew at their highest rate during the sample period.

Contribution of the Fisheries Sector to Domestic Nutrition

This section highlights the contribution of the fisheries sector to the national consumption pattern. The peculiarity of the fisheries sector lies in its being a cheap source of food. The analysis in this section is undertaken in two perspectives. First, time series data on per capita availability of fish and other consumption items were analyzed with the help of descriptive statistics and econometric estimates of constant growth rates. Time series data are also available on the daily per capita intake of nutrients from different groups of food including fish. The three food nutrients for which data are available are energy, protein, and fats. Data on each food nutrient have been explained with the help of descriptive statistics and regression analysis tables.

Analysis of Per Capita Availability of Consumption Items

Descriptive Statistics on Per Capita Availability

The Statistical Yearbook of Bangladesh publishes data on per capita availability of 24 items, although it does not record data on the per capita availability of fish. Other sources were used for calculating the per capita availability of fish. We selected 14 items of consumption, of which 10 items were from the food group and 4 items were from the non-food group. Data on the per capita availability of consumption items are available for 19 years (1979 - 97).

Table 8 shows the descriptive statistics on the per capita availability (consumption) of food and non-food items. As the staple, food grain is the first item, with a mean per capita availability of 163.12 kg•annum^{-1}. Secondly, the mean per capita consumption of milk and milk products was 10.65 kg •year^{-1}. Fish, the third item, showed a mean per capita consumption of 8.36 kg•year^{-1}. The mean per capita availability of meat was 3.51 kg•annum^{-1}, much less than that of fish. The mean per capita annual availability of pulses, sugar, and edible oil were 3.56 kg, 2.11 kg and 1.41 kg, respectively. The mean per capita availability of eggs was 14 per annum. Among the non-food items, the mean per capita availability of cement, new cloth, paper, and electricity stood at 17.00 kg, 8.58 m, 0.42 kg and 36.94 kWh, respectively. Comparison of the mean values with current values of per capita availability of different consumption items shows declines in per capita availability of three items, viz. food grain, paper and milk and milk products. The per capita availability of other consumption items increased during the survey period.

Table 8. Contribution of the fisheries sector to national food balance: Per capita availability of consumption items.

Item	Unit	Quantity	Mean per capita avail.	Estimated growth rate
Food Grain	kg	162.00	163.12	0.04
Pulses	kg	4.50	3.56	5.14[b]
Sugar	kg	2.23	2.11	3.11[a]
Meat	kg	3.68	3.51	2.34
Eggs	no.	19	14	2.47[a]
Cement	kg	27.71	17.00	6.22[a]
New Cloth	m	11.10	8.58	3.73[a]
Paper	kg	0.39	0.42	0.46
Electricity	kWh	61.05	36.94	8.77[a]
Edible Oil	kg	1.88	1.41	1.99
Milk and Milk products	kg	10.10	10.65	-2.93[a]
Fish	kg	10.18	8.36	2.14[a]
Inland Fish	kg	8.09	6.30	1.32
Marine Fish	kg	2.21	1.90	2.93[a]

Note: [a] = significant at 1% level; [b] = significant at 5% level.

Growth Rates of Per Capita Availability

Estimates of constant growth rates of the per capita availability of different consumption items are also given in Table 8. The positive growth rates for eight items are significantly different from zero. The per capita availability of eggs, cement, new cloth, pulses, sugar, electricity, fish and marine fish grew at the rates of 2.47%, 6.22%, 3.73%, 5.14%, 3.11%, 8.77%, 2.14%, and 2.93% per year, respectively. The per capita availability of milk and milk products in fact declined at the rate of 2.93% per year over a period of 18 years (1979 - 97). Growth rates of the per capita availability were not significantly different from zero for food grains, meat, paper, edible oil, and inland fish. Per capita availability of non-food items like cement, new cloth, paper, electricity, etc., registered quite high positive growth rates.

Analysis of Availability of Nutrients

The quantity of nutrients available in a given quantity of a food item is important. Time series data on daily per capita intake of three types of nutrients from different food items are available. These data were subject to the same techniques of analysis used earlier. First, descriptive statistics on each of the three types of nutrients from different food items were explained. Second, estimates of constant growth rates for each nutrient were made.

Descriptive Statistics on Energy Intake

Table 9 shows descriptive statistics on the daily per capita intake of the three types of nutrients, energy food, protein and fat from different food groups.

Table 9. Contribution of the fisheries sector to national food balance: Current (1995 - 96) and mean (over 18 years) levels of nutrients in different foods.

Food item	Energy food, current, calories·capita^{-1}·day^{-1}	Mean Energy, calories·capita^{-1}·day^{-1}	Protein, current, g·capita^{-1}·day^{-1}	Mean Protein, g·capita^{-1}·day^{-1}	Fats, current, g·capita^{-1}·day^{-1}	Mean Fats, g·capita^{-1}·day^{-1}
Total	2 081	2 032.4	52.7	52.54	49.1	40.49
Vegetable Products	2 000	1 959.3	43.9	44.76	45	36.65
Animal Products	81	73.07	8.8	7.79	4.1	3.82
Cereals	1 662	1 681.5	37.6	38.61	27.4	27.51
Roots & Tubers	37	39.57	1.0	0.99	0.1	0.10
Sugar/Syrup/Honey	66	75.29	0	0	0	0
Pulses	43	38.07	3.1	2.71	0.2	0.16
Treenuts/Oilcrops	2	2.00	0	0	0	0
Vegetables	15	12.86	0.5	0.55	0.2	0.20
Fruits	25	27.64	1.2	1.36	0.2	0.20
Meats and Offals	12	12.29	2.3	2.47	0.2	0.24
Eggs	5	3.57	0.3	0.23	0.4	0.26
Fish	37	35.5	4.9	4.24	1.4	1.74
Milk	19	15.36	0.9	0.71	1.1	1.34
Vegetable Oils and Fats	151	74.79	0	0	16.8	8.32
Animal Oils and Fats	9	6.86	0.1	0.13	1.0	0.67
Spices	11	12.36	0.5	0.51	0.2	0.21

Table 9 shows that 96.4% of the total energy food came from vegetable products. The most important source of energy was cereals, supplying 82.75% of the total energy. In the vegetable products group, on the average, roots and tubers supplied 1.95%; sugar, syrup and honey as one item 3.71%, pulses 1.87%, fruits 1.36%, and vegetable oils and fats 3.66% of the total energy. In the animal products group, the first item was fish, supplying 1.75% of the total energy. The mean percentage shares of milk, meats and offals and eggs were 0.75%, 0.61% and 0.18%, respectively.

Descriptive Statistics on Protein Intake

From Table 9, fish was the second most important source of protein among all food items supplying, on the average, 4.24 g of protein per capita per day. Table 10 shows that fish provides around 8% of the daily protein needs.

Descriptive Statistics on Fats Intake

From Table 9, the mean per capita daily intake of fats was 40.49 g. In the animal products group, the biggest contributor was fish, supplying 1.74 g of fat daily. Table 10 shows that the mean percentage shares of cereals, and vegetable oils and fats in the daily total intake of fats were 68.53% and 19.90%, respectively. In the animal products group, the mean percentage shares were 4.35% for fish, 3.30% for milk, and 1.65% for animal oils and fats.

Regression Analysis of Nutrient Intake

The estimates of constant growth rates of different nutrients were obtained by using both the GLS and OLS methods. Table 10 shows the estimates of constant growth rates of the daily per capita intakes of various nutrient groups such as energy food, protein and fat. Among the animal products group,

Table 10. Contribution of the fisheries sector to national food balance: Shares and growth rates of the contributions of various foods to nutrient supply, shown as percentages.

Food Item	Current Share in Energy	Mean Share in Energy	Current Share in Protein	Mean Share in Protein	Current Share in Fats	Mean Share in Fats	Growth Rate of Energy	Growth Rate of Protein	Growth Rate of Fats
Total	–		–		–		0.09	-0.06	1.37[b]
Vegetable Products	96.11	96.40	83.30	85.17	91.65	90.46	0.10	-0.12	1.63[b]
Animal Products	3.89	3.60	16.70	14.83	8.35	9.54	0.13	0.55	-1.08[b]
Cereals	79.87	82.75	71.35	73.48	55.80	68.53	-0.30	-0.51[b]	0.150
Roots & Tubers	1.78	1.95	1.90	1.89	0.20	0.25	-1.68[a]	-0.68	0
Sugar/Syrup/Honey	3.17	3.71	0	0	0	0	-1.49[a]	0	0
Pulses	2.07	1.87	5.88	5.16	0.41	0.41	8.82[a]	8.69[a]	6.29[a]
Treenuts/Oilcrops	0.10	0.10	0	0	0	0	0	0	0
Vegetables	0.72	0.63	0.95	1.05	0.41	0	1.71[a]	-2.27[b]	0
Fruits	1.20	1.36	2.28	2.59	0.41	0	-1.93[a]	-2.51[a]	0
Meats and Offals	0.58	0.61	4.36	4.71	0.41	0.61	-1.87	-2.17	-3.21[b]
Eggs	0.24	0.18	0.57	0.44	0.82	0.63	3.45[b]	2.5[b]	4.68[b]
Fish	1.78	1.75	9.30	8.07	2.85	4.35	-0.24	1.55[b]	-3.03[b]
Milk	0.91	0.75	1.71	1.36	2.24	3.30	2.22	1.52	1.65
Vegetable Oils and Fats	7.26	3.66	0	0	14.79	19.90	5.63[b]	0	5.67[b]
Animal Oils and Fats	0.43	0.34	0.19	0.24	0.88	1.65	-0.53	-3.66	0.95
Spices	0.53	0.61	0.95	0.96	1.08	0.53	0	0.55	0.46

Note: [a] = significant at 1% level; [b] = significant at 5 % level.

fish was the most important source of energy. Excluding the cereals, fish was also the most important source of protein, and fish was the third most important food item as a supplier of fats.

Conclusions

This section highlight the role of the fisheries sector in economic growth and welfare. To start with the analysis of value-added by sectors, we found that the proportion of the agriculture sector in the GDP decreased from 51% in 1971 to nearly 32% in 1997. The shares of the industry and fisheries sectors were stable at approximately 10% and 3%, respectively. The share of the services sector rose from 42% in 1974 to around 56% in 1997. These results on the sector shares were supported by the results on sector growth rates. The annual growth rates of the fisheries sector, although initially lagging behind the annual growth rates of other sectors, finally caught up with the higher growth rates of the services and industry sectors. It is also evident from the analysis of constant growth rates. The estimated constant growth rate of 1.95% per annum in the fisheries sector lagged far behind the highest growth rate of 5.99% per annum in the industry sector. Analysis of employment and income shows that the agriculture sector is still the biggest employer, providing on the average 69% of all jobs in the country. The services and the industry sector on the average created 22% and 9% of all jobs, respectively. The fisheries sector was responsible for approximately 3% of the total employment level in the country. The real wage rate of the fishers increased at the rate of 2.28% per annum. Although the mean average productivity of labor in the fisheries sector was significantly greater than mean average productivity of labor in the agriculture and industry sectors, the employment level in the fisheries sector did not increase during the sample period. Employment levels in the agriculture, industry and services sectors, however, grew at positive rates. This may be explained by the fact that people are very reluctant to enter the profession of fishing after observing the widespread poverty of fishing folk. Fishers in the marine fisheries sub-sector had the lowest level of average productivity of labor.

Despite its low role in employment creation, the fisheries sector has important potential as a source of foreign exchange. The export value of fish grew at the highest rate of 25.17% per annum between 1972 and 1996. Moreover, the share of fish and fish products in total export value has been increasing over a period of 24 years.

Analysis of food nutrients showed that fish is the largest source of energy from the animal products group. Fish is also the second largest supplier of protein and the third most important source of fats.

Socioeconomic Analysis of the Artisanal or Small Scale Fishery Sector

This section is devoted to an analysis of socioeconomic indicators for artisanal fishers. In some places we appended the national survey results for some socioeconomic variables.

The fishers in Bangladesh play an important role in enhancing economic development by providing the requisite value-added for GDP growth. The fisheries sector employs a large number of people, supplies the essential protein base for the poor section, and earns a significant amount of foreign currency for our national exchequer. We discuss these contributions of the fisheries sector in more detail using secondary data. Our objective in this section is to supplement our previous analysis by microanalysis of primary data on important but interrelated aspects of a fisher's life. We analyze primary data on different socioeconomic indicators of the standard of living of the fisher. We compare our findings on socioeconomic indicators for fishing units with national findings on similar indicators obtained by the Bureau of Statistics, *Household Expenditure Survey* (HES) 1995 - 96. This comparison provides the scenario of the relative positions of fishers among the different occupations.

Data and Methodology

Our results in this section are based on primary data collected through the questionnaire method. We collected data from four classes of fishers belonging to different income groups with variations in the size of capital investment in 1995 - 96. At the bottom lies the class of artisanal fishers living in coastal areas and fishing in shallow waters. Although they use both non-motorized and motorized boats, these boats are the smallest in terms of horsepower and size. We selected two sites of small scale fishers to survey considering the following criteria for selection:

1. The proximity of the fishing village to the nearest city

2. Accessibility of selected site through different means of transport

3. The heterogeneity of fishing units with regard to fishing gear

The two villages selected as survey areas for small scale fisheries were Peshkar Para in the district of Cox's Bazar and North Salimpur in the district of Chittagong. Peshkar Para is only 2 km to the west of Cox's Bazar town. North Salimpur, situated in Situkunda Thana, is about 10 km to the north of Chittagong City. Fishers in the two villages come from low-income groups, and are representative of the artisanal fishers in Bangladesh. There are sub-categories of fishers in these two villages, depending on the ownership of fishing craft and gear and on the supply of manual labor used in fishing. We selected 50 fishing units from each sample village using the stratified random sampling technique.

Assessment of the Socioeconomic Status of the Fishing Households and Communities in Peshkar Para and North Salimpur

Educational Levels

Information on the educational levels of respondents and their wives is provided in Table 11. In North Salimpur 40% of the respondents had some formal school education, but they had dropped out at different stages. None of them, however, had passed the SSC (Secondary School Certificate) examination. Thirty-two percent of the respondents achieved non-formal education so the proportion of respondents with formal and non-formal education is 72%. Twenty-eight percent of the respondents were completely illiterate. The general level of education was higher in Peshkar Para where 54% of the respondents had formal school education, although none of them had passed the SSC examination. Forty-two percent of the respondents had attained non-formal education so that the percentage of literate people in Peshkar Para stood at 96%. Only 4% were totally illiterate.

Adult literacy in Bangladesh for both sexes is 35% as recorded in the census report of 1991. The Bureau of Statistics, Household Expenditure Survey of 1995 - 96 quotes 52% of all Bangladesh household heads as being illiterate.

The level of educational attainment is low among the wives in Salimpur. Only 62% of the wives had any kind of education, formal or non-formal, and 38% of them were totally illiterate. The level of education is low among the wives in Peshkar Para. Only 60% of them had any kind of education, 40% of them being illiterate. The level of illiteracy was higher among the wives in both sample villages. The illiteracy rate among the adult female population is 63% compared to 47% among males.

Data on education of the children of the fishers are given in Table 12. The children of fishers in North Salimpur go to one primary school, two NGO schools and one secondary school. The children of fisheries in Peshkar Para can be admitted in one primary schools, two secondary schools and two colleges.

Table 11. Education levels in the two villages.

Level of Education (Class)	North Salimpur		Peshkar Para	
	Respondent	Wife	Respondent	Wife
Non-formal	16	8	21	5
One	2	8	0	1
Two	7	0	1	5
Three	2	3	4	2
Four	2	0	8	1
Five	2	2	6	4
Six	0	2	5	1
Seven	0	0	0	1
Eight	4	1	2	1
Nine	1	0	1	1
Illiteraate	14	15	2	15

Table 12. Number of schools.

Category of School	North Salimpur	Peshkar Para
Primary	1	1
NGO School	2	0
Secondary School	1	2
College	0	2

Table 13. Reasons for not sending children to school.

Reason	North Salimpur	Peshkar Para
No economic gain	0	0
Not able to meet expenses	17	9
No prospect for future job	0	0
Environment not suitable	4	0
The child is not interested	4	2
Miscellaneous	0	4
TOTAL	25	15

The schools and colleges are located within short distances of these villages, but we were informed that incentives for sending the children to school are non-existent. In North Salimpur, only two respondents reported that they send their children to school. Table 13 summarizes the reasons for not sending the children to schools. Seventeen families in North Salimpur and 15 families in Peshkar Para do not send their children to school. Most families identify the high expense of education as the main reason. A few families blame the non-academic environments of the fishing villages for this trend. Lack of interest among the children is another common trend in the region.

Structure of Households

Information on the structure of households is provided in the Appendix (Table 3). Households in Peshkar Para have more rooms than households in North Salimpur; the mean number of rooms is 4.08 for Peshkar Para and 3.6 for North Salimpur. The mean area of the main room is almost the same in both villages, 36.3 m^2 in Peshkar Para and 35.97 m^2 in North Salimpur.

Table 14 shows the types of walls, roofs and floors at the two sites. Most houses in the two villages have bamboo walls. There are five houses with brick walls in Peshkar Para and five houses with wooden walls in North Salimpur. Forty-nine households in North Salimpur have earthen floors with the exception of one household having a brick floor.

Almost 50% of all households in the two areas use tin roofs and another 50% use roofs made of thatch and leaves. The national percentage of households using corrugated iron sheets (tin) as roof material was 48% in 1991. Considering brick walls and tin roofs as symbols of economic prosperity, we can conclude that the fishers in Peshkar Para are financially better-off than the fishers in North Salimpur.

Table 14. Structure of houses.

	Wall		Floor		Roof	
	North Salimpur	Peshkar Para	North Salimpur	Peshkar Para	North Salimpur	Peshkar Para
Brick	0	5	1	6	0	0
Wood /Tin/Tally	5	1	0	0	22	25
Earth	0	4	49	43	0	0
Bamboo/Chan/leaf	45	39	0	3	28	23
Straw/Chan	0	1	0	1	0	2

Health and Sanitation

The survey collected data on toilet and drinking water facilities and food availability at the two sample sites.

Drinking Water and Toilet Facilities

Table 15 shows that all families surveyed in Peshkar Para and 46 families in North Salimpur drink tube-well water. There are five sanitary toilets in Peshkar Para and one sanitary toilet in North Salimpur. Forty-four households in North Salimpur and 24 households in Peshkar Para use ring-toilets. The numbers of non-sanitary toilets are one in North Salimpur and 21 in Peshkar Para.

General and Specific Food Availability

Bangladesh is a developing country with a large population to feed. The people of Bangladesh are so poor that most of them find it difficult to eat two meals a day. We gathered data on overall food availability in the survey areas and on availability of some popular food items. Table 16 shows that in our North Salimpur sample 39 families normally face a food deficit and 11 families face an occasional food deficit.

In Peshkar Para 17 families reported normal food deficit, 15 families occasional food deficit and 18 families no food deficit, thus Peshkar Para is better off than North Salimpur in terms of food availability.

More information on food availability is provided in the Appendix (Table 4), which summarizes opinions about the adequacy of some popular food items and gives the frequency of intake of these food items. The quantity of fish eaten by the fishers is considered "normal" or more than normal by all families in North Salimpur and Peshkar Para; these families eat fish almost every day.

Table 15. Drinking water and toilet facilities *(in percentage of households).

Drinking Water				Toilet			
Type	N. Salimpur	P. Para	Bangladesh	Type	N. Salimpur	P. Para	Bangladesh
Tube-well	92	100	94	Sanitary	2	10	25
Pond/Well	8	0	2.5	Sanitary (Wheel)	88	48	0
				Kuchchaa	2	42	45
				No. Toilet	8	0	30

Note: * Bangladesh national figures are quoted from Bureau of Statistics, HES 1996 - 97.

Table 16. Overall food availability.

Nature of Availability	North Salimpur		Peshker Para	
	Frequency	Percent	Frequency	Percent
Normal food deficit	39	78	17	34
Occasional food deficit	11	22	15	30
No food deficit	0	0	18	36
Surplus food	0	0	0	0

Durable Assets of Households

One indicator of financial solvency of households is the number of durable assets. The current survey gathered data on durable assets in the two villages. Appendix Table 5 shows the distribution of durable assets in North Salimpur. There are 19 families with one radio and one family with two radios in North Salimpur. Members of 52% of the families use wristwatches with the number of wristwatches varying between one and four. Forty-six percent of the households own a wall clock. Forty-six percent households use chairs and 54% own tables. Twenty percent of the families have black and white television sets and 8% have colour television sets. The national figures for owners of radio and television are much lower. Only 18% own a radio/transistor and 4% own a television of any type. Appendix Table 6 provides information on durable assets in Peshkar Para. Seventeen families have radio sets and members of 28 families use wristwatches. There are seven households owning wall clocks, 31 households owning chairs and 27 households owning tables. Eleven families use black and white television sets and one family uses a colour television set. The fishers in the two sample sites have almost identical amounts of durable assets.

Credit Facilities

This section examines the nature of fishers' access to formal and informal sources of credit. Fishing households in North Salimpur are largely dependent on formal sources such as NGOs and banks. Aratdars (local fish buyers) are also a major source of credit in North Salimpur. The average amount of loan ranges between Tk.8 588 from relatives to Tk.23 912 from banks. Informal sources like relatives and aratdars provide the bulk of loans to fishers in Peshkar Para.

Banks provided the most and the largest loans to households in both North Salimpur and Peshkar Para. The overall average amount of loan was Tk.19 872 in North Salimpur while it was Tk.67 332 in Peshkar Para (Table 17).

Assessment of the Linkage of the Small Scale Fishery Sector to Other Sectors of the Economy

This subsection is devoted to the analysis of ownership of different types of household assets in the two sample villages. Possession of wealth by fishing households is an important indicator of overall welfare of the fishers.

Land Ownership

None of the fishers living in North Salimpur own agricultural land, but they do possess a small amount of homestead land. It is amazing, although not unusual, that 13 respondents out of 50 reported no homestead land. These fishers live in rented houses. Each of 10 families has homestead land equal to an area of 2 decimals (247 decimals = 1 ha). Only two families have ponds and two families have fallow land. The mean size of homestead land is 3.87 decimals.

Seven families in Peshkar Para possess agricultural land with the mean size of agricultural land being 144 decimals. All families own homestead land and the average size of homestead land is 9.5 decimals. Four families own a pond and four families own fallow land. The fishers in Peshkar Para have more land property than those in North Salimpur.

Table 17. Average loan of fishing households (Tk). 1 Tk = 0.022 US$ (1997).

Source of Credit	North Salimpur Average Loan	North Salimpur No. of Households	Peshkar Para Average Loan	Peshkar Para No. of Households
NGO	17 250	30	3 000	1
Relatives	8 588	17	57 361	18
Aratdars	23 912	34	53 617	23
Banks	22 829	45	84 819	32
Overall	19 872	–	67 337	–

Table 18. Ownership of land by categories.

Homestead			Pond			Agricultural Land			Fallow Land		
Value (decimal)	NS	PP	Value (decimal)	NS	PP	Value (decimal)	NS	PP	Value (decimal)	NS	PP
0	13	0	0	48	46	0	50	43	0	48	46
1	1	0	2	0	1	8		1	7	1	0
2	10	4	8	1	1	40	0	1	40	0	2
3	8	2	10	0	1	120	0	1	50	1	0
4	9	12	16	1	0	160	0	1	120	0	1
5	4	11	40	0	1	200	0	1	240	0	1
6	3	13	–	–	–	240	0	2	–	–	–
8	1	12	–	–	–	–	–	–	–	–	–
10	0	1	–	–	–	–	–	–	–	–	–
12	0	1	–	–	–	–	–	–	–	–	–
14	0	1	–	–	–	–	–	–	–	–	–
16	1	0	–	–	–	–	–	–	–	–	–
30	0	1	–	–	–	–	–	–	–	–	–
80	0	1	–	–	–	–	–	–	–	–	–
88	0	1	–	–	–	–	–	–	–	–	–
Mean	3.87	9.5		12	15			144		29.5	10

Note: NS = North Salimpur; PP = Peshkar Para. 100 decimal = 1 Acre; 247 decimals = 1 ha.

Livestock and Poultry of Households

Livestock and poultry are always sources of extra income to the rural households. Fishing households in the two sample locations raise different types of livestock to supplement their fishing income. Appendix Table 7 contains important statistics on livestock. Ten families in North Salimpur and seven families in Peshkar Para rear goats. None of the families in North Salimpur has cows and buffaloes whereas in Peshkar Para one family has cows and two families have buffaloes. Peshkar Para has more poultry than North Salimpur; 30 families in North Salimpur raise poultry whereas 57 families do so in Peshkar Para.

Demography, Labor Mobility and Other Transitions

Demography

Household Size

Distribution of households by size is shown in Table 19. This is based on the sample Survey in 1998 and House hold Expenditure Survey in 1995 - 96. Although the traditional joint-family system in Bangladesh is near;y extinct, the survey results from both North Salimpur and Peshkar Para show the fisher's inclination towards this old family system. Table 19 reveals that fishers have bigger families than typical Bangladeshi villagers.

Small families with less than six members are notas frequent here than elsewhere in Bangladesh. In Peshkar Para the percentage of big families with 7 or more members exceeds the national percentages. The mean family size in North Salimpur is 7, which is higher than the national average of 5, as it was in 1995 - 96. The mean family size of Peshkar Para is higher than both the average sizes of North Salimpur and the nation. Families with 8 or more members constitute 40% of all families in Peshkar Para and 14% of all families in the country.

Table 19. Distribution of households by size (percentages).

Size of family	North Salimpur	Peshkar Para	HES National	1995 - 96 Rural
1	0	2	2.2	2.4
2	0	0	5.8	5.7
3	8	0	13.6	13.8
4	6	8	19.0	18.7
5	12	8	20.3	20.3
6	22	14	15.6	15.4
7	12	12	9.6	9.7
8	14	18	6.1	6.2
9	6	10	3.2	3.2
10 and above	20	28	4.7	4.6
Mean	7.02	10	5.26	10.0

Age Profiles of Respondents and Their Wives

The age distribution of the respondents and their wives is presented in Table 8 of the Appendix. Most of the respondents and wives (75%) in both villages came from the age group between 22 years and 46 years. The mean age for the wives was 32.23 years. The respondents' age averaged 38 years.

Occupational Patterns

Table 17 (Appendix) shows the occupational patterns of the respondents. Sixteen fishers give fish trading as their second job and 6 persons engage in other occupations. In Peshkar Para, 48 families are dependent on fishing, 1 family in trading in fish and 1 family in another business. Nine families in Peshkar Para earn additional income from trading in fish. The fishers in Peshkar Para are less likely to find jobs elsewhere. Traditionally occupational mobility has been very limited for fishers in Bangladesh. Lack of education and skills, widespread poverty among the fishers and non-availability of jobs elsewhere inhibit such occupational mobility. The fishers in North Salimpur are less vulnerable to occupational immobility, perhaps because of the close proximity to Chittagong Metropolitan City and the industrial belt of Sitakunda Thana in the northern part of Chittagong district.

Occupational mobility of households

Fishing as a profession is not very lucrative in Bangladesh. This is especially true for artisanal fishers, but socioeconomic factors restrict their exit from this centuries-old occupation.

Changes of employment patterns over generations in North Salimpur are shown in Table 20, and the changes in Peshkar Para are shown in Table 21. Occupational mobility in North Salimpur has been very low over several generations. The minors who did nothing 10 years ago entered the fishing occupation 5 years ago. The picture is a little different in Peshkar Para. More fishers have switched to fish trading over the years. Table 20 shows that the total number of fish traders increased from 12 ten years ago to 22 five years ago.

Table 10 (Appendix) depicts changes in the role of fishing over generations in North Salimpur and shows four classes of fishers. The number of fishers in the group "owners of boats and nets who participate and organize" has increased remarkably over the years. The number of fishers in this group was 18 fifteen years ago and rose to 32 five years ago. There is some evidence of a fall in the number of fishers who own nets and participate in fishing. The number of non-participating owners of boats and nets remained steady at a low level. In Peshkar Para, the numbers of fishers has increased over the generations. This can be seen from Table 11 (Appendix), which shows the changes of roles in fishing in Peshkar Para. Previous changes have been larger than the recent changes. Recent increases in the number of organizing and participating owners of boats and nets is larger than the increase in the number of any other category of fishers. In both cases, most fishers identify monetary gain as the primary cause for changes in roles in fishing.

Table 12 (Appendix) shows the current attitudes of fishers towards fishing. Forty-seven respondents in Peshkar Para are either anxious or not satisfied with their current occupations. The numbers of fishers satisfied with their current occupations are 3 in North Salimpur and 7 in Peshkar Para. Some fishers in Peshkar Para are financially solvent.

Table 22 shows the intentions of fishers to change their occupations. Most fishers are willing to change their occupations for themselves and for their children. In North Salimpur more fishers want new professions for their children than in Peshkar Para.

Table 20. Change of employment patterns in North Salimpur. (1st person - first person employed in the family; 2nd person - second person employed in the family).

Occupation	15 Years Ago		10 Years Ago		5 Years Ago	
	1st Person	2nd Person	1st Person	2nd Person	1st Person	2nd Person
Fishing	4	3	10	7	13	9
Nothing	46	47	39	43	37	41
Student	0	0	1	0	0	0
TOTAL	50	50	50	50	50	50

Table 21. Change of employment patterns in Peshkar Para.

Occupation	15 Years Ago		10 Years Ago		5 Years Ago	
	1st Person	2nd Person	1st Person	2nd Person	1st Person	2nd Person
Fishing	2	2	5	2	4	2
Nothing	43	47	31	38	26	35
Student	4	0	5	4	3	1
Trade in fish	0	1	7	5	14	8
Housewife	0	0	1	1	1	1
Other business	1	0	1	0	2	2
TOTAL	50	50	50	50	50	50

Table 22. Intention to change occupation.

	North Salimpur		Peshkar Para	
	Parents	Children	Parents	Children
1. Want to change present occupation	40	46	49	45
2. Do not want to change present occupation	10	4	1	5

The reasons for intended changes in occupations are given in Table 23. Fishers in both sample sites opt for new occupations for themselves and for their children with a view to freeing themselves from the curse of poverty as well as elevating their social status. Thirty-four fishers in North Salimpur and 23 fishers in Peshkar Para want to change their present occupations for a higher income. Thirty-nine fishers in Peshkar Para and 36 fishers in North Salimpur think that their children can improve their social status by changing occupations.

Conflicts Between the Small Scale Fishery and the Commercial Fishery

Commercial fisheries on the Bangladesh coast appeared in 1974 - 75 when the size of the trawl fleet was only 12. Now it is comprised of 53 trawlers, 41 of which are shrimp trawlers and 12 are fish trawlers. There is, however, an overlap with respect to catch between the two kinds of trawlers, since shrimp trawlers catch some fish and fish trawlers catch some shrimp. The small scale fishery has a

Table 23. Reason for change of occupation. (1st person - first person employed in the family; 2nd person - second person in the employed in the family).

	Parents				Child			
	North Salimpur		Peshkar Para		North Salimpur		Peshkar Para	
Reason for Change	1st Person	2nd Person	1st Person	2nd Person	1st Person	2nd Person	1st Person	2nd Person
Low income	34	1	23	0	9	13	0	0
Low status	5	23	12	0	36	6	39	0
Hard work	2	5	0	0	0	0	0	0
Irregular income	0	0	0	0	1	0	0	0
Other trade	0	0	6	0	0	0	2	0
Dependence on others	0	0	5	0	0	0	8	0

very large fleet of both mechanized and non-mechanized boats. Motorization of boats started in 1972 and the fleet has now grown to 8 000 or more. Alongside these motorized boats a large fleet of non-motorized boats also fish. However, its size has been on the decline since 1974-75 when it was 4 600 in number.

Small scale and commercial fisheries had their separate fishing grounds. The former was fishing in waters less than 40 m deep while the latter was fishing in waters beyond. This arrangement prohibiting trawling within 40 m was instituted by the Marine Fisheries Ordinance of 1983. In the late 1980s and early 1990s, when fishing in the deeper sea came under pressure (the fleet had increased to 64 and foreign trawlers went almost unchallenged), trawlers started to encroach on the near shore fishery. In 1996 the Marine Fisheries Association, a club of trawl owners with origins in the rich urban elite, brought a writ petition to the High Court and managed to obtain a court injunction over the clause of the MFO, 1983, prohibiting trawl fishing in waters less than 40 m deep. The conflict between small scale fishing and industrial fishing has now taken serious shape in the fishing grounds.

Fish trawlers catch a number of species which the small scale fishery also catches. Prominent among them are ribbonfish, Jew fish, croaker, and hilsha. Shrimp trawlers also catch some fish and discard a part which would otherwise have been available to the small scale fishery. Now that both these trawler types are fishing in near-shore waters, they catch all species. They destroy nets set by small scale fishers and sometimes steal these nets. Such incidents have been increasingly reported in recent years. The Coastal Fishermen Coordination Committee, an organization of the fishers in our study site at Chittagong, has reported that 200 such cases took place in the first two months of fishing in the 1999 season. Physical assault on small fishers is also a common feature. All this has implications for the costs of fishing by the small scale fishers and increases their risks.

As a deterrent to the increase of pressure on deep sea fishing, a moratorium has been imposed on increasing the number of trawlers. The association of trawlers (MFA) also favours restricting the trawl fleet, but the investment authorities in Bangladesh are ready to provide finance for new trawlers. The Marine Fisheries Boat Owners' Association is fighting to restrict the fishing grounds as well as the numbers of the trawl fleet. They suggest that a new organization be created to look after the diverse interests of marine fisheries and bring all types of fishing crafts under its control. Instead of the present system of control and support by a variety of institutions such as the Mercantile Marine, Marine Fisheries, Port Authority, Inland Water Ways and a host of others, a central authority should regulate all aspects of coastal fishing.

To mitigate the unhealthy competition between the industrial and small scale fisheries, legal provisions should be made to restrict the former to its separate grounds. Incidence of attacks can be obviated by a strong presence of coast guards. The Navy should be used only to keep the foreign fleet at bay.

Characteristics of the Labor Force in the Commercial Fishery

The commercial fishery, which is composed of the trawlers fishing the high seas, is highly capital-intensive. Fishing laborers who work on large mechanized boats are reported on in this section. The large boat owners are locally known as the "company". They do not participate in fishing. In our Peshkar Para study site, 34 respondents are such large boat owners, and 16 are laborers who work along with other laborers. Many laborers come from far-off areas during the fishing season. The company hires a chief who is known as a *Majhi*, and asks him to organize fishing for the season. Some *majhis* work on a boat of the same company for several seasons. Very large boats require two *majhis*. In such circumstances a second *majhi* is hired under the first. Crew-members are then contacted by the *majhi*. Employment is seasonal.

While on a voyage the laborers receive food on board. They also receive payment at the end of the trip. The company receives a portion of the value of the catch as compensation for the costs incurred, for fuel, equipment, and food for the crew. The rest is divided into two - one half goes to the company and the other to the crew including the *majhis*. This latter half is distributed among *Majhis*. I, *Majhi* II and members of the crew in the proportion 4:2:1. Crew-members receive in advance a portion of their income ("future") which is used to sustain their family when they are away fishing. The mean income per voyage received by crewmembers is Tk.13 487 in our study area.

The laborers go to sea at their own risk, no insurance scheme is there to cover them. The sea is very rough in the fishing season, but no compensation for any loss is ever paid. In case of accident, the laborer loses his life and his family loses their breadwinner.

Institutional Factors in the Fishery Sector

Fishing in the coastal waters of Bangladesh was the exclusive domain of the traditional low caste Hindu community, locally known as *"jaladas"*. The tradition of *"jaladas"* started to break down under continuous pressure from the mid - 1960s when Muslims entered the profession in increasing numbers. The traditional caste fishers as well as the poor Muslim fishers, together now constitute the artisanal fishery community. Some of them own small, non-mechanized (oar/sail) boats and fish with *behundi* (SBN), *khapla* and *fash jal* (gillnet), while others own only the nets, but not any other gear.

The Bangladesh Fisheries Development Corporation (BFDC), set up in 1964 to help develop the fisheries (by providing landing, processing, storage and other facilities), introduced motorization of boats, and distributed 285 outboard engines of 6 hp - 12 hp to poor fishers on a hire purchase basis. These were later replaced by inboard marine diesel engines of 15 - 33 hp in boats 12 - 14 m long. The more affluent among the fishing community adopted mechanized boats and the poor continued with non-mechanized country boats.

The BFDC obtained some trawlers in 1972 and operated five of them until 1985 and leased them out afterwards. In the early 1970s intrusion by Thai trawlers into Bangladeshi waters and exploitation of its fishery took a menacing turn. This led to the introduction of a trawl fleet in the private sector under the aegis of three different schemes:

1. Bangladeshi ownership with assistance of loans from DFIs (development finance institutions);

2. PAYE (pay as you earn) scheme between Bangladeshi entrepreneurs and foreign partners;

3. Joint ventures in which Bangladeshi and foreign partners both invested.

In 1974 - 75 the fishing fleet contained 20 trawlers, which rose to 72 in 1983 - 84. Today, 53 Bangladeshi trawlers (41 shrimp and 12 fish) exploit its offshore fishery resource.

The Directorate of Fisheries (DOF) of the Government of Bangladesh (GOB) issues licenses to trawlers having a loading capacity of 150 tons (t) or above. The vessel license specifies the type of fishing gear used, method of fishing and location of fishing by the vessel. The license holder provides information to DOF on catches and sales in a prescribed form. To receive the license a vessel has to be registered with the Mercantile Marine Department (MMD) of the Ministry of Shipping of GOB. This department also issues a certificate of fitness of the vessel annually. This certificate is a condition for the vessel to receive a fishing license. Thus, DOF exercises control on fishing by the vessel, while MMD is responsible for its registration and safety.

This bifurcation of responsibility-registration and annual inspection by MMD and licensing by DOF has resulted in an unnecessarily lengthy process and boat owners complain about the delay in moving from one office to another in procuring the license. The DOF admits that it lacks facilities for effective monitoring. Fishing by boats without a valid license is not a rarity. A large number remains outside the purview of DOF control.

Conflicts often arise between trawl fishers and artisanal fishers. The latter complain about the intrusion of trawlers into their territory, damage to their nets and destruction of fishing grounds. A court case by the trawl owners has led to the passing of a stay order on the legal provision prohibiting trawl fishing in near-shore waters (within 40 m depth).

The Bangladesh Fishermen Cooperative Society is the association of fishers in both marine and inland fishing sectors. All government assistance to fishers is channeled through this organization. Like cooperatives in other sectors, the representation of fishers and their participation in it is not deemed satisfactory. The boat owners in the marine sector have their national association with their head office at Chittagong. There are owners' associations in different parts of Bangladesh. There is coordination in the working of these associations with the national association, although they exist independently. They have been successful in safeguarding the rights of their members against intrusion by the large trawler owners. It is due to their insistence that the recommendation to halt the growth of the trawler fleet has been effectively implemented.

Effects of Development Interventions, Investment and Other Trends in Coastal Communities

From the latter part of the 1960s the fishery has received increased attention from the government. Cyclones and tidal bores have become a regular phenomenon on the coast of Bangladesh. Small traditional fishing craft are the hardest hit in such calamities. In 1966 - 69, the BFDC introduced motorization of the vessels as described above. The BFDC procured 10 trawlers from the Soviet Union in 1972. This proved lucrative and attracted large private investment in deep-sea fishing. Today the number of motorized boats fishing in 18 m to 40 m depth has surpassed 500 vessels, and trawlers which once numbered 72, are now stable at around 55 in number. With change in craft used, there occurred a revolution in gear used. Nylon nets in place of cotton nets were introduced. The BFDC provided landing facilities, cold storage and some marketing facilities for large scale catches. The above led to drastic changes in coastal fishing. Fishing became capital-intensive and ordinary fishers who could not afford a large investment became hired laborers. Fishers from adjacent and outlying areas join the fishing operation as laborers during the fishing season, which extends to about eight months with mechanized boats and new nets. Fishing expeditions last 8 to 10 days. Fishers who live away from their villages can visit their families at intervals when they come to unload the fish at landing sites for marketing.

As a result of large gains from the new technology, investment in fishing increased very rapidly, which then endangered the resource stock. Government became aware of this and began to limit the fleet. New rules were introduced. One such important rule was the Marine Fishing Ordinance of 1983. The DOF was given unlimited power to check the fishing vessels. But as has already been explained, there are controversies regarding jurisdiction over fishing waters. Again, the authorities involved in the sea are many and their roles overlap, so that proper control of fishing is not possible. DOF is responsible for regulating fishing but its resources are limited.

The small artisanal fishers have suffered most in terms of catch and area of operation. They are compelled to resort to destructive fishing nets and methods in their bid to make their living. In the Chittagong site many fishers were found to use '*current jal*', a net which catches everything, including juveniles, and therefore is prohibited by law. They are often found to use mesh sizes smaller than the minimum. This is however also found in the case of nets used in mechanized boats. The economic and social problems that the new technology, facilitated by government intervention and new investment, has produced need to be remedied by joint efforts of government, NGOs and the community.

Fleet Operational Dynamics

The State of the Fishing Fleet

Number of Fishing Craft and Gear

The method of gathering and preserving statistics

on fishing craft and gear in Bangladesh is not adequately developed. Lack of information on fishing craft and gear originates from confusion about legal requirements, inadvertence, and negligence of the owners of boats and nets to register their ownerships with government fisheries offices. The existing administrative machinery of the fisheries department of the Government of Bangladesh cannot monitor registration by all fishing craft and gear. Data on the numbers of fishing craft and gear used in small scale fishing are scanty and not reliable.

Some information on fishing craft and gear in Bangladesh is given in Table 24. Bangladesh started with a fleet of 10 trawlers and 200 motorized boats after liberation in 1972. The number of trawlers more than doubled to 21 in a year and then jumped to 26 two years later. The numbers of trawlers changed abruptly in the early 1980s and reached a maximum of 73 in 1984. The number then fell gradually and stabilized at a little more than 50. The current number of trawlers is 54, of which 41 are shrimp trawlers and the remaining are fish trawlers.

The number of motorized boats also experienced three abrupt changes. It increased from 276 in 1974 to 1 000 in 1975, growing more than three times in a year. The number of motorized boats increased again from 1 300 to 2 000 between 1980 and 1981 and from 2 100 to 3 347 between 1983 and 1984. After some fluctuations, it finally settled at the current number of 3 317.

An alternative source has said that 2 500 motorized boats obtained licenses from the DOF, while another 2 500 boats are registered with the Mercantile Marine Department, thus bringing the total to 6 000. Still another source puts the total of mechanized boats at more then 15 000, including the unregistered boats.

Appendix Table 13 shows the number of fishing craft and gear used for different kinds of marine fishing. Two points about Table 13 should be noted. First, some fishing techniques require equal numbers of craft and gear. Second, the number of fishing boats and nets unexpectedly remained fixed in a period of seven years between 1990 and 1997. Appendix Table 14 presents a detailed breakdown of the total fishing craft and gear used in marine fishing.

Table 24. State of the fishing fleet.

Year	Trawlers	Mechanized boats	Non-Mechanized boats	Fishing gear
1972 - 73	10	200	N/A	N/A
1973 - 74	21	276	N/A	N/A
1974 - 75	21	1 000	N/A	N/A
1975 - 76	26	1 000	N/A	N/A
1976 - 77	26	1 050	N/A	N/A
1977 - 78	26	1 100	N/A	N/A
1978 - 79	26	1 200	N/A	N/A
1979 - 80	26	1 300	N/A	N/A
1980 - 81	24	2 000	N/A	N/A
1981 - 82	35	2 050	N/A	N/A
1982 - 83	53	2 100	N/A	N/A
1983 - 84	73	3 347	N/A	N/A
1984 - 85	67	3 300	N/A	N/A
1985 - 86	45	3 137	N/A	N/A
1986 - 87	49	3 317	N/A	N/A
1987 - 88	52	3 317	N/A	N/A
1988 - 89	52	3 317	N/A	N/A
1989 - 90	53	3 317	N/A	23 810
1990 - 91	53	3 317	14 014	23 810
1991 - 92	53	3 317	14 014	23 810
1992 - 93	53	3 317	14 014	23 810
1993 - 94	53	3 317	14 014	23 810
1994 - 95	53	3 317	14 014	23 810
1995 - 96	53	3 317	14 014	23 810
1996 - 97	54	3 317	14 014	23 810

Source: Bureau of Statistics, 1998. N/A = information not available.

Fishing Seasons, Monthly Trips and Other Characteristics of Fishing

Since national data on different characteristics of marine fishing are unavailable, we present here the results from micro surveys.

In North Salimpur, the fishers catch fish in two seasons using mainly two types of nets, viz. *Tong* nets and set bag nets (SBN). The peak season for *Tong* nets consists of four months and the peak season for SBN eight months. The slack season of SBN consists of four months. The seasons of different fishing gear are characterized by varying sizes of catch per unit of effort (CPUE) and normally the catch is large during the peak season. The peak seasons of *Tong* nets and SBN coincide during the first four months of the year and the next four months constitute the peak season for SBN only. The remaining four months comprise the non-peak season for SBN. In the peak season, each trip for the *Tong* net and SBN takes four to five hours. In addition, the fishers go deep sea fishing with SBN in the peak season and this type of long distance trip normally takes seven to eight hours. Each trip with SBN in a slack season takes four to five hours.

The peak and slack seasons last for three and five months respectively, in Peshkar Para. The fishing trips in Peshkar Para are substantially longer and each trip takes two to eight days, depending on the season. In the peak season, each fishing expedition lasts for five to eight days. In the non-peak season, each short-distance trip takes two days and each long-distance trip takes five days. The fishing gear is also different in Peshkar Para. Most fishers in Peshkar Para use floating nets *(Vhaasan Jal)*, pomfret nets *(Failya Jal)* and gillnets *(Lakkha Jal)*. Only a few fishers make use of SBN and purse seine nets. Fishing is in most cases a family business in North Salimpur whereas fishing is a group activity in Peshkar Para. A fishing team there normally consists of more than five persons.

We gathered information on the distance from port, trips per vessel, days or hours per trip, etc., for large motorized boats and trawlers. The average distance from port is 200 km for a trawler and 179 km for a large motorized boat. A trawler on the average makes 11 trips per year, whereas the average number of trips is 21 for a large motorized boat. On the average, a trawler catches fish 200 days a year, whereas a large motorized boat catches fish 239 days a year.

Productivity and Technical Efficiency

Assumptions and Model Specifications

In this section, we attempt to analyze the relationship between input and output in the fisheries sector. Such a relationship can be established by specifying some production functions for the fisheries sector. Regression analysis can then be used to estimate these production functions. A few production models were specified *a priori* as the appropriate models for the fisheries sector and estimated using different econometric techniques. The objectives for estimating the fisheries production models are as follows:

i. To determine the appropriate model for fisheries production on the basis of estimation results.
ii. To examine whether each factor of production is used efficiently.
iii. To calculate the elasticity and share of each factor in total production. The estimated parameters can also be used to calculate elasticity of substitution between any two factors.

Model specification and data

Following Panayotou and Jetanavanich (1987) the fisheries production function can be written as:

$$Q = f(Z,E) \quad (1)$$

Equation (1) says that the catch (Q) depends on the stock of fish (Z) and fishing effort (E). Assuming that the fish stock remains the same for all fishing units during a particular season, equation (1) can be rewritten as:

$$Q = g(E) \quad (2)$$

Where g = parameter of the sustainable yield function.

Fishing effort (E) is, however, a composite index made up of many factors. It can be decomposed into capital stock (fishing craft, fishing gear), service flows (time spent fishing), and managerial ability. Each of these factors can again be represented by one or more characteristics serving as proxy variables. For example, fishing craft may be represented by one or more of the following characteristics: volume, tonnage, horsepower of engine, etc. There may be as many models of fisheries production function as there are combinations of inputs used in fishing.

Two types of models are popular to economists and biologists as the appropriate models for fisheries production functions. Cobb-Douglas and trans-log production functions are widely used.

$$\ln Q_i = a + \sum b_i \ln E_i \quad (3)$$

$$\ln Q_i = a + \sum b_i \ln E_i + [c_{ij} \sum \sum \ln E_i E_j] \quad (4)$$

$$c_{ij} = c_{ij},\ j,i = 1,2 \quad (5)$$

$$\sum c_{ij} = 0 \quad (6)$$

where a, b_i and c_{ij} = parameters to be estimated Equation (3) is the log-linear form of the Cobb-Douglas production function and Equation (4) is the trans-log production function. Equations (5) and (6) are the restrictions that apply to trans-log production function. We estimated these production function models for each of four samples in our study. In Equations (3) and (4), Q stands for the catch of fish in physical units. Similarly E_j stands for fishing efforts measured in physical units. But a fishing unit normally catches different species of fish. It is, therefore, more reasonable to measure catch of fish in monetary terms. Q_i in our survey is measured in nominal values. The Eis can be measured in physical units or in nominal values.

Estimation Results

The estimated fishery production models are presented here (Table 25). For each of four samples, results of two estimated models are given. All factors deemed to represent fishing effort have been included in the first model. These results are shown in Appendix Table 15.

It can be seen from the table that incorporating all seemingly related variables does not produce satisfactory results due to multicollinearity. For example, the independent variables in the model for trawler are area, tonnage and horsepower of the craft, mesh-size of net, and fishing days. The coefficients of these variables are not statistically significant as expected with severe multicollinearity and the fit of the model is not good with adjusted R^2 being as low as 0.24. Some of the variables have signs not consistent with common sense, which is also a symptom of multicollinearity. In the model for Peshkar Para, the coefficient of only one out of seven independent variables is statistically significant. Although the model has a high-adjusted R^2 value, two variables have the wrong signs. Similar results hold for two other models, again due to severe multicollinearity.

To avoid the problems of poor estimation results of the large regression models, we tried several other models for each sample. After a lot of over-fitting, we selected one model for each sample as the best model. The estimation results of the finally selected models are given in Table 25. The selected models fit well to the cross-section data having adjusted R^2 values between 0.54 and 0.89, although R^2 values lose some of their meaning with excessive "data snooping". None of the models have the problem of auto-correlated errors.

Table 25. Estimation results of fisheries production function.

	Model	Method	Tonnage of craft	Area of craft	Weight of all nets	Fishing days	Dep. cost of craft	Dep. cost of gear	Adj R^2	"d" Statistic
Trawler	CD	GLS	–	0.06 (2.40)	–	0.65 (3.10)	–	–	0.73	1.99
Large Motorized Boat	CD	GLS	–	–	–	–	0.25 (5.97)	–	0.89	1.35
Peshkar Para	CD	GLS	0.52 (3.88)	–	0.10 (1.27)	1.21 (3.86)	–	–	0.58	1.57
North Salimpur	CD	GLS	–	–	–	0.35 (2.42)	0.038 (1.05)	0.69 (5.50)	0.73	2.14

Note: CD = Cobb-Douglas; GLS = Generalized Least Squares; Dep. = depreciation.
*** Value in parentheses indicate estimated coefficients.**

In the fishery production function for trawlers, the two independent variables are the area of the craft and fishing days, which both have statistically significant coefficients. The depreciation cost of the craft is the only independent variable in the fishery production function model for a large motorized boat. The coefficient of the variable is statistically significant at the 1% level of significance. In Peshkar Para, the relevant variables of the regression model are the tonnage of the craft, weight of all nets and fishing days. The coefficients of tonnage of the craft and fishing days are statistically significant at the 1% level of significance. The coefficient of weight of all nets is not significantly different from zero. In the fishery production for North Salimpur, the independent variables are fishing days, depreciation cost of craft and the depreciation cost of gear. The coefficients of fishing days and depreciation cost of gear are statistically significant whereas the coefficient of the depreciation cost of craft is not significantly different from zero.

Costs, Earnings and Profitability

Organization of the Study

The questionnaire developed for artisanal fishers contained a section on income and expenditure patterns of fishers. Emphasis was laid on questions about annual income and expenditure from fishing expeditions. These questionnaires were administered to 50 respondents in each of the two sample villages. Separate questionnaires were framed on cost-earnings from owners of large motorized boats and trawlers. Data were collected from 10 owners of trawlers and 12 owners of large motorized boats. Trawl fishing is an example of large scale industrial fishing. Large motorized boats represent medium-scale commercial fishing. The sample from Peshkar Para is an example of commercial artisanal fishing. Lastly, the sample from North Salimpur represents the case of subsistence artisanal fishing. In all, data were collected from four sample areas for four different groups of fishers.

About 320 fishers live in North Salimpur, of whom 200 fishers own boats and nets, participate in fishing and organize the fishing activities. One hundred owners of nets only participate in fishing. There are 20 fishers who do not own boats or nets but work as hired laborers for other fishers. To make our sample representative of all categories of fishers, we stratified our sample of 50 fishers from North Salimpur according to the following scheme:

1. Owners of nets and boats who participate in fishing:	35
2. Owners of nets who participate in fishing:	12
3. Laborers who participate in fishing:	3
Total:	50

Net fishing income was calculated for every fisher in each of the three categories. Mean income levels and other descriptive statistics were calculated for each group.

Unlike in North Salimpur, there are fishers in Peshkar Para who own boats and nets, but who do not participate in fishing activities. The stratified random sample in Peshkar Para comprised the following categories of fishers:

1. Owners of boats and nets who do not participate in fishing:	11
2. Owners of boats and nets who participate in fishing:	11
3. Owners of nets who do not participate in fishing:	1
4. Owners of nets who participate in fishing:	1
5. Laborers who participate in fishing:	26
Total	50

We calculated the net fishing income for each fisher in the five groups.

Profitability analysis in this section is largely based on primary data collected for this purpose. Cost-earnings data were analyzed by calculating and sharing benefits in each of the four sample sites. Net economic profits from fishing activities were estimated for trawl fishing, large motorized boats and North Salimpur. In Peshkar Para, gross income from fishing activities is estimated first by deducting all operating costs from the total revenue. This gross income is then distributed among different groups of fishers according to the agreed-upon formula of sharing. Although we collected data from 122 fishing units in four different samples, we had to delete the observations with negative values for either gross income or net income. Table 26 shows

Table 26. Number of dropped observations.

Sample	Observations with negative values		Total observations dropped
	Gross income	Net income	
North Salimpur	0	7	7
Peshkar Para	3	5	
Large Motorized Boat	0	6	6
Trawler	0	5	5

the number of observations dropped in four samples. Two reasons can be cited for deleting these observations. Technically, the observations with negative values for gross income and net income cannot be analyzed, and secondly negative values create suspicion about the reliability of the data. The negative observations are perhaps due to over-reporting of the costs incurred.

Fishing Assets

We gathered information on present and past ownership of fishing assets in the two survey sites. Appendix Table 16 provides statistics on fishing assets in North Salimpur and Peshkar Para. In our sample of 50 households in North Salimpur, 43 families have at least one boat and 6 of them have two boats each. Seven non-motorized boats are also used in North Salimpur. The 50 fishers surveyed in North Salimpur also own 300 *Tong* nets, 174 SBN, 26 push nets and two other nets. The table also gives information on parents' ownership of fishing assets. We find that the previous generation in North Salimpur owned 7 non-motorized boats, 30 motorized boats, 210 *Tong* nets, and 125 SBN. There is a significant increment in the possession of motorized boats and nets by later generations. Motorized boats increased by 16 units, *Tong* nets increased by 90 units and SBN increased by 49 units. The number of non-motorized boats, however did not increase over the two generations. The fishers in Peshkar Para lag behind their counterparts in North Salimpur in fishing assets. The 50 families surveyed in Peshkar Para owned 12 non-motorized boats, 39 motorized boats, 9 floating nets *(Vhasaan Jaals)*, 34 pomfret nets *(Faillya)*, 29 gillnets *(Lakkha)* and 17 other nets. The number of motorized boats in the possession of the current generation increased to 39 from 7 in the possession of their parents. Similarly, the numbers of different types of nets increased significantly in the current generation over the previous generation. The number of floating nets increased significantly in the current generation over the previous generation. The number of floating nets increased to 9 from 3 and pomfret nets rose to 34 from 16.

Investment Costs

Fishing, like any other economic activity, needs services of many inputs, which can be broadly classified into three categories. Firstly, there are fishing craft and gear, secondly, sailors, engine drivers and helpers (labor input), finally, there must be an organizer who may or may not overlap with other inputs. The entrepreneur has to invest a large amount of money for procuring the capital inputs.

Investment costs were calculated for the total fishing assets, craft and gear for each of four samples. The mean investment costs are shown in Table 27.

The total investment in trawl fishing is much higher compared to investment costs in any other type of fishing (Table 27). The average total investment cost in trawl fishing is Tk. 38 million, whereas the average investment cost in large motorized boats is Tk.1.64 million. The average investment cost is Tk.316 000 in Peshkar Para and Tk.118 000 in North Salimpur. The average investment costs for all large motorized boats, for the village of Peshkar Para and for North Salimpur constitute only 4.3%, 0.83% and 0.31%, respectively, of the average investment cost of trawlers. The variations in investment costs are mainly due to variations in the cost of fishing craft. Table 27 shows depreciation costs, also known as replacement investments. In the case of fishing gear, the depreciation cost equals the total value of fishing equipment divided by its lifetime. In the case of fishing craft, depreciation cost is calculated using the same procedure after deducting 10% of the total value as the scrap-value.

Table 27. Average investment costs for fishing. (in Taka; 1 Tk = 0.022 US$, 1997)

Sample	Investment Cost for Craft	Dep. Cost for Crafts	Investment Cost for Gear	Dep. Cost for Craft	Total Investment Cost	Total Dep. Cost
Trawler	37 768 000	1 432 902	321 580	2 461 123	38 089 580	1 679 025
Large Motorized Boat	1 291 700	156 781	349 170	76 706	1 640 870	233 488
Peshkar Para	207 588	29 078	108 529	21 702	316 118	50 780
North Salimpur	46 170	3 463	719 487	17 271	118 155	20 774

Note: Dep. = depreciation

Cost Structure

The cost structures of various fishing units are given in Table 28 and Table 29. As Table 28 shows, the fuel cost, a major expenditure item, averaged Tk.5.06 million for trawlers, Tk.0.22 million for large motorized boats, Tk.85 000 for Peshkar Para and Tk.35 000 for North Salimpur. The mean annual expenditure on food was Tk.0.5 million for trawlers, Tk.135 000 for large motorized boats, Tk.43 000 for Peshkar Para and Tk.12 000 for North Salimpur. The trawler owners spent on the average, Tk.1.54 million per annum on salary of crews and officers, whereas the total expenditure on hired labor was Tk.41 000 per annum in North Salimpur.

Table 28. Cost structure - absolute values (Tk).

Item	North Salimpur	Peshkar Para	Large Motorized Boat	Trawler
Total revenue from forward selling	196 204	426 933	1 239 300	18 998 000
Fuel cost	35 721	85 380	216 260	5 061 600
Food cost	12 343	43 113	135 220	543 470
Labor cost/salary of crews	40 686	0[a]	0[a]	1 538 200
Maintenance cost		7 844	159 080	942 010
Other variable cost	5 348	17 574	40 000	3 019 600
Total variable cost	85 753	178 467	550 560	8 624 700
Depreciation cost	22 999	41 758	224 210	1 411 400
Interest payments	0	0	31 510	3 146 200
Registration cost & licensee	0	0	11 800	98 770
Total fixed cost	22 999	41 758	267 520	7 136 600
Total cost	108 753	220 227	818 080	15 761 000

Source: Bureau of Statistics 1998.
Note: [a] Remuneration for laborers according to the sharing system.

Table 29. Cost structure - proportions (percentages).

Item	North Salimpur	Peshkar Para	Large Motorized Boat	Trawler
Fuel cost	38.1	38.7	26.0	32.0
Food cost	8.4	19.5	16.5	3.7
Ice cost	0	10.7	18.7	0
Labor cost	27.1	0	0	9.6
Other variable cost	4.8	8.7	4.7	8.3
Total variable cost	77.6	80.8	67.1	53.6
Depreciation cost	27.4	19.2	27.6	20.2
Interest payments	0	0	4	19.7
Office cost	0	0	0	5.6
Registration cost	0	0	1.3	0.9
Total fixed cost	27.4	21.1	32.9	46.4

In Peshkar Para and the case of large motorized boats, income of labor is calculated as a share in the gross net revenue, which is the difference between total revenue from forward selling and operating costs. Trawler owners spent a huge amount of money, Tk.3.02 million on the average, on other components of variable cost. The average other variable cost was Tk.5 000 in North Salimpur, Tk.18 000 in Peshkar Para, and Tk.40 000 for large motorized boats. The total variable cost amounted to Tk.8.63 million for trawlers, Tk.551 000 for large motorized boats, Tk.179 000 in Peshkar Para and Tk. 86 000 in North Salimpur. Average values of total fixed cost were Tk.7.14 million for trawlers, Tk. 268 000 for large motorized boats, Tk.42 000 in Peshkar Para and Tk.23 000 in North Salimpur. Annual total cost equaled Tk.15.76 million for trawl fishing, Tk.818 000 for large motorized boats, Tk.220 000 in Peshkar Para and Tk.109 000 in North Salimpur.

Table 29 gives the proportions of different components of the total cost. Among the individual items, fuel cost constitutes a major expenditure item, claiming on the average 32% of the total cost in the case of trawlers, 26% in the case of large motorized boats, 39% in Peshkar Para and 38% in North Salimpur. The mean share of food-cost was 20% in Peshkar Para, 8% in North Salimpur and 17% in the case of large motorized boats. It was a minor expenditure item for trawlers with a mean share of 4%. In North Salimpur another major expenditure item was the labor cost with a mean share of 27%. The mean share of salary of crews was 10% for trawlers.

Mean share of total variable cost was 78% in North Salimpur, 81% in Peshkar Para, 67% for large motorized boats and 54% for trawlers. The total fixed cost was on the average 27% of the total cost in North Salimpur, 21% in Peshkar Para, 33% for large motorized boats and 46% for trawlers. The meanshare of the total fixed cost was found to increase with the degree of capital intensity (defined by the ratio of capital investment to the number of laborers engaged).

Earnings and Profitability

Net Income Levels of Fishing Units

Net income levels of fishers in each sample were calculated using the cost and revenue figures. Profit of net fishing income was calculated as the difference between the total revenue and total cost inclusive of total depreciation cost. It seems that the cost figures reported by some owners of trawlers and large motorized boats were biased upward. Consequently, net fishing income levels of five trawler-owners and seven large motorized owners turned out to be negative. We decided to exclude the observations with negative profit levels in calculating the mean profit levels of trawler-owners and motorized boats owners. Table 30 shows the mean profit levels of fishing units in four samples.

Table 30. Net income levels of fishing units for 1998.

Item	Sample Size	Average Fishing Income	Total Income	Per Capita Income
Trawler	5	3 236 800	N/A	N/A
Large Motorized Boat	6	421 220	N/A	N/A
Peshkar Para	27	120 394	126 179	25 834
North Salimpur	40	87 452	100 365	14 932

Note: N/A = not available

A trawler owner earned on the average Tk.3.24 million per annum from fishing. The mean annual income of the owner of a large motorized boat was Tk.421 000. The mean annual profit of a fishing unit in Peshkar Para was Tk.120 000, whereas its total income was Tk.126 000, yielding a per capita income of Tk.26 000. A fishing unit in Peshkar Para normally consists of many persons, *viz*. owners of boats and nets, sailors, laborers, etc. The mean fishing income in North Salimpur was Tk.88 000 per annum, whereas the mean total income was Tk.100 000. The annual per capita income in North Salimpur averaged Tk.14 932, which is greater than the national per capita income of Tk.12 680. The net income levels of the owner of a large motorized boat, a fishing unit in Peshkar Para and a fishing unit in North Salimpur averaged 6%, 5% and 3% of the total net income of a trawler owner.

Net Income by Fishing Gear

Table 31 shows the net income levels by fishing gear. In North Salimpur, most fishers use both *Tong* nets and set bag nets (SBN). *Tong* nets are one of the local variants of purse seine in Bangladesh. Fishers use *Tong* nets during four months of the peak season while they use SBN nets the whole year. As expected, *Tong* nets, which are much larger in size and weight, yield a higher level of profit than SBN. The average net income from operating *Tong* nets and SBN in our study was Tk.50 000 and Tk.41 000, respectively. In Peshkar Para, average profit from another local variant of purse seine nets called floating nets was Tk.195 000, which is more than four times the average profit made from two local variants of gillnet, pomfret nets (Tk.49 000) and *Lakkha* nets (Tk.41 000). Few fishers surveyed in Peshkar Para had floating nets because these nets involve a large investment.

Net Income by Fishing Groups

Table 32 shows the net income levels in 1998 of different groups of fishers in North Salimpur and Peshkar Para.

The average net income of nine owners of boats and nets was Tk.75 000 whereas the average net income of participating owners of boats and nets was Tk.115 000. The rate of return from capital investment was then estimated as the ratio of net returns (to capital investment) to total investment cost multiplied by 100. The average net income of a senior sailor was Tk.51 000 per annum. The average net income levels of the junior sailor, engine driver and laborer in Peshkar Para were Tk.51 000, Tk.26 000 and Tk.14 000, respectively. The number of senior sailors is low, only two in selected 27 cases. Each employee in a labor group comprising the senior sailor, junior sailor, engine driver and crew earns much less than an owner of boats and nets. There is an inegalitarian distribution of income among groups of fishers in Peshkar Para.

Table 31. Net income by fishing gear in 1998 .

Sample	Gear	Total revenue	Total variable cost	Total cost	Net income
North Salimpur	Purse Seine (Tong)	89 160	22 622	39 220	49 940
	Set bag net	115 724	68 250	75 170	40 553
Peshkar Para	Purse Seine (Floating)	N/A	N/A	N/A	194 487
	Gillnet (Pomfret)	N/A	N/A	N/A	49 169
	Gillnet (Lakkha)	N/A	N/A	N/A	47 674

Note: N/A = not available

Table 32. Net income of groups of fishers.

Sample	Group	Sample size	Fishing income	Total income	Per capita income
Peshkar Para	Owners of boats and nets	9	74 898	80 471	39 221
	Participating owners of boats and nets	8	114 710	123 440	17 072
	Senior sailors	2	50 845	N/A	N/A
	Junior sailors	27	26 301	N/A	N/A
	Drivers	27	14 068	N/A	N/A
	Laborer	27	13 441	N/A	N/A
North Salimpur	Boat owner	31	89 146	103 538	1 529
	Net owner	9	81 617	89 439	13 681
	Laborer	3	21 667	33 768	9 461

Note: N/A = Not Available.

There was no significant difference in income between participating and non-participating owners of boats and nets.

We also calculated mean values of income levels for three categories of fishers in North Salimpur (Table 31). Each boat owner in North Salimpur earned on the average Tk.89 000 per annum, which is a little higher than the corresponding figure in Peshkar Para. The mean annual income of a net owner in North Salimpur was Tk.82 000 whereas a laborer on the average earned Tk.22 000 per year. The results of "t" tests for differences in mean income levels showed no significant differences between owners of boats and owners of nets in North Salimpur.

In addition to calculating net profit of fishing households, we also worked out the capital: labor ratio for every fishing unit in each sample by dividing the total investment cost of a firm by the number of persons engaged in fishing. Table 33 below shows the average capital-labor ratio for four samples:

Table 33. Capital-labor ratio and net profit.

Sample	Capital-labor ratio (Tk.)	Net fishing profit (Tk.)
North Salimpur	15 902	96 387
Peshkar Para	13 490	162 132
Medium sized engine boat	109 389	210 869
Trawler	963 053	3 236 381

It is clear that fishing is most capital intensive in the case of trawlers and most labor intensive in Peshkar Para.

Economic Profit in North Salimpur

We calculated economic profit for all fishing households in North Salimpur. Economic profit was calculated by deducting from the net fishing income the implicit wages and food expenses for active family members who participate in fishing. Assuming that the peak season for two types of net consists of eight months in North Salimpur, we used the following formula to calculate economic profit of fishing households:

Economic Profit = Net Fishing Income - 20 800*
No. of Participating Members

In the above formula, monthly salary has been assumed to be Tk.2 000 per person and monthly food expenses have been assumed to be Tk.600 per head. We derived the frequency distribution of economic profit of 50 fishing households. The mean economic profit was found to be Tk.54 156. It was found that 14 families of North Salimpur out of 50 had negative economic profits. Despite negative economic profits, these families are bound to stay in fishing because the opportunity for alternative employment is restricted. That is, their opportunity cost of labor is sufficiently low as to retain their employment in the fishery sector. The sufficiently high transactions and friction costs of exit from the fishery reinforces this labor inertia.

Forward Buying and Selling: *Dadan*

The artisanal fishers in North Salimpur often take loans from NGOs and local stockists, popularly known as *aratdars*. Instead of charging interest rates for the loans forwarded, the *aratdars* buy the fish from the fishers at a predetermined price, which is normally less than the spot market price, and sell at a higher price in the wholesale market. This method of selling fish to the *aratdars* at an agreed upon lower price may be called forward selling, popularly known as *dadan*. The difference between the selling and buying prices of the *aratdars* is the gain to the *aratdars* and the interest payments to the fishers. All fishers do not sell forward and those fishers who do so may not sell the whole lot of their fish at the predetermined price. In North Salimpur, a portion of fish caught in the *Tong* nets during the peak season is sold forward. The total amount of gain to the *aratdars* and wholesalers from forward buying or the amount of *dadan* has been calculated using data on the spot market price and forward price of fish. Using the customs of the fishers in the area, the quantity of fish is multiplied by the forward price where applicable at the time of calculating the total gross revenue of fishing households. The system of forward buying and selling is also in practice in Peshkar Para, but there is no partial forward selling in Peshkar Para. The implicit rates of interest per annum for a boat in North Salimpur and Peshkar Para are 340% and 162%, respectively.

The Sharing System

In North Salimpur, the sharing system is non-existent. Most of the fishers own either boats or nets or both, and they participate in fishing. In most cases, all active members of a family participate in fishing and the owners hire extra labor if necessary. The owners bear the expenses of food for the hired labor and pay a predetermined amount of monthly salary to the hired labor. The net gain of fishing expeditions goes to the owners of boats and nets.

The sharing system is very effective in Peshkar Para. Gross revenue of a fishing unit is calculated as the product of quantity of fish and price of fish. In the case of forward transactions, the quantity of fish is multiplied by the forward price, which is normally less than the spot price. Gross income of the fishing unit is equal to gross revenue less operating costs of fishing. Operating costs include the fuel cost, food cost, ice cost, maintenance cost, other cost, etc. Gross income is distributed among different factors of fishing units according to a traditional system, which may be called the residual sharing system. In the case of small motorized boats with less than 22 hp engines, one half of gross income goes to the owners of boats and nets. The remaining 50% of gross income is divided among the total number of persons engaged in fishing. Each sailor receives two shares, each engine operator receives one share and each of the remaining persons receives one share. In the case of large motorized boats with engine hp ranging between 22 and 33, the owners of boats and nets receive 62% of total gross income. The remaining 37.5% is divided among other crews and persons according to the sharing system. The senior sailor receives two shares, the junior sailor receives one share, and each of the remaining crew receives one share. For large motorized boats with engines having 33 hp or more, the distribution takes a different mode. The senior sailor receives Tk.60 out of each Tk.1 000 of gross income. Similarly, the junior sailor receives Tk.30, the engine operator receives Tk.20 and each other hired person receives Tk.20 for every Tk.1 000 of gross income. The remaining gross income after payments to the senior sailor, junior sailor, operator and all other crew is distributed to the owners of boats and nets. In some cases, the junior sailor may receive one and a half share or Tk.30 out of each Tk. 1000 of gross income, depending on the predetermined agreement. In the case of separate owners of boats and nets, the returns for boats and nets are equally divided between the owners.

Market Structure and Price of Fish

Owners of large motorized boats land their catch in landing stations. These are stations built by the BFDC in Cox's Bazar, Chittagong and other major fishing areas. Wholesale agents are available in these stations. After fish is landed, it is sold in open auction among the agents. Fish is then carried to the *arats* generally situated in large centers. In big market centers, the *aratdars* form a cartel, and decide on prices of different species. The retailers, who generally have fixed stalls or selling sheds in the market, receive fish from the *aratdars* at prices fixed by the latter. The retailers then sell to the general consumers at prices that may be established through bargaining. Nonetheless, all the stalls sell the major species at about the same price. Buyers' knowledge of fish and their respective prices in the markets is perfect. The story is different in a host of fishers' villages, where fishing is done with small motorized and non-motorized boats. Here the

landing stations known as *ghats* are not equipped with modern facilities. Most of these are traditional landing spots near the village without any *pucca* structures. Wholesale agents frequent these places during peak seasons. At other times, small traders who have connections with *aratdars* in local market centers or who themselves are fish traders, attend the *ghats* at the time of landing. If the amount of fish catch is small, the fisher conveys his catch to the local market himself. Table 34 shows the numbers of agents involved in marketing in peak and slack seasons in one of our study villages, which is the abode of traditional fishers. Forty-two out of 50 fishers used the services of wholesalers in the peak season, and in the slack season 21 fishers used the services of local traders while 22 fishers sold their catch themselves.

Table 34. Fish marketing in North Salimpur.

Agents	Peak Season	Slack Season
Wholesaler	42	7
Aratdar	4	0
Local trader	2	21
Fishers	2	22
TOTAL	50	50

Fishers of this village complained that they do not get a fair price for their catch. The reasons are twofold. One, they have to sell to those people (wholesaler, *aratdar* or trader) from whom they previously received loans on condition of selling fish after harvest. Two, there is collusion among traders who also maintain "musclemen" to compel the fishers to sell at prices dictated by them.

Bioeconomic Modeling

Rationale

Bioeconomic analysis combines biological and economic analyses for efficient management of the fisheries. Economic analysis of management issues underlying the fisheries sector, which is sometimes based on modeling of economic relationships, is complementary to biological modeling.

Objectives

Both under-utilization and over-utilization of fishery resources are undesirable. In a developing country like Bangladesh, it is the over-exploitation, not under-utilization, which concerns us most. The objective of this study is to examine the degree of the over-utilization of the fishery resources taking place over time in Bangladesh.

In Bangladesh much of the fish comes from the inland sector. Coastal fisheries account for a small percentage of the total fisheries. Still, the number of artisanal fishers living along the coastal belts of the Bay of Bengal is quite large. The number of small and medium sized fishing crafts engaged in fishing in estuaries and shallow waters of the sea is rapidly increasing. Fisheries biologists and experts are of the opinion that the number of trawlers fishing offshore has exceeded the sustainable level. The coastal fishery in Bangladesh is subject to over-exploitation. The objective of this paper is to develop some economic models to assess the nature and extent of the over-exploitation. For lack of data, bioeconomic modeling of coastal fisheries will be limited to large scale fishing by trawlers. There are two types of bioeconomic models widely used in fisheries economics. These two models are Schaefer's surplus production model (Schaefer 1954) and Fox's variant of the model (Fox 1970). Equation (1) and equation (2) show the two types of models in econometric formats:

Schaefer's Model:

$$Y = \beta_1 f + \beta_2 f^2 + \in \qquad \beta_1 > 0,\ \beta_2 < 0 \qquad (1)$$

Fox's Model:

$$Y = f \exp(\alpha_1 + \alpha_2 f + V) \qquad \alpha_1 > 0,\ \alpha_2 < 0 \qquad (2)$$

where exp = exponential e.

The term "$\in$" in equation (1) and "V" in equation (2) signify random errors with population mean zero and identical variances. "Y" and "f" stand for total fish catch in physical units and total fishing days, respectively. β_1, β_2, α_1 and α_2 are the parameters to be estimated from regression analysis.

Framework and Estimation

Model Specification

The models shown by equations (1) and (2) cannot be easily estimated. The first model has no intercept and the second model is non-linear. To facili-

tate estimation, rearrangement of the above models is necessary. Dividing equation (1) by " f " on both sides, we get the following equation:

$$\frac{Y}{f} = \beta_1 + \beta_2 f + \in \quad (3)$$

Equation (3) is normally estimated using ordinary least squares method by regressing catch per unit of effort ($\frac{Y}{f}$) on effort (f). Estimated values of β_1 and β_1 can be used to estimate maximum sustainable yield (MSY), which is defined as the maximum rate of catch of fish which can be sustained during a long period of time without affecting the size of the stock of the fishery resources. The level of fishing effort corresponding to MSY is called maximum sustainable effort, MSY_f. MSY and MSYf from model (3) are given by:

$$MSY = (-\hat{\beta}_1^2 / 4\hat{\beta}_2) \qquad \hat{\beta}_1 \equiv \text{Estimate of } \beta_1$$

$$MSY_f = \frac{-\hat{\beta}_1}{2\hat{\beta}_1} \qquad \hat{\beta}_2 \equiv \text{Estimate of } \beta_2$$

Catch of fish in physical units (Y) in equation (3) can be converted into the value of the catch of fish in money terms, V (Y). A new estimable equation can be written as follows:

$$\frac{V(Y)}{f} = \theta_1 + \theta_2 f + U^* \quad (4)$$

A linear total cost function can be estimated using data on the total cost and fishing effort.

$$TC = \delta f + E \quad (5)$$

Open access equilibrium is obtained at the level " f " at which the total revenue and total cost of fishing is equal.

$$\hat{\theta}_1 f + \hat{\theta}_2 f^2 - \hat{\delta} f = 0 \quad (6)$$

Maximum economic yield (MEY) and maximum economic rent (MER) occur at the value of " f " which satisfies the following equations:

$$\hat{\theta}_1 f + 2\hat{\theta}_2 f - \hat{\delta} = 0 \quad \text{or} \quad f^* = \frac{\hat{\delta} - \hat{\theta}_1}{2\hat{\theta}_2} \quad (7)$$

MEY and MER are given by the following equations:

$$MEY = \hat{\theta}_1 f^* + \hat{\theta}_2 f^{*2} \quad (8)$$

$$MER = \hat{\theta}_1 f^* + \hat{\theta}_2 f^{*2} - \hat{\delta} f^* \quad (9)$$

The Fox model given by equation (2) can be rearranged as follows:

$$\text{In}\left(\frac{Y}{f}\right) = \alpha_1 + \alpha_2 f + V^* \quad (10)$$

Parameters of model (10) can be estimated by applying the OLS method to transformed data. MSY and MSY_f are given by the following equations:

$$MSY = -\exp(\hat{\alpha}_1 - 1) / \hat{\alpha}_2 \quad (11)$$

$$MSY_f = -1/\hat{\alpha}_2 \quad (12)$$

MEY and MER are obtained by estimating the following non-linear equation:

$$\exp(\hat{\alpha}_1 + \hat{\alpha}_2 f^*)(1 + \hat{\alpha}_2 f^*) - \hat{\delta} = 0 \quad (13)$$

Where f* denotes the level of fishing effort at which MEY and MER are obtained. The values of MEY and MER are given by the following equations:

$$MEY = f^* \cdot \exp(\hat{\alpha}_1 + \hat{\alpha}_2 f^*) \quad (14)$$

$$MER = MEY - \hat{\delta} f^* \quad (15)$$

where $\hat{\delta}$ is the estimated slope of the total cost function.

Data: Catch, Effort, Fishing Effort and Fish Price

Although artisanal fishing dominates marine fisheries of Bangladesh, time series of catch and fishing effort are not available for this type of marine fishing. Data on catch and effort in trawl fishing can be obtained for a period of 16 years from 1981 to 1997. Statistics on catch measured in metric tons (t) and on effort measured in fishing days are available for both shrimp and fish trawlers. Non-availability of data in Bangladesh restricts bioeconomic modeling to trawl fishing only.

Catch and effort data for trawl fishing published by the Department of Fisheries (DOF) need modifications for three reasons. First, the DOF publishes data on the total number of fishing days of all trawlers operating in a year. These data do not include the number of nets used by each trawler. A standard fishing day is defined as one fishing day of a trawler using two nets, each with a 25-m long head rope. On that count, a shrimp trawler fishing one whole day with one shrimp net is deemed to exert

half a day of fishing effort. Since the total revenue from a fish trawler measures a very small percentage of the total revenue from a shrimp trawler, more emphasis is placed on the catch and effort by the shrimp trawlers. It is, therefore, necessary to convert the effort level of a fish trawler into that of a shrimp trawler. Time series of catches by the shrimp and fish trawlers give the average daily shrimp catch of a shrimp trawler as 650 kg and that of a fish trawler as 190 kg. Based on the ratio of shrimp catches of the two types of trawler, productive capacity of one shrimp trawler is assumed to be at a par with that of three and a half fish trawlers. Effort data adjusted for the number of nets and the type of trawler used gives a standard fishing day (SFD). Dividing the total shrimp catch by SFD, we obtain the first type of catch per unit of fishing effort, CPUE1.

Second, standardization of effort data makes use of the fact that CPUE increases gradually over time due to technological progress. Hence, a fishing day in a later year is equal to more than a fishing day in an earlier year. To purge the DOF data of the effect of technological progress, two modification methods were used. First, data on the CPUE of the DOF research vessel, Anusandhani, were collected and used to estimate a trend line of CPUE values. Information about shrimp catch from different fish and shrimp cruises of Anusandhani carried out during 1984 to 1987 were processed to calculate the catch per fishing day (CPUE). The CPUE observations were then used to estimate a trend line, which gave the predicted CPUE values for different years. These trend values were supposed to be free of technological progress since the same research vessel was used during the whole period. The estimated trend and predicted values of the CPUE were then adjusted to match the average shrimp catches of the shrimp and fish trawlers. The CPUE values thus estimated were labeled CPUE3 and were used to find the standardized effort values as the ratios of the annual total shrimp catch to CPUE3 .

An alternative method of removing the upward bias in the CPUE due to technological progress sets out by regressing CPUE1 on standardized effort and a time variable. The estimated time effect is deducted from CPUE1 and the adjusted CPUE value, called CPUE2, is then regressed on the standardized fishing effort. The different sets of the CPUE data are shown in Table 35. As can be seen from the Table, CPUE3 is less than both CPUE1 and CPUE2 at initial stages, but exceeds them during the later years. This is contrary to expectations, and may be attributed to poor estimation results based on three data points only. The estimated coefficient showing the effect of technological progress using the second method was not found to be statistically significant. This led to using the CPUE1 series in the estimation of the bioeconomic models.

The preceding discussion focused on standardization of the fishing effort, but we need to standardize catch also. This is because the total shrimp catch consists of many species whose prices differ widely. For example, the price of the most valuable fish is almost two hundred times as high as the price of the least valuable fish. It is meaningless to add together the quantities of different fish species with divergent prices. Standardization of catch data can solve the problem of heterogeneity of fish species. This standardization can be based on the percentage catch composition. Data collected from 10 trawl fishing firms in Chittagong City give the following catch composition of shrimp:

Tiger shrimp	8.27%
White shrimp	5.88%
Brown shrimp	57.69%
Small shrimp	28.25%
TOTAL	100.00%

Data on prices of different categories of shrimp were also collected from the Sample Survey. Standardization of catch data proceeded as follows. First, data on the total shrimp catch were separated into catch data for different types of shrimp and fish using the percentage composition figures shown above. Small shrimp was chosen as the standard category because it has the lowest price among species of shrimp. The ratio of the price of a particular species of shrimp to the price of small shrimp was calculated and this ratio was then used to convert the quantity of that particular species into standard units of small shrimp. The following table shows the different price ratios.

Table 35. Catch and effort data for trawl fishing.

Year	Total fishing days	Total shrimp catch (t)	Standard Fishing Days (SFD)	CPUE1 (t)	CPUE2 (t)	CPUE3 (t)
1981 - 82	N/A	1 697	3 782	0.449	0.457	0.232
1982 - 83	N/A	3 120	7 024	0.444	0.461	0.139
1983 - 84	N/A	5 461	9 662	0.565	0.591	0.046
1984 - 85	N/A	5 518	8 159	0.676	0.710	0.047
1985 - 86	6 114	4 034	6 444	0.626	0.668	0.140
1986 - 87	6 969	4 488	6 928	0.648	0.698	0.233
1987 - 88	7 699	3 523	6 583	0.535	0.594	0.326
1988 - 89	8 423	4 893	6 945	0.705	0.772	0.419
1989 - 90	8 384	3 134	5 546	0.565	0.641	0.512
1990 - 91	6 379	3 430	4 499	0.762	0.847	0.605
1991 - 92	6 950	2 902	6 122	0.474	0.569	0.698
1992 - 93	8 133	4 188	7 065	0.593	0.694	0.791
1993 - 94	8 341	3 480	7 169	0.485	0.595	0.885
1994 - 95	8 045	2 416	6 761	0.357	0.475	0.978
1995 - 96	7 934	3 588	7 394	0.485	0.612	1.071
1996 - 97	8 470	3 536	7 107	0.498	0.633	1.164
1997 - 98	8 900	2 444	7 491	0.326	0.470	1.257

Source: Department of Fisheries, Ministry of Fisheries and Livestock.
Note: N/A = Not available.

Table 36. Price ratios of different varieties of shrimp.

Numerator	Denominator	Ratio
Price of tiger shrimp	Price of small shrimp	7.9099
Price of white shrimp	Price of small shrimp	3.6465
Price of brown shrimp	Price of small shrimp	2.0737

The total catch figures were converted into t of small shrimps by using the following conversion formula:

$$(SCST + SCFT) * 2.3473804 \qquad (16)$$

where
SCST = Total Shrimp Catch of Shrimp Trawlers
SCFT = Total Shrimp Catch of Fish Trawlers

Thus equation (16) measures the total shrimp catch in t of the small shrimp catch. Multiplication of the quantity of small shrimp catch by the price of small shrimp, (Tk.137 327.60 per t), gives the monetary value of the total shrimp catch.

Model Estimation

Schaefer and Fox models were estimated using each of the three CPUE series. The estimation results of the selected models have been given in Appendix Table 18. Each of these models was estimated using 14 observations covering the period 1984 - 98. Consideration of standardized effort data and estimation results led to acceptance of Schaefer's and Fox's models estimated by using CPUE1 series. Results of these models are shown in Table 37. Both the models have moderately large values of adjusted R^2 and the errors are not auto-correlated.

The estimated figures using Schaefer's model and Fox's model are shown in Figures 6 and 7, respectively. The MSY according to Fox's model is greater than the MSY of Schaefer's model. Similarly, the MSY effort level of Fox's model is much higher than the corresponding MSY effort level of Schaefer's model. However, in both cases the current effort level exceeds the MSY effort levels. It is evident from Table 37 that the levels of the MSY from both the models are much greater than the current level of catch. MSY is 4 029 t according to Schaefer's model and 4 136 t according to Fox's model. Both values of MSY exceed the current catch level of 2 444 t. The MSY effort level is 9 317 standard fishing days according to Schaefer's model and 11 822 standard fishing days according to Fox's model. The current effort level of 7 491 standard fishing days is smaller than the MSY effort levels in both models.

Although the current levels of catch and standardized fishing effort are less than the corresponding optimum (MSY) values determined by the Schaefer and Fox models, the maximum values of shrimp catch and effort level obtained previously in Bangladesh were much higher than these optimum values. For example, the maximum shrimp catch of 5 518 t caught in 1985 is higher than the MSY values in both models. Similarly, the maximum effort level of 9 662 standard fishing days exerted in 1984 exceeds the MSY effort level in Schaefer's model. Moreover, some of the previous catch and effort levels are greater than the MSY values and MSY effort levels. Figures 8 and 9 bear testimony to this observation. Some of the real catch values lie above the maximum points of the estimated Schaefer and Fox curves. It can be concluded that industrial fishing in Bangladesh is subject to over-exploitation. It is likely that the marine resources for trawl fishing will soon be exhausted. Signs of the extinction process of valuable commercial species in the Bay of Bengal are very visible these days. The government should take immediate steps to stop the massive over-exploitation of the fishery resources taking place in the EEZ of Bangladesh.

An estimated model expressing fish catch in money values is essential for estimating maximum economic rent (MER) and the corresponding fishing effort level. Such a model also provides information about the level of fishing effort corresponding to open access equilibrium. A linear total cost function relating the total cost to fishing effort is a prerequisite for finding the open access equilibrium. The standardized units of fish catch were multiplied by the average price of small shrimp. Data from our trawler sample gave the average price of small shrimp as Tk.137 327.60 per t. The estimated slope of a linear total cost function from the origin was Tk.87 459, implying that total cost increases by Tk.87 459 for each additional standard fishing day.

Table 37 shows the estimated values of MER and MEY and the corresponding effort levels for both Schaefer and Fox models. Figures 19 and 20 present the open access equilibrium positions in Schaefer's and Fox's model respectively. Table 37 shows that the MEY effort level in each models is much less than both the current effort and the MSY effort levels.

Table 37. Results of bioeconomic modeling.

Model	MSY (t)	MSY Effort (SFD)	Current Catch (t)	Current Effort (SFD)	MEY Effort (SFD)	MEY Million Tk.	MER Million Tk.	Result
Schaefer	4 029	9 317	2 444	7 491	6 452	1 176.0	622.8	Over Exploitation
Fox	4 136	11 822	2 444	7 491	6 223	1 126.8	593.2	Over Exploitation

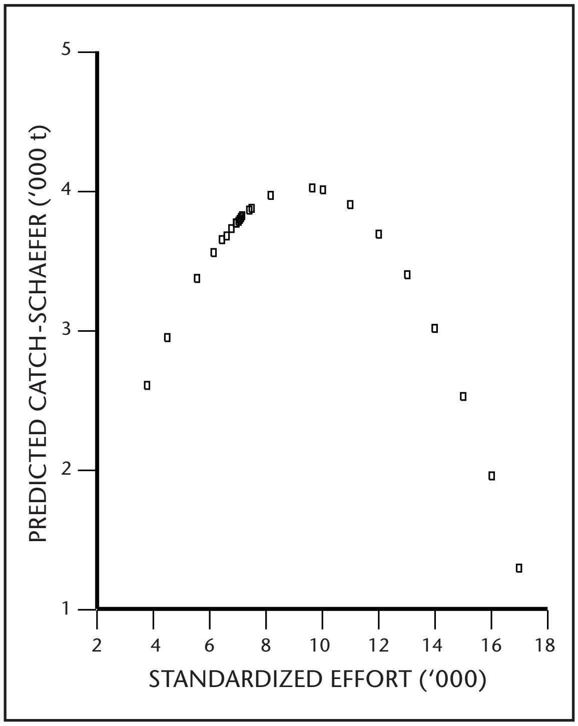

Fig. 6. Schaefer's Model: MSY = 4 029 t, MSY Effort = 9 317 SFD.

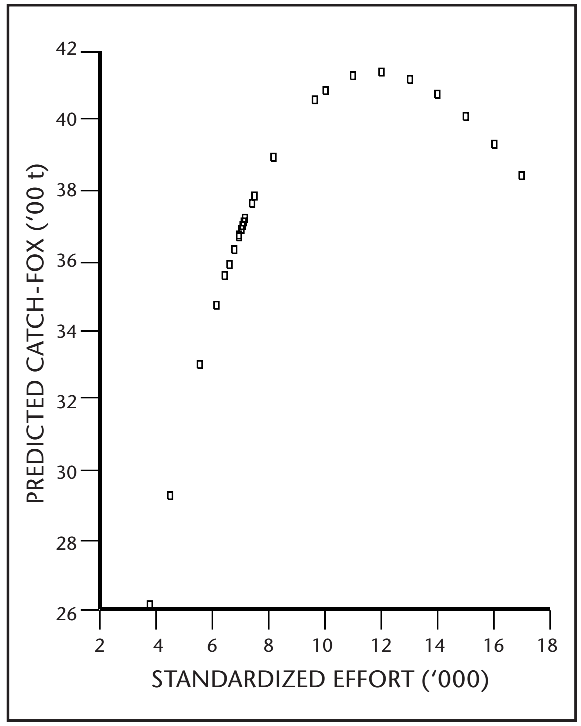

Fig. 7. Fox's Model: MSY = 4136 t, MSY Effort = 11 822 SFD.

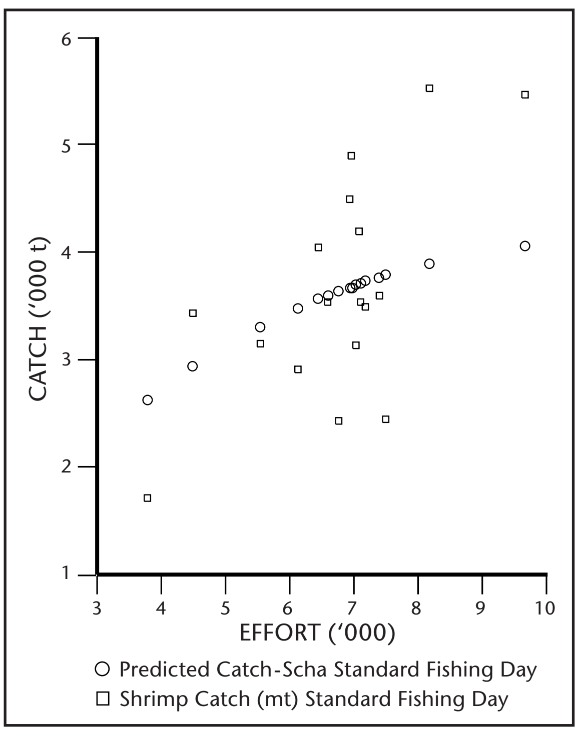

Fig. 8. Real and predicted catch using Schaefer's Model.

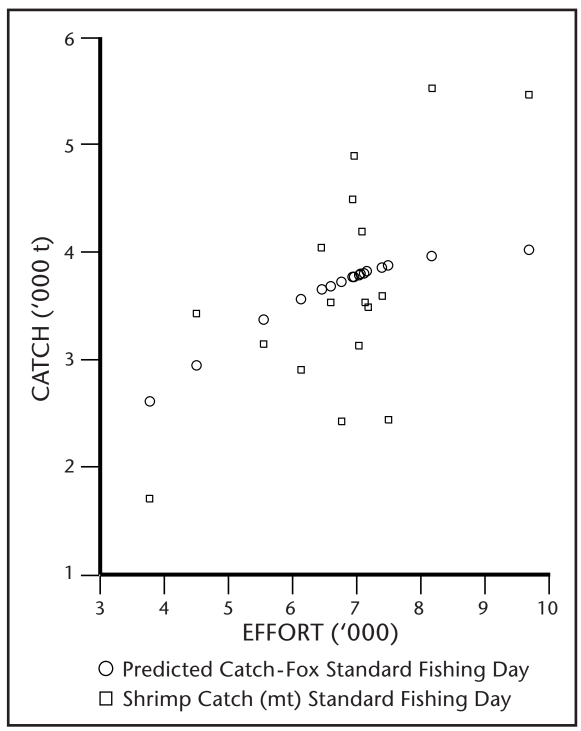

Fig. 9. Real and predicted catch in Fox's Model.

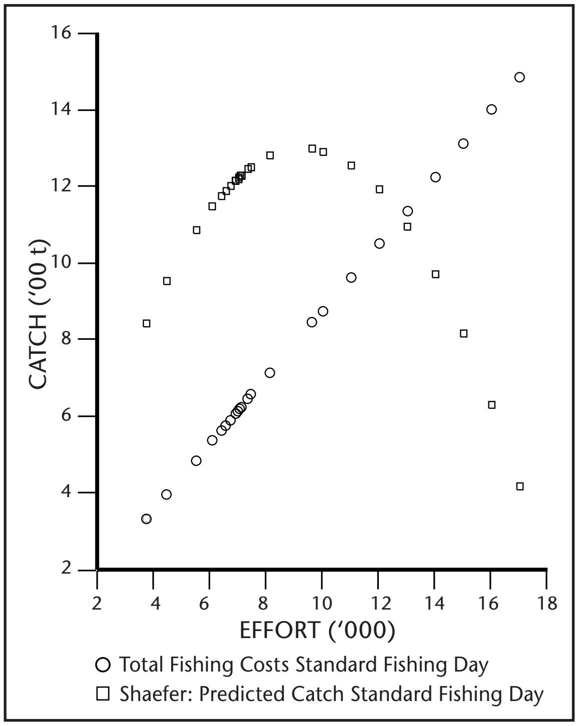

Fig. 10. Open access equilibrium in Schaefer's Model.

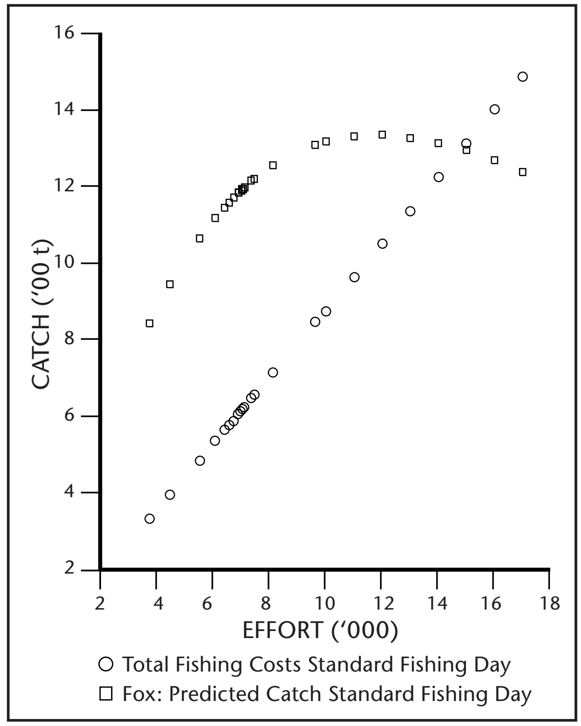

Fig. 11. Open access equilibrium in Fox's Model.

Conclusion and Recommendations

Time series data on catch and effort for trawl fishing in Bangladesh were standardized and used in estimating Schaefer's surplus production model and Fox's production model. The estimation results were good in terms of different statistical criteria used to judge estimated models. The estimated models show that industrial fishing in Bangladesh has already exceeded the maximum sustainable yield (MSY) level. There is no point in increasing the number of trawlers used in industrial fishing or increasing the intensity of fishing effort by increasing the number of annual fishing days. The previously caught maximum volume of total catch in industrial fishing is much higher than the MSY levels of catch. If this tendency of over-fishing lasts for long, the fishery resources in the EEZ of Bangladesh will soon be exhausted. The recent trend in coastal fishing shows omens of bad harvests and finally extinction of marine fishery resources in the Bay of Bengal. All fishers whom we interviewed in four sample sites reported declining fish catch in their daily fishing trips.

The responsibility for the stocks lies with all the parties involved in the use of the Bay of Bengal. The government, by enacting laws and ensuring their enforcement, has a key role to play. The present number of trawlers is very large - their number should not be allowed to increase. The trawl and large mechanized boat owners have to avoid intrusion into near-shore areas and over-fishing. Discarding by-catch at the present high rate should be stopped immediately. The artisanal fishers should give up some gear harmful to fish. Certain gear like ESBN, push nets and *"current jaal"* killing juveniles of Hilsha must be abandoned. However, to make all the stakeholders involved in the use of coastal waters do whatever is needed of them, some kind of co-management has to be developed, so that they act in an agreed manner. The initiative must come from the government, with cooperation of the international agencies.

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APPENDICES

Appendix Table 1. Volume of Fish Production in t.

Year	Marine Capture Fishery		Inland Capture Fishery	Culture Fishery		Total
	Large Scale	Small Scale		Coastal	Inland	
1985 - 86	11 898	195 503	441 799	19 951	124 772	144 723
1986 - 87	12 356	205 228	431 006	22 050	144 050	166 100
1987 - 88	10 395	217 187	435 598	25 248	150 677	175 925
1988 - 89	10 353	222 928	424 140	27 172	156 333	183 505
1989 - 90	11 379	227 684	423 872	27 505	165 087	192 592
1990 - 91	87 60	232 778	443 404	28 431	182 562	210 993
1991 - 92	96 23	235 851	479 742	30 147	196 716	226 863
1992 - 93	12 227	238 265	532 419	33 773	203 970	237 743
1993 - 94	12 454	240 590	573 376	39 447	224 743	264 190
1994 - 95	11 715	252 935	591 145	47 331	269 742	317 073
1995 - 96	11 959	257 743	609 151	68 349	310 738	379 087
1996 - 97	13 564	261 140	599 900	79 020	353 115	432 135

Source: Bureau of Statistics 1998.

Appendix Table 2. GNP* and value-added by sectors at constant prices (Million Taka) (Base Year 1984 - 85).

Year	GNP	GDP	Agri.	Fishery	Marine	Inland	Industry	Marine
1972 - 73	221 687	220 802	117 376	14 317	627	13 690	14 280	4
1973 - 74	254 025	254 356	129 640	14 362	724	13 638	16 781	8
1974 - 75	262 454	262 973	128 335	14 412	822	13 590	27 036	4
1975 - 76	294 752	295 184	1 432	14 367	920	13 447	28 989	4
1976 - 77	299 040	299 122	138 976	14 367	1 017	13 350	30 173	4
1977 - 78	319 889	318 593	150 979	14 536	1 115	13 421	30 627	20
1978 - 79	335 219	333 114	148 775	10 494	1 212	9 282	34 849	16
1979 - 80	341 925	337 480	149 018	10 464	1 344	9 120	35 564	16
1980 - 81	367 753	360 361	156 987	10 484	1 359	9 125	37 498	4
1981 - 82	369 616	363 294	158 412	11 088	1 426	9 662	38 090	8
1982 - 83	389 930	376 412	165 725	11 842	1 545	10 297	37 478	4
1983 - 84	404 198	392 346	168 383	11 927	1 738	10 189	38 844	4
1984 - 85	413 549	406 933	169 970	12 206	1 816	10 390	40 112	4
1985 - 86	435 435	424 593	175 549	12 406	2 000	10 406	41 156	3
1986 - 87	455 091	442 347	176 250	12 685	2 106	10 579	44 403	4
1987 - 88	470 751	455 135	174 901	12 822	2 202	10 620	44 682	2
1988 - 89	482 581	466 603	173 037	12 871	2 251	10 620	45 927	3
1989 - 90	512 546	497 527	190 354	13 135	2 270	10 865	49 256	66
1990 - 91	530 789	514 442	193 421	13 899	2 308	11 591	50 423	80
1991 - 92	556 219	536 189	197 662	14 799	2 361	12 438	54 117	94
1992 - 93	583 159	560 229	201 230	15 780	2 435	13 345	59 033	107
1993 - 94	611 399	583 840	201 915	17 145	2 508	14 637	63 665	121
1994 - 95	638 802	609 793	199 822	18 803	2 684	16 119	69 165	137
1995 - 96	672 071	642 441	207 126	19 914	2 696	17 218	72 823	174
1996 - 97	714 641	680 206	220 456	21 626	2 928	18 698	75 401	222
1997 - 98	753 570	718 674	226 959	23 485	3 180	20 305	82 601	293

Note: * - Data collected and adjusted from different issues of Statistical Year Book of Bangladesh.

Appendix Table 3. Structure of households in Peshkar Para (PP) and North Salimpur (NS).

Value	Number of rooms		Area of main room (ft²)		
	Freq. (NS)	Freq. (PP)	Class	Freq. (NS)	Freq. (PP)
1	5	0	15 - 40	0	3
2	6	5	40 - 65	4	4
3	8	11	65 - 90	13	16
4	20	22	90 - 115	7	15
5	9	6	115 - 140	16	8
6	1	1	140 - 165	7	2
7	0	4	165 - 190	2	1
8	1	0	190 - 215+	1	1
9	0	1			
Mean	3.6	4.08	Mean	109	109.91
Median	4	4	Median	120	96
Mode	4	4	Mode	120	90
Std. Dev	1.4	1.4	Std. Dev	34.27	109.44

Source: Bureau of Statistics 1998.
Note: PP = Peshkar Para, NS = North Salimpur, Freq = Frequency of families.

Appendix Table 4. Availability and frequency of eating specific food items.

	Normal		More than normal		Less than normal		Never		Always		Weekly		Monthly	
	NS	PP	NS	PP	NS	PP	NS	PP	NS	PP	NS	PP	NS	PP
Beef & Mutton	0	4	0	0	9	46	41	0	1	3	2	21	39	26
Chicken	0	4	0	0	11	46	39	0	1	3	10	18	39	29
Eggs	0	5	1	0	48	45	1	0	1	4	43	23	6	23
Fish	48	38	1	11	1	1	0	0	47	45	2	5	0	0
Gur	3	3	1	0	45	37	1	8	3	6	32	33	15	1
Milk	1	6	0	1	12	33	36	9	0	7	11	30	11	3
Sugar	48	4	0	1	2	43	0	2	49	5	1	41	0	2
Pulse	0	12	0	0	0	33	0	5	50	12	0	33	0	0

Source: Bureau of Statistics 1998.
Note: PP = Peshkar Para, NS = North Salimpur.

Appendix Table 5. Durable assets of households (North Salimpur).

Radio			Wrist watch		Wall clock		Chairs		Table		W. TV		Color TV	
Va.	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.
0	30	60	23	46	27	54	27	54	33	66	40	80	46	92
1	19	38	8	16	18	36	3	6	12	24	10	20	4	8
2	10	2	13	26	5	10	7	14	5	10	0	0	0	0
3	0	0	5	10	0	0	7	14	0	0	0	0	0	0
4	0	0	1	2	0	0	4	8	0	0	0	0	0	0
5	0	0	0	0	0	0	2	4	0	0	0	0	0	0
1 - 5	20	40	27	54	23	4	23	46	17	34	10	0	4	8

Source: Bureau of Statistics 1998.
Note: Va.= Value, F. = Frequency of families, P.= Percentage of families.

Appendix Table 6. Durable assets of households (Peshkar Para).

Radio			Wrist watch		Wall clock		Chairs		Table		W. TV		Color TV	
Va.	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.
0	33	66	19	38	43	86	19	38	23	46	39	78	49	98
1 - 5	17	34	28	56	7	14	19	38	27	54	11	22	1	2
6 - 10	0	0	3	6	0	0	8	16	0	0	0	0	0	0
11 - 15	0	0	0	0	0	0	3	6	0	0	0	0	0	0
16 - 20	0	0	0	0	0	0	1	2	0	0	0	0	0	0

Source: Bureau of Statistics 1998.
Note: Va.= Value, F. = Frequency of families, P.= Percentage of families.

Appendix Table 7. Livestock of households.

	Goats				Cows				Buffalo			
	N. Salimpur		Peshkar Para		N. Salimpur		Peshkar Para		N. Salimpur		Peshkar Para	
Value	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.	F.	P.
0	40	80	43	86	50	100	49	98	50	100	47	94
2	0	0	1	2	0	0	0	0	0	0	0	0
3	3	6	3	6	0	0	0	0	0	0	0	0
4	1	2	0	0	0	0	0	0	0	0	0	0
5	1	2	2	4	0	0	0	0	0	0	1	2
6	2	4	0	0	0	0	1	2	0	0	1	2
7	1	2	1	2	0	0	0	0	0	0	0	0
9	1	2	0	0	0	0	0	0	0	0	0	0
12	1	2	0	0	0	0	0	0	0	0	0	0

Source: Bureau of Statistics 1998.
Note: F. = Frequency of families, P.= Percentage of families.

Appendix Table 8. Age distribution of respondents and wives.

Age Limit	North Salimpur		Peshkar Para	
	Respondent	Wife	Respondent	Wife
17 - 21	2	5	0	10
22 - 26	9	7	7	10
27 - 31	4	5	10	10
32 - 36	7	10	17	2
37 - 41	7	4	9	2
42 - 46	10	4	2	2
47 - 51	4	3	4	3
52 - 56	2	1	0	0
57 - 61	4	0	1	0
62 - 66	0	0	0	0
67 - 71	1	0	0	0

Source: Bureau of Statistics 1998.

Appendix Table 9. Main and non-main occupations of respondents.

Occupation	North Salimpur				Peshkar Para			
	Occupation		Non-main Occupation		Occupation		Non-main Occupation	
	F.	P.	F.	P.	F.	P.	F.	P.
Fishing	46	92	3	6	48	96	3	6
Trade in fish	2	4	16	32	1	2	9	18
Other business	1	2	6	12	1	2	2	4
Housewife	1	2	25	50	0	0	1	2
Nothing	0	0	0	0	0	0	35	0

Source: Bureau of Statistics 1998.
Note: F. = Frequency of families, P.= Percentage of families.

Appendix Table 10. Change of roles in fishing -north salimpur.

Group of the fishermen	Owner of boat	Owner of net	Participate	Organize	Frequency 15 years ago	Frequency 10 years ago	Frequency 5 years ago
1	Yes	Yes	No	Yes	3	1	3
2	Yes	Yes	Yes	Yes	18	20	32
3	No	Yes	Yes	No	22	27	15
4	No	Yes	No	Yes	No	02	00

Source: Bureau of Statistics 1998.

Appendix Table 11. Change of roles in fishing - Peshkar Para.

Group of the fishermen	Owner of boat	Owner of net	Hired net & boat	Participate in fishing	Organize fishing	Frequency 15 years ago	Frequency 10 years ago	Frequency 5 years ago
1	Yes	Yes	Yes	No	Yes	1	4	5
2	Yes	Yes	Yes	Yes	Yes	1	2	3
3	Yes	Yes	No	Yes	Yes	3	5	6
4	No	Yes	No	Yes	No	12	24	25
5	Other					10	10	11

Source: Bureau of Statistics 1998.

Appendix Table 12. Attitudes towards Fishing.

Attitude	North Salimpur	Peshkar Para
Satisfied	3	7
Anxious	2	16
Not Satisfied	45	27

Source: Bureau of Statistics 1998.

Appendix Table 13. Numbers of fishing craft and gear.

	Type of Fishing											
	Industrial		Gillnet		SBN Fishing		Long-line		Trammel		Other fishing	
Year	Craft	Gear	Craft	Gear	Craft	Gear	Craft	Gear	Craft	Gear	Craft	Gear
1989 - 90	53	53	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222
1990 - 91	54	54	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222
1991 - 92	51	51	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222
1992 - 93	51	51	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222
1993 - 94	53	53	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222
1994 - 95	53	53	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222
1995 - 96	53	53	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222
1996 - 97	54	54	6 389	6 389	7 452	12 615	1 382	2 064	500	500	1 608	2 222

Source: Department of Fisheries, Ministry of Fisheries and Livestock.
Total: Trawler - 53; Total Mechanized - 3 317; Non- Mechanized 14 014.

Appendix Table 14. Number of fishing craft and gear by type.

	89 - 90	90 - 91	91 -92	92 -93	93 - 94	94 - 95	95 - 96	96 - 97
A. Industrial Fishing								
1. No. of shrimp trawlers	40	41	37	37	41	41	41	41
2. No. of fish trawlers	13	15	14	14	12	12	12	13
3. Total no. of trawlers	53	54	51	51	53	53	53	54
B. Gillnet Fishing								
1. No. of mechanized boats & nets	2 880	2 880	2 880	2 880	2 880	2 880	2 880	2 880
2. No. of non-mechanized boats	3 509	3 509	3 509	3 509	3 509	3 509	3 509	3 509
C. Set Bag net Fishing								
1. No. of seasonal MB	182	182	182	182	182	182	182	182
2. No. of nets of seasonal MB	5 400	5 400	5 400	5 400	5 400	5 400	5 400	5 400
3. No. of seasonal NMB	2 680	2 680	2 680	2 680	2 680	2 680	2 680	2 680
4. No. of all seasons NMB	4 590	4 590	4 590	4 590	4 590	4 590	4 590	4 590
5. No. of nets of all seasons NMB	7 215	7 215	7 215	7 215	7 215	7 215	7 215	7 215
D. Long-line Fishing								
1. No. of MB	255	255	255	255	255	255	255	255
2. No. of nets of MB	1 121	1 121	1 121	1 121	1 121	1 121	1 121	1 121
3. No. of NMB	127	127	127	127	127	127	127	1 127
4. Other long-line NMB	1 000	1 000	1 000	1 000	1 000	1 000	1 000	–
5. Nets of other long-line NMB	963	963	963	963	963	963	963	963
E. Trammel Net Fishing								
1. No. of NMB & net	500	500	500	500	500	500	500	500
F. Other Gears Fishing								
1. No. of NMB	1 608	1 608	1 608	1 608	1 608	1 608	1 608	1 608
2. No. of nets of NMB	2 222	2 222	2 222	2 222	2 222	2 222	2 222	2 222

Source: Department of Fisheries, Ministry of Fisheries and Livestock.
Note: MB = mechanized boats
NMB = non-mechanized boats

Appendix Table 15. Estimation results of first type of production functions.

Sample	Model/ Method	Area of craft	Tonnage of craft	HP of craft	Wt. of FM/ *Tong* nets	Wt.of FM/SB nets	Wt. of *Lakkha* nets	Wt. of other nets	Mesh size	Length of head rope	Fishing days	Dep. cost of nets	Adj. R^2
Trawler	CD - OLS	0.17 (1.02)	0.46 (1.09)	-1.44 (-1.72)	–	–	–	–	-0.45 (-0.46)		1.29 (0.85)	-	0.24
Motorized	CD - OLS		0.37 (0.55)	-62 (-0.64)	–	–	–		-0.62 (-0.74)	0.62 (0.43)	1.26 (0.98)	–	0.31
Peshkar Para	CD - OLS	-0.29 (1.14)	0.50 (1.82)	0.66 (1.67)	0.06 (1.48)	-11 (2.00)	0.16 (2.00)	0.08 (1.94)	–	–	–		0.66
N. Salimpur	CD - OLS	0.65 (0.42)	0.46 (27)	-0.11 (0.15)	0.61 (4.47)	0.05 (-0.34)	–	–	–	–	0.65 (1.75)	-0.65 (-1.44)	0.78

Source: Bureau of Statistics 1998.
Note: CD = Cobb Douglas Production Function, OLS = Ordinary Least Squares, Dep. = depreciation.
Figures in parentheses indicate "t" values.

Appendix Table 16. Fishing assets.

Types of Assets		North Salimpur				Peshkar Para			
		Present		Past		Present		Past	
		Full.	Partial	Full.	Partial	Full.	Partial	Full.	Partial
Boat	Non-Motorized	7	0	7	0	12	0	14	0
	Motorized	43	3	29	1	37	2	7	0
Net	*Tong Jal*	300	0	210	0	0	0	0	0
	SBN	174	0	125	0	0	0	0	0
	Floating	0	0	0	0	9	0	3	0
	Pomfret	0	0	0	0	30	4	16	0
	Lakkha	0	0	0	0	20	1	0	0
	Push Net	26	0	0	0	0	0	0	0
	Other	2	0	0	0	17	0	0	0

Source: Bureau of Statistics 1998.

Appendix Table 17. Estimation Results of Schaefer's Production Models.

Serial	Model	Type	Method	Intercept	Slope	R^2	'd' statistic	MSY	MSY_f
1.	Schaefer	SU-P	OLS	0.86491	-4.642E-05	0.11	1.56	4 029	9 317
2.	Fox	SU-P	OLS	-5.031E-02	-8.459E-05	0.10	1.42	4 136	11 822
3.	Schaefer	SU-M	OLS	0.27883E+06	-14.964	0.11	1.56	4 029	9 317
4.	Fox	SU-M	OLS	12.633	-8.459E-05	0.10	1.42	4 136	11 822

Source: Bureau of Statistics 1998.
Legend SU = Standardized Units, P = In Physical Units, M = In Monetary Units, OLS=Ordinary Least Squares.

A Preliminary Assessment of the Coastal Fishery Resources in India - Socioeconomic and Bioeconomic Perspective

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Abstract

India is endowed with a continental shelf of 0.5 million km^2 and an exclusive economic zone (EEZ) of about 2 million km^2. Almost half (39%) of the Indian population utilizes the marine fisheries resources. India ranked sixth worldwide in total fish production (4.95 million t) and second in inland fish production (2.24 million t) during 1995 - 96. Fish production expanded from 0.75 million t in 1950 - 51 to 4.95 million t in 1995 - 96, giving a significant increase at a cumulative growth rate of 4.2% per annum. Marine fish production increased from 0.53 million t in 1950 - 51 to 2.71 million t in 1995 - 96.

The contribution of the fisheries sector to the total gross domestic product (GDP) improved from 0.75% in 1980 - 81 to 1.28% in 1994 - 95, with marine fisheries providing employment opportunities both in the production and post-harvest sectors. Subsidiary employment in fishing includes boat building and repair, net mending, repair of engines and supply of diesel, kerosene and other essential items. Women are mostly engaged in post-harvest operations like net mending, fish processing, packing and selling of fish and fish products.

The contribution to foreign exchange earnings by the fishery sector substantially increased from Rs46 crores in 1960 - 61 to Rs4 697 (US$121*) in 1997 - 98. India exports about 55 types of marine products to different countries in Southwest Asia, Europe and USA. The total quantity of marine product exports rose from 97 200 t in 1987 - 88 to 307 337 t in 1994 - 95 giving an equivalent export value of Rs53 000 lakhs to Rs357 500 lakhs**.

The marine fishing sector can be classified into: (a) non-motorized artisanal sector using country craft with traditional gear; (b) motorized sector; (c) mechanized sector using inboard engines of 50 to 120 HP; and (d) deep sea fishing with bigger boats (25 m and above) and engines of 120 HP and above. In 1996, India had a total fishing fleet of 238 125 units comprising 160 000 traditional craft, 31 726 motorized craft (converted from traditional) and 46 918 mechanized vessels operating different gear combinations.

* 1US$ = Rs38.82 in 1997 - 98; source: oanda.com
** 1Lakh = 100,000

For artisanal fishing, the use of canoe and boat seine in Kerala provided the highest net income of Rs0.10 lakh with an annual catch of 51 t and an initial investment of Rs0.85 lakh. In motorized fishing, canoe and ring seine in Kerala offered a net income of Rs0.98 lakh with an annual catch of 220 t and an initial investment of Rs5.0 lakh. All major fishing units in Kerala, Tamil Nadu and Gujarat have higher profits not because of higher levels of fish catch but due to a better fish price. In the motorized sector, the increase in the price of fish over the years is greater than the increase in fuel expenditure.

Small trawlers, purse seiners, dol-netters, gillnetters, pair trawlers and sona boats are the major types of mechanized fishing units operating in the inshore waters (up to 50 m depth). Trawlers and gillnetters are mostly operated along the Indian coasts whereas the fishing fleet mentioned above is confined to certain regions only. A small trawler (32' - 36') has a net income of Rs0.90 lakh with an annual catch of 72 t and initial investment of Rs5.2 lakh in Karnataka. A purse seiner has a net earning of Rs3.14 lakh per year with an annual catch of 280 t and an average investment of Rs10 lakh. However the average value of fish caught in a purse seiner is Rs4.29 per kg set against the break-even cost of Rs3.16 per kg.

To assess the economic sustainability of Indian marine fisheries in the period 1985 to 1998, the surplus production model or Schaefer Model was applied. Based on this, the maximum sustainable yield (MSY) was estimated at 2 353 726 t with an estimated effort of 984 586 annual fishing hours (AFH). Using the Fox surplus production model, MSY was equal to 2 973 752 t with an effort of 6 126 232 AFH. Note that actual yield during that period was 2 441 043 t with an effort of 12 97 092 AFH. This is indicative of over-fishing in the Indian Sea and Bay of Bengal.

A number of management strategies can be applied to reduce the fishing pressure on the coastal areas of India. These are: (a) a ban of certain fishing gear and restricted entry to over-exploited fishing grounds; (b) the promotion of alternative/ subsidiary income and emphasizing the importance of mariculture/aquaculture; (c) effective implementation of small scale fishery development projects like infrastructure and service facilities; (d) coastal zone management including protection of marine habitats; and (e) information dissemination and education on the importance of fisheries resources.

Socioeconomic Profile

Review of the Status of Fishery Resources

India is endowed with a continental shelf of 0.5 million km^2 and an exclusive economic zone (EEZ) of about 2 million km^2. A considerable proportion (39.1%) of the Indian population utilizes the marine fishery resources. Marine fisheries contribute enormously to the Indian economy by way of export earnings and provide wider employment opportunities to millions in the rural sector.

On the global level, India currently stands sixth in total fish production and ranks second in the production of inland fish. The country still possesses immense potential in fish production as the marine sector and in particular, the inland resources, have not yet been exploited to the fullest extent.

India has ten maritime states in which the marine fishery occupies a prominent position. Gujarat State has the longest continental shelf of 164 000 km^2 (Table 1). Marine fish are landed in 2 333 landing centers and the number of coastal villages is approximately 3 726.

Based on the available scientific information, exploratory surveys, experimental fishing and other data, the potential harvestable fish stock is 3.9 million t (Table 2). The potential from three different sources has been estimated: inshore fishing (up to 50 m depth) along the east and west coasts contributing 2.28 t, offshore and deep sea (50 - 500 m depth) contributing 1.4 t and the oceans providing 0.3 t

Table 1. Scenario of Indian fisheries, 1996.

State	Continental shelf ('000 km²)	Number of landing centers	Number of villages	Approximate length of coastline (km)
Andhra pradesh	31	376	409	974
Goa	10	87	91	104
Gujarat	164	854	851	1 600
Karnataka	27	28	204	300
Kerala	40	226	222	590
Maharashtra	112	184	395	720
Orissa	24	63	329	480
Tamil Nadu	41	362	442	1 000
West Bengal	17	47	652	157
Andaman & Nicobar	35	57	45	1 912
Pondicherry	1	28	45	45
Lakshwadeep	4	11	10	132
Daman & Diu	0	7	31	27
TOTAL	506	2 330	3 726	8 041

Table 2. Potential resources available, level of exploitation and potential available for exploitation (million t).

Depth range (m)	0 - 50	50 - 200	200 - 500	Oceanic	Total
Demersal	1.28	0.625	0.028	–	1.933
Neretic pelagic	1	0.742	–	–	1.742
Oceanic pelagic	–	–	–	0.246	0.246
TOTAL	2.28	1.367	0.028	0.246	3.921
	(58%)	(35%)	(0.7%)	(6.3%)	
Level of exploitation	2.08	0.63	Negligible	Negligible	2.71
Available for exploitation	0.20	0.737	0.028	0.246	1.211

of tuna and other commercial species.

Table 3 shows that mackerel, penaeid prawns, lesser sardines and other clupeiods are over-exploited. Seer fishes, crabs, lobsters and polynemids are exploited to almost the optimum level. The under-exploited stocks include anchovies, tunas, billfishes, perches, elasmobranchs, carangids, pom-frets and sciaenids.

Intensive effort in bottom trawling has enhanced the demersal fish catch over the years. The notable increase in prawn production in recent years is perhaps due to extended trawler fishing.

Table 3. Potential (PTN) and present (PRN) (1994 - 95) yield ('000 t) of major fishery resources in India.

Resources	Northwest		Southwest		Southeast		Northeast		Total		*Status
	PTN	PRN	PTN	PRN	PTN	PRN	PTN	PRN	PTN	PRN	
Bombay duck	10	5	–	–	5	2	–	1	15	8	OE
Mackerel	5	22	80	147	15	36	–	1	100	206	OE
Penaeid prawn	30	79	95	83	20	47	35	4	180	213	OE
Lesser sardines	5	12	40	23	–	50	15	2	60	87	OE
Oil sardines	5	–	180	3	–	44	–	–	185	47	OE
Others clupeiods	55	57	10	33	40	62	45	37	150	189	OE
Seer fishes	5	15	10	10	15	10	10	5	40	40	NOE
Crabs and lobsters	5	10	10	7	20	14	5	1	40	32	NOE
Polynemids	10	5	–	–	5	2	–	1	15	8	NOE
Non penaeid prawns	90	67	–	–	5	5	–	2	95	74	UE
Sciaenids	70	119	20	22	20	23	100	19	210	183	UE
Pomfrets	30	15	–	8	–	7	40	8	70	38	UE
Cat fishes	90	28	120	1	25	6	75	8	310	43	UE
Ribbon fishes	90	69	110	25	45	11	25	4	270	109	UE
Carangids	70	28	110	73	25	35	–	3	205	139	UE
Elasmobranchs	45	25	45	8	–	22	40	3	130	58	UE
Perches	30	31	120	73	75	41	–	1	225	146	UE
Tunas and billfishes	10	9	60	24	10	5	–	–	80	38	UE
Anchovies	–	–	160	42	60	18	–	–	220	60	UE
Miscellaneous	155	126	310	205	440	166	330	2	1 220	430	
TOTAL	880	816	1 480	787	820	605	740	109	3 920	2 316	UE

Source: Sathiadhas et al. 1995.
Note: * OE - over-exploited, NOE - nearly optimum exploitation, UE - under exploited.

Growth of Marine Fisheries in India

In the past, fishing was primarily conducted by traditional craft in the near-shore areas. Drastic change was brought about by the entry of mechanized fishing vessels using trawl nets and the motorisation of craft. Ring seines were introduced along the southwest coast during the 1970s. Enhanced knowledge of potential stock areas and greater investment in this sector have resulted in the expansion of fishing areas and increased production. As the demand for fish increased, indigenous craft were motorized to meet demand. Fishers also began to use different types of gear such as drift gillnets, trammel nets, hook-and-lines, ring seines and mini-trawlers, thereby increasing production. All of these-contributed to the increase in- harvest from about 0.6 million t in 1950 to 2.36 million t in 1994 showing a steady growth over a period of about four decades.

The growth also resulted in the annual catch reaching the optimum level and a decrease in the per capita active fisher area and per boat area, and in catch per unit effort, warranting effective management of the exploited stocks in the coastal waters up to 50 m depth (Table 4).

Table 4. Area (ha) of inshore and offshore available per active fisher and fishing boat (non-mechanized) from 1961 to 1990.

State	Per capita area (ha)	Inshore (0 - 50 m)				Offshore (50 - 200 m)			
		1962 - 61	1973 - 77	1980	1990	1961 - 62	1973 - 77	1980	1990
Gujarath	Per active fisher	554	228	177	136	843	439	271	207
	Per boat	1 453	1 095	862	499	2 214	1 669	1 314	760
Maharashtra	Per active fisher	125	62	54	37	415	207	181	124
	Per boat	257	251	205	108	852	833	680	359
Goa	Per active fisher	120	73	33	23	280	172	78	55
	Per boat	3 030	229	87	94	7 070	534	204	220
Karnataka	Per active fisher	89	36	31	37	189	78	67	79
	Per boat	114	109	89	51	244	233	190	109
Kerala	Per active fisher	17	16	9	6	36	33	20	13
	Per boat	59	57	44	40	123	118	92	84
Tamil Nadu	Per active fisher	42	33	24	31	30	23	17	22
	Per boat	78	74	52	53	55	53	36	38
Pondicherry	Per active fisher	–	36	27	6	–	24	18	4
	Per boat	–	82	77	25	–	55	51	17
Andra Pradesh	Per active fisher	35	26	20	11	29	21	16	9
	Per boat	84	64	46	31	69	53	38	25
Orissa	Per active fisher	169	165	48	13	192	187	55	15
	Per boat	528	317	147	96	599	359	166	109
West Bengal	Per active fisher	359	199	60	14	149	82	25	6
	Per boat	1 503	599	234	192	626	249	97	80
Laccadives	Per active fisher	–	–	–	–	–	–	–	103
	Per boat	–	–	–	–	–	–	–	347
Andamans	Per active fisher	–	–	–	–	–	–	–	1 090
	Per boat	–	–	–	–	–	–	–	3 043

Table 5. Fish production in India (in lakh tonnes where 1 lakh = 100,000).

Year	Marine	Inland	Total
1950 - 51	5.34	2.18	7.52
1960 - 61	8.80	2.80	11.60
1970 - 71	10.86	6.70	17.56
1980 - 81	15.55	8.87	24.42
1981 - 82	14.45	9.99	24.44
1982 - 83	14.27	9.40	23.67
1983 - 84	15.19	9.87	25.06
1984 - 85	16.98	11.03	28.01
1985 - 86	17.16	11.60	28.76
1986 - 87	17.13	12.29	29.42
1987 - 88	16.58	13.01	29.59
1988 - 89	18.17	13.35	31.58
1989 - 90	22.75	14.02	36.77
1990 - 91	23.00	15.36	38.36
1991 - 92	24.47	17.10	41.57
1992 - 93	25.76	17.89	43.65
1993 - 94	26.49	19.95	46.44
1994 - 95	26.92	20.97	47.89
1995 - 96	27.07	22.42	49.49

Production of fish (both marine and inland) has significantly increased at a cumulative growth rate of 4.2% per annum since 1950 - 51 when the production was about 7.52 lakh tonnes (Fig. 1). Fish production increased by 6.6% on an average per annum from the beginning of the seventh five year plan in 1985 - 86 to 1992 - 93 (Table 5). The average growth of marine and inland fish production was 6.5% and 7.1%, respectively during the same period. Out of the total yield of 4.8 t during 1994 - 95, the marine and inland sectors yielded 2.8 and 2.04 t, respectively. Of the 1996 production of 2.83 t of marine fish, about 98.5% is contributed by the small and the artisanal sectors. Growth in fish production has been the fastest of any item in the food sector except potatoes, eggs and poultry meat.

Contribution of the Fisheries Sector to Economic Growth and Welfare

Contribution of the Fisheries Sector to GDP and GVA

The contribution of the fisheries sector to the gross domestic product (GDP) has been increasing over the years, as indicated by the rising share of the fisheries sector in the GDP (Table 6). With the two exceptions of 1988 - 89 and 1991 - 92, fisheries as a proportion of GDP increased throughout the period. On average, the fisheries sector contributed approximately 1% of the GDP during the period 1986 - 94. The average annual growth rate of the fishery sector, estimated at 18% per annum, exceeds the average annual growth rate of GDP, estimated at 14% per annum.

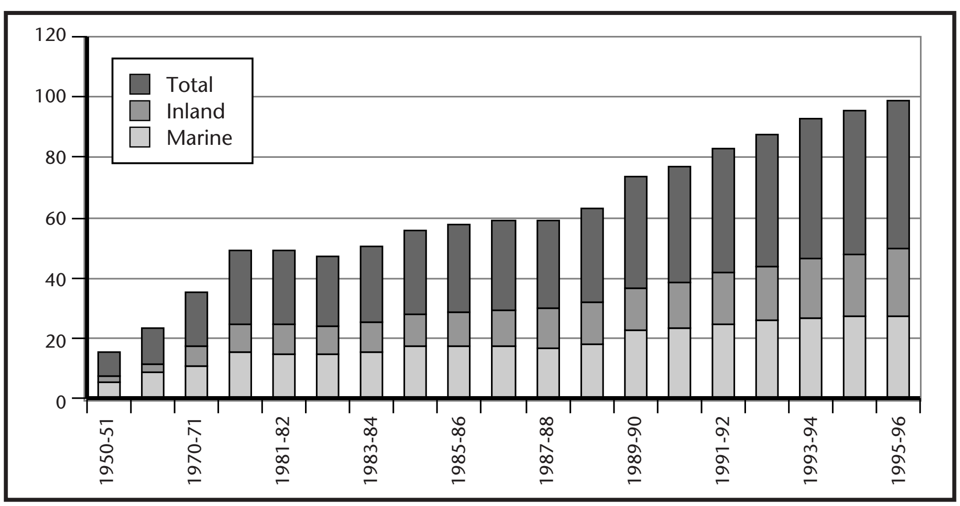

Fig. 1. Fish production (lakh t) in India during 1950 - 96.

Table 6. GDP at factor cost in India (Rupees in crores).

Year	Contribution of Fisheries	Total for Agricultural Sector	Total GDP	Contribution of Fisheries to Agricultural Sector	Contribution of Fisheries to total GDP
1980 - 81	921	46 649	122 - 427	1.97	0.75
1986 - 87	2 250	82 413	260 - 030	2.73	0.87
1987 - 88	2 686	92 379	294 - 851	2.91	0.91
1988 - 89	3 142	114 073	352 - 706	2.75	0.89
1989 - 90	3 781	127 051	408 - 662	2.98	0.93
1990 - 91	4 558	148 001	477 - 814	3.08	0.95
1991 - 92	5 082	172 771	552 - 768	2.94	0.92
1992 - 93	6 281	193 045	630 - 182	3.25	1.00
1993 - 94	7 534	221 746	723 - 103	3.40	1.04
1994 - 95	10 963	265 914	854 - 103	4.12	1.28

Source: Ministry of Agriculture. Department of Agriculture and Cooperation (Fisheries Division) 1996.

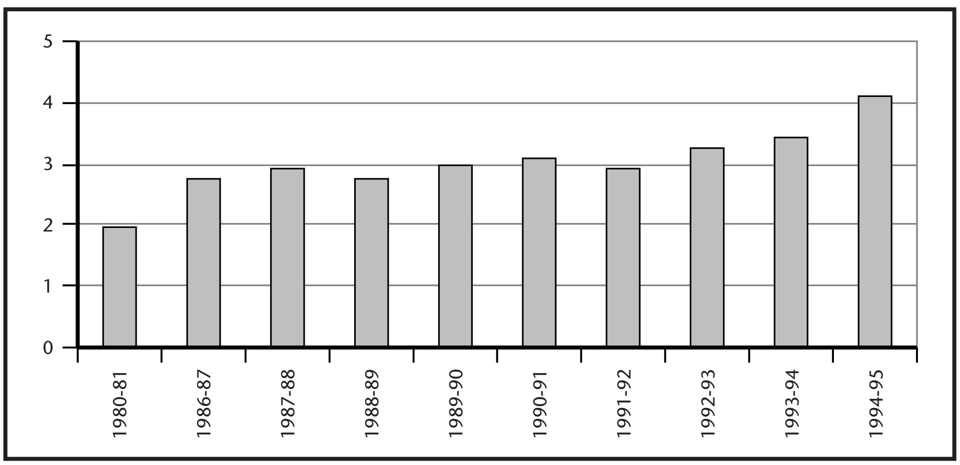

Fig. 2. Contribution of fisheries to total GDP from the agricultural sector (%) 1980 - 95.

Contribution of the Fishing Industry to Income and Employment

Marine fisheries provide employment both in the production and post-harvest sectors. The labor force in the marine sector has shown positive growth over the years. Even though total marine fish landings have significantly increased, catch per unit of operation and per capita production have steadily declined over the years. In spite of the decline in per capita production, different types of fishing unit remain profitable due to price appreciation for all varieties of marine fish. Income from the fishery sector in the total national income has substantially increased over the last five decades.

Employment

The actively employed manpower in marine fisheries is currently estimated at 10.25 lakhs. Nearly 12 lakh

are engaged in pre- and post-harvest operations that include the internal and external marketing. On average, every 5 kg of marine fish produced gives employment to about two persons, one in harvesting and the other in post-harvesting.

Employment in Active Fishing

Manpower employed in active fishing in the mechanized sector is estimated at 2 lakh, of which 1.5 lakh fishers are engaged in trawl fisheries and the remaining 0.5 lakh in gillnet, dol-net, purse seine and other fisheries such as sona boats and deep-sea vessels. The motorised sector employs 1.7 lakh people in active fishing; 66% are engaged in the operation of ring seines, mini trawls and gillnets. Motorised dugout canoes, catamarans and plywood boats provide employment for 58 000 persons in active fishing. The non-mechanised sector provides employment to 6.55 lakh people; 2.7 lakh people are engaged in catamarans, 2 lakh in plank-built boats and the rest in dugout canoes, *masula* boats and others.

Employment in Subsidiary Activities

Subsidiary activities offer employment to about 12 lakh people in India. Activities like boat building and repairing, net mending, supply of diesel and repair of engines, kerosene and other essential items at the landing centers afford active employment for 1 lakh. About 25% of those employed in post-harvest operations are women, primarily engaged in net making.

External and internal marketing including transportation, processing, packing and selling at different stages provide employment to 11 lakh people, 2 lakh in export marketing and 9 lakh in internal marketing.

Fifteen fishmeal plants with a capacity of 330 t per day and 900 peeling sheds with a capacity of 2 684 t·day^{-1} are commissioned in the country. The capacity utilisation of the processing plants is hardly 25%, primarily due to a shortage of raw materials. The idle capacity of 75% in the processing plants leads to the under-employment of 2 lakh people in export marketing. Internal fish marketing provides employment for 9 lakh fisherfolk. The auctioneers at landing centers and wholesale markets, persons involved in transportation, loading, unloading, packing and distribution of ice, commission agents, wholesalers and retailers come under the post-harvest sector. The number of persons involved in wholesale and retail marketing is estimated at 5 lakhs, of which 50% are women.

The gross income generated by marine fisheries at landing centers was Rs10 170 crores during 1995, and the value of fish at the consumer level was estimated at Rs20 340 crores, of which Rs4 000 crores came from the export market. The share intermediaries from fishers to consumers including the marketing cost income came to Rs10 170 crores. The marketing cost came to 10% of the total share and the remaining was paid as wages. In this process Rs9 153 crores was shared by about 11 lakh people involved in the post-harvest sector. Although the average annual income varied in 1995 from Rs3 600 for a peeling worker to more than Rs10 lakhs to an exporter, the overall average annual per capita income of the workers involved in post-harvest operation was Rs8 321.

Contribution of the Fishery Sector to Foreign Exchange Earnings

The foreign exchange earnings to the fishery sector increased from Rs46 crores in 1960 - 61 to Rs4 501.11 crores during 1995 - 96 and Rs4 697.48 crores in 1997 - 98. About 55 varieties of marine products are exported to different countries in Southwest Asia, Europe and USA. The total quantity of marine product exports increased from about 97 200 t in 1987 - 88 to 307 337 t in 1994 - 95 and the export value increased from Rs53 000 lakhs in 1987 - 88 to 3 57 500 lakhs in 1994 - 95 (Table 7).

About four decades ago, a humble beginning was made to export shrimp, and by 1994 - 95 the Indian Marine Product Export Industry exported 273 243 t of fish and fish products, reaching a foreign exchange equivalent of Rs3 501 crores. The year also marked a milestone in marine product export, crossing the US$ one billion mark for the first time. There was an appreciable growth in marine product exports during 1994 - 95. Shrimp constituted about 50% of the total exports in quantity and about 70% in value of export earnings.

Table 7. Item-wise exports of marine products from India.

Items		1997 - 98	Share %	1997 - 98	Share %	1997 - 98	Share %
Fresh Shrimp	Q	100 720.00	26.11	1 05429.00	27.86	95 724.00	32.31
	V	3 134.15	66.72	2 701.79	65.52	2 356.81	67.32
Fresh Fish	Q	188 029.00	48.74	173 005.00	45.74	100 093.00	33.78
	V	726.73	15.47	636.92	15.45	372.26	10.63
Fresh Squid	Q	35 095.00	9.10	40 294.00	10.82	45 025.00	15.20
	V	270.89	5.77	290.45	7.05	319.58	9.13
Fresh Cuttlefish	Q	37 258.00	9.66	31 778.00	8.40	33 845.00	11.42
	V	323.41	6.89	272.37	6.61	260.86	7.45
Fresh Lobsters	Q	1 289.00	0.33	1 172.00	0.31	1 587.00	0.54
	V	47.79	1.02	43.87	1.06	51.06	1.46
Chilled items	Q	3 183.00	0.82	1 578.00	0.42	2 773.00	0.94
	V	44.31	0.94	18.74	0.45	26.08	0.74
Live items	Q	1 700.00	0.44	2 030.00	0.52	1 755.00	0.59
	V	29.34	0.62	33.97	0.82	21.31	0.61
Dried items	Q	5 669.00	1.47	10 475.00	2.57	7 292.00	2.46
	V	33.45	0.71	47.03	1.00	40.32	1.15
Others	Q	12 875.00	3.33	11 808.00	3.34	8 183.00	2.76
	V	87.41	1.86	76.22	2.04	52.83	1.51
TOTAL	Q	385 818.00	100	378 199.00	100	296 277.00	100
	V	4 697.48	100	4 121.36	100	3 501.11	100

Source: Marine Product Export Development Authority, 1995.
Note: Q = quantity in t; V = value in US$ units.

Contribution of the Fishery Sector to Human Nutrition

A direct nutrition effect of fish could be achieved by better exploitation, increasing availability of fish to low income groups, and better marketing and distribution by linking national nutrition policy with the national fisheries policy.

Indirect nutrition effects of fisheries are assured through employment and income, more food purchasing power and better living conditions.

Very little information is available on the health and nutrition status of small scale fisherfolk of India. A few microlevel studies and baseline surveys in Tamil Nadu, Andra Pradesh and West Bengal present the basic idea.

Andhra Pradesh

A comparative study in 1984 of the nutritional status of fisherfolk from Jalanipet area and farm laborers from Serhachalam block (both in Vishakahapattinam District), indicated that child mortality and gastro-intestinal infections were higher among fisherfolk. However, the reverse was the case with nutritional deficiencies and skin disorders.

A socioeconomic survey conducted in 1978 in seven fishing villages from five coastal Districts of the State provides data on food expenditure. It accounts for 58% to 83% of the total income, of which 5 to 23% is spent on fish.

Another survey (1979) of 22 fishing villages in the Monsema area of East Godavari District showed

that 51.40% of income is spent on food and liquor, of which 11.6% is on fish.

Regarding the calorific value of food, the dietary habit of fisher families is far from satisfactory. Most of the children suffer a very high degree of vitamin deficiency and malnutrition, which makes them susceptible to serious illness.

Orissa

No specific study has been undertaken on the nutritional status of Orissa fisherfolk. However, a socioeconomic survey (1981) in the Choumukh area, Balasore District, gives information on mortality and morbidity rates among Orissa fisherfolk. Mortality for children below five was higher for boys. Cholera and anemia were the two main causes of death among children aged 0 - 10.

Tamil Nadu

A nutritional survey (Bay of Bengal Programme (BOBP) 1997) in Nochikuppam and Ayodyakuppam marine fishing hamlets in Madras City, indicated that out of 482 children under five years of age, 55% were malnourished.

Xerosis (Vitamin A deficiency) and angular stomatitis (Vitamin B deficiency) were the major deficiencies. Malaria, measles, respiratory infections and diarrhoea were the diseases common among children.

The families' dietary patterns showed quantitative and qualitative variations over the year, depending on the fishing season. Seventy-five percent of the families spent Rs10 to Rs20 a day on food, while the daily income ranged from Rs10 to Rs30. Fish constituted the major source of protein to most families. Milk, meat and fruit were eaten rarely.

Another survey undertaken in the coastal villages of Kanyakumari and Tirunelveli District (1984), reports that a considerable number of women and children suffered from partial blindness because of vitamin A deficiency.

A socioeconomic study (Narayanan et al. 1982) conducted in three fishing villages in Chingleput District showed that nearly 60% of the families go without a meal on some days due to low or no catch. Vegetables, meat and milk are consumed occasionally and fish during at least half the year.

Another study (Immanuel and Srinath 1985) conducted in the same village identifies the status of women in the family and society as one of the major reasons for their poor health and nutrition. Fish in many families is served mainly to men, and little or nothing is left for women.

West Bengal

A community survey (1985) conducted in Basanti, a marine village, indicates that 44% of the children below five years of age are slightly malnourished, 26% moderately and 5% severely. Fish is a highly appreciated food in all income groups due to its availability, affordable price, taste and nutritive value. Consumers with low and middle incomes perceive fish as one of the cheapest items which add value to their food intake.

Projected Fish Demand

The fish demand for a projected population of 1 011 million (unpublished data from IXth Plan Document) at the end of the IX Plan period has been assessed following the FAO Year Book of Fishery Statistics (FAO 1995). The assessment was as follows.

a. The requirement for fish considering per capita availability at the rate of 5.5 kg annually will be 5.56 million t.
b. The requirement for exports considering a 15% compound growth rate per annum will be 0.7 million t.
c. Other uses of fish at the rate of 10% of the total production is estimated to be 0.63 million t.

Thus the total demand of fish would be 6.89 million t. The projection is close to a similar assessment made by Nair and Girija as cited in (FAO 1995). The envisaged production would enable the country to register an increased annual per capita fish availability (5.5 kg) by the end of the IX Plan period, as against 4.5 kg during 1995 - 96 and 3.4 kg during 1990 (Table 8). This is well below the world average of 13.3 kg.

Contribution of the Fisheries Sector to National Food Security

The human population of India by 2020 is expected to be 1.3 million, which is about 450 million larger

Table 8. Fish and fishery products-food balance sheet

Year	Country	Catch (lakh t)	Live weight (lakh t)				Population (million)	Per capita availability kg·year^{-1}	Per capita annual consumption of a fish-eating population
			Non food uses	Imports	Exports	Food supply			
1990	India	32.18	3.02	Nil	1.321	27.84	818.9	3.4	6.0
1995 - 96	India	49.50	4.95	Nil	3.0	4.55	923.0	4.5	8.0
2001 - 02	India	68.88	6.26	Nil	7.0	55.62	1 011.0	5.5	9.8
1990	World	975.41	299.45	170.45	166.43	680.96	5 113.0	13.3	23.7

than the present. The proportion of people eating fish in India grew from 27.7% in 1987 - 88 to 39.7% in 1996 - 97. Assuming that this will increase to at least 50%, the total population eating fish in India by 2020 will be around 650 million. Considering the per capita nutritional requirement of fish of 11 kg•year^{-1}, the total quantity of fish required for domestic consumption will be around 7.2 t, of which at least 4.2 t has to be realised from the marine sector. This result shows that the country needs to produce at least an additional 2 t of marine fish to meet the domestic requirements alone. Besides meeting the increased demand for export and foreign exchange earnings, a total of 0.6 t of marine products will be required. Thus the total increase in marine fish production required to meet the demand by 2020 is around 2.6 t over and above the current annual production (capture and culture) of about 3 t. However, the additional scope from the marine capture sector is only another 0.5 to 0.6 t.

Socioeconomic Analysis of the Artisanal or Small Scale Fishery Sector

The target of the fisheries development programme is mainly to improve the socioeconomic status of fishers. Socioeconomic factors such as age, educational level, occupation, annual income, ownership of fishing tools and implement indebtedness and credit facilities, income and expenditure patterns influence the response of fishers to innovations, and to their participation in developmental activities.

Fishing villages as a whole are similar in their under-development. Microlevel studies were conducted at selected fishing villages in different maritime states of India. General conclusions were drawn and comparisons made between traditional fishing villages and predominantly mechanised villages. Traditional fishing villages refer to centers where non-mechanised and motorised fishing units are operating (category 1), and mechanised villages (category 2) refer to centers next to major harbours where mechanised fishing predominates. Housing is one of the most important yardsticks to measure socioeconomic status. About 80% of the fishers in traditional villages and 50% in mechanised fishing villages live in huts and Kutcha houses. The overall literacy rate is 29% in category 1 and 33% in category 2 villages. With regard to occupational pattern, 45% are owner-operators in category 1 villages and 50% are wage earners in category 2 villages. There are more people engaged in fishing-related activities in category 2 villages.

About 64% of fisher households in category 1 villages and 70% of households in category 2 villages are in debt; the average outstanding debt per household in category 2 villages is Rs60 000 as against Rs12 000 for category 1 villages. About 55% of the credit requirement of fishers in category 1 villages is supplied by money lenders. In category 2 villages, banks advance a maximum of about 57% of the credit requirements. With regard to the annual household expenditure pattern of fisher families, about 80% of the household expenditures in category 1 villages and 67% in category

2 villages are for food items. In all fishing villages, fishers spend very meagre amounts on health care and education.

Credit

Poverty still dominates in the coastal population in spite of the modernization of fishing craft and gear, mechanisation of indigenous boats and the introduction of synthetic nets. Even though the credit facilities under the successive Five Year Plans have steadily increased, there has not been any significant improvement in the living standard of most fishers, who are in debt and in the grip of money lenders.

Sakthikulangara and Neendakara are two important fishing villages in the Quilon district of Kerala state, where great advancement has been made in recent years, with the introduction of mechanized boats. An account of the indebtedness of fishers of this area is given below.

Extent of Indebtedness

Out of 429 families in Neendakara, 263 (61%) are in debt, and out of 1 209 families in Sakthikulangara, 770 (64%) are in debt. The total debt incurred by the fisher families of both villages amounts to 17.5 and 229.2 lakhs respectively. The average outstanding debt per indebted household is Rs6 671 and Rs29 766 respectively.

Supply of Fisheries Finance

Credit is an essential requirement for people engaged in fishing and fishery-related activities for the purchase of mechanized and non-mechanized craft, engines for boats, transport vehicles, etc. Financial support is executed through commercial banks, the Kerala Financial Corporation, money lenders and cooperative societies. Of these, Kerala Financial Corporation and commercial banks play a leading role in credit supply. Money lenders are an important source of credit for the fishers. Credit offered by cooperatives is very limited.

Money lenders rank highest in credit supplied to the fishers of Neendakara (46%), while commercial banks ranked highest in Sakthikulangara (57%). In Neendakara, money lenders followed by banks supply 31% of the credit, Kerala Financial Corporation supplies 18%, and the cooperative societies supply 3%. In Sakthikulangara, 28% of the credit is supplied by Kerala Financial Corporation, and only 1% by the cooperative societies. Credit from friends and relatives comes to 2% in Neendakara and 1% in Sakthikulangara.

Demand for Credit

Loans for purchase and repairing of craft and gear, purchase of land and gold ornaments, construction and maintenance of houses and working capital for businesses are here considered as for investment purposes. Loans used for household expenses during the lean season, expenditure on social and religious functions, medical treatment and for miscellaneous items are considered as for consumption purposes. Fishers in category 1 villages utilize 32% of the loan amount for the purchase of craft and gear as against 66% for the same in category 2 villages. Altogether 54% of the fishers' credit in category 1 villages and 87% in category 2 villages are utilized for investment purposes. The proportion of credit for consumption purposes is higher among lower income groups. Credit utilisation by the fishers of Neendakara and Sakthikulangara differs accordingly.

In Neendakara 62% of loans are for investment as against 90% in Sakthikulangara. In Sakthikulangara a large amount of loans (79%) is utilised for the purchase of craft and gear as against only 31% in Neendakara. Eighteen per cent of the loans in Neendakara and 8% in Sakthikulangara are available for the purchase of land and gold ornaments and construction and maintenance of houses. The amount withdrawn for household expenditure during the lean season is as high as 15% in Neendakara as against 1% in Sakthikulangara. For social and religious functions 12% and 7% of loans is utilised by the fishers of Neendakara and Sakthikulangara respectively, and 6% of loans goes towards medical expenditure. The people of Sakthikulangara only spend 1% towards the same cause.

Credit support enhances the growth of the fisheries sector, however exorbitant interest rates slow advancement of this sector.

Analysis of the ownership pattern of the means of production indicates that about 40% of the fisher households in traditional fishing villages do not have any fishing equipment. Fishing units like catamarans and canoes are economically sustainable and efficient only with 3 or more resource-specific nets for operating in all seasons. About

11% of the fisher households in traditional fishing villages possess three or more types of nets. Only about 30% of the owners in traditional fishing villages invest Rs15 000 or more in fishing implements. The basic amenities such as schools, banks, post offices, primary health centers, private dispensaries, housing societies, drinking water taps and other infrastructure facilities are comparatively few in all fishing villages. In spite of the introduction of several development schemes and enhanced economic activities in fisheries, traditional fishers in general remain one of the least developed sectors of society.

Farming and Livestock Activities of Fishers

The primary occupations of fishers are fishing and allied activities. Subsidiary activities such as farming and livestock rearing are done by only a few fishers at the homestead level. Only a meagre income is realised from this secondary enterprise. Studies in these areas are very limited.

Conflicts Between Small Scale Fisheries and Commercial Fisheries

The fisheries sector in India is classified into three majors groups namely, the mechanized, motorized and artisanal sectors. Conflicts arise within these sectors due to the inequalities existing among and between them. Demarcation of fishing areas for the three groups is defined. Conflicts result within the sector mainly because of fishing in areas assigned to other groups. Other conflicts arise due to social and economic reasons.

Configuration of the Fisheries Labor Force and Migration

In 1997, of the one million active marine fishers, about 0.2 million were in the mechanized sector, 0.17 million in the motorized sector and the rest in the artisanal sector. Among those engaged in the mechanized sector, 75% worked in trawl fisheries and 25% in the fisheries operating gillnets, dol-nets, purse seiners and deep-sea vessels. In the motorized sector, 60% were engaged in ring seine fishing alone, which is operating predominantly in the States of Kerala and Karnataka, and the rest in various other types of motorized fishing. In the artisanal sector of the total of 0.63 million active fishers, 41% were engaged in catamarans, 31% in plank-built boats and the rest in other types of craft. Among the fisherfolk engaged in marine activities, about 0.7 million worked as laborers, of whom 65% were engaged in artisanal fishing. The annual income of laborers working in a mechanized boat was estimated to be Rs34 200, in a motorized boat Rs15 200, and in an artisanal unit Rs8 000 during 1995 - 96. Thus only 30% of the fisherfolk possess some sort of ownership of fishing capital, while a large number (70%) work as laborers.

Gender Issues

There are 10 lakh fisherwomen in India, not including the inland and aquaculture sector. Women play a prominent role in fisheries, substantially for inshore-based activities. Multi-faceted activities performed by them are often not recognized.

Traditionally women stayed at home and attended primarily to domestic chores. Head-loading and fish vending are two significant activities of fisherwomen. Many also conduct fish drying and net making.

Curing, Drying and Trading of Fish

Once the catch is landed, women attend to sorting, on-the-spot auctioning, gutting and salting, (curing) drying and carrying the dried fish to market. Grading and processing are also under their purview.

Net Mending

Hand braiding of fishing nets is a leisure activity. Commissioning of nylon net factories have been done by women.

Fishing in Canals

Women fishing in canals and impounded water for prawns and fish at low tide is a common feature. They also support their husbands in cast netting and the collection of prawn larvae from the surf.

Decision-making by Fisherwomen

Women play a primary role in family budgeting. In health and family planning, 75% of women actively participate in decision-making while less than 40% play an active role in deciding the education of their children, and less than 50% play an active role in finding a suitable match for their children. Women have a principal role in deciding matters in food, health and clothing.

Participation of Women in Shore-based Activities

Women in Tamil Nadu are engaged in fish curing, marketing, net making and prawn seed and seaweed collection. In Andhra, they perform the task of collecting fish and mollusc shells. They also manage cooperatives, organizing hand braiding of fishing nets, supply of twines, etc. In Orissa, the major contribution by women to small scale fisheries is in drying, curing, marketing, shrimp processing and net making. In West Bengal, women play a limited role since the number of days spent by the fishers in actual fishing is relatively low, and they are engaged in net making, which in other states is dominated by women. Fish drying and curing in West Bengal is managed by women from other communities and not by fisherwomen. In Maharashtra, the entire fishing economy revolving around Mumbai is controlled by women. In Gujarat, the handling and processing is done by women. In Kerala, net making, fish curing and drying, shrimp processing, and fish and clam shell collection are the areas in which women have major roles to play. In Lakshadweep, particularly in Minicoy, the major fishery product of tuna (known as *Masemein* and *Riha Akru*) is processed by women. In salt production from seawater in Tamil Nadu, the labor ratio of women to men is 4:1.

The introduction of mechanised fishing (1952) under the Indo-Norwegian project in Quilon, Kerala, brought the large scale commercialization of fishing operations, and fish landings moved from the village to the centralised jetty and harbours. Women living nearby started receiving ample opportunities in peeling and processing.

Motorization requires centralized landings in at least some seasons and as a result, women in traditional fishing communities have lost their access to fish. Mechanization of net making has also marginalized them.

However, notable improvements have been seen in the general standard of living of the fisherfolk brought about by increased fishing efficiency and by the overall rise in fish prices. Improvements have been seen in the levels of education, health, sanitation and communications. The increase in the volume of fish exported, development of the fish processing industry and aquaculture, all present employment opportunities for women from non-fishing communities.

Role of Fisherwomen in Seaweed Collection

Seaweeds are either collected from the shore or islands in Tamil Nadu. Women join in a group of 5 - 10 and hire a boat for collecting. The product is sold to the local agencies either fresh or dried.

Effects of Development Interventions, Investment and Other Trends in Coastal Communities

Mechanization of the fishing fleet has increased the yield but in turn it has seriously affected the employment status and income level of artisanal fishers. A study was undertaken in Karnataka in 1978 to assess the socioeconomic impact of mechanization on traditional fishers operating *rampani* gear and results showed a decline in *rampani* operations; the number of *rampani* nets operating in South Kanara District declined from 75 in 1977 to 30 in 1979, and a marginal reduction was observed in North Kanara District. About 14% of fishers engaged in *rampani* operations were thrown out of employment during 1978 - 79. The average annual revenue received by a *rampani* unit declined from Rs2.7 lakhs in 1977 to Rs13 000 in the first half of 1979. But in North Kanara District, the earnings from *rampani* remained more or less the same because of the limited operations of purse seiners. The annual per capita revenue of a *rampani* unit declined from about Rs3 370 in 1977 to Rs300 - 400 in 1979, i.e. one-eighth of the income received earlier. In Sakthikulangara and Neendakara of Kerala, the proportion of *kutcha* houses had decreased from 44% in Sakthikulangara and 29% in Neendakara in 1954 to 16% in both places in 1980. The proportion of *pucca* houses and mansions had increased from 9% to 51% in Sakthikulangara and from 6% to 20% in Neendakra. Employment opportunities in fishing and fishery-related activities increased by about three times. The number of non-mechanised crafts had declined from 493 in 1953 to 214 in 1980 and the number of mechanised boats had increased from 138 in 1963 to 336 by 1980. Infrastructural facilities improved with the expansion of ice production capacity from 25 t to 350 t and freezing capacity per day from 9 t to 75 t between 1963 and 1980. This led to an income increase from Rs624 in 1954 to Rs4 975 in 1980, an eight-fold increase. The impact of mechanised fishing was greater in Sakthikulangara than in Neendakara, because of developmental activities in the former.

Another socioeconomic survey was conducted in 1981 covering 41 landing centers between Quilon and Manjeshwar in Kerala State, to find the impact of purse seine operations on the indigenous fisheries. The results indicated that heavy landings by purse seiners at Cochin and Mangalore were transported by truck to various parts of the State. The head-load and bicycle vendors then waited for these trucks and ignored the catch from country craft, which were irregular, undependable and provided only small quantities of catch. The introduction of purse seine gear had also affected the catch of country craft. About 10% of the active fishers shifted from marine fishing to backwater fishing, at least temporarily. The annual average income of a fisher family was reduced by about 50% in 1980 as compared to 1979. About 250 traditional fishers were employed in purse seiners in Cochin Fisheries Harbour.

A study was undertaken in Tirunelveli and Kanyakumari Districts of Tamil Nadu during 1981 to assess the impact of mechanisation of indigenous crafts with outboard motors on the economy. The results indicated that in the Tirunelveli District, the impact of mechanisation was not significant. The gear used by the fisherfolk in this area was drift-net and hook-and-line. In Kanyakumri District, the gear used by motorized units was hook-and-line with the aid of artificial baits. The gross returns of the motorized catamarans ranged from Rs100 to Rs2 000 per trip, with an average of Rs500. The average operational expenditure was Rs130 per trip. Owing to motorization, employment opportunities doubled since a motorized catamaran requires three to five persons instead of only two in non-mechanized units. There was no marketing problem for disposal of catch. The fishers reported that they were able to recover 70% of the capital invested during the short span of operation of five months.

An attempt was made to analyse the problems of the monsoon fishery and its socioeconomic implications along the west coast of India during 1992. During the monsoon season (June to August) fishing as a family occupation was at a subsistence level except for trawlers and gillnetters at a few centers. The number of mechanized units under operation was reduced to about 10% of the total units, and non-mechanized units including motorized to 25%. The household income was low since employment fell to 25% during the monsoon season. Consumers had to pay a high price for fish, but the producer's share was low.

In Karnataka *rampani* boats, dug-out canoes and outrigger boats were used until the 1970s. In the mid-1970s, the mechanized craft and gear dominated the marine fishery, resulting in the disappearance of *rampani* boats in addition to causing a structural change in the socioeconomic frame work of the Karnataka marine fishery. Before the large scale introduction of purse seiners, fishing was conducted mostly by *rampani* at the subsistence level in village-based operations; however after the introduction of purse seiners, marine fishing activity shifted to urban landing centers and 75% of the landings during the mid-1980s were at urban landing centers, viz. Mangalore, Malpe, Ganguli, Bhatkal, Tadri and Karwar. Although this change paved the way for all-round development of the fishing industry in the area, the villages where there were *rampani* operations incurred a considerable loss of income. The purse seiners earned an average annual net profit of about Rs1.3 lakhs with a 32% rate of return on capital. The large scale motorization revived the traditional fishing of gillnetters and introduced new gear like *mattubala*. As a result the rural landing centers have once again become busy. These developments have also improved the fish marketing system in the region.

Aquaculture has gained momentum in the coastal regions in the past ten years and large scale farms have developed. The environmental and the socioeconomic impacts of shrimp farming were studied in the Nagapatinam District of Tamil Nadu during September 1995. Because of the commencement of shrimp farming, the land value had increased from about Rs18 000 to Rs1.8 lakh (1 lakh = 100,000), registering a ten-fold increase in the last few years. The change of land ownership was another significant impact. The reasons cited by the respondents for the sale of land included the small area of land (20% of respondents), high price offered (40%), uneconomical crop production (30%) and lack of labor availability to cultivate crops (10%). The employment-generating capacity had considerably increased since the average labor requirement per hectare of paddy cultivation is about 180 days per year, whereas in shrimp farming it provides about 600 labor-day per crop. There is little scope for employment of female labor on shrimp farms but there is demand for labor in paddy fields of the adjoining areas. The establishment of aqua-farms has created subsidiary occupations such as catering, transport and handling of construction materials and other related activities. The average annual

income of a shrimp farm laborer was estimated as Rs12 000 as against Rs7 500 earned by an agriculture farm laborer in 1995.

Fleet Operational Dynamics

The State of the Fishing Fleet

Indian marine fishery resources comprise an exclusive economic zone (EEZ) of 2.02 million km^2 with an estimated annual harvestable catch of 3.92 million t (Anonymous 1991). Fishery resources of the Indian EEZ were harvested in 1996 with a fleet strength of 238 125, comprising 160 000 traditional crafts, 31 726 motorized craft (converted from traditional craft), and 46 918 mechanized vessels, operated with different gear combinations. The phenomenal increase in the fleet strength during the past five decades has made fishing a major industry in India.

Table 9 indicates that among the maritime states, Orissa, Andhra Pradesh, Pondicherry, Karnataka and Gujarat experienced an increase in the capacity of their traditional (artisanal) non-motorized fleets, while the remaining faced a decline during the same period. Motorized crafts became popular in Kerala and Gujarat well ahead of other maritime states as indicated by the increase in their numbers from 5 337 to 13 634 vessels and 1 566 to 3 575 vessels, respectively. In the remaining states, these crafts became popular during the late 1980s or early 1990s. Among them Maharashtra had the maximum motorized crafts (11 005), followed by Tamil Nadu (5 904) and Andhra Pradesh (2 660). All states have an increasing number of mechanized craft.

The growth in the fishing fleet and production paved the way for the development of infrastructure, which in turn has led to the emergence of ancillary industries.

Table 9. Growth of the fishing fleet in India from 1985 to 1995.

Maritime state	Year	Artisanal			Mechanized				
		Non-Motor	Motor	Total	Trawl	Purse seine	Others	Total	Catch (x 00 t)
West Bengal	1985	4 211	0	4 211	73	0	1 394	1 467	23
	1995	4 100	300	4 400	205	0	1 840	2 045	73
Orrissa	1985	11 759	0	11 759	962	0	170	1 132	47
	1995	13 873	730	14 603	1 700	0	500	2 200	43
Andhra Pradesh	1985	43 173	0	43 173	1 981	0	350	2 331	119
	1995	50 547	2 660	53 207	3 767	0	665	4 432	148
Tamil Nadu	1985	41 656	0	41 656	2 495	0	1 069	3 564	201
	1995	33 456	5 904	39 360	3 412	0	1 463	4 875	422
Pondicherry	1985	3 522	0	3 522	31	0	55	368	16
	1995	5 582	420	6 002	511	0	60	4 032	14
Kerala	1985	25 353	5 337	30 690	3 224	90	726	4 032	326
	1995	13 633	13 634	27 267	4 181	10	1 050	5 226	532
Karnataka	1985	9 401	0	9 401	1 814	390	663	2 867	119
	1995	12 523	321	12 844	2 065	374	2 155	4 594	149
Goa	1985	24 541	25	2 479	700	58	64	822	49
	1995	759	754	2 513	723	60	67	850	31
Maharashtra	1985	12 685	0	12 685	2 792	40	2 753	5 585	336
	1995	7 336	11 005	18 341	4 079	20	2 699	6 798	316
Gujarat	1985	7 749	1 566	9 315	1 835	0	2 722	4 557	288
	1995	8 745	3 575	12 320	3 456	0	2 839	6 295	505

Productivity and Technical Efficiency

Economic parameters for calculating the productivity and technical efficiency have been calculated using the results of cost-and-returns analysis. This section deals with the cost-return and profitability of different fishing units.

Cost-earnings and Profitability

The cost-earnings and profitability estimates are based on the economics of different fishing units. Each fishing unit is considered as a firm in the fishing industry. The economic feasibility of each unit depends on several factors such as input and output prices, level of production and its functions, and marketing avenues and prospects. Hence, the economic evaluation is the base for rational allocation of resources. For the purpose of economic evaluation of different fishing units, the marine fishing sector has been classified into four groups namely, (1) a non-motorized artisanal sector using country craft with traditional gear, (2) a motorized sector, (3) a mechanized sector using inboard engines of 50 to 120 hp, and (4) deep-sea fishing with bigger boats (25 m and above) and engines of 120 hp and above.

Operating Cost

The operating cost includes the labor wage, fuel cost, cost of ice, food, repair and maintenance charges and other incidental costs.

Fixed Cost

The fixed cost was computed by adding the depreciation of fishing equipment and interest on fixed capital.

Table 10. Economic performance of different types of artisanal fishing units in the marine sector, 1993 - 94.

Economic parameter	Catamaran + Hook-&-Line (Tamil Nadu)	Catamaran + Gillnets (Tamil Nadu)	Canoe + Boat-seine (Kerala)	Canoe + gillnet (Kerala)	Canoe + Hook-&-Line (Kerala)
Initial Investment (Rs in lakhs)	0.17	0.32	0.85	0.65	0.40
Annual catch (t)	7.50	13.00	51.00	17.50	11.60
Value (Rs in lakh)	0.45	0.55	1.28	0.71	0.75
Operating cost (Rs in lakh)	0.36	0.42	0.98	0.46	0.58
Fixed cost (Rs in lakh)	0.04	0.08	0.20	0.19	0.12
Total cost (Rs in lakh)	0.40	0.50	1.18	0.65	0.70
Net operating income (Rs in lakh)	0.09	0.13	0.30	0.25	0.17
Net income (Rs in lakh)	0.05	0.05	0.10	0.06	0.05
Rate of return (%)	44	31	27	24	28
Pay back period (year)	2.5	3.9	4.6	5.2	4.4
Value realised per kg of fish ($Rs \cdot kg^{-1}$)	6.00	4.23	2.51	4.06	6.47
Average total cost per kg of fish ($Rs \cdot kg^{-1}$)	5.33	3.85	2.31	3.71	6.03
Average operating cost per kg of fish ($Rs \cdot kg^{-1}$)	4.80	3.23	1.92	2.63	5.00

Source: Sathiadhas 1996.
Note: 1 US$ = Rp 31.38 (average of 1993 - 94; source: oanda.com)

Net Operating Income

Net operating income is defined as the return over variable or operating expenses.

Net Return

The annual net return was calculated by subtracting the annual total cost from annual gross returns.

Pay-back Period

Pay-back period (years) = Investment/average annual cash flow (Rs)

Non-motorized Artisanal Sector using Country Craft with Traditional Gear

The most widely used traditional craft are catamarans and canoes with gear such as hook-and-lines, gillnets and boat seines. The investment requirement for catamarans operating hook-and-line (H&L) or gillnets varies from Rs17 000 to Rs75 000 and the investment for a canoe operat-ing H&L or boat seine varies from Rs40 000 to Rs85 000 (Table 10).

The average annual revenue for a catamaran with H&L in Tamil Nadu in 1993 - 1994 is estimated to be Rs45 000 and Rs55 000 for a gillnet unit. In Kerala state, the average annual revenue for a canoe H&L unit is estimated to be Rs75 000, Rs71 000 for a canoe-gillnet unit and Rs1.28 lakhs for a canoe-boat seine unit. All these fishing units earn a net profit, ranging from Rs5 000 in Tamil Nadu to Rs10 000 in Kerala per annum after deducting all costs. The rate of return ranges from 24% in Kerala to 44% in Tamil Nadu and the payback period for the capital investment is from 2.5 years for a catamaran-H&L unit in Tamil Nadu to 5.2 years for a canoe-gillnet unit in Kerala state.

Motorized Sector

In the motorized sector, the ring seine unit requires the maximum investment of about Rs5 lakhs and the average annual revenue per unit is estimated to be Rs6.43 lakhs (Table 11). After deducting the total annual costs of Rs5.45 lakhs, the net profit is Rs98 000. Among the motorized catamarans, the gross earnings are more for H&L units than for the gillnet units. But the net operating income and net profit are comparatively more for the motorized catamarans operating gillnets since the costs are less variable than for the H&L units. In the artisanal sector, both for motorized and non-motorized units, about 60% of the revenue is paid as wages to the crew or fishing workers and most units are owner-operated. Hence the fishing income received by the owners is the net income plus the wages shared by family laborers.

All major types of fishing units in Kerala, Tamil Nadu and Gujarat shown in Table 10 made a profit not because of the higher levels of catch, but because of the better price. In the motorized sector, the increase in fish price over the years is more than the increase in fuel expenditure.

Small Mechanized Units with Inboard Engines

Small trawlers, purse seiners, dol-netters, gillnetters, pair trawlers and sona boats are the major types of mechanized fishing unit operating in the inshore waters (up to 50 m depth). The operations of trawlers and gillnetters are conducted widely all along the Indian coast, whereas the operations of purse seiners, dol-netters, pair trawlers and sona boats are confined to only certain regions.

Purse seiners are operated only along the southwest coast, comprising Kerala, Karnataka, Goa and southern Maharashtra. Dol-net operations are popular along the Gujarat and Maharashtra coasts and pair trawlers are popular in the Gulf of Mannar and Palk Bay regions of Tamil Nadu coast. The operations of sona boats are prominent along the Andhra and Orissa coast. The economic performance of different types of small mechanized fishing units operating in the different regions of the Indian coast has been worked out on the basis of several studies conducted by the CMFR and is given in Tables 12 and 13.

Table 11. Economic performance of different types of motorized fishing units in the marine sector, 1993 - 94.

Economic parameter	Catamaran + Hook-&-Line (Tamil Nadu)	Catamaram + Gillnets (Tamil Nadu)	Canoe + Ring seine (Kerala)	Canoe + Gillnets (Kerala)	Canoe + Hook-&-Line (Kerala)	Canoe + Gillnets (Gujarat)
Initial Investment (Rs in lakhs)	0.35	0.50	5.00	1.00	0.75	1.20
Annual catch (t)	14.50	16.20	220.00	21.00	18.40	16.95
Value (Rs in lakh)	0.82	0.76	6.43	1.08	1.50	1.50
Operating cost (Rs in lakh)	0.65	0.54	3.98	0.69	1.09	1.15
Fixed cost (Rs in lakh)	0.09	0.13	1.47	0.26	0.25	0.20
Total cost (Rs in lakh)	0.74	0.67	5.45	0.95	1.34	1.35
Net operating income (Rs in lakh)	0.17	0.22	2.45	0.39	0.41	0.35
Net income (Rs in lakh)	0.08	0.09	0.98	0.13	0.16	0.15
Rate of return (%)	38.00	33.0	35.0	28.0	36.0	28.0
Pay back period (year)	3.0	3.6	3.4	4.4	3.2	4.1
Value realised per kg of fish ($Rs \cdot kg^{-1}$)	5.66	4.49	2.92	5.14	8.15	8.85
Average total cost per kg of fish ($Rs \cdot kg^{-1}$)	5.10	4.14	2.48	4.52	7.28	7.69
Average operating cost per kg of fish ($Rs \cdot kg^{-1}$)	4.48	3.33	1.81	3.29	5.92	6.78

Source: Sathiadhas 1996.

Table 12. Economic performance of small trawlers (32′ - 36′) in different maritime states, 1993 - 94.

Economic parameter	Kerala	Karna-taka	Goa	Guja-ratha	West Bengal	Orissa	Andhra Pradesh	Tamil Nadu	Maha-rashtra
Initial Investment (Rs in lakhs)	5.6	5.2	5.5	5.25	4.20	4.50	4.85	5.20	6.00
Annual catch (t)	89	72	43.5	68	34	40	51	99.6	57
Value (Rs in lakh)	11.24	9.04	7.22	9.25	6.01	6.78	9.10	10.71	9.34
Operating cost (Rs in lakh)	8.72	6.58	5.13	6.85	3.90	4.57	6.75	8.39	6.49
Fixed cost (Rs in lakh)	1.68	1.56	1.38	1.58	1.26	1.35	1.46	1.56	1.80
Total cost (Rs in lakh)	10.40	8.14	6.51	8.43	5.16	5.92	8.21	9.95	8.29
Net operating income (Rs in lakh)	2.52	2.46	2.09	2.40	2.10	2.21	2.35	2.32	2.85
Net income (Rs in lakh)	0.84	0.90	0.71	0.82	0.85	0.86	0.89	0.76	1.05
Rate of return (%)	33.00	35.28	30.90	33.60	38.24	37.11	36.40	32.60	35.50
Pay back period (year)	3.7	3.41	4.01	3.62	3.11	3.21	3.29	3.75	3.39

Table 12. Economic performance of small trawlers (32′-36′) in different maritime states, 1993 - 94. (continued)

Economic parameter	Kerala	Karna-taka	Goa	Guja-ratha	West Bengal	Orissa	Andhra Pradesh	Tamil Nadu	Maha-rashtra
Value realised per kg of fish ($Rs{\cdot}kg^{-1}$)	12.60	12.55	16.60	13.60	17.70	16.95	17.84	10.75	16.39
Average total cost per kg of fish ($Rs{\cdot}kg^{-1}$)	11.69	11.31	14.97	12.40	15.18	14.80	16.10	9.98	14.54
Average operating cost per kg of fish ($Rs{\cdot}kg^{-1}$)	9.80	9.10	11.79	10.07	11.47	11.43	13.20	8.42	11.39

Source: Sathiadhas et al. 1995.
Note: 1 US$ = Rp 31.38 (average 1993 - 94; source: oanda.com).

Table 13. Economic performance of other mechanized boats, 1993 - 94.

	Gillnetters		Purse seiners	Dol-netters		Pair trawlers	Sona boats
Economic parameter	Maha-rashtra	Tamil Nadu	Kerala	Maha-rashtra	Gujarath	Tamil Nadu	Orissa
Initial investment (Rs in lakhs)	3.3	3.5	10.00	3.2	3.75	9.0	11.00
Annual catch (t)	22	23	280	51	52	150	22
Value (Rs in lakh)	3.36	4.38	12.00	4.54	5.25	13.0	20.00
Annual operating cost (Rs in lakh)	2.02	2.63	5.80	2.95	3.0	8.8	15.00
Fixed cost (Rs in lakh)	1.0	1.05	3.06	0.96	1.13	2.25	2.75
Total cost (Rs in lakh)	3.02	3.68	8.86	3.91	4.13	11.05	17.75
Net operating income (Rs in lakh)	1.34	1.75	6.20	1.59	2.25	4.20	5.00
Annual net profit (Rs in lakh)	0.34	0.70	3.14	0.63	1.12	1.95	2.25
Rate of return (%)	28.30	38.00	46.00	37.69	34.10	37.00	35.00
Pay back period (year)	4.48	3.13	2.4	3.20	3.34	3.20	3.3
Average value realised per kg of fish ($Rs{\cdot}kg^{-1}$)	15.26	19.64	4.29	8.90	10.10	8.67	90.91
Average total cost per kg of fish ($Rs{\cdot}kg^{-1}$)	13.73	16.00	3.16	7.60	7.49	7.37	80.68
Average operating cost per kg of fish ($Rs{\cdot}kg^{-1}$)	9.80	11.43	2.07	5.78	5.76	5.87	68.18

Source: Sathiadhas et al. 1995.

Economics of Deep-sea Fishing

The economics of some of the major types of fishing vessels used for deep-sea fishing is reported in Table 14. Most of the deep-sea vessels (Mexican trawlers) operating from Visakhapatnam harbor are defunct. Of late, the Mexican trawlers find it very difficult to cover the break-even cost. During the 1980s, a fishing voyage of 13 days duration was sufficient to catch about 2 t of shrimps and 18 t of good quality fish. In the 1990s a voyage of 30 - 90 days was required for the break-even catch of 1 - 2 t of shrimps, 15 - 18 t of good quality fish and 30 - 40 t of other fish, usually dried on deck, to cover the operating cost of Rs7 - 8 lakhs.

Deep-sea Trawler

The average operating costs in 1989 - 92 was Rs33.00 lakh, of which fuel cost contributes about 70%. The average annual fixed cost, estimated at Rs28.00 lakh was comprised of depreciation and interest on investment at 15%. After deducting all costs from the annual revenue, the net profit was Rs17.20 lakhs.

Deep-sea Multipurpose Vessel

Deep-sea multipurpose vessels (26 m OAL) catch both prawns and fish. The average annual catch in quantity per unit is almost the same for both prawn and fish. As given in Table 14, the catch per unit was 36 t for prawn and 40 t for fish. However, the value realised for prawn amounted to Rs63 lakh and Rs5.30 lakh for fish. Such a high value for prawns is due to the high demand in the export market. Thus, multi-purpose deep-sea vessels give more emphasis to catching prawns. The annual turn-over of a multipurpose deep-sea vessel was Rs68.30 lakhs against the total annual cost of Rs56.00 lakh, leaving a net profit of Rs12.30 lakh.

Deep-sea Tuna Long-liner

The initial investment for a tuna long-liner unit (34 m OAL and engine with 825 HP) was estimated at Rs164 lakhs. The average annual catch per unit was about 910 t consisting mainly of tuna, billfishes, and pelagic sharks. For a fixed cost of Rs40 lakhs (which includes depreciation and interest for the investment at 15%) the total cost was Rs81.00 lakhs. Thus the net profit earned per year per unit was Rs20 lakhs.

Table 14. Annual economic performance of different types of offshore vessels operating in the marine sector, 1989 - 92.

Economic parameter	Deep-sea trawler (25 m OAL)	Multipurpose (26 m Deep-sea)	Tuna Long-line (30 m OAL)
Initial investment (Rs in lakhs)	160.00	150.00	164.00
Annual catch (t)	46.00	76.00 (P-36, F-40)*	910.00
Value (Rs in lakh)	78.20	68.30	101.00
Operating cost (Rs in lakh)	33.00	26.00	41.00
Fixed cost (Rs in lakh)	28.00	30.00	40.00
Total cost (Rs in lakh)	61.00	56.00	81.00
Net operating income (Rs in lakh)	45.20	42.30	60.00
Net income (Rs in lakh)	17.20	12.30	20.00
Rate of return (%)	26.00	24.00	27.00
Pay back period (year)	7.6	7.6	4.7
Value realised per kg of fish ($Rs \cdot kg^{-1}$)	170.00	90.00	11.00
Average total cost per kg of fish ($Rs \cdot kg^{-1}$)	133.00	74.00	9.00
Average operating cost per kg of fish ($Rs \cdot kg^{-1}$)	72.00	40.00	4.50

Source: Sathiadhas et al. 1995. Note: * P = prawns, F = fish.

The Sharing System

The share system operates in all types of fishing unit. The net earnings after deducting the fuel and other operational expenses are shared between the owner of the craft and the labor force. Almost 70% of the gross earnings of mechanized units and 50% of the same in motorized units are used up by the operating expenses, whereas the non-mecha-nized units have negligible operating expenses. In this process, a third of the net earnings in mecha-nized and motorized units and two-thirds of the gross earnings in non-mechanized units are paid as wages. Thus the per capita earnings of a fishing laborer per trip is Rs171 for mechanized boats, Rs76 for motorized units and Rs40 for non-mechanized units. Assuming 200 fishing days per annum, the annual income of a laborer would be Rs34 200 in a mechanized boat, Rs15 200 in a motorized boat and Rs800 in a non-mechanized boat.

Table 15. Average catch per trip and per year for three types of boats in 1993 - 94.

	Mechanized	Motorized	Non-mechanized
Average catch per trip (kg) (200 fishing days)	378	189	51
Average annual catch (t)	75.6	37.8	10.2
Idle fleets	56.5%	66.4%	85.3%

Discarding and By-catch

Approximately 15% of the total annual marine fish landings of 2.7 t in 1995 - 96 was exported, 44% of the catch was used in fresh or iced condition for domestic consumption, 3% for curing and drying, and 15% used for fish meal, canning, and freezing (Sathiadhas 1994). Species such as the Bombay duck, white bait, ribbon fishes and a few others were cured in fresh condition, but the bulk of the landings (25% to 30%) was processed. This result-ed in the non-availability of fresh fish in the demand centers .

Discarding the by-catch is unfavourable in the marine fisheries sector not only in India but throughout the world. There is also an urgent need to utilize the discards of finfish for human con-sumption. Suitable methods of onboard collection of discards need to be developed and implemented.

By-catch of Shrimp Fishing in India

With the increasing demand for shrimps and con-sequent large scale shrimp trawling operations, considerable quantities of other fish are discarded.

Fish by-catch from shrimp trawling as well as indigenous shrimp fishing consists of both trash fish and quality table fish. There is considerable demersal fishing in the country. In a total marine catch of 1 388 380 t in 1979, 640 027 t were demersal catches including those of the indigenous fishery. In total landings of 398 945 t by smaller trawlers, the fish and other miscellaneous by-catch apart from shrimp amounted to 315 902 t, forming 79.18% in 1979 (Table 16, Fig. 3). Maximum by-catch occurred in seas in Tamil Nadu followed by Gujarat, Kerala and Maharashtra. The percentage of by-catch is highest in Gujarat followed by Tamil Nadu and Pondicherry, and the minimum amount occurs in Maharashtra and Kerala.

Table 16. Landings of prawn and by-catch from commercial shrimp trawlers in various maritime states in 1979.

Maritime States	By-catch (t)						
	Total landings	Prawn	Other Crusta-ceans	Cepha-lopods	Fish	Total	% of by-catch in total landings
Gujarat	75 903	5 632	939	4 824	64 508	70 271	92.58
Maharashtra	80 030	31 242	880	3 104	44 804	48 788	60.96
Goa	8 052	1 559	1 315	73	5 105	6 493	80.63
Karnataka	22 014	3 857	2 459	41	15 657	18 157	82.47
Kerala	79 464	24 512	7 384	1 536	46 032	54 952	69.15
Tamil Nadu	91 712	8 216	2 290	837	80 369	83 496	91.04
Pondicherry	3 650	492	98	39	3 021	3 158	86.52
Andhra Pradesh	28 685	5 373	352	474	22 486	23 312	81.26
Orissa	9 435	2 160	–	–	7 275	7 275	77.10
All India	398 945	83 043	15 717	10 928	289 257	315 902	79 18

Source: Ministry of Agriculture. Department of Agriculture and Cooperation (Fisheries Division) 1996.

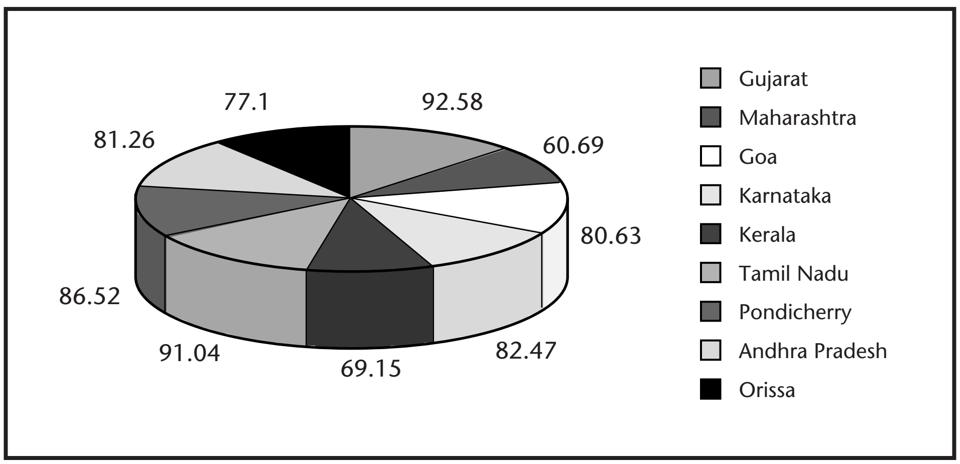

Fig. 3. Percentage of by-catch in total landings in India.

The details of landings (provisional) of commercial shrimp trawlers at some selected centers in the different maritime states during 1980 is given in Table 17. Among all the centers, Sakthikulangara (Neendakara) in Kerala state shows the maximum units operated as well as landings of both fish by-catch and shrimps. The percentage of by-catch during the year is also minimal at 54.98 % in this center. At Cochin, the other center of observation in Kerala, the percentage of by-catch is comparatively low. Sassoon dock in Bombay comes next in the quantity of by-catch and shrimps landed by the trawlers (Table 17). From the total by-catch, including various groups of fishes and miscellaneous items consisting of crustaceans other than shrimps, cephalopods etc. only a negligible quantity is discarded. From a total by-catch of 315 902 t in 1979, only an insignificant quantity of 5 000 t (1.5%), consisting of squilla and miscellaneous items such as young fish and shrimp and crab, were discarded. In the case of the smaller trawlers, when the shrimp catches are unusually heavy the fish by-catches are discarded due to lack of space. From the larger trawlers, most of the smaller fish by-catch is discarded at sea.

Table 17. Landings of prawn and by-catches (t) of commercial shrimp trawlers at selected centers during 1980.

	By-catch (t)							
Centers	No. of units operated	Total landings	Prawn	Other Crusta ceans	Cepha-lopods	Fish	Total	% of by-catch in total landings
Bombay	21 469	18 144	5 138	4	12 924	78	13 006	71.68
Mangalore	7 922	2 417	353	1	1 779	284	2 064	85.39
Cochin	46 096	7 912	3 514	704	3 416	278	4 398	55.58
Sakthikulangara	172 732	81 213	36 559	4 167	36 607	3 880	44 654	54.98
Tuticorin	31 517	6 417	534	12	5 871	–	5 883	91.67
Mandapam	25 143	2 533	217	151	2 047	118	2 316	91.43
Rameswaram	78 758	14 378	1 367	602	11 692	717	13 011	90.49
Nagapatnam	9 307	2 007	125	26	1 729	127	1 882	93.77
Cuddalore	16 012	1 969	121	31	1 642	175	1 848	93.85
Pudumanikuppam	13 154	1 416	165	62	919	270	1 251	88.34
Kakinada	41 174	9 025	2 698	352	5 557	418	6 327	70.10
Visakhapatnam	35 406	8 051	784	400	6 325	542	7 267	9 026

Source: Ministry of Agriculture. Department of Agriculture and Cooperation (Fisheries Division) 1996.

Details of seasonal landings of by-catches during 1979 by state are reported in Table 18. In all the states along the west coast of India except Kerala, the by-catches are maximum during the southwest monsoon (June to August). However, Kerala state shows the maximum landings in these months, mostly brought about by the peak activity of the shrimp fishing boats in the Neendakara area. In Tamil Nadu along the east coast, the by-catches are more or less evenly landed almost all the year around, the maximum occurring in February, March and June and the minimum in September. Andhra Pradesh landed the most in September, October and the least in May and June. In Pondicherry, the maximum by-catch landed was in June to September, with the maximum occurring in November to January.

Table 18. Landings of shrimp by-catch (t) in different maritime states during 1979.

Maritime State	Total
Gujarat	70 271
Maharashtra	48 788
Goa	6 493
Karnataka	18 157
Kerala	54 952
Tamil Nadu	83 496
Pondicherry	3 158
Andhra Pradesh	23 312
Orissa	7 275
All India	315 902

Source: Ministry of Agriculture. Department of Agriculture and Cooperation (Fisheries Division) 1996.

Analysis of Market Structure and Price of Fish

Marketing

Post-harvest fisheries activities, including processing, product development, transport and marketing, provide greater employment than the harvesting sector. As the demand and price of fish continuously increase in the domestic and export markets, the opportunities for the above activities correspondingly grow. Fresh fish once inaccessible to distant locations are now easily available due to the vast improvement in handling technologies together with fast transportation and consequent market penetration. However, the infrastructure of fish marketing is still principally oriented towards the export market.

The fishers' share in the consumer rupee is the best index to measure the efficiency of the fish marketing system. Marketing studies at all levels in India indicate that the fisher's share in the consumer's rupee ranges from 30% to 68%. The wholesalers receive 5% to 32% and the retailers 14% to 47% of the consumer's rupee for different species/groups of marine fish.

The fishers in Gujarat receive 37% (catfish) to 83% (ribbonfish) of the consumer's rupee, while in Maharashtra, it ranged from 36% (barracudas and sharks) to 81% (seerfish) (Table 19). Fishers receive the highest share for cephalopods (71%) in Karnataka and Kerala, for big-jawed jumper (67%) in Tamil Nadu and for sardines (57%) in Andhra Pradesh.

In the past marine fish sales were confined to the coastal and adjoining regions. In 1994, about 50% of fish is consumed fresh in and around the producing centers, 43% in a demand center located up to a distance of 200 km from the coast, and only 5% in the centers located beyond 200 km (Sathiadhas 1994). The distribution system could be enhanced through private investment in the preservation, processing and transportation sectors. Approximately 30% of the total landings become unpalatable for fresh consumption and offer scope for market development of value-added products for domestic consumption.

Table 19. Fisher's share in consumer's rupee for selected varieties of fish in different maritime states, 1996 - 97.

		Percentage share to fishers					
	Name of fish	Gujarath	Maharashtra	Karnataka	Kerala	Tamil Nadu	Andhra Pradesh
1	Seerfish	71	81	40	65	49	49
2	Pomfrets	64	68	46	43	51	53
3	Barracudas	–	36	55	53	54	23
4	Tuna	63	43	–	51	60	36
5	Sharks	45	36	40	63	60	17
6	Catfish	37	76	35	58	63	33

Table 19. Fisher's share in consumer's rupee for selected varieties of fish in different maritime states, 1996 - 97. (continued)

	Name of fish	Percentage share to fishers					
		Gujarath	Maharashtra	Karnataka	Kerala	Tamil Nadu	Andhra Pradesh
7	Mackerel	50	50	33	50	55	26
8	Sardines	60	57	54	43	63	58
9	Ribbonfish	83	60	41	37	55	36
10	Rays	–	–	–	30	57	40
11	Whitebaits	–	–	33	26	48	22
12	Lizardfish	44	43	31	30	53	36
13	Goatfish	–	–	–	60	60	42
14	Threadfin	43	–	–	–	53	23
15	Croakers	56	45	38	31	63	27
16	Silverbellies	–	–	–	35	32	21
17	Big-jawed jumper	–	–	60	45	67	44
18	Mullets	–	45	42	56	46	38
19	Half & full beaks	–	–	–	61	65	–
20	Cephalopods	63	75	71	71	51	44

Source: Sathiadhas et al. 1995.

Marketing - Price Variation, Marketing Cost and Margins

Marine fish are procured from 2 244 landing centers and inland fish from supply centers located throughout the country. Operational systems of both markets are similar.

Monopsony characterizes the fish marketing structure in India at various stages, and hence fishers are precluded from receiving the benefits of the high price prevalent in the consumer markets. Basic economic theory indicates that in a perfectly competitive market no factor of production earns more than its opportunity cost, and profit cannot exist in the long run because it is eliminated through competition.

Price variation is observed in the case of seer fish, rainbow runner, pomfrets, barracudas and other quality fish over the years, but the price variation is less than that of other low quality fishes (Table 20). The price difference is mainly dependent on the market value and demand of the fish.

The retail price behaviour of the fish is also very much in accordance with the price behavior (Table 21). From 1984 to 1989, the variation observed is not very perceptible. Price difference is more in the case of high quality fishes.

Table 20. Average price behavior of selected varieties of marine fish in Tamil Nadu.

Fish species	Average Price ($Rs{\cdot}kg^{-1}$)			
	Madras region		Kanyakumari region	
	1973 - 74	1984 - 85	1989 - 90	1994 - 95
Seerfish	4.00	19.00	28.90	40.00
Rainbow runner	3.50	11.00	24.60	32.00
Pomfrets	5.00	17.50	23.15	35.00
Barracudas	2.00	11.25	15.20	24.00
Tuna	1.50	10.00	13.45	20.00
Sharks	1.00	11.25	13.85	24.00
Catfish	2.00	7.75	13.00	20.00
Mackerel	1.00	6.25	9.00	15.00
Sardines	2.00	4.00	6.90	10.00
Whitebaits	2.00	5.00	5.85	8.00
Ribbonfish	1.00	5.00	6.15	11.00
Rays	1.00	6.00	6.40	9.00
Silverbellies	2.50	3.00	4.20	6.00

Source: Sathiadhas 1996.

Table 21. Retail price behavior of selected varieties of marine fish in Tamil Nadu.

Fish species	Average Price ($Rs{\cdot}kg^{-1}$)			
	Madras region		Kanyakumari region	
	1973 - 74	1984 - 85	1989 - 90	1994 - 95
Seerfish	9.00	27.00	35.50	60.00
Rainbow runner	5.00	12.00	31.25	40.00
Pomfrets	9.00	22.50	29.15	45.00
Barracudas	2.50	13.35	21.00	35.00
Tuna	3.00	16.50	18.50	32.00
Sharks	2.50	17.00	17.00	35.00
Catfish	2.50	11.00	16.50	30.00
Mackerel	3.00	9.85	12.50	22.00
Sardines	2.00	6.70	10.00	18.00
Whitebaits	3.00	8.00	9.00	14.00
Ribbonfish	2.50	8.50	10.00	18.00
Rays	2.00	10.00	10.75	15.00
Silverbellies	3.50	6.00	6.25	9.00

Source: Sathiadhas 1996.

In the fisher-wholesaler-retailer chain, the marketing margins ranged from Rs4 per kg for silverbellies to Rs14 per kg for seerfish (Table 22). The wholesaler's share in marketing margins ranged from 14% for mackerel to 35% for catfish, and the retailer's margin ranged from 56% for reef cod to 74% for mackerel and ray.

Marketing Channels

Five market channels exist. They are:

1. Producer - Retailer - Consumer
2. Producer - Wholesaler - Retailer - Consumer
3. Producer - CA - Wholesaler - Retailer - Consumer
4. Producer - Wholesaler - CA - Retailer - Consumer
5. Producer - CA - Wholesaler - CA - Retailer - Consumer (CA - Commission Agent)

In the first channel, the fish vendors purchase

Table 22. Marketing margins for different varieties of fish in channels during April 1989 - March 1990.

Name of the fish	Marketing margins ($Rs{\cdot}kg^{-1}$)	Percentage of distribution		
		Marketing costs	Wholesalers	Retailers
Group I				
Seerfish	14.00	7	28	65
Rainbow runner	13.55	7	26	67
Pomfrets	11.75	9	22	69
Pig-face bream	12.75	8	24	68
Red snapper	8.35	12	30	58
Barracudas	10.70	9	22	69
Group II				
Reef cod	7.75	10	34	56
Tuna	8.45	9	30	58
Sharks	8.10	9	26	65
Catfish	9.35	8	35	57
Wolf herring	6.15	12	23	65
Mackerel	6.25	12	14	74
Scads	6.50	12	19	69
Group III				
Goat fish	7.00	7	28	65
Ribbonfish	6.10	8	24	69
Thread fin bream	4.55	11	25	64
Rays	7.20	17	32	57
Lizard fish	3.00	17	32	57
Indian pellona	5.05	10	26	64
Gold striped sardine	6.30	8	25	67
Whitebaits	5.80	9	23	68
Silverbellies	4.00	13	23	64

Source: Sathiadhas 1996.

the fish from the landing center and directly sell to the consumer either in a market place or by home delivery. Wholesalers exist in all other channels. Wholesalers are involved either at the landing center or at the consumer market, and sometimes at both landing and consumer centers. Commission agents are typically arranged by the wholesalers to purchase and to dispense the consignments. These commission agents receive a certain percentage of the fish value (5% to 10%) from the wholesaler. In fish marketing, the money transaction for the product is conducted on a credit basis.

The marketing margins were comparatively lower for most of the species in the fisher-retailer chain. They ranged from Rs3.30 per kg for lizardfish to Rs11.50 per kg for seerfish (see Table 23). The marketing costs, including transportation, accounted for 6% to 12% of the marketing margins of different varieties. However, the retailers received a higher proportion of the margins, ranging from 88% to 94%, since there were no wholesalers in the distribution channel.

Table 23. Marketing margins for different varieties of fish in channel 2 during April 1989 - March 1990 (Fisher's-retailer chain).

Name of the fish	Marketing margins ($Rs \cdot kg^{-1}$)	Percentage of distribution	
		Marketing costs	Retailers margin
Group I			
Seerfish	11.50	7	93
Rainbow runner	10.80	7	93
Pomfrets	9.55	8	92
Pig-face bream	10.40	8	92
Red snapper	10.50	8	92
Barracudas	9.15	9	91
Group II			
Reef cod	10.00	6	94
Tuna	8.70	7	93
Sharks	5.45	11	89
Catfish	7.10	9	91
Wolf herring	5.15	12	88
Mackerel	5.00	12	88
Scads	7.00	9	91
Group III			
Goat fish	7.25	6	94
Ribbonfish	6.20	6	94
Thread fin bream	5.15	8	92
Rays	6.20	6	94
Lizard fish	3.30	12	88
Indian pellona	5.35	7	93
Gold striped sardine	4.00	8	92
Whitebaits	4.95	8	92
Silverbellies	3.40	12	88

Source: Sathiadhas 1996.

Table 24. Percentage distribution of consumer's rupee for different fish species in channel I during April 1989 - March 1990.

Name of the fish	Percentage share to			
	Fishermen	Handling and transport	Wholesalers	Retailers
Group I				
Seerfish	63	3	10	24
Rainbow runner	60	3	10	24
Pomfrets	62	3	9	26
Pig-face bream	50	4	12	34
Red snapper	55	5	14	26
Barracudas	53	4	10	33
Group II				
Reef cod	55	5	15	25
Tuna	55	4	13	28
Sharks	58	4	11	27
Catfish	49	4	18	29
Wolf herring	53	6	11	30
Mackerel	54	6	6	34
Scads	43	7	11	39
Group III				
Goat fish	37	5	17	41
Ribbonfish	41	5	14	40
Thread fin bream	46	6	14	34
Rays	39	4	11	46
Lizard fish	42	10	18	30
Indian pellona	44	6	14	36
Gold striped sardine	43	5	14	38
Whitebaits	41	5	14	40
Silverbellies	41	8	13	38

Source: Sathiadhas 1996.

The fisher's share in the consumer's rupee ranged from 37% (goat fish) to 63% (seerfish) in channel I (Table 24) and 36% to 68% in channel 2 (Table 25), respectively. For almost all species, fisherfolk received a higher share of the consumer's rupee in channel 2 where there are no wholesalers. The fewer the number of intermediaries in the marketing chain, the higher the fishers' share.

Table 25. Percentage distribution of consumer's rupee for different species of fish in channel 2 during April 1989 - March 1990.

Name of the fish	Percentage share to		
	Fishers	Handling and transport	Retailers
Group I			
Seerfish	68	2	30
Rainbow runner	65	3	32
Pomfrets	67	3	30
Pig-face bream	55	4	41
Red snapper	49	4	47
Barracudas	56	4	40
Group II			
Reef cod	49	3	48
Tuna	54	3	43
Sharks	67	4	29
Catfish	56	4	40
Wolf herring	58	5	37
Mackerel	60	5	35
Scads	42	5	53
Group III			
Goat fish	36	4	60
Ribbonfish	40	4	56
Thread fin bream	43	4	53
Rays	43	4	53
Lizard fish	40	7	53
Indian pellona	43	4	46
Gold striped sardine	50	4	46
Whitebaits	44	5	51
Silverbellies	45	7	48

Source: Sathiadhas, 1996.

Fisherfolk received a higher share for seerfish (63% to 68%) in group I, sharks (58% to 67%) in group II and sardines (43% to 50%) in group III categories of fish (Table 25). Similarly, a lower share was received by them for pig-face breams (50% to 55%) and red snapper (49% to 55%) in group I, scads (42% to 43%) in group II and goat fish (36% to 37%) in group III categories.

The percentage share for marketing expenses of handling and transportation ranges from 3% to 10% of the consumer's rupee. The wholesaler's share ranges from 6 paise (cents) to 18 paise of the consumer's rupee for different fish species. The retailer's share ranges from 24 paise to 46 paise in channel 1 and 30 paise to 60 paise in channel 2 of the consumer's rupee. In general, the wholesalers and retailers received more of the consumer's rupee for cheaper species, even while incurring higher handling and transportation charges.

Implications for Fishery Management

Regulations should be implemented to keep the level of fishing effort under control, especially in the inshore region. Community participation in the management of marine fisheries should be introduced.

The discards of cheaper species of fish by deep-sea fleets require immediate attention. Discards from the mechanized trawlers should be lifted using carrier boats and could be processed.

An all-India census on socioeconomic parameters should be collected to provide the information base for planning of fisheries development and coastal zone management.

Since fisheries form the major source of income to the vast majority of coastal communities, experts in capture and culture fisheries, including socioeconomics experts, should be included in the preparation of coastal zone management and development plans and adequately represented in the state and national level Coastal Zone Development Authorities.

Product diversification, such as the promotion of live fish trade and value-added products, should be given top priority in export marking strategies. Similarly, pharmaceutically important marine products should be identified, catalogued, and patented, and a better utilization policy should be evolved.

A cautious fish marketing policy giving parallel importance to domestic and export marketing should be framed in the context of liberalization of economic policies.

Regulatory marketing systems are to be established, as in the case of agriculture. The periodical dissemination of information on prevailing prices of commercially important varieties of fish in different markets will be very useful to the fishers, traders and consumers.

Frequent conflict between the traditional fishers and those in the mechanized sector over fishing zones is an important problem that disturbs the peaceful coexistence of different groups in many fisherfolk societies. At times, these tensions extend beyond normal limits and even precipitate into serious riots. The formation and enactment of suitable legislation to demarcate distinct areas of operation seems to be the only feasible solution.

Ensuring adequate linkages between different developmental organisations and harnessing their efforts would help the fisherfolk enjoy the fruits of various developmental programmes designed by the government for this sector.

Involvement of middle persons who incur exorbitant price spreads during the marketing process has to be curtailed to the maximum extent possible. Empowering the cooperatives of fishers and equipping them with legal authority and facilities to procure fish and market fish would bring about positive results.

A lack of credit facilities is yet another problem that hinders development in this sector. Liberal policies that would enable the fisherfolk to get credit at lower interest rates would speed up motorization and eventually improve their socioeconomic status. Making people aware of the importance of prompt repayment of loans is very important, since this is a reason widely quoted by the money-lending agencies to turn down loan requests of fishers.

More welfare schemes exclusively catering to the needs of different socioeconomic groups of the fisherfolk, *viz*. women, backward communities, schedule caste, etc., are to be instituted.

Complementary and supplementary activities such as aquaculture, poultry and livestock rearing, would help fisherfolk increase their income.

A scientific and objective review of the ongoing developmental programmes needs to be conducted. The lacunae noted by the implementing agencies at different levels have to be sorted out in consultation with experts and the beneficiaries from the concerned sectors.

Extensive and comprehensive area development programmes for the entire coastal belt are required to improve the socioeconomic conditions of the marine fisherfolk.

Technological interventions of various magnitudes and at various levels are necessary to enhance production from culture fisheries.

Mariculture provides good opportunities for: (1) sea farming and associated activities of stock enhancement through sea ranching and artificial fish habitats, (2) land-based saline aquaculture in coastal zones using pump-fed or tide-fed seawater or brackish-water, and (3) hinterland aquaculture in saline soil and saline aquifer ecosystems (Devaraj and Murthy 1998).

In this regard, the efforts by the Coastal Marine Fisheries Institute (CMFRI) in preliminary ranching experiments on prawns in the Palk Bay at Mandapam, Tamil Nadu, clams in Ashtamudi lake, and pearl oysters and sea cucumbers in the Gulf of Mannar deserve special mention.

The socioeconomic feasibility and viability of the technologies should be thoroughly assessed before recommending them for adoption. The impacts of technological adoption on the physical environment and the fabric of the society are crucial factors that determine the rate of dissemination of the technology. Refinement of the technology in tune with the socioeconomic and physical environment of the end-user should be an important factor to the research organizations working in this sector.

Equipping deep-sea vessels for multipurpose operations would enhance production from deep-sea zones.

Introduction of navigation and guidance equipment and fish finders among the fisherfolk, assisted through subsidies, would help the fishers locate the resources.

Strict enforcement of laws to regulate marine fishing activities to prevent indiscriminate fishing would help to avoid exhaustion of resources.

In the wake of many hurdles and challenges, the marine fishery sector in India shows signs of a take-off, assisted by technological advancements and policies of the government. Along with the initiation of promotional steps to increase foreign trade and exchange earnings, the interests of impoverished fisherfolk should also be taken care of. Upgrading their capabilities is no mean task. This is the real challenge that the Indian marine fisheries sector faces.

Bioeconomic Modeling

Rationale

Fish resources can be competed for by many operators, since it is a common-pool resource and its exploitation and use are not under the control of a single operator. Hence the economic choice the operator makes about the application of inputs is more difficult. Highly competitive fishing can result in the depletion of a particular resource. For many fish stocks, there is grossly inadequate knowledge of their size and behavior.

Investment and decision-making are difficult. Fishing represents a way of life. Capital equipment used in fisheries is highly specific. The fisher has no security of tenure. He/she may make sudden unexpected profits or losses and the profitability of fisheries is highly volatile, creating considerable risk and uncertainty.

The formation of an Exclusive Economic Zone (EEZ) has given the coastal states the opportunity to manage their fish resources and to decide how much effort will be applied, and who has the right to fish.

In marine fish marketing, the market price depends on the day-to-day level of production. The individual fisher has little idea what the total fleet's catch will be until the produce arrives at the port. A sudden good catch may dim the market demand. The fish farmer, to a much greater degree, is able to regulate harvesting to suit market conditions and under certain conditions can be a price maker rather than a price taker.

Originally oceans were the common heritage of mankind but under maritime law, EEZs have been declared by individual countries, and coastal countries have the right of exploitation and management of these resources. With the increased use of science and technology, it is hoped that this century is going to be an era of "oceans". Governments have been paying attention to increased production of fish to fight malnutrition, meet protein needs, and to increase export earnings and generate employment.

In India, exploitation of coastal seas yields around 1.8 million t of fish annually. However, to meet the essential protein needs for the year 2000, around 13.0 million t of fish were required. Liberal estimates are that 4.5 million t may come from oceans.

Concerns about over-fishing are not confined to India alone. It is a world-wide phenomenon. Fishing circles all over the world are worried over the decline in the catch from the ocean. The tendency to over-fish has led fishers to turn to stocks of lesser value while fishing at lower trophic levels. Over-fishing has social implications for people in the fishing industry.

The bioeconomic analysis of fisheries is designed to:

1. develop an appropriate bioeconomic model;

2. assess the biological status of a fishery;

3. characterize the economic and social component of the fisheries resource system;

4. identify and analyse the impacts of appropriate fishery management alternatives;

5. provide directions for fisheries rationalization.

Review of Fisheries Legal Environment

In India, various organizations deal with management of the coastal fisheries including the Department of Fisheries and Cooperation, Ministry of Food and Agriculture, Government of India, Indian Council of Agricultural Research, Central Marine Fisheries Research Institute, Fisheries Survey of India, Integrated Fisheries Project and Department of Fisheries of maritime states and Union Territories. The Bay of Bengal Programme is also engaged in management of the coastal fishery resources of India. The different organizations work in cooperation with the objective of increasing marine fish production.

The coastal fishery resources of India have the typical problems of tropical regions. The fishery is multi-species, comprised of a very large number of species which are exploited with different types of gear throughout the year. Some of the maritime states have attempted restrictions either by enactment of statutory regulations or by orders placing restriction on fishing by mechanized units beyond inshore waters; for example, beyond 10 km from the coast of Andhra Pradesh and beyond 7 fathoms depth in Pondicherry. The non-mechanized units are to fish within the limits laid down, but often this coincides with the mechanized sector, which in turn leads to conflicts. Another problem is class conflicts which are resolved by the Departments of Fisheries of the concerned states. There is a great need for cooperation between non-mechanized and mechanized sectors as well as between mechanized vessels of the neighbouring states in the implementation of regulations.

The production potential from the continental shelf of India has been estimated to be 4.5 million t. The estimated marine fish production of the country in 1993 was 2.2 million t. Considering this, the potential exists to increase the production of the different groups by extending fishing operations to unexploited areas and to depth zones of 70 - 100 m.

Mesh size regulation of trawl nets to 25 mm is one of the important requirements for obtaining maximum sustainable yield. The importance was stressed by the Central Marine Fisheries Research Institute (CMFRI) and has to be implemented for achieving the maximum production without affecting recruitment, which is of paramount importance.

Another problem is that the trawlers which go for long trips discard large quantities of low quality fish caught and land only prawns and quality species of finfish. This practice can be minimized, if not totally prevented, by increasing the fish-holding capacity of the vessels, leading to a substantial rise in production.

If appropriate management measures are imposed on the fishing industry, there are possibilities for increasing the fish production from the continental shelf of India.

Government Policy and Present Management

For managing the marine fisheries, the Government of India has issued guidelines to all the maritime states to formulate rules and regulations to be passed by the respective state legislatures. These guidelines are intended mainly to avoid confrontation between the mechanized and artisanal sectors rather than as suitable regulatory measures for the sustainability of the resources. The guidelines were first issued in 1978 and later modified in 1980.

Among the maritime states bordering the Bay of Bengal, Tamil Nadu and Orissa have passed Marine Fishing Regulation Acts. Other states are following ad hoc measures to prevent or tackle conflicts between the artisanal and mechanized sectors. Tamil Nadu passed the Act in January 1983 and issued the rules in August 1983. Orissa passed the Act in June 1982 and issued the rules in January 1984. These Acts provided for (i) the registration of all fishing vessels, including non-mechanized country craft at their respective base ports; (ii) licensing fishing vessels for fishing in specified areas, (iii) regulation, restriction or prohibition of fishing in any specific area by such class or classes of fishing vessels which may be used for fishing in any specified areas, and (iv) regulation, restriction or prohibition of catching in any specified area of such species of fish and in such periods as may be specified. These acts have thus equipped the State Governments with the authority to regulate and control fishing activities in their respective states according to the specific local needs.

In both the states of Gujarat and West Bengal, there are not any restrictions on the area and the type of operations for any type of boat. In the states of

Goa, Tamil Nadu and Orissa, the area of operation of artisanal units is restricted to 5 km and for Kerala and Andhra Pradesh it is 10 km. The area of operation of mechanized vessels in different states ranges from 10 to 23 km (Table 26). As the density of fish biomass availability generally depends upon the depth of water, there have been complaints. In the Gulf of Mannar region, the depth is only 20 m at a distance of 5 km, whereas it is 100 m in certain other areas (e.g. off Cuddalore on the Coromandal coast). In order to remove this conflict some of the state governments have also considered the depth factor. For instance, the Kerala Length Marine Fishing Regulation Act 1980 divides the coastline into two sectors, a southern sector of 78 km coastal length and a northern sector of 512 km length. In the southern sector, the area from the shore up to 32 m depth, and in the northern sector the area from the shore up to 16 m depth, have been reserved exclusively for the artisanal craft. In the 32 to 40 m depth zone in the southern sector, and in the 16 to 20 m depth zone in the northern sector, only motorized craft are permitted to operate. The small mechanized vessels (< 25 GRT) are allowed to operate between 40 and 70 m depths in the southern sector and between 20 m and 40 m depths in the northern sector. Larger vessels (> 25 GRT) are supposed to operate beyond the 70 m and 40 m depths in the southern and northern sectors respectively. These guidelines are not always followed, resulting in conflict between the artisanal and mechanized sectors.

Table 26. Demarcation of fishing area for craft of different capacity (OAL - overall length).

State	Area and type of operation
Gujarath	No restriction
Maharashtra	Artisanal: 10 - 20 m depth mechanized: beyond 20 m depth
Goa	Artisanal: up to 5 km mechanized: beyond 5 km
Karnataka	Artisanal: up to 6 km mechanized: < 15 m OAL: 6 - 20 km > 15 m OAL: beyond 20 km
Kerala	Artisanal: up to 10 km mechanized < 25 GRT: 10 - 22 km > 25 GRT: beyond 23 km
Tamil Nadu	Artisanal: up to 5 km Mechanized : beyond 5 km
Andhra Pradesh	Artisanal: upto 10 km mechanized < 20 m OAL : 10 - 23 km > 20 m OAL ; beyond 23 km
Orissa	Artisanal: upto 5 km mechanized < 15 m OAL : 5 - 10 km > 15 m OAL : beyond 10 km
West Bengal	No restriction

In certain states trawling is conducted throughout the year. Enforcement of a temporary ban on trawling during the peak spawning season of the major species or when there is a high proportion of juveniles in the population may effectively reduce large scale exploitation of spawners and juveniles. Although most of the fish such as cephalopods and crustacean species, in the tropical region are frequent/continuous spawners, the northeast monsoon season is a period of intense spawning activity for most of the species.

Since the target of trawl exploitation is mainly prawns, intensification of trawling may pressure the prawn stock more than any other resource. Since the prawns are landed mainly by the shrimp trawl nets, operation of shrimp trawl nets may be suspended in November and December.

A very few number of gillnets operate on the east coast. It is advantageous to convert some of the mechanized vessels to trawlers cum gillnetters, as on the northwest coast of India, thereby facilitating the operation of gillnets during November and December. Since a gillnet with sufficiently large mesh size targets large fish and spares juveniles of fishes and prawns, an increase in the number of gillnetters will not be detrimental to the fishery resources.

To reduce the exploitation of enormous quantities of juvenile finfish and cephalopods, the cod-end mesh size of the fish trawl nets may be increased, as a first phase, to 25 mm. This may decrease catch in the first year. After a time lapse (about 1 year), the non-retained juveniles will have grown to be caught by the larger mesh (25 mm). The increase in individual weight of the fish caught by the larger mesh will more than balance the reduction after the time lapse and the total catch will increase. The second phase in mesh regulation may be implemented after assessing the performance of the 25 mm cod-end for about two years (Behera 1996).

Intensification of trawling has reached a stage in which the management of the resources has become imperative. Implementation of management measures involving restriction/reduction of effort, enforcement of closed seasons/areas or a change in mesh size or shape, requires information on the response of the fisher and on the impact of such measures on their livelihood. Introduction of management measures must be in consensus with the planners and the fisherfolk. A meaningful linkage of bioeconomic and socioeconomic parameters may be established by assessing the possible differences in catch rate and species composition in different fishing seasons.

Acceptance and implementation of fisheries management ideas are a slow and gradual process. It is not realistic to be too ambitious and optimistic. Nevertheless a socioeconomic approach coupled with a bioeconomic approach, handled with understanding, tact and foresight may ensure sustainability of the resources.

Surplus Production Model

The surplus production model deals with the entire stock, the entire fishing effort and the total yield obtained from the stock, without entering into any details such as the growth and mortality parameters or the effect of the mesh size on the age of fish captured, etc.

The objective of the application of surplus production models is to determine the optimum level of effort. This is the effort that produces the maximum yield that can be sustained without affecting the long-term productivity of the stock, the so-called maximum sustainable yield (MSY). The theory behind the surplus production models has been reviewed by many authors, for example, (Caddy 1980; Gulland 1983; Pauly 1984; Ricker 1975).

Holistic models are much simpler than analytical models and the data requirements are also less demanding. There is, for example, no need to determine cohorts and therefore no need for age determination. This is one of the main reasons for the relative popularity of surplus production models in tropical fish stock assessment. The surplus production models can be applied when reasonable estimates are available of the total yield (by species) and/or catch per unit of effort (CPUE) by species and/or CPUE by species and the related fishing effort over a number of years (Table 27).

Table 27. Catch and effort data used for developing the models.

Year	Catch (t)	Effort (AFH)*	Catch/effort (Kg)
1985	1 522 517	12 855 900	110
1986	1 679 373	11 388 900	147
1987	1 649 165	13 559 846	122
1988	1 785 549	16 144 963	111
1989 - 1990	2 208 598	12 998 543	170
1991	2 142 713	12 479 013	173
1992	2 222 111	11 614 013	191
1993	2 276 964	12 089 170	188
1994	2 245 124	12 240 099	183
1995	2 325 146	11 969 670	194
1996	2 225 028	12 012 370	185
1997	2 388 239	11 733 576	204
1998	2 709 862	12 545 330	216

Note: * annual fishing hours

The linear relationship between fish production and fishing hours is written as (Schaefer 1954):

$$Y/f = a - bf, \qquad (1)$$

where
Y = annual fish landings (t)
f = annual fishing hours

a and b = *parameters to be estimated*

Rewriting Equation (1) gives:

$$Y = af - bf^2 \qquad (2)$$

Taking the first and second derivatives of Y with respect to f in Equation (2) gives:

$$\frac{dy}{df} = a - 2bf; \quad \frac{d^2y}{df^2} = 2b \text{ (Hence maxima exists)}$$

Equating $\frac{dy}{df} = 0$, we can solve for the level of effort that yields maximum sustainable yield, f_{msy}:

$a - 2bf = 0;\ f = a/2b = f_{msy} = a/2b$.

Next we solve for maximum sustainable yield (MSY).

Substituting $f_{msy} = a/2b$ in (1) we get

$MSY = a^2/4b$

Table 28. Schaefer's and Fox's models fitted to the fishery data of India from 1985 to 1998.

	Actual yield (t)	Actual effort (AFH)	Fitted models	MSY	f_{MSY}
Schaefer	2 441 043	12 097 092	Y/f = 478.115 - 0.000 248f	2 353 726	984 586
Fox	2 441 043	12 097 092	Y/f =7.185 - 0.000 000 163f	2 973 752	6 126 232

The exponential relationship between relative yield and annual fishing effort is written (Fox 1970):

$Y = fe^{(a+bf)}$ $MSY = -e^{(a-1)/b}$

$f_{msy} = b$

The estimates of MSY and f_{msy} by the Schaefer model are near to the actual yield and effort (Table 28). The actual yield was obtained with more effort (12 097 092 annual fishing hours, AFH) than the predicted f_{msy} (9 845 861 AFH), which indicates more effort is applied than the optimum effort to harvest a sustainable yield. These estimates have to be updated periodically to capture the quantitative expansion in fishing (Devaraj 1987).

Analysis of Management Objectives and Schemes

The efforts by the government and various research and development organizations contribute to the high production level in fisheries. Development programmes and schemes for the welfare of the fishers were begun in India several decades ago. Even though fisherfolk-societies/cooperatives are established, the results of these organizations are not fully realized by the end-users. Many agencies, including the Fish Farmers Development Agencies, Brackish-water Fish Farmers Development Agencies and other organizations governed by the central and state governments, function fully throughout the coastal states. Financial support is given through the supply of subsidized items. Credit facilities offered to the fisher provide incentives.

A needs-based approach and participatory planning during the initial stages of programme implementation form the concrete baseline for the success of the strategic programs. The information lag prevailing in the fisher community makes them unaware of the schemes and policies formulated for their welfare. Research studies conducted on the impact of the development programs offer suggestions for the effective implementation of the schemes.

Conclusions and Recommendations

Many management strategies could be explored for the better utilization of the marine resources and enhancment of fish production, and in turn the life of the fisherfolk. These are as follows:

1. Limitation of over-exploitation. The banning of certain gear and restricted entry into over-exploited fishing grounds are some ways of limiting over-exploitation.

2. Promotion of alternate/subsidiary income. Most of the fishers are downtrodden and live below the poverty line.

3. Information sources/dissemination/communications and education. Updated information about the latest innovations in the technology should be accessible to the fisher groups. Education among the fisher communities should be encouraged.

4. Protection of marine habitat. Exploitation of coral reefs and other fish habitats should have restrictions in place.

5. Effective implementation of small scale fishery development projects. To upgrade the standard of living of the fishers, development programmes should be implemented more effectively.

6. Emphasis on the importance of aquaculture/sea-farming. India has great potential for aquaculture development.

7. Infrastructure and service facilities availablility to the artisanal fisher. Improving the landing centre facilities will improve processing, marketing and quick transportation of the harvested fish.

8. Coastal zone management. The coastal fisheries environment should be well preserved. Research studies in the area need to be strengthened.

9. Increasing deep-sea fishing effort. Deep-sea fishing should be intensified by encouraging the fisher to adopt a dory type of fishing, in which a series of indigenous boats are involved in fishing and transportation of catch.

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Socioeconomic and Bioeconomic Analysis of Coastal Resources in Central and Northern Java, Indonesia

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Abstract

Indonesia's fisheries exports rose from 2 206 t in 1970 to 598 385 t in 1996 with a subsequent export value rise from US$0.69 billion to US$1.78 billion. The surplus in the balance of trade (BOT) was US$1.59 billion in 1996. The fisheries exports were predominantly shrimp, tuna, skipjack and demersal fishes. Large scale fisheries operations are prevalent in the Java Sea. The dominant fishing gear is hook-and-line (40%), gillnet (31%), traps (10%), seine net and lift-net (6%), purse seine (1%), shrimp net with BED (0.04%) and others (6%). The large scale fisheries e.g. purse seine, tuna long line, shrimp trawl and fish net use larger vessels, while most of the large scale fisheries utilize boats between 5 - 30 GT. Small scale fisheries exploit the coastal waters resulting in overcrowding in the Java Sea.

In terms of production and technological efficiency, the combination of manpower inputs, total volume of fuel/day and total number of vessels are not optimal either for small or large scale vessels. It is recommended in the large scale fisheries that the volume of fuel/day should be increased, while the total number of boats should be reduced. Conversely the use of fuel/day for large scale fisheries should be increased. Expanded use of fuel/day for large scale vessels would increase offshore operations, which would lessen the fishing pressures in near-shore waters. In the northern part of Java, large scale fisheries do not generate any discards or by-products because most of the fishers utilize the fish captured for family consumption, local market or commercial export purposes.

Budget analysis, using the internal rate of return (IRR), net present value (NPV), payback period (PP) and benefit-cost analysis (B/CA), showed that almost all vessels are profitable and ready for new capital investment, except for Danish seine A vessels. Results using the Schaefer surplus yield production model indicate that the existing total fishing effort remains lower than the maximum sustainable yield (MSY) level in the inshore waters. The utilization rate in 2001 is currently 99.4%.

It is recommended that an in-depth study be conducted using simultaneous equation modeling that will integrate the Schaefer model, demand function, production, taxation policy and the feasibility constraints into one general model.

Socioeconomic Profile

Review of the Status of Fishery Resources: Volumes and Values of Fish Production

Over 1960 - 96, the national fisheries production increased nearly 5.88 times, increasing from 756 765 t to 4 452 000 t. The national fish production includes the marine capture sector that provides the highest share at 75.98%, followed by the coastal brackish-water culture at 9.08%, and finally by the inland fish production (capture at 7.54% and culture at 7.39%).

Marine capture fisheries consist of the small pelagic fish (37.21%), demersal fish (28.58%), large pelagic fish (9.978%), coral fish (2.45%), penaeids (1.89%), squids (0.58%) and ornament fish, estimated at around 1.5 billion of fish. The large pelagic fish are the skipjack (3.37%), eastern little tuna (*tongkol*, 2.92%), tuna (2.05%), king mackerel/*tenggiri* (0.84%) and shark/marlin/sailfish/sword fish (0.42%).

Following (Kmenta 1971) the logistic growth curve (LGC) model of marine capture production in Central and Northern Java can be estimated using:

$$\text{Ln } Z = 2.700\,245 - 0.071\,79\ T$$
t test: (-47.23)

$R^2 = 0.98$; $n = 37$; $df = 35$

Where :
Z = equal to the value of (MSY/X - 1)
MSY = maximum sustainable yield estimated at 6 285 000 t annually
X = production of marine capture annually (t)
T = time trend

Table 1. Projected marine capture fish production using the LGC model.

Year	Production (t)
1996	3 073 353
1997	3 186 139
1998	3 298 812
1999	3 411 085
2000	3 522 670
2001	3 633 292
2002	3 472 680
2003	3 850 580
2004	3 954 109
2005	4 060 961
2006	4 163 011

Fish production from the capture fisheries (marine and inland) and culture (coastal brackish-water and inland) during 1960 - 96 showed that the growth of marine capture fisheries is relatively high, compared to other fish production that more or less remained the same (Table 2, Fig. 1).

Table 2. National fish production (t) from capture and culture fisheries, 1960 - 96.

Year	Capture		Culture		Total
	Marine	Inland	Coastal	Inland	
1960	410 043	249 674	43 078	53 970	756 765
1961	525 198	297 988	32 807	54 288	910 281
1962	537 983	281 449	32 704	56 157	908 293
1963	558 970	279 165	39 239	57 720	935 094
1964	590 000	272 860	42 421	87 573	992 854
1965	665 107	296 007	53 413	87 808	1 102 335
1966	720 236	347 591	54 067	79 934	1 201 828
1967	677 933	364 875	56 750	80 876	1 180 434
1968	722 512	320 410	43 528	72 590	1 159 040
1969	785 344	314 201	51 876	62 978	1214 399
1970	807 391	286 519	55 908	78 694	1 228512
1971	820 447	285 745	60 788	77 595	1 244 575
1972	836 289	301 412	51 203	80 005	1 268 909
1973	888 518	249 592	60 481	78 921	1 277 512
1974	948 566	240 893	66 756	80 053	1 336 268
1975	996 856	228 511	78 776	85 871	1 390 014
1976	1 081 589	246 711	80 158	74 484	1 482 942
1977	1 157 691	254 243	87 604	72 314	1 571 852
1978	1 227 386	249 146	87 995	83 137	1 647 664
1979	1 317 744	248 161	93 664	88 848	1 748 417
1980	1 401 000	250 900	95 300	93 000	1 840 200
1981	1 408 272	264 983	112 916	128 334	1 914 505
1982	1 490 719	265 348	129 279	112 195	1 997 541
1983	1 682 019	265 562	134 072	132 328	2 213 981
1984	1 712 804	269 321	142 404	136 460	2 260 989
1985	1 821 725	269 266	156 367	148 204	2 395 562
1986	1 922 781	273 012	170 310	163 787	2 529 890
1987	2 017 350	276 291	192 123	184 649	2 670 413
1988	2 169 557	281 264	233 283	197 065	2 881 169
1989	2 272 179	296 385	258 491	208 213	3 035 268
1990	2 370 107	292 537	287 073	212 752	3 162 469
1991	2 537 612	294 477	323 156	194 356	3 349 601
1992	2 692 068	300 896	337 431	212 937	3 543 332
1993	2 886 289	308 649	355 284	245 100	3 795 322
1994	3 080 168	336 141	346 214	251 308	4 013 831
1995	3 292 930	329 710	361 239	279 708	4 263 587
1996	3 382 457	335 706	494 335	328 760	4 541 258

Source: Directorate General of Fisheries (DGF) 1998.

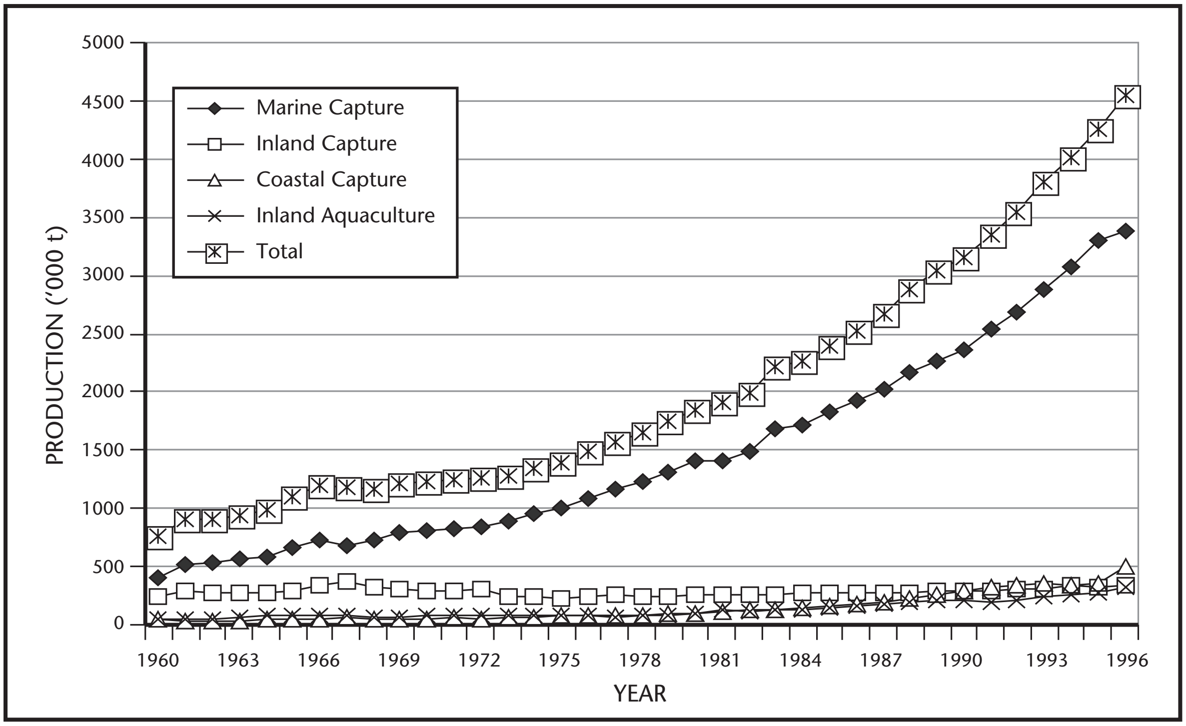


Fig. 1. National fisheries production from capture and culture fisheries 1960 - 96.
Source: Directorate General of Fisheries (DGF) 1998.

Economic Growth and Welfare: Contribution of the Fishery Sector to Economic Growth and Welfare

Below are the major analyses based on relevant fisheries statistics from 1985 to 1997.

- During 1985 - 97, the gross domestic product (GDP) valued at constant market price increased from 79 679 to 433 685 billion Rupiahs (1US$ = 2 360 Rupiah, annual average from 1993 - 97), an increment of almost 5.44 times. Similarly, the gross national product (GNP) at constant market prices also multiplied from 76 602 to 418 418 billion Rupiahs a rise of 5.46 times.
- The human population increased on average by 2.21% between 1980 - 87 and by 1.57% between 1988 - 97.
- Per capita GDP during 1985 - 97 rose from 487 730 to 2 170 200 Rupiahs annually (almost 4.45 times). Economic growth was thus increasing significantly during these periods.
- The per capita gross regional domestic product (GRDP) in DKI-Jakarta was the highest among all provinces with an annual average of Rps 7 324 400. From the agricultural sector and industries, the manufacturing of oil, non-oil and gas made the highest contribution to the national GDP at 21.86%. Other contributions came from trades/hotel and restaurants at 13.74%, agriculture/livestock/forestry and fisheries at 14.79% and other services at 8.22%.
- The fisheries sector with a 1.51% share contributed minimally to the GDP.
- In 1988, the contribution of non-oil and gas to the national GDP increased at a rate of 90.86%. This suggests that oil and gas will be less important in the future.
- Information on the national GDP, gross national product (GNP) and population is given below (Table 3, Fig. 2).

Table 3. Indonesian GNP, GDP and GVA gross value-added from 1985 to 1997 at constant market prices.

Year	Total GNP (billion Rupiah)	Total GDP (billion Rupiah)	Industry and Others (billion Rupiah)	Services (billion Rupiah)	Agriculture (billion Rupiah)	Fishery (billion Rupiah)	Population (million)	GDP per Capita (Rupiah)
1985	76 602	79 679	57 086	3 291	19 302	1 311	163 367	487.73
1986	78 646	90 014	59 518	3 270	19 687	1 398	166 358	495.77
1987	90 270	94 302	62 655	3 422	20 230	1 484	169 850	530.20
1988	96 454	99 936	75 198	3 570	21 168	1 557	173 415	576.28
1989	103 723	107 321	81 519	3 716	22 086	1 626	177 056	606.14
1990	110 986	115 217	88 879	3 981	22 357	1 745	178 170	646.67
1991	118 746	123 181	96 303	4 215	22 663	1 814	181 384	679.12
1992	126 146	131 102	102 466	4 497	24 139	1 893	184 491	710.61
1993	135 872	139 707	110 241	4 897	24 569	2 053	187 584	751.83
1994	341 676	354 641	261 065	34 285	59 291	5 660	190 676	1 859.91
1995	367 012	383 767	286 594	35 406	61 767	5 974	193 750	1 980.74
1996	402 376	414 419	414 419	36 610	63 743	6 249	196 813	2 105.65
1997	418 418	433 685	433 685	37 724	64 149	6 562	199 837	5 170.20

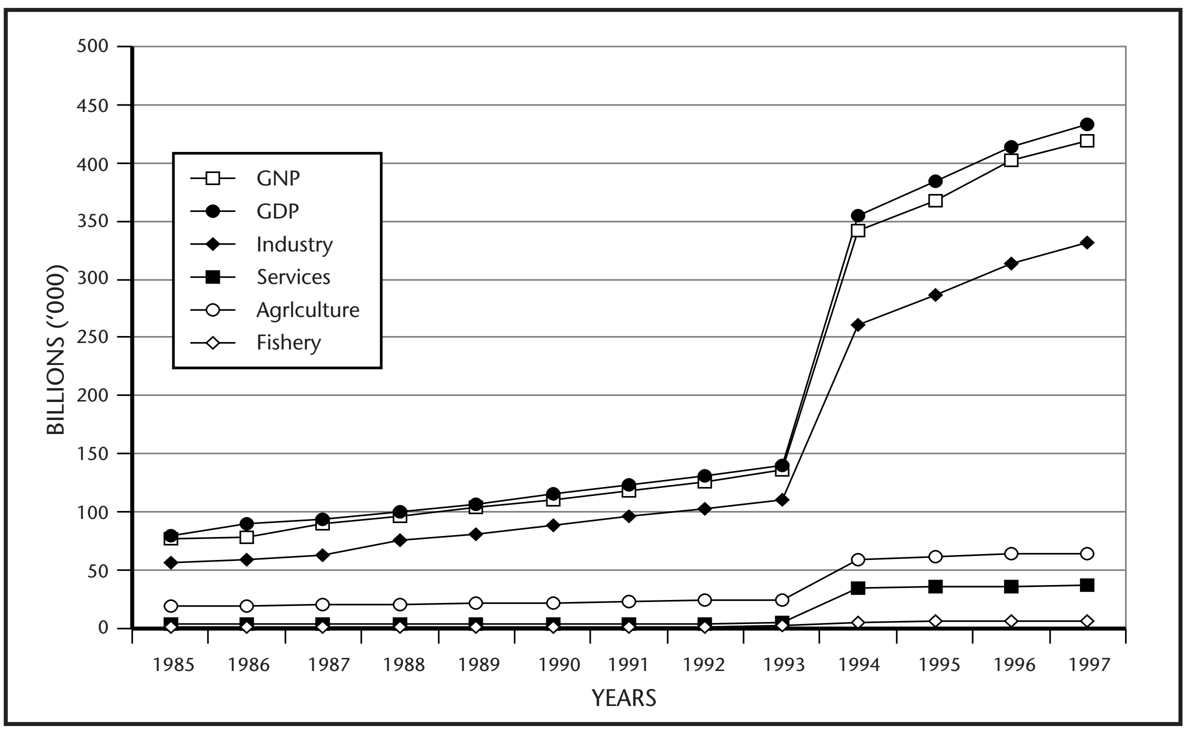


Fig. 2. Contribution to the GNP and GDP by agricultural, non-agricultural and fisheries sectors in Indonesia from 1985 to 1997.

Gini Coefficient

In 1986, the Directorate General of Fisheries (DGF) studied the Gini Ratio using Lorenz Curves to show the family income distribution of the gillnet and purse seine activities on the north coast of Java. Gini coefficient is a measure of the degree of inequality of a variable (e.g. income) in a distribution of its elements and ranges from 0 where there is no concentration (perfect equality) to 1 where there is total concentration (perfect inequality). Table 4 gives the results of the study suggesting the presence of inequality on the family income distribution for those fishers using purse seine and gillnet.

Table 4. Gini ratio of family income distribution using two types of fishing gear.

Type of Gear	Gini Coefficient Ratios of Total Income
Purse Seine	0.425
Gillnet	0.371

The main results of the study are given below.

- In Pekalongan, Central Java where there are mostly purse seiners and gillnetters, there is more equal income distribution. A study done in 1988 showed that a Gini Coefficient below 0.40 means a more equal income distribution.
- Purse seine fishers in the northern part of Java operated full time for 6 - 30 days•trip^{-1}, either to the South China Sea or to Masalembo-Matasiri at Makasar Strait in the east. These are medium/semi large scale fisheries and more efficient than gillnetting.
- Fishers using gillnets operate along the coast line for 1 - 6 days•trip on a smaller scale.
- Income distribution between skipper and engineer are more varied for purse seiners.

Lorenz curves for the purse seine and gillnet activities are reported in Figs. 3 and 4.

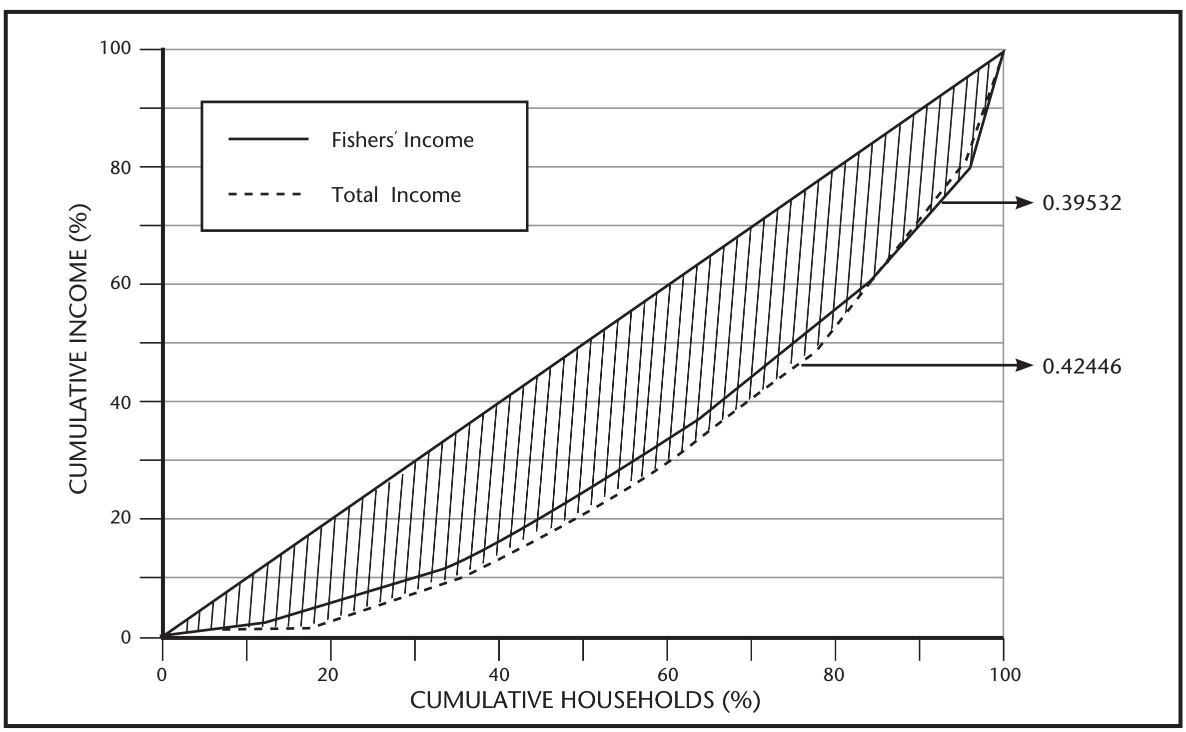


Fig. 3. Total fishers' income using purse seine as derived from the Lorenz curve.

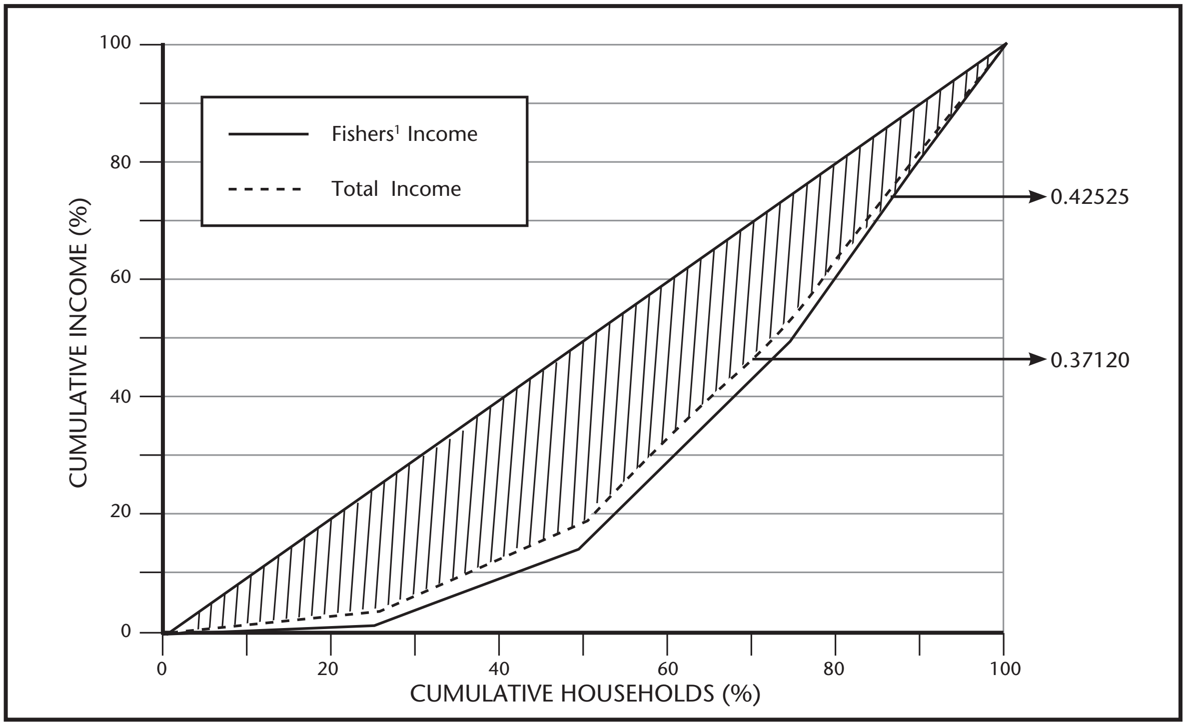


Fig. 4. Total fishers' income distribution using gillnet as derived from the Lorenz curve.

Volumes and Values of Fish Exports and Imports 1970 - 96

From 1970 to 1996, the balance of trade (BOT) showed a surplus for Indonesia, increasing from US$5 994 000 (1970) to US$1 658 827 000 (1996), giving an annual average increase of 10.25%. The foreign exchange earnings (FEE) in 1996 were US$1 658 827 000.

In 1997, the volume of exports was more than twice (2.14 times) as large as imports. The biggest share of the imports came from fishmeal at 82.07% and this quantity increased by 26.65% over 1985 to 1994. In terms of values, exports were 17 times higher than imports in 1997. Shrimps (tiger, banana and white species) contributed 16.75% and tuna and skipjack contributed 14% to the total fish exports. The total exports increased at an average rate of 18.25% over 1987 - 96, when shrimp increased an annual rate of 22.52% while tuna and skipjack increased annually by 21.41%.

Table 5. The quantity and the value of fish export and imports and the balance of trade (BOT) in Indonesia from 1970 to 1996.

Year	Quantity (t)			Value (US$'000)		
	Exports	Imports	BOT	Exports	Imports	BOT
1970	2 206	2 801	19 259	6 959	965	5 994
1971	30 756	6 741	24 015	18 994	1 518	17 476
1972	41 156	4 883	36 273	34 941	1 605	33 336
1973	52 178	7 732	44 446	68 185	2 463	65 722
1974	54 953	6 980	47 975	92 344	2 438	89 406
1975	40 738	6 696	34 042	8 891	2 374	85 817
1976	54 389	26 784	27 605	131 380	10 339	121 941
1977	57 510	25 437	32 073	163 018	10 481	152 557
1978	63 485	27 099	36 386	193 424	10 029	183 395
1979	68 264	31 018	37 246	236 827	6 716	230 111
1980	78 705	39 517	39 188	226 354	20 971	505 383
1981	75 178	63 220	11 958	225 387	38 475	186 912
1982	89 629	83 140	6 219	254 416	45 544	208 872
1983	88 365	57 878	30 487	257 048	34 347	222 701
1984	75 695	50 668	25 027	248 063	28 789	219 274
1985	84 497	54 287	30 210	259 444	23 891	235 553
1986	107 443	57 426	50 017	374 113	28 177	345 940
1987	140 378	65 371	75 007	475 523	27 832	447 691
1988	181 218	37 861	143 357	712 199	20 704	691 495
1989	228 590	56 726	171 864	825 125	32 884	792 241
1990	320 241	73 285	246 956	1 039 680	47 684	991 996
1991	409 043	71 552	337 491	1 255 663	52 383	1 203 280
1992	421 367	81 082	340 285	1 263 535	64 688	1 198 847
1993	529 213	177 200	352 013	1 503 748	109 197	1 394 551
1994	545 371	276 829	268 542	1 678 720	136 713	1 542 007
1995	563 065	163 240	399 825	1 783 489	115 917	1 667 572
1996	598 385	154 893	443 492	1 785799	126 972	1 658 827

Socioeconomic Analysis of the Artisanal or Large Scale Fishery Sector

The majority of Indonesia's fishing fleet is small scale with a limited capacity to sail offshore, and powered by sails or both sails and engine. The DGF in Indonesia has divided the small scale fishing fleet into three categories.

a. Dug-out boats (*jukung*) comprised 31.8% of Indonesia's fishing boats in 1993. Most (77%) of these boats were in the eastern part of Indonesia, such as Moluccas, Irian Jaya, Sulawesi and the Lesser Sunda Island.
b. Three types of non-powered plank-built boats divided into: (i) small (< 7 m in length), (ii) medium (7 - 10 m) and (iii) large (> 10 m). The total number of vessels in this fleet was 57 557 or 14.7% of all Indonesian fishing boats.
c. Outboard engine boats. Some have modified gasoline or diesel engines mounted along the side with a long trailing propeller shaft and 2 - 15 HP engines. About 21% of all boats were outboard and 42.9% of all boats were operated in the north coast of Java.

Large scale boats are classified according to the fishing gear used. Commonly used gear in large scale fishing are seine nets, gillnets, traps and other traditional methods, such as shellfish collection, seaweed collection and cast net. The total number for each gear type is shown in Table 6.

In general, a crew of two to three fishers is adequate for most large scale operations, and in some cases vessels are operated alone.

Table 6 provides information on the fishing gear employed in Indonesia. The dominant gear in the large scale fisheries are hook-and-line (40%), gillnet (30.60%), traps (10%), lift-net (5.80%), seine net (5.84%), purse seine (1.34%), shrimp net with BED (0.04%) and other gear (7.37%).

Table 6. The types of fishing gear and production per gear in Indonesia from 1993 to 1997.

Type of Fishing Gear	1993		1994		1995		1996		1997	
	Gear (Unit)	Production (t)	Gear (Unit)	Production (t)	Gear (Unit)	Production (t)	Gear (Unit)	Production (t)	Gear (Unit)	Production (t)
1. BED shrimp net	359	56 652	894	79 619	1 449	95 536	1 387	113 596	296	85 667
2. Seine net	38 584	411 549	32 314	380 679	41 662	369 686	37 193	408 437	40 641	467 984
3. Purse seine	8 599	515 291	6 891	611 464	7 300	586 241	7 386	554 573	9 341	637 458
4. Gillnet	183 984	636 795	179 706	685 307	191 079	708 428	183 485	748 414	213 024	813 759
5. Lift-net	45 902	306 889	40 355	294 099	44 025	430 183	42 268	308 215	40 457	359 445
6. Hook-and-line	251 052	511 013	285 082	556 784	269 700	599 091	277 750	640 455	271 321	661 678
7. Traps	47 757	217 090	45 096	221 870	61 722	235 315	16 237	247 062	69 864	249 489
8. Other gear	59 747	231 010	50 484	251 346	52 675	268 450	53 990	363 122	51 332	337 481
TOTAL	635 984	2 886 289	640 822	3 081 168	669 612	3 292 930	619 696	3 383 874	696 276	3 612 961

Source: Directorate General of Fisheries (DGF) 1998.

Characteristics of the Fishery Labor Force in Commercial Fisheries

Total Number of Fishers in Indonesia

The fishers population in Indonesia accounts for only 1% of the total labor force and has not changed significantly since 1990. Most of the fishers are working full-time (51.1% in 1997), part-time as major occupation (34.3%), and part-time as minor occupation (14.8%). A combination of fisheries, agriculture and traditional fish processing as a means of livelihood is common in the coastal villages of Indonesia.

Most fishing households have 4 - 5 family members working in non-fishing activities. In 1997, 49.4% of the fishing population were owners of non-powered boats used for large scale fishing, 22.3% had boats with outboard engines, 16.8% had in-board engines and 11.5% did not have boats. As regards marine fishing, during 1988 - 97, 60.6% of the fishers had non-powered boats, 23.2% owned boats with outboard engines and 16.2% owned boats with inboard engines .

Table 7. Total number of fishers (full-time and part-time) in Indonesia from 1988 to 1997.

Year	Total Fishers	Full-time	Part-time	
			Major	Minor
1988	1 417 000	702 000	525 000	191 000
1989	1 464 000	727 000	540 000	197 000
1990	1 524 000	755 000	564 000	205 000
1991	1 633 000	817 000	618 000	198 000
1992	1 742 000	859 000	619 000	264 000
1993	1 890 000	937 000	667 000	285 000
1994	1 850 000	925 000	648 000	277 000
1995	1 958 000	979 000	686 000	292 000
1996	2 055 000	1 037 000	713 000	305 000
1997	2 088 000	1 067 000	717 000	308 000

Source: Directorate General of Fisheries (DGF) 1998.

Table 8. Total fishing households and fishing population using various fishing vessels in Indonesia from 1988 to 1997.

Year	Number of fishing households	Without boat	Population per fishing vessels		
			Non-powered boats	Outboard engines	Inboard engines
1988	356 000	53 000	202 000	64 000	37 000
1989	258 000	45 000	208 000	65 000	40 000
1990	380 000	53 000	216 000	69 000	42 000
1991	377 000	44 000	216 000	71 000	46 000
1992	406 000	60 000	225 000	74 000	47 000
1993	426 000	53 000	231 000	90 000	53 000
1994	426 000	57 000	232 000	82 000	55 000
1995	436 000	58 000	228 000	89 000	61 000
1996	450 000	55 000	240 000	90 000	66 000
1997	435 000	50 000	215 000	97 000	73 000

Source: Directorate General of Fisheries (DGF) 1998.

Effect of Development Interventions, Investment and Other Trends in Coastal Communities

Fishing communities in Indonesia exploit fishery resources in the fishing grounds close to their home base, particularly in the coastal areas. Thus, over-exploitation of fisheries resources in Indonesia is mainly in the Java Sea and Malacca Strait. Fishery resources in the eastern part of Indonesia, mostly in the offshore zone and EEZ, are considered to be under-exploited. Except in the Arafura Sea, where the targeted fishing is shrimp trawling, the fishery resources in the eastern part seem to be very close to over-fishing conditions. Generally, the issues of developing marine fisheries in the eastern part of Indonesia lack human skilled resources, limited availability and capacity of capital and fisheries infrastructure, and a low level of demand. The demand for fish is very high in the western part of Indonesia, especially in Java and Sumatra, contributing to a higher GRDP. The supply of fish is relatively more abundant in the eastern part of Indonesia. This situation creates several problems such as: (1) transportation costs, (very expensive), (2) processing development in the eastern part of Indonesia, (3) lack of infrastructure, (4) insufficient or lack of training and extension and (5) requires more research and development.

The large scale fishing fleet is usually more efficient than the small scale fishing fleet if the target species is a highly valuable fisheries commodity such as shrimp, tuna and skipjack and demersal fishes. The government of Indonesia is exerting efforts to closely manage the coastal fishing zones, but the marine fishery is an open-access one. This is due to ineffective monitoring, and lack of compliance, surveillance and enforcement of regulations. Consequently, there is competition among the various fishing groups, large scale vs. large scale. In most cases, the large scale fishers are the less effective.

The National Scientific Committee on the Assessment of Marine Fishery Resources has studied the level of utilization of fishery resources (Table 10). Other issues on the utilization of fishery resources are functions of recruitment, growth, harvesting and natural mortality.

Deteriorating environmental conditions can reduce recruitment and growth rates and intensify mortality rates. Unfortunately, there is continuous degradation of the environment due to natural occurrences and human interventions that threaten the sustainability of the coastal ecosystem and the fishery resources.

Table 9. Classification and number of marine fishing boats in Indonesia from 1991 to 1995.

	Indicators	1991	1992	1993	1994	1995	Increasing rate (% per year)
1.	Non-powered boat	231 659	229 377	247 745	245 486	245 162	1.49%
	Powered boat	123 125	129 529	141 753	150 699	159 491	6.70%
2.	Outboard engines	75 416	77 779	82 217	87 749	94 024	5.68%
	Inboard engines	47 709	51 750	59 536	62 950	65 467	8.31%
3.	Boats according to size						
	< 5 GT	35 179	37 913	43 396	45 331	48 855	8.62%
	5 - 10 GT	7 391	7 936	9 791	9 604	9 562	7.10%
	10 - 20 GT	2 726	3 156	2 812	3 376	2 789	1.89%
	20 - 30 GT	909	984	1 558	1 688	1 519	16.23%
	30 - 50 GT	738	1 049	1 170	1 869	1 682	25.85%
	50 - 100 GT	185	208	351	567	687	40.97%
	100 - 200 GT	272	184	213	340	253	4.36%
	> 200 GT	309	320	245	175	120	-19.97%
	TOTAL	354 784	358 906	389 185	396 185	404 653	3.38%

Source: Directorate General of Fisheries (DGF) 1998.

Table 10. Maximum sustainable yield (MSY) and production of marine fisheries of Indonesia in 1997.

	Commodities	Resource potential (t)	Total Production (t)	Percentage
1.	Small pelagic	3 235.8	1 415	43.73%
2.	Large pelagic	1 053.5	364	34.55%
	- Tuna	223.7		
	- Skipjack	392.5		
	- King mackerel	150.5		
	- Eastern little tuna	235.1		
	- Billfish	51.7		
3.	Demersal	1 786.4	1 087	60.85%
4.	Shrimp	78.6		
	- Penaeid	73.8	70	94.85%
	- Lobster	4.8	2	41.67%
5.	Squid	28.3	22	77.74%
6.	Coral fishes	76.0	93	122.00%
7.	Ornamental fishes*	1.5 x 1 000 000	N/A	N/A
	TOTAL	6 285	3 803	60.51%

Source: Directorate General of Fisheries (DGF) 1995.
Note: * Number of individuals; N/A = Not available.

Fleet Operational Dynamics

The State of the Fishing Fleet

The study covered six districts in the northern part of Java. It was based on questionnaires and interviews from the boat owners or the skippers.

Since the declaration of Presidential Decree (Keppres No. 39/80) that banned trawl operations in Indonesian waters, except in the Arafura Sea, many fishers have modified the trawl into traditional gear such as *arad*, *cantrang*, *dogol*, *lampara dasar*, gillnet and others. This traditional gear also captures demersal and bottom fishes and is operated similarly to the traditional trawlers with some modifications.

The socioeconomic variables of demersal fishing were studied in the northern part of Java. Respondents were selected by the type of fishing gear they operate. There were twelve different types of gear for fish, shrimp, molluscs, squid and crabs. These are (1) shrimp-trawl, (2) *payang/dogol* (Danish seine A), (3) *arad* (Danish seine B), (4) *pukat pantai* (beach seine), (5) *jaring klitik* (monofilament gillnet), (6) *jaring insang tetap* (set gillnet), (7) trammel net, (8) *bagan tancap* (stationary lift-net), (9) *rawai tetap* (traditional long-line), (10) *cantrang* (Danish seine C), (11) mini purse seine, and (12) large purse seine. In every area, at least one to two respondents were chosen for each type of gear. For the shrimp-trawl, data for production efficiency were collected through logbook fisheries in the Arafura Sea.

Stratified random sampling was chosen to include the different qualitative measures between location and technology. Table 11 presents the number of respondents per area. During the study in the northern part of Java, the total samples covered 46 unit vessels. However, these were incomplete data sets that made the cost and return analysis and the production function of demersal fisheries difficult to estimate.

Table 11. Number of respondents per fishing area in northern Java in 1999.

Fishing gear	Location							
	Indramayu	Pemalang	Pekalongan	Batang	Tuban	Brondong	Arafura	Total
1. Shrimp-trawl	–	–	–	–	–	–	70	70
2. Danish seine A	1	1	1	1	–	–	–	4
3. *Arad* (Danish seine B)	1	1	1	1	–	1	–	5
4. Beach seine	1	1	–	1	–	–	–	3
5. Monogillnet	1	1	1	1	1	1	–	6
6. Set gillnet	1	1	1	1	1	1	–	6
7. Trammel net	1	–	–	–	–	1	–	2
8. Stationary lift-net	1	–	–	–	–	–	–	1
9. Traditional long-line	1	1	1	1	1	1	–	6
10. Danish seine	1	1	1	1	1	1	–	6
11. Mini purse-seine	1	1	1	1	1	1	–	6
12. Large purse-seine	–	–	1	–	–	–	–	1
TOTAL	10	8	8	8	5	7	70	116

Vessels, Engine and the Fishing Grounds

The large scale fishing vessels range between 7 - 34 GT with 10 - 160 HP engines and employ 3 - 10 crew, except beach seines and mini purse seine which are more labor- intensive using 25 - 34 crew members. They mostly fish in the coastal areas of the Java Sea leading to a highly crowded fishing ground. The average total number of boats per gear is nearly 3 959 units or an equivalent of 47 503 units for all fishing gear operating in the northern part of Java. The large scale boats operate for 1 - 12 days/trip at a distance of 1 - 30 miles. The exception is mini purse seine vessels, which sometimes travel up to 60 miles from the fishing-base to capture scads, sardinella, mackerel, trevallies, etc.

A boat's average CPUE (catch per unit effort) (catch/craft/day) is between 90 - 488 kg which is composed of *ikan sebelah* (Indian halibut), *peperek* (pony fishes), *manyung* (sea catfishes), *bambangan* (red snapper), *kerapu* (grouper), *kakap* (giant perch), *tiga waja* (druns), *cucut* (shark), *pari* (rays), *bawal hitam/putih* (black/silver pomfret), *alu-alu* (barracuda), *layang* (scads), *selar* (trevallies), *tembang* (Sardinella), *lemuru* (*Sardinella longiceps*), *kembung* (Indian mackerel), *tenggiri* (mackerel), *layur* (hairtails), *tongkol* (eastern little tuna), *rajungan* (crabs), *udang dogol* (*Metapenaeus* spp), *udang putih* (white shrimp), *cumi-cumi* (squids), and *sotong* (cuttle fish).

The large purse seine vessels employ 39 crew members, are constructed of wood, have an average size of 96 GT and have 325 HP engines. These vessels are capable of operating from their Pekalongan fishing-base to the South China Sea (in the west) and Masalembo Island and Makasar Strait in the east. Amazingly, boats are able to capture on the average 32 168 kg•trip^{-1}. Thus, with an average per trip of 30 days, CPUE of the large purse seine can be up to 1 072 kg, composed mostly of scads, Sardinella, Indian mackerel, trevallies and others.

The shrimp-trawl represents the large scale fishery using 17 - 18 crew, larger boats of 193 GT and 597 HP engines and are constructed of steel/fiberglass. These vessels are capable of operating from their Ambon and Sorong fishing bases to the Arafura Sea, near Dolak Island at the southern part of Merauke. The shrimp-trawl has the capacity to capture shrimp at an average of 13 772 kg and other fish at 20 657 kg•trip^{-1}. Since one trip is equivalent

to 66 days on the average, catch/craft/day of the shrimp-trawl is 522 kg, including shrimp and other fish. Catch composition is mainly *udang dogol* (*Metapenaeus* spp), *udang putih* (white shrimp), *udang windu* (jumbo-tiger prawn), other shrimp and other fish. Log book data from P.T. Dwibina Utama showed that the catch composition covers 19.59% *Metapenaeus* spp, 13.84% white shrimp, 6.58% jumbo tiger prawn and 60% other shrimp and fishes. Tables 12 and 13 show information on the types of fishing gear and its operation and investment costs. The dominant fishing gear and species that are targeted by this gear in northern Java are presented in Table 14.

Table 12. Types of fishing gear and fishing operations in the northern part of Java in 2000.

Types of fishing gear	Fishing distance from port (nm)	Man-power	$days \cdot trip^{-1}$	Fishing days $\cdot month^{-1}$	Fishing months $\cdot year^{-1}$	Catch (kg)	CPUE (kg)	No. of vessels in Northern Java
1. *Payang/Dogol* (Danish seine A)	7	8	2	22	11	421	211	5 473
2. Beach seine	1 - 3	25	1	25	10	714	714	701
3. Mini purse seine	60	34	12	22	11	5 850	488	2 968
4. Monofilament-gillnet	7	4	1	25	10	116	116	8 434
5. Gillnet (JIT)	3 - 12	7	4	25	11	360	90	4 464
6. *Bagan tancap* (Stationary lift-net)	1 - 3	3	1	25	10	114	114	1 244
7. *Cantrang* (Danish seine C)	3 - 6	7	2	25	11	960	480	2 598
8. Bottom - longline	30	5	7	22	11	655	116	844
9. Large purse seine	100 - 400	39	30	24	10	32 168	1 072	297
10. Shrimp trawl	400 - 500	17 - 18	60	28	10	14 044	234	6306
11. *Arad* (Danish seine B)	7	5	1 - 3	25	10	371	185	5 473
12. Trammel net	12	10	1	30	10	200	200	14 401

Table 13. Investment costs and details of the fishing fleet operating in Northern Java in 2000.

Types of fishing gear	No. of vessels in Indonesia in 1997*	Average capital investment (in mil Rp)	Length of boats (m)	Tonnage (GT)	HP (PK)	Length of gear (m)	Mesh size (inch)	Fuel (t)	Labor (persons)	Fisher age	Education
1. *Payang/Dogol* (Danish seine A)	6 173	39.75	9 - 12	5	25 - 30	140 - 200	1 - 1.5	32.25	8	30 - 40	SD, SMP
2. Beach seine	10 268	28.00	9 - 12	5	25	1 500	1 - 1.75	6.37	25	40 - 50	SD, SMP
3. Mini purse seine	24 200	224.00	15	34	160	810	1	76.20	30	25 - 40	SD, SMP
4. Monofilament - gillnet	24 470	15.50	7	2 - 5	12 - 16	750	1.75	3.50	4	40 - 50	SD, SMP
5. Gillnet (JIT)	58 129	45.00	11 - 12	10	65	4 000	3 - 4	27.00	7	30 - 40	SD, SMP
6. *Bagan Tancap* (Stationary lift-net)	11 738	11.50	6	3 - 4	10	6 x 6	1	1.16	3	40	SD, SMP
7. *Cantrang* (Danish seine C)	N/A	200.00	13.75	20	100	145	1 - 2	41.50	11	25 - 40	SD, SMP
8. Bottom - long-line	24 710	17.50	8	6	25	2 500	–	9.85	5	25 - 40	SD, SMP
9. Large purse seine	9 341	675.00	25	96	325	500	1 - 2	117.00	39	20 - 40	SD, SMP
10. Shrimp trawl	1 387	4 500.00	26	193	597	27.4+warp	N/A	127.54	17 - 18	20 - 40	SMP, SMA
11. *Arad* (Danish seine B)	N/A	70.00	11.24	10 - 15	45 - 65	N/A	1 - 1.5	35	5	30 - 40	SD, SMP
12. Trammel net	30 931	N/A	N/A	55	20	N/A	N/A	45	10	40	SD, SMP

Source: *Directorate General of Fisheries (DGF), 1998; Field studies for Indramayu (West Java), Pemalang- Pekalong-Batatang (Central Java), and Brondong-Tuban (East Java).
1 US$ = 8,005 Rupiah (source: oanda.com)
Note: N/A = Not available.

Table 14. Target species captured by various fishing gear in Indonesia.

Traditional bottom longline	Shrimp trawl	Danish seine	Beach seine	Mini purse seine	Monofilament gillnet and hand line	Gillnet (JIT) and hand line	Danish seine B (Cantrang)	Statutory lift-net	Large purse seine
1. Rays	*Metapenaeus* spp	Drums	Yellowtail	Scads	Pony fishes	Mackerel	Pony fishes	Pony fishes	Scads
2. Shark	White shrimp	Hairtails	Drums	Indian mackerel	Ray	Giant-perch	Drums	Drums	Indian mackerel
3. Red snapper	Tiger shrimp	Finger scale Sardinella	Rays	*Sardinella longiceps*	Sea catfishes	Shark	Deep leatherskin	Eastern little tuna	Trevallies
4. Sea catfish	Other fishes	Barred garfish	Squids	Trevallies	Drums	Red snapper	Trevallies	Shark	Shark
5. Groupers		Common window-shell	Common window-shells		Barracuda	Sea Catfish	*R. sardines*	Hairtails	*Sardinella longiceps*
6. Hairtails		Rays			Silver pomfrets	Grouper	Squid	Squid	Rainbow Sardines
7. Giant perch		Squids			*Metapenaeus*		Cuttlefish	Cuttlefish	
8.		*Metapenaeus*				Rays			
9.		Shark							
10.		Indian halibut							
11.		Black pomfret							
12.		Eastern little-tuna							
13.		Sea catfishes							

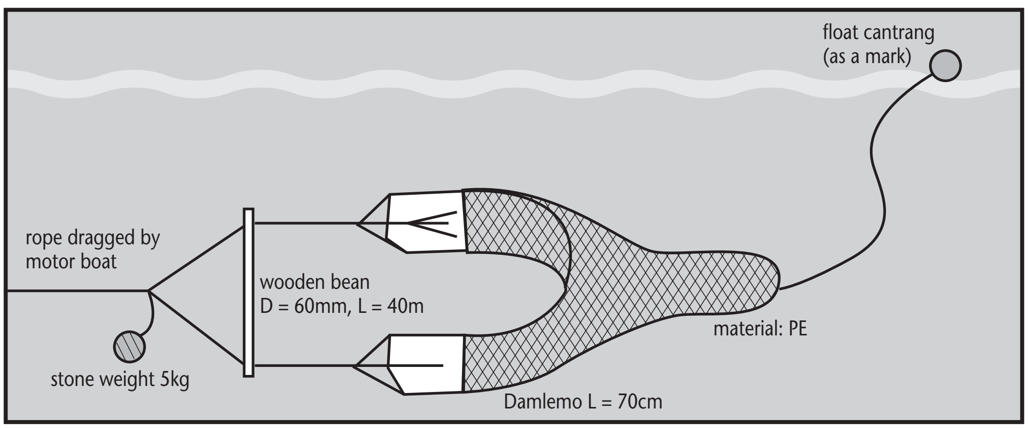
A description of the design and operation of each fishing gear is provided below.

a. *Cantrang* (Danish seine C) and *Dogol* (Danish seine A). The design and construction of the gear are similar to *payang* or *pukat kantong* that use an extra sinker. They encircle the fish school, tightening two edges with ropes and winches, which in turn help to pull out the net during adverse weather.

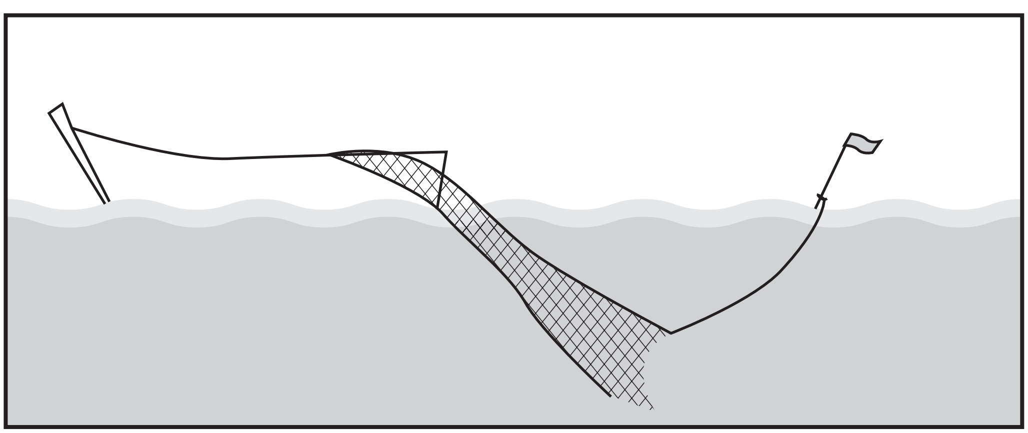
The differences between the trawl operations and the *cantrang* or *dogol* are:

- trawl operations are established in a straight line while *cantrang* or *dogol* encircle the fish school;
- *cantrang* is a modification of *dogol* in which the former utilizes small lengths of wood (± 6 metre length) such as in the beam trawl operation (Fig. 5 and 6);
- *dogols* have 5.5 - 13 GT and 10 - 18 HP engines while *cantrangs* have 15 - 37 GT with 16 - 40 HP engines. In the northern part of Java, the fishers who construct their fishing boats use teak wood and engines made by Dong Feng (China). Mitsubishi, Kubota, and Yanmar are the most popular brands of engine in the fishing villages but most fishers find their prices too expensive.
- *cantrang* or *dogol* boats use compass (diameter 15 - 25 cm) and winch/capstan; crews consist of skipper, engineer, and crew (6 - 7 persons); and
- fish captured by the *cantrang* or *dogol* include shrimp, *gulamah*, *beloso*, *pepetek*, *kurisi*, squid, red snapper and *bawal putih*.

Fig. 5. Danish seine C (*cantrang*) fishing gear used in Indonesia.

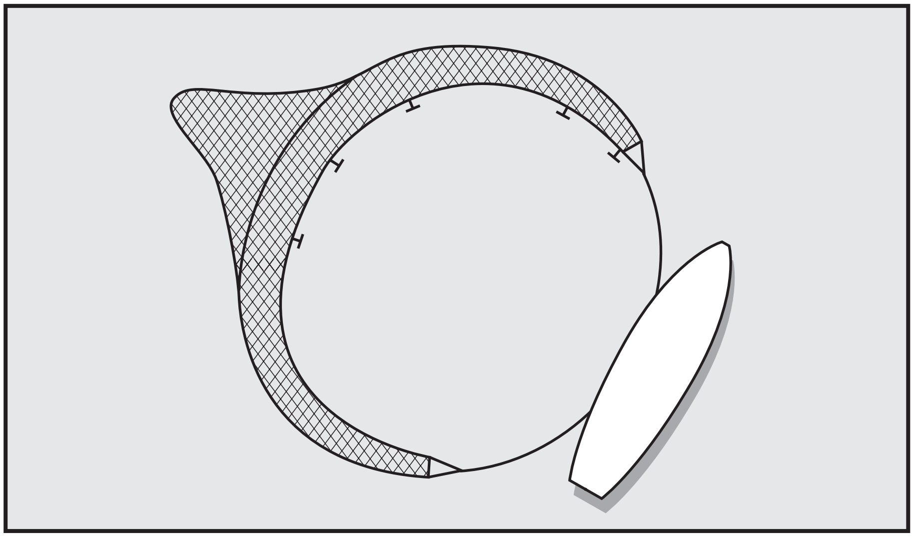


a. assembly of the net.



b. hauling the net

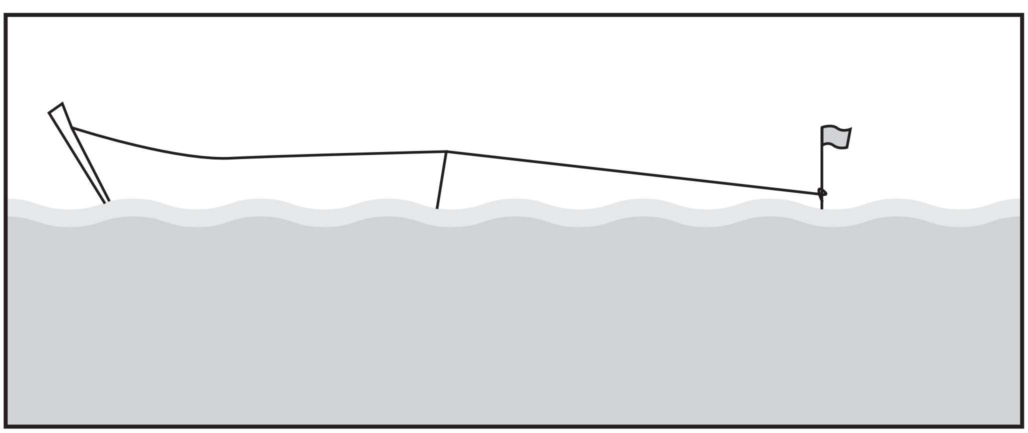
Fig. 6. Danish seine A (*dogol*) encircling the fish school.



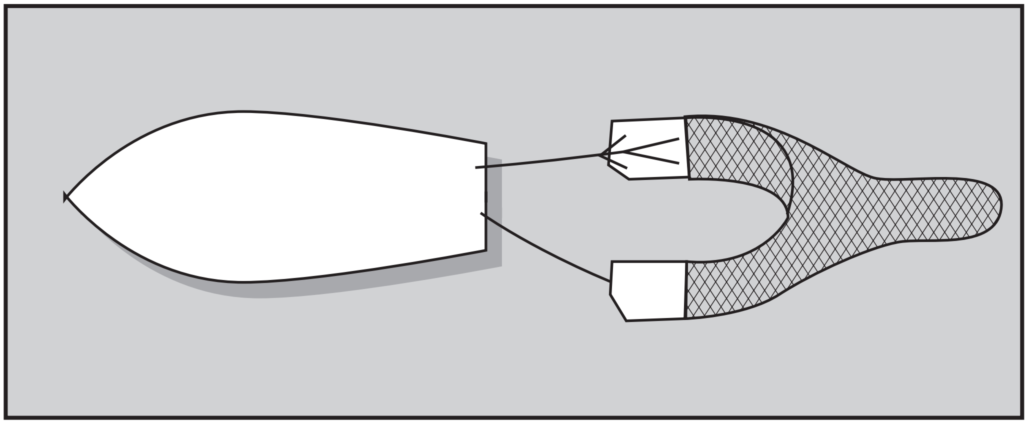
b. *Arad* (Danish seine B). The design and construction of this net is similar to a beam trawl using an extra sinker. When the boat is moving forward, the net will be dredging the bottom thereby capturing the demersal fish (Fig. 7). The size of the vessel is 5.5 - 43 GT with 12 - 25 HP engines (Dong Feng, China) and the body is built of teak. The *arad* boats usually use com pass (diameter 12 - 25 cm) and winch/capstan for pulling the net from the water. The fishing team consists of skipper, engineer and crew (5 persons). The species captured by the *arad* are shrimp, *beloso*, *pepetek*, *kurisi*, *kuniran*, halibut, crab and sea cucumber.

c. *Rawai dasar* (Traditional bottom long-line). The design and construction is almost similar to a traditional long-line which is operated at the bottom of the sea. Vessel size ranges from 10 - 42 GT with engines of 10 - 95 HP (Kubota, Yanmar and Mitsubishi) while the body is of teak wood. The *Rawai* dasar uses compass and the fishing team is comprised of skipper, engineer and crew (6 persons). The fish species captured by this fishing gear are red snapper, groupers, *kurisi*, shark, stingrays, *manyung* and others.

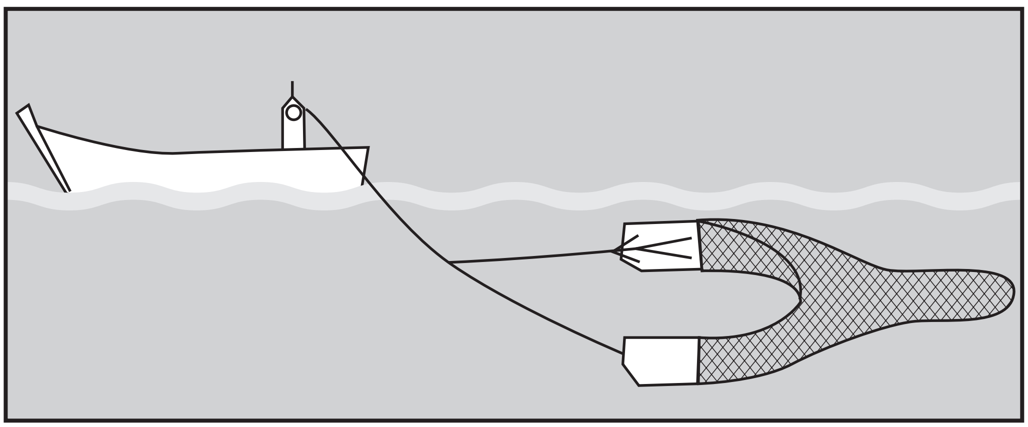
Fig. 7. Danish seine B (*arad*) fishing gear used in Indonesia.



a. Hauling the flag



b. Hauling the net and otter board.



c. Danish Seine B in operation.

Table 15. Summary of information on fishing gear operated in Indonesia in 1999.

Item	*Arad*	*Cantrang*	*Dogol*	Gillnet	*Rawai Dasar*
1. Vessel					
a. size (GT)	5.5 - 43	15 - 37	5.5 - 13	18 - 42	10 - 42
b. engine (HP)	12 - 25 (Dong Feng)	16 - 40 (Mitsubishi, Kubota, Yanmar)	10 - 18 (Dong Feng)	25 - 95 (Yanmar, Dong Feng)	10 - 95 (Mitsubishi, Kubota, Yanmar)
c. compass	Merk Seco O 15 - 25 cm	Seico/Honocon	Seico/ Columbus	Seico/ Honokon	Honokon
d. auxiliary gear	Capstan O 20 cm	Capstan O 25 cm	Capstan O 25cm	Capstan	–
e. winch,	–	Winch, SSB	–	Winch, SSB	–
2. No. of crew					
a. skipper	1	1	1	1	1
b. engineer	1	1	1	1	1
c. crew	3	4	5	5	4

Productivity and Technology Efficiency

Using 92 samples of cross-section data from large- and large scale boats, the Cobb-Douglas production function with the dummy variable for the groups was introduced in order to provide the best-fitted model. The catch per craft per day depends on the following variables: (1) total number of boats/gears operated in the area (JUK), (2) the distance from the fishing ground (JFG), (3) total manpower for each gear (MP), (4) the boat size (GT), (5) the engine size (HP), (6) total volume of fuel consumed (FDAY) and (7) the dummy variable (D1) which captures the differences between large- and small scale boats or the differences between fishing areas or the efficiency differences between gears.

Cobb-Douglas Production Function

$$
\begin{array}{lll}
\text{CPUE} & = & 774.78 * JFG^{-0.1884} * JUK^{-0.31057} * \\
\text{t-test} & & (7.043) \quad (-2.06) \quad (-2.64) \\
 & & MP^{0.747386} * RGTHP^{0.3818} * \\
 & & (6.69) \quad (2.47) \\
 & & FDAY^{0.235585} * EXP^{0.398295\, D1} \\
 & & (3.54) \quad (1.97)
\end{array} \quad (1)
$$

$R^2 = 0.78$; Adjusted $R^2 = 0.76$; F-test = 49.05; n = 92; df = 85

where,

CPUE = catch•craft^{-1}•day^{-1} for all gears; covering two kinds of fisheries namely,
- The shrimp-trawl operated in the Arafura Sea (by assumption) captured 40% shrimp and 60% fish;
- The *payang/dogol*, beach seines, purse seine, monofilament, gillnet, bottom gillnet, trammel net, stationary lift-net (*bagan tancap*), Danish seine C and traditional long-line all operated in the northern part of Java.

JFG = distance of operation between the fishing base to the fishing ground
JUK = total number of boats/gears
MP = total number of manpower/gears
RGTHP = ratio of gross tonnage to horsepower
FDAY = total volume of fuel/day

Dummy variable,
D_1 = 1, if the group is a large scale fishery, using > 30 GT
D_2 = 1, if the group is a small scale fishery, using < 30 GT

Results showed that all variables are statistically significant with F-test at 95% level of significance and an R^2 of 78%. The distance of operations between the fishing base to fishing ground (JFG) and the total number of boats/gears (JUK) show negative results indicating that if the distance from fishing base to fishing ground becomes extensive or farther away, then the catch•craft^{-1}•day^{-1} will decline. Also an increase in the number of boats operating in the same fishing area reduces the catch•craft^{-1}•day^{-1}. On the other hand, the total number of manpower/gears (MP), the ratio of gross tonnage to horsepower (RGTHP), total amount of fuel/day (FDAY) and D_1 (dummy variable = 1, if the group is a large scale fishery, using > 30 GT) are positive, denoting that an increase in manpower of 10% increases the catch•craft^{-1}•day^{-1} by 7.47 t. In addition, an increase in the ratio of GT to HP by 10% raises the catch•craft^{-1}•day^{-1} by 3.82 t. Similarly, an increase in fuel/day by 10% increases the catch•craft^{-1}•day^{-1} by 2.36 t. The positive dummy variable indicates that the catch•craft^{-1}•day^{-1} of shrimp trawl for large scale fishing vessels is greater than that for small scale boats.

From the above model, the two groups of fishing vessels namely, *the large scale boats* (the shrimp-trawl and the large purse seine) and t*he small scale boats* (the *payang/dogol*, beach seine, monofilament gillnet, stationary lift-net, *cantrang*, bottom long-line, set gillnet, and mini purse seine) can be separated as follows.

a. The small scale fishing vessel production function for the average product of effort (CPUE):

$$
\begin{aligned}
CPUE_1 = 774.78 * JFG^{-0.1884} * JUK^{-0.31057} * \\
MP^{0.747386} * RGTHP^{0.3818} * \\
FDAY^{0.235585}
\end{aligned} \quad (2)
$$

b. The large scale fishing vessel production function:

$$
\begin{aligned}
CPUE_2 = 777.28 * JFG^{-0.1884} * JUK^{-0.31057} * \\
MP^{0.747386} * RGTHP^{0.3818} \\
FDAY^{0.235585}
\end{aligned} \quad (3)
$$

These two groups of production function show that the slope for all variables is the same while the intercepts differ. Hence, if the individuals use the same number of inputs, the catch·craft^{-1}·day^{-1} of large scale vessels is greater than the large scale. This may be due to the use of better technology by large scale boats (gross tonnage, horsepower, gear, etc.) compared to small scale.

Both vessel size classes have returns to scale = 0.865881 < 1. This result indicates that both fishing vessels are at the "decreasing return to scale" condition wherein if all inputs of production are increased by 10% then the output of production will increase by less than 10%. This situation is very close to the "flat and mature" condition.

Assuming that the total number of boats (JUK), total number of manpower (MP) and total volume of fuel/day (FDAY) were considered as important variables in the model while others are considered as "*ceteris paribus*", then using the production efficiency analysis the results will be as follows:

a. large scale fishing vessels

$$\frac{MP_{JUK}}{P_{JUK}} = \frac{MP_{FDAY}}{F_{DAY}} = \frac{MP_{MP}}{P_{MP}}$$

$$\frac{0.10308584}{JUK} = \frac{0.00362438462}{FDAY} = \frac{0.24006472}{MP}$$

$$2.3288\ (JUK) = 66.23594\ (FDAY) = 1\ (MP) \qquad (4)$$

b. large scale fishing vessels

$$\frac{MP_{JUK}}{P_{JUK}} = \frac{MP_{FDAY}}{F_{DAY}} = \frac{MP_{MP}}{P_{MP}}$$

$$\frac{0.00207913}{JUK} = \frac{0.00362438462}{FDAY} = \frac{0.08496402}{MP}$$

$$40.87\ (JUK) = 23.44\ (FDAY) = 1\ (MP) \qquad (5)$$

c. combination factors of production at optimum condition.

Table 16 shows that the use of some input variables is not optimal in terms of cost and production, i.e. there is not allocative efficiency. In small scale boats, the fuel/day should be increased while the total number of large scale boats operating in the same fishing areas should be reduced. It is possible that the total number of small scale boats has already exceeded the optimal condition. In large scale fishing vessels, the fuel/day should be augmented for the vessels to reach farther fishing grounds while the number of vessels fishing in the Arafura Sea can also be improved to reach optimal use of the fishery resources.

Table 16. Combination factors for large scale and large scale fisheries in Indonesia.

Item	Combination factor production			Result
	MP	FDAY	JUK	
a. Large scale boats - At optimal condition - Combination input production at this period	 1 1	 66.24 2.72	 2.33 354.62	not optimal either for small- or large scale fishing fleet
b. Large scale boats - At optimal condition - Combination input production at this period	 1 1	 23.44 7.76	 40.87 33.77	

Costs, Earnings and Profitability

Investment Costs

In terms of capital investment, shrimp-trawls and large purse seines require the biggest capital investment. Shrimp-trawl, Danish seine B (*arad*), large purse seine and Danish seine C (*cantrang*) are capital-intensive gear. The payback period usually exceeds 35 months (> 3 years), especially for the shrimp-trawl, gillnet, bottom long-line, Danish seine B (*arad*) and large purse seine gear. Mini purse seine, beach seine, monofilament gillnet and Danish seine A (*payang/dogol*) are less capital intensive and more profitable (benefit-cost ratio higher). The characteristics of each fishing gear are presented in Table 17.

Table 17. Investment costs of the different fishing boats/gear operated in Indonesia in 2000.

Boat/Gear	No. of vessels Indonesia (1997)	No. of vessels North Java	Capital Investment (in million Rp)	Ratio Capital Productivity	Ratio Capital Intensity (Rp/Craft)	B/C benefit/cost ratio	Payback periods (months)
1. Danish seine A (*Payang/Dogol*)	6 173	5 473	3 975	0.36	2 656	1.48	8
2. Beach seine	10 268	701	2 800	0.78	685	1.53	4
3. Mini purse seine	24 200	2 968	22 400	0.45	3 824	1.66	16
4. Monofilament Gillnet	24 470	8 434	1 550	0.48	2 500	1.53	2
5. Gillnet (JIT)	58 129	4 464	4 500	0.15	3 929	1.41	8
6. Stationary lift-net	11 738	1 244	1 150	0.49	2 639	1.45	6
7. Danish seine C (*Cantrang*)	N/A	2 598	20 000	0.51	16 369	1.19	40
8. Bottom long line	24 710	844	1 750	0.28	1 983	1.28	10
9. Large purse seine	9 341	297	67 500	0.35	8 547	1.26	35
10. Danish seine B (*Arab*)	N/A	5 473	7 000	0.31	8 167	1.28	36
11. Trammel net	30 931	14 401	N/A	–	–	1.17	–
12. Shrimp trawl	1 387	–	4 500	0.08	69 450	1.30	78

N/A = not available
1 US$ = 9,725 Rupiah in 2000; source: oanda.com

Cost Structure

The total variable cost of all operations averages 87.68% of the total cost with 67% for the labor cost. The shrimp-trawl, mini purse seine, Danish seine A and Danish seine B vessels operate at further areas, so that they have higher running costs. The shrimp-trawl, Danish seine B, large purse seine and mini purse seine vessels have higher fixed costs since they have more equipment and engine to operate. The beach seine, monofilament gillnet, bottom long-line and stationary lift-net have higher labor costs, with the exception of the large purse seine, which usually operates in areas such as from Pekalongan/Juwana to the South China Sea in the west and Makassar Strait in the east. The total fixed cost is larger than the running cost for these. Fishing vessels with 96 GT and 325 HP engines may be considered as capital intensive. Table 18 shows the cost structures for each type of fishing gear.

Table 18. Cost structure for various fishing gear/boats in Indonesia in 1999.

Items	Fishing Vessel/Gear Indicators										
	Danish seine A	Beach seine	Mini purse seine	Mono filament gillnet	Gillnet (JIT)	Stationary Lift-net	Danish seine B	Bottom Long-line	Large purse seine	Shrimp-trawl	Average
1. Total Variable Cost (%)	94.50	96.26	85.20	93.68	93.60	91.90	85.18	94.22	85.38	57.02	87.68
Running cost	19.38	3.58	23.40	9.25	12.86	14.60	17.64	12.48	12.92	33.10	15.92
Labor cost	70.67	88.13	57.42	79.52	71.20	72.96	63.98	77.92	68.69	20.22	67.07
Share cost	4.45	4.59	14.42	4.63	9.62	4.34	3.56	3.82	3.78	3.70	4.69
2. Total Fixed Cost (%)	5.50	3.71	14.76	6.60	6.32	8.10	14.82	5.78	14.62	42.98	12.32
Total Cost (%)	100	100	100	100	100	100	100	100	100	100	100
In Cash (Rp Million)	141.70	221.21	263.16	58.30	167.58	56.29	226.44	81.85	732.05	3.072	

1 US$ = 7150 Rupiah in 1999; source: oanda.com

Earnings and Profitability

Cost and Return of Fishing Gear in the Northern Part of Java

Costs and returns of *payang/dogol* (Danish seine A), *pukat pantai* (beach seine), mini purse seine, *jaring klitik* (monofilament gillnet), JIT (set gillnet), *bagan tancap* (stationary lift-net), *cantrang* (Danish seine C), *rawai dasar* (bottom long-line) and large purse seine were calculated based on the average values of each different gear in the six districts of the study.

The information varies depending on the season (dry and rainy), however the data were gathered during the dry season. If pooling of cross section and time series were available, the result of the analysis would be more accurate.

Financial results of cost-and-return analysis are reported in Table 19. The earnings after tax (EAT) range from Rp 19 000 000•year^{-1} for the bottom long-line to Rp 160 890 000•year^{-1} for large purse seines. The budget financial analysis was calculated using several assumptions including:

- each fishing vessel has an economic lifetime of ten years and after five years the main engine, auxiliary engine and the gear should be replaced;
- profits diminish by 15% after the sixth year;
- in the tenth year, salvage values are added to the profit where the salvage value is 10% of the capital investment.

Using the above assumptions, the estimated cash flow can be established (Table 19).

With the exception of *cantrang* (Danish seine type C), all fishing vessels are profitable at the interest rate (r) = 27% (Table 20). If the fisheries activities are assumed to have a "medium risk" (risk factor + 10% and the existing interest rate = 27%) then we can conclude that:

1. Danish seine A, beach seine, mini purse seine, monofilament gillnet, set gillnet, stationary lift-net, bottom long-line and large purse seine are profitable and investment feasible (assumption: if boat type is profitable NPV (r = 27%) should be positive and if feasible the internal rate of return IRR > 37%);

2. Danish seine C is not profitable and thus investment not feasible

3. Payback period (PP) showed that Danish seine A, beach seine, mini purse seine, monofilament gillnet, set gillnet, stationary lift-net and bottom long-line were considered as "quick yielding" while others like large purse seines and Danish seine C need longer time periods to recover capital investment.

Table 19. Cost-and-return analysis of demersal gear in the northern part of Java in 1999.

Items	Fishing vessel/gear Indicators								
	Payang/ Dogol	Beach seine	Mini purse seine	Monofilament gillnet	Gillnet (JIT)	*Bagan tancap*	*Cantrang*	Bottom Long-line	Large purse seine
1. Total Variable Cost (million Rupiah)	133.91	213.01	224.32	54.45	156.98	51.73	192.89	77.12	625.05
a. Running cost									
- Fuel and oil	22.99	6.07	53.81	3.28	18.83	1.25	31.63	8.40	79.57
- Ice	1.89	–	3.63	1.16	2.45	–	2.74	0.70	2.88
- Other (kerosene, water, daily repairs and administration cost)	2.58	1.84	4.14	0.95	0.27	6.97	5.58	1.11	12.11
b. Labor cost									
- Total labor (in cash)	73.04	138.32	79.60	35.56	97.68	32.80	116.73	44.62	429.69
- Total labor (in kind)	9.60	36.00	36.00	4.80	8.58	4.35	8.40	6.00	46.80
- Food	17.51	20.63	35.50	6.00	13.6	3.92	19.75	13.16	26.36
c. Share cost									
- traditional taxes and fee	6.30	10.15	11.64	2.70	7.11	2.44	8.06	3.13	27.64
2. Total Fixed Cost (million Rupiah)	7.79	8.20	38.84	3.85	10.60	4.56	33.55	4.73	107.00
a. Depreciation cost	5.10	3.95	31.20	2.40	6.60	1.90	27.50	2.38	80.00
b. Annual repairs and maintenance	2.64	4.20	7.50	1.40	3.90	2.61	6.00	2.35	26.00
c. Annual fishing fees	0.05	0.05	0.14	0.05	0.10	0.05	0.05	0.05	1.00
3. Total Cost (million Rupiah)	141.70	221.21	263.16	58.30	167.58	56.29	226.44	81.85	732.05
4. Total Revenues (million Rupiah)	209.89	338.16	436.82	89.20	236.76	81.39	268.73	104.31	921.33
5. Gross Profit (million Rupiah)	68.19	116.95	173.66	30.90	69.18	25.10	42.29	22.46	1889.28
6. EAT	57.96	99.41	147.61	26.27	58.80	21.34	35.95	19.10	160.89

Table 20. Economic characteristics of the fishing fleet in Indonesia in 1999.

Items	Danish seine A	Beach seine	Mini purse seine	Monofilament gear	Danish seine C	Set Gillnet	Statutory Lift-net	Bottom Long-line	Large purse seine
1. EAT	63.06	103.36	178.81	28.67	65.40	23.24	63.45	21.48	240.89
2. NPV (r = 27%)	129.31	244.637	276.74	60.23	(9.90)	133.45	50.39	40.38	66.27
3. IRR (%)	158	369	78	184	25	145	202	122	31
4. Patback-period (mo)	8	16	16	2	40	8	6	10	35

The Sharing System

The sharing pattern for earnings was almost the same for the different craft-gear, the details of which are provided below.

(Option 1)
Crew share = 50% {Total Revenue - (Running costs + Share costs + Food + Total labor in "kind")}
Owner of gear and vessel gets the same as the crew

(Option 2)
In other places, the crew's share is 40% and the share of the owner of gear and boats is 60%

(Option 3)
For some fishing gear such as Danish seine A (*payang/dogol*), mini purse seine, Danish seine C (*cantrang*) and large purse seine, the owner of the fishing vessel and gear also provides a bonus (5 - 10% out of his share) to the captain and engineer. This is done to show appreciation to the captain and engineer for the profits made each trip. In many areas, after several years of experience on fishing vessels, one can establish oneself as the owner of a brand-new or second-hand fishing vessel.

Cost efficiency and cost effectiveness of fishing vessels

Using annual cost-and-return data, the B/C ratio analysis shows that all fishing vessel types are profitable. However, this calculation is not made over the entire economic-life of the boat, the engineer, and the gear. The B/C ratio value is calculated only for that year where the present value (NPV), internal rate of return (IRR) and payback period (PP) presented for this study are more favourable than the first. Table 21 presents a comparison of the fishing gear in terms of B/C ratio ("annual"- cost efficiency), NPV (total profit of boat's economic-life time), IRR (profit efficiency of boat's economic-life time) and PP capital recovery). Beach seine, stationary lift-net, monofilament gillnet and Danish seine A are cost- and profit-efficient fishing gear while large purse seine and Danish seine C are not.

Results from this study indicated that the large purse seine and Danish seine C are considered as capital-intensive vessels compared to the others. Also, Danish seine C and beach seine are labor-intensive and capital-productive (Tables 21 and 22).

Together with the set-gillnet and shrimp-trawl, the mini purse seine is the least labor productive in contrast to the Danish seine C, which is the most labor productive. The set gillnet is the least capital productive while beach seines and stationary lift-nets are the most capital productive (Table 23).

Table 21. Cost efficiency, profit and capital recovery of the various types of fishing gear in Indonesia (in ratio).

Item	Danish seine A	Beach seine	Mini purse seine	Mono-filament gear	Danish seine C	Set Gillnet	Staturory Lift-net	Bottom Long-line	Large purse seine
B/C analysis	4	2	1	2	9	6	5	7	8
NPV analysis	4	2	1	6	9	3	7	8	5
IRR analysis	4	1	7	3	8	5	2	6	9
PP analysis	4	2	7	1	9	4	3	6	8

Table 22. Cost efficiency and effectiveness of fishing vessels in Indonesia.

No.	Type of Gear	Rank	Capital Intensity (Rp)	Cost Effectiveness	
				Catch/TVC	B/C ratio
1.	*Payang/Dogol* (Danish seine A)	5/4	2 656.00	0.38	1.48
2.	Beach seine	1/2	658.00	0.81	1.53
3.	Mini purse seine	6/1	3 824.00	0.52	1.66
4.	Monofilament gillnet	3/3	2 500.00	0.51	1.53
5.	Gillnet (JIT)	7/6	3 929.00	0.16	1.41
6.	*Bagan Tancap* (stationary lift-net)	4/5	2 639.00	0.53	1.45
7.	*Cantrang* (Danish seine C)	9/9	16 369.00	0.60	1.19
8.	Bottom long-line	2/7	1 983.00	0.29	1.28
9.	Large purse seine	8/8	8 547.00	0.41	1.26
10.	Shrimp-trawl	–	69 450.00	–	1.30

Notes:
1. Capital intensity = investment per person - day
2. Catch landed per variable cost = Catch/TVC
3. Gross revenues/operating cost = B/C ratios
4. Rank in terms of capital intensity and B/C ratios

Table 23. Labor and capital productivities from the various types of fishing gear in Indonesia.

No.	Type of Gear	Labor Productivity (kg/person-day)	Capital Productivity ($kg{\cdot}Rp{\cdot}1000^{-1}$)
1.	*Payang/Dogol* (Danish seine A)	26.38	0.36
2.	Beach seine	28.56	0.78
3.	Mini purse seine	14.35	0.45
4.	Monofilament gillnet	29.00	0.48
5.	Gillnet (JIT)	12.86	0.15
6.	*Bagan Tancap* (stationary lift-net)	38.00	0.49
7.	*Cantrang* (Danish seine C)	68.57	0.51
8.	Bottom long-line	18.72	0.28
9.	Large purse seine	27.49	0.35
10.	Shrimp-trawl	32.50	0.08

Problems of Discarding by Species

In contrast to other fishing nations, Indonesia has few problems in terms of fish discards, because large scale fisheries do not generate by-products or discards. Most of the fishing gear/boats utilize all the fish captured either for family consumption or for commercial purposes. In the case of sharks captured by the traditional bottom long line and gillnet, the fishers use the shark's skin as snack-crackers, the fins for soup gourmet, the bones for traditional medicine, and the meat is salted and dried. In large scale fisheries, where the fishing gear targets only specific fish species (e.g. tuna-long line and shrimp-trawl), discards present a problem. Fortunately, tuna long-liners operate in the Indian Ocean and the shrimp-trawlers operate in the Arafura Sea.

Analysis of the Market Structure and Price of Fish

Fish and fishery products are sold mostly at the landing sites with few provisions for the fisher's family consumption, or sold elsewhere. In the landing places, fish are sorted for three purposes: (1) fresh fish for export, demersal fish and other valuable fish; (2) fresh fish transported to fill the demand in the big cities; (3) fish processed traditionally for local consumption (Fig. 8). Traditional fish processing usually includes less valuable fish such as *peperek* (pony fishes), *ekor kuning* (yellowtail), *tiga waja* (drums), *cucut* (sharks), *pari* (rays), *layang* (scads), *selar* (trevallies), *lemuru* (sardinella), *kembung* (Indian mackerel) and others. The main objective of fish processing is to fill the local demand.

Table 24 presents the cross-section data of catch composition and price of fish using the different types of gear and Table 25 provides the Indonesian and English names of some fish species captured in the northern part of Java.

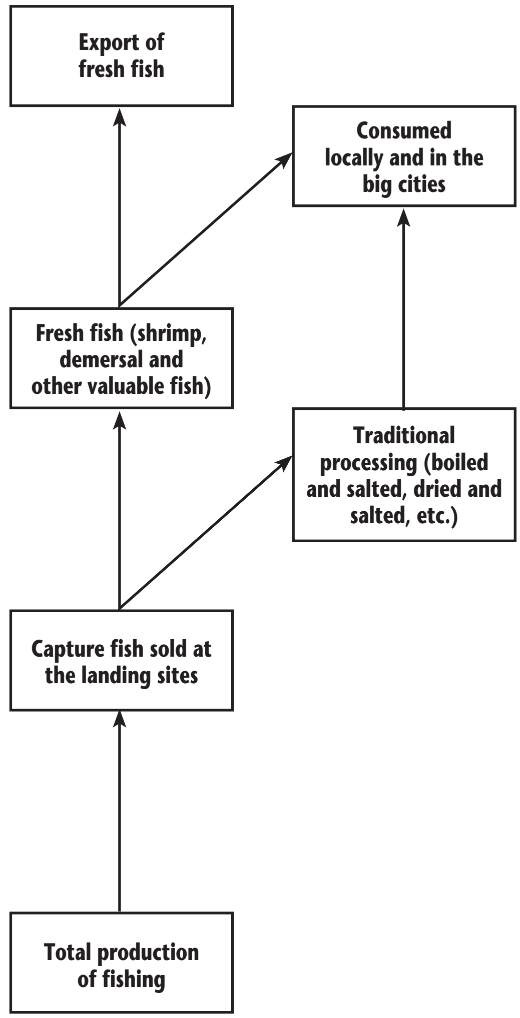


Fig. 8. Marketing system of fish captured in the northern part of Java.

Table 24. Total catch, catch composition and price of fish by type of fishing gear in Java, Indonesia in 2000.

Fish Species	Total Catch (t)·Year^{-1}									Price of fish (Rp·kg^{-1})
	Payang/ Dogol	Beach seine	Mini purse seine	Monofi-lament gillnet	Gillnet (JIT)	*Bagan Tancap*	*Cantrang*	Bottom Long-line	Large purse seine	
Ikan Sebelah	720						2 400			5 000
Ikan Lidah							2 400			5 000
Peperek				7 440		12 480	67 800			1 125
Manyung	480			2 880	500			2 229		5 850
Bambangan					1 532			3 086		8 000
Kerapu					510			2 160		8 850
Kakap					7 950			206		10 650
Ekor Kuning		147 360								1 875
Tiga waja	15 840	12 000		2 880		5 040	12 000			2 075
Cucut	1 680				2 701		6 000	6 034	2 400	4 050
Pari	4 080	9 600		6 000	701		4 680	7 577		2 250
Bawal Hitam	960									6 875
Bawal Putih				1 600					400	8 000
Alu-alu				2 880					800	2 000
Layang			40 000						180 864	3 150
Selar			16 220			1 200			17 600	3 900
Talang-talang						3 120				1 800
Julung-julung	4 800									2 100
Teri						2 400				12 000
Japuh						960			800	2 500
Tembang	5 520									2 500
Lemuru			20 780						4 800	2 000
Kembung	720		40 000						49 440	5 150
Tenggiri					11 685		600		160	10 300
Layur	6 960					240	6 000	1 166		3 250
Tongkol	480						10 920			6 000
Rajungan						480				7 500
Dogol (udang)	2 640									22 000
Simping	2 880	1 200		2 160						5 500
Cumi-cumi	2 880	1 200		1 920		720	2 400		80	7 300
Sotong						720				8 000
TOTAL	50 640	171 360	117 000	27 760	25 534	27 360	115 200	22 458	257 344	

1 US$ = 9725 Rupiah in 2000. Source: oanda.com

Table 25. Indonesian and English names of some fish species in Northern Java.

No.	Indonesian Name	English Name
1.	*Ikan Sebelah*	Indian halibuts
2.	*Ikan Lidah*	Fourlined tongue sole
3.	*Petek/Peperek*	Pony fishes, ship mounts
4.	*Manyung*	Sea catfishes
5.	*Bambangan*	Red snapper
6.	*Kerapu*	Grouper
7.	*Kakap*	Giant perch
8.	*Ekor Kuning*	Yellow tail
9.	*Tiga waja*	Drums
10.	*Cucut*	Shark
11.	*Pari*	Rays
12.	*Bawal Hitam*	Pomfret black
13.	*Bawal Putih*	Pomfret silver
14.	*Alu-alu*	Barracuda
15.	*Layang*	Scads
16.	*Selar*	Trevallies
17.	*Talang-talang*	Deep leatherskin
18.	*Julung-julung*	Berred garfish
19.	*Teri*	Anchovies
20.	*Japuh*	Rainbow sardines
21.	*Tembang*	Fringescale sardinella
22.	*Lemuru*	Sardinella
23.	*Kembung*	Indian mackerel
24.	*Tenggiri*	Mackerel
25.	*Layur*	Hair tails
26.	*Tongkol*	Eastern little tuna
27.	*Rajungan*	Swimming crabs
28.	*Dogol (udang)*	Crustacea (*Metapenaeus*)
29.	*Simping*	Common window shell
30.	*Cumi-cumi*	Squids
31.	*Sotong*	Cuttlefish

Bioeconomic Analysis of Demersal Fishing in the Northern Part of Java

Rationale - Bioeconomics Concepts: Optimal Utilization of the Fishery Assets

The best use of fishery resources as economic assets was determined. Based on Surplus Yield models (Schaefer, 1954), there is a certain natural increase F(x) for each level of biomass, and the expression X(t) represents the biomass at time t (see Equation 1). F(x) may also be interpreted as the natural surplus production and is positive for $0 < x < k$, where k is the natural carrying capacity of the aquatic environment.

$$\partial x / \partial t = F(x) \qquad (1)$$

In accordance with capital theory, F(x) may be interpreted as the rate of investment in the stock of natural capital. Biological equilibrium is the condition where F(x) = h(t) and h(t) is the rate of withdrawal due to fishing. Hence, the basic resource management problem is to determine the rate of withdrawal, h(t), that will optimize the benefits from the fishery resources. To do this, assume a specific form of the harvest function by employing the model below. Equation (2) is the sustainable yield equation which implies the equality of Y_t and F(x).

$$Y_t = a\,E_t - b\,E_t^{\,2} \qquad (2)$$

where

E_t is the fishing effort per unit time

Y_t is the corresponding catch or yield from the resource or the rate of harvest

The Schaefer model implies that yield increases with fishing effort until it reaches a maximum, and then declines as effort is further increased. The Schaefer model may be transformed into the following form:

$$(Y_t / E_t) = CPUE = a - b\,E_t \qquad (3)$$

Equation (3) means that the CPUE (catch per unit effort) is a linear function of effort where maximum yield is,

$$E_{t\,(msy)} = \frac{\{\ a\ \}}{2b} \qquad (4)$$

$$Y_{t\,(msy)} = a\,\{ a/2b \} - b\,\{ a/2b \}^2$$

Suppose a (constant) price of output, p, cost of fishing effort, $c(E_t)$ and net return from the use of the resources may be represented by fishing profits, π.

$$\pi = p.(a E_t - b E_t^2) - c(E_t)$$

The optimal rate of harvest may be denoted by,

$$\partial\pi / \partial Et = p.(a - 2 b E_t^*) - c = 0 \qquad (5)$$

The value of E_t * is the optimal fishing effort that maximizes the differences between marginal revenues and marginal costs of effort. However, this will only occur if the fisheries resource is dictated by "sole owner" conditions, wherein the individual chooses the level of effort that will maximize profits. In reality however, fisheries resources are open-access. This Open-Access Equilibrium can be denoted by Equation (6).

$$\pi = p.(a E_t - b E_t^2) - c(E_t) = 0 \qquad (6)$$

The value of $E_{t\ (OAE)}$ is the level of fishing effort at open-access equilibrium where the profit from the fishery is zero or at "break-even point" (BEP).

Objective

When the goal of sustainable fishery management is to maximize the yield of the resource where the state of *responsible fisheries* occurs, then the society will choose $E_{t,\ (MEY)} < E_{t^*\ (existing)} < E_{t,\ (msy)}$, this $E_{t^*,\ (existing)}$. This represents the precautionary approach where management approaches can be applied in two situations. Firstly, control can be applied to the total amount of effort at $E_{t^*,\ (existing)}$ to retain the yield at a sustainable level for the future or secondly, the total amount of effort at $E_{t^*,\ (existing)}$ that will maximize the profits can be limited. In other words, the $E_{t^*,\ (existing)}$ will ensure that both yield and profit are at a sustainable level.

The participation of the government and the community through community-based fishery management and other schemes is important in order to attain the above conditions. When $E_{t^*,\ (existing)}$ is known, policies and regulations should be established by the government. These policies should then be applied to all sectors involved in the fishing industry. Furthermore, monitoring, control, surveillance (MCS) and enforcement should be developed to prevent illegal fishing.

Review of the Fisheries Legal Environment

In order to attain the objectives of fisheries management, the government of Indonesia has issued several laws and regulations, namely:

1. Act No. 9, 1985 - enacted to deal with all aspects of fisheries;
2. Ministerial Decrees No. 277, 1986 on fishing permits in Indonesian waters and EEZ;
3. Presidential Decrees No. 39, 1980 on banning the use of trawls from Indonesian waters;
4. Presidential Instruction No. 11, 1982 on extending the trawl ban throughout all Indonesia waters except the Arafura Sea;
5. Ministerial Decree No. 995/Kpts/Ik-210/0/1999 on potential of the resources and total allowable catch (TAC) in Indonesian waters;
6. Ministerial Decree on Monitoring, Controlling, Surveillance and Enforcement;
7. Ministerial Decree on fishing zones for Indonesian waters.

The results of this study, together with the application of the laws and regulations including the MCS and enforcement, will support fisheries management of demersal resources, so that their health and sustainability is maintained.

Framework and Estimation

Model Specification

Application of the surplus yield production model will correspond to three specification models that can be used to determine the sustainable use of fishery resources.

1. (Schaefer, 1954) Model
   $Y_t = a_1 E_t - a_2 E_t^2$
2. (O'Rourke, 1971) and (Anderson, 1977)
   $(Y_t / E_t) = CPUE = b_1 - b_2 E_t + b_3 T$
3. (Fox, 1970) and (Pauly, 1984)
   $Ln\ CPUE = c_1 - c_2 E_t$

where a, b and c are parameters to be estimated

Data: Catch-effort of Traditional Gear (Using Standard Effort Of Danish Seine A):

The time series data of catch-effort using Danish seine A (*payang/dogol*) is presented in Table 26, together with information of the demersal species from 1977 - 1995 using traditional gear like Danish seine B (*arad*), bottom long-line, set gillnet (*jaring insang tetap*) and beach seine (*pukat pantai*) from the regional statistics offices in West Java, Central Java and East Java. This showed that from the average CPUE per gear, the fishing power index (FPI) was as follows: (a) Danish seine A = 1, (b) Danish seine B = 0.822071, (c) set gillnet = 0.242506, (d) bottom long-line = 0.330667 and (e) beach seine = 16.077598.

Model Estimation

Following (Schaefer, 1954), the surplus yield production with a quadratic function was estimated to be:

$$Q_t = 0.092729\, E_t - 0.000000033321\, E_t^2$$
t-ratio: (3.74) (-2.35)

$$+ 5188.068\, T \quad (a)$$
(6.80)

$R^2 = 0.77$; F-test = 26.82

where,
Q_t = total catch of Danish seine A in time Tt ($t{\cdot}year^{-1}$)
E_t = total effort of Danish seine A in time T ($units{\cdot}year^{-1}$)
T = time trend to capture the other variables that were not available in the database

Comparison among the three models namely, (1) the linear CPUE model by (O'Rourke 1971) and (Anderson 1977), (2) the exponential function by (Fox 1970)and (Pauly 1984) and (3) the quadratic function by (Schaefer 1954), indicates that the Schaefer model has the best linear unbiased estimator (BLUE) characteristics. The Schaefer model is statistically significant at 95% confidence levels for t-test and F-test (partial and joint significant test). The algebraic sign of each variable is theoretically sound. The model also shows no serial auto-correlation by the Durbin Watson test (a test statistic designed to detect errors). Therefore, this model is statistically acceptable for further economic analysis.

Table 26. Catch and effort data of traditional gear in the northern part of Java in 1977 - 95.

Year	Total standard effort using *dogol* (fishing trip days)	Total yield (t)	CPUE ($kg{\cdot}trip^{-1}{\cdot}day^{-1}$)
1977	1 503 209	78 613	52.30
1978	1 247 665	87 665	70.26
1979	1 853 206	100 033	53.98
1980	1 534 702	104 790	68.28
1981	1 545 191	77 602	50.22
1982	1 144 009	92 306	80.69
1983	1 511 106	86 080	56.97
1984	1 563 211	86 821	55.54
1985	1 615 316	92 10	57.21
1986	1 881 144	98 189	52.20
1987	1 679 298	112 023	66.71
1988	1 477 452	111 045	75.16
1989	1 110 388	112 034	101.81
1990	1 275 347	125 777	98.62
1991	1 184 138	134 047	113.20
1992	1 180 475	143 125	121.24
1993	1 069 277	168 233	157.34
1994	1 473 618	179 538	121.84
1995	1 342 004	186 195	138.75

Source: Directorate General of Fisheries (DGF), 1998.
Note: *dogol* = Danish seine A

From the model (a) the total effort and total yield can be calculated at maximum sustainable yield (MSY) as follows,

$E_{t\,(msy)}$ = 1 391 434 trip-days of Danish seine A/annum

$Q_{t\,(msy)}$ = 116 187 $t{\cdot}year^{-1}$

The total allowable catch (TAC) and the important point where the code of conduct for responsible fisheries (CCRF) can be allocated according to the precautionary approach is estimated at,

$E_{t\ (TAC)}$ = 1 252291 trip-days of Danish seine A/ annum

$Q_{t\ (TAC)}$ = 115 542 t·year^{-1}

On average 5 218 units of Danish seine A can operate for 240 days annually in the northern part of Java.

The open-access equilibrium (OAE) point is where the total revenue equals total cost of Danish seine A operation, or where there is an absence of economic profit. The calculated result was as follows,

$E_{t\ (OAE)}$ = 1 435 746 trip-days of Danish seine A/ annum

$Q_{t\ (OAE)}$ = 116 122 t·year^{-1}

At open-access equilibrium, there would be 5 982 units of Danish seine A gear operating in the area.

The optimum economic yield (OEY) point can be found whenever the marginal revenues equal the marginal cost of effort for the Danish seine A operation. Suppose the price of fish that was captured by Danish seine A is on the average equal to Rp 7 300 000·t^{-1}. The average cost of effort is the total cost per boat (or the opportunity cost of the vessel) divided by the total trip-days per boat. Annually, this equals Rp 590 416.67·trip-day^{-1}.

TC = 590 416.67 * E t

TR = 7 300 000 * Q t

The result will be,
$E_{t\ (OEY)}$ = 67 108.3 t annually

$Q_{t\ (OEY)}$ = 177 812 trip-days of Danish seine A

Where
TC = total cost
TR = total revenue

Analysis of Management Objectives and Schemes

a. The relationships between total allowable catch (TAC) with maximum sustainable yield (MSY) and optimum economic yield (OEY) with open-access equilibrium (OAE) are given below.

- Table 27 explains the relationship between these points (OEY, TAC, MSY and OAE), the changes of total yield, total effort, total number of vessels (standard *dogol*), which is calculated from total effort divided by total trip-days/boat annually, CPUE, the changes of profit/boat annually and the changes of profit after income taxation and ad valorem taxation in each condition.
- Fig. 9 explains the relationships between total yield, total effort, marginal cost (derived from the derivative of cost to quantity) and average cost (derived from total cost divided by quantity).

Results of the calculations can be seen in Table 28. Prior to 1988, the total amount of effort is relatively high, so that on many occasions the mean total effort is larger than total effort at MSY or OAE level. In the last five to eight years, the total amount of effort has been smaller than E_t, MSY.

b. Suppose income taxation of 2.5 % is introduced, then theoretically the result will be,

$$\pi = (TR - TC) * (1 - 0.025)$$

The producer should not pay tax if the firm experiences loss of profits. If the price of output is a fixed number, then the output will not change when a tax is introduced.

c. Suppose an ad valorem tax of 2.5 % is introduced, then theoretically the outcome will be,

$$\pi = TR * (1 - 0.025) - TC$$

The producer should pay the tax even though the firm has experienced loss of profits. If the price of output was estimated through the demand function where the 'price' and 'output' fluctuated continuously, then whenever a tax is introduced by the government, the price of output will increase and the quantity of output will decline. The ad valorem tax has a bigger impact since increasing price will reduce the total quantity of supply and profits of the industry. Therefore, in the long run, the producer will reduce the total amount of effort. The result can be seen in Table 27.

d. Suppose there are several changes in the "existing total effort". Alternative 1 will be when the existing total effort ($E_{t,\ existing}$) is the mean of total effort during 1977 - 95. Alternative 2 is

when $E_{t,\ existing}$ is the mean of total effort for the last ten years (1985 - 95). Alternative 3 is when the $E_{t,\ existing}$ is the mean of total effort for the last five years (1990 - 95). Alternative 4 is whenever the $E_{t,\ existing}$ is the mean of total effort for the last five years - given income taxation at 20%.

Results from Table 27 show that:

i. profit after income taxation declined up to the point where $E_{t,\ OAE}$ is approaching and at $E_{t,\ OAE}$ profit has disappeared;
ii. at $E_{t,\ existing} > E_{t,\ OAE}$, (Alternative 1), the industry suffers from loss of profits;
iii. profit after ad valorem taxation will place more burden on the industry. The calculation shows that "profit after income taxation" has a bigger impact compared to "profit after ad valorem taxation". For example, at $E_{t,\ OAE}$, profit after income taxation was zero but ad valorem taxation reduces the zero profit to Rp 3 540 785. Comparing Alternatives 3 and 4, if the income taxation level increases to 20% then the result of "profit after income taxation" will be equal to "profit after ad valorem taxation".

The fishing industry would be better off if the government introduced income taxation rather than ad valorem taxation.

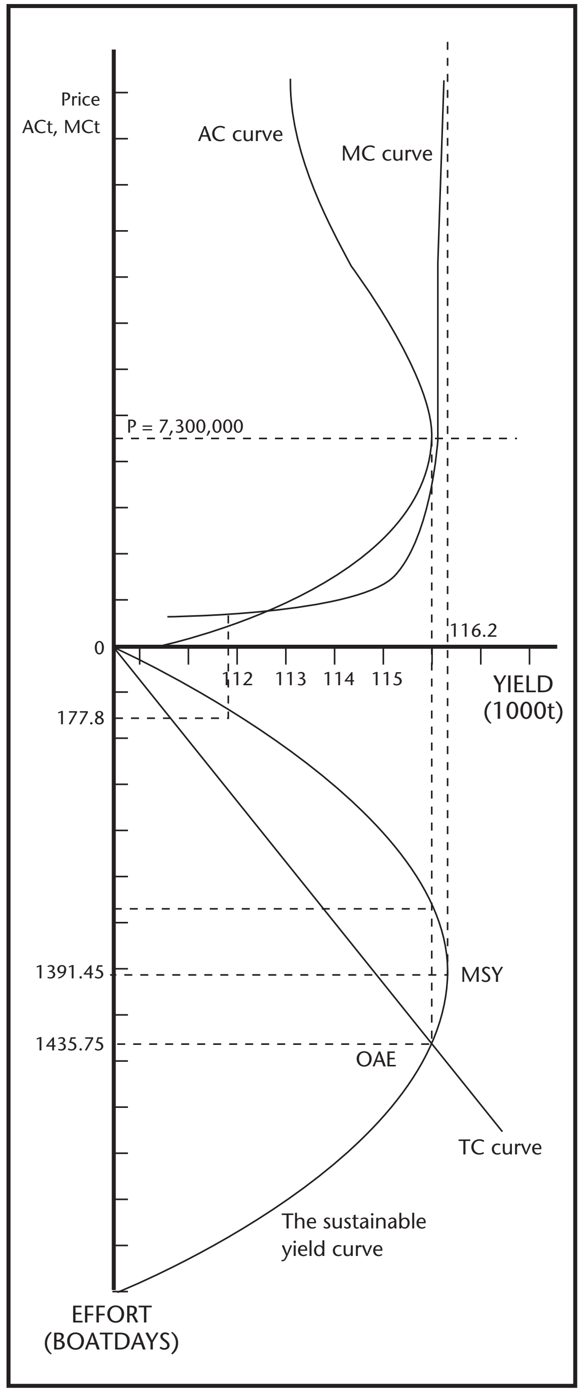


Fig. 9. Relationship between efforts, yield, MC_t, AC_t, P_t.

Table 27. The relationship between MSY, OEY, and OAE points.

No.	Items	Qt ($t \cdot year^{-1}$)	Et (trip-days)	Total number of boats (units)	CPUE ($kg \cdot trip\text{-}day^{-1}$)	Profits* $boat^{-1} \cdot year^{-1}$ (Rp)	after 2.5% taxation* Income taxation (Rp)	Ad valorem taxation
1.	Optimum Economic Yield (OEY) points	67 108.30	177 812	3 568	377.41	519 522 054	506 534 003	502 991 761
2.	Total Allowable Catch (TAC)	115 543	1 252 305	5 218	92.27	19 946 991	19 448 316	15 915 613
3.	Maximum Sustainable Yield (MSY)	116 188	1 391 450	5 798	83.50	4 594 423	4 479 563	934 699
4.	Open Access Equilibrium (OAE)	116 122	1 435 746	5 982	80.88	–	–	(-3 540 785)
5.	Existing Total Effort (Alternative 1) (Alternative 2) (Alternative 3) (Alternative 4)	114 554 116 168 115 520 115 520	1 435 882 1 367 315 1 249 903 1 249 903	6 058 5 697 5 208 5 208	78.79 84.96 92.42 92.42	(-3 656 743) 7 149 919 20 219 839 20 219 839	0 6 971 171 19 714 434 16 171 843**	(-7 110 923) 3 428 671 16 171 843 16 171 843

*** Assuming price of output (P_{Qt}) and AC of effort, or q is a fixed number; calculation, results, using the Schaefer model, data price of output (P_{Qt}), average cost of effort (q).**

**** When approaching alternative 3 with 20 % income taxation.**

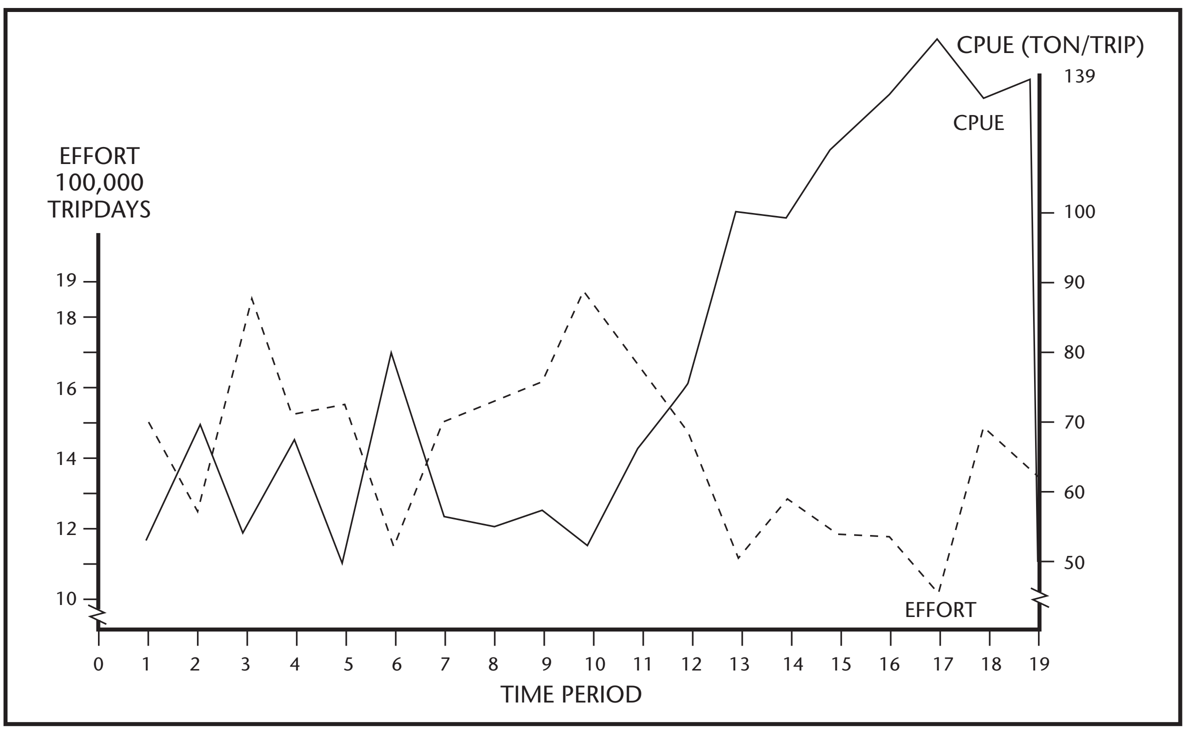


Fig. 10. Relationship of CPUE and Effort to Time period.

Table 28. The relationships between effort, yield, MC_t, AC and P.

No.	Total effort (1 000 trip-days)	Yield (t)	MC_t	AC	P	Items
1.	177.81	67 108.3	7 299 963	1 564 370	7 300 000	OEY
2.	1 069 30	112 729	27 499 375	5 600 445	7 300 000	E_t,'93
3.	1 110 39	113 555	31 519 667	5 773 350	7 300 000	E_t,'89
4.	1 144 00	114 147	35 801 104	5 917 253	7 300 000	E_t,'82
5.	1 180 48	114 705	42 001 570	6 076 240	7 300 000	E_t,'92
6.	1 249 90	115 520	62 593 469	6 388 174	7 300 000	Average E_t,
7.	1 252 31	115 543	63 700 474	6 399 217	7 300 000	TAC
8.	1 391 45	116 188	Infinity	7 070 741	7 300 000	MSY
9.	1 435 75	116 122	Negative	7 299 98	7 300 000	OAE
10.	1 503 21	115 771	Negative	7 666 171	7 300 000	E_t,'77
11.	1 545 19	115 771	Negative	7 880 263	7 300 000	E_t,'81
12.	1 615 32	114 517	Negative	8 328 125	7 300 000	E_t,'85
13.	1 679 30	113 426	Negative	8 741 255	7 300 000	E_t,'87
14.	1 853 21	109 082	Negative	10 030 675	7 300 000	E_t,'79
15.	1 881 15	108 197	Negative	10 265 186	7 300 000	E_t,'86

Following (Anderson 1977), MC_t can be calculated as,

$$MC_t = \frac{q}{\{ (b)^2 - 4 * (a) * (c) \}^{½}}$$

$$= \frac{590\ 416.67}{\{ (0.092\ 729)^2 - 4 (0.000\ 000\ 033\ 321 * (Q_t - 51\ 673.67) \}^{½}}$$

$$= \frac{590\ 416.67}{\{ (0.008\ 598\ 667\ 441) - 0.000\ 000\ 133\ 284 * (Q_t - 51\ 673.67) \}^{½}}$$

$$AC_t = \frac{TC}{Qt} = \frac{590\ 416.67 * E_t}{0,092\ 729\ E_t - 0,000\ 000\ 033\ 321\ E_t^2 + 518\ 80.67\ T}$$

Comparison with Other Demersal Resource Potential Studies

a. At a similar location in the northern part of Java and southern Kalimantan, studies conducted by Martosubroto et al. (1997) and Badrudin et al. (1997) showed similar results. In the northern part of Java $Q_{t,(msy)}$ = 116 187 t•year^{-1} with an average landing of 115 520 t while the $E_{t,(msy)}$ = 1 391 450 trip-days and the average total effort equals 1 249 903 trip-days (Alternative 3). These figures indicate that the demersal fisheries in the northern part of Java are still below the MSY level where the $E_{t,OAE} > E_{t,MSY} > E_{t,existing.}$ These conditions imply that demersal fisheries in the northern part of Java was still profitable since $E_{t,existing} < E_{t,OAE}$. Given the 2.5% income taxation level, annual profit/boat equals Rp 19 714 343, and at the 2.5% ad valorem taxation level, annual profit/boat declines to Rp 16 171 843.
b. Other studies done by Martosubroto et al. (1997) and Badrudin et al. (1997) illustrate that in the northern part of Java, the average utilization rate is 92% for the demersal resources.
c. For the northern part of Java and southern Kalimantan, studies on the demersal potential resource conducted by Badrudin et al. (1997) and Martosubroto et al. (1997) showed similar results. The quantity of maximum sustainable yield ($Q_{t,MSY}$) ranges from 153 100 - 161 900 t•year^{-1}, with average landings equal to 132 965 t, and the utilization rates are lower - between 82% and 87%, (see Table 25).
d. In the northern part of Java if $E_{t,existing} < E_{t,TAC} < E_{t,MSY}$ then the total amount of effort could be increased by 590 trip-days which is equal to two additional units of fishing vessel (Danish seine A standard).

Conclusions and Recommendations

In 1997, Indonesia fisheries export values were around 17 times higher than import values. Fisheries export commodities are composed mostly of shrimp, tuna and skipjack and demersal fish. The balance of trade (BOT) showed a surplus rising from US$5 994 000 (1970) to US$1 658 827 000, or an annual increase of 10.25%. The future of fisheries is promising. In 1998, the DGF introduced PROTEKAN 2003, an export program.

In the small scale fishery, the dominant fishing gear is hook-and-line (40%), gillnet (30.6%), traps (10%), seine net (5.84%), lift-net (5.80%), purse seine (1.34%), shrimp net with BED (0.04%) and other gear (7.3%). The vessels used are (i) non-powered boat (49.4%), (ii) with outboard engines (22.3%), and (iii) with inboard engines (16.8%). The inboard engines could be further divided into sizes: (a) between 5 - 10 GT (14%), (b) 11 - 30 GT (1.3%), (c) 31 - 100 GT (1.2%), and (d) >100 GT (0.3%). Since small scale fishery activities are limited to the coastal areas, over-fishing occurs in the Java Sea.

In terms of production and technology efficiency, the combined inputs of manpower (MP), total fuel/day and total number of vessels (JUK) are not optimal either for small- or large scale vessels. For large scale fishing vessels (< 30 GT), the amount of fuel/day should be increased while the total number of boats should be reduced. In large scale fishing fleets (> 30 GT), fuel/day should be increased while the total number of fishing fleets (purse seine in the South China sea/Masalembo-Matasiri and shrimp-trawl in the Arafura sea) should be increased. If the volume of fuel/day either for small- or large scale fishing vessels is increased, then these fleets must fish offshore and in larger fishing areas.

On average, labor costs were the dominant expenditures except in shrimp-trawling, where total fixed costs are the dominant expenditure. Note however, that this kind of vessel is the most capital-intensive fishing vessel while cantrang (Danish seine C) may be regarded as the most labor-intensive vessel.

Budget analysis showed that almost all vessels except *cantrang* (Danish seine C) were profitable during the relevant period and at prevailing interest rates (r = 27%). Assuming that fisheries activities have a medium risk factor of 10% and the existing interest rate is 27%, then beach seine, stationary lift-net, monofilament gillnet, Danish seine A and set gillnet are profitable and feasible for investment.

In large scale fisheries, the operations do not entail discarding the by-catch product. In the northern part of Java, most of the fish captured are utilized either for family consumption or for commercial purposes.

For traditional long-line and gillnet, where accidental capturing of sharks occurs, fishers utilize the skin for snack crackers, the fin for "soup-gourmet", the bones for Chinese traditional medicine and the meat is salted and dried and consumed locally.

Problems of by-catch products might occur in the commercial tuna long-liner and shrimp-trawler fisheries but these fisheries operate away from the northern part of Java (i.e. in the Arafura Sea and Indian Ocean).

The Schaefer surplus yield production model, applied to *dogol* (Danish seine A) indicates that the existing total effort in inshore waters is smaller than the total effort at MSY (or $E_{t,OAE} > E_{t,MSY} > E_{t,existing}$ and $Q_{t,MSY} > Q_{t,existing}$). Therefore, on average, profits of the industry show a positive annual response.

At the maximum sustainable yield, the total existing number of fishing vessels could expand from 5 208 units to 5 797 units, so that the CPUE would be reduced from 92.42 $kg \cdot day^{-1}$ to 84 $kg \cdot day^{-1}$. At the same yield level, if 2.5% income taxation is introduced by the government to the industry then on the average, the $profit \cdot boat^{-1} \cdot year^{-1}$ might decline from Rp 4 594 425 to Rp 4 479 565. At OAE, income taxation cannot be introduced, since the industry shows no profit at that level.

Other studies (Table 29) showed that during the period of 1991 - 2000, the average utilization rate of the demersal fishes was 92% while this study obtained a utilization rate almost approaching the MSY level.

For future studies, simultaneous equations which integrate the Schaefer, demand function, production technology, taxation policy and the feasibility study constraints, should be used in one general model in order to incorporate the endogenous variables whenever the government policy and the exogenous variables change. This is called modeling in system thinking and system analysis, and might be done to model all parameters affecting demersal fisheries.

Table 29. Demersal resource studies in the Java Sea, Indonesia.

No.	Location	Model	$Q_{t,MSY}$ (t)	$E_{t,MSY}$ (effort)	Average landings (t)	Utilization rates (%)	Average existing total effort (trip-days)	Authors
I.1.	Northern part of Java and Southern Kalimantan	Schaefer	153 100	–	132 965 (1995)	87	–	Badrudin et al. (1997)
2.	Northern part of Java and Southern Kalimantan	Schaefer	161 900	–	132 965	82	–	Martosubroto et al. (1997)
II.1.	Northern part of Java	Schaefer	94 700	–	87 240 (1989)	92	–	Martosubroto et al. (1997)
2.	Northern part of Java	Schaefer	116 100	–	87 240	75	–	Badrudin et al. (1997)
2.	Northern part of Java, Southern Kalimantan, Eastern Sumatra	Schaefer	367 100	–	–	–	–	Badrudin et al. (1997)

Sources: Badrudin et al. 1997 Widodo et al. 1998.

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An Overview of the Socioeconomic Status of Fisheries in Malaysia

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Abstract

Fish production in Malaysia increased steadily at 4.5% per annum from 801 000 t in 1985 to 1 280 906 t in 1997. Most of the production was contributed by marine capture fisheries, amounting to 1 168 973 t (91% of total production) in 1997, while the rest (132 700 t or 8%) came from inland fisheries and aquaculture. About 72% of the marine landings, or 837 574 t, were from Peninsular Malaysia while the rest were from the states of Sabah, Sarawak, and the Federal Territory Labuan. Marine fisheries thus contributed significantly in terms of employment in Peninsular Malaysia compared to Sabah and Sarawak.

In 1997 the value added by the fisheries sector was estimated at about RM2 million (US$0.71 million at 1 US$ = RM2.82), which represents about 1.5% of gross domestic product (GDP) or 11.1% of the agricultural GDP. Manufacturing, services and construction sectors are the other contributors to GDP in Malaysia. Fisheries net export earnings reached a negative value (-RM39.6 million or US$14.04 million) because Malaysia was a net importer of fish in terms of both quantity and value in 1997. Furthermore, the number of fishers decreased at a rate of 2.2% per annum from 102 900 in 1985 to 82 200 in 1995. In 1997, there were 79 616 fisherfolk in Malaysia and this constituted only about 1% of the total employment in the country. With declining catch and a higher incidence of poverty among the fishing households, fishers, particularly the younger ones, are attracted to better job opportunities in other sectors such as manufacturing.

Fish and fish products comprise about 60% of total animal protein consumed in the country (compared to poultry, beef and pork), a rate much higher than in other Asian countries. Per capita annual consumption of fish increased from 9.42 kg in 1960 to 23.05 kg in 1989, and further to 39.1 kg in 1995. This is expected to rise to 56 kg•capita•annum^{-1} in 2010.

Fishing operations in Malaysia can be classified into commercial and non-commercial (traditional). Trawl nets, fish purse seines, shrimp trawl nets and anchovy purse seines are classified as commercial gear, while drift nets and other traditional gear such as hook and lines, traps and lift nets are classified as non-commercial. About 63% (15 611) of fishers are involved in non-commercial (traditional) fishing and the rest in commercial operations.The majority of traditional fishers are involved in

other economic activities such as farming, contract work, retailing and tourism.

Due to limited fisheries resources, the number of registered fishing vessels decreased from 22 026 units in 1980 to 14 211 units in 1997 on the West Coast of Peninsular Malaysia. Commercial fishing vessels are generally larger than 25 GRT (gross registered tonnage) with engine capacities up to 180 HP, while traditional fishing vessels are generally less than 15 GRT with engine capacities less than 18 HP. Normally commercial fishing boats use modern navigational aids like Geographic Positioning Systems (GPS) and are fitted with Refrigerated Sea Water (RSW).

The capital investment for a trawler and purse seiner of 25 - 69.9 GRT was RM100 000 in 1989, including the boat hull, engine, gearbox, net and accessory equipment. Annual net profit derived from a 25 - 39.9 GRT trawler in 1989 was RM36 520, while that from a 40 - 69.9 GRT trawler was RM43 601. For the fish purse seine, 25 - 39.9 GRT and 40 - 69.9 GRT vessels made net profits of RM40 102 and RM63 562 respectively. In terms of productivity efficiency, the larger vessels, trawl and purse seine (40 - 69.9 GRT) are more efficient than the smaller fleet (25 - 39.9 GRT). Labor productivity for large trawls is 219 kg per person-day compared to the smaller trawl of only 129 kg•person-day^{-1}. For the purse seine fishery, large vessel labor productivity is 69 kg•person-day^{-1} and for the smaller vessel only 53 kg•person-day^{-1}.

The government has decided to reduce the number of trawl vessels especially those operating in inshore areas, and to encourage fishers to explore new areas in the offshore waters. In order to conserve fishery resources, the government has tried to provide incentives through tax deductions for 'pioneer status', investment tax allowances, tax exemptions for imports and a sales tax on fishing machinery, raw materials and equipment.

Socioeconomic Profile

Review of the Status of Fishery Resources

The fishery sector in Malaysia plays an important role with regards to the generation of income, employment, foreign exchange and the supply of protein, particularly to the rural population. Fish production in Malaysia increased steadily at 4.5% per annum from 801 000 t in 1985 to 1 241 000 t in 1995. During this period, marine capture fisheries registered a production growth of 4.0% per annum from 746 000 t in 1985 to 1 108 400 t in 1995, while aquaculture registered a growth rate of 9.2% per annum, from 55 000 t to 132 700 t.

Landings from marine capture fisheries were 1 168 973 t or 91% of total production in 1997 while production from aquaculture and inland fisheries was 111 933 t or 9%. Within the marine capture fishery, production from the inshore fishery was 1 037 887 t, which accounted for 89% of total marine landings while the deep-sea fishery contributed 11% (131 086 t). About 72% of the marine landings, 837 574 t, were from Peninsular Malaysia while the rest were from the states of Sabah, Sarawak and Federal Territory Labuan.

The number of fishers in Malaysia decreased at a rate of 2.2% per annum from 102 900 in 1985 to 82 200 in 1995. This is consistent with the Government's efforts to ensure sustainable fishing, particularly in inshore waters, and improve the catch from the available resources for the remaining fisher population. In 1997, there were 79 616 fisherfolk in Malaysia and this constituted only about 1% of total employment in the country. Out of the total number of fishers, 7 048 were foreign crew permitted to work in local fishing vessels.

The total demand for fish and fish products was estimated at about 809 300 t in 1995. Out of the total national production, consumable supply was estimated at about 764 500 t; therefore achieving a self-sufficiency level of 94.5%. The marine capture fishery in Peninsular Malaysia is the most important one in terms of total marine landings as well as employment. Hence, this study focuses only on Peninsular Malaysia's marine capture fisheries.

Contribution of the Fisheries Sector to Economic Growth and Welfare

Contribution of the Fisheries Sector to GDP and GVA (Gross Value-Added)

The Malaysian economy has expanded rapidly over the last decade with strong output recorded particularly in the manufacturing, services and the construction sectors. Since 1987, the manufacturing sector has been the leading growth sector in the economy with its contribution to GDP surpassing that of the agricultural sector. Major exports of manufactured goods are electrical and electronic products and machinery, chemical and chemical products, textiles and apparel, wood and wood products, transport equipment, iron, steel and fabricated metal products. The manufacturing sector is expected to remain the main engine of growth under the Second Industrial Master Plan (1996 to 2005). However, there is now a shift in government focus to give more emphasis to the agriculture sector.

New sources of growth are expected to emerge such as agro-forestry, specialty natural products, biotechnology and aquarium fish. Strong growth is also expected from the food sub-sector, arising from intensified efforts in resolving supply-side constraints and strengthening its economic foundation. Its value-added is expected to expand from about RM6.8 billion (US$1.96 billion)[1] to about RM10.3 billion for the 1995 - 2010 period, while its contribution to the sector's value-added is expected to increase from 42% to 46% during the same period.

In 1997, the total production from marine captured fisheries amounted to 1 168 973 t with a wholesale value of RM3 675 billion. The value-added for the fisheries sector is estimated at about RM2 million, which represents about 1.5% of GDP or 11.1% of the agriculture GDP.

Contribution of the Fishing Industry to Income and Employment

There were 88 972 fisherfolk operating in Peninsular Malaysia in 1980 and this number declined to 59 801 in 1990 and then to 50 735 in 1997. This was mainly due to the Government's efforts to prevent over-fishing and to reduce fishing pressure by placing a moratorium on the issue of new fishing licenses for coastal waters. With declining catch and a high incidence of poverty among fishing households, fishers, particularly the younger ones, are attracted to better job opportunities in other sectors.

Table 1. Number of vessels and fishers by states and by types of fishing in 1997.

State	Vessel			Fishers		
	Commercial	Traditional	Total	Commercial	Traditional	Total
West Coast:						
Perlis	297	292	589	3 353	620	3 973
Kedah	534	806	1 340	3 173	1 667	4 840
Penang	222	1 296	1 518	827	1 747	2 574
Perak	1 757	2 192	3 949	4 309	2 881	7 190
Selangor	819	1 891	2 710	2 359	3 266	5 625
N.Sembilan	1	197	198	1	301	302
Malacca	3	729	732	3	967	970
W. Johore	268	3 068	3 336	675	4 109	4 781
Sub-total	3 901	10 471	14 372	14 700	15 558	30 258

[1] 1 US$ = 3.46 Ringgit Malaysia, average from 1995 - 2003

Table 1. Number of vessels and fishers by states and by types of fishing in 1997. (continued)

State	Vessel			Fishers		
	Commercial	Traditional	Total	Commercial	Traditional	Total
East Coast:						
Kelantan	186	882	1 068	2 160	1 673	3 833
Terengganu	538	1 681	2 219	5 259	3 119	8 378
Pahang	386	739	1 125	2 380	1 330	3 710
E. Johore	310	271	1 581	2 076	2 480	4 556
Sub-total	1 420	4 573	5 993	11 875	8 602	20 477
TOTAL	5 321	15 044	20 365	26 575	24 160	50 735

Source: Department of Fisheries (DOF) 1971 - 97.

Of the total number of 50 735 fishers in Peninsular Malaysia in 1997, 60% were operating on the west coast (Table 1). More than half (52%) were involved in commercial fishing. The state of Johore has the highest number of fishers with 9 340, followed by Terengganu and Perak with 8 378 and 7 190 respectively.

Contribution of the Fisheries Sector to Foreign Exchange Earnings

In 1995, Malaysia was a net importer of fish in terms of quantity but a net exporter in value terms due to the export of high value fish and fish products. The import of fish and fish products increased from 200 700 t valued at RM363.6 million in 1990 to 230 000 t valued at RM762.4 million in 1995. During the same period exports increased from 145 400 t valued at RM606.1 million to 185 200 t valued at RM807.4 million. However, in 1997, Malaysia was a net importer of fish in terms of both quantity and value, exporting about 107 600 t of fish and fish products valued at RM939.6 million, and importing some 297 800 t valued at RM979.2 million.

Contribution of the Fisheries Sector to Domestic Nutrition

From the early 1960s to the mid-1980s, fish formed about 60% of the total animal protein consumed (Table 2), a rate much higher than in other Asian countries. From 1960 to 1989, the mean per capita consumption of fish was about 23 kg per annum. It is expected to increase to 56 kg per annum in 2010 (Table 3), in line with changing consumer preferences for fish and fish products as health food. Fish is popular because it is the cheapest and most accessible form of protein acceptable to all ethnic groups of the multiracial population (Ishak 1994).

Contribution of the Fisheries Sector to National Food Security.

The total demand for fish and fish products was about 809 300 t in 1995. Out of the total national production, consumable supply was estimated at about 764 500 t, which is equivalent to a self-sufficiency level of 94.5%.

The country has the potential and the necessary resources to further increase supply to meet domestic and export demand. The annual demand for fish and fish products by 2010 is estimated to be 1.59 million t (Table 4).

Table 2. Per capita annual consumption of various types of protein from 1960 to 1989.

Year	Source of Protein (kg)					Percentage of fish
	Poultry	Beef	Pork	Fish	Total	
1960	3.02	0.56	5.46	9.42	18.46	51.0
1970	6.51	0.63	5.88	21.11	34.12	61.9
1980	8.70	1.28	9.01	24.50	43.49	56.3
1989	13.60	1.53	8.85	23.05	47.03	49.0

Source: Department of Statistics 1985 - 2000.

Table 3: Production and demand for fish in Malaysia from 1985 to 2010.

Year	1985	1990	1995	2000	2005	2010
Fish production (capture) ('000 t)	746.0	951.3	1 108.4	1 255.8	1 305.6	1 331.9
Food fish supply ('000 t)	500.0	564.6	764.5	1 012.0	1 228.2	1 500.4
Per capita consumption (kg)	33.4	34.8	39.1	49.0	53.0	56.0
Food fish demand ('000 t)	527.0	619.9	809.3	1 142.0	1 369.5	1 591.0
Self-sufficiency level (%)	94.9	91.1	94.5	89.0	89.7	94.3
Export of fish ('000 t)	149.0	145.4	185.2	170.0	179.7	225.4
Import of food fish ('000 t)	176.0	200.7	230.0	300.0	321.0	316.0

Source: Ministry of Agriculture 2000.

Table 4. Production and demand for fish 1985 - 95 and forecast of production and demand, 2000 to 2010.

Year	1985	1990	1995	2000	2005	2010
Fish Production ('000 t)	801.0	1 003.6	1 241.1	1 511.0	1 708.8	1 933.3
Aquaculture ('000 t)	55.0	52.3	132.7	255.2	403.2	601.4
Capture fisheries ('000 t)	746.0	951.3	1 108.4	1 255.8	1 305.6	1 334.9
Food Fish Supply ('000 t)	500.0	564.6	764.5	1 012.0	1 228.2	1 500.4
Annual per capita consumption (kg)	33.4	34.8	39.1	49.0	53.0	56.0
Food fish demand ('000 t)	527.0	619.9	809.3	1 142.0	1 369.5	1 591.0
Self-sufficiency level (%)	94.9	91.1	94.5	89.0	89.7	94.3
Export of food fish ('000 t)	149.0	145.4	185.2	170.0	179.7	225.4
Import of food fish ('000 t)	176.0	200.7	230.0	300.0	321.0	316.0

Source: Ministry of Agriculture 2000.

Socioeconomic Analysis of the Small Scale Fishery Sector

The study on the socioeconomic profile of the fishing community was confined to Peninsular Malaysia, and was obtained mainly from Annual Fisheries Statistics published by the Department of Fisheries (DOF), and various socioeconomic studies conducted by DOF and the Fisheries Development Authority (FDA). Most of the information was based on a Socioeconomic survey of fishers conducted by FDA in 1995; a follow-up of a similar survey carried out by FDA in 1982.

The survey conducted by FDA in 1995 covered all categories of fisherfolk in Malaysia, and both commercial and traditional fishing. Trawl nets, fish purse seines, shrimp trawl nets and anchovy purse seines were classified as commercial gear while drift nets and other traditional gear such as hook-and-lines, traps and lift nets were classified as non-commercial.

The number of fishers surveyed in Peninsular Malaysia was 24 949, representing about 45% of the total fisher population of 55 002 in Peninsular Malaysia. Of the total number surveyed, 15 611 or 63% were traditional while the rest were commercial fishers (Table 5). About 65% of the respondents, 16 124, were heads of households. Among the heads of household surveyed, 78% were involved in traditional fishing. The survey also involved 4 537 foreign fishers (or 18% of the total respondents) the majority (93%) of which were involved in commercial fishing. The number of vessels surveyed was 11 893, about 52% of the total number of 22 982 vessels operating in Peninsular Malaysia.

Table 5. Number of sample respondents by states, by types of fishing and by nationality in Peninsular Malaysia, 1995.

State	Commercial			Traditional			Total
	Malaysian	Non-Malaysian	Sub-total	Malaysian	Non-Malaysian	Sub-total	
West Coast:							
Perlis	64	1 397	1 461	243	195	438	1 899
Kedah	572	834	1 406	1 283	16	1 299	2 705
Penang	194	3	197	1 456	–	1 456	1 653
Perak	890	–	890	2 821	–	2 821	3 711
Selangor	434	2	436	1 627	6	1 633	2 069
N.Sembilan	–	–	0	119	–	119	119
Malacca	–	–	0	691	38	729	729
W. Johore	169	7	176	2 278	5	2 283	2 459
Sub-total	2 323	2 243	4 566	10 518	260	10 778	15 344
East Coast:							
Kelantan	360	402	762	1 259	24	1 283	2 045
Terengganu	1 167	1 008	2 175	1 258	2	1 260	3 435
Pahang	622	330	952	834	4	838	1 790
E. Johor	638	245	883	1 433	19	1 452	2 335
Sub-total	2 787	1 985	4 772	4 784	49	4 833	9 605
TOTAL	5 110	4 228	9 338	15 302	309	15 611	24 949

Source: Fisheries Development Authority (FDA) 1995.

Educational Level of Fisherfolk

The majority (66%) of the fishers surveyed received only primary education (Table 6). About 11% of the fishers did not receive any formal schooling. The percentage of fisherfolk who received lower secondary education was about 22%. Hardly 1% of the fishers surveyed had higher secondary or tertiary education.

Occupational Status of Fishers

The occupational status of fisherfolk can be broadly classified into four categories namely skipper, owner, owner-operator and fishing crew. The skipper (captain of the vessel) makes decisions regarding the fishing operation. Skippers are either employed by owners of vessels or they can be owners themselves. A *towke* is a vessel-owner who does not go out to fish but either hires other fishers to operate his vessel, or allows other fisherfolk to operate his vessel with attached conditions. An owner can also be a fish wholesaler or fish merchant. Crew members are workers in the fishing units and are mainly unskilled.

Of the total 9 338 commercial fishers surveyed, about 82% were crew members (Table 7). Owner-operators (i.e. owner-cum-skippers) represented about 10% while skippers and owners formed about 5% and 2% of the total surveyed respectively.

In traditional fishing, the majority of the fishers (57%) were owner-operators. This was mainly due to a condition of the license, which requires traditional fishing to be operated by owners only. However, a small number (about 3%) of owners allowed their vessels to be operated by their children or relatives.

Table 6. Number of fishers by states, by types of fishing and by education levels in Peninsular Malaysia, 1995.

State	Commercial					Traditional					Total
	No Formal	Primary	Lower Secondary	Higher Secondary	Tertiary	No Formal	Primary	Lower Secondary	Higher Secondary	Tertiary	
West Coast:											
Perlis	4	34	26	3	–	23	133	77	2	1	303
Kedah	16	348	163	1	1	119	903	240	7	2	1 800
Penang	6	144	41	1	–	65	1 067	316	2	1	1 643
Perak	73	695	118	1	–	228	2 204	370	13	1	3 703
Selangor	32	245	156	–	–	193	965	458	9	–	2 058
N. Sembilan	-	-	–	–	–	10	61	44	4	–	119
Malacca	-	-	–	–	–	38	481	195	5	–	719
W. Johore	11	118	43	1	–	266	1 424	530	5	2	2 400
Sub-Total	142	1 584	547	7	1	942	7 238	2 230	47	7	12 745
East Coast:											
Kelantan	42	176	139	1	2	289	661	198	10	–	1 618
Terengganu	135	691	339	21	5	223	812	212	7	–	2 445
Pahang	32	263	178	1	–	76	496	186	1	–	1 233
E. Johore	37	258	89	–	1	156	914	233	5	–	1 693
Sub-Total	246	1 388	745	23	8	844	2 883	829	23	–	6 989
TOTAL	388	2 972	1 292	30	9	1 786	3 059	70	70	7	19 734

Source: Fisheries Development Authority (FDA) 1995.

Table 7. Number of fishers by state, by type of fishing and by occupational status in Peninsular Malaysia, 1995.

State	Commercial					Traditional					Total
	Skipper	Owner	Diver	Owner Operator	Fishing Crew	Skipper	Owner	Diver	Owner Operator	Fishing Crew	
West Coast:											
Perlis	7	52	–	9	1 393	11	50	–	89	288	1 899
Kedah	36	19	–	22	1 329	178	44	–	594	483	2 705
Penang	16	11	1	20	149	24	8	–	991	433	1 653
Perak	127	14	–	297	452	175	35	–	1 619	992	3 711
Selangor	24	15	–	281	116	115	85	–	1 152	281	2 069
N. Sembilan	–	–	–	–	-	3	3	–	86	27	119
Malacca	–	–	–	–	-	44	5	–	459	221	729
W. Johore	11	3	-	75	87	28	20	–	1 975	260	2 459
Sub-Total	221	114	1	707	3 526	578	250	–	6 965	2985	15 344
East Coast:											
Kelantan	24	6	2	24	706	132	26	198	502	621	2 045
Terengganu	27	46	339	126	1 863	191	48	212	424	597	3 435
Pahang	71	5	178	61	815	107	4	186	343	384	1 790
E. Johore	53	25	89	28	766	74	91	233	694	593	2 335
Sub-Total	275	82	745	239	4 150	504	169	829	1 963	2 195	9 605
TOTAL	496	196	1 292	943	7 676	1 082	419	70	8 928	5 180	24 949

Source: Fisheries Development Authority (FDA) 1995.

Fishing Experience of Fisherfolk

Skippers generally have more than 20 years of fishing experience. In commercial fishing, about 40% of the skippers have more than 20 years experience while in traditional fishing, the percentage is higher, about 47% in 1995. (Table 8).

Dependency Ratio of Fishing Households

The ratio of non-working to working members was higher in the commercial fishing household (1.9:1) than in the traditional fishing household (1.5:1) (Table 9). The non-working members in the family were mainly children below 18 years of age, spouses of fishers and their aged parents or relatives.

Income of Fishers from Fishing

The average monthly income from fishing in 1995 was RM766 (Table 10). In general, fishers on the west coast received a higher monthly fishing income (RM840) than those on the east coast (RM663). On the average, the monthly fishing income of commercial fishers (RM976) was about 67% higher than that of the traditional fishers (RM583). In both categories owners received the highest income, followed by owner-operators. Skippers of commercial fishing vessels received an average income of RM1 089 per month while those in traditional fishing received only about half that (RM571). Commercial fishing crew received slightly higher average monthly incomes (RM515) than those in traditional fishing (RM431).

Table 8. Number of skippers by state, by type of fishing and by years of fishing experience in Peninsular Malaysia.

State	Commercial					Traditional					Total
	< 5	6 - 10	11 - 15	16 - 20	> 21	< 5	6 - 10	11 - 15	16 - 20	> 21	
West Coast:											
Perlis	4	11	10	5	33	4	27	21	31	67	150
Kedah	4	7	8	21	37	38	82	98	169	408	795
Penang	1	1	4	5	28	30	139	122	206	519	1 016
Perak	15	62	70	108	175	84	261	262	364	840	1 811
Selangor	21	66	73	92	67	124	297	246	299	378	1 344
N. Sembilan	–	–	–	–	–	6	5	21	21	38	91
Malacca	–	–	–	–	–	39	83	67	83	233	505
W. Johore	5	23	23	23	14	102	334	325	445	814	2 020
Sub-Total	50	170	188	254	354	578	1 228	1 162	1618	3 297	7 732
East Coast:											
Kelantan	1	6	6	8	22	132	63	69	116	370	648
Terengganu	15	28	28	48	157	191	41	54	100	421	640
Pahang	2	11	21	34	54	107	49	51	92	245	452
E. Johore	-	17	19	21	34	74	95	93	135	465	817
Sub-Total	18	62	74	111	267	504	248	267	443	1 501	2 557
TOTAL	68	232	262	365	621	1 082	1 476	1 429	2 061	4 798	10 289

Source: Fisheries Development Authority (FDA) 1995.

Table 9. Dependency ratios of fishing households by state and by type of fishing in Peninsular Malaysia, 1995.

	West Coast			East Coast	
	Commercial	Traditional		Commercial	Traditional
Perlis	1.4	1.4	Kelantan	2.4	1.8
Kedah	1.8	1.7	Terengganu	2.2	1.8
Penang	0.9	1.0	Pahang	1.8	1.6
Perak	1.9	1.8	E. Johore	2.0	1.6
Selangor	1.7	1.4			
N. Sembilan	–	1.2			
Malacca	–	1.3			
W. Johore	1.7	1.4			
Overall	1.7	1.5		1.9	1.5

Income of Fishing Households

Fishing household income is defined as the total income of head of household from fishing and other sources plus any other income in the household. The average monthly income of fishing households in 1995 was RM1 260 with income on the west coast (RM1 406) higher than that on the east coast (RM1 051) (Table 11). The average monthly income of commercial fishing households was higher at RM1 416, than traditional fishing households at RM1 126. Vessel-owners' households in both categories had the highest income followed by households of owner-operators. For both types of fishing, households of crew members had the lowest average monthly income at RM833 for commercial fishing and RM826 for traditional fishing.

Assessment of the Linkages of the Small Scale Fishery Sector to Other Productive Sectors

About 30% of fish production is processed. The main products include chilled, frozen and canned fish, surimi and surimi-based products, and dehydrated and fermented fish products. The processing industry is dominated by small and medium-scale enterprises (SMEs). The fishing industry is also linked to other industries such as plastic products, paper products, printing, machinery and equipment, wholesale and retail trade and business services. It also has significant linkages with the transport sector in terms of input supplies as well as distribution of fish and fish products.

Table 10. Average monthly fishing income (in RM) of heads of households by state, by type of fishing and by occupational status in Peninsular Malaysia, 1995.

State	Commercial					Traditional					Total
	Skipper	Owner	Owner Operator	Fishing Crew	Diver	Skipper	Owner	Owner Operator	Fishing Crew	Diver	
West Coast:											
Perlis	3 800	4 551	3 100	350	–	547	1 897	573	446	–	3 358
Kedah	1 031	4 533	1 089	450	–	461	457	454	381	–	559
Penang	1 643	3 209	2 391	809	–	848	764	790	611	–	890
Perak	1 132	1 256	1 343	660	–	738	802	736	534	–	861
Selangor	1 123	961	1 268	646	–	681	751	746	478	–	889
N. Sembilan	–	–	–	–	–	500	1 133	1 092	487	–	962
Malacca	–	–	–	–	–	454	675	488	393	–	464
W. Johore	1 103	1 549	2 178	661	–	764	551	625	548	–	742
Sub-Total	1 178	3 630	1 451	591	–	618	957	674	498	–	840
East Coast:											
Kelantan	560	4 225	2 205	405	–	402	414	397	301	266	510
Terengganu	884	3 254	2 232	365	1 349	525	627	543	337	–	663
Pahang	1 131	4 720	1 088	554	–	605	504	579	386	–	673
E. Johore	1 391	2 224	3 273	681	600	589	590	528	418	–	780
Sub-Total	1 009	3 118	2 053	460	1 118	517	570	506	351	266	663
TOTAL	1 089	3 399	1 617	515	1 222	571	765	635	431	266	766

Source: Fisheries Development Authority (FDA) 1995.

Table 11. Average monthly income (RM) of fishing households by state, by type of fishing and by occupational status in Peninsular Malaysia, 1995.

State	Commercial					Traditional					Total
	Skipper	Owner	Owner Operator	Fishing Crew	Diver	Skipper	Owner	Owner Operator	Fishing Crew	Diver	
West Coast:											
Perlis	6 925	5 858	4 113	410	–	941	2 460	1 166	860	–	4 458
Kedah	1 219	6 865	1 568	643	–	817	1 070	849	655	–	883
Penang	2 901	6 536	3 689	1 686	–	1 771	1 804	1 756	1 320	–	1 860
Perak	1 588	2 989	1 806	1 023	–	1 087	1 468	1 173	889	–	1 285
Selangor	1 725	1 452	1 851	1 443	–	1 216	1 727	1 326	1 244	–	1 504
N. Sembilan	–	–	–	–	–	1 260	3 230	2 244	936	–	1 997
Malacca	–	–	–	–	–	1 226	1 320	1 296	1 062	–	1 236
W. Johore	1 532	2 744	2 691	1 182	–	1 287	1 673	1 314	961	–	1 390
Sub-average	1 682	5 299	1 996	986	–	1 074	1 745	1 312	964	–	1 406
East Coast:											
Kelantan	949	10 983	2 626	610	–	785	730	795	563	846	881
Terengganu	1 265	3 834	2 720	621	1 533	965	1 112	1 058	675	–	1 029
Pahang	1 536	5 326	1 708	853	–	1 132	1 711	1 142	706	–	1 080
E. Johore	1 768	3 386	3 820	997	1 070	973	1 631	1 021	763	–	1 232
Sub-average	1 395	4 354	2 575	1 391	1 391	951	1 324	991	663	846	1 051
Overall average	1 532	4 874	2 156	1 391	1 391	1 017	1 569	1 238	826	846	1 260

Source: Fisheries Development Authority (FDA) 1995.

Involvement of Fishers in Other Economic Activities

Besides fishing, a small percentage of fishers were involved in other economic activities. Of the total number surveyed who were heads of household, 5.9% were involved in farming, 5.4% in contract work, 3.5% in retailing (i.e. operating sundry shops) and 2.3% in tourism (Table 12). Only 1.6% were involved in fish processing while 1.2% were involved in aquaculture.

Some 6.9% of the traditional fisherfolk surveyed were involved in farming and 6.4% were involved in contract works, compared to commercial fishers with 2.2% and 1.6% in farming and contract works respectively. However, the participation of commercial fishers in fish processing was slightly higher at 2.2% compared to traditional fishers at 1.4%.

Returns From Other Economic Activities

Among the other economic activities carried out by fishers, aquaculture provided the highest additional income in 1995 for both the commercial and traditional fishing population at RM590 and RM438 per month respectively (Table 13). Fish processing provided a monthly return of RM291 for the commercial fishers and RM156 for the traditional fishers. Farming, which was the most important side occupation of the traditional fishing population, gave a return of RM191 per month to these fishers.

Table 12. Percentage of heads of fishing households who were involved in other economic activities by type of fishing and by area in Peninsular Malaysia, 1995.

Area	Aqua-culture	Fish Processing	Farming	Animal husbandry	Tourism	Carpentry	Repairing (w/shop)	Contract Works	Retailing
Commercial:									
west	0.2	1.6	1.2	0.1	0.6	0.2	0.3	1.1	2.2
east	0.1	2.8	3.2	0.4	0.3	0.6	2.5	2.1	2.8
Sub-average	0.1	2.2	2.2	0.2	0.4	0.4	1.4	1.6	2.5
Traditional:									
west	2.0	1.0	7.5	0.3	1.9	1.0	0.4	7.5	3.3
east	0.3	2.2	5.7	0.7	5.0	1.1	0.9	4.1	4.7
Sub-average	1.5	1.4	6.9	0.4	2.8	1.0	0.6	6.4	3.7
Overall	1.2	1.6	5.9	0.4	2.3	0.9	0.8	5.4	3.5

Table 13. Average monthly additional income in RM of heads of households from other economic activities by state and by type of fishing in Peninsular Malaysia, 1995.

State	Commercial					Traditional				
	Aqua-culture	Fish Processing	Farming	Animal husbandry	Tourism	Aqua-culture	Fish Processing	Farming	Animal husbandry	Tourism
West Coast:										
Perlis	4	34	26	3	–	23	133	77	2	1
Kedah	16	348	163	1	1	119	903	240	7	2
Penang	6	144	41	1	–	65	1 067	316	2	1
Pera	73	695	118	1	–	228	2 204	370	13	1
Selangor	32	245	156	–	–	193	965	458	9	–
N. Sembilan	–	–	–	–	–	10	61	44	4	–
Malacca	–	–	–	–	–	38	481	195	5	–
W. Johore	11	118	43	1	–	266	1 424	530	5	2
Sub-Total	142	1 584	547	7	1	942	7 238	2 230	47	7
East Coast:										
Kelantan	42	176	139	1	2	289	661	198	10	–
Terengganu	135	691	339	21	5	223	812	212	7	–
Pahang	32	263	178	1	–	76	496	186	1	–
Pahang	32	263	178	1	–	76	496	186	1	–
E. Johore	37	258	89	–	1	156	914	233	5	–
Sub-Total	246	1 388	745	23	8	844	2 883	829	23	–
TOTAL	388	2 972	1 292	30	9	1 786	3 059	70	70	7

Demography, Labor Mobility and Other Transitions Gender Distribution

The survey conducted by FDA in 1995 found that almost all (99.6%) of the respondents were males (Table 14). There were only 92 females (or 0.4% of the total number of respondents) involved in fishing. Most of the females (77%) were concentrated in traditional fishing which does not require much physical strength, while those involved in commercial fishing were mainly vessel owners and did not go to sea.

Table 14. Number of fishers by state, by type of fishing and by gender in Peninsular Malaysia, 1995.

State	Commercial			Traditional			Total
	Male	Female	Sub-Total	Male	Female	Sub-Total	
West Coast:							
Perlis	1 458	3	1 461	434	4	438	1 899
Kedah	1 403	3	1 406	1 290	9	1 299	2 705
Penang	197	–	1 406	1 451	5	1 456	1 653
Perak	887	3	890	2 801	20	2 821	3 711
Selangor	436	–	436	1 627	6	1 633	2 069
N. Sembilan	–	–	0	118	1	119	119
Malacca	–	–	0	728	1	729	729
W. Johore	176	–	176	2 262	21	2 283	2 459
Sub-Total	4 557	9	4 566	10 711	67	10 778	15 344
East Coast:							
Kelantan	761	1	762	1 282	1	1 283	2 045
Terengganu	2 175	–	2 175	1 260	–	1 260	3 435
Pahang	942	10	952	837	1	838	1 790
E. Johore	882	1	883	1 450	2	1 452	2 335
Sub-Total	4 760	12	4 772	4 829	4	4 833	9 605
TOTAL	9 317	21	9 338	15 540	71	15 611	24 949

Source: Fisheries Development Authority (FDA) 1995.

Marital Status of the Fishing Population

About 71% of the fishers surveyed were married (Table 15). The percentage of married fishers was higher for the traditional fishing population (80%) than for the commercial fishing population (57%). This was mainly age-related, as traditional fishers were older than commercial fishers.

Size of Fishing Household

The average size of the traditional fishing household was 5.61 persons while the average number of persons in the commercial fishing household was 5.59 (Table 16). The size of a fishing household was generally larger than the national average of 4.8 persons per household (Department of Statistics 1991). Fishing households on the west coast were smaller than those on the east coast for both categories of fishing.

Table 15. Number of fishers by state, by type of fishing and by marital status in Peninsular Malaysia, 1995.

	Commercial				Traditional				
State	**Married**	**Divorce**	**Single**	**Sub-Total**	**Married**	**Divorce**	**Single**	**Sub-Total**	**Total**
West Coast:									
Perlis	480	13	968	1 461	279	4	155	438	1 899
Kedah	489	11	806	1 406	1 096	23	180	1 299	2 705
Penang	157	1	39	197	1 191	25	240	1 456	1 653
N. Sembilan	–	–	–	0	101	2	16	119	119
Malacca	–	–	–	0	614	18	97	729	729
W. Johore	122	4	50	176	1 880	76	327	2 283	2 459
Sub-Total	2 349	40	2 177	4 566	8 645	196	1 937	10 778	15 344
East Coast:									
Kelantan	422	6	334	762	1 093	24	166	1 283	2 045
Terengganu	1 410	29	736	2 175	1 030	20	210	1 260	3 435
Pahang	589	19	344	952	637	21	180	838	1 790
E. Johore	557	7	319	883	1 097	61	294	1 452	2 335
Sub-Total	2 978	61	1 733	4 772	3 857	126	850	4 833	9 605
TOTAL	5 327	101	3 910	9 338	12 502	322	2 787	15 611	24 949

Source: Fisheries Development Authority (FDA) 1995.

Table 16. Number and average size of fishing households by state and by type of fishing in Peninsular Malaysia, 1995.

State	Commercial		Traditional	
	No. of Household	Average size	No. of Household	Average size
West Coast:				
Perlis	58	5.74	201	5.08
Kedah	426	4.73	1 109	5.38
Penang	160	5.33	1 202	5.50
Perak	717	5.45	2 221	5.57
Selangor	284	5.91	1 272	5.45
N. Sembilan	–	–	106	5.08
Malacca	–	–	615	5.78
W. Johore	117	5.17	1 923	5.38
Sub-Total	1 762	5.33	8 649	5.48
East Coast:				
Kelantan	220	5.92	1 104	6.20
Terengganu	908	6.28	1 070	6.53
Pahang	374	5.46	629	6.00
E. Johore	293	4.92	1 115	5.03
Sub-Total	1 795	5.84	3 918	5.92
TOTAL	3 557	5.59	12 567	5.61

Source: Fisheries Development Authority (FDA) 1995.

Age of Fisherfolk

The study by FDA in 1995 revealed that most (41%) of traditional fishers were in the age group 41 to 55 years (Table 17). As for commercial fishers, more than half (53%) were in the 21 to 40 age group. Most of the young fishers in commercial fishing were crew members whose tasks required little skill or knowledge. The percentage of fishers above 55 years was higher in the traditional fishery (17%) than in the commercial fishery (8%).

Table 17. Number of fishers by state, by type of fishing and by age group in Peninsular Malaysia, 1995.

State	Commercial					Traditional					Total
	< 20	21 - 40	41 - 55	< 55	Sub-Total	< 20	21 - 40	41 - 55	< 55	Sub-Total	
West Coast:											
Perlis	–	18	31	15	64	5	108	93	37	243	307
Kedah	69	291	183	29	572	41	526	512	204	1 283	1 855
Penang	–	70	96	28	194	25	491	676	264	1 456	1 650
Perak	33	429	347	81	890	62	1 303	1 067	389	2 821	3 711
Selangor	22	272	132	8	434	42	786	641	158	1 627	2 061
N. Sembilan	–	–	–	–	0	3	54	50	12	119	119
Malacca	–	–	–	–	0	12	199	285	195	691	691
W. Johore	11	95	49	14	169	14	895	912	457	2 278	2447
Sub-Total	135	1 175	838	175	2 323	204	4 362	4 236	1 716	10 518	12 841
East Coast:											
Kelantan	32	215	91	22	360	23	458	547	231	1 259	1 619
Terengganu	64	579	414	110	1 167	52	428	552	226	1 258	2 425
Pahang	47	343	177	55	622	34	355	316	129	834	1 456
E. Johore	30	396	181	31	638	37	566	550	280	1 433	2 071
Sub-Total	173	1 533	863	218	2 787	146	1 807	1 965	866	4 784	7 571
TOTAL	308	2 708	1 701	393	5110	350	6 169	6 201	2 582	15 302	20 412

Source: Fisheries Development Authority (FDA) 1995.

Conflicts Between Small Scale and Commercial Fisheries

The introduction of trawl gear in the early sixties created serious conflicts between the trawlers and the inshore traditional fishers who felt their livelihood was being threatened (Goh 1976). The trawl fishers were fishing for prawns and bottom dwelling fishes which are more abundant in shallow waters. The traditional fishers using small seines, lift nets, drift nets, trammel nets, bag nets, traps and fish stakes were fishing in the same area. Physical conflicts between them led to the government ban on trawling in early 1964 (Selvadurai and Lai 1977). However, because of the highly profitable nature of fish trawling and the need to increase fish production to meet the growing demand for food, it was impolitic for the government to enforce the ban. The ban was then lifted in October 1964 and methods for better regulation of trawling were considered (Lam and Pathansali 1977). These methods were encapsulated in the Fisheries (Maritime) Amended Regulations 1980. The regulations defined not only the minimum cod-end mesh size for trawl nets of 1.5 inches (38 mm), but also the distance from the shore where trawling is allowed.

Four fishing zones were established to further reduce conflict between the traditional and commercial fishers. Each zone was designated for specific fishing gear, class of vessel and ownership. Waters inside 30 nautical miles (nm) are classified into three fishing zones, namely Zone A, B, and C or C1. Waters beyond 30 nm to the limit of the EEZ are classified as Zone C2. Zone A is less than 5 nm from shore and reserved solely for small scale fishers. They operate traditional fishing gear, using boats of less than 20 gross tonnage (GRT) and must be owner-operated.

Characteristics of the Labor Force In Commercial Fishing

In 1997, the fishing industry directly employed about 79 616 fishers or about 1% of the total labor force in the country. The contribution of the fisheries sector to national employment decreased continuously from 2.4% in 1970 to 2.3% in 1980 and 1.9% in 1990.

Based on a survey conducted by FDA in 1995, about 63% of the fishers in commercial fishing received only primary education. About 8% did not receive any form of formal schooling. The percentage of fishers who received lower secondary education was about 27% and hardly 1% of the fishers attended higher secondary or tertiary education. The poverty rate of commercial fishing households was higher at 10.2% as compared to the traditional fishing households at 7.1%. This figure results from the large percentage of crew members in commercial fishing at 82%, as against traditional fishing with only 33%.

The majority of fishers believed that the local fishing communities should be given exclusive rights over the resources but felt that the government should be the resource manager and law enforcer (Jahara 1993).

Institutional Factors in the Fishery Sector

There are various types of fishers' institutions that are formed by the fishing population themselves. They include the National Fishers' Association (NEKMAT), the State Fishermen Association, the Area Fishermen Associations and Fishermen Cooperatives. To date there are 116 such institutions of which over 60% of the fishers in Malaysia are members. The State and Area Fishermen Associations are also members of the Malaysian Investment Cooperative, which acts as an investment arm that helps promote savings, investment and business through its activities.

Social Implications of Fisheries Policies

The marine capture fisheries is the most important sub-sector as a provider of animal protein food and employment. It has undergone several phases of development and it is believed that Peninsular Malaysian marine capture fisheries have reached their maximum level of exploitation. As modernization has taken place, the proportion of non-powered fishing vessels has decreased. Due to limited fisheries resources, the number of registered fishing vessels has decreased, but the amount of effort is compensated for by technological improvements in fishing. Fishing is a physically demanding job, hence it has been monopolized by people with a low level of education, and it gives them a reasonable income.

In Malaysia equity considerations have been given a strong bias in fisheries management policies and strategies (Jahara 1993). This emphasis arises from the socioeconomic inequities that exist between groups of fishers, mainly along racial lines. Such economic inequities are most distinct between Malay and Chinese fisher. While Chinese fishers are relatively wealthy, Malay fishers have remained poor. Therefore, in line with the New Economic Policy, the government has made a serious political commitment to improve the Socioeconomic status of the Malay fishers. This is not being done at the expense of the other fishing communities.

Fleet Operational Dynamics

The State of the Fishing Fleet

The fishing fleet in Malaysia can be categorized into commercial and traditional fleets. The commercial fleet practices fishing with trawl and purse seine. The traditional fleet is comprised of vessels using a variety of traditional gear, of which the drift/gillnet is the dominant. Besides being classified by type of gear, the commercial and traditional fishing fleets in Malaysia are generally differentiated through size of vessels and the use of technology on board. From 1980 to 1997, a steady decrease in the number of licensed fishing vessels was recorded on the West Coast of Peninsular Malaysia (Department of Fisheries (DOF) 1971 - 97). Of the large scale or commercial fishing vessels, trawlers made up the largest number, ranging from 3 000 to 4 000 units. The largest number of small scale vessels was the drift-netters, their numbers ranging from 11 000 to 18 000 units of powered and non-powered vessels (Table 18).

Commercial fishing vessels are generally larger than 25 GRT (Gross Registered Tonnage). Licensed vessels average 45 GRT, but of those estimated to be in operation, there is a large number of trawlers in the 10 - 24.9 GRT category. Most commercial fishing vessels perform daily fishing trips but there

are increasing numbers of larger vessels that fish for up to a week or 10 days.

Commercial fishing vessels are only allowed to operate beyond 5 nm from shore in Zones B (5 - 12 nm), C (12 - 30 nm) and C2 (> 30 nm), with the exception of the anchovy purse seine which can fish in Zone A (0 - 5 nm). In addition commercial fishing vessels, > 40 GRT must fish in Zone C and beyond. Larger sized vessels in the commercial category catch mainly finfish further offshore, while the smaller of these vessels target shrimps in fishing grounds nearer shore.

Licensed traditional fishing vessels average 5 GRT but it is estimated that most vessels in operation are generally less than 15 GRT. There is a proportion of traditional fishing vessels that still use outboard engines of varying capacity. Fishing vessels operating traditional fishing gear are allowed to fish in Zone A. Most of these operate trammel nets targeting shrimps. There are some drift nets targeting the more valuable finfish. Besides these, there are several varieties of gear for specific and mixed species. Fishing trips are only day trips, with the exception of some portable fish trap operators who fish further away from shore and remain at sea for up to a week.

Another basic difference between the commercial and traditional fishery is the level of capital input and technology. The commercial fishery presently operates large fishing nets with the aid of power blocks, net haulers and net drums as well as sophisticated fish detecting equipment such as fish finders, echo-sounders and sonar. They also use modern navigational equipment such as the GPS (Geographic Positioning System) and are fitted with RSW (Refrigerated Sea Water) systems to maintain the quality of their catch. Engine capacities average 180 HP for commercial fishing vessels and 18 HP for traditional fishing vessels.

Commercial fishing vessels can operate throughout the year on the West Coast of Peninsular Malaysia but there is generally a slow-down in activities of the purse seine during the northeast monsoon season from November to February/March.

Most of the traditional or small scale vessels are not fitted with RSW, however some do use portable echo-sounders and GPS. Fishing nets are mostly handled manually but some drift netters use net haulers. The operation of traditional fishing vessels is usually tide-dependent, therefore they operate around 10 - 20 days per month. There is usually no fishing during inclement weather.

Table 18. Number of licensed fishing vessels in the commercial and traditional fishery on the West Coast of Peninsular Malaysia, 1980 - 97.

Year	Commercial	Traditional	Total
1980	3 975	18 051	22 026
1981	3 943	17 849	21 792
1982	3 908	15 695	19 603
1983	3 758	13 936	17 694
1984	3 539	14 515	18 054
1985	3 236	13 273	16 509
1986	3 146	12 903	16 049
1987	3 104	12 735	15 839
1988	2 948	12 091	15 039
1989	3 360	13 783	17 143
1990	3 294	13 510	16 804
1991	3 229	13 243	16 472
1992	3 077	12 622	15 699
1993	2 773	11 373	14 146
1994	2 605	10 682	13 287
1995	3 198	13 116	16 314
1996	2 844	11 668	14 512
1997	2 785	11 426	14 211

Source: Department of Fisheries (DOF) 1971 - 97.

Table 19. Average catch per unit effort (CPUE) ($t \cdot unit^{-1} \cdot year^{-1}$) by fisheries on the West Coast of Peninsular Malaysia.

Fishery	1996	1997
Trawl < 40 GRT	53.29	56.96
Trawl 40 - 69.9 GRT	211.80	222.77
Trawl > 70 GRT	331.42	286.51
Fish purse seine < 40 GRT	250.61	416.25
Fish purse seine 40 - 69.9 GRT	226.59	199.92
Fish purse seine > 70 GRT	274.73	272.61
Drift net	7.10	6.91

In terms of production, it can be seen from Table 19 that on the West Coast of Peninsular Malaysia, the trawler > 70 GRT lands more fish than the purse seiner of the same category while for vessels < 40 GRT, the purse seiner performs better.

Costs, Earnings and Profitability

This section looks at the cost efficiency of trawlers, purse seiners and drift-netters on the West Coast of Peninsular Malaysia.

Investment Costs

The capital investment for a trawler and purse-seiner between 25 - 69.9 GRT was RM100 000 in 1989 (Kamaruzaman and Lim 1999). The main capital cost incurred is in the engine, the boat hull, gear box, net and accessory equipment.

Cost Structure

The production costs of the large scale and small scale fisheries on the West Coast of Peninsular Malaysia for 1989 are shown in Table 20. Fuel, labor, maintenance, ice (for vessels without RSW) and food for crew constitute the main items in the operating costs.

Earnings and Profitability

The average costs and earnings of trawlers and purse seiners by state on the West Coast of Peninsular Malaysia and size of vessel are given in Table 20. The annual net profit derived from a 25 - 39.9 GRT trawler in 1989 was RM36 520, while that from a 40 - 69.9 GRT trawler was RM43 601. The gross profit for the same categories of trawlers are RM46 393 and RM57 163 respectively. For the purse-seiner a 25 - 39.9 GRT vessel made a net profit of RM40 102 and a gross profit of RM46 950 while a purse-seiner of the 40 - 69.9 GRT category made a net profit of RM63 562 and a gross profit of RM72 686 in 1989.

Table 20 also shows the costs and earnings for drift-nets, a traditional fishing gear on the West Coast of Peninsular Malaysia. An average net profit of RM6 636 and a gross profit of RM7 995 per year were recorded in 1989.

The Sharing System

Although slightly different sharing systems are practiced among the diverse fisheries in several localities on the West Coast of Peninsular Malaysia, basically, there are three main systems based on owner/crew division and commission (Ishak 1994).

For the trawl fishery, catches are divided into shares after deduction of operating costs. The number of shares will have been earlier agreed upon between boat-owners and crew and the shares accorded to the boat-owner and each crew member depends on their relative contributions to capital, skills and responsibilities. For example, on a four-member trawler, there are eight shares. Out of these, 4.75 shares go to the boat-owner, 1.25 shares go to the skipper while the remaining crew members get one share each. If the boat-owner goes to sea himself as the skipper, then he gets a slightly higher share. In terms of percentage of shares, a trawler or purse-seiner owner gets between 20% - 60% of shares (Anonymous 1995).

For a purse-seiner, the share system is more complex in that the first 450 kg of catch go to the crew, consisting of about 14 workers according to their respective shares. This fish is usually sold back to the boat-owner, who does not receive any reward when the catch is < 450 kg. Catches in excess of 450 kg are divided into shares after deduction of operating costs. From a total of 20 shares, the boat-owner requires 5 shares and the remaining 15 shares are distributed to the crew. The skipper receives 1.5 shares, the engine-man 1.25 shares and the rest of the crew receive one share each.

For the operation of the anchovy purse-seiner, each crew member receives a fixed monthly wage, the amount depending on the relative responsibilities and skills. In addition, each crew member will be paid a commission per basket of catch. Again, the amount of commission per basket varies according to responsibilities and skills. The skipper is also awarded a bonus of about 3% of the net value of the catch. Workers who boil anchovies on board are paid fixed wages.

For the traditional or small scale fisheries, catch sharing systems are also practiced. Generally the number of shares, after deduction of operating costs, are agreed upon among the boat-owner, skipper and crew members. Where the boat-owner is also the skipper, then the shares are divided between the boat-owner/skipper and crew. A boat owner receives between 20% - 60% of shares (Anonymous 1995). Certain fisheries are owner-

Table 20. Average costs and earnings in RM of trawlers, purse seiners and drift netters by size of vessel on the West Coast of Peninsular Malaysia in 1989.

Size of vessel (GRT)	Trawlers*		Purse seiners		Drift-netters
	25 - 39.9	40 - 69.9	25 - 39.9	40 - 69.9	
No. of days per trip	2	2	1	2	1
No. of trips per month	14	15	19	16	17
No. of trips per year	168	180	232	186	204
No. of workers	4	3	14	15	2
Annual Landings:					
Quantity (kg)	173 781	236 936	173 473	386 100	5 765
Value (RM)	186 407	217 392	193 008	403 278	21 095
Annual Operational Costs:					
Fuel (RM)	81 298	76 355	53 789	152 670	3 529
Ice (RM)	8 406	7 400	18 547	34 740	950
Food for workers (RM)	4 639	3 113	7 147	18 840	1 681
Wages (RM)	35 445	64 707	53 260	102 597	3 734
Maintenance cost (RM)	9 606	7 933	12 053	21 100	3 192
Others (RM)	620	721	1 262	645	14
Total (RM)	140 014	160 229	146 058	330 592	13 100
Annual gross earnings (RM)	46 393	57 163	46 950	72 686	7 995
Monthly gross earnings (RM)	3 866	4 764	3 913	6 057	666
Annual depreciation (RM)	9 873	13 562	6 848	9 124	1 359
Annual net earnings (RM)	36 520	43 601	40 102	63 562	6 636

Source: Department of Fisheries (DOF) 1989.
*** These vessels use a (RSW) system**

operated so that the whole catch belongs to the owner-operator.

Cost Efficiency and Cost Effectiveness of Fishing Vessels

This section evaluates the cost efficiency of commercial and traditional fishing gear. Table 21 shows a comparison of the commercial fishing vessels, the trawler is more productive in terms of labor, although production costs are slightly higher than for the purse-seiner. For both the trawl and purse seine fishery, the larger vessels of the 40 - 69.9 GRT category are more efficient than the smaller category of 25 - 39.9 GRT. The capital intensity of the trawl in terms of initial investment per person-day is the highest. The capital intensity for the purse seine fishery is lower than the trawl and close to that of the drift net. This could be explained by the low capital investment of RM100 000 estimated for the purse seine fishery of both categories and the same initial investment estimated for the trawl. The number of crew on board the trawl is four whereas on the purse-seiner there are 14 - 15 workers. For comparison, approximate current fixed costs for the trawler and purse-seiner of the 40 - 69.9 GRT categories are given in Table 22 below. The majority of purse seiners on the West Coast of Peninsular

Table 21. Productivity efficiency indicators of selected fisheries on the West Coast of Peninsular Malaysia.

Fishery	Production Costs (RM kg^{-1})	Labour Productivity (kg person-day)$^{-1}$	Capital Intensity (RM person-day)$^{-1}$
Trawl (25-39.9 GRT)	1.24	129	74.40
Trawl (40-69.9 GRT)	1.48	219	92.59
Purse seine (25-39.9 GRT)	1.19	53	30.79
Purse seine (40-69.9 GRT)	1.17	69	17.92
Drift net	0.44	14	29.41

Table 22. Approximate current fixed costs (RM) by fishery using 40-69.9 GRT vessels.

Fishery	Boat	Engine	Gear	Net	Others *	Total
Trawl	120 000	100 000	110 000	27 000	17 000	374 000
Purse seine	120 000	92 000	70 000	50 000	128 000	460 000

* Mainly fishing and navigation equipment.

Malaysia are now of the 40 - 69.9 GRT category. Capital investment can vary considerably depending on the sophistication of equipment used.

The drift net as a small scale gear is the most cost-effective, although production effectiveness per variable cost is the lowest. This benefit can probably be explained by the small quantities of high-valued catch.

By-catch

Before the intensification of coastal mariculture activities, a significant portion of by-catch from commercial fishing vessels was discarded at sea and usually only the by-catch from the last haul was brought ashore and landed. In the late 1970s, fishing vessels in Malaysia began installing RSW on board their vessels. This has improved storage on board, thereby enabling nearly all by-catch to be kept and sold in port especially during lean fishing seasons.

Aquaculture activities such as the culture of finfish and fattening of crabs in floating cages, depend on trash fish for their feed. In addition to fishmeal, certain species of fish are selected for processing. Traditionally, croakers are salted and dried. Since the early 1980s, mullids have been selected for making barbequed fish and snacks. Mantis shrimps and shovel-nosed lobsters formerly discarded are now collected and sold. Many other low valued species like synodontids and bull eye are now collected and processed into fish cakes and surimi-based products (Chee 1997).

Currently, the estimation of by-catch in Malaysian fisheries is based on the quantity of "trash fish" landed. Trawlers land the most by-catch compared to purse seiners and other traditional fishing gear. As by-catch constitutes a certain proportion of small and immature fish of commercial value, research is being conducted to develop more selective fishing gear.

Analysis of Market Structure and Price of Fish

Fish landed by commercial fishing vessels at the landing sites are initially traded at privately owned jetties or LKIM (Fisheries Development Authority) fish landing complexes. The main trading activities are conducted by boat owners, either operators themselves or non-operators, fish-collecting agents for coastal wholesalers, coastal wholesalers, commission agents, retailers, itinerant dealers and a small number of consumers. The bulk of fish consigned by coastal wholesalers is channeled to

wholesalers at inland or terminal markets, which are usually located in the larger towns. From here fish supplies are redistributed to other wholesale centers, retail outlets, institutional buyers like hotels and restaurants and consumers (Ishak 1994).

LKIM is a statutory body established in November 1971 to upgrade the socioeconomic status of fishers, in particular to enhance their incomes and to develop and expand the fishing industry. Through LKIM, the government strives to develop an efficient marketing system so that fishers are able to receive fair and stable returns while consumers are supplied with quality fish at reasonable prices (Megat Muhaiyadin 1995). LKIM now manages 26 fish landing complexes, and has powers of regulation and enforcement over the entire fish marketing system. To ensure an efficient and healthy fish marketing system, LKIM enforces regulations established in 1973 under the Fish Marketing Act, 1971. Besides providing for the designation of a fish marketing control area and the management of fish trade within it, these regulations also provide for the licensing of all fish dealers, wholesalers, exporters and importers.

In international fish trade, about 82% of the inflow of fish from Thailand passes through the LKIM fish inspection complex at Bukit Kayu Hitam. These fish are widely distributed to the large wholesale centers in Peninsular Malaysia. One-third of the fish supply in the Kuala Lumpur market is estimated to be from Thailand. Most of the fresh fish are exported to Singapore. These originate mainly from the east coasting landing complexes of Kuala Sedili and Mersing in Johore.

The factors that influence the price of fish in the wholesale market are freshness and quality, volume of fish in the market, time of day, monsoon season and the price level of the previous day. For the wholesale operation, prices for species are scouted around, usually from large wholesalers, to establish the initial price. Price formation and adjustments in the market are rapid and less than about 10% of fish are left unsold. Retailers buying at the wholesale markets usually patronize their regular wholesalers and varying price levels and bargaining are communicated through the use of hand signals as codes. Auctioning was not reported in the Ipoh and Kuala Lumpur wholesale markets (Ishak 1994).

Implications for Fishery Management

The inshore fisheries resources on the West Coast of Peninsular Malaysia are generally maximally exploited and a few fisheries, such as the inshore demersal fisheries, are over-exploited.

Over the years the total amount of commercial fishing gear estimated to be in operation has decreased. This decline is mainly due to a decrease in the number of smaller vessels. The number of larger vessels of the 70 GRT category has increased.

The increased efficiency and power of fishing vessels, through the use of new technology and larger nets coupled with larger engine capacities, has tremendously increased the overall fishing effort. While the number of vessels and fishing gear licensed can be strictly enforced and monitored, the actual effective fishing effort exerted is difficult to estimate and enforce. In particular, the actual HP of engines cannot be determined since most fishing vessels use converted engines from lorries and buses for their vessels. This has resulted in difficulties in the use of specific models for assessment, and hence insufficient scientific support for formulation of fisheries management measures. The assessment of effective fishing effort, fishing power and population abundance are further complicated by the multi-species and the multi-gear nature of tropical fisheries.

The trawl is more productive than the purse-seine although the production costs and capital intensity are higher (Table 21). This leads to an increase in the number of trawlers. Trawlers are less demanding in terms of labor, since four persons can operate a large 40 - 69.9 GRT category trawler, but a purse-seiner of the same size requires a minimum of 14 crew to operate the net. Labor is a problem in the west coast commercial fisheries and only a certain percentage of approved foreign labor is allowed. In the long term, there will probably be a continuous decline in the number of purse seiners because of the relatively high capital and operating costs. Technical modifications are also continuously being made to the trawls, so that they are now larger, have very high mouth openings, and are used on boats with high engine capacities. Trawlers now catch substantial proportions of pelagic fish in addition to their catch of demersal finfish, which gives rise to interaction between trawlers and purse seiners in the commercial fishery

The number of drift nets estimated to be in operation has increased although the number licensed has decreased. This is probably due to the low capital investment, low labor requirement and cost effectiveness of this gear. With good returns supported by the relatively good catches, the number of drift-netters is expected to further increase. This will lead to new entrants, and further improvement in nets and equipment will lead to over-capacity. There is a need to maintain the drift net fishery at a traditional level if this fishery is to provide job opportunities and food for traditional fishers. In addition, the problem of this gear and commercial gear fishing the same resources in the same limited fishing grounds has to be considered in relation to sustainability.

The prevalence of traditional small scale fisheries as opposed to commercial large scale fisheries in Malaysia has provided managers with a great challenge to achieve the objectives of sustainability of resources and the provision of food and employment. The demand for fish is expected to increase with increasing population. Further demand is expected from the increasing awareness of fish as a health food. Resources from capture fisheries are not infinite, and have to be rationally exploited to ensure their sustainability. Aquaculture is expected to meet the shortage in supply for fish. However, current practices that use trash fish as feed should be replaced by alternatives based on the use of formulated feeds. Efforts must be urgently focused on this area to supply feed to the aquaculture industry.

Two fundamental policy questions face fisheries on the West Coast of Peninsular Malaysia:

1. how to reduce over-fishing of the inshore areas and induce a recovery of the west coast's demersal fisheries resources without reducing fishery production and employment;

2. how best to utilize the west coast's offshore vessels and their technological advantages.

This is a difficult task for the fishery that deals with multi-species and multi-gear fishing activities and makes it difficult to define the target species for the existing fisheries. It is difficult to think of management interventions that will not involve curtailment of fisheries production, employment and increased conflicts, at least in the short-run.

Increased catches can be taken by increased fishing of some of the unexploited stock. The long-term prosperity of the fisheries depends on any expansion of fishing being selectively applied and combined with control of the amount of fishing of the more heavily exploited stocks. This selectivity might be achieved in terms of fishing area (distance offshore, water depth), general type of fishing gear, or the modification of specific fishing gear (e.g. control of mesh-size used by trawlers, use of high opening nets). There is a particular problem regarding the inter-relationship between shrimp and fish. The bulk of demersal fish of the west coast fishery resources are taken by trawlers but the main financial return for the trawlers come from shrimp. As the catch rates of demersal fish have fallen because of increased fishing, the west coast trawlers have concentrated on the shrimps in the shallow and inshore areas. Substantially larger mesh size than those currently used (say an increase of more than 40 mm) would probably benefit the fish stock and lead to greater increase in fish catches but reduce shrimp catches. Similarly, an introduction of high opening trawl nets, a modification of the original trawl, will lead to a substantial increase in pelagic catch (Lui 1992). This will minimize catches of demersal and shrimp resources of the west coast that form the bulk of the fishery.

As evidenced by the National Fisheries Policy and other official statements, the government does perceive these issues and attempts are being made towards the exploration of new areas in the offshore waters. At the same time, the DOF Malaysia will continue to place great importance on maintaining the existing coastal fisheries which are expected to provide the bulk of the marine landings and give employment to a major portion of the fishing labor force. The question is whether the existing legal and policy frameworks are appropriate and sufficient in dealing with these issues especially in the light of budgetary and manpower constraints, and the high enforcement costs. A review of the existing legislation and policy framework is necessary to investigate this question.

Conclusions and Recommendations

It is important that comprehensive studies based on a multi-disciplinary approach of integrating both biology and economic aspects be made for better management of the fisheries resource. Two fundamental policy issues need to be adressed. They are first, how to reduce over-fishing of the inshore

areas and induce a recovery of the west coast's demersal fisheries resources without reducing fishery production and employment and second, how best to utilize the west coast offshore vessels and their technological advantages. Management measures to eliminate competition and ensuing conflict between traditional fishers and inshore trawlers have proved successful. However, enforcement of banning push nets and control on minimum mesh size of 38 mm for cod-ends of otter trawls is still difficult to implement, due to constraints on manpower, facilities, budget and political interference.

Conservation programs will seldom succeed if they do not consider realistic alternatives. Therefore, before introducing any restriction on fishing gear or strictly enforcing regulations to eliminate illegal gear such as push nets, realistic alternative income-generating activities should be provided to the fisherfolk to compensate them for their losses. In view of the limited alternatives available in the fishery-related and non-fishery sectors, one of the options available is to encourage them to use other methods that are less damaging to the resources, such as trammel net fishing. Adnan and Lim (1994) noted that trammel net fishing exhibits good economic performance with the least damaging effect on marine resources.

One way of reducing costs for effective enforcement is to involve local people and stakeholders in the conservation process at all levels and activities. The villagers should be given the right and the authority to manage and look after their local fisheries resources. The local government agencies need to support the village organizations. The government agencies need to actively stop any illegal fishing by other groups who enter the area.

All coastal areas face the threat of devastation and little concerted action is being taken to conserve them. Thus, education and public awareness programs should be available to the stakeholders so as to change attitudes of groups that over-exploit vulnerable resources.

Coordination in the area of optimizing usage of coastal and marine resources should be given emphasis. The use of limited coastal resources should be determined by the developers, planners, policy-makers and scientific personnel that will make well-informed decisions based on scientifically sound methods of resource assessments. Issues arising from conflicts must be resolved.

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Socioeconomic and Bioeconomic Performance of Philippine Fisheries in the Recent Decades

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Cruz-Trinidad, A. 2003. Socioeconomic and bioeconomic performance of Philippine fisheries in the recent decades, p. 543 - 576. *In* G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings 67, 1 120 p.

Abstract

The fishing industry in the Philippines was tantamount to a marine capture fishery in the 1950s to 1960s. Aquaculture and inland fishery production were not significant. Only during the 1970s did aquaculture and inland capture fisheries contribute significantly to fish production. From 250 000 t fish production in 1951, this increased substantially to 1.6 million t in the 1990s.

An average 4.3% was contributed by fisheries to the gross domestic product from 1988 - 98. Fisheries export earnings reached P12 billion in the 1990s. Exports of fishery products include tuna, shrimps, prawns and seaweed.

Fishing industry employees in the Philippines are distributed thus: 70% in the municipal (artisanal) sector, 25% in aquaculture and 5% in the commercial sector.

Fish and fish products comprise more than 50% of total animal protein intake vis-à-vis meat and meat products and poultry. However per capita consumption of food fish decreased from 40 kg•year^{-1} in 1988 to 36 kg in 1998.

In the Philippines, small scale fishing is defined as fishing within municipal waters using fishing vessels of 3 GT or less, or fishing without vessels. In 1948, there were 63 005 fishers rising to 743 544 in 1995. There was a declining trend in catch per unit effort (CPUE) from 2.10 t•HP^{-1} in 1948 to 0.29 t•HP^{-1} in 1985.

Time-series data from 1976 - 87 showed that small pelagics accounted for 38% of total catch followed by demersals, 26%; tuna, 16%; seaweeds, 14%; large pelagics, 6% and invertebrates, 9%. The most important fishing gear in terms of contribution to total catch are gillnets (30%), hook and line (24%) and beach seine (8%). Hook and line accounts for almost 60% of tuna catch while hook and line, gillnets, and fish corrals account for 60% of demersal catch.

Commercial fishing can be classified into: (a) small scale commercial fishing (fishing with passive or active gear and utilizing vessels of 3.1 GT up to 20 GT); (b) medium-scale commercial fishing (fishing with active gear and utilizing vessels of 20.1 GT up to 150 GT); and (c) large scale commercial fishing (fishing with active gear and vessels of more than 150 GT). In the 1950s the three dominant types of gear were

bag net, the trawl (including beam and otter types) and the round haul seine. The larger tonnage category (more than 100 GT) became more significant in the 1980s.

There are 35 species comprising 70 - 95% of total commercial fish production grouped as demersals, small pelagics and large pelagics. Roundscads dominated the small pelagics, followed by slipmouth, a demersal species.

Declining catches, disappearance of high value species and increasing volume of juveniles are indications that the fishery is biologically over-fished. This translates as declining profit for the fishery sector. It also means that the fishery employs excess labor and utilizes capital that could be used in other economic sectors.

The Fisheries in the Philippines: A Panorama of Contradictions

The importance of fisheries in the Philippines has been frequently extolled.

- The fishery sector contributes significantly to the income. An average 4.3% was contributed by the fishery to GDP over 1988 - 98. Its contribution to gross value-added to agriculture averaged 19% during the same priod.
- The fishery sector contributes to foreign exchange earnings. Exports of fishery products such as tuna, shrimps, prawns and seaweed garnered top earnings together with garments and semiconductors. During the 1990s, fisheries contributed an average of P12 billion to export earnings, a huge boost during the financial crisis.
- The fishery sector employs a total of one million people broken down as follows: municipal sector, 70%; aquaculture, 25%; and the commercial sector, 5% (Bureau of Fisheries and Aquatic Resources (BFAR) 1998). This figure represents about 3% to 4% of the labor force.
- The fishery sector provides food. Fish and fish products comprise more than 50% of total animal protein intake vis-á-vis meat and meat products and poultry. In rural coastal communities, up to 80% of the animal protein may be supplied by fish caught in municipal waters (Savina and White 1986).

These attributes of the fishery are being dissipated.

- While fisheries contribute significantly to national income, the people behind this economic sector remain poor. Various studies indicate that poverty along the coast is worsening due to increasing population and fewer income opportunities in other sectors (Añonuevo 1989; Librero et al. 1985; Smith 1979).
- Production from the marine capture fishery has leveled at 2.7 million t. This mirrors the trend in global fisheries where production has leveled at 90 million t. Over 60% of the world's main fish stocks are fully exploited, over-exploited or depleted (Williams 1994). The reasons are similar: the extraction rate is greater than the resources' regenerative capacity, habitats are severely degraded and population increase results in varied stresses, such as higher demand for food fish and higher generation of waste and discharge into coastal waters.
- Empirical studies provide evidence of economic over-fishing in both pelagics and demersal fish stocks. (Dalzell et al. 1987) estimated that maximum sustainable yield (MSY) for small pelagics was attained in 1975 at a production level of 544 000 t. (Trinidad et al. 1993) support this finding and suggest that open access equilibrium (OAE) had already been reached during the early 1980s. Both studies support an effort reduction ranging from 20% to 60% of current levels to attain MSY and/or maximum economic yield (MEY). Biological and economic over-fishing in the demersal fishery was also verified by (Silvestre and Pauly 1987). MSY and MEY for demersal stocks were breached in the early 1970s translating to a loss of P2.0 to P3.2 billion (US\$100 - 160 million•year $^{-1}$) if MEY level was otherwise attained.
- Aquaculture has suffered declines in productivity on a per hectare basis (Coastal Resource Management Project (CRMP) 1998a). This productivity decline is due to a scale-back in extension services for fish-pond operators (Juliano 1996), water quality problems such as that experienced in Laguna de Bay (Librero 1988), shortage of

breeders, and disease. The contribution of aquaculture should also be evaluated in the context of destruction of a highly productive resource, the mangroves. Of the 450 000 ha of mangrove that existed in 1918, only 138 000 ha exist now. An average of 3 100 ha of mangroves have been lost every year to alternative uses including fish-ponds. From 1970 to 88, the rate of mangrove destruction increased to 8 000 ha per year attributable to expansion of fish-ponds. Unfortunately, fish-pond productivity is one of the lowest in Asia, i.e. less than 1 $t{\bullet}ha^{-1}$ and a significant hectarage of ponds is now unproductive, unutilized or abandoned. Furthermore, the (World Bank 1989) estimates that sustained use of one hectare of mangroves would provide the equivalent of about a person-year's earnings for a typically poor fisher, whereas conversion to fish-ponds would provide only one months' earnings to labor. (White and Trinidad 1998) estimate that mangroves yield an average of US$600 per year from direct benefits alone (wood, fish and crustaceans). If the existing mangrove cover were maintained in a healthy state, this would yield a total of US$83 million per year.

- Per capita consumption of food fish is decreasing. In 1988, this was 40 $kg{\bullet}year^{1}$; ten years later, this figure had dropped to 36 kg. Per capita consumption of fish is estimated using two parameters: food fish production and population. Both parameters counteract each other and the result is a decline in per capita consumption. This decline is even more pronounced in the very communities that make consumption of fish possible for the urban consumers. This is a worldwide trend; UNICEF for the first time, reported a protein-calorie deficiency in fishing communities (Coastal Resource Management Project (CRMP) 1998a). If population growth continues at its current pace and nothing is done to arrest the pattern of fishery extraction, the use of destructive fishing practices and degradation of marine habitats, it is estimated that by the year 2010, only 10 kg of fish would be available on an annual per capita basis (Bernascek 1994). While the country has embarked on various food security programs, we have yet to see some degree of importance given to fish vis-á-vis its more privileged cousins, rice and corn.

Trends in Fisheries Production, Trade and Prices

Our period of analysis encompasses five decades, beginning during the 1950s and culminating in the late 1990s. For the first two decades, fisheries production was tantamount to the marine capture fishery with aquaculture and inland capture fisheries contributing to production only during the mid -1970s. Fishery production was 250 000 t in 1951 doubling after 15 years. By the 1970s the million-ton mark was breached; thereafter, production hovered at 1.2 million t for almost the entire decade of the 1970s. Modest but constant growth was registered thereafter finally reaching a plateau of 1.6 million t in the 1990s (Fig. 1).

Average growth rates for the entire fishery sector (including aquaculture) show that production peaks occurred during the 1960s and to a lesser extent, the 1970s (Table 1). These peaks were fuelled by the large scale sector from 1960 - 65 and the small scale sector from 1966 - 70. After 1976, growth rates of the capture fishery sector registered negative and/or minimal growth. This is particularly true for the small scale sector. Aquaculture continued the growth trend for the fisheries sector. Unlike industries which start off low on the growth curve, aquaculture began with a “bang”. For the first five years, it posted double-digit growth, i.e. a 15% average for the first four years. In 1980, aquaculture yielded 300 000 t, almost 25% of total capture fishery production and by 1990, this figure doubled. By 1996, total aquaculture production had already eclipsed production from both the large scale and small scale fishery sectors.

The main contributors to fisheries production are the small scale or municipal sector and the large scale fishery. These two sectors dominated the fishing industry for the first two decades during the period of analysis. During the early 1950s, the small scale sector comprised the bulk of fisheries production which was, on average, 150% greater than the commercial sector. Towards the 1970s and well into the 1990s, this ratio drastically dropped to a little over 30% indicating either a stagnation in the catch of the municipal fishery or increased activity in the commercial sector. By the 1990s, the advantage of the small scale sector would be completely overturned (Fig. 1).

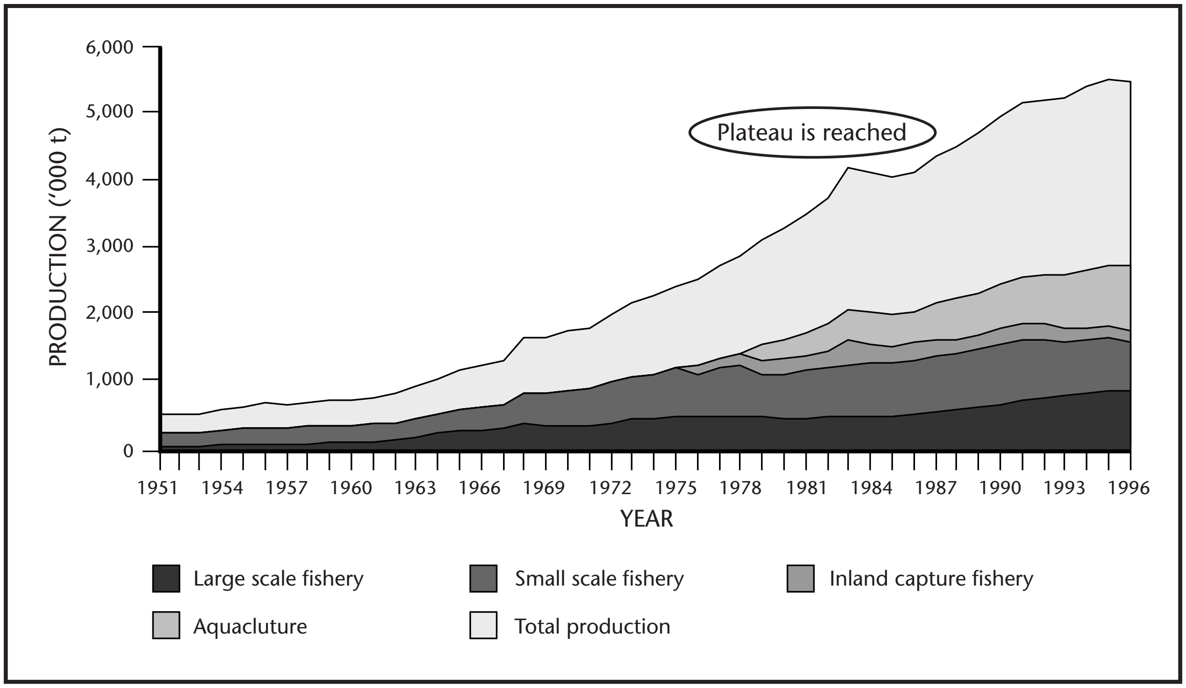

Fig. 1. Fisheries production in the Philippines, contribution by major sector, 1951 - 96.

Table 1. Average production growth rate of the fisheries sector for 5-year periods, 1952 - 95.

Period	Average growth rate per sector (%)				
	All	Capture fishery	Large scale	Small scale	Aquaculture
1952 - 55	5.4	5.4	12.8	2.7	–
1956 - 60	3.4	3.4	2.8	4.0	–
1961 - 65	9.5	9.5	20.6	2.9	–
1966 - 70	8.4	8.4	5.4	11.2	–
1971 - 75	6.7	6.7	5.6	7.5	–
1976 - 80	6.4	-1.3	-0.4	-1.5	–
1981 - 85	4.3	2.7	1.0	4.0	11.5
1986 - 90	4.1	4.2	6.5	2.7	6.5
1991 - 95	2.2	1.0	5.0	-2.5	6.5

Inland capture fisheries and aquaculture only began to contribute to official production statistics during the 1970s, however there was an undocumented but robust inland capture fishery especially in freshwater lakes such as Laguna de Bay and Sampaloc Lake. Aquaculture started during the late 1970s with fish-pens and ponds.

According to available trade reports, the Philippines was a net importer of fisheries products from 1970 - 77; thereafter, the balance of trade turned positive for the next 10 years. This reversal is largely due to tuna and aquaculture products notably shrimp, prawn and seaweed (Fig. 2). Towards the 1990s the country again became a net importer of fish but the balance of trade in value terms remained favorable due to the depreciation of the peso against the dollar. Exports hovered at P12 billion during this period. More than half of the volume was accounted for by tuna while shrimps and prawns accounted for a significant share (> 40%) in value terms (Fig. 3).

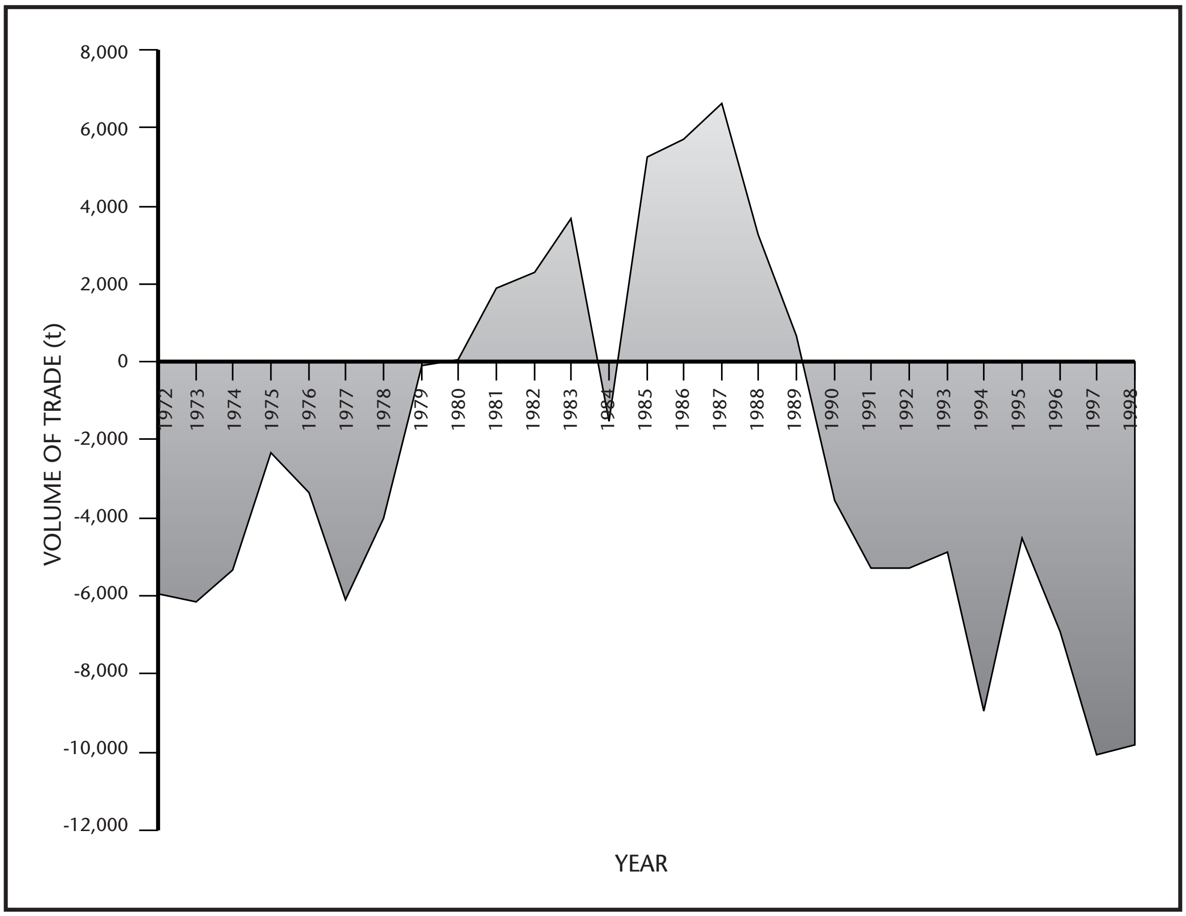

Fig. 2. Balance of trade in fisheries products, in volume terms, 1972 - 98.

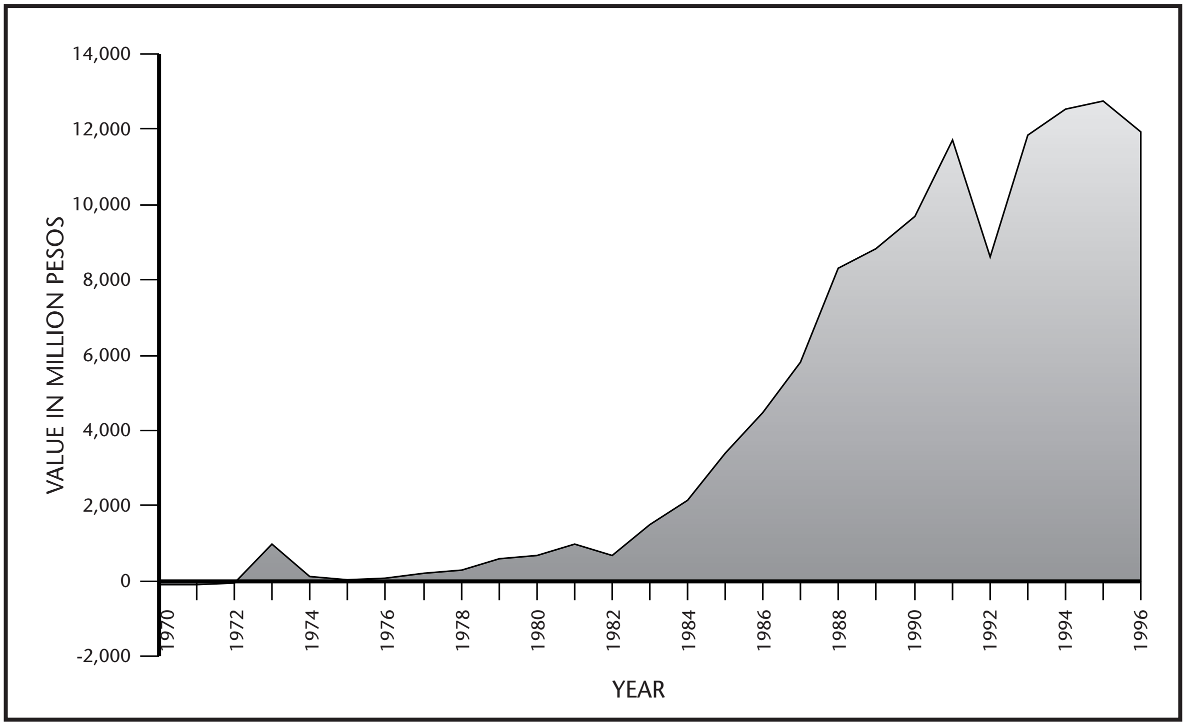

Fig. 3. Balance of trade in fisheries products, in value terms, 1970 - 96.

Price data of fish are rather patchy; thus, the five decades cannot be characterized completely. Wholesale or producer prices of seven major fish species comprising tuna (*tulingan*), roundscads (*galunggong*), anchovies (*dilis*), slipmouths (*sapsap*), threadfin breams (*bisugo*), Indian mackerel (*alumahan*) and Indian sardines (*tamban*) were observed to move in tandem with the inflation rate over 1979 - 96 (Fig. 4). Fish prices also generally move a little faster than the composite price of commodities (Fig. 4). The period 1982 - 1985 saw prices of all fish species increasing faster than inflation generating an increase in the real (inflation-adjusted) price of fish. This corresponds to the years of the financial crisis with inflation reaching all-time highs of 40% or greater. In 1984, prices of the above-mentioned fish species almost doubled. *Alumahan*, *sapsap* and *bisugo* were the species with the highest price change. Price change was also above inflation in 1987 - 1990 although to a lesser extent. Changes in fish prices were generally slower than inflation during 1981, 1985 - 86, and 1991.

For urban consumers, the retail price is a more appropriate price barometer. A comparison of wholesale and retail prices for six species including milkfish (*bangus*) indicates that the wholesale and retail prices move in the same direction (Figs. 5 - 10). A widening gap is noticeable starting in the 1990s attributable to increasing costs of transportation and marketing.

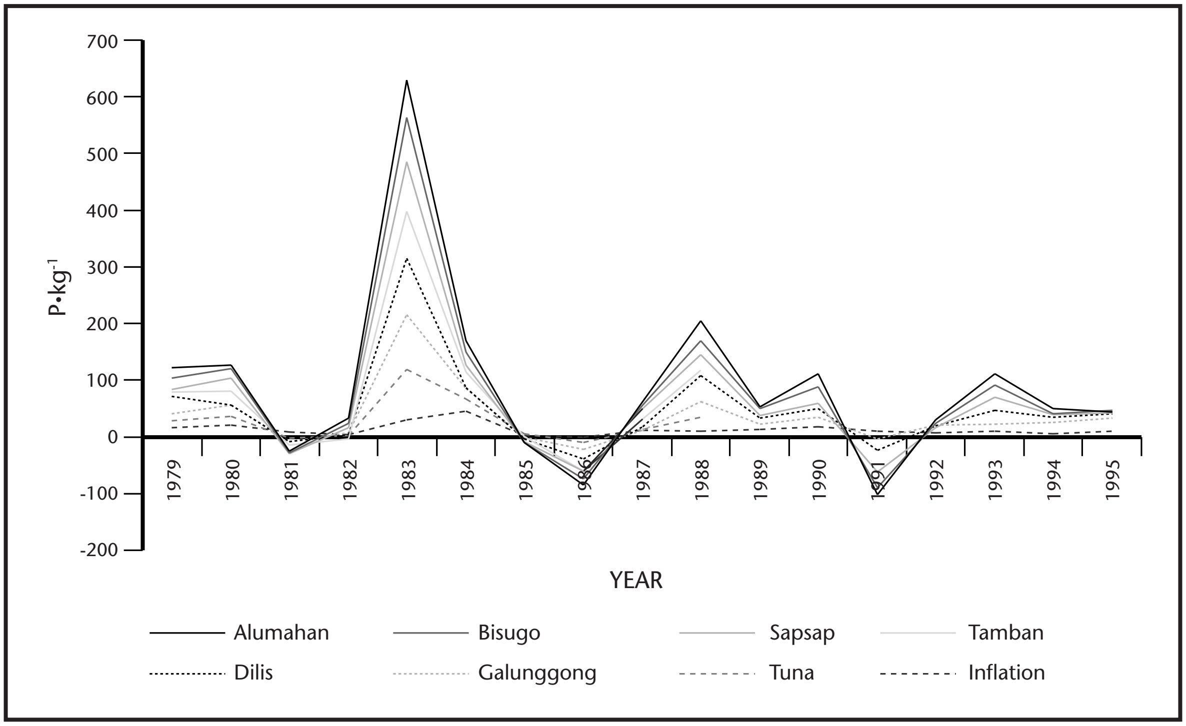

Fig. 4. Comparison of fish wholesale price movements with inflation rate, 1979 - 96.

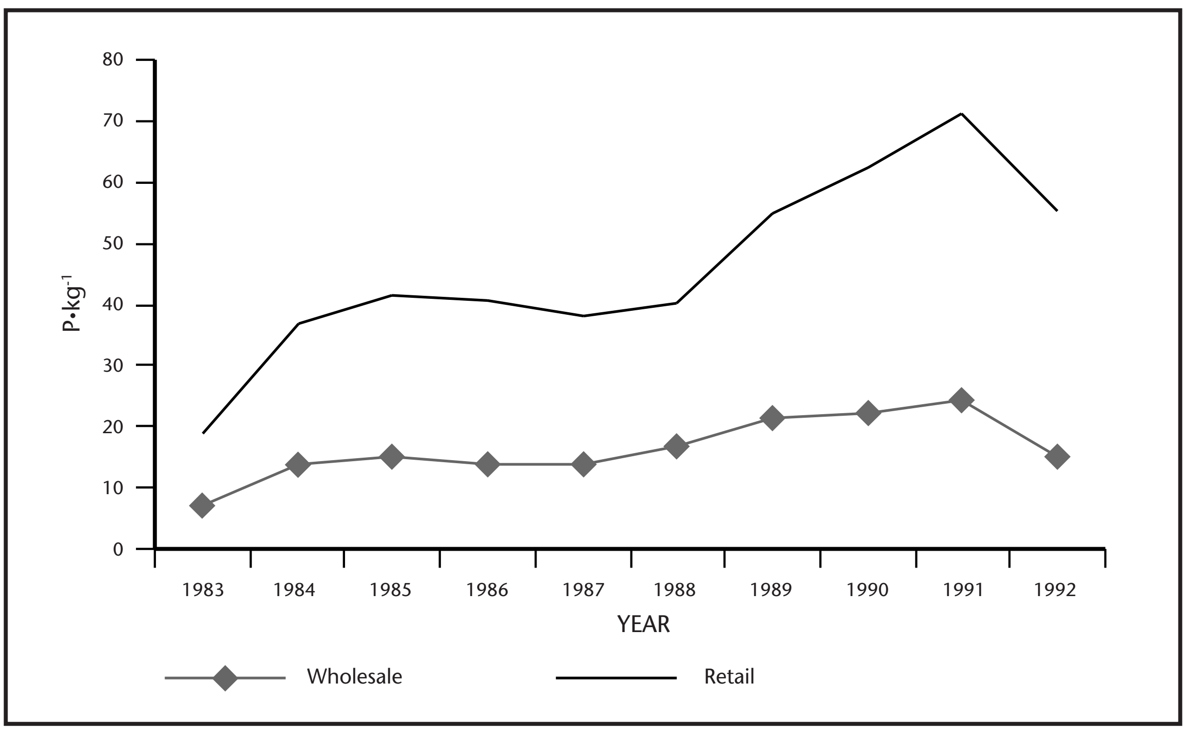

Fig. 5. Wholesale and retail price of *sapsap*, 1983 - 92.

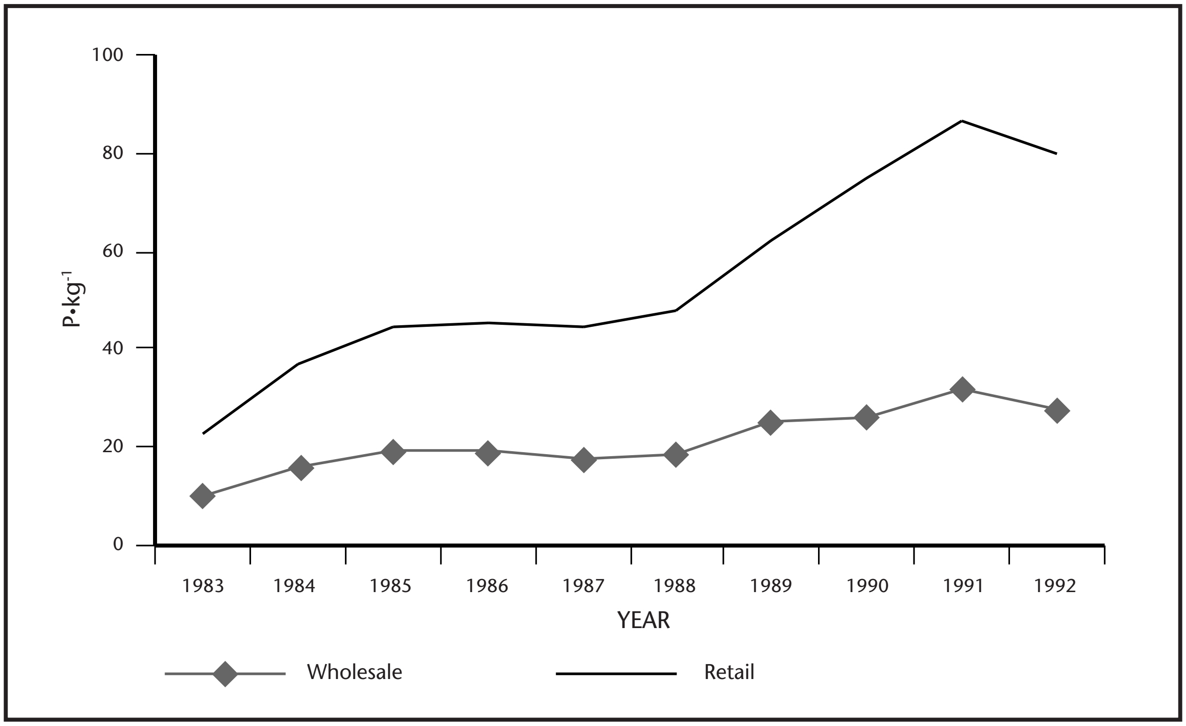

Fig. 6. Wholesale and retail price of *alumahan*, 1983 - 92.

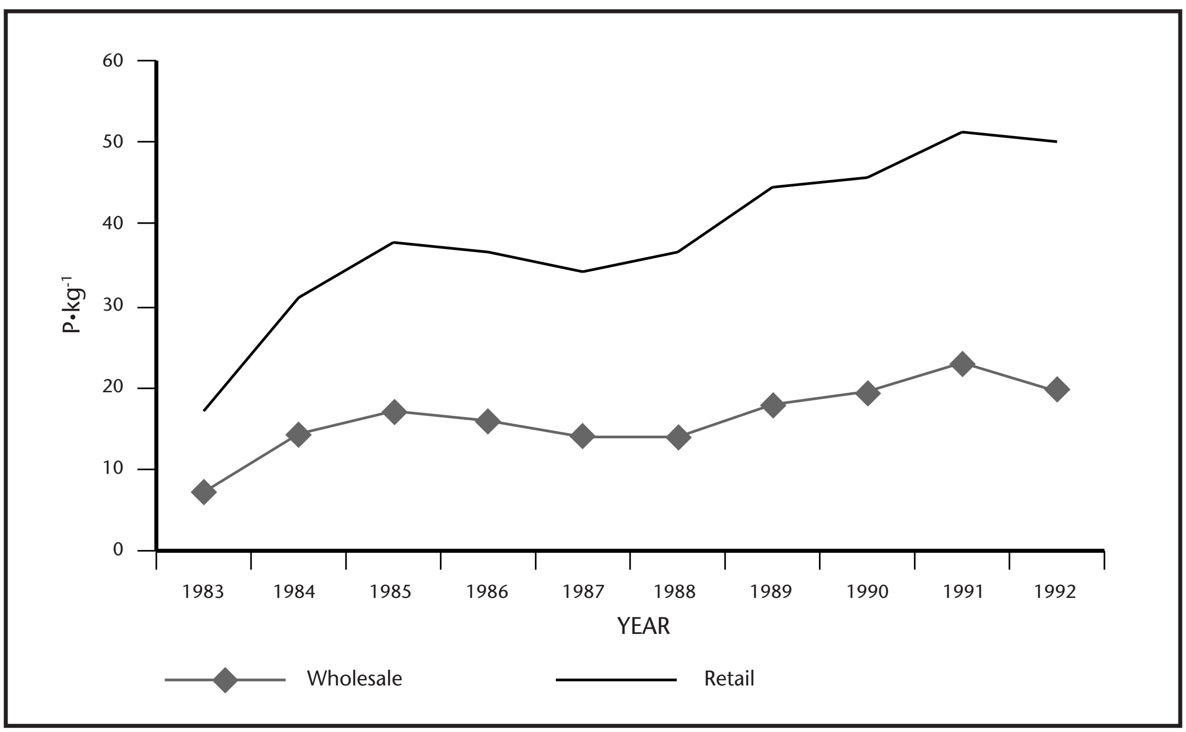

Fig. 7. Wholesale and retail price of *galunggong*, 1983 - 92.

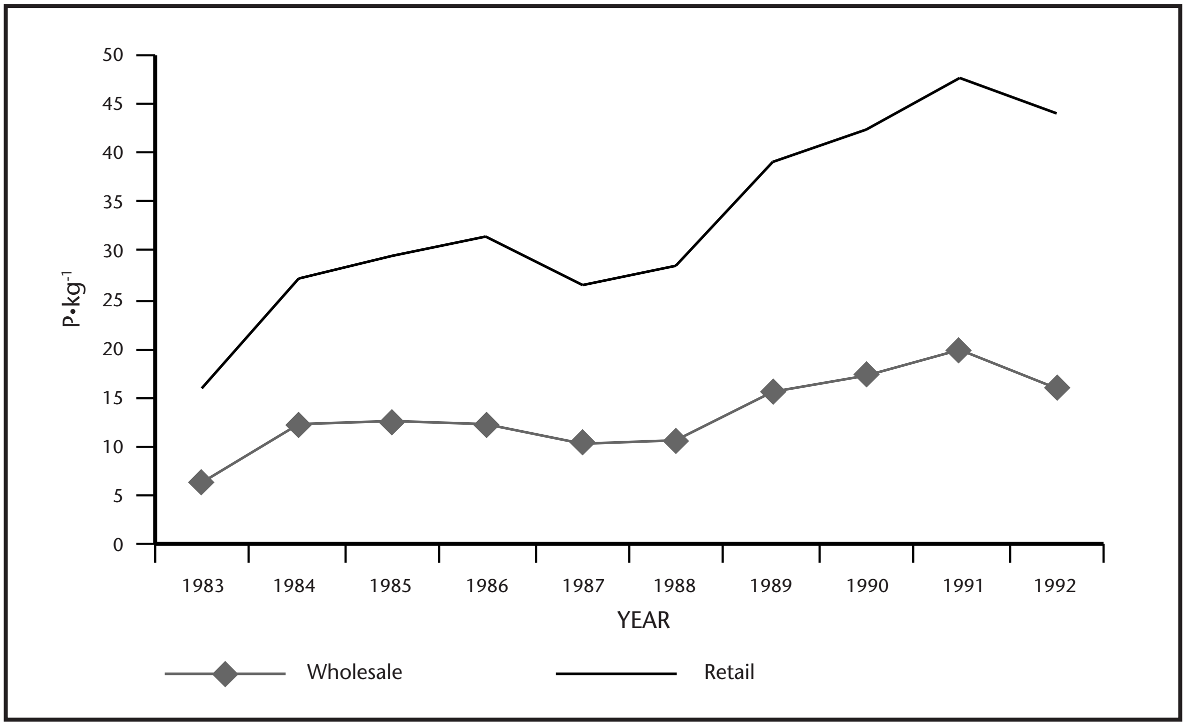

Fig. 8. Wholesale and retail price of *dilis*, 1983 - 92.

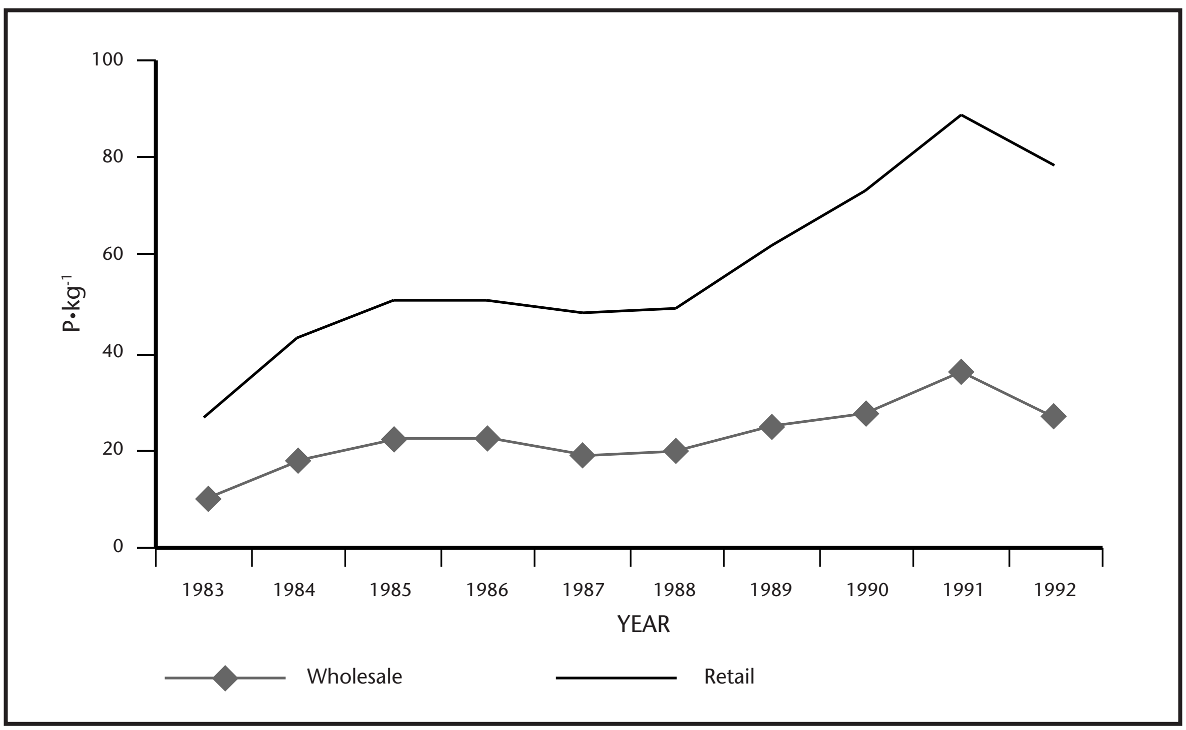

Fig. 9. Wholesale and retail price of *bisugo*, 1983 - 92.

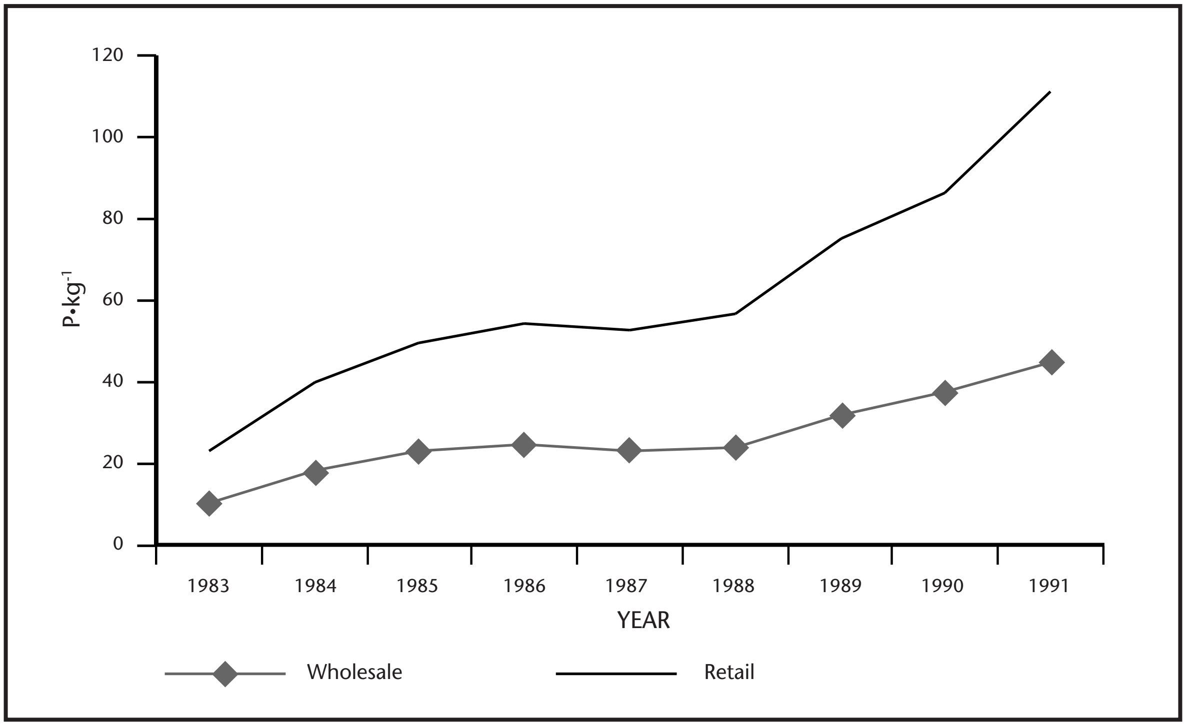

Fig. 10. Wholesale and retail price of *bangus*, 1983 - 91.

A possible explanation for this trend is the shortage of fish coupled with strong demand. Thus, the prices of severely exploited demersal stocks, such as *sapsap* and *bisugo*, topped this list for which prices moved faster than the consumer price index (CPI). Escalating costs of fishing, especially that of fuel, contributed to the fast change in prices, which also implies that the costs were being passed on to the consumers.

An earlier analysis done by (Smith 1979) using retail prices and the CPI from 1970 - 78 tells a different story. During this period, prices of fish moved in the same direction as the CPI but were noticeably lower. The study inferred that the price change in the fuel component of the CPI far outweighed the ability of fishers to pass on the costs to the consumers.

Characteristics of the Municipal Fishery

Definition

The Fisheries Code of the Philippines (1998) defines municipal fishing as "*fishing within municipal waters using fishing vessels of three (3) gross tons or less, or fishing not requiring the use of fishing vessels*. The literature uses the terminology "small scale", "artisanal" and "traditional" fishing interchangeably with municipal fishing.

Characteristics of the Fleet

Production and Employment

Data concerning the municipal fisheries sector is patchy. Except for production data, which is aggregated at the macro-level, information about vessel and gear, employment, target species, operational regimes, etc, are to be found in specific case studies. (Dalzell et al. 1987) attempted to consolidate selected information on vessels and employment from various national censuses (Table 2). The total number of vessels in the municipal sector was estimated at 20 000 in 1948 of which 83% were non-motorized. After 40 years, the municipal vessels grew to 500 000 units with the number of motorized vessels increasing substantially but not fully. An appraisal by the Fisheries Sector Project (FSP) noted that as of 1989, more than 60% of the fisher-participants at the Rapid Social Assessments were still using non-motorized vessels (PRIMEX 1996).

Table 2. Number of vessels and fishers in the municipal sector for selected years.

Year	Number of non-powered vessels	Number of powered vessels	Number of fishers
1948	16 618	3 384	63 005
1971	129 793	59 875	330 505
1977	144 742	80 774	365 388
1980	262 748	105 090	675 677
1985	270 419	193 976	700 369
1990	–	–	721 633
1995	–	–	743 544

Source: Dalzell et al. 1987; Bureau of Fisheries and Aquatic Resources (BFAR) 1948/1971/1977/1980/1985 - 95, were estimated based on a 0.06% average growth rate computed from 1948 to 1971.

Development studies suggest that municipal fishers eventually "graduate" and become commercial in nature. In the Philippine setting, the "graduation" is equivalent to motorization and improvement of gear. As the data shows, motorization has never been completed and to this day, the municipal sector exists side by side with the commercial fishery. In fact, the motorized category of the municipal sector already approximates the level of fishing effort of small commercial vessels. A good example would be baby trawlers prevalent in San Miguel Bay. While these are classified as municipal by virtue of tonnage, their operation is at par with commercial counterparts putting to great disadvantage the non-motorized fishers.

The number of fishers provided in Table 2 represents full-time and occasional fishers (Dalzell et al. 1987). Total employment in the municipal sector was 63 000 in 1948; 20 years later, the number had swelled to 330 000 fishers representing an average increase of 20% per year. The number of fishers doubled in 1980.

There are indications that the official statistics on employment are under-estimated. First, there are an estimated 500 000 fishing vessels in the municipal sector. Assuming that two people operate each boat, then the one million estimate would represent the small scale fishery alone. Second, the inputs of women engaged in processing and marketing are not accounted for, in addition to those employed in ancillary activities such as fish transport, marketing and processing.

(Dalzell et al. 1987) constructed a time series of catch and effort for the municipal fishery from 1955 - 85. Catch refers to total catch of small pelagics while effort is represented by horsepower used by motorized vessels; labor is also converted into its HP equivalent. The analysis shows a declining trend in catch per unit of effort (CPUE) (Fig.11). From an estimated 2.10 $t{\bullet}HP^{-1}$ in 1948, CPUE has gone down to 0.29 $t{\bullet}HP^{-1}$ in 1985, a mere 15% of original values. Various case studies also support the declining trend in catch rates (Table 3). Data from Olango and Candijay indicate that current catch rates represent only a tenth of the catch rates in the 1960s.

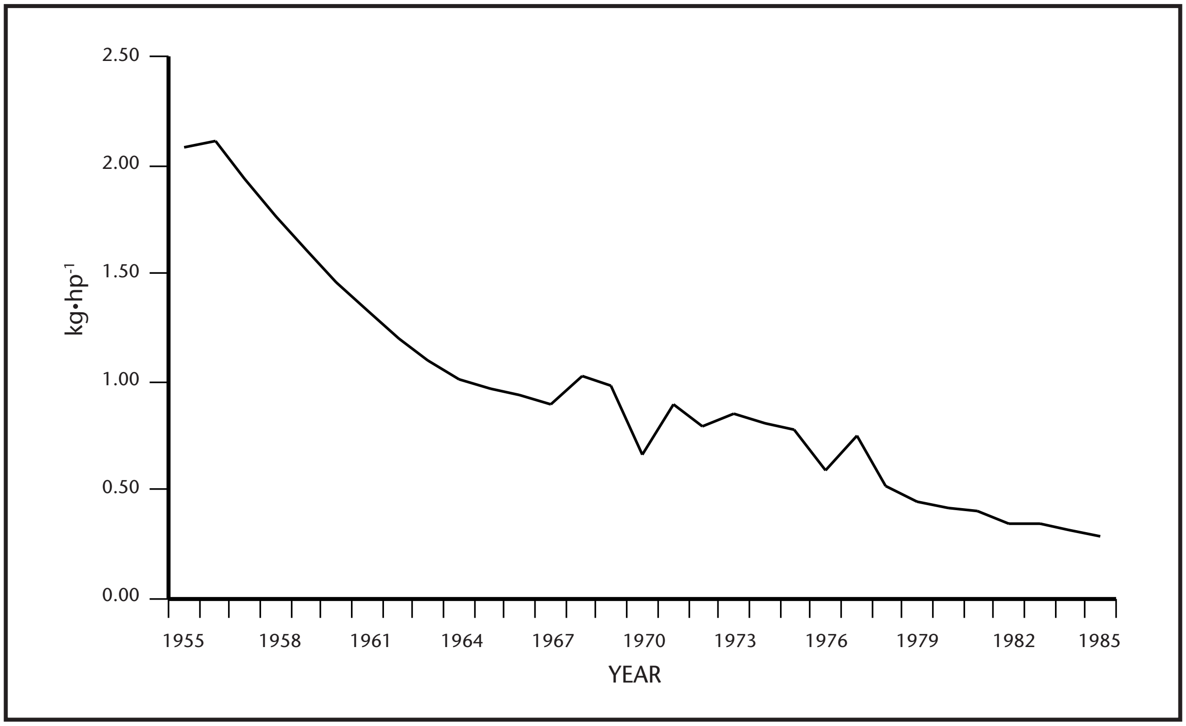

Fig. 11. Catch per unit of effort for the municipal fishery, 1955 - 85.

Table 3. Catch rates in the municipal fishery sector, various sites.

Study site	Estimated Catch Rate[1]	Source
Misamis Oriental	2 590 kg•year^{-1} for motorized vessels; 990 kg•year^{-1} for non-motorized vessels	Herrin et al. (1978)
Olango Island	6 000 kg•year^{-1} in 1960; 600 kg•year^{-1} in 1998	Coastal Resource Management Project (CRMP) (1998b)
Candijay, Bohol	6 000 kg•year^{-1} in 60s; 600 kg•year^{-1} in 90s	Katon et al. (1998)

Note: [1] Assuming 300 trips per year.

Gear and Species

Towards the end of the Spanish period (1898), municipal fishers employed various methods of fishing, such as fish corals and pots adopted from the Malays and lever net *(salambao)*, cast net *(dula)* and push net *(sakag)* adopted from China.

Gear used by municipal fishers to capture reef fish are traps, hook and line, drive-in nets, gillnets and makeshift spear guns. Up to 23% of all municipal fisheries catch is derived from coral reef areas. In addition to coral reef fisheries, there are the small pelagic stocks such as anchovies and tuna. Times series data from 1976 - 87 show several generalizations concerning gear type and species composition of the municipal fishery:

- Small pelagics accounted for 38% of catches, followed by demersals, 26%; tuna, 16%; seaweeds, 14%; large pelagics, 6% and invertebrates, 9%;
- The most important gear in terms of contribution to total catch are gillnets, 30%; hook-and-line, 24% and beach seine, 8%;

- Hook and line accounts for almost 60% of tuna catch for the municipal sector;
- Hook and line, gillnets and fish corrals account for 60% of the demersal catch in the municipal sector (Pagdilao et al. 1991).

The contribution of the various gear types and species caught in municipal fishery production remains similar for 1995 (Table 4).

Table 4. Marine municipal fish catch by major fish species and fishing gears, CY 1995 (in t).

	Major Species	Major Fishing Gear						% of Total
		Hook and line	Ringnet	Fish corral	Gillnet	Others	Total	
1.	Squid (*Pusit*)	7 407	223	1 394	14 857	19 420	43 309	5.5
2.	Fimbrated Sardines *(Tunsoy)*	1 640	1 765	1 672	33 187	4 999	43 263	5.5
3.	Frigate tuna *(Tulingan)*	20 171	3 385	1 561	7 462	9 780	42 359	5.4
4.	Anchovies *(Dilis)*	265	2 576	3 858	7 072	28 137	41 908	5.3
5.	Indian Sardines *(Tamban)*	2 377	11	391	15 901	13 922	32 602	4.2
6.	Yellowfin Tuna *(Tambakol)*	25 505	78	58	1 658	3 004	30 303	3.9
7.	Blue Crabs *(Alimasag)*	21	38	838	16 695	10 349	27 941	3.6
8.	Indian Mackerel *(Alumahan)*	1 919	1 673	197	19 939	3 881	27 609	3.5
9.	Big-eyed Scad *(Matangbaka)*	16 743	614	388	4 363	1 895	24 003	3.1
10.	Roundscad *(Galunggong)*	4 620	6 219	83	6 901	6 132	23 955	3.1
11.	Others	106 834	23 934	20 616	129 986	166 755	448 117	57.1
	TOTAL	187 502	40 516	31 056	258 021	268 274	785 369	100.0
	% of TOTAL	23.9	5.2	4.0	32.9	34.2	100.0	

Municipal Tuna Fishing

Tuna fishing started during the 1960s (Thomas 1999). Organized fishing by municipal fishers started in South Basilan, Jolo, Siasi and Tawi-tawi with the use of hand-line and troll lines in boats without outriggers. About 2 000 craft were estimated to operate during this period. Fishing operations were usually done at night in near-shore areas. Later, tuna fishing would be exported to the Visayan seas and by 1968, an organization of 500 fishers from Negros Occidental had been contracted for deep-sea tuna fishing in the Sulu Seas (Thomas 1999). The municipal fishery was invigorated during the 1980s because of the strong demand for sashimi-grade tuna. Municipal fishers from General Santos City cashed in on this boom.

Socioeconomics

(Smith 1979) provides a graphic description of the ordinary life of a municipal fisher.

"On extreme days when bad weather precludes any fishing from the small barrios of Ilocos Norte, Philippines, for example, it means that the day's meals consist of rice and salt and nothing more. Even on good days the catch is so low that it does not go far when sold in order to purchase other necessities. It means that some families have never consulted a doctor, even though several are located only a few kilometers away, because they cannot afford the nominal fee. It means that the family's sole possessions, besides its single room nipa palm house and the clothes they are wearing, are cooking utensils and some sleeping mats. It means that with

no savings and materials possessions, the poorest fishing families can never hope to secure loans for gear purchase from collateral-minded banks, whose experience with previous loans to fishermen has been anything but rewarding. It means that with little or no education, and few non-fishing skills, the poorest fishermen have little hope of shifting to another occupation ...".

After almost 30 years, the Socioeconomic situation remains the same. Preparatory reports of the FSP (PRIMEX 1996) noted that 80% of fisherfolk households were living below the poverty threshold. Average family size is 5.5 members, larger than the average for the rural sector and certainly larger than the national average. Houses are constructed of light materials and 60% do not own the land on which their houses are built, so they are renting or squatting. Access to education, electricity and water is limited.

A comparison of income estimates indicates that fishing income is mired below poverty levels. (Librero et al. 1985) estimated annual net household income (including non-fishing activities) of municipal fishers at P5 000 (P7.40 = US$1), which was above those of rice farmers, P3 500, and slightly lower than coconut farmers. Nevertheless, this estimate was still lower than the rural average of P8 500 (Table 5). In 1989, average net returns from fishing in the Lingayen Gulf area were estimated at P17.20 per day or P344/month (Añonuevo 1989). The study further shows that among four types of traditional fishing including that of bottom set gillnet, baby trawl, lift net and dynamite, the latter resulted in the highest level of net returns. This is because of the relatively low fishing cost and high catch volume.

The PRIMEX study estimates a higher income level because sampled respondents were in FSP project sites. The study was a post-FSP impact assessment. Furthermore, the peso-dollar exchange rate had by then dropped to P24:US$ 1.

The Large Scale or Commercial Fishery

Definition

Commercial fishing is defined by the Fisheries Code as follows: "the taking of fishery species by passive or active gear for trade, business or profit beyond subsistence or sports fishing, to be further classified as:

1. *Small scale commercial fishing - fishing with passive or active gear utilizing vessels of 3.1 gross tons (GT) up to twenty (20) GT;*
2. *Medium-scale commercial fishing - fishing utilizing active gears and vessels of 20.1 GT up to one hundred fifty (150) GT; and*
3. *Large scale commercial fishing - fishing utilizing active gears and vessels or more than one hundred fifty (150) GT."*

Commercial fishing and large scale fishing are used inter-changeably in this report.

Characteristics of the Fleet, Catch Rates and Species Landed

Prior to World War II, the commercial fishing industry was limited to beam trawls or "utase" which were pulled by sail and motorized sampans. After the war, various motorized war-surplus craft were converted to trawl fishing vessels.

Table 5. Income estimates of municipal fishers from various case studies.

Study site	Estimated Income	Source
Misamis Oriental	$750 for owners of motorized vessels; $625 for owners of non-motorized vessels	Herrin et al. (1978)
Nationwide	$675 of fishing households but including non-fishing activities	Librero et al. (1985)
Lingayen Gulf	$206 per year	Añonuevo (1989)
Fisheries Sector Project selected areas	$1 059 weighted average for owners of motorized (27%) and non-motorized (63%) vessels	PRIMEX (1996)

The development of the large scale fishery during the last four decades is characterized by increasing tonnage and horsepower of fishing vessels and changes in dominance of gear types (Table 6). In the 1950s, the three dominant gear were the bagnet, the trawl (including beam and otter types) and the round haul seine. However, it was the *muro-ami* that had the highest catch rate per vessel. In 1952, the total number of commercial fishing vessels was 1 200. Of this figure, only 75% were powered, 15% were non-powered and the rest unreported. At the end of the decade, there was an average of 1 277 vessels with tonnage ranging mostly from 3 GT to 10 GT, i.e. 54% of the total.

During the 1960s, the number of commercial fishing vessels increased dramatically by 67% with *muro-ami* and purse seines growing by more than 200% and trawler and bagnets growing by more than 50%, on the average. The average catch rate per vessel also increased from 73 t to 122 t. Purse seines recorded the highest increase followed by bag-nets, trawlers and *muro-ami*.

The total number of fishing vessels increased minimally, i.e. 15%, during the 1970s, with specific gear types such as *muro-ami* and round haul seines decreasing in numbers during this period. Nevertheless, catch rates especially for purse seines and trawlers continued to increase.

The fishery experienced the doldrums during the 1980s with minimal expansion and a decline to modest catch rates. Vessels with engine displacement of 300 HP and greater became a significant force during the 1980s; meanwhile those which utilized engines with 50 HP and less were reduced to roughly 1% before the decade ended. Bagnet and trawl started to decrease in number to be replaced by purse seines. However bagnets and trawls still apparently dominate despite the fact that the use is decreasing. This is also true for tonnage. During the 1970s, the contribution of vessels from 3 GT to 5 GT diminished and was replaced by those ranging from 5 GT to 10 GT. The significance of the larger tonnage category became more distinct towards the 1980s with vessels of 100 GT and greater accounting for 10%. Of these, half were in the 450 GT category.

There are 35 species comprising 70% - 95% of total commercial fisheries production which are grouped as follows: (a) demersals; (b) small pelagics and (c) large pelagics. Small pelagics have dominated commercial catches since the 1950s with roundscads, locally known as "*galunggong*", being the single most important species in terms of volume. Slipmouths, a demersal fish of lesser value, is the second most important species caught. A comparison of major species caught by different gear for selected years shows changes in species composition and dominant gear (Fig. 12). Big-eyed scad featured prominently in 1965 but diminished towards the 1970s; this was replaced by frigate tuna in the 1980s and 1990s. Roundscads clearly dominated catches in 1965; this had diminished by the 1990s and had been replaced by sardines.

Table 6. Selected characteristics of the large scale fishery sector.

Parameter	Period			
	1950 - 59	**1960 - 69**	**1970 - 79**	**1980 - 89**
Total number of vessels	1 277	2 043	2 348	2 489
Average gross tonnage	30 291	62 321	96 620	75 981
Modal HP (HP category, % to total)	50 - 125, (32%); 200 - 300, (45%)	50 - 125, (22%); 200 - 300, (58%)	125 - 200 (17%); 200 - 300 (52%)	125 - 200 (21%); 200 - 300 (27%); > 300 (17%)
Modal tonnage (tonnage category, % to total)	3 - 10 (42%); 10 - 20 (27%)	3 - 10 (38%); 10 - 20 (15%)	5 - 10 (23%); 50 - 100 (18%)	5 - 10 (22%); 50 - 100 (22%)
Modal gear type	Bagnet (54%); Trawl (26%)	Bagnet (45%); Trawl (29%)	Bagnet (32%); Trawl (36%)	Bagnet (24%); Trawl (32%)

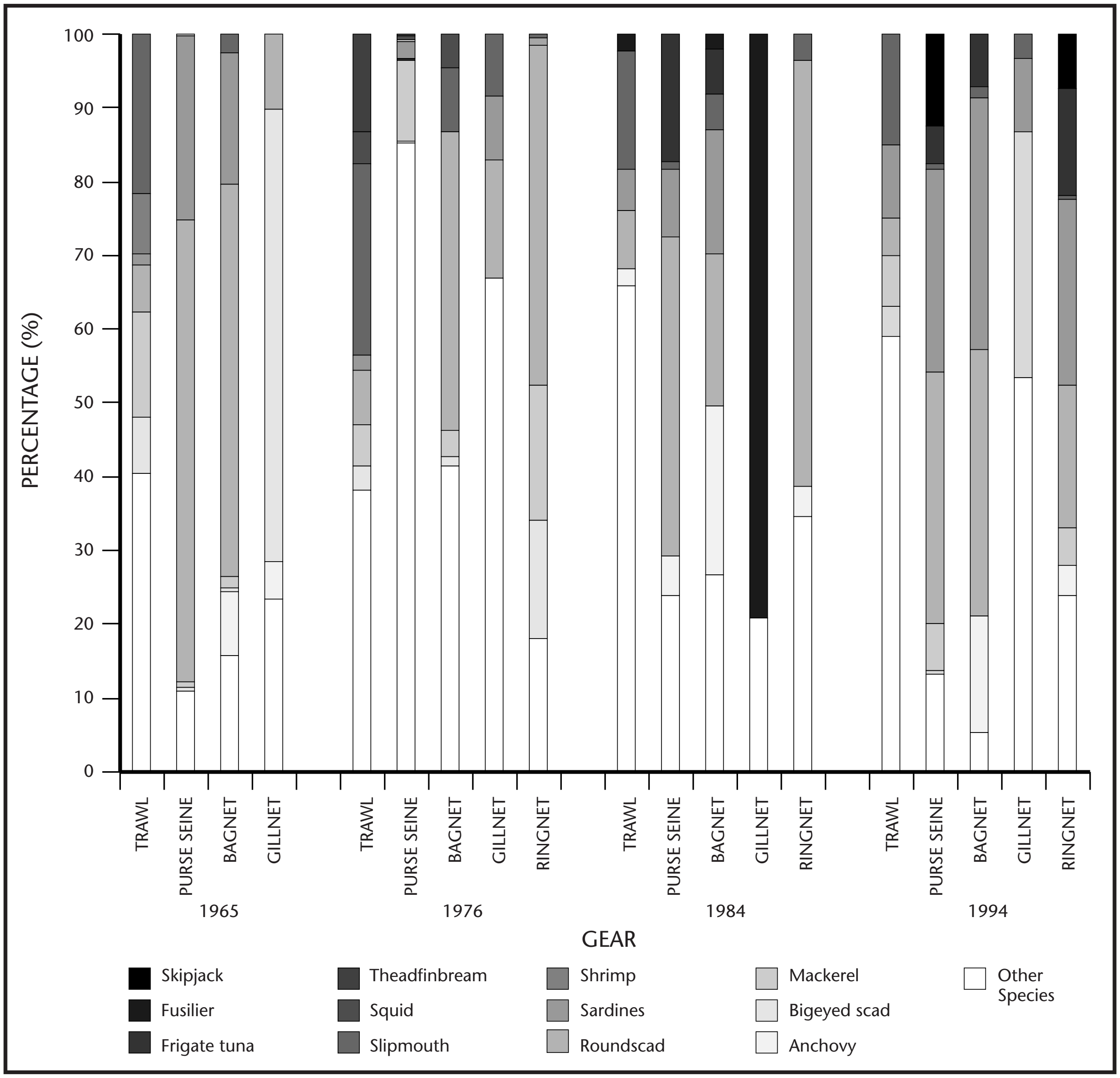

Fig. 12. Changes in species composition of selected fishing gear in the Philippines (1965 - 94).

Socioeconomics

The socioeconomic analysis in this report is based on two studies of the Development Academy of the Philippines: (a) The National Statistics Office (NSO) survey of establishments for fisheries (Development Academy of the Philippines 1996a) and (b) Cost and returns study of the Philippine commercial fishing industry (Development Academy of the Philippines 1996b). Both studies were undertaken in fulfillment of a larger project entitled "Economic rent study for commercial fishing vessels" done under the Fishery Sector Project.

NSO Survey

Background

The "Annual Survey of Establishments, Fishery" is part of a larger survey of establishments covering other sectors including mining and quarrying, aquaculture and other industries. A fishery establishment is defined in the NSO survey as "*one which*

engages in ocean and coastal water fishing, operation of fish farms, inland fishing and gathering of pearl, shells, seaweeds, pearl culture, seaweed farms and gathering of fry." The NSO survey contains information on employment, compensation, revenue, costs, assets, capital expenditures and inventories.

Raw data were collected from 61 and 62 fishing establishments for the years 1991 and 1992, respectively. These establishments were categorized according to tonnage and HP (Table 7).

Table 7. Tonnage and horsepower categories of sampled commercial fishing vessels.

Category	Tonnage Categories (GT)	HP Category
1	1 - 500	1 - 2 000
2	501 - 1 000	2 001 - 4 000
3	1 001 - 1 500	4 001 - 6 000
4	1 501 - 2 000	6 001 - 8 000
5	2 001 - 2 500	8 001 - 10 000
6	2 501 and up	10 001 and up

Analysis and Estimation of Profitability

Out of the 62 sampled fishing establishments, 73% had vessels totaling 500 GT and below. Only five fishing establishments (8%) had vessels greater than 2 000 GT. In turn, these fishing establishments accounted for 89% of tonnage for the whole fishing industry. In terms of horsepower, 46 establishments, or 74% of total, had fishing vessels using 2 000 HP engines and below. Only three fishing vessels utilized engines of 10 000 HP. Less than five fishing establishments accounted for 88% and 74% of total tonnage and horsepower, respectively, for the entire fishing industry.

Revenues from fishing included three primary fishery products which unfortunately did not allow further categorization. Total revenue of the marine fishery sector amounted to P2.28 billion (US$ no conversion available) in 1991 and P2.17 (US$ No Conversion Available) billion in 1992. For both years, at least 74% of the combined revenues were accounted for by vessels belonging to tonnage and HP category 6, i.e. greater than 2 500 GT and 10 000 HP. The rest of the categories accounted for 5 to 7% of total revenue (Tables 8 - 9).

Average revenues for the entire industry were P38 million (US$ no conversion available) and P35 million for 1991 and 1992, respectively. Between tonnage categories, however, average income is greatly dispersed. Vessels belonging to category 1 had an average income of P4 million in 1991 compared to those in category 6 which earned 120% more at P556 million (Tables 10 - 11).

Table 8. Combined revenue, cost, and net profit by total tonnage of fishing vessel fleet.

Category GRT	1991 Revenue	1991 Cost	1991 Net Profit	1992 Revenue	1992 Cost	1992 Net Profit
1 - 500	169 316 719	140 469 760	28 846 959	222 984 926	179 837 046	43 147 880
501 - 1 000	125 064 729	109 268 625	15 796 104	108 151 312	90 641 185	17 510 127
1 001 - 1 500	168 403 743	122 325 452	46 078 291	43 645 317	47 286 048	(3 640 731)
1 501 - 2 000	141 515 325	130 701 498	10 813 827	147 554 252	120 588 440	26 965 812
2 001 - 2 500	–	–	–	–	–	–
Above 2 500	1 670 976 652	1 077 143 672	593 832 980	1 646 859 884	1 206 605 864	440 254 020
All Establishment	2 275 277 168	1 579 909 007	695 368 161	2 169 195 691	1 644 958 583	524 237 108

Table 9. Combined revenue, cost and net profit by total engine horsepower of fishing vessel fleet.

Category HP	1991			1992		
	Revenue	Cost	Net Profit	Revenue	Cost	Net Profit
1. 1 - 2 000	201 064 347	166 323 739	34 740 608	227 597 752	193 878 913	33 718 839
2. 2 001 - 4 000	59 244 175	54 541 101	4 703 074	94 298 751	82 249 704	12 049 047
3. 4 001 - 6 000	81 079 069	66 371 312	14 707 757	47 318 899	34 853 281	12 465 618
4. 6 001 - 8 000	140 297 600	90 319 220	49 978 380	123 451 931	113 233 378	10 218 553
5. 8 001 - 10 000	122 615 325	125 209 961	–	53 847 442	31 651 422	–
6. Above 10 000	1 670 976 652	1 077 143 672	593 832 980	1 622 680 916	1 189 091 885	433 589 031
All Establishment	2 275 277 168	1 579 909 005	695 368 163	2 169 195 691	1 644 958 583	524 237 108

Table 10. Average revenue, cost and net profit by total tonnage of fishing vessel fleet.

Category GRT	1991			1992		
	Revenue	Cost	Net Profit	Revenue	Cost	Net Profit
1. 1 - 500	4 031 350	3 344 518	686 832	4 955 221	3 996 379	958 842
2. 501 - 1 000	17 866 390	15 609 803	2 256 587	21 630 262	18 128 237	3 502 025
3. 1 001 - 1 500	28 067 291	20 353 867	7 713 424	10 911 329	11 821 512	(910 183)
4. 1 501 - 2 000	47 171 775	43 567 166	3 604 609	49 184 751	40 196 147	8 988 604
5. 2 001 - 2 500	–	–	–	–	–	–
6. Above 2 500	556 992 217	359 047 891	197 944 326	329 371 977	241 321 173	88 050 804
All Establishment	37 299 626	25 900 147	11 399 479	34 987 027	26 531 590	8 455 437

Table 11. Average revenue, cost and net profit by total engine horsepower of fishing vessel fleet.

Category HP	1991			1992		
	Revenue	Cost	Net Profit	Revenue	Cost	Net Profit
1. 1 - 2 000	4 569 644	3 780 085	789 559	4 947 777	4 214 760	733 017
2. 2 001 - 4 000	14 811 044	13 635 275	1 175 769	18 859 750	16 449 940	2 409 810
3. 4 001 - 6 000	20 269 767	16 592 828	3 676 939	15 772 966	11 617 761	4 155 205
4. 6 001 - 8 000	35 074 400	22 579 806	12 494 594	30 862 983	28 308 345	2 554 638
5. 8 001 - 10 000	61 307 663	62 604 981	(1 297 318)	53 847 442	31 651 422	22 196 020
6. Above 10 000	556 992 217	359 047 891	197 944 326	540 893 639	396 363 962	144 529 677
All Establishment	37 299 626	25 900 147	11 399 479	34 987 027	26 531 613	8 455 414

Cost items include materials and supplies, fishing equipment rental, fuel, electricity, industrial and non-industrial services. Also included are fixed expenses such as interest, indirect taxes, and depreciation. Indirect taxes in the NSO survey include all other forms of taxes (other than income tax) including business licenses, franchise, real estate and other local taxes.

Fuel was the most important cost component contributing an average of 37% to total cost in 1992[2]. Next to fuel in importance is supplies and materials at 28%. Indirect taxes make up 2% of total cost. Operating costs account for more than 80% of total cost allowing wider flexibility to earn profit.

Total cost for the entire industry averaged P1.6 billion in 1991 and 1992. As in revenues, costs were characterized by a huge disparity across tonnage and HP categories. For example, average costs of category 1 amounted to P3.3 million in 1991 compared to that of category 6 which reached P359 million in the same year.

Generally, commercial fishing establishments realized net profits amounting to P695 million and P524 million in 1991 and 1992, respectively. As with the cost and revenue structure, that of profit is highly biased towards vessels in category 6. Vessels in category 6 accounted for more than 80% of industry profit. Meanwhile, average net profit ranged from a low of P686 000$\cdot$year^{-1} to a high of P198 million.

Limitations of the NSO Study

The NSO survey provided a good source of data to compute fishing industry profitability. However, it was not possible to make any inference about profitability estimates across tonnage and HP categories as well as within each category due to the absence of basic information on operational characteristics, i.e. gear used, species caught, travel time, fishing area, etc.. While the NSO survey is accurate, the statutory limitation on confidentiality of information meant that data could not be cross-checked because information on ownership was not provided.

The Cost and Returns Study

Background

This study embarked on a sampling of commercial fishing vessels from August to December 1994 using a combination of simple random sampling and quota sampling. The sample population consisted of commercial fishing vessels that landed in 47 fish landing sites covered by the National Fisheries Statistics Program (NFIS) of the Bureau of Agricultural Statistics (BAS). The sampling design was based on the 1987 BFAR Statistics which categorizes commercial fishing vessels by gear type, region and tonnage. A survey questionnaire was developed to elicit information on cost and revenue. The questionnaires were administered by BAS enumerators.

The method used to estimate financial and economic returns to capital and labor is depicted schematically (Figs. 13 and 14).

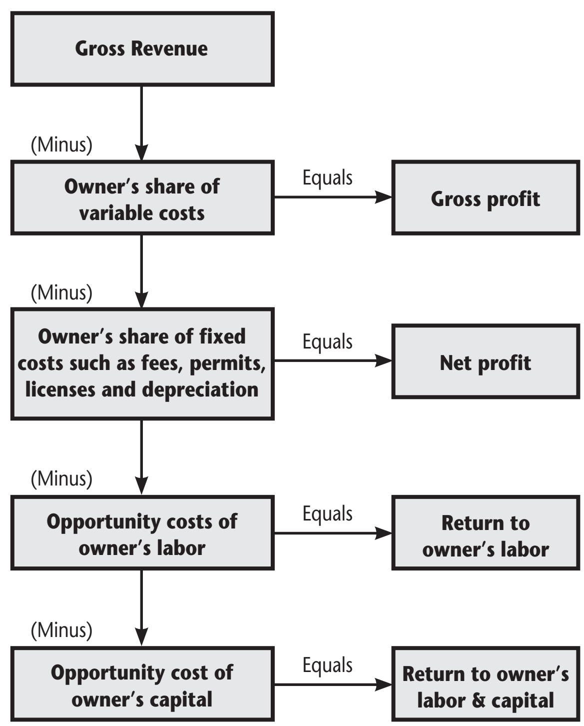

Fig. 13. A flowchart depicting the estimation of owner's profit.

[2] Similar proportion were observed for the 1991 data

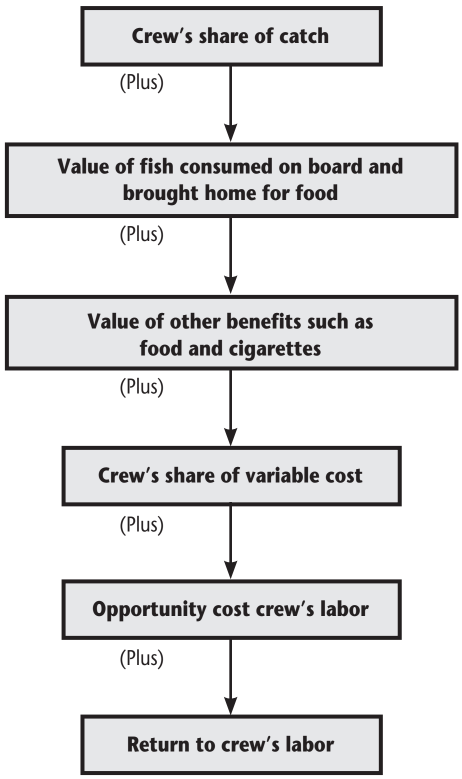

Fig. 14. A flowchart depicting the estimation of crew labor's rent.

Characteristics of Sampled Vessels and Gears

The number of vessels sampled totaled 675, or 50% of the target. On a regional basis (see Table 12), the sample ranged from a low of 20% (Regions 6 and 8) to a high of 86% (Regions 5 and 9) of target. Bagnets, ringnets and Danish seines accounted for more than 60% of gear sampled, half of which operate in Regions 4, 5 and 9. More than 75% of the sample consisted of vessels weighing 3 to 15 GT.

The survey allowed for replication, i.e. one vessel could be re-surveyed, provided that the same vessel was not surveyed twice within one week. This was because operational regimes vary per trip. The survey information including that of replicates totaled 1 351 vessels. The breakdown based on tonnage, horsepower, gear type and region is consistent with the sample size without replicates.

The survey respondents included owners, owner/operators and captains, all of whom are credible sources of information on fishing operations. Twenty-two percent of respondents had college degrees or better while the majority (65%) had either elementary or high school education. Only 2% of respondents had no formal education.

Purse seiners were the largest vessels sampled with an average tonnage of 68 GT while the smallest were those using drift filter net, gillnet, round haul seines and hook and line, i.e. from 5 - 7 GT. The smaller vessels used smaller engines, ranging from 35 to 82 HP. Trawlers, which have an average tonnage of 22 GT - a considerable deviation from the size of purse seiners, utilized the highest powered engines, 266 HP on average. Other information on the number of boats, size and number of gear is provided in Table 12.

Operational Regime of Sampled Vessels

The gear prevalent in a particular fishing ground depends on the geophysical characteristics of the fishing ground, target species, technological adaptation and economic factors (Development Academy of the Philippines, 1996b). Trawlers dominate the fishery in Lingayen Gulf, Manila Bay, Guimaras Strait and the Visayan Sea. Bag-nets are also prevalent in Manila Bay, Lamon Gulf, and Ragay Gulf, since they target small pelagics. In Regions 10, 11 and 12, where tuna is the targeted species, the more popular gear are purse seines, ring-nets and troll lines.

Table 12. Selected characteristics of commercial fishing vessels sampled from August to December 1994, by gear type and region.

Gear type	Size of boat (GT)	Size of Engine (HP)	Number of boats	Age of boats (years)	Number of gear	Age of gear (years)
Bagnet	11	132	1	8	4	–
Region 4	12	162	1	10	1	4
Region 5	11	170	1	9	7	1
Region 9	13	80	1	5	1	3
Danish seine	13	166	1	3	1	–
Region 1	19	200	1	3	1	1
Region 6	8	97	1	4	1	< 1
Region 9	23	132	1	3	1	3
Drift filter net	7	39	1	2	2	–
Region 2	7	39	1	3	2	2
Gillnet	5	75	1	7	49	–
Region 3	5	75	1	2	50	< 1
Hook and line	5	82	2	4	15	–
Region 9	3	83	1	5	17	2
Region 12	5	81	3	4	13	< 1
Purse seine	68	235	5	3	1	–
Region 1	208	550	4	7	1	< 1
Region 4	15	190	5	10	1	< 1
Region 5	118	290	5	4	1	< 1
Region 8	6	80	2	2	1	< 1
Region 11	57	220	6	4	1	3
Ringnet	13	130	2	5	1	–
Region 5	3	88	1	6	1	9
Region 7	25	225	2	5	1	4
Region 11	16	128	1	6	1	3
Round haul seine	5	35	9	3	1	–
Region 11	3	80	9	6	1	< 1
Trawl	22	266	1	3	1	–
Region 5	10	227	1	13	1	2
Region 6	34	249	1	5	2	< 1
Region 9	15	235	2	4	1	1

Cost Structure

Costs are broken down into investment and operating costs; the latter are further decomposed as fixed and variable. The main investment items are boat(s), engine, gear/net, and motors. For larger vessels, assets may include sonars, radios, radars, and on-board processing equipment. Average investment costs for hull, engine and gear of the major types of fishing operations surveyed are provided in Table 13.

Variable costs are incurred when fishing, while fixed costs are incurred regardless. Fixed costs include different types of licenses and fees including operating license, BFAR licenses, coast guard fees, insurance, police clearance, and cost of plate. Fixed costs were observed to vary between gear types and among tonnage classes; however, there was no evident pattern in the frequency and amount of fixed costs among tonnage categories. A likely explanation is the unstructured collection of fees and charges and the often arbitrary manner in which these are collected. Depreciation, which is based on estimates of acquisition (or replacement) cost, accounts for more than 95% of fixed cost. Given that depreciation does not involve any cash outlay, the only cash outflow of a commercial vessel is meagre (Table 14).

Variable cost is related to the type and duration of the fishing operation. The main variable cost items are fuel, ice, food, labor and repairs and maintenance. Fuel and ice are the major components of material expense. Purse seiners and trawlers have the highest operating expenses, mainly because of fuel cost. Material expenses generally increase in tandem with tonnage (Table 15). Repairs and maintenance expense, i.e. wharfage, dry-docking, hull and engine repair, and gear repair, were positively correlated to age of the asset (Development Academy of the Philippines 1996b).

Crew size ranged from 8 members, for hook and line, to 27 members, for gillnetters and purse seiners. Some variability was observed for crew size across tonnage classes for particular gear types. For example, smaller bagnetters (< 5 GT) counted 11 crew members while those ranging from 26 to 50 GT had 26 crew members. On the other hand, hook and line operations maintained a uniform number of crew, i.e. 4 to 5 people, despite a wide range of boats, from 5 to 50 GT.

Table 13. Average investment (acquisition and replacement) costs, age, and economic life of commercial fishing vessels sampled from August to December 1994, by gear type.

Gear type	Hull				Engine				Gear			
	Age (yrs)	Economic Life (yrs)	Acquisition Cost (P'000)	Replacement Cost (P'000)	Age (yrs)	Economic Life (yrs)	Acquisition Cost (P'000)	Replacement Cost (P'000)	Age (yrs)	Economic Life (yrs)	Acquisition Cost (P'000)	Replacement Cost (P'000)
Bagnet	8	11	208.5	259.9	7	8	51.1	38.0	2	7	86.6	105.1
Danish seine	3	4	354.0	513.0	2	4	48.0	60.0	1	3	66.0	94.0
Gillnet	7	10	161.1	132.1		2	95.2	91.1		9	213.6	73.3
Drift filter net	2	8	24.4	30.9	2	8	55.4	61.7		6	20.2	24.0
Hook and line	4	8	86.0	152.0		8	23.0	30.0	1		1 850.0	973.0
Purse seine	5	14	472.0*	360.0*	5	12	76.0	220.0		10	3 200.0	3 700.0
Ringnet	6	8	362.0	470.0	4	6	54.7	50.9	3	7	258.2	403.8
Round haul seine	3	10	23.0	25.0	3	10	30.2	39.3	4	10	116.7	137.1
Trawl	7	8	339.0	568.1	4	6	110.1	132.3		2	82.6	112.0

1 US$ = P26.60 in 1994 (source: oanda.com)
Note: * larger variance (see text for detail)

Table 14. Average annual fixed costs incurred by commercial fishing vessels sampled from August to December 1994, by gear type and tonnage, in pesos.

Gear Type	Depreciation	Licenses and Fees	Total
Bagnet			
< = 5	114 858	1 878	116 736
5 - 15	52 950	5 412	58 362
16 - 25	35 360	4 334	39 694
26 - 50	20 678	2 932	23 610
Danish seine			
< = 5	73 556	1 260	74 816
5 - 15	142 163	2 554	144 717
16 - 25	153 275	7 897	161 172
> - 50	159 778	9 125	168 903
Drift filter net			
< = 5	36 982	1 165	37 547
5 - 15	45 398	1 217	376 481
Gillnet			
< = 5	65 466	2 086	67 552
5 - 10	70 913	1 704	72 616
Hook & line			
< = 5	241 348	1 630	242 978
5 - 15	160 608	1 305	161 913
25 - 50	140 224	180	140 404
Purse seine			
< = 5	10 279		10 279
5 - 15	48 029	1 125	49 154
50 - 100	1 069 697	475	1 070 172
> = 100	873 893	950	874 843
Ringnet			
< = 5	35 615	233	35 847
5 - 15	80 031	1 540	81 570
16 - 25	214 862	3 301	218 163
26 - 50	194 668	2 866	197 554
Round haul seine			
< = 5	10 914	210	11 124
5 - 15	15 813	311	16 124
Trawlers			
< = 5	16 388	5 556	21 944
5 - 15	172 726	1 331	174 057
16 - 25	1 571 807	1 519	1 573 327
26 - 50	144 514	6 481	145 009
51 - 100	427 038	245	427 283
> = 100	125 546	713	126 258

Table 15. Average material expenses of commercial fishing vessels sampled from August to December 1994 in peso per trip, by gear type and tonnage category.

Gear Type	Fuel	Oil	Kerosene	LPG	Ice	Salt	Food	Cigarettes	Others	Total
Bagnet										
< = 5	409	115	0	0	183	0	10	1	8	726
5 - 15	871	189	12	8	507	2	186	12	34	1 821
16 - 25	1 262	223	3	2	421	2	228	2	2	2 145
26 - 50	1 412	93	0	5	330	0	90	5	15	1 950
Danish seine										
< = 5	1 252	85	0	0	1 027	0	373	246	12	2 995
5 - 15	3 729	424	15	48	2 888	5	605	93	63	7 870
16 - 25	2 105	256	0	70	1 823	0	1 159	108	105	55 626
> - 50	3 281	477	0	40	1 483	0	1 130	103	74	6 588
Drift filter net										
< = 5	248	31	40	0	0	0	410	180	30	939
5 - 10	278	29	0	0	0	0	467	190	22	986
Gillnet										
< = 5	702	410	33		2 398	116	943	123	0	4 742
5 - 15	652	473	53	17	2 151	55	1 891	194	0	5 524
Hook & line				55						
< = 5	3 582	545	2 810	0	1 736	50	646	100	275	9 690
5 - 15	7 821	1 030	108	0	2 063	150	1 044	236	900	13 352
Purse seine										
5 - 15	2 839	72	1 095	5	1 085	0	110	40	10	5 256
50 - 100	2 550	6 800	0	0		4 125	1	3 232	0	39 707
> = 100	53 194	843	0	98	4 056	0	744	50	0	58 985
Ringnet										
< = 5	457	53	27	1	90	1	118	10	12	769
5 - 15	1 163	162	75	0	419	13	298	32	32	2 194
16 - 25	2 194	73	2	0	1 047	1	310	1	28	3 656
26 - 50	2 112	501	5	86	1 577	2	405	24	80	4 910
Round haul seine										
< = 5	434	60	160	0	0	0	120	40	27	841
5 - 15	583	90	287	0	0	0	150	60	55	1 225
Trawlers										
< = 5	2 860	42	3	22	576	0	350	0	0	3 853
5 - 15	5 922	592	3	12	1 955	56	584	122	45	9 291
16 - 25	10 583	1 301	6	42	3 016	133	1 096	146	27	16 350
26 - 50	5 293	571	0	30	1 322	4	592	153	57	8 022
51 - 100	35 000	4 179	325	67	4 581	26	1 054	317	350	45 899
> = 100	46 570	713	0	73	8 655	5	1 208	11	74	57 309

In this study, labor was considered from two perspectives: (i) as a cost to the owner and (ii) as a benefit to the crew member. From the owner's perspective, labor cost is a component of operating cost. From the laborer's perspective, "return to labor" is computed based on the prevailing compensation system and other benefits earned per fishing operation. The most common form of payments to labor is that of the share system which varies according to gear (Table 16). Other fringe benefits include food and cigarettes provided on board and fish taken for home consumption. A crew member sometimes receives a fixed salary on top of his share; however, the bulk of the fisher's earning comes from his share. This then depends on the volume of catch.

Table 16. Average crew size and crew/owner sharing system by gear type.

Gear Type	Average Crew Size	Owner: Crew Sharing Ratio
Bagnet	13	54:46
Danish seine	11	50:50
Drift filter net	10	75:25
Gillnet	27	47:53
Hook and line	8	63:37
Purse seine	27	57:44
Round haul seine	8	50:50
Ringnet	20	55:45
Trawler	9	58:42

Revenue Structure

Revenues of commercial fishing vessels depend on three things: total volume of catch, species composition, and prices. A higher volume of catch results in higher revenues; this is further enhanced when the species caught are commercially desirable.

Catch per trip for purse seiners was 13 259 kg, the highest among the gears surveyed. On a regional basis, purse seine catch of region 11 (55 000 kg) was higher than the national average despite the fact that the vessels sampled here were smaller than those surveyed in regions 1 and 5. Trawlers ranked next followed by Danish seiners and gillnetters (Table 17).

Table 17. Average catch of commercial fishing boats by gear type, region and average tonnage.

Gear Type	Region	Tonnage GT	Catch (kg)
Bagnet	4	12	421
	5	11	2 158
	9	13	785
Danish seine	1	19	759
	6	8	636
	9	23	15 230
Drift filter net	2	7	258
Gillnet	3	5	4 452
Hook and line	9	3	3 098
	12	5	741
Purse seine	1	208	7 428
	2	415	207
	5	118	4 120
	8	6	1 474
	11	57	55 000
Ringnet	5	3	232
	7	25	837
	11	16	2 262
Round haul seine	11	3	50
Trawler	5	10	1 278
	6	34	2 361
	9	15	1 298

Dominant species varied across gear and region. Catches of Danish seiners in regions 1 and 6 were dominated by demersals (lizard fish, moonfish and threadfin bream) while those of region 9 were dominated by Indo-Pacific mackerel. Purse seiners operating in regions 1 and 11 yielded skipjack and yellowfin tuna; however those operating in regions 4 and 5 yielded pelagics such as big-eyed scad, short-bodied mackerel, and roundscads (Development Academy of the Philippines 1996b).

Ex-vessel prices for species caught varied across different landing sites due to market dynamics and micro transactions that include quality and type of species landed, its volume in relation to aggregate landing and preferential relationships between buyer and fisher (Table 18).

Profitability, Productivity and Efficiency Parameters

Average gross and net profit were positive for all

tonnage categories (Table 19). Profit was positively correlated with tonnage. Returns on investments (ROIs) were all positive and greater than one. Hook and line vessels had the largest ROIs especially those of less than 5 GT (Development Academy of the Philippines 1996b). This is because of the relatively smaller investment and the high-valued species targeted (tuna).

The operating ratio is a measure of the efficiency of converting inputs into outputs. A low operating ratio means that a peso spent on operating expense results in more than a peso worth of gross profits and *vice-versa*. According to the data collected, only tonnage categories 1 and 8 are cost-efficient (operating ratio is less than 1) while the least efficient category are those with vessels from 30 to 50 GT (Table 20). Another measure of efficiency used is the Fuel to Fish ratio (FF) which indicates how much fish is produced per liter of fuel. The FF ratio is observed to increase with tonnage; among gear types, the FF ratio is highest for trawlers and lowest for hook and lines and gillnets.

The study also computed the pure net profits accruing to owner and labor (Figs. 13 and 14). Pure profits to owner and labor are positive for all tonnage categories (Table 21). The implications are as follows: for the owner of capital, investing in fisheries is profitable even when compared to alternative uses of capital and owner's labor; for the laborer, working in fisheries results in earnings greater than alternative forms of labor. In total, the industry earned P11 billion in pure profits during 1994.

Table 18. Comparison of ex-vessel prices of important fish species landed by commercial fishing vessels from August to December 1994, by landing site.

Fish Species	Damortis	Palawip	Hagonoy	Dalahican Lucena	Sabang Calabanga	IFPC Iloilo City	Hinigiran	CDCP Fort Pilar	Naga	Lions' Beach
Anchovies			18		8		17		13	
Big-eyed herring		37								
Big-eyed scad	60	46		47				11	18	37
Cavalla		76			48		45	35	34	
Crevalle	40	59			17		12	21	19	
Goatfish	34	38			19	21	22		16	
Grouper	80	120					78	46	30	
Hairtail			10	33		19	19			
Indian sardines					17			8	12	
Indian mackerel	65	58					31		16	
Indo-pacific mackerel	69	60	46			27	21			
Mackerel			20							
Round herring									12	
Roundscad		38		36			26	8	11	20
Sardines		10							13	18
Skipjack tuna										
Slipmouth	70	59				26				
Spanish mackerel		78	56				183	70		
Squid	83	70	66	65		35	33	40	25	
Threadfin bream	77	57		50			41			
Yellowfin tuna						55	58	20		

Table 19. Average annual profitability parameters of commercial fishing vessels sampled by DAP from August to December 1994, by tonnage class.

Category number/Tonnage class	Number of vessels sampled	Gross profit (P'000)	Net profit (P'000)	Return on investment (%)
Category 1 / < 5 GT	40	3 149.4	3 064.7	29.94
Category 2 / 5 to 10 GT	374	5 032.2	4 933.6	19.41
Category 3 / 10 to 15 GT	232	4 661.3	4 554.3	13.73
Category 4 / 15 to 20 GT	76	2 703.6	2 580.9	7.25
Category 5 / 20 to 25 GT	89	2 735.8	2 309.6	4.31
Category 6 / 25 to 30 GT	51	6 800.0	6 623.3	10.62
Category 7 / 30 to 50 GT	70	6 426.6	6 228.0	12.75
Category 8 / 50 to 100 GT	9	29 866.2	29 441.0	22.01
Category 9 / 100 GT and up	8	18 380.8	17 966.5	2.48

Note: 1 US$ = P26.60 in 1994

Table 20. Efficiency parameters of commercial fishing vessels sampled by DAP from August to December, 1994.

Category number/ Tonnage class	Operating ratio	Fuel to Fish ratio (liter of fuel: kilo of fish)
Category 1 / < 5 GT	0.25	0.23
Category 2 / 5 to 10 GT	2.49	0.62
Category 3 / 10 to 15 GT	7.99	0.64
Category 4 / 15 to 20 GT	1.37	0.88
Category 5 / 20 to 25 GT	2.10	0.86
Category 6 / 25 to 30 GT	2.36	0.87
Category 7 / 30 to 50 GT	18.2	0.42
Category 8 / 50 to 100 GT	0.91	1.13
Category 9 / 100 GT and up	3.46	2.22

Table 21. Estimates of average pure profit to owner and labor in the commercial fishing industry.

Tonnage	Pure profit to Owner (P'000)	Pure profit to labor (P'000)	Total pure profit of the fishing unit (P'000)
< 5	3 024.6	2 683.1	5 707.7
5 to 10	4 870.2	5 202.3	10 072.6
10 to 15	4 475.2	4 928.2	9 403.4
15 to 20	2 471.1	1 917.0	4 388.0
20 to 25	2 146.2	2 559.1	4 705.3
25 to 30	6 447.7	6 202.2	12 650.0
30 to 50	6 005.0	4 888.7	10 893.7
50 to 100	29 179.5	5 578.0	34 757.6
100 and up	17 282.0	3 654.8	20 936.7

Limitations of the Study

A possible limitation of this study is the fact that data collection and the short duration of the survey automatically excluded vessels which stay out at sea for months. The survey thus focused on the "small" commercial vessels, those greater than 3 GT but less than 50 GT.

Bioeconomics of Fisheries

This section discusses the available bioeconomic analyses done for the fisheries sector instead of reconstructing the models. These studies utilized theoretical constructs called "surplus production models" to determine whether or not a particular fishery is over-fished. Over-fishing is viewed from both the biological and economic angles.

Three studies focused on the small pelagics fishery: (Dalzell et al. 1987; Padilla and de Guzman 1994; Trinidad et al. 1993). An earlier study on the demersal fishery was authored by (Silvestre and Pauly 1987).

(Dalzell et al. 1987) analyzed both the municipal and commercial sectors which were exploiting small pelagics. Data used were published statistics of the BFAR. The authors employed extrapolation to compete the time series for 1948 - 85 especially for the municipal sector. MSY was reached in 1975 while MEY was reached in 1970 at 500 000 t.

The study of (Trinidad et al. 1993) used both primary and secondary data. The primary data were collected through a cross-section survey conducted in selected sites in six regions of the country which accounted for a significant share in total small pelagics catch including: Navotas Fish Port; Dalahican, Lucena City; Mercedes, Camarines Norte; Banago Wharf, Bacolod City; Guinhalaran, Silay City; Danao City, Cebu; and, Cawa-cawa Blvd and Labuan, Zamboanga. The study also analyzed the cost and revenue components, technical efficiencies and pure profits of commercial and municipal gears exploiting the small pelagics fishery. The study bolstered the earlier findings of (Dalzell et al. 1987) by confirming that the small pelagics fishery was truly over-fished and that open-access equilibrium had been reached during the 1980s. This meant that on average, pure profits accruing to labor and capital were either zero or negative. A 20% reduction in fishing effort was recommended in order to attain MSY levels.

The (Padilla and de Guzman 1994) study focused on developing a method for environmental resource accounting in the fishery. The study utilized the same techniques as in the above-mentioned studies and resulted in similar observations, i.e. that the small pelagics fishery is overfished and that at the time of writing, about P7 billion was being lost by not operating at MEY levels.

(Silvestre and Pauly 1987) used trawler horsepower as a measure of fishing effort given that it is the major gear for catching demersal species. The study concluded that the demersal fishery was already over-fished during the 1970s.

Table 22. A comparison of selected results of bioeconomic studies in Philippine fisheries.

Study	Time series	Fishery analyzed	Model used	MSY parameters
Dalzell et al. (1987)	1948 - 85	Small pelagics, municipal and commercial sector	Fox model	Catch level = 544 000 t Effort = 256 000 HP
Trinidad et al. (1993)	1949 - 85	Same	Schaefer and Fox model	Catch level = 515 000 t Effort = 320 000 HP
Padilla and de Guzman (1994)	1948 - 91	Same	Fox model	Catch level = 573 000 t Effort = 294 000 HP
Silvestre and Pauly (1987)	1952 - 84	Demersal, municipal and commercial sector	Fox model	Catch level = 340 000 to 400 000 t

Policy Highlights in the Fisheries Sector

The policy environment for fisheries in the past half decade has been generally characterized by the following:

a. shift in governance from centralized to localized
b. shift from open access to limited access
c. shift from full development to management.

A timeline showing the policy highlights in fisheries is depicted in Table 23. Centralized governance was the prevailing management regime during the 1950s and 1960s. The (then) Secretary of Agriculture and Natural Resources (and designated deputies) had full control over management and regulation of fisheries including that of local legislation. Presidential Decree (PD) 704 recognized municipal fishing as being within the purview of municipalities since it already provided for licensing and granting of fishing rights even before the Local Government Code (LGC) was enacted. The trend towards localized participation is affirmed by both the LGC and later by the Fisheries Code. A listing of the responsibilities of local governments in the implementation of coastal management, and in particular, fisheries management, is contained in the "Legal and Jurisdictional Guidebook for Coastal Resource Management in the Philippines" (Department of Environment and Natural Resources (DENR) et al. 1997). The LGC further expanded, causing much confusion, the coverage of municipal waters to 15 km. Local governance also entails genuine community participation as guaranteed by the creation of Fisheries and Aquatic Resources Management Councils (FARMCs) through Executive Order EO 240 and reiterated and strengthened by the Fisheries Code.

The impact of the LGC on the expansion of municipal waters to 15 km is twofold: (a) it limited access to commercial fishers and (b) it highlighted the need for a more equitable distribution of benefits to the marginalized municipal sector. The policy was driven by issues of economic efficiency and food security, especially of urban consumers. The policy prescription of the LGC came at a time when catches from the marine capture fishery, both f rom the commercial and municipal sector, were on a continuous decline. Given this scenario, a possible intent of the LGC was to limit access to both the municipal and commercial sectors, especially of the near-shore municipal waters. Access limitations are more straightforward in the Fisheries Code with such mechanisms as: (1) registry of municipal fisherfolk; (2) exclusion of non-resident fishers in certain municipal waters with the attendant coding of vessels; (3) mapping and delineation of municipal waters; (4) traditional limitations such as closed areas and seasons; and (5) non-traditional access limitations such as use of economic rent indicators to set production targets for the fishery. Access limitations are strategies that veer away from full development to that of management. The policy framework, as well as the analysis of fleet development, depict a short period of robust growth during the 1960s. This was reduced during the mid-1970s as evidenced by the enactment of PD 704 and the ultimate "takeover" by the aquaculture sector.

Presently, the Fisheries Code "seals the fate" of the ailing capture fishery sector. The Code's policy biases are seen through various provisions for incentives (and disincentives) to the commercial and municipal sectors (Tables 24 and 25). Specific provisions, i.e. those which limit access and tend towards the protection side, are unfavourable to both sectors. Incentives for commercial fishers to utilize the offshore fishing grounds portent another "development" phase while limiting their options in municipal waters, i.e. through exclusion and prohibition of active gear. Municipal fishers have been granted greater advantage in the 15 km area but are also subject to controls and stringent penalties administered by local governments.

Table 23 . Fisheries policy highlights in the last 50 years.

Year	Milestone
2000	The DENR and DA sign the Joint Memorandum Order on the implementation of the Fisheries Code
1999	Philippines is signatory to the implementation of the Rome Declaration on the Code of Conduct for Responsible Fisheries Pres. Proclamation No. 57 declares the yearly celebration of May as Month of the Ocean
1998	RA 8550 (Fisheries Code) establishes coastal resource management as the approach for managing coastal and marine resources
1997	RA 8435 (AFMA) recognizes the importance of fisheries to food security and providing for Integrated Coastal Management Training
1996	Memorandum Order 399 directs operationalization of Philippine Agenda 21
1995	EO 241 creates Fisheries and Aquatic Resources Management Councils (FARMCs)
1994	DA-DILG MOA, s1994 devolves some regulatory functions pertaining to fishing regulations to LGUs The Philippines becomes a signatory to the Law of the Sea
1991	RA 7160 (LGC) devolves primary mandate for managing municipal waters to LGU
1990	The Presidential Commission on Illegal Fishing and Marine Conservation coordinates all government and non-government efforts in the planning and implementation of a national program for the conservation of marine and coastal resources
1987	DA abrogates and subsumes BFAR's administration, regulatory, and enforcement functions The DENR and BFAR are given mandates for fisheries development
1986	Ban on operations of commercial trawl and purse seine in marine waters within 7 km from shoreline of all provinces in the Philippines *Muro-ami* and *kayakas* are prohibited from operating in Philippine waters
1985	Distant water fishing fleets are encouraged
1984	Regulation on gathering, catching, taking, or removing of marine tropical aquarium fish
1981	The Philippines becomes a signatory to CITES
1979	A Coastal Zone Management Committee composed of 22 government agencies is formed
1977	Assignment of the Secretary of the National Resources to train barangay officials as deputy fish wardens or deputy forest wardens
1976	Commercial and other fishing gear operating within a distance of 7 km from the shoreline may be banned by the President of the Philippines upon the recommendation of the Secretary of Natural Resources
1975	PD 705 declares mangrove forests under DENR jurisdiction but areas released for fishponds under BFAR PD 704 (Fisheries Decree of 1975) develops rules and regulations on the fishing industry, upholds provisions of the Fisheries Act of 1932
1972	PD No. 43, Fishery industry development decree of 1972, providing for the accelerated development of the fishing industry of the Philippines; fishing industry considered as a Board of Investments pioneer project
1963	RA 3512 created the Philippine Fisheries Commission under the Department of Agriculture and Natural Resources
1950	RA 428, as amended, declared as illegal the possession, sale or distribution of stupefied and/or disabled fish and aquatic animals
1932	Act. No. 4003, Fisheries Act, Provided for the Secretary of Agriculture and Natural Resources to issue rules, regulations and instructions consistent with the law All ordinances of fishing should be approved by Department Secretary

Source: Department of Environment and Natural Resources (DENR) et al. 1997.

Note: AFMA - Agriculture and Fisheries Modernization Act
DILG - Department of Interior and Local Government
BFAR - Bureau of Fisheries and Aquatic Resources
DENR - Department of Environment and Natural Resources
DA - Department of Agriculture
CRMP - Coastal Resources Management Project

Table 24. Provisions of the Fisheries Code and its impact on municipal fishing.

Relevant provision*	Impact on municipal fishing (✔, if favourable; X, if non-favourable)	Comment
Limitation of access to non-resident fishers	X	Limits fishing areas; increases cost if non-resident fishers look for farther areas
Establishment of FARMCs at various governance levels	✔	Ensures participatory mechanism
Grant of fishing privileges in municipal waters	✔	Increases fishing areas accessible to municipal fishers and cooperatives
Ban on commercial fishing in municipal waters increased to 15 km from the coastline	✔	Defuses conflict with commercial fishers in municipal waters; potential to increase revenue for municipal fishers
Support to fishers from DA and the LGUs	✔	Technical assistance from NGO and LGUs
Prohibition against the use of active gear in municipal waters and bays and other fishery management areas	X	Discriminates against municipal fishers using round haul seine, bag net, drive-in net and motorized push nets

Note: * Annotated only.

Table 25. Provisions of the Fisheries Code and its impact on commercial fishing.

Relevant provision*	Impact on municipal fishing (✔, if favourable; X, if non-favourable)	Comment
Ban on commercial fishing in municipal waters and mapping/delineation of municipal waters	X	Excludes commercial fishing in municipal waters
Incentives for fishing in the Exclusive Economic Zone	✔	Increases revenue for commercial fishers
Establishment of FARMCs at various governance levels	X	Participatory mechanism might be unfavourable to commercial fishers
Prohibition against the use of active gear in municipal waters and bays and other fishery management areas (Sec. 90)	X	Discriminates against commercial fishers (from 10.1 to 15 km) using trawl, purse seine, Danish seine, etc.
Licensing of commercial vessels	✔	Minimal increase in license fees

Note: * Annotated only.

Epilogue: Issues and Prospects for the Next 50 Years

The socio and bioeconomic performance of the fisheries sector of the last 50 years was one of growth and eventual decline. Robust growth occurred during the 1960s due to the expansion of the commercial and municipal fleets. After this, there were several growth spurts in fisheries production attributable to gear development and the opening of new markets for specific fisheries commodities. Aquaculture induced a growth spurt during the mid-1970s, when marine capture fisheries were in the doldrums. Meanwhile the municipal sector, specifically in Southern Mindanao, rallied during the 1980s in response to the great demand for sashimi-grade tuna.

These developments resulted in a predictable trend: increase in numbers of vessels, increase in tonnage and horsepower, and increase in the numbers of fishers. These increases were made possible not only because of a policy to expand the fishery but more so by an open access regime. Open access was the de-facto management system before the advent of access limitation mechanisms espoused by the Fisheries Code. For both the commercial and municipal sectors, the entry barriers have been very low: few licenses needed, relatively low capital investment, and low production costs.

Declining catches, disappearance of highly valued species, and an increasing volume of juveniles are indications of biological over-fishing. Economic over-fishing, diagnosed by several studies as discussed, implies that the fishery employs excess labor and utilizes capital that should have been used in other economic sectors. The result of economic over-fishing is declining profits for the participants in the fishery.

What does economic over-fishing mean for the municipal fishery? The municipal fishery has been the traditionally beleaguered sector. Studies indicate that income levels of fishers have not improved (or have even worsened) over the last 50 years. (Lawson 1975) provides an explanation, *"as industrial fisheries expand, the standard of living of traditional fishermen relatively declines"*. This is because both sectors exploit the same resource and cater to the same market. Most likely, the commercial sector can lower the price substantially because its cost of production per unit of catch is lower. From the marketing end, traders would also prefer to purchase fish by bulk instead of from a multitude of fishers, thereby lowering transaction costs.

What does this mean for the commercial sector? The commercial sector utilizes the same near-shore grounds, now classified as municipal waters, for their fishing operations but their access to these grounds have been gravely impaired by the Fisheries Code. Commercial fishers are now encouraged to seek farther areas for fishing. This means increased costs (due to higher fuel consumption) and the threat of small catches. Already, a large number of commercial vessels have ceased operations in anticipation of strict enforcement of this prohibition. Certainly, a shake-out of the less efficient and under-capitalized firms is to be expected.

How should the fishery sector gear up for the next 50 years? The following basic strategies should be considered: resource rehabilitation, enhancement of the roles of LGUs, national agencies and communities, and heightened appreciation of the "real" values of the fishery resource.

Resource Rehabilitation

Improvement of the resource base is not an option for the next 50 years: it is a survival strategy. Current policies show how several layers of stakeholders can make this happen. First, the LGUs should comply with the provisions of the Fisheries Code that mandates them to set aside a certain portion of the coastal area for establishment of marine protected areas. In relation to this, mechanisms should be in place to ensure that marine protected areas achieve what they were intended for, to improve fish catch and preserve biodiversity. These mechanisms might include local legislation, manpower and logistics to support monitoring and enforcement, a well-informed community, and an attendant budget. Second, national agencies such as the DA-BFAR and to a certain extent, the DENR can provide technical assistance in the establishment and monitoring of these marine protected areas. Third, the communities which include the municipal fishers should ensure that local regulations concerning no-catch areas and selective fishing areas are faithfully adhered to. Illegal fishing with cyanide and dynamite should be shunned and local norms and cultural relationships utilized to penalize offenders. It must be stressed that efforts to rehabilitate the resource does not single out the possible harmful effects of commercial fishing in near-shore waters; it recognizes the potent role of municipal fishers in resource rehabilitation.

A good question to ask is: will it take 50 years to fulfill this strategy? No. Evidence from learning sites of the Coastal Resource Management Project (CRMP) and a sampling of municipalities that have initiated coastal management programs indicate that after two years (at the very least), fish catch and biodiversity will improve, inside and outside the marine protected area (Coastal Resource Management Project (CRMP) 2000).

Role of Local Governments and Community Participation

Local governments, day-to-day managers of the resource, must accept their responsibility in fisheries

and overall coastal management. The Local Government Code and the Fisheries Code articulate their roles and responsibilities that include: protection and conservation, regulation, legislation, planning and program implementation, enforcement, and resource generation. LGUs must view the fishery as an asset base that needs to be protected in order for the benefits to be enhanced.

LGUs must also recognize the role of communities and participatory processes which have been enshrined through the Fisheries and Aquatic Resources Management Councils (FARMCs). FARMCs can be a potent force in decision-making pertaining to coastal management if their roles are viewed seriously. Meanwhile, genuine participation should be encouraged by LGUs through facilitating meetings and sponsoring training programs. Genuine participation ensures acceptability and sustainability of initiatives. All these need to be accomplished in the interim period.

Role of National Agencies

National agencies such as the DA-BFAR and DENR should reorient their roles to usher in a new governance order. Instead of directly implementing programs and projects which have been the norm of the past 50 years, national agencies should redirect their efforts to provide technical support for LGU (Local Government Units) implementation in the form of training, standard setting and provision of information materials. Likewise, a collaborative mechanism should be established among national agencies to respond to emergency situations and to questions pertaining to jurisdiction.

Putting the Right Value to the Fishery

An essential framework for fisheries management is proper valuation. Proper valuation implies assigning both economic and ecological values to the fishery. In the past, the fishery has been managed based on economic values alone. This results in under-estimation of the costs of production because embedded costs are not considered. These costs might include the cost of fish (which has been considered as a free good), cost of extraction (especially of juveniles) and its impact on biodiversity, and the costs of habitat destruction such as that of coral reefs and mangroves. Ecological valuation might also include some values assigned to future users of the resource (Option Value) and for those who have no intention of using it, and yet derive value from knowing that the fishery still exists (Existence Value). Proper valuation will guide managers into determining how it should be used in the following practical matters: (a) amount and value of licenses to be distributed; (b) area allocated for establishment of fish-pens, cages, etc. and how much to charge; (c) areas to be maintained for protection purposes.

The immediate challenge is to initiate national agencies and LGUs in this “mode of thinking”. Acceptance of this approach and its application in practical matters will then make it appropriate to educate the rest of the populace.

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Socioeconomic Assessment of Marine Fisheries of Thailand

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Abstract

Thailand is currently one of the ten largest fishing nations in the world. In 1996, fish production reached 3.7 million t with 90% of the production coming from the marine fisheries sector and 10% from inland fisheries. Thai fishing operates in four fishing grounds namely, the Gulf of Thailand, the Andaman Sea, the South China Sea and the Bay of Bengal. However with the establishment of the Exclusive Economic Zone (EEZ) in 1977, Thailand lost over 300 000 km^2 of traditional fishing grounds.

Gross domestic product (GDP) of Thailand was estimated at 4 598 billion Baht (US$ 181 billion at 1 US$ = 25.36 Baht) in 1996 with 87.8 billion Baht (US$3.46 billion) (1.9%) coming from the fish industry. In 1997, fishery product exports reached 138 624 million Baht (US$4 million at 1 US$ = 31.18 Baht) or 69% (200 795 million Baht including fish) of the total agriculture exports and 7.3% (1 898 276 million Baht) of total exports. However, the rapid growth of manufacturing and service sectors has diminished the contribution of the fisheries sector to GDP in the recent years.

Of the estimated 35.6 million labor force in Thailand in 1998, 43% were employed in the agricultural sector including fisheries. The 1995 Census of Marine Fishery showed that the total number of fishery households including fisheries employees' households in the country was 109 635. No census was conducted for inland fisheries. The fisheries sector also supports a substantial level of employment in industries like fish processing, cold storage, fishmeal, ice making, boat construction and the like. The labor force of these industries was estimated to be at 211 682 in 1995.

Fish is the primary source of animal protein for most of Thailand's population, particularly in the coastal and near-coastal provinces. The average per capita fish consumption is 24 kg annually.

Marine capture fisheries can be broadly divided into commercial and small scale sub-sectors. Commercial vessels are those vessels over 10 m in length or 5 GT, that use modern fishing gear and have the capacity to fish offshore for several days. Small scale vessels are usually less than 10 m in length and either employ outboard- or inboard-engines, or are non-motorized and operate in near shore areas. From

1985 to 1995, the number of small scale fishing boats increased by 7.5%, while the commercial boats increased by 11%. One reason for the change has been the creation of a boat-tenure system within the commercial fishing sector, resulting in a decrease in the number of boats per household.

The major fishing gear used by the small scale fishers are gillnets, small push nets, lift nets or other modern small scale gear, set traps, bagnets and other stationary gear in estuaries or protected inshore waters. In the fishing household of Songhkla Province, Southern Thailand, shrimp gillnets, cuttlefish trammel nets, Indo-Pacific mackerel gillnets, other gillnets and Acetes trawl nets are the major fishing gear. The fishers direct their effort towards high value species like shrimp, cuttlefish, pomfret fish and crabs, but they also obtain by-catch low value fish species. The most important determinant of profit for small scale fisheries is the interaction between types of gear and fishing ground.

Commercial fishing vessels utilize otter trawls, pair trawls, beam trawls, push nets, purse seines and king mackerel gillnets as the major fishing gear. The analysis of investment, cost, revenue and return on demersal and pelagic fishing operations shows that (a) returns differ markedly among size of fishing boats and types of fishing gear; (b) ability to generate profit is greater in large fishing boats than small due to their higher ability to adjust to both economic (investment) and biological (fishing ground) changes; and (c) among the trawlers, medium and large boats can best adapt to maintain continuous profit, while for push nets, all size of boats show declining net profit. In pelagic fishing operations, purse seiners have been developed to make high profits and yield a higher return than trawlers and gillnet fishing operations.

The Schaefer Model was applied to estimate the maximum sustainable yield (MSY) and maximum economic yield (MEY) for demersal fish and trash fish in the Gulf of Thailand. Results indicated that the present catch and the corresponding effort of demersal fishing in the Gulf of Thailand surpassed both MEY and MSY. In order to obtain the maximum net benefit in the long run, the present fishing effort of catching demersal fish must be reduced to about 50% of present levels. This would lead to the rehabilitation of marine resources and minimize the by-catch.

Socioeconomic Profile

Review of the Status of Marine Fisheries

Introduction

The production from fishery industries in Thailand has demonstrated remarkable growth over the last three decades. Thailand is now ranked among the top ten fishing nations of the world. Its fisheries production exceeded 2 million t for the first time in 1977, after which a decline followed. Production recovered to over 2 million t by 1983, and increased to 3.6 million t in 1995. Ninety per cent of total production comes from marine fisheries.

Before the 1977 proclamation of an Exclusive Economic Zone (EEZ) by the neighbouring countries, the Thai fishing fleet operated in four major fishing grounds: the Gulf of Thailand, the Andaman Sea, the South China Sea and the Bay of Bengal. Thailand lost over 300 000 km^2 of traditional fishing grounds due to the establishment of EEZs. Among the marine fishing grounds that fall within Thailand's EEZ, the Andaman Sea is an important one, with a total area of about 316 000 km^2, and a coastline of 2 630 km.

In 1995, the total marine catch was 2.8 million t, (Table 1) valued at 45 183 million Baht (US$1 737 807)[1]. Compared with 1990 figures, it had increased 42% in volume but 2.2 times in value. Of the total marine catch, about 70% is caught in Thai waters and the rest from other countries' zones.

[1] 1US$ = Baht 26 at 1995 exchange rate.

Table 1. Fisheries production of Thailand by subsectors, 1977 – 98.

Year	Total		Capture				Culture			
			Marine		Inland		Coastal aquaculture		Freshwater culture	
	1 000 tons	%	1 000 tons	%	1 000 tons	%	1 000 tons	%	1 000 tons	%
1977	2 189.9	100.0	2 064.4	94.3	89.2	4.1	3.2	0.1	33.1	1.5
1978	2 099.3	100.0	1 947.7	92.8	102.1	4.9	10.1	0.5	39.4	1.9
1979	1 946.3	100.0	1 802.3	92.6	103.7	5.3	10.9	0.6	29.4	1.5
1980	1 792.9	100.0	1 587.9	88.6	110.4	6.2	60.1	3.4	34.5	1.9
1981	1 989.0	100.0	1 756.9	88.3	116.5	5.9	67.5	3.4	48.1	2.4
1982	2 120.1	100.0	1 949.7	92.0	87.7	4.1	36.9	1.7	45.8	2.2
1983	2 255.4	100.0	2 055.2	91.1	108.4	4.8	44.8	2.0	47.0	2.1
1984	2 134.8	100.0	1 911.5	89.5	111.4	5.2	61.5	2.9	50.4	2.4
1985	2 225.2	100.0	1 997.2	89.8	92.2	4.1	60.6	2.7	75.2	3.4
1986	2 536.3	100.0	2 309.5	91.1	98.4	3.9	39.1	1.5	89.3	3.5
1987	2 779.1	100.0	2 540.0	91.4	87.4	3.1	61.9	2.2	89.8	3.2
1988	2 629.7	100.0	2 337.2	88.9	81.5	3.1	108.9	4.1	102.1	3.9
1989	2 740.0	100.0	2 370.5	86.5	109.1	4.0	168.7	6.2	91.7	3.3
1990	2 786.4	100.0	2 362.2	84.8	127.2	4.6	193.2	6.9	103.8	3.7
1991	2 967.7	100.0	2 478.6	83.5	136.0	4.6	230.4	7.8	122.7	4.1
1992	3 239.8	100.0	2 736.4	84.5	132.0	4.1	229.3	7.1	142.1	4.4
1993	3 385.1	100.0	2 752.5	81.3	175.4	5.2	295.6	8.7	161.6	4.8
1994	3 523.2	100.0	2 804.4	79.6	202.6	5.8	345.8	9.8	170.4	4.8
1995	3 572.6	100.0	2 827.4	79.1	191.7	5.4	357.5	10.0	196.0	5.5
1996*	3 489.7	100.0	2 769.0	79.3	203.5	5.8	311.3	8.9	205.9	5.9
1997**	3 412.2	100.0	2 666.3	78.1	212.5	6.2	317.2	9.3	216.2	6.3
1998**	3 665.4	100.0	2 867.5	78.2	235.4	6.4	333.2	9.1	229.2	6.3

Source: Fisheries Economics Division, Department of Fisheries 1972 – 97.
Note: * Preliminary data
**** Estimated data**

Historical Development of Marine Fisheries

Historically, Thai marine fisheries were small scale fisheries along the coast of the Gulf of Thailand and Andaman Sea. The most popular fishing gear was fixed gear such as trap and set bag, which operated in river mouths and along the coast at a depth of not more than 20 m. Most catches landed were pelagic species. In 1925, the Chinese purse seine from China was introduced, and was used experimentally at a depth of less than 50 m. After the end of the 2nd World war (1951), the drift gillnet was introduced, which was effective in catching pelagic species and was widely accepted among Thai fishers. In 1960, there was a major development with the introduction of the otter trawl. This gear drew attention towards demersal species, and away from labor-intensive fishing to commercial fisheries with heavy investments in modern technology. There was a rapid increase in trawlers both in size and efficiency. Hence, over the decades two different fisheries - pelagic and demersal - have emerged in the Thai fishing industry.

Development of Pelagic Fisheries

The development of pelagic fisheries up to the present can be divided into three phases. The final phase is complex and involves management necessary to control its development.

Phase 1 (1925 - 64). The most important fishing gear for pelagic species was fixed gear such as traps, while Thai purse seine, Chinese purse seine and mackerel gillnet became widely used (Table 2). Eighty percent of pelagic species landed were mackerel.

Phase 2 (1965 - 73) was the period of growth for pelagic fisheries. Thai purse seine and mackerel encircling gillnet vessels increased, both in number and size, and these replaced trap fishing. Production from pelagic fisheries doubled that of Phase 1, and led to the expansion of the fish processing industry such as canning. The management techniques of pelagic fisheries changed from searching for more fishing grounds to the study of population dynamics and stock assessment to be used subsequently.

Phase 3 (1974 - present) witnessed the highest level of pelagic fisheries development. New fishing gear, such as luring purse seine, was introduced during this phase. This replaced Thai purse seine and mackerel encircling gillnet used during Phase 2. The number of luring purse seiners increased dramatically both in terms of size and quantity from 1 in 1972 to 730 vessels in 1981. During 1974 to 1977 catching methods were developed from searching for fish schools to aggregation methods using electrical equipment. Since 1977, there has been another major development with the introduction of sonar and power block. Concurrently, medium size trawlers, which were affected by fuel price increases, were converted to purse seiners, and fishing vessels became larger in size and capable of offshore fishing.

The development of pelagic fisheries was clearly demonstrated by a four-fold increase in production[2] from 223 900 t in 1974 to 953 900 t in 1994 (Table 2). Almost all pelagic fish resources in the Gulf of Thailand are fully exploited and there is some sign of stock depletion.

Table 2. Number of selected types of gear (fishing unit) registered and marine fish caught in Thailand, 1957 – 98.

Year	Pelagic fishing gear				Demersal fishing gear		Marine catch (1 000 tons)		
	Stake traps	Purse[1/] seines	Mackerel encircling gillnet	King mackerel drift gillnet	Trawlers[2/]	Push nets	Demersal[3/] species	Pelagic species	Total
1957	1 287	324	N/A	N/A	N/A	N/A	133.7	37.2	170.9
1958	1 344	392	N/A	N/A	N/A	N/A	94.9	50.1	145.0
1959	1 470	379	N/A	N/A	N/A	N/A	89.4	58.4	147.8
1960	1 409	323	48	N/A	99	N/A	82.8	63.7	146.5
1961	918	251	233	N/A	201	N/A	110.2	123.1	233.3
1962	792	228	386	N/A	976	N/A	118.3	151.4	269.7
1963	662	212	537	N/A	2 026	N/A	95.9	227.5	323.4
1964	602	144	890	N/A	2 360	N/A	128.1	371.0	499.1
1965	697	226	634	N/A	2 393	N/A	148.3	392.7	541.0
1966	663	228	409	N/A	2 695	N/A	202.5	445.0	647.5
1967	447	278	417	N/A	3 077	N/A	601.0	161.1	762.1
1968	457	361	329	N/A	3 182	N/A	792.5	211.5	1 004.0

[2] including catch from outside Thai waters.

Table 2. Number of selected types of gear (fishing unit) registered and marine fish caught in Thailand, 1957 – 98. (continued)

Year	Pelagic fishing gear				Demersal fishing gear		Marine catch (1,000 tons)		
	Stake traps	Purse seines[1/]	Mackerel encircling gillnet	King mackerel drift gillnet	Trawlers[2/]	Push nets	Demersal species[3/]	Pelagic species	Total
1969	374	314	224	N/A	3 185	N/A	948.5	231.0	1 179.5
1970	371	716	260	235	3 082	354	998.0	337.6	1 335.6
1971	313	475	244	151	3 608	610	1 265.9	204.2	1 470.1
1972	236	506	254	138	4 486	1 327	1 428.7	119.4	1 548.1
1973	189	680	228	231	5 837	1 628	1 338.2	199.8	1 538.0
1974	229	657	188	148	5 271	1 213	1 127.7	223.9	1 351.6
1975	262	625	187	177	4 962	1 075	1 130.7	263.9	1 394.6
1976	222	726	226	157	5 204	844	1 197.5	345.3	1 542.8
1977	242	706	314	244	6 288	1 177	1 552.1	515.5	2 067.6
1978	250	843	359	151	6 453	1 426	1 515.9	441.9	1 957.8
1979	258	681	256	227	8 747	1 923	1 386.1	416.2	1 802.3
1980	225	781	307	287	10 421	2 262	1 259.7	328.2	1 587.9
1981	277	833	258	327	7 525	1 216	1 368.5	388.4	1 756.9
1982	233	840	238	281	11 475	1 899	1 554.2	395.5	1 949.7
1983	225	846	144	264	9 390	1 326	1 542.6	512.6	2 055.2
1984	254	961	245	265	9 131	960	1 338.9	572.6	1 911.5
1985	234	951	227	269	8 325	759	1 409.1	588.1	1 997.2
1986	258	996	203	329	7 407	664	1 739.4	570.1	2 309.5
1987	253	1 174	223	365	7,343	624	1 910.4	629.6	2 540.0
1988	231	1 456	146	461	6,950	531	1 699.2	638.0	2 337.2
1989	208	1 443	114	282	13 113	1 907	1 666.9	703.6	2 370.5
1990	188	1 629	101	299	12 905	1 879	1 643.0	719.2	2 362.2
1991	188	1 614	88	338	10 298	1 047	1 752.5	726.1	2 478.6
1992	204	1 452	72	362	9 465	818	1 895.2	841.2	2 736.4
1993	190	1 509	94	271	9 086	808	1 896.9	855.6	2 752.5
1994	190	1 511	99	280	8 346	651	1 850.5	953.9	2 804.4
1995	139	1 397	82	330	7 995	634	1 858.7	968.7	2 827.4

Source: Fisheries Economic Division, Department of Fisheries 1972 – 97.
Note: [1/] Chinese purse seine, Thai purse seine, Luring purse seine and Anchovy purse seine.
[2/] Otter trawl, Pair trawl and Beam trawl.
[3/] Demersal fish, Trash fish, Cephalopod, Crab, Shrimp, Mollusc and others.
N/A = Not available.

Development of Demersal Fisheries

Demersal fisheries were not popular prior to 1960. There was an unsuccessful introduction of trawl by private companies in 1952. This type of fishing requires experienced and skilled crews and the demersal species caught had yet to find a market. Nevertheless, some fishers were successful in converting the trawl into beam trawl by using smaller-size vessels and harvesting shrimp along the coast. In 1960, the Government of the Republic of Germany rendered technical assistance in marine fisheries development by surveying fishing grounds and providing suitable fishing gear for harvesting marine resources. The otter trawl was the most effective gear and became widely deployed. The number of fishing vessels increased rapidly from 99 in 1960 to 13113 in 1990, and decreased to 7 995 in 1995. During this time, Thai trawl fisheries went through both expansion and crisis, in three distinct phases.

Phase 1 (1960 - 73) had the same rapid development of demersal fisheries as Phase 2 of pelagic fisheries. This was the period of great expansion of trawl such as pair trawl and beam trawl, and especially otter trawling. The number of trawlers increased 59 - fold from 99 in 1960 to 5 837 in 1973. Since demersal resources were abundant and newly discovered, and the financial return from trawling higher than from other fishing gear at that time, investment in trawlers became attractive. Investment in trawling increased both in terms of the number and size of fishing boats, which ventured into international waters for the first time.

Concurrently in 1967 - 71, the Department of Fisheries discovered fishing grounds in the Bay of Bengal, the best grounds for trawling, and large fishing boat construction began. The increase in fishing boats resulted in an increment in demersal catch of 2.1 - fold, from 63 700 t in 1960 to 1 338 200 t in 1973 (Table 2). However, crises immediately followed. Demersal fisheries resources especially in the Gulf of Thailand, began to suffer from over-exploitation. Sustainable yield of this fishery is about 768 000 t with a fishing effort of 8×10^6 hours (Boonyubol and Pramokchutima, 1984). At the same time, fuel prices increased by four times in 1973 and 1974. The rise in fuel price also had implications on the world economy, causing a drop in demand by importers of Thai fisheries products, and eventually affecting the domestic price.

Phase 2 (1974 - 81). The number of trawlers and demersal catches landed in 1974 dropped by 34% and 16% respectively compared with 1973. Another fuel price increase during 1979 - 80 forced many fishers to operate the more fuel-efficient purse seine. Landings of pelagic species consequently showed an increase against the decline of demersal species (Table 2). The final crisis affecting trawl fisheries, especially the medium and large size trawlers, came with the declaration of EEZs. Neighbouring countries, particularly the archipelagic ones benefited from this declaration. However, Thailand as a shelf-locked state, surrounded by EEZs of other nations, cannot expand its economic zone. Coupled with little shelf area, the division of territorial waters based on the equidistance principle generated a great loss to Thai fisheries resoures. Other countries claimed parts of the high seas that were formerly utilized by the Thai fishers, thus decreasing fishing grounds by about 300 000 km^2. The number of trawlers in the Gulf increased, thereby depleting the resources. These additional fishing vessels raised the fishing effort and the effort levels of individual trawlers also increased. Fishing boats that continued to fish outside the Gulf needed additional investment for more effective engines and navigational aids, such as radar, to avoid arrest.

This situation led to a recommendation to reduce the number of trawlers and initiate control measures in 1981. In the final period of this phase, negotiations were started on joint ventures in fisheries with other nations, with the main objective to seek sectional new fishing grounds and to settle the problems of intrusion of Thai vessels. A Joint Venture Agreement between Thailand and Bangladesh was signed in 1980. This was the first time that Thai fishing vessels could legally operate in international waters after the proclamation of the EEZs of the neighbouring countries.

Phase 3 (1981 - present). Various crises brought about the decline of trawlers during the early period of fuel price adjustment. However after the adjustment, growth in fishing effort and fishing gear with small mesh size cod-ends, along with inshore fishing increased the catch of trash fish and thus fishers' incomes. This practice created problems with the artisanal fishers. Catching the fingerlings as trash fish leads to a decline in the population of demersal

fish. At the same time, medium and large trawlers were not profitable since improvement in efficiency was needed, by increasing engine capacity and introducing navigational aids such as radar to operate along the boundary or sometimes in the neighbouring waters. The problems of arrests increased. Nonetheless, the number of trawlers reached 9 393 in 1983 due to newly constructed fishing vessels (Table 2). The Department of Fisheries issued measures to control the construction of new trawl vessels, including issuance of fishing licenses for trawl fishing. However, these measures were not strictly enforced due to lack of coordination among concerned agencies. The fishers had more interest in the negotiation of joint ventures, charter vessels and hire purchase agreements with Australia, Indonesia, Myanmar, Bangladesh and India. Fish, thus caught are brought back to Thailand, resulting in a slight increment in marine fishery production at the present time.

Contribution of the Fisheries Sector to Economic Growth and Welfare

Contribution of Fisheries Sector to Gross Domestic Product (GDP)

Thailand's gross domestic product (GDP) was estimated at 4 598 billion Baht in 1996, of which the fishing industry contributed 87.8 billion Baht or 1.9% of GDP, a decline from the average of 3% of GDP during the period 1994 to 1996. The main reasons for the diminished contribution to GDP by the fisheries sector in recent years were the rapid growth of manufacturing and service sectors and the comparatively slow growth of the fisheries sector. These factors were partially offset by increases in real fish prices. In constant (1983) price terms, the aggregate value of fish production peaked in 1978 at 21 000 million Baht. Furthermore, although the fisheries sector makes a relatively small contribution to Thailand's GDP, it makes an important contribution to export earnings and employment, and provides the Thai people with the principal source of animal protein in their diet (Table 3).

Contribution of Fishing Industry to Income and Employment

The labor force of Thailand was estimated at 35.6 million in 1998, of which some 15.4 million (43%) were employed in the agricultural sector (including fisheries).

The 1995 Census of Marine Fishery revealed that the total number of fishery and fishery employees' households in the country was 109 635. They are comprised of 50 312 households exclusively engaged in capture fishery; 27 388 households engaged in coastal aquaculture; 3 001 engaged in both marine capture fishery and coastal aquaculture; and 28 934 households of fishery employees. The population engaged in marine fisheries was 535 210 persons (Table 4).

The inland fisheries census was not conducted, however most rice-growing farmers know how to catch fish, i.e. they are part-time fishers. Millions of farmers routinely catch freshwater fish for their own consumption.

A survey on freshwater fish-farm production since 1974 was conducted, but unfortunately not all aquaculturists and employees were recorded. The survey showed that the number of freshwater fish farms continuously increased from 61 980 farms in 1990 to 161 504 farms in 1994. This indicates that at least 300 000 persons were involved in freshwater aquaculture in 1994.

Additionally, the fisheries sector supports substantial employment in industries such as fish processing, cold storage, fish meal, ice making, boat construction, etc. The labor force of these industries was estimated at 211 682 in 1995.

Contribution of Fisheries Sector to Foreign Exchange Earning

The contribution to Thailand's export earnings by the fishing and fish processing industries has increased steadily in recent years (Table 5). The positive trade balance in fish and fish products increased from 11 584 million Baht to 111 185 million Baht (US$3 566 million at 1 US$ = 31.18 Baht in 1997) between 1983 and 1997. Although the industry relies on imported inputs such as diesel fuel and netting, material earnings remain substantial, particularly in relation to the level of employment in the industry. Fishery product exports in 1997 totaled 138 624 million Baht (US$4 446 million), equivalent to 69% of total agriculture exports (200 795 Baht million including fish) and 7.3% of total exports (1 898 276 million Baht).

Table 3. Gross domestic product (GDP) and national income at current market prices by industrial sectors in Thailand, 1989 - 96.

Industrial Sectors	1989		1990		1991		1992		1993		1994		1995		1996	
	Bahts (millions)	%	Bahts (millions)	%	Bahts (millions)	%	Bahts (millions)	%	Bahts (millions)	%	Bahts (millions)	%	Bahts (millions)	%	Bahts (millions)	%
Gross Domestic Product (GDP)	1 620 882	100.0	1 895 034	100.0	2 506 635	100.0	2 830 914	100.0	3 170 258	100.0	3 630 805	100.0	4 188 929	100.0	4 598 288	100.0
Agriculture	279 094	17.2	273 973	14.5	317 085	12.6	348 127	12.3	329 878	10.4	390 233	10.7	464 171	11.1	507 339	11.0
Crops	174 809	10.8	159 992	8.4	181 918	7.3	197 058	7.0	166 564	5.3	206 264	5.7	258 432	6.2	289 570	6.3
Livestock	29 797	1.8	32 770	1.7	37 430	1.5	35 001	1.2	32 275	1.0	35 802	1.0	42 599	1.0	44 457	1.0
Fisheries	27 449	1.7	32 214	1.7	43 139	1.7	55 764	2.0	67 410	2.1	76 138	2.1	83 097	2.0	87 800	1.9
Forestry	8 181	0.5	6 665	0.4	7 110	0.3	6 705	0.2	6 443	0.2	6 145	0.2	6 098	0.1	6 291	0.1
Agricultural Services	10 678	0.7	10 795	0.6	10 958	0.4	11 525	0.4	11 149	0.4	12 477	0.3	12 779	0.3	13 519	0.3
Simple Agricultural and Processing Products	28 180	1.7	31 537	1.7	36 530	1.5	42 074	1.5	46 037	1.5	53 407	1.5	61 166	1.5	65 702	1.4

Source: NESDB

Table 4. Fisheries sector employment in Thailand, 1995.

Type of employment	No. of Fishers, Fish farmers and Employees
Marine capture[1]	157 377
Coastal aquaculture[2]	45 898
Inland culture[3]	404 344
Related fisheries industry[4]	220 370
TOTAL	827 989

Sources: [1, 2] 1995 Marine Fishery Census.
[3] No. of farmer = (no. of fishfarm x 2 persons).
[4] Ministry of Labor and Social Welfare.

Table 5. Trade balance in the fisheries sector of Thailand, 1983 - 97.

	Import		Export		Trade Balance	
Year	Q (tons)	V (M. Baht)	Q (tons)	V (M. Baht)	Q (tons)	V (M. Baht)
1983	58 942	1 093	344 899	12 677	285 957	11 584
1984	119 064	2 119	411 722	15 081	292 658	12 962
1985	152 707	3 857	466 219	18 528	313 512	14 670
1986	268 089	7 590	602 486	26 829	334 397	19 239
1987	227 327	7 017	663 650	32 654	436 323	25 637
1988	347 666	14 713	798 572	44 437	450 906	29 724
1989	455 755	19 067	875 293	53 705	419 538	34 638
1990	507 737	20 653	904 973	61 070	397 236	40 418
1991	724 668	27 353	1 087 395	78 463	362 727	51 110
1992	714 012	24 569	1 106 141	82 469	392 129	57 901
1993	760 919	21 629	1 115 078	91 018	354 159	69 389
1994	893 588	21 329	1 214 946	110 285	321 358	88 956
1995	872 818	21 924	1 192 560	116 578	319 742	94 654
1996	797 389	22 425	1 146 949	110 781	349 560	88 356
1997	710 115	27 439	1 181 255	138 624	471 140	111 185

Sources: Custom Department, Ministry of Finance.

Contribution of Fishery Sector to Domestic Nutrition

The contribution of fish and other food to the Thai diet during 1995 is reported in Table 6a. Fish is the primary source of animal protein for most of Thailand's population, particularly in the coastal and near-coastal provinces. Over the period 1978 to 1997, the per capita consumption of fish in Thailand averaged 24 kg annually and fluctuated between highs of about 32.8 - 33.8 kg in 1994 and 1995 and lows of about 18.8 -18.9 kg in 1987 - 88 (Table 6b).

Table 6a. Per capita food intake in Thailand, 1995.

Items	Whole Country		Urban Area		Rural Area	
	Grams/day	%	Grams/day	%	Grams/day	%
Cereals, Roots and Tubers	305.7	41.4	281.4	37.4	312.3	42.4
Sugar and Honey	13.7	1.9	14.6	1.9	13.4	1.8
Pulses, Nuts and Oilseeds	17.1	2.3	19.7	2.6	16.3	2.2
Vegetables	113.2	15.3	101.4	13.5	116.7	15.9
Fruit	76.8	10.4	93.9	12.5	72.0	9.8
Oils and Fats	14.0	1.9	12.3	1.6	14.4	2.0
Meats	71.4	9.7	83.4	11.1	68.1	9.3
Fish	46.6	6.3	47.3	6.3	46.5	6.3
Eggs	21.4	2.9	17.2	2.3	22.5	3.1
Milk	29.3	4.0	44.6	5.9	25.1	3.4
Others	29.9	4.0	35.8	4.8	28.4	3.9
TOTAL	739.1	100.0	751.6	100.0	735.7	100.0

Table 6b. Apparent consumption of fish in Thailand, 1970 - 97.

Year	Total Production (1 000 tons)	Fish used for fishmeal (1 000 tons)	Trade		Apparent Consumption		
			Imports (1 000 tons)	Exports (1 000 tons)	Total consumption (1 000 tons)	Population (Million)	Consumption per capita (Kg)
	(1)	(2)	(3)	(4)	(5) = (1) - (2) + (3) - (4)	(6)	(7) = (5) / (6)
1978	2 099	887	114	237	1 088.7	45.2	24.1
1979	1 946	808	364	250	1 251.9	46.1	27.1
1980	1 792	773	140	227	932.3	47.0	19.8
1981	1 989	797	152	269	1 076.1	47.6	22.6
1982	2 121	813	128	338	1 098.4	48.4	22.7
1983	2 255	803	116	405	1 162.4	49.5	23.5
1984	2 135	758	166	547	996.4	50.5	19.7
1985	2 225	776	207	639	1 015.8	51.5	19.7
1986	2 536	976	362	847	1 074.2	52.5	20.4
1987	2 779	1 106	220	881	1 012.7	53.5	18.9
1988	2 630	956	343	993	1 023.8	54.6	18.8
1989	2 740	980	436	1 095	1 100.7	55.2	19.9
1990	2 786	978	475	1 174	1 108.7	56.1	19.8
1991	2 958	982	664	1 359	1 281.0	56.9	22.5

Table 6b. Apparent consumption of fish in Thailand, 1970 - 97. (continued)

Year	Total Production (1 000 tons)	Fish used for fishmeal (1 000 tons)	Trade		Apparent Consumption		
			Imports (1 000 tons)	Exports (1 000 tons)	Total consumption (1 000 tons)	Population (Million)	Consumption per capita (Kg)
	(1)	(2)	(3)	(4)	(5) = (1) - (2) + (3) - (4)	(6)	(7) = (5) / (6)
1992	3 240	1 001	637	1 393	1 482.6	57.6	25.7
1993	3 385	1 027	788	1 438	1 708.5	58.5	29.2
1994	3 523	930	883	1 535	1 940.5	59.1	32.8
1995	3 573	916	864	1 510	2 010.7	59.5	33.8
1996	3 500	900	737	1 438	1 899.5	60.1	31.6
1997*	3 460	900	728	1 645	1 642.7	60.8	27.0
Average	2 684	903	426	911	1 295.4	53.5	24.0

Source: Fisheries Economic Division, Department of Fisheries 1972 - 97.
Note: * Preliminary data.

Socioeconomic Analysis of the Small Scale Fishery Sector

Assessment of Status of Fishing Households and Communities

The coastline of Thailand is 2 614 km in length. Twenty-three provinces are situated along the coast. The Department of Fisheries has divided the provinces into five coastal fishing regions. Regions 1 - 4 cover the Gulf of Thailand and the fishing gear of these regions is given in Figure 1. Region 5 covers the coastal areas of the Andaman Sea.

According to a Preliminary Report on Marine Fishery Census in 1995 (National Statistics Office (NSO), 1992a; National Statistics Office (NSO), 1992b), there are 80 701 marine fishing households that can be classified into three types. Households that engage exclusively in fisheries account for 62.3%; those in coastal aquaculture account for 35%; and those engaged in both fisheries and aquaculture account for 3.7%. In 1995, about 53 112 fishing households were engaged in marine fisheries, of which 85.5% can be classified as small scale fishing households[2] and 15.5% can be classified as commercial-scale fishing households (Table 7a).

A structural change in Thailand's fisheries has taken place during the last 10 years. From 1985 - 90, the number of fishing households and fishing boats decreased by 6.7% and 2.3% respectively (Tables 7a - b). Small scale fishing households and small scale fishing boats decreased by 5.9% and 0.6% respectively whereas commercial-scale fishing boats decreased by 9.8%. The decrease in the number of small scale fishing boats was largely due to the decrease in coastal fishing resources on the one hand, and conflicts between small scale and the commercial-scale fishers on the other.

During 1990 - 95, the number of fishing households and fishing boats in Thailand increased by 11.0% and 5.4% respectively (Tables 7a - b). The increase in fishing households has largely been in commercial fisheries.

The increase in fishing boats has been in the small scale sector. Small scale fishing boats account for 8.1% of the total increase while commercial boats have actually decreased in number by 3.7%. One reason for the change in commercial boats has been the creation of a boat-tenure system within the commercial fishing sector, which resulted in a decrease of the number of boats per household.

Three major factors have led to the increase in small scale fishing households and small scale fishing boats during the last five years. First, the

[2] Small scale fishing households are defined as those which use non-powered boats or outboard-powered boats or inboard-powered boats with less than 5 gross ton (GT) engine is fishing operations.

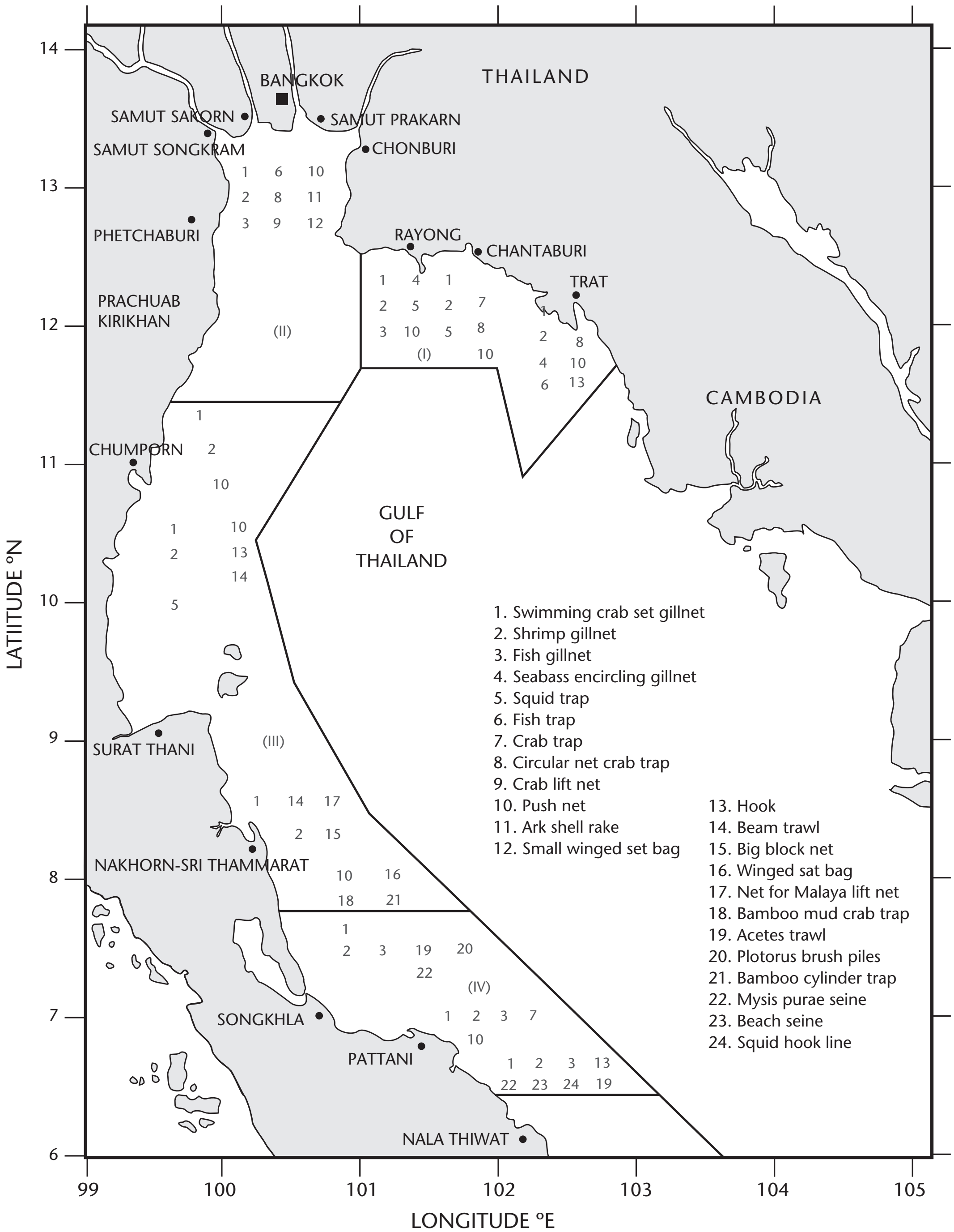

Fig. 1. Map of coastal fishing region.

Table 7a. Change in fishing households in Thailand, 1985, 1990 and 1995.

Year	Small scale			Commercial-scale			Total		
	Number	%	% of change	Number	%	% of change	Nuumber	%	% of change
1985[1/]	41 592	81.2		9 653	18.8		51 245	100.0	
1990[2/]	39 127	81.8	-5.93	8 709	18.2	-9.78	47 836	100.0	-6.65
1995[3/]	44 867	84.5	14.70	8 245	15.5	-5.33	53 112	100.0	11.00

Table 7b. No. of fishing boats classified by type of fishing operations, 1985, 1990 and 1995.

Year	Small scale			Commercial-scale			Total		
	Number	%	% of change	Number	%	% of change	Number	%	% of change
1985[1/]	40 095	86.2	–	12 855	13.8	–	52 950	100.0	–
1990[2/]	39 870	84.9	-0.56	11 887	15.1	-7.53	51 757	100.0	-2.25
1995[3/]	43 092	86.7	8.10	11 446	13.3	-3.71	54 538	100.0	5.40

Source: [1/] National Statistics Office and Department of fisheries (1987)
[2/] National Statistics Office and Department of Fisheries (1992)
[3/] National Statistics Office (1996)

population in coastal fishing communities has increased. Second, coastal fishery resources have partly recovered because of artificial reefs. The reefs have become additional fishing areas and have also been able to inhibit coastal trawl fishing. Third, fishing communities are enthusiastic in locating more fishing areas by themselves.

Socioeconomic Conditions of Small Scale Fishing Communities

Most small scale fishing communities are located in the coastal areas of Thailand. In 1992, there were 2 562 fishing communities in Thailand (National Statistics Office (NSO) and Department of Fisheries (DOF), 1992). Of these, 76% are situated on the coast of the Gulf of Thailand and 24% are on the Andaman Sea coast. Of the small scale fishing households in the coastal fishing communities 61.7% are Buddhists and 38.3% are Muslims (Panayotou 1985).

Structure of the Small Scale Fishing Households

According to the 1990 survey, the average size of small scale fishing households is 5.5 persons. Fishing households in Region 4 are the largest with 7 persons per household. In Regions 5, 2, 1 and 3, the average size are 5.5, 5.3, 5.1 and 5.1 persons per household, respectively. Custom and religion affect the size of fishing households. For instance, in Region 4 (consisting of Nakorn Sri Thammarat, Songkhla, Pattani and Narathiwas Provinces) and in Region 5 (Ranong, Phang-nga, Phuket, Krabi, Trang and Satun Provinces) where most of the fishing households are Muslim, the average household size is larger (Adulavidhaya 1980).

Occupational Structure of Small Scale Fishing Households

Some members of the fishing households may earn additional income depending on the location of village or fishing community. Examples include jobs in marine animal culture, marine animal processing, fishing boat crew, processing factories and shrimp culture. Activities in agriculture include rice growing, horticulture, crop growing and animal raising. Other jobs include those of technician, and small scale merchant. Reasons for supplementary occupations are: (a) low income from fisheries; (b) instability in fisheries; (c) unemployed labor in households, especially women; (d) off-season unemployment.

Income Structure of Fishing Households

Income of small scale fishing households comes from various sources, although fishing generates the main income. According to a 1992 income and expenditure survey (National Statistics Office (NSO), 1992b), the annual national average income was 58 776 Baht. Fisheries income accounts for 77.3% of the total. For small scale fishing households on the Andaman Sea coast and those in the Gulf of Thailand, fisheries income accounts for 75.2% and 78.3% respectively of the total income (Table 8a). Therefore, the condition of coastal resources is a major factor that determines the income and living conditions of small scale fishing households.

Living Conditions of Small Scale Fishers

The living standard of small scale fishing households can be calculated using two approaches. The first is comparison of the per capita income. The second is estimation of Engel's coefficient (ratio of the household's food expenditure to the total expenditure). A ratio greater than 50% indicates that food expenditure is a major household expense and that such households have a low standard of living. This is based on the principle that household income will be spent on food as a priority and that any remaining surplus will be spent for other purposes.

In 1990, the annual national average per capita income of small scale fishers was 10 687 Baht. Average per capita income on the Andaman Sea coast was 9 836 Baht and 11 953 Baht for the Gulf of Thailand (National Statistics Office (NSO) and Department of Fisheries (DOF), 1992). Annual national per capita income of all sectors was 16 463 Baht and 14 054 Baht in southern Thailand (National Statistics Office (NSO), 1992a). The per capita income of small scale fishers on the Andaman Sea coast was not only less than the national and the southern per capita income but also less than that of small scale fishers nationwide. Small scale fishers in the Gulf of Thailand have the lowest per capita income compared to small scale fishers nationwide and people living in the southern region (Table 8a).

In 1990, Engel's coefficients of the small scale fishing households were 60.4 for the whole country, 61.3 for the Andaman Sea coast and 59.1 for the Gulf of Thailand. Comparing these figures with the national coefficient of 39.2 and the southern coefficient of 42.4, the living standard of small scale coastal fishers is lower than the national average and that of southern Thailand. The living standard of small scale coastal fishers on the Andaman Sea coast is not only lower than the national and the regional average in southern Thailand, but also lower than that of the nationwide average of small scale fishers (Table 8b).

Occupational and Geographical Mobility

The open-access theory assumes perfect factor mobility in and out of fishing. Fishers, especially small scale fishers, are occupationally and geographically immobile for reasons which include: attachment to fishing as a way of life, gambling behavior, socio-cultural constraints, sunk capital costs, low education, ignorance of alternative opportunities, unresponsiveness to economic incentives, etc.

Panayotou and Panayotou (1986) in surveys taken five years apart in a number of villages in Chumporn (Gulf of Thailand) and Phang Nga (Andaman coast), and employing different methods of analysis, showed that fishers are responsive to economic incentives and do move between occupations and locations; less so between locations. Capital tends to be less mobile than labor, at least in the short run. Fishers do not admit to having an emotional attachment to fishing, but they like the freedom and independence of being one's own boss. For this reason they reject employment in factories, but are prepared to take up crop or fish farming if given land or other assistance.

Fishers admit attachment to their own areas and they distrust unknown, far-away places. Given a choice, they prefer to move to rural areas than to the big city. This is true especially of fishers who live in more isolated fishing communities, such as those of the Andaman Sea coast. Both religion and distance appear to constrain geographical mobility. Muslim fishers and their families travel less than Buddhist and, when they do, they visit neighbouring Muslim provinces.

Mobility in and out of fishing is lower than mobility in and out of non-fishing occupations. Mobility of labor out of fishing is greater than mobility into fishing. Fishing is losing ground as an occupation while the population of fishing communities stabilizes as a result of (a) the drying-up of the permanent in-migration of the sixties and the seventies, and (b) the reduction in population growth.

Table 8a. Annual income of Thai household and small scale fishing households, 1990.

Types of Income	Whole country (Baht·yr⁻¹)	Southern region (Baht·yr⁻¹)	Small scale Fishing Households					
			Total Average		Gulf of Thailand		Andaman Sea Coast	
			(Baht·yr⁻¹)	%	(Baht·yr⁻¹)	%	(Baht·yr⁻¹)	%
Total Income	67 500	61 836	58 776	100.0	63 351	100.0	54 098	100.0
1. Cash Income			43 333	73.7	50 856	80.3	42 257	78.1
1.1 Fisheries Income:								
- Fishing Income			37 501	63.8	40 652	64.2	33 765	62.4
- Fish Culture			139	0.2	216	0.3	417	0.8
- Fish Processing			1 567	2.7	2 201	3.5	1 008	1.9
1.2 Non-fisheries Income:								
- Salary and Wage			3 749	6.4	4 623	7.3	3 051	5.6
- Farming Income			1 656	2.8	1 271	2.0	2 279	4.2
- Small scale Business			1 301	2.2	1 226	1.9	1 577	2.9
- Others			420	0.7	667	1.1	160	0.3
2. Non-cash Income:			12 443	21.2	12 495	19.7	11 841	21.9
2.1 Fishing Income			6 216	10.6	6 528	10.3	5 484	10.1
2.2 Goods and Services			1 764	3.0	1 401	2.2	2 227	4.1
2.3 Housing Rent			4 463	7.6	4 566	7.2	4 130	7.6
Family Size (persons)	4.1	4.4	5.5		5.3		5.5	
Income per Capita (Baht·yr⁻¹)	16 463	14 054	10 687		11 953		9 836	

Source: National Statistics Office 1992b.

Table 8b. Annual expenditures of Thai household and small scale fishing household, 1990.

Items	All Household in Thailand[1]				Small scale Fishing Household[2]					
	Whole Country		Southern Region		Total Average		Gulf of Thailand		Andaman Sea Coast	
	(Baht·yr⁻¹)	%	(Baht·yr⁻¹)	%	(Baht·yr⁻¹)	%	(Baht·yr⁻¹)	%	(Baht·yr⁻¹)	%
Total expenditure	65 244	100.0	61 920	100.0	49 474	100.0	54 347	100.0	44 798	100.0
- Food and Drink	25 584	39.2	26 268	42.4	29 885	60.4	33 307	61.3	26 489	59.1
- Clothing	3 816	5.8	3 768	6.1	1 695	3.4	1 637	3.0	1 761	3.9
- Housing rent	14 628	22.4	11 616	18.8	8 147	16.5	8 906	16.4	7 267	16.2
- Medical care	2 220	3.4	2 100	3.4	818	1.7	948	1.7	758	1.7
- Others	18 996	29.1	18 168	29.3	8 929	18.0	9 549	17.6	8 523	19.0
Engel's coefficients	39.2		42.4		60.4		61.3		59.1	

Source: [1] National Statistics Office 1992a.
[2] Small scale fishing households are defined as those which use non-powered boats or outboard-powered boats or inboard-powered boats with less than 5 gross ton (GT) engine is fishing operations.

Out-migration is temporary and usually in response to economic incentives, such as fishing activities elsewhere. In-migration is more permanent and socially rather than economically induced.

In Chumporn Province (Gulf of Thailand), occupational mobility narrowed the gap between the fishing and non-fishing wage rate from 33 Baht (US$1.05 at 1 US$ = 31.18 Baht in 1997) to 2 Baht (US$0.06), but in Phang Nga province (Andaman Sea Coast) the gap widened from 4 Baht (US$0.13) to 50 Baht (US$1.60). However, Phang Nga was in temporary imbalance as a result of a decline in non-fishing activities, especially offshore tin mining. In Phang Nga, there were temporary resource rents created partly by a recovery of the fishery, and partly by the fall in the opportunity cost of labor, following the decline in non-fishing activities.

The work of Panayotou and Panayotou (1986) suggests the potential for new activities such as fish farming and cottage industries. However, fishers are already engaged in a variety of non-fishing activities and they are quite responsive to differential earnings between these and fishing. What is needed is the support for the activities that have been neglected in the past because of a bias towards fisheries development. Such support may be in the form of infrastructure, credit and dissemination of information on employment opportunities, new technologies and markets. Geographical mobility should be encouraged especially out of the isolated communities of Phang Nga, but not in other large urban centers like Bangkok. To forestall an influx of new entrants into fisheries as resource rents are created, it would be necessary to accompany the promotion of non-fishing alternatives with effective controls on entry, perhaps through the granting to the small scale fishing communities of exclusive territorial rights to the coastal fisheries.

Competition and Conflicts in a Dualistic Sector

The last 30 years have revolutionized Thailand's coastal fishing industry. Rapid and often unfettered development, however, has degraded the coastal resources and encouraged conflicts between large- and small scale fishing fleets and among small scale communities themselves. At the root of these inter- and intra-sectoral conflicts are uncontrolled development of land and water concessions surrounding small scale communities, increasing competition, and the introduction of environmentally-destructive technology.

Land Encroachment

Many of Thailand's small scale fishing communities live in marginal areas and they conduct most of their fishing activities within close proximity to where they live. This creates two types of problems. Firstly, small scale fishing communities tend to be highly dependent on local resources; when not fishing, they work in local, resource-intensive industries, such as rubber extraction and processing, rice farming or aquaculture.

Secondly, small scale fishing communities are extremely vulnerable to the negative effects of environmental degradation. In particular, encroachment from land developers and environmentally-destructive technologies pose a substantial threat to small scale communities. Rubber plantations, for instance, take up land that could otherwise be used for farming, landing fish or home-steading. Likewise, shrimp farms occupy large areas of land, employ little labor and discharge harmful chemicals into coastal areas.

These encroaching activities provide local communities with few economic benefits or opportunities and impose significant economic and environmental costs. Because of the lack of land title and power, local communities are often at the mercy of local entrepreneurs and government officials. The latter are particularly important as they are responsible for defining and enforcing regulations regarding land use. The policy of local land departments seems to be one of *laissez-faire*, permitting a wide array of private concessions such as rubber plantations and shrimp farms.

Over-exploitation of Coastal Fisheries

A second type of conflict stems from escalating competition between small scale and large scale fishing communities, and among the small scale communities themselves. Conflicts between small scale and large scale fleets generally occur when the latter enter the fishing areas used by the small scale communities, degrading local fishing grounds, depleting local fish stocks, or tearing up stationary gear. Conflicts among the small scale communities tend to follow the same general pattern, whereby fishing communities use destructive gear (such as push net or cyanide).

There are many destructive technologies pursuing fewer fish, creating persistent and violent conflicts within Thailand's coastal zones. Surveys by the

Department of Fisheries show that catch per unit of effort (CPUE) rates have been declining since the 1960s (Table 9).

Fleet Operational Dynamics

The State of the Fishing Fleets

Fishing Fleet Classification

The marine capture fisheries can be broadly divided into commercial and small scale sub-sectors. Vessels over 10 m in length or 5 GT which use modern fishing gear and have the capacity to fish offshore for several days, are classified as commercial vessels. They typically operate from the larger ports and commonly use ice to preserve their catch. Refrigeration is employed on some of the larger vessels. Small scale vessels are usually less than 10 m in length and either employ an outboard-engine or inboard-engine or are non-motorized. Most small scale fishers operate from fishing villages.

According to the Marine Fisheries Census, a structural change in Thailand's fisheries took place between 1985 and 1995. The overall number of fishing boats increased by 3.0% (Table 10); small scale fishing boats increased by 7.5% whereas commercial fishing boats decreased by 11.0%. One reason for the change was the creation of a boat-tenure system within the commercial fishing sector, which resulted in a decrease in the number of boats per household.

Fishing Methods and Gear

Small scale vessels typically employ gillnets, small push nets, lift nets or other modern small scale gear, or alternatively set traps, bag nets and other stationary gear in estuaries or protected inshore waters. They rarely spend more than 12 hours at sea and generally fish within 5 km of the shore. Some fishers employ cast nets or hand-lines from the shore or from non-powered boats. The composition of the commercial fleet since 1958 is provided in Table 11. In theory, mechanized vessels using active gear must be licensed but in practice a significant proportion of vessels are unlicensed. Trawlers and purse seiners are the most important components of the fleet. Push nets and gillnets also take significant catches.

Table 9. Effort and CPUE in the Gulf of Thailand, 1986 - 85.

Year	Fishing effort (1 000 hours)	CPUE ($kg{\cdot}hr^{-1}$)
1961	358	279
1962	515	199
1963	672	295
1964	114	288
1965	1 147	233
1966	2 051	177
1967	2 773	158
1968	3 493	147
1969	3 621	143
1970	3 875	137
1971	6 065	100
1972	7 362	97
1973	8 644	85
1974	6 382	93
1975	9 273	77
1976	7 726	92
1977	10 265	75
1978	8 806	81
1979	8 923	80
1980	8 847	62
1981	11 470	50
1982	12 296	49
1983	13 351	46
1984	10 390	60
1985	11 928	54

Source: Somporn et al. citing Phasuk and Boobyubol and Pramok-Chutima, 1990.

Table 10. Number of fishing boats classified by type of fishing operations, 1985 and 1995.

Year	Small scale			Commercial scale			Total		
	Number	%	% of change	Number	%	% of change	Number	%	% of change
1985[1/]	40 095	86.2		12 855	13.8		52 950	100	
1995[2/]	43 092	86.7	7.5	11 446	13.3	-10.96	54 538	100	3.0

Sources: [1/] National Statistics Office and Department of Fisheries 1987.
[2/] National Statistics Office 1996.

Table 11. Number of selected types of gear (fishing units) registered and marine fish caught in Thailand, 1957 - 95.

Year	Pelagic fishing gear				Demersal fishing gear	
	Stake traps	Purse seines[1/]	Mackerel encircling gillnet	King mackerel drift gillnet	Trawlers[2/]	Push nets
1957	1 287	324	N/A	N/A	N/A	N/A
1958	1 344	392	N/A	N/A	N/A	N/A
1959	1 470	379	N/A	N/A	N/A	N/A
1960	1 409	323	48	N/A	99	N/A
1961	918	251	233	N/A	201	N/A
1962	792	228	386	N/A	976	N/A
1963	662	212	537	N/A	2 026	N/A
1964	602	144	890	N/A	2 360	N/A
1965	697	226	634	N/A	2 393	N/A
1966	663	228	409	N/A	2 695	N/A
1967	447	278	417	N/A	3 077	N/A
1968	457	361	329	N/A	3 182	N/A
1969	374	314	224	N/A	3 185	N/A
1970	371	716	260	235	3 082	354
1971	313	475	244	151	3 608	610
1972	236	506	254	138	4 486	1 327
1973	189	680	228	231	5 837	1 628
1974	229	657	188	148	5 271	1 213
1975	262	625	187	177	4 962	1 075
1976	222	726	226	157	5 204	844
1977	242	706	314	244	6 288	1 177
1978	250	843	359	151	6 453	1 426
1979	258	681	256	227	8 747	1 923
1980	225	781	307	287	10 421	2 262

Table 11. Number of selected types of gear (fishing units) registered and marine fish caught in Thailand, 1957 - 95. (continued)

Year	Pelagic fishing gear				Demersal fishing gear	
	Stake traps	Purse seines[1/]	Mackerel encircling gillnet	King mackerel drift gillnet	Trawlers[2/]	Push nets
1981	277	833	258	327	7 525	1 216
1982	233	840	238	281	11 475	1 899
1983	225	846	144	264	9 390	1 326
1984	254	961	245	265	9 131	960
1985	234	951	227	269	8 325	759
1986	258	996	203	329	7 407	664
1987	253	1 174	223	365	7 343	624
1988	231	1 456	146	461	6 950	531
1989	208	1 443	114	282	13 113	1 907
1990	188	1 629	101	299	12 905	1 879
1991	188	1 614	88	338	10 298	1 047
1992	204	1 452	72	362	9 465	818
1993	190	1 509	94	271	9 086	808
1994	190	1 511	99	280	8 346	651
1995	139	1 397	82	330	7 995	634

Source: Fisheries Economic Division, Department of Fisheries 1981 - 95.
Note: [1/] Chinese purse seine, Thai purse seine, Luring purse seine and Anchovy purse seine.
[2/] Otter trawl, Pair trawl and Beam trawl.
N/A = Not available.

Costs, Earnings and Profitability of Small Scale Fishing Operations

The study unit I was the fishing household in Songkla Province, Southern Thailand. Eight major fisheries in six villages along the coastal gulf of Thailand were selected. The major types of gear are shrimp gillnets, cuttlefish trammel nets, Indo-Pacific mackerel gillnets, other gillnets and Acetes trawl nets. The survey was made in May 1999, using the cross-sectional data for the previous year. The 33 sample fishing households were selected in six villages. These households were grouped according to the major types of fishing gear used.

Characteristics of Fishing Operation

Fishing Boats and Engines

Table 12 shows the details of fishing boats by type and size. About 93% of the boats were powered with outboard engines (long-tail). The boats' average length was 7.0 m. About 94% of the engines were diesel and the average HP was 8.3 HP.

Type of Gear and Definition of Gear Group

Fishing units were classified by the type of gear employed. Some fishing units use a two-gear combination, three-gear combination, or a four-gear combination. Based on these criteria, three groups of single gear, four of two-gear combination, one of three-gear combination and one four-gear combination were identified.

Initial Investment and Variable Input Use

Initial Investment

The initial investment in fishing assets (boat, engine and gear) by type of gear group is given in Table 13a. Small scale fishing units had average

Table 12. Boats and engine used of small scale fishing operation, Southern Thailand, 1998.

Items	Number of sample	%
Type of boats:	33	100.0
Outboard	32	97.0
Inboard	1	3.0
Length of boat:	33	100.0
Less than 6 meters	4	12.1
6 - 8 meters	27	81.8
9 - 10 meters	2	6.1
Average boat length:	7.0 meters	
Type of engine:	33	100.0
Benzene	2	6.1
Diesel	31	93.9
Engine power:	33	100.0
Less than 6 HP	11	33.3
6 - 10 HP	21	63.6
More than 10 HP	1	3.0
Average engine power:	8.29 HP	

investment assets worth 63 316 - 201 000 Baht (US$ 1 531 - 4 861 at 1 US$ = 41.35 Baht in 1998). The highest initial investment was in the OA (other gillnets and Acetes trawl net) gear, while the lowest was in shrimp gillnets.

Variable Input Use

The main variable inputs used were labor, nets and fuel, with the operator's household providing the main source of crew. Among the fishing villages they were all similar in family labor, with an average of 1.0 - 1.7 persons per fishing unit, using all types of fishing gear. There were significant differences in person-days (based on an 8-hour day) of family labor and wider differences between gear groups (Table 13b).

Cost Structure

Fixed cost is the cost that does not depend on the level of fishing operations but on the value of fishing assets. This may be 28.9% of total costs for shrimp gillnets, 35.0% for cuttlefish trammel nets and 31.9% for Indo-Pacific mackerel gillnets (Table 14a), all of which are single gear. There was a significant difference in the share of fixed costs between two-gear combination, three-gear and four-gear combination operations.

Table 13a. A16 Initial investment of small scale fishing by types of fishing gear, Southern Thailand, 1998.

Types of fishing gear	Initial Investment (Bahts)			
	Boat	Engine and equipment	Fishing gear and equipment	Total
Single gear:				
Shrimp gillnets	24 833	16 667	21 817	63 316
Cuttlefish trammel nets	42 000	27 800	27 400	97 200
Indo-pacific mackerel gillnets	36 500	10 000	17 500	64 000
Two-gear combined:				
SC	37 143	13 857	19 932	70 932
SI	35 000	12 000	41 000	79 000
CI	40 000	10 000	70 950	120 950
OA	100 000	20 000	81 000	201 000
Three-gear combined:				
SCO	38 750	26 750	83 500	149 000
Four-gear combined:				
SCIO	46 000	34 750	102 250	183 000

Table 13b. Labor input use by types of small scale fishing gear, Southern Thailand, 1998.

Types of fishing gear	No. of fishing day (days)	No. of family labors (persons)	No. of person-day Family labor	Hired labor	Total
Single gear:					
Shrimp gillnets					
Cuttlefish trammel nets	118	1.6	140	126	266
Indo-pacific mackerel gillnets	141	1.2	138	138	276
	110	1.5	49	30	79
Two-gear combined:					
SC	234	1.4	230	203	433
SI	135	1.0	132	132	264
CI	280	1.0	280	280	560
OA	218	1.0	213	213	426
Three-gear combined:					
SCO	254	1.7	302	127	429
Four-gear combined:					
SCIO	291	1.2	301	248	549

Note: SC = Shrimp gillnets, and Cuttlefish trammel nets
SI = Shrimp gillnets, and Indo-pacific mackerel gillnets
CI = Cuttlefish trammel nets, and Indo-pacific mackerel gillnets
OA = Others gillnets, and Acetes trawl nets
SCO = Shrimp gillnets, Cuttlefish trammel nets, and Other gillnets
SCIO = Shrimp gillnets, Cuttlefish trammel nets, Indo-pacific mackerel gillnets, and Other gillnets

Variable costs ranged from 65.0% to 71.1% of total fishing costs for single gear groups. This included hired labor, which is the main cash cost component. It accounted for about 25.9% - 48.7% of total costs in the case of two-gear combinations, and as much as 42.7% in the case of three-gear combinations.

In general, fixed costs consisted of interest on debt, depreciation of fishing assets and the opportunity cost of owned capital. Variable costs consisted of payment to hired labor, fuel, opportunity cost of family labor and nets, ice, fees and maintenance. Total cost and its components varied considerably among gear types (Table 14b). Single gear groups averaged a total cost of 36 263 - 98 873 Baht (US$ 877 - 2 391 in 1998) per year whereas two-gear combined operations ranged between 120 588 and 240 510 Baht (US$2 916 - 5 816 in 1998). In addition, three-gear combined operations averaged a total cost of 196 548 Baht (US$4 753) per year, whereas four-gear combined operations averaged 232 162 Baht (US$5 615). CI gear groups (cuttlefish trammel nets with Indo-Pacific mackerel gillnets) had the highest total cost with an average cost of 240 510 Baht (US$5 816) per year while Indo-Pacific mackerel gillnets had the lowest, with an average total cost of 36 263 Baht (US$877) per year. This is an indication of the dualism in coastal fisheries, i.e. one type of gear group has annual expenses over 10 times higher than that of another gear group. As noted, the latter is more than 10 times more profitable than the former, although profitability is not always correlated with the scale of operations, as reflected in total fishing costs or in the capital cost of the fishing assets.

Species Composition of Catch and Revenue Structure

The catch consists of a variety of species commanding such widely diverging prices that aggregate catch figures make little sense. This is due to the multi-species nature of the fisheries in coastal areas and the non-discriminating gear employed. Although total value of catch is more meaningful than quantity, the relative contribution of different species to value, as well as the individual catch and unit price of these important fish species, is important.

The fishers direct their effort toward high value species such as shrimp, cuttlefish, pomfret fish and crab but they obtain as by-catch low-value species called trash fish. There is considerable variation among gear groups in both the catch of individual species per year and the price obtained (Table 15).

The OA groups, on the average, obtain larger quantities and receive lower prices than shrimp gillnetters and other groups. The former's less valuable catch, such as trash fish, contributes sufficiently to total revenue to be considered more of a target catch than a low-price fish. For example, mackerel fish and edible fish contributed almost 94.1% of the total (Table 15)

Table 14a. Cost structure of small scale fishing operation by types of fishing gear, Southern Thailand, 1998.

Type of gear combination	Fixed costs (%)			Variable costs (%)					Total cost (%)
				Cash cost					
	Depreciation	Opp. cost of capital	Sub-total	Hired labor	Fuel	Others	Opp. Cost of family labor	Sub-total	
Single gear:									
Shrimp gillnets	24.6	4.3	28.9	16.9	4.5	13.5	36.3	71.1	100.0
Cuttlefish trammel nets	29.4	5.6	35.0	27.6	6.1	10.2	21.1	65.0	100.0
Indo-pacific mackerel gillnets	17.2	14.7	31.9	4.7	10.0	29.2	24.2	68.1	100.0
Two-gear combined:									
SC	29.5	3.1	32.5	25.9	9.9	10.1	21.6	67.5	100.0
SI	20.9	4.0	24.9	48.7	5.7	11.6	9.1	75.1	100.0
CI	19.3	1.8	21.2	46.8	6.9	10.0	15.1	78.8	100.0
OA	15.8	7.8	23.6	46.3	12.5	11.9	5.8	76.4	100.0
Three-gear combined:									
SCO	11.7	3.0	14.7	42.7	8.3	6.6	27.8	85.3	100.0
Four-gear combined:									
SCIO	19.7	2.2	22.0	30.5	14.5	13.2	19.8	78.0	100.0

Table 14b. Major cost items (Baht/year) per fishing unit by types of fishing gear, Southern Thailand, 1998.

Type of gear combination	Fixed costs ($Bahts \cdot year^{-1}$)		Variable costs ($Bahts \cdot year^{-1}$)				Cash cost ($Bahts \cdot year^{-1}$)	Imputed cost ($Bahts \cdot year^{-1}$)	Total cost ($Bahts \cdot year^{-1}$)
			Cash cost						
	Depreciation	Opp. cost of capital	Hired labor	Fuel	Others	Opp. Cost of family labor			
Single gear:									
Shrimp gillnets	20 626	3 600	14 181	3 742	11 322	30 415	29 244	54 641	83 885
Cuttlefish trammel nets	29 087	5 520	27 261	6 060	10 080	20 865	43 402	55 472	98 873
Indo-pacific mackerel gillnets	6 244	5 340	1 703	3 630	10 572	8 775	15 904	20 359	36 263
Two-gear combined:									
SC	40 203	4 166	35 379	13 521	13 741	29 491	62 642	73 860	136 502
SI	25 167	4 800	58 763	6 930	13 960	10 969	79 653	30 935	120 588
CI	46 457	4 440	112 500	16 613	24 100	36 400	153 213	87 297	240 510
OA	35 100	17 400	103 040	27 747	26 400	12 968	157 187	65 468	222 654
Three-gear combined:									
SCO	22 999	5 850	83 850	16 300	12 934	54 616	113 083	83 465	196 548
Four-gear combined:									
SCIO	45 820	5 160	70 700	33 757	30 657	46 069	135 113	97 049	232 162

Note: SC = Shrimp gillnets, and Cuttlefish trammel nets
SI = Shrimp gillnets, and Indo-pacific mackerel gillnets
CI = Cuttlefish trammel nets, and Indo-pacific mackerel gillnets
Opp = Opportunity
OA = Others gillnets, and Acetes trawl nets
SCO = Shrimp gillnets, Cuttlefish trammel nets, and Other gillnets
SCIO = Shrimp gillnets, Cuttlefish trammel nets, Indo-pacific mackerel gillnets and Other gillnets

Table 15. Annual catch fishing unit and composition of catch by types of small scale fishing gear, Southern Thailand, 1998.

Types of gear combination	Catch per unit (kg)	Value of catch per kg. (Baht·kg^{-1})	Catch composition (%)					
			Mackerel fish	Edible fish	Trash fish	Shrimp	Crab	Cephalopods
Single gear:								
Shrimp gillnets	637	117.8	23.6	28.7	0.2	32.4	8.2	6.9
Cuttlefish trammel nets	2 119	42.3	2.8	30.6	0.1	0.0	16.5	49.9
Indo-pacific mackerel gillnets	3 024	25.8	27.6	71.6	0.0	0.4	0.3	0.2
Two-gear combined:								
SC	2 782	48.4	4.5	30.5	0.1	2.6	15.9	46.4
SI	6 129	27.5	27.5	70.8	0.0	1.0	0.4	0.3
CI	10 077	32.8	17.1	54.2	0.0	0.2	7.2	21.3
OA	28 724	8.4	39.5	54.6	0.0	5.8	0.0	0.0
Three-gear combined:								
SCO	8 306	28.6	22	46.2	0.0	1.5	7.8	22.1
Four-gear combined:								
SCIO	6 846	37.5	18	55.1	0.0	2.2	6.9	18.0

Note: SC = Shrimp gillnets, and Cuttlefish trammel nets
SI = Shrimp gillnets, and Indo-pacific mackerel gillnets
CI = Cuttlefish trammel nets, and Indo-pacific mackerel gillnets
OA = Others gillnets, and Acetes trawl nets
SCO = Shrimp gillnets, Cuttlefish trammel nets, and Other gillnets
SCIO = Shrimp gillnets, Cuttlefish trammel nets, Indo-pacific mackerel gillnets and Other gillnets

Fishing Income and Profit

Gross Revenue

As expected, the highest value of catch or gross revenue was found in the CI gear groups with 330 495 Baht (US$7 993 in 1998) per year followed by the SCIO gear group (shrimp gillnets, cuttlefish trammel nets, Indo-Pacific mackerel gillnets and other gillnets) at 256 652 Baht (US$6 207) per year (Table 16). The lowest gross revenues were observed among the single gear groups and averaged between 75 017 - 89 584 Baht (US$1 814 - 2 166) per year. This indicates that the value of catch by fishing gear group reflects the availability of fisheries resources.

Gross Family Income

Gross family income is obtained by subtracting cash costs from gross revenues and is the maximum income from fishing that the household can consume in the short-run. It is not, however, sustainable over the long run, because no allowance is made for depreciation of fishing assets. There were several gear groups (e.g. shrimp gillnetters) that earned gross incomes that would not have allowed bare subsistence without supplementary income from non-fishing sources (Table 16).

Net Family Income

Net family income is obtained by subtracting depreciation from gross family income and can be consumed in its entirety without impairing the household's ability to continue fishing in the future. Net family income consists of returns to the family on factors such as capital, family labor and management, and rents, such as resource rent and rents from ability (e.g. rent is a 'wage' for some fixed resource like land). All households had positive net family incomes. However, the single gear groups (shrimp gillnetters) had extremely low net family incomes. The CI fishing unit group was the highest income group (Table 16).

Operating Profit

Operating profit (or gross economic profit), is defined as the difference between gross revenues and operating (or variable) costs. The importance of this measure of profitability lies in the economic principle that zero operating profits forms the dividing point between operation and close-down in the short-run. As long as operating (or variable) costs are covered, the fishing unit can continue operating until either the situation improves or fixed assets can be liquidated. Again, single gear groups

Table 16. Profitability (Baht/year) by types of small scale fishing gear, Southern Thailand, 1998.

Types of gear combination	(Baht·year^{-1})				
	Gross revenue	Gross family income	Net family income	Operating profit	Net profit
Single gear:					
Shrimp gillnets	75 017	59 112	38 486	15 358	(8 869)
Cuttlefish trammel nets	89 584	89 584	60 498	25 318	(9 289)
Indo-pacific mackerel gillnets	78 079	62 642	57 302	53 400	41 816
Two-gear combined:					
SC	134 663	72 021	31 818	42 530	(1 839)
SI	169 160	89 508	64 341	78 539	48 572
CI	330 495	330 495	284 038	140 881	89 985
OA	242 659	208 127	173 027	72 505	20 005
Three-gear combined:					
SCO	237 552	124 469	101 470	69 852	41 004
Four-gear combined:					
SCIO	256 652	256 652	210 832	75 470	24 490

Note: SC = Shrimp gillnets, and Cuttlefish trammel nets
SI = Shrimp gillnets, and Indo-pacific mackerel gillnets
CI = Cuttlefish trammel nets, and Indo-pacific mackerel gillnets
OA = Others gillnets, and Acetes trawl nets
SCO = Shrimp gillnets, Cuttlefish trammel nets, and Other gillnets
SCIO = Shrimp gillnets, Cuttlefish trammel nets, Indo-pacific mackerel gillnets and Other gillnets

(shrimp gillnetters) had very low operating profits. The five most profitable types of gear were CI, SI, SCIO, OA and SCO, respectively (Table 16).

Net Economic Profit

Net profits were calculated by deducting fixed costs from operating profit to determine the long-run profitability of various types of fishing gear. On strictly economic criteria, fishing units not covering their total costs (i.e. having negative net profits) leave the fisheries in the long-run, switching to the next best alternative from which, by definition, they could earn more. If net profits are made, new fishing units are attracted into open-access fisheries, until all pure profits (net profits minus management costs) disappear due to competion.

The most profitable types of gear were CI gear groups making a profit 89 985 Baht (US$2 176 in 1998) per year, followed by SI gear groups, Indo-Pacific mackerel gillnets and SCO gear groups, at an average 48 572 Baht (US$1 175) per year, 41 816 Baht (US$1 011) per year and 41 004 Baht (US$992) per year, respectively. Cuttlefish trammel net, shrimp gillnets and SC gear groups suffered greater losses than other groups, due to high operating costs and small catches. SCIO and OA gear groups also earned a reasonable profit, slightly more than 24 490 Baht (US$592) per year and 20 005 Baht (US$484) per year respectively. (Table 16).

Factor Returns

In terms of returns to labor, OA gear groups paid the highest wage rate at 272 Baht (US$6.58) per person-day mostly by share, followed by CI gear groups, 266 Baht (US$6.43), shrimp gillnet, 146 Baht (US$3.53) and SI gear groups, 264 Baht (US$ 6.38). The returns to labor for three types of gear groups namely, SC, SCO and Indo-Pacific mackerel gillnets were below the national minimum wage rate of 164 Baht (US$3.97) per person-day in 1998 (Table 17).

The returns on capital, that is, profit as a percentage of investment cost, was highest in the case of CI and CS gear groups because of the very high profit involved. The concept of returns on capital makes little sense for small scale fishing units.

Explaining Variation in Profitability

The high returns for CI and SI gear groups reflect the fishing skills and entrepreneurial ability of their operators as well as of the abundance of fisheries

Table 17. Return to investment and labor by types of small scale fishing gear Southern Thailand, 1998.

Types of gear	Return to investment (%)	Return to labor (Baht/person-day)
Single gear:		
Shrimp gillnets	(8)	168
Cuttlefish trammel nets	(4)	174
Indo-pacific mackerel gillnets	74	133
Two-gear combined:		
SC	3	150
SI	68	264
CI	78	266
OA	19	272
Three-gear combined:		
SCO	31	140
Four-gear combined:		
SCIO	16	213

Note: SC = Shrimp gillnets, and Cuttlefish trammel nets
SI = Shrimp gillnets, and Indo-pacific mackerel gillnets
CI = Cuttlefish trammel nets, and Indo-pacific mackerel gillnets
OA = Others gillnets, and Acetes trawl nets
SCO = Shrimp gillnets, Cuttlefish trammel nets, and Other gillnets
SCIO = Shrimp gillnets, Cuttlefish trammel nets, Indo-pacific mackerel gillnets and Other gillnets

resources in the Songkla coastal area. Thus, this return consists partly of rents of ability and quasi-rents for fixed factors and partly of resource rents. This is also reflected in the higher wages paid by these two gear groups. From the society's point of view, it appears that there are grounds for maintaining these gear groups and their contribution to employment and fish production.

The most important determinant of profit appears to be the interaction between types of gear and fishing grounds. Having the right type of gear at the right fishing grounds with appropriate skill and entrepreneurial spirit appears to be the recipe for high profits. These three components are present in the three most successful types of fishing group, CI gear groups, SI gear groups and Indo-Pacific mackerel gillnets. The question is how a small scale Songkla fisher with a relatively large debt and small funds of his own can take advantage of changing economic conditions by acquiring a shrimp gillnet.

The small scale fishers in the Songkla coastal area are in the worst possible situation because of the paucity of funds, of fish resources and of non-fishing alternatives. In this situation, not only credit and training are necessary but eventually relocation of the surplus fishers is inevitable, unless imaginative government projects such as small scale coastal aquaculture developments provide viable alternatives to coastal fishing.

Costs, Earnings and Profitability of Commercial Fishing Operations

This section is confined to operations of commercial fishing vessels, which use six major types of fishing gear, accounting for approximately 75% of the total quantity of marine products caught. The types of gear are otter trawls, pair trawls, beam trawls, push nets, purse seines and king mackerel gillnets. The various types of gear are applied in different sized fishing vessels. The study therefore concentrated on size of fishing vessels. Data were obtained from 100 samples. The survey was made in April - May 1996 and obtained the cross-sectional data for the previous year's activities in Thai waters.

Classification of commercial fishing operations varies. In this study, the length of fishing boats is used to be comparable with the classification used by the Department of Fisheries. (Gross tonnage and engine power have a correlation with vessel length of 0.95 and 0.75, respectively). Otter trawl boats are further classified into three categories, i.e. < 14 m, 14 - 18 m and 18 - 25 m. Pair trawls (one fishing

unit comprising two vessels) are classified into the same three categories: < 14 m, 14 - 18 m and 18 - 25 m. Beam trawlers are classified into two categories, i.e. < 14 m and > 14 m. Push net boats and purse seiners are classified into three categories: < 14 m, 14 - 18 m and 18 - 25 m. Other fishing boats like king mackerel gillnetters are classified into two categories, 14 - 18 m and 18 - 25 m.

Inputs Use in Fishing Operations

In fishing operations, two major inputs are applied: labor or crew (hired labor and family labor) and materials, i.e. fuel, oil, ice and others (containers and food). Table 18 indicates that the number of crew in trawlers increases with vessel size, i.e. 3 - 14 crew are needed with otter trawls, 4 - 8 are needed with pair trawl vessels and 3 - 5 are needed with beam trawl vessels. Vessels deploying push nets require 3 - 5 crew. As for purse seiners, a large number of crew (17 - 25) is needed. Finally, vessels with king mackerel gillnets require 9 - 10 crew. Small otter trawls can work at sea for 10.6 months per year, but time spent fishing depends on the weather (monsoon), and Government measures that specify closed seasons during spawning of some resources.

The unit "person-day" measures the services of labor used in fishing operations. Otter trawlers utilize 103 - 210 person-days, pair trawlers of all sizes need 122 - 255 person-days, beam trawlers and push netters of all sizes need 43 - 120 person-days and 46 - 63 person-days respectively. The number of person-days needed in purse seiners varies from 374 - 575 while king mackerel gillnetters need 171 - 200 person-days per month.

Apart from labor, the other most important input in fishing operations is fuel, especially for trawls and push nets where the engines have to operate during harvesting. Fuel consumption per month varies depending on the types of vessels: 4 537 - 10 693 litres for otter trawls (from small to large sizes), 12 032 - 21 547 litres for pair trawls and 3 559 - 15 915 litres for push nets. While the fuel consumption is much less in purse seiners and gillnetters than trawlers, these vessels do not differ significantly in size and fishing gear. Fuel consumption per month is between 4 730 - 10 521 litres for purse seiners and 3 563 - 5 145 litres for gillnetters.

Preservation of marine products during and after harvesting is important for the quality and price of products. Currently, ice is mainly used; the amount required depends on the duration of the trip. Otter trawlers (< 14 m), beam trawlers and push netters that spend only 1 - 2 days per trip require 0.01 - 5.3 t of ice per month. Larger fishing vessels require 11.7 - 26.3 t per month; king mackerel gillnet boats need only 0.7 - 0.8 t per month (Table 18).

Composition of Catch

Species and volume of catch differ according to the type of gear, and the fish harvested with similar types of gear further differs according to boat size. Table 19 indicates that monthly catch by each otter trawler has a volume between 8 027 and 39 593 t. Most of the catch is trash fish, comprising 45.4 - 62.5% of the total catch. Edible fish comprises 14.4 - 29.1% of the total catch. Small otter trawls (< 14 m) harvest shrimp comprising 31.8% of the total catch, but most are small size. Average catch per month of pair trawlers for all boat sizes varies between 25 316 and 57 921 t. The catch is completely different among small pair trawlers (< 14 m), medium pair trawlers (14 - 18 m) and large pair trawlers (18 - 25 m). Medium and large pair trawlers have a similar ratio of catch, i.e. edible fish, trash fish and cephalopods comprising 18.1 - 24.3%, 51.5 - 59.0% and 10.9 - 18.2% of total catch respectively. Average catch per month of beam trawlers for both boat sizes varies between 817 and 4 157 t. Shrimp comprises a large proportion of beam trawl catch, but most shrimp caught are small in size and receive low prices. Medium beam trawlers also catch a large quantity of cephalopods which comprises 27% of total catch. Finally, all sizes of push netter have a similar ratio of catch, i.e. edible fish, trash fish, shrimp and cephalopods are caught in the ratios 6.5 - 8.4%, 54.5 - 60.7%, 16.5 - 21.3% and 3.1 - 5.2% of total catch respectively.

Catch obtained from purse seiners and gillnetters consists mainly of edible fish making 31.0 - 80.0% of total catch. Catch by size of purse seiner varies between 36 760 and 55 351 t per month. Most of the catch is economic pelagic species, i.e. Indo-Pacific mackerel and sardinellas. King mackerel gillnet is the fishing gear catching high quality fish of similar size, with average price per kg of about 37.49 - 41.05 Baht (US$0.91 - 0.99), while the average price of other fish caught by purse seines is between 6.86 - 9.55 Baht (US$0.17 - 0.23) per kg. Major pelagic fish caught are king mackerel and little mummy.

Table 18. Variable input use per fishing unit by type and size of vessels, 1995.

Type of fishing gear	Length of boat (meters)	No. of crews	No. of fishing days per month	No. of fishing months per year	No. of person-days per fishing month			Fuel (litre·month^{-1})	Oil (litre·month^{-1})	Ice (litre·month^{-1})
					Hired labor	Family labor	Total			
Otter trawls										
< 14 meters	12.0	4	25	10.6	85	18	103	4 537	31	5.1
14 - 18 meters	16.2	7	26	9.8	156	8	164	9 126	61	11.7
18 - 25 meters	19.3	8	25	10.0	208	3	210	10 693	95	19.2
Pair trawls										
< 14 meters	13.5	10	27	8.0	122	–	122	12 032	41	
14 - 18 meters	16.4	11	18	9.3	216	5	221	14 993	65	5.5
18 - 25 meters	18.8	14	17	10.0	255	–	255	21 547	161	18.9
										26.3
Beam trawls										
< 14 meters	12.0	3	17	9.8	17	26	43	190	7	0.1
> 14 meters	15.7	5	24	9.0	96	24	120	5 317	26	5.2
Push nets										
< 14 meters	10.0	3	20	9.3	22	24	46	3 550	16	0.9
14 - 18 meters	17.0	4	22	9.3	66	13	79	6 250	19	2.0
> 18 meters	20.7	5	25	9.8	25	38	63	15 915	40	5.3
Purse Seine										
< 14 meters	12.1	17	22	6.0	352	22	374	4 730	13	21.1
14 - 18 meters	17.1	21	23	10.0	460	23	483	8 159	53	21.5
18 - 25 meters	20.7	25	23	10.0	575	–	575	–	108	25.0
King Mackerel gillnet										
14 - 18 meters	16.6	9	19	10.0	152	19	171	3 563	27	0.7
18 - 25 meters	19.2	10	20	10.0	180	20	200	5 145	51	0.8

Investment Costs

Investment costs consist of three parts, i.e. the investment in the hull, (all wooden hulls); the investment in the engine and other navigational aids; and the investment in fishing gear and equipment. Initial investment in fishing operations varies according to type and size of fishing boat. The ratio of initial investment to number of crew indicates capital intensity of each type and category of fishing vessel (Smith and Mines 1982).

Investment Costs of Demersal Fishing Gear

Capital investment for different types of trawlers primarily depends on hull construction. Thus the cost for hull construction of otter trawlers and pair trawlers comprises an average 50% and 42% of total investment, respectively. Table 20 shows that capital outlay on otter trawlers of small size differs on the average from 423 225 Baht (US$10 235 in 1998) to 2 220 907 Baht (US$53 710), a 5.2 times difference. This is because the size of < 14 m is mainly for coastal fisheries and merely needs used engines, which cost less, and the gear is also not expensive. Otter trawlers of > 18 m in length employ modern equipment, such as echo-sounder and radar, etc. The ratio of capital to number of crew, which measures capital intensity, slowly increases according to size of boat ranging from a low of 105 806 : 1 to a high of 277 613 : 1. Capital investment in pair trawlers does not differ significantly with boat size for several reasons. Fishing grounds are not far from shore, vessels can only operate during day-time and less fishing gear and equipment are needed compared with otter trawls of similar size. Capital outlay from small to large fishing boat sizes (< 14 m up to 18 - 25 m in length) is between 1 197 825 Baht (US$28 968) to 3 895 937 Baht (US$94 218) per unit, or a difference of 3.3 times. Capital intensity ranges from 119 783 : 1 to 278 281 : 1, a difference of 2.3 times.

Table 19. Catch, value of catch and catch composition per fishing unit by type and size of vessels, 1995.

Type of fishing gear	Length of boat (meter)	Total catch (Kg)	Value of catch (Baht)	Average price of catch (Baht·Kg^{-1})	Catch Composition				
					Edible fish (%)	Trash fish (%)	Shrimp (%)	Cephalopods (%)	Others (%)
Otter trawls									
< 14 meters	12.0	8 027	79 249	9.87	14.4	45.4	31.8	6.4	2.0
14 - 18 meters	16.2	22 852	196 227	8.59	25.4	62.5	4.0	7.4	0.7
18 - 25 meters	19.3	39 593	290 158	7.33	29.1	59.9	1.2	9.5	0.3
Pair trawls									
< 14 meters	13.5	25 316	245 610	9.70	24.3	51.5	2.7	18.2	3.3
14 - 18 meters	16.4	29 857	445 544	14.92	18.1	59.0	11.3	10.9	0.7
18 - 25 meters	18.8	57 921	633 668	10.94	14.4	73.4	3.7	8.1	0.4
Beam trawls									
< 14 meters	12.0	817	22 091	27.04	7.0	-	80.0	3.1	9.9
> 14 meters	15.7	4 157	125 336	30.15	18.3	14.7	39.3	27.0	0.7
Push nets									
< 14 meters	10.2	3 668	67 802	18.48	8.4	54.5	21.3	3.1	12.7
14 - 18 meters	16.7	6 861	128 690	18.76	6.5	57.4	20.8	4.0	5.2
18 - 25 meters	20.6	9 880	242 650	24.56	9.5	60.7	16.5	5.2	8.2
Purse Seines									
< 14 meters	12.1	36 760	252 137	6.86	31.0	68.5	-	-	1.0
14 - 18 meters	17.1	40 821	349 020	8.55	36.7	63.0	-	-	0.5
18 - 25 meters	20.7	55 351	528 602	9.55	49.5	48.6	-	1.0	1.0
King Mackerel gillnets									
14 - 18 meters	16.6	4 106	153 946	37.49	85.0	13.0	-	-	2.0
18 - 25 meters	19.2	6 470	265 594	41.05	80.0	19.0	-	-	1.0

Source: Fisheries Economics Division, Department of Fisheries 1995.

As for beam trawlers, capital outlay ranges from 71 881 Baht (US$1 738) to 313 383 Baht (US$7 579) on the average, a difference of about 4.4 times.

Capital outlay on small-sized push net vessels ranges from 132 357 Baht (US$3 201) to 1 031 030 Baht (US$24 934), a difference of 7.8 times. This size boat, < 14 m, is mainly used in coastal fisheries and needs only used engines that cost less. Fishing gear is not complicated and requires only low investment. On the other hand, push netters of 18 - 25 m in length employ modern equipment. The capital-labor ratio increases according to size of boat from 44 119 : 1 to 206 206 : 1.

Investment Cost of Pelagic Fishing Gear

Capital investment in pelagic fisheries such as purse seiners and king mackerel gillnetters differs from trawl fisheries, in that investment in assets for equipment is more than that for the hull. Purse seine investment in equipment and gear requires higher investment compared to other types of boat. Between 53.6 and 74.9% of total investment is for equipment and 16.0 to 30.9% is needed for the hull. Investment in gear and equipment for king mackerel gillnetters is 52.8% and 54.4% of total capital outlay respectively, while the cost of hull is between 31.5% and 33.3% of total costs. Table 20 indicates that of all pelagic fishing gear, large purse seiners (18 - 25 m) require the highest investment at an average of 4 339 790 Baht (US$104 953) per unit, followed by medium size (14 - 18 m), requiring an average capital outlay of 2 743 886 Baht (US$ 66 356) per unit. King mackerel gillnetters require an average capital investment of 1 989 489 to 2 666 849 Baht (US$48 113 - 64 494) per unit. King mackerel gillnetters have the highest capital intensity ranging from 221 054 : 1 to 266 685 : 1, while purse seiners (< 14 m) have

Table 20. Investment costs per fishing unit by type and size of vessels, 1995.

Type of fishing gear	Length of boat (meters)	Horse-power (HP)	Initial Investment								Capital Intensity*	
			Hull		Engine		Gear & equipment		Total			
			Value (Baht)	%	Value (Baht)	%	Value (Baht)	%	Value (Baht)	%		
Otter trawls												
< 14 meters	12.0	103	182 500	43.1	120 318	28.4	120 407	28.4	423 225	100.0	105 806	:1
14 - 18 meters	16.2	203	703 929	53.6	287 522	21.9	320 989	24.5	1 312 515	100.0	187 502	:1
18 - 25 meters	19.3	323	1 161 111	52.3	617 555	27.8	442 161	19.9	2 220 907	100.0	277 613	:1
Pair trawls												
< 14 meters	13.5	217	546 250	45.6	317 750	26.5	333 825	27.9	1 197 825	100.0	119 783	:1
14 - 18 meters	16.4	516	795 000	36.8	884 000	40.9	483 500	22.4	2 162 500	100.0	196 591	:1
18 - 25 meters	18.8	646	1 725 000	44.3	935 000	24.0	1 235 937	31.7	3 895 937	100.0	278 281	:1
Beam trawls												
< 14 meters	12.0	46	41 333	57.5	24 617	34.2	5 931	8.3	71 881	100.0	23 960	:1
> 14 meters	15.7	183	81 250	25.9	157 000	50.1	75 133	24.0	313 383	100.0	62 677	:1
Push nets												
< 14 meters	10.0	154	39 250	29.7	50 620	38.2	42 487	32.1	132 357	100.0	44 119	:1
14 - 18 meters	17.0	300	79 142	19.9	135 000	34.0	182 657	46.0	396 799	100.0	99 200	:1
> 18 meters	20.7	312	313 600	30.4	305 590	29.6	411 840	39.9	1 031 030	100.0	206 206	:1
Purse seines												
< 14 meters	2.1	188	292 222	16.0	166 250	9.1	1 365 771	74.9	1 824 243	100.0	107 308	:1
14 - 18 meters	17.1	249	721 429	26.3	221 429	8.1	1 801 028	65.6	2 743 886	100.0	130 661	:1
18 - 25 meters	20.7	333	1 342 105	30.9	670 553	15.5	2 327 132	53.6	4 339 790	100.0	173 592	:1
King Mackerel gillnets												
14 - 18 meters	16.6	233	627 143	31.5	311 429	15.7	1 050 917	52.8	1 989 489	100.0	221 054	:1
18 - 25 meters	19.2	268	887 273	33.3	329 000	12.3	1 450 576	54.4	2 666 849	100.0	266 685	:1

Source: Fisheries Economic Division, Department of Fisheries 1995.
Note: * Capital/crew ratio indicating investment cost per crew.

the lowest capital intensity at 107 308 : 1. This is because king mackerel gillnetters require less labor than any other type of fishing boat.

Cost Structure

Inputs in fishing operations are divided into two main groups, fixed input or fixed assets invested, and variable inputs. Fixed cost or input consists of the depreciation cost of durable assets (boats, engine, and other durable equipment), the opportunity cost of capital (measured at an interest rate of 12%) and the interest cost on debt. These costs are incurred whether there are fishing operations or not. Variable cost or input consists of three subparts, revolving cost (fuel and oil, ice and repair costs), labor cost (hired labor, family labor and food) and marketing costs (commission, transport and various fees).

The cost structure in Table 21 shows that for all types of fishing gear, the main costs are variable costs at 73.5 - 89.4% of the total cost (variable plus fixed) with 7.0 - 26.5% of total costs as fixed cost. Trawlers and push netters have high fuel and oil expenses, i.e. 32.1 - 51.0% of total costs. Variable costs of purse seiners and gillnetters differ in that the majority of expenses are for labor at 26.5 - 51.0% of total costs, and only 16.0 - 21.1% of total cost is fuel expense. Trawl and push net fisheries, with their high proportion of fuel costs, have a high degree of instability due to the possibility of fuel price changes or the introduction of fuel-saving measures during a period of scarcity.

Table 21. Cost structure by type and size of vessels, 1995.

Type of fishing gear	Fixed cost (%)				Variable cost (%)						
	Depre-ciation (%)	Opp. cost of capital (%)	Interest on debt (%)	Sub total (%)	Labor (%)	Fuel & Oil (%)	Ice (%)	Repair & main-tenance (%)	Others (%)	Sub total (%)	Grand total (%)
Otter trawls											
< 14 meters	4.0	4.8	1.9	10.6	23.6	44.1	6.1	14.0	1.6	89.4	100.0
14 - 18 meters	5.6	9.1	1.1	15.8	26.6	33.6	6.4	15.8	1.8	84.2	100.0
18 - 25 meters	6.4	9.3	3.8	19.6	19.6	32.1	6.9	11.3	10.5	80.4	100.0
Pair trawls											
< 14 meters	5.4	8.3	1.3	15.0	21.0	37.7	5.2	19.5	1.6	85.0	100.0
14 - 18 meters	5.6	7.3	2.4	15.4	19.7	37.3	5.5	20.7	1.4	84.6	100.0
18 - 25 meters	6.5	10.4	1.5	18.4	17.8	36.5	4.9	20.5	1.9	81.6	100.0
Beam trawls											
< 14 meters	2.6	3.0	1.4	7.0	46.0	33.0	1.5	11.3	1.2	93.0	100.0
> 14 meters	4.6	7.0	2.4	13.9	32.3	38.4	4.0	9.9	1.6	86.2	100.0
Push nets											
< 14 meters	4.8	7.4	2.0	14.1	29.1	39.5	1.1	8.1	4.1	81.9	100.0
14 - 18 meters	4.4	8.0	4.7	17.2	27.2	37.3	1.6	15.5	1.2	82.7	100.0
18 - 25 meters	5.7	11.2	3.2	20.0	17.6	51.0	2.1	7.6	1.7	80.0	100.0
Purse Seines											
< 14 meters	1.6	6.6	2.6	10.8	51.0	16.0	4.2	17.3	0.6	89.2	100.0
14 - 18 meters	2.1	11.4	2.5	16.0	44.8	21.1	4.8	12.0	1.2	84.0	100.0
18 - 25 meters	2.7	9.4	3.4	15.5	35.9	18.1	4.9	22.2	3.4	84.5	100.0
King Mackerel gillnets											
14 - 18 meters	4.0	15.5	7.0	26.5	34.7	20.3	3.0	15.1	0.4	73.5	100.0
18 - 25 meters	3.0	14.4	5.9	23.3	26.5	16.9	2.6	16.4	14.4	76.7	100.0

Source: Fisheries Economics Division, Department of Fisheries 1995.

Monthly Fishing Costs

Fishing effort by different types of fishing gear varies greatly throughout the year, whether by the number of trips, days or months of operation. Costs of various types of fishing operation also differ per trip, per month or per year. To standardize the costs this study uses the average cost per month (total costs per year divided by number of months in operation). Apart from dividing costs as fixed and variable, it is also possible to divide them into cash and imputed costs (depreciation cost, opportunity cost of capital and opportunity cost of family labor) as discussed below.

Otter Trawls

This type of fishing operation requires 25 - 26 days of operation per month. From Table 22, the average total cost per vessel of large size (18 - 25 m) is maximum at 227 520 Baht (US$5 502 in 1998) per month, followed by 14 - 18 m size at 158 851 Baht (US$3 842), and then at < 14 m, 77 866 Baht (US$ 1 883). The majority of these costs are for fuel and oil, crew, ice, repairs and maintenance, interest on debt and others (marketing expenses, food and fees). Fuel comprises the highest cash expense followed by crew cost. Pair trawls (18 - 25 m) incur higher costs for repair than crew costs owing to high investment in modern equipment, as well as by fishing offshore. The imputed costs for depreciation, opportunity cost of capital and family labor make up an average of 16% of total cost.

Table 22. Cost items (Baht·month^{-1}) per fishing unit by type and size of vessels, 1995.

	Fixed cost (Baht·month^{-1})			Variable cost (Baht·month^{-1})						(Baht·month^{-1})		
	Cash cost			Cash cost								
Type of fishing gear	Interest on debt	Depre- ciation	Opp. cost of capital	Crews	Fuel & Oil	Ice	Repair & main- tenance	Others	Opp. cost of family labor	Cash cost	Impu- ted cost	Total cost
Otter trawls												
< 14 meters	1 449	3 077	3 713	15 752	34 355	4 772	10 862	1 237	2 650	68 426	9 440	77 866
14 - 18 meters	1 789	8 940	14 475	38 756	53 451	10 107	25 075	2 808	3 450	131 986	26 865	158 851
18 - 25 meters	8 657	14 520	21 111	42 173	73 003	15 878	25 647	24 160	2 371	189 518	38 002	227 520
Pair trawls												
< 14 meters	3 208	13 111	20 250	51 000	91 894	12 640	47 413	3 967	–	210 122	33 361	243 483
14 - 18 meters	7 000	16 217	21 000	53 873	108 362	16 037	60 051	4 478	3 520	249 801	40 737	290 538
18 - 25 meters	7 083	29 888	48 000	81 839	168 389	22 562	94 302	8 789	–	382 964	77 888	460 852
Beam trawls												
< 14 meters	375	718	829	6 424	9 018	421	3 083	326	6 167	19 647	7 714	27 361
> 14 meters	2 484	4 832	7 367	32 273	40 617	4 227	10 436	1 685	1 875	91 722	14 074	105 796
Push nets												
< 14 meters	1 391	3 377	5 232	9 464	28 054	747	5 371	2 673	9 724	47 700	18 333	66 033
14 - 18 meters	6 000	5 610	10 083	32 808	47 093	1 988	19 570	1 515	1 543	108 974	17 236	126 210
18 - 25 meters	7 500	13 390	26 350	38 637	120 072	4 900	17 938	3 721	2 850	192 768	42 590	235 358
Purse seines												
< 14 meters												
14 - 18 meters	6 250	3 849	15 722	121 392	38 266	10 147	41 543	1 518	823	219 116	20 394	239 510
18 - 25 meters	7 500	6 239	34 464	133 521	63 635	14 541	36 324	3 568	1 685	259 089	42 388	301 477
	15 000	12 048	41 250	155 754	79 759	21 705	97 731	14 929	2 568	384 878	55 866	440 744
King Mackerel gillnets												
14 - 18 meters	10 000	5 804	22 281	47 850	29 162	4 328	21 776	562	2 089	113 678	30 174	143 852
18 - 25 meters	14 980	7 660	36 477	63 836	42 871	6 486	41 647	36 483	3 524	206 303	47 661	253 964

Source: Fisheries Economic Division, Department of Fisheries 1995.

Pair Trawl

A pair trawl consists of two boats, making its cost of operation higher than other type of fishing operation of similar size. It requires 17 - 27 days of operation per month. Table 22 indicates that the highest monthly operation costs are incurred by the large pair trawlers (18 - 25 m) at 460 852 Baht (US$11 145), followed by the medium size (14 - 18 m) at 290 538 Baht (US$7 026) and the smaller size (< 14 m) at 243 483 Baht (US$5 888). Most costs are cash, averaging about 85% of total costs. Fuel and oil comprise the highest cash costs followed by crew cost, repairs and maintenance, ice and others. The rest are imputed costs (depreciation, opportunitycost of capital and family labor) at 15% of total costs.

Beam Trawls

Beam trawls require 17 - 24 days of operation per month. Table 22 indicates that medium beam trawls (> 14 m) incur the highest monthly operation costs at 105 796 Baht (US$2 558), while the small size (< 14 m) incurs costs of 27 361 Baht (US$662). Most costs are cash, averaging about 84% of total costs. Fuel and oil comprise the highest cash costs, followed by crew cost, repairs and maintenance, ice and others. The rest are imputed costs (depreciation, opportunity cost of capital and family labor), at 16% of total costs.

Push Nets

This type of fishing operation requires between 20 and 25 days of operation per month. The average total cost per vessel of large size (18 - 25 m) is maximum at 235 358 Baht (US$5 692) per month, followed by 14 -18 m size vessels and < 14 m vessels at 126 210 Baht (US$3 052) and 66 033 Baht (US$1 597) respectively (Table 22). The majority of these are costs for fuel and oil, crew, ice, repairs and maintenance, interest on debt and others (marketing expenses, food and fees). Fuel comprises the highest cash expense, followed by crew cost. Imputed costs (depreciation, opportunity cost of capital and family labor) comprise on the average 18% of total cost.

Thai Purse Seines

The three sizes of purse seine operations involve 22 - 23 days per month. Total costs of operation of large boats (18 - 25 m), medium boats (14 -18 m) and small boats (< 14 m) are 440 744 Baht (US$ 10 659), 301 477 Baht (US$7 291) and 239 510 Baht (US$5 792) per month respectively. Most of these costs are cash expenses, averaging 88% of total costs. These costs consist of wages and crew share, fuel and oil, repairs and maintenance, ice, interest charge on debt (fixed cost) and others. Cash expenses differ from those of trawl and push net operations because wages and crew share are the largest expenses while imputed costs (consisting of depreciation, opportunity cost of capital and family labor) constitute 12% of total costs. Family labor cost in large purse seine boats is 3 times higher than that of the small boats due to more family members being employed in large purse seine boats (Table 22).

King Mackerel Gillnets

This type of gear requires the lowest cost of all types of pelagic fishing. Operations of king mackerel gillnets involve 19 - 20 days•month^{-1}, and have an average cost between 143 852 Baht (US$3 479) and 253 964 Baht (US$6 142)•boat^{-1}•month^{-1}. Cash cost comprises 80% of total costs, the majority of which are wages and crew share averaging 47 850 - 63 836 Baht (US$1 157 - 1 544)•boat^{-1}•month^{-1}. The cost of ice to preserve fish is only 4 328 - 6 486 Baht (US$105 - 157)•month^{-1} (Table 22), which is minimal when compared with other gear types of similar size. This is due to the fact that catch by gillnets is good quality and of large size. In some boats, king mackerel are salted soon after harvest, thereby requiring less ice, but requiring salt, (included under the item “others”). Imputed costs consist of about 20% of the total cost, more than half of which are opportunity cost of capital and the rest are depreciation cost and opportunity cost of family labor.

Share System

Among the stated operational costs, the wages of crew are significant. They rank second to fuel cost, especially for pelagic fishing, which incurs the highest crew cost. Benefit sharing between crew and boat owner differ according to the type and size of boats. Benefit sharing can be classified into two systems: (1) wage or salary payment, and (2) sharing value of products sold. Systems of sharing have different effects on risk. In the regular wage system, risk (including expected profit) in both catch and its price for each trip, solely belongs to the boat owners. Crew receive definite wages but lose the opportunity of sharing in the event of a good harvest. In the sharing system, both crew and boat owners jointly share the risk in catch and its price. The fixed wage system induces less enthusiasm from the crew, although the benefit-sharing system is risky due to lack of regular income and job security as in other sectors. This leads to the adoption of a mixed system of part regular wage and part sharing in the value of the catch.

The sharing system differs according to type and size of fishing gear. In small otter trawls < 14 m in length, about 80% of cases studied employed fixed wages. Medium and large sized otter trawls (14 - 18 m and 18 - 25 m) employ a mixed system. Between 50 - 75% of pair trawls employ fixed wages. Most of the beam trawls and push nets use benefit sharing based on net value of catch after deduction of operating expenses. This net value is divided in a ratio of 7 : 3 between boat owner and crew. The crew share is divided according to rank and responsibility with the master fisher receiving the biggest share. If the catch is higher than the target, the crew receives a bonus, in addition to regular wages and shares. Taking into account all benefits, crew members of medium size push netters (14 -18 m) receive an average of 8 588 Baht (US$208)•month^{-1} (Table 23). As for pair trawlers, each crew member of a small boat (14 - 18 m) receives 4 197 Baht (US$102)•month^{-1}.

Pay for purse seiners and gillnetters is based on a

Table 23. The sharing system by type and size of vessels, 1995

Type of fishing gear	No. of crews	Percentage of fishing units by type of sharing system			Average crew cost (Baht·month^{-1})	
		Fixed wages	Share	Fixed wages & share	per fishing unit	per crew
Otter trawls						
< 14 meters	4	80	–	20	18 402	4 601
14 - 18 meters	7	25	39	36	42 206	6 029
18 - 25 meters	8	11	23	66	44 548	5 569
Pair trawls						
< 14 meters	10	50	–	50	51 000	5 100
14 - 18 meters	11	25	–	75	57 393	5 218
18 - 25 meters	14	25	25	50	81 839	5 846
Beam trawls						
< 14 meters	3	–	100	–	12 591	4 197
> 14 meters	5	–	100	–	34 148	6 830
Push nets						
< 14 meters	3	10	90	–	19 188	6 396
14 - 18 meters	4	–	100	–	34 351	8 588
18 - 25 meters	5	–	100	–	41 487	8 297
Purse Seines						
< 14 meters	9	5	13	82	121 392	7 141
14 - 18 meters	7	–	11	89	133 351	6 350
18 - 25 meters	19	–	9	91	155 754	6 230
King Mackerel gillnets						
14 - 18 meters	8	8	16	76	47 850	5 317
18 - 25 meters	11	5	20	75	63 836	6 384

Source: Fisheries Economic Division, Department of Fisheries 1995.

mixed system of fixed monthly wage and sharing catch value. About 82 - 91% of purse seiners and 75 - 76% of gillnetters use this system. Net value after the deduction of expenses is divided between boat owners and crew in a ratio of 6 : 4 in the case of king mackerel drift gillnet vessels. Among all types of purse seine and gillnet boats, crew of small boats receive at most 7 141 Baht (US$173)•month^{-1}.

Revenue and Profit

Gross Revenue

Gross revenues are the total value of the catch. Gross revenue of large pair trawlers (18 - 25 m) is highest at 521 289 Baht (US$12 607)•month^{-1} and lowest for small beam trawlers (<14 m) at 34 129 Baht (US$825)•month^{-1} (Table 24). Gross revenue of trawling varies significantly among boat sizes (Table 24). Three sizes of otter trawler namely, small, medium and large yield revenues of 79 249 Baht (US$1 917), 196 227 Baht (US$4 746), and 290 158 Baht (US$7 017)•month^{-1} respectively. Small boats have gross revenue 2.5 times less than medium-size boats, but medium-size boats have gross revenue close to that of large boats. Three sizes of push netters namely, small, medium and large yield revenues of 67 802 Baht (US$1 640), 128 690 Baht (US$3 112), and 242 650 Baht (US$5 868) •month^{-1} respectively. Gross revenue of large purse seiners (18 - 25 m) is highest at 528 602 Baht (US$ 12 784)•month^{-1} and lowest for medium-size king mackerel gillnetters (14 - 18 m) at 153 946 Baht (US$3 723)•month^{-1}.

Cash Flow

Cash flow indicates the highest revenue received and is derived from gross revenue less total cash costs. Cash flow of trawlers and push netters and

Table 24. Profitability per fishing unit by type and size of vessels, 1995.

Type of fishing gear	(Baht·month^{-1})				
	Gross revenue	Cash flow	Net income	Operating profit	Net profit
Otter trawls					
< 14 meters	79 249	10 823	7 746	9 622	1 383
14 - 18 meters	196 227	64 241	55 301	62 580	37 376
18 - 25 meters	290 158	100 640	86 120	106 926	62 638
Pair trawls					
< 14 meters	245 610	35 488	22 377	38 696	2 127
14 - 18 meters	322 483	72 682	56 465	76 162	31 945
18 - 25 meters	521 289	138 325	108 437	145 408	60 437
Beam trawls					
< 14 meters	34 129	14 482	13 764	8 690	6 768
> 14 meters	122 180	30 458	25 626	31 067	16 384
Push nets					
< 14 meters	67 802	20 102	16 725	11 769	1 769
14 - 18 meters	128 690	19 716	14 106	24 173	2 480
18 - 25 meters	242 650	49 882	36 492	54 532	7 292
Purse Seines					
< 14 meters	252 137	33 021	29 172	38 448	12 627
14 - 18 meters	349 020	89 931	83 692	95 746	47 543
18 - 25 meters	528 602	143 724	131 676	156 156	87 858
King Mackerel gillnets					
14 - 18 meters	153 946	40 268	34 464	48 179	10 094
18 - 25 meters	265 594	59 291	51 631	70 747	11 630

Source: Fisheries Economic Division, Department of Fisheries 1995.
Note: 1. Cash flow (Gross revenue) - (Cash cost)
2. Net income (Cash flow) - (Depreciation cost)
3. Operating profit (Gross revenue) - (Variable cost): or
(Cash flow) - (Opp. cost of family labor) + (Interest on debt)
4. Net profit (Gross revenue) - (Total cost)

large pair trawlers (18 - 25 m) have the highest at 138 325 Baht (US$3 345)•month^{-1}, while small beam trawlers (< 14 m) have the lowest cash flow at 14 482 Baht (US$350)•month^{-1}. Large purse seine boats (18 - 25 m) have the highest cash flow of 102 490 Baht (US$2 479)•month^{-1} and medium-size gillnetters (14 - 18 m) have the lowest cash flow at 40 268 Baht (US$974)•month^{-1}.

Net Income

Net income is cash income less depreciation. This value indicates the fisher's ability to sustain a long-term fishing operation. Net income is the return on inputs such as capital, family labor, management and rent (resource rents and rents of ability). In demersal fisheries, the highest net income is received by large pair trawlers (18 - 25 m), totaling 108 437 Baht (US$2 622)•month^{-1} and the lowest net income is for small beam trawlers (< 14 m) at 13 764 Baht (US$333)•month^{-1} (Table 24). Large purse seiners (18 - 25 m) yield the highest net income at 131 676 Baht (US$3 184)•month^{-1} and medium-size gillnetters yield the lowest net income at 34 646 Baht (US$838)•month^{-1}.

Operating Profit

Operating profit is the difference between gross revenue and variable costs. Operating profit indicates whether a fishing operator can continue to operate during the working life of running assets.

The results in Table 24 indicate that operators of all types and sizes of fishing vessels can continue working. Large pair trawlers (18 - 25 m) yield the highest operating profit at 145 108 Baht (US$ 3 509)•month^{-1} while small beam trawlers (< 14 m) receive the lowest operating profit, at 8 690 Baht (US$210)•month^{-1}. This is due to the fact that large trawlers can fish in distant fishing grounds that sometimes include the waters of neighbouring countries, while the small trawlers can only fish along the coast. Large purse seine boats (18 - 25 m) yield the highest operating profit of 156 156 Baht (US$3 776)•month^{-1} while smaller boats of this type (< 14 m) yield 38 448 Baht (US$ 930) operating profit•month^{-1}.

Net Profit

Net profit is the difference between gross revenue and total costs. Fishers should not continue operations if net profit is not higher than depreciation cost plus interest on debt and opportunity cost of capital. This study showed that almost all types and sizes of operation could maintain their work (Table 24). However, many types of fishing gear continue to operate owing to the fact that any adverse effect is lower than opportunity cost of capital plus interest on debt. These are small otter trawlers, small pair trawlers, small purse seiners and all sizes of push net and gillnet boats, on which this return is higher than taking other work. Large otter trawlers (18 - 25 m) return the highest net profit in demersal fishing at 62 638 Baht (US$1 515) •month^{-1} while for pelagic fisheries, large purse seiners (18 - 25 m) yield the highest net profit at 87 858 Baht (US$2 125)•month^{-1}, with the mackerel gillnetters yielding the lowest at 10 094 Baht (US$244)•month^{-1}. On average, all types and sizes of purse seine and gillnet boats yield higher net profits than any other type of fishing gear.

Factor Return

Return on Capital

Return on capital indicates feasibility of fishery investment. Since fishing is one of the highest natural risk operations, its return is high for certain types of fishing gear. This study examines return on initial investment. Return is defined as percentage of net profit and opportunity cost of capital on initial investment. Return on capital for trawlers and push netters is higher than for purse seiners and gillnetters. Return on capital for small beam trawlers is the highest at 104% owing to the lower investment requirements than for other types of gear of similar size (Table 25). Purse seiners that yield highest returns on capital are medium purse seiners (14 - 18 m) and large purse seiners (18 - 25 m) at 30%. Large gillnetters (18 - 25 m) yield the highest return on capital at 18%.

Returns to Labor

Return to labor is the compensation per working day of operation. When comparing the return against the national minimum wage (145 Baht (US$5.82 at 1 US$ = 24.92 in 1995, source: oanda.com) per day in 1995), the return in the fisheries sector is higher on the whole (Table 25). This value includes food which hired crew receive in addition to wages and share.

Table 25. Return to labor and capital by type and size of vessels, 1995.

Type of fishing gear	Return to capital (%)[1/]	Return to labor (B/person-day)
Otter trawls		
< 14 meters	13	180
14 - 18 meters	39	257
18 - 25 meters	38	212
Pair trawls		
< 14 meters	15	420
14 - 18 meters	23	260
18 - 25 meters	28	321
Beam trawls		
< 14 meters	104	296
> 14 meters	68	285
Push nets		
< 14 meters	49	417
14 - 18 meters	29	434
18 - 25 meters	32	664
Purse Seines		
< 14 meters	9	327
14 - 18 meters	30	280
18 - 25 meters	30	275
King Mackerel gillnets		
14 - 18 meters	16	292
18 - 25 meters	18	337

Source: Fisheries Economic Division, Department of Fisheries 1995.
Note: [1/] Return to initial investment = (net profit per year + opportunity cost of capital per year) * 100/ (initial investment)

Discarding and by-catch

The percentage of marine fish utilization during the past 30 years indicates that the availability of fish for human consumption has declined significantly. The main reason is the substantial increase in the amount of trash fish that is mostly channeled into the fishmeal industry. This is not justifiable when the per capita fish consumption is declining due to increase in population and in export requirements, while malnutrition is a serious problem in the rural areas. The main cause of malnutrition is poverty and inequality of food distribution. The marine fisheries sector that provides protein food should help in alleviating this problem.

In response to the misuse of the fish resources, the Department of Fisheries has created a program for converting trash fish and small pelagic fish, now used for fishmeal, into food for direct human consumption. This can be done through employing appropriate techniques in handling at sea and during transport, These fish can be processed into edible products. This will improve income for those who harvest by-catch fish and increase value-added in the fisheries sector.

Improved utilization may not satisfy the fishmeal industrialist who will be a competitor in buying trash fish at higher prices. The higher cost may become a barrier to exporting fishmeal. Fishmeal might not be distributed to the domestic animal feed industry; this industry would then import fishmeal or substitute fishmeal with other feeds. If the cost of fishmeal is partially passed to the animal feed industry, the burden will fall heavily on consumers. However, this may not be serious as long as consumers have other choices of protein food.

Analysis of Market Structure and Price of Fish

Marine Fish Marketing in Thailand

Setting Up the Fish Market

The government institution that deals with fish marketing in Thailand is the Fish Marketing Organization (FMO). The functions of the FMO are: (1) to provide fishers with a place for distribution of their produce, (2) to manage and control the agents who sell the fish, (3) to collect fees and service charges from people who use the facilities of the market, and (4) to assist, promote development and provide welfare for fishers and their villages, as well as their cooperatives or organizations.

Operation of the FMO

At present, the FMO operates three wholesale markets in Bangkok, Samut Sakorn south of Bangkok and Samut Prakran east of Bangkok. The FMO also operates eleven fishing ports along the coast (two in the east, nine in the south, of which six are along the Gulf coast and two along the Andaman coast).

The FMO acts as the owner of the market and people involved in the market must obey their rules and regulations. For example, fish agents cannot charge fishers more than 6% of the total value of sales, and 1% must go to the FMO. Other service charges that the FMO receives include renting space, parking lots, containers etc. The role of the FMO is not only providing a market place but also stimulating production.

Market Structure and Marketing Channels

Traders in the marine catch are fishers themselves, fish agent collectors, wholesalers and retailers. Fishers may contemporaneously conduct fishing, selling and processing. Some large scale fishers are also marine product traders and fish agents. Fish agents may be registered with the FMO, or non-registered and conduct their business in private or at municipal landing ports. Fish agents may receive fish from fishers and trade by means of auction as well as negotiation. In remote areas, there are fish collectors who buy from fishers and/or fish agents and sell to wholesalers who run large wholesale markets in big cities and sell to the retailers. The trading method employed at the FMO fish market and landing ports is mainly auction. At landings the non-registered fish agents bargain for fish.

Generally, fishers who land catch at private fishing ports have contracts with the agents who usually own the port. Thus, the agents influence the price, rather than the fishers. Small scale fishers, however, also usually perform as fish agents and have other market outlets. In addition, there are many places where fishers can land their catch, and even fishers with contracts can land their catches somewhere else. The degree of monopoly is thus not too strong at this stage.

Fish marketing facilities are inadequate, which makes possible the non-competitive trade. The central wholesale markets are limited to areas close

to Bangkok (e.g. Samut Sakorn for fish and cuttlefish, Samut Prakran for shellfish, and Rayong for squid). The Bangkok wholesale fish market seems to have reached its maximum capacity. Landing points are numerous and scattered. More marketing facilities are required such as markets with auctions, ice plants, cold storage facilities and refrigerated truck transportation. Improvement in quality control to minimize loss in trading should be implemented.

Fish Price Determination

Price Determination in Fisheries Products

In theory "price determination" deals with the price theory and the manner in which economic forces influence price under the various market structures and the length of run, while "price discovery" is used to express the process of struggling between buyers and sellers to arrive at a price. There are five pricing system methods: (a) individual negotiation, (b) trading on organized exchange or auctions, (c) formula pricing, (d) group bargaining, and (e) administrative decisions, including those made in both the private and public sectors.

The criteria for choosing a method are that it should not create excess supply, it should have some social welfare aspects, i.e. that price is an incentive to the fishers for further fishing, provide quick and reliable information and provide a mechanism at low cost for price setting.

Methods of Setting Price of Fish

The bidding among buyers for fisheries products is the most appropriate one. Since fish are difficult to standardize and have a wide range of quality (size and freshness), physical inspection for each lot must be observed by buyers. If there are many buyers and the manipulation of price is difficult or impossible, the bidding price is a competitive price.

There should be more than one method of pricing fish among the fish agents and fish buyers in a fish market. A study of the system for fresh cephalopods in Thailand (Tokrisna et al. 1985) showed that cephalopod traders had four buying methods namely, consignment, auction, bargaining and price setting. However, trading at the levels of fish agents and collectors, the setting of sale prices was classified into three types, by buyers, by sellers and bidding among buyers. At the wholesaler and retailer levels, sellers set the prices. Setting fish prices at each level of trade should be more or less similar to that for squid.

Factors Affecting Fish Price Setting

Tokrisna et al. (1985) described the factors affecting the sales price of fresh cephalopods as follows: (a) buying price, which means the cost of products, (b) quality of the products (size and freshness) so that prices can be set by sellers, (c) market situation, which means the demand for and supply of products in the market at that time and (d) prices of processed products, especially the export price which the exporters use as the basis of estimating the purchasing price of raw material.

Tokrisna et al. (1985) found that the fishers knew not only the amount and species of fishes in their boats before approaching the port but also had price information at all the major ports. Therefore, searching for a marketing place had already been done. Selecting the species of fish is also dominant in each fish market or fishing port.

Summary and Implications for Fisheries Management

Summary

Small Scale Fisheries

The exceptionally high return on some groups of fishing gear is because of the monopolistic power of these fishing technologies in the coastal areas. The high returns are a reflection of the fishing skills and entrepreneurial ability of their operators as well as of the abundance of fisheries resources in coastal areas. Thus, this return consists partly of rents of ability and quasi-rents and partly of resource rents. This is also reflected in the higher wages. From the economic point of view, it appears that there is reason for maintaining those gear groups and their contribution to employment and fish production.

Thus, the most important determinant of profits appears to be interaction between type of gear and fishing ground. Having the right type of gear at the right fishing ground with appropriate skill and entrepreneurial spirit appears to be the recipe for high profits. The small scale fishers living in the coastal areas are in the worst possible situation because of the paucity of funds, of fish resources and of non-fishing alternatives.

Commercial Fisheries

The analysis of investment, cost, revenue and returns on demersal and pelagic fishing operations can be summarized as follows: (1) the returns differ markedly by size of fishing boat and type of fishing gear; (2) the ability to generate profit is greater in large fishing boats than small boats due to their greater ability to adjust to both economic (investment) and biological (fishing ground) changes; and (3) among all trawlers, medium and large size boats can best adjust and maintain continuous profits while for push nets, all sizes of boats have declining net profits. As for pelagic fishing operations, purse seiners have been developed to make high profit and still yield a higher return than trawlers and gillnet fishing operations. Finally, the return to labor, or daily wage, on average is higher than the national minimum wage rate.

Due to the open-access fisheries resources, it can be forecast that: (1) without restrictions on involvement in the fisheries sector, profits will encourage new fishers into the system; and (2) new entrants under static marine resources and price conditions will result in a declining trend in profit over the long-run. This decline will restrict employment and investment since revenue will not exceed opportunity loss. Will the rapid growth of the fishing industry reduce profit? Will this profit slowly decline with expansion of fishing effort? These questions could not be clearly answered due to insufficient data to indicate fisheries status; and results obtained from studies during previous years are applicable to the situation only under constant economic and biological conditions. Changes in these conditions may conceal a decline of profit, so that profit is ostensibly increasing (real profit may even decline), leading to the entry of new fishers.

Implications for Fisheries Management

The present level of exploitation of demersal fisheries resources in inshore waters of the Gulf of Thailand up to 50 m depth is higher than the estimated maximum sustainable yield (MSY) for this area. It is clear that this over-fishing is brought about by intensive trawl operations in the area and that it is the root cause of the current difficult fisheries situation. The current situation is clearly reflected in the index of abundance or catch per unit effort, which has measurably decreased in recent times. At the same time, the amount of trash fish in the demersal catches has increased significantly. Immediate action is therefore needed to tackle these problems, and to conserve the resources through such measures as reduced fishing effort, and by further promoting cooperation between fishers and the Department of Fisheries. Fisheries management practices to conserve marine resources in Thai waters also need further improvement and existing fisheries regulations need to be more strictly enforced.

The measures of fisheries management undertaken by the Government of Thailand so far are: (i) to control and limit entry into fisheries; (ii) the "Command program" (see The Command Program for fisheries management) for fisheries management; and (iii) adopt a community-based fisheries management regime.

Control and Limited Entry Into Fisheries

The marine capture fisheries of Thailand presently face many problems arising from the enforcement of EEZs, resulting in a realignment of fishing grounds and a decrease in available marine resources. In addition, the excessive fishing effort and the types of fishing gear used by trawlers often cause conflicts with the local fishers because of encroachment into their traditional fishing grounds, and the destruction and interference caused to the small scale and fixed fishing gear.

In 1978, the Thai Cabinet adopted a resolution to control and reduce the number of trawlers and push nets. The Cabinet Resolution and the subsequently adopted Fisheries Act of Thailand have had considerable influence in bringing about improvements in the fisheries management practices and rationalization of fishing effort in Thailand. Several specific rules and regulations to limit entry into both demersal and pelagic fisheries have since been declared with different objectives and results, both positive and negative.

Operation of fishing gear in Thai waters requires a license from the Department of Fisheries and a navigation certificate from the Harbour Department. The license was originally issued automatically on a routine basis on payment of nominal fee, and only some small scale fishing gear and certain types of small fishing boat were exempted. Issuance of fishing licenses has since been made subject to closer scrutiny on a case-to-case basis.

The basic objective of a ministry regulation issued in March 1990 was to gradually reduce the number

of trawlers and push netters and thereby bring down demersal catches to the optimum sustainable level. This entailed cutting down the total number of trawlers operating from 6 576 units to 3 200 units in the Gulf of Thailand and 300 units along the Andaman Sea coastline. Push nets were to be gradually phased out as they invariably operate in shallow waters and catch very small fish.

The license regulations of the Ministry were based on the following strategies:

1. The number of trawlers and push netters to be regulated by controlling the entry of new boats into these fisheries as follows:

   - new fishing licenses not to be issued for any type of trawler or push netter;
   - a fishing license for other types of fisheries should not be transferred or utilized to operate trawlers and push netters;
   - only the licenses and navigation certificates of the holders of the license/certificate for the preceding year to be renewed; transfer of these licenses to another person not to be allowed or negotiated under any circumstances, except as instances of family inheritance.

2. The number of currently operating trawlers and push netters to be reduced by various measures as follows:

   - transfer of licenses issued for trawling and push net fisheries to other types of fishing to be encouraged;
   - diversification and alternative utilization of vessels used in fisheries for tourism, cargo transport, passenger transport, etc. to be promoted;
   - licenses of vessels which become involved in trespassing and encroachment into the jurisdictional waters of other countries to be forfeited and not reissued.

In 1982, the above regulations were implemented. Their effectiveness became evident during the 1981 - 1988 period, as the number of registered trawlers and push netters gradually decreased. However, the total number of registered trawlers and push netters then again increased to accommodate demands for expansion of fisheries into the EEZs of other countries through bilateral agreements.

The Command Program for Fisheries Management

Under the 1947 Fisheries Act, a series of ministerial rules and regulations concerning the conservation of marine resources was issued in six groups:

1. Prohibition of the use of certain types of fishing gear during the spawning and breeding seasons of some commercially important species.

2. Prohibition of certain types of fishing gear in some areas.

3. Protected areas are those adjacent to temples and monasteries or any other area designated as such by the governors of provinces. All such areas are considered as fish sanctuaries where fishing of any sort is not permitted.

4. Prohibition of catching endangered and threatened species.

5. Ban on the use of poisons and stupefying chemicals, explosives and electric stunning.

6. Prohibition/restrictions on certain types and sizes of fishing gear.

The enforcement of the above regulations has not been very effective to date, since they apply to a very extensive area spread over the entire coastline of Thailand. The number of officials in the field to inspect and enforce the regulations is too few. The laws of the country require that the fishers need to be caught in the actual act of illegal fishing or violating the regulations for the law to be upheld in court.

It can thus be concluded that more effective management of marine resources on a long-term basis requires implementation and enforcement of all current regulations in the field. In particular, there is a need for more officials in the field, better infrastructure facilities to accomplish effective enforcement, and delegation of sufficient enforcement authority rather than only to the provincial fisheries officers.

Community-based Fisheries Management Regime

The existing control measures have limited success for the following reasons: (a) the number of enforcement staff and patrol boats is limited compared with the coastal length of 2 614 km and the huge

number of fishing boats operating the various types of fishing gear, (b) lack of cooperation from fishers, (c) high enforcement costs and (d) lack of coordination among relevant agencies.

Community-based fisheries management, as initiated by the government, has been implemented in coastal areas, particularly in the Phang-Nga Bay (Andaman Sea) and Bang Sapan Bay (Gulf of Thailand). These projects aimed to change the perceptions and attitudes of fisherfolk from that of a user to a manager. Activities on grouping, training, social development programs, and fish landing-site management which unite fisherfolk, and awareness-building and participation in resource conservation, have been implemented in the target villages. Regular meetings among working committees of each village have been organized to monitor the progress and problems of implementation in each village. Visits to the target villages have been regularly carried out. When the fisherfolk learn how to manage and conserve the fisheries resources for sustainable utilization, the provision of fishing grounds in their village or group of villages as part of village property and as a source of their livelihood will be extended to them.

Bioeconomic Modeling

Rationale

Thai marine fisheries have experienced rapid growth during the last 30 years. Endowed with a large Exclusive Economic Zone (EEZ) and productive marine resources, Thailand has been one of the top ten fishing nations of the world since 1972. However, fisheries development has created huge pressure on the resources, especially for the demersal species in the Gulf of Thailand. The demersal fisheries are declining due to over-fishing by trawling at a depth of more than 50 m. Catch per unit effort (CPUE) by trawlers has steadily declined while the number of trawlers of all sizes and types has continued to increase. Fishers began to use a small cod-end mesh size so that more trash fish could be caught to compensate for declining production. In addition, many trawlers which used to fish in foreign fishing grounds returned to the Gulf of Thailand after the declaration of EEZs in the neighbouring countries. Increases of fuel prices from time to time, a part of total costs, forced the fishers to reduce unit cost by increasing fishing effort while the catch of trash fish increased to 60 - 70% of total catch. All of these factors contributed to the depletion of valuable marine species and decline of fishery resources. The CPUE steadily decreased from 231.6 kg per standard fishing hour (kg•sfh^{-1}) in 1963 to 47.3 kg•sfh^{-1} in 1977 (Jetanavanich, 1981) and to 15.85 kg•sfh^{-1} in 1995. New investment is still taking place to increase fishing effort in order to maintain or increase the production volume. Overall, current fishing effort in the Gulf of Thailand has expanded far beyond the biological and economic maximum yields.

Despite the number of studies on demersal fisheries, few have been done on the economics of fisheries in the Gulf of Thailand. Of these, the most notable was the study by (Panayotou and Jetanavanich, 1987), which made the first attempt to determine the levels of catch and fishing effort that give rise to the static MEY. They found that the optimum catch and effort (given a mesh size 2.5 cm) for demersal fisheries were 958 000 t and 15.7 million standard fishing hour respectively. More importantly, the results implied that the demersal catch had surpassed the level of static MEY.

The past and current conservation measures are based purely on biological data, but the integration of economics and biological factors in determining the optimal utilization of demersal resources is necessary to manage these fish stocks. For this purpose, a multi-disciplinary approach is needed. A detailed analysis of demersal fishing in the Gulf of Thailand that includes both fisheries population dynamics and economic considerations would be highly valued.

This study focuses on the bioeconomic modeling of demersal fisheries in the Gulf of Thailand with the objective of providing the basis for more effective management of the demersal resources in the area. The study employs a dynamic approach to arrive at the optimal level of demersal stock, yield and fishing effort. Also, recommendations for demersal fisheries management are provided.

Review of Fisheries Legal Environment

The Fisheries Act of 1947 empowers the responsible Minister with the authority to introduce a licensing system and fishing regulations such as closed areas and seasons, mesh size limitations, gear restrictions and catch quotas, and with the authority to enforce these measures. In practice, however, the Minister has not used these powers to introduce an effective

licensing system and other fisheries regulations because of both administration constraints and political considerations. As in many other countries, the budget, manpower and the authority of the Department of Fisheries (DOF) are clearly inadequate for operating and enforcing a licensing system and other fisheries regulations. Moreover, political considerations militate against a substantial reduction of effort and against restrictions on its expansion.

Even the licensing scheme, which freezes the number of trawlers and prohibits their transfer and the construction of new vessels, may be inadequate. First, as the fishing vessels are to be registered with the Harbour Department while the gear is licensed by the DOF, a loophole exists which enables registered fishing vessels to operate without a license for gear. Second, with the current budget and manpower it is not easy for the DOF to enforce the licensing system over an extensive and technologically advanced fleet which can operate from foreign ports. Third, even if the system could be enforced, it can block new entrants and may reduce fishing effort by normal attrition, but it will take a very long time to cut effort to about half its current level, as required. Last, even if effort could be reduced to its optimum level, without an effective mechanism of creaming off resource rents, the newly established rents (as a result of the reduction in effort) would create such a potent incentive to increase effort that rents would again be dissipated through either excess effort or higher enforcement costs.

Similarly, other regulations such as the prohibition of push netting and trawling within 3 km from the shore and the recommendation for a 4 cm mesh size are generally ignored, as evidenced by the large numbers of push netters and trawlers in the prohibited zone, and the use of 2.5 cm mesh size. A two-month seasonal closure of the central western Gulf was not well accepted.

Input policies, such as subsidized credit and tax exemptions for fishing machinery and equipment, are intended to relieve short-term hardships. However, these policies are certain to deepen capital intensity at the expense of labor employment, to encourage new entry to the resources and to widen the dualism between small- and large scale fishers. Moreover, new entries will nullify any temporary gains to the fishers, necessitating new subsidies in the future which, having created a precedent, will be difficult to resist.

Output policies such as price supports, while intended to raise fishers' incomes and to ensure increased fish supplies for human consumption at low prices, are self-defeating in the long run under open-access. To the extent that they are effective in raising fishing incomes, new entrants are attracted into the fishery, and, as a result, the resource base deteriorates, incomes fall, and new supports are required.

Intervention in international trade, such as promotion of exports and tariffs on fish imports may temporarily succeed in raising fishing incomes, in improving the balance of payments and in protecting the local industry, but no lasting benefit can be expected under the present open-access status and the depleted state of the resource. At present, increased fishery exports can be had only through destructive or 'piratical' fishing.

Effort is also being made to conserve fishery resources by encouraging distant-water fishing, especially through joint fishing ventures and other fishery agreements with neighbouring countries (e.g. with Bangladesh, Malaysia, Myanmar and Indonesia). Although some additional fish supplies have been forthcoming as a result of these ventures, there is no evidence that over-fishing in Thai waters and encroachment on foreign resources have diminished. To the extent that joint ventures are successful, they tend to encourage the construction of new, larger vessels rather than the utilization of existing ones.

Framework and Estimation

Model Specification

Size of fishing effort is a major determining factor in the production from and sustainability of a developed fishery. Hence, for optimal resource use (Panayotou and Jetanavanich, 1987), it is often recommended that fishing effort be controlled to prevent over-fishing or dissipation of economic rents. From the economic point of view, the optimal level of effort is the level at which economic rents are maximized. This level of effort generates the MEY which is the return on the scarcest factor of production, the fish stock. Of course, a managing authority may define as optimum yield that which maximizes other benefits such as "employment, equity or stability", but here we will assume that the objective is to maximize the economic return from the fishery (MEY).

MEY is determined by maximizing the spread between total fishing revenues and costs, which is accomplished by equating the marginal revenue (MR) of effort to the marginal cost (MC) of effort. This requires estimation of revenue and cost functions. Assuming constant cost per unit of effort (c), the cost function (TC) presents no difficulty. The total marginal and average costs may be written respectively as:

$$TC = cf \tag{1}$$

$$MC = AC = c \tag{2}$$

where f denotes fishing effort and AC denotes average costs.

However, estimation of the revenue function involves estimation of the underlying sustainable yield function, which is a relationship between sustainable catch (Y) and effort (f). In the case of single species fisheries or when species are aggregated, a sustainable function can be estimated by fitting a logistic growth curve to catch and effort data; the Schaefer (Schaefer 1954) and Fox (Fox 1970) Models can be used.

The Schaefer Model, a linear model is specified as:

$$Y/f = a + bf \tag{3}$$

where a and b are estimated parameters

The Schaefer model, a parabola, has its MSY at an effort level of:

$$f_{MSY} = -0.5\ a/b \tag{4}$$

with the corresponding sustainable yield:

$$MSY = -0.25\ a^2/b \tag{5}$$

The Fox Model gives a straight line when the logarithms of Y/f are plotted on effort:

$$\text{Ln}\ (Y/f) = c + df \tag{6}$$

The Fox Model can be rewritten as:

$$Y/f = e^{c + df} \tag{7}$$

where c and d are constant parameters.

The level of effort generating the MSY can be obtained from (7) through differentiation as:

$$f_{MSY} = -1/d \tag{8}$$

MSY itself is obtained by combining equations (7) and (8) to give:

$$MSY = (-1/d)e^{c-1} \tag{9}$$

Then the total (TR), marginal (MR) and average (AR) revenue functions for the Schaefer Model may be written respectively as:

$$TR = p\ (af + bf^2) \tag{10}$$

$$MR = p\ (a + 2bf) \tag{11}$$

and

$$AR = p\ (a + bf). \tag{12}$$

The total, marginal and average revenue functions for Fox Model may be written respectively as:

$$TR = p\ (fi\ e^{(c + df)}) \tag{13}$$

$$MR = pG\ (f(d)e^{(df)} + e^{(df)}) \tag{14}$$

$$AR = p\ (e^{(c + df)}) \tag{15}$$

where, TR = total revenue
p = fish price.

G = estimated constant; parameter of the sustainable yield function

The optimum or MEY level of effort is obtained by equating the MR and MC of effort, i.e.

Schaefer Model may be written, as:

$$p\ (a + 2bf) = c$$

$$f_{MEY} = (c-pa) / 2bp \tag{16}$$

Fox Model may be written, as:

$$pG\ [dfe^{df} + e^{df}] = c, \text{ or}$$

$$dfe^{df} + e^{df} = c/pG \tag{17}$$

Under open-access, fishers attempt to maximize their profits but because of lack of exclusive prop-

erty rights over the resource, they have no incentive to take into account the effect of their fishing effort on other fishers' catch. The guiding variable for expansion of effort is the expected average revenue of effort rather than the marginal revenue. That is, under open-access the profit-maximizing rule for the individual fishers (but not society as a whole) is to expand effort as long as the average revenue (AR) of effort exceeds the average cost (AC) of effort, no matter what this might do to other fishers' revenues and to future revenues. Thus, under open-access the effort for the fisheries as a whole expands to point where AR = AC, or

For the Schaefer Model

$$f_{OA} = (c\text{-pa}) / \text{bp} \tag{18}$$

for the Fox Model

$$\text{pe}^{(c + df)} = c\text{, or} \tag{19}$$

$$e^{(c + df)} = c / p \tag{20}$$

By taking the natural logarithm ln to both sides we obtain (12) as:

$$ln\ e^{(c + df)} = ln\ c/p\text{, or}$$

$$c + df = ln\ (c/p)\text{, or}$$

$$f_{OA} = [ln\ (c/p) - c]/d \tag{21}$$

Thus at the f_{OA} level of effort profits are totally dissipated:

$$TR_{OA} - TC_{OA} = 0 \tag{22}$$

At the f_{OA} level of effort, neither do the fishers earn profit nor does the society earn economic rents for its scare fishery resource. All potential surplus of revenues over costs has been totally dissipated in excessive effort under open-access. Reduction of effort from f_{OA} down to f_{MEY} would generate substantial profits to remaining fishers (or rents to the society), and at the same time increase the size of the fish stock, even if at f_{OA} the stock is severely depleted.

Data: Catch, effort, fishing costs and fish price

Catch

The data for dermersal fish and trash fish catches in the Gulf of Thailand for the 1971 - 95 period were collected from the Fisheries Statistics Base on the Sample Survey (various issues), officially reported by the Fisheries Economics Division of DOF. For this study, demersal harvests were divided into demersal fish (17 species) and trash fish. Species of demersal fish included barracuda, croaker, threadfin bream, monocle bream, lizardfish, hairtail, snapper, sweetlip, bigeye, sand whiting, barbell eel, marine catfish, rays, sharks, flatfishes, Indian halibut and conger eel. Inconsistencies in the way in which the data were reported were evident, and they were therefore adjusted to attain greater accuracy.

For the period 1971 - 84, the data reported the catch of the demersal fish and trash fish from Thai waters, but were broken down by gear type and vessel size. The proportion of demersal fish and trash fish from the Gulf of Thailand was estimated from the 1985 - 95 Marine Fisheries Statistics Base on the Sample Survey.

The 1985 - 95 report showed the catch of demersal fish and trash fish from the Gulf of Thailand and Andaman Sea broken down by gear type and vessel size.

Fishing effort

To match demersal catches with their corresponding levels of fishing effort, data were collected in the Gulf of Thailand for vessel-fishing-hours. During 1971 - 95, fishing effort was obtained from the Marine Fisheries Statistics Base on the Sample Survey. Since demersal resources are caught by various types of gear and size of vessels, it was necessary to translate fishing effort into equivalent, or standardized units. For commercial fishing, gear is shown in Appendix Table 1, namely: otter board trawl, pair trawl, beam trawl, push net, purse seine, anchovy purse seine, mackerel encircling gillnet, king mackerel gillnet, and nominal fishing hours. Since engine horsepower (HP) is different for different sizes of vessels and types of gear, nominal fishing hours were standardized by using the 14 - 18 m otter board trawl as the standard, and an index of vessel HP is shown in Appendix Table 2. Standard effort was calculated by multiplying the HP index of each gear by nominal fishing hours for that gear, and is shown in Appendix Table 3. For small scale fisheries and bamboo stake traps, data on fishing hours were unavailable. Standard effort was calculated by dividing catch by the catch per hour of a 14 - 18 m otter board trawl vessel. The total standard effort is the sum of the standard effort of all the gear-types, and is shown in Appendix Table 3. Since effort is

affected over time through gear improvement, a technological adjustment factor is calculated by dividing catch per hour of the standard vessel by catch per hour of a research vessel (Ahmed 1991). The catching power of the research vessel remained unchanged over time, allowing it to serve as a technological standard. CPUE of the research vessel is shown in Appendix Table 4. In 1990, 1992 and 1994, no experimental survey was conducted. For these years the mean CPUE of the preceding and the following year was used as an estimate of CPUE. The adjusted effort was calculated by multiplying standard effort by a technological adjustment factor.

Fishing Cost

The unit cost is represented by cost per standard unit of fishing effort. The total cost of fishing for demersal fish and trash fish was calculated from the Cost and Earnings Survey of Major Fishing Gear in 1995 (Department of Fisheries (DOF) 1972 - 97). The major fishing gear was otter board trawl, pair trawl and push net. By using the annual cost of major fishing gear per vessel, the major cost of each fleet was calculated by multiplying the annual major fishing gear cost per vessel by the total number of vessels in the Gulf of Thailand in 1995 employed in that fleet. The total fleet cost is the sum of the costs of all the gear-types, and it represents the total cost of total catches in the Gulf of Thailand. The proportion of demersal fish and trash fish catch value was estimated from Fisheries Statistics of Thailand in 1995 (Department of Fisheries (DOF) 1972 - 97). The demersal fish and trash fish cost was calculated by multiplying percentage of demersal fish and trash fish value by the total cost. The demersal fish and trash fish cost of major fishing gear divided by the total standard fishing effort of those gears gave CPUE .

Fish Price

Figures on demersal fish and trash fish prices from the Gulf of Thailand are available in Fisheries Statistics of Thailand in 1995. (Department of Fisheries (DOF) 1972 - 97).

Model Estimation and Results

Having described the economics and the state of Thai marine fisheries resources, the optimal level of resources use can now be determined. The optimal resource use was postulated to be the level of catch and effort that maximize the sustainable economic yield (MEY) or rent from the fisheries, that is, the excess of sustainable revenues over costs. Of course, it is always possible to increase current economic rents (profits) beyond this level but, in the same way that catch above MSY cannot be sustained for long, profits above MEY cannot be sustained. Thus, ignoring adjustment and enforcement costs which could be substantial, fisheries management should aim at the attainment of the MEY level of effort, as it can be shown to be superior to all other levels of effort, including that of MSY in terms of return on a limited resource. The purpose of this study is to determine MEY for the Gulf of Thailand and the corresponding levels of effort, catch, revenues, costs and profits and compare them to those prevailing under open-access and MSY management. Following our theoretical framework, this estimation is based on an assumption of fixed prices.

The State of the Resources - MSY

Both the Schaefer model and the Fox model were used to obtain estimates of MSY for a mesh size of 2.5 cm (commercial fleet), using 1971 - 95 data (see Model specification).

$$Y/f = a + bf,$$

$$\mathrm{Ln}\,(Y/f) = c + df,$$

where Y is catch, and f is standardized fishing effort, and a and b are parameters to be estimated. Estimation was derived by dividing equation by effort to obtain the CPUE as a function of effort. We then regressed CPUE on standardized effort to obtain estimates of the parameters a and b. The empirical results indicate that the Schaefer model and the Fox model fitted the catch and effort data. The results are as follows:

Schaefer Model

$$Y = 57.134\,589\,1 - 0.000\,000\,821f$$

$$R^2 = 0.90,\ F = 222.824\,7,\ df = 24$$

Fox Model

$$Y = fe^{(4.19 - 0.000\,000\,026f)}$$

$$R^2 = 0.96,\ F = 618.8,\ df = 24$$

where R^2 is the coefficient of determination adjusted

for degrees of freedom, F is the F-ratio, and df denotes degrees of freedom.

Based on these estimates, we calculated MSY and corresponding level of effort using equations (5), (4), (9) and (10) of our theoretical framework. The results are as follows:

Schaefer Model

f_{MSY} = 34.76 x 10^6 standard fishing hours (sfh)

MSY = 993 x 10^3t

Fox Model

f_{MSY} = 37.69 x 10^6 sfh

MSY = 915 x 10^3 t

Optimal Resource Use (Fixed Price Model) - MEY

Recall that the level of effort yielding the MEY, f_{MEY} of the Schaefer model and the Fox model were given in equations (16) and (17) respectively as:

$f_{MEY} = (c\text{-}pa) / 2bp,$

$dfe^{df} + e^{df} = c / pG,$

where p is the price of fish per kg, c is the cost per unit of standard fishing effort and a, b and G are the parameters of the sustainable yield function. The 1995 value for fish price and cost per unit effort were estimated as: price (p) = 6.68 Baht·kg^{-1} and cost (c) = 69.67 Baht·sfh^{-1} (for a mesh size of 2.5 cm). Substituting these values into the equation above we obtain the result for Schaefer model as follows:

f_{MEY} = 28.42 x 10^6 sfh

MEY = 960 x 10^3 t

Solving the equation for effort (f_{MEY}) of the Fox model, f_{MEY} = 25.86 x 10^6 sfh with a mesh size of 2.5 cm. The corresponding catch is obtained by substituting the value of f_{MEY} in equation (7) to obtain:

$Y_{MEY} = f_{MEY} .e^{a + bf\,MEY}$

where a and b are the parameters of the function. Substituting these values into the equation above we obtain: Y_{MEY} = 960 x 10^3 t with a mesh size of 2.5 cm.

The results reported are in Tables 26 - 27 and Fig.2 with the corresponding actual 1995 figures, and the estimated MSY and open-access figures. From Table 26, the MEY level of effort is about 50% of the actual 1995 level and 82% of the MSY level. However, the actual catch is 93% of MEY and 90% of MSY catch. Profits are as expected, i.e. highest at MEY, amounting to 4 433 million Baht (US$178 million at 1 US$ = 24.92 Baht in 1995) or 5% higher than at MSY. From Table 27, the MEY level of effort is about 46% of the actual 1995 level and 69% of the MSY level. However, the actual catch is 98% of MSY catch. Profits are highest at MEY amounting to 3 943 million Baht (US$158 million) or 5% higher than at MSY. According to these findings, MEY management would earn the industry and the country an additional 1 904 - 2 394 million Baht (US$48 - 96 million) in profits, gross of management costs. If the fishery is left unmanaged, it is expected to reach an open-access (zero profits) level at 56.62 - 69.56 x 10^6 sfh, with a sustainable catch of 593 000 - 725 000 t, and society would lose 3 943 - 4 433 million Baht (US$158 - 178 million) in resources rents.

Table 26. Comparison of catch, revenues, costs and profits at different levels of effort based on the Schaefer Model and 1971 - 95 data, the Gulf of Thailand.

Items	Effort (sfh x 10^6)	Catch (t x 10^3)	Revenues (Baht x 10^6)	Costs (Baht x 10^6)	Profits (Baht x 10^6)
MSY	34.76	993	6 634	2 422	4 212
MEY	28.42	960	6 413	1 980	4 433
Open-access	56.84	593	3 960	3 960	0
Actual (1995)	56.62	896	5 983	3 945	2 039

1 Baht = US$0.04 in 1995 (source: oanda.com)

Table 27. Comparison of catch, revenues, costs and profits at different levels of effort based on the Fox Model and 1971 - 95 data, the Gulf of Thailand.

Items	Effort (sfh x 10^6)	Catch (t x 10^3)	Revenues (Baht x 10^6)	Costs (Baht x 10^6)	Profits (Baht x 10^6)
MSY	37.69	916	6 116	2 626	3 491
MEY	25.86	860	5 745	1 802	3 943
Open-access	69.56	725	4 846	4 846	0
Actual (1995)	56.62	896	5 983	3 945	2 039

1 Baht = US$0.04 in 1995 (source: oanda.com)

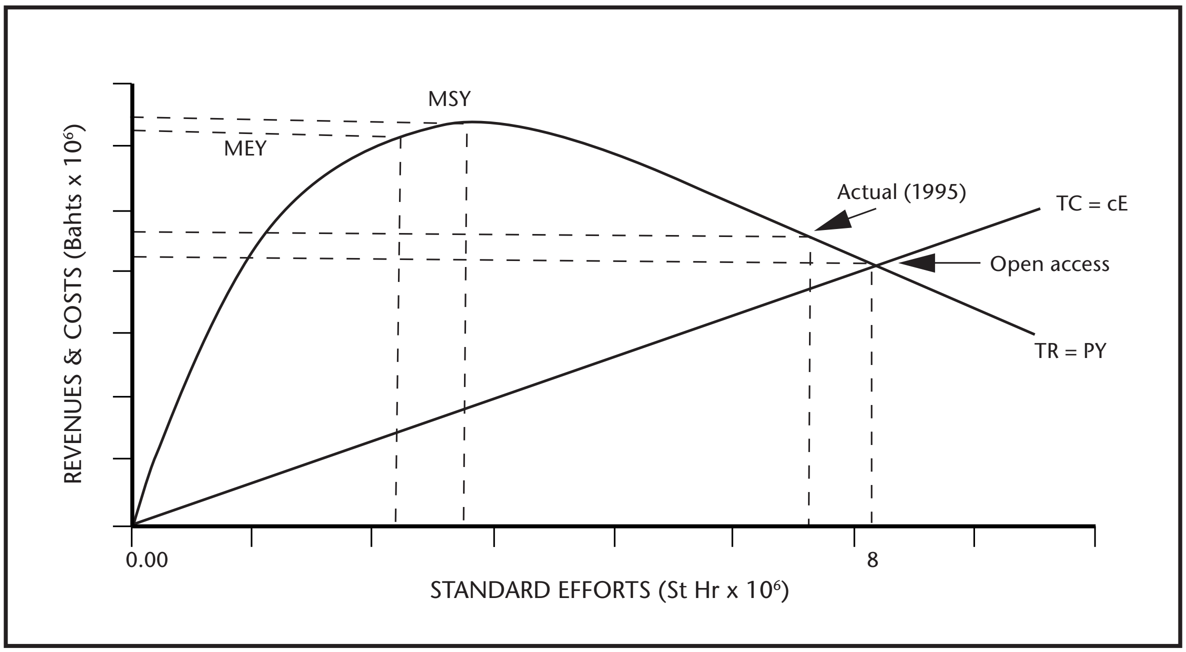

Fig. 2. Fixed price model applied to demersal fisheries (demersal fish and trash fish) in the Gulf of Thailand.

Discussion

In the light of our findings, the feasibility of stated government objectives and the effectiveness of current policies in achieving these objectives are evaluated. Modifications of fishery policy targets in the context of the country's broader development objectives as well as alternatives are proposed.

Policy Issues

From the preceding analysis of the Thai fisheries three fundamental policy issues emerge: (a) how to reduce over-fishing and induce a recovery of Thailand's demersal resources without reducing fishery production and employment; (b) how best to utilize Thailand's sizeable distant-water fleet and technological advantage; (c) to reduce the encroachment into neighbouring countries' EEZs and improve Thailand's international image. Taken together these three issues amount to a quest for a national fisheries policy which would maximize the overall benefits from the fishery to the society with due concern for their distribution and short-run adjustment problems.

This is admittedly a difficult task for any country, but especially for a developing country such as Thailand, which has little tradition and experience in sustainable resource management and limited enforcement capability. With the notable exception of joint fishing ventures, it is difficult to think of management interventions that will not involve curtailment of fisheries production and employment and increased conflict, at least in the short run. As our models have shown, whether the maximization of physical or economic yield is selected as the objective of management makes little difference by comparison to a situation of no management or open-access.

As evidenced by the National Fisheries Policy and other official statements, the government does perceive these issues, and attempts are being made to tackle them. The question is whether the existing legal and policy frameworks are appropriate and sufficient to deal with these issues, especially in the light of budgetary and administrative constraints and the high enforcement costs. To investigate this, it is necessary to review the existing legislation and policy framework.

In addition to the fisheries legislation and related management policies which aim at regulating fishing effort, the policy framework for Thai fisheries includes input, output and trade policies which aim to raise fishers' incomes, thereby subsidizing fishing effort. Such policies include financial support at subsidized interest rates, fuel price and fish price subsidy, tax exemptions for fishing machinery and equipment, provision of storage and processing facilities, price support, export promotion and import discouragement. These policies are usually introduced as second-best solutions or stop-gap measures at a time of a sudden shock or crisis, but usually outlive their original purpose.

Towards a National Fisheries Policy

Problems such as those facing the Thai fishing industry require a comprehensive fisheries policy in line with broader development objectives. One possibility worth considering is to empower the Department of Fisheries with the formulation and implementation of a national fisheries policy with upgraded authority and budget, thus strengthening its enforcement capability.

The first step in such a policy would be an immediate and effective freeze in the number of trawlers and push netters, in particular through prohibition of the construction of new vessels and the compulsory registration of existing vessels with the Department of Fisheries. The next step would be the issuance of fishing licenses to existing vessels based on their current level of catching power, unless it is determined that the current mesh size is smaller than the optimum, in which case a larger mesh size should be specified. Licenses would need to be made non-transferable without exemptions and be retracted upon the retirement of either the owner or the vessel, whichever comes first, until the fleet is reduced to its optimum size. The license fees which are now negligible (e.g. 5 Baht (US\$0.12 in 1998)•m^{-1} foot-rope for trawlers, 2 Baht (US\$0.05 in 1998)•m^{-1} foot-rope for gillnetters and purse seiners and 150 Baht (US\$3.63 in 1998) per gear for push netters) would need to be raised to the estimated market value of the license. As effort is reduced (or fish prices rise), the license fees should be revised upward to extract the newly created rents and to reduce the incentive for expansion of effort. Annual adjustments of the allowable effort and license fees may be necessary to take account of natural fluctuations in the resources and changes in fishing costs.

The government could speed up the attrition process by offering to buy back and cancel the licenses of fishers who choose to leave the fishery. This could be made more attractive by offering to retrain and/or relocate those who leave the fishery as well as by developing alternative employment opportunities. It is possible to use the licensing mechanism to discourage certain gear, such as trawl, and encourage others such as purse seine, if they are judged to have a differential impact on the state of the resources.

Finally, every effort needs to be made to minimize enforcement costs through technical means and self-policing. This is particularly applicable to the government's efforts to improve the Socioeconomic position of small scale fishers and to reduce their conflicts with large scale fishers. One of the regulations most difficult to enforce has been the prohibition of trawling and push netting within the 3 km from shore strip reserved for small scale fishers. These boats not only compete with coastal fishers for a limited resource but they destroy the inshore nursery grounds and habitat, by catching large quantities of juvenile fish and causing damage to stationary and other gear employed by small scale fishers. Small scale fishers, unable to compete, often resort to equally destructive fishing methods such as dynamite, poison and fine mesh nets.

The ultimate success of a national fisheries policy lies in the correct and timely mix of fisheries management and non-fisheries development. Under the prevailing conditions of rising landlessness and swelling unemployment in the rest of the economy, only broad-based rural development will put an end to the continual drift into 'common-property' resources and major urban centers. In its absence, fisheries regulation cannot be effective. Unemployed fishers have little choice but to encroach on reserved forests, mineral concessions and public land, or move into urban centers creating a host of social and environmental problems.

Conclusions and Recommendations

The management of the demersal fisheries in the Gulf of Thailand that began in the 1980s by controlling the number of trawlers has been based purely on biological data. A detailed analysis of the fishery that includes both bioeconomic and Socio-economic factors would be highly valuable in determining the optimal utilization of the demersal resource (including trash fish). Unfortunately, data on socio-cultural and human factors are limited and subjective. This study has focused on bio-economic modeling of demersal fish and trash fish with the objective of providing an effective foundation for the utilization and management of the demersal fisheries in the Gulf of Thailand.

The bioeconomic model based on (Fox 1970) of demersal fish treats the stock as a single entity or biomass, and growth is assumed to be density-dependent. The result indicates that demersal fish are economically over-fished. The fishery could earn additional rents by curtailing both excessive fishing effort and catch. For a start at controlling the demersal fisheries, a license limitation and mesh size enlargement scheme are recommended.

Optimal resource utilization based solely on achieving economic efficiency may fail to reflect broader social issues. Any controls or constraints on fishers' behaviour that will be acceptable must incorporate social, political, and legal concerns. Nevertheless, departure from economic efficiency as the objective should only be allowed within limits.

In Thailand, the fishing industry is very complex, with multi-species, multi-gear fisheries, and different scales of fishing operations. Actions directly targeted on one species can be expected to affect all other species. This suggests that optimal fishing for one species considered alone may mean sub-optimal fishing in other fisheries. This makes fisheries management in Thailand a difficult task.

However, the Thai fishing industry needs proper regulation and fishing effort should be reduced through prohibition of construction of new trawlers and a ban on push nets, change from destructive fishing gear to other methodologies or aquaculture, and purchasing of excess fishing vessels from fishers.

Other important fishery policy issues not covered by this study include prohibition of fishing by all type of fishing gear at all times in protected areas. Coral reefs, seagrass beds and mangroves are important habitats and spawning grounds of several marine resources. Additional measures include minimization of by-catch, by improving fishing techniques, controlling mesh size and limiting the amount of time spent fishing.

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Appendix Table 1. Demersal catch, efforts, catch per effort (CPUE), 1966 - 95.

Year	Commercial Catch: Demersal Fish and Trash Fish (tons)	Average catch by research vessel at mesh size 2.5cm ($kg \cdot hr^{-1}$)	Estimated total efforts ($St \cdot hr^{-1} \times 10^6$)
1966	348 683	140.72	2.48
1967	388 333	120.72	3.22
1968	531 762	104.13	5.11
1969	577 621	97.86	5.90
1970	607 225	94.17	6.45
1971	624 067	60.35	10.34
1972	737 939	51.16	14.42
1973	738 136	45.64	16.17
1974	848 424	45.46	18.66
1975	814 828	44.49	18.31
1976	588 622	54.62	10.78
1977	791 839	42.24	18.75
1978	792 230	46.81	16.92
1979	727 212	47.85	15.20
1980	725 864	44.42	16.34
1981	740 180	35.00	21.15
1982	744 191	37.83	19.67
1983	729 040	38.26	19.05
1984	690 458	47.18	14.63
1985	711 691	44.98	15.82
1986	889 600	38.08	23.36
1987	1 029 209	29.69	34.67
1988	920 631	21.76	42.31
1989	903 741	15.59	57.97
1991	774 132	20.40	37.95
1993	869 601	27.45	31.68
1995	899 899	15.82	56.88

Source: Marine Fisheries Economic Division, Department of Fisheries 1946 - 95.

Appendix Table 2. Annual costs of trawl and push net fisheries by size of fishing vessel in Gulf of Thailand, 1995.

Type of fishing gear	Size of vessel (Meters)	No. of fishing (Unit)[1/]	Average annual cost (Baht·unit^{-1})[2/]	Amount cost (Bahts x 10^6)
Otter trawl	< 14	1 784	825 380	1 472.48
	14 - 18	1 948	1 556 740	3 032.53
	18 - 25	1 496	2 275 200	3 403.70
			Sub-total	7 908.71
Pair trawl	< 14	16	1 947 864	31.17
	14 - 18	186	2 702 003	502.57
	18 - 25	491	4 608 520	2 262 78
			Sub-total	2 796.52
Push Net	< 14	402	614 107	246.87
	14 - 18	85	1 173 753	99.77
	18 - 25	35	2 306 508	80.73
			Sub-total	427.37
Grand Total				11 132 60

Source: Fisheries Economic Division, Department of Fisheries.

Appendix Table 3. Computation for catch cost of demersal fisheries per standard efforts.

Amount Cost (Baht x 10^6)	11 132.60
Percentage of catch value (%) (demersal fish and trash fish)	34.33
Catch cost for demersal fish and trash fish (Baht x 10^6)	3 821.82
Standard effort (Hr x 10^6)	54.82
Cost per unit effort (Baht•St Hr^{-1})	69.72

Appendix Table 4. Summary of Fox's Model Output

Regression Statistics			
Multiple R			0.8529548
R Square			0.72753188
Adjusted R Square			0.71663316
Standard Error			0.42318985
Observations			27
ANOVA			
	Regression	**Residual**	**Total**
df	1	25	26
SS	11.95492447	4.477241209	16.4321657
MS	11.95492447	0.179089648	
F	66.7538553		
Significance F	1.597E-08		
		Intercept	Variable (X)
Coefficients		2.130987563	-4.864E-06
Standard Error		0.115928278	5.9531E-07
t Stat		18.38194785	-8.1703033
P-value		4.89686E-16	1.597E-08
Lower 95%		1.892228973	-6.09E-06
Upper 95%		2.369746154	-3.638E-06
Lower 95.0%		1.892228973	-6.09E-06
Upper 95.0%		2.369746154	-3.638E-06

The Role of Fisheries Sector in the Coastal Fishing Communities of Sri Lanka

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Abstract

Sri Lanka is an island country with a land area of 65 610 km^2. With the declaration of the exclusive economic zone (EEZ) in 1976, the country gained sovereign rights over an ocean area of 536 000 km^2 and EEZ extending from 24 to 200 nm. The continental shelf is about 26 000 km^2 with an average width of around 22 km, and the coastline is 1 100 km long.

The total annual fish production of Sri Lanka was 25 000 t in 1952 and 269 850 t in 1998. Major fish species caught in Sri Lankan waters are skipjack, blood fish, yellow fin tuna, mullet, shark, trevally, Spanish mackerel, prawns, lobsters. Gross domestic product (GDP) is composed of services, agriculture including forestry and fishery, manufacturing, construction and mining and quarrying. Of these, the agriculture sector contributed 21% with 2.5% coming from the fisheries subsector in 1998. In 1975, fisheries contributed Rs420 million to GDP and substantially improved to Rs24 823 million (US$382 million at 1 US$ = 64.90 Sri Lanka Rupee; source: oanda.com) in 1998. Export volume from fisheries was 3 240 t in 1985, and 11 433 t in 1998; equivalent to an export value of Rs453 mil (US$7 million) to Rs6 732 mil. (US$104 million).

The fisheries sector has provided direct employment opportunities to over 115 000 people and indirect benefits to 100 000 people in related occupations such as fish processing, boat building and other equipment manufacture and trade and public sector organizations. A socioeconomic survey conducted in 1996 noted a fisher population of 83 776 with 81.7% having fishing as their sole source of income, 12.5% as their main source and 4.3% as their second source.

Fish is the main and preferred source of animal protein in Sri Lanka. Fish consumption accounts for 5% of the total food consumption and per capita fish consumption was 12.77 kg in 1998. However fish constitutes a substantial share of expenditure on food because of its high domestic price.

The policy of almost all fisheries projects in Sri Lanka has been to maximize the fisheries resource utilization for direct extractive purposes rather than for sustainable resource management. This short-range orientation has increased the efficiency of fishing operations through the application of advanced technologies in fish capture, leading to a shift from the traditional fishing methods to the adoption of modern fishing gear. This has led to the depletion of fishery resources, particularly in the coastal waters. Thus there is a need to adopt programmes that emphasize the development of offshore fishing and thereby reduce fishing pressure in the coastal areas. Implementation of alternative livelihood opportunities would also improve the quality of life of coastal fishers.

Introduction

Sri Lanka is situated between 6º and 10º N latitude and 80º and 82º East longitude in the Indian Ocean. The Palk Strait and the Gulf of Mannar separate India and Sri Lanka. The island has a land area of 65 610 km^2. With the declaration of the Exclusive Economic Zone (EEZ) in 1976, the Government of Sri Lanka obtained sovereign rights over an ocean area of 536 000 km^2 and the natural resources therein. Sri Lanka's sea area is approximately 7 times its land area and the sea area consists of a territorial sea extending up to 12 nm, a contiguous zone extending from 12 to 24 nm and an EEZ extending from 24 to 200 nm. The continental shelf of about 26 000 km^2 is narrow with an average width of around 22 km. The coastline is 1 100 km long, meanders along sandy beaches, extensive lagoons and estuaries, mangroves, coastal marshes and dunes. Seawards lie reefs of sandstone or coral and shallow beds of coastal and estuary seagrass.

Sri Lanka is divided into nine provinces, within which there are 25 administrative districts and about 317 subdivisions with clusters of villages headed by a divisional secretary. The total number of villages in Sri Lanka is approximately 38 000 and the total estimated population is 18.7 million (1998), which consists of Sinhalese (74%), Tamil (18%), Ceylon moors (7%) and Burghers and Malays (1%). Out of the total population, about 0.6% are estimated to be active fishers who live in 1 269 fishing villages in 15 District Fisheries Officer's Divisions. Accordingly, the estimated fishing population is around 538 560 (18.7 million x 0.6% x 4.8 average family size).

Two monsoons and two inter-monsoon periods mainly influence Sri Lanka's climate. From May to September is the southwest monsoon. It is also associated with cyclones, wind circulation or depressions. The southwest monsoon brings heavy rainfall especially to the southwestern region of the country. The northeast monsoon period falls between December to February and then the northeastern part of the country experiences heavy rainfall. One inter-monsoon period is from March to April and the other is from October to November. This makes coastal fishing activities seasonal.

"Within Sri Lanka's coastal zone are found:

- *approximately 24% of the land area with 32% of the population;*
- *nearly 80% of the annual fish production, contributing 30% of the consumable animal protein;*
- *production of 40% of the gross domestic product (GDP);*
- *almost 70% of the industrial output;*
- *65% of the urban area;*
- *principal road and rail transport infrastructure, for e.g. coastal highways such as Galle Road and Negombo Road and railway lines form Colombo to Matara and Colombo to Puttalam;*
- *the country's salterns, commercial ports, fishery harbours and anchorages, and areas of brackish-water aquaculture;*
- *80% of tourism-related infrastructure, with the majority being located in the western and south-western coastal belt (most of them 15 m away from the shoreline);*
- *80% of the country's fish production which, in 1996, was 228 550 t;*
- *some of the richest biodiversity areas include coral reefs, seagrass beds, mangroves, coastal wetland, estuaries, lagoons and sanctuaries covering 160 000 ha;*
- *substantial reserves of valuable minerals (e.g. Pulmudai mineral sands);*
- *a significant extent of agricultural land;*
- *sizable areas of usable land not yet developed;*
- *nearly 100 sites of special historical, archaeological, cultural, or religious significance; and*
- *another 100 sites of special scenic or recreational*

importance." (Pacific RIM Innovation and Management Exponents, 1999).

The socioeconomic profile presented here encompasses the status of fishery resources and production, contribution of the fisheries sector to the economic growth and the social and economic status of small scale fishers in Sri Lanka.

In Sri Lanka, the following features identify small scale fisheries:

a. Fishing fleet comprised of outboard motor craft, non-motorized traditional craft and traditional stationary fishing gear.
b. Fishing operations carried out within a day and limited to coastal waters (40 km), lagoons, rivers and freshwater bodies.
c. Foreign components as well as modern technical inputs are minimal and the fishing operations are controlled by seasonal changes.
d. Operations mostly depend on family labor and a high level of owner participation.
e. The important fishing gear used is drift-net.

The large-scale fishing operations in Sri Lanka embody the following features:

a. Fishing fleet comprised of multi-day boats, which are propelled by in-board engines.
b. Fishing operations generally continue from 10 to 45 days, beyond 40 km from the shore.
c. Fishing generally is not affected by seasonal changes and the quantity of fish production is fairly high.
d. Foreign component in production input is high. The use of modern equipment and technology is also high.
e. Operations are capital intensive, but the owner's participation in the fishing operation is negligible.
f. The important fishing gear in use is primarily drift-net, long line and troll line.

Generally, in Sri Lanka, the term 'small scale fisheries' is almost synonymous with coastal fisheries and 'offshore/deep-sea fishery' is synonymous with large scale fishery. (National Aquatic Resources Research and Development Agency (NARA) 1998).

Method and Limitations of the Study

The Ministry of Fisheries and Aquatic Resources Development in Sri Lanka is developing a database with special emphasis on coastal fisheries under the project on Sustainable Management of Coastal Fish Stocks in Asia (ADB-RETA5766). Data collected from secondary sources on socioeconomic profiles of coastal fishery areas and population were used for the study.

Unfortunately, regular comprehensive assessment of fishing activities in Sri Lanka is seldom undertaken. The first national census of marine fisheries was conducted in 1972, and since then marine censuses have been confined to the west, south and the east coastal districts. Smaller regionally based studies have been conducted e.g. (Bay of Bengal Programme 1991), but Sri Lanka has been unable to conduct a general census of population and statistics due to ethnic conflicts in the north and east of the country. This paper is thus confined to a cross-sectional analysis of the social and economic conditions of coastal fisheries in Sri Lanka. The dearth of socioeconomic data related to other sectors makes it difficult to compare the quality of life of fishing households with those of others.

The statistics data were gathered from information collected under Research Study No. 99 by Hector Kobbekaduwa (Agrarian Research and Training Institute) on "Farming System of Kirindi Oya Irrigation and Settlement Project".

Status of Fishery Resources

The marine fisheries industry in Sri Lanka has a long history. During the early stages of development, traditional methods of fishing using canoes and gear, such as beach-seines, hand-line, nets made out of coir and stake nets, were used in coastal areas. The coastal inhabitants were primarily engaged in exploiting resources close to the shore in and around their settlements. Fish production in the 1940s was in the region of 40 000 t (de Zylva 1954). A high percentage of this production came predominantly from beach seines. The major fisheries such as beach seining and stake netting were under traditional control.

A stage of rapid development in fisheries began in the late 1950s with motorization and the introduction of modern craft and methods (Joseph 1983). With these technological developments and the open-access nature of operations, fishing effort has accelerated over the years, both by increasing fishing power and fishing units. In addition, the

state provided incentives in the form of subsidies on capital goods and institutional credit (De Silva et al. 1996) The technological inputs increased coastal fish production from 84 400 t in 1962 to 152 750 t in 1999.

The stable phase of coastal fisheries development, with a reduced rate of increment in production has led to a leveling off at around 150 000 - 160 000 t since the 1980s. The fishing effort has increased with the catch remaining static. The fishing sector has reacted to this declining catch rate by investing in new fishing gear such as purse seine, ring net in pelagic fisheries and bottom long-line and trammel nets in demersal fisheries. This type of gear is beyond the capital resources of the majority of small scale fishers. There is therefore inequitable distribution of income from fishing, leading to increased conflicts among fishers in traditional fisheries and in modern fisheries (Fernando 1984). However, improvement in technology has led to marginal increases in catch per unit effort (CPUE), but also to the over-exploitation of coastal resources. The involvement of around 120 000 fishers in mostly small scale fishing in the coastal waters has forced the government to consider small scale fisheries in Sri Lanka as a priority target for poverty relief.

Reliable and up-dated information on fishery resources in Sri Lanka is a major deficiency. The following excerpt presents some of the assessments arrived at in a past survey.

"The Fridtjot Nansen" Survey in 1978 - 80 estimated the potential yield from coastal fish resources within the continental shelf to be 250 000 t per year of pelagic and demersal species; pelagic fish were estimated to have a maximum sustainable yield of 170 000 t per year and demersal species 80 000 t. The present yield from demersal species is around 35 000 t. Inshore demersal resources of shrimp (5 000 - 7 000 t) and spiny lobster (600 t) are most valuable". (Atapattu 1996)

"Preliminary estimates of Sri Lanka's offshore resources indicate that 50 000 - 90 000 t per year could be taken without the risk of overexploitation. The species include yellow fin tuna, skipjack tuna, big-eye tuna, billfishes and pelagic and sharks. The total marine fisheries resources, including Sri Lanka's offshore area, could thus perhaps yield up to 350 000 t per year (Atapattu 1996)"

Fish Production

The total annual Sri Lankan fisheries production in 1952 was of the order of 25 000 t (De Bruin et al. 1994). In 1960, it reached 53 359 t of which 91% (48 760 t) was from the coastal fisheries. The percentage of coastal fish production out of total fish production had been within the range of 80 - 90% until 1990. In 1983, when coastal fish production peaked at 184 000 t, the coastal fishery contribution to the total production was 80%. The total fish production in 1998 was 269 850 t. Out of this, 62% was from coastal fisheries, 27% was from the offshore and deep-sea fisheries, whereas only 11% was from the inland fisheries.

The highest level of coastal fish production in the recent past was recorded in 1994 (Table 1). Production declined by 12% in 1995 and 13% in 1996 from 1994 levels. There is now a continuing downward trend in the contribution of the coastal fish production to total fish production. This decline is mainly in the north and the east of the country.

Table 1. Contributions of coastal fish production to total fish production.

Year	Coastal Fish Production (t)	Percentage of Total Production
1960	48 760	91
1970	85 015	88
1974	100 805	90
1983	184 049	80
1984	136 642	80
1990	134 132	81
1993	169 900	76
1994	174 500	78
1995	157 500	66
1996	149 300	65
1997	152 750	63
1998	166 700	62

Source: Ministry of Fisheries and Aquatic Resources Development (MFARD) 1999b.

Coastal fish production by major fish species is shown in Table 2. (The category 'others' shows the weaknesses of the data collection system). Beach seine species (mackerel, sardines and anchovies etc.) have continuously added a marked tonnage to coastal fish production. The total coastal fish production in 1991 was 156 150 t and the individual contributions of skipjack and beach seine species and 'others' is shown as 10%, 21% and 27% respectively. By 1998, the total coastal fish production of major species had risen to 16 670 and the percentage addition of the 'others' category had decreased to 19% while skipjack and beach seine species increased to 17% and 29% respectively. The total percentage of skipjack, yellowfin tuna and other tuna in 1991 was 23% and continued to increase; in 1996 it was 36.4% and in 1998 it was 34.3%. Tuna have been the major catch in Sri Lanka's coastal waters over the years, and there has been a diminishing catch of seer, travelly and sharks.

Table 2. Coastal fish production (t) by major fish species from 1991 to 1998.

Fish species	Year							
	1991	1992	1993	1994	1995	1996	1997	1998
Seer (Spanish mackerel)	3 916	3 524	3 369	3 200	2 993	2 170	2 400	2 500
Trevally	8 975	8 526	8 378	8 000	6 910	6 090	6 900	7 000
Skipjack	16 690	18 359	19 316	20 475	23 548	25 630	27 600	28 200
Yellow Fin	10 664	11 730	11 981	13 180	12 050	12 740	14 600	13 900
Blood fish (Other tuna)	9 325	10 258	10 681	11 215	17 642	15 940	14 800	15 100
Shark	19 045	18 306	19 061	19 500	14 017	7 110	8 800	8 500
Mullet	8 658	9 870	10 277	10 585	7 088	8 970	9 100	9 200
Beach seine	33 426	35 097	37 379	38 870	49 785	48 220	42 700	49 800
Prawns	5 176	6 470	6 737	7 000	**	**	**	**
Lobsters	789	828	862	1 000	400	**	**	**
Others	42 486	40 202	41 859	41 475	23 067	22 430	25 850	32 500
TOTAL	156 150	163 170	169 900	174 500	157 500	149 300	152 750	166 700

Note: ** Included under others
Source: Ministry of Fisheries and Aquatic Resources Development (MFARD) 1999b.

Contribution of Fisheries Sector to Gross Domestic Product (GDP)

After the liberalization of the economy in 1977, the sectoral composition of the GDP of Sri Lanka changed and the service sector became the major contributor. The agricultural sector with the subsectors of forestry and fisheries contributed 21% percent to GDP in 1998 (Fig. 1). The fisheries sub-sector contribution to GDP in 1998 was 2.5%.

The total GDP in 1975 increased 36-fold to Rs985 586 million (US$15 186 million) by 1998 and to Rs773 500 million (US$13 115 million at 1 US$ = 58.98 Rs), a 28-fold increase by 1997 (Table 3). The fisheries sector contribution to GDP of 1975 increased by 59-fold to Rs24 823 million (US$384 million) by 1998 and to Rs21 265 million (US$361 million), a 50-fold increase by 1997.

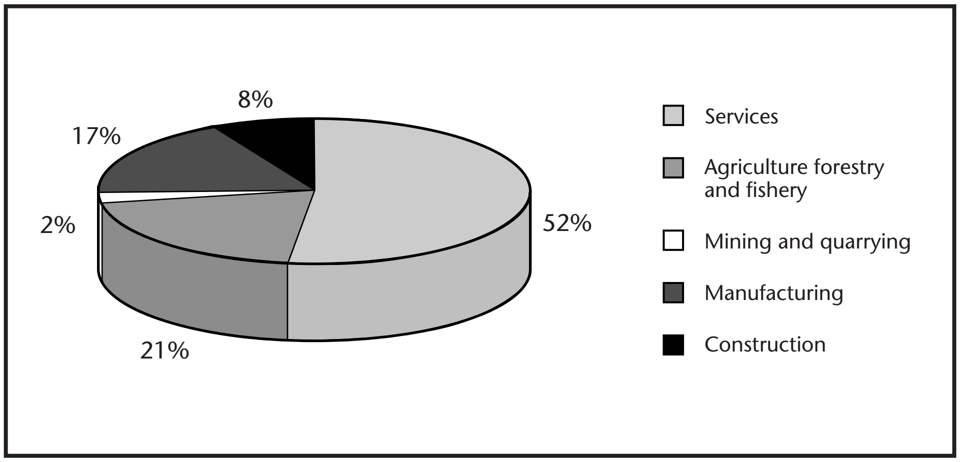

Fig. 1. Sectoral composition of GDP in Sri Lanka 1998.

Table 3. Contributions of the fisheries sector to GDP.

Year	Total GDP (Rs million)	Fisheries Sector (Rs million)	Percentage
1975	27 040	420	1.5
1983	119 202	1 733	1.4
1984	147 344	2 590	1.7
1989	248 230	5 087	2.0
1990	317 904	5 800	1.8
1994	571 131	14 376	2.5
1996	669 934	18 763	2.7
1997	773 500	21 265	2.7
1998	985 586	24 823	2.5

Source: Central Bank of Sri Lanka 1998 - 99.

Environmental Impacts

Due to the inefficient planning of fishery harbours, Sri Lanka experiences some erosion in the vicinity of such structures. In addition, coral reefs have been endangered by destructive fishing practices (use of dynamite), over-harvesting and pollution.

"Mangroves which are closely associated with estuaries and lagoons have also been harvested for various uses. Apart from the domestic uses, shrimp culture has become an exterminating factor where the mangroves in Puttalm District are concerned. Mangrove areas are converted for use as shrimp pond aquaculture and for lowland agriculture. Over 600 ha of coastal areas between Chilaw and Puttalam, much of it mangrove forest, has been developed for aquaculture. The conversion process not only results in direct loss of mangroves by clear-cutting but also alters water flow patterns that may cause the surrounding mangroves to die. A loss of 63% of the previously existing mangroves in Puttalam lagoon has been reported to have occurred in the ten-year period from 1981 - 92 (Dayaratne and De Silva 1995)".

Seagrass beds as well as lagoons and estuaries are

also adversely affected by fishing and related activities. In respect of seagrass beds, beach seining and dragging of propellers cause degradation. When lagoons such as those in Negombo, Mawella and Chilaw are used as harbours, various forms of effluents discharged by fishing boats contribute to contamination and pollution.

Contribution of Fishing to Income and Employment

Although the fisheries sector has contributed only around 2% to the gross national product (GNP) of the country over the years, it has provided direct employment opportunities to over 115 000 and further employment to 100 000 in related occupations such as fish processing, boat building and other equipment manufacture, and also in trade and public sector organizations. According to the Census of Marine Fisheries in 1972, there were 969 marine fishing villages in the entire coastal region of the country. Of them, 51.3% were in small villages with 1 - 19 households, 36.3% lived in medium size villages with 20 - 99 households and 12.4% were in large fishing villages with 100 or more households. The percentage of fishing and fish processing households in small villages amounted only to 8.4%. In contrast, 54% of the households are from larger fishing villages. Over 50% of the households were in larger villages and the balance were scattered in many villages along the coastal belt. Table 4 shows a comparison of the numbers of fishing villages and the active fishers by district in 1972 and 1995. The fishing villages in the four District Fisheries Extension Officer (DFEO) divisions, namely Mannar, Jaffna, Mullativu and Killinochchi located in the northern part of the country, were excluded from the marine fisheries survey conducted in 1995.

Table 4. Active fishers by district and fishing population at the village level in Sri Lanka.

DFEO Divisions	Fishing Villages		Active Fishers by District		Fishing Population	
	1972	1995	1972	1995	1972	1995
Colombo	25	36	2 583	2 235	11 088	8 756
Negombo	23	82	5 102	10 146	21 877	38 601
Puttalam	132	108	10 806	9 795	35 665	35 812
Mannar	32	N/A	2 849	N/A	12 022	N/A
Jaffna	107	N/A	10 827	N/A	41 613	N/A
Mullativu	20	N/A	1 350	N/A	4 874	N/A
Trincomalee	61	120	2 815	7 557	13 283	33 900
Batticaloa	91	225	5 571	13 533	25 323	57 922
Kalmunai	45	246	5 826	13 224	25 691	59 064
Tangalle	91	79	1 823	4 843	8 727	19 844
Matara	53	72	3 280	5 120	16 240	21 967
Galle	231	158	3 472	5 134	18 182	21 054
Kalutara	58	78	2 210	4 150	10 477	16 667
Chilaw	N/A	65	N/A	8 039	N/A	30 901
Kilinochchi	N/A	N/A	–	–	–	–
TOTAL	969	1 269	58 514	83 776	245 062	344 488

Source: Department of Fisheries (DOF) 1973; Department of Fisheries (DOF) 1989.
Note: N/A = Not available.

Contribution of the Fisheries Sector to Foreign Exchange Earning

The details relating to foreign exchange earnings are given in Table 5. The import value in 1985 was 10 times greater than the export value for the same year. This adverse ratio escalated to a ratio of 28 kg of imported fish to 1 kg of exported fish in 1991. However, the balance of payments of fish trading shown in Table 5 has improved since 1994. The export and import volume ratios were 1:10 in 1995, and 1:6 in 1998

Table 5. Contribution of the fisheries sector to foreign exchange earnings in Sri Lanka.

	Export		Import		Balance of Payment	
Year	Volume (t)	Value (Rs million)	Volume (t)	Value (Rs million)	Volume (t)	Value (Rs million)
1985	3 240	453	35 974	756	32 733	(303)
1986	3 410	608	32 399	838	28 988	(230)
1987	2 376	575	38 135	956	35 758	(381)
1988	3 496	824	45 632	437	42 135	(312)
1989	3 982	1 137	35 996	1 059	32 013	(48)
1990	3 162	883	37 627	949	34 464	(66)
1991	1 827	855	52 107	2 003	50 279	(1 147)
1992	3 734	1 303	55 000	2 334	51 265	(1 030)
1993	5 895	2 144	53 485	2 187	47 590	(43)
1994	7 193	3 291	56 261	2 893	49 068	398
1995	7 457	3 655	68 343	3 369	60 886	286
1996	8 364	4 125	62 883	3 426	54 518	699
1997	8 477	4 326	73 951	4 120	65 475	205
1998	11 433	6 732	71 214	3 923	58 780	2 809

Source: Central Bank of Sri Lanka 1998 - 99.

Contribution of the Fishing Sector to Domestic Nutrition

Fish is the main and preferred source of animal protein in Sri Lanka even though the level of retail fish prices has remained consistently high. All income groups consume fish in varying amounts. Fish accounts for 5% of total food consumption, although it constitutes a substantial share of expenditure on food.

According to the food balance sheet from the Department of Census and Statistics the total fish consumption in 1976 amounted to 115 000 t, representing a per capita annual consumption of 8.38 kg (Table 6). This had risen to 240 000 t and 12.77 kg respectively by 1998. The Medical Research Institute of Sri Lanka has recommended an intake of 21.0 kg of fish•head^{-1}•annum^{-1}, however this is not realistic in rural areas due to the high price of fish.

The wholesale and retail prices of fresh fish•kg^{-1} in the Pettah Market (Colombo) are given in Table 7. During the period 1995 - 98, the retail price of every species of fish increased.

Per capita availability of calories•day^{-1} in 1992 amounted to 2147.1 and out of this 51 calories (2.4 % of the total) was from fish. (Table 8). In 1998 the calorie intake from fish was 60 calories (2.7% of total calories 2 230)•day^{-1}.

Table 6. Contribution of fisheries sector to domestic nutrition in Sri Lanka.

Year	Production ('000 t)	Available domestic supply ('000 t)	Population ('000)	Per capita supply (kg)
1976	135	115	13 730	8.38
1980	187	155	14 738	10.56
1982	232	194	15 189	12.77
1994	224	190	17 865	10.67
1995	237	197	18 112	10.90
1996	228	240	18 315	11.47
1997	242	224	18 552	12.08
1998	260	240	18 800	12.77

Source: Department of Census and Statistics (DCS) 1976 - 98.

Table 7. Wholesale and retail prices of fresh fish in Pettah Market, Sri Lanka.

	1995		1996		1997		1998	
Species	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail
Sardine (Salaya)	40.00	47.00	34.00	5300	45.00	65.00	46.00	65.00
Trenched Sardine (Hurulla)	53.00	63.00	58.00	81.00	61.00	86.00	65.00	86.00
Skipjack (Balaya)	62.00	77.00	66.00	110.00	100.00	116.00	66.00	86.00
Yellow Fin Tuna (Kelawalla)	85.00	135.00	90.00	152.00	104.00	166.00	98.00	162.00
Seer (Thora)	180.70	248.00	173.00	279.00	133.00	298.00	200.00	283.00
Travelly (Paraw)	107.20	154.00	140.00	190.00	125.00	203.00	129.00	210.70
Shark (Mora)	45.00	60.00	57.00	108.00	82.00	117.00	82.00	118.00
Mackerel (Kumbalawa)	89.90	103.00	58.00	90.00	114.00	96.00	95.00	113.00
Sail Fish (Talapath)	76.00	118.00	97.00	170.00	142.00	185.00	140.00	190.00

Source: Department of Census and Statistics (DCS) 1976 - 98.

Table 8. Per capita availability of calories, protein and fat from vegetables, fish and animal resources in Sri Lanka from 1992 to 1998.

Item	1992	1993	1994	1995	1996	1997	1998
Calories per day							
Total	2 147.10	2 141.00	2 314.40	2 259.80	2 183.40	2 208.20	2 230.60
Vegetable	2 006.60	1 992.20	2 170.90	2 108.80	2 035.30	2 056.00	2 059.30
Fish	51.30	59.53	50.82	51.69	53.46	58.54	59.86
Other Animal	89.20	89.27	92.68	99.31	94.64	93.66	101.44
Protein (g/day)							
Total	51.60	53.20	56.10	56.50	54.30	54.40	54.20
Vegetable	37.20	36.90	41.00	40.80	38.90	38.10	36.90
Fish	8.81	10.56	8.99	8.97	8.98	9.76	9.97
Other Animal	5.59	5.74	6.11	6.73	6.42	6.54	7.33

Table 8. Per capita availability of calories, protein and fat from vegetables, fish and animal resources in Sri Lanka from 1992 to 1998. (continued)

Item	1992	1993	1994	1995	1996	1997	1998
Fat (g/day)							
Total	39.40	39.00	43.20	43.10	42.00	41.00	43.60
Vegetable	32.30	31.90	36.30	35.60	34.70	33.60	35.80
Fish	1.56	1.66	1.43	1.56	1.73	1.96	2.00
Other Animal	5.54	5.44	5.47	5.94	5.57	5.44	5.80

Source: Department of Census and Statistics (DCS) 1991 - 98.

Contribution of the Fishery Sector to National Food Security

In a broad sense, food security is the stock of food available for consumption. The stock of food comprises the total production along with the imports but excluding the exports. Table 9 provides the figures on per capita fish availability for consumption during the period 1985 - 98.

The total fish production of the country in 1985 was 175 403 t of which 2.5% was exported. The total fish availability in 1985 was 208 137 t, including imports of 35 974 t. Thus the per capita fish availability amounted to 13.1 kg in 1985; subsequently it declined to 8.9 kg in 1988 and to 9.8 kg in 1989. From 1991, per capita availability increased and by 1998 the per capita fish availability was 17.0 kg•annum^{-1}.

A projection of the fisheries sector contributions to national food security for the coming years is depicted in Table 10. A greater promise is seen in the deep sea and in the aquaculture harvest for the targeted per capita fish supply in the future. The supply of fish is expected to reach the target of 19.6 kg•capita^{-1}•annum^{-1} by 2004.

Table 9. Contribution of the fishery sector to national food security in Sri Lanka.

Year	Production (t)	Export (t)	Import (t)	Total Supply (t) (P+ I - E)*	Mid Year Population ('000)	Per Capita Fish Availability (kg)
1985	175 403	3 240	35 974	208 137	15 842	13.1
1986	183 060	3 410	32 399	215 624	16 127	13.3
1987	190 005	2 376	38 135	225 944	16 361	13.8
1988	197 527	3 496	45 632	148 392	16 586	8.9
1989	205 285	3 982	35 996	165 304	16 806	9.8
1990	183 900	3 162	37 627	218 365	16 993	12.8
1991	198 012	1 827	52 107	248 292	17 247	14.3
1992	206 170	3 734	55 000	257 436	17 405	14.7
1993	220 900	5 895	53 485	288 490	17 619	15.2
1994	224 000	7 193	56 261	273 068	17 885	15.4
1995	235 750	7 457	68 343	296 636	18 112	16.3
1996	228 550	8 364	62 883	283 063	18 315	15.4
1997	242 000	8 477	73 951	307 474	18 532	16.5
1998	260 100	11 433	71 214	319 881	18 800	17.0

Source: Ministry of Fisheries and Aquatic Resources Development (MFARD) 1999a.
Note: * P + 1 - E = production plus imports minus export

Table 10. Estimated per capita fish supply for Sri Lanka in 1999 - 2004.

Sub sector	1999	2000	2001	2002	2003	2004
Coastal (t)	185 000	191 000	197 000	203 000	209 000	215 000
Offshore/Deep sea (t)	65 000	69 000	74 000	80 000	86 000	92 000
Inland and Aquaculture (t)	30 000	32 000	35 000	40 100	45 900	51 000
Total (t)	280 000	292 000	306 000	323 100	340 900	350 000
Import (t)	71 266	68 898	65 790	64 000	63 000	58 000
Export (t)	8 915	10 202	11 696	13 434	15 460	17 827
Fish supply for local consumption (t)	342 351	350 660	360 094	373 666	388 440	398 173
Mid year population (millions)	19.0	19.2	19.4	19.7	20.0	20.3
Per capita fish supply per annum (kg)	18.0	18.2	18.6	19.0	19.4	19.6

Source: Ministry of Fisheries and Aquatic Resources Development (MFARD) 1999b.

Socioeconomic Status of Coastal Fishers

Fishing Households by Ethnic and Religious Group

Sri Lanka is a multi-ethnic and multi-religion country. Its population comprises Sinhalese, Tamils, Moors, Malays and others. The majority (74%) of the population is Sinhalese (Table 11), of which 60% are Buddhists Tamils are generally Hindus. Moors and the Malays follow the Islamic faith.

The total population in 1998 was 18.7 million of which 0.6% representing 538 580 persons could be treated as the fishing population belonging to 107 716 fishing households.

Table 11. Population by ethnic group and religion in Sri Lanka.

Race	Percentage	Religion	Percentage
Sinhalese	73.98	Buddhist	69.31
Tamils	18.16	Hindu	15.46
Moors	7.12	Muslim	7.64
Malays	0.29	Christian	7.49
Others	0.46	Others	0.10

Source: Department of Census and Statistics (DCS) 1976 - 98.

According to the Census of Marine Fisheries - 1972 of Sri Lanka, there were 969 fishing villages around the coastal belt with 43 352 households and 58 298 fishers engaged in active direct fishing. The total fishing population was 245 065. A survey conducted by the Census of Marine Fisheries in Sri Lanka in 1996 gave the following information: total villages in the DFEO divisions from the south, west and east numbered 1 269, with 72 133 households. These households consisted of 83 776 active fishers, totaling 344 497 people.

Munasinghe and Cruz (1994) pointed out that more Catholics and Hindus are engaged in fishing than Buddhists. However, the socioeconomic study of the fisherfolk of four fisheries districts carried out in 1991 under the Bay of Bengal Program (BOBP) revealed the rates of the fishing households in relation to ethnic groups and religions depicted in Figure 2.

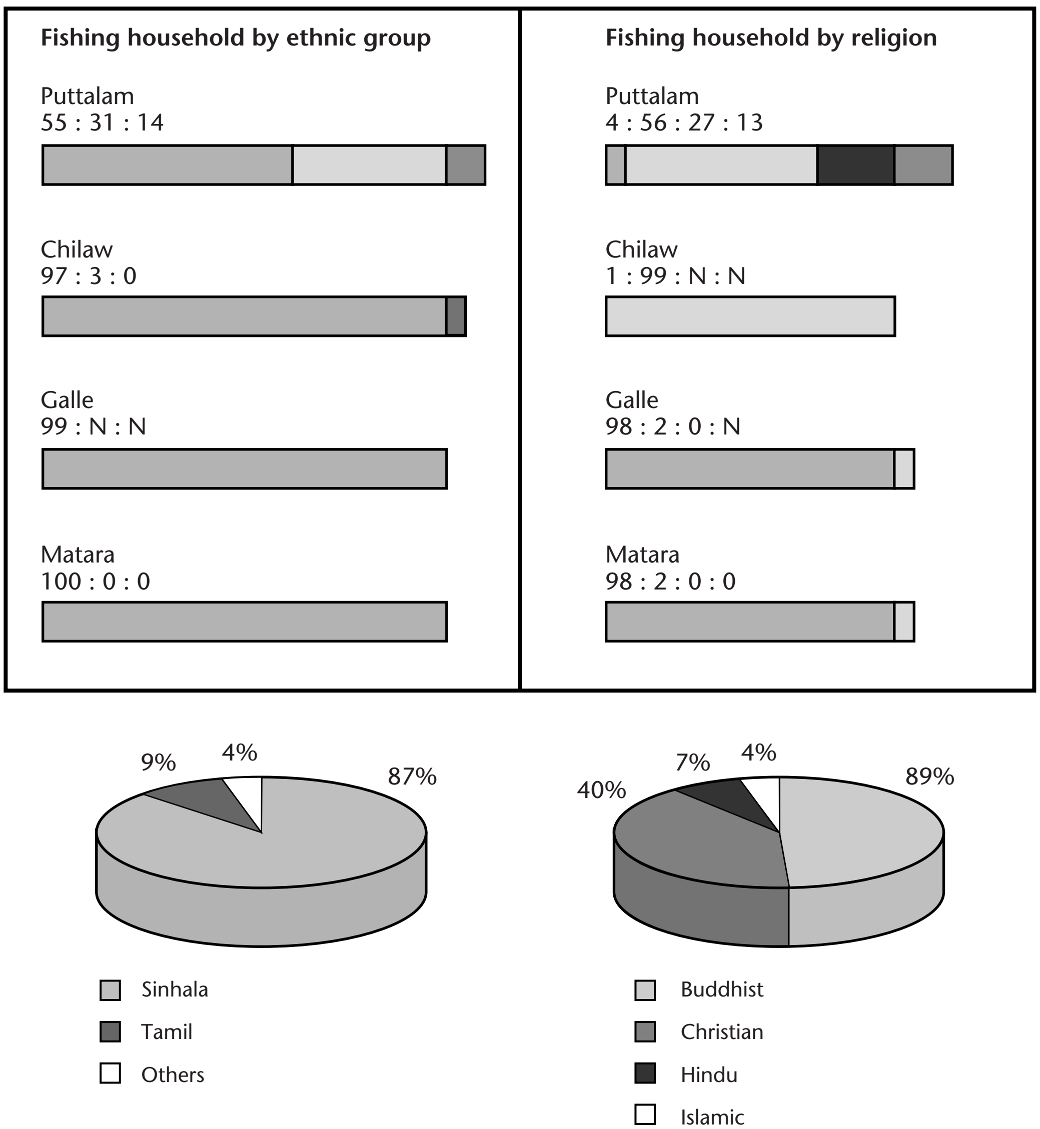

Fig. 2. Percentage of ethnic and religious groups in Sri Lanka.

The Census of Marine Fisheries in Sri Lanka 1996 (Department of Fisheries and Aquatic Resources (DFAR), 1997) indicated that there were 55 782 (77%) nuclear family households out of the total fishing households of 72 133, of which 75% (54 124) have their own houses. In some DFEO Divisions (Colombo, Kalutara, Galle, Matara, Tangalle and Puttalam), this percentage varied from 56% - 66%. The number of household members in a fishing family varied from one to nine. In 1996, there were 129 357 persons below 15 years of age and 6 614 persons over 65 years of age. The age distribution of the total work force is as follows: 20% are aged 15 to 24, 15% are aged 25 to 34, and 13% are between 35 and 44 years old. The age distribution among working fishing folk over 12 years is as follows: the age group of 35 - 44 years constitutes 28.8% of the active fishers, and the 25 - 34 years group constitutes 27.5%.

Women's participation in active fishing is minimal since the gender distribution of the fisherfolk is totally in favour of males (99.3%). The women are treated as unpaid laborers while child-caring, housekeeping and family management activities are totally entrusted to them. Some women take part in fish collection, net mending and fish marketing etc.

Although fishing in Sri Lanka is reported to be an open access activity, there is a high degree of family linkage among the fishing population. Out of the total active fishers (83 776) in 1996, 75.2% were the sons of fishermen.

Fishing as a Source of Household Income and Employment

Table 12 provides data on the significance of fishing as a source of employment and income. Fishing in 1996 was still around 92% in terms of both sole and main income sources. There is very little fishing activity during the off-season. Fishers may be content to stay at home, or be unable to find other employment because of lack of opportunities in their own areas, or because of social barriers that do not permit change of occupation.

Table 12b. Fishing as source of employment in coastal fishing villages in Sri Lanka in 1996.

Fishing involvement	Fishers	%
Sole job	68 481	81.7
Main job	10 476	12.5
Second or Other	570	4.3
No Income from Fishing	1 249	1.5
TOTAL	83 776	100

Source Department of Fisheries and Aquatic Resources (DFAR) 1997.

Table 12a. Fishing as a source of household income in coastal villages in Sri Lanka.

Sources of Income	1972		1996	
	No. of Households	%	No. of Households	%
Sole income	35 773	82.7	51 332	71.2
Main	4 467	10.3	15 234	21.1
Second or Other	3 029	7.0	4 590	6.4
No Income from Fishing	–	–	977	1.4
TOTAL	43 269	100	72 133	100

Source: Department of Fisheries (DOF) 1973; Department of Fisheries and Aquatic Resources (DFAR) 1997.

Table 13 gives a general view of the average monthly net income obtained by the different craft owners of four DFEO divisions. The level of income varies from place to place even if the same kind of craft is used for fishing. The average income of a fisher depends on four major factors namely, method of fishing operation, size of the crew, type/category of the craft and the sharing system between the craft owner and the crew members.

The study covered gillnet fishing operations. The number of crew members in the study was as follows. For multiday boats 5; FRP boats 2 to 3; motorized traditional boats 2; non-motorized traditional *oru* 2 and non-motorized *theppam* 1 or 2. Table 13b is based on a sharing scheme for fishing crew members recommended by a committee.

Traditional crop farmers in the Kirindi Oya Irrigation and Settlement Project receive incomes of Rs2 066 (US$31.83 in 1998) and 2 756 (US$42.46 in 1998) respectively, very similar to the income of a crew member of non-motorized traditional orus and theppams. The level of income of the crew of FRP boats is comparable to the rural sector income level, and to the level of the crop and livestock farmers under the new system of the Kirindi Oya Irrigation and Settlement Project (Table 14). A multiday boat crew member's income (Rs5 000 - 6 000; US$ = 77 - 92) is comparable to the average income of an urban sector employee, and to the average income of a livestock farmer under the old system in the Kirindi Oya Irrigation and Settlement Project. (Tables 14, 15 &16)

Table 13a. Average monthly net income obtained by craft owners in four DFEO divisions in Sri Lanka.

DFEO Division	Multiday Boat	FRP* Boat	Traditional Motorized craft	Non Motorized Traditional *Oru*	Non Motorized *Theppam*
Chilaw	28 827	17 815	–	–	6 456
Negombo	24 171	8 420	–	–	1 831
Kalutara	24 601	4 630	–	1 263	–
Galle	20 183	6 048	5 329	1 516	–
Total Average	24 445	9 228	5 329	1 389	4 143

Source: Comparative study on the economics of large and small scale fishing operations, Sri Lanka June 1998.
Note: * FRP - local name in Sri Lanka which stands for fiberglass reinforced boat.

Table 13b. Income sharing system in four DFEO divisions in Sri Lanka.

	Sharing proportions									
	Multiday Boats (MB)		FRP		Traditional Motorized (TM)		Non-motorized Traditional *Oru* (NMTO)		Non-motorized *Theppam* (NMT)	
DFEO Division	Owner	Crew	Owner	Crew	Owner	Crew	Owner	Crew	Owner	Crew
Chilaw	1/2	1/2	3/5	2/5	1/3	2/3	–	–	1/3	2/3
Negombo	1/2	1/2	1/2	1/2	1/3	2/3	–	–	1/2	1/2
Kalutara	1/2	1/2	1/2	1/2	1/2	1/2	–	–	–	–
Galle	1/2	1/2	–	–	1/2	1/2	–	–	–	–

Table 14. Average monthly income per fisher depending on type of craft used.

Type of boat for crew member	Monthly income (Rs)
Multiday	5000 - 6000
FRD	2500 - 4500
Traditional motorized	2000 - 2750
Non motorized traditional *Oru*	1250 - 2500
Non motorized *Theppam*	1800 - 4000

Table 15. Kirindi Oya Irrigation and Settlement Project annual family income.

Category of Farmer	New System	Old System
	Average Farm Income	Farmer Income
Crop	24 800	32 717
Livestock	–	76 621
Crop- livestock	56 445 (4 703)	110 421

Source: Survey data 1993, Kirindi Oya project .

Table 16. Average monthly income in Sri Lanka.

Sector	Average income per income receiver			
	1995/96	1990/91	1985/86	1980/81
All island	3 367	1 819	941	469
Urban	5 662	3 374	1 428	694
Rural	3 065	1 470	836	431
Estate	1 923	1 084	609	313

Source: Department of Census and Statistics (DCS) 1995 - 96.

A rapid social assessment survey conducted under TA No. 3034-SRI, Coastal Resource Management Project showed that there are about 76 500 households in the project area which covers six districts namely, Puttalm, Gampaha, Colombo, Kalutara, Galle and Hambantota, with an average annual income of Rs80 000 (or $1 174 at an exchange rate of US$1 = Rs68.17 in 1999). This income level is attained by 76% of the total population in the area. The majority of these households (39%) belong to low to moderate income earners with an annual income of Rs30 000 - 63 000. The next largest group constitutes the "poor" (13%), with annual household income of around Rs30 001. The "downright poor" (24%) have an annual household income between Rs18 001 and 30 000. The remaining households, estimated to be about 24 200 are those of moderate and high income earners with annual household incomes over Rs81 000. About 24 000 households fall below the poverty line of Rs30 000 per year.

Non-fishery Sources of Employment

The employment status of all fishers can be divided into four basic groups: fishing as the sole job, the main job, the second or other job and occupation without income. Fishing is the sole source of income /employment for a very high percentage (81.7%). Table 12b shows that the number of fishers who do not earn an income from fishing is 1 249 (1.5%) of the total 8 3776 active fishers. There are 570 fishers who regard fishing as another source of employment (Table 12b).

Commercial Fishers with Other Employment

Commercial fishers are those who obtain any income from fishing activities including any trading/ bartering with the fishers. As per the 1996 Census of Marine Fisheries, the commercial fishers with other forms of employment by industry are given in Table 17. Fish drying and trading employed 1 378 commercial fishers and the agriculture sector employed 3 650 commercial fishers.

Level of Education

Sri Lanka's literacy rate is outstanding when compared with other countries in the region. This applies to the fisheries sector too, even though there are generation links in those engaged in fisheries. There is a free education system in the country, and MFARD (Ministry of Fisheries and Aquatic Resources Development) provides basic equipment for nurseries in fishing villages.

Of the total number of active fishers, 40.6% have received education below grade five (Table 18). In the bracket "primary schools not completed (grade 1 - 5)", there are some fishers who are illiterate. The socioeconomic study conducted by Bay of Bengal Programme (1991) showed that the over-all literacy rate of fishers was 87%, 40.4% of the sample had passed grade 5, and 15.4% of them

Table 17. Forms of employment of commercial fishers in Sri Lanka in 1996.

Forms of Employment	Number	Percentage
Fishing related activities (drying, trading)	1 378	9.7
Agriculture	3 650	26.0
Govt. sector	426	3.0
Other Industries	8 592	61.2
TOTAL	14 045	100.0

Table 18. Educational qualifications of fishers in Sri Lanka.

Level of Education	Number	Percentage
Primary school - not completed - completed	34 014 33 876	40.6 40.4
Junior secondary school completed	12 908	15.4
Senior secondary school completed	2 978	3.6
Tertiary completed	0	0
TOTAL	83 776	100.0

Source: Census of Marine Fisheries 1998.

had passed General Certificate of Education, which is the minimum qualification required for government or private sector employment.

The level of education of the fishing community is on a par with the national level. Relative to the Kirindi Oya Irrigation and Settlement Project secondary education in the fisheries sector is not satisfactory.

Health and Nutritional Status

Sri Lanka has serious nutrition problems, especially in the rural sector as indicated by anthropometric evidence in neonates, children and perhaps mothers. However, malnutrition is not generally a serious problem in the fisheries sector

"It could be stated from general observation that malnutrition is not a problem in the two villages. The extremely emaciated or ulcerised children or those with enlarged abdomens are not in evidence. This absence of under nourishment could perhaps be attributed to the high protein intake in the form of seafood in these villages resulting in high resistance despite health hazards which prevailed... The main problems relating to health seem to be related to sanitation and environmental factors. Twenty one percent of the houses in Nainamadama and 31% in Mankuliya do not have toilet facilities at all. It is not uncommon to find children de-faecating within the home compound, and adults using the beach in lieu of a latrine in Nainamadama, creating problems of health and environmental pollution (Leitan and Gunasekara 1995)".

Coastal Fishing Conflicts

In Sri Lanka there was offshore commercial trawl fishing from 1920 to1975 on the Wedge Bank. As a result of the Indo-Sri Lanka border demarcation, the whole of the Wedge Bank and one-third of the Pedro Bank were connected with the Indian Exclusive Economic Zone from 1976. This inter-governmental policy decision eliminated trawl fishing in these waters and such fishing was confined to the north and northwestern coast where the trawling grounds are suitable for prawn fishing. Unfortunately, the terrorist activities starting in the 1980s crippled the fishing industry, particularly in the north and the east of the country, making those valuable fishing grounds unavailable for trawling. Therefore, trawling for prawn is limited to the Chilaw area. This prawn trawling is conducted by 3.5 GT mechanized boats. The number of boats in operation is about 140 and they trawl throughout the season. The small scale fishers were badly affected and a conflict rose to its peak in 1991.

The Old Dutch Canal and the Mundel Lagoon fishing regulations in 1994 were spawned by the dispute that broke out between the Mundel and Udappuwa fishers. Trap net and drag net operators of Udappuwa controlled the lagoon preventing the drift netters from operating, and the Mundel fishers objected to their use of drag nets.

Purse seine gear was introduced to the fishing industry in 1950 but was not continued. As a result of the UNDP survey conducted in the 1980s on the use of the live bait and small pelagic resources, the fishers in the southwest and the northwest coastal areas started using the purse seine. Although this gear was very effective, artisanal fishers were opposed, since their areas were badly affected.

Recently, as a result of the uncontrolled proliferation of shrimp farms adjoining the Puttalam lagoon

in the Mundal lake and along the Hamilton Canal that flows through the lake ending in a lagoon in the northwestern province, conflicts have erupted between the traditional fisherfolk and the shrimp culture farmers. These shrimp culture farms have adversely affected the livelihood of the fishing communities and to a lesser degree, a small community of paddy cultivators in the area. There were 5 950 traditional fishing families in 27 villages whose livelihood was directly related so the sea, using simple "catemarans" or boats with outboard engines. When the monsoons came, they confined their fishing to the lagoon for prawn, crab and wild shrimp. The shrimp farms emitted pollutants into the lagoon, threatening its biodiversity, and this has damaged the ecosystem. As the shrimp farmers had obtained legal title deeds for the land they have converted into shrimp farms, the traditional fishers' common property rights have diminished, resulting in conflict.

Institutions in the Fisheries Sector

The Village Communities Ordinance No. 24 of 1889, a piece of historical evidence, indicates that fishing has been an economic activity in the coastal area of Sri Lanka since time immemorial. However, the fisheries sector became a separate entity only in 1940 with the establishment of the Department of Fisheries under the provision of the Fisheries Ordinance No. 24 of 1940. A separate Ministry for Fisheries was established in 1970. Until then the Fisheries Department had been attached to large ministries such as Agriculture, Industries or Irrigation. There are four specialized divisions in addition to the Administration and Finance Divisions in the Ministry, namely, Fisheries Social Development, Planning and Monitoring Export Development and Controlling Surveillance and Air Sea Rescue. The two departments under the Ministry are the Department of Fisheries and Aquatic Resources (MFARD) and the Department of Coast Conservation. These two departments execute the Fisheries and Aquatic Resource Act No. 2 of 1996 and the Coast Conservation Act No. 57 of 1981. Apart from these, there are six agencies under the MFARD, namely, Ceylon Fisheries Harbours Corporation (CFC), Ceylon Fishery Corporation (CFC), National Aquatic Resources Research and Development Agency (NARA), Cey-nor Foundation Ltd. (Cey-nor) and the newly established National Aquaculture Development Authority (NAQDA) and National Institute of Fisheries and Nautical Engineering (NIFNE).

The 13th amendment to the constitution of Sri Lanka of November 1987, brought the provincial councils into existence. Accordingly, the 25 existing districts were grouped into eight provinces (presently nine provinces) in the north and east, and have been amalgamated into one provincial council. Four of these councils are maritime, namely northwestern, western, southern and northeastern. The provincial council does not include any matters pertaining to fisheries in its jurisdiction. "Fishing and fisheries beyond territorial water" are matters for the central government, but "fisheries other than fishing beyond territorial waters" comes under both provincial councils and the central government.

Non-governmental Organizations (NGOs)

Several non-governmental oganizations (NGOs) are concerned with the fisheries sector in Sri Lanka. Some NGOs were established solely for the welfare/ development of fisherfolk and others have a history of partial involvement in fisheries/fisherfolk development, particularly the marine fisherfolk. Most of the NGOs started during the 1980s and basically fall into the category of voluntary social service organizations. They are required to register with the National Secretariat for NGOs established recently under the amendment No 8 of 1998 to the Voluntary Social Services Organizations (Registration and Supervision) Act No. 31 of 1980. NGOs are registered under numerous acts and ordinances; sometimes as approved charities under the company act or incorporated bodies under an Act of Parliament or under legislation such as the Catholic Bishop Conference Act, Mutual Societies Ordinance or the Trust Ordinance. Therefore, it is very difficult to determine the number of NGOs working in the fisheries sector. The National Secretariat for NGOs had registered five NGOs working in the fisheries sector in July 2000: National Fisheries Solidarity, Small Fishers Federation, United Negombo Lagoon Fisher-Peoples Organization and Center for Fisheries Development Cooperation. The NGOs' activities in the fisheries sector involve marketing programmes for lagoon prawn fisheries, the provision of small fishing craft, poultry farming, projects for the fishing community, assistance to migrant fishers, assistance to fishers to obtain bank loans, relief for displaced fishers, lace making, coir, rope and sewing projects to improve the income of women in the fishing communities, saving-credit schemes for fishers, small scale brackishwater prawn farming projects, leadership training, assistance in setting up fishers' organization etc.

Fisheries Cooperative Societies

The fisheries cooperative societies are formed by the fisherfolk themselves. These societies constitute a three layer structure namely, primary societies, secondary unions and an apex federation. These societies come under the supervision of both the Department of Fisheries and the Department of Cooperatives. The fishery and community aspect is handled by the Fisheries Department whereas the Department of Cooperatives is involved in the regulatory and management aspects of the fisheries cooperatives. There are 723 village level marine fishery cooperative primary societies with a membership of 92 772 (Table 19). Fisheries subsidy schemes were of great assistance to the cooperative societies until this scheme was scrapped and the fisheries companies were formed under the Company Act.

Fisheries Cooperative Banks (IDIWARA BANKS)

Village level fisheries cooperatives, dedicated to service and highly concerned with fishing community living standards, were transformed into Idiwara Banks. This enabled the use of the managerial skills in the banking sector to strengthen the fishing community. The number of fisheries banks so established as of December 1999 was 43.

Social Implications of Fishery Policies

The policy thrust of almost all fisheries projects in Sri Lanka has been to maximize the resource utilization for direct extractive purposes rather than for sustainable resource management. This short-sighted orientation has increased the short-term efficiency of fishing operations through the application of modern advanced fish capture technology. The resulting shift from traditional fishing methods to advanced technology has depleted fish resources, particularly in the coastal waters. The lesson learnt emphasizes the necessity for reducing pressure on coastal fishery resources. Accordingly, some programmes have been implemented which encourage offshore fishing, and others which aim to improve the quality of life through providing alternative livelihood opportunities.

A novel programme has been introduced to transform fishers into entrepreneurs. This scheme established limited liability companies with the production subsidy that was earlier given to individual fishers or cooperative societies. This program selected five fishers to become the shareholders of a limited liability company registered under the Company Act. Unfortunately this has not been successful, partly due to non-availability of a legal involvement between the MFARD and the limited liability companies.

Table 19. Status of the fisheries cooperative societies in Sri Lanka as of December 1998.

Fishery Cooperative Societies	Number of Societies	Membership
Village level marine fishery co-operative primary societies	723	92 772
Reservoir-based freshwater co-operative societies	101	5 016
District level mechanised boat owners' societies (28' day boats and multi-day boats)	6	650
All ceylon madel owner's co-op. society Ltd.	1	145
District fishery co-op. unions	8	–
Other fishery societies (marketing, societies, boat building societies, ornamental fish co-op. societies)	5	205
National Fisheries co-op. Federation	1	–
TOTAL	845	98 827

MFARD has established a separate statuary body, the National Aquaculture Development Authority of Sri Lanka. This is a major policy change in the recent past, backed by another policy decision to enhance the quality of life of fishers by providing them with better shelters along with the basic infrastructure facilities, such as access roads, electricity, potable water etc. The government under its budget for 1999 allocated Rs200 million (US$2.8 million) for a housing programme. A Japanese grant was also received for a scattered housing scheme. The government included inland reservoir areas in the housing programme.

The Ceylon Fisheries Corporation (CFC) that was listed for privatization in 1990 has continued its operation as a statuary body, coming under the preview of the MFARD. CFC, which at one time had a fleet of vessels for fish exploitation, has now confined itself to fish sales and distribution, and plays a role in providing fair prices to coastal fishers, and also quality fish at fair prices for consumers. CFC has a number of freezer-trucks and a network of attractive trade outlets. Unfortunately CFC's service is limited to selected areas owing to financial constraints.

Fisheries Cooperative Societies were a good mechanism for years for empowering fishers. These cooperative societies were reorganized in the 1980s to provide subsidies, boats, loans and assistance for income generation activities offered by the government. As these facilities are no longer available, there is little interest among members and 165 cooperative societies are now semi-active and 231 inactive out of the total 824 cooperative societies.

Development Interventions

Sri Lanka has floated seven fisheries development plans starting with the first ten-year plan in 1959. The prime objective of this multi-sectoral plan was for Sri Lanka to achieve self-sufficiency in fish production. Mechanization of the craft, deep-sea fishing by the public sector and the provision of concessionary assistance to coastal fishers were the strategies adopted towards achieving self-sufficiency. Inboard motorization of the 28ft craft (9m) was undertaken in 1958. The introduction of nylon netting, etc. in 1962 was intended to increase fish exports to the level of tea exports. The second ten-year CFC plan (1965 - 75) included a strategy of self-financing fisheries development.

Aiming at a production target of 1 756 000 t, the number of mechanized boats was increased by the third planning cycle that began during 1971 - 76. A major development project was undertaken with the assistance of the Asian Development Bank, introducing 200 9m (28ft) inboard motorized boats and 30 large 12m (38ft.) boats under the Producer/Institutional Credit.

The Fisheries Sector Five-Year Master Plan was implemented in 1979 - 83. New fishing vessels sized 28 ft - 32 ft (9 m - 10 m) and 17 ½ ft - 23 ft (5.6 m - 7 m) were introduced. Inboard and outboard motors were issued to replace existing ones and to mechanize traditional craft.

During the fifth planning cycle government assistance to fisherfolk was channeled through the Fisheries Cooperative Societies. Under this policy shift about 750 FCSs were established and subsidized. The 1994 - 2000 plan has been replaced by the Six Year Development Programme for 1999 to 2004.

The government capital expenditure on fisheries is shown in Table 20. It increased by about 5.5 times between 1986 and 1999.

In 1998, the government spent Rs676.5 million as capital expenditure to produce 265 100 t of fish valued at Rs28 222 480 (calculated at an average price of fish per kg as Rs142 irrespective of price differences; adopted and modified from Sri Lanka Fisheries Year Book 1999). The Government thus spent Rs255 •kgfish^{-1} in capital expenditure.

In 1998, the total GDP recorded was Rs985 586 million and the contribution of the fisheries sector to GDP amounted to Rs24 823 million (2.5% of GDP). If the capital expenditure on the fisheries sector (Rs676.5 million) is taken as a percentage of the fisheries sector contribution to GDP, the fisheries contribution comes to 2.7%, which is equivalent to the treasury allocation to the fisheries sector.

Foreign Assistance

Development efforts in the fisheries sector have been supported by foreign assistance through loans, technical assistance, grants and regional cooperation projects across the multilateral and bilateral funding agencies. ADB, UN/FAO, UNDP and World Bank are the multilateral donors. Abu Dhabi fund, CIDA, DANIDA, EU. GTZ, JICA, KOICA, NORAD,

Table 20. Summary of the capital expenditure in million Rs by the MFARD.

Year	MFARD	DFAR#	Total
1986	214.0	N/A	214.0
1987	192.8	N/A	192.8
1988	185.5	N/A	181.5
1989	242.4	N/A	242.4
1990	96.3	23.7	120.0
1991	50.4	49.7	100.1
1992	137.2	117.1	254.3
1993	118.0	94.7	212.7
1994	*	*	*
1995	436.3	77.7	513.0
1996	289.5	104.0	392.5
1997	557.7	22.0	576.7
1998	637.0	39.5	676.5
1999	1 270.2	20.0	1 290.2
2000**	1 171.8	19.4	1 191.2

Source: Ministry of Finance (MF) 1986 - 2000.
Note: * There was no national budget
** Estimate
# Department of Fisheries and Aquatic Resources
N/A = Not available

ODA, SIDA and USAID are among the bilateral donor agencies.

During 1972 - 98, the total foreign assistance to the fisheries subsector amounted to US$130 million. Over the 15 year period (1983 - 98), 20 fisheries projects amounting to US$60 million were implemented with technical assistance grants from ADB, FAO, JICA, SIDA and UNDP. Through these projects, the following activities were undertaken in the fisheries sector:

i. Purchase of new fishing boats and gear;
ii. Institutional strengthening;
iii. Development of inland fisheries and coastal aquaculture;
iv. Improvement of post-harvest facilities;
v. Fish stock assessment;
vi. Coastal fisheries management;
vii. Improvement of living conditions of fishers;
viii. Infrastructure facilities including development of fishing harbours and anchorages.

Catch-Effort Analysis

Past experience has shown that biological assessment alone did not help much in the management of fishery resources in Sri Lanka (Fernando 1984). The lack of information pertaining to resources, technology and socioeconomic aspects of the small-scale fisheries has hindered the planning and development of an effective management scheme.

A study on bio and socioeconomics of small pelagic fisheries in the western coastal waters of Sri Lanka built an information base for policies to solve the conflict between the purse seine fishers and other small scale fishers (Dayaratne and De Silva 1995). With a similar objective, Vidanage and Wimalasena (2000) undertook a socioeconomic study of a small tuna fishery using ring-nets and gillnets on the southern coast. The economics of fishing with various craft-gear combinations in different localities was compared by Fernando (1984) and Wimalasena and Rupamoorthy (1998).

Materials and Methods

Secondary data used in this study were obtained from various sources such as the National Aquatic Resources Research and Development Agency (NARA), Ministry of Fisheries and Aquatic Resource Development (MFARD) and the other institutes. The information on costs associated with coastal fishing operations and the fish prices were gathered from the following:

1. Bioeconomics of fishing for small pelagic fish along the southwest coast of Sri Lanka (Dayaratne and De Silva 1995)

2. Comparative study on the economics of large and small scale fishing operations in Sri Lanka (Wimalasena and Rupamoorthy 1998), Biosocioeconomics of ring net and gillnet fishing for small tuna on the southern coast of Sri Lanka (Vidanage and Wimalasena 2000), Biosocioeconomics of demersal fisheries off Negombo on the west coast of Sri Lanka (Maldeniya 2001), Cost and profitability of small scale fishing operations in Sri Lanka (Fernando 1984).

Fisheries statistics were gathered from the Department of Fisheries (MFARD).

Cost

Costs are differentiated into fixed cost and variable cost. Fixed cost (FC) constitutes those items that in the short-run cannot be varied by the fishers. This includes cost of depreciation of fishing assets (craft and gear), license and insurance fee. Fishing crafts operating in coastal waters are generally not insured, but gear has had to be licensed since 1998.

The annual depreciation (D) cost was estimated as

$$D = P/L,$$

where
P = purchasing price of fishing assets
L = economic life in years

Fixed cost (FC) was estimated as

$$FC = D + l,$$

where
D = depreciation cost
l = license fee.

Variable cost (VC) is the sum of costs of all inputs that are incurred only when the fishing unit operates. There are two kinds of variable cost namely, operational cost (fuel, ice, bait, food, maintenance etc.) and labor cost (crew share). Thus the total cost (TC) is

$$TC = FC + VC.$$

All cost items were generally calculated on an annual basis but in this study cost items were assigned in proportion to fishing effort (fishing day). The number of days of fishing per annum was taken as 240 for all coastal fisheries except the demersal fisheries in Negombo area. For the demersal fisheries, the number of fishing days was considered to be 300.

Revenue

The revenue of fishing operations was estimated by multiplying the catch by its unit price.

Sharing System

The income of crew is derived from divisible income (revenue - operational cost) according to the prevailing sharing system. Craft owner and crew generally base the share system on acceptable norms.

Profitability

Profitability is the margin between revenue and cost. The profitability measures used include operating or gross profit and net profit or financial profit.

$$\text{Gross profit} = TR - VC,$$

where
TR = Total revenue
VC = Variable cost

$$\text{Net profit} = TR - TC.$$

A fishing unit is expected to continue operating as long as a gross profit is earned. Net profit is a prerequisite for the long-term viability of a fishing unit.

Coastal Fishing Operations

Coastal fisheries mainly target pelagic resources (small and large), demersal resources, and shellfish such as prawns, lobsters and crabs. The present study is limited to pelagic and demersal fisheries.

Small Pelagic

Small pelagic fishing is mainly conducted with small mesh gillnets and also by beach seine. Small mesh gillnets vary normally from 0.5” to 1.75”. They target anchovies and sardines, mainly spotted sardinella (*Ambligaster sirm*). Outboard motor 17 - 22ft (5m - 7m) FRP boats and motorised traditional crafts are mainly engaged in small mesh gillnet operations.

Large Pelagic

Medium mesh (2.5” - 3.5”), large mesh (5” - 6”) and ring nets (1.2” - 2.5”) are mainly used in large pelagic fishing. Two kinds of crafts, 3.5 ton 30 - 32ft (9m - 10m) IBM (inboard motor boats) and 17 - 22ft (5m - 7m) FRP OBM (outboard motor boats), are generally involved in drift-net fishing. Ring-nets are operated with motorized out-trigger canoes called ‘*vallam*’. Both vessels target small tuna species namely, *Auxis thazard* (frigate mackerel), *Auxis rochei* (bullet tuna) and *Euthynnus affinis* (kawakawa).

Demersal

In the Negombo area, demersal fishing is conducted mainly with FRP OBM boats. In addition, some of the 3.5 ton inboard motor prawn-trawling boats conduct fishing during the lean season for prawn trawling. The main fishing methods operating in the area are hand-line, bottom long-line, bottom set gillnet, trammel net and a few spear fishing units. Two types of hand-line are used, hand-line alone or combined with small mesh drift nets.

Economic Aspects of Coastal Fishing

The craft-gear combinations engaged in major coastal fisheries are summarized in Table 21.

Capital Investment

Average replacement costs of assets were used to find investment costs. Table 22 provides the investment cost of fishing assets in different fisheries.

Table 21. Types of fishing craft engaged in different fisheries in Sri Lanka.

Fishing craft	Fishery		
	Small pelagic	Large pelagic	Demersal
17 - 22′ OBM	Small mesh gillnet	Medium mesh drift net	Hand-line, bottom long-line, trammel net, bottom set gillnet
3.5 ton IBM	–	Large/medium mesh gillnet	–
Traditional craft-OBM	Small mesh gillnet	Medium mesh gillnet/Ring net	–

Table 22. Investment costs of fishing assets in Sri Lanka.

Craft details	Investment Cost (Rs)		Depreciation Cost (Rs) daily equivalent		Economic life years	
	17 - 22′* OBM	Traditional craft OBM	17 - 22′ OBM	Traditional craft OBM	17 - 22′ OBM	Traditional craft OBM
Hull	43 500	72 411	11.33	18.85	16	16
Engine	72 409	74 117	30.17	30.88	4	4
Fishing gear						
Small mesh drift net	25 000	25 000	34.72	24.72	3	3
Medium mesh drift net	73 409	73 409	101.96	–	3	3
Ring net	–	87 823	–	121.98	–	3
Bottom long-line	9 245	–	15.41	–	2	–
Trammel net	26 115	–	29.02	–	3	–
Bottom set gillnet	30 575	–	33.97	–	3	–

Note: * 5m - 7m outboard motor boats.

To estimate the depreciation costs average economic life was calculated. The average economic lifetime as well as the estimated depreciation costs of the assets adjusted to daily equivalents are given in Table 22.

Variable Cost

The variable costs of a fishing day using various craft-gear combinations is given in Table 23.

Labor is the most important input in all fishing activities followed by fuel cost. In the ring-net fishery labor costs accounted for 64% of the variable cost. In the hand-line and bottom long-line fisheries, bait cost is more important than fuel cost.

Fishing Price and Revenue

Coastal fisheries are multi-species and multi-gear. Thus the unit price of the catch varies with the gear

Table 23. Daily variable costs by different craft-gear combinations in Sri Lanka.

Craft-gear combination	Cost items (Rs)						Variable cost per fishing day
	Fuel	Bait	Food	Ice	Labor	Repairs	
Large pelagic							
17 - 22'OBM/DN	439.00		217.80		736.90	330.80	1 718.50
TR OBM/RN	689.20		327.90		3 085.90	237.90	4 340.00
Small pelagic							
17 - 22'OBM/DN	309.34		96.68		219.33	N/A	1 126.15
TR OBM/DN	N/A		N/A		148.70	N/A	884.37
Demersal							
17 - 22'OBM/HL	286.70	344.93	78.20	93.65	996.78	N/A	1 852.29
17 - 22' OBM/BLL	369.57	409.84	107.71	43.13	1 413.20	N/A	1 611.09
17 - 22' OBM/BTN	281.97				459.51	N/A	795.88
17 - 22' OBM/BSN	331.69				835.30	N/A	1 219.70

Note: DN = Drift net RN = Ring net HL = Hand-line OBM = Out board motor
BLL = Bottom long-line BTN = Bottom trammel net BSN = Bottom set gillnet. TR = Traditional crafts (*Vallam*)
N/A = Not Available

Table 24. The average daily revenue of fishing operations in Sri Lanka.

Fishing gear	Unit price of fish (Rs)	Daily revenue (Rs)
Large pelagic		
17 - 22'OBM/DN	44.90	2 087.85
TR OBM/RN	55.30	7 819.42
Small pelagic		
17 - 22'OBM/DN	NA	808.50
TR OBM/DN	NA	
Demersal		
17 - 22'OBM/HL	89.68	2 098.51
17 - 22' OBM/BLL	88.12	2 613.64
17 - 22' OBM/BTN	54.76	1 024.01
17 - 22' OBM/BSN	43.97	1 776.83

used. The average unit price by different gear and the estimated daily revenue are given in Table 24.

Lowest revenues were for small pelagic fish in the gillnet fishery, due to relatively low prices and low catches.

Total Cost

The estimated daily total costs of fishing operations by different craft-gear combinations are given in Table 25.

Profitability

Table 26 presents the daily profitability for coastal fishing operations with different craft-gear combinations.

The variation of gross profit closely follows the variation of net profit. Ring-net and bottom long-line are the most profitable gear operating in the coastal waters. Trammel net, hand-line and small mesh gillnet earned low profits during 1998 - 99. All types of craft-gear combinations operating in coastal waters generated net profits, indicating the long term viability of the fisheries.

Income and Income Distribution

The income of the boat owner and the crew depends on the volume of the catch, fish price and running costs. The volume of the catch in turn depends on the size, quality and type of the catch and the marketing competition. The size and the type of the catch depend on the type of craft-gear combination used.

Table 25. Estimated daily total cost of fishing operations by different craft-gear combinations.

Craft-gear combinaton	Fixed cost (Rs)	Variable cost (Rs)	Total cost (Rs)
Large pelagic			
17 - 22'OBM/DN	143.46	1 718.50	1 861.96
TR OBM/RN	171.71	4 340.00	4 511.71
Small pelagic			
17 - 22'OBM/DN	76.22	1 126.15	1 202.37
TR OBM/DN	74.45	884.37	958.82
Demersal			
17 - 22'OBM/HL	41.50	1 852.29	1 893.79
17 - 22' OBM/BLL	56.91	1 611.09	1 668.00
17 - 22' OBM/BTN	70.52	795.88	866.40
17 - 22' OBM/BSN	75.47	1 219.70	1 295.17

Table 26. Profitability indicators of fishing.

Craft-gear combination	Gross profit (Rs)	Net profit (Rs)
Large pelagic		
17 - 22'OBM/DN	369.35	225.89
TR OBM/RN	3 479.42	3 307.71
Small pelagic		
17 - 22'OBM/DN	314.58	238.36
TR OBM/DN	305.23	230.78
Demersal		
17 - 22'OBM/HL	246.22	204.72
17 - 22' OBM/BLL	1 002.55	945.64
17 - 22' OBM/BTN	228.13	157.61
17 - 22' OBM/BSN	557.13	483.66

Table 27. Crew size and sharing system between boat owner and crew by craft-gear combination.

Craft-gear combination	Crew size	Sharing system: Boat owner	Sharing system: Crew
Large pelagic			
17 - 22'OBM/DN	2.3	1/2	1/2
TR OBM/RN	7.6	1/3	2/3
Small pelagic			
17 - 22'OBM/DN	2	1/2	1/2
TR OBM/DN	2	1/2	1/2
Demersal			
17 - 22'OBM/HL	4	1/5	4/5
17 - 22' OBM/BLL	2	1/2	1/2
17 - 22' OBM/BTN	2	1/2	1/2
17 - 22' OBM/BSN	2	1/2	1/2

Table 28. Income distribution between boat owners and crew members.

Craft-gear combination	Net revenue (Rs)	Net income (Rs): Boat owner	Net income (Rs): Crew
Large pelagic			
17 - 22'OBM/DN	1 106.25	829.69	212.74
TR OBM/RN	6 565.32	2 764.31	575.91
Small pelagic			
17 - 22'OBM/DN	533.91	400.44	133.48
TR OBM/DN	453.93	340.45	113.48
Demersal			
17 - 22'OBM/HL	1 243.00	497.20	248.60
17 - 22' OBM/BLL	1 639.74	1 229.80	409.94
17 - 22' OBM/BTN	687.64	515.73	171.91
17 - 22' OBM/BSN	1 392.42	1 044.33	348.11

Generally, the boat owners are engaged in fishing. They earn a crew share in addition to the capital share. The number of crew engaged in different fisheries and the sharing system is summarized in Table 27.

The income distribution between boat owner and crew is listed in Table 28.

Pure Economic Profit

Opportunity Cost of Fishing

The pure economic profit from the fishery was estimated by deducting the opportunity cost of labor and capital from the income earned by the owners and crew. The opportunity cost of an owner's capital is the income that could be derived from the most profitable investment next to fishing. The opportunity cost of capital investment was computed using the prevailing interest rate for fixed deposit of 12% in 1999, multiplied by total investment.

In coastal fisheries, in most instances, the boat owner also functions as a crew-member. The owner gets the pure profits share of labor. The opportunity cost of the owner's labor is the income foregone by managing his fishing gear instead of working in another job. The average skilled labor wage rate was Rs225•day^{-1}, (US$3.18 at 1 US$ = 70.77 Rs in 1999; source: oanda.com) in 1999.

Table 29. Estimated pure profit of boat owners and crew per day.

Craft-gear combination	Pure profit (Rs)		Resource rent (Rs)
	Boat owner	Crew member	
Large pelagic			
17 - 22'OBM/DN	510.04	32.74	542.78
TR OBM/RN	2 422.14	395.91	2 818.05
Small pelagic			
17 - 22'OBM/DN	104.99	46.52	58.47
TR OBM/DN	29.50	66.5	96.00
Demersal			
17 - 22'OBM/HL	139.25	48.60	187.85
17 - 22' OBM/BLL	868.80	209.94	1 078.74
17 - 22' OBM/BTN	28.19	28.09	56.28
17 - 22' OBM/BSN	674.15	148.11	822.20

Resource rent is a kind of 'wage' for some fixed resource which is necessary for and valuable in a transaction e.g. use of boat.

The pure profit of boat owner = Net income - opportunity cost of capital + opportunity cost of labor.

The opportunity cost of crew labor was calculated from the average wage of unskilled labor of Rs180•day^{-1}.

The pure profit of a crewmember = Net income - opportunity cost of labor.

The estimated pure profit of fishing is given in Table 29.

Consideration of a wide range of data and information is necessary to examine the social and economic dimensions of coastal fisheries. In Sri Lanka, such data are distinctly limited with respect to catches and landing. The collected data are also unreliable. On this account, a comprehensive database comprising the data collected periodically by the DFEO Division as the basis on the socioeconomic profile of coastal fisheries is essential for the formulation of practical fisheries policies. Piecemeal measures based on scanty irregular data could scarcely effect any sustainable development in the fisheries sector.

Conclusion

Coastal fisheries play a dominant role in the total fish production and employment of Sri Lanka. Though Sri Lanka is endowed with an extensive sea area and fishing has been a chief source of livelihood of coastal communities since time immemorial, fishing has not been able to adequately harness the resources of the sea for the well-being of the country. Coastal fisheries typically are the employer of last resort due to the open access nature of the fisheries. Many social and economic conflicts arise due to the over-supply of labor. Even though the government has invested millions of rupees in the fishery sector over the years, problems of poverty in coastal fishing communities are particularly serious, especially among those engaged in traditional fishing operations. Exploitation by middlepersons is one of their problems.

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A Preliminary Analysis on the Socioeconomic Situation of Coastal Fishing Communities in Vietnam

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Abstract

Fish production in Vietnam increased rapidly from 420 000 t in 1981 to 1 130 680 t in 1998. Likewise, there was an expansion in the number of motorized fishing boats from 29 584 units with an average horsepower (HP) of 19.8 boat^{-1} in 1981 to 71 800 units with an average HP of 26.2 in 1998. In 1995, fish production was valued at VN$2 475 billion (US$0.02 billion at 1 US$ = 11 041 VN$; source: oanda.com). However 93% of the total fishing boats in Vietnam have engine capacity of less than 84 HP, thus fishing operations are still small scale and fishing grounds are limited to the coastal waters. The infrastructure facilities for fishing operations and post-harvest are still minimal.

Fisheries contribute 3% of the gross domestic product (GDP) in Vietnam. In 1990, the GDP of fisheries was VN$1 281 billion and reached VN$6 664 billion (US$0.60 billion) in 1995. Fisheries labor in Vietnam includes labor for aquaculture, processing, fishery services and fishing. Fisheries labor increased from 1 860 000 persons to 3 030 000 giving a relative increase of 63% from 1990 to 1995. The average level of fish consumption in Vietnam is estimated at 13.5 kg•capita^{-1}.

In 1980, there were 28 021 motorized fishing boats that steadily increased to 71 800 in 1998. Likewise, the average engine capacity per boat increased from 19.8 HP in 1980 to 26.2 HP in 1998. The types of fishing gear that provide substantive catch in Vietnam are the trawl, purse seine, gillnet, long line, hand line, lift net and stick-held falling net. The fishing grounds in Vietnam can be classified into: (a) North: trawl, gillnet, lift net, purse seine, hook and line fishery; (b) Central: purse seine, lift net, gillnet, trawl fishery; and (c) South: trawl, purse seine, gillnet and line fishery. In terms of fish catch and net profit contribution the most important are the trawl and purse seine fisheries. Fish production in the Southern provinces is more developed compared to the northern and central provinces.

Most of the commercial scale fishing vessels bring trash fish or by-catch to the shore for fish sauce or fish powder processing. Only trawlers that fish offshore and thus stay at sea for several days discard the trash fish.

An attempt to estimate the maximum sustainable yield (MSY) of the coastal fishery resources in Vietnam was made. Using the Schaefer and Fox Models, it was found that MSY is equal to 976 378 t and 1 006 850 t respectively, as against the annual catch of 1 130 660 t, implying biological over-fishing. Thus, the total fish catch in the traditional fishing areas of Vietnam is beyond the sustainable limit of 582 000 t. The Government of Vietnam has therefore developed policies and plans to reduce the fishing pressure on the coastal waters and pursue development of offshore fisheries.

Socioeconomic Profile

Review of the Status of Fishery Resources

In general, small scale fisheries predominate in Vietnam. Fishing boats less than 84 HP constitute 93.6% of the total fishing boats. Almost all fisheries activities have been conducted in coastal waters. In recent years, the number of fishing boats and the total horsepower used have continuously increased. In 1987 - 97, the total horsepower increased from 597 022 HP to 1 880 000 HP (an increase of 3.15 times) while the total catch increased from 624 445 t to 1 130 660 t (only 1.81 times as much). However, in 1997 the total catch declined to 0.6 t•HP^{-1} compared to 1.04 t•HP^{-1} in 1987.

The over exploitation in coastal areas has become very apparent. The Government of Vietnam has been attempting to reduce the fishing effort in coastal areas and promoting a development program for offshore fisheries.

Together with the development of fisheries, the infrastructure, fishing techniques and catches have increased as shown in Table 1.

Table 1. Comparison of Vietnamese fisheries in 1980 and 1998.

Criteria	1980	1998
Number of mechanized fishing boats	28 021	71 800
Total Horsepower (HP)	553 995	1 880 000
Average HP•boat^{-1}	16.3	26.2
Catch per year (t)	419 740*	1 130 660

Source: MOFI-Vietnam 1995 - 98.
Note: * catch in 1981.

Because 93.6% of fishing boats in the region are less than 84 HP, fishing grounds are mainly in near-shore waters (< 50 m). Thus, the majority of catches (estimated at 80%) come from coastal fishing grounds. Based on results of the Research Institute of Marine Fisheries (RIMF) by Bui Dinh Chung et al. (1999), the total allowable catch in the coastal waters for depths of less than 50 m is 582 200 t. The catches in coastal seawaters have been over this limit since 1992. During that period, the increasing number of fishing boats contributed to a decrease in mean catch•HP^{-1} from 1.14 t•HP^{-1}•year^{-1} in 1984 to 0.6 t•HP^{-1}•year^{-1} in 1998. As the mean catch per boat unit decreased, fishers tried to raise the fishing effort by:

- increasing the number of hauls per fishing day or number of fishing days per year
- reducing the mesh size, thereby contributing to an increase in the ratio of juvenile caught
- applying various fishing techniques, such as using high-powered light, different kinds of fishing gear or other means with negative impacts on the environment.

Given the above fishing practices, the Ministry of Fisheries is seeking ways to reduce the fishing pressure in near shore waters.

Status of Fisheries in Vietnam

Fisheries in Vietnam are small scale, multi species, multi-gear and utilize traditional fishing techniques. Fishers have limited ability for capital investment.

The Fishing Fleet Structure and Fishing Area

The number of fishing boats increased considerably from 28 021 mechanized boats in 1980, to 71 800 boats in 1998. For the whole period, the average annual percentage growth in the number of fishing boats was 5.3%. The mean HP•boat^{-1} of 16.3 in 1983 increased to 26.2 in 1998.

The size and the number of fishing boats differ from region to region. In 1997, there were 20 409 fishing boats having an average of 16.4 HP•boat^{-1} in Northern Vietnam, 26 676 fishing boats and

16 HP•boat^{-1} in Central Vietnam, and 23 971 boats and 47.7 HP•boat^{-1} in the South. Those provinces where fisheries have developed strongly with many big fishing boats are Ba Ria-Vung Tau, Ca Mau and Kien Giang.

Catches of Marine Fisheries

The growth in catch rates of marine fisheries from 1981 to 1998 is provided in Table 2. The total fish catch increased from 419 749 t in 1981 to 1 130 660 t in 1998. However, when total HP is taken into account, before 1994 the total fish catch increased rapidly after which it became stationary. The total HP in 1998 had increased 4.14 times as much as that in 1981 while the total catch had increased only 2.7 times.

Fishing effort in coastal waters is still expanding since fishers in the coastal provinces are dependent on the near shore waters for livelihood. To address the issue, the Ministry of Fisheries has attempted the following approaches:

1. Provided funds to fishers as credit for invested capital to encourage them to shift fishing from near shore to offshore fisheries. This allowed the fishers to raise a bank loan at low interest rates of 0.61% to 0.81%.

2. Implemented programs of coastal aquaculture to provide alternative work.

3. Limited the number of small fishing boats active in coastal waters.

Table 2. The growth in total fish catch of marine fisheries in Vietnam from 1981 to 1998.

Year	Total catch of whole country (t)
1981	419 740
1982	476 597
1983	519 384
1984	530 650
1985	550 000
1986	582 077
1987	624 445
1988	622 364
1989	651 525
1990	672 130
1991	730 420
1992	737 150
1993	793 324
1994	878 474
1995	928 860
1996	962 500
1997	1 078 000
1998	1 130 660

Source: MOFI-Vietnam 1995 - 98.

Contribution of the Fisheries Sector to Economic Growth and Welfare

The Contribution of Fisheries to the National Economy

The annual total fish production (Table 3), in the Southern provinces is higher than that in the northern and central provinces. The average annual level of fish consumption in Vietnam is currently estimated at 13.5 kg•capita^{-1}.

Fisheries in Vietnam have rapidly grown to become one of the key economic sectors of the country. The fisheries sector contributes 3% of the total GDP. The average annual increase in GDP (gross domestic product) for the fisheries sector is 40%. In 1990, the GDP of the fisheries sector was 1 281 billion VN$ and in 1995 reached 6 664 billion VN$ (US$0.60 billion). The average indicator of GDP per fisher is about 160 US$•person^{-1}•year^{-1}, which is far below the average per capita standard of living throughout the country. Thus, fishers remain below the poverty line.

Contribution of the Fishing Industry to Income and Employment

From 1990 to 1995, fisheries labor (in aquaculture, processing, fishery services and fishing) increased from 1 860 000 to 3 030 000 persons giving a relative increase of 62.9%. The labor consisting of fishers only increased from 270 587 persons in 1990 to 420 000 persons in 1995, contributing

Table 3. Total value (billion VN$) of fish production from Vietnam 1986 - 95.

Year	Whole Country	Key Provinces		
		North	Central	South
1986	987.8	90.8	198.6	561.7
1987	1 074.7	84.6	202.7	584.6
1988	1 325.5	82.1	207.5	624.1
1989	1 449.0	79.5	213.5	620.1
1990	1 500.3	91.1	214.5	668.6
1991	1 561.9	114.5	147.4	947.9
1992	1 662.2	132.2	161.1	1 008.3
1993	1 780.0	422.2	168.9	1 131.7
1994	2 224.2	154.8	220.6	1 520.9
1995	2 475.0	180.6	284.5	1 574.9

Source: Bureau of Statistics 1996.
Conversion: 1 US$ = 11 041 VN$ (in 1995); source: oanda.com

55.2% to the total increase in employment. On average, fishing labor increased by 29 882 persons•year^{-1} during this period.

In 1995, 420 000 employees worked for marine capture fisheries, of which 86% was male and 14% was female. Among these, 91% were employed by privately-owned businesses, 8.6% joined fishing cooperatives and 0.43% worked for state-owned enterprises. Of the 14% female employees, most are middle-persons or engaged in small fish processing businesses, sewing or making fishing nets. Of the total of 420 000 in 1995, 73% were involved in smallscale fisheries and 27% were engaged in offshore and commercial scale fisheries (Table 4).

Institutional Factors in the Fishery Sector

Four types of fishing enterprises exist in Vietnam's fisheries sector. These are state-owned fishing enterprises, fishing cooperatives, fishing groups and private businesses. The state-owned fishing enterprises are characterized by steel-hulled boats equipped with engines of more than 135 HP. In recent years, due to a reduction of the resource and management inflexibility, these enterprises have received very low economic returns, and the number of boats has declined.

Table 4. Number of persons involved in fisheries labor in Vietnam, 1990 - 95.

Year	Number of persons ('000)	
	Various fisheries activities	Fishers
1990	1 860	27 058
1991	2 100	27 508
1992	2 350	33 892
1993	2 570	36 348
1994	2 810	38 953
1995	3 030	42 000
Relative increase (times) 1995 - 90	1.629	1.552

Source: MOFI-Vietnam 1995 - 98.

After 1985, most of the fishing cooperatives withdrew because of poor economic returns (Table 5). In 1997 new cooperatives were established, with the purpose of raising bank loans. Earnings are distributed according to a share system in which the proceeds of sales, after deducting operational expenses, are divided between a ship owner (65%) and crew members (35%).

Table 5. Changes in number of fishing cooperatives and fishing groups in Vietnam from 1985 - 97.

Year	Number of fishing cooperatives	Number of fishing groups
1985	673	2 205
1990	398	2 884
1995	95	3 773
1996	94	3 886
1997	184	5 542

Source: MOFI-Vietnam 1995 - 98.

Fishers form groups to share investment costs. Private businesses in marine fishing can be classified according to: (a) households owning fishing boats and employing less than 5 persons; (b) skippers owning one or two fishing boats and employing more than 5 staff and (c) private capital owning more than two fishing boats with > 250 HP capacity. From 1985 to 1996, these three groups increased rapidly in number, but in 1997 the increase was not substantive (Table 6). This shows inter-generational change in the number of fishing households and boat owners. With the exception of boat owners with more than 250 HP, the numbers of skippers owning other categories of boats increased more than three times between 1985 and 1997. The highest growth rate was recorded for owners of boats of more than 90 HP. The private sector in Vietnam rapidly expanded as evidenced by a 2.45-fold increase in the number of boats with HP greater than 250.

In general, the educational level of fishers is low, with 68% not having finished primary school, about 20% having finished primary school, nearly 10% attaining secondary school level, and 0.65% reaching high school or college graduation.

Fisheries Management

The development of fisheries from 1980-1995 was very intense. The total fish catch grew from 419 740 t in 1981 to 672 130 t in 1990 and to 928 860 t in 1995. Concurrent with the expansion of total fish production, the number of fishing boats also increased from 29 594 units in 1984 to 68 000 units in 1995. However, this increase was in small and medium sized boats, suitable for coastal fishing grounds and the skills of the fishers.

In 1995 - 98, the sector was at a standstill. Although fish production increased the economic situation declined due to excessive growth of the fishing fleets in coastal waters. The productivity dropped from 1 $t \cdot HP^{-1} \cdot year^{-1}$ in 1987 to 0.6 - 0.65 $t \cdot HP^{-1} \cdot year^{-1}$ in 1995 - 98. Most of the fishing was in coastal waters with the total number of boats reaching 71 800 mechanized boats with a total of 1 880 000 HP, and 28 700 non-mechanized boats in 1998. The total fish catch in 1998 was 1 130 660 t but the fishing productivity was only 0.6 $t \cdot HP^{-1} \cdot year^{-1}$.

To improve the situation, the Ministry of Fisheries of Vietnam has developed policies and plans for the fisheries sector. These are:

1. Reduce the fishing pressure in coastal waters through:

   a. reduction in the use of fishing boats with engines of < 15 HP;

   b. spatial and temporal closure of fishing activities;

   c. limits on the number of small fishing boats;

   d. specifying the total allowable number of fishing boats by gear and by fishing grounds or sea area;

   e. promoting programs for aquaculture in the coastal waters as alternatives to small scale fishing.

2. Develop offshore fisheries as enumerated below:

   a. Running credit funds programs to support fishers in offshore waters where the resources are under-exploited. From 1997 to 1999, the Government of Vietnam provided a credit fund of 1 300 billion VN$ (US$92.8 million) at a low interest rate of 0.81% for new fishing boats and gear for offshore fishing. Other policies such as tax reduction, price supporting and low bank interest rates were developed to encourage offshore fishing.

   b. Investing and developing service systems through the following:

      - Establishment of fishing port systems and landing sites, such as construction of “Fisheries Services-Processing-Trading Centers”.

Table 6. Change in marine fishing private enterprises in Vietnam from 1985 - 97.

Type	1985	1990	1995	1996	1997
1. Household	10 180	20 595	25 337	26 920	27 426
2. Skippers:	1 325	2 004	3 143	3 730	4 105
- Own 2 small boats with 2 employees	967	1 556	2 284	2 706	2 951
- Own 2 boats > 90HP	173	244	474	674	718
- Own 1 boat > 250HP	185	204	385	530	436
3. Private capital					
- Own 2 boats > 250 HP	115	130	160	302	282

Source: Institute of Fishery Economic and Planning (IFEP) - DANID 1998.

- Aside from the existing 20 fishing ports operating in the provinces with quay length of 15 - 270 m, the Government has also funded another 16 fishing ports in the islands.

- Establishment and management of fish markets in fishing ports and landing places to promote export products. Development of more processing plants.

- Strengthening the building capacity of ship yards to provide good quality fishing boats for offshore fisheries; reducing the use of wood as material for boats; encouraging the use of steel and composite as material for boat hulls.

- Providing grants for research programs in marine resources and offshore fisheries development.

- Strengthening resource management and conservation by regulating fishing gear structure and controlling fishing fleets in near-shore and offshore waters.

- Supporting human capacity development to provide qualified and skillful captains, chief engineers, crews and scientists.

- Promoting the development of the economic components of the fisheries sector.

State-owned business enterprises for marine fishing and fisheries services should be developed to serve as bases for fishers involved in offshore fisheries. Cooperatives for offshore fisheries, shipyards, processing units and fisheries services should be encouraged. The Government should offer incentives to encourage fishers to invest in offshore fisheries. New processing units should be built, and alternative jobs for fishers should be provided in the fishing communities.

Fleet Operational Dynamics of Vietnamese Fisheries

The State of the Fishing Fleet

From 1983 to 1998, the number of fishing boats increased considerably from 29 117 mechanized boats to 71 800 boats, an annual average increase of 6.2%. The mechanization level rose as well, with an average horsepower per boat of 16.3 HP in 1983 expanding to 26.2 HP in 1998.

Figure 1 shows the rapid increase in the number of fishing boats from 1980 to 1994. This expansion was influenced by changes in government fishery management policies. Before 1985, when fisheries were managed and operated in the form of cooperatives, there were no proper fisheries techniques for the fishers, resulting in low marine capture fisheries production. After 1985, when Vietnam applied a new policy ("*Doi moi*" Policy), privately owned business and market mechanisms were accepted. Development of the fisheries sector was improved with a remarkable increase in number and size of boats, catch and productivity. During 1994 - 98, the increase in the number of boats was low in spite of the increase in the total horsepower. Fishing boats built in this period were high-powered engine boats which allowed for offshore fisheries.

Table 7. The total number of fishing boats and engine capacities in Vietnam, 1980 - 98.

Year	Total number of motorized fishing boats (unit)	Total engine capacities (HP)	Average horsepower per boat (HP·boat^{-1})
1980	28 021	553 915	19.8
1981	29 584	453 871	15.3
1982	29 429	469 976	15.9
1983	29 117	475 832	16.3
1984	29 549	484 114	16.4
1985	29 323	494 507	16.9
1986	31 680	537 503	17.0
1987	35 406	597 022	16.9
1988	35 744	609 317	17.0
1989	37 035	660 021	17.8
1990	41 266	727 585	17.6
1991	43 940	824 438	18.1
1992	54 612	986 420	18.1
1993	61 805	1 291 550	20.9
1994	67 254	1 443 950	21.5
1995	68 000	1 500 000	22.1
1996	69 953	1 543 163	22.1
1997	71 500	1 850 000	25.9
1998	71 800	1 880 000	26.2

Source: MOFI-Vietnam 1995 - 98.

The number of fishing boats by HP classification presented in Table 8, shows that the number of fishing boats of less than 45 HP comprises 85.5% of the total Vietnamese mechanized fishing fleet. The Southern provinces have more high-powered fishing vessels than the north and central provinces.

Fisheries Structure and Gear Types

Fishing operations in Vietnam are conducted using different types of fishing gear. High catch rates are mainly recorded using trawl, purse seine, gill-net, long-line, hand-line, lift net, and stick-held falling net. Fishing grounds in Vietnam can be classified into the following types: (a) North: - trawl, gillnet, lift net, purse seine, hook-and-line fishery, (b) Central: - purse seine, lift net, gillnet, trawl fishery and (c) South: - trawl, purse seine, gillnet and line fishery, see Table 9.

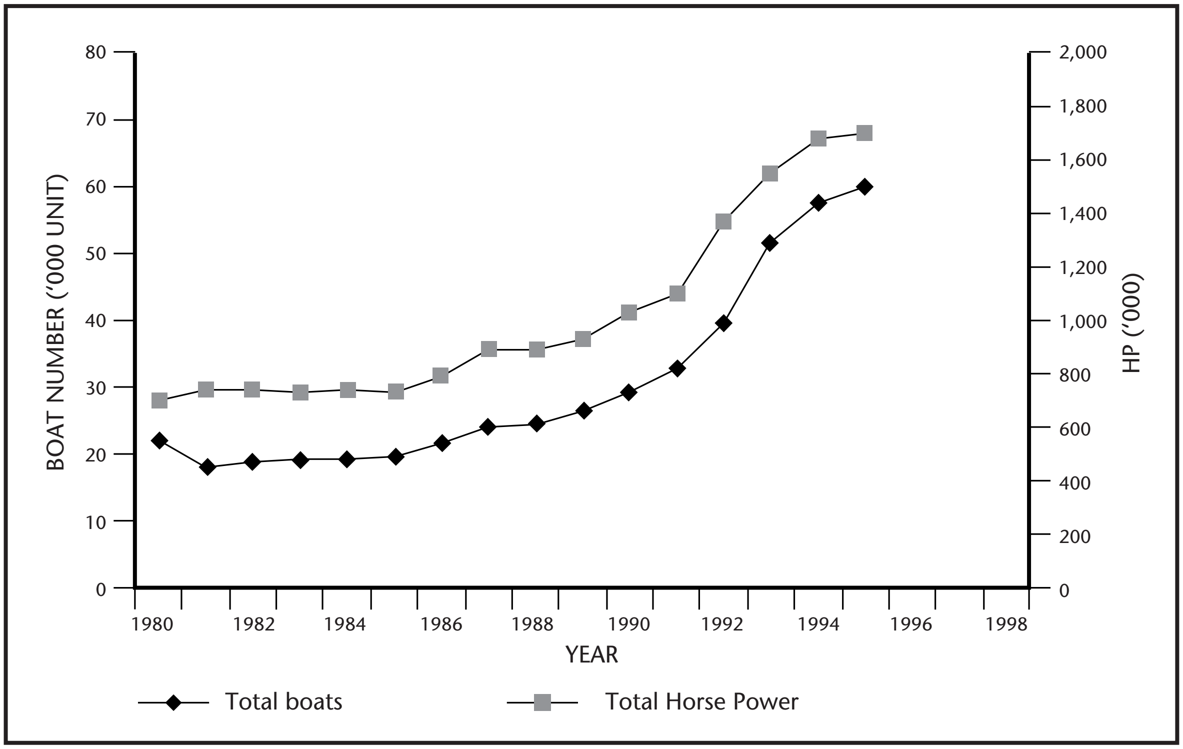

Fig. 1. Increase in the number of fishing boats during 1980 - 98.

Table 8. Number of fishing boats by horsepower capacity in Vietnam, October 1997.

	Number of fishing boats by horsepower capacity			
	North	**Central**	**South**	**Total**
Total motorized fishing boats	20 409	26 675	23 971	71 055
Average capacity (HP•boat^{-1})	16.4	16.0	47.7	26.8
< 45HP	19 161	24 651	16 988	60 800
46 - 84HP	198	1 839	3 922	5 959
85 - 150HP	57	185	1 459	1 701
151 - 200HP	21	0	416	437
250 - 400HP	19	0	928	947
> 400HP	0	0	21	21

Source: MOFI-Vietnam 1995 - 98.

Table 9. Total fish catch by type of fishing gear from the 14 provinces of Vietnam 1997.

	Fish catch (t) by fishing gear							
Fishing ground	**Total catch**	**Trawl**	**Purse seine**	**Gillnet**	**Hook-and-line**	**Lift net**	**Fixed net**	**Others**
North region (6 provinces)	73 703 100%	27 182 36.9%	4 880 6.6%	18 728 25.4%	4 773 6.5%	14 110 19.1%	1 240 1.7%	2 391 3.2%
Central region (4 provinces)	173 218 100%	31 078 17.9%	41 614 24%	34 674 20%	23 793 13.7%	36 534 21.7%	841 0.5%	4 504 2.6%
South region (4 provinces)	283 415 100%	169 958 60%	62 593 22%	18 729 6.6%	16 452 5.8%	– –	13 371 4.7%	2 322 0.8%
TOTAL (14 provinces)	530 336 100%	228 218 43%	109 087 20.6%	72 131 13.6%	45 028 8.5%	50 644 9.5%	15 452 2.9%	9 217 1.7%

Source: MOFI-Vietnam 1995 - 98.

Cost, Earnings and Profitability

The Development of the Trawl Fishery

The trawl fishery in Vietnam contributes 43% of the total marine capture production. Use of this fishing gear evolved in the different regions at various periods.

In the northern region, the trawl fishery was developed in state-owned fishing enterprises before 1985. At that time, almost all of the fishing boats used engines of more than 200 HP while the fishing pattern was single boat fishing (single trawl fishery). However, due to low economic returns, this gradually went into closure. Private businesses operating trawl fisheries mainly use small fishing boats of 15 to 84 HP constituting 99.3% of the total trawlers in the region. These fleets are used for shrimp trawling and operate in waters within 30 m depth.

In the central region, the trawl fishery is limited, due to the continental shelf sloping near to shore. Boats commonly employ an engine of 15 - 84 HP, constituting 98.4% of the total trawlers in the region.

In the Southern region, the wide and even continental shelf and abundant resources allow efficient trawl fishing, leading to a total of 7 798 trawlers. Of these, 23.5% or 1 838 trawlers utilize 90 - 750 HP engines. The capture fish production of trawlers in the region is 6.25 times as much as that of the north region and 5.47 times as much as that of the central region. The southern trawl fishery uses single trawl and pair trawl fishing methods.

Number and Size of Trawlers

According to the survey conducted in 1997 in 20 key provinces of Vietnam, the number of recorded trawlers was 18 240. Of these, 4 974 were from the north, 5 648 from the central region and 7 798 were found in the southern region. There were 4 941 small scale trawlers fishing in near shore waters in the Gulf of Tonkin, constituting 99.34% of the total trawlers in the region (Table 10). Fishing boats are small, almost all using engines of 15 - 30 HP, and with lengths of 9 - 13 m. Due to their small size, these trawlers mainly fish in coastal areas conducting one or two day fishing trips.

From the central region, 5 557 trawlers fished in the near-shore waters, i.e. around 98.44% of the total trawlers in the region. The fishing boats are bigger than those in the Gulf of Tonkin and have engines of 22 - 45 HP. The length of the boats ranges from 12 - 15 m, and one fishing trip takes about three to seven days.

There were 5 960 trawlers fishing in the near shore waters of the Southern region making up 76.4% of the total trawlers of the region. The fishing boats in this region were larger than those of the other areas, however there were only 1 838 trawlers with 90 - 750 HP capacity. The length of the boats ranges from 14 to 22 m. These boats can endure strong winds and one fishing trip can last from 15 - 25 days.

Table 10. The number of trawlers by horsepower class from 20 coastal provinces of Vietnam in 1997.

Fishing ground	Non-powered boat	< 23 HP	25-45 HP	54-84 HP	90 - 150 HP	155 - 225 HP	250 - 400 HP	440 - 750 HP	Total
North region	290 5.8%	3 351 67.4%	1 052 21.1%	248 5%	15 0.3%	8 0.16%	10 0.2%	– –	4 974 100%
Central region	– –	1 591 28.2%	3 540 62.7%	426 7.5%	89 1.6%	– –	2 0.03%	– –	5 648 100%
South region	– –	961 12.3%	2 589 33.2%	2 410 30.9%	877 11.2%	212 2.7%	732 9.4%	17 0.2%	7 798 100%
TOTAL	290 1.6%	5 903 32.2%	7 181 39.4%	3 084 16.9%	981 5.4%	220 1.2%	744 4.1%	17 0.1%	18 240 100%

Source: MOFI-Vietnam 1995 - 98.

Table 11. The cost of a wooden hull in the provinces of Vietnam 1997.

Province	Length of boat Lmax (m)	Length x Width x Height (m^3)	Cost price of hull (mil. VN$)
Da Nang	16.00 17.30 18.00 18.80	128.0 117.9 198.7 163.4	230 185 212 257
Khanh Hoa	15.20 16.20	88.9 137.2	150 152
Vung Tau	18.30 19.20 20.00	266.8 368.6 301.7	472 475 560
Kien Giang	13.45 15.00 17.40 18.00 18.94 19.91	70.3 102.0 187.6 183.4 247.0 260.7	225 270 350 460 620 640

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.
Conversion: 1 US$ = VN$ 13 861 11 705 in 1997; source: oanda.com

Investment Capital for Trawlers

Cost of Hull

The cost of the hull depends on the size, the style, the technical specifications of the boat, and the quality of wood. Shortage of wood has pushed the price up (Table 11).

The cost of the hull in Da Nang and Khanh Hoa (Central provinces) is often 44 - 47% lower than in Vung Tau and Kien Giang (Southern provinces), mainly due to the architectural structure which is less robust; thinner wood is used, and the boat is not strong enough to sail during bad weather.

Cost of Engine

An investigation of 81 single trawlers and 268 pair trawlers showed that fishers are using diverse kinds of engines, made in the USA, Japan, Germany and Russia. There are three main kinds of engine used, brand new engines, second hand engines and high-power truck engines. The cost of a second hand engine is 40% of a brand new one for the same power. Thus, second hand engines are commonly used for fishing boats. Fishers also use second hand truck engines with a restructured gearbox. The cost price of a truck engine is 16.9% that of a brand new boat engine and 42% that of a second hand.

Cost of Fishing Gear

The fishing gear depends on the size of the engine used. For a single trawl vessel the trawl can have a length of head-rope from 12 - 42 m depending on the size of the engine. The price for a complete set of gear was 10 - 70 million VN$ (US$854 - 5 980) in 1997. For pair trawling the trawls used often have a length of head-rope from 12 - 52 m with a cost price of 7-65 million VN$ (US$598 - 5 553) for a complete set of gear.

Total Investment Capital of a Trawler

Table 12 presents the level of investment capital for single trawlers by engine power and by province.

Table 12. The level of investment capital for a single trawler in Vietnam 1997.

Province	Number of boat owners interviewed	Horsepower class (HP)	Total investment capital (x1000VN$)	Number of crew members
Minh Hai	10	91 - 135	154 216	5 - 6
	1	136 - 200	68 115	10
	5	201 - 300	238 552	6 - 8
	3	301 - 450	335 917	8 - 10
Kien Giang	1	61 - 90	296 650	8
	2	91 - 135	254 485	8 - 9
	7	201 - 300	468 970	10 - 15
	32	301 - 450	601 954	12 - 16
	1	> 450	1 206 010	16
Vung Tau	7	301 - 450	582 775	11 - 12
	3	> 450	720 925	12 - 13
Nam §inh	1	201 - 300	370 000	9
	2	> 450	812 500	10

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.
Conversion: 1 US$ = 11 705 VN$ in 1997; source: oanda.com

Table 13. The level of investment capital for pair trawl fishing (2 boats) in Vietnam 1997.

Province	Number of pair trawler owners interviewed	Horsepower class (HP)	Total investment capital (x 1000VN$)	Number of crew members
Kien Giang	2	36 - 45	960 770	14 - 16
	2	61 - 90	840 315	10 - 14
	2	91 - 135	767 970	16
	1	136 - 200	1 021 990	16
	20	201 - 300	943 551	14 - 20
	7	301 - 450	1 271 667	16 - 20
Vung Tau	7	61 - 90	986 148	8 - 9
	29	91 - 135	785 683	8 - 10
	4	136 - 200	1 160 686	8 - 10
	3	201 - 300	1 130 270	10 - 15
Khanh Hoa	1	26 - 35	253 510	10
	8	36 - 45	339 160	10
	8	46 - 60	375 923	10
	1	61 - 90	375 330	10
Da Nang	1	26 - 35	169 104	8
	7	36 - 45	410 926	8 - 12
	4	46 - 60	470 217	7 - 14
	4	61 - 90	640 363	7 - 10

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.
Conversion: 1 US$ = 11 705 VN$ in 1997; source: oanda.com

The capital cost includes fishing boat and equipment on board, as well as a complete set of fishing gear. The level of investment capital for trawl fishing varies by province because the quality of hull, type of fishing gear etc. differs, depending on the areas fished.

Economic Significance of Trawl Fishery

To evaluate the economics of the trawl fishery, the following indexes will be used:

- Catch (t) is the total fish catch per year per one gear unit excluding the discarded species.
- Revenue (VN$) is the total amount received from selling marine capture fish per one year per one gear unit.
- Variable cost (VN$) is the total amount of expenses and costs for operating one gear unit in one year. Expenses can be fuel and oil, ice, salt, provisions, salary/wages for crew in cash, repair and maintenance of boat and fishing gear, insurance, taxes and other miscellaneous expenses.

The annual depreciation costs and the interest payments on initial investments are excluded from this list. Net profit (VN$) is the remainder of the gross revenue after subtracting variable cost.

Net profit = Total Gross Revenue - Total Variable Cost

Table 14 presents the results of the analysis for the 81 single trawlers and Table 15 for the 134 pair trawlers in Vietnam in 1997.

Purse Seine Fishery

Development of Purse Seine Fishery

The purse seine fishery is one of the most important fisheries in Vietnam, contributing 20% of the total marine capture production. In the Gulf of Tonkin, the purse seine fishery is not fully developed. Almost all the purse seiners are equipped with an engine of less than 23 HP. Their catch constitutes only 4.5% of the total production of the purse seine fleet. Because of their small size, purse seine boats operate in near-shore waters within 30 m depth. However, there are 800 purse seine boats of 45 - 60 HP from the Southern and the central provinces active in this region every year. These boats are capable of fishing offshore and are equipped with more modern fish devices than the local boats.

In the central region, the near shore waters are deep, but have abundant resources. Thus the purse

Table 14. Economic operation of single trawlers in Vietnam 1997.

Province	Number of boat owners interviewed	Horsepower class (HP)	Catch per year of single boat (t)	Revenue per year of single boat (mil VN$)	Variable cost per year of single boat (mil VN$)	Net profit per year of single boat (mil VN$)
Minh Hai	10	91 - 135	106 632	390 765	284 318	106 447
	1	136 - 200	145 566	500 000	434 620	65 380
	5	201 - 300	135 662	411 122	351 608	59 514
	3	301 - 450	118 361	671 883	456 416	215 467
Kien Giang	1	61 - 90	324 000	710 000	512 500	197 500
	2	91 - 135	129 250	525 123	442 925	82 198
	7	201 - 300	272 643	1 034 685	793 313	241 372
	32	301 - 450	347 275	1 189 261	935 324	253 937
	1	> 450	550 000	1 634 500	1 151 000	483 500
Vung Tau	7	301 - 450	617 130	1 225 729	948 210	277 519
	3	> 450	685 866	1 375 183	1 014 297	360 886
Nam §inh	1	201 - 300	–	353 711	239 806	113 905
	2	301 - 450	330 000	1 100 000	883 900	216 100
Hai Phong	1	301 - 450	466 191	1 236 800	1 161 096	75 704
	4	> 450	417 763	2 101 000	1 763 767	337 233

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.
Conversion: 1 US$ = 11 705 VN$ in 1997; source: oanda.com

Table 15. Economic operation of pair trawlers in Vietnam 1997.

Province	Number of boat owners interviewed (pair)	Horsepower class (HP)	Catch per year of 2 boats (t)	Revenue per year of 2 boats (mil VN$)	Variable cost per year of 2 boats (mil VN$)	Net profit per year of 2 boats (mil VN$)
Kien Giang	2	36 - 45	301.25	1 200.00	1 039.49	160.51
	2	61 - 90	231.30	885.500	693.431	192.069
	2	91 - 135	298.80	1 243.319	1 009.293	234.026
	1	136 - 200	400.00	1 664.00	1 270.00	394.00
	20	201 - 300	367.258	1 337.704	1 078.156	259.548
	7	301 - 450	396.529	1 569.200	1 270.636	298.564
Vung Tau	7	61 - 90	196.543	1 220.714	1 027.63	193.084
	29	91 - 135	194.23	1 098.113	880.433	217.68
	4	136 - 200	179.675	1 126.013	951.066	174.947
	3	201 - 300	661.40	1 521.550	1 056.00	456.55
Khanh Hoa	1	26 - 35	47.08	384.20	219.17	93.03
	8	36 - 45	35.063	246.25	185.40	60.85
	8	46 - 60	36.586	283.463	204.569	78.894
	1	61 - 90	49.23	346.00	255.88	90.12
Da Nang	1	26 - 35	56.32	370.00	259.26	110.74
	7	36 - 45	82.716	498.243	377.344	120.899
	4	46 - 60	42.739	397.50	309.401	88.099
	4	61 - 90	63.355	516.765	388.887	127.878
Nghe An	14	16 - 25	43.922	96.912	81.268	15.644
Nam §inh	1	91 - 135	210.00	396.600	310.360	86.240
	2	201 - 300	580.00	1 836.365	1 542.500	293.865
	1	301 - 450	440.00	1 980.000	1 774.500	205.500
Hai Phong	2	201 - 300	416.25	1 540.000	1 430.212	109.788
	3	301 - 450	736.666	3 167.949	2 354.960	812.989

Source: Research Institute of Marine Fisheries (RIMF)-DANIDA 1998.
Conversion: 1 US$ = 11 705 VN$ in 1997; source: oanda.com

Table 16. The number of purse seiners by horsepower class in 18 coastal provinces of Vietnam 1997 .

Fishing area	Non-powered boats	< 23 HP	25 - 45 HP	54 - 84 HP	90 - 150 HP	155 - 255 HP	250 - 450 HP	Total
North region	–	981 97.8%	9 0.9%	7 0.7%	6 0.6%	0	0	1 003 100%
Central region	142 5.4%	780 29.6%	1325 50.4%	372 14.1%	15 0.6%	0	0	2 634 100%
South region	–	213 13.8%	501 32%	404 26.3%	153 9.9%	146 9.5%	120 7.8%	1 537 100%
TOTAL of 18 provinces	142 2.7%	1974 38.2%	1835 35.5%	783 15.1%	174 3.4%	146 2.8%	120 2.3%	5 147 100%

Source: MOFI-Vietnam 1995 - 98.

seine fishery is more developed in this region. The number of purse seine boats of 25 - 45 HP constitutes 50.4% of the total fishing fleet of the region. The purse seine fleet in this area contributes 38.1% of the total production of purse seiners in the country. Purse seine boats are active in different fishing grounds around the region, and every year they fish in the Gulf of Tonkin and Southeast waters of Vietnam.

In the Southeast, the purse seine fishery is strongly developed. Fishing boats are equipped with engines of 15 - 400 HP. Of the total purse seine boats in the region, most have 25 - 45 HP engines, and many purse seine boats run big engines of 90 - 400 HP. The purse seine catch of the region constitutes 54.4% of total marine production of purse seiners in Vietnam.

Number and Size of Purse Seine Boats

Although the purse seine fishery constitutes 20.6% of total marine production of the whole country, the number of purse seine boats constitutes only 7.6% of the total number of fishing boats (Table 16). In 20 key provinces in 1997, the number of purse seine boats by region recorded is as follows.

In the Gulf of Tonkin, there were 1 003 purse seine boats, making 19.4% of the total number in the country. However, the common size purse seiner in this region was very small, with 97.8% of the boats less than 23 HP.

In the central region, there were 2 634 purse seine boats constituting 50.9% of the total number of purse seiners. Of this, 1 325 (50.4%) were purse seine boats of 25 - 45 HP, 780 (29.6%) were purse seine boats of less than 23 HP and 372 (14.1%) were purse seine boats of 54 - 84 HP.

For the Southeast, 1 537 boats made up 29.7% of the total number of purse seiners. Although the number of purse seiners was less than that in the central provinces, the catch was 1.5 times higher. This is because there were 419 big purse seiners (90 - 400 HP) in the southeast region, compared to only 15 in the central provinces.

Purse seine boats in Vietnam commonly have a length of 12.7 - 19.5 m with an engine size from 16 - 400 HP, and the big purse seiners are found mainly in the Southern provinces.

Investment capital for purse seine boats

Cost of Hull, Engine, Fishing Gear and Equipment

Most of the big purse seine boats fishing offshore in Vietnam belong to the Southern provinces such as Ba Ria-Vung Tau, Tien Giang, Ca Mau and Kien Giang. Costs are similar for the hull of a purse seiner and a trawler of the same size. As for the engines, it is very common for purse seiners to use second-hand engines, like the trawlers do.

For purse seiners 300 - 720 m long, 45 - 180 m high, the engines used are 33 - 300 HP, and the costin 1997 ranged from 110 million to 320 million VN$ (US$0.009 million to 0.027 million) depending on the height, the length of the net and the structure of the gear.

Modern fishing equipment is used. Most of the boats of more than 30 HP are using echo-sounder. The power supplied is 5 KW, 7.5 KW and 10 KW. Light systems and light-controlling techniques have been upgraded.

Total Investment Capital of a Purse Seine Boat

Table 17 presents the total investment capital of a purse seine boat, including hull, engine purchase and installment, complete set of purse seine gear, fishing equipment, light system, aggregating devices, and fishing machine systems. The level of investment capital depends on the size of hull, type of fishing gear etc.

Economic Factors for Purse Seine Fishing

The profit of a purse seine operation depends on several factors, such as fishing ground, size of boat, size of fishing gear and fishing technique. Therefore, in some cases, profits of big purse seine boats are lower than profits of smaller ones. The results of the analysis are shown in Table 18.

Line Fishery

Development of the Line Fishery

The line fishery has good prospects for fishing in the offshore waters of Vietnam. Production of the line fishery reaches 45 028 t•year^{-1}, constituting 8.5% of the total marine capture production of Vietnam.

The line fishery in the Gulf of Tonkin mainly catches squid. This small scale fishery has been

Table 17. Total investment capital for one unit of purse seiner in Vietnam 1997.

Province	Number of boat owners interviewed	Horsepower class (HP)	Investment capital for one boat (mil. VN$)	Crew members
Minh Hai	1	91 - 135	346.5	16
	2	136 - 200	652.805	14
	3	201 - 300	550.289	14 - 16
	8	301 - 450	697.143	14 - 16
Kien Giang	3	46 - 60	501.585	10 - 20
	11	61 - 90	281.528	10 - 20
	8	91 - 135	488.814	10 - 20
	5	136 - 200	639.775	12 - 20
	13	201 - 300	699.970	11 - 20
Khanh Hoa	2	26 - 35	277.815	15
	10	36 - 45	266.177	15
	2	46 - 60	324.683	15
	1	61 - 90	318.210	15
Vung Tau	12	61 - 90	493.442	18 - 25
	13	91 - 135	633.635	16 - 28
	5	136 - 200	747.014	16 - 25
	2	210 - 300	728.935	25
	6	301 - 450	917.759	20 - 28
Da Nang	4	61 - 90	804.575	14 - 15
	1	91 - 135	396.625	14
	3	136 - 200	664.083	13
Nghe An	2	46 - 60	150.00	12
	5	61 - 90	374.360	12 - 15
	4	91 - 135	416.45	12 - 16
	11	136 - 200	682.763	12 - 17

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.
Conversion: 1 US$ = 11 705 VN$ in 1997; source: oanda.com

widely introduced. Line boats are small and equipped with an engine of less than 30 HP. Squid line boats are often used in combination with purse seiners, lift netters, or stick-held falling net boats. Beside the squid line fishery, long-line fishing and line fishing for other species are very limited. Fishing boats are small and only active in near-shore waters. Production constitutes only 10.6% of the line fleet's total production.

The squid line fishery is strongly developed in the Central region. The long-line fishery for shark or ocean tuna is also developed. The common size of a long-line boat is 54 - 84 HP. The line fishery in this region provides 52.8% of the total production of the line fishery in the country. Long-line is also commonly used. Fishing boats of less than 20 HP use line of 2 - 5 km long with 900 - 2 000 hooks. Boats of 60 - 275 HP are using line 24 -30 km long with 8 000-10 000 hooks and are active in fishing grounds of 40 - 60 m depth. The main target species is pike conger (Congridae), which constitutes 80 - 90% of the total production of the fishery. The production of line fishing in the region constitutes 36.5% of the total line fishery production of the country.

Number and Size of Line Boats

In the Gulf of Tonkin, 1 364 (75.5%) of the total 1 806 line boats have motors of less than 23 HP, and the remaining 24.5% have 25 - 45 HP motors. In the Central region, 2 529 (55%) of the total 4 601 line boats have 25 - 45 HP motors, 1 490 (32.4%) have less than 23 HP and 439 (9.5%) have 54 - 84 HP. There are also 14 line boats of 90 - 150 HP.

Table 18. Economic analysis of purse seiners in Vietnam 1997.

Province	Number of boat owners interviewed	Horsepower class (HP)	Catch per year of one boat (t)	Revenue per year of one boat (mil. VN$)	Variable cost per year of one boat (mil. VN$)	Net profit per year of one boat (mil. VN$)
Minh Hai	1	91 - 135	213.95	517.53	404.378	113.152
	2	136 - 200	173.086	512.88	358.411	154.469
	3	201 - 300	159.482	422.644	340.038	82.606
	8	301 - 450	203.859	681.171	487.212	193.959
Kien Giang	3	46 - 60	195.102	251.013	171.805	79.208
	11	61 - 90	171.528	219.031	171.224	47.807
	8	91 - 135	160.824	236.398	174.111	62.287
	5	136 - 200	261.819	284.112	219.632	64.480
	13	201 - 300	250.37	337.756	284.887	52.869
Vung Tau	12	61 - 90	186.12	625.833	608.099	44.734
	13	91 - 135	188.628	728.205	584.688	143.517
	5	136 - 200	183.30	749.000	631.94	117.06
	2	201 - 300	252.00	930.250	786.016	144.234
	6	301 - 450	155.10	859.391	802.949	56.442
Da Nang	4	61 - 90	200.14	1143.33	676.754	466.576
	1	91 - 135	52.50	310.00	218.45	91.55
	3	136 - 200	126.453	460.00	283.814	176.186
Khanh Hoa	1	16 - 25	52.00	78.00	55.68	22.320
	4	26 - 35	168.00	252.00	175.155	76.845
	11	36 - 45	185.10	291.60	206.208	85.392
	2	46 - 60	81.00	121.50	96.658	24.842
	1	61 - 90	104.00	156.00	108.60	47.40
Nghe An	2	46 - 60	44.0	276.00	175.03	100.97
	5	61 - 90	41.9	288.90	158.857	130.043
	4	91 - 135	30.75	209.063	161.183	47.880
	11	136 - 200	45.93	407.372	282.875	124.497
Hai Phong	2	26 - 35	80.00	400.00	324.679	75.321
	12	36 - 45	63.90	332.33	258.22	74.613
	6	46 - 60	67.61	338.075	274.705	63.370
	9	61 - 90	61.893	299.745	241.803	57.942
	3	91 - 135	68.298	341.420	262.963	78.457

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.
Conversion: 1 US$ = 11 705 VN$ in 1997; source: oanda.com

In the South, there are a total of 5 085 line boats. Of these, 4 415 (86.7%) have less than 45 HP and 670 (13.2%) have 54 - 400 HP. Big line boats are mainly from the southern part of the region.

The line boats in Vietnam have engines in the range of 6 - 450 HP and the length of hull ranges from 8 - 21 m. Line boats of less than 35 HP are often active in near shore waters while those of more than 36 HP are capable of fishing offshore. However, in order to be able to fish offshore, fishing boats should have a running engine of more than 135 HP to endure rough weather. Fishers in the Southern region often use high-powered capacity engines for medium sized fishing boats to increase boat speed and quickly transport fish to shore, thereby receiving better economic returns.

Table 19. Number of hook-and-line boats by horsepower class for 20 coastal provinces in Vietnam 1997.

Fishing area	Non-powered boats	< 23 HP	25 - 45 HP	54 - 84 HP	90 - 150 HP	155 - 255 HP	250 - 450 HP	Total
North region	–	1 364 75.5%	442 24.5%	–	–	–	–	1 806 100%
Central region	132 2.9%	1 490 32.4%	2 529 55%	439 9.5%	11 0.2%	–	–	4 601 100%
South region	–	2 673 52.5%	1 742 34.2%	507 10%	123 2.4%	31 0.6%	9 0.2%	5 058 100%
TOTAL for 18 provinces	132 2.9%	5 527 48%	4 713 41%	946 8.2%	134 1.2%	31 0.6%	9 0.2%	11 492 100%

Source: MOFI-Vietnam 1995 - 98.

Investment Capital for Line Boats

Cost of Hull, Engine and Line Set

Like the purse seine fleet, the big line boat fleet is mainly in the Southern provinces. The cost of the hull of a line boat depends on the size, as for other types of fishing boat. The use of second hand engines is again very common.

Based on the target species (groups), the line fishery can be divided into a long line fishery for yellowfin tuna and big-eye tuna, a long line fishery for shark and a long line fishery for pike congers. The common capacity of fishing boats is 22 - 400 HP with a length of line ranging from 2 - 40 km. The cost by type of line fishery is listed below.

- Long line for pike conger - The length of the line depends on the size of engine. The average long line is 1.4 - 42 km with 900 - 10 000 hooks. The average price for long line of 1 000 m is 400 000 - 600 000 VN$.
- Long line for tuna - The length of the line is 18 - 32 km with 558 - 1 322 hooks. The average price for long line of 1 000 m is 1 - 1.4 million VN$.
- Long line for shark - The length of the line is 24 - 32 km with 620 - 1 322 hooks. The average price for long line of 1 000 m is 680 000 - 830 000 VN$.
- Long line for mackerel, hairtail scad - The length of the line is 10 - 18 km with 1 500 - 2 700 hooks. The average price for long line of 1 000 m is 154 000 - 250 000 VN$.

Total Investment Capital of a Line Boat

The investment capital of one line boat includes the hull, engine, a complete set of long line, navigational equipment and hauler for long line.

Economic Variables of the Line Fishery

Gillnet Fishery

The gillnet fishery is a very traditional method of fishing in Vietnam. However, gillnet boats are very small in size. Most of the gillnet boats are less than 45 HP. The number of non-powered gillnet boats comprises 10.6% of the total, while those less than 23 HP comprise 49.5%. These boats are active mainly in waters within 30 m depth, using a gillnet of short length and small height. The main target species of the near shore gillnet fishery is shrimp (captured by shrimp trammel net), cuttlefish (captured by cuttlefish trammel net) and some other nearshore demersal fish species.

Although the boats of the gillnet fishery are small in size, their number is high, with a total of 18 694 boats in 1997. The gillnet fishery in Vietnam is a small scale fishery.

Other Fisheries

Apart from trawl, purse seine, gillnet and line fisheries, there are several other kinds of fisheries in Vietnam. Total marine production of these comprises 14.1% of the total production from a total of 13 800 fishing boats. These are small in size and fish mainly in estuaries and near shore waters.

Table 20. Investment capital for one unit of hook-and-line boat in Vietnam 1997.

Province	Number of boat owners interviewed	Horse power class (HP)	Investment capital for one boat of hook-and-line (mil. VN$)	Crew members
Minh Hai	6	45 - 60	124.983	9 - 12
	3	61 - 90	119.100	8 - 12
	1	91 - 135	110.970	10
	2	136 - 200	172.010	8 - 12
Kien Giang	3	26 - 35	103.65	10
	8	36 - 45	237.25	10
	2	46 - 60	208.362	9 - 12
	3	61 - 90	286.37	10 - 12
	1	201 - 300	150.45	10
Khanh Hoa	1	26 - 35	164.95	10
	4	36 - 45	171.71	10
	6	46 - 60	169.00	5 - 10
	2	61 - 90	186.875	9 - 10
	2	91 - 135	313.15	10
Da Nang	2	26 - 35	219.00	14
	4	36 - 45	212.567	12 - 15
	2	46 - 60	265.737	14 - 15
	5	61 - 90	386.676	16 - 18
Nghe An	7	< 15	25.040	6
	8	16 - 25	29.317	7 - 8
	8	26 - 35	31.211	6 - 8

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

Discard and By-catch

In April 1989, the Ministry of Fisheries of Vietnam introduced the "Resource Protection Regulations". This regulation limits the allowed mesh size by gear and minimum length of fish for capture. Unfortunately, this regulation has not been strictly implemented.

The fishing grounds for small scale fisheries are in the coastal waters and estuaries. The mesh sizes of fishing gear actually used are often smaller than the ones allowed while prohibited fishing gear such as tow net and push net is still very much in existence. Some of the traditional gear is of very small mesh size leading to 30 - 80% of the catch coming from juvenile and trash fish.

Most of the commercial scale fishing boats bring trash fish or by-catch to the shore for fish sauce or fish powder processing. Only trawlers that fish offshore for many days, discard the trash fish. The rate of trash fish captured by trawlers of less than 90 HP is 80.7% of the total catch, and 50 - 60% for trawlers of more than 90 HP.

Concerns of Fisheries in Vietnam

Small scale fishing predominates in Vietnam and concerns about this are described below.

Size of Fishing Boats

Fishing boats are mainly constructed of wood, are small and not able to sail in bad weather and conduct long cruises. This limits the offshore fishing.

The size of the boat hull varies according to region. In the northern region, fishing boats commonly use 15 - 30 HP engines. The size of the hull is small, usually 12 - 13 m, and fishing operations are mostly in coastal areas. Fishing trips last for one or two days. Boats are bigger in the central region compared to that in the North. The common length of the hull ranges from 12 - 15 m and engines are 22 - 45 HP. One fishing trip lasts for 3 to 7 days.

The southern region of Vietnam has the largest fishing boats. The average length ranges from 14 to 22 m and the size of engine ranges from 33 to

Table 21. Economic variables for hook-and-line boat in Vietnam 1997.

Province	Number of boat owners interviewed	Horse power class (HP)	Catch per year of one boat (t)	Revenue per year of one boat (mil VN$)	Variable cost per year of one boat (mil VN$)	Net profit per year of one boat (mil VN$)
Minh Hai	4	46 - 60	6.84	127.535	107.654	19.881
	2	46 - 60*	33.28	343.55	275.328	68.222
	3	61 - 90	8.3	153.46	126.697	26.763
	1	91 - 135	7.42	137.4	103.520	33.880
	2	136 - 200	7.72	147.3	130.176	17.214
Kien Giang	3	26 - 35	20.5	347.5	94.606	252.894
	8	36 - 45	42.75	727.684	654.797	72.887
	2	46 - 60	22.95	350.738	242.453	108.285
	3	61 - 90	19.8	331.00	294.274	36.726
	1	201 - 300	33.0	450.00	347.616	102.384
Khanh Hoa	1	26 - 35	41.4	770.000	440.600	329.400
	4	36 - 45	30.78	741.25	414.670	326.58
	6	46 - 60	16.47	463.34	301.893	161.447
	4	46 - 60*	23.34	647.5	376.750	270.75
	2	61 - 90	34.82	725.00	407.609	317.391
	2	91 - 135	29.26	705.00	427.350	277.650
Da Nang	2	26 - 35	7.433	298.39	231.842	66.548
	4	36 - 45	4.538	241.73	216.123	25.267
	2	46 - 60	2.538	192.945	172.110	20.835
	5	61 - 90	3.354	249.85	224.490	25.360
Nghe An	7	< 15	9.617	118.524	65.159	53.365
	8	16 - 25	10.681	150.319	87.228	63.081
	8	26 - 35	10.04	138.939	88.733	50.206
Hai Phong	1	301 - 450	40.0	3 000.00	2 403.360	596.64
	1	> 450	40.0	3 000.00	2 462.640	537.36

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.
Conversion: 1 US$ = 11 705 VN$ in 1997; source: oanda.com

400 HP. One fishing trip can last for 15 - 30 days.

Boat Engines

To minimize the initial invested capital and optimize economic return against the decline of resources, many fishing boats have been equipped with second hand engines (with 70% - 80% remaining life). Ninety percent of fishing boats utilize second-hand engines. Except for newly-built fishing boats produced in the Government program for offshore fisheries development in 1997 - 99, almost all the boats of more than 200 HP are equipped with second hand engines.

Distribution of Fishing Gear

The structure of the fishing gear varies from area to

Table 22. Mesh size of some small scale fishing gear in Vietnam.

Type of fishing gear	Mesh size (mm)
Shrimp trawl	18 - 20
Shrimp trammel net	46 - 48
Fish bottom gillnet	60 - 90
Purse seine	18 - 30
Lift net	10 - 14
Stick-held falling net	20 - 25

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

area due to the characteristics of the fishing ground.

Gulf of Tonkin

The geographical characteristics of the Gulf are: (a) an even bottom with an average depth of 38.5 m and the deepest part under 100 m, which is suitable for trawl fisheries; (b) abundant aquatic resources thereby providing an estimated stock of 681 166 t. The provinces have developed various types of fishery as discussed below.

a. Trawl fisheries for shrimp - This type of fishery occupies 18% of the total in the region. Vessels are 10 - 12 m in length and commonly run two engines of 15 HP made in China. The fishing ground is the coastal zone where the depth ranges from 20 to 22 m. One fishing trip lasts for one to two days.

b. Gillnet fisheries, such as the bottom gillnet for fish, trammel net for shrimp and squid. This type of gear is used by 60% of the boats in the region. Boats are small with a length of 8 - 9 m, and engines of 15 - 22 HP. One fishing trip usually lasts for one day.

c. The squid line fishery is fully developed although the boats are small.

Aside from the above fishing gear, trawl and purse seine fisheries also exist but involve a small number of boats. In 2000, there were thousands of fishing boats of 33 - 45 HP from Central provinces fishing in this area and employing purse seine, gillnet, offshore squid line and lift net.

Central Region

The physical characteristics of the area include: (a) narrow continental shelf, depth not suitable for trawl fisheries; (b) abundant pelagic fish suitable for purse seine and tuna/mackerel gillnet fisheries; (c) an estimated stock of 606 399 t. The following fisheries are developed in this region:

a. Gillnet fishery - This is more developed in both near shore and offshore waters with around 25% of the total fishing boats in the region involved. The boats run engines of 30 - 45 HP and one fishing trip lasts from three to seven days.

b. Trawl fishery - Around 21% of the total fishing boats of the region are engaged in the trawl fishery which operates in nearshore waters. The boats have engines of 33 - 45 HP, and in general a single trawl is used for shrimp, and a pair trawl for capturing fish.

c. Purse seine fishery - This fishery is highly developed in Quang Nam, Quang Ngai and Binh Dinh, engaging approximately 5% of the total fishing boats in the region. The boats use engines of 33 - 45 HP.

d. Lift net fishery - This type of fishing is conducted in near shore areas engaging 8% of the total fishing boats of the region. The boats use engines of 10 - 33 HP.

e. Tuna long line fishery - This fishery recently started in the region with boats using engines of 45 - 60 HP. The target species are yellowfin tuna and big-eye tuna.

Southeast Vietnam Waters

This region is characterized by an even bottom with a large, shallow continental shelf very suitable for trawling. Aquatic resources are abundant with an estimated stock of 2 075 889 t. The fishing fleet is bigger in size and has more fishing boats than those in Central provinces and the Gulf of Tonkin. This region has developed the following fisheries:

a. Trawl fishery - This is mainly pair trawling by boats of 60 - 150 HP. It involves 37% of the total fishing boats of the region, and takes place in grounds around Con Dao island and the Southern waters. Fishing depth ranges from 30 to 60 m.

b. Purse seine fishery - This occupies approximately 5% of the total fishing boats in the region. The boats commonly use engines of 70 - 110 HP but there are some larger boats using engines of 300 - 350 HP. Fishing depth ranges from 40 to 60m.

c. Tuna gillnet fishery - This fishery occupies 15% of the total fishing boats of the region. Fishing boats use engines of 45 - 90 HP and the fishing depth ranges from 25 to 40 m.

Gulf of Thailand Waters

The Gulf of Thailand is characterized by an even bottom which is very suitable for trawl fishing. The average depth is around 52 - 55 m and the

estimated stock is 506 679 t. The Gulf has abundant shrimp resources. This region also has the highest density of fishing boats and has developed the following types of fisheries:

a. Trawl fishing for shrimp and fish - Trawling for shrimp is conducted by large fishing boats of 250 - 300 HP but these operate mainly in the 15 - 30 m depth zone and in the pattern of single-boat fishing. Trawling for fish is conducted by groups of two boats (called pair trawlers) commonly of 250 - 300 HP, at depths ranging from 20 to 35 m. Around 40% of the fishing boats in this region are trawlers.

b. Gillnet fishery - This fishery involves 30% of the total fishing boats in the region. The boats commonly use engines of 20 - 45 HP and make trips of one to five days. Fishing depth ranges from 10 to 25 m.

c. Long line fishery - The line boats used for this type of fishery are less than 20 HP and use a main line from 2 - 5 km long with 900 - 2 000 hooks. The bigger line boats with engines of 60 - 275 HP, use a main line from 24 - 30 km long with 8 000 - 10 000 hooks. Fishing depth ranges from 40 to 60 m. The target species is pike conger, which often constitutes 90% of the total catch. Around 17% of the total fishing boats in the region are long liners.

d. Purse seine fishery - Only 2.3% of the total boats in the region are involved in purse seine fishing. These boats use big engines of 45 - 350 HP. The size of gear used ranges from 400 - 60 m long and 50 - 80 m high and fishing depth ranges from 25 to 35 m.

Infrastructure of Fisheries

By 1994, Vietnam had built 52 fishing ports with a total berth length of 2 905 m serving big fishing boats. There are also small and medium scale fishing ports and other ports that provide basic supplies such as ice, fuel, fresh water and repair services as well as shelter for fishing boats. There is still a shortage of modern facilities especially for post-harvest activities such as fish sorting areas, vehicles for fish transport to market, ice plants or warehouses, to name a few. Many coastal locations have no fishing ports so that most of the catch must be transported by small boats to the shore. In some places, fish harvests are discharged directly from fishing boats to sandy beaches leading to post-harvest spoilage.

In recent years, the Government has made efforts to improve the infrastructure facilities for fisheries. Many new fishing ports have been built and the old ones modernized. New quays have been built.

Many fishing ports have been in operation since 1996 such as: Cat Ba (Hai Phong city), Cua Hoi (Nghe An province), Xuan Pho (Ha Tinh province), Gianh (Quang Binh province), Thuan Phuoc (Da Nang city), Phan Thiet (Binh Thuan province), Tac Cau (Kien Giang province), Phu Quy (Binh Thuan provine), Con Dao (Ba Ria-Vung Tau province), Ca Mau (Ca Mau province). The Government has made a total investment of 71 million US$, including Cat Lo fishing port (Vung Tau), a huge fishing port costing 24 million US$.

In 2000, there were 75 shipyards for fishing boats, providing a total building capacity of 4 000 boats and repairing around 8 000 fishing boats per year. Apart from these, there are many small shipyards at the district level, which build small fishing boats in the traditional way. In terms of post-harvest facilities, there are 126 freezer stores providing a total capacity of about 20 000 t and 120 ice-making enterprises throughout the country.

The fisheries communities constitute 2.5 - 3% of the total population of the whole country, of which 49% are male and 51% are female. The rate of population increase in the fishery communities is often higher than the average for the whole country, around 2.6 - 2.8%. The average number of persons per fishery household is 6 - 7. The rate of population increase particularly in the fisheries labor force is 3.5 - 4%. High density and high population in the fisheries communities causes difficulties in terms of employment. Many fishers, due to a shortage of capital, can invest only in small boats. This results in increasing fishing pressure in coastal waters leading to the over-exploitation of coastal resources.

Marketing

In Vietnam auction or bidding at fish markets does not exist. Thus trading for the fish harvests is done by middlepersons. Essentially, there are two types of trading. First, middle persons offer to buy the whole catch and in return, provide the skippers with supplies such as ice, fresh water, fishing gear,

and other provisions for the next fishing trip. Secondly, the middle-persons who have enough financial resources may provide contracts to the skippers/fishers, to take the whole catch. Middle-persons normally lend the fishers the capital of 20 - 70 million VN$ (US$1 709 - 5 980 in 1997) $\cdot boat^{-1}$ to cover the fishing costs.

The fish harvest is often sorted and classified according to fish species and size to satisfy the two key markets. The export market takes high value fish given proper storage and handling. The middle-persons will sell the fish to export processing plants or export them directly to China and other countries. The other market is the domestic market, where the fish are classified for domestic consumers and are usually transported in frozen form by road to big cities, or to processing plants to make them into dried products for the domestic market. For fish sauce processing, about 40 - 50% of total production is provided by the trawl fishery. Trash fish and low value fish such as herring, and anchovies, are processed into fish sauce. The production of fish sauce reached 160 million litres in 1998.

Aside from middle-persons, there are minor business people in small fish landing areas. These are mostly women from coastal villages/communes or wives of fishers working on small fishing boats. They purchase the harvest from the fishers and resell the fish at local fish markets.

Processing and Exporting Marine Products

The number of processing plants in Vietnam increased from 20 plants in 1980 to 164 plants in 1995. The total capacity for freezing fish is 800 $t\cdot day^{-1}$ and for ice making it is 3 300 $t\cdot day^{-1}$. The total processing capacity for the whole country ranges from 130 000 - 150 000 $t\cdot year^{-1}$. Of the total processing plants in the country, 80% are state-owned and 20% are privately owned.

The majority of export products are frozen (fish, shrimp, squid), which comprise 90% of total exports. Of this amount, 66% of quantity and value comes from frozen shrimp. In addition to shrimp, cuttlefish, dried squid and filleted fish are also exported. Another export product is canned fish, but this is still limited in quantity.

Fisheries export products have been growing in quantity and value. The export quantity increased from 3 441 t in 1980 to 64 366 t in 1990. The export value was also enhanced from 11.2 million US$ in 1988 to 550 million US$ in 1995, an increase of 40 times. In 1990 - 95, national export earnings also increased to 168%, with an average annual increase of 33.6%.

Implications for Fishery Management

In recent years, the number of fishing boats, their size and engine capacity have expanded rapidly. In 1983, the number of fishing boats was only 29 117 units with an average engine capacity of 16.3 $HP\cdot boat^{-1}$. In 1998 there were 71 800 units with 26.2 $HP\cdot boat^{-1}$. Most of the fishing boats are of small size. Fishing boats with less than 45 HP represent 85.5% of the entire number for the whole country although this varies from region to region; for example, in Northern Vietnam 93.9% of the boats are small, in Central region 92.4% and in the Southern region 70.9% .

The ratio of fish catch by type of fishing gear is: trawl fishing takes 43% of total catch, purse seining 20.6%, gillnetting 13.6%, long lining takes 8.5% and lift netting takes 9.5% of the total fish harvest. In general, all the fishing gear types have low economic returns because of the depleting resources in the coastal waters due to over-fishing.

Bioeconomic Modeling

Rationale

The total fish catch in the Vietnamese traditional waters (depth under 50 m) is 1.59 times greater than the total catch allowable. From 1991 onwards, total profits continuously declined, so that it is now necessary to reduce the number of fishing boats operating in the coastal waters and promote offshore fishing.

Relationship Between Fishing Capacity of Boats and Living Marine Resources

Based on research done in 1999 by the Research Institute of Marine Fisheries (Bui Dinh Chung et al. 1999), the living marine resources and total allowable catch (TAC) in Vietnam is given in Table 23. The coastal zone is the area having a depth of under 30 m in the North and the South regions, and under 50 m in the Central region.

Table 23. Marine living resources and TAC in Vietnamese seas.

Sea area	Resources (t)	TAC (t)
Coastal area	999 095	461 738
Offshore area	2 765 275	1 347 510
TOTAL	3 764 370	1 809 248

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

Fishing Capacity

From 1983 to 1998, the number of fishing boats expanded from 29 127 units to 71 800 units with a total horsepower of 475 832 HP to 1 880 000 HP giving an increase of 3.95 times. Based on the size and engine capacity, around 85.5% of the total motorized fishing boats have less than 45 HP capacity. This suggests that most of the fish catch is harvested from the coastal areas.

Framework and Estimation

The Influence of Fishing Operations in the Coastal Area

Vietnam has not yet established a statistical system that will account for and monitor the fish catch in coastal areas. Therefore, an estimation method was used to describe the current status of the fishing operations in Vietnam. The following formula was used to calculate the ratio of coastal catch to total fish catch.

$$T = \frac{\sum_{i=1}^{n} Ai \cdot Ni \cdot Yi}{\sum_{i=1}^{n} Ni \cdot Yi}$$

where

T is the ratio of the coastal catch to the total fish catch (%).

A_i is the coefficient for every type of fishing boat group's offshore operations. It depends on the size of the fishing boat group, the type of fishing gear and the fishing area or region. In the Vietnamese fishery, the coefficient A varies from 0.3 - 1.0. For example, shrimp trawlers with less than 45 HP and operating only in the coastal areas will have an A value equal to 1.0.

N_i is the number of fishing boats in group i (unit).

Yi is the average catch (t) per year for one fishing boat in group i .

n is the number of the fishing boat groups.

Using the above method, a survey was conducted in traditional fishing grounds (< 50 m depth) in six important coastal provinces for 700 fishing boats in 1997-1998. The results are given below:

- Northern region = T_1 = 95.9%
- Central region = T_2 = 72%
- Southern region = T_3 = 83%
- For the whole country = T = 82.1%

Based on the ratio for the whole country T, one can account for the fish catch in the traditional fishing grounds by the following formula:

$$\mathbf{C_C = C_T \cdot T}$$

where

C_C is the catch in traditional fishing grounds of the country (t)

C_T is the total fish catch for the whole country (t)

T is the ratio of the fish catch in the traditional fishing grounds to the total fish catch in the country (%).

Assuming that the ratio of the fish catch in the traditional fishing ground to the total fish catch of the whole country has not varied since 1980, then the total fish catch in the traditional fishing ground per year can be estimated. However, this ratio varies every year. For example in 1990, the number of big fishing boats operating in the offshore fishing grounds of the Southern provinces increased rapidly, leading to a decreasing fish production ratio. During 1997-1999, the government implemented an offshore fishing program under which 721 offshore fishing boats with engine capacity 100 - 500 HP were built, but the ratio of the catch production decreased.

Based on the results of the research study for the assessment of marine living resources in Vietnam (Research Institute of Marine Products (RIMP)-DANIDA, 1998), the total allowable catch in the traditional fishing area is about 582 000 t, but the actual total catch of the area was higher in 1991 (Fig. 2, Table 24). The fish catch in the traditional fishing area in 1998 was 928 272 t, 1.59 times higher than the allowable level. This shows the fishing pressure in the coastal area is high, and requires a suitable management policy plan for sustainable fisheries development.

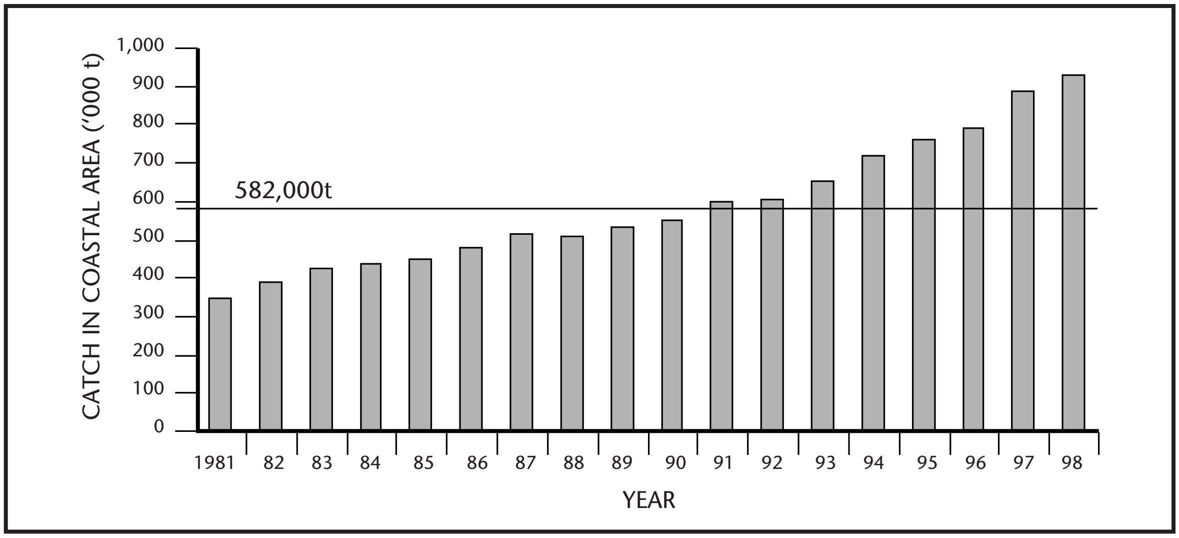

Fig. 2. The catch in traditional fishing areas in Vietnam 1981 - 98.

Table 24. The total fish catch in the traditional fishing areas of Vietnam 1981 - 98.

Year	Total catch of whole country (t)	Catch in traditional fishing areas (t)
1981	419 740	344 606
1982	476 597	391 286
1983	519 384	426 414
1984	530 650	435 664
1985	550 000	451 550
1986	582 077	477 885
1987	624 445	512 669
1988	622 364	510 960
1989	651 525	534 902
1990	672 130	551 818
1991	730 420	599 675
1992	737 150	605 675
1993	793 324	651 319
1994	878 474	721 227
1995	928 860	762 594
1996	962 500	790 212
1997	1 078 000	885 038
1998	1 130 660	928 272

Source: MOFI-Vietnam 1995 - 98.

Table 25. Average total fish catch per unit horse power per year in Vietnam 1981 - 98.

Year	Total catch (t)	Total of engine capacities (HP)	Average catch per unit HP ($t \cdot HP^{-1}$)
1981	419 740	453 871	0.92
1982	476 597	469 976	1.01
1983	519 384	475 832	1.09
1984	530 650	484 114	1.10
1985	550 000	494 507	1.11
1986	582 077	537 503	1.08
1987	624 445	597 022	1.05
1988	622 364	609 317	1.02
1989	651 525	660 021	0.99
1990	672 130	727 585	0.92
1991	730 420	824 438	0.89
1992	737 150	986 420	0.75
1993	793 324	1 291 550	0.61
1994	878 474	1 443 950	0.61
1995	928 860	1 500 000	0.62
1996	962 500	1 543 163	0.62
1997	1 078,000	1 850 000	0.58
1998	1 130 660	1 880 000	0.60

Source: MOFI-Vietnam 1995 - 98.

Fishing Operations in Offshore Areas

The total fish production at depths greater than 50 m was estimated at 202 388 t in 1998 while the total allowable catch in the offshore area was 1 227 000 t. This indicates a high potential for the development of offshore fishing in Vietnam.

Reduction of the Marine Living Resources in the Coastal Waters

Time series data on total catch (t) and fishing effort (HP) of motorized boats are available from 1981 to 1998. These data along with the information on catch per unit of effort (CPUE) measured as tonne of fish per unit of horsepower are given in Table 25.

During recent years, the Vietnamese boats have operated mainly in coastal waters as shown in Table 25. The coastal fish harvest in 1998 was 1.59 times higher than the allowable catch. It is also a reality that fishing effort (e.g. more fishing hours, more net hauling) will be increased in the coming years. This poses a serious problem in terms of the aquatic resources.

Figure 3 shows that the mean catch per horsepower decreased from 1.10 t•HP^{-1} in 1985 to 0.6 t•HP^{-1} in 1998. The reduction in catch of some of the main fishing gear in Tonkin Bay is reflected below.

a. Trawl fishery - annual catch of a trawler

- 250 HP = 360 t•boat^{-1} in 1976;
  200 t•boat^{-1} in 1990

- 400 HP = 480 t•boat^{-1} in 1976;
  240 t•boat^{-1} in 1990

b. Purse seine = 100 - 150 t•boat^{-1} in 1976;
   20 - 30 t•boat^{-1}/ in 1990

c. Lift net = 100 - 150 t•unit^{-1} in 1976;
   30 t•unit^{-1} in 1990

Model Estimation

The data obtained above were used for estimating the Schaefer and Fox models. The results are given in Table 26.

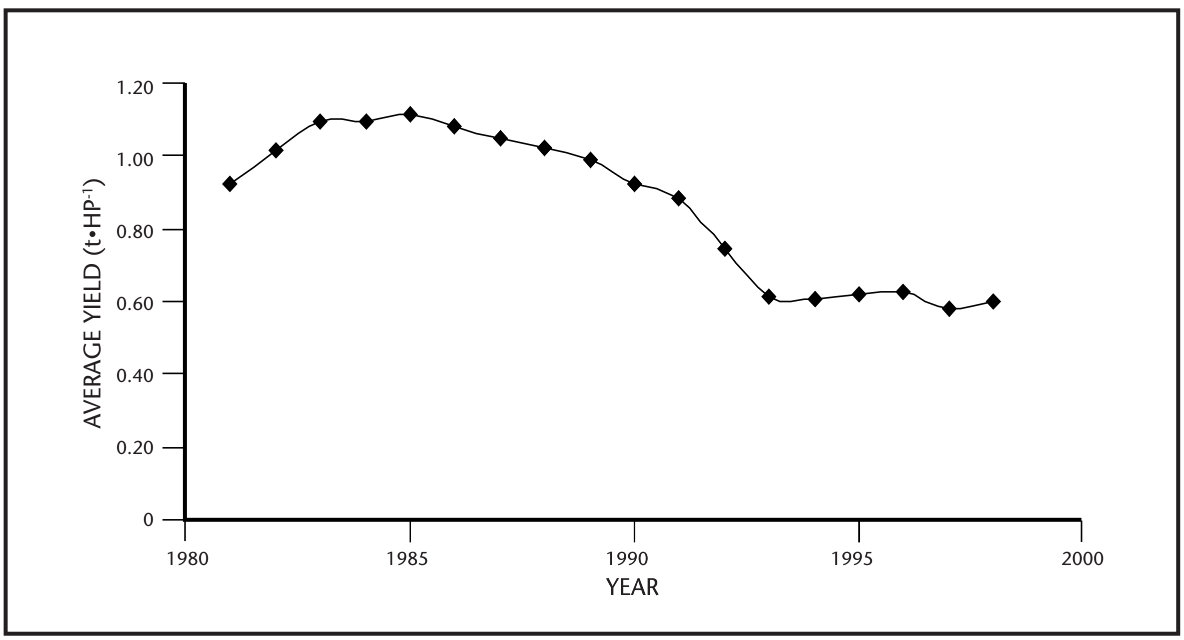

Fig. 3. Annual average catch per horsepower in 1981 - 98.

Table 26. Results of model estimation using Schaefer and Fox Model.

Model	Intercept	t-value for intercept	Slope	t-value for slope	R^2	d-statistics
Schaefer	1.22	34.42	$-38*10^{-6}$	-11.49	0.89	0.46
Fox	0.27	7.14	$-48*10^{-6}$	-13.32	0.92	0.51

Table 27. Comparison of catch and effort information from actual and estimated statistics for Vietnam fisheries.

	Schaefer Model	Fox Model	Actual
Catch: MSY (t)	976 378	1 006 850	1 130 660
Effort: MSY (HP)	1 595 650	2 079 478	1 880 000
Profit: MEY (million VN$) (1 US$ = 11 705 VN$ in 1997)	1 625 954	–	1 299 761
Effort MEY (HP)	1 025 410	–	1 880 000
Implication	Over-fishing	Over-fishing	–

Both models display good estimation results with their R2 values close to around 90%. The t-ratios for the estimated coefficients show that the estimated coefficients are statistically significant at 1% level of significance. The signs of the coefficients satisfy the expectations about the signs. The Durbin-Watson 'd' statistic values, however, indicate the presence of auto-correlated errors in these models. These models were estimated using the Cochrane-Orcutt iterative procedure adjusting for auto-correlated errors, but the auto-correlation problem could not be removed altogether. The original OLS (Ordinary Least Squares) regression results were therefore retained, considering all the criteria used for evaluating estimated models. The estimated coefficients of these models were then used in estimating the static maximum sustainable yield (MSY) and maximum economic yield (MEY) levels of catch and the corresponding levels of fishing effort. The estimated levels of catch and effort are compared with the actual levels of catch and effort in Table 27.

The above results indicate that the actual level of yield is much greater than the MSY levels obtained from both the Schaefer and Fox models. This means that biological over-fishing is taking place in Vietnam. The actual effort level is greater than the MSY level of effort in the Schaefer model but less than the MSY in the Fox model. This result implies that both the catch and effort level of fishing should be reduced in Vietnam. If immediate actions are not taken to prevent excessive fish harvesting, the fisheries resources will be exhausted. The results of the Schaefer model also indicate that the actual level of effort is much greater than the economic rent-maximizing level of fishing effort. The economy is actually losing a substantial amount of economic rent through over-fishing. Though the fishing effort level still falls short of the open access level, the sustenance of profit from fishing will induce more rent-seeking activities in the form of increased effort.

Bioeconomics of the Vietnamese Fishery

At present, because there are no proper statistical systems that keep track of fishery records in Vietnam, only minimal information is annually published. This information includes the total catch of the country, total number of fishing boats by horsepower group, total horsepower of boat engines and total export value of sea products. Hence the annual statistical data cannot be obtained for catch and number of fishing boats for every type of fishing gear and major fish species. Therefore, bioeconomic models cannot be made for every fish species and type of fishing gear. Nonetheless, an estimation method was used to analyze the economic status of the Vietnam fisheries.

The information provided below was collected from the survey of fishing boats using fishing gear such as trawl, purse seine, gillnet, long line and others, and from the survey of fishing boat groups

having different engine capacities and in various fishing areas such as the Northern, Central and Southern regions of Vietnam. These data were processed to calculate the following:

Total revenue (I) is obtained by multiplying the average price of one tonne of product (V) by total annual catch (Y) as given below

$$I = V \cdot Y$$

Assume that the average price of one tonne of product (V) did not change from 1981 to 1998.

Total cost defines the average cost of one horsepower for every fishing gear group mentioned above. This is based on the ratio of total engine capacity for every fishing gear group and accounting the average cost of one horsepower of all fishing gear groups in general (C). This can be obtained by multiplying the average cost of one horsepower (C) with the total annual horsepower (H) to give the total annual cost for the whole fishery (L) as shown below.

$$L = H \cdot C$$

Assume that average cost of one horsepower (C) did not change from 1981 to 1998.

The average price of one tonne of fish is 4.214 mil VN$ (US$304 in 1997), and the average cost of one horsepower is 1.843 mil VN$per year (equivalent to US$133 ($HP^{-1} \cdot year^{-1}$ in 1997) (Table 28)

Fig. 4 shows that from 1981 to 1998, the total engine capacity increased from 453 871 HP to 1 880 000 HP and the total cost of fishing operations expanded from 836 484.21 million VN$ to 3 464 840 million VN$ (an increase of 4.14 times). Although the total revenue grew from 1 768 784 million VN$ to 4 764 601 million VN$ (2.69 times increase), the total engine capacity also increased continuously (e.g. increased number of fishing boats) therefore the total profit declined gradually.

Table 28: Total annual revenue and total annual cost of Vietnamese fishery 1981 - 98.

Year	Total catch (t)	Total revenue (mil. VN$)	Total horse power (HP)	Total cost (mil. VN$)
1981	419 740	1 768 784.36	453 871	836 484.25
1982	476 597	2 008 379.76	469 976	866 165.77
1983	519 384	2 188 684.18	475 832	876 958.38
1984	530 650	2 236 159.10	484 114	892 222.10
1985	550 000	2 317 700.00	494 507	911 376.40
1986	582 077	2 452 872.48	537 503	990 618.03
1987	624 445	2 631 411.23	597 022	1 100 311.55
1988	622 364	2 622 641.90	609 317	1 122 971.23
1989	651 525	2 745 526.35	660 021	1 216 418.70
1990	672 130	2 832 355.82	727 585	1 340 939.16
1991	730 420	3 077 989.88	824 438	1 519 439.23
1992	737 150	3 106 350.10	986 420	1 817 972.06
1993	793 324	3 343 067.34	1 291 550	2 380 326.65
1994	878 474	3 701 889.44	1 443 950	2 661 199.85
1995	928 860	3 914 216.04	1 500 000	2 764 500.00
1996	962 500	4 055 975.00	1 543 163	2 908 012.57
1997	1 078 000	4 542 692.00	1 850 000	3 510 553.77
1998	1 130 660	4 764 601.24	1 880 000	3 464 840.00

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

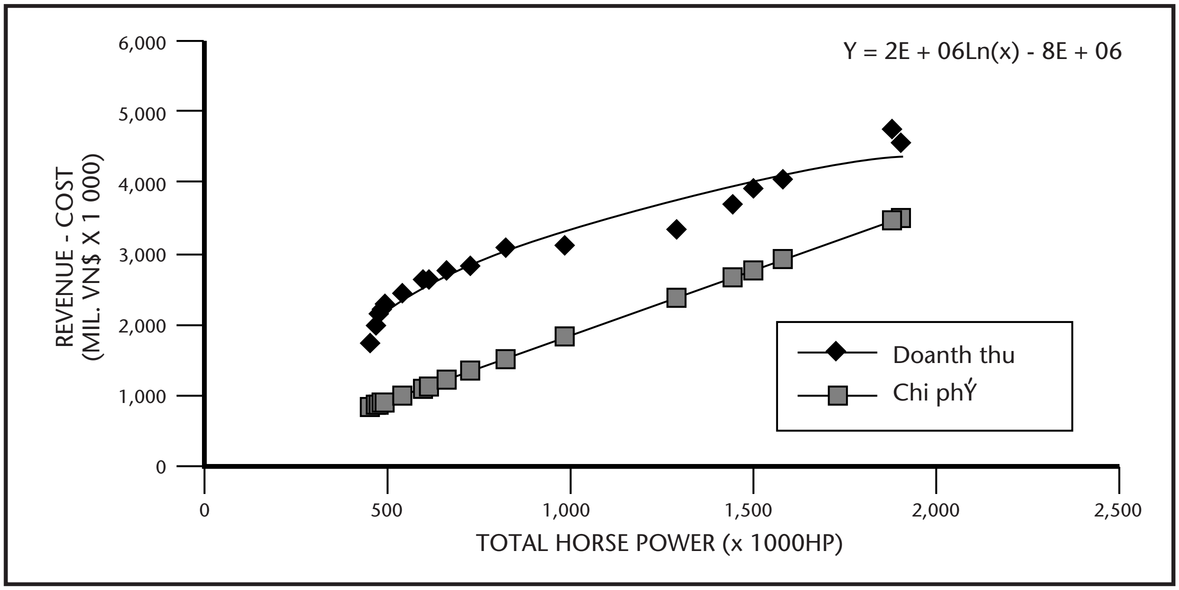

Fig. 4. Relationship between revenue and cost of fishing operations of Vietnamese fisheries, 1981 - 98.

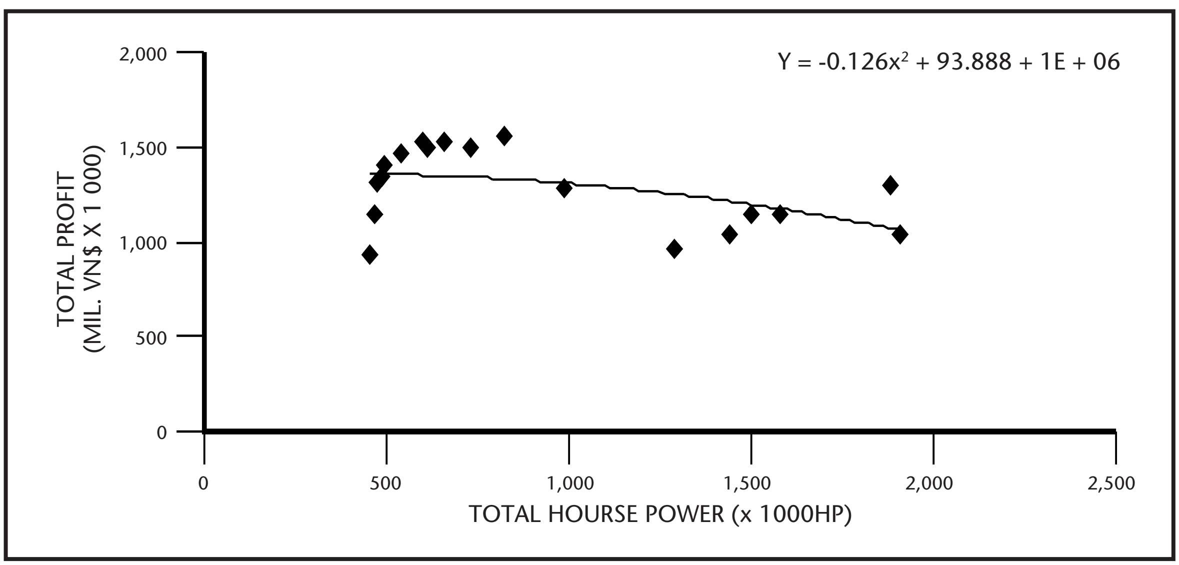

Fig. 5. Relationship between total profit and total engine capacity.

Table 29 provides information on the total annual revenue from 1981 to 1998 where the revenue was maximum from 1986 to 1991, ranging from 1 462 billion VN$ to 1 558 billion VN$. From 1991 to 1998 the total profit decreased, while the total engine capacity increased by 2.28 times between 1991 and 1998. This result shows the excessive fishing operations in the traditional fishing grounds yielding poor economic returns to the fishers. Thus for the development of a sustainable fishery in the country, the number of fishing fleets operating in the coastal areas must be limited, and the development of the offshore fishing vessels must be enhanced.

Table 29. Annual profit of fishing operations in Vietnam 1981 - 98.

Year	Annual profit (mil. VN$)	Year	Annual profit (mil. VN$)
1981	932 300.11	1990	1 491 416.67
1982	1 142 213.99	1991	1 558 550.65
1983	1 311 725.80	1992	1 288 378.04
1984	1 343 937.00	1993	962 740.69
1985	1 406 323.60	1994	1 040 689.59
1986	1 462 254.45	1995	1 149 716.04
1987	1 531 099.68	1996	1 147 962.43
1988	1 499 670.67	1997	1 032 138.23
1989	1 529 107.65	1998	1 299 761.24

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

Fishing Effort of Some Types of Fishing Gear in Different Sea Waters

Based on the survey results of about 22 000 net hauling times of fishing boats in 1996 - 98, the average fishing effort of some types of fishing gear in the Vietnam waters is provided below (Tables 30 - 33).

Relationship Between Total Engine Capacity and Total Fish Catch

The relationship between the total engine capacity and the total catch during 1985 - 98 shows that the total engine capacity increased by 4.14 times, but total fish catch had only expanded by 2.69 times, i.e. from 419 740 t in 1985 to 1 130 660 t in 1998 (Fig. 6). Given the dependence of the fishers on the resources, this trend may continue, resulting in over-exploited fishery resources with decreasing profit.

Table 30. Average fishing effort of pair trawl fishery in Vietnam.

Area	Size of fishing vessel (HP)	Coastal fishing		Offshore fishing	
		Number of net haulings surveyed (unit)	Fishing effort ($kg \cdot HP^{-1} \cdot hr^{-1}$)	Number of net haulings surveyed (unit)	Fishing effort ($kg \cdot HP^{-1} \cdot hr^{-1}$)
North region	≤ 45	1215	0.6337	153	0.489
	46 - 74	10	0.228	50	0.289
	75 - 140	24	0.705	7	0.364
	141 - 300	14	0.339	16	0.128
	301 - 600	–	–	2	0.235
Central region	≤ 45	538	0.324	964	0.584
	46 - 74	116	0.280	201	0.411
	75 - 140	9	0.337	42	0.382
	141 - 300	2	0.235	–	–
	301 - 600	–	–	–	–
South region	≤ 45	13	0.812	55	0.433
	46 - 74	19	0.944	132	0.440
	75 - 140	25	0.471	69	0.265
	141 - 300	28	0.243	46	0.491
	301 - 600	9	0.150	14	0.253

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

Table 31. Average fishing effort of single trawl fishery in Vietnam.

Area	Size of fishing vessel (HP)	Coastal fishing		Offshore fishing	
		Number of net haulings surveyed (unit)	Fishing effort (kg•HP^{-1}•hr^{-1})	Number of net haulings surveyed (unit)	Fishing effort (kg•HP^{-1}•hr^{-1})
North region	≤ 45	3941	0.186	6	0.167
	46 - 74	21	0.388	6	0.86
	75 - 140	3	0.27	1	0.22
	141 - 300	–	–	–	–
	301 - 600	1	0.04	2	0.06
Central region	≤ 45	5094	0.389	103	0.445
	46 - 74	251	0.407	16	0.186
	75 - 140	6	0.30	–	–
	141 - 300	–	–	–	–
South region	≤ 45	2044	0.427	21	0.488
	46 - 74	765	0.227	17	0.225
	75 - 140	219	0.168	19	0.194
	141 - 300	77	0.105	60	0.202
	301 - 600	35	0.108	86	0.482

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

Table 32. Average fishing effort of gillnet fishery in Vietnam.

Area	Size of fishing vessel (HP)	Coastal fishing	
		Number of net haulings surveyed (unit)	Fishing effort (kg•HP^{-1}•hr^{-1})
North region	≤ 45	1175	0.890
	46-74	36	5.019
	75-140	6	0.54
	141-300	0	0
Central region	≤ 45	1232	0.931
	46-74	28	0.421
	75-140	5	0
South region	≤ 45	692	1.504
	46-74	38	1.55
	75-140	4	0.485

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

Table 33. Average fishing effort of purse seine fishery in Vietnam.

Area	Size of fishing vessel (HP)	Coastal fishing		Offshore fishing	
		Number of net haulings surveyed (unit)	Fishing effort ($kg \cdot HP^{-1} \cdot hr^{-1}$)	Number of net haulings surveyed (unit)	Fishing effort ($kg \cdot HP^{-1} \cdot hr^{-1}$)
North region	≤ 45	249	125.2	122	303.17
	46 - 74	-	-	25	376.938
	75 - 140	-	-	16	582.838
	141 - 300	-	-	8	491.668
Central region	≤ 45	1076	170.008	282	2 008.062
	46 - 74	439	295.509	136	1 246.386
	75 - 140	10	435.00	36	1 264.738
	141 - 300	1	500.00	1	428.57
South region	≤ 45	28	866.99	87	470.195
	46 - 74	50	758.653	94	886.836
	75 - 140	30	807.973	128	694.118
	141 - 300	70	910.020	90	864.97
	301 - 600	27	615.68	75	867.456

Source: Research Institute of Marine Fisheries (RIMF) - DANIDA 1998.

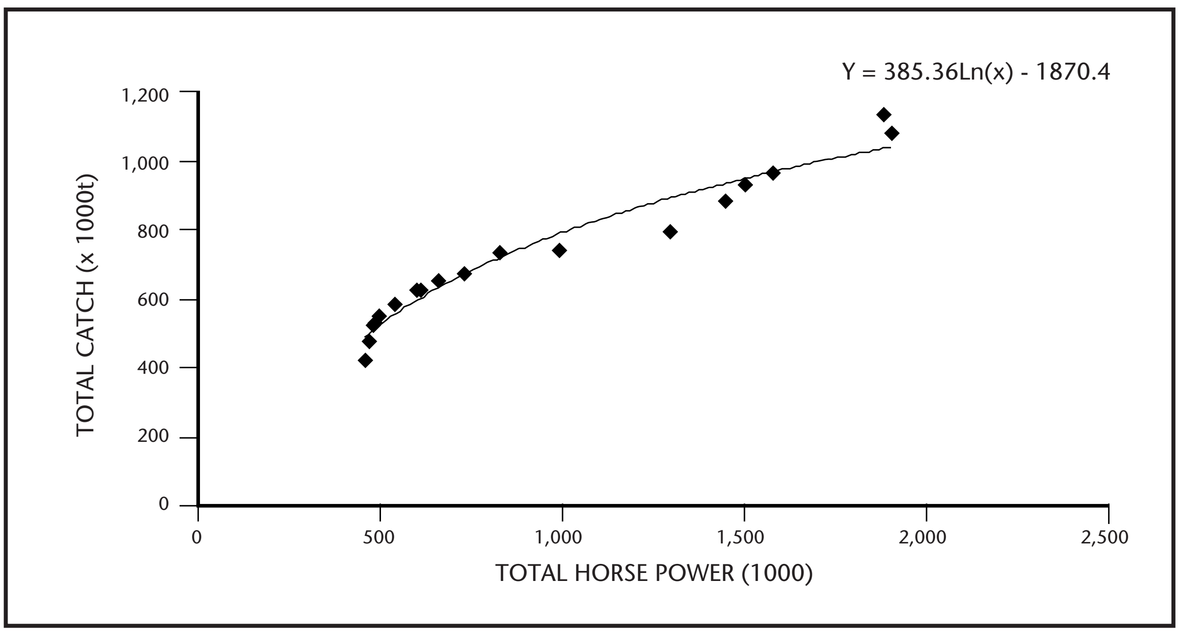

Fig. 6. Relationship between total engine capacity of fishing boats and total catch in Vietnam 1985 - 98.

Conclusions and Recommendations

The following recommendations are given for the development of the fishery sector in Vietnam:

1. Regulate the use of coastal fishery resources through the following:

   a. Control the number of fishing boats, e.g. in 2010, 15 000 non-powered boats and 38 900 motorized boats of less than 23 HP should not be allowed in the coastal fishing grounds; fishing boats of 24 - 45 HP should be limited to a maximum of 30 000 units and 46 - 89 HP to 20 000 units, making 50 000 units of fishing boat allowed in 2010.

   b. Resolve the labor problems. Currently, there are 423 600 fishers working on fishing boats in Vietnam. If the number of fishing boats is reduced, many fishers will lose their jobs. Therefore, the government will need to develop programs for offshore fishing, aquaculture, fish processing and other fishery services that provide alternative sources of income.

   c. Protect the marine resources through implementation of sound fisheries policies and regulations.

   d. Support credit funds that will enhance the development of offshore fishing. The government needs to institute credit policies that will support more fishing in the offshore waters.

2. Build high-powered fishing vessels for fishing operations in offshore waters. Based on the development plan for offshore fishing, by 2010 there will be more than 700 fishing boats with engine capacity of more than 90 HP for offshore fishing activities. This will result to a projected total fish catch ranging from 1 200 000 - 1 400 000 t in 2010.

3. Develop processing-service-market centers for post-harvest handling of fishery products. According to government plans, six centers will be established to accommodate post-harvest fish products:

4. Establish fishery statistic systems, monitoring an information system that will keep all fishery records through time and region. Also, to improve the safety of fishers, a two-way communication system between them and security services should be put in place.

From 1997, the Vietnamese government has implemented programs for developing offshore fishing. This government program provided a credit fund with a low interest rate of 0.81% to fishers to build new fishing boats. From 1997 onwards, the government supported the credit fund to build 918 fishing boats with an engine capacity of 135 - 500 HP with 728 units now in operation in offshore fishing.

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Coastal Resources Management, Policy and Planning In Bangladesh

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Rahman M.M, Z.A Chowdhury and M.N.U Sada. 2003. Coastal resources management, policy and planning in Bangladesh, p. 689 - 756. *In* G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceeding 67, 1 120 p.

Abstract

This paper reviews the coastal fishery resources of Bangladesh emphasizing the coastal environment, capture fisheries and management issues relative to the sector. Bangladesh's Exclusive Economic Zone (EEZ) covers an area of about 166 000 km^2. This area has abundant natural resources such as fish, shrimps, crabs and other marine products. Shrimp and fish trawling is the most important economic activity in this area. The fishery sector makes a significant contribution to the national economy in terms of foreign exchange, income generation and employment. It is very important in nutrition, especially in providing animal protein. In 1997 - 99, the marine fisheries sector contributed 22% of the total fishery production of 1 373 000 t. However, the resources are being destroyed in many ways. The fisheries resources have declined and fishers are getting poorer. The decline is partly due to estuarine set bag net, push net, and beach seine fishing, which result in recruitment over-fishing. A multiplicity of factors adversely affect the coastal fishery resources of Bangladesh.

Various laws, ordinances and acts have been formulated to manage the fisheries resources and to protect the coastal zone environment. Most of the laws have been amended to meet current needs. However, marine fisheries are not being well-managed because the laws are not properly implemented, due to a shortage of man power, lack of infrastructure and funds. Moreover, there are legislative and communication gaps between the law-enforcing agencies. In addition to sectoral issues, a number of cross-sectoral issues such as pollution and habitat destruction impact the coastal zone and the long-term sustainability of coastal fishery resources. The main objectives of coastal fisheries management in Bangladesh should include the following: (1) rational utilization of resources; (2) protection/conservation of the environment or habitat; (3) maximization of the benefits from utilization of the resources within sustainable limits; (4) minimization of conflicts among users; (5) promotion of equity in sharing benefits from utilization of the resources; (6) reduction of poverty among small scale fishers; and (7) promotion of alternative livelihood opportunities for fishers.

Introduction

Bangladesh is a South Asian Country of 147 570 km^2 situated between India and Myanmar and bordered by the Bay of Bengal in the south. It is located between latitude 20° 34' and 26° 38' North and longitude 88° 01' and 92° 41' East (Fig. 1). The country is divided into six administrative Divisions, Rajshahi (Northwest), Dhaka (Center), Khulna (Southwest), Chittagong (Southeast), Barisal (South) and Sylhet (North East). Each division is further divided into districts (*Zilla*), which consist of *Thanas*, or police stations, as administrative units. There are 64 *Zilla* and 640 *Thanas* with 85 650 villages. Although one of the most densely populated countries of the world, it has abundant natural resources such as the Sundarbans, the world's largest single compact mangrove forest; an intricate network of rivers with rich fish habitats, a vast communications network and ample fertile lands to grow crops. It also has promising gas reserves to meet the increasing energy needs.

Bangladesh declared an Exclusive Economic Zone (EEZ) of 200 nautical miles (370 km) in 1974. As a result, an area of about 166 000 km^2 is now under the economic jurisdiction of the country for exploration, exploitation, conservation and management of its living and non-living resources. Several surveys have been conducted by national and international agencies to assess and estimate the marine fisheries resources potential of Bangladesh since 1958. Most of these surveys were of an exploratory nature and repeatedly targeted the demersal fishery resources. These surveys gave good information on the standing stocks of demersal finfish and shrimp. However, no detailed surveys were conducted for pelagic fishery resources.

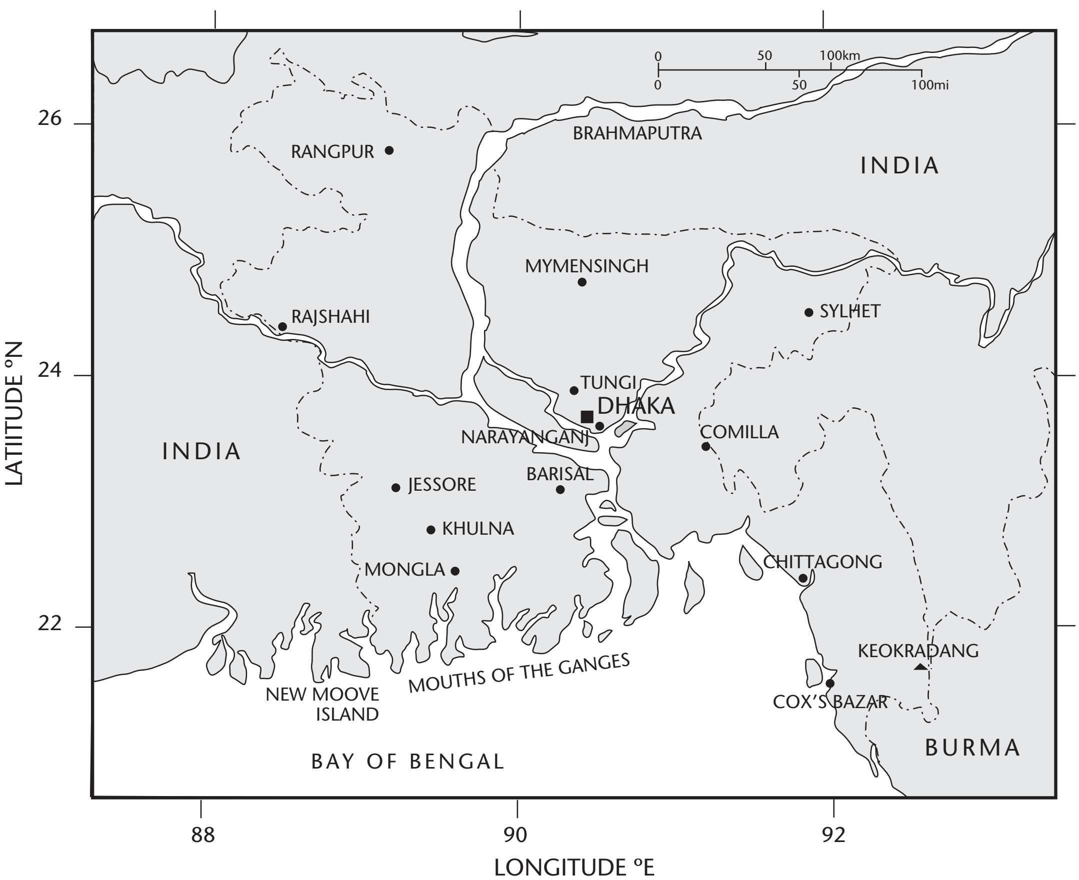

Fig. 1. Map of Bangladesh.

The freshwater area is being reduced by encroachment for agricultural production, and fish habitats and routes of migration have altered due to various water resources development activities. Therefore, it is difficult to fulfill the minimum protein requirement of the teeming millions from the freshwater sub-sector alone. Greater priority has always been accorded to freshwater fisheries as reflected in the large number of fisheries development projects implemented since independence, despite the fact that the marine fisheries sector provides the majority of foreign exchange earnings.

The fisheries sector in Bangladesh plays an important role in the national economy in terms of foreign exchange earning, income generation, employment and providing nutrition. It contributes nearly 4.2% of the national GDP, 7% to the agricultural GDP and 7.6% of the country's total export earnings. It provides full-time employment for 1.2 million professional fishers and 11 million part-time fishers, or about 10% of the total population.

The fisheries sector provides about 80% of the animal protein consumed in Bangladesh. But, in spite of continuous increases in fish production, it has not been able to cope with the demands of the fast growing population. The country's fish production increased from 640 000 t (metric tonnes) (inland 545 000 t, marine 95 000 t) in 1975 - 76 to 1 373 000 t (inland 1 079 000 t, marine 294 000 t) in 1996 - 97. However, per capita daily fish consumption decreased from 33 g to 20 g.

At present the marine fisheries sector contributes about 22% of the country's total production despite a reasonable marine and brackish water area under the EEZ. The strategic development of this sector has not been properly implemented. Rather, because of unplanned and irrational increases in fishing effort, many of the marine fish and shrimp stocks have already declined. As a result, coastal fishing has become non-remunerative and fisherfolk are getting poorer, thus putting more and more damaging pressure on the resources. This may give the impression that marine resources exploitation has become saturated, but the practical situation is different. We are destroying the resources in many ways.

The marine and brackish water fish production has increased yearly and accounts for about 95% of the total marine landings. However, knowledge on catchability, exploited size range, mortality rates and the optimum fishing efforts required to exploit these resources are inadequate for management.

While there is strong and continuous competition for demersal fin fish and shrimp between the shrimp trawl industry and the traditional artisanal fishing operations within the 100 m isobath, demersal resources beyond 100 m and the pelagic waters beyond 40 m are not being harvested to their potential. Various exploratory surveys and research data show that considerable resources are available for harvesting in these areas, particularly the pelagic resources such as mackerels, tunas, sharks, anchovies, sardines and cephalopods. Planning for the development of these resources is lacking, but this could be the most effective means of boosting fish production to reach the national target.

Coastal Environmental Setting

Planning Area

Bangladesh is endowed with a vast area of marine, brackish and inland waters having great fisheries potential. The Republic has a 710 km long coastal line on the southern zone of the country (Fig. 1), from the mouth of the Naf River in the southeast, to the mouth of the Raimangal River in the southwest, and approximately one million hectares of territorial waters extending 19 km seawards. The nation's EEZ extends 200 nautical miles (nm) seawards encompassing an area of 166 000 km^2. Details are given in Table 1.

The continental shelf of Bangladesh covers an area of 66 440 km^2, of which 37 000 km^2 are no deeper than 50 m (Table 2). Fleets of motorized small scale fishing craft, using gear such as set bag nets

Table 1. Total marine water area of Bangladesh

Marine water area	Area (km^2)
Base line from the coast line to 10 fathom	25 140
Territorial waters up to 12 nm from the base line	9 060
EEZ (200 nm from the base line including territorial water)	140 860
Total sea water area	166 000

Source: Fisheries Information Bulletin, GOB 1986.

Table 2. Area of the shelf of Bangladesh.

Depth Zone (m)	Area (km^2)
Up to 10	24 000
10 - 24	8 400
25 - 49	4 800
50 - 74	5 580
75 - 99	13 410
100 - 199	10 250
TOTAL	66 440

Source: Saertre 1981.

(*behundies*), trammel-nets, beach seines, long-lines and gillnets operate in these areas. The substrate to 40 m is mostly alluvial silt and mud. Sand bottom occurs in deeper waters.

The coast of Bangladesh forms a part of the massive Gangas-Brahmaputra-Meghna delta. The coastal zone is characterized by sprawling estuaries, dense mangrove forests, islands and coral reefs. The great rivers empty into the large estuary at the apex of the Bay of Bengal, carrying large quantities of nutrients that mix with large quantities of organic and inorganic elements derived from the decomposition of litter of mangroves. Endowed with a warm tropical climate and high rainfall, the coastal waters are further enriched with nutrients from land that enable them to support a wide biotic diversity and rare endemic genetic material.

Biophysical Environment

A large proportion of the shelf of Bangladesh is shallower than 10 m, covering about 24 000 km^2. The shelf area down to about 150 m appears to be very even; obstacles hazardous to bottom trawling were only observed in two areas at depths more than 60 m in the northern part of Swatch of No-Ground and at depths more than 100 m southwest of St. Martin's Island. The continental edge is at depths of 160 - 180 m. The slope is very precipitous and it seems impossible to carry out bottom trawling in waters deeper than 180 m. The areas under different depth zones are given in Table 2. The oceanic large scale surface currents are generally wind-driven. The surface circulation is generally clockwise from January to July and counter-clockwise from August to December in accordance with the reversed monsoon wind systems.

The coastal zone consists of the complex delta of the Ganges-Brahmaputra-Meghna (GBM) river systems. Much of the country is drained by these rivers, constituting one of the largest river systems in the world, with their origins in the Himalayas and the Khasi-Jainta Hills in the north of the country. The estimated annual sediment load of 2.5 billion tonnes is dumped in Bangladesh. These sediments are subject to coastal dynamic processes activated mainly by river flow, tide and wave action, leading to erosion and accretion in the coastal zone.

During flooding, the rivers also transport massive amounts of suspended sediment loads, of the order of 13 million $t \cdot day^{-1}$, into the Bay of Bengal. About 80 - 90% of the suspended sediment is transported during the monsoon season. This is calculated at some 1 500 million tonnes, of which only a small portion is deposited in the flood plains or in the lower delta; most of it is flushed out into the deeper parts of the Bay (Eysink 1983).

A number of studies have been made on the morphological changes and sedimentation in the coastal and offshore areas of Bangladesh. Pramanik (1983) made a detailed analysis of over 44 000 km^2 of the coastal zone for the period 1972 - 79, taking full advantage of the synoptic view provided by Landsat data. The coastal region of Bangladesh is divided into three broad regions, the Eastern Region, the Central Region and the Western Region. The Eastern Region paralleling the young folded hills of the Chittagong area is the site of a 154 km long sandy beach, the Central Region is the locale of active delta building processes, while the Western Region is a region of active subsidence due to compaction of sediments. A study on the application of satellite data from 1960 - 84 found that both erosion and accretion are prominent in the coastal zone with an overall seaward extension of the delta.

The surface water temperature of the Bay of Bengal varies from 17° C to 33° C. The surface water salinity varies from 18 to 37%. The bottom water salinity ranges from 28 to 39%. The depth to the thermocline is usually 30 - 40 m in summer and about 70 m during winter. Strong haline stratification was observed in the northern part, while in the more offshore areas the upper layer was more homohaline down to the thermocline. There was usually a slight increase in salinity towards the surface in the upper 20 - 30 m.

Oxygen concentrations varied from 4.8 ppm at the surface and 4.0 ppm at 35 m. The oxygen content decreased rapidly with depth within the upper part of the thermocline. The isoline for 1 $ml \cdot L^{-1}$ was situated at about 80 m in summer compared to about 20 m shallower in winter. The deep layer oxygen content decreased to less than 0.2 $ml \cdot L^{-1}$. There seemed to be a minimum in the vertical oxygen distribution between 200 and 400 m. pH values vary from 8.6 to 8.7 near St. Martin's Island.

The planktons are the most diverse group of organisms in the ocean. Some good information on estuarine and marine planktons of Bangladesh is available (Das and Das 1980). Two maximum areas of plankton density were observed on the continental shelf of Bangladesh, one along the eastern coast from Cox's Bazar to St. Martin Island and another in the northern part of Swatch of No-Ground (Saetre 1981).

Total phytoplankton counts have been estimated in the range of 2 100 - 22 479 $cells \cdot L^{-1}$ in the neritic water off the southeast coast (Noori 1999), depending on seasonal and regional environmental variables.

Very little is known about the hydrological features of the water bodies of the Bay of Bengal. Generally, in the inshore water near estuaries the turbidity is very high due to heavy run-off from the major rivers while the offshore waters are clearer. A maximum secchi disc reading was recorded at 27 m in offshore waters.

Critical Coastal Habitats

St. Martin's is the only coral reef island in Bangladesh. Locally known as Jinjiradwip, this gradually decaying island (Anwar 1988) is about 10 km south of the mainland. It is about 8 km long in an approximate north-south direction and has a maximum width of 1.6 km (in the north). Its area is a little over 7.5 km^2 (Haque et al. 1979).

There is little information on Bangladesh offshore corals. Haider and Mahmood (1992) recorded four species of the genus ***Acropora*** (*A. pulchra, A. horrida, A. humilis* and *A. variabilis*) from the reefs at St. Martin's Island. Additionally, coral of ten more genera, namely *Stylocoeniella, Pocillopora, Stylophora, Porites, Pavona, Favia, Favites, Pseudosiderastrea, Goniastrea* and *Monstastrea*, under six families, have been recorded (Mahmood and Haider 1992).

Mangroves, locally known as *sundarban* or *peraban,* play a vital role in the national economy. Besides being a source of different renewable resources, they also serve as buffer zones against cyclones and tidal surges. The coast supports about 587 400 ha of natural mangroves (Mahmood 1986) and a further 100 000 ha of planted mangroves.

The densest mangrove block, the Sundarbans (beautiful forest), is situated in the southwest, mostly in Khulna District. It covers an area of 577 040 ha (FAO 1984), one third of which comprises tidal channels. It is not only the largest single forest resource in the country, but also the largest single compact mangrove resource in the world.

The natural mangroves of the country are being destroyed by ecological changes caused by biotic factors and salinity increases due to reduced waterflows because of the by construction of dams, barrages and embankments. An estimated 40 - 45% of the two major species of the Khulna Sunderbans forest reserve declined in this way between 1959 and 1983. The worst form of destruction has been going on in Chakaria, Cox's Bazar, due to the uncontrolled expansion of coastal shrimp farming. The beautiful Kewa forest of the Jaliardwip on Naf River has been cleared for conversion into shrimp ponds (Mahmood 1995).

Information on seagrass beds is lacking. *Halodule uninervis* has been reported from the sandy littoral zone around St. Martin's Island (Islam 1980). The seafronts of newly formed islands (*chars*), as well as some low-lying coastal areas, are often carpeted with seagrass.

Seaweeds are found in the littoral and sub-littoral zones of St. Martin's island. According to Islam (1976), 133 species of marine algae have been recorded in Bangladesh, especially from St. Martin's island, and 138 species of algae have been recorded in the eastern part of Bangladesh (Zafar 1992). Ten species are very common, namely; Green algae (*Caulerpa sertularioides, C. racemosa* and *Entromorpha* sp.), Brown algae (*Hydroclathrus clathratus* and *Sargassum* sp.)*, Red algae (*Gelidiella tenuissima, Helimenia discoide, Hypnea valentiae*, H. pannosa** and *Gelidium pusillum*).

* Common species.

Watersheds

Bangladesh is the combined delta of three major river systems, the Ganges, Brahmaputra and the Meghna. Additionally, a number of large and small rivers with their tributaries and branches criss-cross the country. Of these, 54 are shared with India. All these rivers have extensive flood plains along both banks. The estimated total area under flood plains is 2 832 792 ha. These remain inundated at depths ranging from very shallow (0 - 30 cm) to deeply flooded (> 1.8 m) during the monsoon season. Within the flood plains, there are deep depressions, locally termed *beels*. The permanent *beels* retain water year-round while the seasonal ones dry out during the peak of the dry season (March and April). The deeply flooded areas in the north-east of the country are known as haors.

Besides the flood plains and *beels*, another set of large water bodies known as *baors* or oxbow lakes occur largely in the districts of Jessore and Kushtia in the southwestern region. The *baors* are bends of meandering rivers, which have become cut off from the main river courses and have little or no connection with the open water system.

A large hydro-electric reservoir was created in the Chittagong Hill Tracts by building a dam across the Kharnaphuli River at Kaptai in the 1950s. This reservoir, popularly called Kaptai Lake, covers an area of 68 800 ha. It is not connected with the remainder of the open water system of the country.

In addition to the above, the country has an estimated 1 288 222 man-made ponds and ditches which together provide a total water area of about 215 000 ha.

The country has 25 000 km^2 of intertidal lands, which provide temporary nursery and feeding grounds for the fry and post-larvae of various species of finfish, shrimp or prawns during the tidal inundation. Extensive traditional brackish water aquaculture is carried out in intertidal areas in the southeastern and southwestern regions of the country (MPO 1987). Areas under rivers, beels, flood plains, oxbow lakes, ponds and brackish water farms in the coastal areas are shown in Table 3.

Table 3. Areas of different types of inland water-bodies.

Water-bodies	Area (Hectares)
A. OPEN INLAND WATERS (Sub-total)	4 920 316
1. Rivers	479 735
Ganges	27 165
Padma	42 325
Jamuna	73 666
Meghna upper	33 592
Meghna lower	40 407
Other rivers and canals	262 580
2. Estuarine area	551 828
Sub-Total	1 031 563
3. Beels and Haors	114 161
4. Flood plains	2 832 792
5. Kaptai Lake	68 800
6. Polder/Enclosure	873 000
B. CLOSED WATERS (Sub-total)	361 841
1. Ponds and Ditches	215 000
2. Baors (Oxbow lakes)	5 488
3. Shrimp farms	141 353
GRAND TOTAL	5 282 157

Fishery Resources and Potential

Demersals

A number of surveys have been conducted since 1958 in the marine waters of Bangladesh. Most of these surveys were of an exploratory nature and oriented to studies of fishing feasibility. However, some surveys were made to assess the standing stocks of the marine resources, particularly the demersal fish and shrimp resources.

The demersal fish assessment survey results vary to a great extent. West (1973), through a desk study, estimated the standing stock of demersal fish at 264 000 - 374 000 t and the maximum sustainable yield (MSY) at 175 000 t. Saetre (1981) estimated the MSY at 100 000 t, on the basis of data collected by the R.V. Dr. Fridtjof Nansen survey during

1978 - 79, and Khan (1983) estimated that 40 000 - 55 000 t of demersal finfish could be harvested annually from the offshore fishing grounds. This includes some part of the shallower zone within 10 - 100 m. The potential yield was estimated at 47 500 - 88 500 t within the 10 - 200 m isopleths (Lamboeuf 1987).

The finfish species that are presently exploited are mainly demersal, shallow water estuarine species, but include a few pelagics. Most are common to both artisanal and industrial fisheries. About 100 species are taken, of which the commonest are as follows: ***Pampus argenteus*** (Silver pomfret) *Pampus chinensis* (Chinese pomfret), *Pomadasys hasta* (Lined silver grunter), *Lutjanus johni* (Red snapper), *Polynemus indicus* (Indian salmon), *P. paradiseus* (Paradise threadfin), *Eleuthero nema tetradactylum* (Four-finger threadfin), *Leptu-racanthus savala* (Ribbonfish), *Arius* spp. (Catfish), *Johnius argenteus* (Sillver pennah croaker), *Otolithes maculates* (Blotched tiger toothed croaker), *Nemipterus japonicus* (Japanese threadfin bream), *Upeneus sul- phureus* (Goatfish), *Saurida tumbil* (Lizardfish), *Ilisha filigera* (Bigeye Ilisha), *Sphyraena barracuda* (Great barracuda), *Muraenesox telabonoides* (Indian pike conger), *Harpadon nehereus* (Bombay duck), *Lates calcarifer* (Sea perch or Sea bass), *Sillago domina* (Ladyfish) and *Epinephelus lanceolatus* (Grouper).

Pelagics

Detailed surveys for pelagic fish resources have not yet been carried out in Bangladesh waters. However, some information is available from the demersal fish surveys. Saetre (1981) estimated the standing stock of pelagic fish at 60 000 - 120 000 t during the R.V. Dr. Fridjof Nansen survey in 1979 - 80, through an acoustic study, but it was suggested that this might be an underestimate.

In 1979, a Thai-Bangladesh joint survey cruise with the R.V. Fishery Research No. 2 found a good abundance of large pelagics such as tuna and tuna-like fish and sharks in Bangladesh waters. A number of species available on the continental shelf of Bangladesh are either not exploited or are taken only as incidental catches by the bottom trawl, shrimp trawl or drift gillnet fisheries. The most important species are *Euthynnus affinis* (Eastern little tuna), *Katsuwonus pelamis* (Skipjack tuna), *Thunnus obesus* (Bigeye tuna) *Thunnus tonggol* (Longtail tuna), *Auxis rochei* (Bullet tuna), *Auxis thazard* (Frigate tuna), *Scomberomorus guttatus* (King mackerel), *S. commerson* (Spanish mackerel), *Rastrelliger kanagurta* (Indian mackerel) and *R. brachysoma* (Short-bodied mackerel).

Other pelagic fish that appear as by-catch include four species of sardine (mainly *Sardinella gibbosa* and *S. fimbriata*), thirteen species of sharks and rays (mainly *Scolliodon sorrakowa, Carcharhinus menisorrah, Sphyrna blochii, Dasyatis uarank*), thirteen species of carangids (mainly *Decapterus maruadsi, Megalaspis cordyla* and *Atropus atropus*) and six species of clupeoids (mainly *Chirocentreus dorab*).

Shrimps

Few surveys were conducted for assessing the standing stock of penaeid shrimp and there are large variations in the estimates, ranging between 1 000 and 11 000 t. West (1973) reported a standing stock of shrimp of 11 000 t and an MSY of 9 000 t. However, his estimates were criticized by several authors (Saetre 1981; Penn 1983; Rashid 1983; White and Khan 1985).

Later Penn (1983) estimated the standing stock of shrimp at 2 000 - 4 000 t and an MSY of the same amount, on the basis of commercial shrimp trawl data. This result agrees with the studies carried out later by the DOF. The standing stock estimates varied from 1 500 t to 4 000 t (White and Khan 1985; Mustafa et al. 1985). The MSY of shrimp was estimated at 4 000 - 4 300 t (Mustafa and Khan 1993) annually within < 30 m, on the basis of commercial trawl data. Khan et al. (1989) estimated the MSY at 7 000 - 8 000 t annually.

Most of the shrimp species taken are common to both artisanal and industrial fisheries. The industrial fishery harvests mostly the adult phases and the artisanal fishery takes pre-adults, post-juveniles and juveniles. This is because the early phases of their life cycles are spent in the brackish water estuaries.

The major exploited shrimp species are as follows: *Penaeus monodon* (Giant tiger shrimp), *P. semisulcatus* (Green tiger shrimp), *P. japonicus* (Kuruma shrimp), *P. indicus* (Indian white shrimp), *P. merguiensis* (Banana or White shrimp), *Metapenaeus monoceros* (Brown or Speckled shrimp), *M. brevicornis* (Brown or Yellow shrimp), *M. spinulatus* (Brown shrimp), *M. affinis* (Brown or Jinga shrimp), *Parapenaeopsis sculptilis* (Pink or Rainbow shrimp), *P. stylifera* (Pink or Kkiddi shrimp), *P. hardwikii* (Pink or Spear

shrimp), *Parapenaeopsis uncta* (Pink or Uncta shrimp), **Solenocera crassicornis* (Mud shrimp) **Acetes indicus* (Paste shrimp), **Macrobrachium rosenbergii* (Giant river prawn) **Palaemon styliferus* (Roshna prawn), and **Alepheus euphrosyne* (Nymph snapping shrimp). *Penaeus monodon* is the most targeted species and fetches a very good price both in local and international markets. The values of the species more or less follow a descending order according to the list. However, the highest contribution (63%) to total production is made by *M. monoceros,* the Brown shrimp.

The non-penaeid shrimps appear in the coastal estuarine areas at certain stages of their life cycle. The caridean shrimps are typically freshwater living animals, while *Acetes indicus* (a sergestid shrimp) is an exclusively brackish water species that is abundantly exploited by the artisanal fishery.

Other Resources

Other than the demersal, pelagic and shrimp species, the coastal fishery resources comprise fifteen species of crabs (mainly the Mud crab, *Scylla serrata, Charybdis cruciaia, Neptunus pelagicus, Paratelphusa lamelliformis*), five species of lobsters (mainly *Panulirus polyphagus* and *P. versicolor*), three species of cephalopods (mainly *Sepia officinalis* and *Loligo* spp.), six species of oysters (mainly *Crassostrea madrasensis* and *Placuna placenta*), one species of green mussel (*Mytilus edulis*), three species of clams (mainly *Anadara granosa*) and one species of sea cucumber.

Socioeconomic Background

Demography

The population of Bangladesh was estimated to be 111.40 million in 1991 (BBS 1997). The urban population was 20.1%. The annual intercensal growth rate of the population, estimated by using the adjusted population of the 1991 census, was 2.1 %. Assuming the median variant of declining fertility and mortality, the country was expected to reach a population of 129.6 million by 2000 A.D. A country-wide intensive family planning measure is aimed at reducing the growth rate. The density of the population was approximately 647 km^{-2} in 1981 and increased to 755 km^{-2} in 1991. The sex ratio of the population is 106 males per 100 females. There were 19.4 million households in the country distributed over 59 990 revenue villages (mauzas).

Bangladesh already has the highest population density in the world and it is assumed that the population will be doubled within the next 35 years. Restraining population growth has therefore been one of the Government's highest priorities. So far it has been remarkably successful. Population growth slowed during 1974-84 and in the early 1990s the average annual growth rate fell from 2.8% to 2.1%. Fertility fell steeply between 1975 and 1990 and the average number of births per woman dropped from 7.0 to 4.6. Even more remarkably, between 1971 and 1990, contraceptive use increased from 3% to 40%.

Income, Labor and Employment

People are Bangladesh's greatest resource. However, if they are to exploit their full potential, their energy and skills must be channeled to productive work. Only about 2% of the work-force is officially unemployed, though in reality many employed may do useful work only for a few hours a day. Most workers cannot survive without an income and must seize every opportunity, however fleeting or poorly paid. If the criterion of under-employment is working less than 40 hours per week, the figures are sobering; 18% of the work-force is under-employed.

The greatest employment challenge is in the rural areas. Around 80% of workers in the rural areas are employed in agriculture, forestry or fisheries and the demand for their labor has been rising to some extent. High-yield varieties (HYVs) of rice and wheat are more labor intensive than the traditional varieties and the modernization of agriculture has also helped increase non-farm employment. This has stimulated inter-regional trade. Between the early 1960s and 1984 - 85, the marketed surplus of rice, for example, increased from 10% to nearly 40%, generating greater employment in trade and transport. Between 1976 and 1985 the volume of freight traffic increased by 5% per year.

Freshwater fisheries are also a major employer. Most of the rural population do some fishing but around 2 million people derive most of their income from fisheries-either in catching, packaging, transporting or marketing.

* Non-penaieds.

While job opportunities have been increasing somewhat, they are still outpaced by the growth in the labor force. This is not because the proportion seeking work (the participation rate) has gone up: it has remained steady in recent years, at 83% for men and 68% for women. The problem is that the rural population has increased at around 2.3% per cent annually.

Unable to find sufficient work, about 1% of the rural population migrates annually to urban areas. Between 1981 and 1991 the urban population increased by 5% per year and rural-urban migration was responsible for two-thirds of this growth.

The limited opportunities for employment and earning have also encouraged many Bangladeshis to work abroad, the majority of them in the Middle East and Southeast Asia. During 1992 - 93, 237 779 workers left; nearly half of them were destined for Saudi Arabia. Their annual remittances of about $1 million are a valuable source of foreign exchange.

Health and Nutrition

Health

Medical services have been increasing gradually as the government continues to expand the health services at the grassroots level. Some steps are being taken to strengthen the system. First, the Government is directing more resources to health. Between 1986 and 1993, it increased health expenditure in proportion to the revenue budget from 2.6% to 4.9%. Despite increasing demands from the wealthy for more sophisticated medical facilities, the Government also redirected funds more towards primary health care. Over the same period, the proportion of the total health budget going to primary health care rose from 32% to 50%.

However, Government health services are still not adequate. Equipment is antiquated and poorly maintained. The distribution of drugs and other essentials is erratic. Even where primary health care workers are available and willing to visit villages, they can be frustrated by lack of transport.

Life expectancy at birth in Bangladesh is low. Poverty, poor sanitation, malnutrition and a host of other health hazards continue to take their toll. Better living conditions would certainly raise health standards. Many of the major killers such as diarrhoeal disease and acute respiratory infection could be brought under control by an efficient basic health service and better health practices.

Nutrition

The first nutritional census of the country was done over 30 years ago. A survey conducted by the World Bank in 1997 (see Khan et al. 1998) showed that two thirds of the population received insufficient food. A person requires 2 039 calories·day^{-1}, but per capita daily calorie in rural areas was 1 892 and in the urban areas it was 1 779. The survey showed that although the urban people spend more, they get fewer calories than the village people. During the 1960s the average calorific intake was 2 118 (Khan et al. 1998).

According to the WB survey, women and children are the most deprived section. While pregnant women and lactating mothers need nutrition most, they get the least. The survey also showed that of the total population, only 26.5% obtained the required calories. Forty-four per cent of people get less than 80% of calories required.

As the pregnant women get fewer calories, their babies are born malnourished. Sixty per cent of the babies between 6 and 71 months get less food than required. This keeps most Bangladeshi children short in height and underweight. Malnutrition also slows down their mental growth and causes diseases like arthritis, anemia and night blindness.

The food supply in Bangladesh has increased in recent years. Rice production has risen significantly, though at the expense of nutritionally important foods such as beans, pulses and those rich in Vitamin A. At present, the per capita calorie consumption is only around 80% of the level recommended by the WHO. This is not entirely because people are poor. Recent studies have shown that malnutrition can be improved by adopting healthy feeding habits and better distribution of family food supply. Many low cost products like pulses and beans can be supplemented for expensive meat or fish to ward off malnutrition.

Education and Literacy

Education

In 1993, the government made primary education compulsory throughout the country and created a National Plan of Action and set ambitious targets

for primary education. By the year 2000 it aimed to raise the gross enrollment rate to 95% and the completion rate to 70%.

Despite the priority given to the education sector, the education system is not yet producing an adaptable, creative work-force. Teaching has largely been by rote. Staffing is inadequate, materials are scarce and classrooms are crowded and dilapidated. The education system has not been able to attract students, as many parents and children regard school as unattractive or irrelevant to their daily lives. Attendance in primary education is no more than 50% and completion only 40%.

For many children the basic problem is poverty - their families are trapped in a vicious intergenerational cycle of deprivation and ignorance. A Dhaka child can earn 40 - 50 Taka per day just by scavenging for waste paper. Breaking out of this cycle will demand a determined national effort.

Literacy

In Bangladesh a person aged > 7 years who can write a letter is considered to be literate . The average rate is 32.4%; male literacy rate is 38.9% and female literacy rate is only 25.4%. There is a gross inequality in geographical pattern. Generally, coastal districts and the Chittagong Hill Tracts show proportionately higher literacy rates, whereas districts in north Bengal show medium and lower rates. The pattern is partially correlated with the pattern of population density (Khan et al. 1998).

Environmental Awareness

Children in the rural areas learn to swim as soon as they can walk. Bangladesh from one perspective is a vast and beautiful water garden; but from another it is one huge drain.

Heavy rainfall and floods regularly replenish the underground aquifers. In most parts of the country the water-table is only around 8 m below the surface. If people use river or surface water they are taking a great risk, since much of it is contaminated by faeces. Faecal contamination is probably the country's most severe environmental hazard. Groundwater extracted through tube wells using hand-operated suction pumps have been found to be contaminated with arsenic and pose a serious health risk (Islam et al. 2000).

Two-thirds of the rural population either defecate out in the open or use unhygienic latrines that release waste into rivers or ponds. This represents a major health hazard: some 80% of disease is related to unclean water and poor sanitation.

There are a number of other poverty-related environmental issues such as deforestation. The forested area has dropped by over half in the last 20 years and now covers less than 8% of the country. The standing volume of the two main species in the Sunderbans mangrove forest has declined by about 45% since 1959. Deforestation has immediate social and economic costs.

Agriculture development may also lead to groundwater pollution through intensive use of fertilizer, and to a lesser extent pesticides - though these impacts and the effects of multicropping on the organic content of the soil have yet to be closely investigated.

The leather and textile industries, which are among the country's most important export prospects, already account for half the 900 identified polluting industrial plants - chiefly affecting the rivers in Chittagong, Dhaka and Khulna. The Hazaribag area of Dhaka has 250 leather factories, which dump toxic effluents into the Buriganga River.

Local communities and NGOs are now more aware of potential dangers from industrial processes or large scale development projects and have become increasingly vocal.

A Ministry of Environment and Forests, and within it a Department of the Environment, exists to assess the environmental impact of development projects and to monitor industrial pollution. However, this has yet to exert any influence on sustainable human development.

According to some projections, global warming, could cause the sea-level to rise by 100 cm and up to 18% of the country would be permanently submerged.

Level of Urbanization

Although Bangladesh is one of the least urbanized countries, it has some serious urban problems. The capital, Dhaka, is one of the fastest growing cities in the world. Urbanization is not due to regional development, but the result of huge migration of

the unemployed rural population in search of job opportunities. There are 107 urban centers in the country. The majority of the towns are local markets with some administrative functions.

In 1961, slightly more than 5% of the population lived in the urban areas, but by 1991 22% of the population was urban. Most urban migrants have limited skills and are often unable to gain entry into the formal sector job market. The consequence has been an explosion of slum and squatter settlements amidst mass poverty and gross inequality.

According to a survey conducted by the Asian Development Bank (ADB) and the Planning Commission, Government of Bangladesh, in 1995 - 96 61.3% of the urban population fell below the absolute poverty line while 40.2% fell below the hard-core poverty line. Only 18% of the urban poor own the plot of land that they occupy. The situation is extreme in the case of Dhaka, with only 3.2% owning their plots, with the reverse situation in the small towns where nearly 90% own their plots. A higher portion (26%) of households own the house they live in, the reason being the many have built their house on land they do not own. At least 9% are squatters and the proportion in Dhaka is 18.5% (Khan et al. 1998).

Economy and Major Development Patterns (Khan et al. 1998)

In the decades since independence, economic growth has averaged 4% per year. This might seem respectable for a country born from the devastation of war and regularly buffeted by natural disasters. However, it is low by the standards of many Asian neighbors and not nearly enough to have a serious impact on poverty. If poverty is to be reduced significantly in the coming decades, economic growth will need to be closer to 7% per year.

In 1993, Bangladesh ranked 147 out of 173 countries in the UNDP Human Development Index - a reflection of low life expectancy, low educational attainment and low GDP per capita. The poverty situation improved somewhat in the 1980s. Between 1983 - 84 and 1988 - 89, in the rural areas the proportion below the poverty line (consuming less than the recommended intake of 2 122 calories•day^{-1}) fell from 57% to 48% - and in the urban areas from 66% to 44%. In the case of the "hard-core poor" (consuming less than 1 805 calories•day^{-1}) the trend is not consistent. The proportion did fall between 1983 - 84 and 1985 - 86 (in the rural areas from 38% to 22% and in urban areas from 35% to 19%), but between 1985 - 86 and 1988 - 89 it rose again to 30% in the rural areas and 21% in the urban areas.

The Government has taken a number of measures to stimulate the economy and in macro-economic terms it has been very successful. Between 1990 and 1992, it reduced the fiscal deficit as a proportion of GDP, from 7.8% to 5.2% and the current account deficit fell from 6.9% to 2.3%. Over the same period, inflation fell from 9.3% to 5.1% and by the end of 1993 was down to 1.3%. This kind of stabilization lays an essential foundation; now the challenge is to build the framework of a more productive and dynamic economy.

The Government is also financing more of its own development expenditure. Until recently the Annual Development Plan was entirely financed from aid; now the Government contributes around 25%.

The Government has taken a number of useful measures to stimulate the private sector. The Government has liberalized some elements of its macro policy framework, and has developed an inter bank foreign exchange market. Bangladesh's nominal rates of protection are roughly double those of the successful countries of East Asia.

Fisheries Sector

Fisheries

Agriculture is the main occupation, employing 68.5% of the labor force. This sector directly contributes around 35% to the GDP. Bangladesh is rich in fish resources. The fisheries sector plays a very important role in the socio cultural and economic life. In 1992 - 93, the fisheries sector contributed 4.2% to the GDP. Within the agricultural sector, fisheries accounted for 13.8% and export earnings amounted to Taka 7 003 million equal to about 7.6% of the country's total export earnings. In 1997 - 98, export earnings amounting to Taka 13 878 million constituted about 5.9% of the country's total export earnings (DOF 1999). Although the quantities are low, fish provides about 80% of the total animal protein intake.

Infrastructure

Fish Landing Facilities

Fishers operating small traditional craft usually

land their catch on the coast. Most places do not have facilities for berthing, ice and chilling. The fish traders usually transport ice from distant places and often the use of ice is not adequate. A large number of fish traders own motorized fish transportation boats wherein they carry ice and collect catches from the fishers operating in rivers and estuaries. These traders bring collected fish to landing centers in large cities. Most of the traditional boats fish inshore and stay out for one or two days and do not use ice to preserve the fish.

The Bangladesh Fisheries Development Corporation (BFDC) operates six fish landing centers in the coastal districts, at Chittagong, Cox's Bazar, Khulna, Barisal, Patherghata and Khepupara, and four fish landing centers in the inland districts, at Ranagamati, Kaptai, Rajshahi and Daborghat. All these centers are provided with landing platforms, auction halls, ice plants, cold storage, drinking water and accommodation for fish traders. The only fish harbor in the country developed by BFDC is located at Chittagong, near Chittagong port, on the north side of the Karnaphuli River. The facilities of this harbor include a spillway to accommodate vessels up to 35 m, a warehouse, workshop, boat building yards and ancillary facilities, an ice plant, cold storage, freshwater supply, auction hall and a fish meal plant. It also houses a Marine Fisheries Training Institute to train personnel for fish trawlers. At present the berthing facilities have become very limited owing to heavy siltation of the harbor mouth and basin due to erosion of the left bank of the river and regular dredging is required. Fishers' co-operative societies also operate a major fish landing center in Chittagong, but it has neither modern nor hygienic facilities. One such landing center is operated by an NGO (CARITAS) at Chittagong. Private fishing vessels use the mooring facilities, created by the Chittagong Port Authority in the midstream of the Karnaphuli River. For using these facilities the boat owners have to pay a charge of US$ 100 per day. Some private trawler companies have their own landing facilities.

Ice-making and Cold Storage Facilities

There is no recent information on the supply of ice. In 1992 - 93 there were 217 ice plants (block and flake) with a combined daily capacity of 4 405 t, located in the coastal districts of Chittagong, Barisal, Cox's Bazar, Patuakhali, Pirojpur, Khulna, Bagerhat and Noakhali.

The supply of ice is limited, particularly during the peak fishing season, and the supply of ice is generally adequate in only 8 out of 18 wholesale markets. Shortage of ice during the peak season is reflected by the price charged. In Chittagong, prices varied between Taka 10 and Taka 330 for a 125 kg block, depending on demand.

Other Infrastructure Facilities

These include two dock-yards, 7 fish/shrimp training centers, 113 fish hatcheries, 1 public and 43 private shrimp hatcheries, 4 private fish meal plants, 5 public and 31 private prawn hatcheries; 2 public shrimp demonstration farms, 20 public shrimp service centers, 7 fisheries research stations or substations and 1 public surveillance check point.

Fish Processing Plants

There are 123 fish processing plants, of which 87 are located in the coastal districts of Chittagong, Cox's Bazar, Khulna, Satkhira, Bagerhat and Patuakhali. For all these plants, a total requirement of around 156 000 t of raw materials is needed, but only about 22 000 t are available and these processing plants are utilizing only 13 - 15% of their capacity. Only 40% of the plants are currently operational at that capacity level and the others have either closed down their operations or are have been declared as "sick industries".

Boat-building Facilities

Construction of traditional boats is carried out at many places along the coast. Four boat-building yards are owned and operated by the private sector and are located at Anowara, Kalurghat and Patharghata in Chittagong and in Cox's Bazaar. The boats constructed in these yards range in size from 9 m (22 hp) to 16 m (110 hp). There are eight engine repair workshops near the landing terminals, six owned by BFDC, one owned by the Christian Council for Development of Bangladesh (CCDB) at Cox's Bazar and one owned by Bangladesh Jatio Matshyajibi Samabay Samity (BJMSS) at Chittagong.

Net-making Facilities

Most of the nets used by small scale fishers are hand-braided by the fisherfolk. BJMSS owns and operates a net factory at Chittagong which produces 27 000 kg of nylon nets per year. The other net factory is located at Comilla and is owned and

operated by BFDC which has an installed capacity of 41 000 kg of nets. Two new net factories, each with a production capacity of 100 000 kg•year^{-1}, are under construction by BFDC at Chittagong and Khulna.

Fishers and Fishing Households

Fishers belong to the poorest of the poor in Bangladesh. They are mostly illiterate. Since fishing is considered to be a low-class profession, fishers are looked down upon socially. The fishing communities are not conscious of their rights and are not well organized, because they lack both education and leadership. They harvest fish at the risk of their lives even in inclement weather. Family members depend fully on the head of the family, but many of them are only part-time fishers. A few of the fisher families earn a secondary income from poultry, vegetable gardening and fish farming.

Artisanal fisheries range from localized subsistence fishing to intensive mobile fishing operations using simple craft and traditional gear. Seasonality and unstable catch composition are characteristics of the capture fisheries. Inadequate infrastructure and supporting service and lack of proper marketing and distribution, also contribute to high variations in activity.

Traditionally, marine fishing was practiced at a subsistence level by the *jaladas* of the Hindu community. However, with the increased commercialization of marine fisheries and the decrease in land assets because of population pressure, a large number of Muslim fishers took up fishing as a full-time job. Most of the motorized small scale fishing boat owners are now Muslims who hire Hindu or Muslim fishermen as crew, mostly on a catch-share basis. The profit-sharing arrangement varies from area, the type of fishery and the fishing season. For instance, in Chittagong and Cox's Bazar, 60% of the value of catch, after covering the operational cost, goes to the boat and gear owner. The remaining 40% is distributed among the hired crew, the share of each crew member depending on the type of functions performed. These may include catching, drying, transporting and support services such as cooking (Hannan 1996).

Fishing is a major economic activity in the coastal areas. Considerable changes have taken place in the traditional structure of fisheries, with many Hindu fishers migrating to India over the last decades. This, in conjunction with increased population pressure and steady contraction of fisheries resources, has resulted in significant changes in the social groups involved in fisheries.

In 1974 - 75, a survey indicated that 250 000 people were engaged in marine and estuarine fisheries. In 1980 - 81 the total number was estimated at 412 000 while in 1983 - 84 the number was estimated at 515 000, indicating an annual increase of 8%. However, the numbers are confusing because the marine fishing village survey of 1983 - 84 found 105 000 active fishers in the coastal area (Draft Master Plan 1998).

A major problem of the different surveys is the definition of "fishers" and it is likely that sometimes "fishers" and the "total household of a fishing family" are mixed up. This is illustrated in Table 4a, where the results of the marine fishing villages survey of 1983 - 84 are summarized. The total number of households with fishing as a major occupation was estimated at 60 500, comprising about 360 000 family members. The active number of fishers from these households, however, was estimated at 105 000 using 15 000 boats. The largest numbers of fishers are living in Chittagong, Cox's Bazar and Laksmipur district.

A comparison of villages or *thanas* surveyed in 1983 - 84, 1990 and 1997 are presented in Tables 4b and 4c. The average annual increase of different parameters is shown in Table 4d.

In 1984 - 85 a survey indicated that 123 562 fishers were engaged in marine artisanal fisheries, and the total number of coastal households was estimated at 70 193. This is shown in Tables 5 and 6 (DOF 1985).

According to the Bureau of Statistics the number of fishers in the coastal region was 507 788 and in the inland waters 768 632 in 1988 - 89. The yearly statistics of fishers in the inland and the other sectors from 1972 - 73 to 1988 - 89 are given in Table 7.

Table 4a. A summary of the results of the marine fishing village survey in 1983 - 84.

District	Marine village HH	Marine village population	Fishing HH	Fishers	Boats	Fishing HH in marine village (%)
Barisal	4 531	25 096	113	177	44	249
Bhola	24 193	85 415	3 176	3 999	417	1 313
Borguna	28 375	159 675	3 389	6 135	924	1 194
Chittagong	102 365	6,4 462	18 191	31 344	5 694	1 777
Cox's Bazar	87 572	585 156	15 980	28 831	2 869	1 825
Feni	8 104	49 291	442	605	30	545
Jhalakati	14 119	70 710	756	1 511	254	535
Khulna	11 479	69 210	1 484	2 668	846	1 293
Laksmipur	18 052	102 358	5 376	12 502	1 276	2 978
Noakhali	35 271	199 818	6 349	7 937	944	1 800
Patuakhali	33 010	185 773	3 177	6 324	991	962
Pirojpur	19 854	113 338	1 668	2 834	567	840
Satkhira	3 217	18 803	162	300	60	504
TOTAL	390 142	2 309 105	60 263	105 167	14 916	1 545

Source: Draft Master Plan 1998.
Note: HH = households

Table 4b. Comparison of frame survey results for marine fishing villages, 1984 and 1990.

Thana name & survey year	Fisher households	Total fisher household members	Total fishers	Fisher households (%)	Fishers (%)	No. of boats
Pathuakhali - 1983	1 180	6 844	1 886	2.0	1.0	435
Patuakhali - 1990	3 182	22 274	4 773	6.0	2.0	N/A
INCREASE (fold)	2.70	3.25	2.53	3.0	2.0	
Mirzaganj - 1983	232	1 392	316	1.0	0.0	91
Mirzaganj - 1990	988	5 928	N/A	5.0	N/A	N/A
INCREASE	4.26	4.26		4.7		
Kalapara - 1983	435	2 610	726	2.0	1.0	163
Kalapara - 1990	2 293	20 840	N/A	9.0	N/A	961
INCREASE	5.27	7.98		5.0		5.9
Galachipa - 1983	1 066	6 289	2 861	3.0	1.0	302
Galachipa & Dasmina -1990	6 848	41 082	N/A	17.0	N/A	1 380
INCREASE	6.42	6.53		6.4		4.6
Barguna - 1983	739	4 360	1 333	2	1.0	192
Barguna - 1990	675	4 050	N/A	2	N/A	N/A
INCREASE	0.91	0.93		0.9		

Table 4b. Comparison of frame survey results for marine fishing villages, 1984 and 1990. (continued)

Thana name & survey year	Fisher households	Total fisher household members	Total fishers	Fisher households (%	Fishers (%)	No. of boats
Patharghata-1983	1 851	11 106	3 336	9.0	3.0	477
Patharghata-1990	3 930	23 580	5 700	20.0	5.0	N/A
INCREASE	2.12	2.12	1.71	2.22	1.7	
Bamna-1983	348	2 018	643	16.0	5.0	119
Bamna-1990	190	1 140	N/A	2	N/A	206
INCREASE	0.55	0.56		0.10		1.7
Betagi-1983	210	1 197	419	3.0	1.0	47
Betagi-1990	1 200	6 642	N/A	7.0	N/A	235
INCREASE	5.71	5.55		2.2		5.0
AVERAGE ANNUAL INCREASE	0.54	0.61	0.21	2.68	0.2	0.7

Source: Draft Master Plan 1998.
Note: N/A = Not available.

Table 4c. Comparison of frame survey results of marine fishing villages, 1984 and 1997 - 98.

	Char Montaz	Nijum Deep	Bara Baishia	Vhar Majid	Kukri Mukri	Urir Char	Avg. annual increase
No. HH 84	121	99	221	N/A	542	497	
No. HH 97	288	1083	150	720	935	2031	
% increase	2.38	10.9	0.7		1.72	4.09	0.30
Tot Pop 84	883	721	1381	N/A	2875	3828	
Tot Pop 97	2081	5719	921	4241	4936	10195	
% increase	2.36	7.93	0.7		1.72	2.66	0.24
No. fish HH 84	45	81	136	N/A	N/A	N/A	
No. fish HH 97	107	569	33	7	168	63	
% increase	2.39	7.02	0.24				0.25
% fish HH 84	37	82	62	N/A	N/A	N/A	
% fish HH 97	37	53	22	1.0	18.0	3.0	
% increase	1.0	0.6	0.36				0.05
Fishers 84	65	131	290	N/A	N/A	N/A	
Fishers 97	298	824	65	20	452	87	
% increase	4.9	6.3	0.23				0.28
Boats 84	25	11	31	N/A	N/A	N/A	
Boats 97	76	N/A	N/A	N/A		N/A	
% increase	3.0						0.23

Source: Draft Master Plan 1998.
Note: N/A = Not available.

Table 4d. The average annual increase in population, fishers and fishing boats in the coastal belt, 1984 - 98.

	Annual increase ratio	Increase since 1984
No. of households	0.30	4.27
Total population	0.24	3.30
No. fishing households	0.44	6.20
Total Fishers	0.25	3.47
Total boats	0.47	6.65

Source: Draft Master Plan 1998.

Table 5. The number of marine artisanal fisher in households villages 1984 - 85.

District	No. of Marine fishing villages	No. of Marine fisher households				No. of Joint Management Units
		Total	Fishery management households		Fishery laborer households	
			with boat	without boat		
Bangladesh	869	70 193	12 442	7 317	50 434	1 744
Chittagong	171	21 101	4 621	2 667	13 813	253
(CTG. South)	(104)	(15 521)	(2 551)	(1 789)	(11 181)	(232)
(CTG. North)	(67)	(5 580)	(2 070)	(878)	(2 632)	(21)
Cox's Bazar	251	21 545	2 242	1 799	17 504	746
Noakhali	64	10 714	1 525	1 236	7 953	228
Borisal	137	8 059	1 673	753	5 633	219
Patuakhali	200	7 128	1 639	622	4 867	297
Khulna	46	1 646	742	240	664	1

Source: Survey results of 1984 - 85, FRSS (Fisheries Resources Survey System) DOF.

Table 6. The number of marine artisanal fishers and fishing boats in 1984 - 85.

District	No. of Marine Fishers				No. of Marine Fishing Boats		
	Total	Fishery management households		Fishery laborer households	Total	With engine	Without engine
		with boat	without boat				
Bangladesh	123 562	21 172	11 189	91 201	17 331	3 317	14 014
Chittagong	36 623	6 886	3 614	26 123	6 400	1 128	5 272
(CTG. South)	(24 804)	(2 267)	(1 749)	(20 788)	(3 785)	(1 114)	(2 671)
(CTG. North)	(11 819)	(4 619)	(1 865)	(5 335)	(2 615)	(14)	(2 601)
Cox's Bazar	39 829	3 636	3 143	33 050	3 911	1 822	2 089
Noakhali	17 350	2 169	1 762	13 419	2 039	179	1 860
Barisal	12 616	2 810	1 091	8 715	1 933	81	1 852
Patuakhali	14 176	4 383	1 113	8 680	2 142	98	2 044
Khulna	2 968	1 288	466	1 214	906	9	897

Source: Survey results of 1984 - 85, FRSS DOF.

Table 7. Number of fishers in Bangladesh during the period from 1972 - 73 to 1988 - 89

Year	Fishers		
	Inland	Marine	Total
1972 - 73	650 000	210 000	860 000
1973 - 74	660 000	220 000	880 000
1974 - 75	600 000	200 000	800 000
1975 - 76	600 000	200 000	800 000
1976 - 77	618 000	206 000	824 000
1977 - 78	709 000	290 060	999 060
1978 - 79	716 970	312 000	1 028 970
1979 - 80	723 781	334 000	1 057 781
1980 - 81	695 000	411 995	1 106 995
1981 - 82	700 500	439 669	1 140 169
1982 - 83	705 950	456 950	1 162 900
1983 - 84	707 000	463 000	1 170 000
1984 - 85	715 000	450 000	1 165 000
1985 - 86	719 000	475 000	1 194 000
1986 - 87	735 177	485 687	1 220 864
1987 - 88	751 718	496 615	1 248 333
1988 - 89	768 632	507 788	1 276 420

Source: BBS 1997.

During the short winter season, fishers migrate along the coast, i.e. from Chittagong district to the Sunderban region (Dubla) and from the adjacent *thanas* of the Sunderbans. Many of the fishers of the Chittagong district switch to river fishing during the off-season.

Professional, Business and Industry Groups

The fisheries sector employs about 1.2 million people who are directly or indirectly dependent on fishing, fish farming, fish processing, etc., which is about 10% of the total population of the country (Hussain 1995). About 685 000 are inland full-time fishers, 412 000 are marine fishers, about 5 - 6 000 are in the processing industry (both regular and casual) and about 87 000 are in shrimp farming, fry collection, crab and frog collection, dry and dehydrated fish industry and in fish carrier boats.

In 1995, about 60% (768 000) of fishers were in inland fisheries. In inland capture fisheries, the number of fishers increased by 6% from 1979 - 80 to 1988 - 89, but in the same period the marine fishers increased by 50% (Islam 1995).

Marine fisheries are dominated by small scale fishers. They contribute about 96% of the total marine catch and employ 497 000 full-time and 252 500 part-time fishers (Chong et al. 1991).

Institutional and Legal Framework

Fisheries-related Policies

The Constitution

The Constitution provides for an unicameral legislature, which is called Jatiya Sangsad. It consists of 300 members directly elected by adult franchise. The members of Jatiya Sangsad elect another 30 female members. Jatiya Sangsad is the national parliament and is vested with all powers under the Constitution to make laws for the country.

Legislation

Various laws have been enacted for the management and conservation of fish and fisheries. Much of the legislation was enacted during the British colonial period. Most of these laws have been amended to meet modern requirements.

Development Plans

The development of the fisheries sector is undertaken through five-year plans. The Fifth Five-year Year Plan (1997 - 98 to 2001 - 2002) targeted the following items for development:

- Socioeconomic development of fisher folk;
- Open water fisheries development;
- Shrimp culture development in both fresh and brackish water;
- Intensive fish culture development;
- Management and conservation of open inland fisheries and marine fisheries;
- Strengthening of extension service;
- Strengthening of the Fisheries Resources Survey System (FRSS);
- Strengthening of fish inspection and quality control services;
- Development of unexploited fisheries.

The first five-year plan (FFYP 1973 - 78) was developed by the Planning Commission in November 1973. This was followed by a two-year plan (TYP 1978 - 80). The second (SFYP), third (TFYP) and fourth (FFYP) five-year plans were implemented during 1980 - 85, 1985 - 90 and 1990 - 95, respectively. The broad objectives and targets of all the development plans have been similar i.e. increasing fish production for domestic consumption and export, generating employment opportunities, improving socioeconomic conditions of fisher folk and conserving the resources. Fish production targets of the plans are given below.

Plans	Target ‘000 t	Production achieved ‘000 t
FFYP (1973 - 78)	1 020	643
TYP (1978 - 80)	808	646
SFYP (1980 - 85)	1 000	774
TFYP (1985 - 90)	1 000	856
FFYP (1990 - 95)	1 200	1 173
TYP (1995 - 97)	1 370	1 307
FiFYP (1997 - 02)	2 075	–

The financial allocation for fisheries development during the plans has always been inconsistent with

the present contributions and further development potential. The rate of utilization of funds available has also been low, as shown below:

Plan	Allocation (Taka in million)	Actual utilization (Taka in million)	% Utiliza-tion
FFYP (1973 - 78)	485	190	39
TYP (1978 - 80)	440	386	88
SFYP (1980 - 85)	1 743	1 583	90
TFYP (1985 - 90)	3 500	1 400	40
FFYP (1990 - 95)	7 500	3 000	40
FiFYP (1997 - 02)	5 862	–	–

The main objectives of the Fifth Five-year Plan (FiFYP) were to develop and strengthen fisheries research and development and management and extension activities aimed at increasing fish production with the following objectives:

- To increase fish production and improve nutritional level;
- To generate additional employment opportunities in fisheries and ancillary industries to help poverty alleviation;
- To improve the socioeconomic conditions of fisher folk, fishers, fish farmers and others engaged in the fishery sub sector;
- To increase export earning from shrimp, fish, fish products and GD;
- To improve environmental conditions and public health;
- To improve the biological and institutional management mechanisms for judicious use of fisheries resources; and
- To strengthen research, extension, management and coordination in order to transfer technology and encourage production activities in the private sector and to ensure sustainable development of fisheries resources, particularly utilizing the water resources of the vast flood plains.

Open-water Fisheries Development

Bangladesh has vast inland open water resources. In order to increase production three strategies were planned. These were: (i) to conserve resources through rigorous implementation of Fish Acts and Ordinances and through motivation of fishers; (ii) to establish fish sanctuaries; and (iii) to increase production by massive stocking of fast-growing carp. Construction of fish passes in flood control and irrigation embankments was also planned.

Closed-water Culture Fishery Development

There are over 1.3 million ponds covering an estimated area of 147 000 ha, some 6 000 ha of ox bow lakes and over 130 000 ha of shrimp farms. The production of freshwater ponds is only 1.4 $t \cdot ha^{-1}$ and of brackish water shrimp farms only 160 $kg \cdot ha^{-1}$. Experimentation by the Fisheries Research Institute and demonstration by the Department of Fisheries has shown that pond production can be increased up to 3.7 $t \cdot ha^{-1}$. If successful, planned extension programs could increase the present pond production from 195 000 t to at least 600 000 t in a 10-year period.

Brackish Water Aquaculture Development

There are an estimated 143 000 ha of coastal land under brackish water shrimp culture. The strategy for development of this sub-sector is to improve the infrastructure, ensure quality seeds, feeds and other inputs, ensure security and provide technical advice and training for the farmers on improved scientific farming systems. With better support and increased resources, a level of production of 400 $kg \cdot ha^{-1}$ can be realized. Semi-intensive farming areas identified will be developed with appropriate inputs.

Marine Fisheries Development

Marine fisheries resources have been under pressure from over-fishing in some areas particularly the inshore and the coastal areas. The detrimental effects of estuarine set bag nets and shrimp larval collection nets have to be reduced through motivation, awareness building and by providing the fisher folks with alternate income sources. Although the demersal stocks are considered to be over-fished, the pelagic resources, such as tuna, tuna-like fish and sharks, are still under-exploited in some areas. Many non-traditional resources like seaweeds, oysters, clams, squids and cuttlefish have scope for expansion. Trash fish, which is discarded by the commercial shrimp trawlers, could be utilized if appropriate uses could be found.

Post-harvest Technology and Marketing

It is believed that 30 - 33% of all fish caught becomes unfit for human consumption. This economic waste could be reduced by better handling, processing, transportation and marketing. The appropriate infrastructure facilities, such as cold storage, ice plants, insulated and refrigerated systems and markets, have to be built and appropriate training provided to reduce these losses. The marketing system must be adjusted to expanding export demand for quality frozen fish, expanding domestic demand for quality fresh and frozen fish and coping with large seasonal fish catches in areas far from the main markets and fish landing centers.

Peoples' Participation in Fisheries Development

Fisheries development is the result of the concerted effort by governmental, non-governmental and private organizations, fisher folk and fish traders. A strong and effective linkage system must be developed among these parties for implementation of a participatory plan for fisheries development. Participation is recognized as an essential part of the planning and development process, which helps to increase access to and maximize the utilization of services. Therefore, participatory planning that has been started recently should involve the members of communities of fishing, farming, trading, marketing and who, as a community, know and accept responsibility for their own development. They will develop their own resources to meet their needs. This requires personal as well as government endeavor, institutions and organizations. The primary focus is to put the people in control of their own problems, resources and activities accordingly to their priorities.

The major constraints are:

- Flood control and irrigation embankment are reducing the available habitat of fish and shrimp and are obstructing their migratory routes and destroying their breeding habitat.
- Pond culture developments are affected by multi-ownership and multiple uses of ponds, and also by lack of technical knowledge and necessary inputs.
- Unplanned brackish water shrimp culture is responsible for mangrove destruction, and is creating conflicts among the paddy farmers and shrimp farmers. The problem of disease and lack of proper infrastructure and necessary materials is hampering its overall development.
- The marine fisheries sector is constrained by the lack of manpower and infrastructure facilities. There is also lack of proper management policy. Many under-utilized and unutilized resources are not being exploited due to the lack of appropriate technology and technical knowledge.
- Pollution from pesticides and agricultural wastes are destroying the ecology of fish habitats and reducing the natural recruitment of fish and shrimp.

Administrative Orders, Regulations and Ordinances

There are many ordinances governing the management and conservation of the fisheries resources in the country (See Appendix I). Most of them are concerned with the freshwater fishery resources. The most comprehensive legislation dealing with the management and conservation of the marine fisheries resources are the Marine Fisheries Ordinance and the Marine Fisheries Rules.

National and Sub-national Fisheries Institutions

Fisheries Administration and Agencies

The formulation of policies on fisheries management remains primarily under the control of the Ministry of Fisheries and Livestock headed by a Cabinet Minister. The major responsibilities of the Department are as follows:

- Assisting the Ministry in formulation of policies on fisheries management and development.
- Surveying and estimating of available resources.
- Management and conservation of fisheries resources, including enforcement of fisheries legislation, rules and orders.
- Formulation and execution of fisheries development projects.
- Demonstration, extension, technology transfer and training related to aquaculture and fisheries management.
- Ensuring quality of exportable fisheries products and issuing certificates in accordance with fish inspection and quality control rules.
- Monitoring of artisanal and marine industrial fisheries, including surveillance of fishing operations in coastal waters.

The existing organizational structure of the DOF is based on the findings and recommendations of a Committee named the "Matin Committee". The DOF is headed by the Director General, who is supported by three Directors; one for marine fisheries, one for inland fisheries and another for the Fisheries Training Academy, Savar, in Dhaka. The Director (Marine) takes care of all functions of marine resources surveys, enforcement of laws and licensing. The Director (Inland) is responsible for administration, finance, training, fish culture, extension activities and management of field offices. He also looks after completed field based projects included in the revenue budget. There are two Principal Scientific Officers, one for the Fisheries Resources Survey System (FRSS) and another for Quality Control.

The field level set-up consists of Deputy Directors in five Divisions, Marine Fisheries and Quality Control Officers, 64 District Fisheries Officers and 456 *Thana* Fisheries Officers. In addition there are 103 Farm Managers and other officers in the Training Institute and the Marine Survey and Management Unit.

The total staff of the DOF under the revenue budget is 3 863. The Marine Wing of DOF is located in Chittagong. According to provisions of the Marine Fisheries Ordinance and Marine Fisheries Rules, the Marine Wing of the DOF issues licenses and monitors operations of fishing vessels. In addition to the Ministry of Fisheries and Livestock, other ministries or agencies directly or indirectly involved in fishery activities are the Ministry of Lands, for leasing of public open water bodies or *jalmahals*; the Ministry of Industries for licensing and promotion of fish processing industries and trawler industries; the Ministry of Commerce for export of fishery products and import of fishery equipment; the Ministry of Irrigation Water Development and Flood Control for the development for embankments and water control; the Ministry of Local Government and Rural Development for registration of fishers' cooperative societies and the Ministry of Environment and Forest for management of water bodies within the Sunderbans Forest Reserve and conservation of mangrove ecosystems.

Mandate of DOF

This covers the following:

Transfer of technology:

- Extension services on aquaculture and management.
- Training and advisory services on aquaculture and management.
- Advisory services to provide credit for fisheries.
- Dissemination of modern technology on aquaculture, fisheries management and hatchery operations.

Conservation of fisheries resources:

- Enhancement of fisheries through conservation and management of fisheries resources.
- Enhancement of fisheries rules and regulations.

Quality control of fish and fishery products:

- Ensuring quality of fish and fishery products and issuance of health certificates for exportable fish products.
- Enforcement of inspection and quality control rules for fish and fish products.

Others:

- Advising the Government in the formulation of policies related to fisheries.
- Collection of data on the fisheries and their compilation, editing and publication.
- Planning, formulation, implementation, monitoring and evaluation of fisheries development projects.
- Socioeconomic uplift of fishing communities.
- Poverty alleviation through fisheries activities.

Other Fisheries Institutions

Bangladesh Fisheries Development Corporation (BFDC)

The BFDC was established in 1964 with a view to promoting the fishing industry, particularly in the marine sector. Activities of the Corporation include the following:

- operating a number of fish and shrimp trawlers.
- managing some large water bodies, such as Karnaphully Reservoir (68 800 ha), the canal and Gulsan Lake.
- undertaking marketing of fish in Dhaka by transporting fish from Chittagong, Rangamati, Cox's Bazar, Jossore and other places.

- operating wholesale fish markets and sale centers in Dhaka and other cities.
- processing shrimp and finfish and undertaking limited export of products.
- operating a number of fish landing centers and three fish net factories.

Fisheries Research Institute (FRI)

The FRI was established in 1984 as an autonomous body under the administrative control of the MOFL. The mandate of FRI is to plan and undertake adaptive research programs for inland, coastal and marine fisheries and develop suitable technology for use of fish farmers and fisheries managers. The Institute has research facilities at four stations, namely the Freshwater Aquaculture Station at Mymensingh, the River Research Station at Chandpur, the Brackish water Station at Paikgacha and the Marine and Technology Station at Cox's Bazar.

Marine Fisheries Academy (MFA)

The academy was established in 1973 to develop qualified manpower such as skippers, gear technologists, engineers and fish processors for the fishing trawlers. At present, the Academy works under the direct control of the MOFL.

Other Institutions Involved in Fisheries and Coastal Zone Management

Fisher Folk's Organizations

There are three fisher folk's organizations in Bangladesh, as shown below:

- Bangladesh Jatio Matshyajibi Samabay Samity (BJMSS) established in 1960.
- Bangladesh Jatio Matshyajibi Samity (BJMS) established in 1986.
- Bangladesh Jatiotabadi Jele Dal (BJJD) established in 1993.

The last two societies were established at the national level under different governments. These societies do not have access to societies at the field level. The BJMSS is the apex society registered with the Department of Cooperatives, which has 88 central and 4 243 primary societies.

Non-governmental Organizations (NGOs)

Many NGOs are working with the fisher folk in the inland and marine sectors. Most of the NGOs in the coastal areas are engaged in socioeconomic development. They mostly work to improve living standards by educating people on sanitation, health and nutrition and also providing them with some facilities. Many provide fishers with credit for engaging in fishing or other non-fishing activities. The notable NGOs working with the coastal fisher folk are CODEC, CARITAS, ASA and OXFAM. The NGOs working with the coastal fisher folk have formed an organization called COFCON to coordinate development activities in coastal areas.

Involvement of Agencies

The involvement of different agencies in the administration, management and development of fisheries is shown in Figure 2.

Financing Institutions Relevant to Fisheries Activities

Donors like IDA (Institute of Defense Analysis), ADB (Asian Development Bank), UNDP (United Nations Development Programme), FAO (Food and Agricultural Organization), DfID (Department for International Development), IFAD (International Fund for Agricultural Development), Danida (Danish Development Assistance), CARE (Co-operative for American Relief Everywhere), EU (European Union), USAID (United State Agency for International Development), CIDA (Canadian International Development Agency) and the Ford Foundation are involved in Bangladesh's fisheries sector with the stated aim of increasing fish production and improving fisheries management. These donors fund studies, research, institutional development and pilot activities. They show concern for the rights of the fishers and their role in management. Among the donors, the World Bank takes the leading role.

The financial banks are also related to fisheries as they advance loans for fish culture activities. Many banks also fund shrimp culture and the fish processing industry. The notable banks are the Khrishi Bank and the Sonali Bank.

Ministry	Department / institution	Involvement
Ministry of Fisheries and Livestock (MOFL)	Department of Fisheries (DOF)	Administration, management and development, extension and training, conservation of resources, enforcement of fishery laws.
	Bangladesh Fisheries Development Corporation (BFDC)	Exploitation and marketing
	Fisheries Research Institute (FRI)	Research, training and extension.
Ministry of Land (ML)	Land Administration Board (Land Reforms Division)	Leasing of public water bodies above 20 acres.
Ministry of local Government Rural Development and Co-operatives (LGRDC)	Bangladesh Rural Development Board (BRDB)	Fisheries component of integrated rural development.
	Registrar of Co-operative Societies	Registration and supervision of fisher's co-operative societies.
	Bangladesh National Fishermen's Co-operative Societies (BJMSS)	Operation of ice-plants import of fishing gear.
	Co-operative Banks	Financing of fisher's co-operatives.
	District parishad	Management of water bodies above 20 acres.
	Thana parishad	Management of closed water bodies below 20 but above 3 acres.
	Union parishad	Management of water bodies below 3 acres, and with rent earlier fixed at Taka 5000 (as of February 1987).
Ministry of Irrigation, Water Development and Food Control (MIWDFC)	Bangladesh Water Development Board (BWDB)	Leasing of reservoir and irrigation channels.
Ministry of Forest and Environment (MFE)	Forest Department (FD)	Exploitation and control of Sundarban-based fisheries loan.
Ministry of Finance (MF)	Bangladesh Krishi Bank (BKB)	Administration of fisheries loan.
	Commercial banks	Administration of fisheries loan.
	Economic Relations Department (ERD)	Administration and co-ordination of foreign assistance for fisheries development.
Ministry of Planning	Planning Commission (planning)	Project evaluation and approval.
Ministry of Shipping	Mercantile Marine Department	Registration of fishing vessels/boats.
Bangladesh of Transport and Communication (BT and C)	Bangladesh Railway (BR)	Leasing of reservoirs and canals on railway land.
Ministry of Defense (MD)	Bangladesh Navy (BN)	Leasing of water bodies in the naval area: Patrolling Exclusive Economic Zone (EEZ) to prevent intrusion of foreign fishing vessels.
Ministry of Commerce (MC)	Department of Commerce	Leasing of fish processing plants.
Ministry of Foreign Affairs (MFA)	EEZ of Bangladesh	Exclusive Economic Zone (EEZ) negotiations.
Ministry of Education	Bangladesh Agricultural University	Higher fisheries education; extension and training.
	Other universities	Fisheries-related education.
NGO affairs Bureau	Various non-governmental organisation (NGOs)	Development activities in the fisheries sector by arrangement with other agencies.

Fig. 2. Involvement of Government of Bangladesh agencies in administration management and development of fisheries.
Source: Kutty et al. 1991.

Research and Training Facilities and Opportunities

Apparently, the marine sector has been a lower priority area in the fisheries development program. Before starting commercial exploitation by deep sea trawlers and mechanized boats, several surveys were conducted in the Bay of Bengal starting in 1958, to evaluate the abundance and promote the exploration of marine fishery resources. The most important findings obtained from the various surveys were as follows:

- Identification of the major fishing grounds in Bangladesh marine areas, covering an area of over 16 000 km^2.
- Identification of shelf area of over 40 000 km^2 and estimation of fishery biomass at depths ranging from 10 to 200 m.
- Estimation of the standing stock and MSY of demersal fish and shrimp.

However, to date no proper assessment of pelagic resources has been made.

The Marine Fisheries Research, Development and Management Project at Chittagong, with a sub-station at Cox's Bazar, was functional under FAO/UNDP assistance during 1984 - 85, when assessments of demersal stocks were done. During the second phase of the project, aspects of artisanal fisheries were studied with technical and financial support from the Bay of Bengal Programme. The resource survey component of the DOF, provided data to compile the official fishery statistics. However, these are qualitatively and quantitatively unsatisfactory and need to be improved. The former Marine Fisheries Survey Project of the DOF also carried out similar programs and undertook research studies in a particular area for only as long as necessary to acquire data for some intended stock assessment. However, complete baseline information on the different parameters of the marine fisheries is lacking.

The Fisheries Research Institute (FRI) was established in 1984 with four research stations; the Freshwater Station at Mymenshingh, the Riverine Station at Chandpur, the Brackish water Station at Paikgacha, Khulna and the Marine Fisheries and Technological Station (MFTS) at Cox's Bazar. The Marine Station was based in the compound of the former Marine Fisheries Research and Development Project. As a government policy decision, the facilities, man power and equipment of that project were to be transferred to the FRI to initiate marine fisheries research in the country. However, this did not happen as planned and the DOF handed over only a part of the building and the staff quarters to the FRI in 1991. The FRI then initiated establishment of its station (MFTS) with limited research activities on mariculture of shrimp and finfish, planktonic mass culture, Artemia biomass production, transportation of live shrimp and the development of fish and shrimp feed formulation. Unfortunately because of lack of personnel, funding and facilities, no research could be undertaken on productivity, stock assessment and catch monitoring.

Training

The Department of Fisheries operates three training institutes for training of fisheries workers and fish farmers and one training academy for in-service training of governments officers. Officers also get foreign training offered by various developed countries, but the officers are not always posted to the sectors for which that they are trained. Government fisheries officers need more training in order to understand fish stock assessment and management.

Coastal Capture Fisheries in Focus

Capture Methods by Sector

Fishing Craft

Fishing operations in the estuaries and coastal waters used to be carried out by traditional craft until the mid - 1960s. From 1966, two organizations, namely the Bangladesh Fisheries Development Corporation (BFDC) and the Bangladesh *Jatio Matshyajibi Samabay Samity* (BJMSS) started the process of mechanization by importing and introducing marine engines. A frame survey of traditional and mechanized boats was carried out by the Fisheries Resources Survey System (FRSS) of the Department of Fisheries (DOF) in 1984 - 85 and according to that survey a total of 17 331 boats were in operation in the marine artisanal fishery, of which 3 317 were mechanized. The distribution of these boats by District is given in Table 6. It is known that the number of boats has substantially increased since 1985, but no substantive data are available. According to an estimate by Nuruzzaman (1991), there were 20 000 traditional and 12 700 motorized boats in the estuaries and coastal waters.

More recently, the Coastal and Marine Fisheries Strengthening Project of the DOF reported a total of 50 530 artisanal boats, of which 28 700 are non-mechanized and 21 830 are mechanized, including 3 317 that are registered as mechanized boats.

Traditional Boats

Three types of traditional boats exist in the country. These are plank-built *dhingi*, *chandi* and *balam* (dug-outs). Characteristics of these boats are given in Table 8.

Mechanized Boats

Mechanized boats of 7 - 8 gross tonnage are powered by 9 - 33 hp engines and have 6 - 10 crew. Most land 2 - 3 t per 4 - 6 day trip.

Trawlers

In additional to the artisanal fishing fleet, commercial fishing is undertaken by a fleet of 44 shrimp and 15 finfish trawlers. Most of the shrimp trawlers are 30 - 40 m long with 450 - 750 hp engines and have 20 - 25 crew. They are mostly double riggers with cod-end mesh sizes of 45 - 50 mm. The shrimp trawlers operate around 180 days per year and land a daily average catch of 610 kg shrimp and 350 kg of white fish. The overall lengths of finfish trawlers range from 28 to 30 m. All are stern trawlers with cod-end mesh sizes of 60 - 65 mm.

Artisanal Fishing Gears

The major gear employed in the estuaries and coastal areas are gillnets, set bag net (SBN), trammel-nets, long-lines and beach seines. Some are operated by boat and some without boats. The types and numbers of gear in operation in the different areas during 1984 - 85 are given in Table 9.

Table 8. Characteristics of traditional and motorized fishing fleet of Bangladesh.

Type of boat	Length of craft (m)	Width (m)	Depth (m)	Number of crew	Propulsion	Cost ('000 taka)	Fishing gear used
A. Traditional							
Dinghi	6 - 7	1.0 - 1.2	0.9	1 - 2	Oar/sail	10 - 15	Gillnets/long lines
Chandi	10 - 15	1.4 - 1.8	1.0	7 - 15	Oar/sail	20 - 30	Gillnets
Balam (medium)	10 - 15	1.5 - 2.0	1.2	10 - 15	Oar/sail	35 - 40	Gillnets
Balam (large)	15 - 20	2.0 - 2.5	1.2 - 1.5	20 - 30	Oar/sail	45 - 60	Gillnets/SBN*
B. Motorized							
Cox's Bazar type Modified	12 - 14	3.0 - 3.2	1.2 - 1.5	8	22 - 33 hp	140 - 180	Gill/SBN*
Cox's Bazar type *Chandi*	12	30	12	6	22 hp	–	Gill/SBN*
Chandi	12 - 13	1.6 - 1.8	1.0	10	9 hp	50 - 60	Gillnets
Longliner	6 - 7	1.0 - 1.2	0.9	6	10 - 15 hp	40 - 50	Long line

Source: Ameen 1987.
Note: * SBN = Set bag net.

Table 9. Type and number of gear in operation in the coastal district of Bangladesh in 1984 - 85.

Gear type District	Gillnet	Set bag net	Long-line	Cast-net	Seine-net	Misc.	Total
Chittagong	1 744	5 952	534	–	60	82	8 372
South	1 118	2 374	186	–	10	–	3 688
North	626	3 578	348	–	50	82	4 684
Cox's Bazar	1 964	2 346	1 115	1 342	346	109	7 222
Noakhali	1 234	461	88	8	24	–	1 815
Barisal	880	795	265	3	22	120	2 085
Patuakhali	1 059	1 500	70	–	10	–	2 639
Khulna	8	1 561	12	–	96	–	1 677
Total Number	6 889	12 615	2 084	1 353	558	331	23 810

Source: Survey results of 1984 - 85, FRSS DOF.

Gillnets

Gillnets include five different types, namely: drift, fixed, large, bottom-set and mullet gillnets. Most are drift gillnets with an average mesh size of 100 mm operated within 20 - 40 m depth and catch mostly *Hilsa*. Skipjack tuna, mackerel and shark are incidental catches. The nets are made of nylon twine and tire cord and are operated by mechanized boats. The large mesh (180 - 200 mm) gillnets are used for catching Indian salmon, sea bass and groupers (BOBP 1985). The number of gillnets in 1984 - 85 was 6 889 (DOF 1985).

Set Bag Nets

These are fixed nets with rectangular mouths that are kept open by two vertical bamboo poles. The nets taper from the mouth and end in a bag of fine (5 - 18 mm) mesh. There are two types, the estuarine set bag net (ESBN) and the marine set bag net (MSBN). In 1989 - 90 there were 12 561 ESBN (Islam et al. 1993) and 3 852 MSBN (Quayum et al. 1993). The ESBN are operated in depths of 3 - 10 m. The gear is considered destructive since it catches juveniles of a large variety of shrimp and finfish species. The marine set bag nets are large with a somewhat bigger mesh size and are operated during the dry season in 10 - 30 m from island bases and catch similar species to the ESBN, but mostly at pre-adult sizes.

Trammel-nets

These are three-layered bottom gillnets targeted at penaeid shrimp, but they also catch valuable finfish species. In 1989 - 90, 400 nets were in use (Islam and Khan 1993). Their operation is concentrated along the Cox's Bazar-Teknaf coast. The mesh size at the inner wall is 40 - 45 mm and the gear is ope-rated by row boats in 5 - 15 m.

Bottom Long-lines

Bottom long-lines are operated at 20 - 30 m, 20 km offshore, mainly from Cox's Bazar. About 2 084 units were engaged in coastal areas in 1985 (DOF 1985). They are operated by 6 - 16 hp mechanized boats. The targeted species are jewfish (croakers), but other species such as Indian salmon, catfish, threadfin and groupers are also captured.

Beach Seines

Beach seines are used throughout the country but are concentrated in the Teknaf-Cox's Bazar area. There were 558 nets in 1984 - 85 (DOF 1985). Since the mesh size is small (12 mm in the middle) and the area of operation is shallow, they mostly catch young and juvenile jewfish, anchovies, clupeoids and small shrimp.

Shrimp Seed Collection Gear

Fine-meshed push-nets, fixed bag nets and drag-nets are used in all areas for harvesting of post-larvae *Penaeus monodon*. In the process of collection, large numbers of the larvae and juveniles of other species of shrimp and finfish are destroyed. It was estimated by the DOF/BOBP survey between November 1989 and October 1990 that 292 397 people, including women and children, are involved in the collection of shrimp seed and 228 658 gear of different types are used in this fishery (Paul et al. 1993).

Catch and Catch Rates

Historical Catches and Landings

Fish production increased from 815 000 t in 1986 - 87 to 159 900 t in 1989 - 99. The fish production from different sources between 1990 - 91 and 1998 - 99 is given in Table 10.

Historical Effort Information

Motorized traditional boats: Marine fishing with motorized boats was practically unknown before 1960. Mechanization of fishing boats and fish carrier boats started in 1957 - 58 and was subsequently taken up through the co-operative sector and the Fisheries Development Corporation (Shahidullah 1983). In 1966 - 67 a FAO-Sida project began motorizing traditional Cox's Bazar type boats with 12 hp petrol outboard engines. Subsequently, these were replaced by inboard marine diesel engines of 15 - 35 hp. The boats are 12 - 14 m long and use mainly gillnets, but also operate *behundi* and/or *funda* nets (BOBP 1985). During 1 or 2 months of the year these boats stay on the Kalidaha fishing ground or off Dubla Island. They carry up to 100 gillnets with a total length of 1 400 m (Mohiuddin et al. 1980). The number of crew per boat is generally 8 - 10.

After independence the mechanization of fishing boats continued rapidly. From 1975 to 76, a modified Cox's Bazar type was built in a boatyard set up at Chittagong under a Danida-aided boat building and motorization project. The boats are 12 m long of 5 GRT and are powered by a 22 hp marine inboard diesel engine and have a crew of six (Ameen 1987). The characteristics of the traditional and motorized fishing fleets are shown in Table 11.

Shahidullah (1983) noted that the number of mechanical boats registered with the Marine Mercantile Department of the Ministry of Shipping was 1 030 in 1976 - 77, which rose to 1 400 in 1979 - 80 and 2 643 in 1982 - 83. However, a large number operated without registration. Nevertheless, it was estimated that about 2 500 - 3 000 boats were engaged in fishing in the sea. The Third Five-Year Development Plan also estimated that the small scale fishing fleet consisted of 12 000 boats of which about 3 000 were mechanized.

Table 10. Fish production from different sources from 1990 - 91 to 1998 - 99.

Year	Total production (t)	Total marine production (t)	Industrial production (t)	Artisanal production (t)
1990 - 91	895 935	241 538	8 760	232 778
1991 - 92	952 079	245 474	9 623	235 851
1992 - 93	1 020 654	250 492	12 227	238 265
1993 - 94	1 090 610	253 044	12 454	240 590
1994 - 95	1 170 365	264 650	11 715	252 935
1995 - 96	1 257 940	269 702	11 959	257 743
1996 - 97	1 306 739	274 704	13 564	261 140
1997 - 98	1 473 673	283 673	15 673	268 000
1998 - 99	1 598 900	291 900	15 900	276 000

Sources: FCS, DOF 1990 - 91 to 1995 - 96.

Table 11. Annual shrimp catch and effort of shrimp and fish trawlers during the period from 1981 - 82 to 1997 - 98.

Fishing season	Standard effort (days)			Shrimp catch (t)			Catch per unit effort kg·fishing day^{-1}
	Shrimp trawler	Fish trawler	Total	Shrimp trawler	Fish trawler	Total	
1981 - 82	2 987	795	3 782*	1 340	357	1 697*	449
1982 - 83	4 510	2 514	7 024	2 004	1 116	3 120	444
1983 - 84	6 087	3 575	9 662	3 441	2 020	5 461	565
1984 - 85	6 267	1 892	8 159	4 239	1 279	5 518	676
1985 - 86	5 941	502	6 444	3 716	318	4 034	626
1986 - 87	6 449	479	6 928	4 178	310	4 488	648
1987 - 88	6 239	344	6 583	3 339	184	3 523	535
1988 - 89	6 615	330	6 945	4 661	232	4 893	705
1989 - 90	5 460	86	5 546	3 086	48	3 134	565
1990 - 91	4 437	62	4 499	3 384	47	3 431	763
1991 - 92	–	–	6 122	–	–	2 902	474
1992 - 93	–	–	7 065	–	–	4 188	593
1993 - 94	–	–	7 169	–	–	3 480	485
1994 - 95	–	–	6 761	–	–	2 416	357
1995 - 96	–	–	7 394	–	–	3 588	485
1996 - 97	–	–	7 107	–	–	3 536	497
1997 - 98	–	–	7 491	–	–	2 444	326

Sources: Khan et al. 1997.
Note: * Estimated fishing effort and production were considered unreliable.

Offshore trawler fishing: Commercial trawling, mainly for demersal finfish, in offshore waters began in 1972 with the introduction of 10 trawlers (Rahman 1999). After the discovery of commercial shrimping grounds in 1976 - 77, some Bangladeshi entrepreneurs and foreign firms became interested in trawl fishing, particularly for shrimp. The GOB subsequently recognized deep sea fishing with trawlers as an industry.

For the acquisition and importation of trawlers, some Bangladeshi firms obtained trawlers with financial credit from various banks, others under Joint Venture Schemes in collaboration with foreign trawling companies. Permission was also accorded to bring trawlers on charter with foreign collaboration. Trawlers charted by Bangladeshi firms were later converted to *pay as you earn* (PAYE) schemes, in which local firms entered into agreements with foreign trawler suppliers to make payment of the cost of trawlers over 5 - 7 years through yearly installments from the earnings of their exports. However, it was observed that in joint venture and PAYE schemes, the ownership and fishing operations remained under the management of foreign trawler suppliers; even the expert crews were also foreigners. Most of the catches of PAYE scheme trawlers were directly exported to Thailand. The local subsidiary companies worked only as agents and earned some money without any investment of their own (Shahidullah 1986).

After the confirmation of the presence of the exportable varieties and quantities, trawling for

penaeid shrimps was introduced in 1978. From 4 shrimp trawlers operating in 1978, the number went up to around 100 in 1984 (White and Khan 1985). Meanwhile, there was a large increase in demersal finfish trawlers due to joint ventures, reaching 137 in 1980 - 81, after which joint ventures were terminated temporarily until January 1985 when the Department of Industry provided licenses for 250 vessels, of which around 100 became operational. In 1985 a reduction in fishing effort was suggested and the fleet stabilized. Currently there are 44 shrimp trawlers and 15 demersal finfish trawlers. The effort in the trawl fishery during the last two decades has been around 5 000 - 7 000 standard fishing days, producing 2 500 - 5 500 t of shrimp (Table 11).

Catch Composition Trends

The catch composition in gillnets during 1982 - 85 is shown in Table 12. The table indicates that the percentage composition of commercial fish such as pomfret, Indian salmon and seabass were declining during 1982 - 85.

The percentage catch composition of the fish trawler F.V. Mitali for demersal fish in 1991 and 1998 and in shrimp trawlers from 1987 - 88 to 1997 - 98 are shown in Tables 13 and 14, respectively. Table 13 shows that the percentage composition of commercially important demersal finfishes like pomfret, jewfish, grunter and snapper were declining from 1991 to 1998. Table 14 shows changes in the percentage composition of commercial shrimps during 1987 - 98.

Table 12. Percentage composition of gillnet catch at Chittagong from mechanized boats during 1982 - 85.

Local name	English name	Scientific name/ Family	Percentage composition			
			1982	1983	1984	1985
Hilsa	River shad	*Hilsa ilisha*	67.7	71.0	72.6	76.2
Poa/Kala datina	Jewfish/croaker	*Sciaenidae*	1.9	3.5	3.0	2.6
Katamach/Gongra	Cat fish	*Tachysuridae*	5.9	4.0	3.8	3.4
Rupchanda	Pomfret	*Stromateidae*	4.2	5.0	2.6	1.5
Lakhua (Lakya)	Indian Salmon	*Polynemus indicus*	2.3	1.5	2.0	1.0
Bhetki/Koral	Giant Seaperch (Sea bass)	*Lates calcarifer*	0.9	1.5	2.0	1.3
Maitta, Champa, Bom-maitya, etc.	Tuna and Mackerel	*Scombridae*	15.6	11.5	12.0	11.0
Skates and Rays	String rays	*Dasyatidae*	1.5	2.0	2.0	3.0

Source: Shahidullah 1986.

Table 13. Percentage species composition of fish trawler F.V. Mitali in 1991 & 1998.

1991		1998	
Pomfret	2.28	Pomfret	1.06
Jewfish	18.48	Jewfish	11.61
Snapper	1.36	Snapper	0.35
Grunter	1.76	Grunter	0.63
Catfish	16.15	Catfish	17.41
Ribbon fish	9.28	Ribbon fish	8.07

1991		1998	
Eel	1.40	Eel	0.99
Pama Croaker	0.62	*Nemipterus* spp.	0.89
Sea perch/Sea bass	0.52	Red fish	11.86
Mixed	3.59		
Others	44.50	Others	47.10

Source: Rahman 1999.

Table 14. Percentage species composition of shrimp trawler from 1987 - 88 to 1997 - 98.

Years	*P. monodon*	*P. indicus*	*M. monoceros*	Small mixed shrimp
1987 - 88	17.30	8.10	52.30	21.30
1988 - 89	11.27	6.90	65.40	16.43
1989 - 90	15.80	6.50	57.50	20.20
1990 - 91	9.79	2.79	72.08	15.34
1991 - 92	18.80	7.60	63.60	10.00
1992 - 93	12.30	7.70	60.60	19.40
1993 - 94	8.91	13.33	50.86	26.90
1994 - 95	12.49	8.01	55.70	23.80
1995 - 96	7.91	9.15	57.85	25.09
1996 - 97	9.58	6.25	59.83	24.39
1997 - 98	8.61	5.44	55.49	30.46

Source : Rahman 1999.

Economics of Coastal Capture Fisheries

Disposition and Value of Catch

Most of the marine catches are marketed fresh. Some are frozen for export, some are dried and a small portion is salted. The facilities are very poor and large portions of the catch are spoiled due to lack of ice or proper processing. There is also a lack of knowledge about sound post-harvest practices.

Catches of most of the ESBN are taken in remote locations and are disposed of locally for human consumption. The catches are of low quality as most of the fish stay in the cod-end for a long time before they are collected by the fishers. The catches, being mostly the juveniles of commercial fish and shrimp, are of low economic value. Some of the Bombay duck and jewfish are collected by fish traders to be taken to wholesale markets. Fishers also take some of the good catches to wholesale markets in the cities.

The MSBNs are usually operated from the offshore islands. Most of the catch is dried but some of the quality fish and shrimp are transported to the cities to be processed for export. There is a seasonal stake-net fishery along the coast of Chittagong. This fishery is operated from July to September. During the season huge quantities of *Hilsa* are harvested; much more than the fishers or fish traders can handle. Large quantities of partially rotten fish are salted at this time and, consequently, the quality is very low.

The beach seine fishery is operated along the coast of Chittagong and Cox's Bazar. This fishery catches mostly juvenile fish and shrimp. As a consequence they fetch very low prices and are seldom transported elsewhere and are usually marketed fresh.

The long-line fishery in the Cox's Bazaar area is wholly oriented towards export. Almost all the jewfish caught by the long-lines are dried using proper scientific methods. The traditional method of drying is not used during processing and as such the quality of the product is very good.

The drift gillnet fishery uses mainly two types of nets: viz. the small-mesh drift-nets for catching *Hilsa* and the large-mesh net for catching Indian salmon and large croakers. The *Hilsa* are marketed fresh and transported to most parts of the country. Some of the *Hilsa* is exported fresh to India with ice and yet others are frozen, to be exported to the Middle East or Europe. The croakers and the Indian salmon caught by the large mesh gillnet are sold fresh in the cities.

The shrimp caught by the shrimp trawlers are processed onboard into different grades. They are exported mainly to Japan. A small quantity of fish cought by the shrimp trawlers are exported, the rest are sold fresh to the local market. A large quantity of fish caught by the shrimp trawler is thrown overboard because it is of low value or the crew has little time to handle the catch or there is a lack of space in the fish hold. It is assumed that the amount of discards may be up to 80% of the actual catch, which is equivalent to 30 - 35 000 t annually. The freezer trawlers refrigerate the fish in gunny bags that are stacked one upon the other in the fish hold. These fish get crushed under their own weight and hence fetch low prices. The fish trawlers keep quality fish on ice to be sold to the local market and a few companies export frozen fish to external markets. Some jewfish are taken by the dry fish exporters at Cox's Bazar. The values of the catches of different fisheries are shown in Tables 14 - 20.

Table 14. Average monthly prices (Taka·kg^{-1}) of species groups at different stations for ESBN catches during 1989 - 90.

Species	Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Mixed shrimp and fish	Maiskhali	30	30	25	20	–	15	30	27	27	30	30	30
	Kumira	24	22	25	25	25	35	27	18	20	15	17	26
	Hatia	17	19	18	18	–	21	25	23	21	28	24	15
	Khepupara	20	25	23	20	15	22	23	14	20	12	15	18
	Morrelganj	15	20	25	24	19	18	22	30	24	18	30	11
	Kaliganj	30	22	30	40	30	20	25	23	20	30	25	26
Penaeus monodon	Maiskhali	–	–	–	–	–	200	250	–	38	80	–	–
	Kumira	–	–	–	–	–	–	–	–	–	–	–	–
	Hatia	–	–	–	–	–	–	–	–	–	–	–	–
	Khepupara	–	25	–	–	210	22	140	–	–	–	–	–
	Morrelganj	–	–	–	–	250	175	–	–	–	250	–	230
	Kaliganj	–	220	210	230	230	–	160	200	260	–	–	40
Macrobrachium rosenbergii	Maiskhali	–	–	–	–	–	–	–	270	50	150	150	–
	Kumira	–	–	200	–	–	–	–	–	–	–	–	–
	Hatia	–	–	–	–	–	–	–	–	120	130	–	–
	Khepupara	60	50	–	–	60	–	–	60	–	140	–	–
	Morrelganj	–	–	–	–	280	282	–	–	220	220	124	138
	Kaliganj	–	–	–	160	–	–	150	150	150	–	130	60
Metapenaeus monoceros	Maiskhali	–	40	–	–	–	–	–	40	–	–	–	–
	Kumira	–	–	–	–	–	–	–	–	–	–	–	–
	Hatia	–	–	35	–	30	–	–	–	–	–	–	–
	Khepupara	–	–	–	–	–	–	–	–	–	–	–	–
	Morrelganj	–	–	–	–	80	–	–	–	50	–	–	–
	Kaliganj	–	–	–	–	–	–	–	–	–	–	–	–
M. brevicornis	Maiskhali	–	40	–	–	–	–	–	–	–	–	–	–
	Kumira	–	–	–	–	–	–	–	–	–	–	–	–
	Hatia	–	–	–	25	–	25	–	–	–	–	–	–
	Khepupara	–	–	–	–	–	–	–	–	–	–	–	–
	Morrelganj	–	–	–	–	–	–	–	–	–	–	–	–
	Kaliganj	–	–	–	–	–	–	–	–	–	–	–	–
Acetes spp.	Maiskhali	7	–	–	–	7	8	–	6	7	8	7	–
	Kumira	6	7	7	8	8	7	–	5	5	6	6	6
	Hatia	3	5	–	–	–	–	–	–	–	–	–	4
	Khepupara	–	–	–	7	4	–	–	–	–	–	4	4
	Morrelganj	–	4	4	8	4	–	–	–	–	–	–	–
	Kaliganj	6	4	5	8	4	4	–	4	4	–	–	4

Source: Islam et al. 1993.

Table 15. Monthly average price (Taka·kg^{-1}) of selected species or species groups in the beach seine catch at two stations of Teknaf in Cox's Bazar during 1988 - 89.

Species name	Station*	Mar. 88	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. '89	Feb.
Shrimp (Mixed)	1	–	–	–	–	–	–	–	–	9	13	13	13
	2	10	10	9	8	–	–	8	8	9	–	–	–
Penaeus indicus	1	–	–	–	–	–	–	–	–	18	20	20	20
	2	20	18	18	18	15	–	–	15	15	18	–	–
Metapenaeus monceros	1	–	–	–	–	–	–	–	–	18	20	20	20
	2	20	18	18	15	–	–	15	15	18	20	20	20
Croaker	1	–	–	–	–	–	–	–	–	10	13	13	13
	2	13	10	10	10	–	–	10	10	10	–	–	–
Ribbonfish and Sillago (Whiting)	1	–	–	–	–	–	–	–	–	10	13	13	13
	2	10	10	10	10	–	–	10	10	10	–	–	–
Bigeye Ilisha and Threadfin Bream	1	–	–	–	–	–	–	–	–	10	13	13	13
	2	13	10	10	10	–	–	10	10	10	–	–	–
Grey Mullet and Pomfret	1	–	–	–	–	–	–	–	–	15	20	20	20
	2	20	15	15	15	–	–	15	15	15	20	20	20
Other clupeids & Engraulids (Anchovy)	1	–	–	–	–	–	–	–	–	9	10	10	10
	2	10	9	9	9	–	–	9	9	9	–	–	–
Mixed finfish	1	–	–	–	–	–	–	–	–	8	10	10	10
	2	8	8	8	8	–	–	8	8	8	–	–	–
Trash fish *(Tricanthidae Tetraodontida)*	1	–	–	–	–	–	–	–	–	2	2	2	2
	2	2	2	2	2	–	–	2	2	2	–	–	–
Crab and cuttlefish	1	–	–	–	–	–	–	–	–	2	2	2	2
	2	2	2	2	2	–	–	2	2	2	–	–	–

Source: Chowdhury et al. 1993.
Note: * 1. Coast Station; 2. Estuary Station.

Table 16. Value of dried fish/shrimp and gross earnings at Sonadia (Taka·haul^{-1}) for MSBN catch.

Month		September		October		November	December		January		February		March
Name of spp./Group	Price Tk·kg^{-1}	Wt.**	Value***	Wt.	Value	Wt.	Value	Wt.	Value	Wt.	Value	Wt.	Value
Pomfret	85	-	-	0.95	80.75	1.20	102.00	–	–	0.05	4.25	–	–
Ribbonfish	22	1.59	34.98	5.11	112.42	6.47	142.34	3.35	73.70	0.21	4.62	0.71	15.6
Bombay Duck	25	9.97	249.25	0.70	17.50	0.88	22.00	19.48	487.00	13.57	339.25	4.47	111.75
Anchovy	15	9.97	149.55	19.06	285.90	24.01	360.15	11.63	174.45	7.45	111.75	4.47	67.05
Croaker	15	25.39	380.85	0.91	13.65	1.15	17.25	1.66	24.90	2.72	40.80	11.38	170.70
Mixed shrimp	25	8.39	209.75	12.30	307.50	15.50	387.50	2.81	70.25	1.08	27.96	3.76	94.00
Misc.	7	9.45	66.15	1.18	8.26	1.49	10.43	0.02	0.14	1.28	8.96	4.23	29.61
TOTAL		64.76	1090.53	40.21	825.98	50.70	1041.67	38.95	830.44	26.36	536.63	29.02	488.73
Hauls·day^{-1}			4		4		4		4		4		4
Fishing day·month^{-1}			9		18		22		22		20		9
Gross earning ·month^{-1}·net^{-1}			39 259.08		59 470.56		91 666.96		73 078.72		42 930.40		17 594.28

Source: Quayum et al. 1993.
Note: ** Wt. = weight as kg·haul^{-1} Dried weight = 60 per cent of wet weight.
*** Value in Taka·haul^{-1} All shrimp prices are dried shrimp rates.

Table 17. Price (Taka·kg^{-1}) of wet shrimp and dry fish from the MSBN Fishery in different areas (1991).

Name of the species/group										
Name of area	White shrimp	Brown shrimp	Pink shrimp	Sergestid shrimp	Silver pomfret	Bombay duck	Ribbon fish	Croaker	Anchovy	Mixed fish
Sonadia	46	28	27	11	84	27	27	17	18	17
Mohipur	45	33	25	9	84	32	29	14	16	14
Dubla	32	14	16	9	84	32	29	15	15	13

Source: Quayum et al. 1993.

Table 18. The quantities of dried croaker exported, the total value and the value per kg from 1986 - 87 to 1990 - 91.

Year	Exported amount (kg)	Value (US$)	Price·kg^{-1} (US$)
1986-87	135 704	612 197	4.51
1987-88	185 516	685 186	3.69
1988-89	845 192	4508 405	5.33
1989-90	1 152 700	5 ,321 978	4.33
1990-91	1 087 718	3 882 927	3.57

Source: Quality Control Laboratory, Chittagong.

Table 19. Wholesale rate (US$·kg^{-1}) of commercial shrimp at BFDC market, Chittagong from 1991 - 93.

Sl. No.	Species (with Grade)	1991 - 92 Value US$·kg^{-1}	1992 - 93 Value US$·kg^{-1}
1	Tiger		
	0 - 5	19.45	23.19
	6 - 8	19.39	23.33
	8 - 12	17.34	20.44
	13 - 15	13.28	14.22
	16 - 20	9.50	12.27
	21 - 25	7.64	9.97
	26 - 30	6.50	–
	Mix	–	4.04
2	Flower Tiger		
	8 - 12	–	19.01
	13 - 15	–	13.00
	16 - 20	–	11.10
	21 - 25	–	9.00
3	Brown		
	21 - 25	7.28	8.02
	26 - 30	6.62	7.07
	31 - 40	5.09	5.87
	41 - 50	4.70	5.08
	51 - 60	4.38	4.64
	61 - 70	3.81	3.81
	71 - 90	3.01	3.21
	91 - 110	2.30	2.40
	Mix	2.17	2.14
4	White		
	8 - 12	–	17.50
	13 - 15	16.50	16.42
	16 - 20	13.86	15.19
	21 - 25	10.70	11.67
	26 - 30	9.57	10.21
	31 - 40	7.79	8.55
	41 - 50	6.20	6.84
	51/60	5.50	5.20
	Mix	2.22	3.80
5	Misc.		
	Red	2.05	2.14
	B.P., G.B.	–	2.00
	Black	2.11	2.07
	Yellow	–	2.00

Source : BFD.

Table 20. Wholesale rates (Taka·kg^{-1}) of commercial fishery at BFDC Market, Chittagong during 1992 - 93.

Species	Value (Taka·kg^{-1})
Chinese Pomfret	114.59
Silver Pomfret	90.37
Salmon big	80.36
Salmon medium	50.00
Salmon small	31.00
Golden Jew big (Croaker)	48.33
Golden Jew small (Croaker)	28.71
Black Jew big (Croaker)	46.85
Black Jew small (Croaker)	28.09
Black Pomfret	46.22
Hilsa	28.00
Hatirkan (Spade fish)	40.00
Long Jew big (Croaker)	31.62
Red Snapper	32.86
Silver Jew big (Croaker)	38.92
Silver Jew small (Croaker)	22.64
Small Jew	15.40
White Grunter	30.98
Lady fish	22.21
Spotted Jew (Croaker)	32.70
Mackerel	18.45
Chapakari (Queenfish)	20.99
Pangash	30.00
Choika (Big eye ilisha)	17.74
Eel	28.00
Cat Big	15.59
Bombay Duck	12.81

Source: BFDC.

Costs and Returns

ESBN Fishery

A survey of the ESBN fishery was conducted from 1989 to 1990 (Islam et al. 1993). Six sampling stations representing 710 km of the coastline were selected, Maiskhali, Kumira, Hatia, Khepupara, Morelganj and Kaliganj. The nets for sampling purposes were classified into four sizes, based on the measurement of the mouth openings: G1a, G1b, G1c and G1d.

The G1a net (width of mouth < 6 m and area of mouth < 15 m^2) was used in four areas (Kumira, Hatia, Khepupara and Kaliganj), and had an annual net profit per gear ranging between Taka 24 969 and 33 342. The highest net income was from Hatia (over 11 months of operation) and the lowest was from Kumira (over 12 months of operation). In Kumira, hired labor was used and the total cost was higher than in Hatia where the labor was mostly provided by members of the owner, households. The average net income (in Taka) per active fishing month ranged from Taka 2 080 to 3 745. The highest net income was from Khepupara and the lowest was from Kumira.

The G1b class nets (mouth 6 - 10 m wide and area of mouth 15 - 50 m^2) were operated at all six stations and the annual net income per gear ranged from Taka 19 540 to 95 739. Maiskhali recorded the highest income and Kaliganj the lowest income over the operations. Morrelganj had the highest operational cost using hired labor, and gave a Taka 370 814 net profit. The average net income per active fishing month was highest for Maiskhali, (Taka 9 573) and the lowest for Kaliganj (Taka 2 171).

The G1c class net (with width of mouth 10 - 15 m and area of mouth 50 - 90 m^2) was operated in three stations (Maiskhali, Khepupara and Morrelganj), and had the highest net annual income per gear of Taka 179 159 over 11 months of fishing, while Khepupara exhibited the lowest income of Taka 37 278 in 12 months. Maiskhali recorded the highest income per active fishing month which is Taka 16 287 and the lowest was recorded for Khepupara, Taka 4 142.

The G1d class nets were used only at Morrelganj and the annual net profit per gear was Taka 20 517 for four months of fishing the estuary. The average net income per active fishing month for Morrelganj was Taka 5 129.

In most stations there were two peaks in income - one in May/June and the other in November/December. These correspond with the beginning of the Southwest monsoon and the Northeast monsoon, respectively. In Maiskhali, whenever crew were engaged, they were paid Taka 400 - 600 per month and provided with free food. In Kumira and Khepupara crews were paid Taka 600 - 1 000 and 250 - 600 Taka per month, respectively. The value of food provided was Taka 450 - 500 per month per ESBN unit. Other operational costs are minimal; most of the craft used in this fishery are non-motorized and generally family members are engaged as labor (Islam et al. 1993).

Beach Seine Fishery

A survey of the beach seine fishery was conducted in 1988 and 1989 (Chowdhury et al. 1993). Two stations at the Naf River estuary and the Teknaf coast were selected. The beach seine owners earned less income in the Naf River estuary than on the Teknaf coast and their maximum gross earnings were Taka 21 253 in October, with a net profit of Taka 3 855. Their minimum gross earnings were Taka 10 242 in March with a net profit of Taka 185. Seasonal gross earnings per unit were Taka 113 029 over seven active fishing months and the net profit to the owner was Taka 15 083.

Owners of gear on the Teknaf coast earned a reasonable income from their fishing units during most months of the year. The highest monthly gross earnings were Taka 101 433 per unit, with a profit of Taka 30 589 in December and the lowest monthly gross earnings were Taka 12 262, with a net profit of Taka 859 in February. Gross earnings per unit were Taka 171 619 during a season of four active fishing months, while the total profit to the owner during this period was Taka 44 292.

The gross revenue on the Teknaf coast was Taka 16 150 while on the Naf river estuary it was Taka 42 900. The average monthly net income on the Naf River estuary was Taka 2 160 and on the Teknaf coast it was Taka 11 070. The average income per month to fishers was Taka 446 at the Naf River estuary and Taka 2200 on the Teknaf coast.

Most beach seines and boats are owned by *bahardars,* better-off people belonging to the fish landing localities. The fishers get paid on a share basis after incidental expenses, generally small amounts, are deducted.

When net revenue from each haul exceeds Taka 400, one third of it goes to the owner of the unit and the remaining two-thirds is equally distributed among the fishers. If the gross revenue is between Taka 200 and 400, a fixed amount of Taka 200 is shared among the fishers and the rest of the money goes to the owner. When gross revenue falls below Taka 200, all of it is distributed equally among the fishers, without anything going to the owner. The beach seine fishing communities generally follow this traditional sharing system.

MSBN Fishery

A study on the MSBN fishery was conducted during 1983 - 86 at three fishing areas: Sonadia, Mohipur and Dubla (Quayum et al. 1993).

An owner of an MSBN and supporting craft is locally known as a *bahardar*. He organizes the fishing units and may use his own craft and gear or, sometimes, hires craft and other equipment for the fishing season.

At Sonadia, remuneration is based on a share system, but in Mohipur and Dubla both share and wage systems are observed. One or a combination, of the two systems is applicable in all three areas. In the share system, the net income is divided into 74 shares and distributed among *bahardar* and the crew. The total share of *bahadar* is 33 and for the crew is 41.

The *bahardar* generally bears all expenses and these are deducted from gross revenue before the net revenue is shared. A typical operation unit comprises two motorized craft (one usually rented) and one rented non-motorized craft. These are used to operate 15 set bag nets. The operational cost includes hire of two craft, craft and gear repair, fuel, food, firewood, utensils, bamboo mats, drying racks, and jute piling.

Trammel-net Fishery

A survey of the trammel-net fishery along the southeast coast of Bangladesh was undertaken during 1989 - 90 by Islam and Khan (1993).

Most trammel-nets and boats are owned by *bahardars*. The fishers are paid on a share basis, after deducting incidental expenses, which are generally small amounts. If the owner is also a member of the crew, he gets an extra crew share. There are also a few cases of fishers jointly owning a set or sets of gear and one or more supporting craft.

When the net revenue from the landed catch exceeds Taka 500, 50% goes to the owner of the gear and craft and the remainder is divided equally among the fishers. If the gross income is between Taka 200 and 500, then a fixed amount of Taka 200 is shared among the fishermen and the rest of the money goes to the owner. When gross revenue falls below Taka 200, all of it is distributed equally among the fishers, without any payment to the owner. This is a traditional sharing system.

In most months, the *bahardars* earn a good income from this fishery, with maximum earnings in December and a minimum in March. The gross income of a boat per day during the study varied from Taka 128 to 3 896, with the average gross revenue per boat per day being Taka 1 036. The deductible expenses being very small, the net revenue would be almost equal to the gross revenue.

The average annual gross earnings per boat were Taka 143 664 in seven fishing months and the annual income of the owner, after deducting the fixed costs (including depreciation, repair and maintenance cost of craft and gear - about Taka 9 000) was Taka 59 437. The operational costs are generally incidentals such as tobacco and minor food items. During the period of the study, the trammel net fishery was profitable in all months except in March, when there was a loss due to a decline in the catch rates of the more valuable species.

The monthly average income per fishers ranged from Taka 2 000 to 7 000 and the highest income was Taka 15 000 in December.

Bottom Long-line Fishery

A study of the long-line fishery was conducted during 1990 - 91 at Chittagong (south), Cox's Bazar, Noakhali and Patuakhali (Haque et al. 1993).

During the survey, a cost and earning analysis (Table 21) showed that the variable cost of the fishery is composed of the fuel, food, bait, salt, repairs and replacement of lost or damaged gear. The price of bait is 35 - 45 Taka·kg^{-1}. The cost of craft and gear are Taka 2 500 000 and 4 000, with average lives of 15 years and 1 year, respectively. The estimates of the costs and earnings for a unit during a whole fishing season are given in Table 22, from

which it appears that the monthly average income per fisher is Taka 1 309 for the lean season (1-day trips) and Taka 2 848 for the peak season (4-day trips).

After deducting the variable cost from the gross revenue, the balance is shared on the basis of eight shares for the craft owner, two for the head fishers and one each for the nine crew members.

Major repairs and maintenance of the boat and gear, about 200 Taka•month^{-1}, are borne by the boat owner. Therefore, after deducting the depreciation and maintenance cost, the boat owner gets 8 804 Taka•month^{-1} in the lean season and 20 909 Taka•month^{-1} in the peak season.

The fish are sold to the factory with the swim bladder intact and the fishermen do not get any additional payment for this. The dried swim bladders of the Silver Pennah Croaker and Belanger's Croaker are worth 200 Taka•kg^{-1} and that of the large Spotted croaker 1 000 Taka•kg^{-1}. The factory owners sell these to middlemen linked with the export of this product - "isinglass".

Table 21. Cost and earning analysis of the bottom long-line fishery for Croaker and the average income to owner and crew member per trip in 1991.

Period	Duration of trip (days)	Avg. value of catch (Tk)	Avg. bait cost (Tk)	Avg. fuel cost per trip (Tk)	Food cost per trip (Tk)	Salt cost per trip (Tk)	Additional cost (Tk)	Net hooks (Tk)	Crew revenue (Tk)	Skipper boat (Tk)	Boat share (Tk)
Aug., Oct. & Feb.	1	4 796	700	1 700	500	–	500	1 396	73	146	587
Nov. - Jan.	4	–	18 136	700	2 000	2 000	800	600	12 036	633	1 266

Table 22. Cost and earnings of a bottom long-line unit, for the whole 1991 season (Values are in Tk.).

	Variable Cost	Depreciation & maintenance	Salaries/ shares	Total cost	Total revenue	Profit to owner
Peak season Nov. - Jan. (3 months)	82 350	5 775	93 984	182 109	244 836	62 727
Lean season Aug. - Oct. (2 months)	122 400	3 850	28 798	155 048	172 656	17 608
**Annual	204 750	9 625	122 782	337 157	417 492	82 335

Note: ** "annual" means one season, i.e. the 5-month fishing period.

a. Depreciation of fixed cost/month = Tk. 1 390 + Tk 335 = Tk 1 725
b. Variable cost/month = Tk. 61 200 (for day trip)
= Tk. 27 450 (for 4-day trip)***
c. Gross revenue/month = Tk. 86 328 (for 1-day trip)
= Tk. 81 612 (for 4-day trip)
d. Profit/month = Tk. 25 128 (for 1-day trip)
= Tk. 54 162 (for 4-day trip)

***** Variable costs are less for a month with a 4-day trip because there are fewer trips per month, resulting in fuel cost being substantially less for approximately the same number of fishing days.**

Incomes and Sharing Arrangements

Traditionally, all kinds of fishing were practiced at subsistence level by the *jaladas* of the Hindu community. However, with increasing demand and commercialization of inland and marine fisheries and decreases in land assets due to population pressure, large numbers of Muslim fishers took up fishing as a full-time job. Most of the small scale fishing boat owners, either motorized or non-motorized, are now Muslim, who hire Hindu and Muslim fishers as crew, mostly on a catch share basis.

Most of the boat owners do not go to sea. They provide the mechanized boat, gear and other necessary fishing materials and the crew work as actual fishers and undertake various responsibilities.

The income-sharing arrangement between boat owner and crews varies from area to area and depends on the type of gear used and the fishing season. For instance, in Chittagong and Cox's Bazar, 60% of the value of the catch, after covering the operational costs, goes to the boat owner and the remaining 40% is distributed among the hired crew. The share of each crew member depends on the functions performed by him (Rahman 1993). These may include catching, drying, transporting and support services, such as cooking.

Very few surveys have been conducted on small scale marine fishing. Thomson et al. (1993) made a socioeconomic survey on estuarine set bag net fishers. Islam and Elahi (1993) studied the socio-economic condition of different categories of small scale marine fishers involved in fishing with gill-nets, long-lines and set bag nets. A fishing team usually consists of one head mazhi, one assistant head mazhi, one driver and 12 to 15 unspecialized fishing laborers.

Annual fishing activities are divided into three sub-periods. The high activity period (AP) comprises the months of September to November, the medium AP comprises the months of December to March, and the low AP five months from April to August. The rainy season, June and July, is the slack period for fishing. There is little variation of employment during the activity period among different categories of fishers.

The head *mazhi*, assistant head *mazhi* and laborers spend more than 90% of their time on fishing. The boat owners and other fishers, such as cooks, helpers, net makers, repairers, are relatively less involved with fishing. The boat owners' second most important job is business, while other fishers are involved with different occupations for varying periods. Thomson et al. (1993) indicated that 35% of the fishing community were involved in productive activities; 37% were children below the age of 10, and 28% did not have any employment. There was a high rate of dependence on the income-earning members.

The different categories of fishers earned about 90% of their income from fishing. Other sources such as agriculture or business did not contribute much. The assistant head *mazhi* earned more than 99% of their income from fishing. Business was the second most important source of income in the case of boat owners, head *mazhi* and other fishers.

The annual income levels and their differences among different categories of fishers are considerable. The annual income of a boat owner is about Taka 461 304, but the fishers get Taka 13 568 annually. The average annual per capita income of different categories within fishing households also varies significantly.

Household expenditures were divided into five categories, of which four relate to basic human needs: food, clothing, education and medication. The boat owners used more than 56% of expenditure on non-basic items, while fishers used most of their income on the basic items. Food is the single most important expense. This conforms with the Engel Law that expenditure on food varies inversely with income. While boat owners spend 34% on food, fishers use more than 82%. The boat owners have substantial savings whereas the other fishers have none.

Fleet Operational Dynamics

Bangladesh started fishing with a fleet of 10 trawlers and 200 motorized boats just after independence. The number of trawlers more than doubled to 21 in a year and then increased to 26 two years later. The numbers of trawlers changed abruptly in the early 1980s and reached a maximum of 73 in 1984. The number then fell gradually and stabilized at a little more than 50. The current number of trawlers is 59, of which 44 are shrimp trawlers and the others are fish trawlers. The operational fluctuations of different trawlers and boats between 1972 - 73 and 1988 - 99 is shown in Table 23.

Table 23. Number of fishing crafts from 1983 to 99.

Years	Trawlers				Boats		
	Shrimp	Fish	Mixed	Total	Non-mechanized	Mechanized	Total
1972 - 73	N/A	N/A	N/A	10	N/A	200	–
1973 - 74	N/A	N/A	N/A	21	N/A	276	–
1974 - 75	N/A	N/A	N/A	21	N/A	1 000	–
1975 - 76	N/A	N/A	N/A	26	N/A	1 000	–
1976 - 77	N/A	N/A	N/A	26	N/A	1 050	–
1977 - 78	N/A	N/A	N/A	26	N/A	1 100	–
1978 - 79	N/A	N/A	N/A	26	N/A	1 200	–
1979 - 80	N/A	N/A	N/A	26	N/A	1 300	–
1980 - 81	N/A	N/A	N/A	24	N/A	2 000	–
1981 - 82	N/A	N/A	N/A	35	N/A	2 050	–
1982 - 83	N/A	N/A	N/A	53	N/A	2 100	–
1983 - 84	27	46	N/A	73	743	3 347	4 090
1984 - 85	30	37	N/A	67	14 014	3 317	17 331
1985 - 86	35	10	N/A	45	14 014	3 317	17 331
1986 - 87	31	10	8	49	14 014	3 317	17 331
1987 - 88	35	10	7	52	14 014	3 317	17 331
1988 - 89	35	10	7	52	14 014	3 317	17 331
1889 - 90	40	9	4	53	14 014	3 317	17 331
1990 - 91	41	15	N/A	56	14 014	3 317	17 331
1991 - 92	37	14	N/A	51	14 014	3 317	17 331
1992 - 93	37	12	N/A	49	14 014	3 317	17 331
1993 - 94	40	11	N/A	51	14 014	3 317	17 331
1994 - 95	43	14	N/A	57	14 014	3 317	17 331
1995 - 96	41	12	N/A	53	14 014	3 317	17 331
1996 - 97	41	14	N/A	55	N/A	N/A	N/A
1997 - 98	48	13	N/A	61	N/A	N/A	N/A
1998 - 99	44	15	N/A	59	N/A	N/A	N/A

Sources: BBS 1997; Frame survey 1984 - 85; Rahman 1995 and FCS. DOF 1983 - 84 to 1995 - 96.
Note: N/A = Information not available.

Fish Marketing, Post-harvest Handling and Storage Facilities

Marketing of Fish

Bangladesh has around 111 million people. At a standard consumption rate of 20 kg•capita^{-1}•year^{-1}, about 2.2 million t of fish would be needed annually. However, the present production of 1.62 million t of fish provides only 8 kg•capita^{-1}•year^{-1} (Hussain 1995). The entire production of marine, estuarine and freshwater fish is easily marketed domestically in Bangladesh, except for a very small quantity of selected species of finfish. People of Bangladesh like to eat fresh fish. Chilled fish are also marketed in large quantities in the towns and cities. However marketing of frozen fish is negligible in the absence of customer preferences and cold-chain marketing developments. Utilization and marketing distribution of fish is around 70% fresh and chilled fish, 25% dried and other forms of locally processed fish, including fermentation and the rest are frozen products. The total production of about 100 000 t of live crustaceans, mainly shrimp and prawns, about 19 000 t (headless; equivalent to 36 000 t live weight) is exported and the remaining 64 000 t, mostly of smaller sizes and non-exportable quality is marketed domestically (Hussain 1995).

Domestic Marketing Situation

As there is a large gap between supply and demand, fish marketing is very easy. All types of fish, irrespective of cost, are easily sold, due to the presence of a heterogeneous mixture of buyers. High cost fish like carp, catfish and other live-fish from inland waters and marine pomfret, Indian salmon, snapper, grunters and eel, are either sold to the affluent or are processed for export. Mixed fish are usually sold to the vast majority of the people, those of the low-income groups. Owing to high domestic and international demand, the prices of exportable species have increased several-fold.

The marketing of fish is generally conducted by fish traders, either individually or as groups, or by Fish Trader Associations or Fishers' Cooperative Societies. Almost all fish markets operated by them are ill-managed and unhygienic. There is no proper handling, washing, cleaning, icing or re-icing of the fish. They care very little for post-harvest management of the resource, being more interested in earning more revenue at the cost of the fishers and the consumers. Most fish markets managed by fish traders in cities, district towns and rural areas have no modern infrastructure facilities, not even over head shelters. In the villages, fish is directly landed on the soil and in bamboo baskets and sold by auction, before being transported to cities and towns for retailing.

City markets built by municipal corporations or municipalities offer better facilities, but are not managed according to any standards. Municipal fish markets are usually a part of the general market. The Local Government Ministry is now constructing small fish markets in the rural areas through the Local Government Engineering Department. These provide better facilities for rural fish marketing. There are no special or modern fish landing centers run by the municipalities or by the private sector.

The BFDC is the only organization which has constructed modern fish harbors and fish landing centers in such coastal areas as Chittagong, Cox's Bazar, Barisal, Khepupara, Patharghata and Khulna. It has also constructed commercial fresh fish landing centers in Rangamati, Kaptai, Rajshahi and Daborghat. These landing centers provide modern and hygienic facilities for the fishers and fish traders and there are facilities for berthing, landing, auctioning, cold storage, freezer storage and transport. Post-harvest resource management is properly taken care of only in these centers. But fishers and fish traders are not interested in utilizing these modern facilities due to ignorance and self-interest. As a result, fish landing centers in Barisal, Khepupara and Patharghata have not been started as planned.

Marketing Systems of the Fish Trade

Four levels of domestic markets or marketing systems are observed in the distribution channels of the fish trade in Bangladesh (Hussain and Uddin 1997). These are the primary, secondary, higher secondary and final consuming markets (Fig. 3).

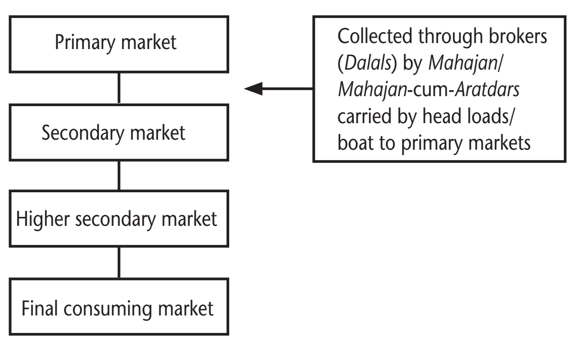

Fig. 3. Four levels of domestic fish market in Bangladesh. Source: Hussain and Uddin 1997.

Primary Market

This is a marketing place at the landing point, usually in a rural area. Fish collectors or assemblers, commonly known as *mahajans* or *aratdar* procure fish from the catchers, with the help of local brokers called *dalals*, who get a commission from the *mahajan*. Part of the catch is also locally sold by the catchers, farmers or local retailers.

Secondary Market

The collectors bring the fish from the primary markets to the landing *ghats*, usually to the nearest *thana* market or to a place well linked by rivers, roads or rail transport. The mahajan sell the fish to the distributors known as *beparies*, generaly with the help of the *aratdars*, the commission agents.

Higher Secondary Market

The *beparies* transport the fish to the nearest city or town markets by rail or boat. These are the main distribution markets and here the *beparies* sell the fish to another set of distributors known as *paikars*, again with the help of *aratdars*.

Final Consuming Markets

On purchasing the fish from the higher secondary market, the *paikars* sell the fish to the retailers. There are two channels of retailing. The urban retailers sell the fish in the urban markets in permanent stalls or set out with the fish on their heads or in tricycle (rickshaw) vans to sell them. Other retailers take the fish to the suburbs or to villages.

In the course of marketing at all these levels, the collector or distributor carries out the function of handling, cleaning, sorting, icing, preservation and transportation at his own cost as far as possible. Expenses on such accounts are deducted from the bills of sellers.

Major Fish Markets and Landing Centers

Major coastal fish landing centers are located at Chittagong, Cox's Bazar, Teknaf, Shaparir Dhip, Kutubdia, Hatiya, Sandip, Sitakunda, Laxmipur, Hajimara, Rangamati, Bhola, Dauladia, Charfessan, Patuakhali, Galachipa, Khepupara, Mohipur/Kuakata, Barguna, Patharghata, Khulna, Bagerhat, Parerhat, Satkhira, Barisal and Chandpur . Most of the catches from the Bay of Bengal are landed at these centers and *Hilsa* is the main species landed (Hussain and Uddin 1997).

Trade flow

Trade flow or movement of marine fish for domestic consumption originates from Cox's Bazar, Chittagong, Barisal, Khulna, Bagerhat, Parerhat, Chandpur and many other coastal landing centers. After meeting local needs, the surplus fish is sent to the major markets, principally Dhaka, Sylhet and Rajshahi.

Marketing Channels

Almost all fish trade for the domestic market passes through the channels described above. The market structure varies from area to area, but in general terms is as illustrated in Figure 3.

While the four levels of markets are the normal trade channels, there is sometimes variation between locations and type of fishers. Sometimes fishers and fish farmers bypass these channels and sell fish directly to the secondary markets, this being most commonly practiced by the mechanized boat operators at the coastal fish landing centers.

Marketing Margins

The fishers' shares and marketing margins in fish sold in Dhaka and Pabna in 1981 were analyzed for freshwater fish like *Hilsa* (river shad), *ruhi* (carps) and *singhi (Heteropneustes fossilis)* and the following were the results (Hussain and Uddin 1997):

Fisher's share in consumer price	: 51 - 63%
Middleman's share in consumer price	: 37 - 49%
Expenses	: 12 - 24%
Net income after expenses	: 24 - 26%
Share of collectors	: 14 - 35%
Share of distributor	: 16 - 20%
Share of retailer	: 5 - 10%

The fisher's share and marketing margin of marine fish sold in Chittagong and Cox's Bazar were as follows:

Fisher's share	: 60 - 63%
Middleman's share	: 40 - 37%

Breakdown of Middlemen's Margins

Marketing costs	: 21.7 - 22.2%
Quality/weight loss	: 1.6%
Net income	: 13.3 - 16.1%

Existing Auction System

Most of the auctioning is carried out by auctioneers, locally called *aratdars*. They follow a price incremental system.

As soon as the fishers land the fish in the market, the *aratdar* takes care of landing, handling, sorting and auctioning by species and size groups. Even though an open bidding system is the most prevalent one, there are other types of price-fixation systems followed by some traders' associations in selected markets. In general, the sales systems are as follows:

Open Bids

Auctioneers call out the bid by the bidders loudly in the presence of the buyers. The incremental system is followed. It is the most competitive form of auctioning and ensures a better price for fishers. It takes place at all levels of fish marketing, except retailing. The auctioneer gets a 3 - 5% commission on sales value plus his actual expenses.

Syndicate-controlled Price Fixing

In fish landing centers in the coastal areas, especially in Cox's Bazar, Chittagong and Barisal, the private auctioneers in some markets have formed associations called "syndicates", which fix the price of fish either in the evening or on the next day, after disposing of local demand. They send the excess fish, properly iced and packed, to distant landing cities or district markets to another set of local *aratdars*, who receive the fish and auction it locally. The fishers, thus, do not know, nor are they able to know, what the auction value was for their fish, neither do the buyers know the beach price. After disposal of the fish, the inland *aratdar* sends information about the price obtained to the auctioneers at the landing centers. The latter collectively fix prices as they wish. This system works on faith and mutual trust only. The fishers are bound to follow the system, since they are tied to the auctioneer by credit given to them. There is plenty of room for malpractices in this system.

Limited Bidding

In this system, the auctioneer fixes the price by negotiation or partial bidding, usually in the absence of the seller. The auctioneer does not make loud calls, but whispers the price to the intending buyers. He then decides the highest price and awards the fish to the so-called highest bidder. This system is also flawed but since both seller and buyer are tied to each other by advances or credit, there can be no protest.

Through Tender

In the case of trawler catches, the owners sometimes sell the fish through tender. In smaller landing centers or production areas, fish is also sold by negotiation between the local buyer and seller. Retail prices are always fixed by negotiation in the private sector. In department stores, however, prices are fixed.

Marketing Infrastructure

Landing facilities and wholesale fish markets are not well developed. Inland fish landing centers are entirely run by the private sector and this sector also dominates coastal landing centers in many places. These centers are not developed due to the indifference of the private sector.

The Government, through its Ministry of Fisheries and Livestock and the BFDC, established a fish harbor in 1972 for deep sea trawlers of 25 - 30 m length. It also established, with Japanese assistance, a modern fish-landing center in Chittagong for the 2 000 to 3 000 strong mechanized fishing fleet operating from that area. This center started operation in August 1994 when about 45 000 t of fish were expected to be landed. BFDC also established fish landing centers at Cox's Bazar, Khulna, Barisal, Khepupara and Patharghata along the coast and at Rangamati, Kaptai and Daborghat (Sylhet) inland. Additional modern fish landing centers and wholesale fish markets are planned by the Government.

Fishers' cooperative societies also run a major fish-landing center in Chittagong, but it has neither modern nor hygienic facilities.

Fish landing centers run by the fish traders are of very poor standard and need improvement. In most cases there are no auction sheds, no packing sheds, no landing terminals, no gangways, no pontoons and no proper drainage or hygienic facilities.

Wholesale fish markets in almost all cities and towns are operated by the municipalities concerned under the Ministry of Local Government. The landing and wholesaling facilities in the municipal mar-

kets are generally inadequate for handling a highly perishable commodity like fish.

In major cities like Dhaka, Chittagong, Khulna and Rajshahi, as well as district towns, the retail markets are managed by the municipalities. Conditions in these markets are also not adequate in respect to sales areas, parking, sanitation, water supply, drainage, cleaning and washing, maintenance and repairs. A few new markets are, however, exceptions. The BFDC runs a modern fish distribution and retail center in Dhaka, with half a dozen modern fish shops and fifty rickshaw vans that sell fish from door to door. A few modern retail fish shops have also been established by private sector entrepreneurs in Dhaka.

Ice Plants and Cold Storage

There has been much improvement in the ice supply during recent years. Many ice plants have been established in Cox's Bazar, Chittagong, Khulna, Barisal, Khepupara, Patharghata and other small fish landing areas along the coast. The number of ice-plants, with their daily production capacity, in the major fish landing centers are listed below (1993 figures):

Name of center	Number	Capacity ($t \cdot day^{-1}$)
Chittagong	68	1 055
Cox's Bazar	30	642
Barisal	39	1 654
Khulna	60	660
Bagerhat	21	180
Mongla	5	34
Parerhat	4	55

Most mechanized fishing boats carry ice and land fish properly iced. There is no shortage of ice supply in these centers for the marine fishery. During peak *Hilsa* catches, which coincide with the full moon and the "dead" moon periods (a short period of 3 - 4 days during the monsoon months of May to October every year) shortages of ice sometimes occur. The average price per block of ice, weighing about 140 kg, varies from Taka. 40.00 to 100.00 depending on fish landings. The average price is around Taka 600 per t. The BFDC has established 14 ice plants in its ten coastal fish landing centers, with a daily ice-making capacity of 260 t (210 t block ice + 50 t flake ice), a chill room capacity of 615 t and an ice storage capacity of 670 t. Cold storage for ice and chilled fish has not received proper attention from the private sector.

Freezing Plants and Frozen Storage

Bangladesh has developed a big shrimp processing industry. There were 115 processing plants by 1993 - 94, having a total daily capacity of 800 t of shrimp or fish or approximately 180 000 t annually, on the basis of 220 days of operation per year. As against this installed capacity, shrimp for export amounts to only around 40 000 t live-weight or about 25 000 t headless weight. Capacity utilization for shrimp freezing was only 19 per cent in 1992 - 93. As a result, most shrimp processing plants are either lying idle or have diversified into finfish processing and freezing for export and domestic marketing. Of the 115 plants, only four are in the public sector (BFDC) and have a daily freezing capacity of 61 t (49 t blast freezing + 12 t freezing) and 1 380 t of frozen storage capacity. BFDC plants are mainly used as service facilities by the private sector exporters.

Trawler Based Shrimp Processing Plants

Shrimp trawlers were introduced in 1978. By 1994, the fleet had grown to 48 shrimp trawlers with a daily freezing capacity of 108 t. These trawlers catch over 4 000 t of marine shrimp annually. Of the 48 shrimp trawlers, only two belong to the public sector (BFDC). There are also 4 white-fish trawlers belonging to the BFDC as against 16 in the private sector.

International Marketing and Exports

Exports of shrimp, fish and other fishery products were unusual before independence, but have increased many times in past years, earning more and more foreign exchange to minimize the national balance of trade.

The major export items are frozen shrimp, frozen fish, chilled fish, salted and dehydrated fish, dried fish, sharkfins and maws, crabs, tortoises and turtles. Small quantities of cephalopods such as squid and cuttlefish are also exported. Exports of fish and fishery products from Bangladesh are shown in Table 24.

Exports of Frozen Foods.

Frozen sea foods were 94.34% of the total exports of fishery products in 1992 - 93 and earned US$165.34 million. Other fishery products earned US$9.80 million (5.66% of exports). In the frozen foods sub-sector, frozen shrimp accounted for US$155.48 million (90.10%), frozen fish US$9.80 million (9.90%) and frozen frog legs had no earnings, since they were totally banned by the Government.

Table 24. Export of fish and fishery products from Bangladesh in t - their value in parentheses in million Taka.

Year	Commodity							% Of national export earnings
	Frozen shrimp/ prawn	Frozen fish	Dry fish	Salted/ Dehyd. Fish	Turtle/ Crab/ Tortoise	Shark fin/ fish-maws	Total	
1981 - 82	6 903 (904.4)	631 (41.8)	39 (03.6)	123 (13.1)	2 358 (134.6)	63 (12.9)	10 117 (1 110.4)	8.84
1982 - 83	9312 (1 499.4)	1 279 (77.0)	79 (08.3)	128 (12.8)	2 357 (143.4)	64 (17.6)	13 219 (1 758.5)	10.88
1983 - 84	8818 (1 555.0)	2 817 (141.7)	74 (08.6)	283 (32.1)	2 935 (217.7)	43 (13.0)	14 970 (1 968.1)	9.89
1984 - 85	12 682 (1 994.5)	3 297 (147.7)	47 (05.5)	382 (36.6)	1 790 (127.0)	108 (21.2)	18 306 (2 332.5)	9.66
1985 - 86	13 631 (26 93.1)	5 017 (365.0)	786 (100.6)	422 (49.5)	3 142 (346.8)	50 (12.5)	23 048 (3 562.5)	14.65
1986 - 87	16 275 (3 417.5)	4 046 (354.1)	402 (49.0)	295 (38.4)	2 629 (346.6)	114 (34.9)	23 761 (4 240.5)	12.99
1987 - 88	15 023 (3 611.7)	4 191 (283.5)	475 (66.9)	372 (48.1)	3 232 (484.8)	130 (46.2)	23 423 (4 541.2)	11.93
1988 - 89	15 386 (3 820.5)	2 427 (225.9)	567 (138.9)	293 (41.2)	2 978 (464.7)	68 (27.7)	21 719 (4 718.9)	11.51
1989 - 90	17 505 (4 143.1)	3 484 (255.8)	1 278 (234.0)	161 (14.4)	876 (112.4)	35 (28.0)	23 339 (4 787.7)	9.62
1990 - 91	17 985 (4 512.2)	5 702 (414.0)	427 (57.5)	1 194 (139.5)	723 (105.8)	78 (37.2)	26 109 (5 266.2)	8.64
1991 - 92	16 730 (4 557.3)	2 604 (301.0)	892 (141.1)	80 (13.9)	1 709 (176.1)	65 (54.1)	22 080 (5 243.5)	6.91
1992 - 93	19 224 (6 040.3)	2 704 (383.1)	1 042 (122.6)	599 (98.4)	2 800 (216.0)	239 (142.5)	26 608 (7 002.9)	7.57
1993 - 94	22 054 (7 877.3)	3 125 (511.8)	2 473 (418.3)	50 (10.6)	4 088 (363.7)	45 (27.9)	31 835 (9 209.6)	9.12
1994 - 95	26 277 (10 456.7)	9 267 (1 802.6)	521 (83.9)	649 (153.5)	4 760 (406.7)	212 (166.0)	41 686 (13 069.4)	9.38
1995 - 96	25 225 (11 063.9)	8 827 (1 766.2)	182 (30.5)	436 (114.7)	4 203 (392.0)	56 (42.1)	38 929 (13 409.4)	8.44
1996 - 97	25 742 (11 889.1)	8 754 (1 767.4)	427 (79.2)	561 (138.1)	5 952 (614.8)	113 (85.5)	41 549 (14 574.1)	7.75
1997 - 98	18 630 (11 814.8)	8836 (1 516.6)	233 (31.1)	1 106 (264.3)	1 198 (143.4)	155 (107.9)	30 158 (13 878.1)	5.93

Source: DOF 1999.

Exports of Other Fishery Products

This sub-sector constituted only 5.66% of the total exports of the sector during 1992 - 93, comprising dried fish (1.80%), salted and dehydrated fish (1.45%), sharkfins and fish maws (2.10%), crabs (0.84%) and tortoises and turtles (0.14 %).

The major export market for frozen shrimps are USA (38.33%), EU (34.49%), Japan (9.88%) and Germany (10.66%). During 1991 - 92 exports of frozen shrimp to world markets were as follows:

USA	38.33%
Germany	10.66%
Japan	9.88%
EU	36.495
Belgium	15.24%
UK	12.79%
Netherlands	5.54%
Italy	1.86%
Denmark	0.53%
Spain	0.30%
France	0.16%
Norway	0.07%
ASEAN/FEA	4.12%
Singapore	2.95%
Malaysia	0.76%
Taiwan	0.29%
Hong Kong	0.10%
Thailand	0.02%

The major export markets for frozen frog legs during 1991 - 92 were USA (92.03%), Belgium (4.49%) and Canada (3.48%). Export of frog legs was totally banned by the Government from 1992 to 93, in order to preserve the environment. The major export markets of this product during 1991 to 92 are given below:

UK	56.18%
Germany	0.22%
USA	4.11%
Japan	2.00%
Netherlands	0.38%
S. Arabia	6.24%
Oman	6.24%
UAE	6.21%
Qatar	2.95%
Kuwait	2.32%
Bahrain	0.24%
Singapore	5.75%
Hong Kong	3.96%
Malaysia	2.70%
Brunei	0.01%
Taiwan	0.18%

The major markets for dried fish during 1991 - 92 were as follows:

ASEAN	88.0%
Hong Kong	66.49%
Singapore	13.59%
Middle East	0.66%
UAE	4.405%
Oman	3.22%
Bahrain	1.83%
Kuwait	0.55%
Qatar	0.43%
S. Arabia	0.23%
EU	8.75%
UK	8.70%
Germany	0.05%

The only market for salted and dehydrated fish was Hong Kong in1991 - 92. During 1990 - 91 the major markets were Hong Kong (76.69%), Japan (11.77%), Singapore (4.75%), USA (4.64%), UK (1.21%), Malaysia (0.54%) and Belgium (0.40%).

Major markets for shark fins and fish maws in 1991 - 92 were Hong Kong (71.69%), Singapore (23.65%), UK (4.40%), Thailand (0.18%) and Malaysia (0.04%).

The major markets for crabs during 1991 - 92 were Singapore (72.18%), Malaysia (9.12%), Taiwan (8.78%), Hong Kong (6.63%), Qatar (1.51%) and UK (1.01%).

Major markets for tortoise and turtles in 1990 - 91 were Singapore (79.28%), China (1.70%), Japan (10.14%), Hong Kong (3.04%), UK (3.13%), Korea (2.42%) and USA (0.29%). This changed during 1991 - 92 to Singapore (34.13%), China (27.82%), Japan (18.62%), Hong Kong (10.48%), Spain (4.75%) and Kuwait (94.21%).

Assessment of Exploitation Status Biological Status

The Estuarine Set Bag Net (ESBN) Fishery

Detailed catch assessment and biological information on the pattern of exploitation by this fishery is available (with DOF) and it is evident that this fishery is most destructive (Islam et al. 1993 and Khan et al. 1994). Table 25 shows the natural mortality, fishing mortality and exploitation pattern of the 19 most significant species in the ESBN fishery, covering three different ecosystems.

It can be seen in Table 18 that the species of brackish water origin, *Acetes indicus* (the sergestid shrimp), *Raconda russeliana* and *Setipinna taty* are under-fished to some extent, while almost all species of marine and freshwater origin which visit the brackish water area for nursery and breeding purposes are seriously over-fished (growth over-fishing). It is observed that all the shrimp are caught by this gear before the adult stage and thus affect the spawning process. For instance it can be seen in Figs. 5 and 6 that the ESBN, push-nets and beach seines harvest members of the same population at sizes much lower than the size at first maturity. As a result about 99 percent of the population do not get a chance to participate in the spawning process.

The Push-net Fishery

More than 2 035 million post-larvae of Tiger shrimp (*P. monodon*) are collected annually by push-net, which is only a little over one percent of the total catch of the push-net fishery (Paul et al. 1993). The rest of the catch is thrown on the sand to die, which is equivalent to about 200 billion post-larval shrimp, and fish larvae and zooplankters. This is serious growth over-fishing.

Beach Seine Fishery

Annual production of the beach seine fishery was estimated at about 7 320 t. of which most of the catches were pre-juveniles and juveniles of jewfish, anchovies, clupeoids and penaeid and caridean shrimp. As a result all the catches by this net do not get a chance to join the spawning process.

Trammel-net Fishery

Trammel-nets only operate on the Teknaf coast on a limited artisanal scale. This is a selective gear and biological studies show that the exploitation rate is below the optimum level, that the size at first capture is above the minimum and that overall exploitation by this gear appears to be biologically and economically rational and socioeconomically acceptable.

Exploitation by Semi-industrial Fisheries

There are no reports on over-fishing of *hilsa* in the marine ecosystem, but juveniles are exploited seriously in the riverine system. The bottom long-lining and marine set bag net fishing with mechanized boats do not appear to be causing over-fishing, but fishing for spawning *hilsa* is a concern for management. Over-fishing of adult Indian salmon and long jewfish by large mesh drift-nets occurs in shallow waters off Cox's Bazar.

The Industrial Trawl Fishery

The effort in the trawl fishery during the last two decades has varied around 5 - 7 000 standard fishing days (Table 12), to produce 2 500 - 5 500 t of shrimp. The MSY of penaeid shrimp is 7 000 t and the optimum effort for producing this amount is 7 000 - 8 000 standard days. In some years effort was around the level of MSY. Some effort was lost due to a major cyclone in April 1991. Thereafter, shrimp production was much below the MSY level.

Table 25. Population parameters of some species common in the catch of estuarine set bag net in Bangladesh.

Species	L_∞ (cm)[a]	K (year^{-1})	M (year^{-1})	F (year^{-1})	L_c (cm)[b]	E = (f/z)
Shrimp						
Penaues monodon	31.36	0.720	1.423	8.377	13.792	0.855
Penaues indicus	22.84	0.550	1.303	3.700	5.919	0.740
Metapenaeus monoceros	19.77	0.437	1.167	3.652	5.860	0.758
Metapenaeus brevicornis	15.57	0.310	0.997	4.235	4.809	0.809
Metapenaeus spinulatus	20.06	0.390	1.079	5.900	5.292	0.845
Parapenaeupsus scuplitis	16.90	0.760	1.752	4.150	15.300	0.703
Parapenaeupsus stylifera	14.37	1.660	3.062	3.000	2.800	0.495
Acetes indicus	5.00	0.730	2.401	1.100	2.036	0.314
Macrobrachium rosenbergii	35.54	0.340	0.841	1.960	7.341	0.700
Palaemon styliferus	15.37	0.630	1.591	3.200	3.736	0.670
Fish						
Raconda russeliana	23.62	0.430	1.099	2.100	2.931	0.657
Setipinna taty	21.27	0.530	1.284	0.800	15.796	0.281
Stolephorus tri	16.83	0.650	1.586	9.000	3.351	0.850
Harpadon nehereus	34.90	0.380	0.909	3.750	6.273	0.805
Lepturacanthus savala	93.00	0.290	0.579	2.620	22.600	0.819
Eleatheronema tetradactylum	38.08	0.100	0.850	3.500	5.300	0.866
Polynemus paradiseus	21.63	0.520	1.276	4.724	2.699	0.787
Sillago domina	43.26	0.380	0.856	2.700	13.057	0.759
Sillago sihama	27.36	0.390	0.993	3.000	5.100	0.751

Source: Khan et al. 1997.
Note: [a] = Asymptotic total length in the Von Bertalanffy growth equation.
[b] = Mean total length of first capture.

But if the shrimp catch of artisanal gear operated in more than 10 m depth is considered, the total shrimp production becomes more than the MSY level. At present, there are 59 trawlers (44 shrimp and 15 finfish), which give a total annual effort of about 7 000 standard days. However, shrimp production has not increased accordingly.

Finfish landed by the trawler fleet is in the range of 8 000 - 12 000 t, which is only 20% of the actual catch, while 80%, equivalent to 35 - 45 000 t (White and Khan 1985), is discarded at sea. Even if the discarded amount is considered as production, the MSY is being achieved. If the finfish catch (35 000 - 50 000 t) of artisanal gear operated in more than 10 m is included, the production exceeds the MSY level. The MSY is 48-88 000 t within the 10 - 200 m zone (Lamboeuf 1987) whereas Khan et. al. (1997) reported an MSY of 40 - 50 000 t within this zone. The tiger shrimp *(P. monodon)* is the targeted species and has been over-exploited (Table 26) by the trawl fishery.

Tuna and Other Pelagic Fish

While there is strong and continuous competition

in the demersal and shrimp trawling industry within the 100 m isopleth, as well as in the traditional artisanal fishing areas, the resources of other areas such as those beyond 100 m depth and the surface areas of 40 m depth are not being harvested. Exploratory survey and research information shows that substantial resources are available in these areas, particularly pelagics such as mackerels, tuna and skipjack, shark, anchovies and sardines. These large pelagic resources are partly exploited as by-catch of the *hilsa* gillnets and some of the small pelagics are harvested as by-catch of the trawlers.

Economic Status

A "long-term prediction" analysis was done with a view to finding the comparative economic gain from the trammel, trawl and ESBN fisheries if only one was allowed to operate and the others were suppressed, or vice versa if only the ESBN is suppressed and the others are allowed to operate as they are.

The analysis indicated that if the trawl fishery is kept and all other interactive fisheries (but not push-net) are suppressed, there would be substantial gain in weight and about a 300% gain in value of the catch. There would be a 250% gain in value of the catch in the trawl fishery if the ESBN fishery was not in operation.

On the other hand, trammel-nets showed an extremely high gain (by about ten times) in revenue when all fisheries (including trawlers, but not the push-net fisheries) were suppressed, but a smaller gain in yield and a large gain in revenue (300%) if only the ESBN is suppressed (Khan and Latif 1995).

Table 26. Population parameters of trawl-caught species in Bangladesh.

Species of fish/shrimp	L_∞ (cm)[a]	K (year^{-1})	Z (year^{-1})	M (year^{-1})	F (year^{-1})	E = (f/z)	L_c (cm)[b]
Shrimp							
Penaeus monodon (F)	30.5	1.14	6.83	1.94	4.89	0.71	17.5
Penaeus monodon (M)	31.5	1.35	5.72	2.14	3.58	0.62	15.7
Metapenaeus monoceros (M)	15.7	1.60	5.89	2.91	2.98	0.50	8.9
Metapenaeus monoceros (F)	18.5	1.65	4.52	2.84	1.68	0.37	9.5
Fish							
Pampus argenteus	30.5	1.66	5.25	2.35	2.90	0.55	–
Upenaeus sulphureus	22.0	1.10	10.59	2.96	7.63	0.72	–
Nemipterus japanicus	25.0	1.06	3.75	1.94	1.81	0.48	–
Saurida tambil	39.0	0.97	2.54	1.66	0.88	0.35	–
Pamadasys hasta	57.0	0.38	1.61	0.81	0.79	0.51	–
Lepteuracanthus savala	105	0.85	2.06	1.33	0.73	0.65	–
Harpadon nehereus	38.3	0.42	1.54	0.94	0.6	0.38	–
Lutjanus johni	64.72	0.28	2.70	0.59	2.11	0.78	–
Arioma indica	22.0	1.12	5.53	2.10	3.43	0.62	–

Source: Khan et al. 1997.
Note: [a] = Asymptotic total length in the Von Bertalanffy growth equation.
[b] = Mean total length of first capture.

From the different analyses, it is evident that withdrawal of the ESBN fishery would not only maintain a healthier stock, but would give a substantial increase in economic returns. The push-net (larval) fishery was kept out of this analysis because necessary data were not available. However, since about 95% of the exploited population is taken by the larval fishery alone, the suppression of this fishery would definitely give a greatly increased economic return. This perception would lead fishery managers and planners to seek higher economic returns from the same stock by changing traditional fishing attitudes.

Management Issues and Opportunities

Fisheries Management Philosophy

Fisheries in Bangladesh have been considered a gift of nature, which everybody can harness for their benefit. However, the increase of fisherfolk and limited employment opportunities in the coastal areas has resulted in the entry of non-traditional fishers who have saturated the coastal areas with nets. This has resulted in the development of some highly destructive gear. Bangladesh fisheries thus face a grave situation. Although the biological solution to destructive practices calls for the total elimination of destructive gear, the Government has taken a cautious approach to the problem and has favored a participatory approach in the management of the fisheries. Interest in community-based fisheries management strategies has increased, giving more emphasis to motivation and awareness-building campaigns than to enforcement of legislation.

Fisheries Management Goals and Objectives

The main goal is the sustainable utilization of the coastal fishery resources of Bangladesh. Fisheries management has three main objectives, ecological, economic and social (Table 27).

These were finalized through joint discussion with participants from DOF, MOFL, FRI, universities, WorldFish and EGIS in a national workshop held during 3 - 5 October 2000 in Dhaka.

Ecological Objectives

These are divided into three branches: (a) rational utilization of the resources; (b) protection/conservation of the environment that sustains the resources and (c) biodiversity protection and conservation of endangered species. Rational utilization of the resources, including shrimps, demersal finfishes and shellfish, pelagic finfish and shellfish migratory species, other invertebrates and sea weeds. These resources should be exploited and utilized rationally. If any one type of resource is over-exploited while others are exploited at lower rates or are unexploited, the entire ecosystem will be depleted.

Protection and conservation of the environment include maintaining the ecological integrity of critical coastal habitat (mangroves, coral reefs). Coastal habitats should not be damaged by any agency and brackish and marine waters should not be polluted (Table 27).

Table 27. Goals/Objectives for the coastal fisheries management of Bangladesh.

Main goal: Sustainable utilization of the coastal fishery resources of Bangladesh	
Ecological objectives	Rational utilization of resources Demersals (shrimps and others) Pelagics Migratory species/straddling stocks Harvestable invertebrates Seaweeds Protection/conservation of the environment that sustains the resources Ecological integrity of critical coastal habitats (mangroves, coral reefs, etc.) Ecological integrity of marine waters Bio-diversity protection/Protection and conservation of endangered species
Economic objectives	Maximize benefits from the utilization of the resources within the limits of sustainable use Increase incomes of small scale fishers Improve the efficiency of input use
Social objectives	Minimize conflicts among resource users Promote equity in sharing benefits from the utilization of the resources Reduce poverty among small scale fishers Promote alternative livelihood opportunities

Economic Objectives

The objective is to maximize benefits from the utilization of resources, within the limits of sustainable use. The small scale fishers should get reasonable incomes from artisanal fishing and the fishing technology should be improved, but over-fishing must be avoided under all circumstances (Table 27).

Social Objectives

These include minimizing conflicts among resources users, promoting equity in sharing benefits from the utilization of the resources, reducing poverty among small scale fishers and promoting alternative livelihood opportunities for the fishers (Table 27).

Fisheries Sector Issues

The multiplicity of issues that impact the coastal fisheries in Bangladesh (Tables 28 - 31) were discussed with participants from DOF, MOFL, FRI, universities, WorldFish and EGIS in the national workshop held during 3 - 5 October 2000, in Dhaka. The consensus was that the coastal fish stocks and fisheries require improved management to sustain the resources and increase the benefits derived from them. The main issues (Tables 28 - 31) that require improved management are briefly described.

Table 28. Productivity efficiency issues, causes, effects and interventions.

Issue	Causes	Effects	Interventions
Stock depletion	Over-fishing on inshore stocks Growth over-fishing (small mesh size) Recruitment over-fishing/brood over-fishing Poaching Poor law enforcement Non-compliance with legislation or capability of the DOF/MOFL Lack of coordination among the government, NGOs, autonomous bodies, private organizations related to fisheries development/exploitation Lack of protection of the productive sensitive zones, i.e. Sunderbans areas	Reduced protein potentiality Reduced fish catch Reduced earning from fisheries Reduced employment opportunities Reduced business activities Seasonal succession disrupted Endangering/extinction of some commercially important species	Limited entry Effort reduction Implementation of legislation supported by motivational programs Management and action program should be participatory (presence of all stakeholders to be ensured) Build-up of information technology for sustainable development of aquatic resources Stocking of selected species from hatchery Creation of field/mobile licensing facilities Closed seasons/areas (during breeding season) for particular species Protect mangrove areas Extend MPA in coastal areas
Inappropriate exploitation patterns	Non-specificity of gear used; absence of gear for pelagic species	Unexploited resources Unequal exploitation of different species /populations	Needs immediate feasibility studies on pelagic fisheries Regulations regarding use of specific gear for particular populations
Technology	Lack of technology and manpower	Wastage of resources/over-exploitation	Technological/manpower development
Research	Lack of resources/infrastructure and planning	Absence of appropriate technology	Mobilization of sufficient funds and resources
Information - database on the catch production	Lack of awareness/facilities	Inability in interaction with other countries	Create facilities for information retrieval systems
Post-harvest losses	Trash fish - non-profitable Inadequate transport and preservation facilities Inappropriate marketing channels	Wastage of resources Local pollution Inbalance in food chain Loss of resources Deprived reasonable prices	Introduction of by-catch reduction device Other means of processing on board the vessel Develop preservation and other facilities like transport Introduction of appropriate marketing channel (elimination of middlemen)

Table 29. Environmental integrity issues, causes, effects and interventions.

Issue	Causes	Effects	Interventions
Over-exploitation of the stocks	Lack of awareness Lack of database	Stock depletion/low productivity	Enforcement of regulations on gear/size/season. Awareness build up
Pollution from oil due to ship breaking/spillage and other sources	Lack of enforcement/tendency not to obey the regulations	Habitat degradation/stock depletion	Creation of awareness enforcement of regulations Valuation of habitats
Mangrove destruction	Lack of awareness/Lack of appropriate policy/Corruption	Habitat degradation	Framing of appropriate policies/creation of awareness Enforcement of regulations Valuation of habitats
Siltation	Deforestation in the catchments areas/Corruption	Habitat degradation	Awareness building/enforcement of regulations Valuation of habitats
Waste dumping and leakage	Lack of enforcement of regulations/disobeying of regulations	Pollution/degradation of habitat	Enforcement of regulations/create facilities for waste receiving dumping/treatment Valuation of habitats
Rigging for oil exploration	Development of economy	Habitat degradation	Mitigation measures should be taken Monitoring program should be launched Valuation of habitats
Industrial wastage	Economic benefits	Habitat degradation	Appropriate mitigation measures should be adopted Valuation of habitats
Pesticides use	Economic benefits	Habitat degradation/health hazards	Appropriate mitigation measures should be adopted
Introduction of exotic species			Strict quarantine rules
Sewage disposal	Lack of enforcement/awareness	Habitat degradation	Enforcement of regulations/awareness
Lack of monitoring program on water quality			Parallel monitoring (multi-agency)
Lack of an environmental section in DOF			Establish an environmental section in DOF
			Overall interventions: Eco-friendly environmental management measures should be adopted in all cases

Table 30. Distributional equity issues, causes, effects and interventions.

Issue	Causes	Effects	Interventions
Small /Large scale fisheries conflicts	Overlapping of interests	Over-exploitation of the resources	Awareness build-up in the stakeholders
Dadon System	Lack of credit for small holders	Economic exploitation of the fisherfolk, resulting increase in poverty	Creation of credit facilities for the poor fishers without collateral
Demarcation of sea/Species types/ Gear types/Seasonality	Lack of awareness/weak enforcement of the existing rules/tendency not to obey the existing regulations	Over-exploitation of the resources affecting interests/ low catch/low income	Awareness building, management and enforcement of regulations
Resource management conflicts in the Sunderbans area	Not managed by DOF	Resource depletion Poor management	Water bodies should be scientifically managed with the collaboration of DOF
Rehabilitation and IGAs for push-net fisheries and ESBN fisheries	Encouraging fishing with destructive gear	Destruction of resources	Closure of the fishery Provision of alternative livelihood

Table 31. Instutional efficiency issues, causes, effects and interventions.

Issue	Causes	Effects	Interventions
Inadequate institutional capacity to address fisheries management	Lack of an independent Marine Fisheries Department	Marine fisheries sector is not properly handled and monitored	Appropriate training programs Recruitment of needed manpower Establishment of independent Marine Fisheries Department and other infrastructure
Lack of scientific manpower with proper academic background	Lack of recruitment rules	Shortage of scientific manpower	Recruitment of adequate scientific manpower
Lack of proper training for scientific personnel	Training facilities are not organized	Personnel face difficulties in research and legislation	Introduction of proper training for scientific personnel
Lack of inter-agency coordination	Unclear responsibilities		Increase awareness among agencies regarding their roles and responsibilities Formulation and assignment of responsibilities by a central government agency/coordinating body Harmonize and simplify laws and regulations Promote dialogue/communication among agencies
Lack of infrastructure facilities and equipment	Due importance to marine fisheries sector not given	Marine fisheries resources are depleted	Infrastructure facilities should be created
Conflict between government and the marine fisheries industry, NGOs, fishing communities	Lack of awareness of better management policy	Marine fisheries management is not developed	Establish Marine Fisheries Department & reorganize the Ministry of Fisheries Increase participation of stakeholders
Irregular stock assessment/ monitoring	Lack of scientific manpower and logistic support facilities	Current information on marine fisheries resources lacking	Creation of facilities for bio-ecological research on marine fisheries resources
Lack of bio-ecological research on the commercial species of fish and shrimps	Lack of appropriate skilled scientific manpower and research facilities	Non-availability of knowledge of the bio-ecology and stock analysis of marine fishery resources	Creation of appropriate research facilities

Productivity and Efficiency Issues

Stock Depletion and Over-exploitation

The stocks of many species of marine shrimps and fish are declining due to growth over-fishing by estuarine set bag nets, push-nets and beach seines and to recruitment over-fishing by the trawler fleets. Problems are increased by poaching by foreign fishing trawlers, improper enforcement and implementation of laws, flouting of laws by trawl and artisanal fishers and lack of coordination among the government agencies, NGOs, autonomous bodies and private organizations.

Inappropriate Exploitation Patterns

Multi-gear, multi-species fisheries characterize the region and there are no specific gear types for particular species. For *Hilsa*, for example, the ESBN, MSBN and trawl-nets catch similar assemblages of species of demersal finfish and shrimp, but all species are not harvested at equal rates.

Technology

There is no specific technology for catching pelagic species, such as tuna and squid, or for other non-traditional fishery resources, such as cuttlefish, octopus, lobster and seaweeds.

Research and Database on the Catch

There is no database for catch and effort statistics and there is a lack of facilities for scientific research and a shortage of skilled scientific manpower.

Post-harvest Losses

The shrimp trawlers target only shrimp, but take substantial by-catch. The high-valued fin-fish are kept, but low-value trash fish are discarded. No facilities have been developed to transport the trash fish to markets and no marketing channels exist for these fish.

Environmental Integrity Issues

Pollution is increasing in brackish and marine waters due to pollutants from domestic, industrial and agricultural sources. Oil spills from ship breaking, spillage and other sources, waste dumping and leakage, sewage disposal, rigging for oil exploration, industrial wastage and pesticides are polluting marine waters and damaging habitats and stocks of aquatic resources. Mangrove destruction is leading to increased flooding, siltation and alteration of hydrological regimes that cause adverse impacts on coastal fishery resources. The degradation of mangroves, seagrasses and algal beds is apparent in coastal areas. All these impacts have repercussions on coastal bio diversity and on the productivity of coastal fishery resources.

Distributional Equity Issues

Small and Large scale Fisheries Conflicts

Fishing in areas less than 30 m deep is quite intense and competition between small scale artisanal and large scale trawl fisheries has increased in recent years resulting in high fishing pressure on the same resources. The trawl fishers should operate their gear beyond 40 m following the marine fisheries ordinance. The trawl fishers are not carrying out the restriction of area and season for conservation of the fishery resources and most of the artisanal fishers are not following the rules and regulations of mesh size of the gear. The instituation could be minimized by DOF/MOFL implementing the marine fisheries rules, supported by awareness building among the trawl and artisanal fishers and other stakeholders.

Rehabilitation and Income Generating Activities for PN and ESBN Fishers

Push-net, estuarine set bag nets and beach seines are destructive fishing methods and need to be banned. However, many thousands of full-time and part-time fishers are involved and alternative income generating activities are needed in the coastal zone.

Institutional Efficiency Issues

The lack of an independent Marine Fisheries Department has resulted in the marine fisheries sector not being properly managed. There is a shortage of scientific manpower due to a lack of proper recruitment rules. Training facilities are not well organized and the sector lacks infrastructure, equipment and funds because it has not been given due importance.

There are gaps in interagency coordination, conflicts between government and the fishing industries, the NGOs and the fishing communities, all resulting in mismanagement of fishery resources. The fisheries sector lacks current information on

the status of stocks and catch statistics and stock assessments have not been made because of the lack of skilled scientific manpower and logistic support.

Cross Sectoral Issues and Opportunities

Apart from these evident fisheries-specific issues, a number of cross-sectoral issues require attention for the long term sustainability of coastal fisheries. Table 32 summarizes the main activities and issues that impact the coastal zone and, ultimately, the coastal fisheries. The complex issues impacting the country's coastal zone require multiple, but integrated, interventions. Integrated coastal zone management (ICZM) requires increased support to resolve the impacts (both actual and potential) on the coastal ecosystems. Various ICZM initiatives in the country emphasize the need for improved collaboration and coordination among relevant government agencies (e.g. Ministry of Fisheries and Livestock, Ministry of Shipping, Ministry of Land, Ministry of Environment and Forests and the Ministry of Defense) as well as an upgrading of their capabilities to effectively resolve coastal zone impacts.

The Ministry of Industry is currently authorized to accord permission for acquisition of fishing trawlers in consultation with MOFL. The mechanized fishing vessels are registered with the Mercantile Marine Department (MMD). For patrolling of the EEZ, the DOF procured two modern gunboats and placed them under the operational control of the Bangladesh Navy.

Several NGOs and fishers cooperatives are involved in marine fisheries development activities in the country. Bangladesh *Jatiyo Matshyajibi Samabay Samity* (BJMSS), for example, had direct involvement in the marine fisheries development, but is now ineffective. Among the NGOs, CODEC, CARITAS and Proshika-MUK are directly involved in the development of the fisherfolk communities.

Table 32. Typical coastal transect showing the main activities and issues relevant to effective integrated coastal zone and coastal fisheries management in Bangladesh.

	Terrestrial			Coastal		Marine	
Major zones	**Upland slope (> 18%)**	**Midland (8 - 18% slope)**	**Lowland (0 - < 8% slope)**	**Interface (1km inland from HHWL* -30m depth)**	**Nearshore (30m - 200m depth)**	**Offshore (> 200m depth - EEZ)**	**Deepsea (beyond EEZ)**
Main resource uses/activities	Logging, mining, urban development agriculture	Logging, mining, urban development, industries, agriculture, brick/boulder, extraction	Logging, agriculture urban development, industries, tourism	Mangrove forestry, aquaculture, ports/marine transport, artisanal fishing	Artisanal fishing, commercial/ industrial fishing, marine transport, pearl collection	No fishing	Marine transport
Main environmental iissues/ impacts on the coastal zone	Siltation, erosion, flooding, agrochemical loading, water, pollution, toxic mine tailings	Siltation, erosion, flooding, toxic mine tailings	Siltation, erosion, flooding, agrochemical loading, sewage pollution, industrial pollution	Reduction of biodiversity, habitat degradation, over-fishing, beach erosion, organic loading, oil spills/slicks	Reduced biodiversity, over-fishing, oil spills/slicks, dumping of waste	Oil spills/slicks, dumping of waste	Oil spills/ slicks

Note: * Highest high water level.

As part of the global initiative taken by the coastal zone management subgroup (CZMS) of the Intergovernment Panel on Climate Change (IPCC), the Bangladesh Center for Advanced Studies (BCAS), in collaboration with Resource Analysis (The Netherlands) and Approach Consultants (Bangladesh), undertook a pilot study on the assessment of the vulnerability of coastal areas to climate change and sealevel rise. The results of the study were presented on behalf of the Ministry of Environment and Forestry, at the World Coast Conference. The objective of the study was to analyze the vulnerability of Bangladesh to sealevel rise and global climate change and to prepare a vulnerability profile. Other objectives included identification of the institutional strengths and weaknesses for implementing integrated coastal zone management (ICZM).

The study focused on assessing the primary physical effects of different scenarios in terms of changes in inundation, salinity intrusion and droughts, as well as cyclones and flash floods. The study revealed that there is clearly a need for integrated coastal zone management, both at the national and local levels.

The Environmental Survey and Research Unit (ESRU) of the Department of Geography, Dhaka University, is a research and study organization committed to gathering information useful for implementing projects of national importance. ESRU also assists development agencies in dealing with development oriented problems, in forms and means best suited to their needs. They have directed and participated in different projects financed by ADB, FAO, Ford Foundation, HABITAT, JICA, UNDP, UNFPA, USAID, World Bank and other organizations.

Recommendations for Immediate Government Action

- Additions of fishing boats and gear in coastal fisheries should be limited.
- Fishing effort should be reduced and all destructive gear like the estuarine set bag net, beach seine and shrimp fry collection nets should be gradually removed and replaced by non-de structive gear, provided that alternative income generating activities can be developed for those fishers who are fully dependent on these fisheries.
- Legislation for the artisanal and trawl fisheries, such as seasonal closures, area restrictions and mesh size regulations, must be properly implemented, supported by awareness building and motivational programs for coastal fishers, fishing vessel owners and other stakeholders.
- Pelagic fishery resources, like tuna and other non-traditional fishery resources, such as squid, cuttlefish, octopus, oysters, mussels, lobsters, crabs, sea cucumbers and seaweeds should be surveyed with a view to their exploitation in a sustainable manner.
- Improved fishing technologies for demersal fish and shrimp and for hilsa should be introduced.
- By-catch reduction devices should be introduced in the trawl fishery.
- The use of non-destructive gears, such as tram mel-nets, bottom set gillnets, bottom longlines and purse seines, should be promoted, through proper training and motivational programs for fishers.
- Improved fishing methods for pelagic fishery resources, particularly for tuna, should be introduced through training and extension programs.
- Regulations should be promulgated regarding the use of the gear with specific mesh sizes for selective harvesting of particular lengths or sizes of various species.
- Databases should be created on the catches of all fish stocks and on all relevant scientific information.
- Coordination between stakeholders should be increased to address the conflicts between government agencies and the marine fishing industry, NGOs and fishing communities, regarding marine fisheries management.
- Awareness building, communication, coordination and dialogue should be increased among agencies regarding their roles and responsibilities (assigned for marine fisheries management by the central government).
- Eco-friendly environmental management measures should be adopted in all cases.
- Multi-agency programs should be introduced for water quality analysis.
- Quarantine rules should be strictly followed by departments concerned regarding introductions of exotic species.
- The possibilities of stocking marine waters with selected, commercially-important species from hatcheries should be investigated.
- Mangrove areas should be protected and Marine Fisheries Department activities should be extended in the coastal areas.
- Appropriate mitigation measures such as awareness building and enforcement of regulations, should be undertaken to protect the marine

environment from pollution due to oil spills from ship breaking, spillage, oil exploration, industrial wastes, pesticide use, sewage disposal, waste dumping and leakage. Facilities should be created for waste treatment before dumping the waste into the marine waters and for receiving it waste from marine industries.
- An Environmental Section should be established in the Department of Fisheries.
- Sufficient funds should be allocated for marine fisheries surveys and research.
- Appropriate steps should be taken for man power development in the marine fishery sector.
- An independent Marine Fisheries Department should be established under the MOFL for proper and effective organizing, monitoring and regulating the overall activities in the sector.

Recommendations for Government Follow-up Action

- Closed periods during the breeding season and marine reserves for the conservation of gravid female shrimp and fish species should be established and implemented.
- Trash fish are to be utilized through shifting to carrier vessels with proper processing facilities on board. Appropriate marketing facilities should be introduced for trash fish.
- Appropriate research facilities should be created for bio-ecological research on marine fishery resources.
- Credit facilities on simple terms and conditions should be created for the poor fishers.
- Field-based mobile licensing facilities for fishing boats should be introduced.
- Appropriate policies for shrimp and fish farming should be made to protect the mangrove forests and regulations to conserve of mangrove forest should be enforced to check corruption.
- Water bodies of the Sunderbans (mangrove) areas should be scientifically managed with the collaboration of the Forest Department.
- Management and action programs for fishery resources conservation should be participatory, with the presence of all stakeholders ensured.
- Appropriate training programs should be introduced for scientific personnel, aiming at man power development.
- Scientific man power, with appropriate academic background, should be recruited by the Marine Fisheries Research and Surveying sector.

Recommendations for Regional Collaborative Efforts

- Marine infrastructure facilities in all member countries of the Indian Ocean Fishery Commission (IOFC) should be developed.
- International funding agencies may provide support for research in the area of exploration and exploitation of under-exploited or unexploited marine fishery resources.
- Governments of countries of the Indian Ocean rim should take necessary measures to prevent illegal poaching of fish by their vessels in the EEZs of other countries.
- Different by-catch reduction methods in trawl fishing should be investigated.
- Regional and national research collaboration should be promoted for increasing institutional capabilities and strengths and for providing information, training and advisory support to members of developing countries.
- Bilateral and multilateral cooperation should be promoted in managing, harvesting and utilizing straddling and migratory high seas fish stocks.
- The Indian Ocean Fishery Commission (IOFS) and other regional bodies such as the Indian Ocean Tuna Commission (IOFC), should take measures for the management and conservation of straddling or highly migratory fish stocks.
- Modern marine science technology should be disseminated to all countries of the Indian Ocean rim through different cooperative programs.
- The dumping of toxic wastes by industrially developed countries along the Indian Ocean should be prevented by building up public opinion and by monitoring the movement of vessels carrying toxic wastes.
- International cooperation by the IOFC, IOTC, IPFC, and the IPTP should be strengthened and made effective by more consultation and the establishment of a Secretariat for these organizations.
- Information networks should be established between the countries of the Indian Ocean rim to facilitate the easy flow of information and ideas which will help the conservation and management of aquatic resources.
- GOB should discuss with relevant international organizations, in the appropriate fora, the idea of initiating a United Nations Ocean Development Programme (UNODP) to overview the "Code of Conduct for Responsible Fisheries" internationally, to coordinate the rational development of ocean resources regionally, and to assist national endeavours in this respect.

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Appendix I. Administration Orders, Regulations for the Management and Conservation of Fisheries Resources in Bengal Bay

Coastal Zone Resources, Policies and Laws

Mangroves

The Sunderbans is a forest reserve. No cutting of mangroves and other trees is allowed without Government permission. Hunting has been banned in this area. However, illegal cutting of wood and poaching of wild animals has not been eliminated. Many of the planted mangrove forests in the Chokaria Sunderbans have been systematically cleared for shrimp farms despite the Government's restrictions. Although the policy and legislation exists to protect the mangrove the Government should be more vigilant to prevent the illegal poaching.

The Government policy and rules regarding mangroves are given below.

<u>The Environment Conservation Rules</u> (ECR), 1997 were promulgated in August 1997, making some vital provisions of the Environment Conservation Act fully operative. The Environmental Quality Standards (EQS) for air, water, soil, mangroves and shrimp culture have been set up. Some degree of ambiguity still exists regarding management in ecologically critical areas.

<u>The National Conservation Strategy</u> (NCS) was formulated in 1991. It identified 16 sectors covering major issues, their current status and strategic options. The following are relevant provisions in the NCS:

- Preservation of mangrove forests which provide nursery, food and shelter to shrimp and other estuarine living resources;
- The Sunderbans are to be managed in an integrated manner;
- Allocation of government-owned coastal land with suitable physical environment for shrimp culture and provision of technological support to farmers for intensive aquaculture. It will be made obligatory for shrimp farmers to grow mangrove forests around farms where such forest does not exist; and
- Establishment of shrimp hatcheries for production of juveniles and discouraging the wasteful method of trapping post-larvae and juveniles in open waters.

<u>The National Fish policy of 1998</u> states that shrimp and fish culture cannot be developed by damaging the mangrove vegetation in coastal areas, that shrimp culture damaging mangroves will be banned and planting of mangroves will be compulsory between the shrimp farms and ponds and the banks of rivers.

Coral Reefs

No laws or acts have been enacted to protect the coral reef island of St. Martin. However, the government is studying the option of making the island and the adjacent areas a marine park in order to better manage and conserve it.

Endangered Wildlife

Many wildlife species have been exterminated in Bangladesh and many more are threatened with extinction. The country has lost 10% of its mammalian fauna, 3% of the avifauna, and 4% of the reptiles over the last 100 years. More than 50 species are critically endangered in Bangladesh, of which 23 species are already declared endangered in the Red Data Book of IUCN. These include elephant, tiger, wildcat, leopard, serao and dolphin among mammals; white-winged duck, comb duck, stork and crane, pheasant and partridge among birds; and crocodile, python, monitor lizard, river terrapin, roofed turtle, soft turtle and all marine turtles among reptiles.

There are specific laws to protect wildlife, which are described below:

The Bangladesh Wildlife (Preservation) Act, 1973 provides for the preservation, conservation and management of wildlife in Bangladesh. The earlier laws on wildlife preservation, namely, the Elephant Preservation Act-1879, the Wild Bird and Animals Protection Act-1912, and the Rhinoceros Preservation Act-1932 have been repealed and their provisions have been incorporated into this law.

The Act encompasses a range of different activities, including hunting and fishing, although the provision of greatest significance relates to the establishment of wildlife sanctuaries and national parks by the MOEF (Ministry of Environment and Forests). Such designations have enormous significance for the type of developments that may take place.

The main provisions are:

- The wild animals specified, as "game animals" shall not be hunted, killed or captured, save in accordance with the terms of a permit issued under this order.
- The wild animals specified in this order shall be known as "protected animals" and shall not be hunted, killed or captured save as otherwise expressly provided in this order.
- No person shall, with a view to carrying on a profession, trade or business, buy, sell or otherwise deal in wild animals, trophies or meat, or process or manufacture goods or articles from such trophies or meat unless he is in possession of a valid permit, issued for the purpose by an authorized officer.
- The government may declare any area to be a national park provided that the government may, for scientific purpose or for betterment of the national park or for aesthetic enjoyment of scenery or for any other exceptional reason, relax all or any of the prohibitions specified.

Article 23 (2) states that:
No person shall:

- Damage or destroy any vegetation in any wildlife sanctuary;
- Cause any fire in a wildlife sanctuary;
- Pollute water flowing in or through a wildlife sanctuary.

Contravention or attempts to contravene the various provisions of the law have been made punishable as specified in the law. This legislation does not provide scope for the creation of a strong organization, which can adopt appropriate measures to protect wildlife. Punitive provisions are not readily usable. The types of endangered and ecologically valuable animals or birds should be highlighted in the legislation. The government should have asked for active participation and specific action from local administration to protect wildlife. The law also does not prescribe seasons when certain animals/ birds cannot be hunted or captured (Chowdhury 1999).

An executive order issued in June 1998 in relation to the Bangladesh Wildlife Preservation Order 1973 imposed a ban for five years on hunting any form of wildlife.

Fisheries Investment Policies

Bangladesh is keen to develop its fisheries potential and has thus identified major areas for investment though development projects. Private sector investments in commercial ventures are also welcome.

Identified fields of fisheries development projects of DOF include:

- Semi-intensive aquaculture technology development and extension service for ponds and other closed water bodies.
- Fisheries development in large water bodies such as beels and baors.
- Development of the socioeconomic conditions of the fishing communities.
- Fish culture development in flood control and irrigation projects areas.
- Paddy-cum-fish culture development and extension.
- Fish and shrimp culture development in the freshwater areas.
- Intensive fish polyculture development in the coastal districts where possible.
- Freshwater shrimp culture development and extension.
- Fisheries resources development, management and conservation in the Bay of Bengal.
- Demersal fisheries harvesting management and conservation in the Bay of Bengal.
- Pelagic fisheries resources harvesting technology development in the extensive economic zones of the countries sharing the Bay of Bengal.
- Shrimp hatchery technology development.
- Marine fisheries resources surveys to explore new commercial fishing grounds and for stock assessment and estimation of maximum sustainable yield (MSY).

- Support services for commercial oyster culture.
- Support services for infrastructure development of marine and freshwater shrimp culture in the private sector.
- Aquaculture development in derelict khas, ponds, ditches and freshwater bodies under the Pond Food for Work (FFW) program for landless and marginal farmers and rural unemployed youth.
- Implementation of inland open water hatchery management programs.
- Implementation of new fisheries management policy.
- Strengthening of extension and information services of the Department of Fisheries.
- Strengthening of fisheries resources survey systems and establishment of a databank.
- Strengthening and improving the fish inspection and quality control service of DOF.
- Modernization of the training infrastructure of the DOF and development of technical man power in both public and private sectors.
- Fish fry and fingerling stocking in open water bodies.
- Introduction of supervisory credit system through a loan guarantee fund scheme.
- Support services to implement aquaculture and fishery credit.

There are two sources of funding, viz. the Revenue Budget and the Development Budget. The Department of Fisheries had an annual revenue budget of Taka 277.9 million and a development budget of Taka 515.8 million•annum^{-1} during 1998 - 99. In order to implement the fisheries development programs, Taka 5 862 million was earmarked for the public sector during the Fifth Plan. Allocations by program are shown in Table 1.

In addition to the public sector allocation of Taka. 5 862 million, an amount of Taka 21 847 million was allocated for programs for fisheries development in the private sector, and for this purpose programs and projects were developed for implementation in the private sector with support and service from the public sector. Fish hatcheries, feed mills, fish culture, fish processing, fish preservation, fish production and export are some of the major areas for private sector participation.

Table 1. Allocation of funding to programs during the Fifth Plan, 1996 - 97.

Program	Allocation million Taka
Survey, investigation, feasibility study, research, etc.	400.00
Fisheries education, training, extension and community development	890.00
Culture and capture fisheries development (including inputs and water bodies development)	4 360.00
Fish landing, storage, processing, marketing, transportation, distribution	211.80
TOTAL	5 861.80

External Policies Affecting Fisheries

General Land Use

The following are relevant principles of settlement of the Non-agricultural *Khas* land under the Ministry of Land, according to the Non-agriculture *Khas* Land Management Act, 1995 (Miah 1999).

- The non-agricultural *khas* land can be leased to a Government office or organization on a payment basis, according to the market price of the land.
- The land can be leased for a religious place, orphanage or graveyard on the basis of 10% of the actual worth of the land.
- The land can be leased for educational purposes on the basis of 10% of the worth of the land.
- The land can be leased by the Government to rehabilitated peoples (5 per family) affected by disasters.
- The non-agricultural *khas* land can be leased for poultry or diary use outside the metropolitan and district towns.
- The government *khas* ponds and *jalmahal* (closed water bodies) will be leased on a long-term basis for scientific farming and fishing.
- Necessary land can be leased to foreign investors or companies to develop industries outside metropolitan areas, but land can be leased to develop hotels or motels of international standard (at least three stars) within metropolitan areas.
- Land can be leased to any person or any company for rubber plantations.

Effect of Policy on fisheries

In Bangladesh most of the water bodies in the inland sector are managed by the Land Ministry. There are serious anomalies in imposing the fisheries management and conservation legislation in the country. Most of the management endeavors are hampered because the water bodies are leased out without any control by the Department of Fisheries. Efforts to increase production by open water stocking have not been very successful due to this dual administrative arrangement regarding water bodies. As a result most of the water bodies leased out by the Land Ministry face total annihilation of the fish stocks by the lease holders who, in order to gain maximum benefit from the lease, totally drain the water body to catch all the fish. The coastal areas are also managed by multiple departments and ministries, which results in conflicting policies and measures. For example, the Sunderbans, which serve as the nursery ground of many marine fish and shrimp, are controlled and leased out by the Forest Department for fishing. The Forest Department does not consider the management aspects while allowing fishing. This results in the deaths of millions of fish fry and juveniles that, if conserved, would add substantially to the fish production.

Pollution and Environmental Protection

In tackling the environmental problems of the country, various environmental laws have been made from time to time. There are more than 200 sectoral laws that are in force dealing with environmental issues (Chowdhury 1999). They focus mainly on land use, air and water pollution, noise, toxic chemicals, solid waste, forest conservation, wildlife protection, mineral resources and coastal zone management. Laws now in force, such as the Forest Act of 1927, the Motor Vehicle Ordinance of 1939 and the Bengal Smoke Nuisance Act of 1876 were inherited. Others were enacted after 1947 due to changed scenarios. On the basis of the broad objectives of environmental laws existing in Bangladesh, the laws may be categorized as follows:

- Protection of environmental health;
- Control of environmental pollution; and
- Conservation of natural and cultural resources.

The National Environmental Policy (EP) of 1992 the marine environment of Bangladesh addresses (MOEF 1992). This was adopted by the Government as a significant component of an overall environmental strategy for multisectoral sustainable development. It specifically identified environmentally desirable policy suggestions for major development sectors, including agriculture, industry, health and sanitation, energy and fuel, water and irrigation, forests, wildlife and biodiversity, fisheries, livestock, food, transport and communication, coastal and marine ecosystems, industry, housing and urbanization, population, public awareness, education and research. The major objectives of the policy are as follows:

- Maintenance of the ecological balance and overall progress of the country through preservation and development of the environment.
- Protection of the country against natural disasters.
- Identification and prevention of all types of activities related to pollution and degradation of the environment.
- Ensuring environmentally sound development in all sectors.
- Ensuring sustainable, long-term and environmentally congenial utilization of all resources.
- Participation as far as possible with all international initiatives related to the environment.

For preservation of the coastal and marine environment, the EP stresses the following:

- Ensuring environmentally sound preservation and development of coastal and marine ecosystems and resources therein.
- Prohibiting all domestic and foreign activities causing pollution in coastal and marine areas.
- Strengthening research for the protection and development of the coastal and marine environment and resources.
- Keeping the fish catch from coastal and marine waters at the maximum sustainable level.

There are many other policy suggestions in the EP that are relevant to marine environment issues, e.g. ensuring a congenial environment for fisheries development and preservation of mangrove and other ecosystems. Reassessment of water development, flood control and irrigation projects having harmful impacts on fisheries, and doing EIA (Environmental Impact Assessments) before taking up new projects were stressed.

The EP recommends that all water bodies in Bangladesh be free from pollution and that industries take up pollution control measures gradually. It suggests a gradual ban on the establishment of any

new industry or the operation of any existing one whose produce is hazardous to the environment. Natural pest control, instead of using chemical pesticides, and the use of manure and agricultural wastes as fertilizers have also been suggested. In respect of an institutional framework, the Ministry of Environment and Forests (MOEF) is responsible for putting it in effect and conducting the inter-ministerial and inter-departmental coordination.

Another industrial policy enunciated in 1991 mentions the maintenance of environmental balance in industrialization and prevention of environmental pollution. The policy emphasized the need to develop industrial growth centers in appropriate locations to ensure environmentally sound industrialization. Existing industries are required to adopt anti-pollution measures within the time-frame to be specified by the government.

It is very significant that a national environmental policy has been formulated in Bangladesh where any industry, any ship or any township can freely dump wastes into the waters, no matter how dangerous or harmful it is to others. This situation has not only been due to the lack of policies, but also due to financial, technical, institutional, administrative and legislative weaknesses and gaps (Mahmood et al. 1994).

Environmental Quality Standards (EQS) for Bangladesh have been drafted, but have not yet been adopted. The scope of DOE's mandatory and DOE's administrative rights are ambiguous and undefined. It is not yet of adequate strength to obtain the needed data or provide the type of good judgement necessary to perform the job with objectivity. Often, industries refuse DOE personnel access to their plants. Sewage and municipal waste management from a water pollution control standpoint is not addressed in the EP. Legislative lacunae and ineffectiveness are still major problems in the country. The Water Supply and Sewerage Authority Ordinance, 1963, established executive responsibilities for WASA authorities. Nevertheless, there is no explicit mechanism for prosecuting WASA for failing to carry through with the assigned responsibilities. Therefore, gradual strengthening of all mechanisms through integrated efforts, actions and motivation is of prime importance.

Legislation Against Threats to the Marine Environment

National environmental legislation provides guidelines relating to the control of environmental pollution, conservation of natural resources and the protection of environmental health. About 45 laws in different areas, including the coastal and marine environment and resources, have a bearing on environmental issues. However, specific standards and enforcement mechanisms are lacking. In fact, there is no appropriate legislation for the protection of the marine environment and the related ecosystems of the country. As for other areas, the existing laws in this regard are also inadequate, contain glaring inconsistencies and are neither enforced nor enforceable due to institutional, technical, strategic and financial constraints. Most of the laws are outdated, inept and incoherent (Mahmood et al. 1994).

The legislative situation in respect to marine pollution can be gauged from the fact that, in 1989, Bangladesh failed to even file a case against a super oil tanker M.T. Filoti, after it was responsible for spilling about 3 000 t of crude oil in national waters. Bangladesh is still not a signatory to the Marine Convention of 1973, under which foreign ships can be sued for damages up to US$80 million for oil spills or dumping wastes (Anon 1992). To become a signatory to the Convention all ports, for instance, should have reception facilities for the treatment of ballast- and bilge-waters and other wastes from foreign ships and the country should have sufficient and competent coastguards to determine the exact nature of accidents at sea. Without coastguard patrols or other law enforcing agencies, punitive legal action is non-existent. Foreign ships discharge ballast- and bilge-waters and hazardous wastes at will. In 1988 - 89, a ship called the Falicia, carrying hazardous wastes, dumped its cargo in the Bay while traveling from Colombo to Singapore (Anon 1992). Bangladesh was not even in a position to determine if the wastes were dumped in its territorial waters or not.

Minerals

Bangladesh has a few proven mineral resources, but the country has enormous deposits of natural gas. To date, 17 gas fields have been discovered, from which natural gas is available for power-generation, industrial uses, etc. Fertilizer factories, including the petro-chemical complex operating at Ashuganj and others to be developed will use sizeable quantities of natural gas. About 1% of the gas reserve is currently being consumed annually. Coal deposits have been found and efforts are under way to exploit them with international assistance. There is a possibility of oil deposits in the country and efforts are being made for their exploration.

Limestone, the basic raw material for the production of cement, has been found in some places and cement factories are being set up for their utilization. Other minerals found include hardrock, lignite, silica sand and white clay.

Salt is not mined but is manufactured on a small scale at several thousand evaporation sites in the coastal areas of Chittagong and Cox's Bazar.

Extensive radioactive sand deposits have been found along the beaches from Kutubdia to Teknaf.

A survey estimates the reserve to be of the order of 0.5 million t of sand containing a significant amount of usable heavy minerals.

So far the Government policy regarding the exploitation of the mineral resources is to meet the growing domestic demand and thereafter seek exports. Natural gas is being used by some multi-national companies under joint ventures with the Government to produce fertilizer for export. Recent trends in the exploitation of the offshore gas field do not seem to significantly affect the fisheries. There is a rule on water purification under the Ministry of Energy and Mineral Resources, called the "Mines and Minerals Rules 1968 27L Water Purification" which states that "during exploration or the mining operation, if polluted waters erupts or if water is polluted in any way, measures shall be taken by the licensee or the leasee to purify it or to separate the harmful elements from the water so that no harm is done to the animals, fisheries, plants or agriculture or environment" (Muminullah 1998).

International and Regional Conventions

Bangladesh is a member of almost all the regional organizations and is active in the pursuance of eco-friendly fisheries, focusing on the conservation of the resources and preserving biodiversity. Bangladesh has actively supported the Code for Responsible Fisheries and the UN Conventions on Highly Migratory and Straddling Fish Stocks and has also signed Agenda 21 and has been actively fulfilling its obligations.

Foreign Trade Laws, Restrictions and Demands

There are a number of international laws and regional laws or measures that hamper fisheries activities. The ban on Bangladesh fishery products by the EU countries for the failure to meet their standard of Hazard Analysis Critical Control Point (HACCP) is one such example. This ban is gradually being overcome by improved management of the processing factories. There is a growing demand for Bangladeshi fishery products around the world. Many traditional fishery products are being exported to the developed countries to meet the demand of the migrants from this sub-continent. There are many trade barriers that come in the guise of other issues such as environmental issues which restrict trade. For example, the legislation imposed by the United States' Department of Commerce against shrimp caught in trawls without turtle exclusion devices.

Responsible International Trade

Bangladesh subscribes to the principles, rights and obligations established in the World Trade Organization Agreement as it pertains to trade in fish and fishery products.

Appendix II. Research Support for Marine Fisheries Development

Oceanography and Productivity

Almost no research appears to have been carried out on the oceanography and primary productivity of Bangladesh waters. Several fisheries resource surveys have gathered basic data on bathymetric as well as geographic distribution of various species, their catch rates and abundances, with particular reference to penaeid shrimp species, and some oceanographic data on temperature, salinity and Secchi disc readings.

Any form of rational fisheries management and development requires data on catch rates, species composition, location, seasonality and fishing gear, together with broad-based biological and Socioeconomic data. The most important areas of research are as follows:

- Oceanographic studies to understand the marine ecology of the area and assessment of primary and secondary productivity of the EEZ of Bangladesh.
- Studies on marine fish stock assessment to relate to marine productivity and marine fish landings.
- Research on methodologies for monitoring catches and fishing effort.
- Development of a catch monitoring system to assess the status of the resources and trends in landings.

Inshore Fisheries and Conservation of Exploited Resources

The inshore capture fisheries of Bangladesh are mainly artisanal, mostly with small non-motorized boats. They normally operate up to 40 m depth. Of the total fishery production the gillnet catch (composed mainly of *Hilsa* spp.) contributes 55%, while the estuarine set bag net (ESBN) contributes about 30%. Most of the catch of the ESBN are juveniles and a DOF/BOBP study in 1991 showed that the ESBN fishery is harmful to the resources and that fishing effort requires control. Before proper management measures are introduced, a better understanding of the issue is necessary to avoid any social tension and economic upset in the target populations. Research is needed to determine the scope of the problems and the ways to tackle them.

Increased yield of *Hilsa* spp. can probably be achieved through better management of stock. The most important strategy should be the extension of the marine fisheries management regime to cover the mechanized and artisanal fisheries. Revision of the Fisheries Ordinance 1983 in order to incorporate all types of gear used by artisanal fishers is necessary so that regulation of fishing effort may become possible. This was also reiterated by the FAO/TSS-Mission. Regulation would involve reduction of fishing effort and closing the fishery during the breeding season. The World Bank (1991) projected that improved management could increase the harvest by 25 000 t per year. Important research studies that are needed are as follows:

- Identification of over-exploited species and their management for conservation, particularly *Hilsa* and shrimp.
- Development of different models of community-level participation in conservation and management.

Offshore and Deep Sea Demersal Resources and Their Proper Exploitation

The Bangladesh offshore fishing fleet presently operates in the zone bordered by the 40 m and 100 m isopleths. Artisanal fishing craft normally operate within 40 m. However, there is a strong and continuous competition between the demersal trawling and artisanal fishing operations within 100 m depth. The most valuable penaeid shrimp species, *Penaeus monodon*, is showing a gradual decline due to over-fishing and inadequate recruitment because of intensive wild shrimp seed collection in the nursery grounds in the estuarine shallows.

If rational management of the exploited resources is not undertaken urgently, there is little prospect of increasing the catch of demersal species. On the other hand, there is untapped potential consisting of valuable pelagic fish species in the offshore areas beyond 100 m, as well as the surface area beyond 40 m. Various exploratory surveys have reported the availability of tuna, skipjack, mackerels, anchovies, sardines, sharks and cephalopods. At present these resources are being caught as by-catch of different gear types. Unfortunately, no real pelagic resources surveys have been made. According to the World Bank projection (1991), if fishing technologies improve, research requirements for this sector are as follows:

- Evolving suitable models for multi-gear-multi-species fisheries in order to forecast fish resources in time and space.
- Diversification of fishing methods to tap under-utilized species, particularly pelagics.
- Developing gear on the basis of fish behavioral studies.

Sea Farming

The farming of selected species appears to be desirable in order to utilize hitherto unexploited technology, for example, the culture of *Bhetki* or seabass *(Lates calcarifer)* and the mixed culture of mullet with shrimp. *Bhetki* is a relatively high-priced species and therefore very attractive for commercial-scale culture.

Mollusc and seaweed culture rank among those with the greatest potential for contributing to income improvement among coastal communities, with the least disruption of their traditional lifestyle. Cockles, clams and seaweeds need to be investigated and culture technology developed. Urgent research areas include the following:

- Development of methods for controlled reproduction of mullet and mass rearing of their larvae.
- Development of methods of mullet fry collection, identification, sorting and transport, pending the development of controlled reproduction and hatchery production of seed.
- Methods of monitoring health and disease problems of seabass and mullets and disease control.
- Documentation and evaluation of genetic resources of commercially important mollusc and seaweeds and development of routines for their culture, including site selection, seed collection, disease control and depuration.
- Diversification of mollusc and seaweed utilization through food product development.

Product Development, Processing and Marketing

Research support for product development from conventional and non-conventional species will have an impact on nutrition and income generation. A significant proportion of trawl by-catch is discarded in the sea. Some estimates suggest that discarded by-catch amounts to about 30 000 t annually. Cost-effective technologies need to be developed to fully utilize the by-catch.

Currently improved methods of fish fermentation are needed, as are investigations of the possibility of using enzymatic or bacteriological methods in the development of new products. Research is also needed to improve handling and processing methods, packing, storage, transport and marketing to improve the economics of operation, to reduce wastage and to improve quality, including hygiene and sanitation to safeguard public health. The important research areas are as follows:

- Development of techniques for processing by-catch and small pelagic fish for the preparation of improved quality *surimi* and other value added products.
- Screening of improved products both qualitatively and quantitatively, from by-catch and small pelagic fish.
- Experiments on deterioration of organoleptic quality of *Hilsa*.
- Studies on all stages of handling, transportation processing and preservation that affect the quality of *Hilsa* and shrimp.
- Studies on the bacteriology of *Hilsa* and shrimp preservation.

While taking into account likely future developments with respect to resource potentials, economic trends and social development, a number of issues need in-depth studies. These include national policies in respect of food production, improvement of the nutritional status of people, generation of employment, rural development, uplifting of women, reducing and erasing foreign debt, sectoral priorities, financing and credit from national sources and technical assistance and financial support from external sources. Only then will Bangladesh be able to formulate plans, programs and projects for the sustainable development of its marine resources.

Marine Fisheries Along the Southwest Coast of India

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Abstract

Marine fisheries production in India has increased from 0.5 million t in 1950 to 2.47 million t in 1997. The gross value of fisheries landings in India was US$2.37 billion in 1997. The contribution of fisheries to the Gross Domestic Product (GDP) has risen from 0.7% in 1980 - 81 to 1.2% in 1994 - 95. The contribution to agricultural GDP has risen from 1.9% to 4%. Fisheries production also plays a critical role in food security and livelihood in rural areas.

The southwest (SW) coast, while only 16% of the Indian coastline, is an important area for marine fisheries production, contributing 31.7% (0.74 million t) in 1993 - 98. This production is dominated by pelagic (59% of landings) and demersal species (23%). However, the open access system has resulted in rapid increases in fishing effort, particularly in the coastal areas. The density of fishers inshore has increased from 3.6 to 8.5 fishers per km^2 in the past four decades. This excess effort has resulted in overfishing of the stocks and lower economic rent from the fishery.

The overall objective of coastal fisheries management along the southwest coast of India is sustainable coastal fisheries development. This requires key ecological, social, economic and administrative issues to be addressed. Ecological sustainability requires the reduction of the excess effort through limited entry and effort reduction schemes, appropriate exploitation patterns through improved gear selectivity and restoration of the degraded coastal environment through integrated coastal zone management initiatives. Key social interventions include: creation of alternative employment to reduce fisher numbers, prevention/management of increasing intra- and inter-sectoral conflicts and empowerment of artisanal fishers through co-management schemes, social legislation and improved support/welfare schemes. The key economic issues include declining earnings, particularly of artisanal fishers, which requires; optimizing fleet composition for economic returns, improvement of the marketing system and cold storage chains, improvement of post-harvest processes to increase product value. The key administrative needs are a strong fisheries policy that balances welfare concerns with sustainability, effective implementation of regulations, and increased government resources for fisheries management. Project briefs covering the key interventions are provided, however these require further review and improvement in collaboration with concerned stakeholders.

Introduction

Indian marine fisheries production was only 0.5 million t in 1950, and rose to a peak of 2.7 million t in 1998. In 1998, production from inshore waters (< 50 m depth) reached the estimated potential yield (2.2 million t), and scope for further increase is limited (Anon 1991). Monitoring in fish landing centers shows that catch rates are declining. Fishers and the number and efficiency of fishing vessels has substantially increased, leading to depletion of fish stocks and conflict among different stakeholders. Improvements in craft and gear technology to increase fish production are becoming counter-productive.

The major problem in Indian marine fisheries is inadequate fisheries management. Considering the country's diverse and vast coastline, efforts must be specific to the fisheries' situation in each coastal zone. With this in mind, this paper reviews the fisheries situation along the southwest (SW) coast of India. The paper focuses on identifying key issues and appropriate management directions for fisheries in the area.

Coastal Environment

The southwest coast region of India extends from about 8° N to 15° 30' N (Fig.1) with a coastline length of 994 km, adjoining three maritime states, Kerala, Karnataka and Goa. The continental shelf area off the southwest coast is 75 400 km^2 (Table 1) and 31% of the area is less than 50 m depth.

Wind patterns and water circulation in the Arabian Sea differ drastically from patterns in similar latitudes (Wyrtki 1973). There is a seasonal change in the winds north of the equator. Winds blow over the equatorial ocean between November and March causing the northeast monsoon. From May to September, the system reverses and the southeast trade winds extend across the equator and blow across the northern Indian Ocean as the southwest monsoon (Tomczak and Godfrey 1994). During the northeast monsoon, there is a north equatorial current, while during the southwest monsoon the circulation in the northern Indian Ocean largely reverses and the westward north equatorial current is replaced by an eastward southwest monsoon current, flowing with the equatorial countercurrent.

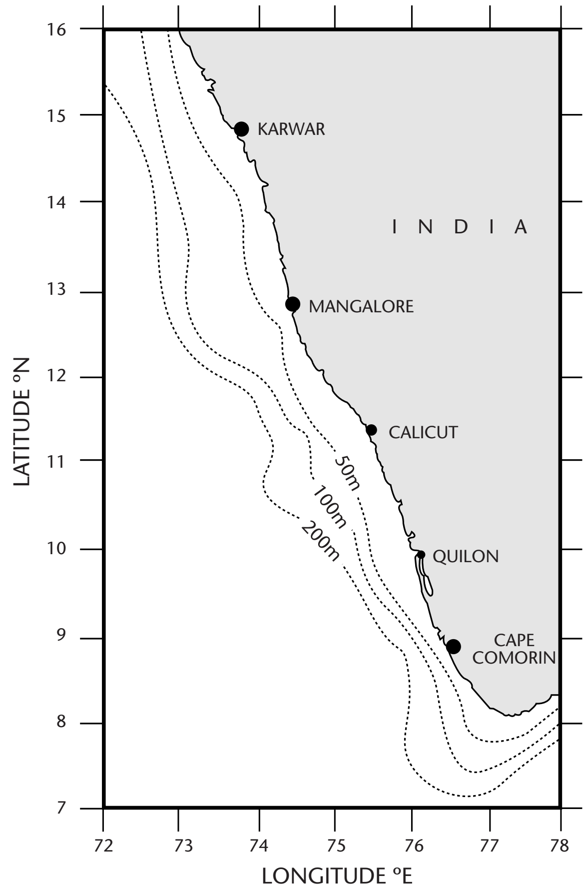

Fig. 1. Study area: the southwest coast of India.

Table 1. Coastline length and shelf area off the southwest coast of India.

State	Location	Length of coast (km)	Area (x10^3 km^2) < 50 m depth	Area (x10^3 km^2) < 200 m depth
Kerala	8° N to 12° N	590	12.6	39.9
Karnataka	12° N to 15° N	300	7.9	25.5
Goa	15° N to 15° 30' N	104	2.9	10.0
TOTAL	8° N to 15° 30' N	994	23.4	75.4

Seasonal changes in winds and currents induce an annual cycle of hydrographic events along the southwest coast (Table 2). During the monsoon, the southerly current spreads over the entire continental shelf. Isolines of water temperature, salinity, dissolved oxygen (DO) and density lift to the surface (upwelling) and occupy the area between the southerly current and the coast. Consequently, dense and cool water with low DO occupies the surface near the coast. During the post-monsoon period (October - January), there is a strong current with northerly flow. On the seaward side of the flow, there exists a southerly flow only in the southern region of the southwest coast. During this period, low saline equatorial waters are advected northwards causing sinking of high saline Arabian Sea water between 10º N and 12º N (Devaraj et al. 1997). During the pre-monsoon period (February - May), the northerly current disappears and the southerly flow constricts to a narrow belt.

The southwest coast, particularly the southern part from 9º N to 13º N, is characterized by mudbanks. The mudbanks are 1 to 3 m thick in calm, turbid waters with a high load of suspended sediment. They appear close to shore in a stretch of 2 to 5 km parallel to the coast, and with a width of 1.5 to 4 km. The mudbanks appear with the onset of the southwest monsoon (May/June) and disappear with its withdrawal (September/October). The mudbanks are formed due to periodic stress from the waves over a muddy bottom, resulting in bed erosion, generation of fluid mud and wave attenuation (Anon. 1984). The combined action of waves and currents transport the fluid mud nearshore. After about 2 months, the fluid mud exhibits downslide movement, dissipating the mudbank. The mudbanks usually form in the same place every year. Year to year shifting of the mudbanks, if any, is due to variations in bathymetric conditions, which determine the magnitude of energy convergence.

The mudbank sediment consists of highly cohesive and flocculated clay. The most dominant texture is silt or clay with sand. Mud density ranges from 1 080 to 1 300 kg•m^{-3} and dispersed particle size ranges between 0.5 and 3 µm (Devaraj et al. 1999). The mudbank area is rich in phytoplankton (70 to

Table 2. Hydrographic conditions during pre-monsoon, monsoon and post-monsoon seasons along the southwest coast of India.

Parameter	Pre-monsoon	Monsoon	Post-monsoon
Current	Northerly current disappears; southerly flow restricted to a narrow belt	Southerly current spreads in the entire shelf. Isolines of water temperature, salinity, DO & density lift to the surface (upwelling) and occupy the area between the southerly current and the coast	Strong northerly flow; on the seaward side of flow, southerly flow only in the southern region; Low saline equatorial waters advected northwards, causing sinking of high saline Arabian Sea water below the high saline equatorial waters between 10º N and 12º N
Temperature	Mean Sea Surface Temperature (SST): 30º C	Mean SST: 24º C; Thermocline on the surface	Mean SST: 23ºC; Thermocline moves from surface (Oct - Nov) and reaches deep water (Dec - Feb)
Salinity	Mean Sea Surface Salinity (SSS): 36 ppt	Mean SSS: 32.5 ppt; Maximum salinity at 30 to 50 m depth	SSS (33 ppt) off Cape Comorin, increases towards north and 35 ppt off Karwar; SSS maximum at 100 - 150 m depth
Dissolved Oxygen (DO)	Shelf waters well-aerated (mean DO: 5 ml•l^{-1})	Oxygen deficient waters start penetrating the shelf by May; completely cover the bottom of the shelf by June - July; by August, oxycline becomes shallow and reaches the surface; remains till Sep - Oct; oxycline remains for 6 months in northern sector and only for 2 months in southern sector. However, DO is higher in the north as the intensity of upwelling is low.	Shelf waters well-aerated (mean DO: 4.5 ml•l^{-1})

130 ml•l^{-1}) and chlorophyll a (11 to 33 mg•m^{-3}). Blooms of phytoplankton (> 10 000 cells•ml^{-1}), mainly *Noctiluca* spp., *Skeletonema* spp. and *Fragilaria* spp. occur in the mudbanks, which are inhabited by 58 species of planktonic algae (Anon. 1984). Zooplankton biomass is high (up to 4.1 ml/per 10 minute haul) in the mudbanks compared to that (1 ml/per 10 minute haul) of pre- or post-mudbank seasons. There are 19 groups of zooplankton dominated by copepods (80%).

The sediments of mudbanks carry rich loads of organic matter (5%). About 90 to 95% of benthic fauna in the mudbank consist of polychaetes and molluscs. The calm sea together with high productivity favors fish and shellfish migration to the mudbanks and yields high catches. Fish production in mudbank areas was estimated to be 56% higher than in non-mudbank areas during 1966 - 75 (Anon. 1984). Furthermore, waves as high as 2 to 3 m outside the mudbank get reduced to 0.5 m on the mudbank. This wave dampening facilitates safe anchorage and smooth fishing for traditional fishers during the monsoon season, which is generally unsafe outside the mudbank area.

The monthly mean seawater temperature varies in space and time along the southwest coast. Off Quilon (9º N, 76º 30' E), for instance, the sea surface temperature (SST) is low (27º C) during January - February and June - August, and high (29 to 31ºC) during May (Devaraj et al. 1997). High values are associated with the summer season, prior to onset of the southwest monsoon. Mean water temperature is higher in the northern part of the coast compared to the southern part. For instance, water temperature is 25º C and 17 to 21º C during January - February and June - August, respectively, at 100 m depth off Quilon, while during the same periods it is 29º C and 30º C off Karwar (15º N, 74º E) (Devaraj et al. 1997). The lower temperature is recorded in areas where the intensity of upwelling is comparatively higher. Mean depth of the top of the thermocline also varies from season to season. The top of the thermocline is deepest during the winter months of December to February off Quilon (120 m) and during January - February off Karwar (70 to 80 m). The thermocline reaches near the surface in April and October, i.e. prior to and after the southwest monsoon.

Mean sea surface salinity has two peaks, one during May - June prior to onset of the southwest monsoon and another during September - October immediately after the southwest monsoon. Monthly mean surface salinity varies between 32.5 and 36.1 ppt. The maxima occur comparatively late in the southern areas and are associated with advection of highly saline Arabian Sea water and the presence of highly saline bottom water brought upward to surface levels in areas of upwelling. The minima are associated with monsoon rains and river runoff, and also the incursion of low salinity equatorial surface waters. The minima occur first in the southern region and progressively move northward following the trend in monsoon rainfall (Devaraj et al. 1997). The salinity maximum occurs at depths of 100 to 150 m during the northeast monsoon and between 30 and 50 m during the southwest monsoon. The salinity maximum associated with the main thermocline probably represents an intrusion of high saline waters below the less saline surface layers (Pillai 1983).

In general, the shelf waters are well-aerated during most of the year except during the southwest monsoon and the associated upwelling season. A good correlation between the depth of the top of the thermocline and oxycline has been observed. By May, oxygen deficient waters start penetrating the shelf. By June/July the oxygen deficient waters penetrate below the thermocline and cover the entire bottom of the shelf. In August, the oxycline becomes very shallow and in the areas of upwelling, the low oxygen intermediate water reaches near the surface. Oxygen deficient water remains on the shelf until October, especially in areas where upwelling is intense. By December, the shelf waters are well-aerated again. Mean monthly sea surface DO values range between 5.35 ml•l^{-1} O_2•l^{-1} and 1.10 ml•l^{-1} O_2•l^{-1}. Oxygen deficient waters remain in the continental shelf of the northern region (off Karwar: 6 months) for a longer duration than in the southern region (off Quilon: 2 months) (Pillai 1983).

From the coastal fisheries point of view, upwelling in the southwest monsoon gyre along the southern part of the southwest coast assumes great importance. Upwelling starts by August, intensifies by September and ends by mid-October (Ramamirtham and Jayaraman 1960). However, depending on the intensity of various factors that promote upwelling, the onset, intensity, duration and area of upwelling vary every year (Pillai 1983). During upwelling, coastal waters exhibit a fall in temperature and DO and an increase in nutrient contents resulting in higher productivity (Table 3). The 23º C isotherm and the 1 ml•l^{-1} DO isoline rise to a

Table 3. Comparison of hydrographic, nutrient and productivity values during upwelling (July to September) and non-upwelling (October to June) season along the southwest coast of India.

Parameter	July-Sep	Oct-June	Source
Sea Surface Temperature (ºC)	27	27 - 31	Devaraj et al. (1997)
Dissolved Oxygen, DO ($ml{\bullet}l^{-1}$)	1.1 to 2.5	2.0 - 5.4	Devaraj et al. (1997)
Nitrate (μM)	3 to 4	< 1	de Sousa et al. (1996)
Chlorophyll a ($mg{\bullet}m^{-3}$)	1.34	0.03 - 0.05	Bhattathiri et al. (1996)
Phytoplankton production ($mg\ C{\bullet}m^{-2}{\bullet}day^{-1}$)	49.9	1.1 - 3.3	Devaraj et al. (1997)
Zooplankton production ($mg\ C{\bullet}m^{-2}{\bullet}day^{-1}$)	27.5	6.4	Goswami et al. (1992)

depth of 10 to 20 m during August - September every year. The nitrate content in the surface waters is high (3 to 4μM) compared to < 1μM during the other months, which results in higher productivity (de Sousa et al. 1996). The density of chlorophyll a is substantially higher (1.34 $mg{\bullet}m^{-3}$) during July - August than that during February - May (0.03 to 0.05 $mg{\bullet}m^{-3}$), resulting in very high primary production of 49.9 $mg\ C{\bullet}m^{-2}{\bullet}day^{-1}$ compared to 1.1 to 3.3 $mg\ C{\bullet}m^{-2}{\bullet}day^{-1}$ (Bhattathiri et al. 1996). In general, the southwest coast is richer in phytoplankton and zoo-plankton biomass than other coastal areas of India. Secondary production along the southwest coast ranges from 6 to 57 $mg\ C{\bullet}m^{-2}{\bullet}day^{-1}$ depending upon the season (Mathew et al. 1990). During upwelling, minimum zooplankton biomass is over 1 $ml{\bullet}m^{-3}$ and at times attains up to 12 $ml{\bullet}m^{-3}$ (Madhupratap et al. 1994).

Coral patches abound off the southern part of the southwest coast of India. These coral reefs exhibit rich biodiversity and provide nursery grounds for commercially important fishes. Mangroves, either discontinuous or patchy, abound in the lower reaches of the estuaries in Cochin (9º 50' N, 76º 15' E), Calicut (11º 20' N, 75º 50' E) and Cannanore (12º 00' N, 75º 10' E). Mangroves serve as nursery for many species of finfish and shrimp.

Numerous estuaries dot the southwest coast. In Kerala State alone, 30 estuaries or backwaters with a total area of 500 km^2 forms about 20% of the total backwater area in India. Reclamation for various purposes has substantially reduced the area (Devaraj et al. 1999). Fishing activities in the backwaters support about 0.2 million fishers. The estuaries maintain high levels of biological productivity and play important roles in: (i) nutrient and organic material transport through tidal circulation, (ii) nursery grounds for many species of shrimp and fish, and (iii) breeding grounds for caridian prawns.

The total length of rivers and canals in the maritime states of Kerala (3 092 km), Karnataka (9 000 km) and Goa (250 km) is 12 342 km. There are 4 672 small (< 1 km^2) reservoirs in these 3 states (Sugunan, 1997). The surface area of all these reservoirs is 236 km^2. There are also 24 medium (1 to 5 km^2) and 13 large (> 5 km^2) reservoirs with total surface areas of 44.6 km^2 and 185.7 km^2, respectively. In addition to the reservoirs, tanks and ponds cover 447 km^2.

Fishery Resources and Potentials

Due to high productivity, the southwest coast is one of the most important areas in terms of marine fish production in India. While the length of the southwest coast is only about 16% of the Indian coastline, it contributed 31.7% (0.74 million t) annually to national marine fish production during 1993 - 98. Landings are higher around the southwest monsoon (July to September: 28.6%) and post-monsoon (October to December: 34.6%) seasons (Table 4). Using stratified multistage random sampling, the Central Marine Fisheries Research Institute (CMFRI) has collected data on marine fish landings along the southwest coast. Information on the fishery resources provided here is based on statistical and periodic publications of CMFRI.

Table 4. Distribution of marine fish landings (%) along the southwest coast of India during 1993 - 98.

State	Jan. - Mar.	Apr. - June.	July - Sept.	Oct. - Dec.
Kerala	18.6	18.1	33.7	29.6
Karnataka	26.9	11.9	19.2	42.0
Goa	23.6	9.5	18.7	48.2
SW coast	21.1	15.7	28.6	34.6

Table 5. Mean annual landings (t) and potential yield (t) of demersal fishes in 0 - 50 m depth zone along the southwest coast of India 1970 - 98.

Taxa	1970 - 74	1975 - 79	1980 - 84	1985 - 89	1990- 94	1995 - 98	1970- 98	Potential yield
Rays (Dasyatidae)	3 781	3 855	3 904	2 100	2 493	2 339	3 079	3 800
Catfish (Ariidae)	22 158	20 896	20 429	13 899	2 951	1 219	14 476	18 900
Lizardfishes (Synodontidae)	3 292	5 945	7 123	10 228	14 163	13 329	8 705	16 800
Threadfin breams (Nemipteridae)	N/A	N/A	5 922	35 177	46 924	44 482	31 865	N/A
Other perch	9 478	16 410	11 823	8 643	16 349	20 164	13 357	N/A
Goatfishes (Mullidae)	24 910	689	127	3 740	9 073	133	6 896	N/A
Threadfins (Polynemidae)	337	87	171	166	204	9	173	N/A
Croakers (Sciaenidae)	10 078	15 827	10 529	15 328	17 637	17 293	14 246	20 800
Ribbonfishes (Trichiuridae)	20 911	17 163	9 740	20 326	11 316	21 049	16 444	27 600
Silverbellies (Gerridae)	14 613	7 739	12 152	10 801	8 094	6 444	10 226	14 700
Whitefish (*Lactarius lactarius*)	5 236	1 428	3 040	4 012	2 448	2 658	3 171	N/A
Pomfrets (Barmidae)	2 693	2 631	3 868	4 672	5 093	5 109	3 933	5 800
Mullet (Sillaginidae)	442	81	196	425	137	428	275	N/A
Flatfishes (Platycephalidae)	10 519	6 906	19 181	19 085	29 445	24 446	17 822	25 900
TOTAL	128 448	99 657	108 205	148 602	166 327	159 102	144 668	

Note: N/A = not available

The demersal fishes are exploited primarily by mechanized trawlers (overall length of 12 to 16 m), bottom-set gillnets, seine-netters (using boats) and mini-trawls. In addition, the demersals are landed by stake nets and shore seines. The average annual demersal fish landings along the southwest coast increased from 128 448 t during 1970 - 74 to 159 102 t during 1995 - 98 (Table 5). Average annual landings of demersals during 1970 - 98 (144 668 t) contributed 23.1% to total landings on the southwest coast. The dominant groups (and species) in demersal landings are threadfin breams *(Nemipterus japonicus, N. mesoprion)*, flatfishes *(Cynoglossus macrostomus)*, ribbonfishes (*Trichiurus lepturus, Lepturacanthus savala)*, catfishes (*Tachysurus thalassinus, T. tenuispinis)*, croakers (*Johnieops sina)*, major perches (*Epinephelus* spp., *Lethrinus* spp. *and Lutjanus* spp), lizardfishes (*Saurida tumbil)* and rays (*Himantura bleekeri, Dasyatis* spp.).

During the 1970 - 98 period, the landings of lizardfishes, threadfin breams, other perches, flatfishes and pomfrets increased. The landings of ribbonfishes, croakers and mullets were almost unchanged during the period. The annual landings of catfishes drastically decreased from 22 158 t (1970 - 74) to a mere 1 219 t (1995 - 98) and those of goatfishes from 24 910 t to 133 t. Landings of rays, threadfins, silverbellies and whitefish also consistently decreased during the period.

Utilizing data on primary and secondary production, exploratory surveys and fish landings, the Ministry of Agriculture, Government of India provided estimates of potential yield of fishery in resources India (Anon. 1991). The estimated potential yield of demersal finfishes for the 0 - 50 m depth zone is provided in Table 5. For most of the groups, landings have come close to or have exceeded the estimated potential at some time during 1970 - 98.

The pelagic resources are exploited by purse seines operated from mechanized craft (11 to 14 m length), drift gillnets, ring-seines, and hooks and lines. The mean annual pelagic fish landings increased from

317 667 t during 1970 - 74 to 425 438 t during 1995 - 98 (Table 6). During 1970 - 98, the average annual landings of pelagics (369 453 t) contributed 59.0% to the total landings on the southwest coast. The dominant groups (and species) in the pelagic landings are oil sardine *(Sardinella longiceps)*, Indian mackerel *(Rastrelliger kanagurta)*, carangids (*Caranx* spp. and *Decapterus russelli)*, whitebaits (*Stolephorus* spp.), lesser sardines (*Sardinella* spp), seerfishes *(Scomberomorus commerson* and *S. guttatus)* sharks *(Scoliodon laticaudus* and *Carcharhinus* spp.*)*, barracudas *(Sphyraena* spp.*)* and tunas *(Euthynnus affinis* and *Auxis thazard)*.

During 1970 - 98, landings of white-baits, *Thryssa* spp., carangids, Indian mackerel, seerfishes, tunas and barracudas increased. Landings of sharks and oil sardine decreased over this period. The catches of pelagic fishes have either been very close to or have exceeded the potential yield at some time during 1970 - 98.

Shrimps are the major target group of bottom trawlers that also take demersal fish resources. Average annual shrimp landings during 1970 - 98 was 54 893 t (Table 7), contributing 8.8% to the mean annual total landings in the southwest coast. Annual shrimp landings decreased from 62 056 t during 1970 - 74 to 37 081 t during 1980 - 84 but subsequently increased to 59 278 t during 1995 - 98. Shrimp landings are dominated by *Penaeus indicus, Parapenaeopsis stylifera* and *Metapenaeus dobsoni*. An important feature of the shrimp fishery is fishing peak for a single species (*P. stylifera*) during the southwest monsoon off Quilon. About 75% of the shrimp landings during the monsoon is contributed by *P. stylifera* along the southern part of the southwest coast (George 1988). The catches of shrimps are below the estimated potential yield (80 300 t) (Table 7).

The non-penaeid prawns *(Acetes* spp.*)*, spiny lobsters *(Panulirus homarus, P. polyphagus)*, crabs *(Charybdis* spp.*)* and stomatopods *(Squilla* spp.*)* are the other crustacean resources along the southwest coast. Cephalopod landings substantially increased from 856 t during 1970 - 74 to 48 586 t during 1995 - 98. The contribution of cephalopods, which was only 0.2% of the annual total landings during 1970 - 74, increased to 7.8% during 1995 - 98. However, catches during 1990 - 94 and 1995 - 98 have exceeded the estimated potential (22 300 t)

Table 6. Mean annual average landings (t) and potential yield (t) of pelagic fishes in 0 - 50 m depth zone along the southwest coast of India 1970 - 98.

Group	1970 - 74	1975 - 79	1980 - 84	1985 - 89	1990- 94	1995 - 98	1970 - 98	Potential yield
Sharks	702	716	725	581	349	335	568	700
Oil sardine (Sardinella longiceps)	1 498	15 890	18 176	12 800	12 114	5 792	13 828	17 400
Lesser sardine (Clupeidae)	3 002	3 039	1 431	1 695	3 263	3 258	2 569	2 300
Hilsa spp.	368	135	203	573	599	91	345	N/A
White baits (Galaxiidae)	1 268	1 235	3 389	4 529	5 124	3 797	3 183	3 340
Thryssa spp.	238	321	289	875	1 165	1 672	695	5 850[1]
Carangids (Carangidae)	1 150	1 204	1 638	6 835	11 302	9 529	4 972	9 280
Mackerel (Scombridae)	9 301	6 350	2 713	9 272	11 772	15 037	8 648	12 580
Seerfishes (Scombridae)	479	653	985	1 222	1 039	917	880	1 490
Tunas (Scombridae)	414	1 046	891	1 857	2 315	1 662	1 343	2 520
Barracudas (Sphyrnaenidae)	193	156	961	178	418	537	225	N/A
Total	31 767	30 521	30 353	399 006	48 919	42 544	369 45	

Note: N/A = not available

[1] includes all clupeids except oil sardine, lesser sardines and whitebaits.

Table 7. Mean annual landings (t) and potential yield (t) of crustaceans and cephalopods in 0 - 50 m depth zone along the southwest coast of India 1970 - 98.

Group	1970 - 74	1975 - 79	1980 - 84	1985 - 89	1990 - 94	1995 - 98	1970 - 98	Potential yield
Penaeid prawns	62 056	51 910	37 081	59 191	61 595	59 278	54 893	80 300
Non-penaeid prawns	1 061	306	450	282	212	390	454	383
Lobster	NA[1]	61	100	128	149	174	118	N/A
Crabs	2 564	5 537	2 220	4 826	6 774	7 205	4 686	N/A
Stomatopods	N/A	N/A	12 924	45 684	47 312	39 108	35 940	N/A
Cephalopods	856	5 006	4 091	16 436	32 069	48 586	15 645	22 300
TOTAL	66 537	62 820	56 866	126 547	148 111	154 741	111 736	

Note: N/A = not available

along the southwest coast (Table 7). The cephalopods consist of squids (*Loligo duvaucelli*), cuttlefishes (*Sepia pharaonis, Sepiella inermis*) and octopi.

The potential yield of fish stocks along the southwest coast has been investigated by different studies (Table 8). The most recent study (Anon. 1991) gives a total potential yield estimate (0 - 500 m depth zone) of 1.31 million t. The mean total annual catch was 0.74 million t during 1995 - 98. While fishing pressure is already heavy in shallow, coastal waters (0 - 50 m depth), there appears scope for expansion of clupeid and tuna catches in deeper areas. The commercial fisheries at present are restricted to the 0 - 70 m depth zone and there is virtually no deep-sea fishing. Viable policies have to be formulated to encourage fishing further offshore.

Table 8. Estimates of potential yield of fish resources along the southwest coast of India.

Depth zone	Potential yield ($x10^3$ t)	Source
0 - 200 m (oceanic)	1 422	George et al. (1977)
0 to 200 m (only demersals)	438	Joseph (1980)
0 to 500 m (oceanic)	853	Joseph et al. (1976)
0 to 200 m	900	Alagaraja (1989)
0 to 200 m (only demersals)	332	Sudarsan et al. (1989)
0 to 50 m (only demersals)	361	Anon. (1991)
0 to 50 m (only pelagics)	589	Anon. (1991)
51 to 100 m	63	Anon. (1991)
101 to 200 m	29	Anon. (1991)
201 to 500 m (only oceanic tunas)	265	Anon. (1991)
0 to 500 m	1 307	Anon. (1991)

Socioeconomic Background

The total marine, freshwater and land area of India is 5.30 million km^2. The marine jurisdictional area (EEZ) is extensive, spanning 2.02 million km^2, which is 38% of the total area of the country. The gross value of marine fish production at landing center prices was about US$2.37 billion in 1997 (Table 9), and the value at consumers level was about US$4.73 billion of which US$1.1 billion is realized from export.

The total population in India is about 1 billion. In the 3 651 fishing villages situated along the 8 129 km coastline, about 1 million are employed full-time in marine capture fisheries (Table 9). Marine fisheries provide employment in the production and post-harvest sectors. Manpower employed in active fishing in the mechanized (large scale) sector is estimated at 0.2 million, of which 0.15 million fishers are engaged in trawl fisheries and the remaining in gillnetters, dolnetters (a specialized type of fixed bag net which targets bombay duck (*Har-*

podon nehereus) and grenadier *(Coilia dussu mieri))*, purse seiners, and sona boats. The motorized (small scale) sector employs 0.17 million in active fishing, 66% of which are engaged in the operation of ring-seines, mini-trawls and gillnets. Motorized dugout canoes, catamarans and plywood boats provide employment to 58 000 persons. The non-mechanised (small scale) sector provides employment to 0.65 million, of which 0.27 million are engaged in catamarans, 0.2 million in plank-built boats and the rest in dugout canoes and masula boats. On average, every 5 kg of marine fish produced provides employment to 2 people, one in the harvesting and the other in the post-harvest sector. While total marine fish landings have significantly increased, catch rate and production per fisher has steadily declined over the years. Operations continue, however, due to appreciation in prices of all varieties of marine fish.

Subsidiary activities provide employment to about 1.2 million people in India. Activities such as boat building and repair, net mending, repair of engines, and sale of diesel, kerosene and other essential items at landing centers provide active employment for 0.1 million. About 25% of those employed in post-harvest operations are women, mostly engaged in marketing. Marketing including transportation, processing, packing and selling provide employment for 1.1 million, 0.2 million in export marketing and 0.9 million in domestic marketing.

The country has 2 271 marine fish landing centers in addition to major and minor fishing harbors (Table 9). There are 47 000 mechanized vessels, 36 500 motorized vessels and 50 000 artisanal craft. There are 372 freezing plants with a freezing capacity of 6 600 $t \cdot day^{-1}$. There are also 450 cold storage plants with a capacity of 80 000 $t \cdot day^{-1}$, 15 fish meal plants with a capacity of 330 $t \cdot day^{-1}$ and 900 peeling sheds with a capacity of 2 700 $t \cdot day^{-1}$. Capacity utilization of processing plants is hardly 25% mainly due to shortage of raw materials. Idle capacity in the processing plants leads to underemployment of about 0.2 million people.

For India, the largest fish production comes from coastal capture fisheries (on average about 62% of total fish production). Gross investment in the marine fishing sector is estimated as US$1 billion in 1996 (Table 9). Of the marine products export of 385 818 t valued at US$1.1 billion during 1997 - 98 (Tharakan 1998), about 310 000 t (80%) was from capture fisheries. This represents only 11.5%

Table 9. Profile of Indian marine fisheries (modified from Devaraj and Vivekanandan 1999).

Characteristic		Estimated Value
Physical		
Length of coastline		8 129 km
Exclusive economic zone		2.02 $x10^6$ km^2
Continental shelf		0.50 $x10^6$ km^2
Inshore area (< 50 m depth)		0.18 $x10^6$ km^2
Biological		
Potential yield in EEZ		3.9 $x10^6$ t
Potential yield in inshore area		2.2 $x10^6$ t
Marine fish production (1997)		2.7 $x10^6$ t
Production from inshore area		2.2 $x10^6$ t
Production from coastal aquaculture (1996)		70 400 t
Human resource		
Fishing villages		3 651
Marine fisher population		5 $x10^6$
Active fisher population		1 $x10^6$
Infrastructure		
Landing centres		2 271
Major fishing harbours		6
Minor fishing harbours		27
Mechanized vessels		47 000
Motorized vessels		36 500
Artisanal vessels		50 000
Processing/Support Facilities	**No.**	**Capacity ($t \cdot day^{-1}$)**
Freezing plants	372	6 600
Canning plants	14	52
Ice plants	148	1 800
Fishmeal plants	15	330
Cold storages	450	80 000
Peeling sheds	900	2 700
Economic		
Gross investment on fishing (1996)		US$1.0 billion
Value of annual production (1997)		US$2.37 billion
Marine products export (1997 - 98)		385 818 t
Value of export		US$1.1 billion

of marine capture fisheries production. Thus, capture fisheries contribute primarily to domestic consumption needs (Devaraj and Vivekanandan 1999).

The increase in marine fish production during the past 5 decades was largely due to efforts of the Government of India and the maritime state governments through successive development plans (Table 10). The major causes for significant increases in marine fish production are:

- Introduction of mechanized fishing vessels and

Table 10. Development thrusts in Indian marine fisheries during various plan periods from 1951 to 1996 (modified from Devaraj et al. 1997).

Plan period	Duration	Major developments	Average annual catch (t)
I	1951 - 55	1. Mechanization of indigenous artisanal fishing craft	565 412
II	1956 - 60	1. Introduction of mechanized fishing vessels	
		2. Introduction of modern gear materials	730 699
		3. Infrastructure for preservation, processing, storage and transportation	
III	1961 - 65	1. Substantial increase in use of synthetic gear materials	730 061
Annual plans	1966 - 68	2. Export trade	904 355
IV	1969 - 73	1. Import of trawlers for deep sea fishing	1 070 264
		2. Indigenous construction of deep sea trawlers	
		3. Fishing harbours construction	
		4. Intensification of exploratory fishery surveys	
		5. Expansion of export trade	
V	1974 - 78	1. Diversification of fishing, introduction of purse seining	1 326 408
Annual plan	1979	1. Diversification of products	1 365 739
		2. Motorization of artisanal craft	
VI	1980 - 84	1. Exploratory surveys in offshore grounds	1 434 914
		2. Declaration of EEZ in 1977	
		3. 1981 Act for regulation of foreign fishing vessels	
		4. Deep sea fishing through licensing, chartering and joint venture vessels	
VII	1985 - 89	1. New chartering policy of 1989	1 724 757
Annual plans	1990	2. Development of deep sea fishing	
	1991	3. Substantial growth in motorized artisanal fleet of ring-seiners	2 182 412
VIII	1992 - 96	1. Deep sea fishing by joint venture	2 295 889
		2. Development of coastal aquaculture	
		3. Substantial growth in motorized artisanal fleet of ring-seiners	
		4. Export trade changes from a resource-based to food engineering-based industry	

modern gear materials during the 1951 - 55 and 1956 - 60 plans.
- Increased use of synthetic gear materials during the 1961 - 65 plan.
- Construction of fisheries harbours during the 1969 - 73 plan.
- Introduction of purse seining during the 1974 - 78 plan.
- Motorization of artisanal craft in 1979.
- Substantial growth in the motorized artisanal fleet operating ring-seines during the 1985 - 96 plans.

The contribution of fisheries (including the marine and inland sub-sectors) to India's Gross Domestic Product (GDP) gradually increased from 0.7% (1980 - 81) to 1.2% (1994 - 95) (Table 11). The share of fisheries in agriculture GDP has increased more conspicuously, from 1.9% to 4.0%. At current prices, the fisheries GDP has increased from US$0.2 billion (1980 - 81) to US$2.5 billion (1994 - 95). Contribution to GDP may not be a true reflection of the actual importance and role of the sector. GDP measures only the value of the produce and employment/services generated by the sector. In the case of fisheries, its significance to food security and livelihood in rural areas of India cannot be over-emphasized.

The total fisher population in India was about 5.4 million in 1980 and 5.8 million in 1990. Of this, the marine fisher population was 2.14 million in 1980 and 3.76 million in 1990. The average size of a marine fisher family varied from 4.7 to 8.6 in the different states during 1980. The active fisher folk population increased from 234 478 in 1961 - 62 to 650 887 in 1990, and at this rate of increase it is estimated that the number of active fishers would have been 1 million in 1998.

While the total and active marine fisher population has increased over the years, the proportion of active fishers to total marine fisher population declined from 23.9% in 1961 to 22.5% during 1973 - 77, and to 19.3% in 1980. At the average rate of decrease of 0.23% per year from 1960 to 1980, the percentage of active fishers to total fisher population in 1998 has been estimated to be only 16.5%. The low percentage of active fishers is due to the following:

i. Fishing is not regarded as a profession of high status in the society.
ii. Most fishers are still illiterate, but literate ones prefer employment in government and private agencies.
iii. Industrialization in coastal areas has lured fishers to land-based industries.
iv. Per capita income from fishing is diminishing and unattractive.

The nutritional contribution of fish can be maximized by increasing its availability to low-income groups and improved marketing and distribution.

Table 11. Contribution of the fisheries sector to GDP of India (Anon. 1996).

Year	Fisheries GDP (US$ x10^9)	Agriculture GDP (US$ x10^9)	National GDP (US$ x10^9)	Contribution of Fisheries to Agriculture GDP (%)	Contribution of Fisheries to National GDP (%)
1980 - 81	0.2	10.8	28.5	1.9	0.7
1986 - 87	0.5	19.2	60.5	2.6	0.8
1987 - 88	0.6	21.5	68.8	2.8	0.9
1988 - 89	0.7	26.5	82.0	2.6	0.8
1989 - 90	0.9	29.5	95.0	3.1	0.9
1990 - 91	1.1	34.4	111.1	3.2	1.0
1991 - 92	1.2	40.2	128.6	3.0	0.9
1992 - 93	1.5	44.9	146.6	3.3	1.0
1993 - 94	1.8	51.6	168.2	3.5	1.1
1994 - 95	2.5	61.8	198.6	4.0	1.2

Very meager information is available on the health and nutritional status of fisher folk involved in small-scale fisheries. A few micro level studies are available from the east coast of India and fishers in the maritime states of Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. These studies indicate:

- High levels of malnutrition among children of fishers, increasing their susceptibility to major diseases;
- High levels of child mortality in fishers' families compared to non-fisher families;
- Fish is the major source of protein for fisher families, with meat and milk consumed only occasionally;
- Substantial numbers of fisher families go without meat on some days due to poor or no catch, especially during the peak of the monsoons.

These conditions are also likely to pertain to families of small scale fishers on the southwest coast.

Capture Fisheries in Focus

This section gives an overview of the capture fisheries sector in India, with relevant institutional and legal aspects given in Annex 1.

Fisheries Sub-sectors

Artisanal

The artisanal sub-sector employs 3 major types of wooden craft-dugout canoes, catamarans and plank-built (with or without outrigger) boats. In 1998, the total number of artisanal crafts was estimated at 127 518 (Table 12). About 46% of the crafts are catamarans. The catamaran, designed to efficiently withstand rough sea conditions, is prevalent along the southeast coast, where wave action is normally high. It is estimated that 54% and 27% of the artisanal crafts are along the southeast and southwest coasts, respectively.

Table 12. Number of artisanal fishing crafts along the Indian coast 1998.

Fishing craft	NW	SW	SE	NE	Total
Motorized	5 096	17 702	23 972	4 152	50 922
Dugout canoes	1 000	5 258	297	0	6 555
Catamarans	0	34	15 822	1 328	17 184
Plank-built	3 894	5 697	5 003	2 509	17 103
Others	202	6 713	2 850	315	10 080
Non-motorized	7 558	17 098	44 382	7 558	76 596
Dugout canoes	2 218	8 414	110	0	10 742
Catamarans	0	6 638	31 650	3 449	41 737
Plank-built					
- with outrigger	3 737	1 209	3 030	3 698	11 674
- without outrigger	775	581	9 440	378	11 174
Others	828	256	152	33	1 269
TOTAL	12 654	34 800	68 354	11 710	127 518

Note: NW - Northwest; SW - Southwest; SE - Southeast; NE -Northeast.

After introduction of motorization in the mid-1980s, the number of artisanal crafts fitted with outboard motors increased. In 1998, about 40% of artisanal crafts were fitted with 7 to 9 HP engines. Motorization was rapid especially along the southwest coast where the number of motorized crafts in 1998 (17 702) exceeded the non-motorized crafts (17 098). With increasing popularity of out-board motors, it is expected that the number of motorized crafts would further increase in the coming years, gradually replacing the non-motorized crafts.

Industrial

Mechanization of fishing crafts commenced in the late 1950s and has accelerated since the mid-1960s. It is estimated that the industrial fishing fleet numbered 49 070 in 1998 (Table 13). Nearly 50% of the mechanized vessels operate along the northwest coast. The fleet consists of 5 major types of craft - trawler, gillnetter, dolnetter, liner and purse seiner. Trawlers, which operate bottom trawls, are the most common; 63.1% of the number of mechanized craft, 42% of which are based on the northwest coast. Small trawlers (LOA < 9 m), which were common in the 1960s and 1970s, are being replaced by larger trawlers. In 1998, about 97% of the trawlers were of 9 to 18 m LOA.

Table 13. Number of mechanized (industrial) fishing crafts along the Indian coast 1998.

Fishing craft	NW	SW	SE	NE	Total
Trawler	13 055	7 342	8 789	1 793	30 979
< 9 m	0	444	506	0	950
9 - 12 m	4 531	4 924	6 077	1 382	16 914
13 - 18 m	8 524	1 974	2 206	411	13 115
Gillnetter	3 981	1 132	867	3 988	9 968
< 9 m	2 266	835	542	965	4 608
9 - 12 m	1 715	297	325	3 023	5 360
Dolnetter	5 423	0	109	6	5 538
< 9 m	3 322	0	5	6	3 333
9 - 12 m	2 101	0	104	0	2 205
Liner	59	32	189	123	403
< 9 m	0	8	111	16	135
9 - 12 m	59	24	78	107	268
Purse seiner	207	799	0	0	
Others	893	3	1	279	1 176
TOTAL	23 618	9 308	9 955	6 189	49 070

Note: NW - Northwest; SW - Southwest; SE - Southeast; NE -Northeast.

Mechanized gillnetters (7 to 12 m LOA) constituted 20.3% of mechanized craft and were common along the northwest and northeast coasts. The length of gillnets used is around 500 m and the nets are operated manually. Dolnetters (7 to 12 m LOA) are operated almost exclusively along the northwest coast. This is a specialized type of fixed bag-net that targets bombay duck (*Harpodon nehereus)* and grenadier (*Coilia dussumieri*). These two fishes occur almost exclusively along the northwest coast.

Purse seiners were introduced in the 1970s but are not as popular as trawlers. In 1998, there were 1 006 purse seiners (9 to 13 m LOA). Purse seiners are restricted to the west coast, particularly the middle part, which is characterized by the abundance of small pelagics such as sardines, whitebaits and Indian mackerel.

Catch and Fishing Effort

Marine fisheries in India are characterized by a large variety of gear. The variety of active gear can be classified as (i) encircling, (ii) drifting, (iii) dragging, (iv) seining, and (v) lining types. The stationary gear can be classified as (i) set nets and (ii) fixed nets. The number of fishing gear along the Indian coast is given in Table 14. Of all the types of gear, gillnets are the most numerous. It is estimated that about 75% of the total number of types of gear are gillnets (drift and bottom-set). The most common craft gear combinations are given in Table 15.

The average annual marine fish production in India increased from 1.17 million t during 1970 - 74 to 2.47 million t during 1995 - 98 (Table 16). The west coast consistently contributed 70% of landings during the period. Catches along the northwest, southwest, southeast and northeast coasts increased by 3.0, 1.5, 2.2 and 2.6 times respectively, between 1970 - 74 and 1995 - 98. The increase was highest along the northwest coast, where the average annual landings increased from 318 060 t (1970 - 74) to 948 650 t (1995 - 98). Consequently, the contribution of the northwest

coast to marine fish production increased from 27.2% (1970 - 74) to 38.3% (1995 - 98) (Table 17). On the other hand, the contribution of the southwest coast decreased from 44.4% to 31.2%.

The fishing effort deployed by artisanal, motorized and mechanized craft from 1985 to 1996 is given in Table 18. Owing to motorization of artisanal craft during the period, fishing effort of artisanal crafts declined from 10.2 million boat-days (bd) in 1985 to 4.7 million bd in 1996, while effort of motorized crafts increased more than 5 times, from 0.7 million bd to 3.7 million bd. Effort of mechanized crafts fluctuated between 2.9 and 3.5 million bd. However, due to introduction of larger mechanized vessels in 1990, efficiency rather than the number of boat-days increased during 1985 - 96.

Table 14. Number and type of fishing gear along the Indian coast 1998.

Fishing Gear	NW	SW	SE	NE	Total
Trawlnet	82 461	35 809	29 093	4 103	151 466
Gillnet	1 172 734	56 307	216 656	28 049	1 473 746
Driftnet	10 998	4 760	42 383	2 668	60 809
Dolnet	48 296	0	0	1 390	49 686
Fixed bag-net	13 438	2 733	2 402	9 323	27 896
Purse seine	284	901	0	31	1 216
Rampanitals	92	165	0	0	257
Ring seine	0	2 613	241	23	2 877
Boat seine	0	2 736	4 605	825	8 166
Shore seine	375	1 784	1 818	504	4 481
Hooks and lines	19 907	8 906	58 581	1 867	89 261
Scoop-net	540	0	2 731	448	3 719
Trap	20	35	3 824	189	4 068
Others	40 017	6 909	25 229	11 495	83 650
TOTAL	1 389 162	123 658	387 563	60 915	1 961 298

Note: NW - Northwest; SW - Southwest; SE - Southeast; NE -Northeast.

Table 15. Common fishing craft and gear combinations in India.

Fishing Craft	Construction	Propulsion	Engine power (HP)	No. of crew	Major gear	Area of operation
Catamaran	5 wooden logs tied as raft	Manual/outboard engines	6 to 10	2 to 4	Driftnet, gillnet, boat-seine, lines	Inshore; east coast
Dugout canoe	Hollow single wooden log	Manual/outboard engines	6 to 10	2 to 8	Castnet, boat-seine	Inshore; west coast
Plank-built craft	Wooden planks nailed as a frame	Manual / mechanized	15 to 30	7 to 12	Gillnet, boat-seine, dragnet	Inshore; southwest coast
"Pablo" boat	Wood	Mechanized	10 to 20	3 to 4	Gillnet, Driftnet, Longline	Inshore; all coasts
Purse seiner	Wood	Mechanized	100 to 120	18 to 22	Purse seine	Inshore; southwest coast

Table 15. Common fishing craft and gear combinations in India. (continued)

Fishing Craft	Construction	Propulsion	Engine power (HP)	No. of crew	Major gear	Area of operation
Shrimp trawler	Wood	Mechanized	65 to 120	4 to 6	Trawl net	Inshore; all coasts
Steel trawler	Steel	Mechanized	100 to 400	6 to 16	Trawl net	Offshore; middle southeast coast

Table 16. Mean annual landings (t) along the Indian coast.

Period	NW	SW	SE	NE	Total
1970 - 74	318 060	519 750	284 143	47 993	1 169 946
1975 - 79	468 038	500 263	340 826	47 993	1 357 120
1980 - 84	488 970	498 068	383 199	63 508	1 433 745
1985 - 89	585 866	699 958	409 858	73 357	1 769 039
1990 - 94	758 667	842 290	494 031	126 752	2 221 740
1995 - 98	948 650	772 656	629 027	124 301	2 474 634

Note: NW - Northwest; SW - Southwest; SE - Southeast; NE -Northeast.

Table 17. Contribution (%) of each coastal area to the marine fish production in India 1970 - 98.

Year	NW	SW	SE	NE
1970 - 74	27.2	44.4	24.3	4.1
1975 - 79	34.5	36.9	25.1	3.5
1980 - 84	34.2	34.7	26.7	4.4
1985 - 89	33.1	39.6	23.2	4.1
1992 - 94	34.1	37.9	22.2	5.7
1995 - 98	38.3	31.2	25.5	5.0

Note: NW - Northwest coast; SW - Southwest coast; SE - Southeast coast; NE - Northeast coast.

Table 18. Fishing effort (in boat days) along the Indian coast.

Fishing craft	1985	1986 - 90	1991 - 95	1996
Artisanal	10 216 950	8 905 205	6 425 388	4 678 579
Motorized	708 165	1 208 091	2 348 112	3 715 571
Mechanized	2 890 935	3 475 191	3 384 564	3 339 426
Purse seiner	56 121	85 336	85 765	100 655
Ring-seiner	0	167 564	251 973	240 277
Gillnetter	774 835	1 044 456	910 058	946 643
Trawler	1 444 604	1 818 617	1 980 276	1 853 567

Landings in India consisted of small pelagics (39.2%), large pelagics (10.1%), demersal finfishes (26.9%) and demersal invertebrates (18.8%) during 1970 - 98 (Table 19). The oil sardine, *Sardinella longiceps* is the single largest fishery, contri-buting 9.2% to total landings, followed by penaeid prawns (8.0%), Indian mackerel (6.8%), croakers (6.4%) and bombay duck (5.8%). The following are evident from Table 19:

- Most of the southwest coast landings are small pelagics, (54.0%), dominated by oil sardine, Indian mackerel, carangids and whitebaits.
- The Northwest coast landings are dominated by Bombay duck (16.2%), non-penaeid prawns (12.0%), croakers (10.7%) and penaeid prawns (9.3%). Small pelagics, demersal finfishes and demersal invertebrates contribute almost equally to northwest coast landings (27.0 - 27.9%). However, the demersal invertebrates contribution was significantly higher along the northwest coast than along the other coasts.
- The southeast and northeast coasts are characterized by high contributions of small pelagics and demersal finfishes. Lesser sardines and silverbellies dominated the southeast coast landings while croakers and *Hilsa* spp. dominated the northeast coast.
- Landings along the Lakshadweep Islands are dominated by large pelagics, especially tunas (69.9%).
- Landings along the Andaman and Nicobar Islands are dominated by lesser sardines and perches.

Table 19. Contribution (%) by resource group to mean annual marine landings in India during the period 1970 - 98.

Group	NW	SW	SE	NE	LAK	A&N	INDIA
Small Pelagics							
Oil sardine *(Sardinella longiceps)*	0.3	22	4.1	0.07	0	0	9.2
Lesser sardines (Clupeidae)	0.4	4.1	11.3	3.7	0	12.5	4.6
Hilsa spp.	1.1	0.05	1.3	13.8	0	0.2	1.4
Whitebaits (Galaxiidae)	0.2	5.1	4.8	0.9	0	5.5	3.2
Thryssa spp.	0.9	1.1	2.4	0.8	0	4.5	1.4
Coilia spp.	4.4	0.01	0.4	3.2	0	0	1.7
Setipinna spp.	0	0	0.1	2.2	0	0	0.1
Bombay duck *(Harpadon nehereus)*	16.2	0	0.2	7.2	0	0	5.8
Flying fishes (Exocoetidae)	0	0.01	0.7	0	0.6	0	0.2
Carangids (Carangidae)	1.9	7.9	4.8	1.7	1.4	6.0	4.8
Indian mackerel *(Rastrelliger kanagurta)*	1.6	13.7	4.7	0.8	0	3.0	6.8
Sub total	27.0	54.0	34.8	34.4	2.0	31.7	39.2
Large Pelagics							
Sharks	2.9	0.9	2.5	2.8	4.5	2.6	2.1
Ribbonfishes (Trichiuridae)	6.3	2.6	4.3	4.1	0	1.6	4.3
Seerfishes (Scombridae)	1.8	1.4	2.4	2.8	1.4	3.0	1.8
Tunas (Scombridae)	0.8	2.1	1.0	0.2	69.9	3.2	1.5
Barracudas (Sphyraenidae)	0.1	0.4	0.8	0.05	0.3	3.5	0.4
Sub total	11.9	7.4	11.0	9.9	76.1	13.9	10.1

Table 19. Contribution (%) by resource group to mean annual marine landings in India during the period 1970 - 98. (continued)

Group	NW	SW	SE	NE	LAK	A&N	INDIA
Demersal Fish							
Rays (Dasyatidae)	0.9	0.5	3	1.4	0.6	0.6	1.3
Eels	1.0	0.01	0.2	0.5	0	0	0.4
Catfishes (Ariidae)	3.4	2.3	2.3	8.1	0	2.1	3.0
Lizardfishes (Synodontidae)	0.6	1.4	1.0	0.2	0	0	1.0
Threadfin breams (Nemipteridae)	2.1	5.1	2.4	0.3	0	0	3.2
Other perches	1.1	2.1	4.2	1.1	3.8	8.6	2.3
Goat fishes (Mullidae)	0.3	1.1	1.3	0.3	0.9	0	0.8
Threadfins (Polynemidae)	0.9	0.03	0.6	0.8	0	0.8	0.5
Croakers (Sciaenidae)	10.7	2.3	5.1	15.5	0	1.1	6.4
Silverbellies (Gerridae)	0.2	1.6	10.4	1.0	0.4	6.2	3.2
Whitefish (*Lactarius lactarius)*	1.0	0.5	0.4	0.08	0	0	0.6
Pomfrets (Barmidae)	3.9	0.6	1.3	8.1	0	1.3	2.3
Mullets (Silliganidae)	0.4	0.04	0.3	0.08	0	4.4	0.2
Unicorn cod (*Bregmaceros mcclellandii*)	0.2	0	0	0	0	0	0.1
Flatfishes (Platycephalidae)	1.2	2.8	0.7	0.4	0	0	1.6
Sub total	27.9	20.4	33.2	37.9	5.7	25.1	26.9
Demersal Invertebrates							
Penaeid prawns	9.3	8.7	5.9	4.5	0	1.1	8.0
Non-penaeid prawns	12.0	0.07	0.7	2.6	0	0	4.3
Lobsters	0.2	0.02	0.1	0	0	0.02	0.1
Crabs	0.7	0.7	2.8	0.5	0	0.5	1.2
Stomatopods	2.4	5.7	0.4	0.6	0	0	3.0
Cephalopods	3.0	2.5	1.4	0.2	0.4	0.3	2.2
Sub total	27.6	17.7	11.3	8.4	0.4	1.9	18.8
Others	5.6	0.5	8.7	8.4	15.8	27.4	5.0

Note: NW - Northwest; SW - Southwest; SE - Southeast; NE - Northeast; LAK - Lakshadweep; A&N - Andaman and Nicobar.

Economics and Marketing

Most of the annual marine landings of 2.7 million t (1998) is used in fresh or iced condition for domestic consumption (44%), with only about 15% exported, 3% for curing and drying and 15% for reduction to fish meal and for canning and freezing (Sathiadhas et al. 1995). Fishes like bombay duck, whitebaits, and ribbonfishes are cured (25 - 30% of landings are processed). This results in low availability of fresh fish in demand centers and poor returns to the producer.

Analysis of economic performance (costs and return) of different fishing units operating in Indian marine waters is given in Pillai et al. (this vol.) Performance of various non-motorized and moto-rized artisanal fishing units, as well as mechanized units operating nearshore and offshore, based on 1993 - 94 data given by (Sathiadhas et al. 1995) were analyzed. These data indicate high rates of return for the various fishing units (24% to 46%).

Owners of fishing craft and the laborers share the net earnings from fishing operations after deducting fuel and other operational expenses. Nearly 70% of gross earnings of mechanized vessels and 50% of earnings of motorized units go to operating expenses, whereas non-mechanized units have egligible operating expenses. About 30% of net earnings in mechanized and motorized units and 65% of gross earnings in non-mechanized units are paid to fishing laborers as wages. The per capita earnings of a fishing laborer per trip is about US$4 for mechanized craft, $1.7 for a motorized unit and $1.0 for artisanal craft. Annual wages of a fishing labourer depend on the actual number of fishing trips. Considering 200 fishing days/year, the annual income of a labourer working in mechanized, motorized and artisanal craft would be $795, $350 and $200, respectively.

The fisher's share in consumer's price provides an index of the efficiency of the fish marketing system. Marketing studies indicate that fisher's share in consumer's price ranges from 30 to 68%. Wholesalers receive 5 to 32% and retailers 14 to 47% for different groups of marine fishes. Fishers in Gujarat receive 37% (catfishes) to 83% (ribbonfishes) of consumer's price while in Maharashtra it ranged from 36% (barracudas and sharks) to 81% (seerfishes) (Table 20). Fishers realize the highest share for cephalopods (71%) in Karnataka and Kerala, for whitefish (67%) in Tamil Nadu and for sardines (58%) in Andhra Pradesh.

The growth of fish production and development of fisheries is enhanced by an efficient marketing system. Post-harvest operations provide more employment than the production sector. Involvement of intermediaries in transporting the fish to the consumer is very high in India. Marine fishes procured from 2 244 landing centers are distributed throughout the country. Monophony characterizes the fish marketing structure in various stages. Five types of marketing channels exist. They are: (i) Producer-retailer-consumer (ii) Producer-whole-saler-retailer-consumer, (iii) Producer-commission agent-wholesaler-retailer-consumer, (iv) Producer-wholesaler-commission agent-retailer-consumer, and (v) Producer-commission agent-wholesaler-commission agent-retailer-consumer.

Table 20. Fisher's share in consumer's price for selected varieties of fish in different marine states 1996 - 97.

Group	Fisher's Share (%)					
	Gujarat	Maharastra	Karnataka	Kerala	Tamil Nadu	Andhra Pradesh
Seerfishes	71	81	40	65	49	49
Pomfrets	64	68	46	43	51	53
Barracudas	0	36	55	53	54	24
Tunas	63	43	0	51	60	36
Sharks	45	36	40	63	60	17
Catfishes	37	76	35	58	63	33
Mackerel	50	50	33	50	55	26
Sardines	60	57	54	43	63	58
Ribbonfishes	83	60	41	37	55	36
Rays	0	0	0	30	57	40

Table 20. Fisher's share in consumer's price for selected varieties of fish in different marine states 1996 - 97.

Group	Fisher's Share (%)					
	Gujarat	Maharastra	Karnataka	Kerala	Tamil Nadu	Andhra Pradesh
Whitebaits	0	0	33	26	48	22
Lizardfishes	44	43	31	30	53	36
Goatfishes	0	0	0	60	60	42
Threadfins	43	0	0	0	53	23
Croakers	56	45	38	31	63	27
Silverbellies	0	0	0	35	32	21
Whitefish	0	0	60	45	67	44
Mullets	0	45	42	56	46	38
Half & full beaks	0	0	0	61	65	0
Cephalopods	63	75	71	71	51	44

Source: Sathiadhas et al. (1995)

Management Issues and Opportunities

Capture fisheries are an example of exploiting renewable but limited natural resources. The resources are common property, with free and open access. Irrespective of the type of fisher, their operation will not be limited until zero profitability thresholds are reached (Anderson 1987). Hence, there is a need for a management system to intervene and regulate activities. The fisheries management system must set up fishing regimes that appropriately match the productive capacity of the resource base (Silvestre and Pauly 1997).

Fisheries management is a dynamic resource allocation process with sustainable production and value to society as the prime objectives. The objectives of coastal fisheries management along the southwest coast of India are given in Fig. 2. With sustainable coastal fisheries development as the overall goal, key third level objectives are given, consistent with the ecological, social, economic and administrative thrusts of fisheries management in the area. These were synthesized from available policy instruments, plans and documents relevant to fisheries in the area.

Fig. 3 gives a summary of the key issues impacting sustainable coastal fisheries development in the southwest coast of India, together with relevant interventions for their resolution or mitigation. The key issues (and interventions) relevant to the ecological objectives are:

- The currently high and increasing fishing intensity off the southwest coast of India (9 308 mechanized and 34 800 traditional fishing crafts in 1998) leading to symptoms of overfishing, particularly in near-shore areas. This requires the introduction of limited entry and effort reduction schemes, together with promotion of fishing in deeper, "far sea" areas.
- Inappropriate patterns of exploitation of available fishery resources via extensive trawling and use of small-meshed nets, as well as the inappropriate temporal and spatial deployment of various types of fishing gear. This requires implementation of relevant provisions of the Code of Conduct for Responsible Fisheries to improve gear selectivity and optimize species and size composition of catches.
- Degradation of the coastal environment from various non-fishing activities. This requires more rigorous implementation of various measures to protect coastal environmental health, including enhancement of the Environmental Impact Assessment systems, coastal zonation schemes and wider implementation of integrated coastal zone management initiatives.

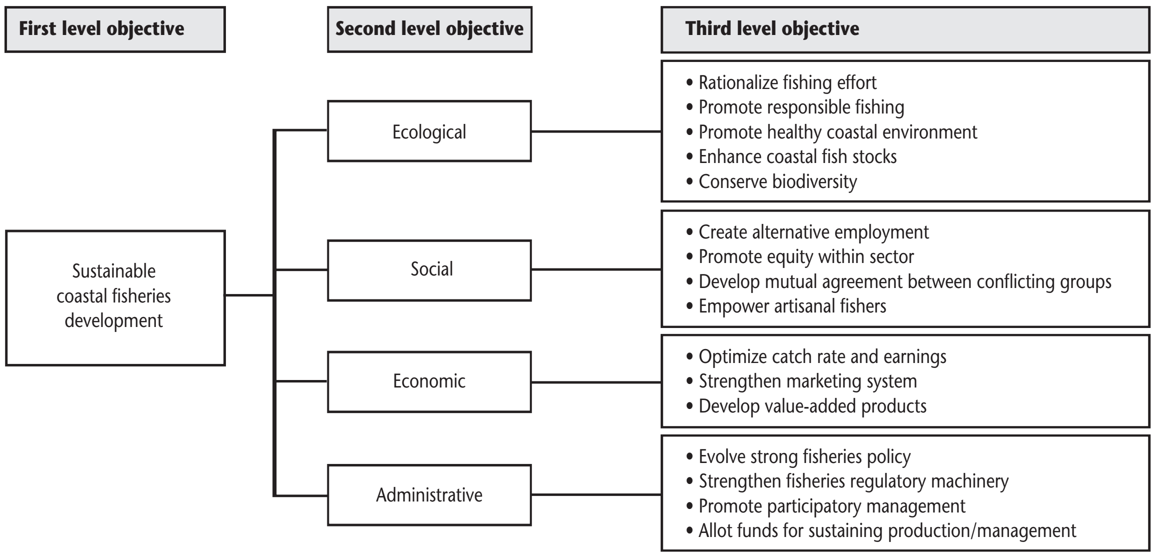

Fig. 2 Goal/objective structure for coastal fisheries management along the southwest coast of India.

- Declines in fish stocks and biodiversity from the combined effects of the above issues. These require the promotion of resource enhancement or restocking, sea farming, and the development of marine parks and sanctuaries. Marine parks have been developed in other Indian coastal areas, but remain to be developed systematically on the southwest coast.

The key issues and relevant interventions related to social objectives for the southwest coast fisheries are:

- High and increasing number of active fishers (from about 85 600 in 1961 to 200 000 in 1998). It is estimated that the density of active fishers in inshore fishing grounds (from the shoreline to 50 m depth) has increased from 3.6 to 8.5 fishers per km^2 in the past four decades. This requires the creation of alternative employment opportunities, given the momentum of increase in the fishers' population and the already high fishing intensity in inshore grounds.
- High and increasing numbers of intra- and inter-sectoral conflicts. Conflicts between and among the artisanal and mechanized fishing sub-sectors for resources and fishing grounds are intensifying, particularly in near shore areas. Conflicts between trawlers and artisanal fishers are of particular concern. Conflicts between fishers and other sectors (e.g. marine transport, mangrove forestry) also require attention. Prevention/management of these conflicts requires mechanisms to promote awareness and equity among various fishers, as well as promote mutually acceptable agreements across sectors. Promotion of spatial zonation schemes in coastal areas and integrated coastal zone management deserves attention. Land-based activities affecting hydrology and the coastal environment should consider their impacts on fisheries.
- High and increasing poverty among artisanal fishers. This requires empowerment of artisanal fishers through co-management schemes, social legislation and improved support/welfare schemes, and assistance in technology upgrading for fishers who remain in fishing.

The key issues and interventions relevant to the economic objectives are:

- Decline in earnings of fishers, particularly those in the artisanal sub-sector. This requires addressing the issue of high fishing intensity in general, and diversifying the fleet composition or configuration to optimize economic returns from fishing. Promotion of gear to utilize under-exploited species and resources in deeper areas deserves attention.
- Inefficiencies in the domestic marketing system. The infrastructure for domestic marketing lags behind that available for export of fishery

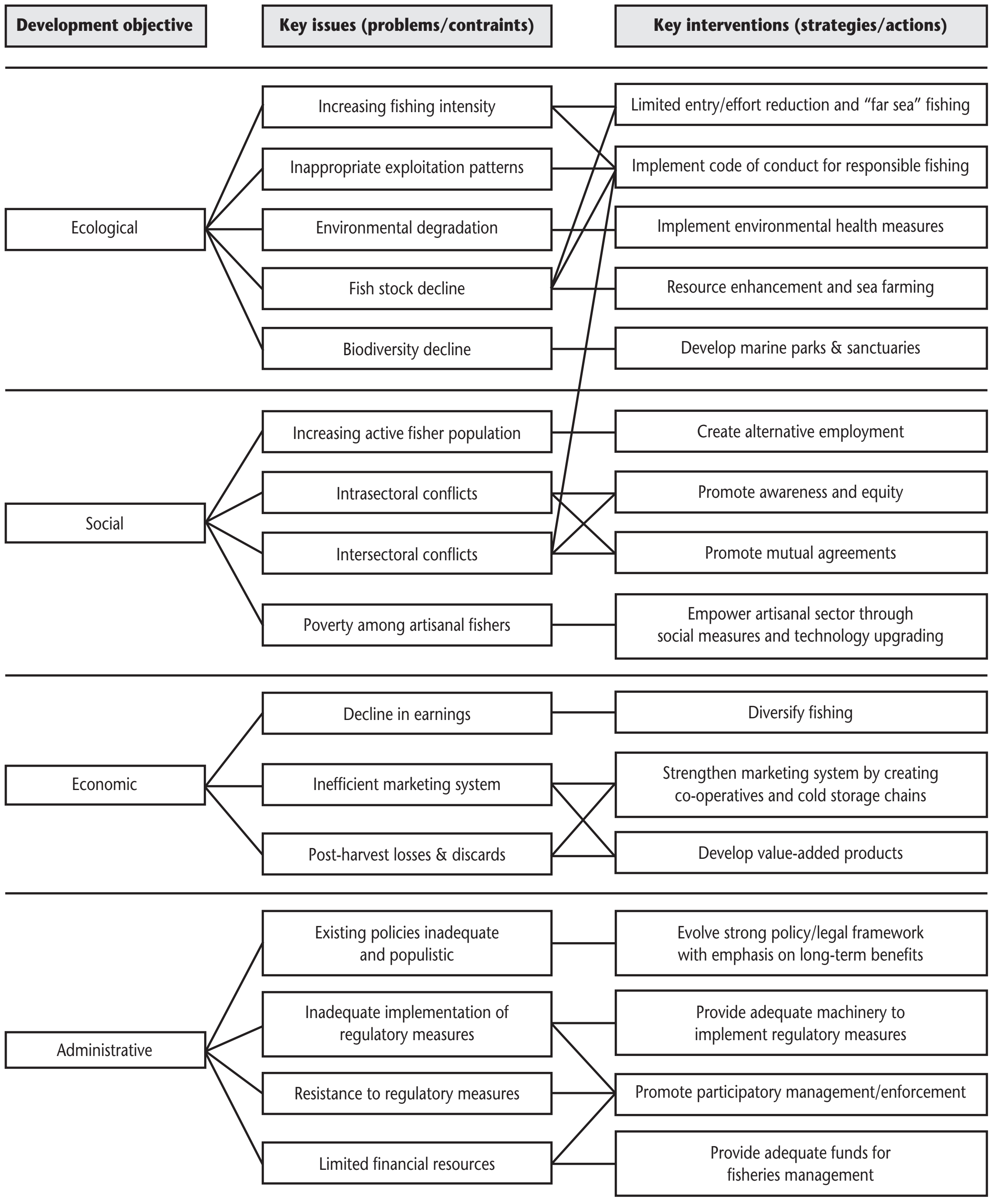

Fig. 3 Problem/opportunity structure for coastal fisheries management along the southwest coast of India.

products. This requires improvement of the marketing system and cold storage chains supporting the 540 landing centers in the southwest coast.
- High post-harvest losses and discards resulting in value losses to fishers. Discarding is particularly a problem for the trawl fisheries principally targeting shrimps. The development of value-added fishery products requires attention, together with improvement of the domestic marketing infrastructure, to be able to reach markets further inland. Large quantities of crabs, stomatopods and non-penaeid shrimps are currently used for reduction to fishmeal, and they alternatively can be used for human consumption.

The key issues and interventions relevant to the administrative objectives are:

- Inadequacy of existing fisheries policies. Existing policies mostly revolve around populist welfare measures. Overall, the country needs a strong fisheries policy that balances welfare concerns with sustainability. For instance, Acts defining fishing zones or areas for artisanal fishers, closed seasons, surveillance and enforcement schemes, and licensing require review and updating, involving various stakeholders.
- Inadequate implementation of, and resistance to, regulations. Many regulations are not adequately implemented due to lack of personnel, limited budgets, poor institutional collaboration, and resistance from fishers. This requires attending to causative factors and appropriate participatory mechanisms or co-management arrangements to allow more effective implementation of regulatory measures.
- Limited financial resources for fisheries management and development. The fisheries sector's contribution to national GDP was about 1.3% in 1995 - 96. The current five-year plan allocates only 0.35% of the plan budget to fisheries. Increasing the government allocation of resources to fisheries requires attention, as well as exploration of cost-sharing schemes for fisheries management with the fishing industry.

The key issues and interventions outlined above need immediate attention by the maritime states in the southwest coast and the Government of India. Table 21 illustrates the key interventions and the most relevant agencies for their implementation, given the existing institutional structure (see Appendix 1). Relevant research support agencies for the interventions are also provided in Fig. 3. Two interventions requiring regional collaboration are included in addition to the ones already discussed above. These pertain to the need for management of straddling stocks and sharing of successful fisheries management policies and practices among developing Asian countries. International agencies with interest in the region should help spur research and collaboration among countries in these areas. Project briefs (covering objectives, scope, implementation arrangements, and indicative costs) for the key interventions given in Fig. 3 and Table 21 for the southwest coast fisheries of India have been prepared by the authors to facilitate their uptake by implementing agencies. These project briefs require further review and improvement in collaboration with concerned stakeholders in the near future and are available upon request from the authors or the TrawlBase project team based at CMFRI.

Table 21. Key interventions and implementing organizations.

Key Interventions	Implementing Organization	Research Support
Limited entry, effort reduction and "far sea" fishing	Ministry of Fisheries (State governments) Ministry of Agriculture (GOI)	CMFRI and FSI
Implement code of conduct for responsible fishing	Ministry of Fisheries (State governments)	CMFRI, CIFT and CIFNET
Implement environmental health measures	Ministry of Fisheries (State governments), NGOs.	DOD, CICEF and Fisheries colleges
Resource enhancement programs	Ministry of Fisheries (State governments), & Ministry of Agriculture (GOI)	CMFRI
Creation of marine sanctuaries	Ministry of Agriculture (GOI), Ministry of Fisheries (State governments), NGOs.	ZSI, CMFRI and NBFGR
Provide alternative employment	Ministry of Fisheries (State governments), NGOs, Financing institutions	CMFRI
Promote awareness	Ministry of Fisheries (State governments), fisher associations, NGOs, Village Panchayats	–
Promote mutual agreements	Ministry of Fisheries (State governments), fisher associations, NGOs, Village Panchayats	–
Empowerment of artisanal fishers through social and technology upgrading	Ministry of Fisheries (State governments), Ministry of HRD, Government of India NGOs, Village Panchayats	–
Diversify fishing	Ministry of Agriculture (GOI), Ministry of Fisheries (State governments)	CIFT, FSI and CIFNET
Strengthen marketing system	Ministry of Fisheries (State governments), Ministry of Agriculture (GOI), Village Panchayat, Fisheries Associations	Fish.co-ops.,CIFT, IFP, Fisheries Colleges
Develop value-added products	Ministry of Fisheries (State governments)	CIFT, IFP, Fisheries Colleges
Evolve strong fisheries policies	Ministry of Agriculture (GOI) & State Governments	CMFRI and IIM
Provide machinery for implementation	Ministry of Fisheries (State governments), fisher associations,NGOs, Village Panchayats	–
Promote participatory management	Ministry of Fisheries (State governments), fisher associations, NGOs, Village Panchayats	–
Provide adequate funds for fisheries management	Ministry of Finance & Ministry of Agriculture Government of India	–
Management of straddling stocks	Regional organizations (Worldfish Center, BOBP, SEAFDEC, APFIC)	CMFRI, FSI and DOD
Experience-sharing with neighbouring countries	Regional organizations (WorldFish Center, BOBP, SEAFDEC, APFIC)	CMFRI and FSI

Note: CMFRI = Central Marine Fisheries Research Institute, FSI = Fisheries Survey India, CIFT = Central Institute of Fisheries Technology , CIFNET = Central Institute of Fisheries, Nautical and Engineering Training, DOD = Department of Ocean Development, CICEF = Central Institute of Coastal Engineering for Fishery, ZSI = Zoological Survey of India, NBFGR = National Bureau of Fish Genetic Resources, IFP = International Fisheries Project, IIM = Indian Institute of Management.

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Appendix 1. Institutional and Legal Background

Fisheries Policies

Fisheries is a state subject under Schedule VII, Article 246 of the Constitution of India. However, fishing and fisheries both in and beyond territorial waters are in the Union List. Hence, matters relating to fisheries, particularly marine fishing within territorial waters are largely within the purview of state governments and fishing beyond territorial waters come directly under the national government. Nevertheless, according to Article 297 of the Constitution, the Government of India exercises a coordinating role in respect of fisheries (both within and outside territorial waters).

Under the enabling provision of the Indian Fisheries Act 1897, various states and union territories of India have introduced fishery regulations. These legislations are enacted to suit local demands and conditions. Under the Maritime Regulation Act, the Government of India has requested maritime states to frame rules for regulation of fishing to protect traditional fishers and the operation of large fishing vessels.

Development plans are carried out through Five Year plans. The Ninth Plan (1997 - 2001) has established targets for selected programs (Annex Table 1). The broad objectives of fisheries development are to: (i) increase fish production and thereby raise nutritional standards of the population, (ii) generate income, employment, and growth and subsidiary industries, (iii) ensure the welfare of

Annex Table 1. Ninth plan targets for the fisheries sector in India, 1997 - 2001.

Particulars	Targets
Fish production (x10^6 t)	
Marine	3.0
Inland	2.5
Total	5.5
No. of mechanized vessels	50 000
No. of deep-sea vessels	350
No. of minor fishing harbours	140
Exports	US$1.5 billion

fisher communities, and (iv) maximize foreign exchange earnings through export of marine products.

Centrally-sponsored schemes currently in operation for development of coastal marine fisheries include the following: (i) financial assistance by way of subsidy to fishers for motorization of traditional craft, (ii) introduction of plywood craft and intermediate craft, (iii) reimbursement of central excise duty on oil used by small mechanized fishing vessels, (iv) assistance to maritime state governments for enforcing marine fishing regulations by way of providing patrol boats and equipment, and (v) resource enhancement through artificial reefs and mariculture.

In addition, the following development directions are in place:

i. The Government of India meets 100% of expenditure in construction of major fisheries harbors, and 50% of expenditure in construction of minor fisheries harbors and fish landing centers. The balance is borne by concerned state governments.
ii Strengthen the infrastructure of state fisheries corporations/federations, and provide assistance for marketing by way of refrigerated vans, cold storage, ice plants, and related equipment.
iii. Under the Fish Farmers' Development Agency, a package of assistance consisting of fish seed/feed, subsidy, training and extension is provided to fish farmers to expand fish culture and to increase productivity of fish farms.
iv. Under the Brackish-water Fish Farmers Development Agency, a package of assistance consisting of brackish-water culturable species (especially penaeid shrimp seed/feed), subsidy training and extension is provided to brackish-water fish/shrimp farmers to expand brackish-water fish/shrimp culture and increase productivity of brackish-water fish/shrimp farms.

Promotion of deep-sea fishing is envisaged through the Deep-sea Fishing Policy, which became fully effective in 1993 - as a number of vessels under joint venture, test fishing and leasing were permitted. However, due to operational, managerial and social problems, there is currently no deep-sea fishing for resources other than shrimps. About 160 deep-sea shrimp trawlers owned by 85 companies are now operating along the central part of the east coast of India. For integrated development of the deep-sea fishing sector, the following schemes are being implemented:

i. Assistance for deep-sea fishing and processing ventures - funds under this scheme are released to the Marine Products Export Development Authority (MPEDA, Ministry of Commerce, Government of India), who in turn participate by way of equity in deep-sea fishing and processing ventures.
ii. Assistance for diversified fishing - funds under this scheme are released to MPEDA, who in turn provide subsidy towards the cost of modification of vessels.
iii. Scheme for providing loans for acquisition of deep-sea fishing vessels - the Shipping Credit and Investment Company of India, Ltd. (SCICI) provides loans to fishing companies for acquisition of fishing vessels.
iv. Communication facilities for coastguard - communication facilities are strengthened by providing funds to set up ship-to-shore radio communication links with fishing vessels.

A major activity is implementation of fishers' welfare schemes. At present, the following welfare schemes are being implemented:

i. Group accident insurance scheme for active fishers - fishers are insured and the premium cost is shared equally by the central and state governments.
ii. Development of model fishing villages - aims at providing civic amenities such as housing, drinking water and community halls in selected fishing villages with the cost shared equally by the central and state governments.
iii. Savings-cum-relief schemes - provides financial assistance to traditional fishers during non-fishing seasons (1/3 of the fund per fisher is provided by the central government, 1/3 by the maritime state governments and 1/3 by the beneficiaries on a monthly installment basis during fishing months with the full amount reimbursed to the beneficiaries during non-fishing months).

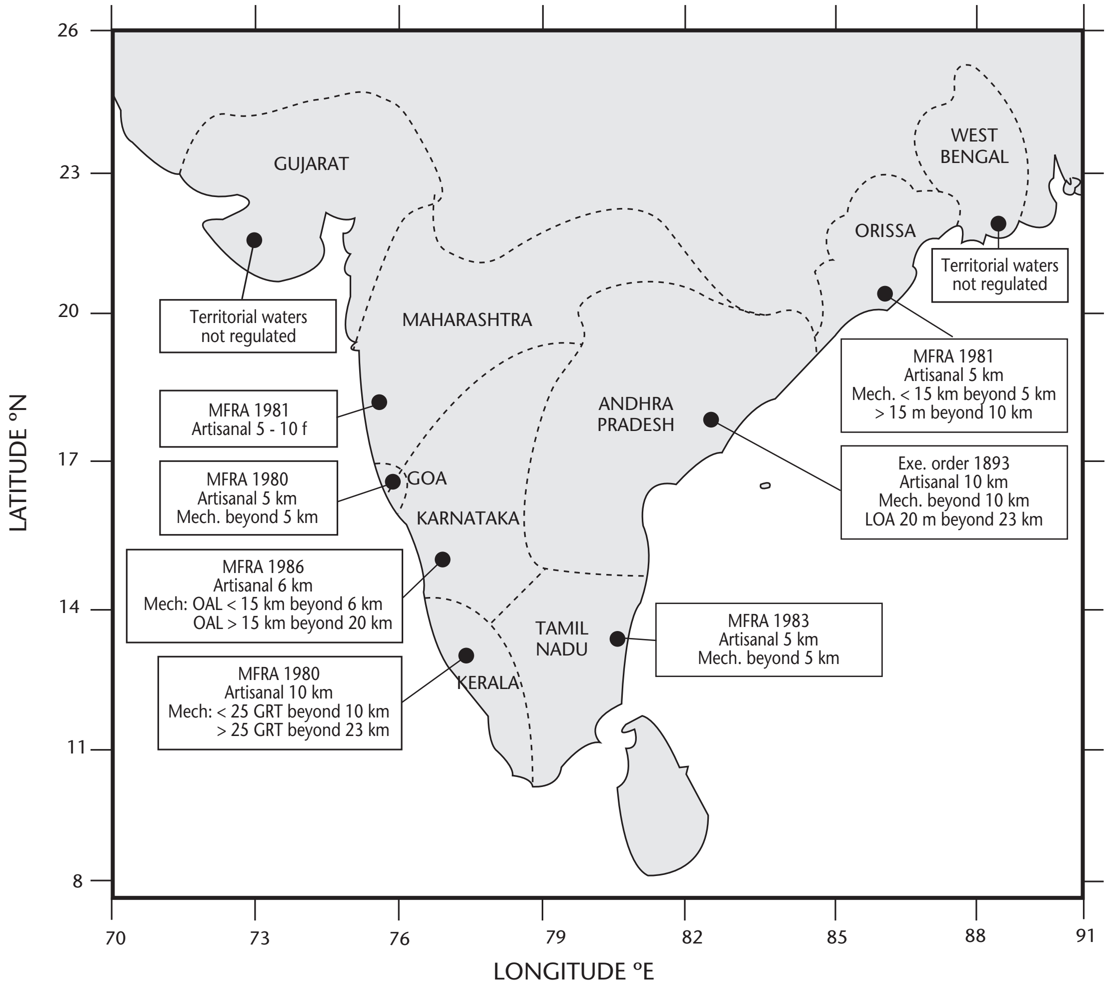
The Indian Fisheries Act 1897 was enacted by the Government of India more than 100 years ago with provisions for the issue of rules by state governments. This Act is still in force and various state governments have issued rules under this Act for regulation and protection of fisheries. Regulations concerning Indian marine fisheries are as follows:

i. Nilgiris Game and Fish Preservation Act 2 of 1879, Government of Madras;
ii. Bengal Private Fisheries Protection Act 2 of 1889, Government of Bengal and Madras amendment Act 1929 (Act 11 of 1929);
iii. The Indian Fisheries Act, No. IV of 1897, Government of India;
iv. The Indian Fisheries Act as adopted and applied by the State of Saurashtra, 1897;
v. The Mysore Game and Fish Preservation Act 2 of 1901, Government of Mysore;
vi. The Game and Fish Protection Regulation Act 12 of 1914, Government of Travancore (1914) (modified 1921);
vii. Cochin Fisheries Act 3 of 1917 (modified 1921), Government of Cochin;
viii. Andaman and Nicobar Islands Fisheries Regulation 1 of 1938;
ix. The United Provinces Fisheries Act 45 of 1948;
x. Government of Travancore-Cochin Fisheries Act 34 of 1950;
xi. The Maharashtra Fisheries Act 1960 (modified 1962), Government of Maharashtra;
xii. The Indian Fisheries (Pondicherry Amendment) Act 18 of 1965;
xiii. The Indian Wildlife Act 1972. 21b-The territorial waters, continental shelf, EEZ and other maritime zones Act 1972;
xiv. The Marine Products Export Development Authority Act 1972;
xv. The Maritime Zones of India (Regulation of fishing by foreign vessels) Act 1981;
xvi. The Kerala Marine Fishing Regulation Act and Rules 1980 (Act 10 of 1981);
xvii. The Goa Marine Fishing Regulation Act, 1980;
xviii. The Maharashtra Marine Fishing Regulation Act 1981, Government of Maharashtra;
xix. The Orissa Marine Fishing Regulation Act 1981 (Orissa Act 10 of 1982) and the Orissa Marine Fishing Regulation Rules 1983;
xx. The Tamil Nadu Marine Fishing Regulation Rules 1983;
xxi. Executive Order 1983 of Government of Andhra Pradesh; and
xxii. The Karnataka Marine Fishing Regulation Act, 1986.

The marine fishing regulation Acts (xvi-xxii above) are being implemented following a "model bill" circulated by the Government of India to all maritime state governments for regulation of exploitation of marine fisheries resources in territorial waters of India. These Acts demarcate fishing zones in ter-ritorial waters for fishing by non-mechanized and mechanized fishing vessels. The distance from the shore earmarked for each category varies according to situations in the state concerned. In general, 5 to 10 km is reserved for operation by non-mechanized vessels (Annex Fig. 1). Mechanized vessels are classified according to size and the area/depth of operation is delineated accordingly. As fish density is generally related to water depth, there were complaints in demarcating the areas of fishing based on distance from the shore. At a distance of 5 km from the shore, the depth may be only 20 m in certain areas like the Gulf of Mannar (SE coast), but 100 m in other areas. In response to complaints, some state governments incorporated the depth factor in their Acts in addition to distance from shore. For instance, the Kerala Marine Fishing Regulation Act 1980 divides the coastline into two sectors, a southern sector of 78 km coastal length and a northern sector of 512 km length. In the southern sector distance from the shore up to 32 m depth, and in the northern sector distance from the shore up to 16 m depth, have been reserved exclusively for artisanal craft. In the 32 to 40 m depth zone in the southern sector and the 16 to 20 m depth zone in the northern sector, only motorized craft are permitted to operate. Small mechanized vessels (< 25 GRT) are allowed to operate between 40 and 70 m depth in the southern sector and between 20 and 40 m depth in the northern sector.

In addition to regulation of fishing areas, there are regulations for cod-end mesh size of trawl nets. However, in the absence of effective surveillance systems, these regulations can not be implemented strictly. Encroachment by mechanized vessels in areas demarcated for artisanal craft and usage of very small mesh size in the cod-ends (< 10 mm) continue even after promulgation of the Acts.

The maritime state governments along the west coast implement seasonal closure of fishing operations by mechanized vessels. Unlike regulations of fishing areas provided in the Acts, the decision on seasonal closure is taken on a year to year basis normally prior to or during the onset of the southwest monsoon (June to September) (Annex Fig. 2). Gujarat has been observing seasonal closure for the past 2 decades, and Karnataka and Kerala for the past decade. Along the east coast, there is no effective seasonal closure. However, mechanized vessels of Andhra Pradesh observed 40 days closure during April - May 1999. Mechanized vessels in the Gulf of Mannar (southern Tamil Nadu) fish only on 3 days a week and artisanal craft on the remaining 4 days.



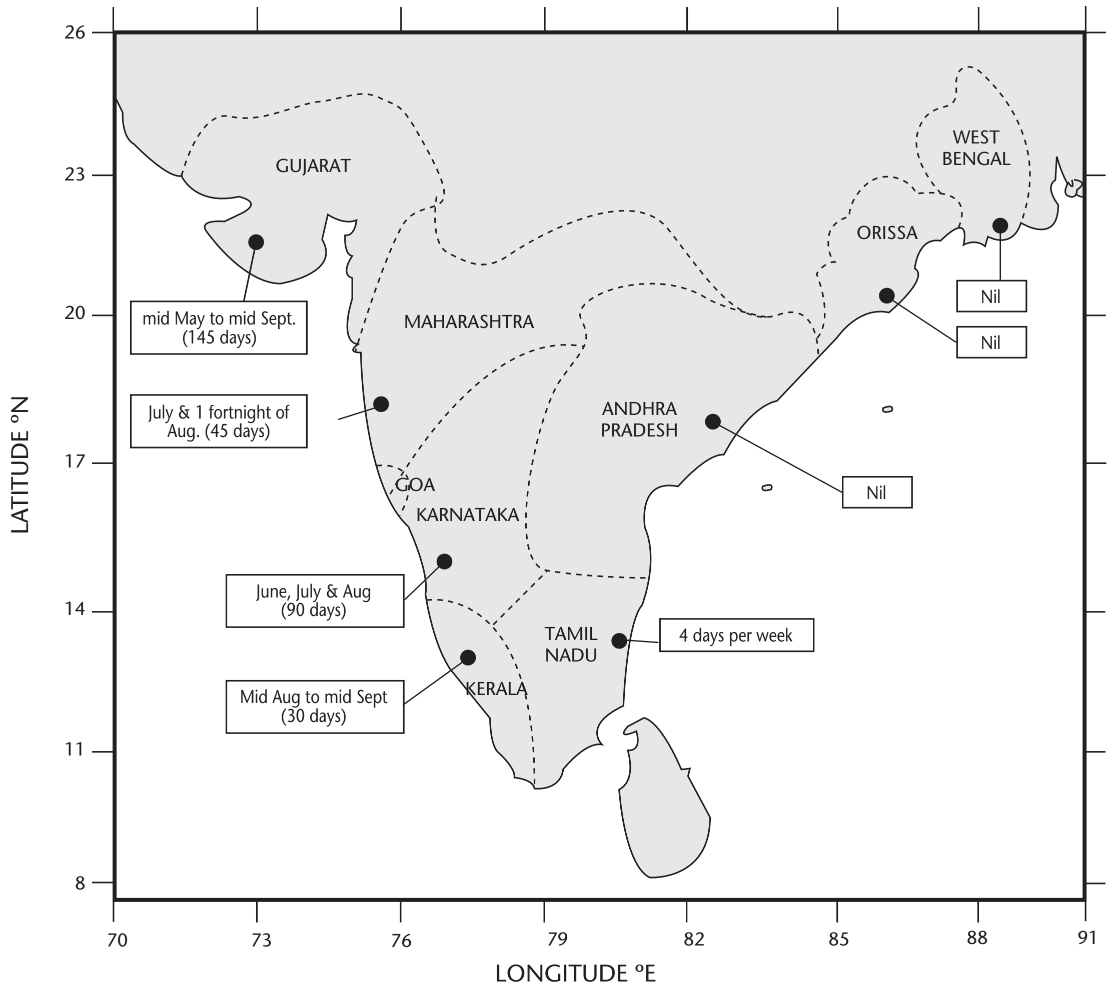
Annex Fig. 1. Regulation of fishing areas in Indian territorial waters.

The state government Acts have a few other restrictions such as a ban on fishing using destructive gears in backwaters, and a ban on fishing by unlicensed vessels. The governments encourage formation of fishermen cooperatives mainly for the purpose of extending welfare measures such as distribution of outboard motors and granting subsidies. However, policies related to restrictive fishing measures are found to be difficult to implement, while the welfare measures are accepted by the fishers.

Fisheries-related Policies

Over the last decade, management of the coastal zone and resources for their sustainable use has become a critically important issue for India. Included among these resources are some of the most extensive mangrove areas and coral reefs and a few endangered and threatened species. Recognizing the importance of coastal ecosystems and the country's reliance upon its endowment of natural resources, several regulations and notifications have been promulgated by the central and state governments. The important ones are:

i. General standards for discharge of wastewaters in marine coastal areas (1993);
ii. Notifications declaring certain coastal areas as a marine sanctuary or marine national park;
iii. Notification declaring coastal stretches as Coastal Regulatory Zone (CRZ) and regulating the activities in the CRZ (1991, 1994, 1996);
iv. Environmental impact assessment notification (1994);



Annex Fig. 2. Seasonal closure in the operation of mechanized vessels during 1997.

v. Indian Ports Act (1963);
vi. Wildlife Act (1972);
vii. Water Act (1974);
viii. Environment Act (1986).

These Acts are primarily concerned with resources and coastal ecology and also in regulating fishing in public and private waters through a system of licensing by government authorities. For conserving the coastal zone specifically, the Ministry of Environment and Forest (MOEF), Government of India, issued the CRZ, under which every maritime state had to prepare a coastal zone management plan. The Government of India identified parameters for development that are permissible in coastal areas up to 500 m from the high tide line (HTL). Coastal areas have been categorized as follows: *CRZ I* - ecologically sensitive areas (such as mangroves, coral reefs) and the area between the low tide line and HTL where no construction shall be permitted within 500 m from the HTL; *CRZ II* - areas already developed up to the shoreline in urban/built-up areas where buildings are permitted only on the landward side of existing roads/ structures; *CRZ III* - relatively undisturbed areas which do not come under CRZ I and II in rural areas under this category, the area up to 200 m from the HTL is a no-development zone and the development of vacant plots between 200 and 500 m is subject to approval by MOEF; *CRZ IV* - Andaman & Nicobar, Lakshadweep and other small islands, where no new construction will be permitted within 200 m from the HTL in the Andaman & Nicobar Islands and permission for

construction in Lakshadweep and other small islands will be decided by MOEF, depending on the size of the island.

Indian coastal areas harbor one of the world's major mangrove systems. It is estimated that mangroves in India cover an area of 0.7 million ha. The Sundarbans in the northern Bay of Bengal makes up the largest contiguous block of mangrove forests in the world, and approximately 40% (about 0.2 million ha) of this area is situated in India. About 12 genera and 45 mangrove and associated species have been recorded in India. Approximately 50% of India's mangrove areas have been destroyed during the last two decades (Brown 1997).

The coastal mainland of India has two widely separated areas of coral reefs. These are the Gulf of Kutch in the northwest and the Gulf of Mannar in the southeast. Other patches of coral growth occur in intertidal zones and up to 50 m depth along the west coast. Extensive reef development can be found in the Andaman & Nicobar and Lakshadweep Islands. A rich biodiversity in stony corals has been recorded along the Indian coast with 9 genera in the Lakshadweep, 21 in the Gulf of Kutch, 32 in the Gulf of Mannar and 39 in the Andaman Islands (Wafar and Whitaker 1992). Some of these sites (e.g. Andaman & Nicobar Islands) have not been intensively studied and it is likely that diversity has been significantly under-estimated (Brown 1997).

Coral reefs are being destroyed to a very large extent. The destruction is due to human exploitation in the Gulf of Kutch and Gulf of Mannar and due to siltation and tourism in the Andaman & Nicobar islands (Mahadevan and Nair 1972). For protection of the corals and coral reefs, there is a provision under the powers conferred under Section 10 (3) of the Mines and Minerals (Regulation and Development) Act 1957. The Government of Tamil Nadu (southeast coast) has issued a mining lease for collection of coral limestone under certain terms and conditions. In order to facilitate periodic growth of corals, the following stringent conditions have been imposed: (i) prohibition of mining in the islands; (ii) restriction of mining to 30 m from the fringe of the island at low tide level and on the seaward side of coral islands; (iii) prohibition of usage of explosives under any circumstance; (iv) reefs not to be mined beyond a depth of 1.5 m from the top of the reef at low tide; and (v) no mining on the live coral fringe. The Act also regulates collection of dead shells.

Marine turtles and mammals such as whales, dolphins and porpoises are the endangered species occurring along the Indian coast. Among the 5 species of marine turtles, the olive ridley *Lepidochelys olivacea* mass nests along Orissa (northeast coast) during December - March every year. It is estimated that, on average, 0.2 million nesting females frequent the Gahirmatha beach of Orissa every year (Rajagopalan et al. 1996). Following large-scale exploitation of nesting turtles and eggs, the Government of India developed conservation and management measures. To protect the turtle population, the Indian Wildlife (Protection) Act (1972) was promulgated wherein all species of sea turtles were placed as endangered species in Schedule I and thereby protected. India is a member of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES), which prohibits trade in turtle products by member countries. In 1981, India became a party to the Bonn Convention on the Conservation of Migratory Species of Wild Animals. To protect sea turtles, about 65 000 ha of intensive nesting beach area in Kanika island and 12 other offshore islands were declared as wildlife sanctuaries in 1975. In addition to this, the coastal mainland has 4 national parks and 17 protected areas. There are 94 sanctuaries in the Andaman & Nicobar Islands. Consequent upon these conservation measures, poaching on nesting females and eggs of turtles has substantially decreased. However, a major threat which persists is incidental catch of turtles in fishing gear such as the trawl and gillnet. It is estimated that about 5 000 turtles are incidentally caught and stranded every year along the Indian coast (Rajagopalan et al. 1996). Efforts are on-going to reduce the mortality by attaching turtle excluder devices to the trawl and by declaring closure of fishing during the mass nesting season.

None of the marine fishes is listed as an endangered species. The whale shark *Rhiniodon typus* is the only species listed as vulnerable. The whale shark is exploited using harpoons off Veraval (northwest coast) when it migrates from oceanic regions of the Indian Ocean to the NW coast of India during February - April to feed on abundant non-penaeid shrimps. It is estimated that about 10 000 sharks (length of 5.6 to 12.0 m) were killed during 1998 for their liver, fins and meat (Vivekanandan and Zala 1994). Proper conservation measures, similar to the programs on marine mammals and turtles need to be taken up for this species. The whitefish *Lactarius*

lactarius and the unicorn cod *Bregmaceros mcclellandi* are treated as indeterminate. According to conservation status classification, indeterminate refers to taxa expected to be endangered or vulnerable. The whitefish occurs along the west coast and the unicorn cod is restricted to the northwest coast. Appropriate strategies have to be devised also to restore the populations of these two species.

Under the Indian Fisheries Act 1897, the sedentary fisheries such as chanks and pearl oysters were declared a monopoly in the Gulf of Mannar and Palk Bay by the erstwhile Madras Presidency (southeast coast) and in the Gulf of Kutch by the then Government of Saurashtra (northwest coast). These sedentary fisheries belonged to the government and are fully protected even now. Seasonal fisheries are conducted by the government departments by issuing licenses.

The coastal zone is extensively used for a large number of activities. These multiple uses are not always compatible, and this results in a wide array of problems for fisheries. The coastal area is in increasingly strong demand for human settlements due to increases in population. (Rajagopalan et al. 1996) listed 16 major causes for degradation of coastal zones/resources in India (Annex Table 2). Of these, population pressure has been identified as the most serious factor, and wastewater disposal, increasing urbanization, solid waste disposal and coastal constructions have been identified as serious factors. For effective management of coastal zones/resources, coastal areas could be set aside for primary uses such as (i) conservation, (ii) fish harvesting, (iii) tourism and recreation, (iv) ports and harbours, (v) industries, (vi) oil exploration and mining, and (vii) ocean dumping (Zingde 1996). For adopting such a classification system, great care is required for formulating and administering legislation.

Agricultural and industrial growth can lead to increased pollutants in coastal areas. Waste waters from industries have potential negative impacts on coastal fisheries. These impacts range from relatively minor disturbances (such as temporary, localized turbidity increase) to major disruptions (e.g. water pollution caused by discharge of toxic chemicals). Aside from outright fish kills, pollution causes pervasive and continuous degradation that is evidenced by gradual disappearance of fish or shellfish or a general decline in natural carrying capacity of the system. The persistence of pesticides and other chemicals in bays and lagoons is of great concern. These can have a direct impact on the suitability of fish for human consumption.

Excess nutrients received by the aquatic environment from land sources often result in negative impacts due to excessive algae and oxygen deficiency. Land-based sources of pollution are believed to be responsible for more than 75% of marine pollution (Clark 1992). The rest comes from shipping, dumping, offshore mining and oil exploration and production.

Annex Table 2. Factors responsible for degradation of coastal zones/resources in India. 43 - most serious factor; 2.5 to 2.0 - serious factors; 1.5 to 1.0 - least serious factors, modified from Rajagopalan et al. 1996.

Factors	Seriousness index
Population pressure	4.0
Destruction of mangroves	2.5
Waste water disposal	2.5
Increasing urbanization	2.5
Solid waste disposal	2.5
Coastal constructions	2.5
Natural disasters	2.0
Ports	2.0
Coastal erosion	2.0
Atmospheric pollution	1.5
Aquaculture	1.5
Tourism	1.5
Increase of seawater?	1.5
Coastal mining	1.5
Power plants	1.5
Sea level rise	1.0
Coastal highways	1.0

Fisheries Institutions

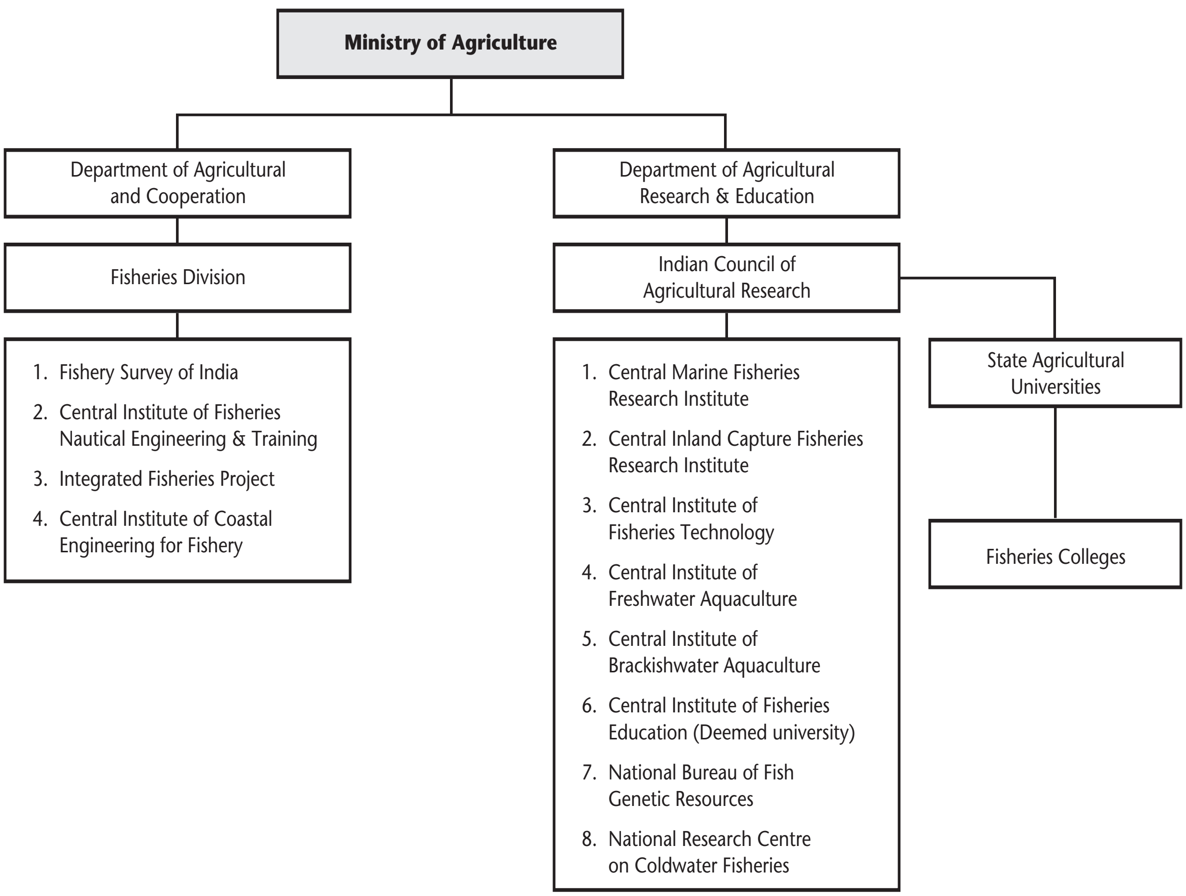
The Government of India firmly believes that the key to increase fish production is through application of science and technology. Consequently, effective research and extension programs, which are critical to the development of fisheries have been given priority. Different ministries, with the Ministry of Agriculture as nodal ministry, are involved in various fisheries activities such as research, management, development and coordination (Annex Fig. 3). The mandate of the institutions under the Ministry of Agriculture are given below:

Department of Agriculture and Cooperation (DAC)

The DAC acts as the nodal agency for development of inland, brackish-water and marine fisheries. It implements various production-oriented, infrastructure development and fishermen welfare programs either directly or through the maritime states/union territories. The department also negotiates with international agencies for obtaining financial technical assistance for specific fisheries projects in state/central sectors.

Fishery Survey of India (FSI)

The activities of FSI are aimed at exploration, development and management of deep-sea fishery resources through survey and biological/technical research, the results of which provide the government with scientific information for formulation of deep-sea fishery policies and development plans. The FSI also provides advice to the fishing industry and to development and financing institutions concerning fishing vessels, fishing gear and fish resources. The FSI has headquarters in Mumbai



Annex Fig. 3. Organization of the Ministry of Agriculture, Government of India.

(Maharashtra) and zonal bases in Porbandar (Gujarat), Mormugoa (Goa), Cochin (Kerala), Chennai (Tamil Nadu), Visakhapatnam (Andhra Pradesh) and Port Blair (Andaman & Nicobar Islands).

Central Institute of Fisheries, Nautical Engineering and Training (CIFNET)

The objectives of the Institute are to: (i) train manpower to man ocean-going fishing vessels, to run infrastructure establishments and to train technical teachers to man fishers' training centers attached to the maritime states and the union territories, (ii) provide a technical consultancy service in marine fisheries with particular reference to technical manpower requirements, (iii) conduct studies on fishing craft, gear and equipment and provide extension training to accelerate advancement in fisheries technology, and (iv) help developing nations in Southeast Asia, Middle East and Africa to train technical manpower for fishing. The CIFNET headquarters is in Cochin (Kerala) and centres are in Chennai (Tamil Nadu) and Visakhapatnam (Andhra Pradesh).

Integrated Fisheries Project (IFP)

The objectives of the project are to: (i) convert low-value fish obtained from the deep-sea into value-added products and study the commercial feasibility of deep-sea fishing, (ii) optimize and popularize the utilization of low-value fishes by converting them into value-added products, (iii) develop suitable animal/poultry feed making use of fish waste offal, and (iv) provide necessary infrastructure and maintenance facilities for fishing vessels belonging to the government and fishing industry. The IFP headquarters is in Cochin (Kerala) and there is a centre in Visakhapatnam (Andhra Pradesh).

Central Institute of Coastal Engineering for Fishery (CICEF)

The objectives of the Institute are to: (i) undertake engineering and economic investigations and the preparation of project feasibility reports for development of fishing harbors, (ii) locate sites suitable for brackish-water farms, develop engineering designs and prepare techno-economic feasiblity reports on the sites, and (iii) establish guidelines for designing coastal farms and train personnel to undertake feasibility studies. The Institute is located in Bangalore (Karnataka).

Department of Agricultural Research and Education (DARE)

DARE is the nodal department for fisheries research and education in the country. Research is carried out through the Indian Council of Agricultural Research (ICAR, which is an autonomous registered society attached to the Ministry of Agriculture) and the state agricultural universities. ICAR sponsors, coordinates and promotes research and education in agriculture, veterinary and fisheries science. The ICAR has 5 central fisheries institutes, one deemed a university, one a national bureau and one a national research center:

Central Marine Fisheries Research Institute (CMFRI)

The mandate of the Institute is to: (i) assess and monitor the status of exploited and unexploited fish stocks in the Indian EEZ in relation to fishery dependent and independent factors, (ii) assess marine capture fisheries potential and production, (iii) evaluate the techno-economics and socio-economics of marine fishing operations, (iv) develop suitable mariculture technologies, test and transfer them to different target groups comprising fishers, farmers and industries, (v) monitor the health of coastal ecosystems in relation to fishing and pollution, (vi) conduct postgraduate teaching at master and doctoral levels in mariculture, and (vii) provide training and consultancy services on various aspects of marine capture fisheries and sea farming. The Institute's headquarters is at Cochin (Kerala) with one regional center, 11 research centers and 29 survey centers.

Central Inland Capture Fisheries Research Institute (CICFRI)

The mandate of the Institute is to: (i) develop systems for monitoring and improving production in natural and man-made inland water resources through stocking, optimum exploitation and conservation, (ii) evolve management systems for optimizing production, and (iii) provide training, extension and consultancy services on various aspects of inland capture fisheries. The Institute's headquarters is at Barrackpore (West Bengal) with 12 research centers and 6 field centers.

Central Institute of Freshwater Aquaculture (CIFA)

The mandate of the Institute is to: (i) develop

intensive and extensive freshwater fish farming systems for commercially important finfishes and shellfishes, (ii) conduct training and extension programs in freshwater aquaculture, and (iii) act as a nodal agency to provide scientific information for freshwater aquaculture development. The Institute's headquarters is at Bhubaneswar (Orissa) with five research centers.

Central Institute of Brackish-water Aquaculture (CIBA)

The mandate of the Institute is to: (i) develop techno-economically viable and sustainable culture systems for brackish-water finfishes and shellfishes, (ii) provide technology support for optimizing brackish-water productivity and production, and (iii) provide training, extension and consultancy services in brackish-water aquaculture. The Institute's headquarters is at Chennai (Tamil Nadu) with three research centers.

Central Institute of Fisheries Technology (CIFT)

Activities revolve around research and extension on fishing craft and gear, fish processing, biochemistry, microbiology, electronics and engineering. The Institute's headquarters is at Cochin (Kerala) with six research centers.

Central Institute of Fisheries Education (CIFE)

CIFE is a deemed University. Its mandate is to: (i) conduct postgraduate diploma and degree courses and doctoral programs, (ii) conduct short- and long-term training courses in different disciplines of fishery science, (iii) conduct research in basic disciplines of fisheries, and (iv) provide consultancy services. The Institute's headquarters is at Mumbai (Maharashtra) with four training centers and three fish farms.

National Bureau of Fish Genetic Resources (NBFGR)

The mandate of NBFGR is to: (i) collect, classify and evaluate information on genetic resources, (ii) catalogue genotypes, (iii) maintain and preserve fish genetic materials especially those of endangered species, and (iv) monitor introduction of exotic fish species in Indian waters. The Bureau is located in Lucknow (Uttar Pradesh).

National Research Center on Coldwater Fisheries (NRCCF)

The Center's mandate is to: (i) conduct research on assessment and management of coldwater fishery resources, (ii) monitor the factors affecting them, and (iii) conduct training and extension programs. The headquarters are at Haldwani (Uttar Pradesh) with two sub-centers.

There are 7 fisheries colleges under the State Agricultural Universities, which are engaged in teaching and research programs.

In addition to the Ministry of Agriculture, the following ministries of the Government of India are involved in the management and development of the marine fisheries sector.

Ministry of Commerce

The Marine Products Export Development Authority (MPEDA), Cochin, under the Ministry of Commerce, Government of India, is the nodal organization for regulation, development and promotion of export of Indian marine products. In addition to promotion of exports, the mandate of the MPEDA includes: (i) developing offshore and deep-sea fishing through promotion of joint ventures, (ii) rendering financial and other assistance and acting as an agency for extension of relief and subsidy, and (iii) helping the fishing industry in processing and exporting value-added seafood.

Ministry of Food Processing Industries

The Ministry has the following two schemes on seafood processing:

i. Scheme for tuna and other fish processing: Under this scheme, it is proposed to assist public sector/joint sector/state level cooperatives by providing grants to the extent of 50% of the capital cost to establish modern fish processing plants for tunas, shrimps, lobsters and trash fishes.
ii. Scheme for setting up of cold chain: This is a scheme for the development of infrastructure facilities such as cold storage, ice plants and insulated vehicles for preservation and supply of fish at major fish producing and marketing centers.

Input for fisheries research and development also comes from the National Institute of Oceanography, NIO (Council of Scientific and Industrial Research), the Department of Ocean Development, DOD, and the National Remote Sensing Agency, NRSA (Department of Space). The NIO conducts research on exploitation of living and non-living ocean resources. The mandate of NIO includes coastal zone management, oceanographic surveys and resources mapping in the EEZ of India. The NRSA is the nodal agency for satellite data acquisition, data processing and dissemination, and various research disciplines including oceanography and forecasting. The NRSA program on marine fisheries has the following two objectives: (i) to provide information on sea surface temperature (SST) and (ii) to utilize the SST information for identifying Potential Fishing Zones (PFZs) and disseminate such information for the benefit of fishers.

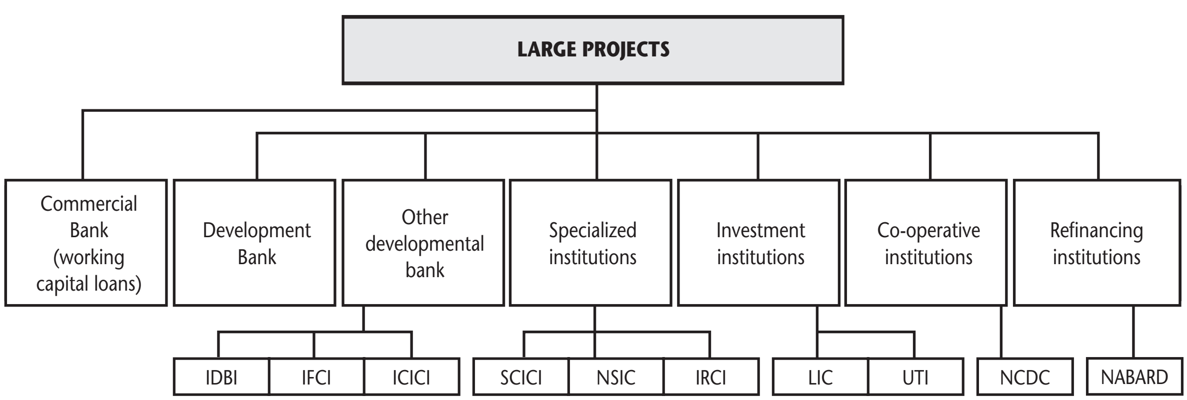
Anna University (Tamil Nadu) and Jadavpur University (West Bengal) are involved in coastal zone management.

In India, the major sources of long-term finance for capital expenditure are various lending institutions such as Industrial Finance Corporation of India (IFCI), Industrial Credit and Investment Corporation of India (ICICI) and Industrial Development Bank of India (IDBI). These apex lending institutions provide financial support either directly through their specialized subsidiaries to deal with specific sectors such as Shipping Credit and Investment Corporation of India (SCICI) or through the State Finance Corporations (SFC). The National Cooperative Development Corporation (NCDC) provides financial support to help cooperative institutions. The National Bank for Agriculture and Rural Development (NABARD) operates as a separate financial agency to provide refinancing facilities for primary lending to agricultural and agro-industrial projects made by the commercial banks. Thus, there exists an elaborate structure of institutional finance which caters to large (Annex Fig. 4) and medium and small projects (Annex Fig. 5) of the fisheries sector.

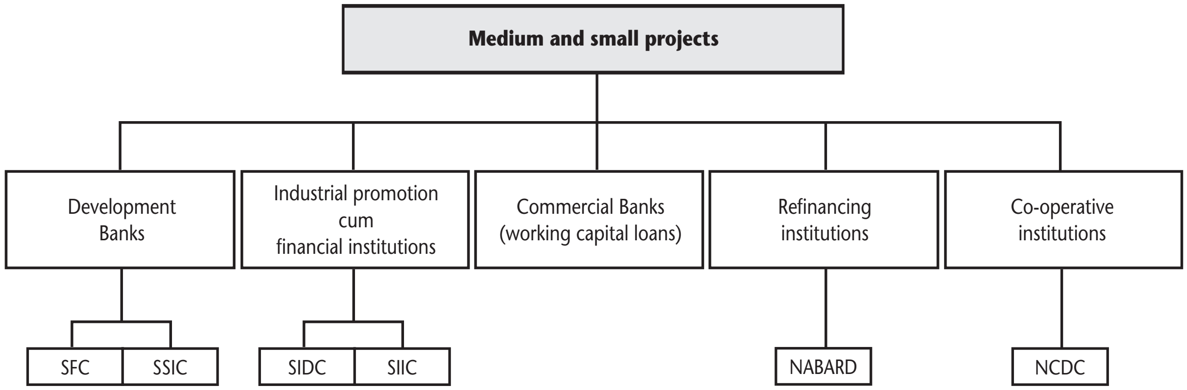
Among the various financial institutions, the role of four institutions currently engaged in providing direct or indirect finance for the fisheries sector is given below:

Shipping Credit and Investment Corporation of India (SCICI)

The involvement of SCICI in the fishing industry is generally confined to providing development finance to deep-sea fishing. In an effort to expand involvement, SCICI has announced its commitment to support shore facilities and processing. In pursuit of its objectives of promoting development, SCICI provides financial assistance to enterprises in the following forms: (i) loans in Indian currency repayable over a period of 15 years; (ii) loans in foreign currencies for acquisition of large fishing vessels, imported capital equipment and technical services; (iii) guaranteeing payments for credit given by Indian and foreign sources; (iv) under-



Annex Fig. 4. Structure of financing institutions for large projects in India.



Annex Fig. 5. Structure of financing institutions for medium and small projects in India. See Text.

writing of public and private issues and offers of sale of industrial securities; (v) direct subscription to such securities; and (vi) credit facilities to indigenous manufacturers for promoting industrial equipment on deferred payment terms, and equipment-leasing facility.

Industrial Development Bank of India (IDBI)

Activities of IDBI may be broadly classified as follows: (i) direct assistance to industrial concerns in the form of loans, underwriting and subscription to shares and debentures and guarantees; (ii) refinancing of industrial loans granted by banks and other financial institutions; (iii) rediscounting of bills arising out of sales of indigenous machinery on deferred payment basis; (iv) finance for exports in the form of direct loans and guarantees by buyers abroad in participation with commercial banks, and refinancing of medium term export credit granted by commercial banks; and (v) assistance to other financial institutions by way of subscription to their shares and bonds.

National Bank for Agricultural and Rural Development (NABARD)

The main objective of NABARD is to extend refinancing support to purchase artisanal and mechanized craft and for the development of infrastructure in the fishing industry with the prime objective of increasing fish production. The majority of schemes submitted by financing banks to NABARD are for financing the purchase of mechanized fishing vessels along with gear and deck equipment. NABARD provides refinance for craft ranging from traditional fishing craft such as catamarans and dugout canoes to deep-sea fishing vessels. However, the majority of refinanced vessels belong to the 8 - 15 m overall length category. Refinance facilities are also available for establishment of ice plants, cold storage, freezing plants, canning plants, fishmeal plants and for transport, distribution and marketing of fish. For instance, refrigerated trucks or insulated trucks, fish stalls and deep freezers are covered by NABARD refinance.

National Cooperative Development Corporation (NCDC)

NCDC has responsibility for planning and promoting country-wide programs through cooperatives by way of additive and supplemental financial assistance to the efforts of state governments. In the fisheries sector, assistance by NCDC is for development of infrastructure facilities. Assistance is provided to fishers cooperatives to set up fish markets and retail booths; for purchase of refrigerated/insulated vans; establishment of processing units, boat-building and repairing yards; and purchase of boats, nets and other equipment. The corporation also implements a central government scheme for introduction of improved beach landing craft for small fishers, and provides assistance in the form of loans and subsidy.

Status and Management of the Java Sea Fisheries

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Purwanto, 2003. Status and management of the Java Sea fisheries, p. 793 - 832. *In* G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceeding 67, 1 120 p.

Abstract

The Java Sea is a major fishing ground in Indonesia contributing 31% of the national marine fisheries production. Demersal and small pelagic fishery resources account for most production in the area. During the 1960s and 1970s, strong demand for fish, which in Indonesia resulted from both increased human population and increased per capita fish consumption, stimulated the development of fishing in the Java Sea. This led to development of up-stream and down-stream industries, increases in employment opportunities, and increases in the number of fishers and fishing households.

Like most Indonesian fisheries, the Java Sea fisheries may be characterized as *de facto* open access with no restrictions on fishing effort. Free competition occurs among large-scale and small scale fishers. Increasing numbers and sizes of fishing gear and boats, as well as extension of operations into new fishing grounds, have resulted in biological and economic over-exploitation. Meanwhile, the quality of coastal habitats such as mangroves and coral reefs has decreased due to adverse effects of human activities. Over-exploitation, as indicated by decreases in CPUE and profit per vessel, and environmental degradation has led to poverty of fishers in coastal areas. Small scale fishers who comprise the majority of fishers have suffered most because the small boats they operate are less efficient.

Fisheries management in the Java Sea would involve controlling fishing effort, which in turn would require the provision of alternative livelihood for displaced fishers. This paper describes key features of an "Integrated Program of Fisheries Management and Development for the Java Sea", and outlines the activities for improving fisheries management in the area. Among other things, the program calls for establishment of a Fisheries Management Body to implement management at a regional level with the central government supervising the provincial governments. All stakeholders should be involved in managing the fisheries. Beyond the Java Sea fisheries, two actions are recommended to promote regional co-operation and sharing of experiences with other countries. These are (1) networking for transfer of information and experiences on fisheries co-management, and (2) regional pilot projects for shared stock management.

Introduction

The Java Sea is an important area for small scale fisheries in Indonesia. The Java Sea fisheries supply fish for consumption and processing, support marketing industries and provide jobs. In 1997, the Java Sea fisheries contributed about 31% of the national marine fisheries production Directorate General of Fisheries (DGF 1999a). Demersal and small-pelagic fishery resources are the main contributors to fisheries production. Various traditional fishing gears have exploited these fishery resources long before Indonesian independence (Butcher 1995; Dwiponggo 1987). The demersal fishery rapidly developed after the introduction of trawl fishing during the late 1960s, prompted by strong international demand for shrimp (Bailey and Dwiponggo 1987). Meanwhile, the small pelagic fishery developed rapidly after the introduction of purse seines during the early 1970s (Bailey and Dwiponggo 1987).

Development of trawl fishing threatened the sustainability of demersal stocks and resulted in serious conflict between small scale fishers and trawl fishers. In response, the Government of Indonesia banned trawl fishing through the promulgation of Presidential Decree No. 39 in 1980. However, other demersal fishing gear emerged after the trawl ban. This increased fishing pressure on coastal demersal fishery resources off the northern coast of Java. Consequently, catch rates decreased again. Increased fishing pressure has resulted in over-exploitation of the demersal resources in inshore areas. Similarly, the purse seine fleet grew rapidly. Sizes of fishing gear and boats have increased to extend fishing areas. Consequently, the small-pelagic resources in the Java Sea are reportedly over-exploited National Commission on Stock Assessment of Marine Fisheries Resources (NCSAMFR) 1998.

Under conditions of open access and free competition among large scale and small scale fishing fleets, the small scale fishers are disadvantaged since they use less efficient gear. The result is widespread poverty among small scale fishers (Purwanto 1995). In addition, the current economic slowdown exacerbates poor socioeconomic conditions among small scale fishers. The problem is extensive since small scale fishers comprise a large majority of fishers Directorate General of Fisheries (DGF 1999a).

Management of the Java Sea fisheries is required to ensure sustainability of the fisheries and to optimise economic benefits from utilization of the resources. Fisheries management will require reducing fishing effort, which in turn will need the provision of alternative livelihood for many fishers. A development program for such a purpose is clearly needed. This study proposes an integrated management and development program for the Java Sea fisheries. It is based on a review of the area's coastal environment, fishery resources, and socioeconomic setting. The study also reviews legal and institutional aspects relevant to fisheries management, then focuses on the coastal capture fisheries, particularly on their economics and exploitation status. Finally, the foregoing are considered in an analysis of management issues and opportunities, and the major elements of the management and development program are briefly described.

Coastal Environment

Indonesia is an archipelagic state composed of over 17 000 islands with a coastline of about 81 000 km. The country has a total land area of about 1.9 million km^2. The marine fishery area of Indonesia is about 5.8 million km^2, consisting of territorial and archipelagic waters of 3.1 million km^2 and an Exclusive Economic Zone (EEZ) of 2.7 million km^2.

The Java Sea is located southeast of the China Sea, bounded by Java on the south, Sumatera on the West, Kalimantan (Borneo) on the north, and Makassar Strait and Flores Sea on the east (Fig. 1). The area of the Java Sea is estimated to be about 542 469 km^2.

The Java Sea consists mainly of shallow waters. About 54% of the Java Sea is less than 40 m; the average depth is about 40 m (Emery et al. 1972).

Environmental conditions in the Java Sea are predominantly influenced by monsoon winds. These winds create substantial seasonal changes in the direction and strength of currents, water salinity, and primary productivity (Wyrtki 1961). The Northwest (NW) monsoon, which coincides with the rainy season, reaches its peak in December to February, and is characterized by very windy periods with frequent rainfall. On the other hand, the Southeast (SE) monsoon coincides with the dry season and peaks in June to August.

The main mangrove areas in Indonesia are in Sumatra, Kalimantan and Irian Jaya. Specifically, mangroves occur in coastal areas of West Sumatra,

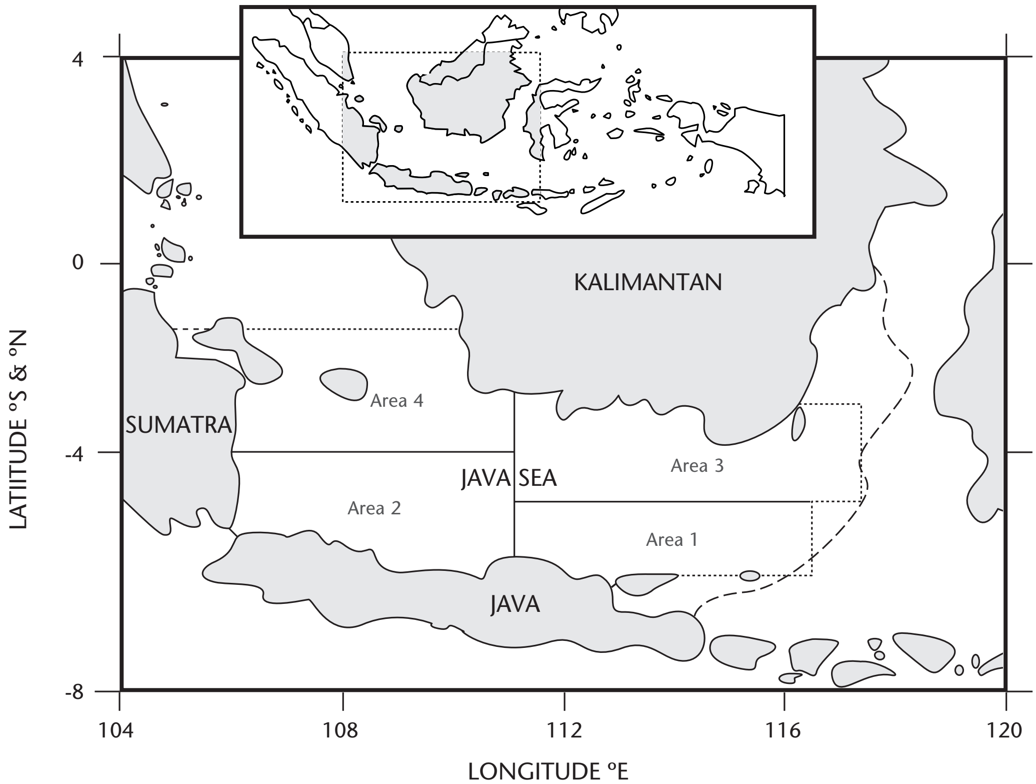

Fig. 1. Location of the Java Sea.

the eastern coast of Sumatra, the southern coast of Irian Jaya, and the western, southern and eastern coast of Kalimantan (Moosa et al. 1996). There are at least 47 mangrove species in Indonesia (Office of the Minister of Environment. Department of Forestry. Indonesian Institute of Sciences. Department of Home Affairs and Mangrove Foundation (OME-DF-IIS-DHA-MF) 1997).

The area of mangrove in Indonesia decreased by about 1 million ha and about 0.8 million ha during the periods 1982 - 87 and 1987 - 93, respectively. The area of coastal aquaculture, brackish-water ponds, by contrast, has only increased by about 40 thousand ha and about 70 thousand ha during the periods 1982 - 87 and 1987 - 93, respectively. It seems that coastal aquaculture was not the main cause of mangrove destruction in Indonesia. Silvofish culture has been introduced in order to conserve the mangrove resources while allowing local people to earn their livelihood (Purwanto 1999).

Table 1. Areas of Mangrove and Brackish-water Ponds in Indonesia (in 1 000 ha).

		1982	1987	1993
1.	Mangrove [a]	4 251.0	3 235.7	2 490.2
2.	Brackish-water ponds [b]	220.4	263.2	331.8

Sources: [a] OME-DF-IIS-DHA-MF 1997; [b] DGF 1997; DGF 1998.

Indonesian coral reef communities are among the most diverse in the world. In 1984, the *Snellius II* Expedition surveyed nine areas in the eastern part of the archipelago and collected approximately 350 scleractinian coral species, belonging to 75 coral genera (Borel-Best et al. 1989). The three most important reef-building coral genera in Indonesia, *Acropora, Montipora* and *Porites*, are represented by a large number of species (Moosa et al. 1996).

The sustainability of Indonesian coral reefs is threatened. An assessment based on living coral cover at 421 stations in 43 different areas reported that only 6.4% of the reef areas are in excellent

condition, 24.3% in good condition, 29.2% in fair condition, and 40.1% in poor condition (Suharsono 1998). Destruction of coral reefs is mainly caused by blast-fishing, the use of poisons for catching ornamental fishes, and coral mining The World Bank (WB 1998).

Fishery Resources and Potentials

The National Commission on Stock Assessment of Marine Fisheries Resources (NCSAMFR 1998) categorised fishery resources of Indonesia into seven groups (Table 2). The maximum sustainable yield (MSY) of fishery resources in Indonesia is estimated to be about 6.26 million t (Agriculture Ministerial Decree no. 995 of 1999) (Table 2). At the national level, small pelagics and demersals can be considered the main resources since they contri-bute 52.4% and 28.9%, respectively, of total MSY.

Table 2. Estimate of maximum sustainable yield ($x10^3$ t) of marine fisheries resources of Indonesia and the Java Sea, 1997 [a].

Fishery Resources Groups	National	Java Sea (includes Sunda Strait)
Small pelagic	3 236	340
Large pelagic	1 054	55
Demersal	1 786	431
Crustacea:		
Penaeid prawns	74	11
Lobster	5	0.5
Carangids	76	9.5
Ornamental fishes [b]	(1.52×10^9)	(3.4×10^7)
Squids	28	5.0
TOTAL	6 259	852

Note: [a] Agriculture Ministerial Decree No. 995 of 1999; [b] number of individuals.

About 13.7 % of potential yield in Indonesia comes from the Java Sea. The MSY of fishery resources is about 852 000 t (Table 2). The two main fishery resources are small pelagic and demersal fishes. The demersal fish stocks contribute about 50.8 % of MSY while small pelagics contribute about 40.1 %.

Table 3 gives mean densities of demersal fish at different areas and depths in the Java Sea estimated during 1974 - 76. The highest stock density of 5.2 t•km^{-2} occurred in the northern coast of the Province of East Java (*Area 1*), between 50 and 59 m depth. The lowest stock density of 0.8 t•km^{-2} occurred in the northern coast of the Province of West Java (*Area 2*), which has heavily exploited shallow waters (Pauly et al. 1996).

Table 4 presents biomass estimates of demersal fish in the Java Sea by area and depth. *Area 4* on the southern coast of Central Kalimantan had the highest standing stock of demersal fish during 1974 - 76.

Socioeconomic Background

The population of Indonesia stood at 195 million in 1995. The annual growth rate has declined, from 2.32% during 1971 - 80 to 1.66% during 1990 - 95. Most of the population is concentrated in the western part of Indonesia, with Java being the most populated island. Java accounts for only about 6.6 % of the total area of Indonesia, but 59% of the population resided there in 1997. In 1997, the population density of Indonesia was about 104 persons/km^2, while the population density in Java was about 926 persons/km^2 Central Board of Statistics (CBS 1998).

In Indonesia most of the employed population (41.2 %) worked in the agricultural sector in 1997 (CBS 1998). The number of fishers was about 2.1 million (435 000 fishing households) (Fig. 2). The number of fishers and fishing households increased from 1.4 million persons and 356 000 households in 1988 Directorate General of Fisheries (DGF 1999a). The rates of increase of the number of fishers and fishing households were about 4.4 % year^{-1} and 2.30 % year^{-1}, respectively, during 1988 - 97.

The fishers can be categorised as full-time fishers, part-time fishers mainly engaged in fishing activities, and part-time fishers mainly engaged in non-fishing activities. The proportion of the population employed as full-time fishers increased from 49.5% in 1988 to 50.9% in 1997. Among part-time fishers, those mainly engaged in fishing and those mainly engaged in non-fishing activities in 1988 accounted for 37.1% and 13.5% of the total number of fishers, respectively. In 1997, part-time fishers mainly engaged in fishing activities and thosemainly engaged in non-fishing activities represented 34.3% and 14.8% of the total number of fishers, respectively.

Table 3. Mean stock density (t·km^{-2}) of demersal fish in the Java Sea by area and depth using data from trawl surveys by the *R/V Mutiara 4* from November 1974 to July 1976 estimated by the swept area method.

Depth range (m)	Area 1 (East Java)	Area 2 (West Java)	Area 3 (West Kalimantan)	Area 4 (Central Kalimantan)
10 - 19	3.0	0.8	2.1	4.8
20 - 29	2.5	2.7	2.4	4.3
30 - 39	1.9	2.4	2.5	2.1
40 - 49	3.2	2.2	2.2	1.4
50 - 59	5.2	1.9	1.6	–
60 - 69	3.4	1.9	1.5	–
70+	1.5	1.5	–	–

Source: Pauly et al. (1996).

Table 4. Biomass (x10^3 t) of demersal fish in the Java Sea by area and depth during the period from November 1974 to July 1976.

Depth range (m)	Area 1 (East Java)	Area 2 (West Java)	Area 3 (West Kalimantan)	Area 4 (Central Kalimantan)	Total
10 - 19	6.2	6.5	37.5	138.6	188.8
20 - 29	14.8	64.0	59.5	124.2	262.4
30 - 39	12.7	34.2	67.7	115.5	230.2
40 - 49	41.7	111.8	61.4	10.1	225.0
50 - 59	85.2	47.3	24.8	–	157.3
60 - 69	142.9	6.8	8.2	–	157.9
70+	58.6	1.4	–	–	60.0
TOTAL	362.2	272.0	259.1	388.4	1 281.7

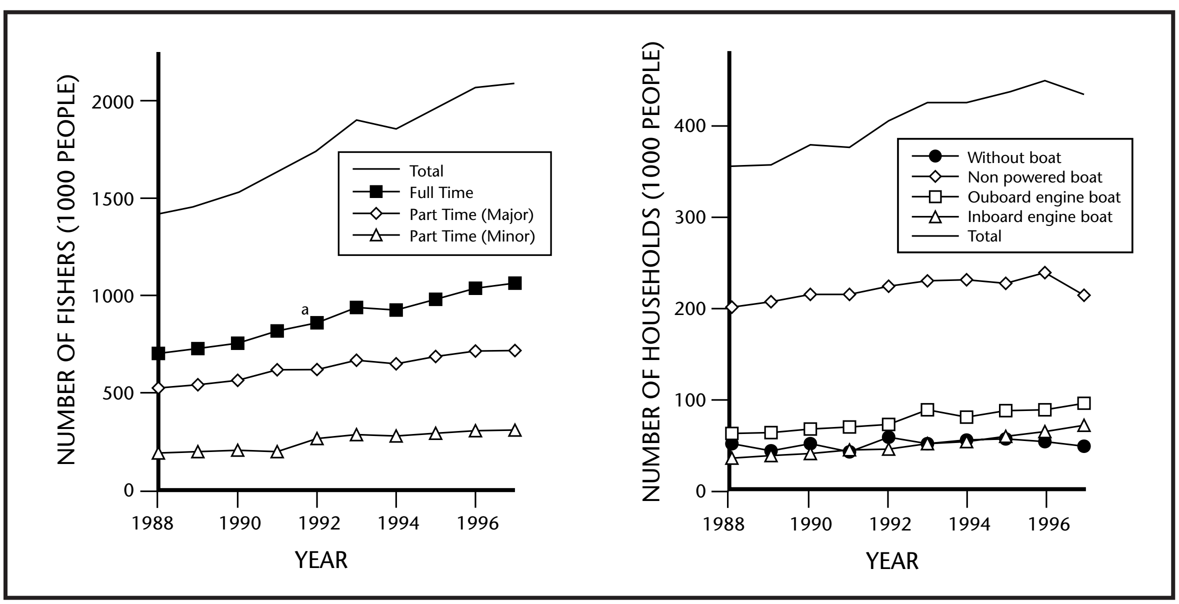

Fig. 2. Number of fishers and fishing households in Indonesia, 1988 - 96.

Most fishing households in Indonesia are engaged in small scale fishing, using non-powered boats, outboard engine boats or small-sized (≤ 5 gross ton) inboard engine boats. In 1997, 49% of fishing households operated non-powered boats, 22% operated boats with outboard engines and 17% operated boats with inboard engines (DGF 1999a). From 1988 to 1997, households operating boats with outboard engines and those operating boats with inboard engines increased at 5% $year^{-1}$ and 8% $year^{-1}$, res-pectively. On the other hand, the number of households without boats and those with non-powered boats increased at lower rates of 0.5% $year^{-1}$ and 0.8% $year^{-1}$ respectively, during the same period.

In 1997, there were 54 000 fishing households on the northern coast of Java and 16 000 on the southern coast of Kalimantan (DGF 1999a), representing 12.3% and 3.8% of the total fishing households respectively, in Indonesia. Most fishing households (77.8%) on the northern cost of Java operate boats with outboard engines. In contrast, most fishing households (54.1%) on the southern coast of Kalimantan operate boats with less powerful inboard engines.

Fish is the main source of animal protein in Indonesia, accounting for about 60.2% of total animal protein consumption in 1997. However, plant products are still the main protein source Central Board of Statistics (CBS 1998). Average per capita fish consumption increased during 1989 - 98 at a rate of 2.41% $year^{-1}$ and stood at 19.3 kg•$capita^{-1}$•$year^{-1}$ in 1998 (Fig. 3).

The gross domestic product (GDP) of Indonesia increased at the rate of 7.1% $year^{-1}$ during 1993 - 97, but decreased during 1998 - 99 due to the economic crisis. The GDP of Indonesia in 1998 was 13.2% lower than in 1997. By 1999, the national economy had not yet recovered from the crisis. Meanwhile, the GDP from fisheries increased continuously, even during the economic crisis. The rate of increase during 1993 - 97 was about 5.3% $year^{-1}$. The GDP from fisheries in 1998 was 4.1% higher than in 1997.

The Government of Indonesia has developed fisheries infrastructure to support the development of marine fisheries. The infrastructure consists of fishing ports and fish landing places. The optimal service capacity of existing fisheries infrastructure in Indonesia is only about 887 000 t•yr^{-1}. This can only accommodate about 25 % of 1997 marine fisheries production. Most fishing ports and fish landing places are located in the western part of Indonesia, primarily in Java and Sumatera. Total service capacity of the infrastructure in western Indonesia is about 671 000 t•$year^{-1}$ (i.e. 76 % of the

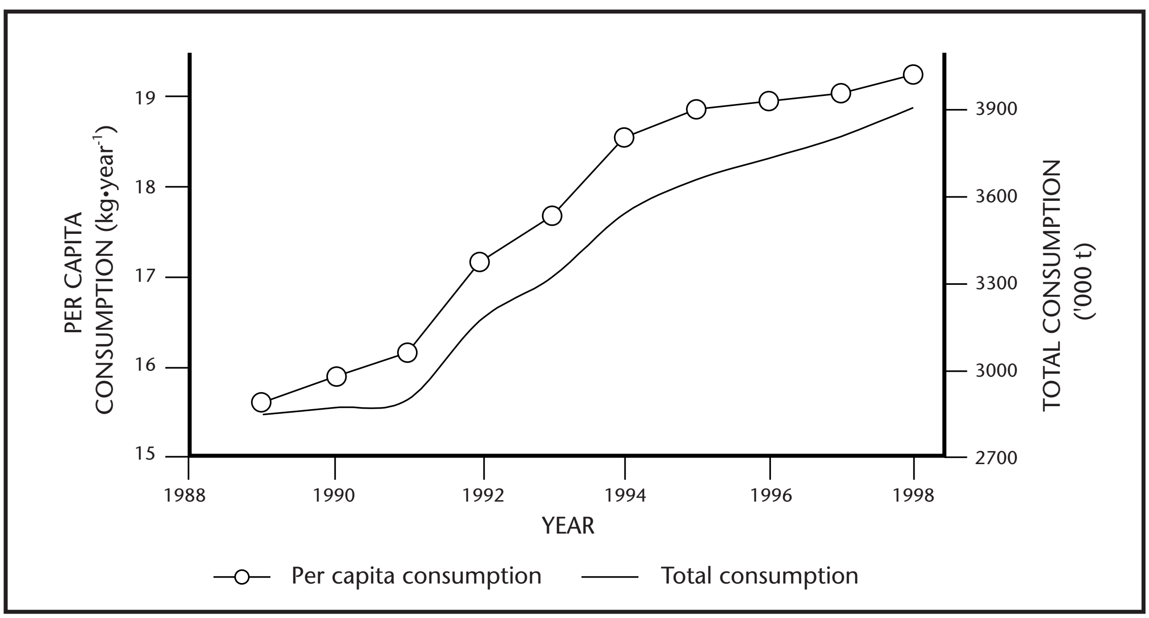

Fig. 3. Fish Consumption in Indonesia, 1989 - 98.

total service capacity country-wide). Infrastructure in western Indonesia can only accommodate 28.4% of marine fishery production. The largest fishing ports of Indonesia are located in Pekalongan and Jakarta on the northern coast of Java.

Institutional and Legal Background

All laws and regulations dealing with fisheries have their roots in the 1945 Constitution, in particular Article 33, Sub-Article 3, which provides the legal basis for State control over Indonesia's land and waters and the natural resources therein. There are two main laws currently in force dealing with fishery-related activities - Act No. 5 of 1983 and Act No. 9 of 1985. Act No. 5 of 1983 deals with the Indonesian Exclusive Economic Zone (IEEZ). Act No. 9 of 1985 deals with all aspects of fisheries, including fishery areas, management, exploitation, development, delegation of authority to local governments, control and surveillance, and penalties. The government has issued a number of regulations to implement Act No. 5 of 1983.

Laws and regulations on marine fisheries before the 1980s focused mostly on coastal and small scale fisheries (Bailey 1987). Since then, concern for small scale fisheries has remained but the coverage of policies has extended to include fisheries in the IEEZ. Such policies reflect the commitment of Indonesia to implement the 1982 UNCLOS.

Sustainability and productivity of marine fishery resources are affected not only by fishing pressure but also by environmental quality. Thus, a number of environmental laws also protect fishery resources. An example is Act No.5 of 1990 concerning the conservation of living resources and their ecosystems. Among the regulations made to implement this Act is a regulation to protect endangered species, including some fish species.

Despite the economic crisis, the fisheries sector contributes positively to the Indonesian economy (Subagyo 1998; Surono 1998). A development program called PROTEKAN 2003 (*Program Peningkatan Ekspor Hasil PeriKANan* 1999 - 2003) seeks to further develop the fisheries sector to assist in the recovery of the Indonesian economy (DGF 1999b). The main objective of the program is to boost the export of fisheries commodities to increase foreign exchange earnings. Other objectives of the program are to increase fishers' and farmers' incomes, to provide new employment opportunities and to increase domestic fish consumption. This program is currently being revised to meet current economic conditions.

The program also seeks to increase aquaculture production and utilization of under-exploited fish stocks. This will require the problems in marine fisheries and aquaculture to be addressed. In marine fisheries, problems include: the lack of infrastructure especially in eastern Indonesia, ineffective surveillance, and the predominance of artisanal fisheries characterized by limited capital and technical capabilities. The problems in aquaculture include: shrimp disease outbreaks and inadequate irrigation systems. Thus, capture fisheries and aquaculture are to be developed and supported via product quality improvement, product diversification, market development, infrastructure development and improvement of the quality of human resources engaged in fisheries. Hazards Analysis and Critical Control Point (HACCP) regulations will be applied to increase the quality of fishery products. Also, the Code of Conduct for Responsible Fisheries Food and Agriculture Organisation (FAO 1995) will be adopted to guarantee sustainability of the resources.

Among under-exploited stocks targeted for increased utilization are tuna, pelagic species (including small pelagics) and demersal species (including shrimps). Increasing productivity and the number of vessels will do increase this utilization. Development of capture fisheries is expected to contribute about one-fourth of targeted foreign exchange earnings. Aquaculture development is expected to contribute the remainder. Aquaculture will be developed through (1) intensification of under-utilised aquaculture areas, and (2) extension of aquaculture areas into potential areas outside Java Island. The main cultured species will be shrimps, which are expected to contribute about two-thirds of targeted foreign exchange earnings. Other species to be cultivated include seabass, grouper, pearl oyster and seaweed.

Management of fishery resources in Indonesia involves a number of activities, including: stock assessment, establishment of total allowable catch, control of fishing effort, surveillance and law enforcement, monitoring of fishery resources utilisation, and protection and rehabilitation of the aquatic environment. Stock assessment is conducted to determine the distribution and abundance of fish stocks as well as the level of exploitation com-

pared to the MSY. If a stock is under-exploited, the possibility of further exploitation is investigated. The Government establishes total allowable catch (TAC) on the basis of biological parameters. Currently, the TAC for most stocks is 80% of MSY and is used as a target reference point. Ideally, the TAC should be established using also the socioeconomic characteristics of fisheries.

To control fishing effort, the Government imposes a licensing system and zoning of fishing activities. Fishing boats of 5 GT or larger require licenses to fish. Surveillance and law enforcement are carried out to ensure compliance with fisheries laws and regulations, and to prevent unauthorised fishing in Indonesian waters. The fisheries management system needs a number of improvements. In particular, monitoring, control and surveillance (MCS) should be integrated and strengthened to ensure effective management. Priority should be placed on strengthening the surveillance component, which is currently the weakest component of the MCS system. In this regard, the Government has conducted training and workshops for fishery officers and representatives from the Police and the Navy.

National institutions directly involved in the administration, development and management of fisheries in Indonesia are the Directorate General of Fisheries (DGF), the Directorate General of Marine Surveillance and Protection (DGSP) and the Central Research Institute for Fisheries (CRIFI). At the local level, the Provincial and the District Fisheries Services regulate fisheries.

The functions of DGF include fishery resources monitoring, evaluation, allocation and management through the issuance of licenses and the formulation of regulations. DGF issues fishing licenses for fishing vessels greater than 30 GT, using engines of more than 90 HP, and those operating in the IEEZ. It has five developmental centres that serve as technical implementation units in various fields, including fishing techniques, and fish quality and processing. In assessing the state of stocks in Indonesian waters, DGF receives support from the National Commission on Stock Assessment of Marine Fisheries Resources, which is composed of scientists from CRIFI / Research Institute for Marine Fisheries (RIMF), Bogor Agriculture University, the National Institute for Aeronautics and Space, and the Agency for the Assessment and Application of Technology.

The DGSP is in charge of marine protected area management, marine biodiversity preservation, living marine resources rehabilitation, management of living marine resource conservation areas, and surveillance of ecosystem utilisation. CRIFI supplies biophysical information on fishery resources to implementing agencies, as well as to fishers and the fisheries industry.

The Provincial and District Fisheries Services are responsible for administration of local fisheries, including implementation of fishery resources management under the technical guidance of DGF. The Provincial Fisheries Services issue licenses for local fishing vessels of 30 GT or less, using engines of not more than 90 HP. The main functions of the District Fisheries Services are to disseminate information and technology, provide technical backstopping through extension, and collect statistics.

To manage fishery resources that are shared by fishers from different provinces, DGF created management zones and initiated establishment of the Coordinating Forum for Management and Utilisation of Fishery Resources (*Forum Koordinasi Pengelolaan Pemanfaatan Sumberdaya Ikan* - FKPPS) for each management zone. The Forum consists of representatives from DGF, Provincial Governments/Fisheries Services, and other government agencies. The main tasks of each Forum include the allocation of fishing effort, coordination in issuance of fishing licenses, monitoring of utilisation of fish stocks, implementation of surveillance, and evaluation of management measures.

Pursuant to the Autonomy Act No. 22 of 1999, responsibilities of government agencies are being redefined and significant changes are expected.

Coastal Capture Fisheries

Catch and Effort

The total number of marine fishing boats in Indonesia was about 402 000 units in 1997, of which 94% were artisanal/small scale units. The small scale fleet consists of non-powered boats, outboard engine boats and in-board engine boats of less than 5 GT. Boats in these categories are allowed to operate in coastal areas. The proportion of non-powered boats has decreased from 66% in 1988 to 57% in 1997. Fishing boats operating in the Java Sea accounted for about 16% of the total number in Indonesia in 1997. Fishers from the northern coast

of Java operated about 47 000 fishing boats while fishers from the western and southern coasts of Kalimantan operated 17 000 units.

Marine fisheries production of Indonesia increased from 2.2 million t in 1988 to 3.6 million t in 1997 (Fig. 4). Demersals, small pelagics and large pelagics largely accounted for the steady increases during the period. These three species groups dominate production at the national level and in the Java Sea (Fig. 4). Marine fisheries production in provinces around the Java Sea in 1997 was about 861 000 t or 24% of national production (DGF 1999a).

Six main types of gear caught about 50.3% of the national marine fisheries production in 1997, namely purse seine, drift and set gillnet, payang seinenets, and skipjack pole and line (Fig. 5). Catches of these fishing gear generally increased during 1988 - 97. Among these types of gear, the purse seine contributed the largest portion of national production in 1997.

The purse seine also contributed the largest portion of production on the northern coast of Java in 1997 (Fig. 6). In comparison, the drift gillnet contributed the largest portion of production off southern Kalimantan in 1997. Marine fisheries production on the northern coast of Java and southern coast of Kalimantan was 750 000 and 110 000 t respectively, in 1997 (DGF 1999a).

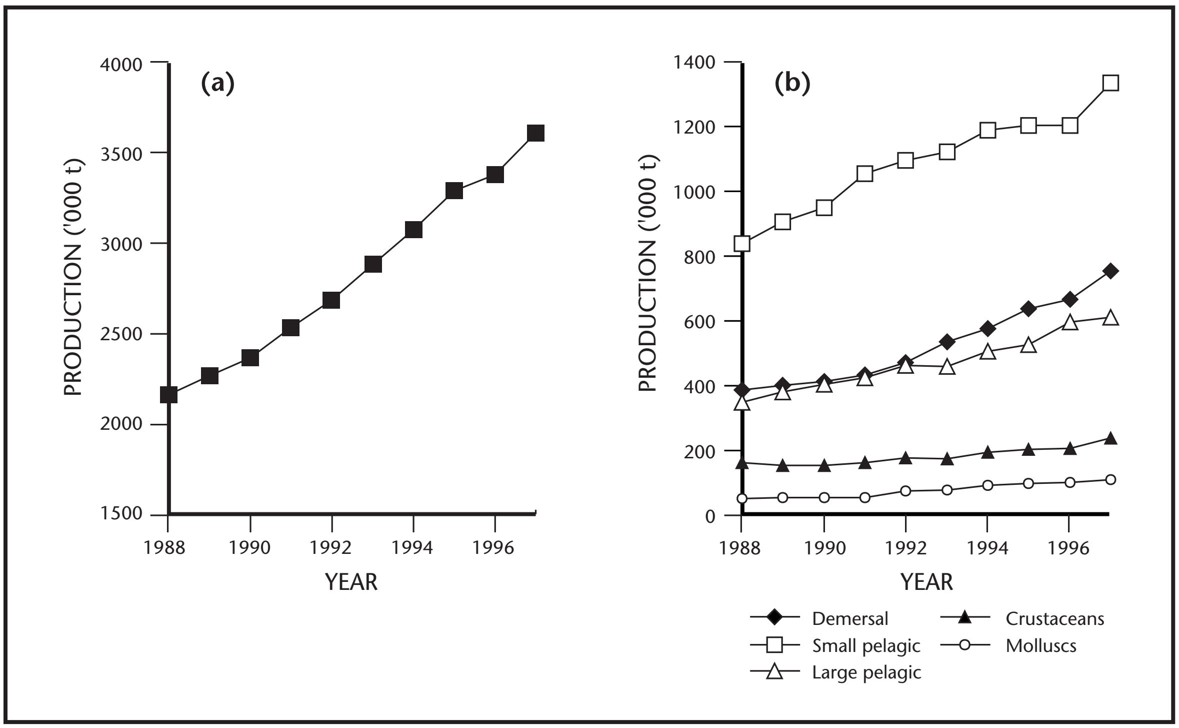

Fig. 4. (a) Marine fisheries production of Indonesia and (b) Marine fisheries production by species group from 1988 to 1997.

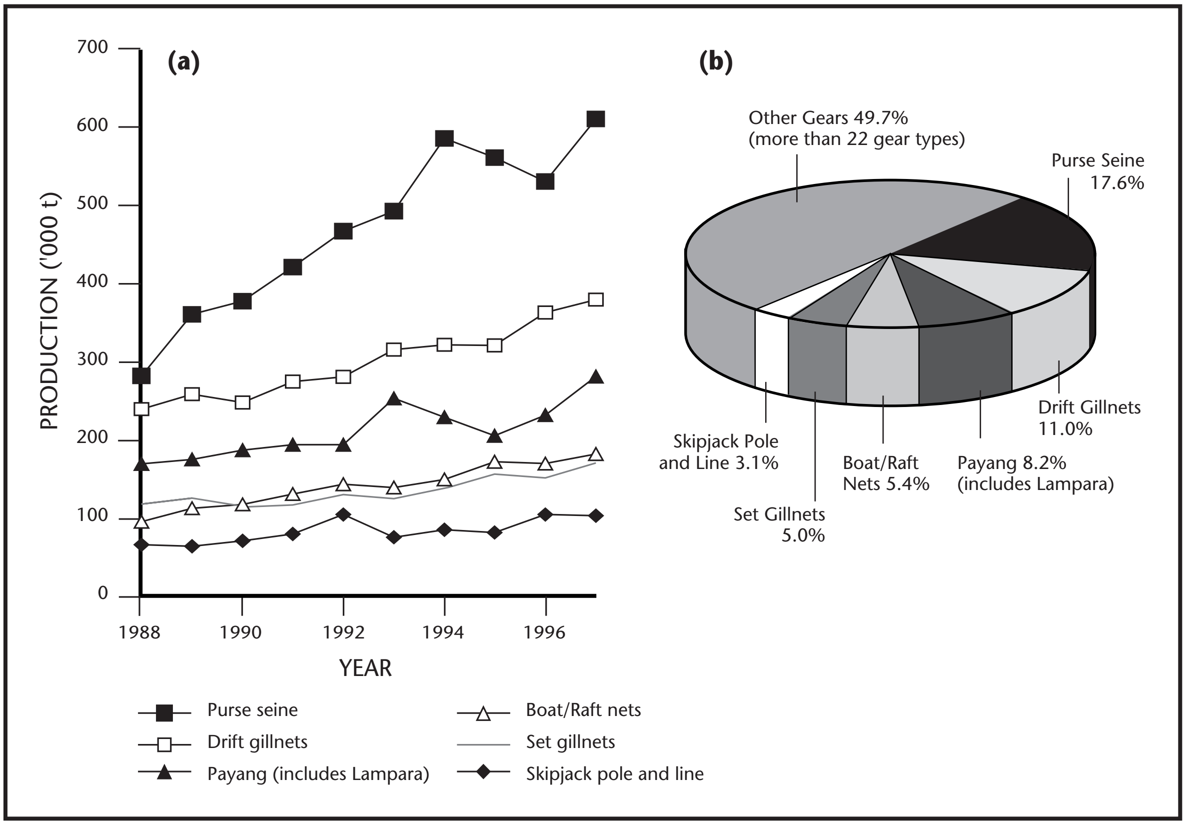

Fig. 5. (a) Production by six main types of fishing gear used in Indonesia (1988 - 97) and (b) Contribution of the six main fishing gears in Indonesia to 1997 production.

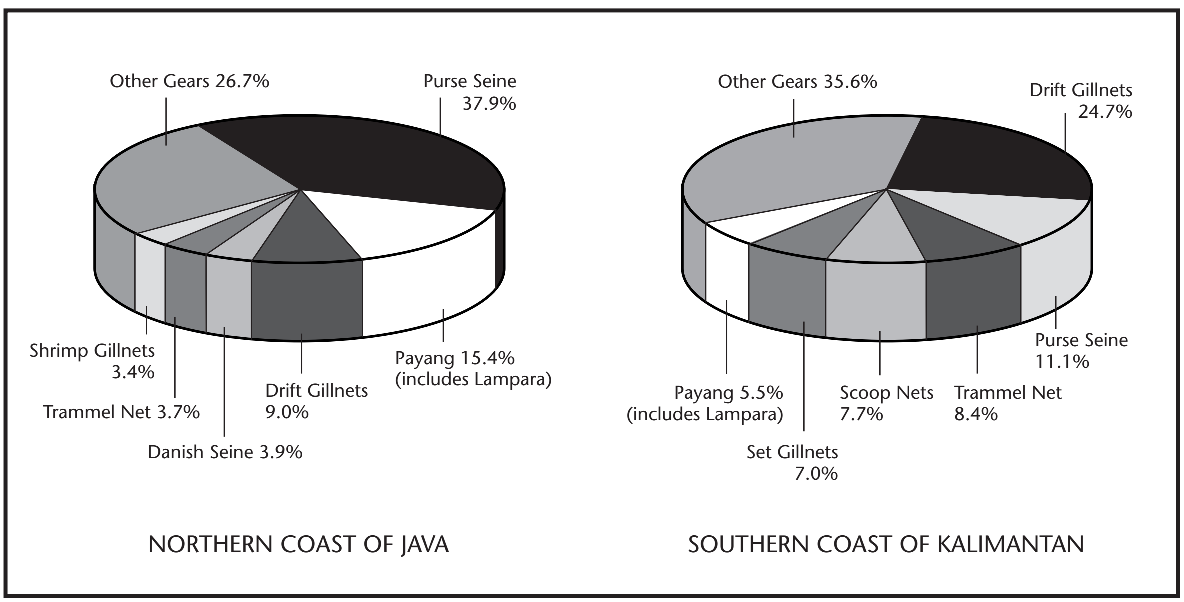

Fig. 6. Production share of six main fishing gears in the northern coast of Java and in the southern coast of Kalimantan in 1997.

Economics of Coastal Capture Fisheries

Most catches in Indonesia are sold fresh. Typically, the quantity of dried or salted fish is about half the quantity sold fresh. During 1997, however, an unusually large proportion (77.6%) of the production was sold fresh (Fig. 7). In the Java Sea, most catches were also sold fresh in 1997 (Fig. 8). Fresh fish accounts for a larger proportion of catches sold in the northern coast of Java than in the southern coast of Kalimantan because frequent over-supply of fish in the latter area makes drying/salting a popular practice.

Fishing ports and landing places in the eastern part of Central Java supply fish to local markets and markets in East Java. On the other hand, ports and landings in the western part of Central Java supply towns in the area as well as towns in West Java, Jakarta and Sumatra. Fish channelled through the ports and landing places in the northern coast of Java may be exported to neighbouring countries or marketed locally in Java and other islands (Clucas and Basmal 1995).

Table 5 presents costs and returns of five demersal fishing gear used in the Java Sea based on recalculation of data given by (Priyono 1999). The large Danish seine, a modification of traditional fishing gear called *dogol* and *cantrang*, is the most economically viable fishing gear.

Table 6 presents the costs and returns of three size categories of purse seiners in the Java Sea based on data of (Soegiarto et al. 1997) and adjusted using the consumer price index and current fish prices. The figures suggest that purse seining is economically profitable and that large boats are economically more efficient than small ones.

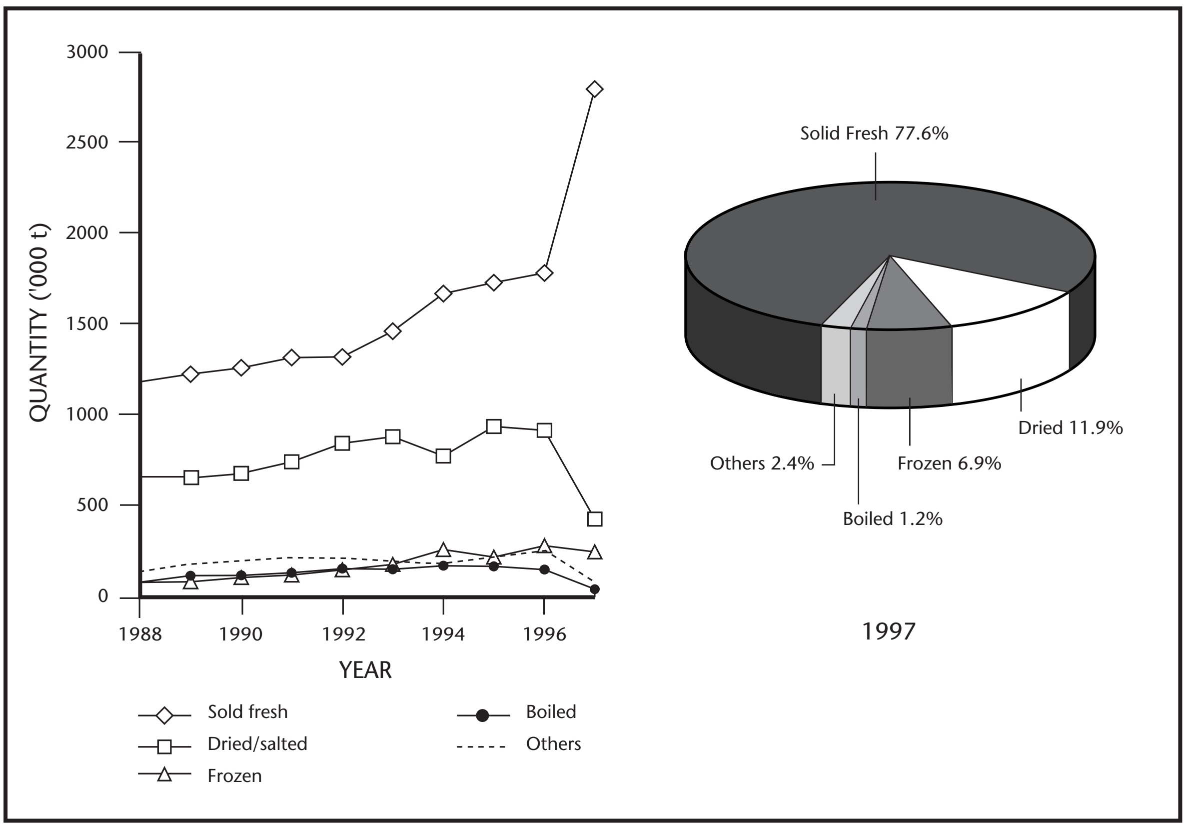

Fig. 7. Disposition of marine fisheries production in Indonesia.

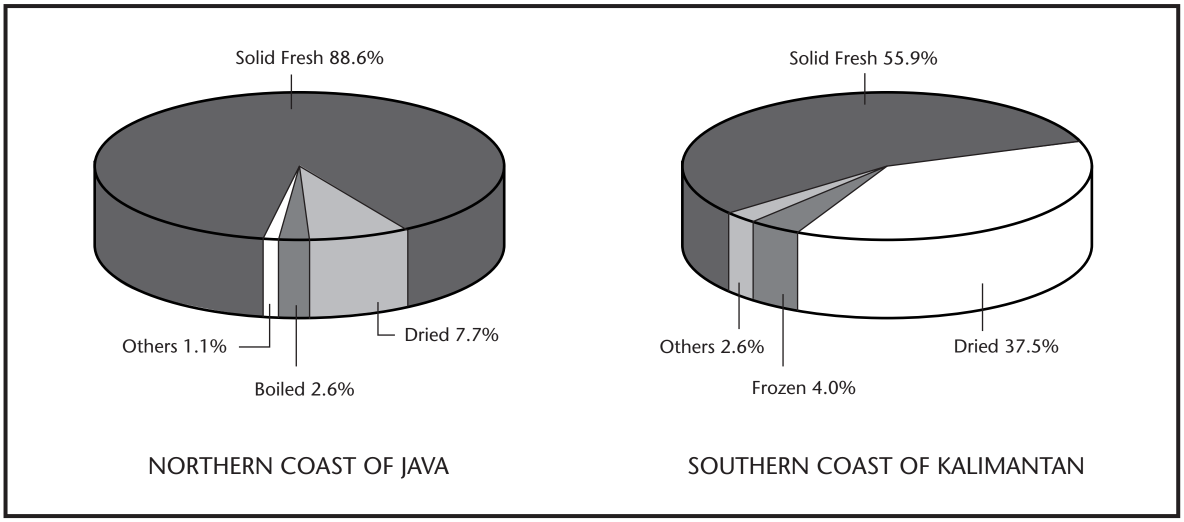

Fig. 8. Disposition of marine fisheries production on the northern coast of Java and the southern coast of Kalimantan in 1997.

Table 5. Costs and returns of five types of demersal fishing gear used in the Java Sea[1].

	Arad	Danish seine		Gillnet	Bottom longline
		Small	Large		
Tonnage of boat (GT)	23		23	25	21
Fishing power index	1.03	0.38	1.00	0.75	0.51
Return (Rp. million/yr)	82.62	30.21	80.43	88.55	101.96
Cost (Rp. million/yr)	65.46	26.33	60.02	72.29	81.76
Margin (Rp. million/yr)	17.16	3.88	20.42	16.26	20.20

Note: [1] Recalculation of data used by (Priyono 1999).
1 US$ = Rp10,000 (1999)

Table 6. Costs and returns of purse seiners operating in the Java Sea[1].

	Small purse seiner	Medium purse seiner	Large Purse seiner
Tonnage of boat (GT)	15	54	114
Engine power (HP)	23 X 2	80	232
Fishing days per year	155	164	149
Fishing power index	4.4	7.0	1.0
Running cost (Rp. million/yr)	121.40	218.76	50.53
Return (Rp. million/yr)	161.20	299.53	62.94
Margin (Rp. million/yr)	39.80	80.77	12.41

Note: [1] Based on data of (Soegiarto et al. 1997).
1 US$ = Rp10,000 (1999)

Exploitation Status

Biological Status

The demersal fishery resources in the Java Sea have a long history of exploitation. Rapid development occurred with the introduction of trawlers during the late 1960s, coinciding with the strong international demand for shrimp. Development of the trawl fleet substantially reduced the abundance of demersal stocks and threatened sustainability. This is shown by the results of demersal surveys conducted by (RIMF) using *R/V Mutiara 4* (Fig. 10). The results are given in (Losse 1981) for the 1976 survey, (Badrudin et al. 1997) for the 1977 - 89 surveys, and unpublished results provided by the RIMF for the 1994 survey. The catch rate of *R/V Mutiara 4* tended to decline during 1976 - 79. (Dwiponggo 1988) reported that the demersal fishery resources in the coastal waters were over-exploited by 1977.

As the operation of trawlers resulted in serious conflict between small scale and trawl fishers, the Government banned the operation of trawlers by promulgating Presidential Decree No. 39 in 1980. The trawl ban policy resulted in recovery of the stocks, as shown by increasing catch rates of *R/V Mutiara 4* after the trawl ban up to 1986. However, the development of other demersal fishing gears, notably the Danish seine, increased fishing pressure on the resources. Consequently, the catch rate decreased.

The relationship between total catch and fishing effort for the coastal demersal fisheries off the north coast of Java is presented in Fig. 9. Two surplus production models (Schaefer and Fox model) are given, using the data reported by (Badrudin et al. 1997). Production functions resulting from the analysis are detailed in Table 7. Based on these production functions, estimates of MSY, fishing effort at MSY (f_{MSY}) and average productivity of vessels at MSY are given.

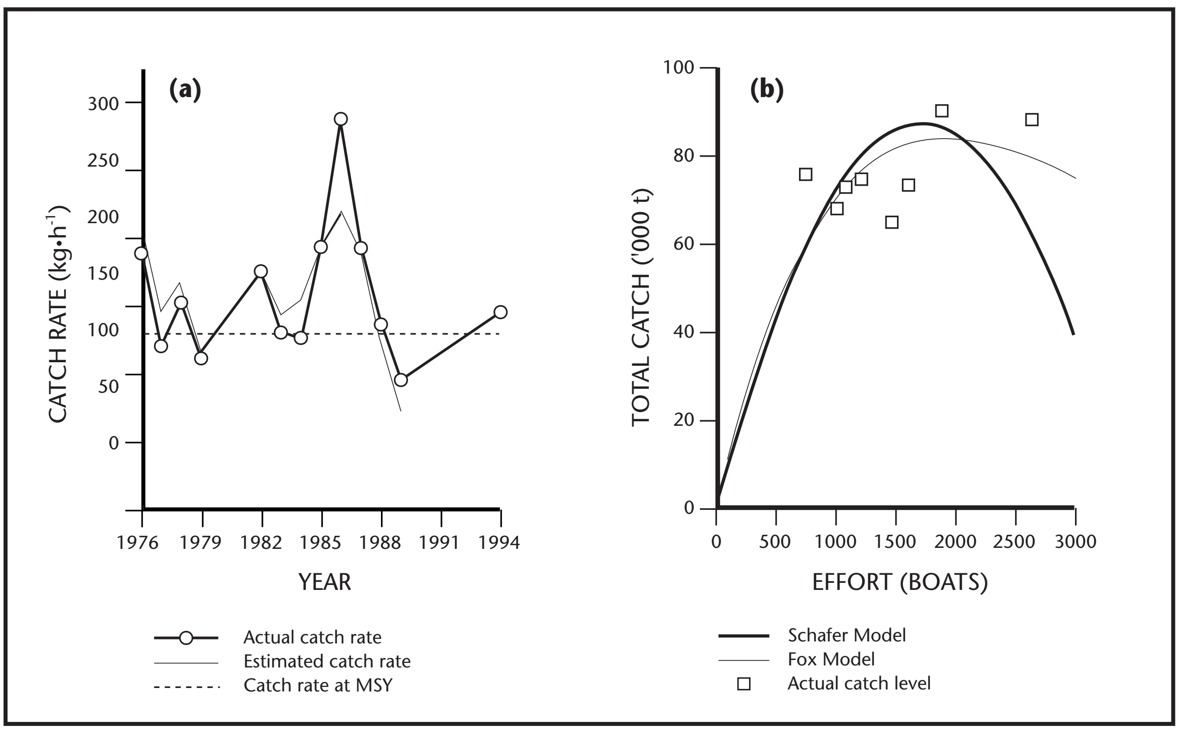

Fig. 9. (a) Catch rates during demersal trawl surveys off the north coast of Java using R/V Mutiara 4 and (b) relationship between total catch and effort for the demersal fishery off the north coast of Java.

Table 7. Fishery production functions for the coastal demersal fisheries off the north coast of Java after the trawl ban[1].

Model	Fishery production function	Maximum sustainable yield (MSY) (x10^3t)	Fishing effort at MSY (f_{MSY}) (units)	Productivity of vessel at MSY (t·boat^{-1})
Schaefer	$h = 100.2 f - 0.029 f^2$	86.2	1721	50.1
Fox	$h = f \exp(4.76 - 0.00052 f)$	82.9	1929	43.0

Note: [1] Analyzed on the basis of the data from (Badrudin et al. 1997); *h* = quantity of catch (metric tonnes); *f* = fishing effort; 1 unit of f equal to 1 unit of Danish seiner operated using 23 GT boat. Data on fishing days·year^{-1} and fishing hours·day^{-1} of *R/V Mutiara 4* from (Dwiponggo 1981) were used in standardizing effort into the number of 23 GT Danish seiners.

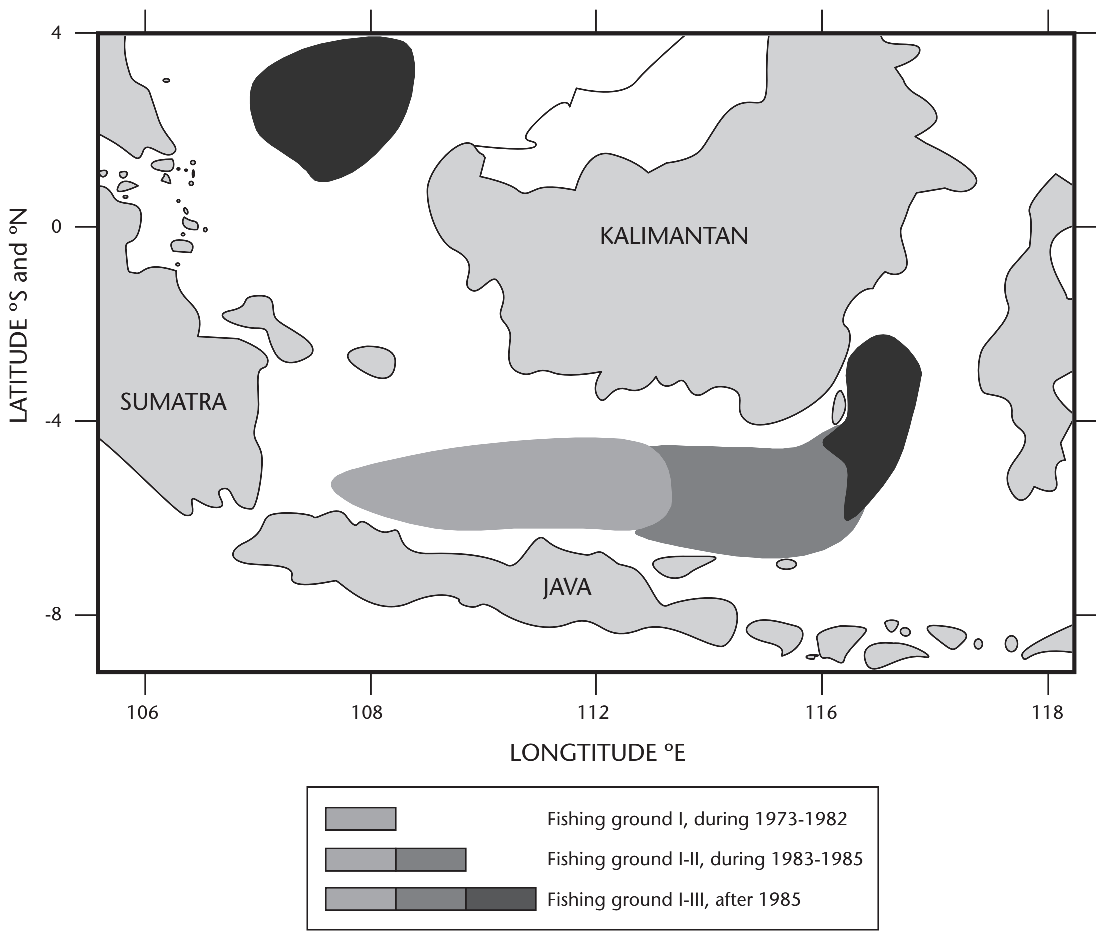

Fig. 10. Fishing ground extension for the small pelagic fishery (Source: Potier and Petit 1994).

Results of the analysis indicate that the demersal fishery resources in coastal waters are over-exploited. Excess fishing effort was about 428 boat units standardised to 25 GT trawlers (Naamin pers. comm.). The demersal resources offshore are reported to be under-exploited (Naamin pers. comm.).

Similarly to demersals, the small pelagic resources in the Java Sea were exploited long before Indonesian independence. However, the small pelagic fishery developed rapidly only after the introduction of the purse seine during the early 1970s. Sizes of fishing gear and boats have increased since then to improve catches and sailing distances, thus extending fishing grounds (Purwanto 1995). The extension of fishing grounds is illustrated in Fig. 10. The traditional fishing ground covered the area north of Central Java Province during 1973 - 82. The fishing ground was extended eastward to areas around Masalembo, Matasiri and Kangean during 1983 - 85. After 1985, the fishing ground was extended further eastward to Makassar Strait and northward to the South China Sea (Potier and Petit 1994).

Based on catch and effort data of *payangs*, mini purse seiners and big purse seiners operating in the Java Sea, the production function of the Java Sea small pelagic fishery has been formulated (Table 8). The mini purse seiner was used as standard fishing effort. Average fishing power index of *payangs*, mini purse seiners and big purse seiners was 0.26, 1.00, and 4.50, respectively. The extension of fishing grounds during 1983 - 85 results in higher MSY and f_{MSY}. Productivity of vessel at MSY also increases.

(Nurhakim et al. 1994) reported that some small pelagic species in the Java Sea were fully and heavily exploited. (Purwanto 1995) also reported that small pelagic fishery resources were heavily exploited. The result of resource assessments conducted by NCSAMFR (1998) show that small pelagic resources in the Java Sea are biologically over-exploited.

Economic Status

Economic evaluation of the Java Sea fisheries include (1) comparison of economic profitability of various fleets, and (2) estimation of the optimum level of fishery resources use. Fishing activities evaluated were those harvesting demersals in coastal waters off the northern coast of Java and small pelagics in fishing ground I of the Java Sea (see Fig. 10).

A bio-economic model was developed and used in the analysis. The model allowed optimisation of multi-gear fisheries exploiting more than one fish stock (demersal and small pelagic). Fishing gear used to harvest demersals includes Danish seine using boats of 5 GT and 23 GT, *arad* seine, bottom longline and gillnet. Fishing gear used to harvest small pelagics include purse seine using boats of 15 GT, 50 GT and 110 GT.

Results of analyses show that economic benefit gained from fishing varied with gear and boat size (Fig. 12). Larger boats resulted in higher profit or economic benefit. The economic benefit per boat decreased with increasing fishing intensity. Therefore, increasing fishing pressure decreased economic benefit earned by each fisher. Among the three fishing gears operated using 20 GT boats for catching demersal fish, the Danish seine resulted in the highest economic benefit. Economic benefit resulting from operation of Danish seine using a small boat (5 GT) was lower than that using a large boat

Table 8. Fishery production function for the Java Sea small pelagic fishery before and after fishing ground extension

Fishing ground	Fishery production function[1]	Maximum sustainable yield (MSY) ($x10^3 t \cdot year^{-1}$)	Fishing effort at MSY (f_{MSY}) ($x10^3$days)	Productivity of vessel at MSY ($kg \cdot day^{-1}$)
I	$h = 284.7\ f - 0.215\ E^2$	94.3	662	142
I - II	$h = 323.9\ f - 0.215\ E^2$	122.0	753	162
I - III	$h = 368.1\ f - 0.215\ E^2$	157.6	856	184

Note: [1] *h* = quantity of catch (t); *f* = fishing effort; 1 unit of f equal to 1 000 days at sea of small purse seiner.
Source: Purwanto 1995.

(23 GT). Similarly, economic benefit resulting from operation of small scale purse seiners was also lower than that of large scale purse seiners. This suggests that under free competition (with no restrictions on increasing fishing effort), small scale fishers are the first to lose and to suffer from poverty.

Table 9 summarizes results of the bio-economic optimisation approach for multi-gear fisheries. The analysis was carried out simultaneously for the demersal and the small pelagic fisheries using a mathematical programming model. The analysis indicates the optimum level of fishing effort, appropriate fishing gear, and optimum size and number of fishing boats resulting in optimum economic benefit to fishers.

There were five types of fishing gear in the demersal fishery evaluated, namely, Danish seines operated by 5 and 23 GT boats, the *arad* seine operated by 23 GT boats, the gillnet operated by 25 GT boats and the bottom long line operated by 21 GT boats. Among these fishing gear, the Danish seine operated by 23 GT boats was found to be the most economical. The optimum number of 23 GT-Danish seiners that should be operated in the northern coastal waters of Java is 1 297 units (Table 9; Fig. 13). Optimum economic benefits that would be gained by demersal fishers would be about Rp117 billion per year. Meanwhile, the number of fishers that should be engaged in the coastal demersal fishery in the Java Sea is about 9 000 people. The demersal fishery in the northern coastal waters of Java would land about 81 200 t of fish.

Three small pelagic fishing fleets (15 GT purse seiner, 50 GT purse seiner and 110 GT purse seiner) were evaluated. Among these three fleets, the 50 GT purse seiner was found to be the most economical for fishing ground I (see Fig. 10). The optimum number of this fleet that should operate is 648 units (Table 9 and Fig. 13). Optimum economic benefits that would be gained by small pelagic fishers is about Rp53 billion per year. Meanwhile, the number of fishers engaged in the small pelagic fishery of Java Sea should be about 22 thousand people. This fishery would land about 83 800 t of small pelagic fishes.

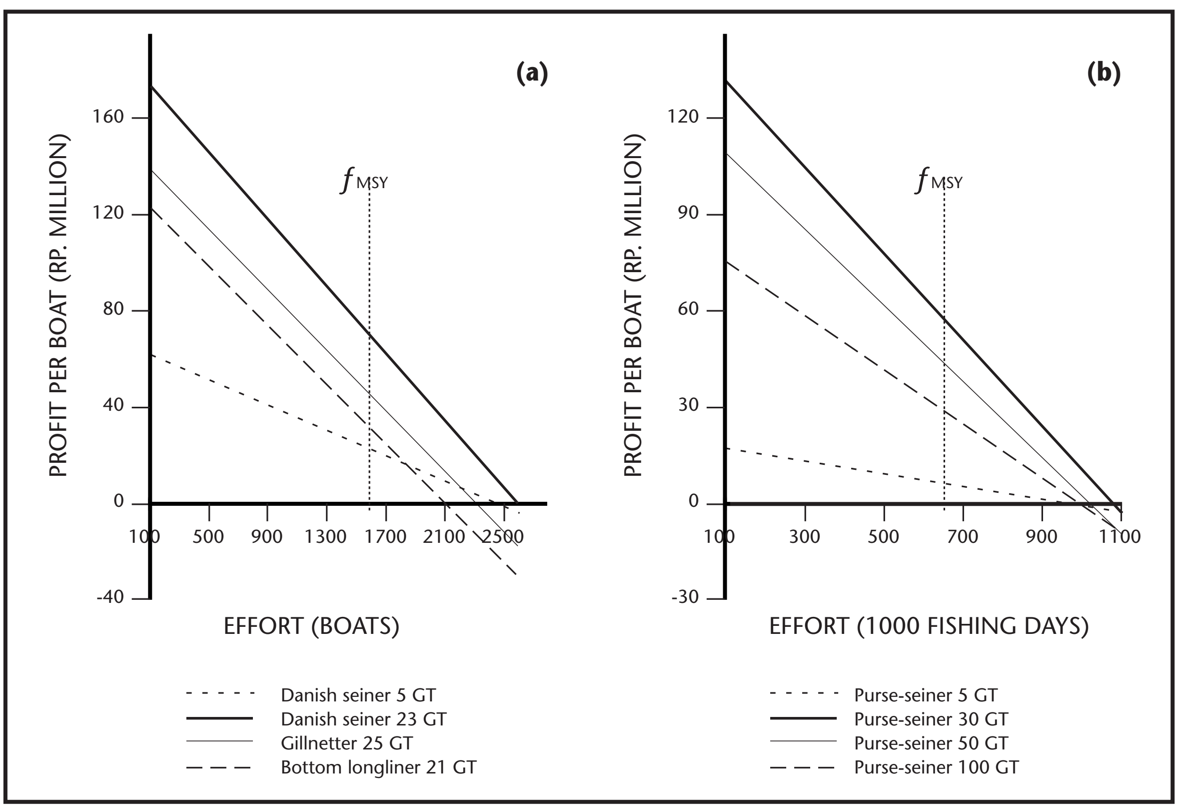

Fig. 11. (a) Profit gained from catching demersals in the Java Sea using different boat sizes and fishing gear. (b) Profit gained from catching small pelagics in the Java Sea using different boat sizes (Purwanto, 1995).

Table 9. Estimate of optimum effort, total economic benefits and number of fishers for the coastal demersal and small pelagic fisheries in the Java Sea.

Fishery	Selected fleet[1]	Optimum effort (f_{MEY})[2]	Optimum Number of boats	Maximum economic yield (MEY) (10^3 t·year^{-1})	Total cost of fishing	Total return	Optimum economic benefit	Total number of fishers
					(Rp. Billion·year^{-1})			
Demersal	DS - 23	1 297	1 297	81.2	78	195	117	10 373
Small pelagic	PS - 50	442 000	648	83.8	52	105	53	22 045
TOTAL			1 945	165.0	130	300	170	32 418

Note: [1] DS-23 = 23 GT Danish seiner; PS-50 = 50 GT purse seiner. [2] f_{MEY} = effort resulting in MEY, that is when optimum economic benefit is achieved; optimum effort of demersal fishery was standardised in number of DS-23 boats, while optimum effort of small pelagic fishery was standardised in number of days at sea of small purse-seiners.

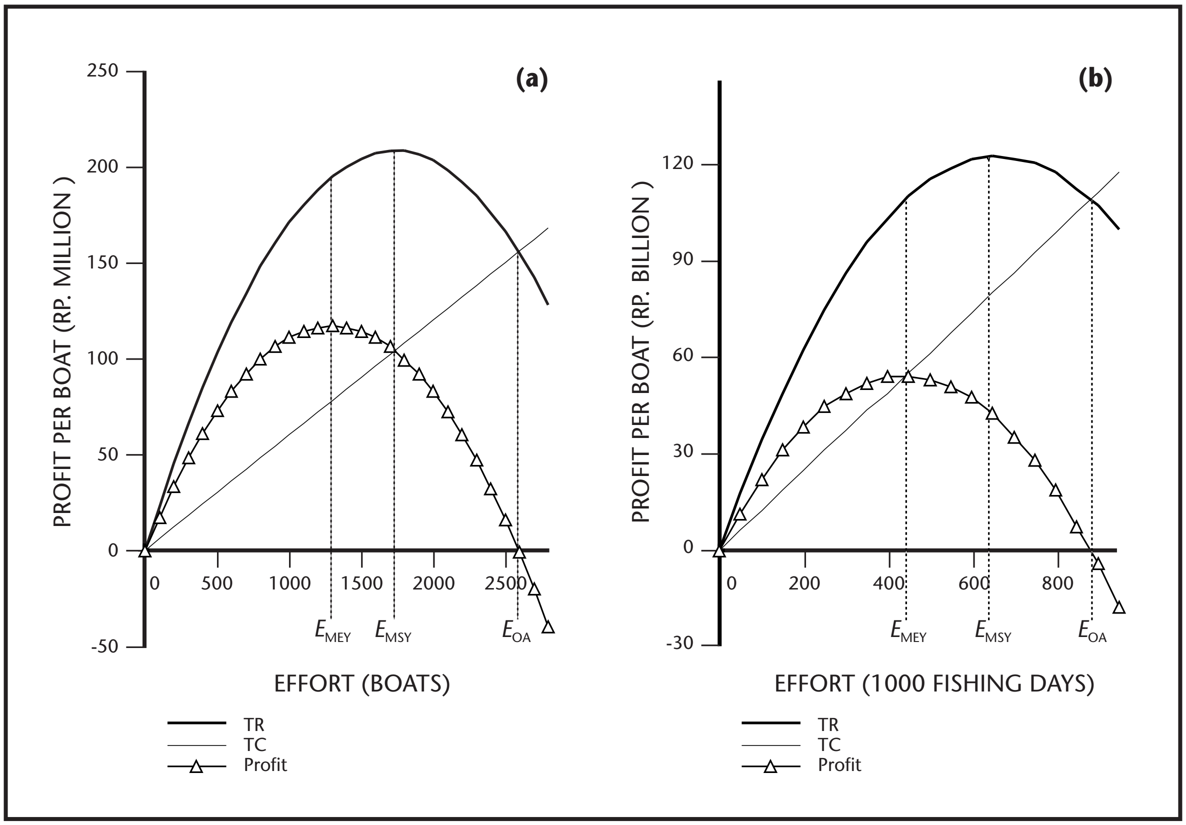

Fig. 12. Total return, cost and economic benefit (profit) from (a) Coastal demersal fishery, and (b) Small pelagic fishery in the Java Sea . (f_{MEY} = level of effort resulting in optimum economic benefit; f_{MSY} = level of effort resulting in maximum sustainable yield; f_{OA} = level of effort when total returns equal total costs).

Fishery resources in the Java Sea are basically common property resources with no single user having exclusive rights to the resources or the right to prevent others from sharing in their exploitation. Consequently, commercial fishers are in competition with one another and are motivated to get a larger portion of the resource for themselves. Under this condition of open access, commercial fishers tend to increase their fishing effort, i.e. the capacity to catch fish, as long as they gain economic profit. The only restriction for fishers against increasing their fishing effort is the level of economic profit. In this open access fishery, economic profit is dissipated. Therefore, fishing effort should be controlled in order to achieve optimum economic benefits. The Government of Indonesia has regulated fishing in the Java Sea with the objectives of sustaining fishery resources and optimizing sustainable yield. However, the Java Sea fishery is in fact an open access fishery since fisheries surveillance and law enforcement is ineffective.

There are different economic consequences of using MSY and MEY as target reference points in management, as presented in Tables 10 and 11. These tables also show the economic consequence of open access fisheries. The use of MEY as target reference point in the management of the Java Sea fisheries results in optimum economic benefits. However, the quantity of fish harvested at this reference point is lower than that obtained at MSY. Moreover, the number of fishers when the MEY is the reference point is lower than at MSY or open access. The use of the MSY as target reference point would result in maximum quantity of fish harvested. However, the economic benefit gained at this reference point is lower than at MEY. The number of fishers when the MSY is the reference point is higher than at MEY but lower than at open access. On the other hand, the open access fishery results in the maximum number of people engaged in the fishery. However, the economic benefit and sustainable yield resulting from open access are lower than that at MEY or MSY.

The open access fishery and the regulated fishery with MSY as target reference point result in dissipation of economic benefits. Therefore, fishery resources exploited with no restriction on the level of effort or exploited beyond f_{MEY} are uneconomical or economically over-fished. As the coastal demersal fishery and small pelagic fishery in the Java Sea are biologically over-fished (NCSAMFR 1998), it follows that these resources are also economically over-fished.

Management Issues and Opportunities

Management Objectives

Fish stocks are renewable resources with the capability to recover when harvested, as long as fishing intensity does not exceed carrying capacity. To sustain fishery resources, fishing effort should be controlled at the level equal to or lower than the level that results in maximum sustainable yield (f_{MSY}). However, fishing is basically an economic activity. Commercial fishers catch fish in order to earn economic profit. If there is open access, commercial fishers will tend to increase fishing effort as long as they still gain economic profit. The restriction for fishers to increase their fishing effort under an open access condition is the level of economic profit, which would be dissipated when fishing effort is continuously increased. Optimum economic benefit can only be gained by controlling fishing effort at the economically optimum level. Restricting fishing effort at the level resulting in optimum economic benefit (f_{MEY}) would also ensure sustainability of fishery resources as f_{MEY} is less than f_{MSY}.

The Java Sea Fishery is *de facto* open access since there are no real restrictions on fishing effort. This has resulted in over-exploitation of fishery resources and dissipation of economic rent, which in turn has resulted in poverty of small scale fishers. The main goal of coastal fisheries management, therefore, should be the alleviation of small scale fishers' poverty (see Annex 1). To achieve this goal, fisheries management in the Java Sea should be aimed at (1) sustaining fishery resources, and (2) increasing fishers' incomes by optimising economic benefits from fishery resources utilisation.

The objectives of the fisheries development in Indonesia are to (1) promote economic development, (2) alleviate poverty by increasing fishers' incomes, (3) provide new employment opportunities and (4) increase domestic fish consumption (DGF 1999b). Considering these development objectives, the objectives of the Java Sea fisheries management and development should be to (1) sustain fishery resources, (2) optimize economic benefits, (3) maximize employment opportunities and (4) increase supply for domestic fish consumption. Fisheries should be managed in order to sustain fishery resources while optimising fishers' incomes, employment opportunity and fisheries' contribution to the national economy. When optimising incomes, however, poverty alleviation and creation of employment opportunities should be

Table 10. Impacts of different management strategies on the economics of demersal fishery in the Java Sea.

Management strategy	Fishing effort [a]	Sustainable production (10^3t·year^{-1})	Total return	Total cost	Economic benefit	Total number of fishers	Productivity of boat (t·year^{-1})	Profit per boat (Rp 10^6·year^{-1})
			(Rp. Billion·year^{-1})					
Effort regulated to attain:								
1.1. MEY	1 297	81 2	194.8	77.8	117.0	9 079	62.6	90.2
1.2. MSY	1 721	86 6	207.7	103.3	104.4	12 047	50.3	60.7
Open access	2 594	64 8	155.6	155.6	0.0	18 155	25.0	0.0

Note: [a] Number of 23 GT Danish seine boats.

Table 11. Impacts of different management strategies on the economics of small pelagic fishery in the Java Sea.

Management strategy	Fishing effort [a]	Number of PS-50 [b] boats	Sustainable production (10^3t·year^{-1})	Total return	Total cost	Economic benefit	Total number of fishers	Productivity of boat (t·year^{-1})	Profit per boat (Rp 10^6·year^{-1})
				(Rp. Billion·year^{-1})					
Effort regulated to attain:									
1.1. MEY	442	648	83 8	104.8	52.2	52.6	22 035	129.4	81.1
1.2. MSY	662	971	94 2	117.8	78.2	39.6	33 003	97.1	40.8
Open access	884	1 296	83 6	104.5	104.5	0.0	44 090	64.5	0.0

Note: [a] In 1 000 days at sea of small purse-seiners; [b] PS-50 = 50 GT purse seiner.

given high priority, since many coastal communities are highly dependent on fisheries for livelihood.

The management strategy intended to optimise economic benefits (objective 2) would also ensure sustainability of fishery resources (objective 1). Meanwhile, maximising employment opportunities (objective 3) and increasing supply for domestic fish consumption (objective 4), which also means increasing fish production to its maximum possible level, would not result in optimum economic benefits. Furthermore, maximizing employment opportunities may threaten sustainability of fishery resources. There are conflicts, therefore, between objectives 1 and 2 on one hand, and objectives 3 and 4 on the other. An appropriate strategy is required to balance these conflicting objectives of fisheries management and development. In order to sustain fishery resources, MSY and f_{MSY} should be used as the limit reference points. This can be accommodated in the evaluation of management strategies by setting up f_{MSY} as the upper limit of the fishing effort function.

A Compromise Strategy to Achieve Conflicting Objectives

There are two major issues in the capture fisheries of the Java Sea. Because coastal demersal and small pelagic fish stocks are over-exploited, the first major issue concerns their sustainability. The second major issue concerns the socioeconomic conditions of fishers and their households, especially the low income and limited livelihood opportunities of small scale fishers. The first three objectives of fisheries management and development in the Java Sea (sustain fishery resources, optimise economic benefits, and maximise employment opportunities) are aimed at addressing these issues. However, these objectives cannot be achieved simultaneously.

Optimising economic benefits to increase fishers' income will sustain fishery resources, but will decrease employment opportunities. Increasing livelihood opportunities for fishers in the Java Sea fisheries, on the other hand, will threaten sustainability of fishery resources and decrease fishers'

income. Fig. 13 illustrates the trade-off between the objectives of optimising economic benefits from utilization of fishery resources and increasing employment opportunities constrained by f_{MSY} as the limit reference point. The levels of employment and total fishers' income at point A result from income optimisation. On the other hand, point B represents maximising employment opportunities constrained by f_{MSY}. Non-feasibility of simultaneously achieving optimum income and optimum employment can be shown from the position of the coordinate of these ideal solutions, that is point C in Fig. 13, which is outside the frontier of the income-employment trade-off.

Optimisation of economic benefits results in an increase in fishers' income by 48% of its optimum level, but decreases the number of fishers by 61%. The best compromise solution for the conflict between the two objectives is represented by point K in Fig. 13. There are a number of consequences of achieving the best compromise solution in Table 12. If priority is given to increasing domestic fish consumption (objective 4) and maximising employment opportunities (objective 3) with f_{MSY} as an upper limit of fishing effort, the best compromise solution should be achieved by reducing the number of small boats used for the demersal fishery. This is relevant as demersal fishery resources in inshore waters are over-exploited. Similarly, the number of large boats (50 GT) used for small-pelagic fishery should also be reduced to achieve the best compromise solution.

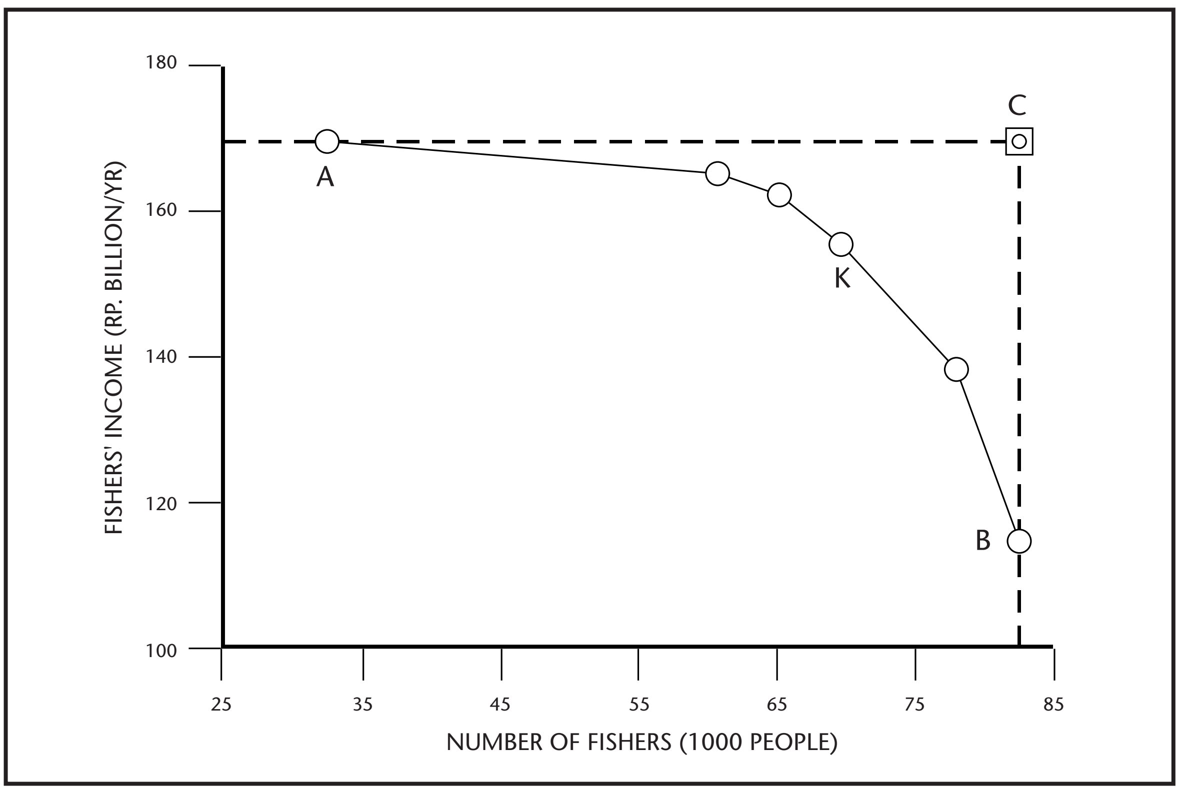

Fig. 13. Trade-off curve for employment opportunity (number of fishers) and total income gained by fishers in the Java Sea fisheries.

Table 12. Economic benefits, number of fishers, fleet structure and fish production at different efficiency points.

<table>
<tr><th rowspan="3">Efficiency Points[1]</th><th rowspan="3">Economic benefits (Rp. Billion ·year^{-1})</th><th rowspan="3">Number of fishers (people)</th><th colspan="6">Fleet structure</th><th colspan="3" rowspan="2">Fish production (1 000 t)</th></tr>
<tr><th colspan="3">Demersal</th><th colspan="3">Pelagic</th></tr>
<tr><th>Boat size (GT)</th><th>Number of boats</th><th>Fishing gear[2)]</th><th>Boat size (GT)</th><th>Number of boats</th><th>Fishing gear</th><th>Demersal</th><th>Pelagic</th><th>Total</th></tr>
<tr><td>A</td><td>169.6</td><td>32 418</td><td>23</td><td>1 297</td><td>D</td><td>50</td><td>648</td><td>PS</td><td>81.2</td><td>83.8</td><td>165.0</td></tr>
<tr><td rowspan="2">K</td><td rowspan="2">155.4</td><td rowspan="2">69 611</td><td>5</td><td>505</td><td>D</td><td>15</td><td>2 221</td><td>PS</td><td rowspan="2">83.4</td><td rowspan="2">91.4</td><td rowspan="2">174.8</td></tr>
<tr><td>23</td><td>1 207</td><td>D</td><td>50</td><td>317</td><td>PS</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">114.5</td><td rowspan="2">82 504</td><td>5</td><td>2 263</td><td>D</td><td>15</td><td>2 221</td><td>PS</td><td rowspan="2">86.2</td><td rowspan="2">94.3</td><td rowspan="2">180.8</td></tr>
<tr><td>25</td><td>1 148</td><td>GN</td><td>50</td><td>485</td><td>PS</td></tr>
</table>

Note: [1] K is the best compromise solution. [2] D, GN and *PS* are Danish seine, gillnet and purse seine, respectively.

Strategic Factors of Fisheries Management and Develo t

A number of strategic factors can affect achievement of fisheries management and development objectives mentioned above. These factors can be divided into two: (1) factors which tend to restrict achievement of the objectives, (restricting factors), and (2) factors which tend to promote achievement of the objectives, (promoting factors). Furthermore, these factors can be ranked according to the strength with which they restrict or promote achievement of the objectives. The author and other fisheries management specialists conducted an exercise to identify and evaluate these strategic factors (Annex 2). The results of the exercise are summarized in Table 13.

There are three restricting factors and three promoting factors that should be given highest priority in formulating a program to sustain fishery resources in the Java Sea. The three restricting factors are (1) inappropriate pattern of fishery resource use, (2) lack of MCS and law enforcement, and (3) destruction of habitats. On the other hand, the three most important promoting factors are, (1) under-exploitation of offshore demersal fish resources, (2) availability of fishers' associations, and (3) high dependency of coastal communities on fishery resources.

The three restricting factors that should receive highest attention to increase incomes of the Java Sea fishers are (1) small scale fleet domination, (2) lack of enterprise managerial skill, and (3) overexploitation of small pelagic fish stock. The three promoting factors that should be given highest attention are (1) availability of fishing cooperatives, (2) availability of potential area of business for fishing households, and (3) under-exploitation of offshore demersal fish resources.

Proposed Management and Development Program

The key features of the proposed "Integrated Program of Fisheries Management and Development for the Java Sea", which was developed as part of this review are given in Annex 3. As mentioned earlier, the two major issues concerning capture fisheries in the Java Sea are the threatened sustainability of fishery resources and the poor socioeconomic conditions of small scale fishers. To cope with these issues, there is a need for an integrated management and development program with the main objectives of sustaining fishery resources and increasing incomes and livelihood opportunities of small scale fishers. The preceding section highlighted the most important promoting and restricting factors relevant to each of the two objectives. These objectives and factors were taken into account in formulating the program.

The key issues and corresponding actions dealing with sustainability of fishery resources and improvement of socioeconomic conditions of fishers and their households are detailed in Annex 3. The actions can be grouped into four program components, namely: fishery resources co-management,

Table 13. Strategic factors to achieve the objectives of coastal fisheries management and development in the Java Sea.

Goal	Objectives	Strategic factors/Issues	Priority rank
Alleviate poverty	*Sustain fishery resources*	*Restricting factors*	
		1. Inappropriate pattern of fishery resource use	I
		2. Lack of MCS and law enforcement	II
		3. Small scale fishing fleet	VII
		4. Use of destructive fishing practices	V
		5. Destruction of habitats	III
		6. Lack of any skill except fishing	VI
		7. Lack of compliance	IV
		Promoting factors	
		1. Under-exploitation of offshore demersal fish resources	I
		2. High dependency of coastal community on fishery resources	III
		3. Availability of fisheries extension officers	VII
		4. Availability of potential area of business for fishing households	VI
		5. Availability of traditional knowledge	V
		6. Availability of fishers' associations	II
		7. Promulgation of laws and regulations	IV
	Increase fishers' incomes	*Restricting factors*	
		1. Over-exploitation of small pelagic and coastal demersal fish stocks	III
		2. Small scale fleet domination	1
		3. Lack of surveillance and law enforcement	VII
		4. Inappropriate pattern of fishers' expenditure	VI
		5. Lack of enterprise managerial skill	II
		6. Lack of technical skill to adopt higher level of post-harvest technology	IV
		7. Lack of capital	V
		Promoting factors	
		1. Under-exploitation of offshore demersal fish resources	III
		2. Good coordination with other institutions	VI
		3. High and increasing demand for fish and fishery products	V
		4. Availability of potential area of business for fishing households	II
		5. Availability of fisheries extension officers	IV
		6. Availability of fisheries training centres	VII
		7. Availability of fishing cooperatives	I

public awareness, business opportunity development and fishers' capacity building. These actions can also be categorized as policy, public campaign and investment actions.

Fishery resources in the Java Sea are shared among fishers from different provinces. Consequently, it would be difficult for each provincial government to manage these shared resources. The provincial governments and the central government should manage these resources collaboratively. Moreover, all stakeholders should be involved in a co-management framework in order to achieve the objectives of management efficiently. Co-management involves sharing responsibility and/or authority between the government and resources users (Pomeroy and Williams 1994). To manage shared fishery resources in the Java Sea effectively, a Fisheries Management Body (FMB) should be set up, that involves all key stakeholders.

The Integrated Program of Fisheries Management and Development for the Java Sea would cover various aspects of fisheries and involve relevant stakeholders. Because government funds are limited, the program should be divided into at least two phases. The first phase would be to initiate the program. In the second phase, investments (consisting of private, cooperative and government investment) would be required.

The duration of the first phase would be three years. The objectives of the first phase would be to:

a. Develop a co-management framework involving all stakeholders;
b. Increase public awareness in sustaining fishery resources;
c. Develop business opportunities other than fishing in order to reduce pressure on heavily exploited fishery resources;
d. Develop fishers' capacity to utilize business opportunities.

Activities that should be carried out during the first phase include:

a. Establishment of fishery resources co-management and formulation of the first management plan. In the first phase, management should not reduce the number of fishing vessels. Decreasing fishing pressure should be carried out by adjusting the number of fishing trips;
b. Formulation of the drafts of government policies;
c. Public campaign;
d. Creation of alternative income sources for fisher's households and coastal communities.

Potential Regional Collaborative Activities

Countries in the region can collaborate in at least two activities, namely: (1) sharing information and experience, and (2) implementing a pilot project on shared stock management.

Some countries can share their experience of co-management of fishery resources. A co-management framework is an efficient way to manage fishery resources, since it involves community participation and a sharing of responsibility and/or authority between the government and local resources users/community. Indonesia has success stories regarding conservation, management of fishery resources and enforcement conducted by local people. The co-management framework is site-specific, but the sharing of experiences on co-management could lead to development of a framework with wider applicability.

Pilot projects on shared stock management could be implemented in the Malacca Straits, involving Indonesia, Malaysia and Thailand; in the Sulu-Sulawesi Seas, involving Indonesia, Malaysia and the Philippines; or in the South China Sea, involving countries around this area. Such pilot projects would be desirable because joint management of shared stocks will help ensure their sustainability. The countries in the region have no previous experience with collaborative management of shared stocks. The pilot projects would provide such valuable experience.

Conclusion

The following are major trends in the Java Sea fisheries:

1. Increasing human population and per capita consumption of fish have combined to raise demand for fish. This promoted the development of fishing in the Java Sea. In order to increase the catch, the size of gear and boats were increased and the fishing grounds were extended.

2. Fishing and fishing-related activities, which tended to increase in response to the increased

demand for fish, became the main livelihood of coastal communities living around the Java Sea.

3. Intensified fishing activities stimulated the development of up-stream and down-stream industries. This increased employment opportunities. The number of fishers and fishing households also increased. This is a significant contribution of the fisheries sector to the regional economy.

4. The Java Sea Fishery was *de facto* open access, indicated by free competition among fishers and no real restriction on fishing effort. In this open access fishery, fishing pressure increased as the number and size of fishing boats increased. This resulted in biological over-exploitation and economic inefficiency.

5. The two main fishery resources in the Java Sea, which are small-pelagic and inshore demersal fishery resources, are over-exploited.

6. The quality of coastal habitats has decreased as a result of destructive human activities. The sustainability of mangroves and coral reefs, two important coastal habitats, is threatened.

7. Economic and biological over-exploitation and environmental degradation has led to poverty of fishers, especially small scale fishers in the coastal areas around Java Sea. This is indicated by decreases in CPUE and profit per vessel exploiting demersal and small-pelagic fish stocks.

8. Although the development of fishing industries had adverse impacts on the sustainability of fishery resources and the socioeconomic conditions of small scale fishers, there has been an increase in the commitment of the Government to develop fisheries and to conserve and manage fishery resources in line with the Code of Conduct for Responsible Fisheries (Food and Agriculture Organization (FAO) 1995). The development policies and programs, the coverage of regulations, and the establishment of the Ministry of Sea Exploration and Fisheries are proof of this commitment.

The Java Sea fisheries, however, remain *de facto* open access since there are no real restrictions on fishing effort. This has resulted in over-exploitation of resources and dissipation of economic rent, which has in turn exacerbated the poverty of small scale fishers. Improved fisheries management is urgently needed.

The fishery resources in the Java Sea are shared among fishers from different provinces. Therefore, concerned provincial governments under the supervision of central government should collaboratively manage these resources. All stakeholders should be involved in the process of management of the fisheries to ensure sustainable fisheries.

The main goal of fisheries management in the Java Sea should be the alleviation of small scale fishers' poverty. To achieve this goal, fisheries management in the Java Sea should be aimed at (1) sustaining fishery resources and (2) increasing fishers' income by optimising economic benefits and employment opportunities. These in turn are expected to have a positive impact on the regional economy.

An integrated management and development program for the Java Sea fisheries is required. The proposed program covers various aspects of fisheries and should involve relevant stakeholders. The activities should include establishment of a Fisheries Management Body involving all key stakeholders.

In the context of regional cooperation, two potential activities are highlighted. These are (1) networking for transfer of information and experience in fisheries co-management and (2) regional pilot projects in shared stock management.

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Annex 1. The Goal and Objectives of Coastal Fisheries Management in the Java Sea

The Goal

The Java Sea Fishery is *de facto* open access, although the Government of Indonesia regulates coastal fishing zones. This open access condition results from ineffective fishery surveillance. Consequently, there are no real restrictions on increasing fishing effort. This open access condition has resulted in the over-exploitation of coastal demersal and pelagic resour-ces. Another consequence is an inefficient allocation of economic resources, where consumers receive more economic benefits than should be the case (Purwanto et al. 1988), and economic rent is dissipated, resulting in fishers poverty (Purwanto 1992; Purwanto 1995; Purwanto et al. 1988).

Under open access conditions, there is free competition between large scale and small scale fleets. As the large scale fleet is usually more efficient than the small scale fleet, small scale fishers typically lose in this competition and suffer from poverty. Unfortunately, the majority of fishers in the Java Sea belong to the small scale sector. Therefore, the main goal of coastal fisheries management should be alleviating poverty of small scale fishers. This is in accord with the current fisheries development program of Indonesia (DGF 1999b).

The Objectives

As discussed previously, poverty alleviation is the main goal of fisheries management in the Java Sea. Efforts to alleviate poverty may be classified as direct or indirect. Direct efforts are carried out by optimising economic benefits that can be gained by small scale fishers from fishery resources utilisation. This includes efforts to increase fishers' income from fishing and creation of new job opportunities other than fishing. The indirect efforts include those to sustain fishery resources and their environment, which involves the adoption of proper fishery management, as fishers' poverty is a result of inappropriate fishery management.

That effort is in accord with the objectives of fisheries management stated in *Fisheries Act No. 9* of 1985, which is the legal basis of coastal fisheries management in Indonesia. This act has its roots in the 1945 *Constitutions of the Republic of Indonesia*, in particular *Article 33, Sub-Article 3,* which provides the legal basis for State control over Indonesia's land and waters and the natural resources contained therein.

Article 33, Sub-Article (3), of the 1945 *Constitution*, stipulates that the natural resources, including fishery resources, of Indonesia are to be used in a manner that best benefits all Indonesians. The management of fishery resources in fishery areas of Indonesia therefore is intended to obtain maximum benefits gained from fishery resources utilisation for all Indonesians (*Fisheries Act* No. 9 of 1985, *Article 3, Sub-Article* (1)). To achieve this objective, the Government shall carry out integrated fishery resources management in order to sustain fishery resources and their environment for the benefits of all Indonesians (*Fisheries Act* No. 9 of 1985, *Article 3, Sub-Article* (2)). It is clear therefore that the objectives of coastal fisheries management in the Java Sea are to sustain fishery resources and to optimise economic benefits that can be gained from fishery resources utilisation.

Annex 2. Strategic Factors to Achieve the Objectives of Coastal Fisheries Management in the Java Sea

Background

As mentioned in Annex 1, the goal of fisheries management in the Java Sea is the alleviation of fishers' poverty. To achieve this goal, two objectives of fisheries management in the Java Sea were derived. These objectives are (1) to sustain fishery resources and (2) to increase fishers' income by optimising economic benefits that can be gained from fishery resources utilisation.

A number of strategic factors can affect the achievement of fisheries management objectives. These factors can be divided into two: (1) factors which tend to restrict the achievement of the objectives, or restricting factors, and (2) factors which tend to promote the achievement of the objectives, or promoting factors. Identification of these strategic factors is presented here. These factors were considered in formulating the management and development program of the Java Sea fisheries in Annex 3.

Methods

The method used here is a modification of that used in Performance Improvement Planning (PIP) (Soedjadi 1997). In the analysis, the strategic factors were identified and ranked in order to determine their levels of priority. The steps of ranking were:

1. *Valuation of the relative impact of the factors on the achievement of the objectives.* Each factor was scored between 1 and 5; score 1 for a factor with very weak impact on the achievement of an objective, and score 5 for a factor with very strong impact.

2. *Valuation of the ability to* (a) *cope with problems or restricting factors or* (b) *control opportunities or promoting factors.* Again, scores between 1 and 5 were used. For problems or restricting factors, score 1 was provided when the factor was very difficult to solve, while score 5 was provided when the factor was very easy to solve. For opportunities or promoting factors, score 1 was provided when the factor was very difficult to control, while score 5 was provided when the factor was very easy to control.

3. *Valuation of the relative force of the factors to restrict or to promote the objective achievement.* The force was valued on the basis of (a) relative impact and (b) the ability to cope with problems/restricting factors or to control opportunities/promoting factors. Scores varying between 1 and 5 was also used in the valuation (score 1 for the factor with very weak relative force, score 5 for the factor with very strong relative force).

4. *Valuation of the degree of factors' inter-relationship.* Scores 0, 1, 3, or 5 were provided to represent the degree of factors' inter-relationship. Score 5 was provided when the inter-relationship between two factors was very strong; score 3 was provided when the inter-relationship between two factors was strong; score 1 was provided when the inter-relationship between two factors was weak; score 0 was provided when there was no inter-relationship between two factors. Then the scores for each factor were added up.

5. *Valuation of the priority rank of the factors.* This was carried out on the basis of the relative forces of the factors and the total scores of factors' inter-relationship. Rank 1, receiving the highest priority, was for the factor with the strongest relative force and the greatest amount inter-relationship. The lowest rank was for the factor with the weakest relative force and the smallest amount inter-relationship.

Using their judgement, the Indonesian Project Team of the WorldFish Center/ADB Project on Sustainable Management of Coastal Fish Stocks in Asia provided the valuation scores.

Results

The results of the analysis are divided into two sections. The first section describes factors affecting the effort to sustain fishery resources, while the second section presents factors that should be considered in increasing fishers' income.

Factors affecting Effort to Sustain Fishery Resources

Identification of Strategic Factors

Restricting Factors

There were seven major problems or factors considered restricting the effort to sustain fishery resources. These factors are (1) inappropriate pattern of fishery resource use, (2) lack of MCS and law enforcement, (3) small scale fishing fleet, (4) use of destructive fishing practices, (5) destruction of habitat, (6) lack of any skills except fishing, and (7) lack of compliance. Justification for each restricting factor is described here.

1. Inappropriate pattern of fishery resource use.
   Lack of coordination between DGF, Provincial Fisheries Services and District Fisheries Services in issuing licenses and in developing the marine capture fishery increases the threat to the sustainability of fishery resources.

2. Lack of MCS and law enforcement.
   Monitoring (M), control (C) and surveillance (S) are the important components of fishery management. With limited capacities and facilities however monitoring and control cannot be carried out effectively. Similarly, limited number and capabilities of personnel and facilities result in ineffective surveillance and enforcement.

3. Small scale fishing fleet.
   Coastal fishery resources of the Java Sea are highly exploited, even over-exploited in some coastal areas. Therefore development of the fish-

ery should be aimed at optimising the utilisation of offshore fishery resources in order to sustain the whole fishery resources. However, the majority of fishing boats are small scale and can only exploit coastal fishery resources.

4. Use of destructive fishing practices.
   There is an increasing tendency to use destructive fishing practices such as blast fishing and use of poisons on coral reefs.

5. Destruction of habitat.
   The sustainability of aquatic habitats is increasingly under threat from human activities such as coral mining and mangrove deforestation, and human-induced impacts such as pollution, and sedimentation.

6. Lack of skills other than fishing.
   As mentioned previously, the small pelagic and demersal fishery resources in inshore waters of the Java Sea are over-exploited. In order to sustain fishery resources, fishing effort in coastal areas should be reduced either by reducing the number of boats or by encouraging fishers to reduce the number of fishing days. However, the reality is that fishing is the only skill of the majority of fishers.

7. Lack of compliance.
   The government has issued a number of policies and regulations that are intended to sustain fishery resources. However, the lack of compliance results in ineffective policies and regulations.

Promoting Factors

Seven major factors that could promote sustaining resources were identified. These are (1) under-exploitation of offshore demersal fish stock, (2) high dependency of coastal communities on fishery resources, (3) availability of fisheries extension officers, (4) availability of potential area of business for fishing households, (5) availability of traditional knowledge, (6) availability of fishers' associations, and (7) promulgation of laws and regulation. Justification for each promoting factor is described here.

1. Under-exploitation of offshore demersal fish stock.
   As mentioned previously, fishery resources in some coastal areas are reported to be over-exploited, so effort in these coastal areas should be reduced. Development of a capture fishery should be carried out in order to meet increasing demand for fish.

2. High dependency of coastal community on fishery resources.
   As fishing is the only skill fishers have, they are highly dependent on fishery resources. Awareness of coastal communities on the benefits of sustaining fishery resources on the sustainability of the fishery resources-based economic activities would promote the effort to encourage fishers to be involved in sustaining fishery resources.

3. Availability of fisheries extension officers.
   The message to sustain fishery resources should be delivered to fishers and other community members. Extension activities can deliver the message effectively.

4. Availability of potential area of business for fishing households.
   As mentioned previously, fishing is the only skill most fishers have. Fishing pressure could be decreased if the fishers could earn additional income in businesses other than fishing. Some areas of business that can be undertaken by fishing households include fish processing and marketing.

5. Availability of traditional knowledge.
   Indonesia has experienced success in conserving fishery resources with the involvement of communities. The communities in the coastal areas around the Java Sea have traditional knowledge concerning the sustainability of fishery resources, which has enabled them to understand the importance of the dynamics of the resources.

6. Availability of fishers association.
   The roles of fishers' associations such as the Indonesian Fishers' Association and the National Fisheries Society are significant in promoting conservation and management of fishery resources. The Indonesian Fishers' Association had the role, for example, of proposing the ban of the operation of trawlers in Indonesian waters in 1980. The National Fisheries Society had an important role in the establishment of the Department of Sea Exploration and Fisheries. This in turn increases the capability of fisheries institutions in sustaining fishery resources.

7. Promulgation of laws and regulations.
   To ensure compliance with fisheries management policies, legal power should be provided to the policies by promulgation of laws and regulations on the policies.

Factor Valuation and Priority Ranking

Valuation of Forces

The relative impacts, solvability and relative forces of restricting factors are presented in Table 2.1. An inappropriate exploitation pattern was consi-dered the main factor with the largest impact in restricting the effort to sustain the resources. As indicated by the relative force solving this problem can result in the highest contribution to the achievement of the objective, which is to sustain fishery resources in the Java Sea.

Relative impacts, solvability and relative forces of promoting factors are presented in Table 2.2. As indicated by the relative force, under-exploitation of demersal fish stock and availability of fishers' associations are the two most important factors that can potentially help sustain fishery resources in the Java Sea.

Priority Ranking

Scores indicating the degrees of inter-relationship among factors are presented in a matrix form in Figure 2.1. Based on the relative forces of the factors and the total scores of factors' inter-relationships, there are three restricting factors and three promoting factors that should be given the highest consideration when formulating alternative management strategies to sustain fishery resources. The most important restricting factors are (1) inappropriate pattern of fishery resource use, (2) lack of MCS and law enforcement, and (3) destruction of habitat. Meanwhile, the three most important promoting factors are (1) under-exploitation of

Table 2.1. Restricting factors in sustaining fishery resources in the Java Sea.

No	Restricting factors	Relative impact	Solvability	Relative force
1	Inappropriate pattern of fishery resource use	5	3	5
2	Lack of MCS and law enforcement	4	3	4
3	Small scale fishing fleet	3	2	2
4	Use of destructive fishing practices	3	2	2
5	Destruction of habitat	4	2	3
6	Lack of any skill but fishing	2	3	2
7	Lack of compliance	3	2	2

Table 2.2. Promoting factors in sustaining fishery resources in the Java Sea.

No	*Promoting factors*	Relative impact	Control-ability	Relative force
1	Under-exploitation of offshore demersal fish stock	4	3	5
2	High dependency of coastal community on fishery resources	3	3	4
3	Availability of fisheries extension officers	2	3	3
4	Availability of potential area of business for fishing households	4	2	3
5	Availability of traditional knowledge	3	2	3
6	Availability of fishers' associations	4	3	5
7	Promulgation of laws and regulation	2	3	3

	P1 *Under-exploitation of offshore demersal fish stock*													
	3	**P2** *High dependency of coastal community on fishery resources*												
	1	1	**P3** *Availability of fisheries extension officers*											
	1	3	3	**P4** *Availability of potential area of business for fishing households*										
	3	3	1	1	**P5** *Availability of traditional knowledge*									
	3	5	3	3	3	**P6** *Availability of fishers' association*								
	3	1	1	1	3	3	**P7** *Promulgation of law and regulation*							
	5	3	1	1	1	1	3	**R1** *Inappropriate pattern of fishery resource use*						
	5	1	1	1	1	1	1	5	**R2** *Lack of MCS and law enforcement*					
	3	1	1	1	1	1	1	3	1	**R3** *Small scale fishing fleet*				
	1	1	1	1	1	1	3	1	3	1	**R4** *Use of destructive fishing practices*			
	3	1	1	1	1	1	3	3	5	1	3	**R5** *Destruction of habitat*		
	1	3	1	1	1	3	1	3	1	3	1	1	**R6** *Lack of any skill but fishing*	
	1	1	1	1	1	1	1	5	3	1	5	3	1	**R7** *Lack of compliance*
Total scores of the inter-relationship	33	27	17	19	21	29	25	35	29	19	23	27	21	25
Relative force	5	4	3	3	3	5	3	5	4	2	2	3	2	2
Rank of priority	I	III	VII	VI	V	II	IV	I	II	VII	V	III	VI	IV
	Promoting factors							*Restricting factors*						

Fig. 2.1. Matrix of the degree of inter-relationship among factors and rank of priority in sustaining fishery resources in the Java Sea.

offshore demersal fish stock, (2) availability of fishers' association, and (3) high dependency of coastal community on fishery resources.

Factors affecting Effort to Increase Income

Identification of Strategic Factors

Restricting Factors

There were seven major factors considered restricting the effort to increase income. These factors are (1) over-exploitation of small pelagic and coastal fish stocks, (2) small scale fleet domination, (3) lack of surveillance and law enforcement, (4) in-appropriate pattern of fishers' expenditure, (5) lack of enterprise managerial skill, (6) lack of technical skill to adopt higher level of post-harvest technology, and (7) lack of capital. Justification for each restricting factor is described here.

1. Over-exploitation of small pelagic and coastal fish stocks.
   Economic incomes gained by fishers tend to decrease with increasing fishing intensity. It is difficult to increase fishers' incomes by developing capture fisheries when fishery resources are over-exploited. Unfortunately, the coastal demersal fish and small pelagic fish stocks are over-exploited, providing no chance to increase fishing intensity.

2. Small scale fleet domination.
   The only opportunity to increase fishers' incomes from capture fishery is by increasing utilisation of offshore demersal fish stock. Unfortunately, the majority of fishers operate small scale boats with limited sailing distance.

3. Lack of surveillance and law enforcement.
   There are a number of laws and regulations to sustain resources and to protect the income-earning capacity of small scale fishers. The effectiveness of the laws and regulations depends on law enforcement and surveillance capabilities, which are presently weak due to limited personnel and facilities.

4. Inappropriate pattern of fishers' expenditure.
   Fishers have a habit of spending most of their income when they obtain good catches and neglecting to save for off-season periods. This habit constrains the effort to increase fishers' incomes.

5. Lack of enterprise managerial skill.
   The utilisation of under-exploited fishery resources, i.e. offshore demersal fish stocks, involves establishing and managing a larger scale of business. This requires a higher level of managerial skill, which unfortunately most small scale fishers do not possess.

6. Lack of technical skill to adopt higher level of post-harvest technology.
   Utilisation of offshore demersal fish stocks will also require a higher level of post-harvest technology to preserve catches during the longer fishing trips. However, small scale fishers have limited skill to adopt more advanced post-harvest technology.

7. Lack of capital.
   Larger boats and different fishing gear are needed to utilise under-exploited offshore demersal fish stocks. However, fishers do not have easy access to funds for new investments.

Promoting Factors

Seven major factors that could promote increasing income were identified. These factors are (1) under-exploitation of offshore demersal fish stock, (2) good coordination among institutions, (3) high and increasing demand for fish and fishery products, (4) availability of potential area of business for fishing households, (5) availability of fisheries extension officers, (6) availability of fisheries training centres, and (7) availability of fishing cooperatives. Justification for each promoting factor is described here.

1. Under-exploitation of offshore demersal fish stock.
   The under-exploited offshore demersal fish stocks provide an opportunity for increasing fishers' incomes.

2. Good coordination among institutions.
   Factors that could affect the success of increasing fishers' incomes include not only technical but also non-technical factors. One of the more important non-technical factors is good coordination among institutions that will collaborate in this effort.

3. High and increasing demand for fish and fishery product.
   Data published by DGF and FAO show the high and increasing demand for fish and fishery products. This tendency would ensure the development of fisheries and could result in increasing fishers' incomes.

4. Availability of potential area of business for fishing households.
   Diversification of business is the other way to increase incomes of fishing households. There are various areas of business that could be conducted by fishing households, for example processing and marketing. These types of business have been conducted by a number of fishing households in some coastal areas, for example in Cilacap, Tegal, Pekalongan and Brondong.

5. Availability of fisheries extension officers.
   Transfer of knowledge and sharing of experience can benefit fishers who want to expand their fishing grounds and business scale. Fisheries extension officers should carry out this extension work. Fortunately, the government has trained extension officers in fisheries and assigned them to work in local offices close to the coastal communities.

6. Availability of fisheries training centres
   Training centres and training equipment are needed as facilities to transfer knowledge to fishers, to share experience among fishers and to train them on new technologies and business skills. Fortunately, there is at least one training centre in each province that could be used to conduct extension and training activities.

7. Availability of fishing cooperatives
   Cooperatives have been established for the welfare of their members. There are a number of cooperatives on the northern coast of Java that have succeeded in increasing their business and welfare of the members. The development of cooperatives was a national development program aiming at increasing welfare. There were many fishery cooperatives established in coastal areas around the Java Sea. These cooperatives can be developed further to support the effort to increase fishers' incomes.

Factor Valuation and Priority Ranking

Valuation of Forces

Relative impacts, solvability and relative forces of restricting factors are presented in Table 2.3. As indicated by the relative force, the domination of the small scale fishing fleet and the lack of fishers' skill in management are the two most important factors that restrict the effort to increase incomes of fishers operating in the Java Sea. Therefore, solving this problem can result in the highest contribution to the achievement of the objective.

Relative impact, solvability and relative forces of promoting factors are presented in Table 2.4. As indicated by the relative force, the availability of fishing cooperatives is considered to be the most important factor that could help increase fishers' incomes.

Priority Ranking

Scores indicating the degrees of inter-relationship among factors are presented in a matrix form in Figure 2.2. The three restricting factors that

Table 2.3. Restricting factors in increasing income of fishers in the Java Sea

No	Restricting factors	Relative impact	Solvability	Relative force
1	Over-exploitation of small pelagic and coastal fish stocks	3	3	4
2	Small scale fleet domination	4	3	5
3	Lack of surveillance and law enforcement	2	3	3
4	Inappropriate pattern of fishers' expenditure	4	2	3
5	Lack of enterprise managerial skill	4	3	5
6	Lack of technical skill to adopt higher level of post-harvest technology	3	3	4
7	Lack of capital	4	2	3

Table 2.4. Promoting factors in increasing income of fishers in the Java Sea

No	Promoting factors	Relative impact	Control-ability	Relative force
1	Under-exploitation of offshore demersal fish stocks	4	3	3
2	Good coordination with other institutions	2	4	2
3	High and increasing demand for fish and fishery products	4	2	2
4	Availability of potential area of business for fishing households	4	4	4
5	Availability of fisheries extension officers	2	3	2
6	Availability of fisheries training centres	2	3	2
7	Availability of fishing cooperatives	5	4	5

should receive the highest attention in formulating alternative fishery management strategies in order to increase incomes are (1) small scale fleet domination, (2) lack of enterprise managerial skill, and (3) over-exploitation of small pelagic fish stock. Meanwhile, the three promoting factors that should receive the highest attention are (1) availability of fishing cooperatives, (2) availability of potential area of business for fishing households, and (3) under-exploitation of offshore demersal fish stock.

Annex 3. Action and Program

Introduction

As presented in Annex 2, there are various restricting and promoting factors affecting the achievement of the objectives of fisheries management in the Java Sea. These factors indicate two major issues on capture fisheries in the Java Sea.

The first major issue concerns the sustainability of fishery resources of the Java Sea. The coastal

	P1	P2	P3	P4	P5	P6	P7	R1	R2	R3	R4	R5	R6	R7	
P1															*Under-exploitation of offshore demersal fish stock*
P2	1														*Good coordination with other institutions*
P3	1	1													*High and increasing demand for fish and fishery products*
P4	3	1	3												*Availability of potential area of business for fishing households*
P5	1	3	1	1											*Availability of fisheries extension officers*
P6	1	3	0	0	1										*Availability of fisheries training centres*
P7	3	1	3	3	3	1									*Availability of fishing cooperatives*
R1	1	0	3	3	1	1	1								*Over-exploitation of small pelagic and coastal fish stocks*
R2	3	0	1	1	1	1	1	1							*Small scale fleet domination*
R3	1	1	0	0	1	0	1	5	0						*Lack of surveillance and law enforcement*
R4	0	0	1	1	0	0	1	0	3	0					*Inappropriate pattern of fishers' expenditure*
R5	1	0	0	1	1	1	1	0	3	0	3				*Lack of enterprise managerial skill*
R6	1	0	0	1	1	1	1	0	3	0	1	3			*Lack of post-harvest technical skill*
R7	1	0	0	1	0	0	1	0	3	0	1	3	3		*Lack of capital*
Total scores of the inter-relationship	18	11	14	19	15	10	21	16	21	9	11	17	15	13	
Relative force	3	2	2	4	2	2	5	4	5	3	3	5	4	3	
Rank of priority	III	VI	V	II	IV	VII	I	III	I	VII	VI	II	IV	V	
	Promoting factors							*Restricting factors*							

Fig. 2.2. Matrix of the degree of inter-relationships among factors and rank of priority in increasing income of fishers of the Java Sea.

demersal fish stock and the small pelagic fish are over-exploited. An appropriate strategy of fishery resources management and its supporting actions are required to sustain these resources.

The second major issue concerns the socioeconomic conditions of fishers and their households, particularly the low incomes and the limited livelihood opportunities of small scale fishers. An appropriate development strategy, its actions and investment programs are required to address this issue.

Action and investment programs of the Java Sea Fisheries Management and Development Program are presented here. This is an integrated program involving various aspects of fisheries and relevant stakeholders. Processes in formulating the action and investment programs include (a) identifying possible actions for each key issue, (b) categorising actions by key issues, (c) defining program components and sorting the actions by these components, and (d) defining the type of actions. The proposed project required to initiate the program is presented here.

Issues, Program Components and Implementation

Issues, Actions and Program Components

As mentioned previously, there are two major issues of the Java Sea fisheries, namely, sustainability of fishery resources and socio-economic conditions of fishers and their households. Six key issues for each of these major issues were selected from the restricting and promoting factors, which were categorised as top three factors (see Annex 2). The key issues and actions dealing with the sustainability of fishery resources and the improvement of socio-economic conditions of fishers and their households are listed in Table 3.1.

An integrated management and development program for the Java Sea fisheries is required in order to sustain fishery resources and to increase the income and livelihood opportunities of small scale fishers. The actions of this program can be grouped into four program components, namely, fishery resources co-management, public awareness, business opportunity development and fishers' capacity building. These actions can be categorised as policy, public campaign and investment (Table 3.2). Data and information are required to establish fisheries co-management, to formulate government policies, management plans

Table 3.1. Key issues and actions needed to sustain fishery resources to increase the income and livelihood opportunities of small scale fishers in the Java Sea.

Key issues	Action or key intervention
Sustaining fishery resources	
Inappropriate pattern of fishery resource use	Formulate appropriate fishery resource uses Involve all stakeholders in the management planning and actions Increase public awareness
Lack of MCS and law enforcement	Strengthen MCS system Increase the participation of coastal communities
Destruction of habitat	Increase public awareness Create alternative income sources
Under-exploitation of offshore demersal fish stock	Formulate appropriate management plan Involve all stakeholders in the management planning and actions Revise spatial planning for fisheries development
Availability of fishers' associations	Involve fishers' associations in the management planning and action Strengthen fishers' associations and increase their awareness
High dependency of coastal community on fishery resources	Increase public awareness Involve coastal communities in the management planning and action
Increasing income and livelihood opportunity	
Small scale fleet domination	Special scheme on access to capital/bank service Increase technical skill in fishing and post-harvest technologies
Lack of enterprise managerial skill	Training program Extension program
Over-exploitation of small pelagic and coastal demersal fish stocks	Control fishing effort Increase public awareness Create alternative income sources
Availability of fishing cooperatives	Strengthen fishing cooperatives Involve fishing cooperatives in the creation of alternative income sources
Availability of potential area of business for fishing households	Create, optimise and use opportunities Training program Extension program
Under-exploitation of offshore demersal fish stock	Formulate appropriate management plan Involve all stakeholders in the management planning and actions Revise spatial planning for fisheries development Minimise free competition between small scale and large scale fisheries Develop offshore demersal fishing fleet

Table 3.2. Components and actions of the Management and Development Program for the Java Sea Fisheries.

Key issues	Action or key intervention	Action category
1. Fishery resources co-management component		
Availability of fishers' associations	Involve fishers' associations in the management planning and action to sustain fishery resources	Government policy
High dependency of coastal community on fishery resources	Involve coastal communities in the management planning and action to sustain fishery resources	
Inappropriate pattern of fishery resource use	Formulate appropriate fishery resource uses	
	Involve all stakeholders in the management planning and actions to sustain fishery resources	
Over-exploitation of small pelagic and coastal demersal fish stocks	Control fishing effort to sustain fishery resources and to increase fishers' incomes	
Under-exploitation of offshore demersal fish stocks	Involve all stakeholders in the management planning and actions to sustain fishery resources and to increase fishers' incomes	
	Formulate appropriate management plan to sustain fishery resources and to increase fishers' incomes	
	Minimise free competition between small scale and large-scale fisheries to sustain fishery resources and to increase fishers' incomes	
	Revise spatial planning for fisheries development to sustain fishery resources and to increase fishers' incomes	
Lack of MCS and law enforcement	Strengthen MCS system to sustain fishery resources	Government policy and investment
	Involve fishing communities in the surveillance	
2. Public awareness component		
Destruction of habitat	Increase public awareness to sustain fishery resources in order to increase fishers' incomes	Public campaign
High dependency of coastal community on fishery resources		
Inappropriate pattern of fishery resource use		
Over-exploitation of small pelagic and coastal demersal fish stocks		
Lack of MCS and law enforcement	Increase the awareness of fishing communities in fisheries surveillance in order to sustain fishery resources	
Availability of fishers' associations	Increase the awareness of fishers' associations to sustain fishery resources	
Availability of fishing cooperatives	Involve fishing cooperatives in the creation of alternative income sources	Government policy
Destruction of habitat	Create alternative income sources	Private investment
Over-exploitation of small pelagic and coastal demersal fish stocks	Create alternative income sources	
Under-exploitation of offshore demersal fish stock	Develop offshore demersal fishing fleet	

Table 3.2. Components and actions of the Management and Development Program for the Java Sea Fisheries. (continued)

Key issues	Action or key intervention	Action category
3. Fishers' capacity building and institutional strengthening component		
Availability of fishing cooperatives	Strengthen fishing cooperatives to increase their capacity to run businesses	Government policy and private investment
Lack of enterprise managerial skill	Extension and training program to increase fishers' skill in managing their business in order to increase income	
Small scale fleet domination	Increase technical skill in fishing and post-harvest technologies	
	Special scheme for access to capital/bank service	Government policy
Availability of fishers' associations	Strengthen fishers' associations to increase their involvement in fisheries management and surveillance	
4. Fisheries research component		
	Up-date data on bio-physical characteristics of the fisheries	Research
	Collect data on socio-cultural characteristics of coastal communities	
	Policies and legal reviews	

and materials for a public campaign, and to create alternative income sources. Therefore, a fisheries research component is also required.

Program Implementation

Background

Fishing effort should be controlled to sustain fishery resources and to optimise the economic benefit gained from these resources. Licensing is one of the management tools to control the development of fishing effort. Based on *Article 10* of the Government Regulation no. 15 of 1990, the provincial government issues licenses for fishing boats with sizes equal or less than 30 GT; the central government issues licenses for fishing boats greater than 30 GT. Both government levels issue fishing licenses in the Java Sea since the fisheries in the area include both small scale and large-scale.

The Autonomy Act no. 22 of 1999 provides greater responsibility to the provincial and district governments to undertake exploration, exploitation, conservation and management of fishery resources in their marine areas (see *Article 10* of the Act). Based on *Article 3* of the Act, the marine area of the province covers waters up to 12 nm from the coastline. However, fish stocks in the Java Sea are distributed from inshore to offshore waters, far beyond 12 nm. These resources are shared among fishers from different provinces. Therefore, it would be difficult for each provincial government to manage shared fish stocks, as management of fishery resources should be as a unit. The concerned provincial governments and the central government should manage fishery resources in the Java Sea collaboratively. Moreover, all stakeholders should be involved in a co-management framework in order to achieve management objectives efficiently.

Program Objectives

The Java Sea Fisheries Management and Development Program is aimed at sustaining fishery resources and optimising the economic benefits that could be gained from fishery resources utilisation in order to alleviate fishers' poverty.

Program Organisation Structure

As presented in Table 3.2, there are four possible program components consisting of various actions. These actions could be categorised into three types of actions, namely policy, public campaign and investment. The policies would be formulated by the governments, either central, provincial or district governments. Public campaigns could be carried out by government and non-government organisations. Meanwhile, investment could be by government or private sectors.

A Fisheries Management Authority (FMA), to be

established with the involvement of all key stakeholders, will implement policies on the management of shared fishery resources in the Java Sea. Stakeholders include government institutions, fishers, fish processors and traders. The government institutions consist of the Directorate General of Fisheries, the Directorate General of Marine Surveillance and Protection, and the Provincial Fisheries Services of East Java, Central Java, West Java, Jakarta, West Kalimantan, Central Kalimantan and South Kalimantan.

The Java Sea FMA would be responsible for ensuring the sustainable use and efficient management of fisheries resources on behalf of the community and key stakeholders. The Java Sea FMA should commit to excellence in managing fisheries resources, considering the needs of the marine ecosystems and current and future generations. The Java Sea FMA would make decisions on fisheries management consistent with national policies.

The Java Sea FMA should be supported by a Management Advisory Committee (MAC). The members of the Java Sea Fisheries MAC would consist of relevant stakeholder groups, including the commercial fishing industry. The Java Sea Fisheries MAC would be expertise-based and advisory in nature, and would make recommendations to the Java Sea FMA on management and operational issues. The Java Sea Fisheries MAC would identify and discuss issues and problems relating to a fishery and develop possible solutions. The outcome of these activities would determine the recommendations the MAC would make to the Java Sea FMA.

The FMA and the MAC of the Java Sea have yet to be established. The FKPPS of management area III could be used in initiating the establishment of this co-management body.

Financial/Resource Requirements

As presented in Table 3.2, the program would consist of various activities categorized into formulation and implementation of policies, public campaign, and government and private investments. A budget would be required to carry out the program. The budget should come from the government and non-government organizations, and the private sector.

In the long-term, the budget for the formulation and implementation of government policies, public campaign, and government investment, needed to manage and develop the Java Sea fisheries, should come from fishery resource rents that would be charged to the resource. In the short-term, however, the budget for the program activities carried out by the government should come from the government. Unfortunately, the government budget is very limited under current economic conditions. Therefore, availability of a grant would be very important to carry out the program.

Monitoring and Evaluation

Monitoring will be done to evaluate the achievement of the program objectives. The main indicators that would be used to measure the objective achievement could be (1) the level of fishing effort, (2) fishing boat productivity, (3) species composition of catch, (4) the average annual income per fisher household, and (5) the frequency of violation (number of cases per year). Problems and constraints encountered in the implementation of the program should also be monitored in order to evaluate the program and adjust the policies.

In order to sustain fishery resources, the level of fishing effort should be equal to the effort achieving a target reference point or lower. Meanwhile, the fishing boat productivity should be equal to that when the target reference point is achieved or higher. Bio-diversity of fishery resources, indicated by the species composition of catch, should remain high. The frequency of violation should decrease. The average annual household income of small scale fishers should increase.

There are two approaches used in monitoring, namely direct and indirect approaches. Official mechanisms are used to monitor programs directly. Indirect monitoring is carried out by the involvement of communities.

Proposed Project Digest

The project, named *the Java Sea Fisheries Management and Development Project*, would implement the *Java Sea Fisheries Management and Development Program*. As government funds are limited, the program coverage is wide and some program activities need to be carried out simultaneously, the project should be divided into at least two phases. The first phase would be carried out to initiate the program. In the second phase of the project, investment, consisting of private and cooperative investment and government investment, would be made.

The proposed project to initiate the program is named *the Java Sea Fisheries Management and Development Project Phase I*. The proposed project would cover various aspects of fisheries and would involve relevant stakeholders. A summary of the proposed project is presented here.

Project Objectives

The objectives of the proposed project are:

a. To develop a co-management framework involving all stakeholders in order to sustain fishery resources and to optimise economic benefits resulting from the utilisation of the resources;
b. To increase public awareness in sustaining fishery resources in order to increase economic benefits resulting from the utilisation of the resources;
c. To develop business opportunities other than fishing in order to reduce fishing pressure on fishery resources that are heavily exploited;
d. To develop fishers' capacity in utilising business opportunities.

Project Description

The project will carry out the following activities:

a. Establishment of fishery resources co-management and formulation of the first management plan. In the first phase, the management intention should not be to reduce the number of fishing vessels. Decreasing fishing pressure should be carried out by adjusting the number of fishing trips;
b. Formulation of the drafts of government policies;
c. Public campaign;
d. Creation of alternative income sources for fisher households and coastal communities.

Project Implementation

The duration of proposed project will be three years. The plan of operation of the proposed project is summarised in Table 3.3.

The executing agencies of the project activities will be government institutions. They would consist of the Directorate General of Fisheries, the Directorate General of Marine Surveillance and Protection, and the Provincial Fisheries Services of East Java, Central Java, West Java, Jakarta, West Kalimantan, Central Kalimantan and South Kalimantan. Effective consultation with relevant stakeholders would be carried out during preparation, implementation and evaluation of the proposed project.

Table 3.3. The plan of operation of the Java Sea Fisheries Management and Development Project phase I.

No	Project activities	Year 1	Year 2	Year 3
1	Project preparation	■		
2	Collection and analysis of data/ information	■	■	
3	Public campaign	■	■	■
4	Establishment of fishery resources co-management		■	■
5	Formulation of the management plan		■	■
6	Formulation of the drafts of government policies		■	■
7	Creation of alternative income sources for fisher households		■	■

Resource/Budget Requirements

Total estimated budget required for the Java Sea Fisheries Management and Development Project Phase I is about US$800 000. The budget will be used:

a. To carry-out the following activities:

1. Project preparation	10 000
2. Collection and analysis of data/information	40 000
3. Public campaign	60 000
4. Establishment of fishery resources co-management	60 000
5. Formulation of the management plan	60 000
6. Formulation of the drafts of government policies	30 000
7. Creation of alternative income sources for fisher households	110 000

b. To hire experts/consultants and project staffs:

1. Experts/consultants specialising in Fisheries Biology, Fisheries Economics, Sociology, Fisheries Management, Aquaculture and Fish Processing, Mass Communication, Fisheries Law	240 000
2. Project staffs (6 people)	15 000
c. To rent office	90 000
d. For transportation expenses (car and its operational/maintenance)	40 000
e. For telecommunication, stationery, and other expenses	45 000

The budget to carry out the proposed project is expected to come from a grant, as government funds are very limited under current economic conditions.

Project Monitoring and Evaluation

Monitoring would be done to identify problems and constraints encountered in the implementation of the project, to evaluate the progress of the project and the achievement of the program objectives or benefits. There would be two approaches used in the monitoring, namely direct and indirect approaches. Official mechanisms would be used to monitor the project and program directly. The involved communities would carry out indirect monitoring.

Monitoring the evaluation of the achievement of the project targets, consisting of physical and financial targets, would be done monthly through a reporting system. Supervision would be carried out in order to monitor the project. Project indicators would be used to evaluate the progress of the project and the achievement of the project objectives. The project indicators would consist of (1) physical target attainment, and (2) financial target attainment.

Monitoring the evaluation of the achievement of the program objectives or benefits would be done annually. The indicators that would be used to evaluate the achievement of the program objectives or benefits would consist of (1) the level of fishing effort, (2) fishing boat productivity, (3) composition of species caught, (4) the average annual income per fisher household, (5) types of business conducted by fisher household, (6) the frequency of violation (number of cases per year).

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Overview of the National Fisheries Situation with Emphasis on the Demersal Fisheries off the West Coast of Peninsular Malaysia

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Abstract

The marine fisheries sector in Malaysia contributes significantly to the national economy in terms of income, foreign exchange and employment. In 1999, marine fisheries contributed 1.245 million t (90% of total fish production) valued at US$1.18 billion. The total value accounted for about 1.53% of national GDP and 11.31% of agricultural GDP. The export of fish and fishery products amounted to about US$210 million. The sector provided employment to about 80 000 fishers.

Fisheries management is currently guided by the Third National Agricultural Policy (NAP3 1998 - 2010). The NAP3 aims to maintain the coastal fisheries production while increasing the production from deep-sea fisheries within Malaysia's Exclusive Economic Zone and the high-seas. Fisheries management of fisheries is centralized and is the primary responsibility of the Department of Fisheries. The key challenges identified for Malaysian fisheries are overfishing, excess fishing capacity and ensuring the well-being of coastal fishing communities. These are issues across the whole of Malaysia.

The West Coast of Peninsular Malaysia produces 44% (1997) of total marine landings and 86% of this came from commercial (large scale) vessels. The landings in 1997 exceeded the estimated MSY and the biomass of demersal species in the region has been severely reduced. A national consultative workshop identified the primary aims for this region to improve production and efficiency of the fisheries, equitable distribution of the benefits, resources sustainability and the viability of the fishing communities.

The workshop also identified key interventions needed. In terms of production and efficiency, overfishing and overcapacity must be addressed, including the illegal fishing. In terms of achieving greater equity, the workshop suggests greater involvement of small scale fishers in marketing of the catch. For resource sustainability, the serious decline in biomass must be addressed but there are also significant cross-sectoral issues. To achieve viable fishing communities, the workshop suggests the need for greater involvement and potentially a co-management approach for fisheries management.

Introduction

The fisheries sector is vitally important to Malaysia. Apart from contributing to the national Gross Domestic Product (GDP), it is also a source of employment, foreign exchange and protein (Department of Fisheries (DOF) 1995a, 1995b). In 1999, marine fisheries catch was 1 245 000 t (90% of total fish production) valued at RM5 billion (US$1.18 billion). The catch value accounted for 1.53% of GDP and 11.31% of agricultural GDP. Demand for fish, which is the main source of protein, is expected to increase from an annual consumption of 630 000 t to 1 580 000 t by the year 2010 (Department of Fisheries (DOF) 1995b). The quantity and value of fishery exports increased from 163 453 t valued at RM295 million in 1985 to 107 622 t valued at RM939.58 million in 1997. However, imports of fish and fishery products also increased from 200 700 t valued at RM363.6 million in 1990 to 297 800 t valued at RM979.2 million in 1997. Malaysia is now a net importer of fish and fishery products in terms of both quantity and value. In terms of employment, the 80 000 persons employed in the fisheries sector in 1999 made up 1% of the national work force. The number of persons employed in the sector has steadily decreased by 2.2% per annum since 1985.

As demand for fish continues to increase, the task of managing fisheries resources on a sustainable basis has become increasingly challenging. The threats of over-exploitation and the degradation of aquatic habitats have become serious problems. Some mangrove forests, which provide important breeding, nursery and feeding grounds for fish, prawns and a variety of invertebrates, have been cleared for development or affected by pollution or diversion of drainage water. Coastal areas are threatened by severe erosion along extensive parts of the coastline. Continued economic growth and industrialization are exerting considerable pressure on sensitive coastal ecosystems. Effluents from industrial and domestic discharges, land reclamation as well as illegal dumping and accidental spills contribute to degradation of water quality in the aquatic environment. Technological advancements and the growing needs of the population have drastically increased utilization of coastal resources. Large scale extraction of hydrocarbons, mining of coral reefs, intensive exploitation of fisheries, marine tourism and transportation often manifest in conflicts of interest that further endanger the resources (Ngoile and Horrill 1993). To ensure sustainable exploitation of fisheries resources in coastal areas, the country must address these issues by formulating sound and integrated management measures.

This paper provides an overview of the national fisheries situation, and then focuses on key management issues and directions for the West Coast

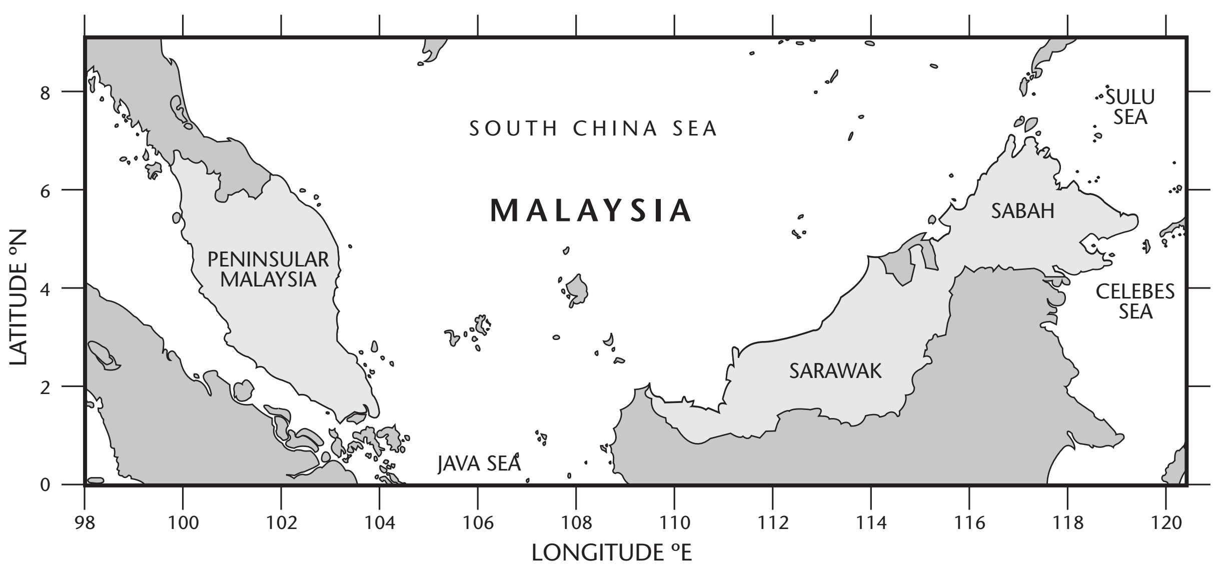


Fig. 1. Location map of Malaysia.

of Peninsular Malaysia (WCPM). The WCPM contributed about 44% or 515 400 t of total marine capture fisheries production in 1997. Total catch in this area consisted of 53% demersal fish, 29% pelagic fish, 13% prawn and 5% squid and cuttlefish. Commercial (large-scale) fishing landed 71% of this catch. Although the area has been known as the most productive in the country, assessments (see Abu Talib et al.paper no. 6) indicate a marked decrease in abundance of demersal fish. Hence, management efforts in the area must be given special attention if the benefits derived from its fisheries are to be maintained.

Environmental Setting

Malaysia is a confederation composed of the Malay Peninsula (or Peninsular Malaysia) at the southeastern tip of the Asian mainland and the States of Sabah and Sarawak in the northwestern part of Borneo Island (Fig. 1). It has a land area of 330 000 km^2 and a coastline of 4 675 km. The Malay Peninsula faces the Indian Ocean in the west and the South China Sea in the east. The state of Sarawak borders the South China Sea. Sabah borders the South China Sea, Sulu Sea and Celebes Sea. The waters off the West Coast of Peninsular Malaysia, with the most extensive mangrove area, are considered the main marine fishing ground.

Coastal waters (up to 200 m depth) of Malaysia have a surface area of 373 500 km^2, which includes territorial waters of 161 200 km^2 (up to 12 nm). Malaysia claims an Exclusive Economic Zone (EEZ) of 548 800 km^2, 29% of which is located off Sarawak State and 16% off Sabah State. The coastal waters represent about 69% of the EEZ.

Malaysian waters are divided into four areas: the West Coast and the East Coast of Peninsular Malaysia, the coast of Sarawak and the coast of Sabah. Located between latitude 1° 01' N and 6° 30' N and longitude 98° 01' E and 103° 30' E, the waters off the West Coast of Peninsular Malaysia (WCPM) form part of the Straits of Malacca. The maritime jurisdiction in this area can be divided into two: the territorial waters of about 56 450 km^2 and the overlapping Malaysia-Indonesia EEZ area of about 11 320 km^2. Off WCPM, depth seldom exceeds 120 m. The bottom gradually slopes downward from the coastline of east Sumatra and from the WCPM (Liong 1974). From the 30-m isobath near One Fathom Bank off Selangor, depth increases northward to the Andaman Sea and southward to the South China Sea.

The East Coast of Peninsular Malaysia (ECPM) is located between latitude 1° 13' N to 7° 49' N and longitude 102° 07' E to 105° 49' E. The maritime jurisdiction in the area can be divided into two: territorial waters of about 35 900 km^2 and EEZ waters of about 99 750 km^2. The ECPM has a relatively flat sea bottom and a maximum water depth of about 80 m.

The coastal waters off Sarawak are located between latitude 1° 30' N to 7° 07' N and longitude 109° 38' E to 114° 05' E. The area is about 132 440 km^2, of which 19% is located in territorial waters. The continental shelf off Sarawak extends up to 220 nautical miles (nm) at its widest span north of Tanjong Po in the south, and its narrowest span is 30 nm north of Tanjong Baram in the north. Beyond the 200-m isobath in this area, depths drop to 1 000 m over a mean distance of 2.5 nm.

The coastal waters off Sabah are located between latitude 4° 50' N to 8° 24' N and longitude 112° 30' E to 117° 00' E. The area extends from the boundary of Brunei Darulssalam waters to Kudat on the northern tip of Sabah. From the coastline the area extends seaward to 30 nm, totaling 30 940 km^2. Most of the area is located within territorial waters.

Throughout the year, surface currents in the Straits of Malacca flow northwestward through the center of the Strait. During the northeast (NE) monsoon from October to April, the northwest current results from the south-going monsoon current in the South China Sea, which passes the extremity of the Malay Peninsula into the Strait. During the southwest (SW) monsoon from May to September, water flows westward in the Java Sea and northwestward through the Kalimantan Strait towards the South China Sea, then passes directly into the Malacca Strait (Hydrographic Department. Admiralty 1964). Current speeds may exceed 1 knot throughout the year in the Malacca Straits.

Surface currents in the South China Sea flow according to the monsoon-driven wind system. The southwesterly current of the northeast monsoon is stronger and more constant than the northeasterly current of the southwest monsoon (Hydrographer of the Navy 1975). The southwesterly flow of the northeast monsoon prevails from October to February, while currents reach their greatest speed and

constancy from December to January.

The northeasterly current of the southwest monsoon occurs in May after the transition period from March to April. The current attains its greatest speed and constancy from June to around August-September. During the monsoons, wind speeds fluctuate considerably due to variations in distribution of atmospheric pressure. The northeast monsoon winds are stronger and less liable to interference than the southwest monsoon winds. The direction of water movement in the eastern side of the South China Sea is largely controlled by eddies which occur in most months, and by the flow of water to or from the Sulu Sea and through the broad straits between Peninsular Malaysia and Borneo. Oceanographic and meteorological conditions within and outside the area control these features. The currents are generally weak with means of less than 0.5 knots in most areas. When monsoons are fully developed (July to August and December to February) the mean speeds increase from 0.5 to 1 knot. On rare occasions, currents may run up to 3 knots between Peninsular Malaysia and Borneo, and 4 knots in some of the passages linking the South China Sea to the Sulu Sea.

Data from trawl surveys show a gradual transition in bottom sediment type along WCPM from mud in the north to rocky and uneven ground in the south. Substrates in the central area are mixtures of mud and sand (Mohammed Shaari et al. 1974). Substrates off ECPM are suitable for trawling, with minor patches of hard and soft corals and mud-clay sediments (Pathansali et al. 1974). Bottom substrates in the continental shelf off Sarawak and the west coast of Sabah generally consist of sandy, mud, mud-sand and coral areas. About 22% of the shelf off Sarawak is composed of reefs and rough grounds, which include areas such as steep undulating grounds and rocky bottom. About 50% of the west coast of Sabah consists of rough ground, mostly due to the presence of reefs.

Sea surface temperature in the Straits of Malacca ranges from 26 to 27° C during the northeast monsoon and 28 to 30° C during the southwest monsoon (Chua et al. 1997). The warmer waters occur nearshore especially at the northern and southern region of the strait (Kassim and Nasir unpublished). During the northeast monsoon off WCPM, salinity ranges from 27 to 33.3 ppt on the surface and between 25.4 to 33.4 ppt at depths of 13 to 21 m. In the South China Sea off ECPM, sea surface temperature during the northeast monsoon varies from 26 to 29° C. The off monsoon period brings water temperatures of 28° C to 30° C. Mean sea surface temperature during the SW monsoon ranges from 29° C to 32°C (Hamid 1989). Sea surface temperature off Sarawak and the West Coast of Sabah during the southwest monsoon ranges between 29° C to 30° C, with salinity varying from 33.8 to 34.0 ppt (Nasir et al. 1988).

In most cases, thermocline depth is between 20 to 50 m (Anon. 1987; Nasir et al. 1988). Water temperature above the thermocline typically ranges from 28° C to 30° C. No thermocline has been observed off the WCPM due to the relatively shallow water. Thermocline layers are present off the ECPM, both before and after the northeast monsoon. The thermocline depth is deeper before the northeast monsoon and becomes shallower after the northeast monsoon (Nasir et al. 1999).

Primary productivity in the South China Sea off the ECPM ranges from 0.29 - 0.47 g $C \cdot m^{-2} \cdot day^{-1}$. It is higher near the surface and gradually decreases with depth (Musikasung et al. 1999a). The most dominant phytoplankton and zooplankton in this area are diatoms and copepods, respectively. Average concentration of chlorophyll a is 0.08 $mg \cdot m^{-3}$ on the surface and 0.21 $mg \cdot m^{-3}$ in the water column (Raihan and Ichikawa 1986). Off Sarawak and the west coast of Sabah, primary productivity varies between 0.13 - 0.88 g $C \cdot m^{-2} \cdot day^{-1}$ in the coastal zone and 0.23 - 0.89 g $C \cdot m^{-2} \cdot day^{-1}$ in the open sea (Musikasung et al. 1999b). Like the waters off ECPM, Sarawak waters exhibit low chlorophyll a values ranging between 0.0493 to 0.1505 $mg \cdot m^{-3}$ (Lokman et al. 1988).

Siltation has been a major problem in Malaysian coastal waters. Intensive land clearing, uncontrolled development, mining and logging in the catchments may be responsible for increased siltation. In addition, effluents from palm oil and rubber processing, which contain very high concentrations of organic material, suspended solids and nutrients (like nitrogen and phosphorus), may also end up in coastal waters.

In the WCPM, average concentration of orthophosphate during post NE monsoon at the surface water, thermocline layer and bottom water is 0.06, 0.32 and 0.72 µM, respectively. During the northeast monsoon, concentrations were 0.11, 0.17 and 0.26 µM, respectively (Tengku-Rozana in press).

Generally, the concentration of ortho-phosphate are higher in surface waters closer to rivers and ports. Total suspended solids concentration off WCPM ranged from 0.2 to 5.4 $mg \cdot l^{-1}$ (in March) and from 0.5 to 18.2 $mg \cdot l^{-1}$ (in November) (Ku-Kassim unpublished). Concentration of heavy metals were reported higher in the WCPM compared to other areas because of more extensive land use and industrialization. Almost all samples collected from the coastal waters of Malaysia had values exceeding proposed standards of 0.05 $mg \cdot l^{-1}$ lead, 0.01 $mg \cdot l^{-1}$ copper and 0.005 $mg \cdot l^{-1}$ cadmium. However, analyses indicated that levels of heavy metals found in Malaysian fish and shellfish do not pose a major threat to public health (Shahunthala 1989).

In the South China Sea off the ECPM average concentration of ortho-phosphate in surface water, the thermocline layer and bottom water were 0.33, 0.33 and 0.36 µM respectively. For coastal waters off Sarawak and the west coast of Sabah, average concentration of ortho-phosphate in surface water, the thermocline layer and bottom water (up to 1000 m deep) were 0.50, 0.49 and 0.69 µM respectively (Tengku-Rozana unpublished). Total suspended solids concentration in the ECPM ranged between 0.1 to 10.0 $mg \cdot l^{-1}$. The highest concentration of suspended solids was recorded near Pahang estuary in the south. The concentration decreased toward the northern region to almost zero. Concentration of suspended solids in Sarawak and Sabah waters ranged from 0.3 to 8.7 $mg \cdot l^{-1}$. The highest concentration was in the outer area and the areas around Rajang estuary (Ku-Kassim unpublished).

Coral reefs are widespread off Peninsular Malaysia as well as Sabah and Sarawak. Along the WCPM, coral reefs are mainly found near the islands of Langkawi, Pangkor, and Sembilan and off the coast of Port Dickson. Off the ECPM, coral reefs are found around the islands off the coast of Terengganu (Redang, Perhentian and Tenggol islands) and Pahang/Johor (Tioman islands group). The more extensive coral reef areas are located off the north coast of Sabah and the Spratleys.

The biggest threat to coral reefs has been exploitation for commercial and tourism purposes, coupled with siltation and sedimentation caused by development projects (Liew and Hoare 1982). These have subjected corals to stress and leaching resulting in deterioration of coral reefs. Actions have been taken to conserve and rehabilitate the country's coral reefs, including gazetting of areas as marine parks and fisheries protected areas. A marine park is a sea area zoned as sanctuary for protection of its marine ecosystems, especially coral reefs and associated fauna and flora. To date, waters surrounding 40 islands are grouped into five marine parks: Pulau Payar Marine Park in Kedah (comprising 4 islands); Pulau Redang Marine Park in Terengganu (11 islands); Pulau Tioman Marine Park in Pahang (9 islands); Mersing Marine Park in Johore (13 islands) and Labuan Marine Park in Labuan (3 islands). Activities that are harmful and destructive to the coral reef and marine ecosystem are prohibited under Fisheries Act 1995 (Section 43). Prohibited activities include fishing and killing of fish; spear-gun fishing; collecting corals, shells and other living marine organisms; collecting sand, dead corals and shells; littering and polluting; anchoring of boats directly on the reef; and constructing and erecting a structure without permission.

Malaysia has the fifth most extensive mangrove area in the world (World Resources Institute (WRI) 1996). About 446 000 ha of the 641 000 ha mangrove forests in the country are gazetted as forest reserves, with the remaining classified as state land forests (Chew 1996). Mangrove forests in Peninsular Malaysia have been estimated at around 103 000 ha mainly located off the sheltered West Coast (Tang et al. 1990). The major areas include the Larut Matang mangroves in the state of Perak (40 000 ha), the mangroves in Johor (25 618 ha), Kelang in Selangor (22 500 ha) and Merbok in Kedah (9 037 ha) (Choo et al. 1994). The Larut Matang mangrove area was reported to be the largest in Peninsular Malaysia and the best managed in the world (Gong et al. 1980). The area has been sustainably managed for timber since the 1920s. Along the ECPM, mangroves are found in small patches within sheltered estuaries of rivers (Chan et al. 1992). More than half of the mangrove forests in Malaysia are found in eastern Sabah. In Sarawak, mangrove forests are distributed along the northern and southwestern coasts. The mangrove forest is an important ecosystem that plays a vital role in the socioeconomic well-being of coastal communities. The main threat to mangroves in Malaysia stem from land conversion for agriculture, industry and aquaculture.

Thirteen species of seagrass have been recorded in Malaysia (Japar 1995; Kushairi 1992). The species are *Halophila beccarii, H. decipiens, H. ovalis, H. minor,*

H. spinulosa, Enhalus acoroides, Thalassia hemprichii, Cymodocea rotundota, C. serrulata, Halodule pinifolia, H. univernis, Syringodium isoetifolium and *Ruppia maritime*. Seagrasses are found in shallow waters between 0.2 and 1.8 m in the Straits of Malacca and off the coasts of Sarawak and Sabah. Threats to seagrasses include land conversion, sand mining, unsustainable marine aquaculture, reclamation, sedimentation, fecal contamination and heavy metal pollution (Kushairi 1992; Phang 1990).

In the ECPM, macrobenthos density decreases with increasing depth (Piamthipmanus 1999a). Macrobenthos, which include polychaetes, crustaceans and echinoderms, show marked changes in density during pre- and post-monsoon periods. Greater density occurs during the pre-monsoon period at an average of 67.6 individuals•m^{-2}, compared to only 16.8 individuals•m^{-2} during the post-monsoon period (Abdul-Hamid and Solahuddin 1999). Average macrobenthos density in Sarawak and Sabah is 100 individuals•m^{-2} during the southwest monsoon and 167 individuals•m^{-2} during the transition period between northeast and southwest monsoon (Piamthipmanus 1999b).

According to the 1995 river water quality survey, of Malaysia's 119 rivers and tributaries, 48 were "clean", 53 were "slightly polluted" and 14 were "polluted" (Department of Environment 1996). This is based on five parameters - biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen (NH_3-N), suspended solids and pH. The main contributors to river pollution were silt due to soil erosion, and organic pollution or nutrients due to sewage and animal wastes.

Fisheries Resources and Potentials

In 1997, total marine landings were recorded at nearly 1 169 000 t (Table 1). Most of these landings came from the WCPM (44%) and the ECPM (28%). Sabah (including Labuan) and Sarawak contributed 17% and 11% of the landings respectively. In the WCPM, the commercial or large-scale fisheries contributed 71% of landings (Table 2). The landings consisted of 53% demersal fish, 29% pelagic fish, 5% squid and 13% prawn. Commercial fisheries contributed 86% of the landings in the ECPM. Landings in this area were 46% demersal fish, 45% pelagic fish, 7% squids and 2% prawns. In Sarawak, 59% of landings was contributed by traditional or small-scale fisheries. Pelagic fish constituted about 48% of the total, followed by demersal fish at 39% and prawn at 9%. Commercial and traditional fisheries are almost equally important in terms of landings in Sabah. Commercial fisheries contributed about 56% of the landings. Demersal fish made up about 47% of landings in Sabah. Pelagic fish and prawn contributed about 43% and 4%, respectively, of the landings in this area. The commercial fisheries involve three main types of gear-the trawl, fish purse seine and anchovy purse-seine. The traditional fisheries includes shellfish collection and fishing with the use of other seines, drift gillnets, traps, hooks and lines, bag nets, barrier nets and push nets.

Landings have stabilized in inshore areas within 30 nm from the shoreline in the west and east coast of Peninsular Malaysia, and in inshore areas within 12 nm of the coastline in Sarawak and the west coast of Sabah. It is believed that yield has already

Table 1. Marine landings (t) in Malaysia by area and resource group in 1997.

Area	Landings (t)				
	Demersal	Pelagic	Prawn	Squid	Total
Peninsular:					
West coast	270 959	151 757	64 722	27 991	515 429
East coast	149 161	146 162	5 431	21 391	322 145
Sarawak	50 329	64 890	11 054	1 920	128 193
Sabah and Labuan	95 730	87 402	11 024	9 050	203 206
TOTAL	566 179	450 211	92 231	60 352	1 168 973

Source: Annual Fisheries Statistics 1965 - 97.

Table 2. Marine landings by area and fishing type in 1997.

Type of Fishing	Landings (t)								Total
	West coast		East coast		Sarawak		Sabah and Labuan		
	t	%	t	%	t	%	t	%	
Commercial									
Trawl	307 277	59.6	160 705	49.9	50 730	39.6	78 047	38.4	596 759
Purse-seine	58 152	11.3	114 962	35.7	25 115	19.6	38 860	19.1	237 089
Sub-Total	365 429	70.9	275 667	85.6	75 845	59.2	116 907	57.5	833 848
Traditional	150 000	29.1	46 478	14.4	52 348	40.8	86 299	42.5	335 125
TOTAL	515 429	100.0	322 145	100.0	128 193	100.0	203 206	100.0	1 168 973

Source: Annual Fisheries Statistics 1965 - 97.

reached (if not exceeded) the resource potential in these areas. Further increases in production to meet projected increases in local demand may now be based only on offshore fishing and mariculture. Reassessment of the sustainability of these possibilities needs attention while sustainable exploitation of fisheries resources in inshore waters is given increased emphasis.

Demersal

In the WCPM, demersal fish resources are caught mainly by otterboard trawlers, drift gillnets and push nets. In 1997, there were 3 107 licensed trawlers and 4 licensed push nets, down from 3 331 trawlers and 41 push nets in 1989. Landings of demersal fishes in this area peaked at about 294 900 t in 1990, declined to about 239 000 t in 1991 and increased steadily to about 315 700 t in 1997 (Table 3). Demersal fish stock density obtained from trawl surveys show that inshore resources have been over-exploited (Table 4). The start of offshore fishing in 1986/87 following declaration of the EEZ resulted in increased landings, which stabilized again in the mid-nineties. The first demersal survey conducted in 1987 beyond 30 nm from the coastline indicated a potential yield of 11 300 t of demersals (Table 5). Since then, a total of 154 offshore (deep-sea) fishing vessels have been licensed to fish in the area. The latest survey in 1997 indicated a 67% reduction in abundance of demersal fish from 1.19 t•km^{-2} in 1987 to 0.39 t•km^{-2} (Table 4). The potential yield for the offshore area is much lower than the landings for 1997 (Table 5 and 6). Exploitation rates of 15 dominant demersal fishes in the area was above 0.60 (Abu Talib et al. paper no.6). Further, analysis of catch and effort data since 1971 indicates an

MSY of 273 000 t, compared to the 1997 demersal landings of 315 700 t. These indicate that the demersal resources in the area are overfished. Changes in species composition were also observed from both onboard and fish landing surveys. Squid has emerged as the most dominant species. Landings of squid increased steadily from 9 000 t in 1980 to 27 991 tin 1997 (Table 7).

In the ECPM, otterboard trawling is the main gear exploiting demersal resources. In 1997, there were 874 licensed trawlers, which is only about one-third of the number for the west coast. The number of licensed trawlers had decreased from 1 535 units recorded in 1982. The decreasing trend is also observed in landings, from about 198 300 t in 1990 to only about 170 300 t in 1997 (Table 3). In the early 1970s, the MSY of coastal stocks was estimated at around 90 000 to 150 000 t (Latiff 1976; Pathansali 1976). In the early 1980s, the MSY was revised to around 50 000 to 80 000 t (Abu-Talib and Hayase 1984) (Ibrahim unpublished). The first offshore demersal survey conducted in 1986 beyond 25 nm from the coastline revealed a potential yield of 82 200 t of demersals (Table 5). Presently, 223 offshore (deep-sea) trawlers have been licensed to fish in the area. The latest survey conducted in 1997, indicated more than 83% reduction in abundance of demersal

Table 3. Landings of demersal fish (t) by area during the period 1971 - 97.

Year	Peninsular Malaysia West coast	Peninsular Malaysia East coast	Sarawak
1971	86 514	30 534	7 126
1972	100 405	26 418	9 132
1973	127 351	39 158	24 483
1974	150 342	52 019	29 726
1975	135 944	39 540	41 134
1976	152 597	54 099	46 396
1977	180 007	44 133	46 870
1978	181 658	53 336	47 392
1979	180 813	50 727	52 487
1980	168 873	43 457	46 256
1981	187 661	63 061	37 315
1982	192 449	52 480	38 749
1983	208 168	56 736	37 138
1984	185 298	51 399	29 880
1985	215 500	50 069	29 778
1986	261 212	70 693	39 248
1987	279 749	87 892	31 072
1988	235 168	136 269	34 796
1989	271 876	147 691	40 092
1990	294 931	198 307	36 943
1991	239 023	183 962	46 669
1992	263 985	175 980	45 212
1993	258 878	198 084	43 078
1994	257 318	192 702	58 460
1995	278 976	178 109	66 790
1996	304 668	169 660	56 053
1997	315 716	170 261	52 902

Source: Annual Fisheries Statistics 1965 - 97.

Table 4. Changes in demersal stock density ($t \cdot km^{-2}$) in the northern part of the West Coast of Peninsular Malaysia obtained during trawl surveys conducted in various years. (Talib et al. this vol.)

Year	Stock Density (Langkawi - Pangkor) ≤ 55 m deep ($t \cdot km^{-2}$)	Stock Density (Langkawi - Pangkor) > 55 m deep ($t \cdot km^{-2}$)
1971	2.45	–
1981	1.34	–
1987	0.87	1.19
1991	0.45	0.84
1997	0.27	0.39

fishes in all four sub-areas both inshore (≤ 55 m depth) and offshore (> 55 m) (Table 8). Exploitation rates of 28 dominant demersals have a mean of 0.58 (Mahyam et al. unpublished). Threadfin bream was previously found to be overexploited by as much as 30% (Kimoto and Ibrahim 1996). This fish is commonly found in coastal waters and is dominant in the catches of trawlers. These findings show that the demersal resources in the ECPM have been exploited beyond sustainable levels. Data from surveys indicate changes in dominant species and the disappearance of jewfish (Sciaenidae). As observed in the west coast, squids became the most dominant, replacing threadfin breams during the 1990s.

As in the WCPM, otterboard trawlers and push nets are the main types of fishing gear exploiting demersal resources in Sarawak waters. In 1997, the number of licensed trawlers and push nets were 579 and 24 respectively, having decreased from 1 010 licensed trawlers and 104 licensed push nets in 1989. Landings fluctuated between 40 000 and 66 790 t between 1991 and 1997 (Table 3). Landings in 1997 was 52 900 t, 60% of which came from the inshore area. Assessments indicate that there is substantive overfishing of coastal demersal stocks in Sarawak waters (see Table 9 and Abu Talib et al. paper no. 6) The first demersal survey conducted in 1986 in the EEZ beyond territorial waters gave a potential yield estimate of 62 300 t (Table 5). Presently, 88 offshore (deep-sea) trawlers have been licensed to fish in the area. The latest

Table 5. Estimates of potential yield and 1997 landings for the various offshore areas.

Area	Potential Yield [a] (t·year^{-1})				Offshore > 30nm, 1997 Landings (t)
	Demersal	Pelagic	Tuna	Total	Total
West Coast of P. M. (> 30nm)	11 300	16 650	–	28 250	29 901
East Coast of P. M. (> 25nm)	82 200	54 600	50 000	186 800	64 007
Sarawak (> 12 nm(D)), (> 30nm(P))	62 300	81 550	–	143 850	21 000
TOTAL	155 800	152 800	50 000	358 900	114 908

Note: [a] estimated from demersal fish and acoustic surveys in 1986 - 87.
D - Demersal; P - Pelagic.

Table 6. Estimates of potential yield and 1997 landings for the offshore area beyond 12 nm from the shoreline.

Area	Potential Yield [a] (t·year^{-1})			Offshore > 12nm, 1997 landings (t)
	Demersal	Pelagic	Total	Total
West coast of P. M. (> 12nm)	62 000	129 945	191 945	370 000
East coast of P. M. (> 12nm)	55 500	222 019	277 519	273 000
Sarawak (> 12 nm)	86 983	456 940	543 923	32 000
TOTAL	204 483	808 904	1 013 387	675 000

Note: [a] estimated from demersal fish and acoustic surveys in 1997 - 98.

Table 7. Landings (t) of squid and cuttlefish off the West Coast of Peninsular Malaysia

Year	Landings (t)
1980	8 923
1985	8 134
1990	20 397
1995	21 824
1997	27 991

Source: Annual Fisheries Statistics 1965 - 97.

survey conducted in 1998 indicated only slight changes in the density of demersal fish in the offshore area (Table 9). The estimated potential yield obtained in this study came to about 87 000 t. In 1997, the estimated landing of demersal fish from the offshore area was only 20 000 t. One of the predominant fish families in the area was Monacanthidae, which inhabits areas near the continental shelf. Changes in dominant species were also observed since the first offshore survey in 1986. Some high quality fish like snappers (*Lutjanus* spp.), grunter (*Pomadasys* spp.) and sharp tooth jobfish (*Pristipomoides* spp.) were no longer dominant.

Table 8. Changes in demersal stock density (t·km^{-2}) off the East Coast of Peninsular Malaysia obtained during trawl surveys conducted in various years.

Year	Kelantan		Terengganu		Pahang		East Johore	
	≤ 55 m (t·km^{-2})	> 55 m (t·km^{-2})	≤ 55 m (t·km^{-2})	> 55 m (t·km^{-2})	≤ 55 m (t·km^{-2})	> 55 m (t·km^{-2})	≤ 55 m (t·km^{-2})	> 55 m (t·km^{-2})
1967	4.78	–	5.76	–	7.61	–	2.69	–
1972	5.68	–	6.78	–	4.07	–	3.64	–
1981	2.17	–	2.42	–	6.78	–	2.29	–
1986	1.34	1.93	–	1.89	2.16	1.71	–	2.29
1991	0.66	–	1.16	–	0.91	–	4.01	–
1998	0.26	0.33	0.33	0.17	0.26	0.09	0.07	0.09

Table 9. Changes in demersal stock density (t·km^{-2}) in Sarawak waters obtained during trawl surveys conducted in various years.

Year	Sub-area I (Tg. Dato -Tg. Sirik)		Sub-area II (Tg. Sirik-Tg. Kidurong)		Sub-area III (Tg. Kidurong-K. Batam)	
	≤ 55 m	> 55 m	≤ 55 m	> 55 m	≤ 55 m	> 55 m
1972	3.69	–	2.39	–	7.49	–
1981	3.39	–	5.90	–	8.10	–
1986	1.29	1.24	1.90	1.28	1.18	0.53
1989/91/92	0.84	1.85	1.44	1.59	1.91	1.57
1998	0.45	0.85	0.76	1.54	1.85	1.07

Small Pelagic

Six main groups comprise the landings of small pelagic fishes in the WCPM, namely: mackerels (*Rastrelliger*), scads (*Atule* spp., *Alepes* spp., *Selar* spp), roundscads (*Decapterus* spp.), sardines (*Sardinella* spp., *Dussumieria* spp.), hardtails (*Megalaspis cordyla*), and small tunas (mainly *Euthynnus affinis, Auxis thazard* and *Thunnus tonggol*) (Chee 2000). These groups are fished mainly by purse seines. Other groups of small pelagic fish are pomfrets (*Pampus* spp. *and Formio* spp.), spanish mackerels (*Scromberomorus* spp.), threadfins (*Eleutheronema* spp., *Polydactylus* spp.), wolfherrings (*Chirocentrus* spp.) and queen fishes (*Scomberoides* spp.). Trawls and drift nets mainly catch these groups of fish. The number of units in operation for both trawls and purse seines havedecreased steadily since 1985. However, drift nets increased from 8 430 units in 1986 to 10 729 units in 1999. There is a substantial catch of anchovies (*Stolephorus* spp.) near to islands by anchovy purse seiners. In 1997, there were 13 092 t of anchovies landed by 60 anchovy purse seiners from this area. Acoustic surveys in 1986 in the area beyond 12 nm gave a potential yield estimate of about 26 000 t of small pelagics. Of these, 60% inhabit offshore areas beyond 30 nm from the coastline (Table 5). The latest acoustic survey in 1997 gives a higher small pelagic potential yield of 130 000 t (Table 6). The 135 000 t landing of small pelagic fishes in 1997 indicates that the resource is over-exploited. This is plausible since the pelagic fisheries in the WCPM is the most developed in the country.

Small pelagic fish resources off Sarawak and the ECPM beyond 12 nm from the coastline have a potential yield of about 679 000 t (Table 6). About

33% of this are found in the ECPM. Among the major groups are round scads, scads, mackerels, hardtail scads and sardines. Most of the small pelagic species in this area have two spawning peaks, one each during the post- and pre-monsoon period (Mansor et al. 1996). The 1997 small pelagic catch beyond 12 nm in the ECPM was 146 983 t. The estimated potential was 222 000 t (Table 6) indicating some scope for expansion. A potential yield of 457 000 t of small pelagic fish was estimated for Sarawak. Landings in 1997 were only around 15 000 t indicating substantive scope for expansion. However, the scattered nature of the resource and distance from markets probably restricts exploitation. Among the main groups fished in the area are Ariommatidae (*Ariomma* spp.), round scads, hardtail, scads, Caesiodidae (*Caesio* spp., *Pterocaesio* spp.), sardines and mackerels.

Prawn

The WCPM and Sarawak are the main fishing grounds for prawn. Analysis of catch and effort data in the WCPM give a potential yield of about 70 400 t at standard effort of about 64 600 units. Landings in 1996 were about 65 000 t using 102 600 standard units of effort, indicating that the resource had already been over-exploited. The main species of prawns in this area are from the genera *Penaeus, Metapenaeus, Metapenaeopsis, Parapenaeopsis, Trachypenaeus* and *Solenocera*. Prawns in Sarawak waters have also been over-exploited. Current landings of about 11 000 t are more than double the estimated potential yield of 5 000 t for the area.

Tuna

A relatively new fishery in Malaysia is that for oceanic tuna. Tunas such as skipjack, kawakawa, frigate and yellowfin are found in deeper waters off the Sarawak and Sabah coast. With the expansion of maritime jurisdiction, tuna stocks are seen as an important resource to be exploited. In 1984, Malaysian and Thai fishers operating in the Gulf of Thailand and off the ECPM landed an estimated 84 000 t of tuna. The dominant species in this catch was longtail tuna. The potential yield of tuna from the ECPM was estimated at about 50 000 t (Table 5).

Squid, Cuttlefish and Jellyfish

As traditional fisheries resources are being fully exploited, 'new' fisheries targeting squid, cuttlefish and jellyfish have emerged. Landings of squid and cuttlefish in Peninsular Malaysia contributed 5% to 7% of marine landings in 1997 (Table 1). In Sarawak, jellyfish landings totaled 49 665 t.

Table 10. Number of fishers by ethnic group working on licensed fishing vessels in Malaysia.

Ethnic Group	Number of fishers				
	West coast	East coast	Sarawak	Sabah & Labuan	Total
Bumiputras	12 207	15 250	6 642	15 284	49 383
Chinese	15 033	2 100	813	191	18 137
Indians	235	1	–	–	236
Portuguese	54	–	–	–	54
Thais	2 470	3 087	–	35	5 592
Indonesians	52	3	–	10	65
Others	207	36	8	5 271	5 522
TOTAL	30 258	20 477	7 463	20 791	78 989

Source: Annual Fisheries Statistics 1965 - 97.

Socioeconomic and Development Background

The multiracial population of Malaysia consists of 55% Bumiputras (Malays and other indigenous people), 34% Chinese and 11% Indians and other groups. The population of 17.8 million in 1990 increased to slightly more than 20 million in 1995. By the year 2010 the population is expected to be around 28 million. The real annual population growth rate for Peninsular Malaysia was estimated at 7.8% in 1970 and 9.8% in 1990 (Government of Malaysia (GOM) 1999). About 83% of the population reside in Peninsular Malaysia, which had a 1997 population density of 101.0 persons•km^{-2}. Sarawak had only 12.2 persons•km^{-2} and Sabah had 17.2 persons•km^{-2}. Peninsular Malaysia consists of 11 states and a Federal Territory that can be divided into two economic regions, the west coast and the east coast. The majority of manufacturing industries, plantations, tin reserves and population are concentrated in the west coast states. The east coast states are sparsely populated and relatively less developed.

Table 11. Number of fishers by ethnic group working on licensed fishing vessels in Peninsular Malaysia during the period 1977 - 97.

Year	Number of fishers				
	Malays	Chinese	Indians	Others	Total
1977	44 373	30 131	541	600	75 645
1978	51 265	30 980	637	812	83 694
1979	50 816	30 232	528	1 259	82 929
1980	55 008	31 802	410	1 752	88 972
1981	54 538	30 084	609	1 694	86 925
1982	49 232	28 306	739	1 960	80 237
1983	47 322	25 238	534	2 496	75 590
1984	48 616	25 077	564	2 111	76 368
1985	42 620	23 532	471	2 907	69 530
1986	34 269	21 357	448	3 378	59 452
1987	33 815	21 634	394	4 726	60 569
1988	32 386	21 367	409	4 121	58 283
1989	35 907	22 443	454	3 776	62 580
1990	34 719	21 364	471	3 247	59 801
1991	35 609	21 385	448	3 867	61 309
1992	35 279	21 094	440	3 597	60 410
1993	28 607	18 466	245	6 569	53 887
1994	27 499	17 984	249	6 463	52 195
1995	30 440	17 976	239	6 347	55 002
1996	28 418	17 010	206	6 676	52 310
1997	27 457	17 133	236	5 909	50 735

Source: Annual Fisheries Statistics 1965 - 97.

In 1997, there were 78 989 people working in licensed fishing vessels, a figure representing slightly more than 1% of total employment in the country. The breakdown of fishers by ethnic group is given in Table 10. On the west coast, nearly 50% of the 30 258 fishers are ethnic Chinese. Bumiputras and Thais make up 40% and 8%, respectively. Over 75% of fishers in the ECPM, Sarawak and Sabah are Bumiputras. The number of fishers in Malaysia decreased at a rate of 2.2% per annum from 102 900 in 1985 to 82 200 in 1995 (Table 11). In Peninsular Malaysia, the rate of decrease was slightly higher at 2.4% per annum from 88 972 fishers in 1980 to 50 735 fishers in 1997. The reduction was more than 50% for all ethnic groups except the "others" group, which represents foreign fishers. For the "others" group, the number of fishers increased three-fold. In 1997, 8 437 foreign crews were permitted to work in local fishing vessels, mostly comprising Thais (97.5%) and Indonesians (0.7%).

The reduction in number of fishers is consistent with Government policy to ensure sustainable fishing particularly in inshore waters and improve the catch for the remaining fishers. It is reported that 44.7% of the 40 500 fishing households in Peninsular Malaysia lived below subsistence level in 1983 (Government of Malaysia (GOM) 1984). The venture into offshore fishing after EEZ declaration in 1985 changed the composition of fishing vessels (Table 12). Non-powered boats that made up 45% of the total in 1965 were reduced to only 2% in 1997. The ECPM with an extensive EEZ has a higher composition of inboard powered vessels (71%) as compared to the est coast (55%) (Table 13). About 58% of the fishers in the ECPM were involved in commercial fisheries, 10% more than the number in the WCPM (Table 14). As a whole, more than half (52%) of the fishers in Peninsular Malaysia were involved in commercial fishing. The state of Johore has the highest number of fishers at 9 340, followed by Terengganu and Perak at 8 378 and 7 190 respectively.

Table 12. Changes in composition of licensed fishing vessels in Peninsular Malaysia between 1965 and 1997 .

	1965		1985		1990		1997	
Vessel type	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Non-powered boats	10 182	45	1 296	6	779	3	393	2
Outboard-powered boats	3 908	18	6 751	29	7 029	30	7 875	39
Inboard-powered boats	8 374	37	15 324	65	15 326	67	12 097	59
TOTAL	22 464	100	23 371	100	23 134	100	20 365	100

Source: Annual Fisheries Statistics 1965 - 97.

Table 13. Composition of licensed fishing vessels in Peninsular Malaysia in 1997.

	West Coast		East Coast	
Vessel type	**Number**	**%**	**Number**	**%**
Non-powered boats	352	2	41	1
Outboard-powered boats	6 194	43	1 681	28
Inboard powered boats	7 823	55	4 271	71
TOTAL	14 372	100	5 993	100

Source: Annual Fisheries Statistics 1965 - 97.

Table 14. Number of fishers by fishing type in Peninsular Malaysia in 1997.

Area	Number of fishers		
	Commercial	Traditional	Total
West coast	14 700	15 558	30 258
East coast	11 875	8 602	20 477
Peninsular Malaysia	26 575	24 160	50 735

Source: Annual Fisheries Statistics 1965 - 97.

In 1995, Malaysia was a net importer of fish in terms of quantity but a net exporter in value terms due to the high value of its fish and fishery product exports. However, the net foreign exchange earnings has declined recently due to increased importation of low-grade fish and the fast increase in import prices. Imports increased from 200 700 t valued at RM363.6 million[1] in 1990 to 260 570 t valued at RM828.4 million in 1995. During the same period exports increased from 145 400 t valued at RM606.1 million to 247 840 t valued at RM892.2 million. Since 1996, however, Malaysia has become a net importer of fish in terms of both quantity and value. In 1997, Malaysia exported about 107 620 t valued at about RM939.6 million and imported 297 780 t valued at RM979.2 million (Table 15).

Average income for commercial and traditional fishers in Peninsular Malaysia in 1995 was RM1 121 and RM715 respectively. In the WCPM, 87% of income came from fishing activities and the balance was from additional activities such as aquaculture, fish processing, farming, animal husbandry and tourism. In the ECPM, only 81% of the income came from fishing. In general, fishers in the WCPM obtained higher fishing incomes for both commercial RM1 110 and traditional RM642 fishers compared to those in the ECPM. The WCPM fishers also received higher additional income than those in the ECPM (Table 16).

In 1997 the fishing industry directly employed about 79 616 fishers or about 1% of the total labour force in the country. The contribution of fisheries to national employment decreased continuously from 2.4% in 1970 to 2.3% in 1980 and 1.9% in 1990. However, if indirect employment in fishery-related activities, such as handling, processing and distribution are included, the figure could be much higher. (Clad 1984) estimated that employment in fisheries and related activities was around 4.3 % of the economically active population.

Based on a survey conducted by the Fisheries Development Authority (FDA) in 1995 that covered 45% of fishers in Peninsular Malaysia, about 63% of fishers in both commercial and traditional fishing received only up to primary education (Table 17). About 8% and 12% of fishers in commercial and traditional fishing, respectively, did not receive any form of formal schooling. The percentage of fishers who received up to lower secondary education was about 27% in commercial fishing and 20% in traditional fishing. Hardly 1% of fishers in both sectors attended higher secondary or tertiary education.

About 71% of the 24 949 fishers sampled in Peninsular Malaysia in 1995 were married (Table 18). The percentage of married fishers was higher for traditional fishers (80%) than for commercial fishers (57%). This was mainly due to age, which was generally higher for traditional fishers compared to commercial fishers. The average size of the traditional fishing household (5.61 persons) was almost the same as that of the commercial fishing household (5.59 persons) (Table 19). The size of a fishing household was generally larger than the national average of 4.8 persons per household (Department of Statistics, 1991). On the average, traditional and commercial fishing households on the west coast were smaller than those on the east coast. The ratio of non-working to working members was higher in the commercial fishing household (1.9 : 1) as compared to the traditional fishing household (1.5 : 1) (Table 20). The non-working members in the family comprised mainly children below 18 years of age, spouses of fishers and their aged parents or relatives.

[1] 1 US$ = RM2.70455 (1990)

Table 15. Import and export of fish and fishery products by Malaysia for various years.

Activity	1990		1995		1996		1997	
	Quantity ('000 t)	Value (RM mil.)	Quantity ('000 t)	Value (RM mil.)	Quantity ('000 t)	Value (RM mil.)	Quantity ('000 t)	Value (RM mil.)
Export	145.40	606.10	247.84	892.22	134.94	826.92	107.62	939.58
Import	200.70	363.60	260.57	828.43	299.92	887.53	297.78	979.23

Source: Annual Fisheries Statistics 1965 - 97.

Table 16. Monthly income (RM) for commercial and traditional fishers in Peninsular Malaysia during 1995.

	Commercial		Total	Traditional		Total
	Fishing	Others*		Fishing	Others*	
West coast	1 110	159	1 269	642	139	781
East coast	846	131	977	451	118	569
Peninsular Malaysia	976	145	1 121	583	132	715

Source: FDA Survey 1995.
* Others: Unskilled labour in Aquaculture, Fishing processing, Farming, Animal husbandry and Tourism.

Table 17. Distribution (%) of fishers by educational levels in Peninsular Malaysia in 1995.

	Commercial					Traditional				
	No Formal	Primary	Lower Secondary	Higher Secondary	Tertiary	No Formal	Primary	Lower Secondary	Higher Secondary	Tertiary
West coast	6	69	24	0.3	0.04	9	69	21	0.4	0.06
East coast	10	58	31	1	0.3	18	63	18	0.5	0
Pennsular Malaysia	8	63	27	0.6	0.2	12	67	20	0.5	0.0

Source: refer FDA Survey 1995.

Table 18. Marital status of fishers by type of fishing in Peninsular Malaysia in 1995 (in %).

	Commercial				Traditional			
	Married	Divorced	Single	Total	Married	Divorced	Single	Total
West Coast	51.4	0.9	47.7	100	80.2	1.8	18.0	100
East Coast	62.4	1.3	36.3	100	79.8	2.6	17.6	100
Peninsular Malaysia	57.0	1.1	41.9	100	80.0	2.0	18.0	100

Source: FDA Survey 1995.

Table 19. Average size of fishing household by type of fishing in Peninsular Malaysia in 1995 (in %).

	Commercial		Traditional	
	No. in household	Average size	No. in household	Average size
West coast	1 762	5.33	8 649	5.48
East coast	1 795	5.84	3 918	5.92
Peninsular Malaysia	3 557	5.59	12 567	5.61

Source: FDA Survey 1995.

Table 20. Dependency ratio of fishing household by type of fishing in Peninsular Malaysia in 1995.

	Commercial	Traditional
West coast	1.7	1.5
East coast	2.1	1.7
Peninsular Malaysia	1.9	1.5

Source: FDA Survey 1995.

In Malaysia, fishers are encouraged to market their catch directly or via middlemen at government-provided landing ports. These ports centralize fish landings, provide efficient facilities such as loading/ unloading machineries and cold-rooms, and facilitate the gathering of catch statistics. More and more of the fish trade is now being handled by fishers' associations, which are well supported by the Malaysian Fisheries Development Authority (FDA), a government organization mandated for fisheries marketing in the country. The FDA controls all major fish ports/harbors in the country.

Fish and fish products will continue to form the essential dietary component of Malaysians. From the early 1960s to mid-1980s, fish formed about 60% of the total animal protein consumed in the country (Table 21), a rate much higher than in other Asian countries (Josupeit 1981). During 1960 to 1989, the mean per capita consumption of fish was about 23 kg. It is expected to rise to 56 kg per annum in 2010 (Table 22) in line with population increase and changing consumer preferences for fish and fishery products. Fish is popular because it is the cheapest and most accessible form of protein acceptable to all ethnic groups of the multiracial population (Ishak 1994). Total demand for fish and fishery products was about 809 300 t in 1995. Out of the total national production, consumable supply was estimated at about 764 500 t, which is equivalent to a self-sufficiency level of 94.5%.

The Malaysian economy has expanded rapidly over the last decade, with strong output recorded particularly in the manufacturing, services and construction sectors. The manufacturing sector was the main driving force in this growth. Since 1987, manufacturing has become the lead growth sector in the economy with its contribution to GDP surpassing agriculture. Major exports of manufactured goods comprise electrical and electronic products and machinery, chemical and chemical products, textiles and apparel, wood and wood products, transport equipment, iron, steel and fabricated metal products. The manufacturing sector is expected to continue to be the main engine of growth under the Second Industrial Master Plan (1996 to 2005). There is already a shift in government focus to give more emphasis to agriculture.

Development of agriculture has been affected by problems including labour shortages and rising wages, and increasing competition for land for other uses. Consequently, the contribution to GDP from agriculture has declined to second after the manufacturing sector since 1987. Favourable industrialization policies have also created conditions not attractive for agriculture investment and consequently have led to the outflow of resources from agriculture.

The Third National Agriculture Policy (NAP3) for 1998 - 2010 was formulated to maximize agriculture's contribution to national income and export earnings, and to maximize incomes of producers through optimal utilization of resources in the sector. New sources of growth are expected to emerge in agriculture by promoting new and emerging industries such as agroforestry, specialty natural

Table 21. Per capita consumption (kg) of various types of meat in Malaysia

Year	Source of Protein					% fish
	Poultry	Beef	Pork	Fish	Total	
1960	3.02	0.56	5.46	9.42	18.46	51.0
1970	6.51	0.63	5.88	21.11	34.12	61.9
1980	8.70	1.28	9.01	24.50	43.49	56.3
1989	13.60	1.53	8.85	23.05	47.03	49.0

Source: Department of Statistics 1991.

Table 22. Production and demand for fish in Malaysia from 1985 to 2010.

	Year					
	1985	1990	1995	2000	2005	2010
Fish production (capture) ('000 t)	746.0	951.3	1 108.4	1 255.8	1 305.6	1 331.9
Food fish supply ('000 t)	500.0	564.6	764.5	1 012.0	1 228.2	1 500.4
Per capita consumption (kg)	33.4	34.8	39.1	49.0	53.0	56.0
Food fish demand ('000 t)	527.0	619.9	809.3	1 142.0	1 369.5	1 591.0
Self-sufficiency level (%)	94.9	91.1	94.5	89.0	89.7	94.3
Export of fish ('000 t)	149.0	145.4	185.2	170.0	179.7	225.4
Import of food fish ('000 t)	176.0	200.7	230.0	300.0	321.0	316.0

Source: GOM 1999.

products, biotechnology and aquarium fish. Strong growth is also expected from the food sub-sector arising from intensified efforts in resolving supply-side constraints and strengthening the economic foundation for this sub-sector. Past and projected value-added for the agriculture sector is summarized in Table 23.

The NAP3 identified the environment and sustainable development at both domestic and global levels as one of the main challenges (Government of Malaysia (GOM) 1999). The policy outlines the need for more innovative and efficient agriculture and forestry practices for economic development as well as the maintenance of the ecological and environmental balance of the country. The country also recognizes the urgent need for a national coastal zone management policy and area-specific coastal zone management plans (CZMPs) to manage coastal resources effectively. The first CZMP in the country was developed in 1986 for South Johore to provide sustainable management of resources and minimize use conflicts, especially among tourism, aquaculture and industrial development. In 1994 the development of CZMP for the coastal zones of Penang and Sabah was initiated. The country has also a National Conservation Strategy, which was initiated in 1993. Since then, people's organizations and NGOs have increasingly participated in natural resource and environmental conservation and management. Their participation can be seen in various activities conducted in the national marine parks throughout the country.

The NAP3 recognizes that the structure and pattern of development within the agriculture sector varies between industries. This includes different characteristics pertaining to structure of production,

Table 23. Agriculture value-added for 1990 - 95 and forecast of value-added for 2000 - 2010.

	1990		1995		2000		2005		2010	
Item	**RM**	**%**	**RM**	**%**	**RM**	**%**	**RM**	**%**	**RM**	**%**
Industrial Crops:										
	10 900	73.5	11 629	71.6	11 991	67.2	12 796	64.6	13 321	59.7
Food Commodities:										
	3 564	24.0	4 340	26.7	5 246	29.4	6 123	30.9	7 256	32.5
Paddy	*622*	*4.2*	*672*	*4.1*	*702*	*3.9*	*742*	*3.7*	*788*	*3.5*
Fruits	*406*	*2.7*	*476*	*2.9*	*576*	*3.2*	*775*	*3.9*	*1 042*	*4.7*
Vegetables	*427*	*2.9*	*503*	*3.1*	*635*	*3.6*	*826*	*4.2*	*1 132*	*5.1*
Fisheries	*1 505*	*10.1*	*1 823*	*11.2*	*2 221*	*12.4*	*2 563*	*12.9*	*2 900*	*13.0*
Livestock	*604*	*4.1*	*866*	*5.3*	*1 112*	*6.2*	*1 217*	*6.1*	*1 394*	*6.2*
Miscellaneous:										
	364	2.5	262	1.6	603	3.4	876	4.4	1 747	7.8
Total Agriculture:										
	14 828	100	16 231	100	17 840	100	19 795	100	22 324	100
Share of Agriculture to GDP		18.7		13.5		12.8		9.5		7.2

Source: Economic Planning Unit and Ministry of Agriculture, DPN3.

markets they serve, stages of development and role in the economy. Fisheries products primarily, though not exclusively, serve the domestic market. The production structure comprising mainly small and medium scale production units is showing signs of consolidation into large scale operations and is becoming more commercialized. The fisheries industry has undergone rapid development in the last ten years with remarkable improvements in fish production. Active participation of the private sector and the use of new technologies have made possible the gradual shift from small scale to large scale fishing. Fisheries is linked to fish processing, fishmeal production and industries such as plastics, paper, printing, machinery and equipment, wholesale and retail trade, and business services. Fisheries is also significantly linked to the transportation sector for input supplies as well as distribution of fish and fishery products.

One of the main challenges in fisheries is the over-exploitation of resources in inshore waters. Although there may be resources in offshore areas, acute shortage of skilled and semi-skilled workers and unwillingness of local fishers to work in deep-sea fishing vessels will limit production from this resource. Limited research to develop appropriate fishing technologies to exploit deep-sea resources and frequent encroachment by foreign fishing vessels deserve attention. Fish processing is dominated by small and medium enterprises that lack managerial and marketing know-how and rely on low-level processing technology.

Despite the challenges, there are good prospects in fisheries. The country has the potential resources to further increase supply to meet domestic and export demand. It is estimated that annual demand for fish and fishery products by 2010 will be 1.59 million t (Table 24).

Total private investment in the agriculture sector during NAP1 (First National Agriculture Policy, 1990 - 95) was only RM9.5 billion compared to RM84 billion in the manufacturing sector. The food sub-sector including fisheries was not able to

Table 24. Production and demand for fish 1985 - 95 and forecast of production and demand, 2000 - 2010 (in t).

Year	1985	1990	1995	2000	2005	2010
Fish Production ('000 t)	801.0	1 003.6	1 241.1	1 511.0	1 708.8	1 933.3
Aquaculture ('000 t)	55.0	52.3	132.7	255.2	403.2	601.4
Capture fisheries ('000 t)	746.0	951.3	1 108.4	1 255.8	1 305.6	1 334.9
Food Fish Supply ('000 t)	500.0	564.6	764.5	1 012.0	1 228.2	1 500.4
Per capita consumption (kg)	33.4	34.8	39.1	49.0	53.0	56.0
Food fish demand ('000 t)	527.0	619.9	809.3	1 142.0	1 369.5	1 591.0
Self-sufficiency level (%)	94.9	91.1	94.5	89.0	89.7	94.3
Export of food fish ('000 t)	149.0	145.4	185.2	170.0	179.7	225.4
Import of food fish ('000 t)	176.0	200.7	230.0	300.0	321.0	316.0

attract much private investment. Consequently, NAP3 outlines the need to encourage participation of the private sector in commercial fishing. Government agencies undertake efforts to unify individual entrepreneurs into consortia led by corporate leaders to venture into commercial fishing and to develop and manage integrated processing complexes and mega-fishing ports in the country. Government aspires to secure economies of scale, modernize operations, enhance ventures into export markets and attract foreign vessels to land their catches in the country. In addition, joint ventures between local and foreign investors will be promoted under regional efforts such as BIMP-EAGA (Brunei, Indonesia, Malaysia and the Philippines-East ASEAN Economic Growth Area), IMT-GT (Indonesia, Malaysia and Thailand-Growth Triangle) and IMS-GT (Indonesia, Malaysia and Singapore-Growth Triangle) to engage in distant-water fishing.

Institutional Background

Fisheries-related Policies

The Department of Fisheries Malaysia under the Ministry of Agriculture is entrusted with the role of developing, managing and regulating the fisheries industry. It is the mission of the Department of Fisheries Malaysia to bring about changes in the country's fisheries that will encourage its evolution into a commercial, modern and progressive sector and to ensure sustainability of fisheries resources for the needs of the nation. With the Government's Vision 2020, the fishing industry will be developed into a modern, efficient and highly commercialized industry. Coastal fisheries will be managed at a sustainable level while deep-sea fisheries will be fully developed in the Exclusive Economic Zone as well as the high seas. The objectives of the Department of Fisheries are to:

a. increase the national fish production
b. manage the fisheries resources on a sustainable basis
c. develop a dynamic fisheries industry
d. intensify the development of fish-based industries
e. maximize the income of the fishing industry

The functions of the Department of Fisheries include:

- formulating policies and strategies for the fisheries industry
- enforcing the Fisheries Act 1985 and the Exclusive Economic Zone Act
- managing, conserving and rehabilitating fisheries resources
- conducting fisheries research
- promoting sustainable aquaculture
- providing fisheries extension services
- training fishers, farmers and downstream industry entrepreneurs
- controlling fish diseases and providing quarantine services
- promoting recreational fisheries
- monitoring pollution affecting fisheries resources
- providing basic fisheries data

- establishing standards and inspecting fisheries products with the cooperation of other related agencies.

The Department of Fisheries Malaysia is headed by the Director General of Fisheries, who is assisted by the Deputy Director-General. There are seven divisions in the Department of Fisheries and a Director heads each of these divisions. These Divisions are:

a. Corporate Planning Division
b. Resource Management and Protection Division
c. Marine Fishery Resources Development and Management Department (MFRDMD)
d. Research Division
e. Extension and Training Division
f. Engineering Division
g. Administration and Finance Division.

There are 33 sections under these divisions. There are also 12 state fisheries offices in charge of all the district fisheries offices throughout the country. A State Fisheries Director heads each of these state fisheries offices. There is currently a total of 2 445 staff - two at the top management level, 246 professional technical officers and 2 197 supporting staff. The organizational structure is detailed in Fig. 2.

The Fisheries Development Authority of Malaysia (FDAM) is a statutory body established in 1971 with the objective of upgrading the socioeconomic status of fishing communities, particularly by enhancing their incomes and developing and expanding the fishing industry. The functions of FDAM are to:

- promote and develop efficient and effective management of fishery enterprises and fish marketing
- create and provide credit facilities for fish production
- engage in fishery enterprises through boat construction, and the production and supply of fishing gear and equipment
- promote, facilitate and undertake economic and social development of the Fishers' Associations
- register, control and supervise Fishers' Associations and Fisheries Co-operatives
- control and coordinate the implementation of the above activities.

There are various types of fishers' institutions that are formed by the fishers themselves. They include the National Fishers' Association (NEKMAT), the State Fishers' Associations, the Area Fishers' Associations and Fishers' Co-operatives. To date there are 116 of such organizations with over 60% of fishers in Malaysia as members. The State and Area Fishers' Associations are also members of the Malaysian Investment Co-operative, which acts as an investment arm that helps promote savings, investment and business through its activities.

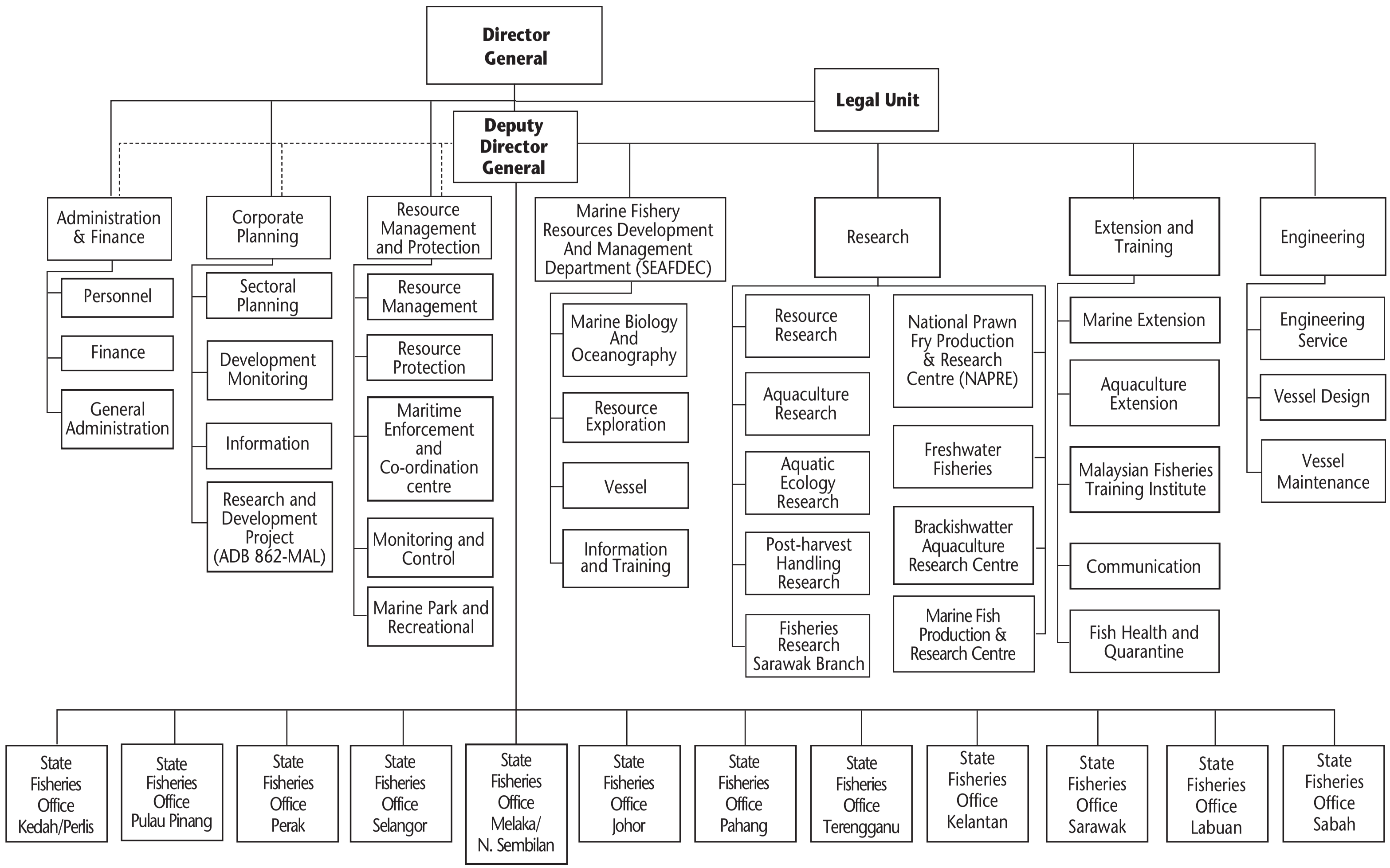
The Fisheries Research Institute of the Department of Fisheries undertakes fisheries research with its headquarters located in Penang. It has its Freshwater Research Branch situated in Batu Berendam, Malacca; Brackish-water Branch in Gelang Patah, Johore; Marine Fisheries Research Development and Management Division (MFRDMD/SEAFDEC) in Chendering, Kuala Trengganu; East Coast Peninsular Malaysia Aquaculture Branch in Tanjung Demong; Fisheries Research Centre, Bintawa, Sarawak; and its National Prawn Fry Production and Research Centre in Pulau Sayak, Kedah. The headquarters in Penang is responsible for research on marine capture fisheries, marine aquaculture and ecology, while the branches specialize in their respective areas of research.

Local universities also conduct fisheries research, namely in resource assessment, fish biology, aquaculture, mangroves, corals, habitat development and rehabilitation, pollution monitoring and assessment, virology, toxicology and others. The universities engaged in such research include the University of Science Malaysia (USM) in Penang; the University Malaya (MU) in Kuala Lumpur; the University Putra Malaysia (UPM) in Serdang, Selangor and Kuala Trengganu; the University Malaysia Sarawak (UNIMAS) in Kuching, Sarawak; the University Malaysia Sabah (UMS) in Kota Kinabalu, Sabah; the National University Malaysia (UKM) in Bangi, Selangor; and the University Technology Malaysia (UTM) in Johore.

The Fisheries Training Institute of the Department of Fisheries is based in Chendering, Kuala Trengganu. Its main objectives are to:

a. produce skilled fishers in line with the needs of the fishing industry
b. provide training for fishers to upgrade their technical capabilities
c. provide training for staff of the Department of Fisheries to enable them to provide better services to the industry.

Fig. 2. Organizational structure of the Department of Fisheries, Ministry of Agriculture, Malaysia (2000).



A more detailed legal/institutional background relevant to fisheries in Malaysia is given in Appendix 1.

Demersal fisheries in the West Coast of Peninsular Malaysia

Catch and Effort

Fisheries in the WCPM use various types of commercial and traditional fishing gears. Commercial gear consists of trawls and purse seines, while traditional gear includes other seine nets, drift/gillnets, bag nets, hooks and lines, trammel nets, lift nets, traps, barrier nets and push nets. In 1997, there were 14 211 licensed fishing vessels (Table 25). About 80% of the vessels use traditional fishing gear, most (88%) of which are powered. The number of licensed vessels in 1997 is 35% less than the number in 1980. The reduction over the last 17 years took place in both commercial and traditional fisheries.

Estimates of the number of fishing vessels actually operating in the WCPM is given in Table 26. Important traditional fishing gear exploiting demersal fish in this area includes drift gillnets, other seines, hook and lines, bag nets, push nets, barrier nets and traps. lift net is the only traditional gear in the WCPM not catching demersal fish. Except for push net and drift gillnet, other gear showed a reduction in number after the peak in 1981 - 82 (Table 26). Drift gillnets and push nets fluctuated with an increasing trend. However, the target species of these two types of gear are not demersal fish but rather pelagic fish and prawns.

The only commercial fishing gear exploiting demersal fish in the area are trawls. The number of trawlers in operation decreased steadily from a peak of 5 265 units in 1980 to 3 735 units in 1997 (Table 26). The number of units in operation in 1997 is similar to those in the early 1970s. A breakdown of the trawlers by size category in 1997 shows that 50% of the trawlers were 10 - 24.9 gross tons (GRT), and only 2% were more than 70 GRT (Table 27).

Table 25: Number of licensed fishing vessels in the West Coast of Peninsular Malaysia during the period 1980 - 97.

		Traditional			
Year	**Commercial**	**Powered**	**Non-Powered**	**Total**	**Total**
1980	3 975	14 254	3 797	18 051	22 026
1981	3 943	14 905	2 944	17 849	21 792
1982	3 908	14 139	1 556	15 695	19 603
1983	3 758	12 692	1 244	13 936	17 694
1984	3 539	12 759	1 756	14 515	18 054
1985	3 236	11 667	1 606	13 273	16 509
1986	3 146	11 342	1 561	12 903	16 049
1987	3 104	11 194	1 541	12 735	15 839
1988	2 948	10 628	1 463	12 091	15 039
1989	3 360	12 115	1 668	13 783	17 143
1990	3 294	11 876	1 635	13 510	16 804
1991	3 229	11 641	1 602	13 243	16 472
1992	3 077	11 095	1 527	12 622	15 699
1993	2 773	9 997	1 376	11 373	14 146
1994	2 605	9 390	1 292	10 682	13 287
1995	3 198	11 529	1 587	13 116	16 314
1996	2 844	10 256	1 412	11 668	14 512
1997	2 785	10 043	1 383	11 426	14 211

Source: Annual Fisheries Statistics 1965 - 97.

Table 26: Number of fishing vessels in operation by gear type in the West Coast of Peninsular Malaysia during the period 1967 - 97.

Year	Commercial	Traditional						
	Trawlers	Drift/ Gillnets	Other Seines	Hooks & Lines	Bag nets	Push nets	Barrier nets	Traps
1967	899	3 321	1 342	–	–	–	–	–
1968	1 028	3 389	1 482	–	–	–	–	–
1969	1 396	3 472	1 879	461	1 161	–	99	712
1970	2 683	3 016	1 556	454	1 307	–	87	704
1971	3 252	3 244	1 460	397	1 202	402	68	642
1972	4 068	3 698	1 488	416	1 249	289	62	638
1973	3 267	3 530	1 446	553	1 244	169	61	623
1974	3 909	4 091	1 535	541	1 93	122	64	524
1975	3 873	4 359	1 687	651	1 248	114	75	423
1976	4 008	5 092	1 425	666	1 050	183	85	538
1977	4 195	5 951	1 204	674	1559	183	191	446
1978	4 463	6 968	1 394	921	1 526	245	152	488
1979	5 112	7 878	1 542	1 039	1 517	306	186	496
1980	5 265	8 453	1 951	1 185	1 630	306	209	530
1981	5 321	8 525	2 081	1 226	1 513	473	207	595
1982	5 259	8 689	2 133	889	1 403	508	147	609
1983	5 116	9 096	2 046	982	1 104	490	75	455
1984	5 255	9 694	1 167	967	1 055	467	147	469
1985	5 163	10 417	2 047	897	1 417	568	124	472
1986	4 505	8 430	1 449	669	419	468	105	249
1987	4 260	8 402	1 176	504	488	639	79	260
1988	4 232	8 660	1 105	500	424	659	80	232
1989	4 469	8 388	1 013	606	469	535	77	231
1990	4 416	9 446	1 004	553	425	490	74	221
1991	4 600	9 095	1 020	517	442	504	77	207
1992	4 185	9 376	948	490	423	582	73	199
1993	3 939	10 232	845	406	412	650	66	187
1994	3 951	10 351	883	369	390	575	64	158
1995	3 933	10 360	871	393	308	317	104	168
1996	4 032	10 716	843	351	369	754	46	159
1997	3 735	10 730	538	334	220	869	180	150

Source: Annual Fisheries Statistics 1965 - 97.

Table 27. Landings (t) of trawlers by tonnage class in the West Coast of Peninsular Malaysia in 1997.

Type of catch	Landings (t) by trawler tonnage class					Total (3 735 units)
	0.1 - 9.9 (660 units)	10 - 24.9 (1879 units)	25 - 39.9 (655 units)	40 - 69.9 (463 units)	≥ 70 (78 units)	
Demersal taxa:	9 021	57 982	68 789	66 726	18 711	229 761
Fish	8 330	52 606	60 571	64 511	16 496	202 514
Squid and cuttlefish	691	5 376	8 218	10 747	2 215	27 247
Pelagic fish	369	5 329	14 102	19 262	1 828	40 890
Prawn	4 449	17 111	3 907	1 174	87	26 728
Jellyfish	13	830	46	7 502	1 507	9 898
TOTAL	13 852	81 252	86 844	103 196	16 496	307 277
Fishing zone	Zone B			Zone C	Zone C2	

Source: Annual Fisheries Statistics 1965 - 97.

Trawl nets contributed 84% of demersal fish landings in 1997. The remaining came from drift gillnets (9%), other seines (3%) hook and lines (2%) and bag nets (1%).

Demersal fish (including squid and cuttlefish) made up 75% of the landings of trawl nets. The breakdown of the catch by trawler size category is given in Table 27. Trawlers in categories 0.1 - 9.9, 10 - 24.9 and 25 - 39.9 GRT operated in fishing zone B (between 5 to 12 nm from shore). Demersal fish comprised about 75% of the landings of trawlers in this zone. The average annual landings of demersal fish increased with the size of trawlers 13.7 t•unit^{-1} for 0.1-9.9 GRT, 30.9 t•unit^{-1} for 10 - 24.9 GRT and 105.0 t•unit^{-1} for 25 - 39.9 GRT. The 40 - 69.9 GRT trawlers operated in fishing zone C (between 12 to 30 nm from shore). Demersal fish contributes about 75% of the landings of trawlers in this zone with an annual average of 162.5 t•unit^{-1}. The big trawlers (70 GRT and above) operate beyond 30 nm from shore (fishing zone C2). Demersal fish made up 85% of their landings with an average of 243 t•unit^{-1}.

In the traditional fisheries, demersal fish was dominant in the landings of hooks and lines (98.2%) and barrier nets (90%). The percentage of demersal fish for drift gillnets, other seines and push nets was between 30% and 45% of landings. For bag nets and fish traps, demersal fish only contributed 10% to 20% of landings. Traditional gear fishers are allowed to fish in any fishing zone, but most of them fished in zone A (within 5 nm from shore).

Total landings of demersal fish in the WCPM was 230 000 t in 1997. Trawl nets landed 246 000 t (84%) while traditional fishing gear landed 46 000 t (16%) (Table 28). Landings of demersal fish by the commercial fisheries reached a peak of 254 000 t in 1990. For the traditional fisheries, landings were in the range of 27 000 - 45 000 t during the 1970s, 27 000 - 60 000 t during the 1980s, and 37 000 - 71 000 t during the 1990s. The highest landings of demersal fish in the WCPM was recorded at 304 000 t in 1996, with the bulk coming from traditional gear.

Table 28. Demersal fish landings (t) by commercial and traditional fisheries on the West Coast of Peninsular Malaysia from 1971 to 1997.

Year	Demersal landings (t)		Total
	Commercial	Traditional	
1971	59 185	27 329	86 514
1972	65 624	34 781	100 405
1973	82 037	45 314	127 351
1974	115 591	34 751	150 342
1975	108 616	27 328	135 944
1976	120 371	32 226	152 597
1977	137 041	42 966	180 007
1978	151 530	30 128	181 658
1979	144 497	36 316	180 813
1980	141 424	27 449	168 873
1981	155 292	32 369	187 661
1982	151 307	41 142	192 449
1983	152 894	55 274	208 168
1984	142 775	51 616	194 391
1985	158 279	57 221	215 500
1986	200 817	60 395	261 212
1987	243 555	36 194	279 749
1988	214 501	20 667	235 168
1989	233 824	38 052	271 876
1990	254 279	40 652	294 931
1991	201 259	37 764	239 023
1992	213 859	50 126	263 985
1993	212 713	46 165	258 878
1994	209 571	47 747	257 318
1995	231 021	47 955	278 976
1996	233 566	71 102	304 668
1997	246 689	45 949	292 638

Source: Annual Fisheries Statistics 1965 - 97.

Trawls in operation on the WCPM numbered over 5 100 units during 1979 to 1985 (Table 26). The number decreased to 3 735 units by 1997. The reduction was a result of government policy since 1987 to reduce effort in coastal areas while encouraging offshore fishing. A steady reduction was observed in 0.1 - 24.9 t and 25 - 39.9 GRT trawlers (Table 29). A 40% reduction was recorded for the 0.1 - 24.9 GRT category from 1981 to 1997. During the same period, trawler numbers of 25 - 39.9 GRT were reduced by about 33%. Although bigger (40 - 69.9 GRT) trawlers increased with time, trawlers of 70 GRT and above declined since 1991. One reason for this was the difficulty in getting crew. Government moves to allow foreign crew on board local fishing vessels has not improved the situation.

Average annual catch-per-unit effort (CPUE) of trawlers < 25 GRT increased from 14.20 t•unit^{-1} in 1981 to 37.44 t•unit^{-1} in 1997, as the number of units decreased by about 38%. The same trend was observed for 25 - 39.9 GRT trawlers. Bigger size trawlers show no clear trend over the last ten years. Overall, a 30 % reduction of the number of trawlers has increased catch rate 2.5 times during the period 1981 to 1997.

Table 29. Number and average CPUE (t·unit^{-1}·year^{-1}) of trawlers in operation in the West Coast of Peninsular Malaysia from 1981 to 1997

	Trawler tonnage class									
	0.1 - 24.9		25 - 39.9		40 - 69.9		> 70		Total	
Year	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
1981	4 095	14.20	972	109.71	254	140.01	–	–	5 321	263.82
1982	4 048	17.32	894	104.92	317	137.51	–	–	5 259	260.12
1983	3 969	17.32	780	93.96	367	194.05	–	–	5 116	305.32
1984	4 083	–	797	–	375	–	–	–	5 255	–
1985	4 012	–	783	–	368	–	–	–	5 163	–
1986	3 481	27.14	608	115.71	363	182.61	53	638.11	4 505	963.58
1987	3 268	26.13	553	138.15	410	337.94	29	372.10	4 260	874.32
1988	3 211	26.11	555	119.71	415	247.09	51	277.39	4 232	670.31
1989	3 374	28.69	603	125.51	430	260.95	62	228.53	4 469	643.67
1990	3 385	30.53	579	160.93	411	257.53	41	544.32	4 416	993.31
1991	3 538	23.86	567	122.40	397	205.58	98	243.85	4 600	595.58
1992	3 165	35.88	558	141.02	379	206.18	83	257.72	4 185	640.80
1993	2 816	32.13	609	123.56	430	189.16	84	277.23	3 939	622.08
1994	2 752	29.62	656	121.31	462	202.37	81	256.02	3 951	609.32
1995	2 695	32.25	679	142.56	481	211.50	78	253.90	3 933	740.21
1996	2 797	37.12	679	119.88	480	211.76	76	331.05	4 032	699.82
1997	2 540	37.44	655	132.59	463	222.88	77	287.44	3 735	680.36

Source: Annual Fisheries Statistics 1965 - 97.

Table 30. Composition of the landings of trawls, purse seines and traditional gear in 1997 in the West Coast of Peninsular Malaysia.

Resource Group	Trawls (%)	Purse seines (%)	Traditional gear (%)
Demersal:			
Food Fish	14.9	–	42.9
Trash fish and others	51.0	9.1	12.1
Squid & Cuttlefish	8.9	–	2.3
Prawn	8.7	0.2	17.5
Pelagic	13.3	90.7	23.9
Jellyfish	3.2	–	1.3
Total landings (t)	307 277	1 163 092	163 092

Table 30 gives the composition of landings by gear type in the WCPM in 1997. Trawl landings consisted mainly of trash fish (51%), demersal fish (14.9%) and pelagic fish (13.3%). The dominance of trash fish is characteristic of trawls. Trawlers in the smaller GRT categories contributed most of the prawn catch. The landings of purse seiners consisted mainly of small pelagic fish such as mackerels, scads and sardines. Recently, about 10% of the landings have consisted of demersal species and prawns due to the use of fish aggregating devices (FADs) and spotlight. Traditional gear caught mainly demersal and pelagic fish as well as prawns. Trammel nets and push nets are the two main traditional gear used for catching prawns. The drift nets/gillnets mainly catch pelagic and demersal fish. The trash fish component is very much lower than that of the trawl.

Mackerels dominated the catch of trawls. *Rastrelliger* spp. became the main catch in the WCPM with the introduction of high opening trawl nets. Among the demersal fish, threadfin beam, lizard fish and croaker were most abundant. The five most abundant groups since 1986 are given in Table 31.

Table 31. Five dominant finfish groups in the landings of trawlers in the West Coast of Peninsular Malaysia from 1986 to 1997.

Percentage of trawl landings						Trawl landings (t)
Year	1	2	3	4	5	
1986	A = 5.3	B = 1.8	C = 1.8	D = 1.2	E = 1.1	192 902
1987	A = 5.4	C = 3.0	B = 2.4	F = 1.1	G =1.0	311 132
1988	A = 4.4	C = 2.9	B = 2.7	H = 1.9	F = 1.8	226 976
1989	A = 5.3	C = 2.8	B = 1.9	E = 1.2	F = 1.0	298 852
1990	A = 5.1	C = 3.7	B = 1.9	G = 1.2	F = 1.0	436 287
1991	A = 4.1	C = 3.9	B = 2.0	G = 1.6	H = 1.3	259 276
1992	A = 5.0	C = 3.1	B = 2.5	H = 2.0	G = 1.3	291 771
1993	A = 4.0	C = 4.0	B = 2.6	G = 1.6	H = 1.5	270 343
1994	A = 7.1	C = 3.3	B = 2.5	I = 2.2	G = 2.0	275 330
1995	A = 10.3	C = 2.2	I = 2.1	B = 2.0	G = 1.9	313 068
1996	A = 7.4	C = 3.3	B = 2.6	G = 2.3	I = 1.8	312 038
1997	A = 5.7	C = 3.0	G = 3.0	B = 2.5	I = 1.7	307 277

Source: Annual Fisheries Statistics 1965 - 97.

Economics and Marketing

One of the basic differences between the commercial and traditional fishery is the level of capital input and technology. Engine capacities average 180 HP for commercial fishing vessels and 18 HP for traditional fishing vessels. The commercial fishery operates large fishing nets with the aid of power blocks, net haulers and net drums as well as sophisticated equipment like fish finders, echo-sounders and sonar. They also use modern navigational equipment and are fitted with Refrigerated Sea Water (RSW) systems to maintain the quality of their catch. The catch is kept in large plastic bins and stored in insulated fish holds cooled by the RSW system. Fishing trips normally do not exceed a week, and thus the catch is kept in very good condition. Traditional fisheries normally use ice blocks on board and insulated fish boxes, except those in remote areas where a regular supply of ice is not available.

Fishers or boat owners are encouraged to market their catch direct or via middlemen at government-controlled landing sites. This is to facilitate statistics gathering, centralize fish landings and provide loading/unloading and cold-room facilities to the fishers. Depending on quality and species, fish are either sold in local markets or exported. Increasingly, fish marketing is being handled by Fishermen's Associations, which are well-supported by the Malaysian Fisheries Development Board (LKIM). The major fish landing/handling harbours are all controlled by LKIM. Fish meant for the major towns is distributed in iced crates by lorries. The availability of cold-rooms at landing jetties provide support to middlemen or the local fishermen's association. Traditional fishers, however, sell their catch locally or to fish traders who collect and send the fish consignment to the wholesale market.

Fish processing has evolved with time and new technologies. There are now more varieties of fish products with longer shelf life. At present, the bulk of demersal fish caught are consumed fresh. These are packed in ice for both the local and foreign markets such as Singapore and Thailand. Some demersal fish are sold dried, salted or boiled. Over the last decade, there has been increased utilization of previously low-priced fish species for the production of value-added fish and fish-based products like surimi, fish cakes, fish fingers, fish balls and fish crackers.

The economics of trawl, purse seine and drift net fishing in the WCPM was studied by (Kamaruzaman and Lim, 1999). Capital investment for a trawler and purse seiner between 25 - 69.9 GRT was RM100 000 in 1989. The main capital costs are for the boat hull, engine, gearbox, net and accessory equipment. The mean costs and earnings for 1989 are given in Table 32. Fuel, labour, maintenance, ice (for vessels without RSW) and food for crew constitute the main operating costs. The mean net profit derived by a 25 - 39.9 GRT trawler in 1989 was RM36 520 while that of a 40 - 69.9 GRT trawler was RM43 601. For purse seiners, a 25 - 39.9 GRT vessel made a net profit of RM40 102 while a 40 - 69.9 GRT vessel made a net profit of RM63 562. Average net profit for drift nets was RM6 636 in 1989.

Although slightly different sharing systems are practiced across fisheries and localities in the WCPM, basically there are three main systems (Ishak 1994). For the trawl fishery, catches are divided into shares after deduction of operating costs. The number of shares are earlier agreed upon between boat-owner and crew, and the shares accorded to the boat-owner and each crew member depending on relative capital inputs, skills and responsibilities. Typically, on a 4-crew trawler, there are a total of eight shares where 4.75 shares go to the boat owner, 1.25 shares go to the skipper and the remaining shares are equally divided among crew members. In terms of percentage, a trawler owner gets between 20% - 60% of shares (Anon. 1995).

For a purse seine, the sharing system is more complex. The first 450 kg of the catch go to the crew consisting of about 14 workers. The boat owner does not get anything when the catch is < 450 kg. Catches in excess of 450 kg are divided into 20 shares after deduction of operating costs. The boat owner gets 5 shares and the remaining 15 shares go to the crew. The skipper gets 1.5 shares, the engine man 1.25 shares and the rest of the shares are divided equally among the remaining crew. For anchovy purse seiners, each crew member instead gets a fixed monthly wage, with the amount depending on their relative responsibilities and skills. In addition, crew members are paid a commission per basket of fish caught. The amount of commission again varies according to responsibilities and skills.

Table 32. Average costs and earnings of trawl, purse seine and drift net boats in the West Coast of Peninsular Malaysia in 1989.

	*Trawler (tonnage)		Purse seine (tonnage)		
	25 - 39.9	40 - 69.9	25 - 39.9	40 - 69.9	Drift nets
No. of day per trip	2	2	1	1	1
No. of trip per year	108	180	232	186	204
No. of workers	3	3	14	15	2
Annual landings:					
Quantity (kg)	173 781	236 936	173 473	386 100	5 765
Value (RM)	186 407	217 392	193 008	403 278	21 095
Annual Operation costs (RM):					
Fuel	81 298	76 355	53 789	152 670	3 529
Ice	8 406	7 400	18 547	34 740	950
Food for workers	4 639	3 113	7 147	18 840	1 681
Wages	35 445	64 707	53 260	102 597	3 734
Maintenance cost	9 606	7 933	12 053	21 100	3 192
Others	620	721	1 262	645	14
TOTAL	166 340	160 229	146 058	330 592	13 100
Annual gross earnings	46 393	57 163	46 950	72 686	7 995
Monthly gross earnings	3 866	4 764	3 913	6 057	666
Annual depreciation	9 873	13 562	6 848	9 124	1 359
Annual net earnings	36 520	43 601	10 102	63 562	6 636

Source: DOF Survey 1989.
Note: * Vessel with Refrigerated Sea Water (RSW) system.

For the traditional fisheries, catch-sharing systems are also practiced. Generally, the number of shares, after deduction of operating costs, is agreed upon among the boat owner, skipper and crewmembers. Where the boat owner is also the skipper, the shares are divided only between the boat owner/skipper and crew. A boat owner gets between 20%-60% of shares (Anon. 1995). For traditional gear which is owner-operated; the whole catch belongs to the owner-operator.

From 1980 to 1997 a steady decrease in number of fishing vessels was recorded in the WCPM (Tables 25 and 26). Most commercial fishing vessels perform daily fishing trips, but there is an increasing number of larger vessels that fish for up to a week or 10 days. Commercial fishing vessels are only allowed to operate beyond 5 nm from shore in Zones B (5 - 12 nm), C (12 - 30 nm) and C2 (> 30 nm), with the exception of anchovy purse seiners which can fish in Zone A (0 - 5 nm). In addition commercial fishing vessels > 40 GRT have to fish in Zone C and beyond. Larger size commercial vessels catch mainly finfish further offshore while the smaller commercial vessels target shrimps near shore.

Licensed traditional fishing vessels average 5 GRT but most vessels in operation are generally less than 15 GRT. There is still a large proportion that use outboard engines. Traditional fishing vessels are allowed to fish in Zone A. Most of these operate

trammel nets targeting shrimps. Drift nets target the more valuable finfish. Besides these, there is a variety of fishing gear targeting mixed species. Fishing trips are only day trips, with the exception of some portable fish trap operators who fish further away from shore and remain at sea for up to a week.

Table 33 gives a comparison of the efficiency of commercial and traditional fishing gears. Among commercial gear, the trawl has higher labour productivity although production costs are slightly higher than the purse seine. For both the trawl and purse seine, larger vessels (40 - 69.9 GRT) have higher labour productivity than the smaller (25 - 39.9 GRT) vessels. However, capital intensity of trawl (in terms of initial investment per person-day) is the highest. Capital intensity for purse seine is lower than trawl and close to that of the drift net. This could be explained by the low capital investment (RM100 000 for both gear) but differing crew size (four for trawl and 14 - 15 for purse seine). For comparison, fixed costs for the trawl and purse seine of 40 - 69.9 GRT are given in Table 34. Majority of purse seiners in the WCPM are currently 40 - 69.9 GRT. Capital investment varies widely depending on the sophistication of equipment used.

Table 33. Productivity indicators of selected fisheries on the West Coast of Peninsular Malaysia.

Fishery	Production Costs ($RM \cdot kg^{-1}$)	Labour Productivity ($kg \cdot person \cdot day^{-1}$)	Capital Intensity ($RM \cdot person \cdot day^{-1}$)
Trawl (25 - 39.9 GRT)	1.24	129	74.40
Trawl (40 - 69.9 GRT)	1.48	219	92.59
Purse seine (25 - 39.9 GRT)	1.19	53	30.79
Purse seine (40 - 69.9 GRT)	1.17	69	17.92
Drift net	0.44	14	29.41

Table 34. Estimate of fixed costs (RM) by fishery for 40 - 69.9 GRT vessels.

Fishery	Boat	Engine	Gear	Net	Others *	Total
Trawl	120 000	100 000	110 000	27 000	17 000	374 000
Purse seine	120 000	92 000	70 000	50 000	128 000	460 000

Note: * Mainly fishing and navigation equipment.

Exploitation Status

Abu-Talib et al. paper no. 6) show that demersal fish density in 1997 in coastal waters of Sub-area I and II (Fig. 3) was only 8% and 14%, respectively, of the value in 1971 - 72. Density in stratum 2 in Sub-area I and Sub-area II was only 38% and 25% respectively, of the values estimated in 1987. Demersal fish density in stratum 3 of Sub-area I was similar to the value obtained in 1987.

Length-based analyses of 15 demersal fish and three cephalopod species give a mean E value of 0.62 and confirm the existence of over-exploitation of the resources. These selected species comprised 48% of demersal fish abundance in 1997. Moreover, the MSY (273 000 t) and f_{MSY} (7.06 million standard trawling hours) estimates for demersal resources in the WCPM had been well exceeded by the 1997 catch and effort in the area.

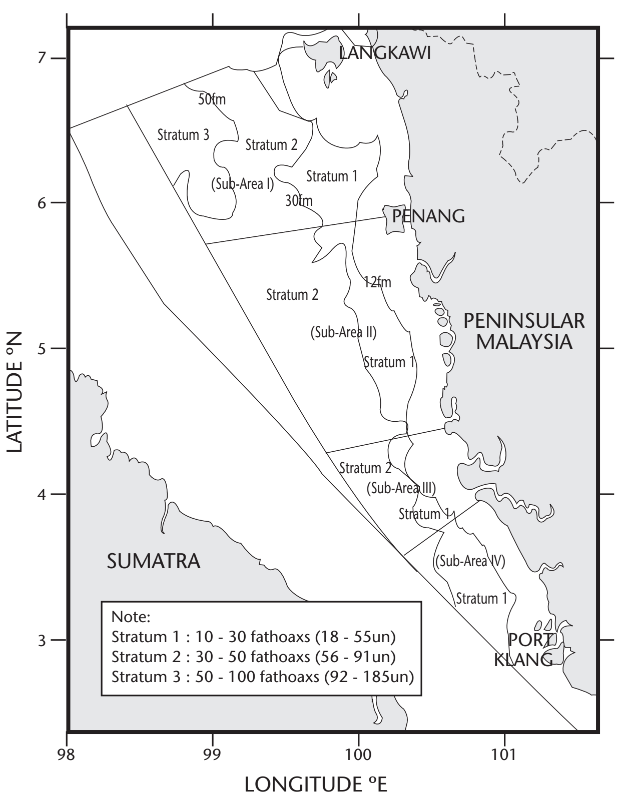


Fig. 3. The West Coast of Peninsular Malaysia showing the sub-areas (I, II, III and IV) and depth strata (1, 2 and 3) used in the study.

The exploitation of demersal fish resources in the WCPM occurred in two phases. The first phase (1973 - 85) is the period before the introduction of offshore vessels. The catch was generated mainly inshore by vessels of less than 70 GRT. During this period, fishing grounds in the WCPM were mostly located in inshore areas less than 30 nm from the coastline. The second phase (1986 - 97), is the period when the fishery experienced reductions in fishing effort with simultaneous increase in fishing area as offshore fishing ventures increased. The introduction of offshore vessels in 1986 resulted in a 15% increase in demersal fish landings (from 261 212 t in 1986 to 279 931 t in 1987).

Alias (paper no. 12) shows that there are two demersal resource assemblages in the WCPM. These two assemblages exhibit a boundary at about 40 m depth. The implications of these findings on spatial zoning of fishing in the WCPM deserve further attention.

Management Issues and Opportunities

The overall goal of management in the WCPM is to sustain production and development in the coastal demersal fisheries. This goal is sough through formulation and implementation of management strategies and actions to improve productivity/efficiency, equity among fishers, resources sustainability and viability of coastal fishing communities. Fig. 4 illustrates the hierarchy of objectives together with illustrative third level objectives that have been translated into various policy/regulatory instruments and management measures. The instruments and measures implemented in the WCPM by the Department of Fisheries have led to considerable progress. The moratorium on new fishing vessel and gear licences indicates the strong commitment on the part of Government in improving management of the fisheries. Substantial challenges however remain, which require concerted action by fisheries agencies and various stakeholders.

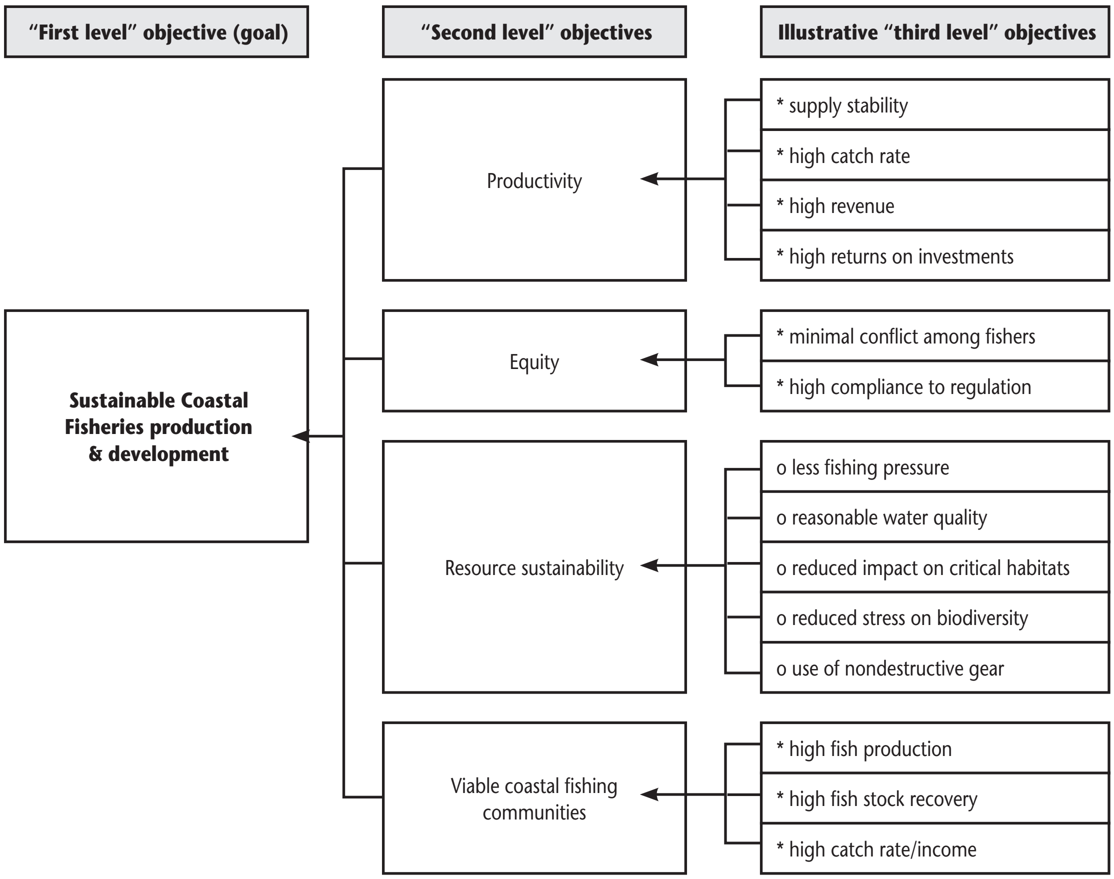


Fig 4: Goals and objectives in management of demersal fisheries on the West Coast of Peninsular Malaysia.

Table 35 gives a summary of key issues (problems/constraints) affecting demersal fisheries in the WCPM, as well as suggested interventions to help resolve or mitigate them. Relative to the management objective to improve productivity/efficiency, overfishing/overcapacity is the core issue and catches exceed the level considered desirable. Assessments indicate the occurrence of biological overfishing in the WCPM. The problem requires better information on resource characteristics and management options, and rationalization of the number and design of fishing gear and vessels operating in the WCPM. Illegal fishing is a problem in both commercial and traditional fisheries - the number of boats in operation is higher than the number of boats licensed and sighting records indicate substantial fishing by foreign vessels. Improved fishing skills and fishing technology have also contributed to overcapacity. Interventions requiring attention include buy-back-schemes, enhancing stakeholders' awareness on the prevailing situation, and strict enforcement against illegal fishing and fishing practices. Inappropriate exploitation patterns whereby under-sized and juvenile fishes are common in the catch is an issue. This mainly emanates from the use of non-selective fishing gear such as trawl (commercial) and push net (traditional). Improving gear selectivity and design requires increased attention. Post-harvest losses remain an issue that requires continuing extension programs on better fish handling methods and research in utilization of low-priced fish species for production of value-added fish and fish-based products. Illegal fishing techniques such as push net continue to pose problems and require community involvement and stringent enforcement activities. Lack of information dissemination about the fisheries situation is also one of the key issues and requires expansion of information and training programs in the area. The Department of Fisheries will establish a

consultative committee (to include representatives from fishers) during preparation of the management plan for demersal fisheries in the WCPM. The plan will be formulated with all relevant stakeholders and information activities will be an integral part of the planning process.

Relative to equity, the low productivity of fishers (particularly traditional fishers) is a key concern. This will require improving fishers' participation in the marketing of their catch. Fishers' associations should be encouraged to participate in fish marketing. Alternative marketing channels should be explored since penetrating the existing marketing channel is very difficult. Low productivity can also be addressed with the use of modern, labour-saving fishing equipment onboard vessels. This should beencouraged, however, without aggravating overcapacity in the fisheries. Differentiation in price of fishery products can be improved via introduction of product eco-labeling (such as "prawn from turtle-free trawl"). This should increase prices, incomes and encourage the use of environment-friendly fishing gear. Poaching by foreign fishing vessels needs to be curtailed by improving enforcement capacity in the area. The Maritime Enforcement Coordinating Centre (MECC) supervises enforcement activities in the country, and involves the Department of Fisheries (DOF), Royal Malaysian Navy, Marine Police and Customs Department. In the WCPM, DOF is equipped with two 75 feet vessels, two 45 feet vessels, and 28 speedboats with twin outboard engines of 150 - 240 HP. The bases of these patrol vessels are in Langkawi (Kedah state), Lumut (Perak state) and Port Kelang (Selangor state). The low fee structure for big vessels is also an equity issue. This requires review and amendment of the fee rates fixed by the Fisheries Maritime Regulation 1967 and Fisheries (Licensing of Local Fishing Vessels) Regulations 1985. Conflicts among commercial and traditional fishers have resulted in introduction of the fishing zone scheme. Review of the existing fishing zone scheme and the introduction of co-management arrangements appear to be in order. The poverty level among fishers is an underlying equity issue and requires enhancement of poverty reduction and livelihood programs for rural areas.

Relative to resource sustainability in the area, resource depletion is an overriding issue and relevant interventions have been discussed above. In addition, a program to encourage landing of fish by deep sea foreign fishing vessels in local ports is proposed. The program (called "Fish for Fuel" or the 3F Program) is intended to attract foreign fishing vessels to land their catch in the country in exchange for cheaper fuel prices. This should bring more fish for the local market. Other issues and suggested interventions relevant to resource sustainability are given in Table 35. A number of cross-sectoral issues need attention in this context, including:

- eutrophication in coastal waters due to excessive fertilizer use in catchment areas
- siltation from clearing of coastal land area for agriculture and aquaculture
- catching of juvenile fish (such as grouper) for aquaculture
- use of trash fish (including under-sized food fishes) as feed in aquaculture
- stress to sensitive coastal ecosystems due to promotion of MPA (marine protected areas) and marine parks as tourism spots
- aggravation of overfishing by recreational fisheries promoted by the tourism sector.

There are 8 key issues pertaining to the management objective of promoting viable coastal fishing communities (Table 35). Ten interventions are suggested in response to these issues. An urgent priority in promoting viable coastal fishing communities is to get them involved in the management of fisheries through CBFM (community-based fisheries management) or co-management arrangements. Training and pilot programs to prepare communities for this concept are needed.

As part of initiatives to improve management of demersal fisheries in the WCPM, many of the key interventions given in Table 35 has been packaged into projects and programs proposed for implementation under the Eight Malaysian Plan (RMK-8) during 2001 - 2005. Table 36 lists the proposed projects incorporating the suggested management interventions identified above. These projects are in line with the overall national goal to achieve sustainable fisheries as stated in NAP3.

Table 35. Summary of key objectives, issues and interventions for management of the demersal fisheries on the West Coast of Peninsular Malaysia.

Management Objectives	Key Issues (Problem/Constraints)	Key Interventions (Strategies/Actions)
1. Productivity/Efficiency	1. Overfishing/Over-capacity	• Rationalize boat/gear design and number
		• Enhance research & information gathering
		• Examine feasibility of buy-back-scheme
		• Ban night trawling
		• Limit engine size & impose higher fee for bigger engine
		• Limited entry
		• Enhance stakeholders' awareness/participation
		• Improve gear selectivity
		• Strict enforcement against illegal fishing
	2. Inappropriate exploitation patterns	• Improve design of shrimp trawl
		• Improve gear selectivity
		• Introduce season & area closures
	3. Post-harvest losses	• Improve fish handling on board vessels.
		• Enhance research on product development
		• Improve transportation & storage
	4. Illegal fishing techniques	• Enhance enforcement
		• Get community involvement in management
	5. Lack of information dissemination	• Expand training and information program
2. Equity	1. Low productivity of fishers	• Increase productivity through involvement in fish marketing
		• Promote the use of labour-saving equipment
	2. Lack of product price differentiation	• Introduce eco-labeling
	3. Minimal participation of fishers' associations in marketing	• Encourage fishers' associations in marketing their products
	4. Poaching by foreign vessels	• Improve monitoring and enforcement
	5. Low fee structure especially for big vessels	• Review and amend fisheries regulations
	6. Conflicts among commercial & traditional fishers	• Review existing fishing zone scheme
		• Introduce co-management arrangements
	7. Poverty	• Enhance livelihood and poverty-reduction programs

Table 35. Summary of key objectives, issues and interventions for management of the demersal fisheries on the West Coast of Peninsular Malaysia (Continued)

Management Objectives	Key Issues (Problem/Constraints)	Key Interventions (Strategies/Actions)
3. Resource sustainability	1. Overexploitation/Resource depletion	• Fish for fuel (incentives) program for foreign fishing vessels
	2. Insufficient scientific information for management	• Enhance research to support management
	3. Insufficient enforcement to curb illegal fishing	• Increase enforcement activities at sea
	4. Use of non-selective fishing gear	• Promote the use of selective fishing gear
	5. Exploitation of undersized fish and fish fry collection	• Review appropriate mesh sizes
		• Regulate fry collection
		• Conduct breeding & restocking program
	6. Environmental and habitat degradation	• Establish ICZM/MPA/Sanctuaries program
		• Ban on sand mining in critical areas
		• Enhance artificial reefs
		• Conduct habitat enhancement/rehabilitation
	7. Loss in biodiversity	• Enhance research and options for biodiversity conservation
4. Viable coastal fishing communities	1. Economic dualism and lack of land-based job opportunities	• Injection of funds to fishers associations for various livelihood/economic activities.
	2. Excess fishers	• Relocation to other economic activities
	3. Existence of foreign crews	• Phase out foreign crews
	4. Unskilled local crew & low level of education.	• Conduct training programs
	5. Lack of awareness on fisheries management	• Introduce CBFM/Co-management arrangements
		• Conduct education & training programs
	6. Conflict within community	• Form/enhance community organizations
		• Conduct leadership development program
	7. Influence of NGOs & politicians	* Establish better interactions with NGOs & politicians.
	8. Lack of financing/credit facilities	• Provision of viable credit programs.

Table 36. Selected programs and projects to be carried out to achieve management objectives for the demersal fisheries on the West Coast of Peninsular Malaysia. These are proposed in the Eight Malaysian Plan (RMK-8) 2001 - 2005.

Program	Project
A. Sustainable Fisheries Management	1. Development of fisheries management information system
	2. Development of sustainable fisheries management plans
	3. Modernization of fisheries surveillance system
	4. Monitoring and protection of fisheries
	5. Development of environment-friendly fishing gear
	6. Conservation of ecosystems and biodiversity
	7. Development of marine parks and artificial reefs
	8. Development of co-management arrangements
B. Development of Capture Fisheries	1. Development of high seas tuna fisheries
	2. Increase in fish/prawn fry production
	3. Development of appropriate recreational fisheries
C. Development of Aquaculture	1. Development of appropriate aquaculture technology Industry
	2. Development of fish fry industry
	3. Development of feeds for aquaculture
	4. Development of sustainable aquaculture

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Appendix 1. Legal and Institutional Framework Relevant to Fisheries in Malaysia.

One of the current goals of fisheries management is to achieve sustainable coastal fisheries. To achieve this goal, various management strategies have been formulated and implemented to control fishing effort and rehabilitate and conserve marine resources and ecosystems. These measures include:

a. Direct limitation of fishing effort via licensing of fishing gear and fishing vessels. A review of effectiveness of the fisheries licensing procedures is a continuing process.
b. Identification of nursery areas that should be protected and managed to ensure survival of juveniles of commercially important fish species. These areas could be gazetted as closed fishing areas or areas that are zoned for specific fishing gear based on tonnage of the fishing vessels.
c. Facilitation of co-operative research efforts to provide data essential for formulation of area management plans.
d. Strict enforcement of regulations that address the problem of illegal fishing.
e. Rehabilitation of resources through establishment of artificial reefs and coral replanting programs.
f. Conservation of turtles and biodiversity of marine ecosystems.

The Federal Constitution of Malaysia 1957

The Federal Constitution, which is the supreme law of Malaysia, was enacted on 31 August 1957. Any law made thereafter that is inconsistent with the Constitution shall be void.

Federal and State governments have jurisdiction over different aspects of natural resources. The Federal Government has jurisdiction over "shipping, navigation and fisheries, including - maritime and estuarine fishing and fisheries excluding turtles". On the other hand, "land, turtle and riverine fishing" fall under the State Government's jurisdiction. However, for the state of Sabah and Sarawak, governance of "shipping under 15 registered tons including carriage of passengers and goods by shipping, maritime and estuarine fishing and fisheries" needs concurrence from both Federal and State Government. The subject of Federal and State laws are dealt with in Article 74 of the Federal Constitution, viz.

- Article 74(1) states that Parliament may make laws on matters in the Federal List or Concurrent List, that is in List I or List III of the Ninth Schedule. In the states of Peninsular Malaysia, "shipping, navigation and fisheries, including - maritime and estuarine fishing and fisheries excluding turtles" fall under the Federal List which means that the Federal Government has the power over the above matters. However, in the States of Sarawak and Sabah the above matters fall under the Concurrent list and the enactment of any law relating to fishing needs the concurrence of the State Government.

- Article 74(2) states that the State Legislature may make laws on matters in the State List, that is in List II set out in the Ninth Schedule or the Concurrent List. Riverine fishing and turtles fall under the State List and the State Government has the mandate to enact legislation on this matter.

In case of inconsistency between State and Federal law, Article 75 of the Federal Constitution states that: "If any state law is inconsistent with a federal law, the federal law shall prevail and the state law shall, to the extent of the inconsistency, be void."

Legislation

Since the early 1900s, the fishing industry in Malaysia has been covered by the Fisheries Ordinance 1909. This Ordinance was subsequently amended in 1912, 1924, and 1926, and finally repealed in 1951 and replaced by the Fisheries Rules of 1951. There were also seven Fisheries Ordinances/ Enactments enforced by the various states. The fishing industry at that time was mostly traditional fisheries and regulation of the industry was minimal.

However, in the 1960s and 1970s, introduction of trawl nets in coastal waters created much conflict with traditional fishers. This led to formulation of the Fisheries Act 1963. This Act provided a more comprehensive legal framework to manage fisheries in Malaysian waters. This Act was formulated to integrate and strengthen the legal framework relating to marine and inland fisheries; to protect the

natural living resources; to protect the interest of fishers; to ensure an equitable allocation of fisheries resources; and to strengthen the administrative activities as well as to reduce conflicts among the fishing communities. This Act was subsequently repealed and replaced by the Fisheries Act 1985.

The Fisheries Act 1985 is an improvement on the previous act, incorporating the exclusive economic zone (EEZ) so as to be consistent with relevant provisions in the 1982 Law of the Sea. Malaysia became a party to the 1982 Law of the Sea on 14 October 1996. Several new provisions have been incorporated in this Act. For instance, the Act now requires the Director-General to formulate and continuously upgrade fishery programs based on the latest scientific knowledge to ensure optimum utilization of fishery resources in line with good management practices. The Fisheries Act 1985 has provisions for monitoring, control and surveillance of fishing vessels in the EEZ. Foreign fishing vessels caught fishing in the Malaysian EEZ are severely dealt with under this Act. The objective of this Act is to provide for better conservation, management and development of fisheries in light of Malaysia's commitment towards implementation of the provisions of the 1982 Law of the Sea. The provisions of the Fisheries Act 1985 follow those provided for in the 1982 Law of the Sea. Briefly, the Act covers:

- Administration of fisheries in Malaysia
- Licensing and management of local/estuarine fishing operations
- Control of fishing by foreign fishing vessels in Malaysian waters
- Offenses, prohibitions and control of certain methods of fishing
- Establishment of marine parks and marine reserves
- Offenses and legal procedures relating to the implementation of the Act.

Subsidiary Legislation/Regulations

The Fisheries Act 1985 is the main law regarding control and management of fisheries in maritime and estuarine waters. This Act provides the Minister of Agriculture with powers to make regulations for management and conservation of marine resources. A number of fisheries regulations have been made under the Fisheries Act, including:

a. Fisheries (Marine Culture System) Regulations 1990

   This regulation provides procedures for establishment of marine culture systems and licensing of such systems. This regulation is for the control of aquaculture activities and pollution arising from such activities.

b. Fisheries (Maritime) Regulations 1967

   This regulation provides procedures for licensing different types of fishing appliances, covering license fees, deposits and conditions attached to such licenses. This regulation is applicable in maritime waters off the east coast and West Coast of Peninsular Malaysia.

c. Fisheries (Maritime) Regulations (Sarawak) 1976

   This regulation is applicable in waters off the coast of Sarawak. It provides procedures for licensing fishing appliances, covering license fees, deposits and conditions attached to the licenses.

d. The Fisheries Regulations (1964)

   This regulation is applicable in waters off the coast of Sabah. It provides procedures for licensing fishing appliances, covering license fees, deposits and conditions attached to the licenses.

e. Establishment of Marine Parks and Marine Reserves Order 1994

   Waters around 40 islands have been gazetted as Malaysian Marine Parks. Fishing and collection of fish and other aquatic animals in these gazetted areas are prohibited.

f. Fisheries (Conservation and Culture of Cockles) Regulations 1964

   This regulation is for management, control and licensing of the collection of adult cockles and cockle spat from natural spat fall areas and culture areas. The size for collection of adult cockles and cockle spat is covered, as well as the fee charged for the license to collect cockles.

g. Fisheries (Prohibition of Methods of Fishing) Regulations 1980

   This regulation prohibits unsustainable fishing practices such as blast fishing, electric fishing and fishing with the use of poisons, pair trawls,

beam trawls and drift nets/gillnets of more than 10 inches for catching rays and other species.

h. Fisheries (Licensing of Local Fishing Vessels) Regulations 1985

This regulation provides procedures for licensing local fishing vessels, including conditions for marking vessels, fees and deposits payable.

i. Fisheries (Closed Season for the Catching of Grouper Fries) Regulations 1996

This regulation is applicable in the state of Kelantan and Trengganu only. Fishing of grouper fry during the month of November to December is prohibited unless permitted by the Director General of DOF.

j. Fisheries (Prohibited Fishing Methods for the Catching of Grouper Fry) Regulations 1996

This regulation prohibits the collection of grouper fry in lagoons and estuaries without a license. Only fish traps can be used to catch grouper fry in lagoons and estuaries.

k. Fisheries (Prohibited Areas) Rantau Abang Regulations 1991

To protect nesting turtles in Rantau Abang, a turtle sanctuary, this regulation prohibits fishing in specific areas.

l. Fisheries (Prohibited Areas) Regulations 1994

The waters around the islands in Sarawak have been gazetted as a fisheries protected area. Collection of shells, mollusks and corals is prohibited. Fishing without a license is prohibited.

m. Fisheries (Prohibition) Regulations 1990

This regulation prohibits the import, export, sale or keeping in captivity of piranhas unless permitted by the Director General of DOF.

n. Fisheries (Control of Endangered Species of Fish) Regulations 1999

This regulation lists all species of fish and mammals which are protected, including endangered species listed in the Convention On International Trade of Endangered Species (CITES) such as the dugong, whale, dolphin, whale shark and the giant clam. It is an offence to fish for, harass, catch, kill, possess, sell, buy, export or transport any endangered species as specified in this regulation. Any of the listed endangered species caught unintentionally shall be released immediately or disposed as directed by a Fisheries Officer.

National Development Plans/Policies

a. The First National Agriculture Policy (NAP1, 1984 - 91)

In 1978, a Cabinet Committee on agriculture policy was established. This committee consisted of eight working groups covering all aspects of agriculture. One of the working groups focused on fisheries development and submitted its report to the Cabinet Committee in early 1979. Following this, the National Council formed another subcommittee to undertake a comprehensive study on the management and exploitation of living marine resources of the country. Based on these reports, NAP1 was unveiled in 1984. In relation to fisheries, the objective of NAP1 was to increase fish production through modern fishing technology. Deep-sea fisheries would be promoted to increase fish production using local and foreign expertise, and to ensure a sufficient number of fishing vessels to exploit the fisheries resources.

b. The Second National Agriculture Policy (NAP2, 1992 - 2010)

In 1990 a review of NAP1 was necessitated by the need to increase the contribution of the agricultural sector to overall growth and development of the economy in the face of structural changes and developments in international trade. The NAP2 was formulated with a vision of creating a market-led, commercialized, efficient, competitive and dynamic agriculture sector in the context of sustainable development. Other national policies such as the New Development Policy and the Vision 2020 were taken into consideration during formulation of NAP2. The NAP2 emphasized optimum and sustainable utilization of resources and commercialization of the sector with market-oriented growth. It was formulated on the basis of the predominant role of the private sector and incorporated

the development philosophies and aspirations of Vision 2020.

Under NAP2 the fisheries industry, in particular the deep-sea fisheries, would be further developed and expanded to support the growth of agriculture and related industries, as well as to further increase and diversify the supply of protein sources. The industry would be highly commercialized through exploitation of available resources on a sustainable basis. To sustain the level of fisheries output, fisheries management and conservation measures would be the main thrust of the industry's development. Inland and inshore fishing would be carefully undertaken to sustain the fisheries resources. The productivity of fishing effort would be the main source of output growth through expanded promotion of the use of modern fishing technology (including fish handling and storage), as well as improvement of marketing infrastructure. Traditional fishing vessels operating within 30 nm from the coastline would be gradually phased out and replaced by modern fishing fleets with efficient fishing gear.

Aquaculture would be promoted to increase fish production. Development of aquaculture estates in suitable water bodies would be promoted. The exploitation of these resources would be on a sustainable basis. Further downstream activities utilizing modern processing technologies in fish canning and production of processed fish would be further promoted.

c. The Third National Agriculture Policy (NAP3, 1998 - 2010)

The NAP3 was initiated in 1996 to cover the period from 1998 - 2010. It seeks to provide gradual but effective transformation of the agriculture and forestry sectors for the next millennium. This policy is in tandem with the National Development Policy, the Second Industrial Master Plan, the Science and Technology Policy and the Biodiversity Policy. The NAP3 provides the policy framework for future growth of fisheries. The objectives of NAP3 for fisheries are to: ensure adequate supply of fish to meet domestic demand for fresh fish as well as for the processing industries; capitalize on export markets for selected high value fish products; and conserve and sustainably manage and utilize fisheries resources. The strategic directions are:

i. to increase efficiency and productivity by intensifying technological improvement and private sector participation;
ii. to rationalize resource use through development of aquaculture development areas;
iii. to strengthen competitiveness by improving market networking, enhancing quality and safety assurance of fisheries products, exploiting market opportunities, and strategic positioning in niche markets;
iv. to strengthen economic foundations by enhancing institutional support via research and development programs;
v. to promote sustainable development by managing sustainable production and rehabilitating depleted fisheries resources.

d. The Fisheries Development and Management Plan

In 1985, "The Fishery Sector Strategy And Development Program until the Year 2000" was published. This plan detailed the strategy, programs and expenditure required for fisheries to achieve the objectives that are outlined in NAP1. It also outlined the strategy, programs and expenditure for five sub-sectors, namely: inshore fisheries, offshore fisheries, aquaculture, development support, and social and institutional development.

Coastal Resources Policies/Laws

a. Mangroves

The National Forestry Act 1984 provides for administration, management and conservation of forests and forest developments within states in Peninsular Malaysia. The states of Sabah and Sarawak have their own state laws on forestry. Section 7(1) of the National Forestry Act 1960 authorizes the state to gazette any land as a permanent forest reserve. Currently, there are 112 mangrove reserves in the country. These reserves form part of the country's Permanent Forest Estate (PFE), which is sustainably managed for production and protection. The Environment Quality (Prescribed Activities) Environmental Impact Assessment (EIA) Order 1987 is designed to protect the forest environment and biodiversity, particularly with regard to logging of natural forests.

b. Coral Reefs

Coral reefs in Peninsular Malaysia occur in offshore islands as shallow fringing reefs and isolated coral patches. The corals in Malaysia are highly diverse with 64 reported genera of hard corals composed of 174 species. Coral reefs are threatened mainly by human activities. The only legislation that protects coral reefs in maritime waters is the Fisheries Act 1985, which provides for establishment of marine parks and marine reserves. So far, Malaysia has established marine parks and marine reserves in waters surrounding 40 islands. Fishing and collection of corals, shells and other marine organisms is prohibited in the waters of these gazetted islands.

c. Seagrasses

Seagrass is a relatively unknown coastal resource in Malaysia. Scientific works have documented 10 genera and 14 species along Malaysia's coastline. The location of seagrass beds in coastal waters makes them vulnerable to both natural and man-induced stresses. Sedimentation, excessive freshwater inputs, coastal reclamation, accidental oil spills and shipping activities have impacted seagrasses in specific areas. To date, there is a distinct absence of legislation that explicitly establishes seagrass protected areas.

d. Endangered/Threatened Species

Malaysia has four species of sea turtles which nest along its coast, namely: the Leatherback (*Dermochelys coriacea*), Green turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricata*) and Olive Ridley (*Lepidochelys olivacea*). The nesting population of sea turtles have declined by as much as 60 - 99 percent since the 1950s (MOSTE 1997). Conservation efforts through development of hatcheries were started in Trengganu in 1961, Kelantan in 1964, Pahang in 1971, Malacca in 1987 and Perak in 1990. Efforts undertaken to control collection and sale of leatherback turtles are regulated through the Trengganu state enactment. Other measures undertaken to conserve turtles include:

i. The gazetting of the Fisheries (Prohibition of Methods of Fishing) Regulations 1990 which bans the use of drift nets/gillnets with mesh sizes of more than 10 inches.
ii. The Establishment of the Rantau Abang Sanctuary in 1990.
iii. The gazetting of the Fisheries (Prohibited Area) Regulations 1991 where waters off the coast of Merchang to Kampung Kuala Abang (Tanjung Jara, Trengganu) was declared a prohibited area.
iv. Establishment of turtle hatcheries and the release of hatchlings into the sea.
v. Research on the biology and migratory behavior of turtles.
vi. Formulation and implementation of education/awareness programs on Malaysia's turtle heritage.

e. Dugongs

Dugongs are protected under the Fisheries (Control of Endangered Fish Species) Regulations 1999, which disallows catching of dugongs and requires the release of these mammals if caught accidentally. In addition, dugongs are protected under the Convention on International Trade of Endangered Species (CITES).

Fisheries Investment Policies

Under the Promotion of Investment Act 1986, the term "company" in relation to agriculture includes agro-based associations and sole proprietorships and partnerships. Incentives offered by the Government for manufacturing, agriculture (including fisheries) and tourism sectors are provided under the Promotion of Investment Act 1986 and the Income Tax 1967. Incentives provided are in the form of deduction or exemption from taxes. Among the incentives offered by the Government for the agriculture sector, including fisheries, are:

a. Pioneer Status
b. Investment Tax Allowance
c. Reinvestment Allowance
d. Agricultural Allowance
e. Deduction for Capital Expenditure on Approved Agriculture Projects
f. Export Credit Refinancing
g. Double Deduction for Export Credit Insurance Premium
h. Double Deduction for Expenses On Promotion of Export
i. Industrial Building Allowance
j. Incentives for Research and Development.

In addition to the above, other incentives related to fisheries activities include:

a. Infrastructure Allowance,
b. Incentives for Small-Scale Companies,
c. Exemption from Import Duty on Direct Raw Materials/Components
d. Drawback of Sales Tax on Materials Used in Manufacture
e. Exemption from Import Duty and Sales Tax on Machinery and Equipment
f. Incentives for Operational Headquarters
g. Drawback of Excise Duty on Parts, Ingredients or Packaging Materials
h. Goods Exported to Free Zones, Labuan And Langkawi.

Priority fisheries activities and products that are eligible for pioneer status and investment tax allowance under the Promotion of Investment Act 1986 include:

a. agriculture production which includes spawning, breeding and culturing of aquatic products and offshore fishing
b. integrated agriculture which includes cultivation and processing of aquatic products
c. processing of agricultural produce which includes aquatic products and aquaculture feeds.

External Policies Affecting Fisheries

General Land Use

As provided for under the Federal Constitution of Malaysia, land use planning falls under the jurisdiction of State Governments. The National Land Code 1965 is an act that introduced a uniform system for land administration in Peninsular Malaysia. Provisions under this Act include the vesting of unalienated land within a state in the state authority, including minerals and rock materials. However, for any land which is being alienated, the power to approve or refuse an application rests with the State Authority (with reference to the Town and Country Planning Department or local authority so that development is in accordance with existing plans). The National Land Council was established to play a role in resolving land-use issues and facilitating the adoption of a comprehensive and coordinated approach to land-use planning. Other related acts include the Town and Country Planning Act 1974 (Amended 1994), Structure and Local Plans and the Land Conservation Act 1960. The latter regulates projects on hill slopes. Although 11 states in Peninsular Malaysia have adopted the Act, only the State of Penang has gazetted this Act.

At the State level, the State Planning Committee was also established to provide a channel for the coordination and proper management of land resources. This committee screens and approves development plans at the state level.

Pollution/Environmental Protection

Environmental policies are backed by laws at the Federal and State level. Malaysia is relatively well-served with legislation that regulates potential environmental threats. The Merchant Shipping Ordinance 1952, Merchant Shipping Ordinance 1960 (Sabah) and the Merchant Shipping Ordinance 1960 (Sarawak) (under the purview of the Marine Department Peninsular Malaysia, Marine Department Sabah and Marine Department Sarawak, respectively) controls pollution from shipping. The Exclusive Economic Zone 1984 also controls pollution from ships and dumping at sea.

The Environment Quality Act 1974 (Amended 1985) provides pollution control regulations and empowers the Department of Environment to regulate air and water pollution and to manage scheduled wastes. However, control of pollution from sewage and animal waste and also soil erosion are under State and Local Government jurisdictions. The Department of Environment has also drawn up guidelines for environmental impact assessment (EIA) to assist proponents of major development projects to meet environmental standards. The types of activities which are subjected to Environment Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987 are agriculture, airport, drainage and irrigation, land reclamation, fisheries, forestry, housing, industry, infrastructure, housing, industry, infrastructure, ports, mining, petroleum, power generation and transmission, quarries, railways transportation, resort and recreational development, waste treatment and disposal, water supply and development of hill-slopes, golf courses, former landfills and ex-mining land.

Minerals

The National Mineral Policy of 1992 guides the sustainable development of mineral resources. In line with this, the Mineral Development Act, which deals with regulatory aspects of exploration and

mining, was gazetted in 1994. The Continental Shelf Act 1966 regulates exploration and exploitation of the continental shelf.

International/Regional Conventions

Malaysia is a party to a number of international treaties /conventions, including the:

a. 1958 Convention on The Continental Shelf
b. 1971 Convention on Wetlands of Importance Especially as Waterfowl Habitat (RAMSAR Convention)
c. 1972 Convention Concerning Protection of the World Cultural and Natural Heritage
d. 1973 Convention for the Prevention of Pullution from Ships (MARPOL)
e. 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
f. 1982 United Nations Convention on the Law of the Sea (LOS),
g. 1987 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
h. 1987 Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol)
i. 1992 Convention on Biological Diversity
j. 1992 Framework Convention on Climate Change, and
k. Forest Principles (Non-legally binding authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests).

The Department of Fisheries Malaysia also maintains direct contact on technical issues with regional and international organizations dealing with fisheries, including the:

a. Food and Agriculture Organization (FAO) of the United Nations
b. ASEAN-Cost Subcommittee on Marine Science
c. Asia Pacific Fisheries Commission (APFIC)
d. Asia Pacific Economic Cooperation (APEC)
e. Association of South East Asian Nations (ASEAN)
f. Bay of Bengal Programme (BOBP)
g. Indian Ocean Tuna Commission (IOTC)
h. International Center For Living Aquatic Resources Management (ICLARM)
i. International Development Research Centre (IDRC)
j. Japan International Research Center for Agriculture Science (JIRCAS)
k. Marketing Information and Advisory Services for Fish Products in the Asia/Pacific Region (INFOFISH)
l. Network of Aquaculture Centers in Asia and the Pacific (NACA), and
m. Southeast Asian Fisheries Development Centre (SEAFDEC).

International regulations play a major role in governing trade, especially for developing countries. Two recent international agreements of particular significance are the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT). These agreements were concluded under the Uruguay Round of multilateral trade negotiations (MTNs) and are binding on all members of the World Trade Organization (WTO).

The SPS Agreement specifies when food safety concerns are a valid reason for exceptions to the principle of non-discrimination in international trade. The agreement encourages WTO members to use international standards. All processing has to adopt the Hazard Analysis of Critical Control Points (HACCP) System and must be enforced in a manner that respects the SPS Agreement.

The TBT Agreement sets out rules for technical regulations that are not directly related to health. The TBT Agreement would apply to a country intending to impose the use of eco-labels on internationally traded fish products. Countries now have to restructure production and trade towards trade liberalization.

Other Institutions Involved in Fisheries and Coastal Zone Management

At present there is no national institution whose exclusive function is for integrated coastal zone management in Malaysia. There are a number of multi-sectoral, inter-agency and consultative Councils and Committees at the federal and the state level which have been established to resolve issues related to land, forestry, local government, water, environment and development. The list of relevant councils and committees is given in Appendix Table 1 and key government agencies involved in development and environment activities in the coastal zone are given in Appendix Table 2.

Relevant non-government organizations and groups include the following:

a. Environmental Management and Research Association of Malaysia
b. Malayan Nature Society
c. Environmental Protection Society Malaysia
d. Malaysian Fisheries Society
e. Malaysian Society of Marine Sciences
f. WHO Western Pacific Regional Center for the Promotion of Environmental Planning and Applied Sciences
g. World Wide Fund for Nature, Malaysia
h. Sahabat Alam Malaysia
i. Malaysian Institute of Maritime Affairs (MIMA)
j. Resident Associations
k. Clubs and charities
l. Fishers' Association
m. Media
n. Tourism promotion association
o. Manufacturer's trade association and Chambers of Commerce
p. Offshore industries like petroleum companies
q. Professional societies

Appendix Table 1. Relevant councils and committees established to resolve issues related to land, forestry, local government, water, environment and development

	Name of Council/Committee	Function	Membership
1	National Land Council (NLC)	Provided for in the Federal Constitution and advises on matters relating to natural resources, land, mining, forestry, agriculture and related subjects. Any policy formulated by NLC is binding on both Federal and State Governments.	Chairman: Deputy Prime Minister Members: Chief Ministers and Federal Ministers.
2	National Forestry Council (NFC)	Similar to NLC but role relates to forestry issues.	Chairman: Deputy Prime Minister Members: Chief Ministers and Federal Ministers.
3	National Council For Local Government (NCLG)	Formulates policies as well as operating mechanisms for all local governments.	Chairman: Minister of Local Government and Housing Members: State Executive Committee members responsible for local government matters and Federal Ministers.
4	National Water Council	Formulates policies on water and helps resolve interstate water issues.	Chairman: Prime Minister Members: Chief Ministers and Federal Ministers.
5	National Development Council (NDC)	Considers matters on implementation of development programs and projects.	Chairman: Prime Minister Members: Chief Ministers and Federal Ministers.
6	National Economic Action Council (NEAC)	Oversees implementation of the national economic recovery action plan.	Chairman: Finance Minister Members: Federal Ministers and private sector representatives.
7	Federal-State Liaison Committee	Resolves issues and conflicts between Federal-State governments.	Chairman: Prime Minister Members: Chief Ministers and Federal Ministers.
8	Meeting of Federal-State Environment Ministers/Executive Council Members For Environment	Discusses matters related to development and environment.	Chairman: Minister of Science, Technology and Environment Members: State Environment Ministers/ Executive Council Members.
9	National Development Planning Committee	Coordinates preparation of the National Development Plans for submission to the Cabinet and Parliament for approval.	Chairman: Chief Secretary Members: Secretary-Generals/Heads of all Ministries.
10	Environmental Quality Council (EQC)	Oversees implementation of Environment Quality Act (EQA) 1974, advise the Minister of Science, Technology and Environment on policies relating to environment and on matters relating to EQA.	Chairman: Appointed by the Minister Members: Secretary-Generals of various Ministries and representatives from the private sector, NGOs and states of Sabah and Sarawak.

Appendix Table 1. Relevant councils and committees established to resolve issues related to land, forestry, local government, water, environment and development. (continued)

	Name of Council/Committee	Function	Membership
11	EIA Review Panel	Reviews detailed EIA reports.	Chairman: Director-General of Environment Members: Government agencies, universities, environmental experts, NGO's.
12	National Coastal Erosion Control Council (NCECC)	Formulates coastal erosion control strategies.	Chairman: Director-General of Implementation and Co-ordination Unit (ICU) Members: Representatives from relevant agencies.
13	State Executive Council	Equivalent to State Cabinet, makes all important decisions on behalf of the State.	Chairman: Chief Minister Members: State Assemblyman in charge of various development and environment portfolios or in the State of Sabah and Sarawak the State Ministers.
14	State Development Council	Supervises implementation of the State Development Plan.	Chairman: Chief Minister Members: State Ministers/Executive Committee (EXCO) Members, State Development Officers, Heads of State Departments.
15	State Environmental Committee	Forum for promoting greater awareness of environmental issues of the state level and identifying and resolving these issues.	Chairman: State EXCO Members in charge of environment or state Minister of environment in Sabah /Sarawak. Members: Heads of State Departments.
16	City Council, Municipal Council or district Council	Forum for promoting greater awareness of environment and development issues at the local level and identifying and resolving these issues.	Chairman: Mayor of City Council or President of Municipal Council or District Council Members: Heads of State Departments/ Heads of Districts.
17	State Planning Committee	Responsible for approval of structure plans and all physical planning issues.	Chairman: Chief Minister Deputy Chairman: An EXCO Member. Secretary: Director, State Town and Country Planning. Members: State Secretary. Director, State Lands and Mines; Director, UPEN; Director, State Public Works; State Legal Advisor; State Financial Advisor; State Development Officer; Director, State Department of Environment; Four additional members (EXCO members).

Source: Economic Planning Unit, Prime Minister's Department. Integrated Coastal Zone Management, September 1999. p. A4 - A7.

Appendix Table 2. Key government agencies involved in development and environment activities in the coastal zone.

	Agency	Objectives and functions
1	Prime Minister's Department (PM)	To plan, formulate and co-ordinate all matters pertaining to implementation of national policies to achieve the stated policies of the Government. To ensure that all administration of development projects, international conferences, etc. are carried out in accordance with policies and procedures formulated from time to time.
2	Economic Planning Unit of the Prime Minister's Department (EPU)	The objective of EPU is to formulate policies, strategies and programs for short-and long-term economic development of the nation. EPU is the reference on national development, planning and economic issues for the Government. Each state has a State EPU or its equivalent. Within State EPUs, sectors or individual officers handle similar fields covered by the Federal EPU, e.g. industry, agriculture, tourism, etc.
3	Implementation and Co-ordination Unit of the Prime Minister's Department (ICU)	The objective of ICU is to be the premier agency in monitoring and coordinating implementation of development programs and projects to ensure the achievement of objectives of the national development policies towards building a progressive and successful nation.
4	Town and Country Planning Department (TCPD) of the Ministry of Housing and Local Government.	TCPD administers and enforces the Town and Country Planning Act 1976 and ensures that development plans form the basis for planning and control of use and development of land.
5	Drainage and Irrigation Department (DID)	DID's objectives are to provide infrastructure and services in irrigation to increase agricultural productivity; provide flood mitigation works, conserve river systems, provide coastal protection works; and to develop a hydrological database for water resource development. DID administers and enforces the Water Enactment 1920 and River and Drainage Enactment 1920. DID operates a national network of hydrological/rainfall stations; river water quality stations; provides technical advice and support to Ministry of Agriculture agencies. DID's Coastal Engineering Technical Centre is the Secretariat to the NCEC chaired by ICU, Prime Minister's Department. .
6	Department of Environment (DOE), Ministry of Science, Technology and the Environment (MOSTE)	DOE's primary objectives are to enhance and improve the quality of the environment, and to balance the goals of economic development and environmental control for sustainable utilization of natural resources. DOE administers the Environment Quality Act 1974. It assesses the EIA for prescribed activities and reviews existing (and introduces new) environmental regulations.
7	Ministry of Transport (includes shipping) (MOT)	The MOT's objective is to plan and formulate transportation policies, to provide for the development and implementation of an efficient, safe and integrated transnational system (air, sea, land) to accelerate socioeconomic development of the country. The Marine Division in MOT oversees the enforcement of shipping legislation such as Port Authority Act 1963 etc.
8	Department of Fisheries (DOF), Ministry of Agriculture (MOA)	DOF's objective is to increase food production to meet the domestic and export market, to sustain production levels of inshore fisheries, develop and manage deep sea fisheries and to increase value of fisheries products. DOD is responsible for the overall management of fisheries and related matters including management of gazetted marine parks, and administers and enforces the Fisheries Act 1985 and EEZ Act 1984. It also undertakes research, provides technical support for the marine and freshwater fisheries industry.
9	Department of Forestry (DoFor), Ministry of Primary Industries	DoFor's objective is guided by the National Forestry Policy i.e. to manage the forest resources sustainably for the continuous production of forest goods and services and their optimum utilization, compatible with environmental requirements. DoFor provides advice and technical assistance to the states, maintains experimental stations and conducts training and research. States are empowered to formulate independent forest policies.

Appendix Table 2. Key government agencies involved in development and environment activities in the coastal zone. (continued)

	Agency	Objectives and functions
10.	Department of Agriculture (DOA), Ministry of Agriculture (MOA)	DoA's objective is to increase farm productivity through effective transfer of technology and research, to involve farmers in technology-use and to increase the contribution of the agriculture sector to the Federal and State level, focusing on farmers' training and development.
11	Geological Survey Department (GSD). Ministry of Primary Industry	GSD is the principal agency for discovery and investigation of mineral, water and energy resources (excluding oil and gas). It produces terrain/topography/aerial photos, studies hill slopes of various gradients and erosion risks. Geological mapping, hydrogeology, engineering geology, mineral exploration etc are some of its functions.
12	Public Works Department (PWD), Ministry of Works	The PWD's objective is to develop the infrastructure and public utilities such as roads, water supplies, building, airports, ports and jetties to meet the needs of the nation.
13	Department of Wild Life and National Parks, (PERHILITAN), MOSTE	PERHILITAN's objectives are to conserve wildlife species with the goal of fulfilling the needs and interests of the people; to create and manage National Parks, wildlife Reserves and Sanctuaries. PERHILITAN administers and enforces the Wildlife Act 1972 as well as being the national agency for international instruments e.g. CITES. It maintains a wildlife database and operates several wildlife breeding projects e.g. Sumatran Rhino, Seladang, Deer, Terrapin and Pheasant; elephant translocation and shore birds conservation. It also manages the National Park and the National Zoo.
14	Ministry of Culture, Arts and Tourism (MCAT)	The objective of MCAT is to develop and promote national culture and to develop and promote tourism as a major industry in the country. It formulates tourism policy plans, monitors the implementation of tourism programs.
15	Department of Mines, (DOM) Ministry of Primary Industries	DoM's objective is to encourage optimum development of the mining industry and advises the Federal and State Governments on matters pertaining to mining, minerals and related activities. DoM administers and enforces mining related laws (Mining Enactment Cap 148 and other State Enactment Ordinances, Mineral Ore Enactment FMS Cap 148) and other state enactments and activities such as exploration, production etc. At state level, it monitors mining activities and surveys their environmental impacts.
16	Department of Veterinary Services (VSD), Ministry of Agriculture (MOA)	VSD's objective is to develop the livestock industry and all aspects of animals and veterinary public health. VSD administers and enforces the Rearing of Pigs Enactment 1980, Animal Quarantine. It also solves animal health problem in the livestock industry and develops vaccines for animal diseases.
17	Marine Department (MD), Ministry of Agriculture (MOA)	The MD's objective is to establish an organized and safe navigation system and ship safety. It administers and implements the Merchant Shipping Ordinance 1952, Merchant Shipping (Oil Pollution) Act 1994. It ensures all ships are seaworthy and safe, merchant shipping navigation is organized and safe, provides ship survey, inspection, registration, sea manning, seafarer examination and administers ports which are not under the Port Authority Act 1963. It undertakes management audits on shipping companies, shipping management companies and ships. It is responsible for compensation with regard to oil spill/pollution damage and provides ferry services for passengers, examines seamen and collects port and shipping statistics.
18	Land and Mines Department, Ministry of Land and Co-operative Development	To formulate laws and policies and develop human resources in land administration geared towards achieving the objectives of the National Development Policy; to motivate and lead reforms in land administration; to improve capacity of management of federal land property so as to maximize returns to the Government.

Appendix Table 2. Key government agencies involved in development and environment activities in the coastal zone. (continued)

	Agency	Objectives and functions
19	Malaysian Industrial Development Authority (MIDA), Ministry of International Trade (MITI)	MIDA's primary objective is to promote and co-ordinate industrial development in Malaysia. It administers the manufacturing license under the Industrial Co-ordination Act 1986. It undertakes industrial promotion, advises State and Federal governments on industries promotion, formulation of policies pertaining to the industrial sector to expedite industrial development.
20	Department of Local Government, Ministry of Housing and Local Government	The objective of the Department of Local Government is to help Local Authorities render efficient and modern urban services, provide public amenities and recreational facilities and also to create economic opportunities for their respective areas. It administers a number of Acts such as Local Government Act 1976 (Act 171), the Street, Drainage and Building Act 1974 (Act 133), the Uniform Building By-Laws 1984 and the Town and Country Planning Act 1976.
21	Ministry of Defense (MOD), Navy	MOD's objective is to maintain the sovereignty and national integrity of Malaysia as well as the strategic interest of the country by military and other means related to defense. It manages the national defense and the Armed Forces and it implements national defense policy
22	Local Authority - City Council, Municipal Council or District Council	The objective of Local Authorities under the Local Government Act 1976 is to perform local government functions, namely provision of urban services, collection of assessment tax, licensing financial management and enforcement. The Town and Country Planning Act 1976 and the Street, Drainage and Building Act 1974 empowers Local Authorities as local planning, control and development agencies.

Source: ICZM Working Document 1999 and Marine Department 1999.

Appendix 2: Two Sample Projects To Be Carried Out in the West Coast of Peninsular Malaysia.

Project Title:

1. Conservation of Habitat Ecosystem and Biodiversity

Project Objective:

The main objective of this project is to conserve the existing habitat ecosystem to increase the fisheries resources naturally and artificially through formation of databases through formation of databases for the ecosystem.

Project Description:

The main activity of this project is data collection on basic information on the ecosystem. A database will be developed for each ecosystem under study. In general, research will encompass mapping of the coral and sea-grass areas, digitizing ecosystems, making an inventory and monitoring the biodiversity of reefs, the open water stocking of giant clams, sea cucumbers and lobsters and monitoring the distribution of groupers and snappers. Besides providing a detailed database on the various ecosystems, this project will also aid in the formulation of management and conservation strategies such as zone demarcations, identifying activities that pose a threat to the habitat, and determining areas with low/high impacts.

Project Implementation:

5 years (Year 2001 - 2005)

Resource Requirement:

Total Funding RM 6.76 million

Year	Budget (RM)
2001	772 000
2002	497 000
2003	497 000
2004	497 000
2005	497 000

Implementing Institutions:

* Staff from the Ecology Branch (FRI), Batu Maung
* Marine Fishery Resources Development and Management Department (MFRDMD), Kuala Terengganu
* Staff from the Ecology Branch (FRI), Sarawak.

Project Monitoring and Evaluation:

This Project will be funded under the 8th Malaysian Plan, which will be monitored and evaluated by the Department of Fisheries and Central Agency (Economic Planning Unit).

Project Title:

2. Development of Fisheries Management Information System

Project Objective:

The main objectives of this project are:

* To detect any changes in the trend of fish landings, fish composition and total catch from inshore and offshore fisheries and to determine the contributing factors.
* To provide scientific information to formulate regulations on the management of inshore (<30 nm from shore) and offshore (>30 nm from shore) fish resources in order to sustain the inshore production and to increase offshore production. Management measures will ensure that the fisheries resource is exploited at an optimum level by reducing fishing effort, especially in the inshore area. This is in line with the third National Agriculture Policy.

Project Description:

This project encompasses several aspects such as monitoring of fish landings; stock and resource assessment; demersal and pelagic stock survey; prawn resource survey; inshore and offshore fisheries survey; biological and oceanographic studies; and potential fishing ground forecasting in Malaysian waters. Data collection will be done in the field and a database will be set up for analysis of data and preparation of reports.

Project Implementation:

5 years (Year 2001-2005)

Resource Requirement:

Total Funding RM 12.49 million

Year	Budget (RM)
2001	15 000
2002	3 145 000
2003	3 050 000
2004	2 745 000
2005	1 835 000

Implementing Institutions:

Staff of FRI, Batu Maung, Penang
Staff of MFRDMD, Kuala Terengganu
Staff of FRI, Sarawak
Staff of Fisheries Management Information System Branch (FMIS), Department of Fisheries.

Project Monitoring and Evaluation:

This Project will be funded under the 8th Malaysian Plan, which will be monitored and evaluated by Department of Fisheries and Central Agency (Economic Planning Unit).

Philippine Coastal Fisheries Situation*

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Abstract

The fisheries sector in the Philippines provides a significant contribution to the national economy in terms of income, foreign exchange and employment. In 2000, total fish production was estimated at 2.94 million t, 84% of which was derived from marine capture fisheries. The export of fish and related fishery products amounted to about US$400 million in the same year. Between 1984 and 1997, the fisheries sector contributed between 3.8% to 5.0% of the national GDP and 18.4% to 20.6% of the agricultural GDP in the same period. The fisheries sector also provided employment to about 1 million people in 1997.

This paper reviews the Philippine coastal fisheries situation in terms of the status of the marine/coastal environment, resource potential, socioeconomic aspects of the fisheries and management measures to sustain the fishery. It also presents the problems, opportunities and recommendations for sustainable exploitation of coastal fish stocks based on a multi-sectoral workshop under the "Sustainable Management of Coastal Fish Stocks in Asia" Project in September 2000.

We highlighted the following areas that should be addressed in attaining improved fisheries management in the context of the Philippines: (1) maintaining integrity of coastal stocks and habitats; (2) maintaining the integrity of shared stocks; (3) maximizing economic benefits from utilization of resources; (4) promotion of equity in sharing benefits from the utilization of the resources; (5) minimizing conflicts among resource users; and (6) minimizing poverty among small scale fishers.

* WorldFish Center Contribution No. 1713

Introduction

The Philippines has a coastline of 17 460 km and territorial waters (including the Exclusive Economic Zone) covering about 2.2 million km^2. Of this area, 12% are considered coastal waters and 88% are oceanic. The coastal zone has coral reef areas of about 27 000 km^2 and swamp-lands covering 3 384 km^2. The fishponds for aquaculture in the country cover about 2 539 km^2, and are mostly located in the coastal zone. They were originally mangrove areas.

The Philippines has been one of the largest fish producers in the world and ranked 12th in 2000 (FAO 2000). In 2000, total fish production was estimated at 2.94 million t (BAS 2001). Of this, marine capture fisheries contributed 2.47 million t or 84% of the total production. Fish exports in the same year were valued at US$400 million (~ Php1.78 billion)[1]. However, due to increasing population size and demand for fish (Cruz-Trinidad this vol.), fisheries resources in most areas of the country are now experiencing over-exploitation. This situation is becoming more serious in some fishing areas due to habitat destruction and pollution from sources such as agricultural activities (see Silvestre et al. 1995; Barut et al. 1997). This complex situation requires improved resource management that is integrated within an overall coastal zone management approach (DA-BFAR 1996; Barut et al. 1997).

This paper reviews the status and management of Philippine coastal fisheries. It begins with the background of the coastal environment, the estimated potential of fishery resources, the socioeconomic setting and the institutional and policy environment. Next, the small scale and commercial fisheries sectors are compared in terms of production, employment, gear, target species and economic contribution and performance. The management of coastal capture fisheries is then examined, including fisheries management philosophy, management objectives, issues and opportunities. Finally, short- and long-term recommendations for the sustained and optimal utilization of Philippine coastal fisheries are presented.

Environmental Setting

The Philippines is an archipelago consisting of more than 7 100 islands located in the western Pacific, north of the equator between latitudes 21º 5' and 4º 23' N and longitudes 116º 00' and 127º 00' E (Fig. 1). The country is bounded by the Pacific Ocean to the East, the Sulu and Celebes Seas to the South, the South China Sea to the west and the Philippine Sea to the North. It extends about 2 000 km in a south-north direction, between 4º 05' and 4º 30' N Latitude, from the northeast coast of Borneo to 150 km off Taiwan. The total area of territorial waters, including the Exclusive Economic Zone (EEZ), is approximately 2.2 million km^2. The shelf area, up to the 200-m isobath, covers 184 600 km^2, and the coral reef area within 10 - 20 fathoms, (20 - 40 m), where reef fisheries occur, is about 27 000 km^2. The Philippines coastline measures approximately 17 460 km, making it one of the longest coastlines in the world.

The marine waters off the eastern part of the country are affected by the large scale currents of the Pacific Ocean (Wyrtki 1961). The North Equatorial Current flows westward across the Pacific, hits the eastern coast of the country and splits into the Kuroshio Current that flows northward and the Mindanao Current flowing southward. The Kuroshio Current flows along the east coast of Visayas and Luzon to Taiwan and Japan.

The Mindanao Current flows farther into the eastward flow, becoming the Equatorial Counter Current (ECC) with a weaker branch flowing along the east coast of Mindanao. The ECC then enters the Celebes Sea between Mindanao and Sangir and Talaud Islands and eventually exits into the Indian Ocean.

On the west coast currents are influenced by the seasonal monsoon winds. During the north-east monsoon (or *Amihan*) between October to March, a cyclonic pattern of surface water movement originates from the South China Sea. This develops into a northwesterly flow along the coast of Luzon and Palawan. During the southwest monsoon (or *Habagat*) from April to August the current flow is north-easterly, flowing out through the straits between Luzon and Taiwan.

[1] 1 US$ = Php44.34 (average value in 2000)

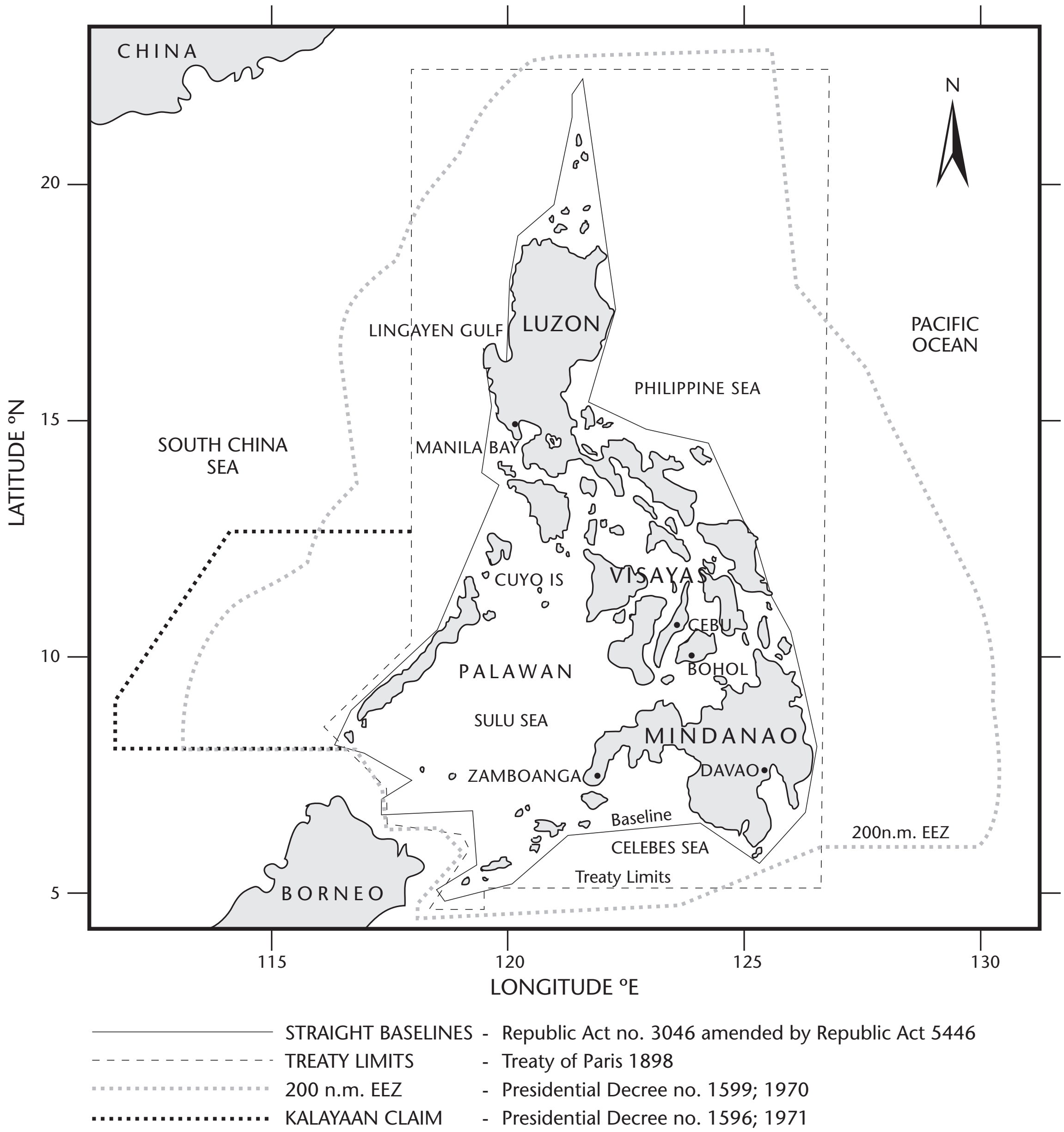

Fig. 1. The marine jurisdictional boundaries of the Philippines.

The country's marine environment is distinctly tropical with relatively warm waters with reduced salinity. Sea surface temperature ranges from 24º C to 30º C and averages about 27º C to 28º C. During the cold months of the north-east monsoon, i.e. from November to March, the temperature drops by a few degrees, mostly in Northern Luzon, where there is an increased inflow of cold water through the Strait of Formosa. Salinity variations in Philippine waters are very small, especially in the eastern parts. For example, sea surface salinity in the west - north-west of the Philippines exhibits minimal variations ranging from 33.7 to 34.6 psu[2]. (SEAFDEC 1999). These variations increase during the period of the south-west monsoon, when the western parts of the country experience rains.

[2] psu = means pratical salinity units which is equivalent to parts per thousand (ppt)

Philippine seawaters are typically poor in nutrients, with some small upwelling, gyres and mixing processes occasionally enhancing local productivity. Wyrtki (1961) also observed relatively low surface productivity in the South China Sea, Philippine and Celebes Seas at less than 0.5 g $C{\cdot}m^{-2}{\cdot}day^{-1}$. Recent estimates of primary productivity in the northern portion of the South China Sea indicated a range of 0.10 to 1.53 g $C{\cdot}m^{-2}{\cdot}day^{-1}$ (Furio and Borja 2000). Water quality in the coastal areas shows signs of deterioration due to a number of factors such as mine tailings, agricultural runoff, siltation, domestic sewage and oil spills (Talaue-MacManus 1999). Water quality parameters such as pH, dissolved oxygen, salinity, turbidity, heavy metal content and coliform counts have been shown to exceed standards set by the Philippine Environmental Management Bureau in many areas (Valmonte-Santos et al. 1996; Talaue-MacManus 1999).

With more than 400 species and 70 genera of hard corals, the Philippines has one of the most diverse coral faunas, with reefs that are on a par with the Great Barrier Reef of Australia (Nemenzo 1986; Gomez 1991; Gomez et al. 1994). The known coral reef area is 27 000 km^2 within the 10 - 20 fathom (20 - 40 m) depth zone. However, based on aerial survey and satellite data, there are approximately 84 928 km^2 of islands and shallow offshore areas, which could be considered as potential coral beds within 0 - 10 fathoms (0 - 20 m) (NAMRIA 1996 cited in DA-BFAR 1997). The province of Palawan and Autonomous Region in Muslim Mindanao (ARMM), which includes Sulu - Tawi-Tawi Islands and Turtle Islands, have 43% and 16%, respectively, of the total coral reefs in the country.

The coral reefs are under threat from siltation and destructive fishing (Yap and Gomez 1985; Gomez et al. 1994, White and Vogt 2000). Based on 85 coral reef sites reviewed by Gomez et al. (1994), they described the coral reefs of the country as 23.5% poor (0 - 25% coral cover), 51.8% fair (26% - 50% cover), 22.4% good (51% - 75% cover) and 5% in excellent condition (76% - 100% cover). In a recent project i.e. DA-BFAR CITES Coral Project (DA-BFAR 1997), the status of reefs in 1995 from 27 study sites was classified into 3.7% excellent, 33.3% good, 55.5% fair and 7.4% poor. With a majority of once pristine reefs now in fair or poor condition, the benefits forgone are substantial. The net value of quantifiable loss from over-fishing and destruction of 1 km^2 of coral reef over a 25 year period is estimated at \$108 900 (White and Trinidad 1998). In addition, the loss in terms of coastal protection forgone is estimated at \$193 000 while the forgone earnings from sustainable fisheries and tourism are estimated at \$86 300 and \$482 000, respectively.

Mangrove communities are an integral component of coastal ecosystems. There are two categories of mangrove habitats in the country: mangrove swamps characterized by the presence of large trees and associates, and *Nipa* swamps having stem-less palm growths. There are at least 39 mangrove species in the country (Calumpong and Menez 1997). The country's mangroves have been gravely impacted by both human and natural causes. The rate of loss in mangroves between 1965 to 1975 was 243 $km^2{\cdot}year^{-1}$, and 60% of this was due to conversion to aquaculture ponds (Primavera 1991). This has prompted the government to suspend permits for mangrove conversions, accelerate reforestation activities in collaboration with non-government organizations, and spur community-based rehabilitation and management of mangroves (White and Cruz-Trinidad 1998).

The country has about 16 seagrass species (Fortes 1995). Seagrass habitats perform various ecological functions such as providing nurseries for certain aquatic species, exporting nutrients to adjacent habitats and promoting the settlement of water-borne silt, thus reducing the impact of siltation. Like other critical coastal habitats, seagrass communities are showing increasing signs of degradation. Biophysical factors (e.g. siltation, pollution, eutrophication, weather and climate change), socio-cultural factors (e.g. poverty, population, social conflicts, aesthetic etc.), and factors such as institutional incapacity, and conflicting and inadequate/inappropriate local and national policies are the identified causes of such effects (Fortes 1995).

The Philippines has about 824 species of marine macrobenthic algae consisting of 214 species of "green algae" (Chlorophyta), 134 species of "brown algae" (Phaeophyta) and 472 "red algae" (Rhodophyta) (Trono 1997). The country produces 70% of the world's supply of carageenan raw material, 95 000 t, annually (BFAR 1997; BAS 1998). Seaweeds rank third in export value next to tuna and shrimp, earning an estimated foreign exchange profit of US\$130 million annually (BAS 1998). About 500 000 people are directly or indirectly dependent on the seaweed industry (Dacay 1992). An estimated 10 000 ha of reefs and shallow coastal areas are utilized to

farm seaweed. As such, seaweed farming is now considered a major source of livelihood in many coastal communities.

There is growing recognition that the health of coastal ecosystems is intimately linked with the conditions of watersheds. As of September 1999, there were 1.38 million ha of proclaimed watershed forest reserves in the country. Among the country's 14 regions, central Luzon (Region III) has the most reserves with a combined area of 221 385.10 ha (DENR 1997).

Fisheries Resources Potential

Fisheries Production

From the fifties to the mid-seventies, the reported fisheries production consisted entirely of marine capture fisheries landings because production from aquaculture and inland capture fisheries only started entering the official statistics during the mid-1970s (Fig. 2). Starting from 250 000 t in 1951, fisheries production doubled after 15 years. By the early 1970s the million-t level had been reached. Thereafter, production was maintained at 1.2 million t for almost the entire decade of the 1970s. Modest but constant growth in production was registered thereafter, finally reaching a plateau of 1.6 million t in the 1990s.

Average growth rates for the entire fishery sector show that production peaks occurred during the decade of the sixties and to a lesser extent, the seventies (Fig. 3). This was fuelled by the large scale sector, from 1960 - 65, and the small scale sector, from 1966 - 70. After 1976, growth rates of the capture fishery sector registered minimal or even negative growth at certain times. This is particularly true for the small scale sector. The continued growth of the fisheries sector was due to aquaculture. Unlike typical industries that start low on the growth curve, aquaculture began with a "bang". For the first five years, aquaculture posted double-digit growth, i.e. 15% average for the first four years. In 1980, aquaculture accounted for almost 25% of total capture fishery production at 300 000 t, a yield that had doubled by 1990. By 1996, total aquaculture production had already eclipsed production from both the large scale and small scale fishery sectors.

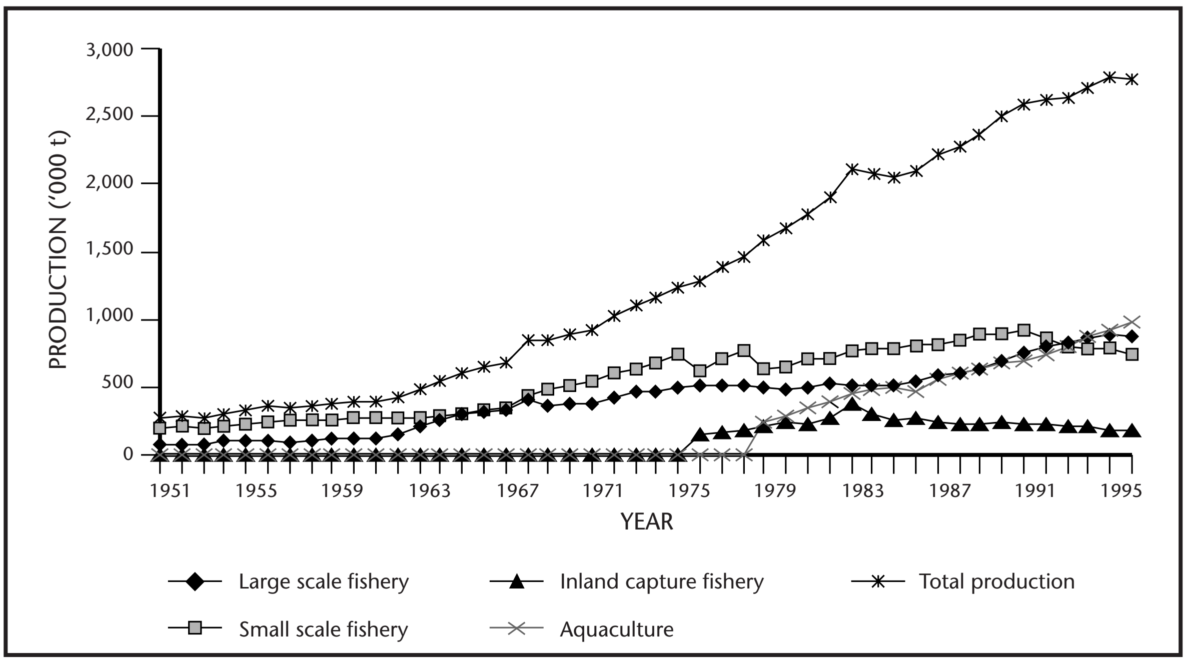

Fig. 2. Philippine fish production, from large scale and small scale marine fisheries, inland capture fisheries and aquaculture between 1951 - 96. Source: BFAR 1950 - 87; BAS 1998.

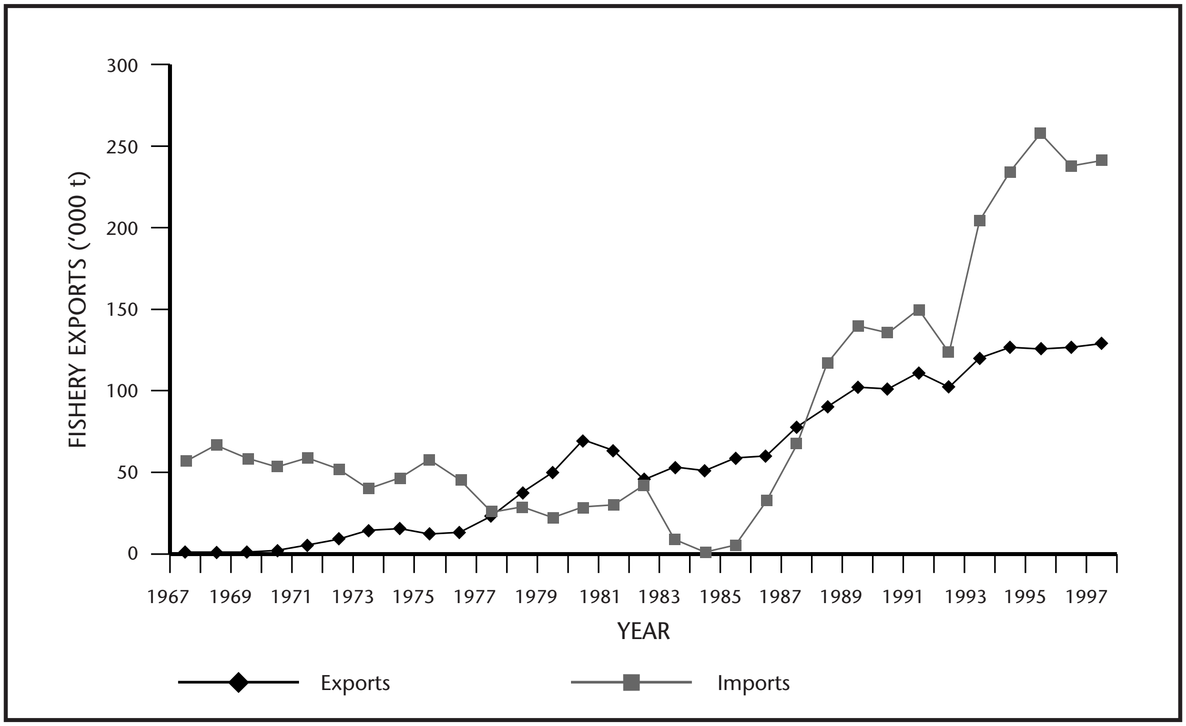

Fig. 3. Volume of Philippine fish exports and imports (1967 to 1997).

The small scale (equivalent to municipal) and the large scale (or commercial) capture fisheries sectors dominated the fishing industry in the fifties and sixties. During the early fifties, the small scale sector contributed the bulk of fisheries production, which was, on average, 150% greater than the commercial sector. Towards the seventies and well into the nineties, this ratio dropped to a little over 30%, indicating relative stagnation in the catch of the small scale sector and increased activity in the commercial sector. By the nineties, the advantage of the small scale sector would be completely overturned (see Fig. 2). Inland capture fisheries and aquaculture began to contribute to official production statistics during the seventies. This does not preclude the existence of undocumented but robust inland capture fisheries prior to this time, especially in freshwater lakes such as Laguna de Bay and Sampaloc Lake. Aquaculture started during the late seventies with fishpens and ponds.

Pelagic and Demersal Resources

The potential yield from the marine fishery resources particularly demersals and small and large pelagic species have been studied extensively (Munro 1986; Silvestre et al. 1986; Dalzell and Ganaden 1987). Estimates of maximum sustainable yield (MSY) from these resources vary widely between 1.1 and 3.7 million t. The higher estimates are based on overly optimistic values of yield-per-unit-area and do not consider productivity decline with depth (Silvestre et al. 1986). Since the 1980s, the consensus on the MSY values of the Philippines for conventional resources has been 1.65 million t, 600 thousand t for demersals, 800 thousand t for coastal pelagic species, and 250 thousand t of tunas or oceanic pelagics (BFAR 1995).

Dalzell et al. (1987) and Silvestre and Pauly (1987) estimated the MSY for exploited demersal resources (excluding offshore hard bottoms off Palawan, southern Sulu Sea area and the central part of the country's Pacific coast) to be around 340 000 to 390 000 t. Adding this figure to the estimated MSY of 200 000 t for unexploited or lightly fished hard bottom areas, results in a total MSY of about 600 000 t. This value is within the consensus mentioned above. However, studies have also indicated that demersal stocks are over-fished. The biomass

of fished stocks declined in the mid-1980s to about 30% of levels in the late 1940s, resulting in an annual rent dissipation of about US$130 million per year, due to over-fishing of demersal stocks (Silvestre et al. 1986)

Dalzell et al. (1987) estimated MSY for small pelagics at 550 000 t, the Maximum Economic Yield (MEY) for fish and invertebrates in the exploited fishing grounds at around 250 000 t and the Maximum Economic Rent (MER) for the latter at US$290 million. Subsequent refinements of this assessment have yielded similar results (Trinidad et al. 1993). The 550 000 t MSY for small pelagics when combined with the MSY estimates of 250 000 t for lightly fished small pelagic resources in waters off Palawan, parts of the country's Pacific coasts and some parts of Mindanao, is within the consensual earlier MSY estimate for small pelagics of 800 thousand t noted above.

Tuna are experiencing high fishing pressure mainly brought about by the magnitude of the catches and the concentration of fishing effort within a small surface area (Dalzell and Corpuz 1990; BFAR 1995). Oceanic large pelagics such as marlin, swordfish and sailfish are not fully exploited at present (Dalzell and Ganaden 1987). From a landing of 17 000 to 25 000 t in the 1980s, the large pelagic landings declined to 9 000 to 15 000 t in the 1990s (BFAR 1997).

Invertebrates

Invertebrate resources also constitute an important source of food and livelihood for Filipinos. Species of prawns and shrimps (e.g. tiger prawn) are cultured and exported, while crabs, octopus, squid and other shrimps are consumed locally. Species of shelled mollusks are processed for the export market.

Evidence of over-exploitation of wild stocks of shrimp/prawn resources has been observed since the late eighties and early nineties (Agasen, pers. com.). The five species considered commercially important are the white shrimp (*Penaeus merguensis*), the "green tiger prawn" (*P. semisulcatus*), giant tiger prawn (*P. monodon*), the brown shrimp (*Metapeneaus ensis*) and *Acetes* spp. The combined total production recorded for these species in 1997 was around 25 334 t mostly coming from small scale fisheries (BAS 1998). The shrimp/prawn production, including that from aquaculture, ranked second to tuna in terms of export earnings at around US$ 4.0 million in 1997 (BFAR 1997).

Other commercially important invertebrate resources include (i) squids and cuttlefishes, (ii) octopus and (iii) crabs. These resource groups contributed 56 958 t valued at Php 2.6 million, 7 991 t equivalent to Php 452 660 and 31 224 t or Php1.0 million, respectively, to the total landings in 1997 (BAS 1998). Oceanic squids and deep-sea shrimps occur in the waters of the country but there is no established fishery for these resources and, consequently, little information to assess potential.

Sharks and Rays

Except for the piked dogfish, *Squalus acanthus*, a species targeted for squalene oil, sharks were generally the by-catch of some major fisheries from the late-1960s to early-1980s (Barut and Zartiga 1999). Since the early 1980s shark meat has been used for producing fishballs, while the fins are dried and sold to local restaurants mainly for shark fin soup. Hong Kong is the leading importer of sharks' fins and meat while Japan is the primary importer of shark liver oil (Barut and Zartiga 1999). The average annual production from sharks for the past 20 years has been 5 882 t. In 1997 the municipal and commercial landings for this fishery were estimated at 3 485 t and 330 t respectively. The three most important shark-fishing grounds in the Philippines are in West Sulu Sea, Lamon Bay and Visayan Sea. Barut and Zartiga (1999) identified 22 species of sharks but believe that more species await discovery and description. Recently, sharks and rays have been receiving much attention because of their vulnerability and conservation status. The catching, taking, possession and exporting of whale shark (*Rhyncodon typus*) and manta ray (*Manta birostris*), for example, have been banned by virtue of Fisheries Administrative Order 193, series of 1998. Other sharks like the great white shark (*Carcharias carcharodon*) have been proposed recently for inclusion in the CITES endangered species list.

Endangered Marine Species

Marine mammals are among the endangered species in the country. To date, 15% of Philippine waters have been surveyed for marine mammals and 25 species have been documented so far (Dolar et al. 1997). Despite the issuance of Fisheries Administrative Orders 185 and 185-1 that ban the catching of marine mammals, incidental and intentional catches for local consumption and for shark bait are still reported. However, such reports have declined after the passage of the said fisheries administrative orders. A concerted effort to increase

public awareness by government, NGOs and the private sector has also considerably minimized threats to these animals (Heany et al. 1998, Dolar 1997 and Dolar 1999).

Marine turtle exploitation was also been banned by virtue of Ministry of Natural Resources (MNR) Administrative Order No. 12, Series of 1979. Five turtle species are known to occur in Philippine waters. Vigorous efforts have been undertaken to protect and conserve these vulnerable and threatened species mainly by the DENR's Task Force Pawikan created by Executive Order No. 542, Series of 1979.

Socieconomic Background

The fisheries sector employed close to one million (990 872) fishers in 1997. Employment in the sector is divided into: aquaculture with 258 480 employees, municipal fisheries with 675 677 and commercial fisheries with 56 715 employees. This employment level is slightly above the 1988 level i.e. about 942 000. Assuming that a typical Filipino family is composed of five to six people, then roughly 5 to 6 million people are directly dependent on the sector. This is equivalent to 7.4% - 8.8% of the country's total population for 1997. Moreover, the sector indirectly provides employment to those engaged in fish distribution and marketing, fish processing (e.g. canning), operation of ice plants and cold storages, and other related industries such as net making, boat building, boat engine or motor sales, and boat repairs among others. The income, employment and other socioeconomic indicators of the fisheries sector may be viewed against similar indicators for the national context, which are presented in Table 1.

For the period 1984 - 1997, the fishery sector contributed 3.8 - 5% of the country's gross domestic product (GDP). From 4.8% of the GDP in 1984, the contribution of fisheries to the GDP peaked at 5.01% in 1987, fluctuated within a 0.5% range until 1996, and then declined to 3.8% in 1997. These figures are based on data from the National Statistics Office (NSO) that utilize 1985 as the base year. In terms of percent share of the gross value-added for the agriculture, fishery and forestry industries/sectors, the fisheries' contribution ranged between 18.4% to 20.6% for the period 1984 to 1997.

Since 1977, foreign trade of fishery products has generated a surplus balance of trade, which means more export earnings or foreign exchange to the economy than importation expenses (Fig. 3). The trade surplus in export and imports of fishery products ranged between US$19.4 million in 1977 to US$439 million in 1987. However, the latter figure declined to US$271.8 million in 1997.

In 1993, the biggest source of foreign exchange earnings among exported fish products was shrimp and prawns, followed by tuna and tuna-like fish, and seaweeds (*Eucheuma* spp.) (BFAR 1997; BAS 1998). In 1997, tuna and tuna-like fish had overtaken shrimp and prawns. In terms of volume, the Philippines shifted from being a net importer of fishery products in 1967 - 77 to being a net exporter in 1978 - 87. For the period 1988 - 97, the country again became a net importer, with imports consisting mainly of fresh/frozen and chilled fish and fishmeal (Cruz-Trinidad, this vol.). These imports were probably the needed inputs for local fish canning facilities and local poultry and livestock feed producers.

The fourth national nutrition survey conducted by the Department of Science and Technology in 1993 revealed that the average Filipino consumes 36 kg of fish per year or 99 grams per day (CRMP-FRMP-ATI 1998; Cruz-Trinidada this vol.). Fish accounts for 18.3% of the total food intake and 66.7% of the animal protein intake. Fish is generally affordable and widely available, particularly in processed form such as canned, smoked and dried. There is a lack of information on nationwide demand and supply of fish. However, estimates can be made to determine if the present fish production is sufficient to meet local demand. With an estimated population of 74.7 million in 1999 and a per capita consumption of 36 kg per year, the total demand for fish can be estimated at 2 689 200 t, which was slightly below the total production of 2 766 507 t in the same year.

In terms of meeting the fish protein supply needs, considering population and fish production, there are some regions which can be considered as surplus regions while the others can be considered deficit regions. In 1997, Region IV (Southern Tagalog), the Autonomous Region of Muslim Mindanao, Region IX (Western Mindanao), and Region VI (Western Visayas) were the top fish producers (BAS 1998). The Cordillera Autonomous

Region, Region II (Cagayan Valley), Region XII (Central Mindanao), and Region X (Northern Mindanao) were the lowest producers. Differences are compensated for by a marketing network that distributes fish from fish-surplus to fish-deficit regions.

Table 1. Philippine Socio-Economic Indicators, 1999

Indicator	Value
Population, mid-year	75.1 million
Population growth rate (%)	2.04
Urban population (% of total population)	57
Labor force	32.0 million
Employment - by sector to total employment (%) Agriculture Government and Social Services Services Manufacturing Construction	 40.1 19.5 44.2 9.5 5.3
Unemployment rate (%)	9.7
Inflation rate (consumer prices)	6.6
Industrial Production Growth rate (%)	0.5
External Debt	$51.2 billion
Gross Domestic Product (GDP)-real growth rate (%)	3.2
Gross Domestic Product - composition by sector (%) Agriculture Industry Services	 17 32 51
Gross National Product	$80.3 billion
Gross National Product (GNP) per capita	$1 050
Poverty (% below national poverty line)	38
Infant mortality rate	35 deaths/1 000 live births
Life expectancy at birth	68 years
Child malnutrition (% of children below 5)	30
Access to safe water (% of population)	83
Illiteracy (% of population age 15+)	5

Source: World Bank 2000.

The value of total fish output has increased through the years except for 1997 when declines in volume and value occurred (Fig. 3). However, the value of catch for the municipal fisheries continued increasing, despite the decline in volume of catches for the periods 1983 - 88 and 1991 - 97 (Cruz-Trinidad this vol.). For aquaculture, total value of fish output has declined since 1994 despite the increase in volume of production (BAS 1998). This can be attributed to declining prices of aquaculture products, particularly prawn and shrimp.

Aquaculture production has been included in official statistics since the mid-1970s. The volume of aquaculture production has been rising ever since, except for 1997 when output slightly declined. Indeed, aquaculture has offset the declines in the municipal catches since 1983 such that total fish production has increased. Since 1984, fish production from aquaculture has registered volumes close to the output of the commercial sub-sector. Aquaculture output overtook commercial fishery production in 1994, and began to exceed municipal output in 1996 (see Fig. 2). A closer look at the aquaculture statistics however, indicates that at least two-thirds of the sector's output comes from seaweed production. Furthermore, several lakes, rivers and swamp-lands can still accommodate aquaculture production at sustainable levels.

In terms of value of total fish output, statistics show an increasing trend through the years except for 1997 when decline occurred, which accompanied the decreased volume (see Fig. 2 and 3). For the municipal fisheries, the value of the catch increased steadily despite the decline in catches for the periods 1983 - 88 and 1991- 97. For aquaculture, total value of fish output has declined since 1994 despite increasing output, which is mainly due to the downward pressure on prices of aquaculture products, particularly prawn and shrimp

Characteristics of Fishers and Fishing Households

Based on the data gathered from the 12 priority bays studied under the Fisheries Sector Program (PRIMEX 1996), the socioeconomic characteristics of small scale fisher folks are given in Table 2.

In contrast to the small scale fisheries sector, there is a dearth of information on the socioeconomics of the commercial sector. This may be attributed to the fact that this sector accounts for a small portion of the total fishing labor force, i.e. a mere 5.72% (or 56 715 of 990 872) for 1997. In addition, many studies have focused on the small scale fishers, usually with the end in view of alleviating their poverty (see Smith et al. 1980, Smith et al. 1983, Panayotou 1982, Librero et al. 1985).

Among the few socioeconomic studies on the commercial sector is the bioeconomic analysis of the

Table 2. The socioeconomic characteristics of small scale fishers in the Philippines.

Characteristic	Value
Average household age	41 years
Average household size	5.1 members
Educational attainment	4 - 6 years of schooling
Average annual household income	Php25 426 (1992)
House owners	82 %, however only 40% owned their lots
Housing type	Nipa and bamboo for 41.1% and nipa and wood for 34 %
Fishing boat owners	Most fishers owned a boat but only 27 % were motorized
Members of community organizations	25 % of households
Availed of loans	20 %, of which 83 % came from informal sources
Main fishing gear	hook and line, gillnet, and beach seine

Philippine small pelagic fishery by Trinidad et al (1993). Twenty-two commercial vessels were monitored in Regions IV, VII, IX and NCR for the period March - April 1988. The average manpower or crew size per boat across six gear types was 23.9, with purse-seiners having the biggest crew size of 67, while encircling gillnetters had the smallest at eight. The average number of trips undertaken during this period was 6.8 trips for all types of gear, with an average duration of 115.1 hours or 4.8 days. The duration of fishing trips was longest among purse-seiners at 456 hours or 19 days and shortest for beach-seiners at seven hours per trip.

The crews of trawlers and purse seiners were given a fixed salary while crews of bag-netters, ring-netters, beach seiners and encircling gill netters were each given a fixed minimum plus a share of the catch (Trinidad et al. 1993). The frequency of payment varied from per trip, weekly, monthly to a combination of these. The pure profit of labor (percent share of crew plus fish consumed, salaries, share of catch and food) amounted to an average of Php 86 307 per monitored vessel assuming a zero opportunity cost of labor. This is equivalent to Php3 611.17 per crew member (laborer) for the average of 32.6 days of fishing operation, i.e. without distinguishing the difference in crew members' skill and pay. This is much larger than the average profit of municipal gear at Php2 886 per boat, which is equivalent to Php303.79 per crew member for an average of 6.2 days of fishing. If converted to a 32.6-day period, this amounts to Php1 591.47, which is less than half of what a commercial crew member could earn over the same period.

The average non-fishing days for commercial fishing vessels amounted to 8.8, with the trawler having an average of 24.6 non-fishing days in a year. The commercial vessels' average was almost double the municipal (small scale) boats' non-fishing days at 4.8 days. This implies more rest days or opportunity for non-fishing productive activities. Although the study covered few boats, we can infer that the commercial fishery labor force is much better off than the labor force in the municipal fishery.

Institutional Background

Table 3 gives a summary of the highlights of fisheries policies in Philippines for the past 50 years. The degree of pressure or exploitation of any fish stock or fishery is largely influenced by institutional factors, such as organizations, established customs or practices, regulations (both formal and informal), and social arrangements. The interaction of these factors with the fishery determines the sustainability of the fishery resources.

Prior to the introduction of centralized fisheries management by the Spanish and American colonizers, the resource utilization and property rights were based on common property principles within a village, and managed by those who belonged to the village (or *barangay*). Pomeroy and Carlos (1997) noted that the Philippines has a long history of indigenous fisheries and resource management systems where the village had jurisdiction over natural resource use and access.

The arrival of the Spaniards meant the establishment of a centralized system of government, including a state-led, centralized system for managing fisheries (Pomeroy and Carlos 1997). This ushered in the decline of common property management and open access to use of resources. Later, American colonizers continued the centralized scheme as well as the thrust of maximizing revenues from the colony. In fisheries, this translated to a development thrust with progressively increasing fishing effort and resource utilization. Several fish companies embarked on large scale (or commercial) fishing, while poor coastal communities were encouraged to intensively exploit their adjacent fisheries resource. The pattern of centralized governance prevailed through the fifties and sixties (Pomeroy and Carlos 1997).

During the 1970s, the expansion, use and development orientation of the country's fisheries policy continued under Presidential Decree 704, which is widely known as the Fisheries Decree of 1975. In particular, the Expanded Fish Production Program implemented the development thrust of the Fisheries Decrees of 1975. However, the effects of a virtually open-access regime began to manifest in declining catches, rent dissipation and increasing poverty among small scale fishers. Thus, during the 1980s fisheries policy gradually shifted towards management. Also, initiatives for decentralized management were started. Although the Fisheries Decree of 1975 granted overall control over management and regulation of fisheries to the then Secretary of Agriculture and Natural Resources, the Decree recognized that small scale or municipal fishing was within the purview of municipalities. The latter had

the authority to issue licenses and grant fishing rights to small scale fishers (which can operate within 7 km from shore). From the mid-1980s, the policy environment for fisheries was generally characterized by the following:

a. a shift in governance from centralized to localized;
b. a shift from open access to limited access, and;
c. a shift from development focus to management.

Table 3. Fisheries policy highlights in the last 50 years.

Year	Milestone
2000	The DENR and DA sign the Joint Memorandum Order on the implementation of the Fisheries Code.
1999	Philippines is signatory to the implementation of the Rome Declaration on the Code of Conduct for Responsible Fisheries. Pres. Proclamation No. 57 declares the yearly celebration of May as Month of the Ocean.
1998	RA 8550 (Fisheries Code) establishes coastal resource management as the approach for managing coastal and marine resources.
1997	RA 8435 (AFMA) recognizes the importance of fisheries to food security and provides for Integrated Coastal Management Training.
1996	Memorandum Order 399 directs operationalization of Philippine Agenda 21.
1995	EO 241 creates Fisheries and Aquatic Resources Management Councils (FARMCs).
1994	DA-DILG MOA 1994 devolves some regulatory functions pertaining to fishing regulations to LGUs. The Philippines becomes a signatory to the Law of the Sea.
1991	RA 7160 (LGC) devolves primary mandate for managing municipal waters to LGU.
1990	The Presidential Commission on Illegal Fishing and Marine Conservation coordinates all government and non-government efforts in the planning and implementation of a national program for the conservation of marine and coastal resources.
1987	DA abrogates and subsumes BFAR's administration, regulatory, and enforcement functions. The DENR and BFAR are given mandates for fisheries development.
1986	Ban on operations of commercial trawl and purse seine in marine waters within 7 km from shoreline of all provinces in the Philippines. *Muro-ami* and *kayakas* are prohibited from operating in Philippine waters.
1985	Distant water fishing fleets are encouraged
1984	Regulation on gathering, catching, taking, or removing of marine tropical aquarium fish.
1981	The Philippines becomes a signatory to CITES.
1979	A Coastal Zone Management Committee composed of 22 government agencies is formed.
1977	Assignment of the Secretary of the National Resources to train *barangay* officials as deputy fish wardens or deputy forest wardens.
1976	Commercial and other fishing gear operating within a distance of 7 km from the shoreline may be banned by the President of the Philippines upon the recommendation of the Secretary of Natural Resources.
1975	PD 705 declares mangrove forests under DENR jurisdiction but areas released for fishponds under BFAR. PD 704 (Fisheries Decree of 1975) develops rules and regulations on the fishing industry, upholds provisions of the Fisheries Act of 1932.
1972	PD No. 43, Fishery industry development decree of 1972, providing for the accelerated development of the fishing industry of the Philippines; fishing industry considered as a Board of Investments pioneer project.
1963	RA 3512 created the Philippine Fisheries Commission under the Department of Agriculture and Natural Resources.
1950	RA 428, as amended, declared as illegal the possession, sale or distribution of stupefied and/or disabled fish and aquatic animals.
1932	Act. No. 4003, Fisheries Act, Provided for the Secretary of Agriculture and Natural Resources to issue rules, regulations and instructions consistent with the law. All ordinances of fishing should be approved by Department Secretary.

Source: DENR, DILG, DA-BFAR and CRMP 1997.

Laws and Policy Instruments

The Local Government Code (LGC) of 1991 firmly established the jurisdiction of municipalities over small scale fishing. The "Legal and Jurisdictional Guidebook for Coastal Resource Management in the Philippines" (DENR, DILG, DA-BFAR and CRMP 1997) lists the responsibilities of local governments in the implementation of fisheries and coastal management. Though causing much confusion, the LGC expanded the coverage of municipal waters from 7 km from the shoreline under Presidential Decree 704 to 15 km from the shoreline. The impact of the expansion was twofold: (a) it limited access to commercial fishers and (b) it highlighted the need for a more equitable distribution of benefits to the marginalized municipal sector. Issues pertaining to economic efficiency and food security, especially of urban consumers, have been affected by such policy bias. The policy prescription of the LGC came at a time when catches from marine fisheries, both from the commercial and municipal sector, were on a continuous decline. Given this scenario, a possible intent of the LGC was to limit access to both the municipal and commercial sectors, especially of the nearshore municipal waters.

The Philippine Fisheries Code of 1998 (or RA 8550) seeks to address widespread coastal poverty and resource degradation, along with other fisheries problems and concerns. At the core of this law is the country's fisheries policy which is aimed at: attaining food security, conservation, protection and sustained management of the country's fishery and aquatic resources; alleviating poverty and the provision of supplementary livelihood among municipal fishermen; improvement of aquaculture productivity within ecological limits; optimal utilization of offshore and deep-sea resources; and upgrading of post-harvest technology. The Fisheries Code reinforces provisions in the LGC that are aimed at strengthening local governance of municipal fisheries. Furthermore, the Fisheries Code seeks to institutionalize community participation through the creation of Fisheries and Agriculture Management Councils (FARMCs) at the village (*barangay*), municipal, regional and national levels.

Compared to the LGC, access limitations are more straightforward in the Fisheries Code with such mechanisms as: (1) registry of municipal fisherfolk; (2) exclusion of non-resident fishers in certain municipal waters with the attendant coding of vessels; (3) mapping and delineation of municipal waters; (4) traditional limitations such as closed areas and seasons; and (5) non-traditional access limitations such as use of economic rent indicators to set production targets for the fishery. These access limitation strategies indicate a progressive shift in policy from full development to management.

In addition to the Local Government Code, the Fisheries Code and the Implementing Rules and Regulations of the Fisheries Code, fisheries are also governed by various fisheries administrative orders issued by the Bureau of Fisheries and Aquatic Resources. Among the latter are administrative orders for the protection of rare, threatened and endangered species, including dolphins, whale sharks, and whales and porpoises. The Agriculture and Fisheries Modernization Act (or RA 8435) also defines policies on fisheries management and development.

International Agreements

The Philippines is signatory to a number of international and regional conventions that have major implications on the conservation and management of the fisheries and aquatic resources. Table 4 presents a partial list of such conventions.

Table 4. Key international conventions that influence Philippine fisheries policy.

Convention	Date signed	Date ratified
UN Convention on the Law of the Sea (UNCLOS), Montego Bay, 10 December 1982	10 December 1982	08 May 1984
Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, London 19 December 1972	29 December 1972	
Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), Washington, 03 March 1973	03 March 1973	18 August 1981
Convention on the Conservation of Migratory Species of Wild Animals (CMS), Bonn, 23 June 1979	20 June 1980	
Convention on Biological Diversity (CBD), Rio de Janeiro, 05 June 1992	12 June 1992	October 8 1993

Structure and Mandate of National Fisheries Institutions

The Fisheries Decree of 1975 established the Bureau of Fisheries and Aquatic Resources (BFAR) under the Department of Agriculture. Essentially, the BFAR was created by renaming the Philippine Fisheries Commission and expanding its functions. The BFAR has the responsibility to formulate, administer and implement fisheries policies.

In 1986, BFAR was changed to a Staff Bureau but was reconstituted to a line agency by virtue of the passage of the Philippine Fisheries Code of 1998. Under this Act, BFAR shall, among others, prepare and implement a Comprehensive National Fisheries Industry Development Plan, establish and maintain a Comprehensive Fishery Information System and formulate and enforce rules and regulations governing the conservation and management of fishery resources. However, BFAR is heavily constrained by a limited budget and facilities that do not match the huge areas it is supposed to manage. The constraints have resulted in the inability to effectively oversee the nation's fisheries utilization, including the enforcement of fisheries laws and the compilation of data for "Philippines Fisheries Statistics".

The Fisheries Code of 1998 also called for the establishment of the National Fisheries Research and Development Institute (NFRDI) to function as the primary research arm of the BFAR and the main Department of Agriculture (DA) unit for the conduct and coordination of fishery research and development in the country. Recently, the DA organized the NFRDI's Governing Board and appointed the current BFAR Director as the interim head of the NFRDI, pending the approval of staff positions for the institute by the Department of Budget and Management. The Philippine Fisheries Development Authority (PFDA) is the principal agency tasked to develop, build and maintain fishing ports in the country.

The Department of Environment and Natural Resources impacts fisheries management through its implementation of the National Integrated and Protected Areas System Act (RA 7586) and various policies and programs to protect critical coastal habitats (e.g. mangroves and coral reefs) and threatened or endangered species (e.g. dugongs).

Annex 1 provides a list of other national and subnational institutions that also play a role in the development, management and conservation of the fisheries resources and the coastal zone.

Coastal Fisheries in Focus

Philippine fisheries are legally categorized into municipal and commercial fisheries sectors. Municipal fisheries involve the use of motorized and non-motorized fishing boats of three gross tons (GT) or lower, as well as fishing without the use of vessels. The literature uses the terminology "small scale", "artisanal", and "traditional" fishing interchangeably with municipal fishing. Commercial fisheries utilize fishing vessels of more than 3 GT and operate legally in fishing areas more than 15 km from the shoreline.

Characteristics of the Fleet, Catch Rates and Species

The total number of vessels in the municipal sector was estimated at 20 000 in 1948 of which 83% were non-motorized (Dalzell et al. 1987). After 40 years, the number of vessels grew to 500 000 units with a substantial reduction in the ratio of non-motorized to motorized vessels. An appraisal of the Fisheries Sector Project (FSP) noted that as of 1989, more than 60% of the fisher-participants in the Rapid Social Assessments were using non-motorized vessels (PRIMEX 1996).

Development studies suggest that municipal fishers eventually "graduate" and become commercial in nature through motorization and improvement of gear (PRIMEX 1996). Although significantly more efficient in catching fish, such fishers retain their municipal status by operating motorized boats below 3 GT. A good example would be the baby (or small) trawlers in San Miguel Bay. While these are classified as municipal by virtue of tonnage, their operations are on a par with commercial counterparts, putting to great disadvantage the non-motorized fishers (PRIMEX 1996).

Dalzell et al. (1987) reported the number of fishers (both full-time and occasional fishers) to have increased from 63 000 in 1948 to 330 000 fishers in 1980, an average increase of 20% per year. Time series analysis of catch and effort data for the municipal fisheries between 1955 to 1985 (Dalzell et al. 1987) indicated a declining trend in catch per unit of effort (CPUE) (see Fig. 4). Catch refers to total catch of small pelagic species while horsepower (hp) used by motorized vessels represents effort; labor is also converted into its hp equivalent.

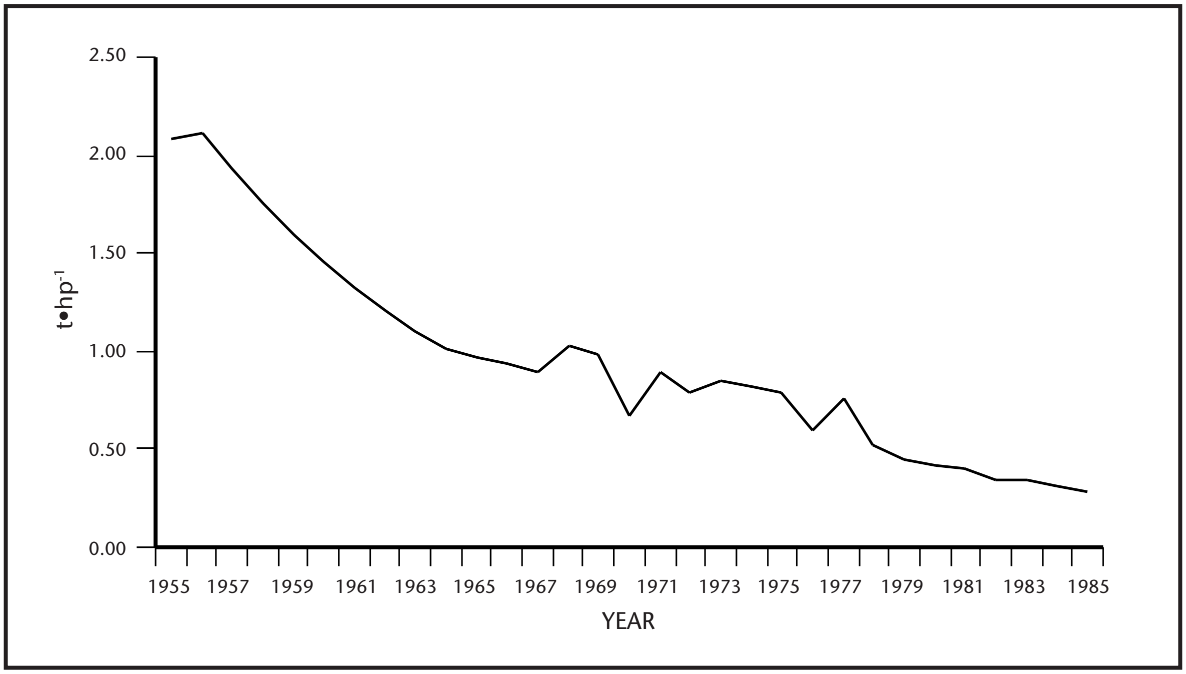

Fig. 4. Catch per unit of effort (CPUE) for small pelagic fishery in the municipal sector. (1955 to 1985).

Coral reef areas contribute up to 23% of the total municipal catch (Munro 1986). Gear used in small scale reef fisheries includes traps, hook and line, drive-in nets, gillnets and makeshift spear guns. Municipal fishers target small pelagic stocks such as anchovies and tuna. Times series data from 1976 - 1987 shows some generalizations concerning gear type and species composition of municipal fisheries (Trinidad this vol.):

- Small pelagics accounted for 38% of catches followed by demersals at 26%; tuna, 16%; seaweeds, 14%; large pelagics, 6%; and invertebrates, 9%;
- The most important gear in terms of contribution to total catch are gillnets, 30%; hook and line, 24% and beach seine, 8%;
- Hook and line accounts for almost 60% of tuna catch by the municipal sector;
- Hook and line, gillnets and fish corrals account for 60% of demersal catch in the municipal sector.

Tuna fishing started during the 1960s. By 1968, an organization of 500 fishers from Negros Occidental had been contracted for deep-sea tuna fishing in the Sulu Sea (Thomas 1999). The municipal fishery was invigorated during the eighties because of the strong demand for sashimi-grade tuna. Municipal fishers from General Santos City cashed in on this boom, which propelled their economic fortunes.

The development of the large scale (or commercial) fisheries during the last four decades has been characterized by increasing tonnage and horsepower of vessels and changes in dominance of certain gear types (see Trinidad this vol.). The commercial sector experienced slow development during the 1980s with minimal expansion and declines to modest catch rates. Vessels with engine displacement of 300 hp and greater became a significant force. Meanwhile, vessels that utilized engines with 50 hp and less were reduced to roughly 1% before the decade ended. Bag-nets and trawls decreased in number while purse seines increased. Today, bagnets and trawls still are dominant gear but their use is decreasing. During the seventies, the contribution of vessels from 3 GT to 5 GT diminished, these were replaced by those ranging from 5 GT to 10 GT. The progressive dominance of larger tonnage vessels became more distinct towards the eighties with vessels of 100 GT and greater accounting for 10%. Of these, half were in the 450 GT category. A detailed analysis on the profitability of the various fishing gear in the commercial sector is described in Trinidad (this vol.). Commercial fishing estab-

lishments in 1992 realized net profits of Php524 million.

The species composition of commercial fisheries production is described in Trinidad (this vol.). There are thirty-five (35) species comprising 70 - 95% of total commercial fisheries production, which are grouped into demersals, small pelagics and large pelagics. Small pelagics have dominated commercial catches since the fifties with roundscads (*Decapterus* spp.), locally known as "*galunggong*", being the single most important species in terms of volume. Slipmouths (Family Leiognathidae), a demersal fish of lesser value, is the second most important species caught. Big-eyed scad (*Selar crumenopthalmus*) featured prominently in 1965 but diminished towards the 1970s and were replaced by frigate tuna (*Auxis thazard*) in the 1980s and 1990s. Roundscads clearly dominated catches in 1965 but had diminished by the 1990s and were replaced by sardines. These changes in species composition may have been influenced by fishing patterns i.e. the use of particular gear types targeting specific species. The changes may also be a result of biological over-fishing problems as documented in some fishing areas (see Silvestre 1990; Silvestre et al. 1995)

Assessment of Exploitation Status

Available bioeconomic analyses of Philippine fisheries are based on surplus production models. Dalzell et al. (1987), Trinidad et al. (1993) and Padilla and de Guzman (1994) focused on small pelagics fisheries while Silvestre and Pauly (1987) investigated demersal fisheries. Dalzell et al. (1987) analyzed published BFAR statistics from 1948 - 85 to investigate the municipal and commercial fisheries targeting of small pelagics. The authors concluded that Maximum Sustainable Yield (MSY) was reached in 1975 while Maximum Economic Yield (MEY) was reached in 1970 at 500 000 t. At the time of writing, the reduction in effort required to attain MSY was estimated at 35%. They also estimated that about US$125 million per year of economic losses via rent dissipation was due to excess fishing effort (Silvestre and Pauly 1987).

Trinidad et al. (1993) studied cost and revenue components, technical efficiencies and pure profits of commercial and municipal gear exploiting small pelagics in Navotas Fish Port; Dalahican, Lucena City; Mercedes, Camarines Norte; Banago Wharf, Bacolod City; Guinhalaran, Silay City; Danao City, Cebu; and, Cawa-cawa Blvd and Labuan, Zamboanga. These areas are known top-producers of small pelagics. Their study confirmed the earlier findings of Dalzell et al. (1987) that the small pelagics fishery was truly over-fished but concluded that open-access equilibrium was reached during the eighties. This meant that on average, pure profits accruing to labor and capital were either zero or negative. A twenty percent (20%) reduction in fishing effort was recommended to attain MSY levels.

Padilla and de Guzman (1994) focused on developing a method for environmental resource accounting in fisheries. Their study utilized the same techniques as in the above-mentioned studies and resulted in similar observations; that the small pelagics fishery was over-fished and that at the time of writing, society was losing about P7 billion by not operating at MEY levels.

Silvestre and Pauly (1987) used trawler horsepower as a measure of fishing effort given that trawl is the major gear for catching demersal species. Their study concluded that the demersal fishery was already over-fished during the seventies. Fig. 5 illustrates the trend of decline in demersal species abundance in Philippine shelf waters during 1947 to 1995. The index of demersal abundance (stock density in $t \cdot km^{-2}$) was computed using the swept area method from various trawl surveys conducted in the Philippines. Data for 1947 to 1980 are from Silvestre et al. (1986), while data for 1981 to 1995 are consolidated from more recent surveys in selected fishing grounds, i.e. Lingayen Gulf (Silvestre et al. 1991), Ragay Gulf and Burias Pass (Federizon 1993), Manila Bay (Armada 1994), San Miguel Bay (Cinco et al. 1995), San Pedro Bay (Armada 1994), and Tayabas Bay (Resource Combines 1997). The data are based on arithmetic means as much of the original data are available for log-transformation and recomputation of geometric means. The stock density estimates also incorporate "learning effects" as given by Silvestre et al. (1986). Despite the paucity of surveys, Fig. 5 clearly illustrates the substantial decline in demersal abundance in the country's shelf waters. Fig. 6 gives the grouping of the data into the country's western, central and eastern shelf waters. Similarly, it illustrates the substantive trend of decline in demersal abundance, but more importantly it shows that the decline is widespread over the country's shelf waters (see also Table 5).

The tremendous decline in demersal biomass is supported by the results of length-based assess-

ments to examine the relative exploitation status of the fishery resources. Fig. 7 shows the mean exploitation ratios (E=F/Z) derived from these assessments, i.e. 0.58. The mean E values are way above the "optimum" values of 0.3 - 0.5 suggested by conventional fisheries theory and imply very heavy fishing pressure from the mix of gear used. In addition, the E value confirms heavy fishing pressure of the fishery resources in the study areas and is consistent with the declines in demersal biomass as previously discussed. A detailed summary of the growth and mortality parameters of various species is given in Appendix III to this volume.

Species composition changes are also observed due to over-fishing. Silvestre et al. (1995) suggested that trends in the species composition changes from trawl surveys in San Miguel Bay for example are reflective of growth, recruitment and ecosystem over-fishing (see Table 6): (1) disappearance or greatly reduced numbers of sharks and rays (together with other large, long-lived species); (2) increased squid (Loliginidae) abundance; (3) increased abundance of shrimps in relation to fish biomass; and (4) increased abundance of cardinal fishes (Apogonidae) and puffer fishes (Tetraodontidae). Similar trends of recruitment and ecosystem over-fishing have been observed for multispecies resources elsewhere in the Philippines (see Silvestre 1990) and Southeast Asia (see Pauly et al. 1989). Moreover, trends in species composition changes from commercial fishery catches have also been noted by Cruz-Trinidad (this vol.). For example, roundscads (*Decapterus* spp.) dominated coastal pelagic fisheries catches since 1965 and have declined in abundance in the 1990s and now replaced by sardines (Clupeid species).

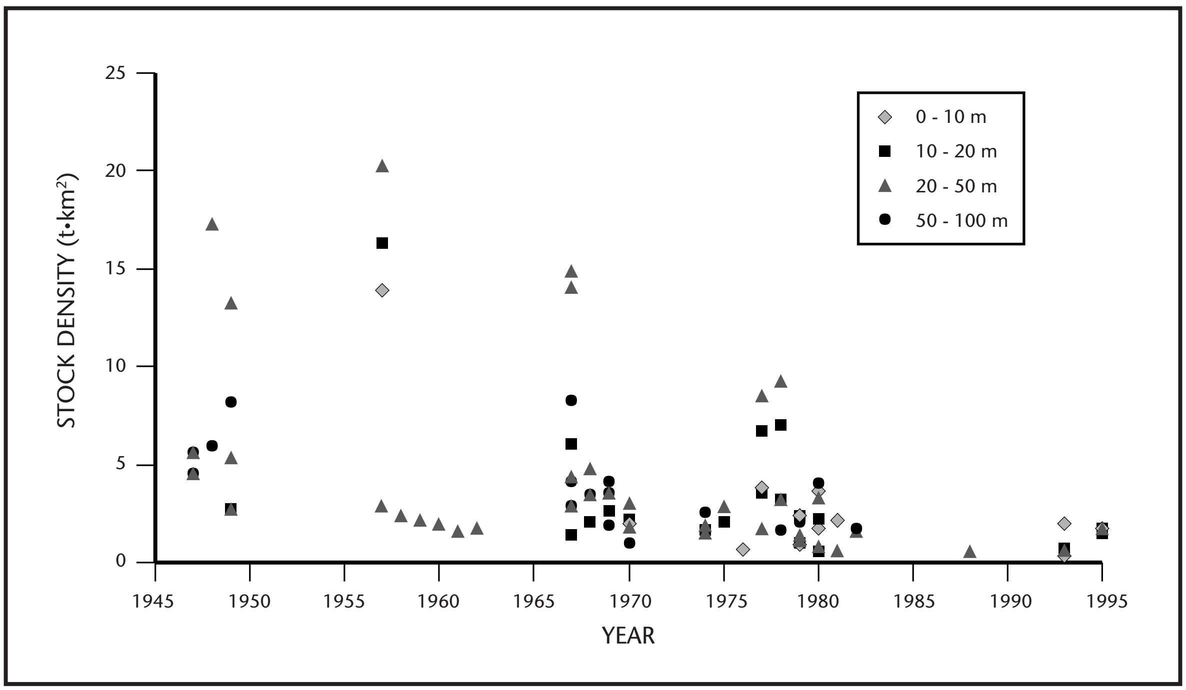

Fig. 5. Scatter diagram of demersal stock density ($t{\cdot}km^{-2}$) estimated from different trawl surveys conducted in the Philippines from 1947 to 1995. The Data for 1947 - 80 are from Silvestre et al. 1986 and data for 1981 - 95 are consolidated from recent trawl surveys.

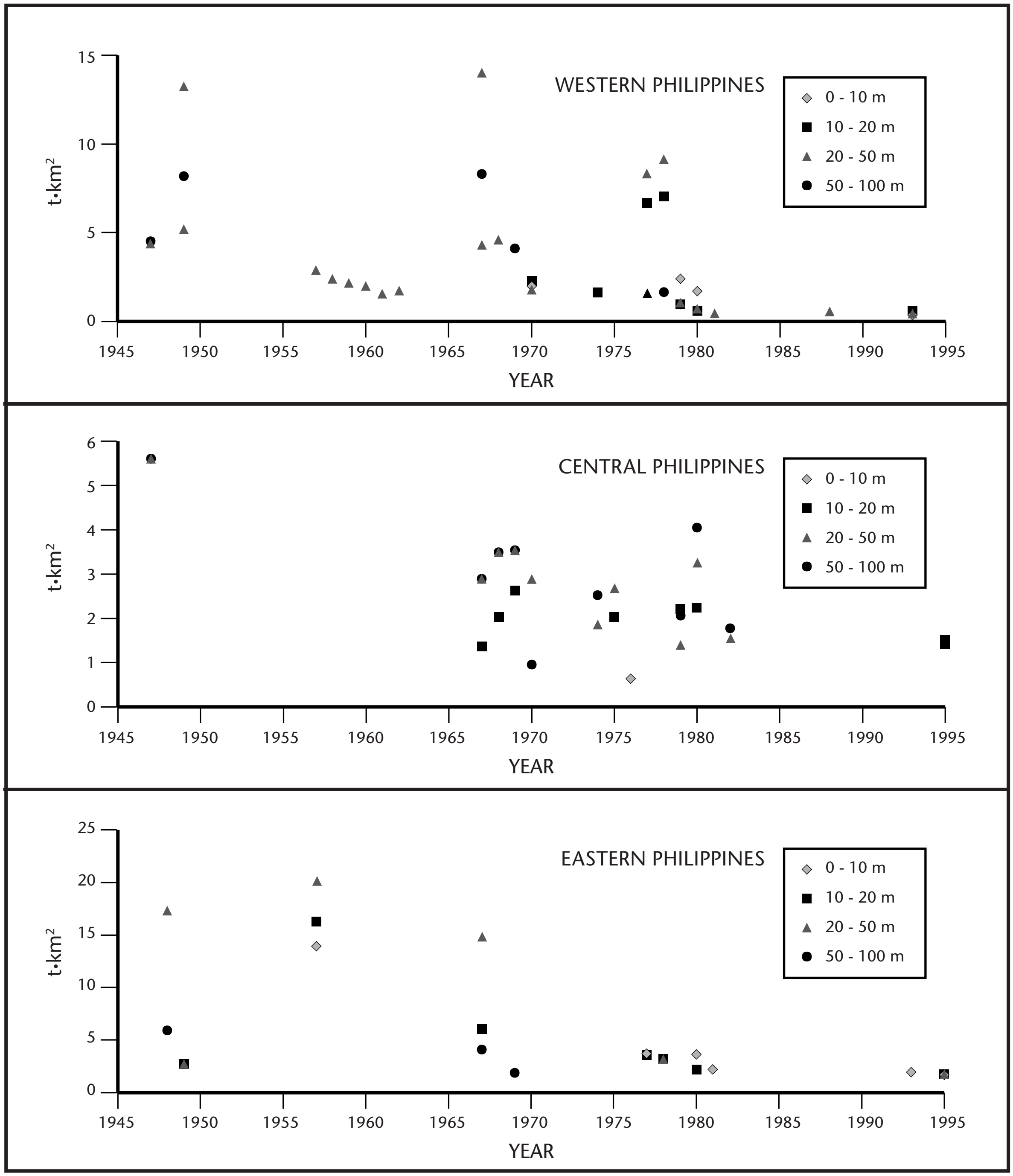

Fig. 6. Scatter diagram of demersal stock density (t•km^{-2}) estimated from different trawl surveys conducted in Western, Central and Eastern Philippines from 1947 to 1995. The data for 1947 - 80 are from Silvestre et al. 1986 and data for 1981 - 95 are consolidated from recent trawl surveys.

Table 5. Estimates of stock density and biomass in selected fishing areas in the Philippines.

Area	Year	Stock density ($t \cdot km^{-2}$)	Relative density (%)	Stock Biomass (t)	Source
San Miguel Bay	1947	10.60	100.0	8 900	Warfel and Manacop (1950)
	1980 - 81	2.13	20.1	1 790	Vakily (1982)
	1992 - 93	1.96	18.5	1 646	Cinco et al. (1995)
	1995 - 96	1.31	12.4	1 107	Soliman and Dioneda (1997)
Carigara Bay	1979 - 80	2.00	100.0	1 624	Armada and Silvestre (1981)
	1995 - 96	1.04	52.0	533	Pura et al. (1996)
Manila Bay	1949 - 52	4.61	100.0	8 240	Warfel and Manacop (1950)
	1992 - 93	0.47	10.2	840	MADECOR (1995)
Sorsogon Bay	1972	1.87	100.0	477	Ordoñez et al. (1972)
	1994 - 95	1.20	64.0	306	Cinco and Perez (1996)

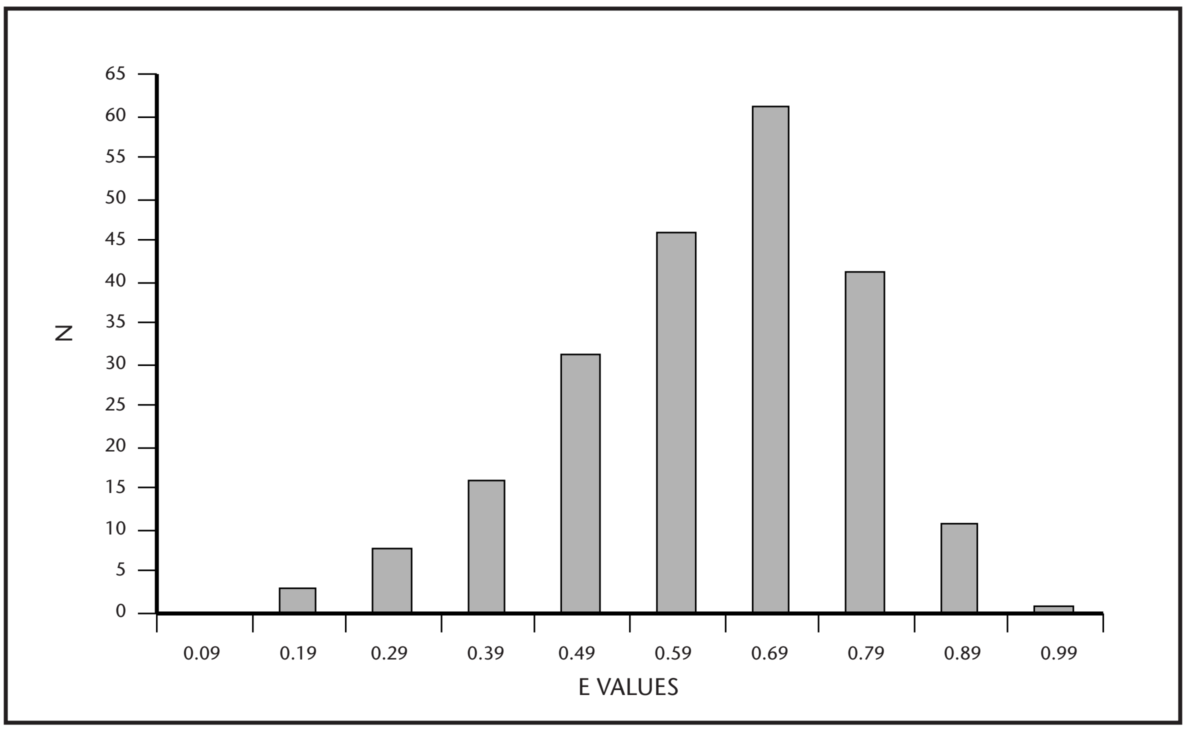

Fig. 7. Distribution of E values for 218 fish stocks in Philippines waters for which estimates are available. Note: Mean E value = 0.58; standard deviation = 0.153; N = 218. (Note: data from Appendix III, this vol.).

Table 6. Evident changes in relative abundance of various families/groups in trawl survey catches. (Adopted from Silvestre 1990).

Family/Group	Observed change in relative abundance	Probable cause
Cephalopoda	Relative increase	Reduced predation
Lactaridae	Disappearance	Recruitment over-fishing
Dasyatidae	Disappearance	Recruitment over-fishing
Balistidae	Relative increase	Species replacement
Lutjanidae	Relative decrease	Growth and recruitment over-fishing
Psettodidae	Relative increase	Growth and recruitment over-fishing
Penaeidae	Relative increase	Reduced predation
"Trash" fish		
Low value species (e.g. Apogonidae)	Relative increase	Reduced predation, species replacement
Juveniles of high value species	Relative increase	Growth over-fishing
Leiognathidae	Massive decrease	No straightforward explanation
Carangidae	Relative increase	Technological (higher trawl opening and trawl speed)

Management Issues and Opportunities

Fisheries Management Philosophy

The Republic Act 8550, otherwise known as the Philippine Fisheries Code of 1998, sets forth the rules and regulations for the development, management and conservation of the fisheries and aquatic resources of the country. The policy under this law constitutes seven basic principles/declarations, namely:

a. *to achieve food security as the overriding consideration in the utilization, management, development, conservation and protection of fishery resources in order to provide the food needs of the population. A flexible policy towards the attainment of food security shall be adopted in response to changes in demographic trends for fish, emerging trends in trade of fish and other aquatic products in domestic and international markets, and the law of supply and demand;*
b. *to limit access to the fishery and aquatic resources of the Philippines for the exclusive use and enjoyment of Filipino citizens;*
c. *to ensure the rational and sustainable development, management and conservation of the fishery and aquatic resources in Philippine waters including the Exclusive Economic Zone (EEZ) and in the adjacent high seas, consistent with the primordial objective of maintaining a sound ecological balance, protecting and enhancing the quality of the environment;*
d. *to protect the rights of fisherfolk, especially of the local communities with priority to municipal fisherfolk, in the preferential use of the municipal waters. Such preferential use, shall be based on, but not limited to, Maximum Sustainable Yield (MSY) or Total Allowable Catch (TAC) on the basis of resources and ecological conditions, and shall be consistent with our commitments under international treaties and agreements;*
e. *to provide support to the fishery sector, primarily to the municipal fisherfolk, including women and youth sectors, through appropriate technology and research, adequate financial, production, construction of post-harvest facilities, marketing assistance, and other services. The protection of municipal fisherfolk against foreign instruction shall extend to offshore fishing grounds. Fishworkers shall receive a just share for their labor in the utilization of marine and fishery resources;*

f. to manage fishery and aquatic resources, in a manner consistent with the concept of an integrated coastal area management in specific natural fishery management areas, appropriately supported by research, technical services and guidance provided by the State; and

g. to grant the private sector the privilege to utilize fishery resources under the basic concept that the grantee, licensee or permittee thereof shall not only be a privileged beneficiary of the State but also an active participant and partner of the Government in the sustainable development, management, conservation and protection of the fishery and aquatic resources of the country.

Fisheries Management Goals and Objectives

The Philippine Fisheries Code of 1998 or Republic Act 8550 sets forth five major objectives for the fishery sector namely:

a. Conservation, protection and sustained management of the country's fishery and aquatic resources;
b. Poverty alleviation and the provision of supplementary livelihood among municipal fisherfolk;
c. Improvement of productivity of aquaculture within ecological limits;
d. Optimal utilization of offshore and deep-sea resources; and
e. Upgrading of post-harvest technology

The objectives of fisheries management in the Philippines were reviewed in a national consultative workshop on 6 to 8 September 2000. This workshop was the culminating activity of the Philippine sub-component under the Sustainable Management of Coastal Fish Stocks in Asia Project (ADB-RETA 5766). Resource persons from the government, the academe and non-government organizations reviewed the outputs of national-level assessments of Philippine fisheries, including biophysical, socioeconomic and management/policy assessments. Workshop participants discussed resource management issues that surfaced from these assessments and raised additional issues for discussion. The participants then identified related issues and formulated fundamental objectives to address the issues. Fig. 8 presents the fundamental objectives of fisheries management in the Philippines as viewed by the workshop participants.

The fisheries management objectives in Fig. 8 are consistent with the spirit of the objectives of the Philippine Fisheries Code (or RA 8550). The difference in the presentation of these two sets of objectives stems from the effort of workshop participants to identify the ultimate ends or the fundamental objectives of fisheries management in the Philippines. In contrast, the Philippine Fisheries Code mixes fundamental objectives with "means objectives" (e.g. upgrading of post-harvest technology), which are not pursued as ultimate ends but are desired for their potential contribution towards achieving objectives that are more fundamental.

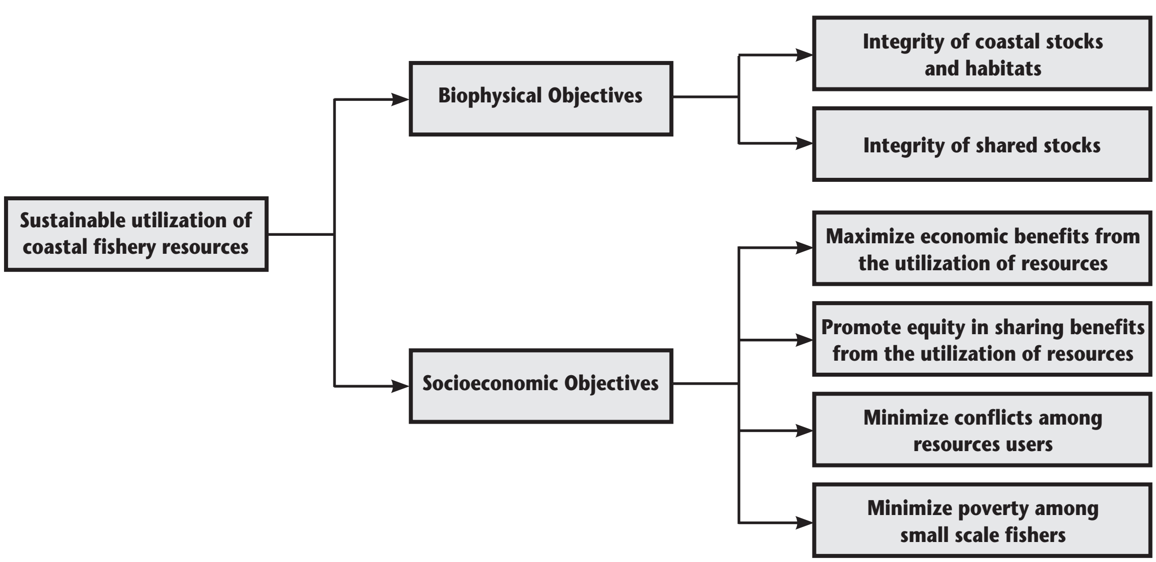

Fig. 8. The fundamental objectives of fisheries management in the Philippines, agreed on by the national consultative workshop.

Fisheries Sector Issues/opportunities/key Interventions

The Philippine Fisheries Code of 1998 sets the policy to sustainably manage the country's fisheries and aquatic resources as a means to contribute to poverty alleviation among the fisherfolk. It also takes into account the issues and concerns that hamper these objectives and as such, it sets forth the provisions that will hopefully address these concerns and ultimately attain the said objectives.

Fisheries sector issues were discussed and analyzed in a national workshop in September 2000. Table 7 lists the issues and corresponding causes, effects and suggested interventions that resulted from the workshop discussions. Opportunities in Philippine fisheries were also noted (Table 8). The following sections provide recommended follow-up actions that need to be undertaken to attain the management objective of sustainable utilization of coastal fisheries resources.

Recommendations for Immediate Government Action

a. Immediate promulgation of the Fisheries Administrative Orders under the Philippine Fisheries Code
b. Immediate implementation by BFAR of specific tasks under the Implementing Rules and Regulations of the Fisheries Code
c. Production of reliable, comprehensive and uptodate Fisheries Statistics
d. Evaluation of completed projects e.g. Fisheries Sector Program, as a basis for management interventions
e. Demarcation of Municipal and Commercial water boundaries by (National Mapping and Resource Information Authority) NAMRIA
f. Collect and publish fishery resource data of the EEZ using M/V DA-BFAR

Table 7. Fisheries Management Issues and Key Interventions.

Issues	Causes	Effects	Interventions
Over-fishing	Increased fishing effort	Habitat degradation Resource depletion	Resource enhancement Effort reduction Strengthen licensing system
	Open access		Limited entry Fishery reserves, refuges, sanctuaries & protected areas Effort reduction Strengthen licensing system
	Destructive fishing		Encourage income diversification
	Poverty		Law enforcement Market denial
	Over-emphasis on profits		Provision of alternative livelihood
	Weak law enforcement		Integration of value formation in IEC
	High population growth		Formulate a law enforcement framework Advocacy

Table 7. Fisheries Management Issues and Key Interventions. (continued)

Issues	Causes	Effects	Interventions
Habitat degradation *(mangroves, coral reefs, seagrasses, algal beds, soft bottom, etc.)*	Siltation		Riparian rehabilitation Mangrove rehabilitation Catchment/watershed management.
	Pollution		Wastewater management (domestic sewage, agriculture-aquaculture, industrial effluents) Implementation of anti-pollution regulations Solid waste management
	Destructive fishing		Law enforcement Market denial
	Increased fishing effort Poverty		(same as above)
	Weak law enforcement		Capability building (Supplemental/alternative livelihood, vocational skills training, credit program for non-capture fisheries livelihood) Formulate law enforcement framework
Inappropriate exploitation patterns *(mesh size, temporal/ spatial, destructive fishing)*	Ignorance		Information and Education Campaigns (IEC)
	Traditional practices (padas, danggit and other fisheries)		Formulate appropriate policy
	Lack of information		
	Market demand (for fry & juveniles)		Research on spatio-temporal dynamics of resources Formulate appropriate policy
Post harvest losses *(Spoilage, loss of value, discarding/by-catch)*	Adherence to traditional patterns Lack of quality consciousness		IEC (e.g. consumer consciousness)
	Lack of technology Improper handling		Technology dissemination & development
	Inappropriate exploitation pattern Lack of appropriate post-harvest infrastructures (e.g. design, absence, location)		Rehabilitation of existing cold storage facilities & construction in strategic locations
	Farm to market roads Air transport Seasonal over supply		Provide infrastructure
	Inadequate understanding/ appreciation of market demand		Develop market/ technologies appropriate for localities

Table 7. Fisheries Management Issues and Key Interventions. (continued)

Issues	Causes	Effects	Interventions
Opportunity losses *(processing)*	Insufficient adherence to quality management Lack of marketing strategies and skills	Lack of quality value-added products	Popularize adherence to quality standards (e.g. HACCP)[3] Initially subsidize entrepreneurship activities
Opportunity losses *(marketing)*	Lack of marketing strategies and skills		Entrepreneurship activities (enhance fisherfolk's business skills)
Small/large scale fishing conflicts *(e.g. encroachment)*	Weak law enforcement Un-delineated municipal boundaries Depleted resources		Formulate law enforcement framework Require transponders for commercial fishing vessels Establish identifiable boundaries (deploy buoys, payaos) (same interventions for over-fishing & habitat degradation)
Intra-municipal conflicts *(spatial)*	Depleted resources Lack of zoning regulations/ management schemes		(same interventions for over-fishing & habitat degradation) Formulate/implement zoning plans
Inter-municipal conflicts *(among municipalities)*	Un-delineated municipal boundaries Regulations/ordinance conflicts		Delineate identifiable boundaries Conflict resolution Propose common management scheme (IFARMC)
Information inadequacy	No information at all Unreliable information Inappropriate information Lack of dissemination of available info No "reading culture"		Tap existing information Generate information Translation of research output into useful form (e.g. print, advocacy) Establish info centers at the national, regional and local levels (e.g. licensing, production statistics, resource assessments info, etc) Advocacy Appropriate packaging of info
Research output inadequacy	Improper research protocol Weak research administration (funding and implementing agencies) Research agenda not driven by the needs of the sector Non publication of research results		Adaptation of scientific international standards Provide incentives for publishing Proper documentation

[3] HACCP mean Hazard Analysis and Critical Control Point.

Table 7. Fisheries Management Issues and Key Interventions. (continued)

Issues	Causes	Effects	Interventions
Institutional weakness/ Constraints	Lack of understanding of mandates	Weak implementation of mandates	Professionalize career system
	Unsustained and conflicting policies		Rationalize and institutionalize key policies
	Lack of coordination Lack of resources		Develop country-wide CRM (coastal resource management) policy framework
	Lack of political will/ political intervention		Implement pertinent provisions of RA 8550
	Lack of government commitment		Popularize CRM and make it a basic service of local governments Institutionalize CRM at local levels
			Clarify national environment and resource management priorities and legitimize in form of an official document (e.g. medium-term development plan)
	Donor-driven priorities		Improve donor coordination
Lack of continuity	Changes of policies due to change in administration		Institutionalize key environmental policies
Overlapping mandates	Lack of coordination		Resolution/rationalization of mandates Operational planning at the local level
	Lack of understanding of mandates		Clarification and prompt dissemination of mandates at all levels

Table 8. Opportunities identified in Philippine fisheries.

Opportunities	Benefits
High biodiversity	Implies ecosystem resilience
High recruitment rate of fishes	Implies high stock recovery rates
High growth rate of fishes	Implies high stock recovery rates
Long experience in implementation of (community-based coastal resource management) CBCRM	Sustained CRM
Wide acceptance of CBCRM	Easier introduction/implementation

Recommendations for Government Follow-up Action

a. Implement Monitoring, Control and Surveillance (MCS) activities
b. Implementation of commitment under various international conventions e.g. FAO Fisheries Code of Conduct (FAO 1995)
c. Incorporate and strengthen relevant concerns e.g. environment impact assessments, biodiversity conservation through sanctuaries, biosafety etc.

Recommendations for Regional Collaborative Efforts

a. International Waters concern to include:
   1. Highly migratory and transboundary aquatic species (e.g. fishes, marine mammals, marine turtles; invertebrates)
   2. Monitoring and evaluation of catch in the high seas by commercial fishing fleets
   3. Bilateral fisheries cooperation (utilization, management, research and development)
b. Stock assessment and stock delineation studies of shared fishery resources using available technologies e.g. surveys, tagging, morphometrics and molecular genetics (Barut and Santos 2000)
c. Establishment of a joint fisheries management framework between and among neighbouring countries sharing resources e.g. the Multilateral High Level Conference on Straddling Fish Stocks (MHLC),
d. Joint management and research of shared threatened and/or endangered biodiversity e.g. marine mammals and whale sharks

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Annex 1

List of national and sub-national (local) agencies involved in the development, management and conservation of the coastal and fisheries resources in the Philippines

a. National/Sub-national Agencies

- Department of Science and Technology - Philippine Council for Aquatic Marine Resources Research and Development (PCAMRRD)
- Department of Agriculture- Bureau of Agricultural Statistics (Fisheries Sector)
- Department of Agricultural- Bureau of Agricultural Research (Fisheries Sector)
- Department of Environment and Natural Resources - Protected Areas and Wildlife Bureau (DENR_PAWB)
- Department of Tourism - Philippine Tourism Authority
- Philippine Council for Sustainable Development (PCSD)
- Southeast Asian Fisheries Development Council (SEAFDEC)
- Agricultural Credit and Policy Council (ACPC)
- Quedan and Rural Credit Guarantee Corporation (QUEDANCOR)
- National Fisheries and Aquatic Resources Management Councils (NFARMC)
- Municipal/City/Integrated Fisheries and Aquatic Resources Management Councils (M/C/IFARMCs)
- Department of Interior and Local Government - Local Government Units
- Department of Foreign Affairs - Maritime and Ocean Affairs Unit
- Department of Transportation and Communication - Philippine Coast Guard
- Department of National Defense - Armed Forces of the Philippines
- State Universities and Colleges (e.g. University of the Philippines, Mindanao State University, Silliman University)
- Non Governmental Organizations (NGOs)
- People's Organizations (POs)
- Project based (e.g. DENR-Coastal Resources Management Project, BFAR-Fisheries Resources Management Project)
- International Organizations e.g. UNDP, UNEP
- Funding Institutions e.g. ADB and WB
- National Economic Development Authority (NEDA)

b. *Research and Training Facilities/Opportunities*

1. Bureau of Fisheries and Aquatic Resources
- BFAR National Centers
  - National Brackishwater Fisheries Technology Center
  - National Freshwater Fisheries Technology Center
  - National Integrated Fisheries Technology and Development Center
  - National Inland Fisheries Technology Center
  - National Marine Fisheries Development Center
  - National Seaweeds Technology and Development Center
  - National Fisheries Biological Center
  - Mindanao Freshwater Fisheries Technology Center
- BFAR Central Office Laboratories
  - Fish Health Lab
  - Microbiology and Chemical Laboratory
  - Biochemical and Genetics Laboratory
  - BFAR Regional Fish Health Laboratories
  - Research and Training Vessel (M/V DA-BFAR)
  - Regional Fishermen's Training Center (RFTC)

2. Southeast Asian Fisheries Development Center (SEAFDEC)

3. State University/Academic Institution Facilities e.g.
- University of the Philippines System
- Silliman University
- Mindanao State University
- Don Mariano Marcos State University

4. Ocean and Littoral Affairs Group of the Navy (OLAG)

5. Department of Environment and Natural Resources Facilities
- National Mapping and Resource Information Authority (NAMRIA)
- Environmental Management Bureau (EMB)
- Ecosystems Research and Development Bureau (ERDB)

6. Local Government Unit Facilities

7. Privately owned facilities e.g. Patrol Boat of the South Cotabato Purse Seiners Association (SOCOPA)

8. Non Governmental Organization (NGO) Facilities
- WWF-Philippines GIS Center
- International Marinelife Alliance Laboratory

c. *Financing Institutions Relevant to Fisheries Activity*

- Japan International Cooperating Agency (JICA)
- Asian Development Bank (ADB)
- World Bank (WB)
- Overseas Economic Cooperation Fund of Japan
- Global Environment Facility (GEF)
- Canadian International Development Agency (CIDA)
- Danish International Development Agency (DANIDA)
- US Agency for International Development (USAID)
- Australian Agency for International Development (AusAID)
- Food and Agriculture Organization (FAO)
- United Nations Development Program (UNDP)
- United Nations Environment Program (UNEP)
- UNESCO
- International NGOs e.g. World Wildlife Fund
- German Technical Assistance (GTZ)
- Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES)
- Convention on Migratory Species (CMS)

Strategic Review of the Fishery Situation in Thailand

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Abstract

Fisheries are an important source of animal protein for most of Thailand's population, particularly in provinces on or near the coast. Between 1978 and 1997 the per capita consumption of fish averaged 24 kg•capita^{-1} annually. In 1995, about 535 210 people were involved in the fisheries sector and 44% of these were engaged in small scale marine capture fisheries. Since 1982, Thailand has faced problems with the development of marine capture fisheries and their over-exploitation which has increased fishery conflicts and disputes with neighboring countries.

The Gulf of Thailand is the major fishing area of Thailand and in 1996, it contributed approximately 70% of the total marine catch in the country. The catch in the Gulf consisted of pelagic fish (33%), trash fish (32%), demersal fish (12%), squid and cuttlefish (6%), shrimps (5%), crabs (2%) and other fish (10%). However, demersal fish and some pelagic fish in the Gulf of Thailand have been over-exploited. This is due to a combination of factors including; increasing human population, increased pressure from Thai trawlers which have lost access to foreign fishing grounds after neighboring countries declared EEZs, development in fish processing techniques and increasing demand from animal feed producers that utilize trash fish.

This paper provides a broad view of the fisheries situation in Thailand, focused mainly on the Gulf of Thailand. It covers aspects of the environment, the status of resources available, the socioeconomic situation, the existing framework for management and development, and also makes recommendations for government action to develop sustainable fisheries management. The main objectives proposed for improving fishery management are: (1) promote fishers' and fisher organizations' participation in fishery development; (2) optimize fishery resources and their environment so as to be sustainable and equitable; (3) increase fishery products and stabilize fishers' and processors' incomes; (4) progressively develop deep sea fisheries; (5) improve export competitiveness.

Introduction

Thailand is a peninsular country located in Southeast Asia, with (Fig.1) a total land area of approximately 514 000 km^2 divided into 76 provinces. The sea-coasts of Thailand are the Gulf of Thailand, the main fishing ground, and the Andaman Sea. The Exclusive Economic Zone (EEZ) of Thailand covers 420 280 km^2, 304 000 km^2 in the Gulf of Thailand and 116 280 km^2 in the Andaman Sea. Thailand's EEZ within the Gulf of Thailand includes overlapping areas between Thailand and Cambodia (34 000 km^2), Thailand, Cambodia and Vietnam (14 000 km^2), and Thailand and Malaysia (~ 4 000 km^2) (adapted from Nakthon 1992) .

Fish is the primary source of animal protein for most of Thailand's population, particularly in the coastal and near coastal provinces. In 1995, the average per capita consumption of fish was 46.6 g•day^{-1} (~ 20.8 kg•year^{-1}) or 6.3% of the daily food intake. In urban and rural areas, the per capita consumption of fish was 47.3 and 46.5 g•day^{-1}, respectively. Over the period 1978 to 1997 the per capita consumption of fish averaged 24 kg annually, and fluctuated between highs of about 33 kg in 1994 - 95, and lows of about 18 kg in 1987 - 88.

During the years 1985 to 1995, the export-to-import ratio of fish and fishery products increased, with a balancing value (total exports minus total imports) of Baht 94 653. 1 million (US$3.8 to 26.2 million)[1] in 1995. The major exports were fresh and frozen shrimp, squid, cuttlefish, short-necked clam, boil-dried anchovy and canned tuna.

Thailand has faced problems with the development of marine capture fisheries since 1982. Marine fisheries are over-exploited. Fishery conflicts are increasing, and disputes with neighbouring countries have arisen. This paper provides a broad review of Thailand fisheries in terms of the environment, the status of resources available, the socioeconomic situation and the existing framework for management and development. The issues and opportunities facing fisheries in Thailand, focused primarily on the Gulf of Thailand, are discussed and interventions suggested for sustainable development.

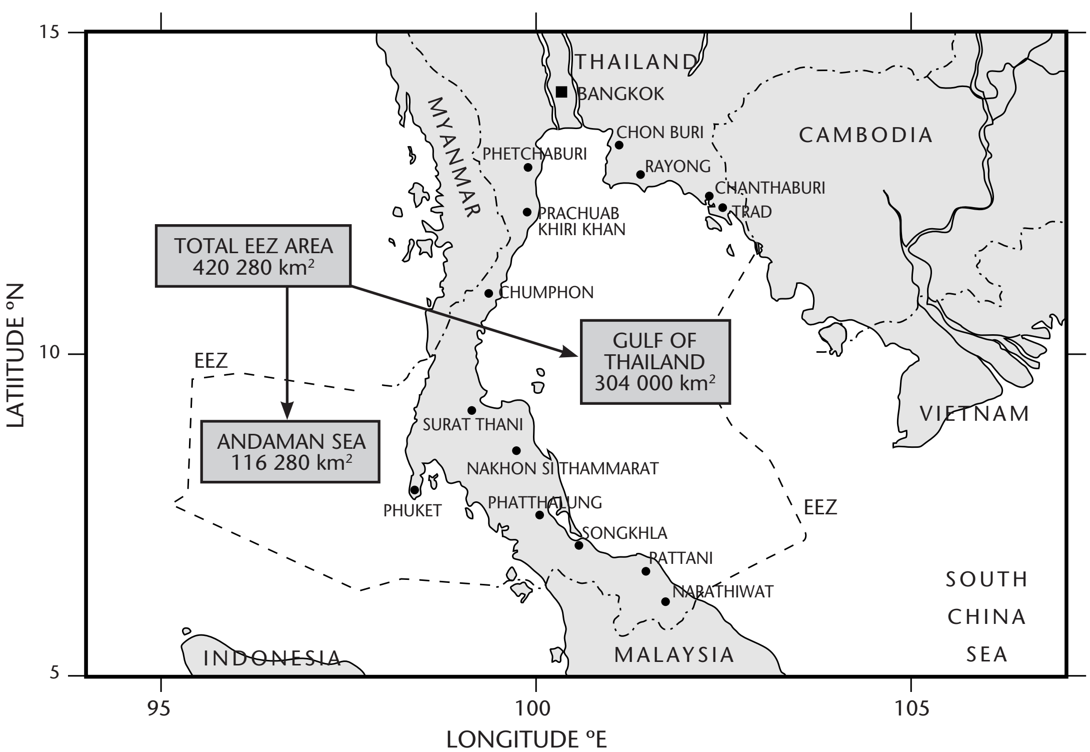

Fig. 1. The exclusize economic zone of Thailand covers 420 280 km^2, 304 000 km^2 in the Gulf of Thailand and 116 280 km^2 in the Andaman Sea.

[1] 1US$ = Bath 24.92 (1995 Annual average)

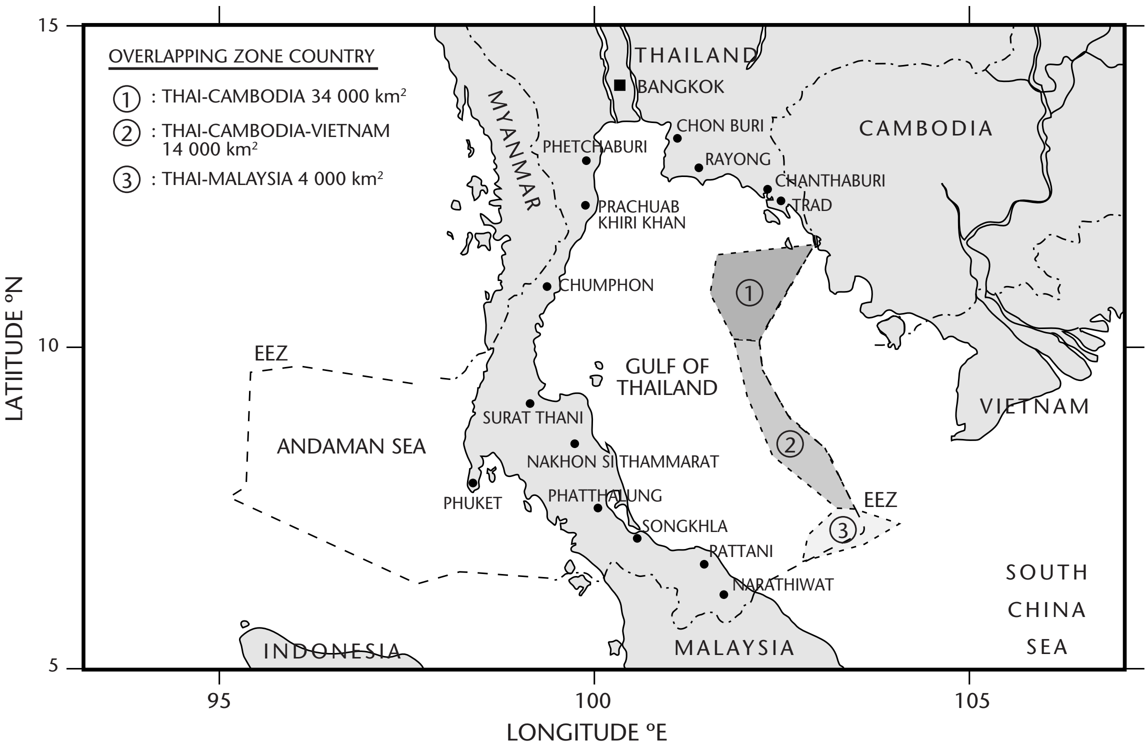

Fig. 2. Overlapping of Thailand's EEZs with those of neighbouring countries.

Biophysical Environment

The Gulf of Thailand

The coastline bordering the Gulf of Thailand is 1 875 km long, and the water is shallow, with an average depth of about 45 m. The deepest part of the Gulf, in the central basin, is about 70 - 85 m deep. The Gulf is partially separated from the South China Sea by underwater ridges, which inhibit the exchange of water. Thus the Gulf can be regarded as an ecologically distinct subset of the South China Sea (Piyakarnchana 1989; Pauly and Christensen 1993).

Four major rivers (the Chao Phraya, the Tha Chin, the Mae Klong and the Bang Pakong) drain into the northern, inner gulf, with an average annual discharge of approximately 1.5 x 10^{10} m^3 (Bunpapong 1987). In the south, high-salinity water from the South China Sea enters (Pongsapipat and Sapsomwong 1973; Robinson 1974). The Gulf of Thailand thus functions as a two-layered, shallow estuary with lower-salinity surface water flowing out, while high-salinity, colder water enters from the South China Sea. In the outer part of the gulf, water temperature ranges from 27.8 to 30º C with an average of 29º C, while surface salinity ranges from 31.4 to 32.7 ppt (Hydrographic Department 1995).

The bottom substrates are predominantly soft mud in the inner Gulf, soft mud in the central basin, and soft or sandy mud in the outer basin (Shepard et al. 1949; Hydrographic Department 1995). The bottom topography of the central basin consists of rolling hills of soft mud 2 - 10 m high. Hence, these areas are not suitable for trawling (Menasveta 1997).

Monsoon winds, tidal currents and the river discharge create complex circulation patterns, including localized upwellings and downwellings. The Gulf's surface water is subjected to two monsoon wind patterns: the northeast monsoon (November to February) and the southwest monsoon (May to September). The mean residual flow in the inner Gulf runs clockwise during the northeast monsoon and counterclockwise during the southwest monsoon. October and April are inter-monsoon months. Neither monsoon wind is constant in direction or speed (Robinson 1974).

Tides in the Gulf of Thailand are composed mainly

of mixed and diurnal tidal constituents. The whole inner Gulf area and the lower part of the west coast are dominated by mixed tides. The east coast and the upper portion of the west coast are dominated by diurnal tides. According to Pukasab and Pochanasomburana (1957), the nodal point exists at latitude 8º 15' N and longitude 102º 30' E.

Primary productivity in the Gulf is high in coastal areas near river mouths, and decreases with depth. Average primary productivity is 2.49 $gC\cdot m^{-2}\cdot day^{-1}$ in the inner Gulf and 2.96 $gC\cdot m^{-2}\cdot day^{-1}$ off the western coast. In the central area it is estimated at 1.37 $gC\cdot m^{-2}\cdot day^{-1}$. High concentrations of phytoplankton are observed in the inner Gulf with cell numbers of up to 4×10^6 - 19×10^6 $cell\cdot m^{-3}$. Zooplankton biomass has increased over a period of 16 years since 1976 and also during 1987 - 89 (Suvapepun 1995).

In general, water quality in the Gulf is considered fair, except for some slight pollution in some specific areas near river mouths. The most common land-based sources of nutrient inputs are domestic wastes and coastal aquaculture effluent. Coastal areas have high levels of nutrients and correspondingly high primary production. This has been associated with extensive blooms of *Noctiluca* along the coast, which have caused anoxic conditions that sometimes result in mass mortalities of fish and benthic invertebrates (Suvapepun 1995). Phosphate concentrations in the inner Gulf ranged from 1.02 to 1.59 mg $P\cdot l^{-1}$ from 1984 to 1989. Nitrate concentration ranged from 9.15 mgt $N\cdot l^{-1}$ to 24.86 mg $N\cdot l^{-1}$ over the same time period (Suvapepun 1991). Secchi disc transparency varied from 14 to 17 m.

Andaman Coast

Tidal currents and along-shore flows dominate the water circulation along the Andaman coast. Similarly to the Gulf of Thailand, the water movements vary with the monsoon period: nearshore surface waters generally move northward during the northeast monsoon and southward during the southwest monsoon. The current speeds are higher during the southwest monsoon (Eiamsa-ard and Amornchairojkul 1997).

The waters of the northern region (Ranong to Phuket) have a high salinity (32.9 - 33.4 ppt) due to deep sea upwelling, while the southern region (Phuket to Satun) has a lower salinity range (32.6 - 32.8 ppt) due to the influence of surface run-off. The temperature range along the Andaman coast is 27.6 - 29.3º C, slightly lower than the Gulf (Eiamsa-ard and Amornchairojkul 1997).

Critical Habitats

Over 300 major coral reefs, covering approximately 12 000 km^2, have been identified, in both the Gulf and Andaman Sea. Over 60% of major reefs are in either poor or fair condition; less than 36% are good or very good[2]. The Trad, Phang-Nga and Trang provinces still have significant coral reefs in good and very good condition The Chon Buri, Rayong, Surat Thani, Phuket and Satun provinces have the most severe coral reef deterioration, due to human activities (Sudara 1999).

Widespread destruction and degradation of coral reefs has occurred over the last four decades (Sudara 1999). It is due to the use of explosives for fishing, the introduction of bottom-trawlers and dragnetss in the early 1960s, and the gross mismanagement and uncontrolled expansion of tourism in the late 1970s. The causes of coral reef degradation differ between locations. Blasting of coral reefs is reported to be declining in many places but damage from coastal trawlers is on the increase. More recent contributing factors include sedimentation and pollution from wastewater discharge associated with rapid and uncontrolled coastal area development (Sudara 1999).

In 1961, there were nearly 367 800 ha of mangroves, 37.1% in the Gulf of Thailand. By 1996, the mangroves of the Gulf were estimated to have been reduced to 34 678 ha, only 25.4% of the 1961 level (adapted from Charuppat and Charuppat 1997). From 1961 to 1996 (35 years), the mangrove loss was approximately 2 900 $ha\cdot year^{-1}$.

The remaining mangroves are particularly extensive in Nakhon Si Thammarat, Trad, Chanthaburi, Chumphon and Surat Thani Provinces. The losses were due to legal and illegal logging, mining, human settlements, industrial development, ports and harbours, dredging, road construction and conversion to shrimp ponds.

Widespread conversion of mangroves occurred in

[2] The condotion rating is categorized by proportion between llive and dead coral as $\geq 3:1$ very good, 2 : 1 good, 1 : 1 fair, 1 : 2 poor and $1:\geq 3$ very poor.

the 1960s to early 1970s for infrastructure development, in the late 1970s until the mid-1980s for extensive shrimp farming, and since 1986 for intensive shrimp farming. The inner Gulf coast, for example, lost most of its mangrove cover during the first expansive phase of brackish water shrimp farming in the 1980s. Despite recent measures to control encroachment on mangroves, and efforts to replant in degraded areas, deforestation has continued, though at a slower rate (Kaosa-ard and Pednekar 1998).

Nine species of seagrass are found in 13 provinces along the Gulf, with extensive seagrass beds at Kung Krabaen Bay in Chantaburi province, Kradad Island and Mak Island in Trad, Samui Island and Pha Ngan Island in Surat Thani, and Pattani Bay in Pattani. The dominant species are *Halophila ovalis*, *Halodule uninervis* and *Enhalus acoroides*. There is clear degradation of seagrass beds due to wastewater discharges from coastal industries, urban development, shrimp farms and other forms of coastal land development, and mining. Trawling and the use of push nets and dragnets can cause severe impacts on seagrasses (Sudara 1999).

Fishery Resources and Potential

In 1996, the Gulf of Thailand contributed approximately 70% of the total marine catch in the country, while the Andaman Sea coast accounted for the remainder. In the Gulf of Thailand, 168 000 t came from small scale fisheries, and 1 735 000 t from large scale or commercial fisheries. These landings were dominated by pelagic fish (33%) and trash fish (32%). The remainder was demersal fish (12%), squid and cuttlefish (6%), shrimp (5%), crabs (2%) and miscellaneous fishes (10%) (Department of Fisheries 1999).

Demersal Fish

Demersal fish are caught mainly by otter-board trawls, pair trawls, beam trawls and push nets. In the Gulf, the number of registered trawls increased from 3 206 units in 1970 to 15 037 in 1989. The annual catch of demersal fish increased from 51 000 t in 1978 to 235 700 t in 1996. In 1996, 64% of the demersal catch originated from the Gulf.

The demersal fish resources in coastal waters have been severely depleted, as shown by estimates of potential yields of various fish stocks, the change in catch composition towards smaller-sized fish and low value species. Trash fish currently constitute about 60% of the total trawl catch from the Gulf of Thailand. Between 18% and 32% of trash fish are juveniles of commercially important fish species (Supongpan 1996 cited in Menasveta 1997).

The demersal resources (demersal fish and trash fish) in the Gulf of Thailand have been over-fished since 1973 with an estimated MSY of 750 000 t and optimal fishing effort at 8.6 million hours of trawling (Panayotou and Jetanavanich 1987). Another analysis based on Thompson and Bell's method (Gayanilo and Pauly 1997) for estimating MSY and MEY of five dominant species in the trawl catch (i.e. *Priacanthus tayenus, Nemipterus hexodon, Saurida undosquamis, Saurida elongata* and *Metapenaeus affinis)* indicated that those species were over-exploited at the current fishing effort (Supongpan 1996a). Several factors may have contributed to over-fishing, notably: increasing human population; increased pressure from Thai trawlers who lost access to foreign fishing grounds after neighbouring countries declared EEZs; development of processing techniques for turning low-priced demersal fish into human food; and increasing number of animal feed plants that utilize trash fish (Eiamsa-ard and Amornchairojkul 1997).

Pelagic Fish

In the Gulf of Thailand, pelagic fish are caught by stake traps, purse seiners (Chinese, Thai, luring and anchovy), encirling gillnets and drift nets. Important pelagic fish are mackerels (*Rastrelliger* spp.), scads (*Decapterus* spp.), sardines (*Sardinella* spp.), anchovies (*Encrasicholina* spp. and *Stolephorus* spp.), king mackerel (*Scomberomorus* spp.), and tuna (*Thunnus* spp. and *Euthynnus* spp.) (Eiamsa-ard and Amornchairojkul 1997).

In the past, Indo-Pacific mackerel (*Rastrelliger brachysoma*) or platu was the most popular fish for Thai consumers. Hence, this species was extensively studied (Kurogane et al. 1971; Hongskul 1974). In 1971, catches of Indo-Pacific mackerel were about 40 000 t, 47% of pelagic fish catches. However, following the development of improved pelagic fishing gear and techniques, the major contributors to the small pelagic catches in 1977 were sardines and round scads, with 205 000 t and 131 000 t, or 41% and 26% of the total pelagic catches, respectively. These high percentages have since declined, due to the development of an off-

shore fishery for large pelagic fishes, especially tuna.

Supongpan (1996a) stated that the Indo-Pacific mackerel (*Rastrelliger brachysoma*) stocks in the Gulf of Thailand had been fully exploited since 1984 (estimated MSY of 105 000 t and an optimal fishing effort of 145 000 fishing days). The catch of this species decreased during 1990 - 91. The sardines (*Sardinella* spp.) have been over-exploited since 1988 (MSY of 104 000 t and an optimal fishing effort of 190 000 fishing days). The anchovy (*Stolephorus* spp.) resources have likewise been fully exploited since 1990 (MSY at 104 000 t and an optimal fishing effort of 53 000 fishing days). The small tuna and round scad stocks have also been fully exploited since 1988 and 1977 with the estimated MSY at 86 000 t and 100 000 t, respectively. Other pelagic fish stocks including the Spanish mackerel (*Scomberomorus commersoni*), carangids and hardtail scads (*Megalaspis* spp.) have not yet been fully exploited.

Shrimps

The penaeid prawn (*Penaeus* spp.) resources have been over-exploited since 1982 (MSY of 22 000 t and an optimal fishing effort of 25 million hours). The small sized shrimps (*Trachpenaeus* spp. and *Metapenaeopsis* spp.) have also been over-exploited with estimated MSY of 110 000 t and an optimal fishing effort of 44 million hours (Supongpan 1996a).

Other Resources

The cephalopods in Thai waters consist of 10 families, 17 genera and over 30 species. The more important species of the squid fishery are *Loligo chinensis, L. duvauceli, L. singhalensis, L. edulis, Loliolus sumatrensis* and *Sepioteuthis lessoniana*; the cuttlefishes; *Sepia pharaonis, S. aculeata, S. recurvirostra, S. lycides, S. brevimana* and *Sepiella inermis* and the octopus; *Octopus membranaceous, O. dollfusi* and *Cistopus indicus* (Chottiyaputta 1993). The squids, *L. chinensis, L. duvauceli, Sepioteuthis lessoniana* and *Loliolus sumatrensis* are abandant both in the Gulf and the Andaman Sea. *L. edulis* and *L. singhalensis* are rare in the Gulf but more abundant in the deeper parts of the Andaman Sea coast (Supongpan 1996b). Cuttlefish, *S. pharaonis, S. aculeata, S. recurviorostra, S. brevimana* and *Sepiella inermis* occur both in the Gulf and the Andaman Sea. *S. lycidas* is common along the Andaman Sea coast, but in the Gulf occurs only in the southern part. *Octopus, O. memnranaceous, O. dollfusi* and *Cistopus indicus* are widely distributed in the Gulf and the Andaman Sea.

From 1985 to 1988, cephalopod catches consisted of squid 56%, cuttlefish 37% and octopus 7%. The cephalopod stocks had by then been fully exploited (MSY of squids, 67 000 t by 1991; cuttlefish 35 000 t and octopus 85 000 t, based on data from 1972 - 1991). The crab resources had been fully exploited as well (Supongpan 1996a).

Socioeconomic Background

Demography

Under the third National Economic and Social Development Plan (1972 - 76), the Thai government set a policy of population control. Successful implementation reduced the population growth rate to 1.2 percent during the years 1992 to 1995. In 1999, the total population was 61 626 480, with 51% being women

In 1998, the labor force was 35.6 million, of which 15.4 million (43 %) were employed in the agricultural sector, including fisheries. The 1995 figures show that an estimated 535 210 people (about 0.9% of the population) belonging to 53 112 households were involved in the fisheries sector, of which 51% were males (National Statistical Office 1997). Of these, 44.2% were engaged in small scale marine capture fishers, and 5.7% in commercial marine fisheries. The total number of fishers increased during the peak season; 47.5% were family members and 52.5% employees. Among employees, 58.1% were non-local and 41.9% were local employees. Among non-local employees, 55.8% came from the northeast of the country, 18.4% from other parts of Thailand and 25.8% from foreign countries (National Statistical Office 1997).

Estimates of fishing income are available from 1990. The income of fishing households, especially small scale fishing households, comes from various sources, however the main source is fisheries. Average annual income of small scale fishing households in 1990 was Baht 58 776 (US$2 358), of which 78.8% was cash income and 21.2% was non-cash income. Average annual incomes of small scale fishing households were higher in the Gulf of Thailand (Baht 63 351) than in the Andaman Sea (Baht 54 098). For the whole country the annual income per capita was Baht 16 463 (National Statistical Office 1992 b).

Education and Literacy

About half of Thai fishers have attained lower elementary education, while about a quarter have reached the upper elementary level (National Statistical Office 1997). Thai fishers are similar to farmers in having less opportunity to get a formal education due to low incomes (Pimoljinda 1997). To break the vicious circle of low income and lack of education, the government must provide information for small scale fishers and formal education for their children (Wongsanga et al. 1997).

Environmental Awareness

The need for participation by stakeholders in natural resource and environmental management has received increased recognition within Thailand, particularly in the Eighth National Economic and Social Development Plan (1997 - 2001). Creating opportunities and an enabling environment to support the participation of all sectors in the development process is one of the main strategies of the national plan. In pursuit of this strategy, the guidelines at the national policy level include:

- Providing opportunities for people and communities to participate in decision-making and to monitor and evaluate public development projects likely to have an impact on natural resources and the environment. The government should facilitate continual public discussion at every step of those projects.
- Providing legal guarantees of the rights of local communities and small fishers to participate in coastal resource management, including the conservation, rehabilitation and maintenance of mangrove forest, sea grasses and coral reefs, to ensure their sustainable use (Tokrisna et al. 1997).

Consequently, upgrading the capacities of rural communities for economic and social development and for conservation of natural resources are priorities.

Infrastructure

To improve the living standard of fishing communities, essential infrastructure such as roads, electricity, small fishing piers and water supply facilities should be built. Some fishing villages in remote areas are in need of basic structures, such as community landings, fishing-gear repair shops, fish processing shops and freshwater tanks. At present, some fishing villages still have no roads for vehicles, or electricity. There is a continual shortage of fresh water and drinking water, especially during the dry season. The fishing communities must buy fresh water, which is expensive. The Department of Fisheries has implemented the Marine Fishery Development Project since the Fifth National Economic and Social Development Plan (1982 - 86). This project aimed to raise the living standard of fishers, especially small scale fishers. The provision of basic fishing infrastructure was one project activity. However many facilities have not been utilized, or have been improperly managed and maintained, largely because of a lack of clarity in objectives (Pimoljinda 1998; Supongpan 1996a).

Level of Urbanization

Human settlements along the coast in Thailand can be classified into five categories (Adulavidhaya et al. 1982):

i. Fishing villages.
   These are the most common type of settlement along the Thai coasts, generally settled in clusters, along estuaries and shores, they vary in size from 20 - 30 households to very large villages composed of several hundred households. Panayotou et al. (1985) estimated a total number of 90 200 fishing households in the 1 563 villages of the 23 coastal provinces, bringing the fishing-dependent population to 800 000 - 1 000 000. People in fishing villages are usually engaged in small scale fisheries with simple technology and these villages are generally self-sufficient (Thailand Development Research Institute 1986).

ii. Fishing and farming villages.
   These are mainly scattered along the eastern coast and the southern provinces. These communities engage in rice farming as a supplementary occupation to fishing and their standard of living is relatively better than those who only fish (Rientrairut 1985). However, rice production is rarely sufficient for household consumption. Increasing salinity of the soil, population growth, additional pressure on land use, and lack of interest in rice cultivation have all resulted in insufficient rice production. Coconut plantations also provide supplementary income to fishers (Suraswadi 1998).

iii. Coastal farming communities.
   These are located in the inner part of the Gulf of Thailand, including areas along the estuaries and deltas of four major rivers of the region (the

Chao Phraya, Mae Klong, Nakornchaisri, and Bang Prakong). The major occupations are salt farming, shrimp and fish farming, mariculture, and coconut farming. This type of settlement is generally in a scattered pattern with a homestead on each farmland.

iv. Coastal urban and industrial communities.
There are mainly located in the vicinity of the inner Gulf of Thailand. Recently these have been industrialized, e.g. Chon Buri and neighbouring Rayong and Chachoengsao have become the focus of the Eastern Seaboard Development Plan, which has brought in development activities including a major new port, a heavy industry zone, oil refineries, a petrochemical industry, a marine product industry and numerous housing estates. The rate of urbanization and industrialization in Chon Buri and neighbouring provinces is increasing rapidly (Office of the National Environment Board 1986). In addition, many coastal provinces have rapidly developed due to the tourism boom.

v. Migratory communities.
These are mainly in some of the southern provinces on the Bay of Bengal coast. The “Chao Le” (*sea dyak* or *sea gypsy*) are the major ethnic group in these communities. Having no permanent settlement, these people wander from island to island in search of fishing areas. It is estimated that the population of sea dyaks in Thailand is about 2 300 people or 400 households. They live in small groups with a unique culture (Adulavidhaya et al. 1982).

Agriculture and Fisheries Sectors

The development of the Thai agricultural sector during the last 25 to 30 years has been achieved largely at the expense of the country’s rich resource base. The country’s vast supply of water, forest, coastal, marine, and other natural resources have been used extensively, while management and conservation processes have remained under-developed. As a result, Thailand’s once abundant natural resources have diminished significantly, with serious implications for the Thai people.

Table 1 presents principal economic indicators for comparing the productivity of the agricultural and the non-agricultural labor force. In 1995, in terms of agricultural GDP per worker, there was an order of magnitude difference between the two sectors.

The Gross Domestic Product (GDP) increased annually from 1991 to 1995. The income per capita also increased, as did the GDP from fisheries, which accounts for 13% to 15% of the total agricultural GDP (Table 2). The annual growth rate of the fisheries GDP decreased dramatically from 24.2% in 1991 to - 0.8% in 1995. During the same period the overall GDP fluctuated over a small range of 8.2% to 8.9% (Table 3).

As Thailand has progressed from being a producer of primary agricultural products to being the fifth largest exporter of food and processed food products in the world, it has come face to face with the

Table 1. Comparison of the productivity of the agricultural and the non-agricultural labor forces in 1991 - 95.

Items	Unit	1991	1992	1993	1994	1995
Gross domestic product	Million Baht	2 506 635	2 834 677	3 179 451	3 634 848	4 202 835
Gross national product	Million Baht	2 469 744	2 771 716	3 116 484	3 559 816	4 107 377
Economic growth rate	Percent	8.6	8.2	8.5	8.9	8.8
Per capita income	Baht	44 307	49 476	54 809	61 909	70 754
Per capita GDP originating from agriculture	Baht•head^{-1}	16 272	17 877	16 963	19 493	22 927
Per capita GDP originating from non-agriculture	Baht•head^{-1}	166 379	186 284	209 879	235 832	267 680

Source: Office of Agricultural Economics 1998.
1US$ = Baht 24.92 (1995 Annual average).

reality of the terms and conditions of being a major trading nation. As its products have penetrated new, more developed, more sophisticated and specialized niche markets, the quality of Thai goods has been of increasing importance. As global awareness of the environmental impacts of unsustainable agricultural development has increased, consumers have become more conscious of the source of their food products. As existing resource bases are depleted or destroyed, producers expand onto increasingly marginal lands and violate the ethics and principles of resource protection. This has resulted in increased linkages between trade and the environment and more intensive scrutiny of Thai agricultural production.

Table 2. Gross Domestic Product originating from agriculture (at 1988 prices). Unit: Million Baht.

Items	1991	1992	1993	1994	1995
GDP originating from agriculture	282 739 (100)	299 570 (100)	299 513 (100)	315 065 (100)	321 957 (100)
- Crops	170 277 (60.22)	180 272 (60.18)	174 466 (58.25)	184 006 (58.40)	191 932 (59.61)
- Livestock	29 370 (10.39)	30 314 (10.12)	31 628 (10.56)	31 334 (9.95)	32 053 (9.96)
- Fisheries	37 305 (13.20)	40 263 (13.44)	45 613 (15.23)	49 247 (15.63)	48 867 (15.18)
- Forestry	5 892 (2.08)	5 671 (1.89)	4 990 (1.66)	4 110 (1.30)	3 817 (1.18)
- Agricultural services	9 509 (3.36)	9 429 (3.15)	8 800 (2.94)	9 041 (2.87)	8 341 (2.59)
- Simple agricultural processing products	30 386 (10.75)	33 621 (11.22)	34 016 (11.36)	37 327 (11.85)	36 947 (11.48)

Source: Office of Agricultural Economics 1998. Numbers in brackets represent percentages.
1US$ = Baht 24.92 (Annual average 1995).

Table 3. Growth rates of the economy and its agricultural sector (at 1988 prices). Unit: percent.

Itens	1991	1992	1993	1994	1995
Gross domestic product	8.6	8.2	8.5	8.9	8.8
Gross national product	8.4	7.4	8.8	8.9	8.7
GDP originating from agriculture	7.2	6.0	0.0	5.2	2.2
- Crops	5.7	5.9	-3.2	5.5	4.3
- Livestock	1.0	3.2	4.3	-0.9	2.3
- Fisheries	24.2	7.9	13.3	8.0	-0.8
- Forestry	-0.6	-3.8	-12.0	-17.6	-7.1
- Agricultural services	-0.9	-0.8	-6.7	2.7	-7.7
- Simple agricultural processing products	9.6	10.6	1.2	9.7	-1.0

Source: Office of Agricultural Economics 1998.

Through the 8th Agricultural Development Plan, the Ministry of Agriculture and Cooperatives is committed to addressing issues related to trade and the environment by implementing policies, programs, projects, and activities that will lead to improved competitiveness of Thai agricultural products through the use of advanced technologies. More sustainable agricultural development will be achieved through improved management of natural resources. Human resource development will be emphasized to increase the capacities of farmers and community-level institutions and organizations to adapt to the globalization of the agricultural sector (Office of Agricultural Economics 1998).

The level of integration of global economic development and increased intensity of international trade has required the global community to devise terms, conditions, and structures that will ensure fairness, transparency, and equality in international transactions. In the light of negotiated General Agreement on Tariff and Trade (GATT) agreements and their strict enforcement by the World Trade Organization, the Thai Government has taken actions to ensure that its agricultural and industrial sectors are responsive to the dynamic and changing nature of the framework for international trade.

The Ministry of Agriculture and Cooperatives, led by the Office of Agricultural Economy (OAE), has initiated several programs that if implemented would lead to more appropriate and sustainable agricultural development, fitted to the demands of the framework for international trade and development. With assistance from the World Bank, the Government of Japan, the Danish Cooperation for Environment and Development (DANCED), United Nations Development Program (UNDP), Food and Agriculture Organization (FAO), and other donors, various on-going or planned activities will ensure improvements in natural resources management and strengthening of policy formulation and implementation among key planning and policy making agencies of the Ministry of Agriculture and Cooperatives. Natural resource areas that have been considered include watersheds, coastal zones, and conservation forests with their adjacent buffer zones. Human resource development initiatives are underway that will lead to strengthening capacities in policy formulation and implementation; planning; provision of training and transfer of technology; natural resources and environmental database management, including bio-diversity; natural resources evaluation; and econometric modeling.

In addition to coordinating activities that are being implemented through various technical assistance projects, the Office of Agricultural Economy (OAE) took the lead in preparing the 8th Agricultural Development Plan, incorporated as part of the 8th National Social and Economic Development Plan for Thailand (1997 - 2001). The 8th Agricultural Development Plan was formulated over a period of more than one year, and involved extensive consultation with representatives from key Thai Government planning agencies, all departments and state enterprises under the Ministry of Agriculture and Cooperatives, farmers, non-government organizations, academics, researchers from independent research institutes, and concerned private sector firms. Three principal strategies for Thailand's agricultural development were identified, namely:

1. Competitiveness (in international markets)

2. Natural Resources Conservation and Sustainable Agriculture Development (in line with international conventions and in light of the increasingly close linkages between trade and the environment)

3. Human Resources and Agricultural Institutional Development

Fishers and Fishing Households (Spatial, Temporal)

A structural change in Thai fisheries has taken place during the last 10 years. From 1985 to1990, the overall number of fishing households and fishing boats decreased by 6.7% and 2.3% respectively (Table 4). Small scale fishing households and small scale fishing boats decreased by 5.9% and 0.6% respectively, whereas commercial-scale fishing households and commercial fishing boats decreased by 9.8% and 7.5%. The decreasing numbers of small scale fishing households and boats were largely due to the decrease in coastal fishing resources and the conflicts between small scale and the commercial-scale fishers.

During 1990 - 95, the number of fishing households and fishing boats in Thailand increased by 11.0% and 5.4% respectively. The increase in fishing households has largely been in small scale fisheries. Commercial fishing households decreased by 5.3%. Likewise, the increase in fishing boats has been in the small scale sector. Small scale fishing boats accounted for 8.1% of the total increase,

while commercial boats have actually decreased in number by 3.7% (Table 4). The creation of a boat-tenure system within the commercial fishing sector is responsible for the decrease in trawling boats. The change to squid light-luring fishing boats has resulted in a decrease in the number of boats per household. To maintain the demersal fishery resources for sustainable development, the Minister of Agriculture and Cooperatives issued a notification to limit entry of new trawl and push net boats. The boat-tenure system has been implemented since 1 November 1996. Owners of trawlers or push netters have to register every fishing year (1 April to 31 March of the following year). Only one type of gear on a motorized boat may be registered, (pair trawl can have two boats with one trawling gear). Immediate notification of a registered boat sinking or being out of order is required, or the registration will be terminated. If a registered boat is arrested in a foreign country, the owner should inform the office within 60 days and the registration will continue after release within that fishing year.

A registered boat can be sold legally, but can be transferred to a son only. The location for registration can be changed anywhere in the Gulf of Thailand and on the Andaman Sea coast.

Three major factors have led to the increase in small scale fishing households and boats during the last five years. Firstly, the population in coastal fishing communities has increased. Secondly, fishery resources have partly recovered because of artificial reef installation. Thirdly, some coastal communities have succeeded in obstructing coastal trawling and have become enthusiastic about looking after fishing areas themselves.

In spatial terms, fisheries are concentrated in the six provinces located in the southern parts of the country both in the Gulf of Thailand and Andaman Sea. These provinces are Songkhla, Nakhorn Sri Thammarat, Phangnga, Satun, Surat Thani and Krabi (Table 5). Small scale fisheries dominate these areas, with shrimp gillnet, shrimp trap, crab gillnet and trawl net as the main fishing gear.

Table 4. Changes in fishery households and fishing boats between 1985 and 1995.

Types	1986[1/]	1990[2/]	1995[3/]	1990/1986 (%)	1995/1990 (%)
Number of fishery households	51 245	47 836	53 112	-6.7	11.0
- Small scale fishery	41 592	39 127	44 867	-5.9	14.7
- Commercial fishery	9 653	8 709	8 245	-9.8	-5.3
Number of fishing boats	52 950	51 757	54 538	-2.3	5.4
-Small scale fishery	40 095	39 870	43 092	-0.6	8.1
-Commercial fishery	12 855	11 887	11 446	-7.5	-3.7

Sources: [1/] National Statistical Office 1987.
[2/] National Statistical Office 1992a.
[3/] National Statistical Office 1997.

Table 5. Distribution and type of the main marine capture fishery establishments.

Province	Number of capture fishery establishments	Main fishing gear
Songkhla	5 885	Shrimp gillnet, shrimp trap, trawl net
Nakhon Sri Thammarat	4 791	Shrimp gillnet, trawl net
Phangnga	3 970	Shrimp gillnet
Satun	3 795	Shrimp gillnet
Surat Thani	3 285	Crab gillnet
Krabi	3 105	Shrimp gillnet

Source: National Statistical Office 1997.

Professional and Business/industry Groups

The post harvest or processing factories in Thailand are rather simple, often at the household level. There are 9 331 households involved and they are distributed over both the Gulf and Andaman Sea coasts. Some households have more than one processing activity. The top three activities are: fermented production 3 216 units (31.4%), dried and boiled products 3 166 (30.9%) and steam products 3106 (30.3%), with a total of 10 255 units. The industrial factories produce chilled and frozen, canned, minced, fish sauce product and salted fish. Related businesses include boat yards, ice factories and machinery import agencies. These provide millions of job opportunities (adapted from Siriekawat 1996).

Institutional Background

Fisheries-related Policies

The Constitution

The present Constitution of the Kingdom of Thailand was enacted on the 11th of October B.E. 2540 (1997). There are 336 sections related to natural resources and environment. The following describes the more important sections:

Section 56. The right of a person to an environment that is not hazardous to his or her health, welfare or quality of life shall be protected. The right of a person and communities to participate in the exploitation, preservation and protection of natural resources and bio-diversity, and in the promotion and preservation of the quality of the environment shall also be protected.

Any project or activity that may seriously affect the quality of the environment shall not be permitted, unless its impacts on the quality of the environment have been studied and evaluated. Prior to the operation of such project or activity, the opinions of an independent organization, consisting of representatives from private environmental organizations and from higher educational institutions that conduct studies in the environmental field, will be obtained, as provided by law.

The law shall protect the right of a person to sue a state agency, state enterprise, local government organization or other state authorities for failure to perform the duties under paragraph one and paragraph two.

Section 69. Every person shall have a duty to conserve natural resources and the environment, as provided by law.

Section 79. The State shall promote and encourage public participation in the preservation, maintenance and balanced exploitation of natural resources and bio-diversity and in the promotion, maintenance and protection of the quality of the environment in accordance with the persistent development principle as well as the control and elimination of pollution affecting public health, sanitary conditions, welfare and quality of life.

Section 290. For the purpose of promoting and maintaining the quality of the environment, a local government organization has powers and duties as provided by law.

The law contains the following matters as its substance:

i. The management, preservation and exploitation of the natural resources and environment in the area of the locality;
ii. The participation in the preservation of natural resources and environment outside the area of the locality only in the case where the living conditions of the inhabitants in the area may be affected;
iii. The participation in considering the initiation of any project or activity outside the area of the locality which may affect the quality of the environment, health or sanitary conditions of the inhabitants in the area.

Legislation

Legislation related to the fisheries of Thailand includes:

- The Thai Vessels Act, B.E. 2481 (1938)
- The Act Governing the Right to Fish in Thai Fisheries Waters, B.E. 2482 (1939)
- The Fisheries Act, B.E. 2490 (1947)
- The Fish Marketing Act, B.E. 2496 (1953)
- The Wildlife Reservation and Protection Act, B.E. 2535 (1992)

The main legislation is the Fisheries Act, B.E. 2490 (1947), covering fisheries management and conservation, aquaculture, registration and application for permits, collection and fixation of fisheries tax, fisheries statistics as well as the provision of

penalties. This Act was drawn up in 1947 before the development of marine fisheries and was drafted primarily with inland fisheries in mind. It has been amended twice, in 1953 and 1984, and empowers the Ministry of Agriculture and Cooperatives and the Provincial Governor to enforce the law means of administrative power (Karnjanakesorn and Yen-Eng 1998).

There are several important sections in this Act. For example:

Section 7 empowers a Provincial Governor, with the approval of the Minister, to make notification about the types of fisheries within his/her province.

Section 12 defines a reserved area for a person or an entity permitted to fish or to cultivate aquatic animals.

Section 13 prohibits unlicensed persons from fishing in the reserved area.

Section 32 authorizes the Minister or the Provincial Governor to enact measures for: (1) controlling types, number and components of fishing gear; (2) prohibiting certain types of fishing tools and methods used for fishing during breeding seasons; and (3) setting a maximum allowable catch of aquatic species including a total ban on catching particular aquatic species.

Administrative Regulations

The Minister of Agriculture and Cooperatives is empowered by the provisions of the Fisheries Act to impose fishery regulations.

a. Prohibition of the use of certain types of fishing gear during the spawning and breeding seasons of some commercially important species, for example:

- Ministerial regulation of 28 November 1984
  A conservation area of approximately 26 400 km^2 was declared in the Gulf of Thailand to protect several commercially exploited species of demersal and pelagic fish during their spawning and breeding seasons from February to 15 May of each year. This regulation prohibits fishing by all types and sizes of trawlers (with the exception of beam trawlers), all types of purse seiners (except for anchovy purse seiners operating in the daytime during February 15 to March 31 only) and gillnets with less than 4.7 cm mesh size, along the coastline of Prachuap Khiri Khan, Chumphon and Surat Thani Provinces.
- Ministerial regulation of 11 April 1985
  Conservation measures for protecting breeding species in their spawning and nursery grounds were extended to the Andaman Sea. A 1 800 km^2 area at Phang-gna and Krabi province was declared as a zone of conservation through selectively controlled fishing by closed seasons and/or prohibition of selected fishing gear during April 15 to June 15 of each year.

b. Prohibition of certain types of fishing gear in some areas, for example:

- Ministerial Regulation of 20 July 1972
  This regulation prohibits fishing by trawlers and push nets within a distance of 3 000 m from the shoreline and within a perimeter of 400 m of any stationary fishing gear in the Gulf of Thailand. This regulation was designed to maintain the productivity of these near shore waters, as the catches from these areas had dropped below their potential yield. Furthermore, 80% of the total catch consisted of small fish, at least half of which were the juveniles of economically important species.
- Ministerial Regulation of 18 February 1974
  The use of any kind of shellfish rack within 3 000 m from the shoreline was prohibited along the entire coastline of Thailand, both in the Gulf and the Andaman Sea. This type of fishing destroys nursery grounds of young shellfish.
- Ministerial Regulation of 14 August 1979
  This regulation prohibits fishing operations using all types of trawlers and push nets within 3 000 m from the shoreline and within a radius of 400 m from stationary fishing gear in the Andaman Sea.

c. Declaration of protected areas, for example:

- Ministerial Regulations of 27 February and 15 May 1989
  These regulations declared the areas around Khai, Charakhay, Thalao, Khalok and Hin Phae Islands off the coast of Chumphon Province in the Gulf of Thailand and coral reefs at Patong Bay of Phuket Province along the Andaman Sea coastline as protected areas for the conservation of coral reefs.

- Ministerial Regulation of 9 May 1991
  A marine turtle nesting area of approximately 1.6 km^2 at Kra Island of Trat Province in the Gulf of Thailand was declared a protected area to shelter the turtles during the breeding season.

d. Protection of endangered and threatened species, for example:

- Ministerial Regulation of 14 April 1949, 19 November 1980, 11 August 1981 and 15 May 1989. These regulations prohibit the catching of sea turtles, collection of their eggs and export of sea turtle shells in a processed or unprocessed form, and became essential to protect dwindling sea turtle populations.
- Ministerial Regulation of 9 August 1961.
  This regulation prohibits catching of dugongs in the Gulf of Thailand and Andaman Sea, as this species was fast becoming endangered in these waters.
- Ministerial Notification Regarding Prohibition of Fishing Any Dolphin of 18 June 1990.
  This notification states that "no person shall fish any dolphin from the sea of all coastal provinces except after receiving the written permission from the Director-General or except any fishing activities done by the authority assigned by the Director-General".

National Development Plans

National fisheries development plans have been aligned with the National Economic and Social Development Plan (NESDP) since the latter came into existence in 1961. Under the **First Plan (1961 - 66)**, trawl fisheries, particularly otter-board trawling of demersal resources, were supported by the Board of Investment and the Government of Thailand in cooperation with the Federal Republic of Germany. The marine production in 1966 increased 88% from the year 1962. Under the **Second Plan (1967 - 71)**, policies and objectives continued to emphasize marine fisheries, with the production target set at 860 000 t in 1971. At the end of the plan implementation period, the production reached 730 000 t, with marine production accounting for 93% of total fisheries production. The fisheries development policy in the **Third Plan (1972 - 76)** was to put more effort into aquaculture development. In this period, there was a decrease in marine production, due mainly to the oil crisis. At the end of 1976, marine production was 1.7 million t.

The **Fourth Plan (1977 - 81)** still called for an expansion of coastal aquaculture, but the conservation of natural resources and the environment were the major concerns. Several regulations were promulgated to preserve and conserve marine fisheries resources, including the provision of more patrol boats to implement conservation regulations. By this time, the pelagic fisheries were also developed. There was a slight increase of total marine production to 2.0 million t. Under the **Fifth Plan (1982 - 86)**, one objective was to increase fish production by about 5.5%•$year^{-1}$. To reach the target, fisheries joint ventures were negotiated with neighbouring countries. In this period, the highest actual production was 2.1 million t, used to meet domestic consumption and to export. The preservation and sustainable management of the fisheries and environment were addressed by regulating and prohibiting fishing in spawning and nursery grounds for specific periods.

Besides the fisheries development policies, one factor that also had a significant influence on the trends in marine production was the increasing number of trawlers. The light-luring fishing gear introduced to pelagic fisheries, which can attract various species including squid, white shrimp and even marine animals, also increased in number. Moreover, there was an increase in medium and large size purse seiners equipped with radar, fish-finders, wireless equipment and refrigeration and freezing technology. Searching and detecting fish schools improved with the increasing use of echo sounders and sonar. Fish processing was developed and improved to produce high quality products for export. The establishment of the Exclusive Economic Zones (EEZs) by neighbouring countries has deprived the Thai marine fisheries of about 300 000 $miles^2$ of fishing grounds. In response, the government has promoted joint fisheries ventures with several countries including Oman, Saudi Arabia, Somalia, Indonesia, India, Bangladesh and Australia.

The rapid increase of marine fisheries production over the last three decades has been due to the development of fishing technology, resulting in several demersal and pelagic fishes as well as invertebrates being heavily exploited, with catches almost higher than the estimated maximum sustainable yields (MSYs). Conflicts between commercial fisheries and small scale fisheries often occur. The heavy exploitation of marine resources has now resulted in declining production.

In the **Sixth Plan (1987 - 91)**, the fisheries policy aimed to maintain marine fisheries production at 1.9 million t and to continue increasing aquaculture production by increasing cultured species other than shrimp (e.g. grouper, white snapper and red snapper). Fish handling was also developed and improved. Trash fish processing was introduced. The **Seventh Plan (1992 - 96)** objectives and policy were to put more effort into developing small scale fisheries, since the small scale fisheries contributed only 13% of total marine production but accounted for about 90% of households engaged in fishing. Increasing the income and improving the quality of life of fishers were the main objectives. The management interventions were to provide aid for the villages such as fishing piers, artificial reef installations to provide fish shelters, spawning areas and feeding areas, and to introduce non-destructive fishing gear to catch a sustainable yield. For large scale or commercial fisheries, the objective was to maintain the marine fisheries production in the EEZ at the level of 1.7 million t. Controlling access to fishery resources needed to be addressed urgently in view of the over-exploitation of many fish stocks and the over-capacity of the large scale distant water fishing fleet.

Eighth National Economic and Social Development Plan (1997 - 2001) sets the following objectives:

- To foster and develop the potentials of all Thais, in terms of health, physical well-being, intellect, vocational skills and ability to adapt to changing social and economic conditions.
- To develop a stable society, strengthen family and community, support human development, improve quality of life and promote increasing community participation in national development.
- To promote stable and sustainable economic growth and to empower the people to play a greater role in the development process and receive a fair share of the benefits of growth.
- To utilize, preserve and rehabilitate the environment and natural resources in such a way that they can play a major role in economic and social development and contribute to a better quality of life for the Thai people.
- To reform the system of public administration so as to allow greater participation of non-government organizations, the private sector, communities and the general public in the process of national development.

With regard to agriculture and natural resources, the main targets of the Eighth Plan were to preserve and rehabilitate forest areas to cover no less than 25% of the country, including no less than 1 600 km^2 of mangrove forest by the last year of the Plan, increase awareness of sustainable alternative agricultural methods, increase opportunities for their application, and promote investment in the rehabilitation and protection of urban and rural environments.

The plan called for natural resources and environmental management, including directions for conserving and rehabilitating natural resources that would promote balance in the ecosystem; maintaining and upgrading environmental conditions to enhance quality of life and to provide an enduring resource base to support development; improving management systems for natural resources and the environment in order to ensure proper supervision, efficient utilization, and fair distribution of benefits to the community and society; and management guidelines for the prevention and relief of natural disasters.

In addition, the plan supported the promotion of popular participation in natural resource and environmental management by providing legal guarantees of the right of local communities and small fishers to participate in coastal resource management, as well as the conservation, rehabilitation and maintenance of mangrove forests, sea grass and coral reefs, to ensure sustainable use of coastal resources, especially those related to the fishing industry. The plan advocated legislation to prohibit methods destructive to coastal ecosystems, particularly the use of push nets and trawls, and fishers encouraged to switch to more sustainable methods.

The Fisheries Development Plan (1997 - 2001) had four main themes as follows:

i. Fishery policy in Thai waters
   Deals with the problems of over-exploitation of fishery resources, conflicts among resources users, and over-capitalization. The objectives of this policy are to manage fisheries resources effectively, to obtain a maximum sustainable production of 1.73 million t a year from Thai waters, and to improve the fishers' quality of life. It also aims to reduce the uneconomic use of fisheries resources by at least 100 000 $t{\cdot}year^{-1}$

ii. Overseas fishery policy
Deals with the promotion and development of sound and stable overseas fisheries, both on the high sea and in joint venture fisheries with other coastal states. It aims to expand fishing grounds for the Thai distant water fishing fleet and to increase fish production for domestic fish processing industries. It is expected that the production from overseas fisheries will reach a minimum level of 1.8 million t annually. Main strategies of this policy include promoting and encouraging cooperation among fishers, especially the large scale commercial fishers, increasing their negotiating power, providing deep sea fishing technological transfer, and increasing fishers' knowledge of law and regulations practiced internationally and in the joint-venture states.

iii. Aquaculture policy
Includes that of freshwater, brackish water and mariculture. It tries to overcome environmental and technical problems in aquaculture. It aims to increase production from aquaculture and to increase fish farmer household income through cost-effective farm management techniques. Improvement of processing to meet international standards is implemented. The environment in farm areas is monitored.

iv. Fishery industry policy
Aims to alleviate the marketing problems and to overcome technical and environmental barriers in international trade. Accordingly, post-harvest quality must be standardized and controlled to meet market requirements that vary from market to market. The policy aim was to develop the domestic market for fishery commodities and increase annual fish consumption for the Thai people from 28 kg·capita^{-1} to 30 kg·capita^{-1} by the end of the 8th Plan.

The National Fisheries Development Plan (2002 - 2006) under the ninth National Economic and Social Development Plan (2002 - 2006) has five main policies as follows:

i. The agricultural farmer and related organization development policy
This deals with the promotion of fishers at all levels, promotion of learning processes, and strengthening the capability in business at all fishery levels.

ii. The fisheries and environment management policy
Aims to bring the Fisheries Act 1947 up to date and to enforce it effectively, to control excessive fishing effort, to strengthen public awareness of natural resource conservation, to promote participation in fishery management at all levels, to rehabilitate fishing grounds with regard to provincial zones, to strengthen conservation of bio-diversity with regard to international agreements and to strengthen institutional resources.

iii. The aquaculture development policy
Aims to develop aquaculture in terms of quality for local consumption and export, promote research and develop bio-technology, improve shrimp culture sustainability, develop aquarium fish and aquarium plants for export.

iv. The deep sea fishery development policy
Deals with the collaboration between Thai fishery agencies and foreign countries, the development of facilities for deep sea fish landing and transportation, and deep sea fisheries management and administration.

v. The development of industrial fishing and fishery related policy aims to provide good quality raw products to meet demand, to promote and develop processing of fishery products to a high standard, to increase market share and expand into new foreign markets, to develop medium- and small scale fishery industries, and to reform fishery organization.

Coastal Zone - Resources, Policies and Laws

Mangroves

In the past, mangroves were used for many purposes, but to a limited extent. However, with recent rapid economic development, mangroves have been destroyed by forest concessions, shrimp farming, mining, urbanization and other developments (Platong and Sitthirach 1997). Before 1961, the Royal Forestry Department permitted logging in mangroves through a concession system. In 1968, the system was changed to a long term concession of 15 years, and the Royal Forestry Department stipulated that the concessionaires should restore the remaining areas at their own expense. Clear felling in alternate stripes was introduced under the 15-year concessions. The concessionaires have not operated according to the rules. In most cases, the entire concession area has been logged. Widespread destruction occurred first in the 1960s and early 1970s for infrastructure development, in the late 1970s till mid 1980s for extensive shrimp farming, and since 1986 for intensive shrimp farming. Mangrove concessions throughout the country are presently cancelled.

Coral Reefs

Coral reefs in Thailand covering 12 000 km^2, are the third largest in Southeast Asia and with over 300 species, rank among the world's top ten reef sites in terms of beauty and diversity. They are most abundant on the Andaman coast, where two sites near Similan and Surin islands occur at about 30 m depth. In a number of areas, particularly in the Gulf of Thailand, coral reefs have been damaged by pollution, destructive fishing (e.g. using dynamite), navigation (anchor dropping, oil spillage) and tourism (Kaosa-ard and Pednekar 1998).

The Office of Environmental Policy and Planning in cooperation with concerned agencies drafted a National Coral Reef Strategy. The strategy aims to reduce conflicting uses of reefs and to promote development in harmony with conservation. The strategy was approved by a cabinet resolution on 3 March 1992. The implementation included the Phuket Coastal Resource Management Project, which was a pilot effort (Pintukanok 1997).

The Corals Management Project of the Department of Fisheries covers surveying, studying and mapping coral areas along the coastal zone, both in the Gulf and Andaman coasts.

Endangered Wildlife

Thailand has issued several Ministerial Notifications since 1974 and passed the Wildlife Reservation and Protection Act in 1992 to ensure protection of endangered species such as marine mammals (dolphin, dugong) and sea turtles.

Fishery Investment Policies

In Thailand, the Board of Investment (BOI) has been established to provide support for investment through the granting of privileges, following agreements with the World Trade Organization. At present the emphasis is on diversification of investment to the provinces. The majority of privileges are tax measures, viz., the exemption of corporate income tax.

External Policies Affecting Fisheries

General Land Use

A number of changes have occurred in coastal land use during the past three to four decades. These include human settlements and urban expansion, infrastructure development, particularly access roads and other modes of communication, tourism and industry development, agriculture, and tree plantations, and not least, coastal aquaculture. The severity of land use change is clearly evident in the change in mangrove forest cover which has been reduced to less than half of what existed before the early 1960s, and in land dereliction following shrimp pond failures in a number of coastal provinces. Land rights are one of the most complicated and political sensitive issues in Thailand. Like their inland counterparts, coastal communities in many places often do not have adequate land rights (Kaosa-ard and Pednekar 1998).

Pollution and Environmental Protection

Land use changes in the coastal areas, as well as increased agricultural and industrial activities and urbanization, have created hydrological changes and pollution from waste and sediments entering the sea. These loads are significant in the Gulf of Thailand, which receives freshwater flow from some of Thailand's major rivers, the Chao Phraya and the Mae Klong, which bring agricultural, urban and industrial waste from Thailand's central, northern and western regions. Owing to the lack of proper sanitary systems for cities and towns, urban waste and drainage water cause serious problems for river water quality (Kaosa-ard and Pednekar 1998). Generally, the seawater quality is within the pollution limits set by the Pollution Control Department (PCD), barring a few exceptions such as areas with high population or intense economic activity. This is true of a number of tourism sites such as Pattaya, Hua Hin, and the island of Ko Samet, and industrial areas such as Samut Prakarn, Rayong and Chonburi Provinces. Some improvements have occurred in coastal water quality in these areas following public outcry and pollution control campaigns (Hua Hin and Cha-am in Prachuap Khiri Khan and Petchaburi Provinces respectively, for example, were declared pollution control zones in 1997 by the Pollution Control Department). Further improvements are expected as drainage water treatment plants are planned in some high pollution risk areas.

In 1975, the Enhancement and Conservation of National Environment Quality Act was promulgated by the Government, under which the Office of the National Environmental Board was established within the Office of the Prime Minister. This Act was strengthened in 1992, and the National Environmental Board was transferred to the Ministry of

Science, Technology and Energy and upgraded. This Office develops environmental policies, which are implemented by various operating agencies (Menasveta 1997).

There are a number of laws concerning environmental matters in Thailand including water management, the control of animal and plant introductions, wildlife conservation, forest protection, and the creation of national parks and reserves. Thailand also has legislation on environmental impact assessment of development projects and the control of pollution and toxic chemicals.

International and Regional Conventions

Foreign Trade Law - Restrictions and Demands

Regional cooperation is needed to solve the issues for sustainable fisheries development. Some of the policy areas are as follows:

- Joint research to find fishing areas within ASEAN waters and biological and ecological studies on species, gear, fleet areas, units of exploitation, stock assessment and management.
- Investigation of management schemes for shared stocks of ASEAN countries (quotas or other methods).
- Establishment of joint ventures among the ASEAN countries, including fishing facilities and infrastructure.

To achieve these policies the Department of Fisheries has worked closely with international and regional organizations and with neighbouring countries through bilateral cooperation.

Group 1. International cooperation

a. The Southeast Asian Fisheries Development Center (SEAFDEC)
   The Southeast Asian Development Center was established on 28 December 1967. There are presently eight member countries: Japan, Singapore, Thailand, Malaysia, Philippines, Vietnam, Brunei Darussalam and Myanmar. The purpose of SEAFDEC is to contribute to the promotion of fisheries development in Southeast Asia by mutual-cooperation among the member governments and through collaboration with international organizations and governments external to SEAFDEC. Four departments have been set up in member countries as follows:

- Training Department (TD) hosted by Thailand
- Marine Fisheries Research Department (MFRD) hosted by Singapore
- Aquaculture Department (AQD) hosted by the Philippines
- Marine Fisheries Research Development and Management Department (MFRDMD) hosted by Malaysia

It is planned that more Departments will be set up in Vietnam or elsewhere. As Thailand is the Depository Government of this Agreement, it has functioned as the host country for the Secretariat office of the Center since 1968. Members agree to provide SEAFDEC money, movable and immovable property, and services necessary for the establishment and operation of the Center. Thailand allocated the budget for the construction of the Training Department at Samut Prakan Province and Secretarial Office in the Department of Fisheries.

The government of Japan has allocated the budget annually for technical assistance to all Departments of SEAFDEC. This includes the provision of scientific equipment, material, short and long-term experts, fellowships for the Center's staff to be trained in Japan, procurement of research vessels, cars, etc.

During 30 years of its operation, about 2 800 personnel have completed the study and training courses organized by TD, MFRD and AQD annually. About 500 - 600 Thai trainees have completed SEAFDEC study and training courses annually. ASEAN has appointed SEAFDEC as the technical organization to work closely with with member countries in the ASEAN Sea Turtle Conservation and Protection Program.

b. The Network of Aquaculture Centers in Asia and the Pacific (NACA)
   NACA is an intergovernmental organization established in 1990 with headquarters in Thailand, the host country. NACA has Regional Lead Centers located in Thailand, China and India. NACA originated as a program supported by UNDP during 1980 - 89. At present, there are 14 member countries. Its main objective is to assist members to expand aquaculture development mainly for the purpose of:

- Increasing production
- Improving rural income and employment
- Diversifying farm production
- Increasing foreign exchange earnings and savings

c. The Bay of Bengal Program (BOBP)
BOBP was a multi-agency regional fisheries program covering seven countries around the Bay of Bengal: Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka and Thailand. The Program played a catalytic and consultative role in developing coastal fisheries management in the Bay of Bengal to help improve the conditions of small scale fishing communities in member countries. It was sponsored by the governments of Denmark, Japan, and the United Kingdom, and the International Maritime Organization of the UN. The executing agency was FAO. Member countries contributed financially to support the activities of the program.

d. The Indian Ocean Tuna Commission (IOTC)
This regional body was established in 1996 to undertake conservation of tuna-like species and to promote sustainable and rational utilization of tuna resources in the Indian Ocean. Members of the Commission include coastal states in the Indian Ocean and other states that harvest tuna and tuna-like species in the region. Each member country agreed to contribute annually its share of the budget in accordance with a scale of contributions. Seychelles is the host of the secretariat office of the Commission. Thailand submitted an Instrument of Acceptance to the Director-General of FAO in 1997 and became a member of this Commission.

Thailand is a leading country in canned tuna exports, but nearly 80% of the raw material is imported from tuna fishing nations. Since Phuket province is the landing base of tuna from foreign fishing vessels, Thai fishers there have become keenly interested in tuna fishing. However, they lack technology as well as the capital needed. The Department of Fisheries approved the participation of M.V. Mahidol in a pilot project for tuna fishing. This is a collaborative project between public and private sectors operating in the Indian Ocean. About 111 fishers were invited to participate in on-the-job training. The fishers gained experience in preparing floating logs, detecting tuna schools, gear operation and other aspects of tuna fishing. This led to the establishment of Thai Tuna Cooperatives in Phuket Province.

e. The Asia-Pacific Fishery Commission (APFIC)
The Agreement establishing the Indo-Pacific Fisheries Council (IPFC) came into force on 9 November 1948. Its title was changed to the Asia-Pacific Fishery Commission (APFIC) in 1994 to reflect new functions that enable it to take action directly related to fisheries management and development in its area of responsibility. The Terms of Reference of APFIC are to promote the full and proper utilization of living aquatic resources by development and management of fishing operations and culture techniques and by the development of related processing and marketing activities. Members of the Commission are Australia, Bangladesh, Cambodia, China, France, India, Indonesia, Japan, Republic of Korea, Malaysia, Union of Myanmar, Nepal, New Zealand, Pakistan, Philippines, Sri Lanka, Thailand, United Kingdom, USA and Vietnam.

f. The Marketing Information and Advisory Service for Fish Products in Asia Pacific Region (INFOFISH)
The INFOFISH is an inter-governmental organization servicing the fishing industry of the Asia-Pacific region and beyond. Originally a regional project of FAO, it is hosted by Malaysia and based in Kuala Lumpur. INFOFISH's services include bringing buyers and sellers together. In addition, it organizes exhibitions, conferences, workshops, seminars and training programs and provides consulting services in all aspects of capture fisheries, aquaculture, processing and marketing. Member countries are Maldives, Malaysia, Papua New Guinea, Solomon Islands, Sri Lanka and Thailand.

g. Others
The Department of Fisheries has close collaboration with other regional organizations such as:

- The International Center for Aquatic Resources and Management (ICLARM), now WorldFish Center
- The International Network on Genetics in Aquaculture (INGA)
- International Development Research Center (IDRC)
- Asia-Pacific Economic Cooperation (APEC)
- FAO of the United Nations

The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, the Code of Conduct For Responsible Fisheries of the FAO, the AFTA 2000 (ASEAN Free Trade Area), TRIMs (Trade Related Investment Measures agreed by the WTO member countries) and the UNCTAD, 2000 (the United Nations Conference on Trade and Development) are all considered in formulating Thailand's fisheries policies.

Group 2. Bilateral cooperation

The following projects are some of the cooperation programs that the Department of Fisheries has initiated with other countries/institutions:

a. Memorandum of Understanding between Thailand and the Republic of the Philippines, signed 30 January 1997. Both sides have agreed to strengthen cooperation in the following fields:-

   - Technical exchange on prawn disease prevention and control
   - Technical exchange on fish processing technology
   - Joint fishing ventures

b. Agreement on bilateral cooperation in fisheries between Thailand and Mexico signed on 22 October 1992. The objectives are to strengthen economic relations, and promote scientific and technical cooperation and to support investment and co-investment in fisheries matters, especially in aquaculture, tuna fishing, and tuna canning.

c. Memorandum of Understanding on cooperation in agriculture between Thailand and the People's Republic of China signed on 2 April 1997, to promote scientific and technical cooperation in the field of agriculture on the basis of quality and mutual benefit.

d. Agreement in fisheries cooperation between Peru and Thailand, to further develop economic relations and promote scientific and technological cooperation as well as to support investment in fisheries matters, especially in the field of aquaculture and deep-sea fishing.

National and Sub-national Fisheries Institutions

The Department of Fisheries, Ministry of Agriculture and Co-operatives, is responsible for regulating fishing in the Kingdom of Thailand, whether inland or offshore. The Department is organized into central and provincial administrations.

The central administration has 28 divisions, which have responsibilities as follows:

a. To conduct studies, research and experiments in every field of fisheries as well as to propose measures for responsible fishery development and management. These research activities are undertaken by many divisions e.g. Marine Fisheries Division, Freshwater Fisheries Division, Coastal Aquaculture Division, Fishery Environment Division, Aquatic Animal Health Research Institute and National Aquaculture Genetic Research Institute.

b. To explore, analyze and research fishing grounds beyond Thai waters. The responsible organizations are Ocean Fisheries Division, Foreign Fisheries Affairs Division and Marine Fisheries Division.

c. To promote and develop all occupations relating to fisheries. The organizations concerned are the Fisheries Economic Division, Fisheries Engineering Division, Fishery Extension Division and Training Division.

d. To implement the various fisheries Acts and measures. This is the task of the Fisheries Resource Conservation Division, Foreign Fisheries Affairs Division and Provincial Fisheries Offices.

The provincial administration has 76 provincial fisheries offices. They are located in every province of the country, and are responsible for conservation, control of fisheries resources, collecting of taxes and fishing fees, providing information on fisheries conservation, professional promotion and extension, and providing guidance and services to fishery employees.

Other Institutions Involved in Fisheries and Coastal Zone Management (Structure & Mandate)

Other government institutions involved in fisheries and coastal zone management include:

- The Royal Forestry Department (RFD), Ministry of Agriculture and Cooperatives. This agency is responsible for managing mangrove forests and marine parks. The RFD implements the National Park Act, the Forest Reserve Act, and the Wild Animals Conservation and Protection Act. These legislative acts enable the RFD to declare specific coastal areas as protected areas. Several coastal areas and beaches have been designated as National Parks under the National Park Act.
- The Department of Cooperatives Promotion, Ministry of Agriculture and Cooperatives, which handles the registration of fishery cooperatives.
- The Harbour Department, Ministry of Transportation and Communications, which handles the registration of fishing boats. The primary function of the Department is to maintain the navigability of the waterways, which include rivers, canals, lakes and ponds that are open to the public, as well as the maritime areas under national jurisdiction.
- The Fish Marketing Organization provides landing piers, auction halls, soft loans, transportation, statistical records and other facilities.
- The Office of Environmental Policy and Planning, Ministry of Science, Technology and Environment, whose main function is the preparation of policies on natural resources, environmental management and conservation.
- Private sector groups that work towards the protection and conservation of natural resources and the environment include foundations, association non-government organizations (NGOs) and people's organizations (POs). These organizations have the following objectives:

  i. Create awareness in the local community of the sustainable management of coastal resources.
  ii. Build up and strengthen local capacity in the conservation and rehabilitation of coastal resources.
  iii. Encourage coordination among local communities, local government agencies, and NGOs.

Financing Institutions Relevant to Fisheries Activities

The Marine Fishery Census in 1995 revealed that about 45.4% of the fishing households are in debt. Loans come from various sources such as the government, the bank for agriculture and agricultural cooperatives, commercial banks and middlemen in villages (Table 6). Over two-fifths of fishing households in debt owed the middlemen in villages. The fishers usually get money or equipment from the middlemen and usually sell their catches to them.

Table 6. Household loans in marine capture fisheries.

Source of fishery loan	Marine capture fishery: No. of households	Marine capture fishery: %
Total	53 112	100.0
Without debt	29 024	54.6
With debt	24 088	45.4
- Government agency	886	
- Bank for Agriculture and Cooperatives	4 984	
- Commercial bank	2 442	
- Middleman	10 500	
- Money lender	4 041	
- Relatives or friends	5 417	
- Others	724	

Source: National Statistical Office and Department of Fisheries 1995.

Research and Training Facilities and Opportunities

Since Thailand has been regarded as a developed country in the last decade, training or research facilities from several donors have been withdrawn. There are still some training opportunities from SEAFDEC and other donor agencies. The collaborative programs between the Thai government and the Japanese government (Japan Society for the Promotion of Science and Mabusho) are still running.

Coastal Fisheries in Focus

Structural Aspects

The marine capture sector can be divided into commercial and small- scale fisheries. The small scale fisheries are defined as those with small boats of less than 12 m LOA (overall length), with or without engine and mostly operated in shallow water. The commercial sector is defined as that with boats of LOA more than 12 m, or more than 10 gross tons (GT), modern fishing gear and operating offshore for several days. They typically land at large ports; some have refrigerators to preserve their catches.

During the period 1985 to 1995, the structure of the marine capture sector changed, the total number of fishing boats decreased by 2%. The number of small scale fishing boats decreased by 3.4% while the number of commercial fishing boats increased by 7.0%. The creation of a boat-tenure system within the commercial sector and the strengthening of the small scale sector according to the 8^{th} National Economic and Social Development Plan (1997 - 2001) resulted in the total number of fishing boats increasing by 4.5%; the small scale fishing boats increasing by 6.5% and the commercial boats decreasing by 7.5% (National Statistical Office 1998; Department of Fisheries 1999; Boonchuwong and Dechboon 2000). Registered fishing boats then numbered 18 182, comprising 49% trawlers, 26% gillnetters, 8% purse seiners, 5% push netters and 12% small scale boats. About 75% of registered boats operated within the EEZ and 25% operated outside Thai waters (Department of Fisheries 1997).

Total marine production for 1996 was 3.112 million t, comprising marine capture (90.3%) and coastal aquaculture (9.7%) production. About 69.7% of the marine catch was caught in the Gulf of Thailand and 30.4% in the Andaman Sea. The catch composition was food fish 47.0%, trash fish 27.8%, shrimp 12.0%, cephalopods 5.6%, and the remaining 7.6% were crab, jellyfish and shellfish (Department of Fisheries 1997).

Capture Methods/techniques (by sector)

The small scale sector conduct fishing about 5 km from the shoreline in one-night operations. The fish are landed at the village and sold directly by the owner's wife. The gear employed are gillnets (fish, shrimp, crab, etc), lift nets, traps, falling nets, entangling nets, set nets, set bag nets, hook-and-line etc. Some use lights to lure the fish, e.g. falling-net and lift net to catch anchovy.

The commercial sector boats include trawlers, purse seiners, push netters and short-necked clam dredgers. The catch is landed at fishing piers and sold by fish agents. Trash fish catch is landed at fish-meal plants separately. The boats are usually well equipped, with echo-sounder or sonar for purse-seine, several crew members and voyages last several days. Lures such as lights or coconut leaves may be used to lure the fish. Trawlers almost all use otter-boards to stretch the net. Pair trawls are also used. Some trawlers use both otter-board and boom to catch shrimp; they catch fish in daytime and catch shrimp at night by changing their nets. The mesh size used is 2.5 cm for cod-end mesh and for shrimp nets the mesh size is 1.5 cm. The fishing grounds of purse seiners are usually in deeper zones, near the middle and southern parts of the gulf.

Catch and Catch Rates

The total production of the Gulf during 1971 to 1995 showed an increasing trend. The production of trash fish and demersal fish combined was between 500 000 and 1 000 000 t. Recently the production of trash fish has decreased slightly, whereas demersal fish have shown the opposite trend (Fig. 3). The overall increase in production came from pelagic fish production. From 1982 onwards, the pelagic fish catch increased substantially due to improved methods using light lures to catch schooling fish, especially anchovy which accounted for 120 000 t in 1995 (Supongpan et al. 2000).

Decreasing Catch Rates

From 1966 to 1996, a monthly survey by research vessel to measure catch rates of demersal resources was conducted by the Marine Fisheries Division. More than 700 fixed grid stations in the Gulf of Thailand were monitored. In 1966, the catch rate was 172.9 $kg \cdot hr^{-1}$. A catch rate of over 300 $kg \cdot hr^{-1}$ had been reported in 1961. The cod-end mesh size used to be 4 cm but in 1971, an additional net with 2.5 cm mesh was applied to the cod-end so that the cod-end mesh size used for surveying was the same as that used by fishermen. This modified method has been carried out up to now, although the number of stations has been reduced due to budget limits. The results showed the catch rate in the period

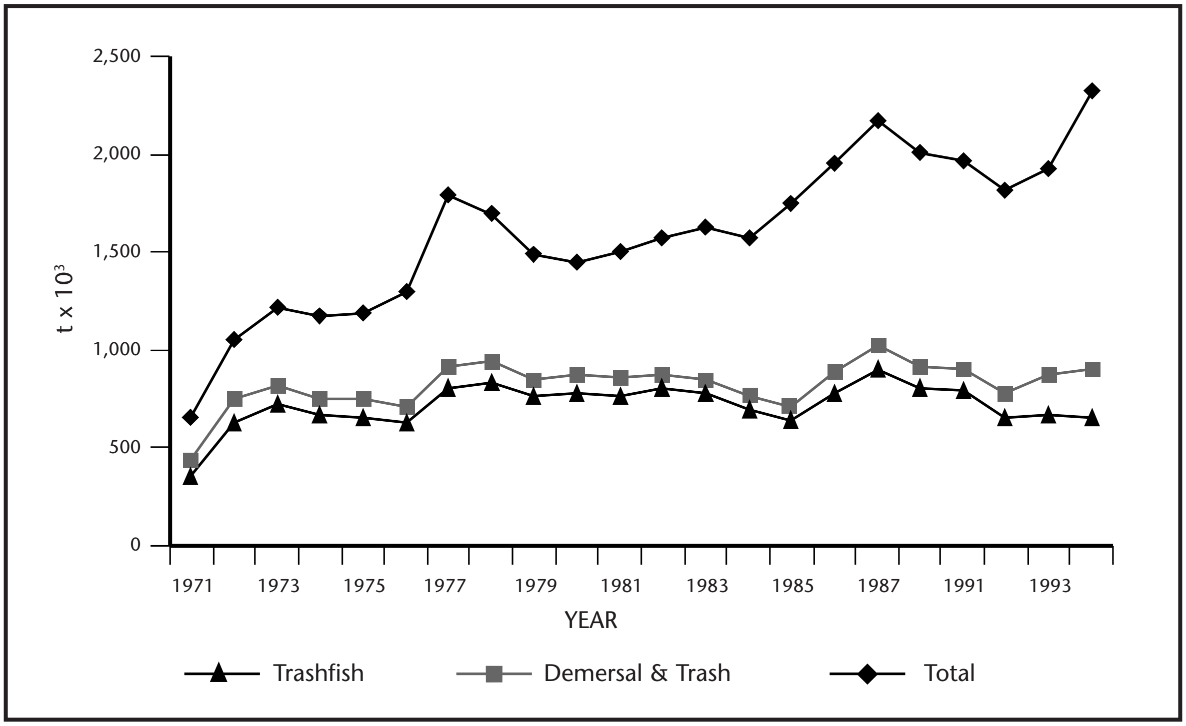

Fig. 3. Total production, demersal fish and trash fish combined and trash fish production in the Gulf of Thailand between 1971 and 1995.

1966 to 1976 declined from 172.9 kg•hr^{-1} to 75.14 kg•hr^{-1}. During this period there was a petrol crisis, in 1973 and 1975, resulting in a temporary suspension of fishing by some trawlers. The catch rates at this time fluctuated between 60 and 80 kg•hr^{-1}, indicating that when fishing stopped for a while, the resources may have recovered slightly (Fig. 4).

The catch rate has continuously decreased since the trawl was introduced into Thailand, from 172.94 kg•hr^{-1} in 1966 to 17.9 kg•hr^{-1} in 1998 (National Seminar 1999). It is likely that the catch rate may drop to near zero if there is no proper management. The Department of Fisheries has issued many management measures to control the fish resources, but it is difficult to enforce the regulations because there are socioeconomic impacts and political interventions.

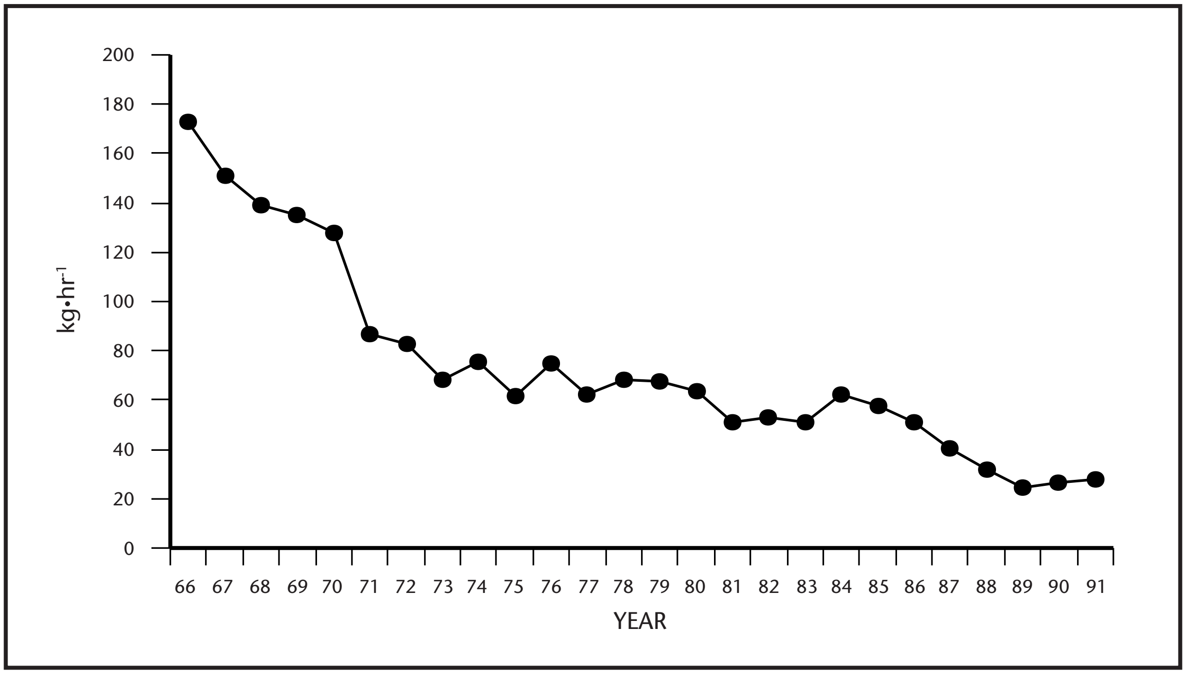

Fig. 4. The catch rates (CPUEs) of total catches and trash fish in the Gulf of Thailand during 1966 to 1991 of Research Vessels Pramong 2 and 9 (National Seminar 1999).

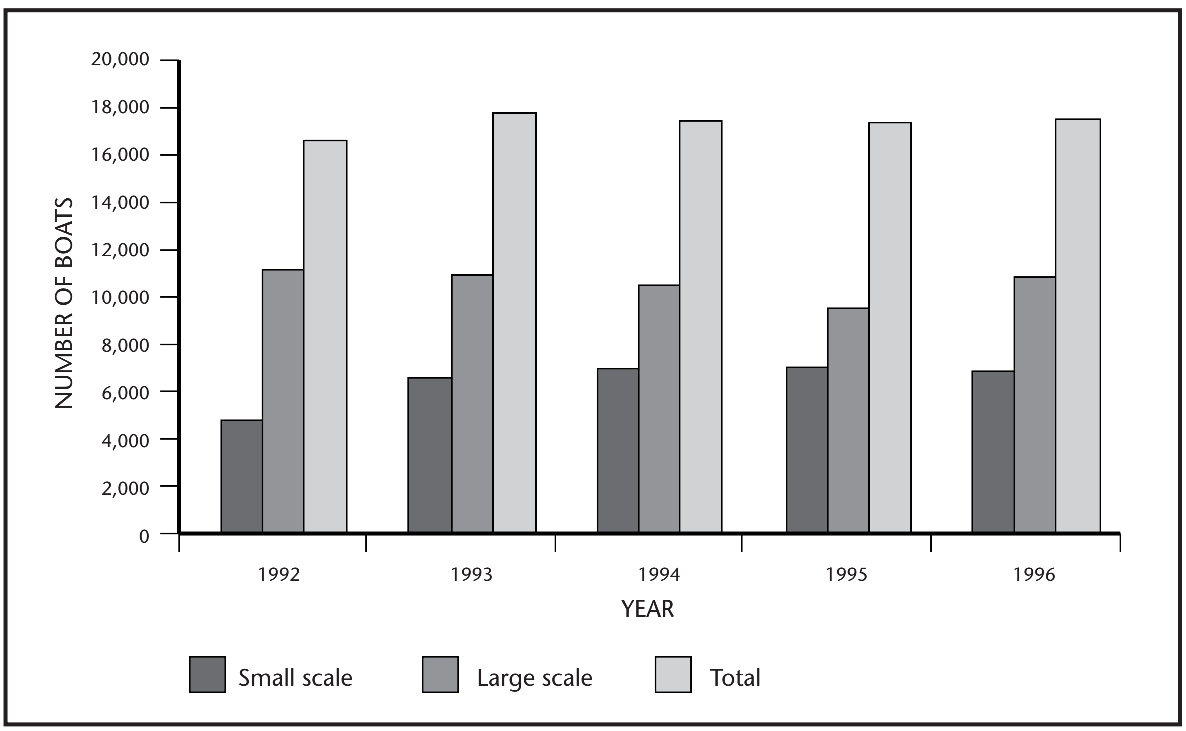

Fig. 5. Registered fishing boats categorized into small scale fishing boats and large scale or commercial fishing boats in Thailand, 1992 - 96.

Number of Fishing Boats

Otter-board trawlers dominated (6 000 to 7 500) from 1992 to 1996 pair trawlers were fewer, and the others gear numbered less than 1 000 (Fig. 6). Squid cast-net, shrimp gillnet and crab gillnet numbered more than other gear in the small scale fisheries sector (Fig. 7).

Catch Composition of Commercial Fisheries

Species composition and volume of catches are different according to type of fishing gear, and the proportion of fish harvested with similar gear further differs according to boat size. The monthly catch of otter trawls is 8 027 - 39 593 t. Most are trash fish, about 45.4 - 62.5% of the total catch. Edible fish comprise between 14.4 - 29.1% of the total. Small otter trawls (< 14 m) harvest shrimp, making up 31.8 % of the total catch. Average catch per month of pair-trawls for all boat sizes varies between 25 316 - 57 921 t. The catch proportion is completely different among size categories (< 14 m, 14 - 18 m, 18 - 25 m). Medium and large pair-trawlers have similar catch ratios of edible fish, trash fish and cephalopods, 18.1 - 24.3%, 51.5 - 59.0% and 10.9 - 18.2% respectively. Average catch per month of beam-trawls of both sizes varies between 817 - 4 157 t. Although shrimp was caught in higher ratios by beam-trawls, they are mostly small shrimp and hence get lower prices. Medium beam trawls can also catch large quantities of cephalopods, 27% of the total catch. Finally, all sizes of push nets have similar ratios of catch, i.e. edible fish, trash fish, shrimp and cephalopods of 6.5 - 8.4%, 54.5 - 60.7%, 16.5 - 21.3% and 3.1 - 5.2%, respectively

Catches from purse-seines and gillnet consist mainly of edible fish, between 31.0 - 80.0% of the total catch. Catch by purse seine is between 36 760 - 55 351 t$\cdot$month^{-1}. Most of the catch is economic pelagic species, i.e. Indo-Pacific mackerel and sardines. King mackerel gillnet can catch high quality fish of similar size to that of other gear with

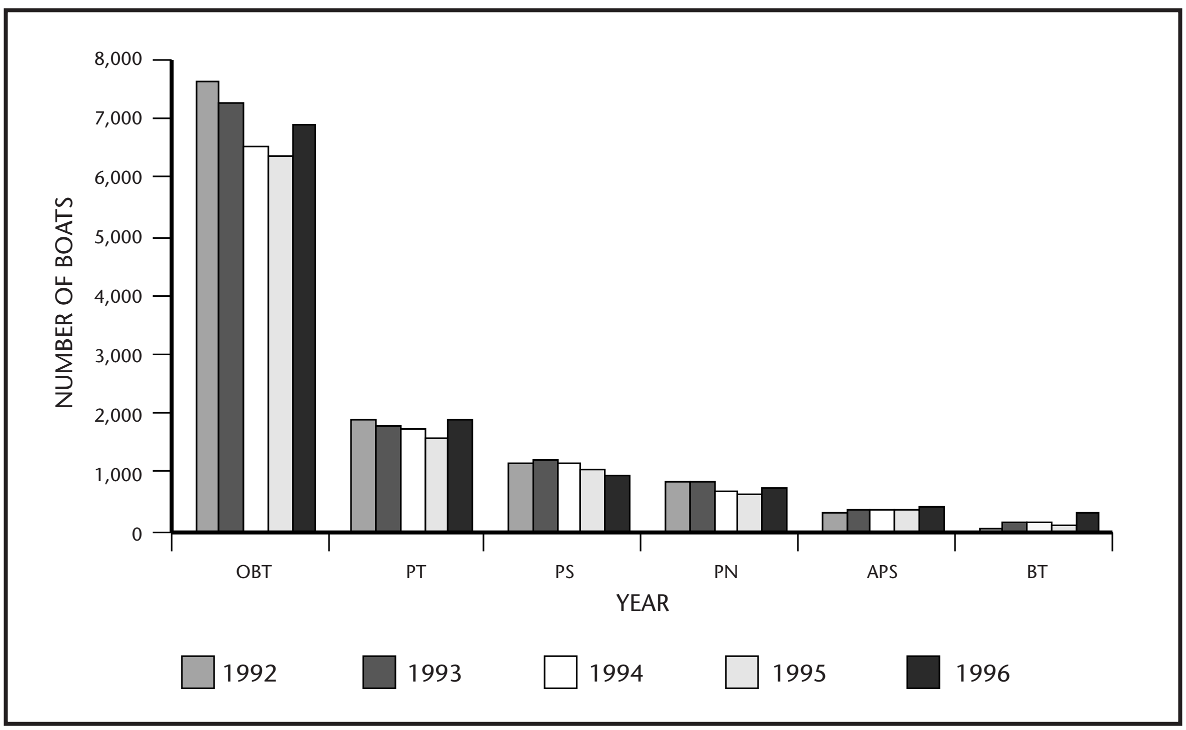

Fig. 6. Registered commercial fishing boats in of Thailand, 1992 - 96.
Note: OBT = Otter-board trawlers, PT = Pair-trawlers, PS = Purse seiners, PN = Push netters, APS = Anchovy Purse seiners, BT = Beam trawlers.

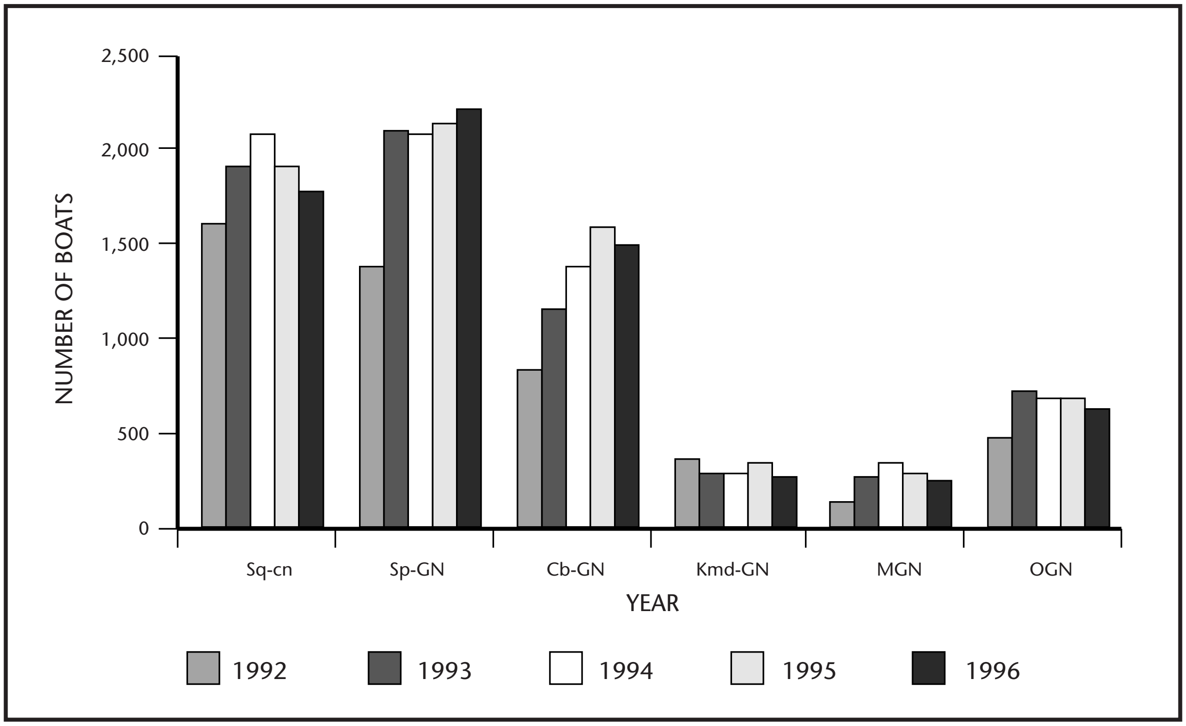

Fig. 7. Registered small scale fishing boats of Thailand, 1992 - 96.
Note: Sq-cn = Squid cast-netters, , Cb-GN =crab gillnetters, MGN = Mackerel gillnetters, Sp-GN = Shrimps gillnetters, kmd-GN = King mackerel drift gillnetters, OGN = Other gillnetters.

an average price of Baht 38 - 41 per kg, while the average price of other fish caught by purse-seines is 7 - 10 Baht•kg^{-1}. Major pelagic fish caught are king mackerel and little tunas.

Catch Composition Trends of Research Vessels

The catch composition trend from research vessels showed somewhat different results. At an initial stage of the fishery development, the demersal fish formed more than 60% of the total catch, while from 1973 to 1992, the ratio was almost stagnant at 30 - 40%. At the end of the period, demersal fish showed a slight downward trend (Fig. 8). These were in contrast to trash fish trends. Trash fish formed 20 - 30% of the catch during 1966 to 1973. From 1974 to 1983, the ratio was 30 - 40% of the total, whereas during 1985 - 86 and 1991 - 96 the ratio was more than 40%.

Economics of Coastal Capture Fisheries

The study by Boonchuwong and Dechboon (this volume) examined the small scale and commer -cial fishing fleets, costs-earnings and profitability, discards and by-catch. They found that there was considerable room for maintaining the small scale fishing fleets due to their contributions to employment and fish production. The profit was greater from larger boats. The larger boats have the ability to adjust to both economic and fishing ground changes. Among trawlers, medium and large boats could best adjust and maintain continuous profits, while push netters of all sizes were declining in net profit. In the case of pelagic fisheries, purse seiners make higher profits and yield higher returns than trawlers and gillnetters. Pelagic fisheries give higher returns to crew-labor and daily wages higher than the national minimum wage.

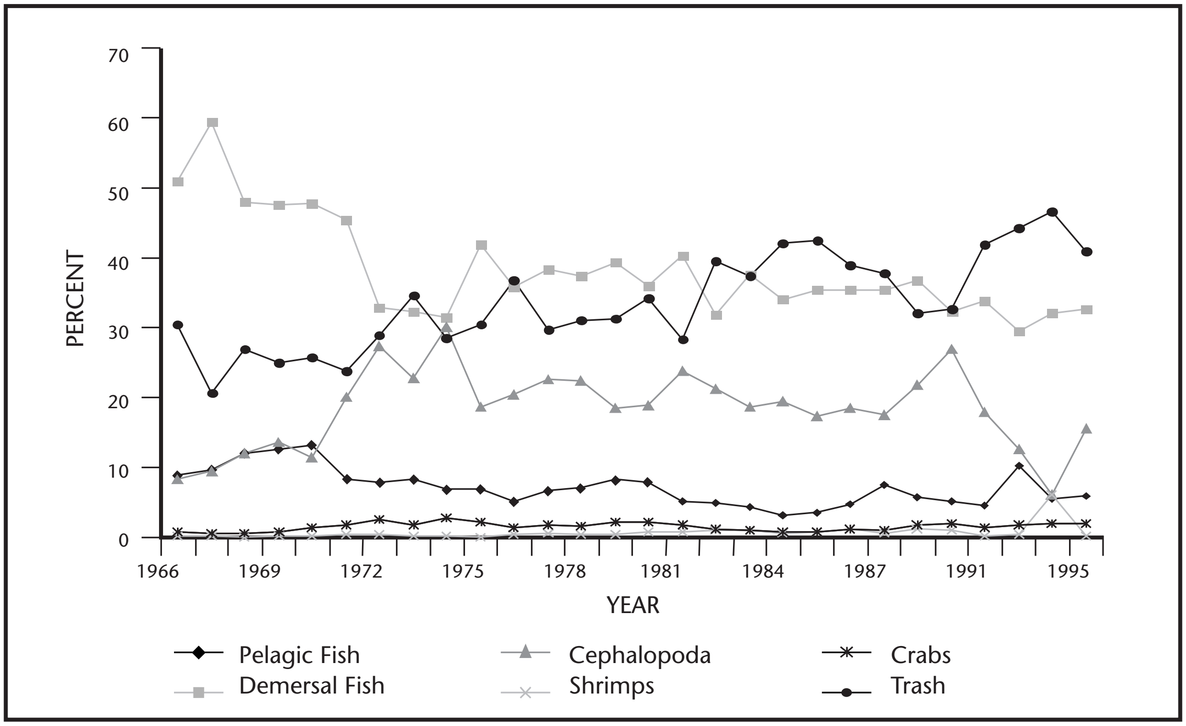

Fig. 8. The percentage species composition of demersal fish and trash fish, caught by research vessels RV Pramong 2 & 9.

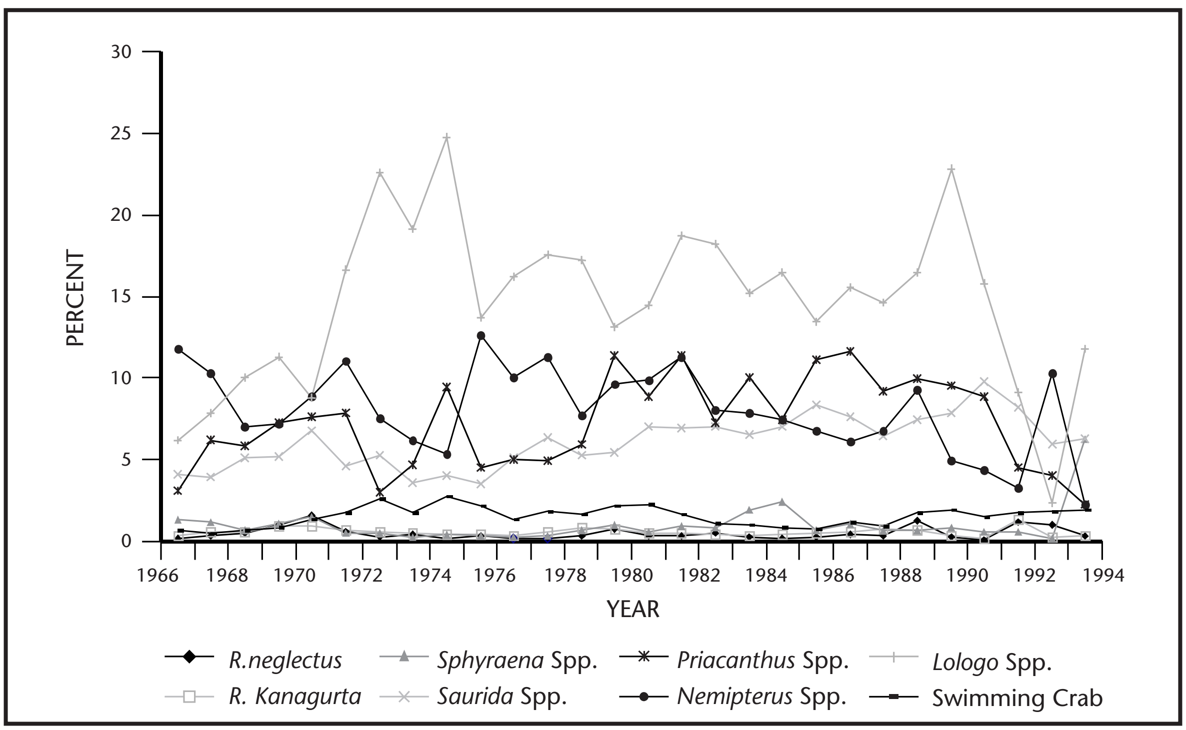

Fig. 9. The percentage species composition of demersal groups, caught by research vessels RV Pramong 2 & 9.

Disposition and Value of Catch

Marine capture fishing operations are managed by various entities as shown in Table 7. More than 90% are operated by fishing households.

Value of Catch

Figure 10 shows the quantity and value of catches from 1987 to 1999. From 1994 to 1999, marine catches in Thai waters showed a decreasing trend. In contrast the value of outside Thai waters increased.

Cost and Return

Costs, Earnings and Profitability of Small Scale Fishing Operations

Boonchuwong and Dechboon (this volume) studied small scale fishing households in Songkla Province, Southern Thailand in 1999. The major fisheries in 6 villages were selected (shrimp gillnet, cuttlefish trammel net, Indo-Pacific mackerel gillnet, other gillnet, and Acetes spp. trawl net fisheries). The fishing boats were long tail engine boats with LOA less than 10 m and less than 10 HP. Fishing labor was usually 1 or 2 family persons. Often only one type of gear was used; two, three or four types of gears in combination could be used when the target species were abundant. Single gear groups averaged a total cost of Baht 36 000 - 99 000•year^{-1} whereas two-gear combinations ranged from Baht 121 000 - 241 000•year^{-1}. Three-gear combinations averaged Baht 197 000•year^{-1} whereas four-gear combined operations averaged Baht 232 162•year$^{-1.}$

The investment range was Baht 63 000 to 201 000 •year^{-1} with variable costs of 65 - 71% of the total cost of a single gear type. The fixed costs were 28.9% for shrimp gillnets, 35.0% for cuttlefish trammel-nets, and 31.9% for Indo-pacific mackerel gillnets. The revenue ranged from Baht 257 000 to 330 000•year^{-1} for catching cuttlefish and Indo-Pacific mackerel in combination and shrimp gillnet respectively. Single gear operations gained lower profits. Cuttlefish and Indo-Pacific mackerel fishing gear gained Baht 90 000•year^{-1}. Shrimp and Indo-Pacific mackerel gained Baht 41 000 to 49 000 •year^{-1}. The lowest profit gear were 'other gear' and the shrimp-cuttlefish-Indo-Pacific-other gear combination, that amounted to Baht 20 000 to 25 000 •year^{-1}. The return to labor ranged from Baht 266 to 272•man-day^{-1} although shrimp operations gave the lowest return to labor - Baht 146•man-day^{-1}.

Costs, Earnings and Profitability of Commercial Fishing Operations

Boonchuwong and Dechbon (this volume) examined the six major commercial fishing gear operations in Thai waters the production of which accounted for approximately 75% of total marine catches. The sampled boats were categorized into LOA < 14 m (small), 14 - 18 m (medium), 18 - 25 m (large).

The study of cost structure showed that variable costs ranged from 74 to 89% and fixed costs ranged from 7 to 27%. Trawls and push nets had high fuel and oil expenses, about 32 - 51% of the total costs. Variable costs of purse seines and gillnets were mainly labor, 27 - 51% of total cost, whilst 16 - 21% was fuel expense.

Sharing System

The sharing systems between crew and boat owner differ according to types and sizes of boats, and can be classified into two systems, namely the fixed wage or salary payment, and the sharing-on-value of products sold systems. Both systems have different risks (including expected profit). The wage or salary payment system gives the crew a definite wage, but they lose the opportunity of sharing a good catch. The sharing-on-value of product sold system means that both crew and boat owner jointly share the risk in catch and fish prices. Fixed wage systems induce less enthusiasm from crew although the benefit sharing system is risky. There is thus a mixed system of part regular wage and part sharing-on-value of catches.

The sharing systems differ according to types and sizes of fishing gear. Most of the small otter-trawls (< 14 m) employed a fixed wage system. The medium and large sizes (14 - 18 m and 18 - 25 m) employed mixed systems. As for pair-trawls, about 50 - 75% employed fixed wages. Most beam-trawls and push nets used sharing systems based on the value of catch. The value for sharing is the net value after deduction of operating expenses (fuel cost, ice, food, fixed wages or salaries and fishing gear repair cost). This net value is divided in a ratio of 70 : 30 between boat owner and crews. Crew share is divided according to rank and responsibility assigned in the boat, the master fisherman receiving the biggest share. If the catches are higher than target, the crew will receive a bonus. Considering

Table 7. Number of marine capture fishery establishments by type of management 1985, 1990 and 1995.

Type of Management	1985	%	1990	%	1995	%
Operators' household	51 087	98.8	47 311	97.7	51 668	97.3
Joint management	590	1.1	1 048	2.2	1 420	2.7
Company and juristic partnership	25	0.1	44	0.1	24	0.05
All types of management	51 702	100	48 403	100	53 112	100

Source: National Statistical Office 1997.

Table 8. Marine capture fishery purchases in 1985, 1990 and 1995.

Type of Management	1985	%	1990	%	1995	%
Without sale	3 579	6.9	1 774	3.7	1 570	3.0
With sale	48 123	93.1	46 629	96.3	51 542	97.0
Consumer	4 707		4 535		5 172	
Retailer	7 065		8 788		6 620	
Middleman	35 524		31 868		38 207	
Fish processor	780		1 438		1 469	
Other	47				74	

Source: National Statistical Office 1997.

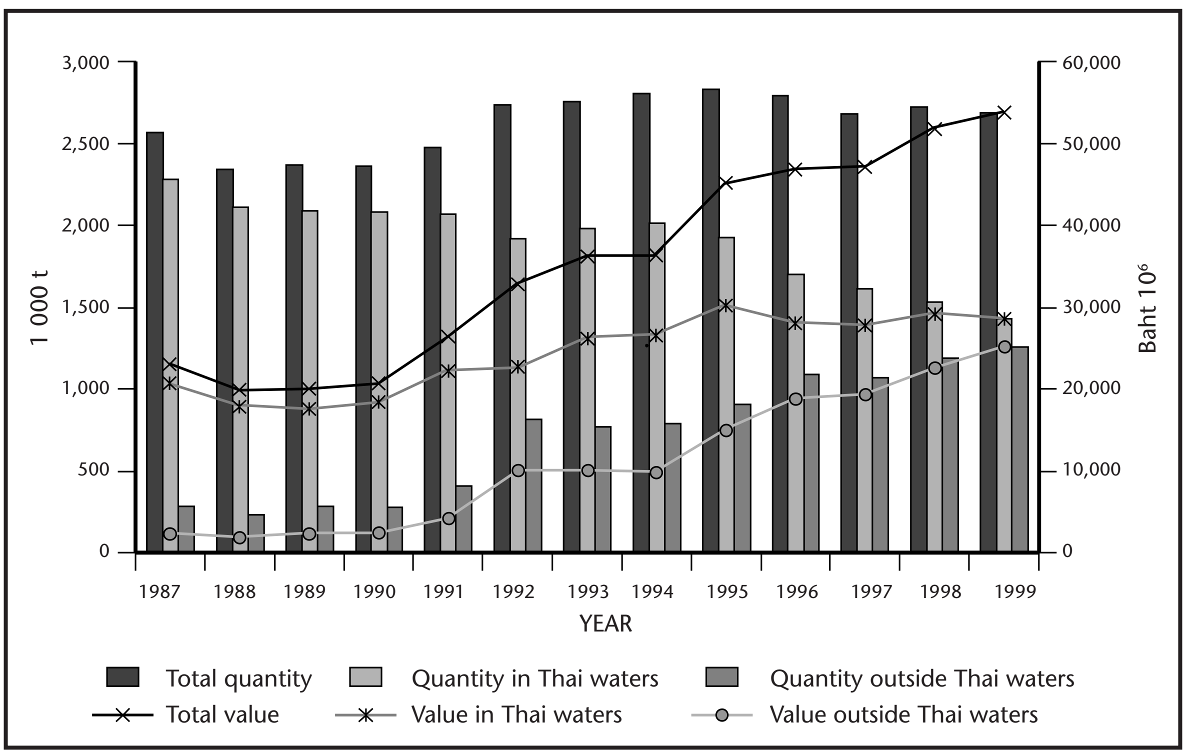

Fig. 10. The quantity and value of marine capture fisheries, 1987 - 99.
1US$ = 24.92 Baht (1995 Annual average).

all benefits, the crew of a medium size push netter (14 - 18 m) receives the highest payment, Baht 8 600•month^{-1}•person^{-1}, whereas the crew of a pair-trawler of the same size will receive Baht 4 200•month^{-1}.

Purse seiners and gillnetters have mixed systems. Net pay after expenses of king mackerel drift gillnet crew are divided into shares between boat owners and crews in the ratio of 60 : 40. Crew of small purse seiners receive Baht 7 000•month^{-1}•person^{-1}.

Revenue and Profit

Gross revenue of large pair-trawlers (18 - 25 m) is Baht 521 000•month^{-1}, and that of small beam-trawlers (< 14 m) is Baht 34 000. The gross revenue of trawling differs greatly according to boat size. The small, medium and large otter-trawlers yield revenues of Baht 79 000, 196 000, and 290 000 •month^{-1} respectively. The small, medium and large push netters yield revenues of Baht 68 000, 129 000 and 243 000•month^{-1} respectively. Gross revenue of large purse seiners (18 - 25 m) is Baht 529 000 •month^{-1} and for medium king mackerel gillnetters (14 - 18 m) Baht 154 000•month^{-1}

Cash Flow

The cash flow of the large pair trawlers (18 - 25 m) is Baht 138 000•month^{-1}, and small beam trawlers (< 14 m) have a cash flow of Baht 15 000•month^{-1}. The large purse seiners (18 - 25 m) have a cash flow of Baht 144 000•month^{-1}, and medium gillnetters (14 - 18 m) have a cash flow of Baht 40 000•month^{-1}.

Net Income

In demersal fisheries, the study showed that the highest net income was earned by large pair trawlers (18 - 25 m) totaling Baht 108 000•month^{-1} and the lowest net income by small otter-trawlers (< 14 m), Baht 8 000•month^{-1}. Likewise the large purse seiners (18 - 25 m) yielded the highest net income of Baht 132 000•month^{-1} and the medium gillnetters yielded the lowest, Baht 35 000•month^{-1}.

Operating Profit

The large pair trawlers (18 - 25 m) yielded the highest profit of Baht 145 000•month^{-1}, while small beam-trawlers (< 14 m) yielded the lowest of Baht 9 000•month^{-1}. Large purse-seine boats (18 - 25 m) yielded the highest operating profit of Baht 156 000 •month^{-1} while the smaller size (< 14 m) yielded Baht 38 000 of operating profit•month^{-1}, less than the medium gillnet boats.

Net Profit

Results of the study showed that for some fishing gear such as small otter trawls, small pair trawls, small purse seines, and all sizes of push nets and gillnets, income is less than the opportunity cost of capital plus interest on debt. In contrast, the large otter trawlers (18 - 25 m) return the highest net profit of Baht 63 000•month^{-1}. While large purse seiners (18 - 25 m) yield the highest net profit of Baht 88 000•month^{-1}, the mackerel gillnetters yield the lowest, Baht 10 000•month^{-1}. All sizes of purse-seiner and gillnetter yield high net profits.

Factor Return

Return on Capital

Return on capital indicates feasibility of fishery investment. Since fishing is one of the highest natural risk operations, return is high for certain types of fishing gear. Return is defined as percentage of net profit and opportunity cost of capital on the initial investment. Return on capital of trawlers and push netters is higher than that of purse seiners and gillnetters. Small beam-trawlers show the highest return at 104%, owing to their lower investment costs. The best return on capital of purse seiners came from medium and large purse seiners, at 30%. Large gillnetters yielded the highest return on capital at 18%.

Return to Labor

Return to labor is the compensation per working day of fishing. Comparison of this value against the national minimum wage 145 Bath•day^{-1} in 1995 shows that the fishery sector has the higher return. This value includes food cost that hired crew receive in addition to wages and shares.

Assessment of Exploited Status

Biological Status

Over-exploitation Status

Most demersal resources and some groups of pelagic fish are over-exploited as clearly shown by several reports (Hongskul 1974; Boonyubol and Pramokchutima 1982; Demersal Fish Working Group 1995; Supongpan 1988; 1993 and 1996a; Vibhasiri 1988; Chullasorn 1998; Kongprom et al.

this volume). Furthermore, the catch rates from the research vessels which have been well known for a long time, have shown decreasing trends since 1966 (Kongprom et al. this volume). In 1961, before the introduction of otter-board trawl to Thailand by the Federation of Germany, the monthly catch rates from research vessel surveys were over 300 kg•hr^{-1}. After 1966, the catch rate was 172.9 kg•hr^{-1} and further declined to 75.1 kg•hr^{-1} in 1976. The catch rate has continuously decreased and was about 18 kg•hr^{-1} in 1998.

The weighted mean exploitation rates of 23 marine fish species from 1971 to 1995 was estimated to be 0.55 with several species having higher exploitation rates over the last five years. In general, it can be concluded that marine resources are over-exploited, and about 86% of the resources have been removed (Kongprom et al. this volume).

Excessive Fishing Effort

The estimation of excessive fishing effort using the optimum fishing effort figure for demersal fish as an index, was 20 x 10^6 trawling hours by research vessels (Kongprom et al. this volume). Based on the efficiency comparison of Boonvanich (1993), the percentage excessive fishing effort was estimated at 44.5% of registered boats in 1996. The excessive fishing boats totaled 2 506, including medium otter-board trawlers 1 024, large otter-board trawlers 1 309, pair trawlers 1 081 and push netters 167.

Utilization of Trash Fish

Trawling gear usually has small mesh size cod-ends and catches fish from a small size. Presently, the size of trash fish caught ranges from 3.5 to 17.5 cm total length. The bigger ones are pelagic fish e.g. sardine and Indo-Pacific mackerel in contrast to the demersal fish which are small, the exception being some long-bodied species e.g. *Saurida elongata.* Indo-Pacific mackerel in the trash fish catch range from 5 to 16 cm total length. The trash fish catch includes juveniles of commercial or economic fish. The amount of trash fish supplied directly to fish mills is high because fish mills purchase all trash fish available. This encourages fishermen to catch more trash fish. Sardines or other big pelagic fish, if not handled well are also sold to fish-can mills when almost rotten. The juvenile economic fish found in the trash fish caught by pair-trawlers includes 13 species of pelagic fish and 15 species of demersal fish. Young economic fish caught by 14 - 18 m trawlers includes 4 species of pelagic fish and 13 species of demersal fish, and those caught by small trawlers includes 15 species of demersal fish, 4 species of pelagic fish, and invertebrates. The ratios between juvenile economic fish and true trash fish differ according to type and size of trawler. Small otter-board trawler catches include 40% of juvenile economic fish, that of 14 - 18 m boats includes 43%, that of pair-trawlers 52%, and push netters 45%. So the pair-trawlers markedly destroy a large number of young economic fish which are sold as trash fish costing Baht 2•kg^{-1}. If those small economic fish grow to marketable size, they are sold for Baht 20 - 50•kg^{-1}. (National Seminar 1999). The biomass of trash fish (kg•km^{-2}) is highest near shore, at a depth less than 10 m (Kongprom et al. this volume).

Trends in Catch Composition of Demersal and Trash Fish

The percentage of demersal fish caught decreased from 1966 to 1996 whereas trash fish increased. The mortality index of these two groups from 1971 to 1986 showed parallel increasing trends. Thereafter, the trash fish index increased, reaching a level 5 times higher than that of demersal fish in 1990 (Demersal Fish Working Group 1995).

Decrease in Benthic Species (Change in Bottom Biodiversity)

The species composition of benthos has been markedly changed as a result of fishing by trawlers. During trawling, the nets disturb the benthic environment. In 1976, there were 394 benthic species recorded, which decreased to 88 species in 1995. In 1966, shellfish were abundant followed by sea stars, sea urchins, and polychaetes. By 1989, the shellfish were still highly abundant but polychaetes had disappeared. Sea stars were also less numerous. In 1992, sea stars and sea urchins were dominant.

Smaller Mean Length of Indo-Pacific Mackerel

The mean length of Indo-Pacific mackerel during the past 30 years up to now has showed a decreasing trend, from 18 cm to 15 cm total length (National Seminar 1999). This is further evidence of over-exploitation.

Too Small Mesh Size Cod-end Used

Trawling gear with small mesh size cod-ends, 2.5 cm

stretch mesh size for fish and 1.5 cm for shrimp on otter-board trawlers, and even smaller mesh on push nets, cause a high percentage of trash fish to be caught, which are directly landed at the fish meal factory. In the South China Sea area, the optimum mesh size for fish trawling should be 5.0 cm (Sinoda et al. 1987). The mesh sizes used in other countries around Thailand are larger than Thai trawlers use e.g. Malaysia 3.8 cm, Bangladesh 4.5 cm (Marine Fisheries Division 1997).

Economic Status

A sample of six small scale fishing villages was studied from the southern part of the Gulf of Thailand, Songkhla Province, in 1999. The five fleets studied were shrimp gillnet, cuttlefish trammel net, Indo-Pacific mackerel gillnet, *Acetes* trawl net and other gillnets. The investment, cost, revenue, return to labor and profit are summarized in Table 9.

The variable costs of these gear combinations were about 65 to 71% of the total cost. The most successful gear types were cuttlefish trammel net + Indo-Pacific mackerel gillnet, shrimp gillnet + Indo-Pacific mackerel gillnet, and Indo-Pacific mackerel gillnet, all of which made more profit than other types.

The Songkhla coastal area fishers are in a bad situation due to the paucity of their funds and the fish resources. For non-fishing alternatives credit and training are necessary, and eventual relocation of the surplus fishermen is inevitable, unless imaginative government projects such as small scale coastal aquaculture development provide viable alternatives to coastal fishing.

For the large scale fisheries, in the long-term they cannot continue their operations. Some fishing gear e.g. small otter trawls, small pair trawls, small purse seines, and all sizes of push nets and gillnets give the owners a better return than other work. In contrast, the large otter trawlers (18 - 25 m), return net profits of Baht 63 000•month^{-1}, while pelagic gear, large purse seiners (18 - 25 m), yield a net profit of Baht 88 000•month^{-1} and the mackerel gillnetters yield the lowest at Baht 10 000•month^{-1}. All sizes of purse seine and gillnet yield the highest net profit. Table 10 shows the summation of the investment, cost, profit and return to labor of commercial fishing gear in the Gulf of Thailand, 1999.

Table 9. Summation of the investment, cost, revenue and return to labor of small scale fisheries 1999.

Gear	Annual Investment	Fixed Cost (% of total)	Annual Revenue Baht	Return to labor Baht•man-day^{-1}
SGN	63 316 - 201 000	28.9		
CTN	Ditto	35.0		
IPMGN	Ditto	31.9		
ATN	Ditto			
OGN	Ditto			
		Total cost•yr^{-1}		
Single gear		36 000 - 99 000		
Two gear combination		121 000 - 241 000		
Three gear combination		197 000		
Four gear combination		232 162		
SGN + CTN			257 000 - 330 000	164
CTN + IPMGN			90 000	266
SGN + IPMGN			41 000 - 49 000	264
OGN			20 000 - 25 000	272
SGN + CTN + IPMGN + OGN			20 000 - 25 000	272

Note: SGN = shrimp gillnet, CTN = cuttlefish trammel-net, IPMGN = Indo-Pacific mackerel gillnet, ATN = Acetes trawl net, OGN = other gillnets. 1US$ = 24.92 Baht (1995 annual average).

Table 10a. Investment and cost, profit and return to labor of commercial fishing gear.

Gear	Crew No.	Investment·unit^{-1} Baht	Cost·month^{-1} Baht	Operating days·month^{-1}	Fuel·month^{-1} (Litres)
OBT	4 - 8	423 225 - 2 220 907	78 000 - 228 000	25 - 26	4 537 - 10 693
PT	3 - 14	1 197 825 - 3 895 937	243 000 - 461 000	17 - 27	12 032 - 21 547
BT	3 - 5	71 881 - 313 383	27 000 - 106 000	17 - 24	
PN	3 - 5	132 357 - 1 031 030	66 000 - 126 000	20 - 25	3 559 - 15 915
PS	17 - 25	2 743 886 - 4 339 790	240 000 - 441 000	22 - 23	4 730 - 10 521
KMGN	9 - 10	1 989 489 - 2 666 849	144 000 - 254 000	19 - 20	3 563 - 5 145

Table 10b. Investment, cost, profit and return to labor of commercial fishing gear.

Gear	Boat type	Return to labor Baht·man-day^{-1}	Hull construction (% of total cost)	Equipment (% of total cost)	Net Profit Baht·month^{-1}
OBT	3 sizes	103 - 210	50		63 000 L - OBT
PT	3 sizes	122 - 255	42		
BT	< 14m, > 14m	43 - 120			
PN	3 sizes	46 - 63			
PS	3 sizes	374 - 575	16 - 31	54 - 75	88 000 L - PS
KMGN	> 14m, > 18m	171 - 200	32 - 33	53 - 54	10 000 L - KMGN

Note: OBT = Otter board trawl, PT = Pair trawl, BT = Beam trawl, PN = Push net, PS = Purse seiner, KMGN = King mackerel gillnet.

Management Issues and Opportunities

Fishery Management Philosophy

Marine fisheries play an important role for the Thai people in terms of a protein source and the economy of the country. Exported fishery products earn more than 100 000 Baht annually. Fishery related activities, aquaculture and other linkages to industry create jobs and incomes. The GDP of the fishery sector in 1995 was 2% and increased to 2.9% in 1998. The fishery sector hires more than 826 980 workers. There are 77 870 aquaculturists and 183 100 fishery related workers (National Fishery Policy 2000).

The marine fishery is continuously over-exploited. Inappropriate fishing gear use, over-fishing capacity as well as excessive fishing effort, changes in marine biodiversity, habitat degradation, gear conflicts and high costs of operation, lack of fishery workers, illegal fishing, fishing in foreign waters, international laws and agreements are all major factors making the situation worse.

The Department of Fisheries recognizes the overfishing situation in the Gulf of Thailand and Andaman Sea. Despite more than 27 issues of Ministerial Notification, the marine resources have still not recovered. Economic outcomes are one factor not under control. Some management regulations are obstructed by the political and social decisions of higher rank. The following examples illustrate the problem:

- The Ministerial Committee has approved selling lower price retail diesel for all kinds of fishing boats since 14 May 1996. This allows 5 400 boats to operate, too many for sustainable harvesting.
- The government has allowed Myanmar aliens to work as crew in the provinces that have large fisheries all over the Gulf and Andaman Sea.

VISION	MISSION	OBJECTIVES	GOAL
Fishers have good quality of life, stability in fishing career, unity to set strong community, to use local knowledge and appropriate technology in developing fishery responsible, participation to managing fishery resources and environment to be sustainable and equitable, Thailand show leadership in producing quality and standard fishery products for domestic consumption and export.	1. Development of knowledge, capability, public participation and public organizer participation	1. Promote fishers and fisher organization to participate in fishery development	1. Fishers and related organizers know how, understands, capable in policy planning, participate in fishery management and reduce conflicts at all level
	2. Management marine fisheries and environment for sustainability, equity and responsibility	2. To optimize fishery resources and environment to be sustainable and equitable	2. Increase Protected areas 3. Destructive fishing gears/ pattern are being solved permanently
	3. Produce qualified domestic fishery product for domestic consumption and export 4. Develop and cooperate for high sea fisheries 5. Produce world standard qualified product for export	3. To increase fishery product and stabilize for fishermen and processor incomes 4. To progressively develop deep sea fisheries 5. To increase capability for export competition	4. Increase aquaculture products from natural potential areas 5. Expand joint venture and increase efficiency of deep sea fisheries 6. Expand domestic markets, stabilize world sharing markets and seek more new markets

Fig. 11. National fishery development plan 2002 - 2006.

- The government has increased surcharges on imported trash fish resulting in fishermen harvesting more trash fish to support fish-meal factories.
- The Agriculture Health Fund subsidizes fishing of little tuna.

Presently, the new constitution is concentrating on the development of the local community. The 9th National Plan of Economic and Social Development has 7 strategies to develop the country:

- Development of human resources, social conservation, restructuring local administration, sustainability
- Management of marine fisheries and environment
- Establishment of a participatory economic administration system
- Increased capability and strengthening of export markets
- Development and strengthening in science and technology
- Revision of management and administration holistically
- Concentration of agricultural development into 3 directions: to develop the agriculturists and agriculturist organizations, to develop agricultural products and marketing, to manage the natural resources.

The National Fishery Development Plan (2002 - 2006) Philosophy, under the 9th National Plan of Economic and Social Development, states the following for fishery development (See also Fig.11):

Vision: Fishers should have good quality of life, stability in fishing careers, unity in strong communities, use local knowledge and appropriate technology in developing fisheries, participate in managing fishery resources to be sustainable, equitable and environmentally friendly. Thailand must show leadership in producing quality and standard fishery products for domestic consumption and export.

Fishery Management Goals and Objectives

The Department of Fisheries has set up the fishery management goals and objectives, and these have been approved by several levels of higher rank officials as well as by fishers, stakeholders and processors (Fig. 11).

The goals are:

- Fishers and related organizers must know and understand policy planning, participate in fishery management and reduce conflicts at all levels
- Increase protected areas
- Destructive fishing gear/patterns banned permanently
- Increase aquaculture products from natural potential areas
- Expand joint ventures and increase efficiency of deep sea fisheries
- Expand domestic markets, stabilize sharing markets and seek new markets

The objectives are:

- Encourage fishers and fisher organizations to participate in fishery development
- Optimize fishery resources to be sustainable and equitable
- Increase fishery products and stabilize incomes of fishers and processors
- Progressively develop deep sea fisheriese. Increase capability for exports

Fishery Sector Issues/Opportunities

The fishery issues and interventions especially for marine resources and their environment are shown in Fig. 12. Management objectives are as follows:

a. Productivity and efficiency. The key issues are over-fishing and over-capacity of the fisheries, the use of destructive practices, changes in biodiversity as well as post-harvest losses due to storage techniques. The key interventions are: to control fishing effort, ban destructive fishing gear, reclaim more protective and nursery areas, assign fishing areas in cooperation with the Department of Interior, install artificial reefs to increase areas for growth and spawning, im prove marketing/post-harvest facilities as well as to promote value-added product.
b. The distribution equity. The key issues are the unequal opportunities for the large scale and small scale fishers. The promotion of fisher organizations, local community administration, stakeholder awareness of natural resources and participation in fishery development management policy, promotion of a management network and the community-based fishery management (CBFM) project are the key interventions.
c. The integrity of the environment. Inappropriate methods used in fisheries and land-use or other activities impact on the environment directly or indirectly, as well as natural causes. One key intervention recommended is regular monitoring surveys of the plankton causing red tide, water properties and pollutants. The reduction of coastal activities has to be in collaboration with those involved.
d. Institutional resource person efficiency. The fishery institutions, private agencies and stakeholders are weak as far as politics and social inter-relations are concerned. The key interventions recommended are to enhance research for efficient management, to highlight management information, strengthen institutional collaboration, upgrade the capability of resource persons, train young people, and improve and reform outdated laws and regulations to allow effective enforcement.

Recommendations for Immediate Government Action

The indicative action and investment programs are summarized in Fig. 13.

The recommendations for immediate government actions are:

a. The DOF should accelerate action to stop severe over-exploitation by reduction of excessive fishing efforts, phase out destructive gear and reduce losses of young economically important fish in the trash fish catch by mesh size enlargement.
b. Spatial management zones should be urgently established to reduce conflicts among fishers using different types of fishing gear. These fishing zones should be agreed with the Department of Interior.
c. The DOF should highlight or strengthen more community based fishery co-management (CBFM) pilot projects in various parts of the Gulf of Thailand and Andaman Sea coasts.
d. The DOF should develop and reform outdated laws and regulations and support full enforcement of the present fishery resource manage-

ment laws, as well as support the local administrative organizations. These laws and regulations should be compatible to global laws and agreements such as the United Nation Convention on the Law of the Sea, the Agreements for the Implementation of the Provisions of the United Nations Conference on the Law of the Sea of 10 December 1982, Highly Migratory and Straddling Fish Stocks, the Code of Conduct for Responsible Fisheries.

e. The DOF should promote the Local Community Administration and public participation in development of the national fishery.
f. The DOF should collaborate with other agencies to build public awareness of coastal resources and fishery management regularly at all academic levels as well as among the fishery sectors, stakeholders and media.
g. Coastal rehabilitation should be highlighted and expanded, more artificial reef installation sites should be provided to protect the fishing grounds by obstructing trawlers.
h. The training program for fishery management resource persons as well as collaborative research should be strengthened and highlighted.

Recommendations for Government Follow-up Action

The follow-up action for fishery management should be to fully enforce laws and regulations.

Recommendations for Regional or International Collaboration

The regional management of highly migratory fish stocks and straddling stocks or trans-boundary fish stocks is recommended. Already existing organizations should be the core bodies in managing these stocks. Joint ventures in fisheries are also recommended.

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Policy	Strategy	Action
Fishery Resources and Environment Policy: ★ Improve management of fishery resource and environment, conservation and rehabilitation, and biodiversity; regularly induce public awareness of valuable natural resource promote public participation at all levels manage fishery resource and environment promote technology development and resources in fishery management	Improve management of fishery resource and environment	Improve and reform The Thai Fisheries Act 1947 Improve efficiency within and between agencies Strengthen control activities impact to natural resources and environment
	Promote public awareness of natural resource preservation and conservation	Strenghten informative and activities to stimulate local community knowledge of valuable natural resources Promote new generation and local community on management for fishery and environment to be sustainable development Provide fishery management and conservation courses at all academic levels
	Promote public participation to manage fishery resource and environment	Promote local community establishment to take care natural resource and environment Promote local management network Increase training of local leader and target person Laws and legal measures amended to serve local right Motivate fishermen efforts to responsible use natural resources Promote collaboration among government, private and local agencies Promte the public participation in community based fishery co-management (CBFM)
	Rehabilitation	Assign fishing areas in coorperation with the national provincial area of the Interior Department Control fishing effort Motivate fishers to change destructive fishing gear, responsible fishing or quit to other job Ban on destructive fishing gears Claim more protected and nursery areas Seed releasing Speed up sea rehabilitation project Installation of artificial reef
	Promote, preserve and conserve biodiversity	listing and researching of species and habitat Conserve local species, endanger and rare species/culture Assign protected area Promote fishery under international commitment Issue law and regulation measures to preserve Biodiversity Regularly evaluate the status of local and non-local biodiverse species
	Promote technology development and management resource person	Develop research and technology for effective management Develop capable management people

Fig. 12. The fishery issues and interventions for marine resources and their environment.

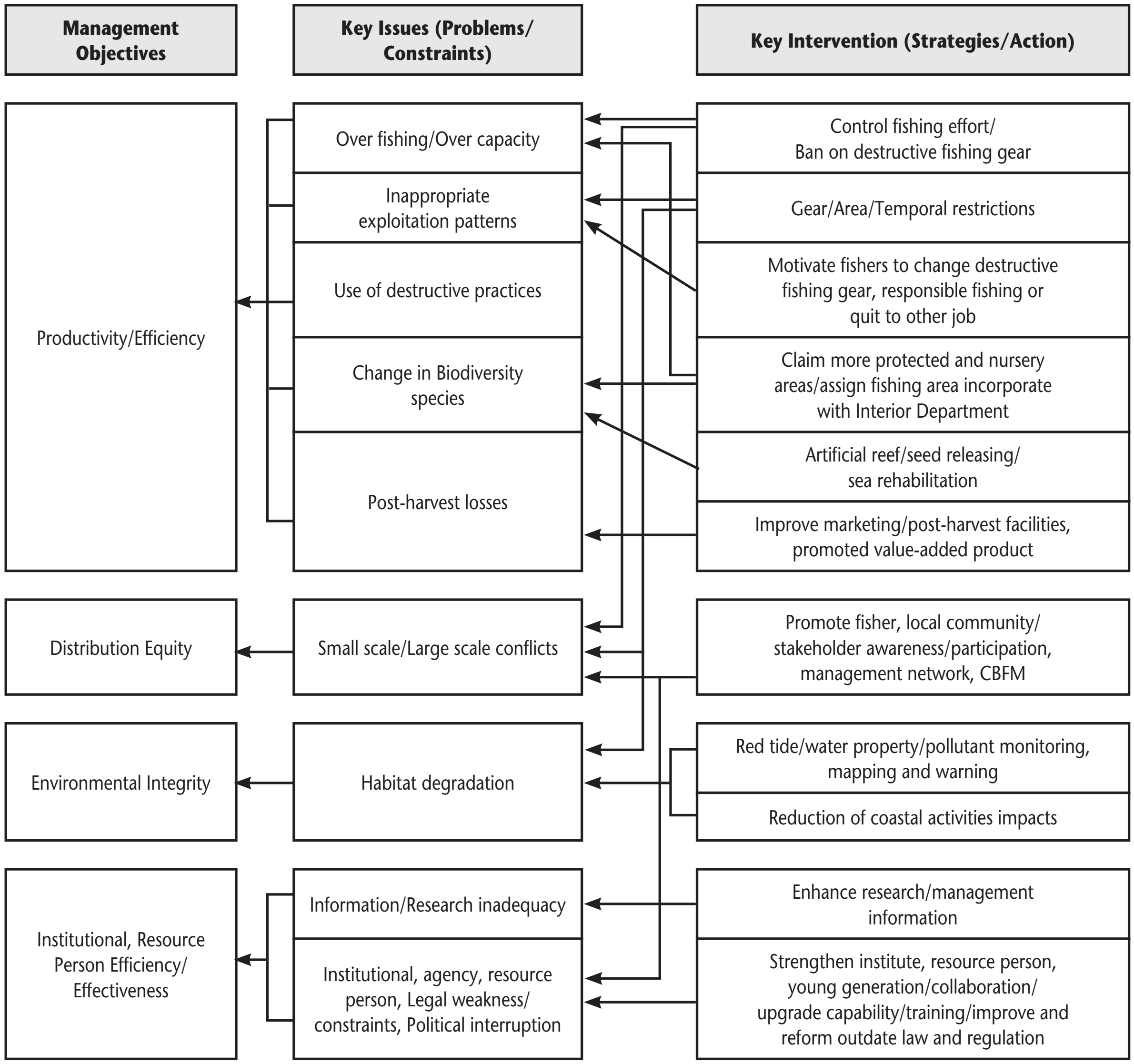

Fig. 13. Indicative action and investment program.

Management of Coastal Fisheries in Vietnam

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Abstract

The fisheries sector of Vietnam plays an important role in the social and economic development of the country. The sector contributes about 3% of the GDP and fish contributes about 40% of animal protein consumption in the country. In 1999, total fisheries production amounted to 1.8 million t. Of this, 1.2 million t was derived from marine capture fisheries and 0.6 million t from aquaculture. Fish exports were valued at US$971.12 million in the same year. Vietnam's marine fisheries and coastal aquaculture have further potential for development. However, overfishing in coastal areas, degradation of the marine environment and conflicts between small-scale and large scale fishers must be resolved to realize the sector's potential.

This report presents the status of coastal fisheries resources, reviews government fisheries policies and suggested management measures. Based on the recommendations from a multisectoral consultative workshop conducted among the key experts on fisheries and resource management in Vietnam, the following fisheries management objectives were suggested for sustainable development of coastal fisheries in Vietnam: (1) optimization of productivity and efficiency of the fisheries exploitation regime; (2) ensuring that the benefits of production are distributed equitably; (3) ensuring that the productivity generated results in minimum damage to the resource base and the supporting natural environment; and (4) upgrading and strengthening the related institutions. Indicative action programs for improved management are also presented.

Introduction

Vietnam, a peninsular country in Southeast Asia, has a coastline 3 260 km long and the Exclusive Economic Zone covers more than one million km^2. The fisheries sector plays an important role in the social and economic development of Vietnam. The sector is estimated to contribute 3% to the Vietnamese GDP, and fish provides about 40% of the animal protein consumption. In 1999,total fisheries production was estimated at 1 827 310 t, of which 1 212 800 t came from marine capture fisheries and 614 510 t from aquaculture. In the same year, fish exports amounted to US$971.12 million (MOFI 1999).

In the past decade, the fisheries sector has achieved considerable growth. However, the sector suffers from many problems that need to be resolved to ensure sustainable development. Such problems include overfishing in the coastal area, degradation of the marine environment and coastal resources, underdeveloped infrastructure, and lack of effective resource management. This report summarizes information on Vietnam's coastal fisheries, including

environmental and socioeconomic status, institutional-legal framework, and fisheries management issues and opportunities. The report presents indicative action programs for improving fisheries management and attaining sustainable development of coastal fisheries in Vietnam. The action programs recommended in this paper are based on a national consultative workshop conducted under

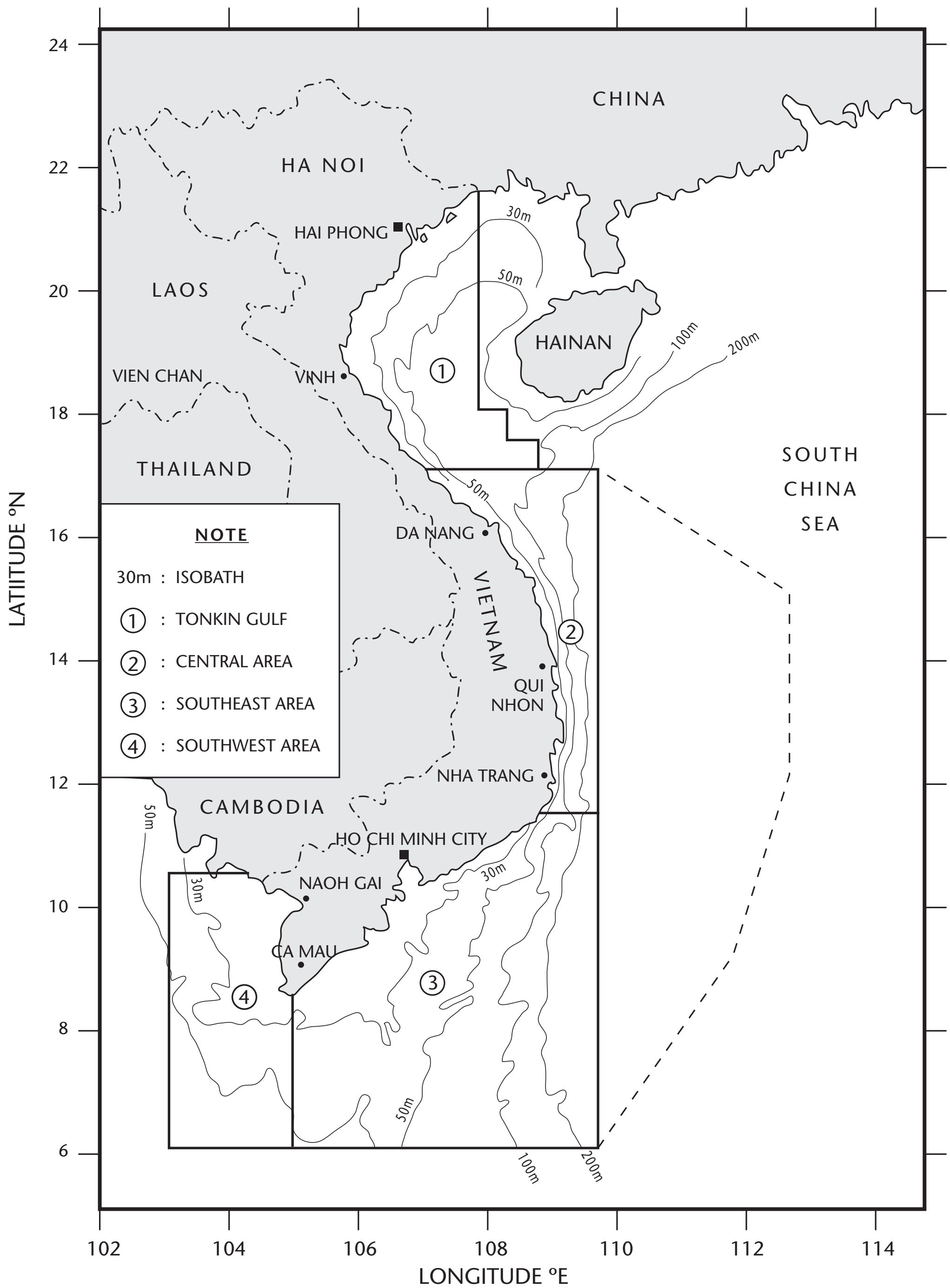

Fig. 1. The Exclusive Economic Zone of Vietnam.

the project "Sustainable Management of Coastal Fish Stocks in Asia" on 28 - 30 August 2001 at the Research Institute of Marine Fisheries (RIMF), Haiphong, Vietnam. The workshop was attended by representatives from various disciplines and from different national institutions and agencies in Vietnam.

Coastal Environment Setting

Physico-chemical Characteristics

Vietnam is under the influence of the tropical monsoon regime. There is considerable difference in climate and environment between the northern and southern parts. In the northern part of Vietnam, the climate can be considered sub-tropical with two seasons. Winter is from November to March and is characterized by mild temperatures of about 16ºC and relatively low rainfall. Summer (from May to September) is usually very hot with temperatures from 27 to 38º C, and humid with frequent typhoons or tropical storms (average rainfall at 1 730 mm•year^{-1}). A more tropical climate is prevalent in southern Vietnam. This region has a dry season between October and March and a wet season from April to September with high precipitation (about 2 000 mm•year^{-1} in Ho Chi Minh City).

The continental shelf, where coastal fisheries operate, is wide and shallow in the north and south, and narrow with a steep slope in the central region. The coastal marine environment is divided into four regions based on their hydrological regimes, namely, the Gulf of Tonkin, central region, southeast and southwest region (see Fig. 1). The Gulf of Tonkin spans an area of 140 000 km^2 and is shared by Vietnam and China. The Gulf is relatively shallow, mostly less than 50 m depth and has a relatively flat bottom with muddy to sandy substrate. In the central region, the depths drop steeply to 200 - 500 m within 30 to 50 km off the coast, with a maximum depth of about 5 000 m. A number of estuaries line the southeast subregion, including the Mekong river system, which discharges large volumes of freshwater and sediments. The southwest subregion (Gulf of Thailand) extends from the border between Vietnam and Cambodia to 6º 00' N latitude and from 105º 00' E to 103º 00' E longitude. This fishing region is shallow (mostly less than 50 m deep), and suitable for bottom trawling.

In general, surface currents in Vietnam, which are induced by the monsoon winds, flow from north to south in winter and reverse direction in summer. Water temperature and salinity vary according to season and location. Average sea surface temperatures usually range from 21 to 26º C. These are generally high in the south and low in the north, especially in January-February, when air temperatures in the north drop to 15 - 16º C. In August, when temperatures are highest, sea surface temperatures range from 28 - 29º C (Thuoc and Long 1997).

Industrial, maritime transportation and oil exploitation activities have not been developed in Vietnam. Thus, pollution is not yet considered a serious matter, and harmful elements in the marine environment are thought to be negligible. However, some coastal areas are starting to be polluted by industrial, agricultural and human wastes coming from the lower rivers. A large proportion of the waste is not treated properly and sometimes contains poisonous chemicals, heavy metals, organic matter and agricultural chemicals. Localized pollution is often from trans-boundary pollution caused by the monsoon and currents bringing polluted products from countries around the Pacific Ocean. In some areas such as Ha Long, Hai Phong and Vung Tau, oil concentrations in the sea have exceeded the threshold for tourism (0.3 mg•l^{-1}). In general, however, the seas of Vietnam are relatively clean compared with other countries in the region.

Critical Coastal Habitats

Wetland ecosystems include large estuarine and delta systems with extensive mangrove swamps and tidal mudflats, seasonally inundated inland marshes and coastal sand dune areas with brackish water saline lagoons. The two largest wetland ecosystems are found in the Mekong Delta in the south and in the Red river in the north. The deltas are heavily populated and are intensively used for agricultural production.

Sedimentation in some coastal aquaculture ponds is a problem in the Red river and Mekong Deltas. Both deltas carry heavy silt loads. Sedimentation is often linked to soil erosion in the watershed, which is influenced by the extent of forest cover. Results from the Mekong water quality monitoring project suggest that suspended solids have increased since 1988; this is possibly related to increased upstream soil erosion caused by deforestation and changing land management practices (Mekong Secretariat 1992). Acid-sulphate soils are particularly common

in the Mekong Delta and some parts of the Red river delta.

Mangrove forests in Vietnam have declined rapidly in recent years. In the 1950s, mangroves covered around 4 000 km^2 along the coastal areas (Hong 1993). The area had decreased to 2 520 km^2 by 1983 and further decreased to 1 570 km^2 by 1994. Of the remaining mangrove forests, 60% are concentrated in the coastal zone of South Vietnam, which is part of the Mekong Delta. In North Vietnam, mangrove forests occupy approximately 10% of the remaining stands of mangroves in the country and are not well developed. In the northeast, an estimated 390 km^2 thrived in the area during the early 1980s, but since then mangrove cover has been significantly reduced due to agriculture, woodcutting and aquaculture development.

The main causes of the decrease in mangrove forests are the cutting of wood and the conversion of mangroves for agriculture and pond aquaculture (Hong 1993). Of the 75 mangrove species in Vietnam, 40% are tree-trunk species that are utilized for timber, fuel wood and charcoal. While a substantial number of mangrove trees have been cut for fuel wood and household uses. The expansion of shrimp aquaculture has contributed to significant loss of mangrove area since the mid-1980s, parti-cularly in the Mekong Delta. Estimates from a survey conducted in 1995 suggest that 49% of semi-intensive and 55% of extensive and traditional shrimp ponds in Vietnam are sited on former mangrove areas, covering a total area of up to 1 310 km^2 (NACA and MOFI 1995). Problems associated with the large-scale cutting of mangroves include dimi-nished coastal fisheries resources, increased erosion and reduced biodiversity.

Seagrass and algal beds are found along the coast and around islands in Central and Southern Vietnam. The biggest seagrass and seaweed beds are concentrated off islands in the southern coast such as Con Dao, Phu Quoc and Spratly islands. There are about 660 species of seaweeds identified in the coastal areas of Vietnam (Dai and Tien 1995). The most common genera are *Sargassum* (about 60 species), *Laurencia* (16 species), *Gracilaria* (15 species), *Caulerpa* (15 species), *Chaetomorpha* (10 species), *Enteromorpha* (8 species). There are 15 species of seagrass reported in Vietnam and their occurrence tends to increase from north (8 species) to south (13 species) (Tien et al 1999).

Coral reefs in Vietnam are common in coastal areas from north to south and islands inshore or offshore. There are approximately 300 coral species belonging to 67 genera (Yet et al. 1994; Tuan and Yet 1995). Of these, 165 species occur in Tonkin Gulf, 171 species in central and southeast waters, 134 species in southwest waters and 180 species in Paracels and Spratly areas. Coral reefs contain resources of economic value such as seaweeds, lobsters, holothurians and coral fishes (Tuan and Yet 1995; Thuoc and Long 1997). A total of 346 species have been identified based on recent faunal studies of coral reef fishes (Thuoc and Long 1997).

The coral reefs in Vietnam exhibit different structural types (Tuan and Yet 1995). Fringing reefs occur along shorelines and around islands in the shelf of the west of Tonkin Gulf, central coast, the eastern and western waters of the South. Bank reefs are dominant on the banks of the shelf of Khanh Hoa, Binh Thuan province and the southeastern areas of Con Dao islands. Bank reefs are found in Spratly and Paracels archipelagos. Atolls are characteristic types for offshore waters outside the shelf. Most near shore corals are heavily exploited (Tuan and Yet 1995; Thuoc and Long 1997). Destructive activities on reefs include coral mining for lime, dynamite fishing and other destructive fishing practices. Siltation has also degraded many reef sites, including the extensive coral reef areas around Cat Ba islands off Hai Phong City on the west coast of Tonkin Gulf.

Fishery Resources and Potential

The marine coastal waters of Vietnam including the EEZ contain large areas with depths of less than 200 m. There are about 2 038 marine fish species belonging to 717 genera and 198 families that have been noted (Huong 1995; Chung et al. 2001). Over a hundred of these species are economically important. The distribution of coastal fishes in the Gulf of Tonkin has a significant seasonal character (Dinh 1995). Under the monsoon regime, fishes in the northern part of Vietnam migrate from nearshore areas to deep areas during winter (October to March). In summer (April to September), the direction of migration reverses. In the southern part where seasonal temperature variations are not pronounced, fishes concentrate in nearshore areas during the dry season and disperse during the rainy season. In general, fish schools are seldom in big shoals but are mostly scattered, and yields are low.

Marine fisheries production consists mainly of pelagic and demersal fish, which contribute 80 to 90% of fisheries yield (Thuoc and Long 1997). The remaining 10 to 20% is contributed by valuable invertebrates such as penaeid and acetes shrimps, crabs, lobsters, cuttlefish, squids and molluscs. Among these, penaeid shrimps and cuttlefish are the most important species for export.

Pelagic Resources

According to the most recent assessments, the standing stock of pelagic fishes in Vietnam waters is about 2.0 million t, while the exploitation potential is 0.8 million t•year^{-1} (Table 1). Of this potential yield, 0.69 million t•year^{-1} was estimated for small pelagic species and 0.12 million t•year^{-1} for oceanic pelagics (Chung et al. 2001). Most of the pelagic stocks are found off the southeast and central region of Vietnam (Vinh and Thu 1997).

Some coastal pelagic fish species concentrate near the bottom during daytime and come to the surface and disperse at night. For example, in a survey using a bottom trawl, the catch for jacks (Carangidae) was 153 kg•hr^{-1} during daytime and only 39 kg•hr^{1} during the night (Dinh 1995). In addition, most fish species living near the coast have average sizes smaller than 250 mm. Offshore species usually have average sizes of about 500 mm or larger. The

growth rate of most fishes is highest during the first 1 - 2 years (Chevey 1933 in Dinh 1995). For example, the round scad (*Decapterus maru-adsi*) reaches 45 - 55% of its maximum size within the first year. The main spawning season time of many pelagic species is from March to July, with peak months in May and June (Dinh 1995).

Demersal Resources

Demersal fishes live near the sea bottom and consist of mixed fish communities. Normally more than 30 species are caught in one haul of bottom trawl and none of them are dominant (Thuoc et al. 2000). Similar to pelagic fish, most demersal species are batch spawners with short life cycles of one to five years (Dinh 1995). Food types are also varied and feeding intensity does not exhibit strong seasonal fluctuation.

The total biomass of demersal fish stocks estimated from bottom catches in Vietnam waters is about 1.4 million t (Table 2). In a more recent study, (Thuoc 2001) estimated that the standing stock for demersal resources in Vietnam is about 3.4 to 3.5 million t with a potential yield of 1.4 to 1.5 million t•year^{-1}. Coastal demersal resources in almost all areas are exploited at or above their sustainable levels (Thuoc et al. 2000; Thuoc 2001). The government therefore emphasizes that any further expansion of the marine capture fishery should be targeted at under-exploited resources and that the fishing pressure on coastal stocks should be reduced (e.g. by establishing alternative employment opportunities for fishers).

Table 1. Estimates of standing stock and potential yield of pelagic resources in Vietnam waters.

Region	Pelagic Resources	Standing stock (t)	Potential yield (t·year^{-1})
Gulf of Tonkin	Small pelagics	390 000	156 000
Central region	Small pelagics	500 000	200 000
Southeast region	Small pelagics	524 000	209 600
Southwest region	Small pelagics	316 000	126 000
Sea Banks	Small pelagics	10 000	2 500
Offshore region	Oceanic pelagics (*)	(300 000)	(120 000)
	TOTAL	2 040 000	814 100

Source: Chung et al. 2001.
Note: * - estimated data.

Table 2. Estimated standing stock biomass of demersal fishes in Vietnam.

Region	Area (km^2)	Estimated biomass (t)	Stock Density ($t{\cdot}km^2$)
Gulf of Tonkin	77 173	115 972	1.50
Central region	78 974	112 070	1.42
Southeast region	222 258	1 051 117	4.73
Southwest region	49 048	92 721	1.90
TOTAL	427 452	1 371 881	

Source: Thouc et al. 2000.

Shrimps and Lobsters

Shrimps are the most important commercial species in Vietnam due to their high price followed by fish, squid, crab and mollusks. There are over 100 shrimp species belonging to 16 genera and 8 families (Thuoc and Long 1997). Among these, the family Penaeidae represents about 20 economically valuable species which are mainly distributed in depths of less than 50 m. There are also five species of flathead lobsters (Scyllaridae) of which two are economically valuable species. There are eight species of spiny lobster (Palinuridae) including five economically valuable species.

The shrimp species diversity varies among the areas. In the western part of Tonkin Gulf, there are 58 shrimp species, in the central coastal area there are 78 shrimp species, about 50 shrimp species are found in the southeast region and there are more than 50 shrimp species in the southwest region. Table 3 presents standing stock and potential yield of shrimps and lobsters in various regions of Vietnam.

The annual yield of shrimp (mainly Penaeidae) during the 1990s was estimated between 40 000 to 50 000 $t{\cdot}year^{-1}$. Most shrimp species are distributed along the coastline from the depth of 50 m to the shore. During their spawning seasons in February - March and June - July, shrimp species concentrate at depths from 15 m to 30 m. Nursery areas of shrimp larvae and juveniles typically occur within depths of 15m , especially mangrove forest or estuaries. The main fishing period of the shrimp fishery is from April to August and the secondary period is from November to December. Shrimp fishing grounds are mostly concentrated along the coast of Tonkin Gulf and around Mekong Delta.

Table 3. Estimated standing stock and potential yield of shrimps and lobsters in the Vietnamese waters.

Region	Area	Standing stock (t)	Potential yield ($t{\cdot}year^{-1}$)	Remark
Tonkin Gulf	Western part	1 390	696	Period from 1975 to 1978
Central region	Area with depth < 50 m Area with depth > 50 m	2 706 15 893 - 17 275	1 353 7 947 - 8 638	–
Southeast region	Area with depth < 30 m Area with depth > 30 m Total	8 237 13 220 - 15 373 21 457 - 23 610	4 119 6 610 - 7 678 10 729 - 11 806	Penaeidae, *Thenus orientalis* Penaeidae, *Thenus* spp. and *Ibacus* 1977 - 1988
Southwest region	–	3 242 3 256	1 621 1 607	1982 - 1985 1993 - 1995

Source: Pham Ngoc Dang and Nguyen Cong Con 1995 and Pham Thuoc 1998.

Other Resources

The estimated standing stocks and exploitation potentials of cuttlefish and squids in the Vietnam are presented in Tables 4 and 5, respectively. There are 53 cephalopod species belonging to 12 genera and six families. Among them, 3 families (i.e. Loliginidae, Sepiidae and Octopodidae) are the most important with the 12 economically valuable species, 7 of which are main export commodities. Squid and cuttlefish are widely distributed in Vietnam waters (Thuoc and Long 1997; Chung et al. 2001). In summer (April - September), squid appear near coastal areas for spawning, with peaks in July and August. In comparison, cuttlefish spawn in winter months with the peak from December to March. Their fishing season coincides with the spawning season. Cuttlefish are becoming increasingly important commercial targets, with the annual yield reaching 25 000 t.

Economically important mollusc populations have declined or disappeared in some areas because of excessive exploitation. For example, in Nha Phu inlet (Khanh Hoa province) the green mussel *Perna viridis*, which yielded 40 - 50 t•year^{-1} prior to 1975, has now been reduced to near extinction. The pearl oyster *Pinctada martensii* in Quang Ninh province, which had a potential yield of 8 000 t in 1969, has been almost exhausted. The annual scallop (*Chlamys nobilis*) yield of 10 000 t in 1986 in Binh Thuan province had been reduced to only 200 - 300 t by 1995.

Table 4. Estimates of standing stock (in t) and potential yield (in t·year^{-1}) of cuttlefish in Vietnam seawaters by depth range.

Region	Parameters	Depth range (m)				Total
		< 50	50 - 100	100 - 200	> 200	
Tonkin Gulf	Standing Stock	1 498	395	-	-	1 893
	Potential Yield	599	158			757
Central region	Standing Stock	3 900	3 836	4 505	1 301	13 542
	Potential Yield	1 560	1 534	1 802	520	5 416
Southern region	Standing Stock	24 933	10 756	7 404	5 613	48 706
	Potential Yield	9 973	4 302	2 962	2 245	19 482
TOTAL	Standing Stock	30 331	14 987	11 909	6 913	64 140
	Potential Yield	12 132	5 994	4 764	2 765	25 655
	Percentage (%)	47.3	23.3	18.6	10.8	100

Source: Chung et al. 2001.

Table 5. Estimates of standing stock (in t) and potential yield (in t·year^{-1}) of squids in Vietnam seawaters by depth range.

Region	Parameters	Depth range (m)				Total
		< 50	50 - 100	100 - 200	> 200	
Tonkin Gulf	Standing Stock	9 244	2 524			11 768
	Potential Yield	3 698	1 010			4 708
Central region	Standing Stock	318	435	2 033	2 982	5 768
	Potential Yield	127	174	813	1 193	2 307
Southern region	Standing Stock	21 319	12 832	2 559	4 867	41 577
	Potential Yield	8 527	5 132	1 024	1 947	16 630
TOTAL	Standing Stock	30 882	15 790	4 593	7 848	59 113
	Potential Yield	12 352	6 316	1 837	3 139	23 644
	Percentage (%)	52.2	26.7	7.8	13.3	100

Source: Chung et al. 2001.

Socioeconomic Background

In 1995, the population of Vietnam was estimated at 74 million, of which 80% resided in rural areas (MOFI 1996). The annual population growth rate decreased from 4.0% in the 1960s to 2.0% in 1995, which translates to a steady increase of 1.5 million people annually. The national population strategy aimed to reduce the annual growth to 1.8% by the year 2000, at which time the population was projected to reach 82 million.

The total median age in 1989 was 19.1 years for men and 21.4 years for women; this is two years higher for both sexes since 1979. The 1989 census data showed that 39% of the population was under 15 years old and only 7% was over 60. This means that a little over half the population consists of adults in their working age. The dependency rate, i.e. the average number of dependent persons (under 15 and over 60) per 100 adults of working age, is 78. The dependency rate is higher in rural areas: 86 dependents per 100 adults of working age, compared to 61 for urban areas. The average number of persons per fishing household is 5.5, which is higher than the average for non-fishing households. On average, 2.4 persons in a fishing household are employed.

The total labour force in 1995 was estimated at 40.3 million people, of which 34.7 million (86%) were employed, 15 million (3.7%) were still in school, 2.1 million (5.2%) were looking after their homes, and the remaining 2 million (5%) were unemployed (MOFI 1996). In 1995, capture fisheries and aquaculture provided full-time employment to about 1 million people. About 447 000 were engaged in capture fisheries and 560 000 were involved in aquaculture (MOFI 1996). Another 59 000 people were employed in the processing industry, giving a total of 1 065 000 people employed full-time in capture fisheries, aquaculture and processing in 1995. This corresponds to 3.1% of the employed labour force. In addition, support industries and sectors related to fisheries generated employment for another 1 962 000 people in 1995, which was equivalent to 5.7 % of the employed labour force. In total, the fisheries sector provided employment for almost 9% of the employed labour force.

MOFI's strategies (MOFI 1992; Danida 1997a & b) for development of the fisheries sector (1990 - 2005) and marine fisheries (1996 - 2010) aim to increase the number of fishermen to 590 000 in 2010. The marine fisheries jobs are predicted to be created by off-shore fisheries. Further, MOFI expects that the number of people employed directly in the aquaculture industry will double by the year of 2010.

Women account for slightly more than half of the total employed labour force. However, there are major differences between state-run and private sectors with regard to participation by gender. While women account for 51.4% of the total employed labour force, they account for only 39% of the employed in the state sector. This is due to the fact that most women are engaged in agriculture, which is predominantly private. Women constitute the majority (53.3%) of employed in the agriculture sector, with female participation in state agriculture being slightly less. Capture fisheries is a male-dominated occupation, with only 27% female participation. However, the fish processing industry differs from the general fishing industry, with female participation at 80 - 85%. Salaries in agriculture and fisheries are generally lower than those in industry and service sectors. Salaries in capture fisheries are related to the actual catch. The salaries in central Vietnam are higher than in the north and south. Employees of private fishing operations are paid as much as double the salary offered by the state owner enterprises. The average monthly salary in the fish processing industry ranges from VND 300 000 to VND800 000 (US$18.83 to 50.20)[1]. Salaries for fish processing are lowest in the north. In contrast to capture fisheries, salaries in the private fish processing plants tend to be lower than in the state-owned enterprises.

Vietnam has 52 fishing ports with a total berth length of 2 905 m. However, these are only small and medium fishing ports or supply ports, that provide ice, fuel, fresh water and repair services, and sheltering places for fishing boats. In general there is a shortage of modern facilities such as discharging vehicles, freezer warehouses or stores. Areas for sorting and classifying fish as well as transportation networks inside ports are still inadequate. Because many coastal locations have no fishing port, most of the catch from fishing boats must be transported by small boats to buyers. In some places, catches are unloaded directly on sandy areas, which is time-consuming and often causes spoilage, especially in hot weather (Long 2000).

[1] 1 US$ = 15,934.27 VND (2002 average)

In recent years, the government has made efforts to improve fisheries infrastructure. Many new fishing ports have been built and many old fishing ports have been enhanced. Since 1996, US$71 million has been invested in new ports and upgrades. In particular, the Cat Lo port in Vung Tau City is planned as a very large fishing port with a total investment of US$24 million. Currently, there are 75 shipyards for fishing boats providing a total building capacity of 4 000 boats and repairing capacity of 800 fishing boats•$year^{-1}$. Apart from these, there are many small shipyards at the district level, which build small fishing boats in the traditional way. There are 126 freezer stores with a total capacity of about 20 000 t and 120 ice-making enterprises.

According to Long (2000), there are different economic organizations in the fisheries sector, such as:

State-owned fishing enterprises

- These enterprises operate steel fishing boats with engines of more than 135 HP. In recent years, the profitability of such enterprises has declined due to dwindling fishery resources and management inflexibility. Consequently, the number of fishing boats of state-owned enterprises has decreased.

Fishing cooperatives

- After 1985, many fishing cooperatives disappeared. In 1997, many new cooperatives were established mainly in order to obtain loans from banks.
  - Fishing groups. Fishers organize into groups mainly to reduce the costs of boats and gear. From 1985 to 1997, the number of fishing groups increased from 2 205 to 5 542.
  - Private businesses in marine fishing. These include households that own fishing boats and employ less than five workers, skippers who own one or two fishing boats and employ more than five workers, and "private capital", which is an entity that owns more than two fishing boats with > 250 HP.

Institutional Background

Fisheries Related Policies

In general, legislation governing fisheries in Vietnam is complex and not very well prepared. The central government and the Ministry of Fisheries issue legislation regarding the management of aquatic resources and aquaculture in Vietnam, which may have wide scope of action and may be issued at all government levels. Provincial governments are usually tasked with implementing legislation enacted by the central government. Annex I provides a comprehensive list of institutions and agencies that are involved directly or indirectly in the development, management and conservation activities for coastal and fisheries resources in Vietnam.

Since 1986, Vietnam has been transforming its general policy and strategy from a centrally planned economy to a market economy under socialism (MOFI 1992). Toward this end, the Ministry of Fisheries has developed a general policy framework for the fisheries sector (see Danida 1997a and b) with the following main objectives under the current social and economic development plan (2000 - 2010):

- To increase domestic consumption of fish and fishery products
- To increase export earnings
- To create substantial additional employment
- To improve the sector's infrastructure, equipment and technology base
- To increase the sector's contribution to the government budget.

During the last two decades, mangrove forests in Vietnam have been degraded considerably by human activities. To protect these resources, the government has enacted legislation and policies including measures on forest restoration and preservation. A directive on the technical procedure for the establishment and maintenance of mangrove forests was issued on 24 October 1984, with Decision No. 975 QPN 7 - 84. In addition, Resolution No. 246/HDBT of the Council of Ministers was enacted on September 20 1985 to promote the rational use of natural resources and environmental protection.

Article No. 5 of the "Law on Forest Protection", which was promulgated on September 5 1972, contains a provision for the establishment of protected areas. Within forest reserves, it is prohibited to fell trees or to kill birds and other wildlife. However, deforestation has continued, mainly as a result of natural calamities. Hence, the Prime Minister enacted instruction No. 53/CT on 24 February 1990 to establish plantations for the protection of the environment, including coastal and estuarine habitats. Based on this, the Ministry of Forestry promulgated decision No. 413/QD on 18 September 1992 initi-

ating a plantation programme for 6 000 ha of suitable area along Minh Hai's coast. As a contracting party to the Ramsar convention[2] on January 20 1989, the Government of Vietnam designated the mangrove islands of Xuan Thuy District in Nam Ha province for inclusion in the RAMSAR list.

The responsibility for coastal development and environmental protection in Vietnam is delegated to local administrations. For example, the Provincial People's Committee of Minh Hai (MHPPC) province has formulated a number of decisions, regulations and instructions to protect and limit the irrational utilization of mangroves. In order to protect and preserve the species of endangered wildlife, the Vietnamese government issued the "Red Data Book of Vietnam, Volume 1 - Animals" in 1992, and "Red Data Book of Vietnam, Volume 2 Plants" in 1996. These books list 365 animal species and 356 plant species for protection.

Vietnam's economy was in decline during the period 1976 - 80 due to the inefficiencies of the command economy. Since the shift to a market economy, beginning in 1981, Vietnam's fisheries have achieved remarkable development in technical capacity, fisheries product quantity and export value. At present, the government concentrates investment in three major programs, namely: offshore capture fishery, aquaculture and fisheries export development.

Offshore Capture Fisheries

Vietnam has policies to protect and restore inshore resources by limiting fishing in coastal areas, while simultaneously encouraging the exploitation of offshore resources. From 1997 to 1999, the government provided soft loans (1 300 billion VND) for building offshore fishing vessels. In late 1999, the fishing fleet grew to 73 397 units with a total capacity of 2 518 493 HP.

Aquaculture Development

In the last decade, both public and private sectors have invested in aquaculture in Vietnam. The government has provided funds for the construction of dykes, main canals and main water gates in aquaculture areas and has invested in experimental hatcheries and feed production units. Presently, the majority of investments in the aquaculture industry are at the farm level (Table 6). Direct public sector investment has played a relatively minor role in the development of the aquaculture industry.

Fish Processing and Export Development

In 1998, Vietnam had 234 fish processing plants, of which 186 were exporting plants with a total production capacity of 200 000 $t \cdot year^{-1}$. Some enterprises have invested in upgrading infrastructure and facilities, renovating technologies, diversifying products, producing high-quality products and applying the Hazard Analysis Critical Control Point (HACCP) system in food processing quality control. To date, 60 plants apply HACCP to export products to EU and American markets. In the coming years, the government is expected to invest heavily in fisheries processing and export development.

Table 6. Investments in the aquaculture industry (1986 to 1995).

Item	Investment (billion VND)
Public sector investment	147.0
Domestic private sector investment	777.0
Farm level investment	2 437.4
Foreign investment	728.0
Sub-total investment	4 089.4

Source: SCP Fisheries Consultants Australia 1996.

[2] The Convention on Wetlands is an intergovernmental treaty adopted on 2 February 1971 in the Iranian City of Ramsar.

External Policies Affecting Fisheries

The use of land and water area for coastal aquaculture development is governed by the new land law, which came into force in October 1993. Articles 48, 49 and 50 provide specific guidance on the use of coastal land and water for aquaculture (along with forestry and agriculture) and the management and use of new alluvial coastal land. According to Article 48, the use of coastal land for aquaculture shall: (i) be in conformity with land use planning; (ii) protect the land and increase accretion; (iii) protect the ecosystem; and (iv) not cause a hindrance to national security protection and navigation.

There are some restrictions on the use of lakes, rivers, mangroves or coastal areas for aquaculture. However, in most cases developments proceed without restriction, although there are a few exceptions. In inland areas, individuals may establish ponds on private land without the need to obtain permission. To establish ponds on public land, permission may be required from the district, provincial or central government. Procedures differ depending on the district. In coastal areas, permission to establish new impoundments may be required from the local government authorities.

The Ministry of Science, Technology and Environment (MOSTE) prepared the Law on Environmental Protection in January 1994. The enactment of the law and the establishment of MOSTE itself have created a framework for environmental management in Vietnam. Following this enactment, the government issued the Decree 175 on Providing Guidance for the Implementation of the Law on Environmental Protection in October 1994. This provides further details on the roles, mandates and responsibilities of the government institutions involved in environmental protection.

The responsibility for coastal development and environmental protection in Vietnam is delegated to local administrations. For example, in Minh Hai province, the people's committee has formulated a number of decisions, regulations and instructions to control the use of mangrove areas for shrimp culture. However, it appears that the culture of shrimps has proceeded without proper consideration of the environmental impacts. On February 17 1992, the Ho Chi Minh City's Agriculture Service issued guidelines prohibiting mangrove forest clearance for the purpose of shrimp pond construction. These guidelines also required registration of all units and households building shrimp ponds in mangroves and approval from the Agriculture Service for ponds greater than 1 ha.

International/Regional Conventions

i. Vietnam is a signatory of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which came into force on July 1st 1975. Among other things, the Convention recognized that international cooperation is essential for the protection against overexploitatio of certain species of wild fauna and flora through international trade. According to the Convention, the export/import of any specimen of the endangered species shall require the prior grant and presentation of an export/import permit with very strict conditions.

National Fisheries Institutions

The Ministry of Fisheries is the main agency that manages fisheries at the national level. It is responsible for:

- Capture fisheries;
- Aquaculture;
- Preservation and development of fisheries resources;
- Fishing vessel registration;
- Fisheries processing, wholesale and retail trade for domestic fish products and import/export;
- Logistic services;
- International cooperation;
- Inspection of production facilities and hygiene standards, issuing quality licenses for domestic and export products;
- Training of fisheries scientists, technicians, managers, workers, granting certificates for captains and operators of fishing vessels;
- Conducting scientific and technical research, applying new technology to fisheries production.

In 1991, the Fisheries Resources Preservation Department was founded under the Ministry of Fisheries. Together with this Department, a system of resource protection agencies, responsible for fisheries resources management and registration of fishing vessels, was established. As of December 1999, there are 36 resource protection agencies with a staff of 888 persons at the provincial level.

The National Environment Agency under the Ministry of Science, Technology and Environment is

also involved in fisheries although in a less direct manner. The agency is the main national organization responsible for coastal zone management. Its responsibilities include: (i) provision of environment documentation and development of environmental management strategies, and (ii) cooperation and coordination with other institutes for study, strategies and policy for coastal management.

Coastal Fisheries in Focus

Scale, Structure and Information Aspects

Fisheries in Vietnam are categorized into small scale and large-scale sectors. Small scale fisheries are defined as those that use non-powered boats or motorized boats with an engine of less than 90 HP. The typical small scale fishing operation is labour-intensive and confined to nearshore waters. Common small scale fishing gear include beach seines, gillnets, lift nets, push nets, trawls, cast nets, traps, hooks, lines, set nets and trammel nets. At present, the small scale fishery in Vietnam accounts for more than 95% of total fishing boats, nearly two thirds of production and value, and 92% of the fisheries labour force.

Large scale or industrial fishing enterprises include those run by private companies, joint ventures and state-owned enterprises. The industrial fishing fleets in Vietnam are small and undeveloped in terms of quantity and quality compared with the industrial fishing fleets of other countries in the region. Most operate in coastal areas of < 100 m depth; few can fish in deep seas. These fishing fleets account for approximately 5% of the total fishing boats, but they produce about 37% of marine capture production and value. The large scale fleets mainly fish for high-value and/or export commodities such as tuna, skipjack, mackerels, dolphin fish and shrimp. The gear used are trawls, purse seines, drift gillnets, tuna longline and trammel-nets for shrimp.

The number of boats engaged in the marine capture fishery by category, their production and value are given in Table 7. In 1998, the total number of fishing boat was 100 500 units, of which 71 799 units were motorized vessels with a total engine capacity of 2 427 856 HP and 28 701 units were non-motorized boats. The distribution of motorized fishing boats according to engine horsepower is as follows: 53% with engine < 20 HP; 30% from 20 HP to 45 HP; 10% from 46 HP to 90 HP; and 7% for engine > 90 HP.

Fishing Methods and Technologies

There are more than 20 kinds of fishing gear used in capture fisheries and these are generally classified into six main types (Table 8). Gillnets and trawls are the most common gear types and collectively account for more than 55% of the fishing gear used. Trawlers concentrate mainly in the southern coastal provinces such as Kien Giang, Minh Hai and Ba Ria-Vung Tau (Figure 1). Purse seine and tuna mackerel gillnets are used predominantly in the provinces from Da Nang to the south, and lift nets from Da Nang to Binh Thuan province. Other fishing gear are widely used all over the coastal areas. Table 9 shows that certain gear types are used by both the small scale and large scale sectors. For such “shared” gear types however, the scale of operations, target species and other aspects differ markedly between the two fishing sectors.

Table 7. Total fishing boats, production and value by marine capture fishery sector in 1998.

Sector	Fishing boats		Production		Value	
	Number	%	t	%	(million US$)	%
Small-scale fisheries	95 493	95.02	708 928	62.70	387.61	62.70
- Motorized boats	66 792					
- Non-power boats	28 701					
Large scale fisheries	5 007	4.98	421 732	37.30	230.59	37.30
TOTAL	100 500	100	1 130 660	100	618.20	100

Table 8. Percentage number of various fishing gear types in Vietnam.

Fishing gear	%
Trawls (otter board trawl, pair trawl and beam trawl)	26.0
Seinenets (beach seine, purse seine)	4.3
Gillnets (drift gillnet, mackerel gillnet, shrimp gillnet and trammel net)	31.4
Lift nets	5.6
Hooks and lines (long-line and hand-line)	13.4
Set nets	7.1
Other gear	12.2

Table 9. Boat capacity by fishing gear type in Vietnam.

Type of fishing gear	Boat capacity (HP)	
	Small scale fisheries	Large scale fisheries
Bottom fish trawl	60 - 150	150 - 600
Shrimp trawl	20 - 60	–
Purse seine	45 - 150	150
Tuna mackerel gillnet	33 - 100	150 - 200
Other fish gillnet	12 - 60	–
Light lift net	33 - 45	–
Long-line, hand-line	12 - 60	150 - 200
Others	Non-power - 22	–

Catch and Catch Rates

The south region of Vietnam leads the central and north regions in fisheries production (Table 10). Overall, the trawl contributes about 43% of the catch, due to the high contribution of trawls in the catch of the north and south regions. The central region however illustrates that purse seines, gillnets and lift-nets contribute about 65% of the total catch.

Marine capture fisheries production increased steadily from 1981 to 1999 (Fig. 2), posting a nearly three-fold increase from 419 740 t in 1981 to 1 212 800 t in 1999. However, average catch per unit effort (CPUE) declined over the same period because the annual increases in production were obtained through greater than proportional increases in total horsepower. Over the two decades, total horsepower increased more than five-and-a-half fold from 453 871 HP in 1981 to 2 518 493 HP in 1999.

CPUE declines were observed in specific fishing grounds (Vinh et al. 2001). The CPUE declined from 1.34 to 0.34 $t \cdot HP^{-1} \cdot year^{-1}$ in the Gulf of Tonkin (1985 - 97), from 1.06 to 0.66 $t \cdot HP^{-1} \cdot year^{-1}$ in the Central area (1986 - 91) and from 2.05 to 1.20 $t \cdot HP^{-1} \cdot year^{-1}$ in South Vietnam (1985 - 88). In the northern coastal provinces, decreased catch rates were observed for the trawl, purse seine and lift net with lights (Table 11).

The catch composition features typical characteristics of tropical assemblages, such as high species richness but low species abundance. A typical trawl

haul normally includes 30 to 40 species. Table 12 lists the common fish species caught by major fishing gear types. Table 13 shows the species composition changes of catches from trawl surveys undertaken in Vietnamese waters. These trends will be further studied using the compiled information on trawl surveys (see Garces and Silvetre this vol.; Thuoc et al. 2000).

Table 10. Total catch (t) (percentage contribution in parenthesis) by fishing gear type in Vietnam (1997).

Region	Total Catch	Fishing gear						
		Trawl	Purse-seine	Gillnet	Lift net	Hook and line	Fixed net	Other
North region	73 703 (100)	27 182 (36.9)	4 880 (6.6)	18 728 (25.4)	14 110 (19.1)	4 773 (6.5)	1 240 (1.7)	2 391 (3.2)
Central region	173 218 (100)	31 078 (17.9)	41 614 (24.0)	34 674 (20.0)	36 534 (21.7)	23 793 (13.7)	841 (0.5)	4 504 (2.6)
South region	283 415 (100)	169 958 (60.0)	62 593 (22.0)	18 729 (6.6)	– –	16 452 (5.8)	13 731 (4.7)	2 322 (0.8)
TOTAL	530 336 (100)	228 218 (43.0)	109 087 (20.6)	72 131 (13.6)	50 644 (9.5)	45 028 (8.5)	15 452 (2.9)	9 217 (1.7)

Source: Long 2000; Long this vol.

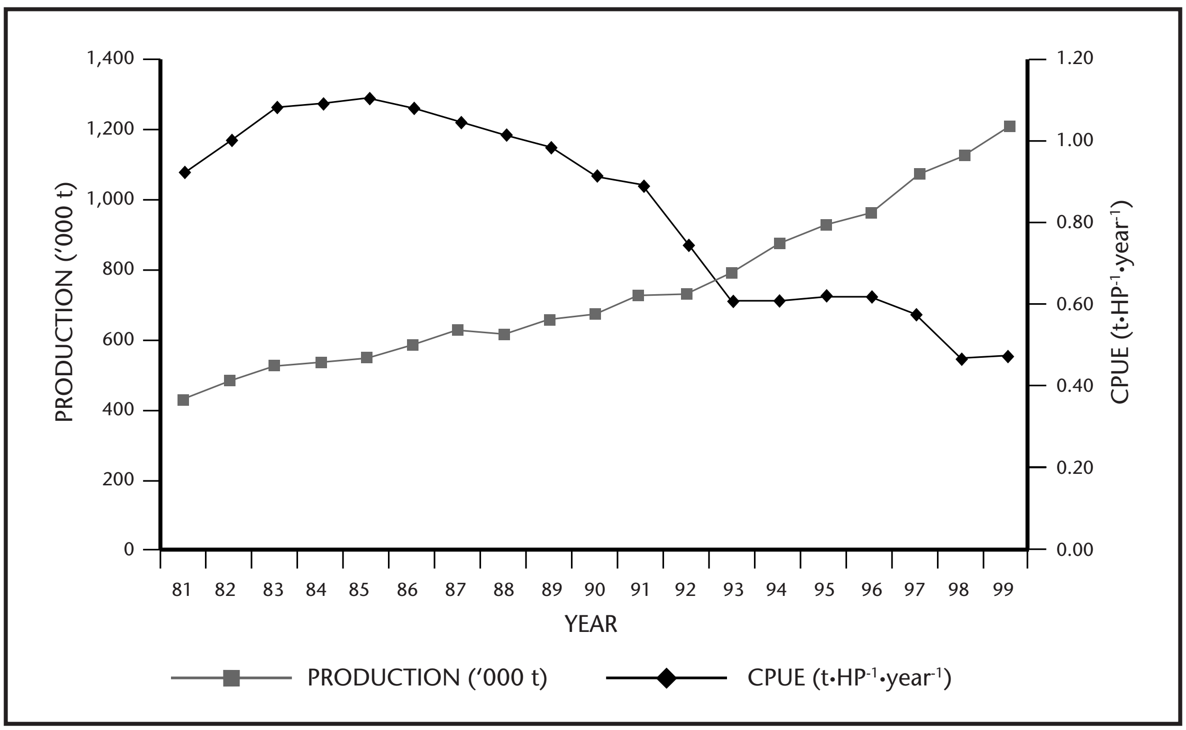

Fig. 2. Marine capture fisheries production and average catch per unit effort from 1981 to 1999. Data source: MOFI 2000.

Table 11. Trends in changes in catch rates of selected fishing gear types in the northern provinces of Vietnam.

Fishing gear type	Catch rates ($t \cdot boat^{-1} \cdot year^{-1}$)	
	1976	1990
Trawling: - 250 HP trawler - 400 HP trawler	 360 480	 200 240
Purse seine	100 - 150	20 - 30
Lift net with light	200	30

Table 12. List of main species caught by major gear types in Vietnam.

Gear type	Dominant species
Purse seine	Yellowtail round scad (*Atule mate*), round scad (*Decapterus maruadsi*), bigeye scad (*Selar crumenophthalmus*), yellow stripe trevally (Carangidae), Indian mackerel (*Rastrelliger kanagurta*), frigate mackerel (*Auxis thazard thaxard*), and eastern little tuna (*Euthynnus affinis*)
Pair trawl	Cuttlefish, swordtip squid, purple-spotted bigeye (*Priacanthus tayenus*), golden threadfin bream (*Nemipterus virgatus*), white croaker (*Pennahia argentata*), barracuda (Sphyranidae), lizardfish (Synodontidae), grouper (Serranidae), and snapper (Lutjanidae)
Lift net	Anchovy (Engraulidae), sardines (Clupeidae), Indian mackerel (*Rastrelliger kanagurta*), yellowtail (*Atule mate*), round scad (*Decapterus maruadsi*), bigeye scad (*Selar crumenophthalmus*), and swordtip squid
Drifting gillnet	Eastern little tuna (*Euthynnus affinis*), bonito (Scombridae), frigate mackerel (Scombridae) king mackerel (*Scomberomorus commerson*), Indo-pacific mackerel (*Scomberomorus guttatus*), barracuda (Sphyranidae) and hairtail (Trichiuridae)

Table 13. Trends in relative abundance of major species in the catch from trawl surveys by region in Vietnamese waters.

Fish species	Catch (% weight) from year to year		
Tonkin Gulf	**1975**	**1987**	**1999**
Decapterus maruadsi	11.7	7.4	4.3
D. lajang	–	1.7	–
Evynnis cardinalis	9.1	–	37.5
Priacanthus tayenus	–	7.4	3.7
P. macracanthus	3.1	5.3	5.5
Scomberomorus guttatus	–	3.3	–
S. commerson	–	8.2	–
Rastrelliger kanagurta	–	1.5	–
Saurida tumbil	2.6	0.5	5.4
Selar crumenophthalmus	–	1.1	–
Selaroides leptolepis	2.3	–	–

Table 13. Trends in relative abundance of major species in the catch from trawl surveys by region in Vietnamese waters. (continued)

Fish species	Catch (% weight) from year to year		
Tonkin Gulf	**1975**	**1987**	**1999**
Formio niger[1]	–	1.3	–
Psenes indicus[2]	–	1.9	–
Upeneus mollucensis	3.5	–	1.0
Others	67.7	60.4	42.6
Central region	**1979 - 1983**	**1987**	**1995**
Pennahia argentata	3.4	–	–
Decapterus kurroides	0.4	6.7	–
D. maruadsi	0.8	2.2	–
Therapon theraps	–	1.5	2.2
Malakichthys wakiyai	29.3	4.6	–
Taius tumifrons	–	2.1	–
Saurida tumbil	7.2	1.5	1.8
Argyrosomus argentatus	–	–	9.3
Psenes indicus	–	1.5	–
Arius spp.	–	1.6	0.2
Priacanthus macracanthus	4.4	0.8	0.1
Upeneus sulphureus	–	0.7	–
Leiognathus rivulatus	–	–	6.3
Trichiurus lepturus	22.2	–	6.1
Others	30.2	76.1	74.0
Southeast region	**1980**	**1988**	**1999**
Decapterus maruadsi	19.4	2.8	3.9
Selaroides leptolepis	5.9	1.1	1.2
Priacanthus macracanthus	4.7	–	12.0
Saurida tumbil	4.4	2.5	1.5
S. undosquamis	3.5	1.8	3.0
Lutjanus spp.	2.6	4.8	1.4
Nemipterus spp.	–	2.3	1.7
Selar crumenophthalmus	1.5	0.7	–
Caranx malabaricus	0.8	0.6	–
Trachynocephalus myops	0.7	1.9	5.1

Table 13. Trends in relative abundance of major species in the catch from trawl surveys by region in Vietnamese waters.

Fish species	Catch (% weight) from year to year		
Southeast region	**1980**	**1988**	**1999**
Pomadasys hasta	0.7	1.6	–
Arius spp.	0.8	0.9	–
Loligo spp.	–	4.0	2.9
Sepia spp.	–	2.3	5.8
Others	55.0	75.0	61.5
Southwest region	**1980**	**1988**	**1995**
Leiognathus equulus	20.7	–	0.1
L. rivulatus	1.1	–	6.3
Argyrosomus argentatus	2.0	31.3	9.3
Selaroides leptolepis	12.5	0.3	0.5
Arius thalassinus	2.2	5.7	0.2
Nemipterus spp.	3.0	2.6	–
Rastrelliger kanagurta	0.8	0.1	0.8
Therapon theraps	2.6	1.1	2.2
Saurida tumbil	0.6	0.7	1.8
Lutianus erythropterus	4.1	0.5	–
Sphyraena jello	1.7	0.3	0.3
Pomadasys hasta	0.4	0.4	0.7
Trichiurus haumela	0.1	–	6.1
Loligo sp.	–	1.8	4.0
Sepia sp.	–	0.5	2.9
Others	48.2	53.7	64.8

Source: Son 1989 and Thuoc et al. 2000.
Note: [1] Valid name in FishBase Parastromateus niger.
[2] Valid name in FishBase Ariomma indicus.

Economics of Coastal Capture Fishery

As mentioned earlier, marine capture fisheries production in Vietnam has been increasing from year to year. In the last two years, it has reached more than 1 million t•year^{-1}. Although, there are more than 2 000 fish species in Vietnamese seawaters, only about 50 species are of major economic importance to commercial fisheries. Most fish species are generally small, short-lived with maximum total body length of 780 mm and an average of 100 - 200 mm.

Currently, the relationship between demand and supply is the basic factor that determines the price of fish. Actual value varies with season, area of production, quantity of landings, strength of demand, size, freshness, etc. It is difficult to clarify the price

of fish at landing sites, because the catches are usually delivered through negotiations between fishers and middlemen, not through auction.

The price of fish at domestic markets is affected by the price at export markets. The former tends to rise at a higher rate than the latter. Normally, frozen fish is not in demand in most domestic markets, while fresh and iced fishes are accepted, together with processed foods. Recently, demand for frozen fish has risen in large cities, typically for consumption at restaurants and hotels by overseas visitors. This new type of consumption is one of the causes for the rise in prices of fish in the domestic markets.

Figure 3 presents the trend in total profits of the marine capture fisheries based on total costs and total returns data from 1981 to 1998. Profits rose steadily from 1981 to 1987, then remained relatively unchanged until 1991, and then dropped sharply over the next two years. The year 1991 seems to have signaled the start of erratically fluctuating total profits, ending the era of progressively increasing profits. In addition, the total profit levels after 1991 were lower than the total profits in previous years, except for the "initial" years of 1981 and 1982. Lower total profits were realized despite continuously increasing fishing capacity as measured by total horsepower. This suggests that total fishing capacity has exceeded the economically optimal level.

In recent years, the number of mechanized fishing boats increased considerably, from 29 117 units in 1983 to 71 799 units in 1998, giving an annual average increase of 6.2%. The average horsepower per boat also increased from 16.3 HP•boat^{-1} in 1983 to 34.3 HP•boat^{-1} in 1999. The number of fishing boats increased rapidly from 1988 to 1994. This was influenced by the changes in fishery management policies of the government. Before 1985, fisheries were managed and operated in the form of fishing cooperatives and enterprises that provided few economic incentives. One of the effects of this policy was low fisheries production. After 1985, Vietnam applied the *Doi Moi* policy, which relied on market mechanisms and encouraged private businesses. This motivated the development of fisheries, resulting in remarkable increases in fishing fleet size and catches. During the period of 1994 -

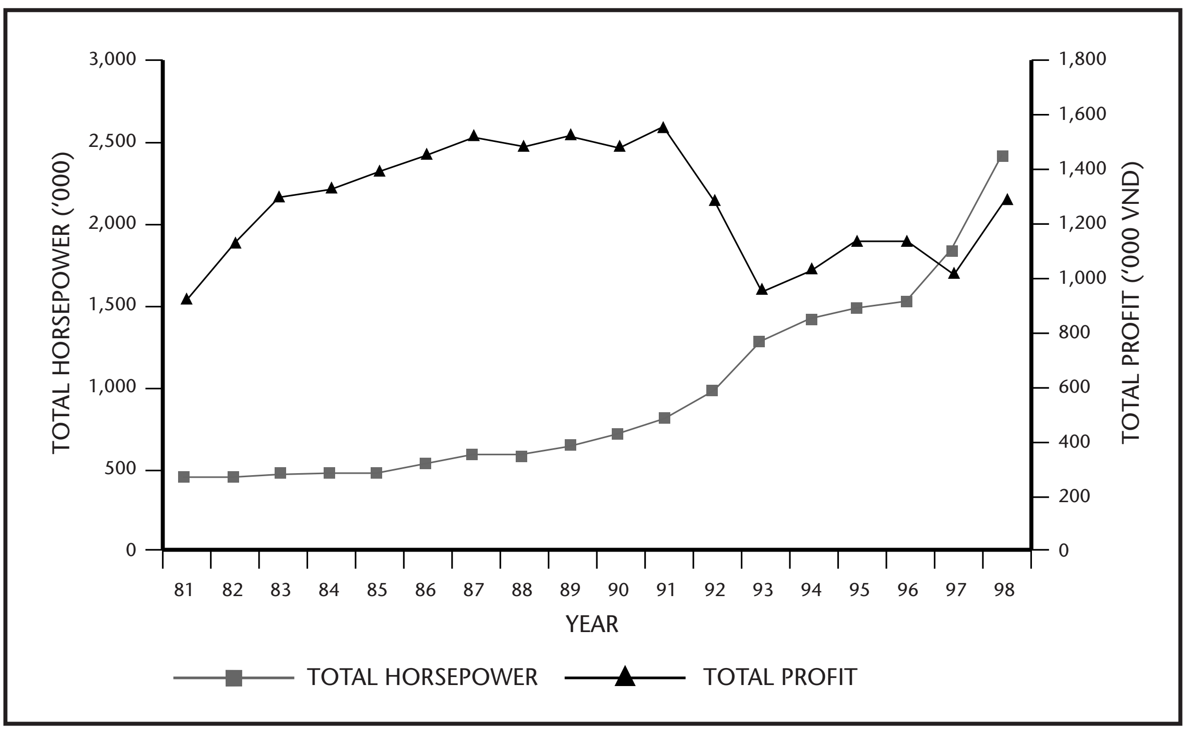

Fig. 3. Total horsepower and total profit from 1981 to 1998. Data source: Long 2000 & this vol..

98, the increase in boat number was slight while the increase in total HP was larger. This indicates that fishing boats built in this period have greater engine capacities, allowing them to operate at greater distances from the coast.

Fishing boats of less than 45 HP account for 85.5% of the total mechanized fishing boats in the country (Table 14). The percentages of boats with less than 45 HP are comparable in the northern and central regions at 93.9% and 92.4%, respectively. In the southern region, such boats comprise 70.9% of the total motorized boats, indicating a higher concentration of larger fishing boats with bigger engine capacities. This is one of the reasons for the higher fisheries production of the southern region.

Based on annual total value of fisheries (Table 15), fisheries in the southern provinces have developed more strongly than those in northern and central provinces. Fisheries export products have been growing in quantity and value. The export quantity increased from 3 441 t in 1980 to 64 366 t in 1990, while the export value increased from US$166.7 million in 1988 to US$971 million in 1999, 5.8 times as much. In 1990 - 99, the national export earning increased 474%, on average 52.6% year^{-1}.

Fisheries in Vietnam, which have been growing rapidly for many years, are becoming one of the key economic sectors of the country. The GDP of fisheries constitutes 3% of the domestic total. The average annual increase of the fisheries GDP is 40% (Nguyen Long this vol.). In 1990, the GDP of fisheries was 1 281 billion VND and in 1995, it reached 6 664 billion VND. The average GDP/fisherman is about US$160 person^{-1}•year^{-1}. When viewed against average living standards throughout the country, fishermen are still mired in poverty.

The marketing channels for fisheries products are varied. Since the introduction of market reform, entry to the marketing industry has been relatively unrestricted. This has resulted in a rapid increase in the number of middlemen servicing the sector. At present, the middlemen play an important role in supplying fish to the domestic market. Middlemen provide financing to fishers. Typically, a middleman lends money to cover the costs of fishing boats, which are normally 20 - 70 million VND•boat^{-1}. In exchange, a fisher grants the middleman exclusive right to purchase the catch. Landed fish

Table 14. Number of fishing boats by horsepower class.

Region	Number of motorized boats	Average capacity HP•boat^{-1}	> 45 HP	46 - 84 HP	85 - 150 HP	151 - 200 HP	250 - 400 HP	> 400 HP
Northern region	20 409	16.4	19 161	198	57	21	19	0
Central region	26 675	16.0	24 651	1 839	185	0	0	0
Southern region	23 971	47.7	16 988	3 922	1 459	410	928	21
TOTAL	71 055	26.8	60 800	5 959	1 701	437	947	21

Source: Long 2000.

Table 15. Total value of fisheries (billion VND) in 1986 - 95.

Year		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Whole country		987.8	1 074.7	1 325.5	1 449.0	1 500.3	1 561.9	1 662.2	1 780.0	2 224.2	2 475.0
Key Provinces	North	90.8	84.6	82.1	79.5	91.1	114.5	132.2	422.2	154.8	180.6
	Center	198.6	202.7	207.5	213.5	214.5	147.4	161.1	168.9	220.6	284.5
	South	561.7	584.6	624.1	620.1	668.6	947.9	1 008.3	1 131.7	1 520.9	1 574.9

Source: MOFI, Bureau of Statistics.

are normally purchased by fish traders or middlemen. Fish is often sorted by species, size class and quality to satisfy specific markets. High valued products are selected for export while lower valued products are sold in large cities as fresh products or to processing plants that make products for the domestic market. Trash fish is processed into fish sauce.

Vietnam now supplies fish to 49 countries including large markets such as Japan, the European Union, America and China. Shrimp, cephalopods and fish are the major commodities for export. The export products are mainly raw and semi-processed products. High-quality products that are exported directly to supermarkets are rare.

Assessment of Exploitation Status

The standing stocks and potential yield of the marine waters of Vietnam are estimated at about 3.5 million t and 1.5 million t, respectively (Thuoc et al. 2000; Thuoc 2001). The total production of marine capture fisheries in 1999 reached more than 1.2 million t, of which more than 80% were taken from coastal fishing grounds. The annual production of the capture fisheries increased from 928 860 t in 1995 to 1 212 800 t in 1999. Fishing operations are mainly carried out in the coastal area in depths up to 50 m. The intensified fishing in the coastal areas has caused over-exploitation. Declining catch rates in recent years suggests that the inshore and coastal fishery resources may have already been fully exploited or are over-fished (Thuoc 2001). Other evidence of the current state of exploitation includes the increased amount of by-catch in trawl fisheries and the smaller sizes of the fish caught.

Recently, the government in cooperation with Japan International Cooperation Agency (JICA) conducted surveys of pelagic fishery resources in the offshore area of Central Vietnam. The results (JICA 1998) indicate that the potential yield of medium and large sized pelagic fish such as bonitos and tunas is approximately 100 000 t (Chung et al. 2001). Knowing that fish resources in offshore areas are still relatively abundant and can be further exploited, the government plans to maintain the fishery production in coastal (near shore) areas at around 700 000 t•year^{-1} and increase catches by shifting fishing effort to deeper waters and offshore areas.

There is a great need for improved fisheries statistical systems in Vietnam (van Zwieten et al. 2002). The effective use of the present fisheries information is currently constrained by its low categorical resolution and the non-transparent aggregation of data into mere administrative or geo-political regions.

Management Issues and Opportunities

Fisheries Management Philosophy

The Ministry of Fisheries, established in 1976 as the General Department of Fisheries, has been mandated to implement the Master Plan of Fisheries at the country level with the goal of achieving sustainable development in fisheries. In order to rationally utilize the fisheries resources for the benefit of Vietnamese people, the Government has issued many legal documents comprising law and by-law provision serving the management of Vietnam fisheries. At present, one measure for the rational utilization and sustainable development of fisheries resources in Vietnam is to limit the fishing effort in coastal areas to about 700 000 t•year^{-1} and increase the fishing effort in deep seas by shifting fishing boats to the offshore areas.

In 1991, the Fisheries Resources Preservation Department was founded under the Ministry of Fisheries. Together with this Department, the system of the resource protection agencies (mentioned previously) was established.

There is an aim to develop the fisheries economics in coherence with building technical infrastructure and addressing social issues of onshore rural areas. The aim is to create more jobs, increase income, raise the people's knowledge and living standards, train human resources, maintain the order of society and build prosperous fishing villages.

In order to realize the visions and aspirations for Vietnam fisheries, the strategic objectives and action plans were established in the Master Plan for Fisheries Development in the period 1996 - 2010 (see Danida 1997a and b). The six important programs and their main objectives are as follows:

1. Usage of the environment and fisheries resources:
    - All capture fisheries and aquaculture activities will be carried out in a manner that is fully consistent with the principle of sustainable

and sound use of the environment on the basis of laws to be established.
  - Development, restoration and conservation capacities for the biological diversity of fisheries resources will be ensured and stimulated.

2. Rational exploitation of offshore fisheries resources:
   - The country's offshore fisheries resources will be exploited in a sustainable manner to maximize the national economic benefits, social and socioeconomic impacts.
   - Reducing gradually, the fishing in inshore areas, increasing the production of the offshore fishery, fulfilling the management measures in order to protect and restore resources.

3. Coastal aquaculture development:
   - Ensuring that the natural resource potential for aquaculture is effectively used to support economic development and growth. Vietnam has considerable potential for aquaculture activities and it is a goal of the Ministry to ensure that these activities are managed in a sustainable manner, for this and future generations.
   - Taking householders as a main force in aquaculture development.
   - Rearranging the system of seed production in the direction of new technologies and disease-free seed production, concentrating on building sea farming in large aquaculture areas.

4. Fisheries export development:
   - Industrialization and modernization of the export fisheries production sector by raising efficiency, playing a key role in changing the structure of the economic sector, boosting fisheries production to become a key sector of the economy, contributing to improved living standards of the people of coastal and rural areas, while contributing to the solving of environmental issues.

5. Coastal and island integrated development, combined with providing basic infrastructure to support fisheries:
   - It is an overriding goal of the Ministry of Fisheries to ensure that fishing communities and the fishing industry are supported by the basic physical infrastructure required to function effectively in a market oriented economic system.
   - Technology development must be an ongoing process. A suitable technological base for fisheries to be established by 2010.

6. Capacity strengthening for fisheries sector management and administration, and human resources development:
   - The Ministry of Fisheries will strengthen its institutional capability and capacity to effectively manage the environment and the living aquatic resources of the nation. This institutional goal is not limited to the Ministry of Fisheries, but includes all its specialized agencies and the fisheries administration as a whole.
   - The integrated process of strengthening the fisheries administration and reforming fisheries will be fully implemented by 2010. However, benefits and impacts will start accruing gradually and show positive impacts starting in 2000.
   - The Ministry of Fisheries will be strengthened to support the fishing industry to develop strong and enduring comparative advantages. To do this, the Ministry is determined to support the combination of using the natural resources with the application of appropriate technologies and the high skill levels of the labour force. The medium to long-term goal of the ministry is to establish a national capability to support technology enhancement and human resources development.

Fisheries Management Goals and Objectives (Strategic)

A National Consultative Workshop on "Sustainable Management of Coastal Fish Stocks in Vietnam" was convened on 28 - 30 August 2000 at the Haiphong Research Institute of Marine Products. The workshop was organized under the ADB/RETA 5766 Project - "Sustainable Management of Coastal Fish Stocks in Asia". A total of 44 participants attended, including scientists, managers and lawmakers in Vietnam. The workshop was also attended by international experts, including three from WorldFish and the adviser of the DANIDA Project "Assessment of the living marine resources in Vietnam". It is important to note that the national consultative workshop conducted in August 2000 was one of the few consultative meetings organized in Vietnam with participation of national experts coming from various disciplines and representing various agencies involved in fisheries and coastal management.

To improve the management and sustainable utilization of coastal fisheries resources and related ecological systems in Vietnam, there is a need to implement a wide range of measures within the confines of the traditional fisheries sector. Interventions also require coordination with other sectoral agencies at various levels of the institutional hierarchy.

Based on the discussion during the national workshop, a consensus was achieved and the suggested goals (see Fig. 4) for improved fisheries management are :

- optimize productivity/efficiency of the fisheries exploitation regime,
- ensure that the benefits of production are distributed equitably,
- ensure that the productivity generated, results in minimum damage to the resource base and the supporting natural environment, and
- upgrade and strengthen the institutions.

Fisheries Sector Issues/Opportunities and Key Interventions

Fig. 5 shows the logical structuring of the management objectives, issues and the suggested interventions relevant to the coastal fisheries management in Vietnam. The structure is very similar to those presented by Silvestre and Pauly (1997). It also provides a summary of the main points introduced in this report and illustrates the need for effective action on a wide front and at various levels of the institutional hierarchy.

As in other countries in Asia, the fisheries resources in the coastal areas of Vietnam in the past decade, have not only been overexploited but also threatened by the use of destructive fishing methods and habitat degradation. In the near future, these problems need to be resolved by a step-wise approach and there is a need for a comprehensive plan for fisheries management, which will address the following issues:

- Overfishing, i.e. excessive fishing effort,
- Inappropriate exploitation patterns,
- Use of destructive fishing methods,
- Post-harvest losses,
- Habitat degradation/destruction,
- Small and large scale fisheries conflicts,
- Coastal soil erosion,
- Mangrove conversion/cutting,
- Domestic/sewage pollution,
- Information and research inadequacies,
- Institutional weaknesses and constraints.

Recommendations for Continued Government Action

Fisheries management is a very complex task and needs to be sustainable in the long term. Currently, significant actions must be continued by the Vietnamese government, including:

- Limiting the number of small fishing boats and building some new offshore fishing vessels to reduce the pressure on overfishing of the coastal fishery;
- Prohibition of the use of destructive fishing methods (dynamite and poison);
- Selectivity of suitable gear and temporal restriction for closed fishing areas and seasons;
- Reduction of coastal environmental impacts through management of habitats and coastal zones;
- Establishment of fishery law.

Recommendations for Government Follow-up Action

There are a number of recommended action plans that need to be implemented in support of the efforts in coastal fisheries management in Vietnam:

- Limited entry and effort reduction, which includes:
  - Monitoring of fish stocks;
  - Development of offshore fisheries;
  - Increasing the sea farming activities;
  - Strengthening fisheries regulation enforcement capacity (control, patrols),
- Continued reduction of coastal environmental impacts, including:
  - Management of the environment, natural resources and ecosystems;
  - Integrated coastal area development;
  - Establishment and consolidation of the marine protected areas system (marine parks, marine sanctuaries);
  - Protection and rehabilitation of coral reef and mangrove systems;

- Upgrading fisheries monitoring, control and surveillance system,
- Improved marketing and post-harvest facilities, including:
  - Upgrading processing plants;
  - Upgrading infrastructure and facilities, renovating technologies.
- Enhancement of stakeholders' awareness and participation, through:
  - Improved education through television or movie documentaries;
  - Greater stakeholder participation in the decision-making process.
- Upgrading and strengthening of institutions,
- Enhancement of fisheries information and research,
- Development of the effective cooperation with other countries in the region for environment and fisheries resources preservation.

Recommendations for regional Collaborative Efforts

In order to attain sustainable development of coastal fisheries resources, it is necessary to establish links and co-operation between Vietnam and neighbouring countries (Son 1998a and b). This collaboration would benefit all countries and organizations, and will be focused on the following:

- Stock assessment methods,
- Shared stock utilization and management,
- Impact study of environmental degradation,
- Reduction of post-harvest losses,
- Sea farming and sea ranching,
- Socioeconomics and policy issues for alleviating poverty,
- Exchange of relevant information and experiences.

<table>
<tr><th>'First level' objective</th><th>'Second level' objectives</th><th>Illustrative 'third level' objectives</th></tr>
<tr><td rowspan="5">Sustainable Coastal Fisheries Development</td><td>Productivity/efficiency</td><td>• High fish production/revenue
• High catch/effort (CPUE)
• High foreign exchange earning
• Supply stability
• High returns on investments</td></tr>
<tr><td>Distribitional equity</td><td>• Equal access to production factors
• Reasonable artisanal catches
• Reasonable fish prices
• Reasonable artisanal incomes
• High employment level</td></tr>
<tr><td>Environmental integrity</td><td>• Reasonable water quality
• Reduced impact on critical habitats
• Reduced stress on biodiversity
• Use of non-destructive gears
• Marine sanctuaries</td></tr>
<tr><td>Efficient water and land use</td><td>• Long-term water and land use rights
• Integrated farming system
• Watershed and urbanization management
• Mangrove reforestation.</td></tr>
<tr><td>Institutional efficiency and effectiveness</td><td>• Effective use of information
• Effective and efficient institutions</td></tr>
</table>

Fig 4. The proposed goals and objectives of fisheries management in Vietnam, agreed on at the national consultative workshop.

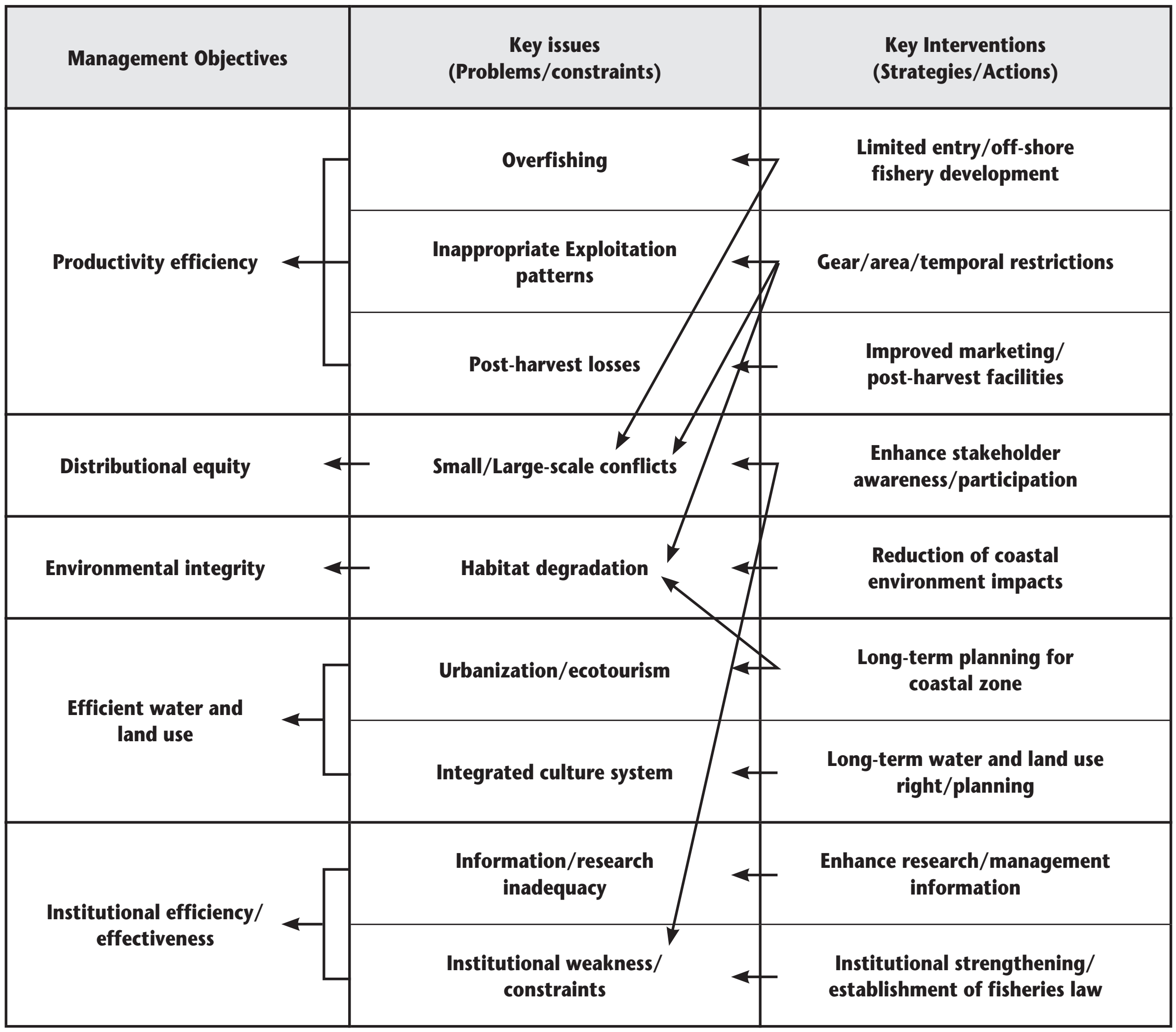

Fig 5. Fisheries management issues and key interventions.

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Annex I.

List of institutions involved in the development, management and conservation of the coastal and fisheries resources in Vietnam.

1. Ministry of Fisheries (Headquarters in Ha Noi)

   At present the Ministry is responsible for:

   - Capture fisheries;
   - Aquaculture;
   - Preservation and development of fisheries resources;
   - Fishing vessel registration;
   - Fisheries processing, wholesale and retail trade for domestic fish products and import/export
   - Logistic services;
   - International Cooperation;
   - Inspection of production facilities and hygiene standards, issuing quality licenses for domestic and export products;
   - Training of fisheries scientists, technicians, managers, workers, granting certificates for captains and operators of fishing vessels;
   - Conducting scientific and technical research, applying new technology to fisheries production.

The Ministry has nine Departments and Inspectors Section as follows:

Department	Function and duties
Science and Technology	Aids the Minister in the fields of science, technology, and environment, building the strategies and policies for fisheries science, technology and environment development.
Planning and Investment	Aiding the Minister in the field of investment planning, capital construction and statistics.
Financial and Accounting	In charge of financial management of MoF, managing accounting activities of the Ministry's administrative department, manages state assistance to the ministry and its administrative units, financial accounting of development investment projects implemented by the ministry.
International Cooperation	Aids the Minister in international cooperation, serving as coordinator in economic and technical cooperation with foreign organizations and countries.
Personnel and Labour	Aiding the Minister in the fields of labour organisation, salary and training.
Fisheries Management	Formulates policies and sets directions for developing fisheries; renovating, building and developing non-state, cooperatives, small - scale fisheries enterprises.
Fisheries Resource Preservation	Assisting the Minister in the conservation and development of fisheries resources, fish health, fisheries safety insurance, organizing and managing the work of fisheries resources preservation and disease prevention, monitoring technical safety, registering fishing vessels and pressurized machines as regulated by the Ministry and inspecting the preservation of fisheries resources.
Legislation	Aids the Minister in the fields of legislation and law concerning the fisheries sector.
Administration	Aiding the Minister in defining and organizing the implementation of working programs, monitoring their implementation, processing information for ministry leaders, following up implementation of the Minister's decisions, carrying out administrative tasks, ensuring logistical and communications requirements of the ministry.
Inspectors Section	Aiding the Minister in inspecting and considering complaint letters, serving as the office for collecting and settling complaints, carrying out inspection in the institutions of the ministry.

2. Scientific research and training institutions

As stipulated by the Government 50-CP Decree on 21 June 1994, the state budget funded scientific research and training institutions belonging to the Ministry of Fisheries as follows:

Institution Name	Established	Main Duties
Institute of Fisheries Economics and Planning (Ha Noi)	1984	To conduct research on the economics and management of fisheries, planning and production restructuring, strategy development, regional planning for fisheries development and training staff in these functions.
Research Institute of Marine Fisheries (Hai Phong)	1961 and reorganized in 1975	- To survey and research living marine resources and study the marine environment and the relations between environment and fishery development. - To study marine bio-diversity and the establishment of marine protection areas. - To study, experiment, develop and apply new technologies for exploiting fish and other sea products, for seed production and aquaculture in brackish-water and coastal areas, and for post harvest technology. - To transfer technologies in the fields of fishing, aquaculture, fish processing to all economic partners. - To provide post-graduate and other training on fisheries science and technology. - To promote international co-operation in the fields of research, implementing research-development and technology transfer projects from international organizations. - To provide information, consultation, investigation, planning and the setting up of econo-technical studies in fisheries resources, environment, capture fisheries, aquaculture and processing. - To organize the production of new specific products in single or small quantities of high quality.
Research Institute for Aquaculture Number 1 (Ha Bac)	1983	To conduct research on the environment and freshwater fish and on genetics in aquaculture, to conduct experimental production and applied research for the areas from Thua Thien Hue to the North: • Genetic selection • Fish breeding • Applied biology • Environment and fish diseases • Information and training • Experimental fish farming • Technology transfer
Research Institute for Aquaculture Number 2 (Ho Chi Minh City)	1975 and reorganized in 1983	To conduct research on the environment and fish resources, scientific research on seed, aquaculture and to conduct experimental production and applied research for the areas in the South (including both freshwater and brackish-water culture).
Centre for Aquaculture Research Number 3 (Nha Trang)	1984	To conduct research on the environment, seed, aquaculture, to conduct experimental production and applied research for the central provinces and central highlands, including both fresh and brackish-water culture, particularly shrimp, lobster and molluscs.
Centre for Science-Technology and Economics Information (Ha Noi)		Responsible for researching and processing information for fisheries management.
Centre for Fisheries Hygiene and Quality Control		Responsible for appraising and granting quality licenses for fisheries products for domestic use and export; monitoring and certifying quality and hygiene of fisheries production nation-wide

3. Training institutions

The Ministry of Fisheries has three training institutions as follows:

Name of Institution	Duties
Technical College for Fisheries Number 1 (Hai Phong City)	Responsible for training cadres, technicians and workers in the fields of exploitation, processing, freezing engineering, hydraulic engineering, training and granting certificates for captains and vessel operators from Thua Thien Hue northwards.
Technical College for Fisheries Number 2 (Ho Chi Minh City)	Responsible for training cadres, technicians and workers in the fields of exploitation, processing, freezing engineering, hydraulic engineering, training and granting certificates for captains and vessels operators from Da Nang to south.
Technical College for Fisheries Number 4 (Ha Bac Province)	Responsible for training workers in fisheries aquaculture, cadres in finance and accounting and aquaculture. It also provides in-service university training in fisheries aquaculture and economics; Training and retraining of the administrative staff in fisheries sciences and foreign languages. Its scope of operation is from Thua Thien Hue northwards.

4. Other institutions involved in fisheries and coastal zone management

The following institutions are involved in fisheries and coastal zone management:

Name of Organisation	Responsibility and major activities
National Environment Agency, Ministry of Science, Technology & Environment (MOSTE)	Environment management: - provision of environment documentation/development of environmental management strategies, - cooperation and coordination with other institutes for study, strategies and policy for coastal management
Nha Trang, Institute of Oceanography	Marine biodiversity studies in the central and south part of Vietnam
Hai Phong, Sub-institute of Oceanography	Same as the Institute in Nha Trang, but with responsibilities for research/environmental monitoring in the northern part of Vietnam.
Centre for Meteorology and Hydrology, Ha Noi	Studies on coastal tidal regimes, and hydrology
Geography Institute, National Centre for Natural Resources and Technology, Ha Noi	Environmental studies on geography of Vietnam, including river and coastal erosion, geology and coastline topography
Environment Protection Centre (EPC), Ho Chi Minh City	Environmental studies of water quality in the river mouths and along coast
National Programme of Marine Investigation, Ha Noi	Coastal and marine studies. Survey on natural conditions of coastal areas and some islands
Institute of Water Resources Planning & Management, Ha Noi	Planning water resources and irrigation. Research on sea dyke construction and climate change
Centre for Remote Sensing, Ha Noi	Preparation of maps from remote sensing
Sub-Institute for forest Inventory and Planning, Ho Chi Minh City	Forest inventory and planning and forest management. Research on growth and area change of mangroves and melal euca.
Institute of Agricultural Inventory and Planning, Ministry of Agriculture and Rural Development, Ha Noi	Inventory and planning of agricultural land, including land use in coastal areas

Name of Organisation	Responsibility and major activities
Vietnam Marine Science Technology Association, Ha Noi	Marine study and dissemination of knowledge. Research on geology, geography, tidal regime and marine biodiversity.
Aquatic Resources University, Nha Trang	Training and graduate studies on aquatic resources, including aquaculture.
Faculty of Biology & Faculty of (Geography) College of Natural Science-Vietnam National University (VNU)	Training engineers, post graduate students in geography, geology & biology. Research on estuaries and river mouth studies and biodiversity.
Centre for Natural Resources and Environmental study (CRES)-VNU	Study & training in natural resources management, wetland and mangrove studies, coastal area study and strategies for wetland protection.
Faculty of Agriculture, Can Tho University	Aquaculture research and education
Faculty of Geology, Ha Noi Technical University of Mining and Geology	Training and research on mining exploitation and coastal geology

5. Financing institutions relevant to fisheries activities

   The financing institutions relevant to fisheries activities in Vietnam are as follows:

   - Ministry of Planning and Investment
   - Ministry of Science, Technology and Environment
   - Ministry of Finance
   - Ministry of Fisheries
   - National Border and continental Shelf Committee of Vietnam
   - Vietnam Bank for Agriculture and Rural Development
   - Rural Shareholders Bank
   - People's Credit Fund
   - The Bank for the Poor
   - Provincial People's Committees
   - Provincial Fisheries Departments

The above mentioned institutions are permitted to fund the budgets for fisheries activities depending on the program, project or special tasks approved by central or local government.

6. Research and training facilities/opportunities

The research activities of the Ministry of Fisheries are undertaken through the Research Institute and its various sub-centres and research stations located throughout the country, see below:

Name of Institutes	Location	Main Responsibility
Research Institute of Marine Products (RIMP)	Hai Phong City	Activities, both in research and training related to fisheries.
Research Institute for Aquaculture No. 1 (RIA 1)	Bac Ninh Province	- ditto -
Research Institute for Aquaculture No. 2 (RIA 2)	Ho Chi Minh City	- ditto -
Centre for Aquaculture Research No. 3 (CAR 3)	Nha Trang City	- ditto -
Institute of Fisheries Economics and Planning (IFEP)	Ha Noi Capital	- ditto -
Faculty of Biology of the Ha Noi National University	Ha Noi Capital	Actively involved in research and training related to the fisheries sector
University of Fisheries	Nha Trang	- ditto -
University of Agriculture and Fisheries of HCM City	Ho Chi Minh City	- ditto -
University of Can Tho	Can Tho	Actively involved in research and training related to the fisheries sector
Fisheries Technical College No. 1	Hai Phong City	- ditto -
Fisheries Technical and Professional College No.2	Ho Chi Minh City	- ditto -
Vocational Secondary School of Fisheries	Bac Ninh Province	- ditto -
Institute of Oceanography	Nha Trang	- ditto -
Sub-Institute of Oceanography	Hai Phong City	- ditto -
Institute of Ecology of Biological Resources	Ha Noi	- ditto -
Sub-Institute of Ecology of Biological Resources of Ho Chi Minh City	Ho Chi Minh City	- ditto -

Review of National Fisheries Situation in Sri Lanka

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New Secretariat Maligawatta
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Samaranayake, R.A.D.B. 2003. Review of national fisheries situation in Sri Lanka. p. 987 - 1012. *In* G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) Assessment, Management and Future Directions of Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings 67, 1 120 p.

Abstract

Fisheries are an important source of protein and employment for Sri Lanka's population. The declaration of the Exclusive Economic Zone (EEZ) in 1976 gave the country a water area larger than its land area. The coastal fisheries resources consist of small and large pelagic fish, demersal and coral reef fish, invertebrates, shrimps and crabs. The small pelagic fish contribute 70% of the catch from coastal waters with an estimated annual production of 152 752 t in 1997.

Some of the fisheries resources in Sri Lanka have been overexploited, although the situation varies across resource types and regions. A major reason for this has been the lack of proper management, particularly at the time of the introduction of motorized craft and synthetic nets which virtually revolutionized the fishing industry. Valuable habitat such as coral reef, mangrove, sea grass and marshland are also extremely susceptible to degradation. Destruction of these critical habitats could lead to reduced coastal fish stocks.

This paper provides a broad review of the national fisheries situation in Sri Lanka, presenting the environment status, coastal capture fisheries situation and fisheries management issues and opportunities. The main objectives for improving the fisheries management in Sri Lanka, as suggested by a national consultative workshop are: (1) promotion of sustainable exploitation of fisheries resources; (2) improvement of habitat protection; (3) maximization of the benefits from the fishery resources; (4) promotion of equitable distribution of the benefits; (5) maximization of the acceptability of interventions; and (6) maximization of the efficiency of institutional/legal system.

Introduction

Sri Lanka is an island state lying between latitudes 5º 30' and 10º 00' North and longitudes 70º 30' and 82º 00' East in the Indian Ocean, bounded on the west by the Arabian Sea and the Gulf of Mannar and on the east by the Bay of Bengal (Fig. 1). It has a coast-line 1 760 km long and a land area of 65 610 km^2. With the declaration of an exclusive economic zone (EEZ)[1], extending up to 200 miles, 436 000 km^2 of ocean have come under national jurisdiction, thus giving Sri Lanka a high water to land ratio.

Over the last five centuries, following foreign occupation, the country's development has been closely related to maritime activities. Prior to this period,

[1] Through Maritime Zones Law No. 22 of 1 September 1976.

its civilization was concentrated in the interior. Today more than half of its population of 18 million live in villages, towns, and cities in the coastal districts. Sri Lanka's coastal area, defined as coterminous with the 67 divisional secretariat areas, contains about 65 percent of the urbanized land area, about 80 percent of the hotel rooms of the tourist industry, and about 67 percent of the industrial facilities in the country.

Coastal fisheries produce about 30 percent of the animal protein crucial to the diet of the populace, and nearly 70 percent of the annual fish production. Coastal habitats are critical for sustained fish production, the maintenance of good water quality, and provide rich bio-diversity reserves including coral reefs, seagrass beds, and mangroves. This paper presents the management issues relative to coastal fisheries in Sri Lanka and recommendations for optimal management.

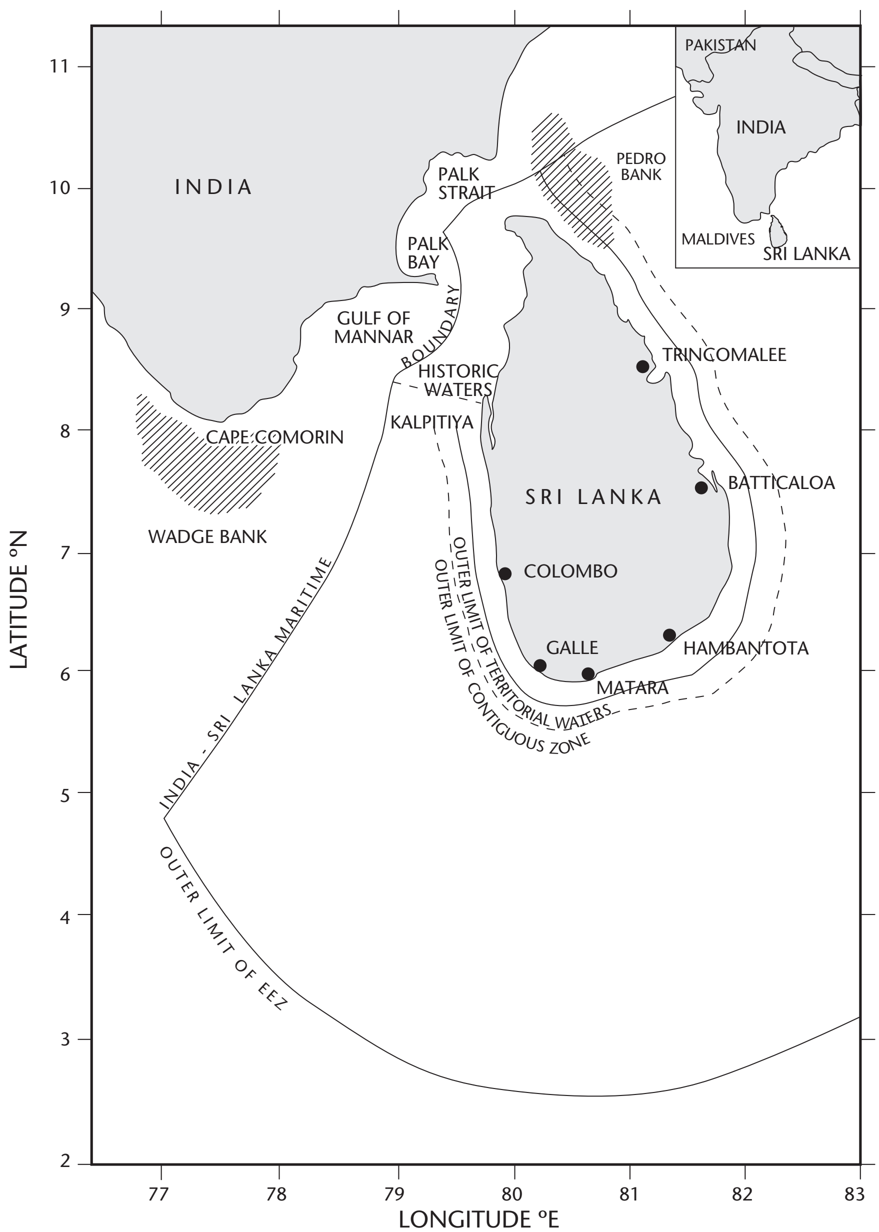

Fig. 1. Map of Sri Lanka's marine waters.

Environmental Setting

The marine area from the shore to the edge of the continental shelf is referred to as coastal waters. The continental shelf averages 15 km wide and 20 - 65 m in depth. The narrowest part is at Kalpitiya, where the width is only 2.8 km. The total area of the continental shelf is about 26 000 km^2, 11% of the EEZ. A large number of submarine canyons, valleys and gullies dissect the shelf and slope. Some of these are seaward continuations of land valleys and some prolonged land fault trends. Many continue down the continental slope, dividing into "tributaries". The largest submarine canyons are confined to the areas of shallow basement rock, opposite areas of Precambrian rocks. Areas of tertiary basin development both on shore and offshore, lack the development of major submarine canyons on adjacent continental shelves and slopes.

The localized drastic depth changes at the canyon heads produce a unique interface between shallow and deep marine hydrodynamic and sedimentary conditions. A complex mixture of sediment types is created by diverse processes. The net movement of sediment in the coastal zone is generally classified as 'long shore movement', movement under the action of waves and currents parallel to the shore line, and 'on shore/off shore movement', sediment transport normal to the coast line. The near shore zone is characterized by the occurrence of reefs, mainly corals, sandstone and crystalline rocks (boulders).

The tidal pattern in Sri Lankan waters is predominantly semi-diurnal and micro-tidal, with the highest amplitudes around the Colombo area and lowest around the Jaffna and Trincomalee coastline (Dassanayake 1994). The tidal range is moderate with an amplitude of 0.6 m, resulting in currents of very low magnitude, up to 0.3 $m \cdot s^{-1}$ in the nearshore area. Wave driven currents are predominant. Hydrographic studies conducted on *RV Dr. Fridtjof Nansen*, identified a water mass of temperature 17° C and salinity 34.9 - 35.1% in the Indian Ocean Equatorial region, which creates a fairly uniform thermo-haline stratification all round the island beyond 150 m depth during August - September and April June, and beyond 175 m during January - February. This survey indicated that the sea surface currents are directly influenced by the monsoons and are often strong at the beginning and end of the south-west monsoon (May to September), and during the entire north-east monsoon (December to February).

During the south-west monsoon the general oceanic circulation is from west to east, with current velocities of 2 - 3 knots near the shelf. The circulation is reversed during the north-east monsoon and current velocities are only 1 - 2 knots in this period. In general, the currents are stronger off the east coast during the north-east monsoon and off the west coast during the south-west monsoon. The strongest currents are recorded off the southern coast. The depth of the thermocline is also dependent upon the prevailing monsoon. It is about 100 - 125 m deep on the west coast during the north-east monsoon and 40 - 60 m deep during the south-west monsoon. On the east coast, the thermocline reaches a depth of 50 - 70 m during the October - November inter-monsoon period and 20 - 40 m after the March - April inter-monsoon period.

Natural ecosystems found within the coastal zone of Sri Lanka are diverse and include lagoons and estuaries, coral reefs, mangrove forests, sea grass beds, salt marshes, beaches and dune systems (Table 1). These habitats play an important role in the daily lives of coastal communities in terms of livelihood and food production. However, the valuable habitats found within the coastal zone are extremely susceptible to degradation, and measurable declines have occurred in the extent and quality of a number of biologically productive coastal ecosystems.

Coral reefs in Sri Lanka can be found along only 2-3% of the total shoreline and they are mostly fringing reefs. Barrier reefs are found in Vanakali and Silvathurai in the north and are very rare. Both fringing and barrier reefs dissipate wave energy and are important for coastal stability and as a source of beach material. Surveys have recorded 171 species of reef building corals in Sri Lanka. The staghorn coral (*Acropora* spp.) is the dominant genus.

A study of eight coral reef areas (NARESA 1991) showed that due to destructive fishing practices and environmental impacts such as siltation and pollution, only two out of eight (i.e Kandakuliya and Talawila) had live coral coverage of greater than 50 %. Two nearshore reefs, Weligama and Polhena, showed a significant proportion (> 50 % and > 80 %, respectively) of dead coral, while at Hikkaduwa and Akurala about 25 % dead corals were noted. Most of this damage is believed to have occurred over a 10 to 15 year period. The percentage of dead corals at Hikkaduwa is now likely to be even higher as a result of a bleaching event in April 1998, probably caused by high water temperatures associated

Table 1. Extent (ha) of coastal habitats in Sri Lanka by district.

District	Mangroves	Salt Marshes	Dunes	Beaches, Barrier Beaches, Spits	Lagoons, Basin Estuaries	Other Water Bodies	Marshes
Colombo	–	–	–	112	–	412	15
Gampaha	122	497	–	207	3 442	205	1 604
Puttalam	2 264	3 461	2 689	2 772	39 119	3 428	2 515
Mannar	1 261	5 179	1 458	912	828	2 371	308
Kilinochchi	312	4 975	509	420	11 917	1 256	1 046
Jaffna	260	4 963	2 145	1 103	45 525	1 862	149
Mullativu	463	517	–	864	9 233	570	194
Trincomalee	1 491	1 401	–	671	18 317	2 180	1 129
Batticaloa	1 421	2 196	–	1 489	13 682	2 365	968
Ampara	292	127	357	1 398	7 235	1 171	894
Hambantota	539	318	444	1 099	4 488	1 526	200
Matara	6	–	–	191	–	234	80
Galle	187	185	–	485	1 144	783	561
Kalutara	70	–	4	77	87	479	91
Total Extent	8 687	23 819	7 606	11 800	15 017	18 839	9 754

Source: Coastal Conservation Department. Coastal Zone Management Plan, Sri Lanka 1997.

with El Niño. Even within the two marine protected areas declared by the Department of Wild Life Conservation (Hikkaduwa and Bar reef) destructive fishing practices continue.

Coral is one of the sources of lime for the construction industry. In parts of the southwestern coastal sector, coral has been mined for almost 400 years, aggravating coastal erosion. Historically, coral is mined from inland deposits of relic coral that are 5 000 to 6 000 years old. More recently, due to reduced supplies and general population pressure, coral mining activities have extended to live corals. Mining of inland deposits outside the coastal zone is allowed by a permit, however mining of live corals, is strictly prohibited. In the southwestern coastal area, the restriction may have played a role in reducing the mining of live corals in 1994.

Mangrove forests in Sri Lanka occur as a narrow inter-tidal belt and extend less than 1 km landward from the mean low water level due to the low tidal amplitude. There are 14 species of true mangroves and 12 species of mangrove associates in Sri Lanka. The most extensive mangroves occur in Puttalam, Batticaloa, Triuncomalee, Jaffna, and Gampaha Districts. Mangroves are absent along exposed shore-lines affected by seasonally high wave energy in the south-western, southern, and north-eastern coastal sectors. Some dense localized stands occur in association with lagoons at Koggala, Rekawa and Kalametiya, which are more or less separated from tidal influence.

Most of the mangrove forests in Sri Lanka are being eliminated, through a combination of encroachment of human settlement, firewood cutting, and clearing of coastal areas for intensive shrimp culture. Mangrove coverage was estimated at about 12 000 ha in 1986, reduced to 8 687 ha by 1993, and estimated to be around 6 000 ha in 2000. Mangrove areas of more than 1500 ha between Chilaw and Puttalam

have been developed for shrimp culture. In Negombo, mangrove areas were cleared and filled in the mid 1980s for a national housing project. Loss of mangroves leads to increased shore erosion in coastal areas.

Seagrasses and seaweeds are inter-mixed in 'seagrass' beds. Seagrass beds have an important nursery role for many species and are also a habitat for several endangered marine mammals including sea turtles and dugongs. Seagrass beds occur along the open coast as well as within estuaries and lagoons. A large seagrass bed covers Dutch Bay to Jaffna Lagoon and Mannar to Rameswaran Island, India. Though not well studied several activities are known to impact seagrass beds, including digging of polychaetes for broodstock feed in shrimp hatcheries, sewage disposal, and use of destructive fishing gear such as bottom trawls and drag-nets. Less extensive damage is caused by beach seining and dragging of propellers.

There are over 23 800 ha of salt marsh lands in Sri Lanka. In the Mannar district where tidal flats are extensive, marsh vegetation contains up to 56 species. In the vicinity of Mundal lake, there are salt marsh and mangrove associates. Salt marsh areas are utilized for small scale grazing, hunting of waterfowl, and collection of milkfish fry for aquaculture. There has been increasing interest in tourism for nature appreciation and bird watching.

Destruction of salt marshes is brought about by certain uses, including conversion for saltpans in Hambantota and Palavi area, conversion for shrimp culture ponds in Puttalam area and conversion for reclaimed lands in Muthurajawela area. In Puttalam lagoon 50 % of the marsh land was lost in a ten-year period (Dayaratne et al. 1997).

Barrier beaches, spits, and dunes are prominent natural features found within the coastal zone. Spits and barrier beaches have been formed as a result of the long shore transport of sand deposited at the discharged points of rivers and estuaries. Spits are projections of sand that are free at the end farthest from the prevailing current. They are usually unstable, and shifting sands may result in changes in the physical location of estuarine outlets (e.g. Negombo). In the case of a barrier beach, the beach structure spans the length of a coastal water body and completely isolates it from the sea (e.g. Koggala lagoon). Dunes are wind-blown accumulations of sand, which are distinctive from adjacent landforms. Unvegetated dunes are unstable and may continue to shift in the wind. Extensive dune systems occur between Ambakandawila, and Kalpitiya, between Kirinda and Sangamukanda point in the Hambantota area and across Mannar island. Some of the country's beaches (e.g. Kandakuliya, Kosgoda, Rekawa, Bundala, Kirinde) are important nesting grounds for sea turtles.

Beaches, spits and dunes have been degraded due to exploitation of sand for construction purposes and reclamation of land. In addition, dune areas are cut and houses are built on sand dune areas (e.g. Hambantota). Grazing of cattle on vegetated dunes and removal of vegetation in sand dune areas also degrade the coastal dune system in Sri Lanka.

Lagoons and estuaries, partially enclosed water bodies connected to the sea, cover about 160 000 ha. Estuaries support many commercially important organisms that contribute both to estuarine and nearshore fisheries. Some 90 % of organisms of commercial importance captured in estuaries and lagoons arrive as migrants from the sea. Lagoons have tremendous socioeconomic importance as major settlement sites for urban and rural communities. They provide natural harbours and anchorages, and sustenance for thousands of people.

The major threats to lagoons and estuaries are pollution and siltation, which are exacerbated by water diversions. Water flow reduction causes accelerated accumulation of sediments within the basin and canals. At Negombo lagoon, the effective water area was reduced by 791 ha between 1956 and 1981 due to high siltation rates (NARESA 1991).

Fishery Resources and Potential

Over 15 fishery resources surveys have been conducted in Sri Lanka since 1920, mostly on demersal resources. Some of the potential yield estimates made in the past based on these surveys are shown in Table 2. However, the accuracy of these estimates is unclear particularly given the fact the surveys did not always follow reliable statistical data collection processes. Under the CRM Project, Sri Lanka (TA No.3034-Sri), an attempt was made to estimate the maximum sustainable yield (MSY) of the exploitable resources, and determine whether the fishing effort of different fleet categories had already reached the point of harvesting the MSY of the coastal resources. Compiled in Table 3 are the

catch and number of operating craft belonging to three different fishing craft categories over the 1979 - 87 period. Applying the surplus production model, the MSY (in t) and the fishing effort (the number of fishing craft) at MSY can be determined. The estimated aggregate MSY for the three categories is about 172 000 t•year^{-1}. The number of boats to attain the MSY for different categories are: 2 715 for inboard motorized craft; 7 839 for outboard motor craft; and 22 146 for artisanal craft (Table 4).

Table 2. Estimates of fisheries resource potential in Sri Lanka.

Resource	Potential Yield (t•year^{-1})	Survey method	Source
Demersals	60 000	Exploratory trawl fishing. Organic productivity	
Demersals	52 000	Acoustic survey	Jones and Banerji (1973)
Demersals	80 000 (70 000 + 10 000 for the Northern Region)		Blindheim and Foeyn (1980)
Demersals	74 000 (44 000 + 30 000 for the Northern Region)	Acoustic survey and swept area survey	Sivasubramaniam (1983)
Pelagics	90 000	Organic productivity	Jones and Banerji (1973)
Pelagics	170 000	Acoustic (inshore + offshore)	Blindheim and Foeyn (1980)
Large Pelagics	29 000	For the EEZ: Production trend and offshore survey of catches	Sivasubramaniam (1977)

Source: Sivasubramaniam 1995.

Table 3. Catch and effort data of the coastal fleet of Sri Lanka, 1979 - 87 (from Atapattu 1991).

Category of Fishing Crafts	Year								
	1979	1980	1981	1982	1983	1984	1985	1986	1987
Inboard motorized Craft									
Annual catch (t)	50 105	54 825	56 454	60 379	57 375	46 625	47 862	49 249	50 960
Number of craft	3 109	2 305	2 209	3 347	2 861	2 781	2 727	2 766	2 657
Catch•craft^{-1}•year^{-1}(t)	16.1	23.8	25.6	18.0	20.1	16.8	17.6	17.8	19.2
Outboard Motorized Craft							49 950		
Annual catch (t)	43 848	57 432	65 512	66 727	70 539	48 660	11 515	47 684	49 341
Number of crafts	9 723	8 020	8 865	9 745	10 086	10 800	4.3	10 340	10 543
Catch•craft^{-1}•year^{-1}(t)	4..5	7.2	7.4	6.8	7.0	4.5		4.6	4.7
Traditional Artisanal Craft									
Annual catch	54 598	53 007	53 109	55 426	56 135	41 454	42 454	47 333	48 977
Number of crafts	15 330	15 721	12 855	14 101	14 312	14 404	13 303	13 412	13 865
Catch•craft^{-1}•year^{-1}(t)	3.6	3.4	4.1	3.9	3.9	2.9	3.2	3.5	3.5
Total Coastal Production	148 551	165 264	1 750 075	182 532	184 049	136 739	140 266	144 266	149 278
Artisanal Fisheries (%)	37	32	30	30	31	30	30	33	33

Table 4. Estimates of MSY and effort at MSY of different fishing craft categories operating in coastal waters.

Category	MSY (t)	Fishing effort at MSY (in number of boats)
Inboard motorized fishing crafts	53 463	2 715
Outboard motorized fishing crafts	60 939	7 839
Traditional artisanal fishing crafts	57 931	22 146
TOTAL	172 333	32 700

Caution should be exercised, however, in the use of these values since they were computed using statistical data that are not reliable. Nevertheless, while the aggregate value may not be the exact MSY, it provides a figure to refer to, and adopting a precautionary approach, the figure can serve as a basis for determining optimum exploitation levels. Also, since there are resource overlaps in fishing activities among the different fleet categories, the estimated fishing effort should not be taken as a fixed value for each category. Instead a moving range should be adopted.

Demersal Resources

In the coastal region, demersal species caught include emperors (F. Lethrinidae), snappers (F. Lutjanidae), groupers (F. Serrandiae), sweetlips (F. Haemulidae), sciaenids (F. Sciaenidae), carangids (F. Carangidae), breams (F. Nemipteridae), goatfishes (F. Mullidae), and leiognathids (F. Leiognathidae) as well as invertebrates like squids, prawns, crabs and lobsters.

The results of the two seasonal surveys conducted by RV Dr. Fridtjof Nansen during 1978/80 (Saetersdal and de Bruin 1979), using primarily the acoustic survey method, are being used in nearly all development plans/ programs in Sri Lanka to this day. Based on the results of that survey, the potential yields from the coastal resources were estimated as 170 000 t for small pelagics and 80 000 t for the demersals. The bottom long-line trials conducted by the Bay of Bengal Programme (BOBP), failed to yield catch rates in keeping with the potential yield estimated on the basis of RV Dr. Fridtjof Nansen surveys (BOBP 1986).

Since the analysis of the original acoustic survey data was based on subjective interpretations, the survey data were re-analyzed, using acoustic survey results and trawl survey data, to identify the species composition of the catch and determine the composition of commercial species in the catch. Density distribution and biomass estimates were obtained by using the swept area method, with stratification based on depth and bottom conditions. The stratum-wise estimates of biomass were separated into species groups with distinctly different natural mortality values before estimating their potential yields. This yielded a potential yield of 44 000 t, which was 37 percent less than the result of Blindheim and Foeyn (1980) acoustic survey analysis, for the total area excluding the north. Of this amount, only around 25 000 t would be high-value, large demersals such as snappers, groupers, emperors and breams. Further, it was considered that the demersals in the north were predominantly much smaller species such as the *Leiognathus* spp. and hence, a higher potential of 30 000 t was allocated to the northern region, as against the 10 000 t estimated by Blendheim and Foeyn (1980).

In 1981, just prior to the civil disturbance in the country, the total demersal production was around 48 000 t. The north and east areas contributed 70 % of total demersal production at this time, however they do not contribute any significant quantity at present. That means that only 14 250 t were produced in the Kalpitiya to Dondra area. Estimates of the present levels of production in this area are shown in Table 5 and are similar to the previous estimates. These figures do not indicate that the demersal stocks are under intensive exploitation. With the extremely reduced fishing pressure in the north and in the east, the stocks in those regions may have been replenished.

The existence of potential unexploited stocks on the continental slope beyond 100 m depth and in the deep waters (200 - 300 m) has been discussed elsewhere (Sivasubramaniam 1985). The deep-water species are not always popular varieties and therefore have to be processed and marketed in appropriate form to increase demand. The cephalopods

are another under utilized resource because of the absence of commercial trawlers capable of capturing them in deep waters.

Table 5. Current estimate of production by demersal gear on the west, southwest, and southern coasts of Sri Lanka, 1997.

Area	Production (t)
West coast	4 500 - 5 500
Southwest coast	1 500 - 2 000
South coast	3 000 - 3 500
Shrimp trawl by-catch	7 000 - 10 000
TOTAL	16 000 - 21 000

Small Pelagic Resources

There are 100 species of small pelagics around Sri Lanka, of which not more than 25 contribute significantly to the commercial production. The dominant sardines and herrings are *Amblygaster sirm, Sardinella gibbosa,* and *Sardinella albella.* Important anchovies are *Stolephorus indicus* and *S. heterolobus.* Among the mackerels, Indian mackerel *(Rastrelliger kanagusta)* dominates the catch. Several species of flying fishes (Family Exocoetidae) are found in the coastal waters. In terms of the small pelagic catch Amblygaster sirm is the dominant species, followed by other *Sardinella* species and *Rastrelliger kanagurta* and *Selar crumenophthalmus.*

Gillnetting is the primary fishing method, contributing about 80 % of the production. Other fishing methods include beach seine, bottom trawl and other forms of entangling/encircling nets and handline. The purse seine came into use in recent years but its future is uncertain because of severe objections from gillnet operators. Fiberglass reinforced plastic boats (FRP), 17'/18' long with open deck and outboard motors, log-rafts *(teppam)*, outrigger canoes, and simple dugout canoes are commonly used in the fishery. Beach seining contributed nearly 40 % of the small pelagics catch prior to the 1960s, but declined with the reduction in the number of beach seines in operation. The present contribution may be around 10 000 t. Purse seining for small pelagics increased rapidly but declined within a decade due to the intensive campaign against its usage by gillnet and beach seine fishers. Purse seining with light lure is prohibited and daytime purse seining is restricted to areas beyond 7 miles from shore, and the license fee is Rs. 20 000.00 (US$28.41)[1].

Catch rates determined by various authors, have varied widely and do not show a clear trend although they are considered to be higher on the northwest and west coasts. The catch rate for motorized craft is generally double that of non-motorized craft. Time series data compiled for about 13 years have been analyzed (Sanders and Dayaratne 1998) and a fall in catch with increasing effort level was described; however there was a high degree of variability in the catch rates without any clear trend. Another source indicated that the overall catch rate showed signs of increasing in Kalpitiya to Dondra. There is a strong feeling that some carangid species such as *Selar crumenophthalmus* and *Megalaspis cordyla* are appearing increasingly in the catches. Some of the carangids (i.e *Decapterus russelli*), scombrids (i.e *Rastrelliger kanagurta*) and Exocoetidae (i.e *Cypselurus oligolepis*) maybe underutilized at present.

Most of these species live up to one or two years, except the roundscad and Indian mackerel which may live up to three or four years. Flying fish, particularly the genus *Hirundichthys*, spawns only once in its lifetime and thus it may not be able to sustain as high fishing effort as the other major species groups. In comparison, *Decapterus* and *Rastrelliger* species tend to migrate towards the bottom in deeper water (100 - 130 m) when their ovaries start ripening, and are thus not available to any of the existing fishing methods in Sri Lanka. The spawning stock is hence unlikely to be subjected to overfishing. The exploitation rates determined by various authors (e.g. Siddeek et al. 1985; Dayaratne 1985; Karunasinghe 1990; Karunasinghe and Wijeratne 1991; Dayaratne and Sivakumaran 1994) do not indicate any over-fishing, even at the present levels of production because the yield levels have not increased significantly since the assessments, as shown in Table 6 below.

These results are not robust due to limitations in the sampling design and reliability of statistical information collected. The effort statistics require greater input into the sampling program particularly for establishing baseline information of craft numbers and craft-gear combinations in use, in different areas and different seasons.

[1] 1US$ = Rs 70.392 (Annual average 1999)

Table 6. Estimated small pelagics landings from gillnets 1986 - 95.

Year	Production (t)	Remarks	Source
1986	41 462	Gillnet catches on northwest, west and south coasts	Sanders and Dayaratne (1998)
1993	48 337	Gillnet catches on northwest, west and south coasts	
1985	60 578	Estimated landings of small pelagics	Dayaratne (1996)
1995	63 443	Estimated landings of small pelagics	

Large Pelagic Resources

Oceanic large pelagics such as tuna (*Thunnus* spp.), marlins (*Makaira* spp.), sharks, sailfish (*Istiophorus* spp.) and swordfish (*Xiphias* spp.) are also caught in coastal waters. Common oceanic pelagics are the yellow-fin (*Thunnus albacores*), skipjack (*Katsuwonus pelamis*), kawakawa (*Euthynus affinis*), frigate tuna (*Auxis* spp.) and seer fish (*Scomberomorus commersoni*).

Though the catch statistics are not very accurate in many of the countries fishing in the Indian Ocean, the tunas and related species account for not less than 800 000 t of fish caught in the area, of which not less than 600 000 t may be attributed to the offshore and oceanic fisheries. The large pelagics are the tuna species, especially skipjack tuna, yellowfin tuna, big-eye tuna (*Thunnus obesus*), billfish, and pelagic sharks. They are exploited mainly in the offshore and oceanic ranges. Relatively smaller tuna species such as the frigate tuna, bullet tuna (*Auxis rochei rochei*) and eastern little tuna (*Euthynnus affinis*), and Spanish mackerel, are concentrated on the continental shelf.

The species on the continental shelf are exploited by outrigger canoes, small FRP craft, and 3.5 GRT (gross registered tonnage) boats, using trolling lines, drift gillnets, and small purse seines. The offshore and oceanic species are primarily caught with drift gillnets and drift long-lines mainly operated from 3.5 GRT boats at the edge of the continental shelf and by the multi-day boats in the EEZ and beyond. The traditional but highly seasonal pole-and-line (live bait) method for skipjack tuna, conducted with large outrigger canoes, is fast disappearing because of the problem of insufficient live bait. The entire catch of the smaller coastal tuna and a small amount of oceanic tunas such as skipjack and yellowfin, is caught in the coastal waters.

Catches of small tunas such as frigate tuna and kawakawa, have declined from about 15 000 t in the early 70s to 8 000 t in recent years, with the decline in the multi-hook troll line fishery. Between 600 to 8 000 3.5 GRT craft are engaged in tuna and shark fishing with drift gillnet, and it is reported that 25 000 - 28 000 t are landed by them, while the offshore/oceanic multi-day fleet contributes around 60 000 - 70 000 t. Landings by the former category are generally in the afternoon and it is not convenient for sampling the catches. There used to be about 45 foreign tuna vessels licensed to operate from bases in Sri Lanka and to trans-ship their catches to their respective countries, but this fleet has been reduced to about 8.

The offshore and oceanic fisheries for large pelagic species is rapidly expanding and the production is increasing. The fleet of multi-day boats has grown very rapidly to about 1 750 boats, the average size of the boat has steadily increased from 32 ft to 60 ft, endurance has increased from one to three weeks, and the fishing grounds have expanded from 100 to > 600 miles from Sri Lanka. The common EEZ boundaries that Sri Lanka has with the Maldives and west coast of India have made it difficult for Sri Lankan boats to sail the high seas of the Arabian sea without the approval of those nations. The only open sea area available beyond the EEZ is on the southern and eastern sides of Sri Lanka, but sailing on the eastern side is restricted by the civil disturbance on the north and east coasts.

According to recent estimates of the production from the offshore/oceanic ranges and the information from the exploratory fishing survey conducted, the yield by multi-day boats was 41 473 t by gillnetting and 2 545 t by long-lining in 1997. The total fishing effort in 1996 was estimated to be 264 fishing days, of which 77 % was in the Kalpititiya-Dondra area and the rest on the east coast; the western area alone produced 47 % of the total effort. Species composition is shown in Table 7.

Table 7. Relative abundance and average total weight of species caught by gillnet and long-line.

Species	Gillnet		Longline	
	%	Average weight (t)	%	Average weight (t)
Skipjack	53.5	3.9	5.6	3.1
Yellowfin	16.8	4.6	10.3	9.9
Big eye	3.2	11.8	19.8	27.5
Other tuna	4.6	1.0	0.5	1.1
Marlin	4.2	48.1	3.9	35.7
Sailfish	2.8	16.6	1.5	15.7
Swordfish	3.2	16.6	9.2	19.8
Shark	7.2	14.7	47.3	18.7
Wahoo	0.4	5.7	0.1	6.3
Others	6.2	4.9	1.8	8.7

The results of (Joseph et al. 1995) suggest that if gillnetting is developed, the yield may be increased. However if the contemporary effort is doubled, the increase would be 60 percent, for both skipjack and yellowfin and the proportion of other species is likely to decline. For the potential yield, 1 000 t of yellowfin and 1 500 t of big-eye have been recommended as sensible upper limits (Joseph et al 1995). If other species have the proportion observed during the survey, the yield from all the species is expected to be 6 700 t. For these predictions to remain valid, it is assumed that competition for these stocks from other fishers would not result in an increased effort. There is no guarantee of this, because there is substantial exploitation of these tunas in the Indian Ocean, by distant nations like France and Spain with purse seines, and Korea, Taiwan, and Japan with tuna long-line. Expansion of the Sri Lankan gillnet fishery could influence only the recruitment of yellowfin to the long-line fishery. Increase of skipjack catches will not have any bearing on the long-line catches of other nations.

The pelagic shark catch rates are declining in the Indian Ocean, and the management measures for pelagic sharks have to be implemented quickly because this resource is more vulnerable to over-exploitation than the tunas. Sri Lanka considers pelagic shark as a targeted species in the gillnet and long-line fishery, but almost all other nations conducting tuna long-line fishing take the fins of sharks and throw the carcass into the sea. Some data collection and analysis is being undertaken by Sri Lanka at present but more in-depth studies on the biology of pelagic sharks have to be undertaken at national and international levels.

Shellfish Resources

In the past, pearl oyster *(Pinctada radiata and P. vulgaris)* fisheries in the pearl banks off Silavathurai on the northwest coast, window pane oyster *(Placuna placenta)* fisheries in the Tampalagem Bay on the east coast, and chank *(Turbinella pyrum)* fisheries on the northeast and north coasts, were covered by special regulations gazetted under ordinances other than the Fisheries Ordinance. These fisheries dwindled in the 1970s but the chank appears to be reviving at present.

Crusteanean Resources

Over 27 species of shrimps, six *Penaeus* spp., 11 *Metapenaeus* spp., 10 *Parapenaeiopsis* spp. and others, have been recorded in Sri Lanka and fished in various lagoons, estuaries, and the sea using traditional methods such as cast nets, stake nets, and set nets. The price of shrimp was not historically high and the catches were entirely for local consumption. The shrimp fishery developed and then declined with the outbreak of civil disturbance on the north and east coasts, areas that used to contribute significantly to this production. Unlike crabs and lobsters, the shrimp resources have not been subjected to such intensive exploitation because of the commencement of shrimp culture activities.

The assessment of the status of shrimp stocks was not properly executed in the past, and has been attempted only recently. Some studies on the shrimp stocks in the Chilaw lagoon, Negombo lagoon, Bolgoda lake, and Rekawa lagoon on the west and south coasts, have been undertaken but those of other regions have yet to be done. Hence, very little can be said on the status of shrimp stocks, except that two cohorts occur. Sri Lanka does not have disputes between small scale and large scale fisheries for shrimp because of the absence of any large scale shrimp trawling.

Lagoon crab or mud-crab *(Scylla serrata)* is found in almost all the lagoons and is also a popular seafood item among Sri Lankans, with most housewives preferring them alive before cooking. A sub-

stantial proportion of the production is also exported. With the decline in the supply of lagoon crab to the local market, the sea crab *(Portunus pelagicus)* has gained popularity in the domestic market, but no estimates on the production of the latter species are available. Mud-crabs from the Batticaloa lagoon used to be very large and fetch very high prices in the international market, but the average size of this crab has declined in recent times. Extremely small quantities of the mud-crab and spiny lobster enter the domestic market at present. The mud-crab has been subjected to intensive exploitation until recently.

The spiny lobsters *(Panulirus homarus, P. longiceps, P. ornatus, P. penicillatus, P. polyphagus, P. versicolor)* were not widely preferred around the island but were collected by diving and handpicking from reefs and rocky areas. With the development of tourism and a heavy demand for export, the price of these crustaceans increased rapidly and the lobsters with relatively small stocks were the first to be intensively fished. The collection of immature lobsters was therefore banned for local consumption and export. According to NARA scientists, lobster resources in the south are exploited with a catch of around 800 t•year^{-1}. The species composition of the catch is: *P. homarus*, 75 %; *P. penicillatus* 15 %; and the other four species, 10 %. In the west, where fishing has been intensive for a long time and management measures introduced very early in the history of the fishery, the production is reported to be poor. On the northwest coast, the fishery is reported to be good; in Puttalum, Kalpitiya and Kalpitiya islands, the potential is considered to be 500 t and the yield of *P. ornatus* is considered to be around 200 t. On the north and east coasts, the production is around 500 t, with Batticaloa, Kalmunai, and Jaffna as the main areas. The catches were brought to Colombo when the flights between Jaffna and Colombo were operational.

Among the cephalopods, *Sepia pharaonis, S. aculeata, S. latimanus, Loligo duvauceli, L. singhalensis* are some of the common species caught around Sri Lanka. With the suspension of commercial finfish trawling, the catches of *Sepia* species have declined. The *Loligo* species are traditionally caught using small outrigger canoes at night with carbide lamp and scoop net. Purse seine operations also resulted in significant catches of cephalopods. No other modern techniques (such as squid jigs) are being used to exploit this resource, which could be an export item.

Coastal Fisheries in Focus

The capture fisheries of Sri Lanka is subdivided into three components: (i) Estuarine fisheries; (ii) Coastal fisheries and (iii) Offshore fisheries. However these three categories may not be enough to establish a definitive delineation of fishing area or the deployment of fishing crafts and gear. Also, the connectivity between different ecosystems means there may be overlap in the stocks they are exploiting.

Fishing Structure Aspects

The concentration of fishing activities in Sri Lanka has slowly expanded from the traditional fishing grounds in lagoons, estuaries, and inshore waters towards the oceanic waters. Larger craft have tried to extend their radius of operation and smaller crafts have tried to fill the void and likewise operated farther from shore. This has been primarily because of motorization and improvement in engine efficiency. Fishing crafts used by Sri Lankan fishermen range from indigenous log rafts *(teppam and kattumaram)*, dugout canoes *(vallam)*, and outrigger canoes *(orus)* to modern boats made of fiberglass reinforced plastic (FRP). The different types of fishing crafts used in the country are shown in Table 8.

Due to the combined influence of monsoon-driven climatic conditions, seaworthiness of fishing crafts, accessibility of resources, and economic value of exploited stock, the fishing pressure has become concentrated in the nearshore area and brackish lagoons and estuaries. In inshore estuarine waters, fishing gear are deployed with or without fishing craft. In waist-deep shallow waters, fishing by push-nets, cast nets, and pull-nets without boats is very common. Gillnets and trammel nets are operated on board traditional dugout and modern FRP boats of all sizes. The fishing pressure in lagoons and estuaries also changes seasonally.

Changes in fishing activities have been influenced by recent significant events, as shown in Table 9. In 1995, the average age of boats comprising the offshore fishing fleet of Sri Lanka was about 2.5 years (see Table 10, Joseph et al 1995). Over 90 % of the boats were built after 1990, which means that the Sri Lankan offshore fishing fleet is made up of relatively new fishing boats. Most boats (84%) were less then 34 - 36 footer class size.

Table 8. Type of fishing crafts used in Sri Lanka. (from Maldeniya 1997 with inputs from the author).

Craft Type	Local Name	Length (m)	Operating Radius (km)	Remarks
Indigenous Craft				
Log rafts	*Teppam* *Kattumaram*	3 - 4 4 - 7	1 - 2 1 - 3	non-motorized/outboard motor non-motorized/outboard motor
Outrigger canoes	*Oru* *Thony*	3 - 5 10 - 12	1 - 3 1 - 15	sail/paddle/outboard motor sail/paddle/outboard motor
Plan beach seine	*Paru, padu*	10 - 12	1 - 3	paddle
Dugout beach seine craft	*Karavalai*	10 - 12	1 - 3	said/paddle/outboard motor
Dugout with outrigger	*Vallam*	3 - 6	1 - 5	outboard motor, 8 - 12 hp
Introduced Craft				
Fiberglass reinforced boat	FRP boat	5.2 - 6.2	1 - 20	inboard engine, 39 - 54 hp
3.5 - 4.5 GRT boat	3.5 GRT boat Abu Dhabi	8 - 10.3	> 20	inboard engine, 54 - 75 hp
11 GRT boat		10.4 - 18	> 20	inboard engine

Note: hp = horse power.

Table 9. Significant events in the development of the Sri Lankan fishery.

Year	Event
1928	Large scale bottom trawling was introduced by a private company which subsequently went bankrupt in 1935 because it could not find a market for the catch.
1941	The Fisheries Department was established to look after the fisheries sector.
1945	Fisheries Department re-started a trawl fishery program which became the forerunner of the large fleet operated by the Ceylon Fisheries Corporation; Wadge Bank was the main fishing ground.
1951	An attempt to introduce purse seine fishery failed because the existing vessels were not ready for it. Mothership operation was initiated for the demersal fishery. Ceylon Fish Sales Union was organized and played an important role in fish marketing.
1958	The motorization program started, which resulted in the introduction of 28 footer (3.5 GRT) boats with inboard engines and inboard motor plank boats which replaced many of the orus and vallams.
1960s	Log rafts (teppam and kattumaran) were replaced with 17 - 18 ft craft with outboard engines. This increased the range and subsequently expanded the coverage of fishing grounds for gillnetting for small pelagics and demersals and handling of demersals.
1970s	Purse seine operation was demonstrated around the country by FAO, which led to the commencement of purse seining for sardines in the southwest coast in the 1980s. Newly designed 3.5 GRT, 8 - 10 m long boats with inboard engines started fishing for small pelagics and small tunas without venturing far from shore and performing only day trips.
1976	Sri Lanka claimed its 200-nautical mile EEZ, adding to its territorial waters a total of 437 000 km^2. Wadge Bank was lost to India as a result of the demarcation of the EEZ boundary between India and Sri Lanka.
1980s	Sardine purse seining commenced on the southwest coast. Abu Dhabi boats equipped with insulated fish hold and crew accommodation allowing trips lasting for several days, were built by the Northwest Coast Fisheries Development Project. The boats were equipped with large-meshed gillnets for catching tunas and used frequently in combination with long-lines for catching larger tunas and sharks.
1990s	With the construction of larger boats for multi-day oceanic fishing, some of the 28-ft boats, FRP open-deck crafts, and outrigger canoes extended their operating radius to exploit small pelagics and small tunas on the outer ridge of the continental shelf.

Table 10. Size profile of the offshore fishing fleet of Sri Lanka 1981 - 95.

Year of Construction	Length Overall (ft)					
	28 - 32	34 - 36	38	40 - 45	> 50	Total
1981 - 83	–	2	–	–	–	2
1984 - 86	1	2	–	–	–	3
1987 - 89	2	3	–	–	–	5
1990 - 92	4	29	1	1	1	35
1993 - 95	2	67	4	4	–	77
TOTAL	9	103	5	4	1	122

Sources: Joseph et al. 1995.

There was a drastic decrease in the number of non-motorized traditional fishing craft in the late 1970s and a drastic increase in the number of fishing craft powered by outboard motors in the same period (see Table 11). This increase was sustained and may be attributed to the liberalization of the country's economy. The number of fishing craft powered by inboard engines has more or less remained within the range of 2 200 to 3 400 boats throughout the years, and around 3 250 boats were recorded in 1996. At present, the Sri Lankan fishing fleet consists of around 26 600 fishing craft, 48 % of which (12 730) are motorized (Table 11).

Though modern craft of varying designs and sizes have been introduced, the original 28' long wooden craft with inboard engine (popularly known as "E 26" design) and the 17'/18' open deck FRP craft with outboard engine have become the popular modern type of fishing craft. The popularity of larger size craft (> 30 ft; popularly known as 11 t, Abu Dhabi boat, BOBP design) introduced by the State for multi-day fishing for large pelagics offshore, lasted a few years. In the 1980s an extended version (32 - 34 ft) of the E26 design as a multi-day boat for offshore fishing quickly gained popularity. With the increasing popularity and entry of more boats of this type, the demand for even larger sizes (up to 60'ft) are being constructed presently for operating drift gillnet and drift long-line for tuna and shark in the Indian Ocean. At the same time, traditional craft such as the log-rafts *(teppam)* of the northwest coast and outrigger canoe *(oru)* on the southwest and south coasts are being rapidly replaced by the 17/18 ft FRP craft with outboard motors.

As updated statistical data are available only for the Northwestern, Western, and Southern Provinces (see Table 12), it is difficult to portray the distribution of fishing effort for the entire country. Non-motorized traditional craft, constituting 48 % of the number of boats, still top the list. FRP boats, which are mostly based in the Northwestern, Western, and Southern Provinces, rank second. Recently the country has tried to expand its offshore fishing industry by building more multi-day boats; a steady increase has been observed from the early 1990s to the present (Table 12).

The fishing craft population has changed significantly from a combination of traditional non-motorized fleet and industrial scale bottom trawlers to the present structure with a combination of traditional and modern types of non-motorized and motorized small scale fishing craft, as shown in Table 13 and 14.

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Table 11. Number and category of fishing craft from 1972 - 96.

Year	Inboard	Outboard	Non-motorized	Total
1972	1 895	3 120	29 240	34 255
1973	2 870	3 182	31 521	37 573
1974	2 959	3 144	33 909	40 012
1975	3 075	3 752	35 634	42 461
1976	–	–	–	–
1977	1 008	5 281	13 594	19 883
1978	2 265	8 265	13 800	24 330
1979	3 109	9 723	15 330	28 162
1980	2 305	8 020	15 722	26 047
1981	2 209	8 865	12 855	23 929
1982	3 347	9 745	14 101	27 193
1983	2 864	10 086	14 312	27 262
1984	2 781	10 800	14 404	27 985
1985	2 722	11 515	13 303	27 540
1986	2 766	10 340	13 412	26 518
1987	2 657	10 543	13 865	27 065
1988	–	–	–	–
1989	–	–	–	–
1990	–	–	–	–
1991	2 459	9 645	14 578	26 682
1992	–	–	–	–
1993	2 336	9 920	14 896	27 152
1994	3 185	10 720	15 444	29 349
1995	2 996	9 713	14 560	27 269
1996	3 253	9 473	13 880	26 606

Table 12. Number of fishing craft by category and by district of Northwestern, Western, and Southern Provinces.

District	Non-motorized Traditional Craft	Motorized Traditional Craft	FRP Boats	3.5 GRT Boats	Multi-day Boats
Puttalam	1 921	128	2 512	48	32
Chilaw	1 624		1 217	57	114
Gampaha	1 607	11	1 160	126	187
Colombo	39		156	65	14
Kalutara	748		189	44	240
Galle	658	278	303	83	150
Matara	848	155	281	199	375
Hambantota	889	353	518	100	199
TOTAL	8 334	925	6 336	722	1 311

Table 13. Number of fishing craft by category from 1993 - 97 (from different sources). Note that the 1993 data include information from Northern and Eastern Provinces.

Year	Non-motorized Traditional Craft	Motorized Traditional Craft	FRP Boats	3.5 GRT Boats	Multi-day Boats
1993	14 896	1 986	7 934	1 907	429
1995	7 153	692	6 826	850	1 098
1997	8 334	925	6 336	722	1 311

Table 14. Structure of the fishing fleet in the marine subsector with probable numbers.

Category	Types of Fishing Craft	1996	Average Crew Size	Endurance
Industrial Scale	Bottom trawlers	(not in operation)	5	1 week
	Tuna long liners	(not in operation)	12 - 15	1 - 2 months
Small scale (traditional)	Outrigger canoe	9 478	2	day-boat
	Log raft	2 949	1 - 2	day-boat
	Paru	126	9	day-boat
	Vallam	2 335	2 - 6	day-boat
Small scale (modern)	FRP	8 179	2 - 4	day-boat
	3.5 GRT	1 256	3 - 5	boat-day
	> 3.5 GRT	1 750	4 - 6	1 - 3 weeks

Although there has been an increase in the introduction of motorized craft and a reduction in the utilization of traditional craft in fishing activities, this is not reflected in the craft population. There is a growing concern about the large number of traditional craft that are not used in fishing but instead in ferrying provisions, crew and catch, between the shore and motorized craft anchored outside anchorages and harbours. According to the Administration Report of the Department of Fisheries and Aquatic Resources, the number of operational inboard engine craft has been fluctuating annually between 2 300 and 3 300 since 1973. The outboard engine craft population also appears to have been fluctuating between 8 000 and 11 500 since 1978. The non-motorized craft population declined from about 31 500 in 1973 to 13 800 in 1978, and has been fluctuating between 12 850 and 15 722 since 1978. The total population stands at 27 765 (NARA, Fisheries Year Book 1998).

Fishing Methods

Like most maritime countries in the tropics, Sri Lanka's fisheries sector has evolved into what it is now a multi-gear and multi-species fisheries. The primary fishing gear in the past was the beach seine, considered the backbone of the industry (Sivasubramaniam 1995). It was the single most important contributor to coastal fisheries in the early days. About 3 000 units were in operation and landings were between 19 000 and 24 000 t in 1961 and 1963, respectively. However, many craft also used other gear such as bottom-set gillnets, bottom long-lines, hand-lines, intertidal traps, setnets, set bag nets, and stake nets, targeting mainly demersal species. The commonly used fishing gear in the country's recent history, their mode of deployment, means of propulsion, and typical catch are shown in Table 15.

Most of these gear are still used today, and the most popular ones include the large and small meshed gillnets designed to catch tunas and sardines, respectively. Beach seine fishermen still continue with their traditional gear. Some gear have lost their popularity while others only deployed in limited areas. Sri Lanka suspended oceanic long-lining in the early 1980s. Trawls are banned in some areas and light-lure purse seines are not allowed in coastal waters of the country. Because of their destructive effects, bottom-set gillnets and trammel nets are also not allowed in coral reef areas.

Table 15. Common types of fishing gear used by Sri Lankan fishermen and their mode of operation (modified from Sivasubramaniam 1985).

Fishing Gear	Mode of Deployment	Boat types	Target Species
Traps	demersal	non-motorized	mixed demersals
Lift-net	pelagic	non-motorized	bait fish
Hand-line	demersal	non-motorized	carangids and demersals
Beach seine	demersal/pelagic	non-motorized	mixed demersals and pelagics
Large-meshed drift gillnet	pelagic	motorized	tuna, king mackerel and sharks
Small-meshed gillnet	pelagic	motorized	sardines, anchovies and Indian mackerels
Bottom-set gillnet	demersal	motorized	large demersals
Trammel-net	demersal	motorized	large demersals
Trawl	demersal	motorized and non-motorized	shrimps and demersals
Trolling	pelagic	motorized	tuna and king mackerel
Pole and line	pelagic	motorized	tuna
Bottom-set long-line	demersal	motorized	large demersals
Tuna long-line	pelagic	motorized	tuna and shark
Purse seine	pelagics	motorized	sardines and small pelagics

Because of the migratory nature of pelagic stocks, pelagic fishing gear are operated in wider areas, targeting specific species. Demersal fishing gear have specific areas of operation. Some fishing gear are operated all throughout the year in specific areas, especially in the Northern and Northwestern Provinces. Others are frequently operated during specific monsoon seasons. Hand-line and bottom-set long-line are more often used during the northeast monsoon while the gillnets are typically used during the southwest monsoon. Because of the relatively shallow and flat bottom topography, demersal fishing gear are more or less concentrated in the northern and northwestern parts of the island.

Motorization and improvement of hull design have enhanced the capability of fishing craft to operate in offshore fishing grounds. This development has significantly altered the mode of pelagic fishing operations. Pelagic fisheries can be conveniently subdivided into small and large pelagic fisheries. Small pelagic species such as sardines, anchovies and mackerels are caught primarily by small-meshed gillnets and to a lesser extent by purse seiners. On the other hand, large pelagics like tunas, sharks, marlins, sailfishes, and Spanish mackerels are caught by large-meshed drift gillnets, long-lines, and hand-lines.

Production

The total annual fish production of Sri Lanka in 1996 was 228 550 t, around 65 % of which was landed by the coastal fisheries, 25 % by the offshore or deep sea fisheries, and only 10 % by the inland fisheries. The total annual production is practically double the figure recorded in 1972 (101 712 t). However, this general trend was marked by a sudden drop in 1983 (169 347 t) because of the civil disturbance in the country at that time, a recovery during the second half of the 1980s as a result of the increase in production by the inland fisheries sector, and a further rise in the 1990s due to an increase in the offshore fisheries production.

The steady increase in production between 1972 and 1983 is attributed to the introduction of more efficient engines, more reliable fishing craft, and improved synthetic fibers. Although 65 % of the total production comes from coastal waters, this proportion is relatively low compared to the sector's 90 % contribution in the 1970s. However, this does not mean that coastal water production has diminished; the decrease in relative value was due to the increase in production by other sectors. In the late 1980s, the increment was primarily due to inland fisheries, in the 1990s much of the increase

Table 16. Fish production (t) from the coastal subsector, by major varieties, 1991 - 97

Variety	1991	1992	1993	1994	1995	1996	1997
Seer	3 916	3 524	3 369	3 200	2 993	2 170	2 400
Trevally	8 975	8 526	8 378	8 000	6 910	6 090	6 900
Skip jack	16 690	18 359	19 316	20 475	23 548	25 630	27 600
Tuna	10 664	11 730	11 981	13 180	12 050	12 740	14 600
Other blood fish	9 325	10 258	10 681	11 215	17 642	15 940	14 800
Shark	19 045	18 306	19061	19 500	14 017	7 110	8 800
Mullet	8 658	9870	10 277	10 585	7 088	8 970	9 100
Beach seine varieties	33 426	35 097	37 379	38 870	49 785	48 220	42 700
Prawns	5 176	6 470	6 737	7 000	–	–	–
Lobsters	789	828	862	1 000	400	–	–
Others	42 486	40 202	41 859	41 475	23 067	22 430	25 850
TOTAL	159 150	163 170	169 900	174 500	157 500	149 300	152 750

Sources: Department of Fisheries.

was attributed to offshore fisheries while coastal production has more or less remained constant throughout the period.

In the coastal subsector, the production of skipjack and other tuna species has shown some increments (see Table 16). Although there was an apparent decline in the catch of sharks starting in 1996, there were no data entries for prawns in 1995 and for both prawns and lobsters in 1996 and 1997. It will have to be verified whether this is due to a data collection problem or to the disappearance of the resource.

The present value of fish production from the three subsectors is shown in Table 17. The total value of highly priced commodities reached Rs. 17 billion in 1997, while that of low-priced species was Rs.1.0 billion. The average price of all species of fish increased by 10 % to Rs.110•kg^{-1} in 1997. Average retail price increased by eight % from Rs.143•kg^{-1} to Rs.154•kg^{-1} in 1997. The highest price was Rs.297•kg^{-1} for Spanish mackerel (seerfish) and the lowest price was Rs.65•kg^{-1} for sardines (Central Bank Report 1997).

Table 17. Present value of production from different fisheries subsectors.

Sector	Production (t)	Value (Rs. billion)
Coastal and marine subsector	152 750	15.7
Offshore/oceanic	62 000	4.1
Brackish and freshwater	24 200	2.7
TOTAL	228 550	22.5

Marketing Channels

Fish, on being unloaded from the boat, are purchased by wholesalers, beach assemblers, and various categories of retailers. Even consumers congregate at the beach to buy the daily quota of fish. Normally, the boat owners who consign fish to the wholesalers obtain loans from them when they are short of cash to buy the boats or to repair the vessel and at times of distress. The wholesalers can be the commission agents who are at St. John's Fish Market (SJM) in Colombo or those operating from various out-station market centres. The beach assemblers operating from the villages also finance the fishermen. Sometimes, the wholesaler finances the assembler so that he is assured of a continued supply of fish. These are non-institutionalized credit arrangements operating on trust without any guarantees or mortgages.

The beach assembler consigns the fish to the wholesalers at SJM or other market centers. Fish mixed with ice is normally packed into wooden boxes, which are transported in lorries or vans to the wholesalers. SJM is the biggest wholesale market for fish in Sri Lanka and receives supplies from all parts of the country. Hundreds of vehicles transporting fish from out-stations congregate at SJM beginning at the crack of dawn. Apart from these wholesalers, there are the retailers who buy their daily market requirements from the numerous fish landing centres along the coastal strip or from SJM. These include those who operate fish stalls at market places or at wayside locations, institutional suppliers, push-bicycle traders, motorcycle traders, pingo carriers, head loaders, and basket carriers.

The entire marketing operation is based on trust and mutual understanding. No elaborate docmentation, paper transactions, or built-in securities exist in the marketing transactions. The beach assemblers and boat owners send fish by weight without any price indications. These are the main risk takers in the marketing chain. The wholesalers sell the fish at a price to be determined by them based on market intelligence and supply levels at the time of opening of the market. These prices are subject to change in the levels of inflow of supply. Normally, the wholesaler retains a commission of up to 10 % and remits the balance to the supplier, as and when he calls for money. The small traders such as push-bicycle traders and *pingo* carriers are fairly poor and do not belong to the fishing community. They reside in distant places and come to the market place to buy the fish. Most of them obtain money on interest from moneylenders operating in the market places. The motorcycle traders deal in larger volumes.

Demand for Fish

The fish landed from the larger multi-day boats are sold at the harbor sites or near anchorages and, in the case of small day boats, at beach landing centres found along the coastal strip. There is seasonal and geographical variation in the supply since weather conditions and lunar phase affect the fishery. Apart from exporters, the rest of the par-

ticipants in the marketing chain are all individuals. The only organization in fish marketing is the Ceylon Fisheries Corporation, a government agency which used to play a dominant role in the capture, marketing, and export of fish and fishery products, but which has been reduced to total insignificance against the private sector. The private sector is able to handle the totality of the fish landed by the fishermen all over the island. Though these individuals are borrowers, the marketing activity is highly organized and the marketing chain functions quite efficiently.

There is no information available on the total demand for fish and fishery products in Sri Lanka but it is believed that the supply is far below demand levels and that this gap is filled through imports of dried and canned fish. Per capita consumption of fish is about 16 kg annually, including domestic production and imports. Traditionally the demand is high for cheaper inshore varieties such as sardines, herrings, mackerels, frigate tuna, bonito, mullet, etc. Among the high-income groups seer, trevally, tuna, and shellfish are in greater demand. The variation in demand for quality is evident in fish-producing areas and in fish markets where prime quality fish always fetches a higher price. Long-line and shore-seine fish command higher prices as compared to gillnet caught fish. Among the poor, price is a foremost consideration and quality is secondary.

In general, small scale traders using push-bicycles, motorcycles, and those carrying fish on *pingos* and on baskets go from house to house on their sales rounds. Static dealers sell from market places as well as through wayside stalls and all of them serve urban, semi-urban, rural, and estate customers. Most of these traders buy a mix of varieties and sell these as better quality fish at a high price. These consumers are unable to distinguish between good and poor quality fish. A survey done by the Lanka Market Research Bureau (LMRB) reported that fish is the preferred source of animal protein by the people of Sri Lanka and that:

- the urban sector spends about 40 % of the family budget on food, of which 12 % is spent on fish;
- the rural sector spends around 56 % of the in come on food, out of which approximately 9.2 % is on fish; and
- the estate sector spends around 68 % of their income on food, of which 5.2 % goes on fish.

The degree to which quality preferences influence demand has been clearly established by the recently concluded DFID Post-Harvest Fisheries Project where insulated fish boxes made out of fiberglass were built, demonstrated, and field-tested. The fishermen who used these boxes reported that the ice melt is reduced by 50 % and that the fish stored in them after capture fetched a price premium of about Rs.5 - 15•kg^{-1} on the beach. The petty fish traders selling fish on push bicycles and motorcycles and other bigger traders who used this box for fish transport have all confirmed a similar increase in benefits.

The foreign vessels operating under joint venture arrangements target the export markets. Most of them cater to the *sashimi* market in Japan to which chilled tuna is air-freighted directly. The onboard handling of fish on these boats is good and high quality standards are maintained.

Price Structures

Down the distribution channel beginning with the beach assembler, all the participants keep a profit margin, which results in a snowballing of the prices. The beach assembler's margin depends on the selling price at the wholesale market. As proper records are not maintained by the commission agents, it is not possible to ascertain the actual commission charged by them, although in general, it is believed to be a maximum of 10 %. The retailers keep around 25 - 50 % or more in their selling price. By the time the fish reaches the consumer, its beach price could have increased by 60 - 80 % or more, as transport, icing, handling, and other overhead charges at each level of activity have to be recovered.

There is also a cost at the fish landing centre. If the fish is auctioned, the auctioneer's commission has to be settled in some of the harbours/anchorages and at fish landing centres. In Negombo, where a cooperative manages the anchorage, multi-day boats using the main anchorage have to pay a commission of 1 % for boats from Negombo or 3% for others.

The main contributory factors related to price variations in the local market are: availability of fish, variability of supply, seasonality, quality of fish, and quantity and species availability.

Transport and Post-harvest Practices

The bulk of the fish production is marketed and consumed either in wet form or as iced fish; there is very little production of frozen fish for the local market. The existing marketing system developed by the private sector and proven to be effective can adequately cope with the supplies without recourse to freezing. What is necessary is an adequate supply of quality ice, chill rooms for storage of fish, refrigerated trucks for transport, use of hygienic fish boxes, and improved handling methods. The wooden fish boxes used in the transport of fish are unhygienic and need be replaced by better quality, more durable, hygienic, and easily cleanable plastic-type nestable crates.

Fish transport is normally done in open lorries and vans. These are neither insulated nor refrigerated. The transport vehicles leave the fish producing area by night and reach SJM by crack of dawn. The fish is packed into wooden boxes and stacked inside the vehicle. Ice melting during transport is very high and by the time fish reaches SJM or any other distant market place, most of the ice has melted. Lately, however, some of the bigger traders, boat owners, and beach assemblers have begun to use refrigerated trucks for fish transport. This trend is more visible in the south than in other areas.

A recent study undertaken by NARA's Socio-economic Division showed that of 52 beach assemblers in 7 major fish landing centres, 19 possessed fishing boats and 12 possessed transport vehicles. Seven out of these 31 had a boat and transport vehicle each. This clearly shows the role and influence of the beach assemblers as producers, transporters and traders. The study has also established that out of the 52 beach assemblers, 13 took advances from the commission agent (wholesaler) at SJM, 11 took loans from commercial banks, 5 from money lenders, 2 from fishermen's cooperatives, and from the ADB-funded Fisheries Sector Project's microcredit component. It is recommended that credit lines be provided through commercial banks for those who wish to purchase refrigerated trucks for fish transport. The cost of a second-hand refrigerated truck of reasonably good condition, imported from Japan, ranges from Rs.0.9 - 1.5 million.

The quality of fish landed from fishing boats is generally poor. More than 50 % t of the catch landed by multi-day boats which undertake extended fishing voyages, is of very poor quality. Quality of the produce is a major concern with regard to the ever increasing fleet of multi-day boats whose prime objective is to catch more and more fish with less and less emphasis on the preservation of the catch. Since the scope to expand inshore fish production is limited in the long term due to resource concerns, emphasis should shift towards value addition through improved post-harvest practices. If the spoilage could be minimized and the quality of the fish improved, there would be no need for extended fishing effort. There is thus a need to improve the quality of the catch by educating the fishermen on improved methods of fish handling and on-board storage. Improving the efficiency of post-harvest handling, processing and marketing will also have a significant impact on the incomes of primary producers, processors, and market intermediaries and consumers will benefit through the availability of better quality fish and fishery products. Measures also need be taken to reduce fish wastage and add value to the catch.

Management Issues and Opportunities

Fisheries Management Goals and Objectives

Fisheries management may be regarded as a dynamic resource allocation process whereby the ecological, economic, and institutional resources of a fisheries exploitation system are distributed with value to the society (see Fig. 2). The fisheries management process includes the resolution of normative and empirical debates to determine the direction of resource allocation decisions.

The objectives of fisheries management in Sri Lanka was reviewed in a National Consultative Workshop in 2000. The workshop was conducted under the "Sustainable Management of Coastal Fish Stock in Asia" Project (ADB-RETA 5766). Fisheries resource specialists and managers from the government, academe, and other organizations reviewed the outputs of National level assessment of Sri Lankan Fisheries, identified fisheries resources management issues and formulated recommendation for improved management. Figure 2 presents the fundamental objectives of fisheries management in Sri Lanka and viewed by the workshop participants.

Management Issues and Problems

Except for a few cases of traditional management systems, most fisheries are open access, common property systems. In the 1940s, when the total fish production was in the level of 40 00 t, the contribution was exclusively from traditional fishing gear such as beach-seine nets and stakenets etc. These have existed for a long period and evolved efficient management systems in their operations. The coastal rural communities had fishing methods which were in harmony with the environment. In addition, these systems had important economic features like the distribution of income among the fisher folk communities. There were rotational systems where many had stakes and thereby the income from these operations was distributed among them. These traditional management systems continue to the present. These management systems were not devoid of conflicts, but the conflicts were resolved by the village leaders to the satisfaction of all parties concerned. These traditional methods, of course, could not supply fish to the increasing population. The per capita supply was low and therefore mass production methods had to be adopted taking the experience from more developed countries. Based on this policy, motorization of fishing craft was commenced in 1958 and introduction of nylon nets was done in 1962. These methods brought about a dramatic increase in fish production.

As with the traditional methods, management measures should have been introduced from the very inception of these schemes. Unfortunately, such a management regime was not considered then and that is the main cause of the present day problems in fisheries. With the incentives given in the form of subsidies on capital goods and institutional credit, within an open access common property regime the fishing effort increased substantially in the coastal fisheries. The popular 9 meter (28 ft) boats were introduced without a proper management plan. A major constraint was the lack of reliable information on the available resource. Thus, sustainable exploitation levels could not be determined. Furthermore, a legal framework was not available for the management, especially of coastal fisheries. The Fisheries Ordinance of 1940 was grossly inadequate to undertake any fisheries management. Increased fish production through increasing fishing effort was necessary in the sixties and seventies. What was lacking was a proper management plan.

As a result, there were many fishing conflicts by the mid 1980s among various groups of fishermen in the coastal areas and inland waters. Many fishermen complained to the authorities regarding their inability to get an adequate income and the non availability of catches in inshore areas. Most of the conflicts were between beach-seine fishermen and others using motorized fishing boats. This led to the framing of Beach-Seine Regulations of 1986. Another major conflict was between purse-seine fishermen and others, which led to the Purse-Seine Regulations of 1986. The conflict between prawn trawl fishermen and others was emerging by that time.

A major reason for present day problems in fisheries is due to the fact that proper management measures were not undertaken at the time of the introduction of motorized craft and synthetic nets which virtually revolutionized the industry. Major issues are the excessive fishing effort and over-fishing. Degradation of coastal habitats due to over-exploitation of resources, coastal pollution due to domestic, agricultural and industrial discharges and oil pollution has contributed to the decline in biomass and the productivity of the coastal fishery resources. Another major issue is the post harvest losses due to mishandling and inappropriate post harvest technologies. Surveys have revealed that about 22 - 25 % of the value is lost by inadequate post-harvest practises. Information and research inadequacies and institutional weaknesses and constraints are some of the issues contributing to the low efficiency of coastal fisheries in Sri Lanka.

Opportunities

In view of the open access, free entry nature of fisheries in Sri Lanka economically wasteful methods are employed in the exploitation of resources. This could be overcome by the following interventions:

Establishment of Property Rights

It is possible to establish property rights to fish stocks and thus the ownership can be fixed. The owner may be an individual or a collection of individuals like a firm, fishermen's cooperative society, etc. If ownership is allocated, there is an incentive to rational and sustainable exploitation. Examples are seen in the beach-seine fishery and stake net fishery in the Negombo Lagoon in Sri Lanka. However, with property rights, there are certain constraints. For instance in cases like tunas which are either straddling or highly migratory stocks, which

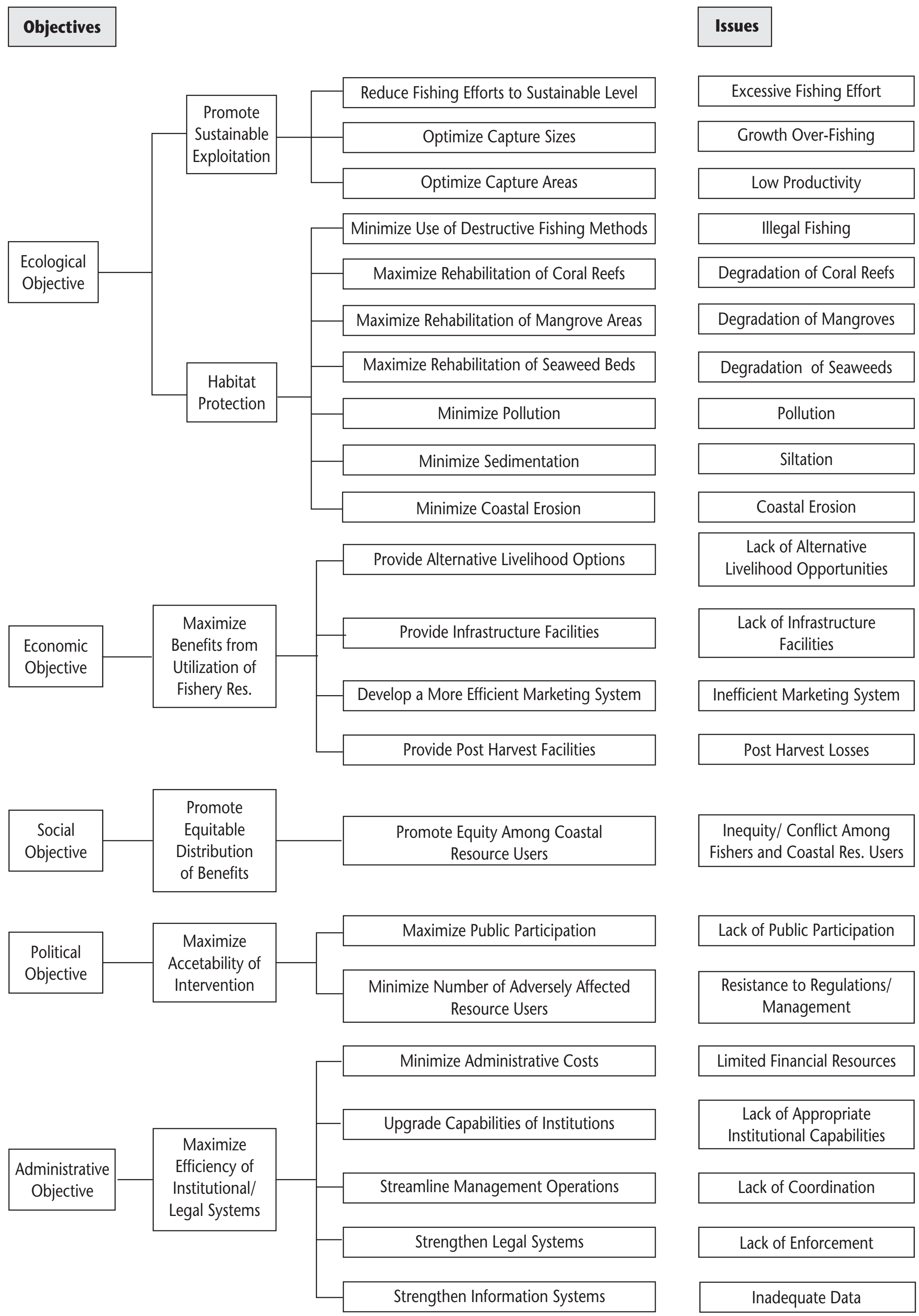

Fig. 2. The objectives for optimal management coastal fisheries in Sri Lanka.

move from one state to another across boundaries, the holder of property rights is at a disadvantage. This could be overcome by either giving exclusive rights to an identifiable fish stock or the implementation of territorial use rights in fisheries (TURFs), whereby full control of an area with reference to stocks is given to the property holders. An example of this is seen in Japan with the fishermen's cooperatives which have exclusive rights to inshore resources and regulate the access of the membership. Bioeconomically, the establishment of exclusive use rights is helpful in breaking the vicious circle of increased supply constraints, which will increase the real price of fish and stimulate more investment in fishing effort, depleting resource leading to additional price increases.

Participatory Fisheries Management

At present, community-based approaches in fisheries management are given high priority. The resource users in a given village participate in the planning and management process in the regulatory system. Participatory management has been successful in beach-seine and stake net fisheries in Sri Lanka. The concept of participatory management is based on the strong human instinct of priority of self-interest over public interest.

There are three methods by which the government can introduce management measures in fisheries. They are: (i) indirect controls through taxation on fishing effort or the landing of fish; (ii) control of fishing capacity and fishing effort and (iii) control of the catch.

Direct control of the catch is widely practiced. The efficiency of this method can be improved by transferable catch quotas. In countries like Australia and New Zealand where fisheries management is comparatively advanced, individual transferable quotas have been introduced. Transferable quotas bring about efficient utilisation of fish stocks, within certain limitations. One such limitation is the misreporting of the catch. This happens mainly with small scale boat operators who supply fish direct to consumers and where proper records are not maintained. Although not perfect, boat-licensing arrangements can also be used as a management tool.

Whatever the controls used in the management process, it is essential to enforce them. It is important to note that the implementation of the management measures themselves incur expenditure. If a management strategy is too expensive to be implemented, it is of little use. A management strategy even with certain limiting factors but applicable at a reasonable cost is more suitable for developing countries like Sri Lanka.

The fisheries policy in Sri Lanka has four main objectives viz, (i) sustainable development of fisheries, (ii) increase in employment opportunities, (iii) socioeconomic improvement of fishing communities and (iv) earning of foreign exchange. For sustainable development of fisheries, sound management measures are necessary. Over the last four decades, the emphasis has been on the development aspect without much consideration for management. This has led to depletion of resources in the coastal waters and decreased incomes. This has also led to low returns on investment, making fishing operations less profitable.

Sri Lanka has attempted fisheries resource management in several ways. The policy has been changed to allow for sustainable development of offshore and deep-sea fisheries and a strict management regime for coastal fisheries has been introduced. Through this policy some fishing effort has been shifted from coastal to offshore fisheries. Legislation has been introduced recently for transforming the open access fisheries to a licensed fishery. Awareness programmes have been conducted to educate fishermen on the importance of fisheries management and a UNDP assisted Marine Fisheries Management Project is being implemented. International conventions and agreements in fisheries management have been ratified and a legal framework drawn up to make provision for these. The value of participation of resource users in the management process has been recognised and legal status given to village fisheries committees. Thus, Sri Lanka is strongly committed to the conservation and management of fishery resources. It is important to apply proper economic principles in management - "Fisheries management is indeed a multidisciplinary subject. Obviously, it must be based on sound biological expertise, but the ultimate objective is economic. Fisheries management that disregards economic aspects may succeed in preserving fish stocks, but it will waste other resources such as investment funds and labor, and it is likely to be distinctly unhelpful for the fishing industry" (Hannesson 1993).

When examining fisheries as a whole in Sri Lanka, we see very efficient traditional fisheries management methods. Beach seine *("madel")* and stake net *("kattudel")* methods are excellent examples. However, there is no proper management regime for the inland fisheries and motorised fisheries which use efficient gear. Under an open access, common property arrangement, efficient fishing methods have been introduced without any limitations.

At present management measures under the Fisheries Act are being instituted. Management measures through limitation of the fishing effort will take time so that socioeconomic ill effects on fishing communities are minimal.

One of the major constraints for the proper management of fisheries is the lack of data on the available resources and the correct level of exploitation. Without these, it is not possible to have a proper management regime.

Based on the above considerations, the following recommendations are made:

- Major constraints on fisheries management have to be resolved. These include the non-availability of data on the resources and the levels of exploitation. Since stock assessment surveys are capital intensive, proper analysis of data from commercial operations should be under taken. These two are not mutually exclusive and stock assessment should be undertaken as soon as possible.
- The fishing effort in the coastal fisheries should be carefully controlled. In this context, producer subsidies to the coastal fishers should be confined to replacements with more efficient craft and gear.
- The fishing effort should be shifted offshore and the necessary infrastructure like fishery harbours built. Other related aspects like training of manpower have to be undertaken.
- Areas where there is heavy fishing pressure have to be identified and alternative methods of employment provided.
- Aquaculture practices have to be intensified with a view to supplement the catch from wild stocks. In this process environmental degradation should be minimized.
- Awareness of fishing communities' concerns in fisheries management has to be increased.
- Areas where the resources are being depleted should be identified and declared as "Fishery Management Areas" under Section 31 of the Act. Suitable management plans for these areas with adequate technical/bioeconomic details should be formulated.
- "Fisheries Management Profiles" are used in many countries with success. Such profiles could be formulated starting with areas where stocks are depleted.
- The most successful approach is community-based fisheries management. Community-based fisheries management plans should prepared on a priority basis.
- To encourage high seas fisheries under the provisions of the Law of the Sea Convention and other international treaties, present day constraints like unlawful apprehensions by neighbouring countries should be addressed.
- Institutional strengthening is of particular importance in fisheries management. National Aquatic Resources Research and Development Agency (NARA) provides information on stocks, National Institute of Fisheries and Nautical Engineering (NIFNE) undertakes awareness and training programmes, Ceylon Fisheries Harbours Corporation (CFHC) oversees infrastructure development and the DOFAR formulates management profiles and enforces policy.
- Management of fisheries should be undertaken in a phased-out manner with the objective of achieving integrated coastal management, incorporating all interests like fisheries, tourism, maritime transport, coast protection and others.
- The species of beach de mer and chanks and other mollusks exploited for export should be identified, and the extent of their resources and exploitation level assessed.
- A project should be implemented to improve onboard handling of fish, facilities at fish landing sites and fish markets, and fish handling and distribution practices to meet the international quality requirements. This should include formulation of necessary regulations.
- Inter-agency cooperation should be strengthened to restore the degraded coastal habitats, including coral reefs, mangroves, sea grass beds, salt marshes etc.
- Awareness of the significance of coastal habitats and their destruction due to man-made causes such as mining, pollution etc. should be promoted among the fishing communities.
- Scientific research on fisheries, aquaculture and coastal habitats should be encouraged and coordinated with the universities and all related research institutions.

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Appendix I

The International Workshop on Management of Tropical Coastal Fisheries in Asia

20 - 23 March 2001
VIP Lounge, 1st floor, Equatorial Hotel, Penang, Malaysia

Program Activities

19 March 2001
Arrival of Workshop Participants

20 March 2001

8:00 a.m. Registration
WorldFish Center/FRI Staff

Opening Program

9:00 a.m. Opening Remarks
Dr. Meryl Williams
Director-General, WorldFish Center

9:15 a.m. Message
Dato' Hashim Ahmad
Director-General
Department of Fisheries, Malaysia

9:30 a.m. Message
Mr Muhammad Mannan
Manager, Forestry and Natural Resources-East, ADB

9:45 a.m. ADB-RETA 5766
- Project Overview/Update
Mr. Geronimo Silvestre
Project Leader, ADB-RETA 5766
WorldFish Center

10:00 a.m. Photo Session/Break

Session 1: FiRST and Assessment of Fisheries in Developing Asian Countries
Chairpersons: *Mr. Geronimo Silvestre*
Dr. Mahfuzuddin Ahmed

10:30 a.m. Workshop Overview
Mr. Geronimo Silvestre

10:50 a.m. Overview of FiRST and Directions for Future Development
Dr. Daniel Pauly
Mr. Geronimo Silvestre

11:20 a.m. Resource Analyses
- Overview of Analytic Approach
Mr. Geronimo Silvestre

11:35 a.m. Country Presentation
- Resource Analyses
Mr. Ali Azam Khan
Dr. Golam Mustafa
Bangladesh NPT

11:50 a.m. Country Presentation
- Resource Analyses
Dr. Srinath
India NPT

12:05 p.m. Country Presentation
- Resource Analyses
Dr. Subhat Nurhakim
Indonesia NPT

12:20 p.m. Break

1:15 p.m. Country Presentation
- Resource Analyses
Mr. Alias Man
Malaysia NPT

1:30 p.m. Country Presentation
- Resource Analyses
Prof. Nygiel Armada
Dr.Wilfredo Campos
Philippines NPT

1:45 p.m. Country Presentation
- Resource Analyses
Dr. Sepalika Jayamanne
Sri Lanka NPT

2:00 p.m. Country Presentation
- Resource Analyses
Dr. Mala Supongpan
Thailand NPT

2:15 p.m. Country Presentation
- Resource Analyses
Dr. Pham Thuoc
Vietnam NPT

2:30 p.m. Regional Synopsis of Resource Analyses Results
Mr. Geronimo Silvestre
Mr. Len Garces

3:00 p.m. Break

3:20 p.m. Socioeconomic Analyses
- Overview of Review Approach
Dr. Mahfuzuddin Ahmed

3:35 p.m. Country Presentation
- Socioeconomic Analyses
Prof. Sirajul Haque
Bangladesh NPT

3:50 p.m. Country Presentation
- Socioeconomic Analyses
Ms. Sheela Immanuel
India NPT

4:05 p.m. Country Presentation
- Socioeconomic Analyses
Dr. Purwanto
Indonesia NPT

4:20 p.m. Country Presentation
- Socioeconomic Analyses
Ms. Mahyam Mohd. Isa
Malaysia NPT

4:35 p.m. Country Presentation
- Socioeconomic Analyses
Mr. Noel Barut
Philippines NPT

4:50 p.m. Country Presentation
- Socioeconomic Analyses
Mr. B. Wijeyaratne
Sri Lanka NPT

5:05 p.m. Country Presentation
- Socioeconomic Analyses
Mr. P. Boonchowong
Thailand NPT

5:20 p.m. Country Presentation
- Socioeconomic Analyses
Dr. Nguyen Long
Vietnam NPT

5:35 p.m. Regional Synopsis of Socioeconomic Analyses Results
Dr. Mahfuzuddin Ahmed

6:00 p.m. End of Session 1

8p.m.-10p.m. Dinner hosted by DOF, Malaysia
Bukit Jambul Country Club

21 March 2001

Session 2: National / Regional Fisheries management Situation

Chairpersons: *Mr. Cesar Luna*
Mr. Geronimo Silvestre

8:30 a.m Fisheries Management Situation
- Overview of Analytic Approach
Mr. Geronimo Silvestre

8:45 a.m. Bangladesh Coastal Fisheries Situation
Mr. Masudur Rahman
Bangladesh NPT

9:15 a.m. SW India Coastal Fisheries Situation
Dr. Vivekanandan
India NPT

9:45 a.m. Indonesia (Java Sea) Coastal Fisheries Situation
Dr. Purwanto
Indonesia NPT

10:15 a.m.	Break
10:30 a.m.	Malaysia (WCPM) Coastal Fisheries Situation *Mr. Abu Talib Ahmad* Malaysia NPT
11:00 a.m.	Philippines Coastal Fisheries Situation *Mr. Noel Barut* Philippines NPT
11:30 a.m.	Sri Lanka Coastal Fisheries Situation *Dr. Samaranayake* Sri Lanka NPT
12:00 p.m.	Lunch Break
1:00 p.m.	Thailand (GOT) Coastal Fisheries Situation *Mr. Monton Eiamsa-ard* Thailand NPT
1:30 p.m.	Vietnam Coastal Fisheries Situation *Dr. Dao Man Son* Vietnam NPT
2:00 p.m.	Synopsis of Regional Coastal Fisheries Situation *Dr. Francisco Fellizar Jr*
2:30 p.m.	Open Forum
3:00 p.m.	Break/End of Session 2

Session 3: Coastal Fisheries Management Issues and Opportunities in South/Southeast Asia

Chairpersons: *Dr. Francisco Fellizar Jr*
Mr. Geronimo Silvestre

3:15 p.m.	Overview of Regional Issues - Objectives structure *Mr. Cesar Luna*
3:40 p.m.	Working Group Discussions - Management Issues/Objectives *Working groups*
5:30 p.m.	End of Session
6:30 p.m.	National Project Team (NPT) Leader's Meeting/Dinner

22 March 2001

8:30 a.m.	Working Group Reports - Management Strategies/ Interventions *Working groups*
9:45 a.m.	Working Group Reports - Management Issues/Objectives *Working groups*
10:15 a.m.	Break
10:30 a.m.	Synopsis of Regional Issues - Objectives Structure *Mr. Cesar Luna*
10:50 a.m.	Overview of Regional Strategies and Interventions *Dr. Francisco Fellizar, Jr.*
11:15 a.m.	Program Overview - South/Southeast Asia Coastal Fisheries *Dr. Purwito Martosoroto,* FAO
11:35 a.m.	Program Overview - South/Southeast Asia Coastal Fisheries *Dr. Somboon Siriraksophon* SEAFDEC
11:55 p.m.	Program Overview - South/Southeast Asia Coastal Fisheries *Dr. Peter Gardiner,* WorldFish Center
12:35 p.m.	Lunch Break
1:30 p.m.	Working Group Discussions - Management Strategies/ Interventions *Working groups*
3:00 p.m.	Break
3:20 p.m.	Working Group Discussions - Management Strategies/ Interventions *Working groups*

5:30 p.m. End of Session

23 March 2001

8:30 a.m. Working Group Discussions
- Management Issues/Objectives
Working groups

9:10 a.m. Synopsis of Regional Strategies And Interventions
Dr. Francisco Fellizar, Jr.

9:30 a.m. Open Forum

10:00 a.m. Break

Session 4: Scope For Regional Collaboration ClosingProgram and Follow-up Actions
Chairpersons: *Mr.Johann Bell*
Mr. Geronimo Silvestre

10:20 a.m. Stock Linkages: Implications to Fisheries Management
Ms. Menchie Ablan

10:40 a.m. Ecopath with Ecosim: Utility for Evaluating Management/ Policy Directions
Dr. Villy Christensen

11:00 a.m. Coastal Fisheries Research and Management Network
Dr. Modadugu Gupta

11:20 a.m. Resources Enhancement: Challenges and Opportunities
Mr. Johann Bell

11:40 a.m. Scope of Activities under RETA 5945
Dr. Mahfuz Ahmed
Dr. Madan Dey

12:00 p.m. Perspective Paper
- Building on the Gains of ADB-RETA 5766
Mr. Geronimo Silvestre

12:20 p.m. Lunch Break

1:00 p.m. Working Group Discussions
- Potential Regional Collaborative Activities
Working groups

3:00 p.m. Break

3:15 p.m. Working Group Reports
- Potential Regional Collaborative Activities
Working groups

3:45 p.m. Indicative Elements for Regional Collaborative Project
Mr. Geronimo Silvestre

4:10 p.m. End of Session 4

Closing Program

4:30 p.m. Synopsis of Main Workshop Results and Recommendations
Mr. Geronimo Silvestre

4:50 p.m. Remarks
Mr. Ismail Awang Kechik
Director , FRI, Malaysia

5:05 p.m. Remarks
Dr. Muhammad Mannan
Manager
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- East, ADB

5:20 p.m. Remarks
Dr. Meryl Williams
Director-General
WorldFish Center

5:35 p.m. Vote of thanks

6:00 p.m. Cocktails

Appendix II

The International Workshop on Management of Tropical Coastal Fisheries in Asia

20 - 23 March 2001
VIP Lounge, 1st floor, Equatorial Hotel, Penang, Malaysia

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Appendix III

Compilation of Population Parameters of Fish species commonly caught in trawls in South and Southeast Asia[1]

Estimates of the population parameters of 697 fish species were compiled from eight countries in the South and Southeast Asia (Bangladesh, India, Indonesia, Malaysia, Philippines, Thailand, Sri Lanka and Vietnam), and other tropical fishing areas in Asia and northern Australia. The species were those most common in trawl catches and belong to 13 families, namely, Leiognathidae, Mullidae, Nemipteridae, Ariidae, Carangidae, Engraulidae, Gerreidae, Haemulidae, Priacanthidae, Psettodidae, Sciaenidae, Synodontidae and Teraponidae.

The information (Tables 1 and 2) covers:

Growth parameters from the von Bertalanffy growth function (Beverton and Holt 1959):

- L_∞ - the asymptotic length,
- K - the curvature parameter of the growth function, i.e. the rate at which L_∞, is approached.

Mortality coefficients (Gayanilo and Pauly 1997):

- Z - the instantaneous rate of total mortality
- M - the instantaneous rate of natural mortality
- F - the instantaneous rate of fishing mortality.

The parameters were compiled from published data, FishBase (www.fishbase.org) and various technical reports under the Population Analysis sub-Component of the Project "Sustainable Management of Coastal Fish Stocks in Asia" (ADB-RETA 5766). The project technical papers include Khan et al. (2001), Pillai et al. (2001), Naamin (2001), Abu Talib et al. (this vol.), Armada (2001), Maldeniya (2001), Kongprom et al. (this vol.) and Thuoc et al. (2001). Most of the growth and mortality parameters were obtained from length-based stock assessments and estimated using the FAO-ICLARM Stock Assessment Tools (FiSAT) software. For each species the range and mean of all available estimates is given (Tables 1 and 2).

For each species the growth performance index (ϕ') and exploitation ratio (E) were estimated based on the available parameters (Tables 1 and 2), using the formula:

Growth performance index: $\phi' = \log K + 2 \log L_\infty$

Exploitation ratio: $E = F/Z$

The main purpose of this compilation was to assist in evaluating the exploitation status of the major fish species in the Asian region, by validating the biomass declines shown in analyses of compiled trawl survey data (e.g. see Talib et this vol., Kongprom et al. this vol). The mortality parameters were also used as input data for the construction of various tropic models using Ecopath software (see Alias this vol., Campos this vol., Garces et al. this vol., Mustafa this vol., Vibunpant et al. this vol.).

The compilation also aims to assist our understating of the trends in population parameters (e.g. mortality) and exploitation patterns of the various species. These values can potentially provide baseline information (as well as reference points) that can be incorporated into wider reference systems relevant to current fisheries assessment and management. They are also relevant to further (multispecies or ecosystem) studies of fisheries in the country and the region. This compilation is also envisioned to complement the information currently stored in FishBase. The detailed compilation of growth and mortality parameters including sources of information is presented in Tables 3 and 4, respectively.

[1] Compiled by Francisco Torres, Jr., Meii bt M. Norizam, Len R. Garces and Geronimo T. Silvestre.

Table 1. Estimates of growth parameters of fish species commonly caught in trawls in the South and Southeast Asia.

Family/Species	n	L_∞ (cm) Range	L_∞ (cm) Mean	K (yr^{-1}) Range	K (yr^{-1}) Mean	ϕ' Range	ϕ' Mean
1. Leiognathidae							
Leiognathus splendens	40	9.40 - 19.00	14.01	0.33 - 1.60	0.96	1.85 - 2.50	2.25
Leiognathus bindus	28	8.20 - 15.80	11.78	0.58 - 2.63	1.28	1.91 - 2.44	2.20
Leiognathus elongatus	6	11.00 - 15.00	12.45	0.80 - 1.40	1.22	2.06 - 2.47	2.22
Leiognathus equulus	11	12.00 - 27.50	21.25	0.35 - 1.50	0.96	1.96 - 2.98	2.58
Leiognathus blochii	4	12.50 - 13.20	12.68	1.16 - 1.25	1.22	2.26 - 2.32	2.30
Leiognathus brevirostris	6	9.75 - 13.80	12.38	0.90 - 1.75	1.25	2.06 - 2.50	2.26
Leiognathus daura	5	8.10 - 9.60	9.04	1.25 - 2.93	2.01	2.06 - 2.28	2.19
Leiognathus decorus	2	12.00 - 13.00	12.50	1.00 - 1.20	1.10	2.23 - 2.24	2.23
Leiognathus dussumieri	1	16.10					
Leiognathus lineolatus	8	8.60 - 17.00	13.00	0.77 - 2.83	1.29	2.11 - 2.35	2.31
Leiognathus leucisius	7	10.80 - 16.20	11.03	0.74 - 1.80	1.71	1.95 - 2.52	2.25
Leiognathus fasciatus	1	11.25		1.6		2.30	
Secutor insidiator	9	9.10 - 12.50	11.41	0.60 - 1.50	1.12	1.86 - 2.26	2.14
Secutor ruconius	11	7.25 - 11.80	8.67	0.70 - 2.40	1.34	1.57 - 2.27	1.96
Gazza minuta	5	11.40 - 22.50	12.35	0.70 - 1.30	1.18	2.01 - 2.82	2.12
2. Mullidae							
Upeneus sulphureus	28	13.70 - 23.50	19.36	0.55 - 1.32	1.01	2.18 - 2.86	2.56
Upeneus tragula	1	18.20		1.04		2.54	
Upeneus japonicus	4	23.40 - 29.00	25.35	0.55 - 0.86	0.70	2.54 - 2.69	2.64
Upeneus luzonius	1	19.00		0.50		2.26	
Upeneus moluccensis	9	20.00 - 39.50	25.37	0.32 - 1.30	0.84	2.56 - 2.92	2.69
Upeneus vittatus	1	24.50		0.71		2.63	
Parupeneus heptacanthus	1	35.20		0.92		3.06	
3. Nemipteridae							
Nemipterus japonicus	46	20.90 - 35.60	28.90	0.29 - 1.06	0.71	2.44 - 3.04	2.74
Nemipterus hexodon	6	22.80 - 31.80	26.15	0.48 - 1.74	0.84	2.50 - 3.24	2.70
Nemipterus nematophorus	11	22.00 - 35.00	28.12	0.24 - 0.99	0.57	2.32 - 3.05	2.61
Nemipterus virgatus	2	32.40 - 38.00	35.20	0.17 - 0.76	0.47	2.39 - 2.90	2.64
Nemipterus balinensoides	1	23.80		0.46		2.42	
Nemipterus bathybius	6	24.60 - 33.50	29.62	0.32 - 0.82	0.55	2.47 - 2.96	2.66
Nemipterus bipunctatus	5	27.10 - 31.00	29.60	0.44 - 0.80	0.69	2.63 - 2.86	2.77
Nemipterus marginatus	3	19.50 - 30.15	26.28	0.52 - 0.63	0.58	2.38 - 2.71	2.58
Nemipterus mesoprion	7	15.50 - 27.50	22.09	0.41 - 1.08	0.78	2.37 - 2.70	2.55
Nemipterus nemurus	4	28.00 - 31.55	29.89	0.28 - 0.80	0.56	2.37 - 2.89	2.66
Nemipterus peronii	9	25.50 - 34.10	29.33	0.31 - 1.60	0.62	2.44 - 3.19	2.67
Nemipterus randalli	1	21.90		0.83		2.60	
Nemipterus tambuloides	2	33.00 - 35.00	34.00	0.61 - 0.74	0.68	2.82 - 2.96	2.90
Nemipterus thosaporni	3	24.50 - 34.00	28.97	0.36 - 0.42	0.38	2.40 - 2.62	2.50
Scolopsis bimaculatus	1	24.50		0.60		2.56	
Scolopsis lineatus	1	20.00		1.33		2.73	
Scolopsis taeniopterus	2	30.50 - 61.50	30.75	0.47 - 1.51	0.76	2.64	2.82
4. Ariidae							
Arius dussumieri	2	103.00 - 120.60	111.80	0.12 - 0.17	0.15	3.24 - 3.26	3.25
Arius tenuispinis	1	82.00		0.21		3.15	
Arius maculatus	2	44.80 - 45.00	44.90	0.73 - 0.76	0.75	3.17 - 3.18	3.18
Arius thalassinus	3	52.70 - 84.80	65.83	0.20 - 0.65	0.37	2.88 - 3.37	3.13
Arius platystomus	1	49.80		0.35		2.94	

Table 1. Estimates of growth parameters of fish species commonly caught in trawls in the South and Southeast Asia. (continued)

Family/Species	n	L_∞ (cm)		K (yr^{-1})		ϕ'	
		Range	Mean	Range	Mean	Range	Mean
5. Carangidae							
Alepes djedaba	3	14.4 - 32.60	21.33	0.61 - 1.20	0.89	2.25 - 2.81	2.53
Alepes kalla	1	17.10		0.83		2.39	
Alepes melanoptera	1	25.00		0.85		2.73	
Atropus atropus	2	44.00 - 45.30	44.65	1.00 - 1.14	1.07	3.29 - 3.37	3.33
Atule mate	8	24.50 - 34.00	29.03	0.70 - 1.40	0.91	2.70 - 3.12	2.69
Carangoides armatus	2	18.50 - 21.50	20.00	0.82 - 0.92	0.87	2.50 - 2.58	2.54
Carangoides equula	2	22.00 - 30.50	26.25	0.40 - 0.80	0.60	2.57 - 2.59	2.60
Carangoides malabaricus	4	25.00 - 38.10	29.33	0.68 - 0.96	0.83	2.63 - 3.05	2.83
Caranx hippos	1	49.80		0.77		3.28	
Decapterus kuroides	2	25.00 - 33.00	29.00	0.63 - 0.80	0.72	2.70 - 2.83	2.77
Decapterus macarellus	2	19.80 - 24.30	22.05	1.00 - 1.80	1.40	2.60 - 3.03	2.81
Decapterus macrosoma	32	21.40 - 33.00	27.03	0.50 - 2.30	0.99	2.56 - 3.10	2.83
Decapterus maruadsi	13	22.70 - 31.20	25.85	0.32 - 1.30	0.96	2.28 - 3.10	2.78
Decapterus russelli	28	23.20 - 35.10	27.96	0.36 - 1.40	0.87	2.61 - 3.24	2.79
Egalatis bipinnulata	1	97.50		0.60		3.76	
Gnathanodon speciosus	1	73.00		0.53		3.45	
Megalaspis cordyla	5	28.80 - 55.40	40.20	0.13 - 2.40	0.95	2.36 - 3.50	3.00
Parastomateus niger	5	29.50 - 56.00	40.00	0.65 - 0.73	0.69	2.77 - 3.36	2.99
Selar boops	1	29.00		1.90		3.20	
Selar crumenopthalmus	17	23.30 - 36.50	27.81	0.86 - 2.40	1.52	2.81 - 3.29	3.04
Selar malam	1	21.00		1.18		2.71	
Selar mate	2	24.50 - 30.00	27.25	0.76 - 1.00	0.88	2.78 - 2.84	2.81
Selaroides leptolepis	20	14.10 - 29.00	20.96	0.53 - 9.06	1.43	2.32 - 3.49	2.68
Uraspis helvola	2	23.20 - 23.80	23.50	1.00 - 1.00	1.00	2.73 - 2.75	2.74
6. Engraulidae							
Coilia dussumieri	3	26.50 - 28.50	27.50	0.07 - 1.10	0.75	1.75 - 2.88	2.31
Coilia ramcarati	1	26.50		0.29		2.31	
Coilia reynaldi	1	18.50		0.70		2.38	
Encrasicholina devisi	2	10.20 - 11.30	10.75	1.24 - 2.04	1.64	2.11 - 2.42	2.63
Encrasicholina heteroloba	8	8.60 - 12.30	10.79	0.80 - 2.41	1.62	1.77 - 2.49	2.24
Encrasicholina punctifer	5	9.20 - 12.40	10.78	1.10 - 1.85	1.31	1.99 - 2.32	2.17
Setipinna taty	1	20.50		0.33		2.14	
Stolephorus waitei	2	11.60 - 13.00	12.30	1.05 - 2.03	1.54	2.25 - 2.44	2.24
Stolephorus commersonii	5	10.80 - 13.00	11.30	0.81 - 1.20	0.97	2.01 - 2.22	2.11
Stolephorus heteroloba	1	11.40		0.95		2.09	
Stolephorus indicus	11	9.60 - 19.00	15.26	0.50 - 1.42	0.95	1.66 - 2.58	2.31
Stolephorus insularis	2	8.60 - 11.90	10.25	1.61 - 2.08	1.85	2.08 - 2.47	2.27
Stolephorus tri	2	14.50 - 14.80	14.65	1.25 - 1.30	1.28	2.44 - 2.44	2.43
Thryssa mystax	2	20.50 - 23.60	22..05	0.76 - 0.76	0.76	2.93 - 2.63	2.63
Thryssa setirostris	1	17.50		1.10		2.53	
7. Gerreidae							
Gerres filamentosus	1	18.30		0.90		2.48	
Gerres kapas	1	23.50		0.95		2.72	
Gerres oyena	1	15.00		1.00		2.35	
Pentaprion longimanus	26	13.40 - 28.50	17.98	0.46 - 1.80	1.02	2.14 - 3.01	2.46

Table 1. Estimates of growth parameters of fish species commonly caught in trawls in the South and Southeast Asia. (continued)

Family/Species	n	L_∞ (cm)		K (yr^{-1})		ϕ'	
		Range	Mean	Range	Mean	Range	Mean
8. Haemulidae							
Pomadasys argenteus	4	54.00 - 74.10	62.28	0.27 - 0.52	0.45	3.16 - 3.29	3.22
Pomadasys argyreus	3	13.60 - 15.10	14.30	0.62 - 0.83	0.74	2.15 - 2.22	2.18
Pomadasys hasta	6	54.00 - 58.80	55.92	0.38 - 0.66	0.48	3.07 - 3.28	3.16
9. Priacanthidae							
Priacanthus hamrur	2	30.00 - 36.00	33.00	0.38 - 0.74	0.56	2.53 - 2.98	2.76
Priacanthus macracanthus	17	22.00 - 42.00	28.19	0.56 - 1.30	1.01	2.75 - 3.25	2.87
Priacanthus tayenus	13	23.00 - 37.80	29.91	0.20 - 1.90	0.79	2.46 - 3.26	2.78
10. Psettodidae							
Psettodes erumei	5	33.10 - 75.00	51.10	0.27 - 0.64	0.46	2.56 - 3.45	3.03
11. Sciaenidae							
Dendrophysa russelli	3	15.30 - 18.50	17.10	0.74 - 1.01	0.90	2.24 - 2.54	2.14
Johnius macrorhynus	3	33.10 - 35.00	34.13	0.54 - 0.82	0.70	2.77 - 2.98	2.86
Johnius borneensis	3	34.50 - 35.40	35.03	0.51 - 0.80	0.68	2.81 - 3.00	2.91
Johnius carutta	2	25.90 - 33.30	29.60	0.44 - 0.73	0.59	2.69 - 2.69	2.68
Johnius dussumieri	3	23.90 - 27.10	25.97	0.78 - 0.96	0.89	2.65 - 2.84	2.77
Nibea maculata	32	28.40 - 31.50	29.95	0.61 - 1.08	0.85	2.78 - 2.94	2.86
Otholithoides biauritus	2	160.00 - 206.00	183.00	0.14 - 0.21	0.18	3.73 - 3.77	3.75
Otolithes cuvieri	4	38.10 - 40.70	39.53	0.52 - 0.59	0.55	2.90 - 2.99	2.93
Pennahia anea	3	23.30 - 34.80	29.05	0.53 - 1.30	0.90	2.81 - 3.07	2.81
Protonibea diacanthus	3	114.00 - 122.00	119.33	0.29 - 0.39	0.33	3.64 - 3.70	3.67
12. Synodontidae							
Harpodon nehereus	8	28.40 - 73.00	41.94	0.18 - 0.85	0.59	2.80 - 3.14	2.94
Saurida elongata	7	37.00 - 46.10	41.56	0.94 - 1.94	1.34	3.25 - 3.62	3.35
Saurida longimanus	4	19.70 - 37.90	27.20	0.35 - 1.00	0.81	2.56 - 2.95	2.71
Saurida micropectoralis	4	19.70 - 43.00	36.55	0.40 - 43.00	0.79	2.56 - 3.23	2.96
Saurida tumbil	23	34.20 - 79.50	49.76	0.08 - 1.30	0.61	2.69 - 3.50	3.07
Saurida undosquamis	26	30.30 - 55.50	38.67	0.16 - 2.34	1.04	2.52 - 3.47	3.12
Trachinocephalus myops	1	36.50		1.60		3.33	
13. Teraponidae							
Leiopotherapon plumbeus	1	16.00		0.78		2.30	
Therapon jarbua	1	26.00		1.00		2.83	
Therapon theraps	2	12.70 - 34.00	23.35	0.61 - 1.84	1.23	2.47 - 2.85	2.66

Table 2. Estimates of mortality parameters and exploitation ratio of fish species commonly caught in trawls in the South and Southeast Asia.

Family/Species	n	Z (yr^{-1}) Range	Z Mean	M (yr^{-1}) Range	M Mean	F (yr^{-1}) Range	F Mean	E (= F/Z) Range	E Mean
1. Leiognathidae									
Leiognathus splendens	22	1.25 - 4.14	2.10	0.55 - 6.95	2.62	2.17 - 9.89	4.54	0.21 - 0.91	0.54
Leiognathus bindus	17	1.20 - 3.10	2.35	1.00 - 6.50	3.66	4.00 - 8.80	7.02	0.30 - 5.20	0.67
Leiognathus elongatus	3	2.30 - 2.80	2.54	2.50 - 7.80	4.37	4.80 - 10.40	6.91	0.50 - 0.80	0.60
Leiognathus equulus	9	0.78 - 2.58	1.96	0.94 - 5.78	2.53	2.20 - 7.86	4.64	0.38 - 0.74	0.51
Leiognathus blochii	4	2.51 - 2.64	2.58	1.81 - 2.96	2.29	4.32 - 5.60	4.87	0.41 - 0.53	0.47
Leiognathus brevirostris	4	2.10 - 3.14	2.63	0.59 - 8.93	4.26	2.79 - 12.00	6.88	0.21 - 0.74	0.50
Leiognathus daura	3	2.84 - 4.01	3.24	3.86 - 5.52	4.82	6.73 - 9.53	8.06	0.57 - 0.64	0.60
Leiognathus decorus	2	2.06 - 2.27	2.17	0.43 - 0.47	0.45	2.53 - 2.69	2.61	0.16 - 0.19	0.18
Leiognathus fasciatus	1	3.25		2.10		7.68		0.39	
Leiognathus lineolatus	4	2.36 - 2.88	2.36	4.63 - 7.12	4.63	6.99 - 9.53	6.99	0.59 - 0.77	0.60
Leiognathus leucisius	7	1.96 - 3.31	2.58	1.44 - 8.97	3.80	3.40 - 11.21	6.38	0.42 - 0.80	0.55
Secutor insidiator	8	1.69 - 3.13	2.48	1.94 - 13.83	4.36	5.01 - 10.70	6.21	0.38 - 0.71	0.56
Secutor ruconius	11	2.10 - 4.20	3.03	2.30 - 20.10	6.32	4.60 - 22.30	9.79	0.50 - 0.90	0.66
Gazza minuta	5	2.03 - 2.60	2.25	0.85 - 6.50	2.83	3.11 - 8.90	5.20	0.27 - 0.70	0.46
2. Mullidae									
Upeneus sulphureus	26	1.00 - 2.40	1.95	0.90 - 9.50	4.12	2.60 - 11.50	6.07	0.30 - 0.80	0.63
Upeneus taeniopterus	1	1.13		1.44		2.57		0.56	
Upeneus japonicus	7	1.30 - 1.79	1.54	1.23 - 5.41	3.34	2.53 - 7.11	4.88	0.49 - 0.76	0.64
Upeneus luzonius	1	1.32		0.90		2.22		0.41	
Upeneus moluccensis	9	0.81 - 2.06	1.58	1.19 - 2.97	1.90	2.54 - 4.83	3.48	0.40 - 0.77	0.53
Upeneus tragula	1	18.20		1.04					
Upeneus vittatus	1	1.51		3.67		5.18		0.71	
Parupeneus heptacanthus	2	1.58 - 1.64	0.61	1.20 - 1.54	1.37	2.78 - 3.18	2.98	0.43 - 0.48	0.46
3. Nemipteridae									
Nemipterus japonicus	32	0.52 - 2.53	1.53	0.19 - 3.39	1.50	1.27 - 5.65	3.03	0.15 - 0.75	0.43
Nemipterus hexodon	4	0.88 - 2.06	1.47	1.17 - 2.68	1.68	2.48 - 4.74	3.25	0.46 - 0.57	0.50
Nemipterus nematophorus	11	0.61 - 1.67	1.28	0.36 - 5.80	2.14	1.20 - 7.15	3.33	0.24 - 0.81	0.52
Nemipterus virgatus	2	0.53 - 1.51	1.02	0.58 - 2.09	1.34	1.11 - 3.60	2.36	0.52 - 0.58	0.55
Nemipterus balinensoides	2	1.17 - 1.74	1.46	2.91 - 3.13	3.02	4.08 - 4.87	4.48	0.64 - 0.71	0.68
Nemipterus bathybius	7	1.03 - 1.92	1.52	0.98 - 3.68	2.77	2.26 - 5.25	4.29	0.44 - 0.70	0.63
Nemipterus bipunctatus	4	1.12 - 1.62	1.46	0.59 - 1.76	1.18	2.18 - 3.27	2.73	0.27 - 0.54	0.41
Nemipterus marginatus	4	1.21 - 1.67	1.45	1.88 - 2.56	2.30	3.21 - 4.23	3.75	0.59 - 0.65	0.62
Nemipterus mesoprion	7	1.05 - 2.84	1.70	1.49 - 33.48	11.18	2.75 - 36.32	12.88	0.42 - 0.94	0.70
Nemipterus nemurus	5	1.11 - 1.58	1.44	0.12 - 1.72	1.25	1.23 - 3.17	2.69	0.10 - 0.54	0.42
Nemipterus peronii	8	0.41 - 4.20	1.65	0.46 - 17.48	4.45	1.52 - 19.92	6.05	0.30 - 0.88	0.58
Nemipterus tambuloides	3	1.30 - 1.48	1.41	1.18 - 1.61	1.37	2.48 - 3.06	2.78	0.47 - 0.53	0.49
Nemipterus thosaporni	4	0.91 - 1.73	1.31	1.27 - 1.98	1.63	2.18 - 3.43	2.81	0.58 - 0.58	0.58
Scolopsis inermis	1	1.61		2.20		3.81		0.58	
Scolopsis bimaculatus	1	1.91		3.08		5.00		0.62	
Scolopsis taeniopterus	3	1.12 - 2.13	1.70	1.62 - 9.40	5.51	2.74 - 11.27	7.01	0.59 - 0.83	0.71
4. Ariidae									
Arius dussumieri	1	0.20		0.90		1.10		0.82	
Arius tenuispinis	3	0.30 - 0.51	0.44	0.49 - 1.70	1.10	1.00 - 2.00	1.50	0.49 - 0.85	0.67
Arius maculatus	2	1.30 - 1.66	1.33	0.98 - 1.11	1.05	2.34 - 2.42	2.38	0.42 - 0.46	0.44
Arius thalassinus	2	1.11 - 1.40	1.26	2.32 - 3.59	2.96	3.72 - 4.73	4.23	0.62 - 0.76	0.69

Table 2. Estimates of mortality parameters and exploitation ratio of fish species commonly caught in trawls in the South and Southeast Asia. (continued)

Family/Species	n	Z (yr^{-1})		M (yr^{-1})		F (yr^{-1})		E (= F/Z)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
5. Carangidae									
Alepes djedaba	3	0.99 - 2.32	1.77	4.16 - 6.54	5.43	5.15 - 8.54	7.20	0.77 - 0.81	0.78
Alepes kalla	1	1.40		1.68		3.08		0.55	
Atropus atropus	2	1.26 - 1.76	1.51	4.69 - 5.59	5.14	6.45 - 6.85	6.65	0.73 - 0.82	0.77
Atule mate	4	1.22 - 2.24	1.64	2.31 - 3.82	2.90	3.53 - 5.30	4.54	0.53 - 0.72	0.64
Carangoides equula	3	1.01 - 1.74	1.25	1.37 - 1.85	1.53	2.38 - 3.59	2.78	0.52 - 0.58	0.56
Carangoides malabaricus	4	1.24 - 1.72	1.48	0.82 - 6.63	4.03	2.06 - 8.11	5.51	0.40 - 0.82	0.64
Carangoides ciliarius	2	1.69 - 1.90	1.80	1.54 - 2.54	2.04	3.24 - 4.44	3.84	0.48 - 0.57	0.52
Caranx hippos	2	1.18 - 1.18	1.18	2.74 - 5.36	4.05	3.92 - 6.54	5.23	0.70 - 0.82	0.76
Caranx malabaricus	2	1.42 - 1.79	1.61	0.81 - 5.95	3.38	2.23 - 7.74	4.99	0.36 - 0.77	0.57
Decapterus macrosoma	18	1.10 - 4.33	1.90	0.10 - 9.45	3.62	1.86 - 11.57	5.14	0.05 - 0.82	0.61
Decapterus maruadsi	12	1.23 - 24.30	4.00	0.32 - 3.46	2.40	1.80 - 5.50	3.34	0.42 - 0.92	0.61
Decapterus russelli	26	0.89 - 4.62	1.77	0.87 - 9.35	4.22	1.80 - 22.31	6.24	0.42 - 0.83	0.63
Gnathanodon speciosus	1	0.89		2.77		3.66		0.76	
Megalaspis cordyla	4	0.93 - 3.25	2.16	1.22 - 7.52	3.55	2.03 - 8.72	3.91	0.00 - 0.86	0.53
Parastomateus niger	4	0.89 - 1.40	1.14	0.64 - 5.42	2.78	2.06 - 6.45	3.93	0.31 - 0.84	0.63
Parastomateus argenteus	1	1.00		4.10		5.10		0.80	
Selar boops	1	2.75		7.35		10.10		0.73	0.60
Selar crumenopthalmus	5	1.57 - 3.39	2.59	1.34 - 13.38	5.55	2.17 - 8.79	4.86	0.46 - 0.71	
Selar malam	1	2.16		2.24		4.40		0.51	
Selar mate	2	1.46 - 1.86	1.66	1.98 - 2.20	2.09	3.65 - 3.84	3.75	0.52 - 0.60	0.56
Selaroides leptolepis	19	1.29 - 23.70	5.21	0.86 - 14.88	3.81	2.21 - 17.08	6.49	0.41 - 0.87	0.59
Uraspis helvola	1	1.87		2.66	4.52		0.59		
Egalatis bipinnulata	1	0.92		0.27		1.19		0.23	
6. Engraulidae									
Coilia dussumieri	2	1.30 - 2.23	1.77	1.40 - 3.20	2.30	2.70 - 5.25	3.98	0.52 - 0.61	0.56
Stolephorus waitei	1	1.30		1.40		2.70		0.52	
Stolephorus commersonii	4	2.06 - 2.66	2.31	1.82 -- 5.37	3.55	4.04 - 7.43	5.47	0.45 - 0.72	0.57
Stolephorus heteroloba	2	2.29 - 3.10	2.70	8.40 - 8.72	8.56	10.69 - 11.82	11.26	0.74 - 0.79	0.76
Stolephorus indicus	7	1.50 - 15.40	3.98	0.81 - 7.91	3.37	4.53 - 10.47	6.03	0.51 - 0.76	0.61
Stolephorus tri	2	2.55 - 2.55	2.55	4.75 - 9.75	7.25	7.30 - 12.30	9.80	0.65 - 0.79	0.72
Thryssa setirostris	1	0.65		1.41		2.06		0.68	
7. Gerreidae									
Gerres filamentosus	1	1.95		3.39		5.34		0.63	
Gerres kapas	1	1.80		2.65		4.46		0.60	
Gerres oyena	1	2.20		3.59		5.78		0.62	
Pentaprion longimanus	27	1.18 - 2.83	1.97	0.81 - 12.37	4.80	1.99 - 15.20	6.75	0.33 - 0.82	0.65
8. Haemulidae									
Pomadasys argyreus	4	1.57 - 1.94	1.83	2.00 - 3.15	2.52	3.90 - 5.08	4.36	0.51 - 0.65	0.58
Pomadasys hasta	6	0.77 - 1.06	0.90	0.67 - 1.31	0.88	1.49 - 2.36	1.77	0.43 - 0.56	0.49
9. Priacanthidae									
Priacanthus hamrur	1	0.93		1.57		2.50		0.63	
Priacanthus macracanthus	13	1.17 - 2.28	1.80	2.02 - 7.28	4.27	3.98 - 9.02	6.08	0.49 - 0.82	0.68
Priacanthus tayenus	18	1.22 - 37.80	5.35	0.20 - 117.40	11.23	1.95 - 122.01	15.15	0.19 - 0.96	0.56

Table 2. Estimates of mortality parameters and exploitation ratio of fish species commonly caught in trawls in the South and Southeast Asia. (continued)

Family/Species	n	Z (yr^{-1})		M (yr^{-1})		F (yr^{-1})		E (= F/Z)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
10. Sciaenidae									
Dendrophysa russelli	1	2.01		3.31		5.32		0.62	
Johnius carutta	1	1.00		4.10		5.10		0.80	
Nibea maculata	2	1.26 - 1.92	1.59	1.67 - 2.49	2.08	2.93 - 4.41	3.67	0.56 - 0.57	0.57
Otolithes rubber	4	0.98 - 1.35	1.11	0.39 - 1.81	0.90	1.46 - 3.16	2.01	0.27 - 0.57	0.41
Pennahia anea	5	1.15 - 2.30	1.86	0.85 - 6.13	3.56	2.28 - 7.76	5.42	0.37 - 0.84	0.60
Protonibea diacanthus	1	0.80							
11. Synodontidae									
Harpodon nehereus	3	1.05 - 1.57	1.66	1.21 - 2.00	1.48	2.68 - 5.30	3.59	0.38 - 0.46	0.42
Saurida elongata	2	2.48 - 2.70	2.59	2.01 - 6.54	4.28	4.91 - 9.02	6.97	0.41 - 0.73	0.57
Saurida longimanus	5	0.87 - 0.96	1.61	2.22 - 2.42	2.32	3.73 - 3.82	3.78	0.60 - 0.63	0.61
Saurida micropectoralis	2	1.40 - 1.50	1.45	2.22 - 2.42	2.32	3.73 - 3.82	3.78	0.60 - 0.63	0.61
Saurida tumbil	24	0.69 - 79.50	9.65	0.08 - 4.14	1.36	1.68 - 5.31	2.93	0.30 - 0.78	0.50
Saurida undosquamis	17	0.77 - 51.80	7.16	0.16 - 7.95	2.26	1.11 - 10.40	4.09	0.27 - 0.81	0.55
12. Teraponidae									
Pelates quadrilineatus	1	0.19		2.64		3.83		0.69	
Therapon jarbua	1	1.89		3.00		4.89		0.61	
Therapon theraps	2	1.25 - 3.44	2.35	2.24 - 3.18	2.71	3.49 - 3.49	3.49	0.48 - 0.64	0.56

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia.

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Leiognathidae						
Leiognathus splendens	Philippines	San Miguel Bay	11.70	1.12	2.186	1
	Philippines	San Miguel Bay	11.70	1.20	2.216	1
	Philippines	San Miguel Bay	13.00	1.60	2.432	1
	Philippines	–	13.50	1.03	2.274	1
	Philippines	–	14.30	1.04	2.328	1
	Philippines	Manila Bay	10.20	1.50	2.193	2
	Philippines	Manila Bay	12.30	0.70	2.025	2
	Philippines	Manila Bay	12.40	0.75	2.062	2
	Philippines	Manila Bay	13.20	0.76	2.122	2
	Philippines	Manila Bay	15.00	0.72	2.210	2
	Philippines	Ragay Gulf	12.20	0.89	2.122	3
	Philippines	Samar Sea	15.00	0.96	2.334	3
	Philippines	Samar Sea	13.10	0.90	2.189	4
	Philippines	Samar Sea	15.00	0.72	2.210	152
	Philippines		14.00	0.86	2.227	5
	Philippines	Manila Bay	14.00	1.08	2.326	5
	Philippines	Visayas	14.50	0.90	2.277	6
	Philippines	San Pedro Bay	13.50	1.00	2.261	7
	Philippines	Samar Sea	14.90	0.96	2.329	3
	Philippines	Lingayen Gulf	11.60	0.79	2.027	8
	Philippines	San Migiel Bay	11.70	1.12	2.186	152
	Philippines	San Migiel Bay	11.80	1.40	2.290	9
	Philippines	San Migiel Bay	14.30	1.04	2.328	152
	Philippines	Sorsogon Bay	9.40	0.80	1.849	10
	Philippines	Carigara Bay	13.90	0.55	2.026	11
	Indonesia		14.00	1.04	2.309	12
	Indonesia		14.50	1.25	2.420	13
	Indonesia	Central Java	16.70	0.90	2.400	13
	Indonesia	South Kalimantan	16.90	1.10	2.497	13
	Indonesia	Central Java	15.00	0.95	2.330	150
	Indonesia	South Kalimantan	15.00	1.10	2.394	150
	Indonesia	South Kalimantan	14.00	1.40	2.438	152
	Indonesia	Riau - Bintan '82	14.50	1.25	2.420	152
	Malaysia	West Coast	19.00	0.85	2.487	
	India	PortoNovo'76 - '77	17.00	0.33	1.974	152
	India	Palk Bay	16.10	0.53	2.136	152

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Leiognathidae						
Leiognathus splendens	Australia	Queensland	11.50	1.30	2.235	152
	India	Gulf of Mannar	16.10	0.53	2.138	14
	India	Gulf of Mannar	14.70	0.92	2.298	15
	Brunei	–	19.00	0.70	2.403	154
Leiognathus bindus	Philippines	Manila Bay	9.50	2.42	2.339	1
	Philippines	Manila Bay	10.20	2.63	2.437	1
	Philippines	Manila Bay	10.30	2.58	2.437	1
	Philippines	Manila Bay	10.50	2.24	2.393	1
	Philippines	Manila Bay	11.30	2.06	2.420	1
	Philippines	San Pedro Bay	10.52	0.77	1.931	7
	Philippines	Manila Bay	8.20	1.25	1.925	2
	Philippines	Manila Bay	8.20	1.30	1.942	2
	Philippines	Manila Bay	10.30	1.25	2.123	2
	Philippines	Burias Pass	13.50	0.96	2.243	3
	Philippines	Ragay Gulf	13.60	1.03	2.280	3
	Philippines	Samar Sea	13.80	0.88	2.224	3
	Philippines	Samar Sea	12.10	0.98	2.157	4
	Philippines	Visayas	13.00	0.95	2.206	6
	Philippines	Manila Bay	10.50	1.10	2.084	16
	Philippines	Lingayen Gulf	12.30	1.05	2.201	8
	Philippines	San Miguel Bay	11.30	0.76	1.987	9
	Philippines	Carigara Bay	13.00	1.30	2.324	11
	India	–	15.80	0.58	2.161	17
	India	–	12.20	1.30	2.287	18
	India	Kakinada	15.80	0.58	2.161	19
	India	Mandapam	12.20	1.30	2.287	20
	India	Calicut	12.20	1.30	2.287	152
	Indonesia	Central Java	12.50	1.38	2.334	13
	Indonesia	Central Java	12.50	1.38	2.334	150
	Malaysia	Sarawak	13.00	0.74	2.097	150
	Australia	Queensland	10.00	0.82	1.914	152
	Brunei	–	11.50	0.85	2.051	154

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Leiognathidae						
Leiognathus elongatus	Philippines	Burias Pass	15.00	1.32	2.473	3
	Philippines	Guimaras Strait	12.30	1.40	2.326	21
	Philippines	San Pedro Bay	11.00	0.95	2.061	7
	Philippines	Carigara Bay	12.00	1.40	2.304	11
	Malaysia	Terengganu	13.50	0.80	2.164	22
	Brunei	–	13.40	1.00	2.254	154
Leiognathus equulus	Philippines	Samar Sea	24.80	1.28	2.896	2
	Philippines	Ragay gulf	20.50	1.08	2.657	3
	Philippines	Samar Sea	27.50	1.25	2.976	3
	Philippines	Samar Sea	24.00	0.56	2.509	4
	Philippines	Visayas	23.00	0.73	2.587	6
	Philippines	Manila Bay	12.00	1.10	2.200	16
	Philippines	Lingayen Gulf	19.00	1.30	2.671	8
	Vietnam	–	23.50	0.68	2.571	23
	Indonesia	Central Java	21.50	1.50	2.841	13
	Australia	Queensland	16.00	0.35	1.957	152
	Brunei	–	22.00	0.75	2.560	154
Leiognathus blochii	Philippines	Manila Bay	12.50	1.16	2.258	2
	Philippines	Manila Bay	12.50	1.25	2.291	2
	Philippines	Manila Bay	13.20	1.20	2.320	2
	Philippines	Manila Bay	12.50	1.25	2.291	2
Leiognathus brevirostris	Indonesia	Central Java	12.00	0.95	2.136	150
	Indonesia	Central Java	12.20	1.00	2.173	150
	Philippines	Samar Sea	13.00	1.69	2.456	2
	Philippines	Samar Sea	13.50	1.75	2.504	3
	Philippines		9.75	1.20	2.057	24
	Sri Lanka		13.80	0.90	2.234	25
Leiognathus daura	Philippines	–	8.10	2.93	2.284	1
	Philippines	–	8.50	2.52	2.260	1
	Philippines	Manila Bay	9.40	2.10	2.268	2

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Leiognathidae						
Leiognathus daura	Philippines	Manila Bay	9.60	1.25	2.061	2
	Philippines	Manila Bay	9.60	1.27	2.068	2
	Indonesia	Central Java	13.00	1.00	2.228	13
	Indonesia	North Queensland	12.00	1.20	2.238	152
Leiognathus dussumieri	Philippines	Gulf of Mannar	16.10			26
Leiognathus leuciscus	Indonesia	Central Java	13.50	1.80	2.516	13
	Indonesia	Central Java	13.50	1.70	2.491	150
	Philippines	Manila Bay	10.80	1.30	2.181	2
	Philippines	Manila Bay	11.80	1.30	2.258	2
	Philippines	Samar Sea	16.20	1.12	2.468	3
	Philippines	Samar Sea	13.70	0.93	2.242	4
	Philippines	San Pedro Bay	11.00	0.74	1.952	7
	Philippines	–	13.50	1.40	2.407	6
Leiognathus lineolatus	Malaysia	Sarawak	17.00	0.77	2.347	Abu Talib et al. (this vol.)
	Philippines	–	8.60	2.83	2.321	1
	Philippines	–	8.80	2.60	2.304	1
	Philippines	–	9.80	2.10	2.305	1
	Philippines	Manila Bay	10.00	1.30	2.114	2
	Philippines	Manila Bay	11.50	1.05	2.143	2
	Philippines	Manila Bay	11.50	1.30	2.235	2
Leiognathus fasciatus	Philippines	Sorsogon Bay	11.25	1.60	2.306	10
Secutor insidiator	Philippines	Manila Bay	9.10	1.40	2.064	2
	Philippines	Manila Bay	10.20	1.50	2.193	2
	Philippines	Manila Bay	11.00	1.35	2.213	2
	Philippines	San Pedro Bay	12.00	0.80	2.061	7
	Philippines	Manila Bay	12.50	1.00	2.194	16
	Philippines	Carigara Bay	11.00	0.60	1.861	11
	India	–	12.30	1.20	2.259	27
	India	Kakinada	12.30	1.20	2.259	28
	Brunei	–	12.30	1.00	2.180	154

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Leiognathidae						
Secutor ruconius	Indonesia	Tegal	9.00	2.20	2.251	150
	Indonesia	Tegal	8.80	2.40	2.269	150
	Indonesia	Central Java	8.30	1.45	2.000	150
	Philippines	Manila Bay	7.60	1.60	1.966	2
	Philippines	Manila Bay	8.40	1.55	2.039	2
	Philippines	Manila Bay	9.20	1.15	1.988	2
	Philippines	Samar Sea	11.80	0.97	2.131	3
	Philippines	San Pedro Bay	7.25	0.70	1.566	7
	Philippines	San Miguel Bay	8.90	0.86	1.833	9
	Philippines	Sorsogon Bay	8.10	0.87	1.756	10
	Australia	North Queensland	8.00	1.00	1.806	152
Gazza minuta	Philippines	Ragay Gulf	22.50	1.30	2.818	3
	Philippines	Visayas	17.40	0.70	2.326	6
	Philippines	Lingayen Gulf	11.80	1.17	2.212	8
	Philippines	San Migiel Bay	11.40	0.79	2.011	9
	Brunei	–	13.50	0.85	2.190	154
Family Mullidae						
Upeneus sulphureus	Philippines	San Miguel Bay	15.30	1.05	2.391	2
	Philippines	Samar Sea	19.50	1.20	2.659	2
	Philippines	Leyte Gulf	23.50	0.81	2.651	29
	Philippines	Ragay Gulf	17.00	1.32	2.581	3
	Philippines	Samar Sea	19.50	1.30	2.694	3
	Philippines	Burias Pass	23.50	1.30	2.856	3
	Philippines	Samar Sea	18.80	0.55	2.289	30
	Philippines	Samar Sea	18.80	1.25	2.654	31
	Philippines	Visayas	20.00	0.96	2.584	6
	Philippines	Samar Sea		0.55		4
	Philippines	Manila Bay	17.00	1.00	2.461	16
	Philippines	San Miguel Bay	13.70	0.80	2.177	9
	Philippines	Lingeyen Gulf	19.90	1.32	2.718	8
	Bangladesh	–	22.40	1.40	2.847	Khan et al. (this vol.)
Family Mullidae						
Upeneus sulphureus	Bangladesh	–	20.87	1.45	2.800	32
	Bangladesh	–	20.35	1.23	2.707	33
	Bangladesh	–	22.00	1.10	2.726	34
	Bangladesh	Bay of Bengal	22.70	0.98	2.703	35
	Indonesia	Central Java	16.50	0.78	2.327	13
	Indonesia	Central Java	17.50	0.90	2.440	13
	Indonesia	–	19.90	0.88	2.542	36
	Indonesia	–	15.80	1.74	2.638	37
	Indonesia	Central Java	17.68	0.86	2.429	150
	Indonesia	Central Java	17.50	0.80	2.389	150
	Malaysia	Terengganu	23.00	1.10	2.765	22
	Malaysia	West Coast	21.00	0.60	2.423	Abu Talib et al. (this vol.)
	Malaysia	West Coast	19.40	0.56	2.324	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	22.00	0.65	2.498	Abu Talib et al. (this vol.)
	Brunei	–	17.00	0.85	2.390	Silvestre & Garces (In press)
Upeneus tragula	India	–	18.20	1.04	2.537	38
Parupenus pleurospilos	Malaysia	East Coast	35.20	0.92	3.057	Abu Talib et al. (this vol.)
Upeneus bensasi	Malaysia	West Coast	25.00	0.55	2.536	Abu Talib et al. (this vol.)
	Malaysia	West Coast	23.40	0.86	2.673	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	29.00	0.58	2.688	Abu Talib et al. (this vol.)
	Malaysia	Sabah	24.00	0.80	2.664	Abu Talib et al. (this vol.)
Upeneus luzonius	Malaysia	West Coast	19.00	0.50	2.256	Abu Talib et al. (this vol.)

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Mullidae						
Upeneus moluccencis	Malaysia	East Coast	39.50	0.32	2.698	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	25.30	0.57	2.562	Abu Talib et al. (this vol.)
	Philippines	Samar Sea	22.50	1.10	2.746	2
	Philippines	Ragay Gulf	20.00	0.93	2.571	3
	Philippines	Samar Sea	23.00	0.97	2.710	3
	Philippines	Burias Pass	24.60	0.95	2.760	3
	Philippines	–	24.10	0.65	2.577	4
	Philippines	Samar Sea	24.10	0.75	2.639	4
	Philippines	–	25.20	1.30	2.917	6
Upeneus vittatus	Philippines	Manila Bay	24.50	0.71	2.630	2
Family Nemipteridae						
Nemipterus japonicus	Philippines	Manila Bay	30.00	0.70	2.799	2
	Philippines	–	21.00	0.95	2.622	29
	Philippines	–	29.40	0.81	2.845	29
	Philippines	–	29.40	0.81	2.845	29
	Philippines	–	30.00	0.58	2.718	29
	Philippines	Carigara Bay	23.50	0.73	2.605	3
	Philippines	Samar Sea	26.50	0.60	2.625	3
	Philippines	Samar Sea	26.60	0.45	2.503	4
	Philippines	–	27.10	0.85	2.795	31
	Philippines	–	29.30	0.84	2.858	21
	Philippines	Samar Sea	25.50	0.43	2.447	4
	Philippines	Manila Bay	25.50	0.90	2.767	16
	Philippines	Lingayen Gulf	27.00	0.62	2.655	8
	Bangladesh	–	24.20	1.06	2.793	39
	Bangladesh	–	26.50	1.04	2.864	Khan et al. (this vol.)
	Bangladesh	–	24.20	1.06	2.793	39
	Bangladesh	–	26.50	0.60	2.625	40
	Bangladesh	–	24.50	0.94	2.751	41
	Bangladesh	–	25.60	0.94	2.790	35
	Bangladesh	–	27.20	0.92	2.833	42

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Nemipteridae						
Nemipterus japonicus	India	–	20.90	0.65	2.453	43
	India	–	30.50	0.31	2.460	43
	India	–	30.70	0.29	2.437	43
	India	–	30.30	0.47	2.635	44
	India	–	32.60	0.51	2.734	44
	India	–	3.14	0.75	2.869	17
	India	–	30.50	1.00	2.969	45
	India	–	33.90	0.52	2.776	46
	India	–	29.80	0.82	2.862	47
	India	–	35.60	0.76	2.984	48
	India	–	33.00	1.00	3.037	155
	India	–	32.60	0.50	2.725	155
	India	Veraval	33.70	0.73	2.919	49
	India	Northwest	29.80	0.82	2.862	47
	India	Mumbai	35.60	0.76	2.984	48
	India	Karnataka	33.00	1.00	3.037	50
	India	Kerala	32.60	0.50	2.725	44
	India	Chennai	30.50	1.00	2.969	45
	India	Kakinada	31.40	0.52	2.710	46
	India	Vizag	30.50	0.31	2.460	51
	Indonesia	Central Java	23.50	0.70	2.587	13
	Indonesia	Central Java	23.50	0.70	2.587	150
	Malaysia	–	29.50	0.46	2.602	12
	Malaysia	–	31.40	0.55	2.734	52
	Malaysia	West Coast	34.80	0.85	3.013	Abu Talib et al. (this vol.)
	Vietnam	–	28.30	0.37	2.472	53
Nemipterus hexodon	Philippines	–	25.50	0.48	2.494	29
	Philippines	San Pedro Bay	22.80	1.09	2.753	7
	Indonesia	Central Java	24.50	0.60	2.556	13
	Indonesia	Central Java	24.50	0.63	2.578	150
	Malaysia	–	27.80	0.51	2.596	12
	Thailand	Gulf of Thailand	31.80	1.74	3.245	54,55

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Nemipteridae						
Nemipterus nematophorus	Philippines	Lingayen Gulf	22.00	0.43	2.318	2
	Philippines	Visayan Sea	27.00	0.65	2.676	2
	Philippines	Ragay-Samar	26.50	0.49	2.537	3
	Philippines	Samar Sea	25.50	0.55	2.553	4
	Philippines	Samar Sea	25.50	0.43	2.447	4
	Philippines	Lingayen Gulf	27.00	0.62	2.655	8
	Malaysia	Sabah & Sarawak	27.30	0.99	2.868	12
	Malaysia	East Coast	35.00	0.34	2.620	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	35.00	0.92	3.052	Abu Talib et al. (this vol.)
	Thailand	Gulf of Thailand	27.00	0.57	2.619	Kongprom et al. (this vol.)
	Vietnam	D	31.60	0.24	2.379	56
Nemipterus virgatus	Malaysia	Sarawak	32.40	0.76	2.902	Abu Talib et al. (this vol.)
	Vietnam	A	38.00	0.17	2.390	23
Nemipterus balinensoides	Malaysia	East Coast	23.80	0.46	2.416	Abu Talib et al. (this vol.)
Nemipterus bathybius	Malaysia	East Coast	29.40	0.41	2.549	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	33.50	0.82	2.964	Abu Talib et al. (this vol.)
	Malaysia	Sabah	32.00	0.80	2.913	Abu Talib et al. (this vol.)
	Philippines	Burias Pass	24.60	0.57	2.538	3
	Philippines		28.00	0.40	2.496	6
	Philippines		30.20	0.32	2.471	152
Nemipterus bipunctatus	Malaysia	–	28.90	0.70	2.767	12
	Malaysia	–	31.00	0.44	2.626	12
Nemipterus bleekeri	Malaysia	Sabah	31.00	0.75	2.858	Abu Talib et al. (this vol.)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Nemipteridae						
Nemipterus delagoa	India	Chennai	27.10	0.76	2.747	57
	Malaysia	West Coast	30.00	0.80	2.857	Abu Talib et al. (this vol.)
Nemipterus marginatus	Malaysia	East Coast	30.15	0.52	2.675	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	29.20	0.60	2.709	Abu Talib et al. (this vol.)
	Brunei	–	19.50	0.63	2.377	152
Nemipterus mesoprion	India	Kakinada	21.90	0.83	2.600	58
	India	Chennai	20.70	1.08	2.665	57
	India	Mumbai	25.60	0.79	2.697	48
	Indonesia	Central Java	21.50	0.80	2.568	13
	Indonesia	Central Java	21.90	0.59	2.452	150
	Malaysia	Sarawak	27.50	0.41	2.491	Abu Talib et al. (this vol.)
	Thailand	Gulf of Thailand	15.50	0.97	2.637	55
Nemipterus nemurus	Malaysia	East Coast	31.55	0.71	2.849	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	28.00	0.45	2.548	Abu Talib et al. (this vol.)
	Malaysia	Sabah	31.00	0.80	2.886	Abu Talib et al. (this vol.)
	Brunei	–	29.00	0.28	2.366	152
Nemipterus oveniides	Philippines	Visayan Sea	25.50	0.42	2.436	2
Nemipterus peronii	Malaysia	East Coast	34.10	0.60	2.844	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	31.50	0.49	2.687	Abu Talib et al. (this vol.)
	Philippines	–	25.50	0.42	2.436	2
	Thailand	Gulf of Thailand	31.00	1.60	3.187	Kongprom et al. (this vol.)

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Nemipteridae						
Nemipterus peronii	Brunei	–	28.50	0.44	2.553	152
	Brunei	–	29.50	0.50	2.639	152
	Australia	–	30.20	0.31	2.451	152
Nemipterus tolu	India	Chennai	28.20	0.83	2.820	57
Nemipterus randalli	India	–	21.90	0.83	2.600	58
Nemipterus tambuloides	Malaysia	East Coast	33.00	0.61	2.822	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	35.00	0.74	2.957	Abu Talib et al. (this vol.)
Nemipterus thosaporni	Indonesia	–	24.50	0.42	2.402	59
	Malaysia	–	28.40	0.36	2.463	12
	Malaysia	East Coast	34.00	0.36	2.619	Abu Talib et al. (this vol.)
Scolopsis bimaculatus	Philippines	Ticao Pass	24.50	0.60	2.556	3
Scolopsis lineatus	Thailand	–	20.00	1.33	2.726	12
Scolopsis taeniopterus	Malaysia	Sarawak	30.50	0.47	2.641	Abu Talib et al. (this vol.)
	Thailand	Gulf of Thailand	31.00	1.04	3.000	Kongprom et al. (this vol.)
Family Ariidae						
Arius dussumieri	India	–	103.00	0.17	3.256	60
Arius tenuispinis	India	–	82.00	0.21	3.150	61
Arius maculatus	Indonesia	Tegal	45.00	0.73	3.170	13
	Indonesia	Tegal	44.80	0.76	3.183	150

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Ariidae						
Arius thalassinus	Indonesia	Central Java	60.00	0.65	3.369	13
	Indonesia	–	52.70	0.27	2.875	62
	India	–	84.80	0.20	3.158	63
Tachysurus (Arius) dussumieri*	India	Kerala	120.60	0.12	3.242	64
Tachysurus (Arius) thalassinus*	India	Kerala		0.36		64
Tachysurus (Arius) platystomus*	India	Palk Bay	49.80	0.35	2.939	153
Tachysurus (Arius) sona*	India	Vizag		0.35		65
Family Carangidae						
Alepes djedaba	Philippines	Ragay Gulf	17.00	1.20	2.540	3
	Philippines	San Miguel Bay	14.40	0.85	2.246	9
	India	SW coast of India	32.60	0.61	2.218	66
Alepes kalla	India	SW coast of India	17.10	0.83	2.385	66
Alepes melanoptera	Philippines	–	25.00	0.85	2.725	67
Atropus atropus	India	SW coast of India	44.00	1.00	3.287	121
	India	Veraval	45.30	1.14	3.369	68
Atule mate	India	SW coast of India	34.00	0.85	2.992	69
	Philippines	–	24.50	1.00	2.778	3
	Philippines	–	30.00	0.76	2.835	3
	Philippines	–	30.30	0.81	2.871	67
	Philippines	–	30.50	0.92	2.932	21
	Philippines	Manila Bay	27.00	0.70	2.708	16
	Philippines	Lingayen Gulf	24.90	0.81	2.701	8
	Thailand	Gulf of Thailand	31.00	1.40	3.219	Kongprom (this vol.)

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Carangidae						
Carangoides armatus	Philippines	–	18.50	0.92	2.498	3
	Philippines	–	21.50	0.82	2.579	3
Carangoides equula	Malaysia	Sarawak	30.50	0.40	2.571	Abu Talib et al. (this vol.)
	Malaysia	Sabah	22.00	0.80	2.588	Abu Talib et al. (this vol.)
Carangoides malabaricus	Malaysia	East Coast	28.70	0.88	2.860	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	38.10	0.78	3.054	Abu Talib et al. (this vol.)
Caranx (Carngoides) armatus (ciliarius*)*	Philippines	Samar Sea	21.50	0.82	2.579	3
Caranx (Carngoides)*	Philippines	Ragay Gulf	18.50	0.92	2.498	3
	Philippines	Samar Sea	25.50	0.96	2.795	3
Caranx carangus (hippos)*	India	Tuticorin	49.80	0.77	3.281	70
Caranx (Carngoides) malabaricus*	Philippines	Samar Sea	25.00	0.68	2.628	3
Decapterus kurroides	Philippines	–	25.00	0.80	2.699	72
	Philippines	–	33.00	0.63	2.836	67
Decapterus macarellus	Philippines	–	19.80	1.00	2.593	67
	Philippines	–	24.30	1.80	3.026	21
Decapterus macrosoma	Indonesia	Java Sea (Pekalongan)	25.40	0.98	2.801	13
	Indonesia	–	24.00	1.15	2.821	72
	Indonesia	–	25.60	1.05	2.838	73
Family Carangidae						
Decapterus macrosoma	Indonesia	–	24.00	1.00	2.760	74
	Indonesia	–	25.70	0.90	2.774	74
	Indonesia	–	27.70	1.20	2.964	74
	Philippines	Palawan	25.00	1.20	2.875	2
	Philippines	Palawan	25.50	0.80	2.716	2
	Philippines	Palawan	25.50	0.85	2.742	2
	Philippines	Palawan	26.50	1.00	2.846	2
	Philippines	Palawan	26.80	0.71	2.708	2
	Philippines	Palawan	27.00	0.90	2.817	2
	Philippines	Palawan	27.50	1.25	2.976	2
	Philippines	Palawan	27.80	0.83	2.807	2
	Philippines	Palawan	30.00	0.74	2.823	2
	Philippines	Manila Bay	31.50	0.65	2.810	2
	Philippines	Manila Bay	31.50	0.71	2.848	2
	Philippines	Palawan	33.00	0.50	2.736	2
	Philippines	Palawan	33.00	0.65	2.850	2
	Philippines	–	33.00	0.61	2.822	29
	Philippines	Samar Sea	23.00	1.25	2.820	3
	Philippines	Ragay Gulf	25.50	1.26	2.913	3
	Philippines	–	26.00	1.00	2.830	75
	Philippines	–	25.00	0.88	2.740	76
	Philippines	–	24.50	0.60	2.556	67
	Philippines	–	21.40	2.30	3.023	21
	Philippines	–	27.30	1.40	3.018	21
	Philippines	–	27.80	1.20	2.967	21
	Philippines	–	28.00	1.60	3.098	21
	Thailand	–	24.20	0.89	2.717	77
	Thailand	–	23.20	1.00	2.713	74
Decapterus maruadsi	Indonesia	Java Sea (Tegal)	25.90	0.98	2.818	13
	Indonesia	Java Sea (Tegal)	26.50	0.95	2.824	13
	Indonesia	Java Sea (Pekalongan)	26.70	1.28	2.960	13
	Indonesia	Java Sea (Pekalongan)	27.00	0.95	2.840	13
	Philippines	Burias Pass	22.70	0.82	2.626	3
	Philippines	Ragay Gulf	23.50	0.52	2.458	3

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Carangidae						
Decapterus maruadsi	Philippines	Samar Sea	23.60	0.81	2.654	3
	Philippines	–	25.10	1.20	2.879	6
	Philippines	–	25.00	1.20	2.875	21
	Philippines	–	27.30	1.10	2.914	21
	Philippines	–	31.20	1.30	3.102	21
	Thailand	–	27.20	1.01	2.873	77
	Vietnam	–	24.30	0.32	2.276	23
Decapterus russelli	India	SW coast of India	24.80	0.78	2.681	121
	Indonesia	Java Sea (Seribu Islands)	26.60	0.95	2.827	13
	Indonesia	–	27.00	1.15	2.923	13
	Indonesia	Java Sea (Seribu Islands)	27.00	1.18	2.935	13
	Indonesia	–	28.40	0.90	2.861	78
	Indonesia	–	26.00	0.90	2.784	79
	Indonesia	–	24.50	0.95	2.756	80
	Indonesia	–	25.20	1.08	2.836	80
	Philippines	–	23.30	1.13	2.788	1
	Philippines	Palawan	26.00	0.73	2.693	2
	Philippines	Palawan	26.90	0.69	2.698	2
	Philippines	Manila Bay	27.00	0.80	2.766	2
	Philippines	Manila Bay	30.00	0.54	2.687	2
	Philippines	Palawan	33.00	0.45	2.690	2
	Philippines	–	33.70	0.36	2.612	76
	Philippines	–	33.70	0.65	2.868	67
	Philippines	–	35.10	1.40	3.237	21
	Sri Lanka	–	27.00	1.18	2.935	13
	Sri Lanka	–	26.60	0.95	2.827	13
	Sri Lanka	–	27.00	1.01	2.867	81
	Sri Lanka	–	24.00	0.81	2.669	81
	Sri Lanka	–	27.90	0.56	2.639	82
	Sri Lanka	–	35.10	1.40	3.237	21
	Sri Lanka	–	33.70	0.36	2.612	76
	Sri Lanka	–	30.00	0.45	2.607	2
	Sri Lanka	–	27.00	0.80	2.766	2
	Sri Lanka	–	23.30	1.13	2.788	1
	India	Kakinada	23.20	1.08	2.764	58

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Carangidae						
Egalastis bipinnulata	Philippines	Moro Gulf	97.50	0.60	3.756	2
Gnathanodon speciosus	Philippines	Ticao Pass	73.00	0.53	3.451	3
Megalaspis cordyla	India	SW coast of India	39.40	0.60	2.969	121
	India	Veraval	55.40	1.03	3.500	68
	Philippines	Ragay Gulf	35.50	0.61	2.886	3
	Thailand	Gulf of Thailand	28.80	2.40	3.299	83
Formio (Parastomateus) niger*	Indonesia	Central Java	29.50	0.68	2.772	121
Formio (Parastomateus)*	Indonesia	Central Java	30.00	0.65	2.767	150
Parastomateus niger	India	SW coast of India	56.00	0.73	3.360	121
	India	SW coast of India	55.00	0.69	3.320	121
	Indonesia	–	29.50	0.68	2.772	13
Selar boops	Philippines	–	29.00	1.90	3.204	84
Selar crumenophthalmus	Indonesia	Java Sea (Pekalongan)	25.90	1.25	2.924	13
	Indonesia	–	26.90	1.35	2.990	73
	Indonesia	–	26.10	1.10	2.875	80
	Philippines	Manila Bay	36.50	0.89	3.074	2
	Philippines	–	26.50	1.25	2.943	75
	Philippines	–	28.80	0.86	2.853	76
	Philippines	–	27.00	2.07	3.179	85
	Philippines	–	29.00	2.05	3.237	85
	Philippines	–	31.20	1.77	3.236	85
	Philippines	–	31.50	1.70	3.227	85
	Philippines	–	25.40	1.00	2.810	67
	Philippines	–	23.30	1.20	2.814	21
	Philippines	–	24.60	1.49	2.955	21
	Philippines	–	24.60	1.50	2.958	21

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Carangidae						
Selar crumenoph-thalmus	Philippines	–	28.50	2.00	3.211	21
	Philippines	–	28.60	1.90	3.191	21
	Thailand	Gulf of Thailand	28.40	2.40	3.287	86
Selar mate	Philippines	Ragay Gulf	21.00	1.18	2.716	3
	Philippines	Samar Sea	24.50	1.00	2.778	3
	Philippines	Samar Sea	30.00	0.76	2.835	3
Caranx (Selaroides) leptolepis*	India	Tuticorin	21.30	1.43	2.812	70
	India	SE	20.20	0.82	2.525	66
	Indonesia	–	18.90	1.10	2.594	13
	Indonesia	Java Sea (Tegal)	22.00	1.20	2.764	13
	Philippines	Manila Bay	23.00	1.15	2.784	2
	Philippines	Manila Bay	29.00	0.80	2.828	2
	Philippines	–	23.00	1.22	2.810	29
	Philippines	Samar Sea	19.20	1.10	2.608	3
	Philippines	Ragay Gulf	26.00	1.32	2.951	3
	Philippines	Samar Sea	19.90	0.53	2.322	4
	Philippines	–	20.40	0.71	2.471	31
	Philippines	–	21.00	0.80	2.548	6
	Philippines	–	19.20	0.67	2.346	67
	Philippines	Manila Bay	25.50	0.95	2.791	16
	Philippines	Lingayen Gulf	18.20	9.06	3.491	8
	Philippines	Carigara Bay	14.40	1.32	2.437	11
	Thailand	–	20.00	1.12	2.651	1
	Thailand	Gulf of Thailand	19.20	1.54	2.754	87
	Vietnam	A	23.70	0.86	2.684	23
	Vietnam	A	23.70	0.86	2.684	23
	Vietnam	C	15.80	0.98	2.389	88
Uraspis helvola	Philippines		23.20	1.00	2.731	3
	Philippines	Ragay Gulf	23.80	1.00	2.753	3
Family Engraulidae						
Coilia dussumieri	India	–	28.50	0.07	1.755	89
	India	NW	26.50	1.07	2.876	66
	India	NW	22.2 - 27.2	1.10		90
Family Engraulidae						
Coilia ramcarati	India	NW	26.50	0.29	2.309	66
Coilia reynaldi	India	–	18.50	0.70	2.379	91
Encrasicholina devisi	Philippines	–	10.20	1.24	2.111	1
Stolephorus (Encrasicho-lina) devisi*	India	Mangalore	11.30	2.04	2.416	92
Encrasicholina heteroloba	Indonesia	–	10.30	2.08	2.344	93
	Indonesia	–	9.70	2.41	2.356	94
	Philippines	–	10.30	1.29	2.136	1
	Philippines	–	11.40	0.95	2.092	2
	Philippines	–	12.10	1.60	2.370	2
	Philippines	–	8.60	0.80	1.772	67
	Philippines	–	11.60	2.30	2.491	21
	Philippines	–	12.30	1.50	2.356	21
Encrasicholina punctifer	Philippines	–	11.60	1.23	2.219	1
	Philippines	–	9.20	1.15	1.988	2
	Philippines	–	10.10	1.10	2.050	2
	Philippines	–	10.60	1.85	2.318	2
	Philippines	–	12.40	1.20	2.266	21
Setipinna taty	India	–	20.50	0.33	2.142	1
Stolephorus bataviensis (waitei)*	India	Mangalore	11.60	2.03	2.436	95
	Philippines	Manila Bay	13.00	1.05	2.249	16
Stolephorus commersonii	Philippines	Manila Bay	11.30	0.96	2.088	2
	Philippines	–	10.80	0.95	2.045	67
	Philippines	San Pedro Bay	11.20	0.81	2.007	7
	Philippines	Manila Bay	13.00	0.95	2.206	16
	Philippines	San Pedro Bay	11.70	1.20	2.216	9

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Engraulidae						
Stolephorus heterolobus	Philippines	Manila Bay	11.40	0.95	2.092	2
Stolephorus indicus	Philippines	–	17.20	1.09	2.508	1
	Philippines	Manila Bay	15.70	1.08	2.425	2
	Philippines	Manila Bay	16.30	1.42	2.577	2
	Philippines	Ragay Gulf	14.50	1.30	2.437	3
	Philippines	–	16.40	1.04	2.447	31
	Philippines	–	16.80	1.15	2.511	67
	Philippines	San Pedro Bay	13.00	0.53	1.952	7
	Philippines	Manila Bay	14.00	0.80	2.195	16
	Philippines	San Pedro Bay	9.60	0.50	1.664	9
	Vietnam	–	15.40	0.81	2.286	23
	Singapore	Singapore Strait	19.00	0.71	2.409	
	Indonesia	–	11.90	2.08	2.469	93
	Indonesia	–	8.60	1.61	2.076	94
Stolephorus tri	Philippines	Ragay Gulf	14.50	1.30	2.437	3
	Philippines	–	14.80	1.25	2.437	6
Thryssa mystax	India	–	23.60	0.76	2.627	96
	India	SW coast of India	20.50			66
Thryssa setirostris	Philippines	Manila Bay	17.50	1.10	2.527	16
Family Gerreidae						
Gerres filamentosus	Philippines	Manila Bay	18.30	0.90	2.479	16
Gerres kapas	Philippines	Samar Sea	23.50	0.95	2.720	3
Gerres oyena	Philippines	Sorsogon Bay	15.00	1.00	2.352	10
Pentaprion longimanus	Indonesia	Semarang	13.50	1.10	2.302	13
	Indonesia	–	15.60	0.95	2.364	97
	Indonesia	–	13.40	1.77	2.502	98
	Indonesia	–	13.70	1.12	2.323	98
Family Gerreidae						
Pentaprion longimanus	Indonesia	–	14.20	1.80	2.560	98
	Indonesia	–	15.60	0.80	2.289	98
	Indonesia	Semarang	13.50	1.10	2.302	150
	Malaysia	–	16.00	1.10	2.450	22
	Malaysia	West Coast	20.00	0.80	2.505	Abu Talib et al. (this vol.)
	Malaysia	East Coast	22.50	0.46	2.367	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	28.50	0.51	2.617	Abu Talib et al. (this vol.)
	Malaysia	Sabah	28.00	1.30	3.008	Abu Talib et al. (this vol.)
	Malaysia	–	16.00	1.10	2.450	22
	Malaysia	East Coast	22.50	0.46	2.367	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	28.50	0.51	2.617	Abu Talib et al. (this vol.)
	Malaysia	Sabah	28.00	1.30	3.008	Abu Talib et al. (this vol.)
	Philippines	Samar Sea	14.00	0.70	2.137	152
	Philippines	Carigara Bay	14.50	0.69	2.162	152
	Philippines	Samar Sea	14.60	0.81	2.237	152
	Philippines	Burias Pass	15.80	1.00	2.397	152
	Philippines	Visayas	15.80	0.84	2.322	152
	Philippines	Samar Sea	16.50	1.55	2.625	152
	Philippines	Samar Sea	17.00	1.22	2.547	152
	Philippines	Carigara Bay	17.00	1.59	2.662	152
	Philippines	Burias Pass	17.20	1.03	2.484	152
	Australia	North Queensland	15.50	0.95	2.356	152
Family Haemulidae						
Pomadasys argenteus	India	–	62.20	0.50	3.287	1
	India	–	74.10	0.27	3.171	1
	Indonesia	Java Sea	51.00	0.50	3.164	152
	Bangladesh	Bay of Bengal	58.80	0.52	3.255	152

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Haemulidae						
Pomadasys argyreus	Philippines	Manila Bay	13.60	0.78	2.159	2
	Philippines	Manila Bay	14.20	0.83	2.224	2
	Philippines	Manila Bay	15.10	0.62	2.150	2
Pomadasys hasta	Bangladesh	–	57.00	0.40	3.114	Khan et al. (this vol.)
	Bangladesh	–	54.80	0.39	3.069	99
	Bangladesh	–	56.90	0.38	3.090	100
	Bangladesh	–	58.80	0.52	3.255	35
	Indonesia	South Kalimantan	54.00	0.66	3.284	150
	Indonesia	South Kalimantan	54.00	0.50	3.164	13
Family Priacanthidae						
Priacanthus hamrur	India	NE	30.00	0.38	2.534	101
	India	NW	36.00	0.74	2.982	102
Priacanthus macracanthus	Indonesia	Central Java	23.00	1.15	2.784	13
	Indonesia	Central Java	23.80	1.30	2.867	13
	Indonesia	Central Java	22.00	1.15	2.746	150
	Indonesia	Central Java	23.20	1.10	2.772	150
	Indonesia	–	23.80	1.30	2.867	13
	Indonesia	Central Java	23.80	1.30	2.867	150
	Indonesia	Central Java	23.00	1.15	2.784	150
	Indonesia	Central Java	23.20	1.10	2.772	150
	Indonesia	Central Java	22.00	1.15	2.746	150
	Malaysia	West Coast	37.00	13.0	3.250	Abu Talib et al. (this vol.)
	Malaysia	East Coast	39.00	0.56	2.930	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	42.00	0.71	3.098	Abu Talib et al. (this vol.)
	Malaysia	Sabah	31.00	0.75	2.858	Abu Talib et al. (this vol.)
	Philippines	Carigara Bay	25.00	1.12	2.845	3
	Philippines	Samar Sea	28.50	0.84	2.834	3
	Philippines	Ragay Gulf	29.00	1.00	2.925	3
	Philippines	–	31.80	0.79	2.902	6
		South China Sea	32.00	0.70	2.855	152
Family Priacanthidae						
Priacanthus tayenus	Malaysia	West Coast	23.00	0.55	2.464	Abu Talib et al. (this vol.)
	Malaysia	East Coast	31.35	0.78	2.885	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	32.00	0.68	2.843	Abu Talib et al. (this vol.)
	Malaysia	Sabah	32.00	0.55	2.751	Abu Talib et al. (this vol.)
	Malaysia	–	27.00	0.60	2.641	22
	Philippines	Samar Sea	29.00	0.65	2.738	4
	Philippines	Samar Sea	29.00	0.70	2.770	3
	Philippines	Samar Sea	29.00	1.25	3.022	2
	Thailand	–	29.00	1.23	3.015	103
	Thailand	Gulf of Thailand	31.00	1.90	3.261	54,55
	Vietnam	–	28.70	0.36	2.472	23
	Vietnam	–	37.80	0.20	2.456	56
		South China Sea	30.00	0.80	2.857	152
Family Psettodidae						
Psettodes erumei	India	–	75.00	0.50	3.449	104
	India	–	75.00	0.50	3.449	104
	India	Orissa	43.00	0.56	3.015	105
	India	Orissa	53.50	0.64	3.263	105
	Thailand	–	50.90	0.27	2.845	1
	Thailand	–	33.10	0.33	2.558	1
Family Sciaenidae						
Dendrophysa russelii	Philippines	San Miguel Bay	17.50	0.95	2.464	2
	Philippines	San Miguel Bay	15.30	0.74	2.239	9
	Thailand		18.50	1.01	2.539	1
Johnieops (Johnius) macrorhynus*	India	Vizag	35.00	0.75	2.963	106
Johnius macrorhynus	India	–	33.10	0.54	2.772	102
	India	Bombay	34.30	0.82	2.984	152

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Sciaenidae						
Johnius borneensis	India	–	35.40	0.51	2.806	102
	India	–	34.50	0.72	2.933	121
	India	–	35.20	0.80	2.996	121
Johnius carutta	India	Chennai	25.90	0.73	2.690	107
	India	Kakinada	33.30	0.44	2.688	108
Johnius dussumieri	India	–	23.90	0.78	2.649	102
	India	–	26.90	0.96	2.842	152
	India	–	27.10	0.92	2.830	152
Nibea maculata	India	Kakinada	31.50	0.61	2.782	109
	India	Gulf of Mannar	28.40	1.08	2.940	110
Otolithoides biauritus	India	–	160.00	0.21	3.730	1
	India	–	206.00	0.14	3.774	111
Otolithes cuvieri	India	Gujarat	38.10	0.55	2.902	106
	India	Maharashtra	39.80	0.52	2.916	106
	India	–	39.50	0.53	2.917	102
Pennahia anea	Malaysia	–	34.80	0.53	2.807	112
	India	Gulf of Mannar	23.30	1.26	2.835	110
Pennahia macropthalmus (anea)*	Malaysia	West Coast	30.00	1.30	3.068	
Protonibea diacanthus	India	–	122.00	0.29	3.635	1
	India	–	122.00	0.32	3.678	113
	India	–	114.00	0.39	3.705	111
Family Synodontidae						
Harpadon nehereus	India	–	28.40	0.85	2.836	1
	India	–	35.00	0.52	2.804	1
	India	–	39.00	0.53	2.906	114
	India	–	73.00	0.18	2.982	115
	India	Saurashtra	36.70	0.76	3.010	116
	India	Mumbai	39.00	0.53	2.906	114
Family Synodontidae						
Harpadon nehereus	India	Saurashtra	42.50	0.76	3.138	117
	India	NW	37.50 - 61.00	0.29 - 0.77		90
Saurida elongata	Malaysia	–	37.00	1.60	3.341	22
	Thailand	–	41.60	1.19	3.314	118
	Thailand	–	42.40	1.24	3.348	118
	Thailand	–	37.70	1.24	3.246	118
	Thailand	–	40.00	1.22	3.290	118
	Thailand	–	46.10	0.94	3.301	118
	Thailand	Gulf of Thailand	46.10	1.94	3.615	118
Saurida longimanus	Indonesia	Central Java	21.20	0.95	2.630	13
	Indonesia	Central Java	19.70	0.94	2.562	150
	Malaysia	East Coast	37.90	0.35	2.701	Abu Talib et al. (this vol.)
	Malaysia	West Coast	30.00	1.00	2.954	Abu Talib et al. (this vol.)
Saurida micropectoralis	Indonesia	Central Java	43.00	0.92	3.231	150
	Indonesia	Central Java	19.70	0.94	2.562	150
	Indonesia	Central Java	42.00	0.88	3.191	13
	Australia	North Queensland	41.50	0.40	2.839	152
Saurida tumbil	Philippines	–	43.60	0.43	2.912	1
	Philippines	Manila Bay	37.50	1.03	3.161	2
	Philippines	Visayan Sea	41.00	0.70	3.071	2
	Philippines	Samar Sea	43.00	0.64	3.073	3
	Philippines	Ragay Gulf	53.00	0.70	3.294	3
	Philippines	–	45.00	0.55	3.047	6
	Philippines	San Pedro Bay	34.20	0.82	2.982	7
	Philippines	Lingayen Gulf	39.00	0.52	2.898	8
	Philippines	San Miguel Bay	39.50	0.60	2.971	9
	Bangladesh	–	40.70	0.64	3.025	
	Bangladesh	–	39.00	0.64	2.988	119
	Bangladesh	–	41.80	0.95	3.220	35
	India	Andhra/Orissa	63.10	0.25	2.998	120
	India	Veraval	59.50	0.58	3.312	152

Table 3. Compilation of growth parameters of trawl-caught fishers in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Synodontidae						
Saurida tumbil	India	Veraval	34.00			152
	Malaysia	West Coast	46.00	1.30	3.439	Abu Talib et al. (this vol.)
	Malaysia	East Coast	62.60	0.80	3.496	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	63.50	0.44	3.249	Abu Talib et al. (this vol.)
	Malaysia	Sabah	36.00	0.95	3.090	Abu Talib et al. (this vol.)
	Vietnam	–	79.50	0.10	2.801	118
	Vietnam	–	78.30	0.08	2.691	118
	Vietnam	A	45.20	0.36	2.867	23
	India	Bay of Bengal	63.70	0.25	3.004	152
Saurida undosquamis	Indonesia	Central Java	33.50	0.95	3.028	13
	Indonesia	Central Java	33.60	1.00	3.053	150
	Malaysia	East Coast	40.50	0.98	3.206	Abu Talib et al. (this vol.)
	Malaysia	Sarawak	55.50	0.41	3.101	Abu Talib et al. (this vol.)
	Malaysia	Sabah	42.00	1.20	3.326	Abu Talib et al. (this vol.)
	Philippines	Visayan Sea	30.50	0.80	2.872	2
	Philippines	–	34.50	0.60	2.854	2
	Philippines	Samar Sea	41.00	0.65	3.038	3
	Philippines	Ragay Gulf	43.00	0.75	3.142	3
	Philippines	–	33.30	0.30	2.522	30
	Philippines	–	43.00	0.85	3.796	6
	Philippines	Samar Sea		0.30		4
	Thailand	–	37.90	0.89	3.107	1
	Thailand	–	41.30	1.13	3.285	1
	Thailand	–	35.20	2.13	3.421	118
	Thailand	–	36.00	1.64	3.327	118
	Thailand	–	42.30	1.02	3.261	118
	Thailand	–	43.00	0.96	3.249	118
	Thailand	–	30.30	2.34	3.332	118
	Thailand	–	31.00	1.89	3.259	118
	Thailand	–	31.80	1.62	3.214	118

Family/ Species	Country	Fishing ground	L_∞	K	ϕ'	Ref.
Family Synodontidae						
Saurida undosquamis	Thailand	–	32.50	1.60	3.228	118
	Thailand	–	40.60	0.60	2.995	118
	Thailand	Gulf of Thailand	40.60	1.80	3.472	118
	Vietnam	–	46.80	0.42	2.964	23
	Vietnam	–	51.80	0.16	2.633	56
	Malaysia	West Coast	34.00	1.20	3.142	Abu Talib et al. (this vol.)
Trachinocephalus myops	Malaysia	–	36.50	1.60	3.329	22
Family Teraponidae						
Leiopotherapon plumbeus	Philippines	–	16.00	0.78	2.300	2
Therapon jarbua	Philippines	Manila Bay	26.00	1.00	2.830	16
Therapon theraps	Philippines	Manila Bay	34.00	0.61	2.848	2
	Philippines	Sorsogon Bay	12.70	1.84	2.472	10

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia.

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Leiognathidae							
Gazza acclamys	Philippines	Lingayen Gulf	2.51	3.40	5.91	0.58	8
Gazza minuta	Philippines	Honda Bay	2.03	4.59	6.62	0.69	2
	Philippines	San Miguel Bay	2.35	6.50	8.85	0.73	2
	Philippines	Ragay Gulf	2.26	0.85	3.11	0.27	3
	Philippines	San Miguel Bay	2.04	1.14	3.78	0.36	9
	Philippines	Lingayen Gulf	2.57	1.07	3.64	0.29	8
Leiognathus bindus	India	–	1.15	4.05		5.20	121
	India	Kakinada	0.80-1.50	3.70-4.40	5.20		121
	India	–	1.15	4.05	5.20		121
	Indonesia	Central Java	2.83	6.01	8.84	0.68	13
	Indonesia	Central Java	2.57	3.09	5.66	0.55	
	Indonesia	–	2.83	6.01	8.84		13
	Malaysia	Sarawak	1.91	6.47	8.38	0.77	122
	Philippines	Manila Bay	2.79	3.91	6.70	0.58	2
	Philippines	Manila Bay	2.97	1.03	4.00	0.26	2
	Philippines	Manila Bay	3.05	1.53	4.58	0.34	2
	Philippines	Manila Bay	2.59	2.38	4.97	0.48	16
	Philippines	Burias Pass	2.14	3.76	5.89	0.64	3
	Philippines	Ragay Gulf	2.23	4.29	6.52	0.66	3
	Philippines	Samar Sea	2.21	2.07	4.28	0.48	4
	Philippines	Lingayen Gulf	2.37	4.50	6.87	0.65	8
	Philippines	San Pedro Bay	2.03	3.95	5.98	0.66	7
	Philippines	Samar Sea	2.01	4.22	6.23	0.68	3
	Philippines	San Miguel Bay	1.99	2.54	4.53	0.56	9
	Philippines	Carigara Bay	2.68	4.69	7.37	0.64	11
Leiognathus blochii	Philippines	Manila Bay	2.53	2.52	5.05	0.50	2
	Philippines	Manila Bay	2.51	1.81	4.32	0.42	2
	Philippines	Manila Bay	2.64	1.87	4.51	0.41	2
	Philippines	Manila Bay	2.64	2.96	5.60	0.53	2
Leiognathus brevirostris	Indonesia	Central Java	2.20	0.59	2.79	0.21	13
	Indonesia	Central Java	2.10	1.11	3.21	0.35	150
	Philippines	Samar Sea	3.07	8.93	12.00	0.74	2
	Philippines	Samar Sea	3.14	6.39	9.53	0.67	3
Family Leiognathidae							
Leiognathus daura	Philippines	Manila Bay	4.01	5.52	9.53	0.58	2
	Philippines	Manila Bay	2.87	3.86	6.73	0.57	2
	Philippines	Manila Bay	2.84	5.07	7.91	0.64	2
Leiognathus decorus	Indonesia	–	2.27	0.43	2.69		13
	Indonesia	Central Java	2.27	0.43	2.69	0.16	123
	Indonesia	Central Java	2.06	0.47	2.53	0.19	150
Leiognathus elongatus	Philippines	San Pedro Bay	2.30	2.52	4.82	0.52	7
	Philippines	Burias Pass	2.53	7.84	10.37	0.76	3
	Philippines	Carigara Bay	2.78	2.76	5.54	0.50	11
Leiognathus equulus	Indonesia	Central Java	2.58	3.10	5.68	3.10	13
	Indonesia	Central Java	1.79	1.79	3.58	0.50	
	Philippines	Samar Sea	2.22	3.75	5.97	0.63	2
	Philippines	Samar Sea	2.08	5.78	7.86	0.74	3
	Philippines	Ragay Gulf	2.05	1.73	3.79	0.46	3
	Philippines	Samar Sea	1.26	0.94	2.20	0.43	4
	Philippines	Manila Bay	2.50	1.51	4.01	0.38	16
	Philippines	Lingayen Gulf	2.41	1.64	4.05	0.40	8
	Vietnam	–	23.50	0.67			23
Leiognathus fasciatus	Philippines	Sorsogon Bay	3.25	2.10	7.68	0.39	10
Leiognathus jonesi	India	–	2.10	2.00	4.10		121
	India	–	1.25	4.01	5.26		121
Leiognathus leuciscus	Indonesia	Central Java	3.31	2.84	6.15	0.46	123
	Indonesia	Central Java	2.89	2.56	5.45	0.47	150
	Philippines	Manila Bay	2.72	4.45	7.17	0.62	2
	Philippines	Manila Bay	2.79	4.63	7.42	0.62	2
	Philippines	Samar Sea	2.24	8.97	11.21	0.80	3
	Philippines	Samar Sea	2.12	1.74	3.86	0.45	4
	Philippines	San Pedro Bay	1.96	1.44	3.40	0.42	7
Leiognathus lineolatus	Malaysia	–	1.82	2.49	4.31		Abu Talib at al. (this vol.)
	Malaysia	Sarawak	1.91	6.47	8.38	0.77	Abu Talib at al. (this vol.)

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Leiognathidae							
Leiognathus lineolatus	Philippines	Manila Bay	2.41	7.12	9.53	0.75	2
	Philippines	Manila Bay	2.77	6.46	9.23	0.70	2
	Philippines	Manila Bay	2.88	0.60	3.48	0.17	2
Leiognathus splendens	India	–	2.10	–	–		14
	Indonesia	South Kalimantan	2.25	1.75	4.00	0.43	13
	Indonesia	Central Java	1.98	1.25	3.27	0.38	13
	Indonesia	Central Java	1.92	0.97	2.89	0.34	150
	Indonesia	South Kalimantan	2.11	0.55	2.66	0.21	150
	Indonesia	–	1.80	–	–		12
	Indonesia	–	2.55	2.09	4.64		13
	Indonesia	–	2.25	1.75	4.00		13
	Indonesia	–	1.98	1.25	3.27		13
	Malaysia	West Coast	1.87	5.29	7.16	0.74	122
	Philippines	Manila Bay	1.89	1.96	3.85	0.51	2
	Philippines	Manila Bay	1.88	5.64	7.52	0.75	2
	Philippines	Manila Bay	1.81	2.65	4.46	0.59	2
	Philippines	Manila Bay	1.76	2.01	3.77	0.53	2
	Philippines	San Miguel Bay	2.94	6.95	9.89	0.70	9
	Philippines	Sorsogon Bay	4.14	1.97	2.17	0.48	10
	Philippines	Carigara Bay	1.50	2.46	3.96	0.62	11
	Philippines	San Pedro Bay	2.25	3.41	5.66	0.60	7
	Philippines	Samar Sea	2.08	2.31	4.39	0.53	3
	Philippines	Ragay Gulf	2.09	3.46	5.55	0.62	3
	Philippines	Samar Sea	2.02	1.11	3.10	0.35	4
	Philippines	Lingayen Gulf	2.00	0.59	2.59	0.23	8
Secutor insidiator	India	–	2.20	3.90		6.10	121
	India	Kakinada	1.80 - 2.60	3.50 - 4.30	6.10		121
	India	–	2.20	3.90	6.10		121
	Philippines	Manila Bay	3.13	13.83	10.70	0.71	2
	Philippines	Manila Bay	2.88	2.43	5.31	0.46	2
	Philippines	Manila Bay	3.10	1.94	5.04	0.38	2
	Philippines	San Pedro Bay	2.01	3.19	5.20	0.61	7
	Philippines	Manila Bay	2.32	2.69	5.01	0.54	16
	Philippines	Carigara Bay	1.69	2.56		0.60	11
Family Leiognathidae							
Secutor ruconius	Indonesia	Tegal	4.22	4.69	8.91		13
	Indonesia	Central Java	3.29	5.57	8.86		13
	Indonesia	Tegal	4.07	5.42	9.49	0.57	150
	Indonesia	Central Java	2.98	2.31	5.29	0.68	150
	Philippines	Manila Bay	3.39	6.18	9.57	0.65	2
	Philippines	Manila Bay	2.72	5.97	8.69	0.69	2
	Philippines	San Pedro Bay	2.12	2.50	4.62	0.54	7
	Philippines	Samar Sea	2.24	20.06	22.30	0.90	3
	Philippines	Manila Bay	3.56	6.79	10.35	0.66	2
	Philippines	San Miguel Bay	2.31	5.19		0.69	9
	Philippines	Sorsogon Bay	2.39	4.85		0.67	10
Family Mullidae							
Parupeneus pleurospilus	Malaysia	–	1.58	1.20	2.78		122
	Malaysia	East Coast	1.64	1.54	3.18	0.48	122
Upeneus bensasi	Malaysia	West Coast	1.31	4.09	5.40	0.76	122
	Malaysia	–	1.67	3.63	5.30		122
	Malaysia	–	1.30	1.23	2.53		122
	Malaysia	–	1.70	5.41	7.11		122
	Malaysia	East Coast	1.79	2.36	4.15	0.57	122
	Malaysia	Sarawak	1.30	1.23	2.53	0.49	122
	Malaysia	Sabah	1.70	5.41	7.11	0.76	122
Upeneus luzonius	Malaysia	West Coast	1.32	0.90	2.22	0.41	122
Upeneus moluccencis	Malaysia	East Coast	0.81	2.79	3.60	0.77	122
	Malaysia	Sarawak	1.34	1.20	2.54	0.47	122
	Malaysia	–	1.79	1.19	2.98		122
	Malaysia	–	1.34	1.20	2.54		122
	Philippines	Samar Sea	1.62	1.85	3.47	0.53	4
	Philippines	Samar Sea	1.84	2.18	4.01	0.54	3
	Philippines	Burias Pass	1.78	2.76	4.54	0.61	3
	Philippines	Ragay Gulf	1.86	2.97	4.83	0.62	3
	Philippines	Samar Sea	2.06	1.96	4.02	0.49	2

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Mullidae							
Upeneus sulphureus	Bangladesh	–	2.21	4.26	6.47		124
	Bangladesh	–	2.41	4.71	7.12	0.66	Khan et al. (this vol.)
	Bangladesh	–	2.40	9.10	11.50	0.79	32
	Bangladesh	–	2.28	6.36	8.64	0.74	33
	Bangladesh	–	2.07	9.45	11.52	0.82	34
	Bangladesh	–	1.91	3.86	5.77	0.67	35
	Bangladesh		2.21	4.26	6.47		124
	Indonesia	–	1.80	–	–		13
	Indonesia	–	1.80	4.90	6.70		125
	Indonesia	Central Java	1.95	2.57	4.52	0.57	13
	Indonesia	Central Java	1.80	0.91	2.71	0.91	13
	Indonesia	Central Java	1.72	2.28	4.00	0.57	150
	Indonesia	Central Java	1.64	0.93	2.57	0.36	150
	Indonesia	–	1.80	–	–		13
	Indonesia	–	1.80	4.90	6.70		125
	Indonesia	Central Java	1.80	0.91	2.71	0.34	13
	Malaysia	West Coast	1.45	4.83	6.28	0.77	122
	Malaysia	–	0.96	2.81	3.77		122
	Malaysia	Sarawak	1.52	3.36	4.88	0.69	122
	Malaysia	East Coast	1.40	1.34	2.74	0.49	122
	Malaysia	–	1.45	4.83	6.28		122
	Malaysia	–	0.96	2.81	3.77		122
	Malaysia	–	1.52	3.36	4.88		122
	Malaysia	East Coast	1.40	1.34	2.74	0.49	122
	Malaysia	Sarawak	1.52	3.36	4.88	0.69	122
	Philippines	Samar Sea	2.33	7.37	9.70	0.76	3
	Philippines	Burias Pass	2.19	3.56	5.75	0.62	3
	Philippines	Ragay Gulf	2.43	4.79	7.22	0.66	3
	Philippines	Samar Sea	1.33	1.34	2.67	0.50	4
	Philippines	Lingayen Gulf	2.40	6.32	8.72	0.72	8
	Philippines	San Miguel Bay	1.95	3.89		0.67	9
	Philippines	Manila Bay	2.13	4.37	6.50	0.67	16
	Philippines	Samar Sea	2.27	4.69	6.96	0.67	2
	Philippines	San Miguel Bay	2.23	0.95	3.18	0.30	2
	Philippines	–	1.99	–	–		29

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Mullidae							
Upeneus teaniopterus	Malaysia	Sarawak	1.13	1.44	2.57	0.56	122
Upeneus vittatus	Philippines	Manila Bay	1.51	3.67	5.18	0.71	2
Family Nemipteridae							
Nemipterus balinensoides	Malaysia	–	1.74	3.13	4.87		122
	Malaysia	East Coast	1.17	2.91	4.08	0.71	122
Nemipterus bathybius	Malaysia	–	1.92	2.96	4.88		122
	Malaysia	–	1.57	2.56	4.13		122
	Malaysia	–	1.57	3.68	5.25		122
	Malaysia	East Coast	1.03	2.01	3.04	0.66	122
	Malaysia	Sarawak	0.68	3.52	5.20	0.68	122
	Malaysia	Sabah	0.57	3.68	5.25	0.70	122
	Philippines	Burias Pass	1.27	0.98	2.26	0.44	3
Nemipterus bipunctatus	Malaysia	–	1.62	–	–		12
	Malaysia	–	1.12	–	–		12
Nemipterus bleekeri	Malaysia	Sabah	1.51	1.76	3.27	0.54	
Nemipterus delagoae	Malaysia	–	1.59	0.59	2.18	0.27	122
Nemipterus hexodon	Indonesia	Central Java	1.36	1.17	2.53	0.46	13
	Indonesia	Central Java	1.28	1.20	2.48	0.48	
	Malaysia	–	0.88	–	–		12
	Philippines	–	0.78	–	–		29
	Philippines	San Pedro Bay	2.06	2.68	4.47	0.57	7
	Thailand	Gulf of Thailand	2.56	65.89	68.45		54,55
	Thailand	–	2.44	19.92	17.48		125
Nemipterus japonicus	Bangladesh		1.65	2.40	4.05		124
	Bangladesh		1.88	–	–		12
	Bangladesh		1.90	1.96	3.86	0.51	Khan et al. (this vol.)

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Nemipteridae							
Nemipterus japonicus	Bangladesh	–	1.97	1.08	3.75	0.47	39
	Bangladesh	–	1.32	3.93	5.25	0.83	40
	Bangladesh	–	0.78	0.55	1.33	0.41	41
	Bangladesh	–	1.79	2.58	4.37		35
	Bangladesh	–	1.74	0.51	2.25	0.23	42
	Bangladesh	–	1.65	2.40	4.05		124
	Bangladesh	–	1.88	–	–		12
	India	–	0.52	–		–	17
	India	–	1.42	–		–	45
	India	–	2.52	–		–	121
	India	–	1.10	1.54		2.64	121
	India	–	2.53	0.46		2.99	121
	India	–	1.00	0.37		1.37	121
	India	–	1.32	0.35		1.67	121
	India	–	1.87	3.78		5.65	121
	India	Kakinada	1.10	1.54	2.64		121
	India	Chennai	2.53	0.46	2.99		121
	India	Cochin	1.00	0.37	1.37		121
	India	North West	1.32	0.35	1.67		121
	India	Karnatika	1.87	3.78	5.65		121
	India	–	0.52	–	–		126
	India	–	1.42	–	–		17
	India	–	2.52	–	–		45
	India	–	1.10	1.54	2.64		121
	India	–	2.53	0.46	2.99		121
	India	–	1.00	0.37	1.37		121
	India	–	1.32	0.35	1.67		121
	India	–	1.87	3.78	5.65		121
	India	SW coast of India	1.87	3.78	5.65	0.67	121
	Indonesia	Central Java	1.53	0.64	2.17	0.30	13
	Indonesia	Central Java	1.39	0.68	2.07	0.33	150
	Malaysia	–	1.88	–	–		12
	Malaysia	–	1.21	2.51	3.72		125
	Malaysia	–	1.88	–	–		12
	Malaysia	–	1.21	2.51	3.72		125
	Philippines	Manila Bay	1.41	1.90	3.31	0.57	2
	Philippines	Samar Sea	1.29	0.80	2.09	0.38	3
	Philippines	Carigara Bay	1.52	0.98	2.49	0.39	3
	Philippines	Samar Sea	1.08	0.19	1.27		4
	Philippines	Manila Bay	1.77	1.72	3.49		16
	Philippines	Lingayen Gulf	1.11	2.88	3.99	0.72	8
	Vietnam	–	28.30	0.37			53
Nemipterus marginatus	Malaysia	–	1.67	2.56	4.23		122
	Malaysia	–	1.33	1.88	3.21		122
	Malaysia	East Coast	1.21	2.21	3.42	0.65	122
	Malaysia	Sarawak	1.57	2.56	4.13	0.63	122
Nemipterus mesoprion	Indonesia	Central Java	1.73	1.54	3.25	0.42	13
	Indonesia	Central Java	1.26	1.49	2.75	0.54	150
	Malaysia	–	1.71	4.79	6.50		122
	Malaysia	Sarawak	1.05	2.81	3.86	0.73	122
	Malaysia	Sarawak	1.33	1.88	3.21	0.59	122
	Thailand	–	2.84	33.48	36.32		127
	Thailand	Gulf of Thailand	2.00	32.28	34.28		55
Nemipterus nematophorus	Bangladesh	–	1.63	–	–		12
	Bangladesh	–	1.63	–	–		12
	Malaysia	–	1.63	–	–		12
	Malaysia	–	1.60	5.31	6.91		122
	Malaysia	Sarawak	1.67	3.48	5.15	0.68	122
	Malaysia	East Coast	0.86	0.83	1.69	0.49	122
	Malaysia	–	1.60	5.31	6.91		122
	Malaysia	–	1.67	3.48	5.15		122
	Philippines	Lingayen Gulf	1.12	0.36	1.48	0.24	2
	Philippines	Visayan Sea	1.39	1.99	3.38	0.59	2
	Philippines	Ragay-Samar	1.13	0.41	1.54	0.26	3
	Philippines	Samar Sea	1.05	0.45	1.50	0.30	4
	Philippines	Lingayen Gulf	1.35	5.80	7.15	0.81	8
	Thailand	–	7.22	–	–		128
	Thailand	Gulf of Thailand	1.29	51.87	53.16		Kongprom et al. (this vol.)
	Vietnam	–	31.6	0.24			56

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Nemipteridae							
Nemipterus nemurus	Malaysia	–	1.49	1.56	3.05		122
	Malaysia	–	1.58	1.43	3.01		122
	Malaysia	East Coast	1.45	1.72	3.17	0.54	122
	Malaysia	Sarawak	1.11	0.12	1.23	0.10	122
	Malaysia	Sabah	1.58	1.43	3.01	0.48	122
Nemipterus oveniides	Philippines	Visayan Sea	1.06	0.46	1.52	0.30	2
Nemipterus peroni	Bangladesh	–	0.41	–	–		12
	Bangladesh	–	1.05	–	–		12
	Malaysia	–	1.62	2.48	4.10		122
	Malaysia	–	1.14	0.88	2.02		122
	Malaysia	East Coast	1.25	1.42	2.67	0.47	122
	Malaysia	Sarawak	1.14	0.88	2.02	0.44	122
	Thailand	–	4.20	–	–		129
	Thailand	Gulf of Thailand	2.44	17.48	19.92		129
Nemipterus tambuloides	Malaysia	–	1.45	1.61	3.06		122
	Malaysia	East Coast	1.30	1.18	2.48	0.48	122
	Malaysia	Sarawak	1.45	1.61	3.06	0.53	122
Nemipterus thosaporni	Indonesia	–	1.73	0 - 3	–		59
	Malaysia	–	1.14	–	–		12
	Malaysia	–	1.45	1.98	3.43		122
	Malaysia	East Coast	0.91	1.27	2.18	0.58	122
Nemipterus virgatus	Malaysia	Sarawak	1.51	2.09	3.60	0.58	122
	Vietnam	A	38.00	0.17			23
Nemipterus inermis	Philippines	Ragay Gulf	1.61	2.20	3.81	0.58	3
Nemipterus bimaculatus	Philippines	Ticao Pass	1.91	3.08	5.00	0.62	3
Nemipterus taeniopterus	Malaysia	Sarawak	1.12	1.62	2.74	0.59	122
	Thailand	–	2.13	9.40	11.27		125
	Thailand	Gulf of Thailand	1.84				Kongprom et al. (this vol.)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Ariidae							
Arius maculatus	Indonesia	Tegal	1.30	1.11	2.42	0.46	123
	Indonesia	Tegal	1.36	0.98	2.34	0.42	150
Arius tenuispinis	India	–	0.51	–	–		130
Arius thalassinus	Indonesia	South Kalimantan	1.11	3.59	4.73	0.76	13
	Indonesia	South Kalimantan	1.40	2.32	3.72	0.62	150
Tachysurus dussumieri	India	–	0.20	0.90	1.10		121
Tachysurus tenuispinus	India	–	0.51	0.49	1.00		121
	India	SW coast of India	0.30	1.70	2.00	0.85	121
Family Carangidae							
Alepes djeddaba	Philippines	San Miguel Bay	2.00	6.54	8.54	0.77	9
	India	SW coast of India	0.99	4.16	5.15	0.81	121
Alepes kalla	India	SW coast of India	1.40	1.68	3.08	0.55	121
Atropus atropus	India	–	1.76	4.69	6.45		121
	India	SW coast of India	1.26	5.59	6.85	0.82	121
Atule mate	India	SW coast of India	1.22	2.31	3.53	0.65	121
	Philippines	Manila Bay	1.48	3.82	5.30	0.72	16
	Philippines	Lingayen Gulf	1.63	2.96	4.59	0.64	8
	Thailand	–	2.24	2.50	4.74		Kongprom et al. (this vol.)
Carangoides equula	Malaysia	Sarawak	1.01	1.37	2.38	0.58	122
	Malaysia	Sabah	1.74	1.85	3.59	0.52	122
Carangoides malabaricus	Malaysia	–	1.24	0.82	2.06		122
	Malaysia	East Coast	1.72	2.04	3.76	0.54	122
	Malaysia	Sarawak	1.48	6.63	8.11	0.82	122
Caranx armatus	Philippines	Samar Sea	1.69	1.54	3.24	0.48	3
	Philippines	Ragay Gulf	1.90	2.54	4.44	0.57	3

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Carangidae							
Caranx carangus	India	–	1.18	5.36	6.54		121
	India	–	1.18	2.74	3.92		121
Caranx leptolepis	India	–	2.19	3.91	6.10		121
Caranx malabaricus	Philippines	Samar Sea	1.42	0.81	2.23	0.36	3
	Philippines	Samar Sea	1.79	5.95	7.74	0.77	3
Decapterus macrosoma	Indonesia		1.86	4.33	6.19		3
	Indonesia	Java Sea (Pekalongan)	4.33	4.33	1.86	0.70	123
	Philippines	Samar Sea	2.19	1.10	3.29	0.33	3
	Philippines	Manila Bay	1.41	2.39	3.80	0.63	2
	Philippines	Palawan	1.72	2.29	4.01	0.57	2
	Philippines	Palawan	1.47	3.24	4.71	0.69	2
	Philippines	Palawan	1.85	5.04	6.89	0.73	2
	Philippines	Palawan	1.61	4.85	6.46	0.75	2
	Philippines	Palawan	1.10	3.70	4.80	0.77	2
	Philippines	Palawan	2.12	8.38	10.50	0.80	2
	Philippines	Palawan	2.12	9.45	11.57	0.82	2
	Philippines	Palawan	1.68	2.46	4.14	0.59	2
	Philippines	Palawan	1.62	3.64	5.26	0.69	2
	Philippines	Palawan	1.31	2.07	3.38	0.61	2
	Philippines	Samar Sea	2.19	1.10	3.29	0.33	3
	Philippines	Ragay Gulf	2.12	2.38	4.50	0.53	3
	Philippines	Palawan	1.47	4.32	5.79	0.75	2
Decapterus maruadsi	Indonesia	–	1.85	3.10	4.95		13
	Indonesia	–	1.80	3.46	5.27		13
	Indonesia	–	1.79	1.65	3.44		13
	Indonesia	–	2.18	3.32	5.50		13
	Vietnam	–	24.30	0.32			23
	Philippines	Ragay Gulf	1.23	0.90	2.13	0.42	3
	Philippines	Samar Sea	1.64	1.82	3.46	0.53	3
	Philippines	Burias Pass	1.67	2.66	4.33	0.61	3
	Indonesia	Java Sea (Pekalongan)	1.65	1.65	1.80	0.48	13

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Carangidae							
Decapterus maruadsi	Indonesia	Java Sea (Pekalongan)	3.32	3.32	2.18	0.60	13
	Indonesia	Java Sea (Tegal)	3.10	3.10	1.85	0.63	123
	Indonesia	Java Sea (Tegal)	3.46	3.46	1.80	0.66	13
Decapterus russelli	India	–	1.90	4.75	6.65		1221
	India	SW coast of India	1.26	2.62	3.88	0.68	121
	India	SWcoast of India	1.87	3.78	5.65	0.67	121
	Philippines	Manila Bay	1.59	5.30	6.89	0.77	2
	Philippines	Manila Bay	1.19	0.87	2.06	0.42	2
	Philippines	Palawan	1.44	2.90	4.34	0.67	2
	Philippines	Palawan	1.51	2.18	3.69	0.59	2
	Philippines	Palawan	1.03	1.59	2.62	0.61	2
	Philippines	San Miguel Bay	2.01	3.31	5.32	0.62	2
	Philippines	San Miguel Bay	1.80	1.74	3.54	0.49	9
	Indonesia	–	1.80	3.00	4.80		125
	Indonesia	–	1.80	2.13	3.73		13
	Indonesia	–	2.03	6.18	8.21		13
	Indonesia	–	2.06	4.62	6.68		13
	SriLanka	–	2.05	9.35	11.40	0.82	13
	SriLanka	–	1.79	7.10	8.89	0.80	13
	SriLanka	–	1.85	7.91	9.76	0.81	81
	SriLanka	–	1.66	4.27	5.93	0.72	81
	SriLanka	–	1.25	4.57	5.82	0.79	82
	SriLanka	–	0.89	4.46	5.35	0.83	76
	SriLanka	–	2.08	5.58	7.66	0.73	1
	Indonesia	Java Sea	2.13	2.13	1.80	0.57	123
Elagatis bipinnulats	Philippines	Moro Gulf	0.92	0.27	1.19	0.23	2
Formio niger	India	SW coast of India	0.89	3.31	4.20	0.79	121
	India	SW coast of India	1.03	5.42	6.45	0.84	121
	Indonesia	–	1.40	0.64	2.06	0.31	13
	Indonesia	Central Java	1.23	1.76	2.99	0.59	150
Gnathanodon speciosus	Philippines	Ticao Pass	0.89	2.77	3.66	0.76	3

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Carangidae							
Megalaspis cordyla	India	SW coast of India	0.93	1.92	2.85	0.67	121
	Philippines	Ragay Gulf	1.19	7.52	8.72	0.86	3
	Thailand	–	1.09	14.38	13.29		127
	Thailand	Gulf of Thailand	3.25		2.03		83
Parastromateus argenteus	India	SW coast of India	1.00	4.10	5.10	0.80	121
Selar boops	Philippines	–	2.75	7.35	10.1		72
Selar crumenolphthalmus	Indonesia	–	2.71	3.39	5.56		13
	Indonesia	Java Sea	3.39	3.39	2.17	0.61	123
	Philippines	Manila Bay	1.57	1.34	2.91	0.46	2
	Thailand	–	2.55	6.24	8.79		127
	Thailand	Gulf of Thailand	3.26	13.38			86
Selar mate	Philippines	Ragay Gulf	2.16	2.24	4.40	0.51	3
	Philippines	Samar Sea	1.86	1.98	3.84	0.52	3
	Philippines	Samar Sea	1.46	2.20	3.65	0.60	3
Selaroides leptolepis	Indonesia	–	2.21	3.54	5.75		13
	Indonesia	–	2.18	2.08	4.26		13
	Indonesia	Java Sea (Tegal)	3.54	3.54	2.21	0.62	150
	Philippines	Manila Bay	1.56	1.20	2.76	0.44	2
	Philippines	Manila Bay	2.11	6.53	8.64	0.76	2
	Philippines	Samar Sea	2.10	4.60	6.69	0.69	3
	Philippines	Ragay Gulf	2.19	14.88	17.08	0.87	3
	Philippines	Samar Sea	1.29	1.35	2.64	0.51	4
	Philippines	Manila Bay	1.84	1.42	3.26	0.44	16
	Philippines	Lingayen Gulf	2.69	12.42	15.11	0.82	8
	Philippines	Carigara Bay	2.63	2.60		0.50	11
	Thailand	–	3.25	-1.22	2.03		127
	Thailand	–	2.56	65.89	68.45		127
	Thailand	Gulf of Thailand	2.72	2.01	4.91		87
	Vietnam	–	23.70	0.86			23
	Vietnam	–	23.70	0.86			23
	Vietnam	–	15.80	0.98			88
Family Carangidae							
Uraspis helvolus	Philippines	Ragay Gulf	1.87	2.66	4.52	0.59	3
Family Engraulidae							
Coilia dussumieri	India	–	1.30	1.40	2.70		121
	India	–	2.23	3.20	5.25		121
Stolephorus bataviensis	Philippines	Manila Bay	2.37	4.31	6.68	0.65	16
Stolephorus commersonii	Philippines	San Pedro Bay	2.06	5.37	7.43	0.72	7
	Philippines	Manila Bay	2.22	1.82	4.04	0.45	16
	Philippines	San Miguel Bay	2.66	4.36		0.62	9
Stolephorus heterolobus	Philippines	–	3.10	8.72	11.82		2
	Philippines	Manila Bay	2.29	8.40	10.69	0.79	2
Stolephorus indicus	Vietnam	–	15.40	0.81			23
	Philippines	Manila Bay	2.67	3.14	5.81	0.54	2
	Philippines	Manila Bay	2.23	2.30	4.53	0.51	2
	Philippines	San Pedro Bay	1.50	3.15	4.65	0.68	7
	Philippines	Ragay Gulf	2.55	7.91	10.47	0.76	3
	Philippines	Manila Bay	1.94	2.76	4.70	0.59	16
	Philippines	San Miguel Bay	1.59	3.49		0.69	9
Stolephorus tri	Philippines	Samar Sea	2.55	4.75	7.30	0.65	3
	Philippines	Ragay Gulf	2.55	9.75	12.30	0.79	3
Stolephorus zollingeri	Philippines	Manila Bay	2.55	5.86	8.41	0.70	2
	Philippines	Manila Bay	3.53	8.47	12.00	0.71	2
	Philippines	Manila Bay	2.69	1.53	4.22	0.36	2
Thryssa setirostris	Philippines	Sulu Sea	0.65	1.41	2.06	0.68	2
Family Gerreidae							
Gerres filamentosus	Philippines	Manila Bay	1.95	3.39	5.34	0.63	16

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Gerreidae							
Gerres kappas	Philippines	Samar Sea	1.80	2.65	4.46	0.60	3
Gerres ovena	Philippines	Sorsogon Bay	2.20	3.59	5.78	0.62	10
Pentaprion longimanus	Indonesia	–	2.00	6.20	8.30		13
	Indonesia	Semarang	2.39	1.36	3.76	0.36	13
	Indonesia	Semarang	2.17	1.62	3.79	0.43	150
	Indonesia	–	2.00	6.20	8.30		13
	Indonesia	–	2.39	1.36	3.76		13
	Malaysia	West Coast	1.78	5.35	7.13	0.75	122
	Malaysia	Sarawak	1.20	5.35	6.55	0.82	122
	Malaysia	Sabah	2.23	4.18	6.41	0.65	122
	Malaysia	–	1.95	6.82	8.77		122
	Malaysia	East Coast	1.18	0.81	1.99	0.41	122
	Malaysia	Sarawak	1.20	5.35	6.55	0.82	122
	Malaysia	Sabah	2.23	4.18	6.41	0.65	122
	Philippines	–	2.41	–	–		29
	Philippines	Carigara Bay	2.83	12.37	15.20	0.81	2
	Philippines	Samar Sea	2.81	9.39	12.20	0.77	2
	Philippines	San Pedro Bay	1.86	2.77	4.63	0.60	7
	Philippines	Samar Sea	2.32	7.64	9.97	0.77	3
	Philippines	Carigara Bay	1.67	2.79	4.46	0.63	3
	Philippines	Burias Pass	2.07	6.56	8.63	0.76	3
	Philippines	Samar Sea	2.08	8.00	10.08	0.79	3
	Philippines	Samar Sea	1.69	0.84	2.53	0.33	4
	Philippines	Lingayen Gulf	2.29	3.05	5.34	0.57	8
Family Haemulidae							
Pomadasys argyreus	Philippines	Manila Bay	1.88	2.02	3.90	0.52	2
	Philippines	Manila Bay	1.57	2.93	4.50	0.65	2
	Philippines	Manila Bay	1.94	2.00	3.94	0.51	2
Pomadasys hasta	Bangladesh	–	0.82	0.67	1.49	0.45	99
	Bangladesh	–	0.77	0.78	1.55	0.51	Khan et al. (this vol.)
	Bangladesh	–	0.79	0.82	1.61	0.51	99
	Bangladesh	–	0.97	0.72	1.69	0.43	13
	Indonesia	South Kalimantan	0.97	0.97	1.94		150
	Indonesia	South Kalimantan	1.06	1.31	2.36	0.56	150
Family Priacanthidae							
Priacanthus hamrur	India		0.93	1.57	2.50		121
Priacanthus macracanthus	Indonesia	Central Java	2.28	4.10	6.38	0.64	13
	Indonesia	Central Java	2.13	2.07	4.20	0.49	13
	Indonesia	Central Java	1.95	2.73	4.68	0.58	150
	Indonesia	Central Java	2.08	2.62	4.70	0.56	150
	Malaysia	West Coast	2.06	6.39	8.45	0.76	122
	Malaysia	–	1.62	5.43	7.05		122
	Malaysia	Sarawak	1.34	4.72	6.10	0.78	122
	Malaysia	Sabah	1.51	3.42	4.93	0.69	122
	Malaysia	East Coast	1.17	5.43	6.60	0.82	122
	Malaysia	Sabah	1.51	3.42	4.93	0.69	122
	Philippines	Samar Sea	1.56	2.95	4.52	0.65	3
	Philippines	Carigara Bay	1.96	2.02	3.98	0.51	3
	Philippines	Ragay Gulf	1.74	7.28	9.02	0.81	3
Priacanthus tayenus	Malaysia	West Coast	1.34	2.51	3.85	0.65	122
	Malaysia	–	1.55	0.38	1.95		122
	Malaysia	Sabah	1.22	1.84	3.06	0.60	122
	Malaysia	East Coast	1.55	0.91	2.46	0.37	122
	Malaysia	–	1.34	2.51	3.85		122
	Malaysia	–	1.55	0.38	1.95		122
	Malaysia	–	1.41	0.74	2.15		122
	Malaysia	Sabah	1.22	1.84	3.06	0.60	122
	Philippines	Samar Sea	2.09	6.86	8.95	0.77	2
	Philippines	Samar Sea	1.39	1.47	2.87	0.51	3
	Philippines	Samar Sea	1.34	1.13	2.47	0.46	4
	Philippines	Samar Sea	2.09	6.86	8.95	0.77	2
	Thailand	–	4.67	117.40	122.10		127
	Thailand	–	2.84	33.48	36.32		127
	Thailand	Gulf of Thailand	2.73	22.48	36.32		54,55
	Vietnam	–	28.70	0.36			23
	Vietnam	–	37.80	0.20			56
Family Sciaenidae							
Dendrophysa russselli	Philippines	San Miguel Bay	2.01	3.31	5.32	0.62	2

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Sciaenidae							
Dendrophysa russselli	Philippines	San Miguel Bay	2.01	3.31	5.32	0.62	2
Nibea maculata	India	–	1.26	1.67	2.93		121
	India	–	1.92	2.49	4.41		121
Otolithes ruber	Philippines	–	1.07	0.39	1.46		2
	Philippines	San Miguel Bay	0.98	0.97	1.95	0.50	2
	Philippines	San Miguel Bay	1.04	0.42	1.46	0.27	2
	Philippines	San Miguel Bay	1.35	1.81	3.16	0.57	9
Pennahia macrophthalmus	Malaysia		1.15	6.13	7.28		125
	Malaysia		2.18	5.58	7.76	0.72	122
	Philippines	Manila Bay	2.30	3.25	5.55	0.58	2
	Philippines	San Miguel Bay	1.43	0.85	2.28	0.37	2
Protonibea diacanthus	India		0.80	–	–		132
Family Synodontidae							
Harpodon nehereus	India	–	1.46	1.22	2.68		121
	India	–	1.57	1.21	2.78		121
	India	–	1.05	2.00	5.30		121
Saurida elongata	Thailand	–	2.70	2.01	4.91		127
	Thailand	Gulf of Thailand	2.48	6.54	9.02		118
Saurida longimanus	Indonesia	Central Java	1.92	1.29	3.21	1.29	150
	Indonesia	Central Java	1.96	1.76	3.29	0.47	150
	Malaysia	West Coast	1.84	3.30	5.14	0.64	122
	Malaysia	–	1.44	3.93	5.37		122
	Malaysia	East Coast	0.87	1.06	1.93	0.55	122
Saurida macropectoralis	Indonesia	Central Java	1.50	2.22	3.73	0.60	150
	Indonesia	Central Java	1.40	2.42	3.82	0.63	150
	Indonesia	–	1.50	2.22	3.73		13
Saurida tumbil	Bangladesh	–	1.26	1.06	2.32		124

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Synodontidae							
Saurida tumbil	Bangladesh	–	1.66	0.88	2.54	0.35	119
	Bangladesh	–	1.57	1.42	2.99	0.47	35
	Bangladesh	–	1.26	1.06	2.32		124
	Malaysia	West Coast	1.93	1.47	3.40	0.43	122
	Malaysia	–	1.21	1.45	2.66		122
	Malaysia	–	0.87	1.88	2.75		122
	Malaysia	–	1.69	1.34	3.03		122
	Malaysia	West Coast	1.93	1.47	3.40	0.43	122
	Malaysia	–	1.21	1.45	2.66		122
	Malaysia	Sarawak	0.87	1.88	2.75	0.68	122
	Malaysia	Sabah	1.69	1.34	3.03	0.44	122
	Malaysia	East Coast	1.54	1.08	2.62	0.79	122
	Philippines	–	0.69	–	–		29
	Philippines	Manila Bay	1.71	3.12	4.83	0.65	2
	Philippines	Visayan Sea	1.30	0.92	2.22	0.42	2
	Philippines	San Pedro Bay	1.52	1.27	2.79	0.46	7
	Philippines	Ragay Gulf	1.17	4.14	5.31	0.78	3
	Philippines	Samar Sea	1.18	0.50	1.68	0.30	3
	Philippines	–	1.08	2.25	3.33		133
	Vietnam	–	79.50	0.10			118
	Vietnam	–	78.30	0.08			118
	Vietnam		45.20	0.36			23
Saurida undosquamis	Indonesia	Central Java	1.29	1.29	3.21	1.29	150
	Indonesia	Central Java	1.69	0.61	2.30	0.26	13
	Indonesia	Central Java	1.60	0.73	2.33	0.31	150
	Malaysia	–	1.98	3.70	5.68		122
	Malaysia	–	0.87	2.13	3.00		122
	Malaysia	East Coast	1.67	3.38	5.05	0.67	122
	Malaysia	Sarawak	0.87	2.13	3.00	0.71	122
	Malaysia	Sabah	1.89	2.06	3.95	0.52	122
	Philippines	Visayan Sea	1.54	2.53	4.07	0.62	2
	Philippines	–	1.19	1.03	2.22		122
	Philippines	–	1.29	5.42	6.72		122
	Philippines	–	0.77	0.34	1.11		122
	Thailand	–	1.96	–	–		131
	Thailand	Gulf of Thailand	2.45	7.95	10.40		118

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Synodontidae							
Saurida undosquamis	Vietnam	–	46.80	0.42			23
	Vietnam	–	51.80	0.16			56
Family Scatophagidae							
Sacatophagus argus	Philippines	Manila Bay	2.12	2.00	4.12	0.49	2
Family Theraponidae							
Pelates quadrilineatus	Philippines	Manila Bay	1.19	2.64	3.83		16
Therapon jarbua	Philippines	Manila Bay	1.89	3.00	4.89	0.61	16
Therapon theraps	Philippines	Manila Bay	1.25	2.24	3.49	0.64	2
	Philippines	Sorsogon Bay	3.44	3.18		0.48	10
Family Albulidae							
Synodus hoshinonis	Malaysia	–	1.64	2.07	3.71		122
	Malaysia	East Coast	1.33	2.14	3.47	0.62	122
Family Ambassidae							
Ambassis gymnocephalus	Philippines	Manila Bay	2.27	2.97	5.24	0.57	2
Family Apogonidae							
Apogon quadrifasciatus	Philippines	Sorsogon Bay	2.02	2.32	4.34	0.53	10
Family Ariommatidae							
Ariomma indica	India	–	1.31	1.03	2.34		121
	Philippines	Samar Sea	2.06	4.06	6.12	0.66	
	Philippines	Ragay Gulf	2.08	3.29	5.36	0.61	

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Belonidae							
Ablennes hians	India	–	0.81	2.61	3.40		121
Family Bothidae							
Pseudorhumbus arsius	Philippines	Sorsogon Bay	1.29	4.04	5.33	0.76	10
Pseudorhumbus oligadon	Philippines	Sorsogon Bay	1.31	3.49	4.80	0.73	10
Family Carcharinidae							
Carcharinus sorah	India	–	0.63	2.37	3.00		121
	India	–	0.54	4.36	4.90		121
Rhizopriono-don acutus	*India*	–	1.12	3.36	4.75		121
	India	–	1.01	1.70	2.71		121
Scoliodon laticaudus	*India*	–	0.72	0.73	1.45		121
	India	–	1.76	1.35	5.11		121
	India	–	1.95	2.20	4.15		
	India	SW coast of India	0.72	0.73	1.45	0.50	
Family Citharidae							
Brachypleura novaezeelandiae	*Malaysia*	–	1.63	4.17	5.80		122
	Malaysia	East Coast	1.61	0.82	2.43	0.34	122
Family Clupeidae							
Amblygaster sirm	Indonesia	Java Sea	3.74	3.74	2.06	0.65	123
Dussumiera acuta	Philippines	Lingayen Gulf	2.44	4.28	6.72	0.64	8
	Philippines	Ragay Gulf	1.97	3.02	4.98	0.61	3
Ilisha filigera	Bangladesh	–	1.21	0.71	1.92	0.37	35
	Bangladesh	–	1.63	1.25	2.86	0.44	42
	Bangladesh	–	1.42	1.95	3.37	0.58	35

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Clupeidae							
Nematolosa nasus	Philippines	Manila Bay	2.09	1.38	3.47	0.40	16
Sardinella fimbriata	Philippines	Manila Bay	1.85	1.75	3.60	0.49	16
	Philippines	Manila Bay	1.63	1.75	3.38	0.52	2
	Philippines	Palawan	2.12	4.44	6.56	6.56	2
Sardinella gibbosa	India	SW coast of India	1.90	2.00	3.90	0.51	121
	India	SW coast of India	2.10	4.70	6.80	0.69	121
	Indonesia	–	2.29	3.95	6.24		13
Sardinella longiceps	India	–	1.12	–	–		149
	India	–	0.67	–	–		91
	India	SW coast of India	0.75	1.40	2.15	0.65	121
	Indonesia	–	2.25	4.32	6.57		13
	Indonesia	–	1.95	2.44	4.39		13
	Indonesia	–	1.72	0.52	2.24		13
	Philippines	Ragay Gulf	2.10	3.42	5.52	0.62	3
	Philippines	Manila Bay	2.10	5.27	7.37	0.72	2
Sardinella malanura	Philippines	Palawan	2.05	5.21	7.26	0.72	2
	Philippines	Honda Bay	1.53	1.83	3.36	0.54	2
Sardinella sirm	Indonesia	–	2.06	3.74	5.80		13
	Philippines	Palawan	1.66	3.70	5.36	0.69	2
Family Cynoglossidae							
Cynoglossus arel	India	–	0.49	–	–		151
Cynoglossus puncticeps	Philippines	Manila Bay	1.43	1.86	3.29	0.57	2
	Philippines	Sorsogon Bay	2.38	5.12	7.50	0.68	10
Family Drepanidae							
Drepane punctata	Indonesia	South Kalimantan	1.26	1.42	2.68	0.53	13
	Indonesia	South Kalimantan	1.15	1.55	2.70	0.57	150
Family Gobiidae							
Callagobius sclateri	Philippines	Sorsogon Bay	1.80	2.80	4.60	0.61	10
Ctenogobius aurocingalus	Philippines	Sorsogon Bay	1.52	1.54	3.06	0.50	10
Fusigabius nephytus	Philippines	Sorsogon Bay	1.48	5.34	6.91	0.79	10
Family Hemiramphidae							
Hemiramphus georgii	Philippines	Manila Bay	1.23	1.09	2.32	1.47	2
Family Labridae							
Xiphocheilus typus	Malaysia	East Coast	1.75	2.32	4.98	0.65	122
Family Lethrinidae							
Lethrinus nebulosus	SriLanka	–	0.27	0.53	0.80	0.66	152
	SriLanka	–	0.29	0.57	0.86	0.66	134
	SriLanka	–	0.49	0.51	1.00	0.51	134
	SriLanka	–	0.31	0.42	0.73	0.58	152
	SriLanka	–	0.91	5.46	6.55	0.86	135
Lethrinus olivaceus	SriLanka	–	0.55	0.14	0.69	0.20	152
	SriLanka	–	0.20	0.14	0.34	0.41	135
	SriLanka	–	0.48	0.23	0.71	0.32	152
Family Lutjanidae							
Lutjanus lineolatus	Malaysia	–	1.29	2.06	3.35		122
	Malaysia	–	0.97	0.72	1.69		122
	Malaysia	East Coast	1.24	2.55	3.79	0.67	
	Malaysia	Sarawak	1.82	2.49	4.31	0.58	
	Philippines	Ticao Pass	1.51	3.38	5.34	0.72	3
	Thailand	–	1.29	51.87	53.16		127
	Thailand	Gulf of Thailand	2.55	6.24	8.79		127

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Lutjanidae							
Lutjanus lutjanus	Malaysia	–	1.68	3.52	5.20		122
	Malaysia	Sarawak	0.97	0.72	1.69	0.43	122
Lutjanus vitta	Philippines	Ticao Pass	1.28	1.26	2.53	0.50	3
Family Meniida							
Mene maculata	Philippines	Manila Bay	2.20	1.65	3.85	0.43	2
Family Monacanthidae							
Thamnaconus hypargyreus	Malaysia	Sarawak	1.30	3.10	4.40	0.70	122
Family Mugilidae							
Liza subviridis	Philippines	Manila Bay	1.25	1.94	3.19	0.61	2
	Sri Lanka	–	0.70				136
Liza macrolepis	Sri Lanka	–	0.56				136
Liza tade	Sri Lanka	–	0.51				136
Mugil cephalus	Sri Lanka	–	0.51				136
Mugil sp.	Philippines	Manila Bay	2.21	4.28	6.49		16
Valamugil buchanani	Philippines	San Miguel Bay	1.80	1.55	3.35	0.46	9
Valamugil cunnesius	Sri Lanka	–	0.65				136
Valamugil seheli	Sri Lanka	–	1.04				136
	Philippines	Manila Bay	1.96	4.87	6.83	0.71	16

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Platycephalidae							
Inegocia japonica	Philippines	Sorsogon Bay	2.40	2.50	4.90	0.51	10
Onigocia macrolepis	Philippines	Sorsogon Bay	1.40	7.59	8.99	0.84	10
Family Scombridae							
Auxis thazard	Indonesia	–	1.25	1.34	2.59		13
	Indonesia	–	1.55	2.86	4.03		13
	Philippines	Bohol Sea	1.28	1.56	2.84	0.55	2
	Philippines	Moro Gulf	1.17	3.35	4.52	0.75	2
	Vietnam		49.00	0.42			137
Katsuwunus pelamis	India	–	0.75	1.81	2.56		121
	Indonesia	–	1.32	2.16	3.49		131
	Indonesia	–	1.46	2.52	3.95		13
	Philippines	Bohol Sea	1.58	3.97	5.55	0.72	2
	Philippines	Sulu Sea	1.14	5.43	6.57	0.83	2
	Vietnam		65.00	0.70			23
Rastrelliger brachysoma	Philippines	Manila Bay	1.84	2.43	4.27	0.57	2
	Philippines	Samar Sea	2.32	6.81	9.14	0.75	3
	Philippines	Samar Sea	2.19	3.30	5.50	0.60	3
	Philippines	Ragay Gulf	2.17	3.94	6.10	0.65	3
	Philippines	Manila Bay	1.90	1.93	3.83	0.50	16
	Philippines	Lingayen Gulf	1.88	3.35	5.23	0.64	8
	Indonesia	–	2.58	–	–		13
	Indonesia	Java Sea	2.83	4.57	7.40	0.62	13
	Indonesia	Java Sea					
	Indonesia	–	4.56	–	–		138
	Thailand	–	2.19	8.47	10.66		127
	Thailand	–	2.45	7.95	10.40		127
	Thailand	–	2.48	6.54	9.02		127
	Thailand	–	1.84	–	–		127
	Thailand	Gulf of Thailand	4.67	117.40	122.07		127
Rastrelliger kanagurta	India		7.80	–	–		91
	India		1.24	2.44	3.68		121

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Scombridae							
Rastrelliger kanagurta	India	–	1.50	3.10	4.35		121
	India	–	1.70	2.92	4.62		121
	India	SW coast of India	1.24	2.44	3.68	0.66	121
	India	SW coast of India	1.50	1.00 - 5.20	2.50 - 6.20	0.40 - 8.40	121
	India	SW coast of India	1.70	2.92	4.62	0.63	121
	Indonesia	–	4.44	–	–		138
	Indonesia	–	1.58	2.26	3.39		72
	Indonesia	Java Sea	2.58	2.50	5.08	0.49	13
	Philippines	Palawan	2.43	5.84	8.27	0.71	2
	Philippines	Samar Sea	2.13	3.19	5.32	0.60	3
	Philippines	Manila Bay	1.90	1.93		0.50	139
	Philippines	Manila Bay	1.73	3.23	4.96	0.65	16
	SriLanka	–	0.72	1.09	1.81	0.60	140
	SriLanka	–	1.26	0.91	2.17	0.42	91
	SriLanka	–	1.63	0.28	1.91	0.15	152
	SriLanka	–	5.40	0.35	5.75	0.06	91
	SriLanka	–	1.60	0.23	1.83	0.13	74
	SriLanka	–	2.56	0.86	3.42	0.25	13
	SriLanka	–	3.70	0.00	3.22	0.00	74
	SriLanka	–	2.04	1.52	3.56	0.43	81
	SriLanka	–	1.52	0.46	1.98	0.23	141
	SriLanka	–	1.44	2.76	4.20	0.66	2
	SriLanka	–	2.43	1.72	4.15	0.41	142
	Thailand	–	0.27	0.25	1.52		125
	Thailand	Gulf of Thailand	2.19	8.47	10.66		Kongprom et al. (this vol.)
	Vietnam	–	34.50	1.34			23
Scomb-eromorus commerson	India	SW coast of India	1.00	3.08	4.08	0.75	121
	Vietnam	A	80.60	0.22			23
	Thailand	–	1.41	4.19	5.60		127
	Thailand	–	3.26	13.38	16.64		127
	Thailand	Gulf of Thailand		1.41	4.19	5.60	143
	Philippines	Visayan Sea	1.23	0.26	1.49	0.17	2
	Philippines	San Miguel Bay	2.23	1.45		0.39	9
Family Scombridae							
Scomb-eromorus guttatus	Vietnam	A	56.8	0.60			23
Thunnus albacare	India	–	0.49	3.00	3.49		121
	Bangladesh	–	0.80	–	–		144
Family Siganidae							
Siganus oramin	Malaysia	West Coast	1.42	1.18	2.60	0.45	122
Family Sillaginidae							
Sillago sihama	Philippines	Manila Bay	1.51	1.19	2.70	0.44	2
	Philippines	Manila Bay	1.57	3.11	4.68	0.66	16
	Philippines	San Miguel Bay	2.55	3.61		0.60	9
	Philippines	Sorsogon Bay	2.43	3.52		0.59	10
Family Sphyraenidae							
Sphyraena jello	Malaysia	–	1.88	2.72	4.62		122
	Malaysia	East Coast	2.19	2.38	4.55	0.52	
Sphyraena obtusata	Malaysia	East Coast	1.52	6.00	7.52	0.80	122
	Malaysia	–	1.42	1.51	2.93		
Family Stromatidae							
Pampus argenteus	Indonesia	Central Java	1.72	0.88	2.60		13
	Indonesia	Central Java	1.73	0.93	2.66		150
	Bangladesh	–	1.35	1.38	2.73	0.51	35
	Bangladesh	–	2.35	2.90	5.25	0.55	34
	Bangladesh	–	1.18	0.79	1.97	0.40	145
Pampus chinensis	Bangladesh		1.32	2.17	3.49	0.62	35
Pampus argenteus	Vietnam	–	60.00	0.26			23

Table 4. Compilation of mortality parameters of trawl-caught fishes in South and Southeast Asia. (continued)

Family/ Species	Country	Fishing ground	M	F	Z	E	Ref.
Family Stromatidae							
Argyrops spinifer	Vietnam	–	27.80	0.38			23
Family Trichiuridae							
Lepturacanthus savala	Bangladesh	–	0.93	1.18	2.11		124
	Bangladesh	–	0.98	1.05	2.03	0.52	39
	Bangladesh	–	1.33	0.73	2.06	0.35	Khan et al. (this vol.)
	Bangladesh	–	1.04	1.54	2.58	0.60	35
Trichiurus sp.	Philippines	Sorsogon Bay	2.45	1.26		0.34	10
Trichiurus haumela	Philippines	Manila Bay	1.06	2.46	3.52	0.70	16
	Philippines	Lingayen Gulf	0.75	1.87	2.62	0.71	8
	Philippines	San Miguel Bay	1.39	2.76		0.66	9
Trichiurus lepturus	Malaysia	–	1.30	1.64	2.94	-	122
	Malaysia	–	1.12	0.76	1.88	-	122
	India	–	0.46	2.70	3.16	-	121
	India	–	1.05	0.91	1.96	-	121
	Malaysia	West Coast	1.30	1.64	2.94	0.56	122
	Malaysia	East Coast	1.08	1.63	2.71	0.60	122
	Philippines	Manila Bay	0.86	2.60	3.46	0.75	2
	Philippines	Manila Bay	0.80	1.49	2.29	0.64	2
	Philippines	Manila Bay	1.08	1.89	2.97	0.64	2
	Thailand	Gulf of Thailand	1.46	9.03	10.49		146
Trichiurus leptolepis	Thailand	–	1.46	9.03	10.49	-	127

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