ICLARM'S STRATEGY FOR INTERNATIONAL RESEARCH ON LIVING AQUATIC RESOURCES MANAGEMENT

March 1992

ICLARM
International Center for Living Aquatic Resources Management

ICLARM's Strategy For International Research On Living Aquatic Resources Management

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PREFACE

A strategic plan for international fisheries research is not a unique construction. It is a structure that could have been designed in as many ways as there are designers - were they asked to undertake the task. We believe that the structure presented herein is sound because we began with first principles, took note of available "materials", the international research issues and the existing organizations in this field including their strengths and weaknesses, and selected carefully the components we decided to use based on criteria familiar to the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR).

During the construction of the plan, we asked a good number of experts from advanced institutions, and national, regional and international agencies for their advice to ensure that first the foundations and then the framework were sound; and that the design was appropriate.

The range of issues that could be covered by an international fisheries research center is enormous. The degree to which they can be addressed depends on funding. The magnitude of our endeavor is therefore the prerogative of the donor community. We can point out, however, that since the value of fisheries as a commodity is a little over 4% of the total value of the major commodity groups (the others being crops, forestry and livestock), a proportionate annual expenditure on fisheries research - based on TAC's projection of CGIAR annual expenditure by 1995 of $307 million - ought to be around $13 million. Our proposed budget for 1996 is close to $12 million.

The draft plan was constructed hurriedly, from December 1990 to May 1991, in order to meet the proposed schedule for ICLARM's entry into the CGIAR system. The title of that draft "A Strategic Plan for International Fisheries Research" reflected its broad coverage - too broad for one center as TAC pointed out when it reviewed the document in June 1991. TAC requested us to narrow the focus to include only what ICLARM could accomplish.

After further consultation, especially with national agencies (or NARS), an addendum was provided to TAC at its next meeting, October 1991. The addendum reduced the number of proposed activities and gave examples of how ICLARM would operate within the framework of the draft plan. However, TAC requested more details and we therefore revised the whole document in time for an External Program and Management Review, January 1992. The Review Panel made a number of recommendations for improvement which were included in the present text for the TAC at its March 1992 meeting, at which TAC recommended inclusion of ICLARM in the CGIAR system.

It would have been impossible to have completed the task without access to the draft reports of the Study of International Fisheries Research Needs for Developing Countries (SIFR), which was sponsored by a number of fisheries donors. We would like to express our thanks that these documents were made available. Equally so, the TAC's 1990 *A Possible Expansion of the CGIAR* was an indispensable guide in framing the research needs in the most appropriate manner. We would also like to thank most sincerely the many fisheries experts who gave their time to attend our planning workshops or who reviewed various drafts of the plan.

Finally, we acknowledge with gratitude the generous funding support of the United Nations Development Programme (UNDP) and the International Development

Research Centre (IDRC) of Canada. Without their timely help, most of the activities and consultations that gave the plan its substance would not have been possible.

Nevertheless, the responsibility for the contents of this plan rests with ICLARM and the Center's staff who took part in its drafting.

Peter Larkin
Chairperson
ICLARM Board of Trustees

Kenneth Tod MacKay
Director General

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EXECUTIVE SUMMARY

Aquatic resources are important for livelihood and consumption. Fish, including finfish, crustaceans, molluscs and seaweeds, are the fifth most important agricultural commodity. Developing countries catch and produce 52 million tonnes annually, over half of the world production. At least 50 million persons are involved in small-scale fisheries.

There have been substantial increases in fisheries catches (35%) and aquaculture (100%) in the past decade. This, however, is misleading as it reflects exploitation of new stocks, heavy fishing pressure on previously fished stocks and a large increase in aquaculture in one country, China. A close examination reveals that most developing-country fisheries have levelled off or are declining. Their sustainability is threatened by overfishing, destructive fishing practices and land-based pollution. In aquaculture, major increases have occurred nowhere other than in China. In spite of these issues, there has been only limited international research effort directed to aquatic resources.

That there is a need for concerted research effort directed to aquatic resources for the benefit of low-income producers and consumers in developing countries was recognized as early as 1971 by the CGIAR but it was not until 1990 that they endorsed TAC's recommendation to include fisheries research and invited ICLARM to develop a strategic plan as part of the process of ICLARM joining the CGIAR.

The planning process involved all ICLARM professional staff, the ICLARM Board, and some 150 managers and scientists from other institutions.

ICLARM planning was facilitated by recent studies by TAC, IDRC and the Study of International Fisheries Research Needs for Developing Countries (SIFR). The SIFR reports were particularly useful as they included the findings of several task forces and missions to various regions of the developing world.

A resource system approach was developed to assist in setting priorities for research. Seven resource systems which reflect the aquatic habitats and the people who rely on the resource have been used. They are similar in concept to agroecological zones used in agriculture. The freshwater systems are ponds (including rice fields); reservoirs and lakes; and streams, rivers and floodplains; and in the marine systems, estuaries and lagoons; coral reefs; soft-bottom shelves; and upwelling area shelves.

A breakdown of data on catch and aquaculture production, numbers of fishers and potential for increase was attempted by resource system. This procedure was useful but there were difficulties with data on small-scale fisheries and in disaggregating the data. This could be an area of research between FAO and ICLARM in order to improve fisheries statistics especially for the small-scale fisheries sector.

Future gains in capture fisheries are possible, especially in coral reefs, upwellings and reservoirs. In coastal fisheries, a major concern will be sustaining them at present levels in the face of pollution and competing coastal resource users. Gains are also possible in aquaculture and enhanced fisheries in ponds, lakes and reservoirs.

Indications are that even without intersectoral conflict, the rate of increase in fish supply will not keep up with projected demand. The supply gap will be further challenged by those factors outside the sector: human population growth, domestic and industrial pollution, competing demands for the same resources, erosion and siltation from unsustainable agricultural and forestry practices, and the overriding but unknown consequence of global climate change. While difficult to predict, the impact of these changes will be to reduce potential growth in fisheries resulting in an increased supply gap.

To decrease the supply gap will require concentrated strategic research. The research must help improve the management and sustainability of current fisheries and establish the biological and social basis for increased aquaculture and enhanced fisheries potential.

The research must focus on the interaction between populations of fish and humans. In addition, the guiding principles must be concern for gender, equity, sustainability, participation of users and a systems approach.

Thus, the priority for research in each resource system was derived by taking into account not only potential for gain but also "modifiers" as used recently by TAC - threats to sustainability and equity. Priorities were assessed on a regional basis.

The seven emerging priority issues for ICLARM's international research using these criteria are:

- Sustainability of coastal fisheries systems
- Improved management of coral reef fisheries
- Improved fish productivity through genetics and husbandry
- Removal of socioeconomic and environmental constraints to aquaculture growth
- Development of farming systems
- Assessing and developing the potential for enhanced fisheries
- Strengthening of national research systems

Asia is to receive the highest priority for research and related activities, followed by SubSaharan Africa, Latin America/Caribbean and West Asia/North Africa.

Using the activity types of TAC, the types of research activities and their proportions to address the priority research issues above were determined to be:

Resource conservation and management	35%
Fish productivity	25%
Social sciences	20%
Institution building	20%

An assessment of the priority for each research type in the various resource systems concluded that the research will focus in ponds, estuaries and lagoons, and coral reefs.

The focus on resource systems provided the basis for research programs. There will thus be three research programs:

- Inland Aquatic Systems (focusing on ponds)
- Coastal Resource Systems (focusing on estuaries, lagoons)
- Coral Reef Resources (focusing on coral reefs)

This program structure allows a high degree of integration, with common themes and methodology underlying clear discrete thrusts to respond to the seven international research issues noted above.

A fourth program: National Research Support, will provide a strong institutional building role for ICLARM. Closely linked to the research programs, it will often rely on their output for NARS strengthening activities.

The Inland Aquatic Systems Program will direct its research activities towards the adoption of sustainable inland aquaculture by resource-poor small-scale producers in three thrusts: Improved fish productivity through genetic gain and better husbandry; Development of integrated agriculture-aquaculture farming systems; and Removal of socioeconomic and environmental constraints to aquaculture development.

The Coastal Resources Systems Program has a clear focus on the sustainability of coastal aquatic resource use. The Program aims to improve the biological, socioeconomic and institutional management mechanisms for sustainable use of coastal resource systems, involving both intra- and intersectoral issues. The Program will accomplish this by: understanding the dynamics of the resources; developing management strategies for the resources; and seeking to integrate management strategies into generalizable management options and policy recommendations compatible with sustainable coastal resource use.

The Coral Reef Resources Program will focus on the sustainable utilization of the reef resources for the benefit of the adjacent coastal communities. This will be accomplished by addressing thrusts: in developing aquaculture and enhanced fisheries systems for coastal communities; understanding the interaction between people and the reef resources; and developing sustainable fisheries management systems suitable for coastal communities.

The National Research Support Program is designed to strengthen NARS through: information (publications, workshops, conferences); training (focusing on researchers); and assisting in priority setting of NARS research policy and research management.

The impact from these research and related activities on fisheries will be: improved fisheries management leading to sustainable increases in fisheries catches; increased aquacultural and enhanced fisheries production; and stronger national programs able to continue the research efforts for the benefit of low-income producers and consumers in developing countries.

ICLARM conforms to many of the requirements of an international center. The current research programs cover some of the proposed research activities. However, in order to achieve the increased mandate for international fisheries research there is a need for a much expanded core staff and resources for a headquarters building, facilities and equipment, and for outreach offices in Africa. The annual unrestricted core budget requirements would need to increase from the current $1.7 (total $6.0) million to up to $12 million by 1996 plus an estimated $15 million for buildings, facilities and equipment. Even at this level the new institute would be one of the smaller CGIAR centers. However, this level of funding is not currently available within the CGIAR. In order to meet the research challenges there is a need for an increased commitment from the donor community for international fisheries research.

ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
AIT	Asian Institute of Technology
ASI	Advanced Scientific Institution
CEC	Commission of the European Communities
CGIAR	Consultative Group on International Agricultural Research
CRSP	Collaborative Research Support Program
FAO	Food and Agriculture Organization of the United Nations
GESAMP	Group of Experts on the Scientific Aspects of Marine Pollution
GTZ	German Agency for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit)
IARC	International Agricultural Research Center
IBPGR	International Board for Plant Genetic Resources
ICAR	Indian Council for Agricultural Research
ICLARM	International Center for Living Aquatic Resources Management
ICRAF	International Council for Research in Agroforestry
IDRC	International Development Research Centre of Canada
IFPRI	International Food Policy Research Institute
IPFC	Indo-Pacific Fisheries Commission (FAO)
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
ISSCAAP	International Standard Statistical Classification for Aquatic Animals and Plants
IUCN	International Union for the Conservation of Nature
NACA	Network of Aquaculture Centres in Asia
NARS	National Agricultural (or Aquatic) Research Systems
NGO	Nongovernmental Organization
OECD	Organization for Economic Cooperation and Development
PCAMRD	Philippine Council for Aquatic and Marine Research and Development
SADCC	Southern African Development Coordination Conference
SEAFDEC	Southeast Asian Fisheries Development Center
SIFR	Study on International Fisheries Research needs
TAC	Technical Advisory Committee (of the CGIAR)
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

CHAPTER 1
Background

Living aquatic resources are important for livelihood, nutrition and the conservation of the biosphere. Fish, including finfish, crustaceans, molluscs and seaweeds, are the fifth most important agricultural commodity. Developing countries catch and produce 52 million tonnes annually, over half of the world production. At least 50 million persons are involved in small-scale fisheries. In spite of this, there has been only limited international research on aquatic resources.

The main recent documentation of the problems and possible international action is by the recent reports of the International Study on Fisheries Research Needs in Developing Countries (SIFR), the TAC in its document "A Possible Expansion of the CGIAR" (1990), and the draft "Strategic Plan for International Fisheries Research" (May 1991), hereafter referred to as SP-IFR, by ICLARM.

The following account is an interpretive summary of these documents, after which the implications for the future ICLARM are discussed.

Aquatic Resource Use

Fisheries catches have grown rapidly since the 1950s as fishing gear improved and fleets and fishing grounds expanded. Production details are given in Table 1.1. The numbers of fishers have increased faster than the fish catch. There was a 35% increase in fisheries harvest in the last decade mainly due to exploitation of newly discovered stocks and heavy fishing pressure on previously fished stocks. New resources that can be harvested economically are fast running out while the numbers of fishers, particularly in developing countries, are increasing and will continue to increase, probably at a faster rate than populations in general, given that fishing is frequently a livelihood of last resort. Fisheries in developing countries, particularly in Asia, are already generally overexploited - catches have levelled off or are declining. This overexploitation (see Illustration 1) is a classic case where excessive effort results in a decline in catches and decreased economic returns. It is apparent that in contrast to agriculture and aquaculture, increase in inputs (fishing effort) will not result in further increase in output, and may even be the cause of a decrease in output. This problem is one of overfishing (see Illustration 2) and forms the basis for the key concepts of fisheries resource management - Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY).

In addition, the process of overexploitation often results in degradation of habitats. Nonsustainable fishing practices only serve to accelerate the decline in fish harvests and the quality of the livelihoods of fishing communities. It was this problem that led the former Director General of ICLARM, Ian Smith to suggest in his "Research Framework for Traditional Fisheries" (ICLARM Studies and Reviews 2, 40 p. 1979) that priority for development and research should be given to those programs that reduce fishing intensity.

Table 1.1. Annual fish production and human population by regions of developing countries.

	Asia/ Pacific	Latin America/ Caribbean	SubSaharan Africa	West Asia/ North Africa	Total
Total production[1] tonnes/year (x 10^3)	29,264	16,206	4,163	1,947	51,580
Aquaculture[2] tonnes/year (x 10^3)	6,722	119	11	80	6,932
Capture fisheries[3] tonnes/year (x 10^3)	22,542	16,087	4,152	1,867	44,648
Population (1985) (x 10^6)	2,575	404	421	245	3,645
Estimated population (2025)[4] (x 10^6)	4,379	761	1,296	609	7,045
Proportion of global population (2025) (%)	52	9	15	7	83

[1]FAO statistics for 1988.
[2]Excludes 1,684 thousand tonnes of seaweeds.
[3]Total minus aquaculture.
[4]From TAC (1990). A possible expansion of the CGIAR.

Definitions

FAO recently published the following definitions:

AQUACULTURE is the farming of aquatic organisms, including fish, molluscs, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated.

For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to **AQUACULTURE**, while aquatic organisms which are exploited by the public as a common property resource, with or without appropriate licenses, are the harvest of **FISHERIES**.

Beyond the FAO definition, Aquaculture can be broadly classified as *extensive*, that is having no feed or fertilizer inputs; *semi-intensive*, having some fertilizer and/or feed inputs; and *intensive*, largely reliant on feed inputs.

Between capture fisheries and aquaculture are various types of *ENHANCED FISHERIES*, in which captive breeding/mass propagation of aquatic organisms or provision of improved and managed environments such as brush parks, to "enhance" their prospects of survival and growth before capture takes place.

FAO now includes enhanced fisheries production data with those of aquaculture production.

ILLUSTRATION 1

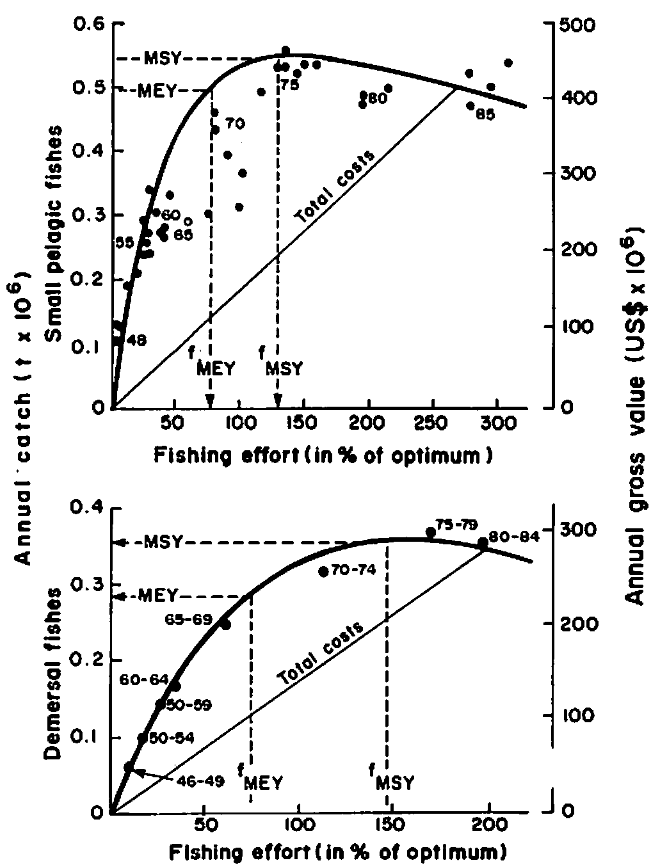
The Case of the Philippine Fisheries Overfishing Problem

The fisheries of the Philippines provide excellent examples of tropical overfishing problems. The multispecies stocks are under threat, not keeping up with an increasing demand, and in urgent need of strong management measures.

These fisheries developed rapidly in the 1950s and 1960s, from a marginal activity to a major sector, producing a total catch of about 2.2 million tonnes of fish per year. Of these, about half are produced by small-scale fishers, the rest by large operators, generally in direct competition with the small-scale fishers, a situation leading to latent and often open conflicts.

Overall, fishing effort, which has increased tremendously in the 1980s, is presently 2-3 times that needed to extract the sustainable yield for both the pelagic and demersal fisheries. Catches have *decreased* in the last decade and will continue to do so if effort is not decreased and the resource protected.

Attempts at effort reduction or to change fishing patterns will be successful if the interactions between fish stocks and fishers are well understood. Much social science research is therefore required as part of the multidisciplinary research efforts needed to produce appropriate management guidelines.



Surplus production models of the Philippine pelagic and demersal fisheries; both models provide rough estimates of total fishing costs and economic rent through the crude assumption of equilibrium in the early 1980s. Fishing effort is expressed in %, relative to the effort required to extract a catch intermediate between maximum economic and maximum sustainable yield (MEY and MSY) (these terms are defined in Illustration 2). Note need for drastic reduction of effort for both resource types.

ILLUSTRATION 2

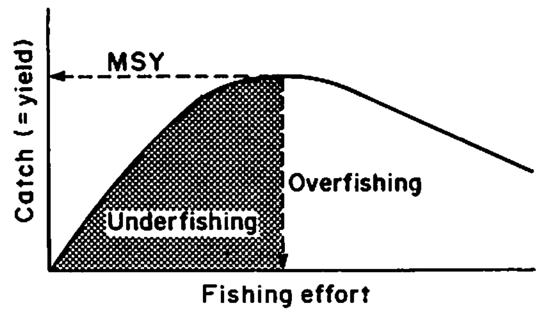
Definitions of Overfishing

Application of an excessive amount of fishing effort to a fish stock results in what is known as overfishing. There are various forms of overfishing, i.e.,

- Growth overfishing. The fish are captured before they have time to grow to the size at which further increase in growth is offset by losses due to natural mortality (e.g., predation). Prevention of growth overfishing involves fishing effort limitations, mesh size regulations and closed seasons or areas.

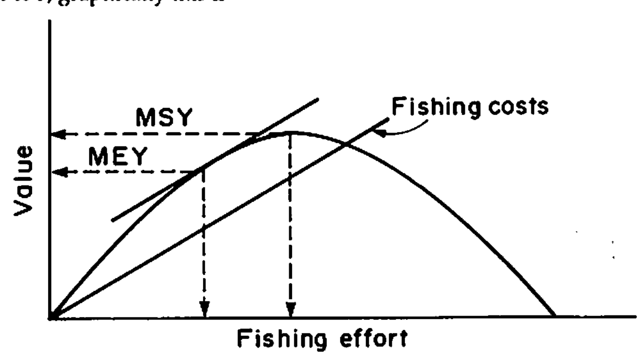
- Recruitment overfishing. The reduction through fishing a stock to such a low level that not enough broodstock are left to produce eggs and hence future recruits to that same stock. Prevention of recruitment overfishing involves definition and protection (e.g., through reserves) of a sufficient number of parental stock.

- Biological overfishing. The combination of growth and recruitment overfishing which occurs when the level of fishing effort in a given fishery exceeds that needed to generate Maximum Sustainable Yield (MSY). Graphically, this is



Prevention of biological overfishing involves management of fishing effort and fishing pattern.

- Economic overfishing occurs when the level of fishing effort in a given fishery is above that needed to extract Maximum Economic Yield (MEY), defined as the maximum difference between the gross value of the catch and all costs of fishing. Note that MEY < MSY; graphically this is



Improved management reduces the costs of produce through reduction of effort and hence of the cost of fishing. This may lead to increased equity, i.e., "more and/or cheaper food for the poor."

In addition to these four "classical" forms of overfishing, applicable to all fisheries and fish resources of the world, we identify two further facets of overfishing, particularly relevant to tropical fisheries; these are

- Ecosystem overfishing. The result of a change in species composition of a stock due to application of excess fishing effort, where target species disappear and are not fully replaced by "successor" species. Generally, ecosystem overfishing implies a transition from high value, large fish to low value, small fish, and ultimately to "trash fish" and/or noncommercial invertebrates such as jellyfish.

- Malthusian overfishing. A term coined to describe the entry into coastal fisheries of labor displaced from other landbased activities, competing against an already excessive number of traditional fishers and tending to use destructive fishing methods such as dynamite for pelagic fish, bleach or cyanide in coral reefs, and/or insecticides in some lagoon fisheries.

These six forms of overfishing, all of wide, and often simultaneous occurrence, reduce the catches that are taken, entail immense social losses, and threaten the biological base of the various fisheries resource systems.

Research directed at overcoming overfishing involves the study of fish growth, mortality and vulnerability to various fishing gears (to deal with growth overfishing), with fish reproduction and the survival of early life forms (to deal with recruitment overfishing), with species interactions, especially predation (to deal with ecosystem overfishing) and the social and economic factors which determine the behavior of fishers, entrepreneurs and policymakers (to deal with economic and Malthusian overfishing).

Production in the other aquatic resource-use subsectors, aquaculture and enhanced fisheries, is less well documented. Only recently have global aquaculture figures emerged. Published statistics report that China produces three-quarters of the world's farmed aquatic produce. Twelve developing countries of Asia produce most of the rest, but it is a small amount, less than two million tonnes. Other developing regions combined produce less than one-quarter million tonnes.

Few data are available on the extent of enhanced fisheries production. Most of the production attributable to enhancement has taken place in temperate waters.

Estimates of the number of people engaged in fisheries and aquaculture are even less reliable than the production data. FAO data suggest that there are at least 13 million people directly involved in small-scale fisheries. This, however, does not include the large number of women, men and children who harvest fish from small-ponds, rivers, ricefields, lagoons and coral reefs. The processing and marketing subsectors may account for another 37 million persons.

Fish Consumption

Overall, fish supply 25% of the total animal protein in developing countries. However, in some countries, e.g., Bangladesh, Malawi, the Pacific Islands and the Philippines, fish supply over 75% of the total animal protein. Average consumption of fish in developing countries is 8 kg per caput per year. However, this is probably an underestimate. Most rural populations supplement their staple diets with wild aquatic organisms and little of this appears in official statistics.

Current population growth projections suggest that an additional 19 million tonnes annually would be needed to maintain consumption at current levels in the year 2000, whereas by 2025 (assuming a doubling of the world's population by then) an additional 100 million tonnes will be required to meet demand, without accounting for additional consumption due to increasing incomes. Most of the increase will be needed in developing countries, particularly in Asia.

The Social and Institutional Context

While fisheries are often assumed to be open access, most coastal small-scale and inland fisheries have or had a system of restricting access and means of reducing fishing effort. The mechanisms used to manage this "common property" are very poorly understood. In fact, many governmental fishing regulations act counter to community use rights allocation and community management, and often turn managed commons into open access. The understanding of these issues will be crucial for any effective management of fisheries.

Evaluation of trade-offs among competing resource uses and consideration of the needs of different groups are keys to sustainable development. For example, urban and industrial development are often given higher priority than aquaculture in the allocation of scarce water resources and sites. Pollution from industrial or agricultural chemicals can affect aquaculture production and coastal fisheries. The widespread conversion of mangrove to other uses in Asia and Latin America may have a negative effect on stocks of marine fish and shrimp.

These issues are of great importance in fisheries management. For example, there is a large intersectoral component of the overfishing problems in small-scale fisheries.

In many cases, the excessive fishing effort stems from large amounts of excess labor pushed out of other economic activities into open access activities such as fisheries. This process exacerbates problems of overexploitation and greatly complicates resource management. Systems for limiting entry into the fisheries need to be tailored to the broader economy. In many parts of Asia, the only practical way to sustain or increase production and improve incomes among small-scale fishers is to encourage movement of labor out of the fishery into other productive activities. In the face of high rates of population growth, this requires structural changes in various sectors and new economic activities capable of productively employing the increasing labor force. Alternative economic activities must be carefully chosen so as to minimize additional management problems, such as pollution and critical habitat destruction, or conflicts with other productive activities.

Fisheries research and development occur within a specific institutional and organizational context. Targeting fisheries research to areas which will best meet the needs of the beneficiaries requires a clear understanding of the context within which development takes place.

There are many formal and informal associations which have often emerged from among producers themselves to meet their own needs. Such associations range from community-based organizations that have assumed responsibility for management of aquatic resources to formal trade associations of fishers, fish farmers and fish processors.

These formal and informal associations fulfill important economic and political functions for their members and are an important mechanism for influencing development policy.

Policy impacts on the fisheries sector at many different levels. At the international level, trade, world economic conditions, the policies of development banks and multilateral and bilateral aid agencies can determine whether emphasis is placed on the capital-intensive or small-scale labor intensive or whether emphasis is on production for export or for local consumption. At the national level, policies on pricing, investment subsidies, resource tenure or ownership and national laws on regulations on fisheries have profound effects on the production, and on fisheries and environmental management.

Externalities, Institutional Concerns

Meeting the supply gap in the future will be further challenged by many factors outside the sector: human population growth, domestic and industrial pollution, competing demands for the same resources, erosion and siltation from unsustainable agricultural and forestry practices, and the unknown consequences of global climate change. The changes to the aquatic environment are much less visible than the results of agricultural and forestry mismanagement. This makes it difficult to raise public awareness of aquatic environmental issues.

These trends are likely to continue. Population increase and its consequences, particularly for the poor in developing countries - increasing pressure on common property resources, increasing income gap between rich and poor; increasing food gap; increasing national debt; increasing energy use - all lead to the unsustainable use of resources and disastrous consequences for future generations. The pressure is often greatest in narrow coastal areas where already 20% of developing-country populations are concentrated.

The combined effects of the present global environmental assault can only be to reduce the attainable yields of aquatic resources in the future. It is not easy to quantify the likely overall losses. It can be assumed that the effects will be most severe on small-scale fisheries in coastal environments in highly populated areas.

National aquatic research systems (NARS) in developing countries, charged with management of aquatic resources, tend to suffer from poor infrastructure, low wages and low operating funds. Researchers in universities are usually much more qualified than those in sectoral research institutes, where the "proportion of senior staff actively engaged in research investigations ... is often low" (SIFR 1991). The quality and management of the research may also be low. These issues have been further elaborated upon by SIFR.

Outlook

For the future, aquatic resources must satisfy not only consumption demands but also the need for livelihoods. Moreover, this must be achieved along with habitat conservation and rehabilitation. Some further increases in marine fisheries catches in developing regions are possible. There are gains to be made in upwelling areas and coral reefs by improved management schemes. There are still unexploited resources in some regions and scope for replacement of foreign fishing activity by national fleets.

For the majority of both marine and freshwater resources in these regions, the challenge will be to maintain existing catch levels - a question of sustainability. New fisheries management strategies are needed to accomplish this feat, simply because existing methods are failing. It is clear that social aspects including policy and equity issues will play a large role. They have been neglected in the past and this neglect is largely to blame for the present failures to manage fisheries in a sustainable manner.

Aquaculture appears to have tremendous potential but there are very few fish farmers in most countries. Moreover, the fish breeds used throughout Asia - taking the area which produces most of the world's farmed aquatic produce - are generally close to wild fish. Scientifically-based husbandry and breeding have scarcely begun and the gains seen in agriculture and livestock production through improved breeds and husbandry are no less applicable to aquatic produce. Similarly, initial farming systems research in this area has pinpointed the possibilities for several-fold increases in aquatic production through appropriate management of farm resources. However, there are many constraints facing the millions of potential new adopters or "entrants" into aquaculture: lack of know-how; lack of appropriate sustainable farming systems and fish breeds; adverse environmental impact; resource use conflicts and lack of confidence of land-based farmers to raise aquatic produce; and availability of trained research and extension personnel.

There are also potentially large gains in fish production through enhanced fisheries. Their magnitude is unknown, however, and there is a need to examine this potential as a first step towards deciding what kind of international strategic research will be needed in this subsector.

There may be scope for gains in coastal aquaculture and enhanced fisheries. However, coastal degradation and resource-use conflicts limit potential. In some coral reef systems there are a number of as yet little explored opportunities for increased aquaculture and enhanced fisheries production.

In summary, to decrease the gap between supply and demand for aquatic resources; to improve the livelihoods of fishing communities; and to maintain or improve aquatic habitats will require international strategic research. Our analysis and the recent documentation shows that this research must focus on 1) improving the management and sustainability of current fisheries and 2) establishing the biological and social basis for increased fish production by aquaculture and enhanced fisheries. In this context, the problems and opportunities, the critical issues that could be addressed by international research to 1) improve the management and sustainability of current fisheries are:

- Sustainability of coastal fisheries systems
- Improved management of coral reef fisheries
- Improved management of fisheries in upwelling areas
- Development of fisheries for currently underexploited offshore resources, e.g., tunas and squids
- Prevention of postharvest losses and food conversion

and 2) establish the biological and social basis for increased fish production by aquaculture and enhanced fisheries are:

- Improved fish productivity through genetics and husbandry
- Removal of socioeconomic and environmental constraints to aquaculture growth
- Development of farming systems
- Assessing and developing the potential for enhanced fisheries

Finally, in order to accomplish the above, there must be:

- Strengthening of national research systems.

Existing Fisheries Organizations

There are many institutions involved in fisheries-related activities, including development banks, international and regional fisheries organizations, national systems, universities, NGOs and the private sector. The broad activities of these groups, as well as their strengths and weaknesses, were considered in selecting the research areas appropriate for the future ICLARM.

Many research and related activities are being carried out at the national level to deal with fisheries problems. Due to national research policies and scarcity of human and financial resources, most research has to be of a "fire-fighting" nature, providing short-term solutions. The strategic framework is often missing for the research to be useful in the long term. As noted above there are often institutional problems also.

There are presently few regional bodies concerned directly with tropical or subtropical fisheries. The Southeast Asian Fisheries Development Center (SEAFDEC) undertakes applied research and provides training in fisheries, aquaculture and postharvest technology. An intergovernmental Network of Aquaculture Centres in Asia (NACA), consisting of a group of NARS, carries out applied research of regional relevance in the various member countries and also provides training. The Gulf and Caribbean Fisheries Institute, based in Miami, USA, exists mainly as a vehicle for presentation of research results at annual meetings. Regional networks, such as are being developed by IDRC, show promise of being useful mechanisms for knowledge transfer.

There are other relevant regional organizations, such as with FAO's regional bodies related to fisheries, and other intergovernmental entities, such as the South

Pacific Commission, the (South Pacific) Forum Fisheries Agency (FFA), and the Southern African Development Coordination Conference.

The field of international fisheries research is small. Not only are there few groups but also the levels of effort are low. There are four main groups - international research, development and conservation organizations, like the CGIAR centers and International Union for the Conservation of Nature; the UN organizations, like FAO, the Intergovernmental Oceanographic Commission, UNESCO and UN Environment Programme; intergovernmental fisheries organizations, like the International Council for Exploration of the Sea; and advanced scientific institutions, principally developed-country universities.

The role of FAO in fisheries research is particularly active, much more so than in agriculture. FAO and ICLARM have two existing joint projects, the Network of Tropical Fisheries Scientists and the development of the database FISHBASE, respectively. ICLARM also has a new Memorandum of Agreement with FAO; initally for future joint work in African aquaculture. It is expected that this special relationship with FAO will strengthen further in time.

Many advanced scientific institutions (ASIs) are involved in biological and social science research in aquatic sciences. These include entire institutes and departments of universities and numerous smaller groups and individuals. ASIs make a special contribution in expensive laboratory-based research. One example is the work on postharvest losses and fish deterioration. However, few ASIs are located in the tropics.

Present Status of ICLARM

ICLARM's Mandate

ICLARM was established in 1975 by the Rockefeller Foundation, with a mandate to "establish, maintain, and operate an international aquatic resources center designed to pursue ... the following objectives: To conduct directly and to assist others in conducting research on fish and other aquatic organisms, on all phases of fish production, management, preservation, distribution, and utilization with a view to assisting the peoples of the world in rationally developing their aquatic resources to meet their nutritive and economic needs; To improve the efficiency and productivity of culture and capture fisheries through coordinated research, education and training, development and extension programs; To upgrade the social, economic, and nutritional status of peoples in the less-developed areas of the world through improvement of small-scale rural subsistence and market fisheries; To work toward the development of labor-intensive systems to aid employment and of low energy systems to minimize capital and cost requirements; To publish and disseminate research findings and recommendations of the Center; and To organize or hold periodic conferences, forums, and seminars, whether international, regional, local, or otherwise for the purposes of discussing current problems."

Staff and Facilities

Current ICLARM staff based at Manila headquarters consist of 11 senior (internationally recruited) researchers, two senior administrators and fifteen midlevel (M.S. degree) professional staff. Project offices in the Bangladesh, Chile, Ghana, Malawi, Philippines and Sierra Leone account for a further eight senior researchers, while the Coastal Aquaculture Centre in the Solomon Islands has one senior researcher and twelve midlevel professionals. Two-thirds of the senior researchers and two-thirds of the midlevel professionals are project-funded; the others are funded from unrestricted core.

ICLARM is headquartered in rented facilities in the business district of Manila. Most of the research is done collaboratively with NARS. In the case of aquaculture where hands-on research is carried out, it is done in national facilities (e.g., Philippines and Malawi). ICLARM's only owned facility (long-lease) is the Coastal Aquaculture Centre in the Solomon Islands. This consists of modest offices, laboratories and a small shellfish hatchery.

Finances

ICLARM since its establishment has been supported by a diverse group of donors (see Box 1). However, there have been considerable difficulties with funding, particularly access to unrestricted core funds. The Rockefeller Foundation withdrew core support in 1983. The Center experienced declining income and was within a week of insolvency at the end of 1985. The situation has improved with the formation of the ICLARM Support Group under the leadership of UNDP. There is, however, a shortage of core funding. In 1992 the unrestricted core grants amounted to $1.7 million which was 28% of the total budget. The funding shortages since 1983 have not only led to restrictions on core staff but have contributed to a compartmentalization of staff and activities while many of the activities have been short term and highly restricted.

Governance

ICLARM is administered by a Board of Trustees. The Board is composed of fifteen members. Two of these members serve on an *ex-officio* basis, while the others, though affiliated or formerly affiliated with various international and national institutions, serve in their personal capacities. The *ex-officio* members of the ICLARM Board are the Center's Director General and the highest ranking Philippine government official with direct responsibility for fisheries (presently the Secretary of the Department of Agriculture). The Board elects its own new members with regard to professional status, geographical distribution and gender in order to provide a representative cross section of clients, donors and fisheries expertise. The Board members act as sources of information, contact, and facilitators of support for ICLARM programs.

The Board's primary responsibilities are:

- to act as the policymaking body of the Center;
- to lay down or approve the Center's programs;
- to review the finances of the Center and approve an annual budget; and
- to review the progress and management of the Center.

The ICLARM Board of Trustees has several standing committees to assist the Board in carrying out its responsibilities. The Board members elect, from among themselves, members to these standing committees. The current standing committees are the Executive Committee, Finance Committee, the Program Committee and the Nominating Committee.

Box 1
Sources of Financial Support for ICLARM
1977-1992

Unrestricted

Australian International Development Assistance Bureau (AIDAB)
Bundesministerium für Wirstchaftliche Zusammenarbeit (BMZ), Federal Republic of Germany
Canadian International Development Agency (CIDA)
Danish International Development Agency (DANIDA), Denmark
Ford Foundation, New York
Rockefeller Foundation (RF)
Royal Norwegian Ministry of Development Cooperation (NORAD)
United States Agency for International Development (USAID)
International Bank for Reconstruction and Development (IBRD)

Restricted

Agence de Coopération Culturelle et Technique (ACCT)
Asian Development Bank (ADB), Philippines
Australia and Pacific Science Foundation (APSF)
Australian International Development Assistance Bureau (AIDAB)
Centre Technique Forestier Tropical - Département du Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CTFT/CIRAD)
Commission of the European Communities (CEC)
Commonwealth Fund for Technical Cooperation (CFTC)
Danish International Development Agency (DANIDA), Denmark
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH, Federal Republic of Germany
Food and Agriculture Organization (FAO) of the United Nations
Ford Foundation, Bangladesh, New York
French Government
French Ministry of Cooperation and Development
Greenpeace International
Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM)
Institut National de Recherche Agronomique (INRA)
International Bank for Reconstruction and Development (IBRD), USA
International Center for Ocean Development (ICOD), Canada
International Development Research Centre (IDRC), Canada
International Fund for Agricultural Development (IFAD)
Kuwait Institute for Scientific Research (KISR)
New Jersey Marine Science Consortium (NJMSC), USA
New Zealand Government
Overseas Development Administration (ODA), United Kingdom
Philippine Council for Agriculture and Resources Research and Development (PCARRD)
Planters Products, Inc. (PPI), Philippines
Programa Cooperativo Peruano (PROCOPA)
Rockefeller Foundation (RF), USA
Royal Norwegian Ministry of Development Cooperation (NORAD)
San Miguel Corporation (SMC), Philippines
L.J. and Mary C. Skaggs Foundation, USA
Swedish Agency for Research Cooperation with Developing Countries (SAREC)
Technical Center for Agricultural and Rural Cooperation (CTA)
United Kingdom Voluntary Service Overseas (VSO)
United Nations Development Programme (UNDP)
United Nations University (UNU)
United States Agency for International Development (USAID)
United States Peace Corps Volunteers

Programs

ICLARM's current programs initially focused on Southeast Asia and the Pacific but have expanded recently to include South Asia, southern and West Africa, and Latin America and the Caribbean.

The current programs at ICLARM are:

- Coastal Area Management
- Capture Fisheries Management
- Aquaculture
- Information

Training is carried out within each program. In addition, senior ICLARM staff supervise graduate students and postdoctoral fellows.

In order to carry out the above programs, ICLARM has worked extensively with many partners. During 1990-91, ICLARM collaborated with 122 institutions. Fifty of these were ASEAN-NARS partners associated with the Coastal Resources Management Project (CRMP). Of the other 72 institutions, 13 received technical assistance, three were training partners, three were sites of thesis supervision, one was a conference partner, 42 were research partners and 10 were institutional research network members. There are presently 31 NARS and 11 ASI research partners.

In addition to these research and training relationships there is also information collaboration. Information exchange agreements are current for 180 institutions, the great majority of which are (associated with) ASIs. ICLARM also provides materials to eleven formal depositories in Europe, the Americas and Africa. The library interacts informally with a large number of other institutions, for example, the (100+) membership of the International Association of Marine Science Libraries and Information Centres (IAMSLIC), which are mainly in American and European ASIs, in information exchange and committee memberships. ICLARM staff are involved in a large number of associations and other affiliations. In 1987, there were over 80 such involvements.

ICLARM collaborates with one other international center, IRRI, on integrated rice-fish research and farming systems training.

Discussions are being conducted with a number of other centers, particularly with a view to closer integration of aquaculture and agriculture.

ICLARM coordinates three major networks:

- The *Asian Fisheries Social Science Research Network*, an institutional strengthening activity involving 90 researchers from Indonesia, Malaysia, the Philippines and Thailand.
- The *Network of Tropical Fisheries Scientists*, a worldwide information network of over 1,000 scientists from 108 countries.
- The *Network of Tropical Aquaculture Scientists*, also an information network of over 550 members from 85 countries.

In addition, the Coastal Aquaculture Centre coordinates a giant clam network. ICLARM is involved in a number of other informal networks on Coastal Zone Management and Farming Systems. ICLARM staff have been instrumental in the establishment and operation of the Asian Fisheries Society; the Society's secretariat is housed in ICLARM.

Achievements

In spite of the financial difficulties of the past eight years, ICLARM has made substantial contributions in approaches, methods, training and national research capacity development.

ICLARM has played a major role in focusing attention on some of the major issues in fisheries development: concern for management issues, the need for interdisciplinary research in capture fisheries, coastal area management and the need to focus aquaculture research and training on low-input systems.

ICLARM has also developed a number of methods and tools that have found wide usage. Some of these tools have helped to lay the foundation for the science of tropical fisheries management. For example, one author noted "the recent revolution in tropical fisheries science initiated...at ICLARM and furthered by FAO, relying on computerized length-based methods."[1] ICLARM-developed methods are now used in over 30 tropical developing countries and are core components of fisheries management training for tropical fisheries.

In aquaculture, the advances have also been in methods and approaches, particularly a focus on the small-scale sector integration with agriculture and new entrants. Preliminary work in fish breeding using tilapia is indicating the scope for genetic gain and methods which can be used by NARS. There have also been some new technologies in rice-fish culture and the development of giant clam aquaculture.

Involvement in aquaculture in Africa has just started but early success is being shown in Malawi. This is leading to experience and methods which can be applied elsewhere in Africa.

In coastal area management, ICLARM's role has been coordination of development of management plans by interdisciplinary in-country NARS teams. The methodologies, approaches and innovations in socioeconomic integration and policy from this approach have important applications to other areas and future research.

ICLARM has played a major role in developing national research capacity. The information program, training and networking have been important in assisting this. ICLARM also receives continuous feedback on the Center's usefulness from many individuals and institutions around the developing world, where ICLARM literature is widely used. NAGA, the ICLARM Quarterly (formerly the ICLARM Newsletter), reaches an estimated 20,000 readers and all publications are exchanged with a large number of institutions. Those in developing countries receive many of them free of charge.

More than 40 cooperative research projects have been initiated in various countries in Asia, Africa and Latin America and scientific linkages are operational with many institutions. Eighteen major reviews have been published and 28 international conferences and workshops have been conducted by ICLARM, which has subsequently published the proceedings. Requests for participation by ICLARM in various research topics far surpass the Center's ability to respond. Research and information networks have been used very effectively to increase the multiplier effect of ICLARM's work.

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[1] H.P. Stirling. Book review in Aquaculture and Fisheries Management 22(1991): 271.

ICLARM's Comparative Advantage

ICLARM has worked for over a decade in developing methods for resource management which have helped to lay the foundation for tropical fisheries science. Its scientists have been involved to a large extent in the creation of globally-useful methods and approaches mainly through development of models and software. ICLARM's role has not been in survey work or large-scale data gathering, but in interpreting such data, devising and testing models. Over the past six years, the Center has also developed expertise in investigating the broader issues of coastal resource management. Further, in its international aquaculture research, ICLARM has taken a systems approach by placing the fish and the pond as resources in the farming environment, requiring an integrated resource management approach. It has also introduced breeding/genetic research into tropical aquaculture.

In over 15 years of conducting nearly all its research in collaboration with NARS, ICLARM has built a sensitivity and strong rapport with national programs. Moreover, its emphasis on information has made ICLARM a key resource for developing-country scientists.

With these strengths, ICLARM has a strong comparative advantage to carry out a more focused program of research and related activities in the field of international aquatic resource management and fish productivity.

Mission, Goal and Objectives

Within the general mission of the CGIAR to contribute to sustainable improvements in the productivity of agriculture, forestry and fisheries in developing countries in ways that enhance nutrition and well-being, especially among poor people, the future ICLARM has the following goal and objectives.

Goal

Improved production and management of fisheries resources for sustainable benefits of present and future generations of low-income users in developing countries.

Objectives

Through international research and related activities, and in partnership with NARS, to:

1. Improve the biological, socioeconomic and institutional management mechanisms for sustainable use of aquatic resource systems.
2. Devise and improve production systems that will provide increasing yet sustainable yields.
3. Strengthen national programs to ensure sustainable development of aquatic resources.

Clients, Beneficiaries

ICLARM's research will not generally reach beneficiaries directly but through organizations and individuals to which the center will direct its output, i.e., clients. The principal clients, those using the output in their research, development planning and management, are international and regional development organizations; national research and development organizations; educational institutions; nongovernment organizations (NGOs); policymakers; individual scientists; and the private sector.

Organizations such as international fisheries organizations, development banks and donors will also make use of the output in planning and implementing their programs.

Amongst the clients of the center, the most important group will be the NARS.

The institute's primary beneficiaries will be actual and potential low-income producers - individuals, families and communities who gain in livelihood, wholly or partially, from products and services based on fisheries resources - and consumers - those for whom fisheries resources form or could form a significant and essential part of the diet - in developing countries.

Guiding Principles

In carrying out its mission, ICLARM will adhere to certain principles, which are seen as essential if it is to provide resource management advice that will impact on the intended beneficiaries. These guiding principles are sustainability, equity, gender sensitivity, participation and a systems approach. They will be built into all aspects of the Center's activities, used in accessing priority, in program review and evaluation and be internalized in the Center operation and management.

<u>Sustainability:</u> The concept of sustainability must be integrated at all levels of the research. Fisheries research can offer considerable insights to the other CGIAR centers as they move to incorporate sustainability into their research agendas. Fisheries was the first resource area to utilize the concept of sustainability. At the core of all capture fisheries management systems lies the concept of Maximum Sustainable Yield (MSY). In addition, there is emerging evidence that the integration of fish into agricultural systems improves not only the yield and income from the system but also its sustainability. For example, recent research on rice-fish suggests that the presence of fish with the rice, in addition to yielding a crop of fish, increases the yield of rice and the efficiency of fertilizer application (both N and P), and may improve disease and pest control.

One of the important indicators of sustainability is biodiversity. Active research will be carried out in this area to show how diversity can be used as an index of sustainability. Sustainability is closely linked to equity, as the former is really an attempt to measure intergenerational equity.

<u>Equity:</u> The issue of equity will be central to the research program. In capture fisheries, the primary emphasis will be directed towards small-scale fishing households.

In aquaculture and enhanced fisheries, research will be directed towards systems that will benefit the vast majority of producers and consumers in developing countries. This will mean emphasis on low input systems that will give attractive economic returns to farmers and at the same time produce fish that is affordable to low-income rural and urban consumers.

However, the social science and policy research will have to address the wider issues that affect development, export and environmental policy and that promote large-scale high-input systems and production of high-value products.

Gender: Gender-related research should be integrated into all the center's activities, recognizing that gender research is concerned not only with sustainability, but also with promoting equity.

Gender research must give equal treatment to all components of the system, documenting the important roles of women, children and men. In addition, this research will generate an understanding of women as agents of development and resource management. Women traditionally have been responsible for a major portion of the value-added fisheries production through their activities in processing, distribution and marketing. Similarly, women engaged in reef gleaning, firewood collection from mangrove and other uses of local/natural resources are vitally concerned with resource sustainability. As these systems come under increasing pressure, women in fishing communities can play an important role in resource management, as have their counterparts in forest-dependent communities.

Results from gender research should provide stimuli to national institutions seeking guidance on how to be more responsive to the situation of women in fisheries and become a resource to international donor institutions.

Participation: The involvement of the eventual beneficiaries, the low-income producers and consumers, is essential for effective research. Methods and approaches will be needed to ensure their involvement in setting research agenda and in the design, implementation and evaluation of research and assessment of policies. This will mean working closely in a few test cases directly with the producers and consumers, and also with NGOs and NARS to develop the participatory approaches.

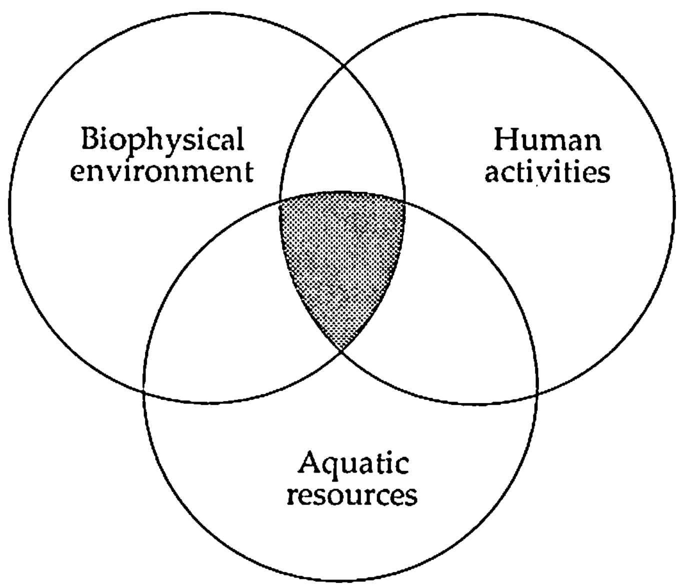
Systems Approach: The problems in the fisheries sector cannot be solved using a species by species approach. Fish species interact with each other often in complex and dynamic environments. Fishers catch several species of fish at the same time for sale in markets that reflect local economic and social traditions. While the relevant components of the systems will have to be examined, component research must be carried out within a systems framework by multi- and interdisciplinary teams who have an overriding systems viewpoint.

In summary, with objectives of improving management mechanisms and production systems for the sustainable use of aquatic resources and of strengthening national programs, directed at low-income producers and consumers (beneficiaries) through NARS clients, coupled to principles of sustainability, equity, gender sensitivity, user participation and a systems approach, ICLARM sees itself as having a tripartite role of strategic research, catalytic activity and NARS strengthening in light of its comparative advantage in international research in living aquatic resources management. ICLARM's approaches to the task of setting priorities among the stated array of key international research issues are presented in the following chapter.

CHAPTER 2
Priorities for the Future ICLARM

This chapter presents the priorities for research and related activities and how they were derived. Various ways of deriving priorities were examined. A commodity approach to allocate research effort was considered impracticable because the resource groups are too numerous and scattered over a wide range of habitats.

The basis chosen for deriving priorities was that of the resource system. Resource systems can be defined as the zone of convergence of the resources, their aquatic environment and the human users, as suggested in the illustration below. It is this interaction which has been missed or avoided in much previous aquatic resource management research. The central, shaded, part of the illustration defines the aquatic resource system - the combination of resource, environment and user.



This approach was chosen because: 1) it supports the future ICLARM's objectives and principles, especially those of sustainability and systems approaches; 2) it encompasses many of the critical international research issues; and 3) it fits with the comparative advantage of ICLARM in resources management. It also adds a new perspective to solving the problems.

Priorities are described first by resource system and then for the regions: Asia, Latin America and the Caribbean (LAC), SubSaharan Africa (SSA), and West Asia and North Africa (WANA). The priority areas of work or activities in the resource systems and regions were derived by first choosing from the array of critical issues for international research presented in Chapter 1 and then matching these choices with activity types suggested by TAC. Before embarking on these descriptions and judgements it is important that the process by which they were derived be fully explained.

Process for Priority Setting

ICLARM's priority setting was done in the framework of a strategic planning exercise at the invitation of the CGIAR in November 1990 to develop such a plan for international fisheries research. The TAC and SIFR studies facilitated the process (ICLARM staff also participated in various aspects of the SIFR study).

All ICLARM professional staff and some 40 scientists from other institutions were involved in the planning process which included four workshops held before May 1991 when a draft was reviewed and approved by the ICLARM Board of Trustees.

TAC agreed with the draft in principle at its June 1991 meeting but asked ICLARM to refine the priorities and focus. Further refinement was requested when the TAC reviewed an Addendum to the May 1991 draft at its October 1991 meeting.

More than 100 additional scientists and managers in NARS (see Box 2) and regional organizations were consulted individually or in workshops between June and October 1991.

In the following, the various steps and iterations in setting the priorities for the future ICLARM are set out in sequence.

There was a series of successive filtrations. World-wide trends related to fisheries production were analyzed and sifted to include only those areas where research had scope for major impact. The resulting broad research agenda was further filtered to separate out that part being or likely to be done adequately by other research groups. What remained was passed through a further filter: the degree of comparative advantage for a CGIAR style center.

Priority setting from the resulting agenda was guided by the following criteria:

1. Number of beneficiaries - producers and consumers - of living aquatic resources likely to be affected by the research.
2. Extent of impact on beneficiaries.
3. Extent of potential use by clients.
4. Extent to which results will strengthen national programs.
5. Contribution to sustainability of aquatic resources and their environments.
6. Probability of achieving research objectives.
7. Potential for spillover to nonclient and nonbeneficiary groups; multiplier effects.
8. Cost-benefit ratio of the research.

Subsequently, the principles and modifiers used in the "Review of CGIAR Priorities and Strategies" by TAC were applied. TAC attempted a quantitative approach to priority setting by which baseline data on commodity production values were disaggregated by agroecosystem and then modified to reflect CG priorities such as equity, sustainability, efficiency, national research system strengthening, and self-reliance.

Box 2
Consultation with NARS

To elicit views of NARS, the following steps were taken in 1991:

Copies of the draft plan were sent to NARS representatives in a number of developing countries. Special efforts were made to ascertain views of NARS where ICLARM has significant presence - Bangladesh, Latin America, Malawi, Philippines and South Pacific - through meetings and consultation. Apart from individual and group interviews, discussions were arranged during: the South Pacific Regional Technical Meeting on Fisheries, New Caledonia (senior scientists and fisheries managers); the meeting of the Committee on Development and Management of Fisheries of the South China Sea, Hong Kong (senior government officials); the SEAFDEC workshop on Aquaculture Development in Southeast Asia, Philippines (senior scientists).

More than one hundred individuals were involved in these various activities. There was general agreement with the context of the plan from all respondents. Many respondents suggested additional topics and geographic areas of focus which the future ICLARM will not be able to address. For example: postharvest production (Malaysia, Philippines); new products from aquatic organisms (Malaysia); seaweed research (SEAFDEC, Philippines); research in fish health (China); and the inclusion of temperate areas (China). Endorsements of the approach and request for specific collaboration were received in genetics breeding and germplasm conservation of Asian fish (India, SEAFDEC); and the farming systems approach and the environmental effects of aquaculture (China).

In Bangladesh, senior officials stressed training and collaborative research on regional issues - rather than networking which was felt to be less useful in least-developed countries like Bangladesh. Assistance was requested in research planning and prioritization, and consideration of a regional center in South Asia.

In Latin America, where some 30 persons were contacted, some general issues included promotion of exchange of personnel and methodology, and global integrated management approaches. The various NARS would like strong linkages, general training assistance and availability of more information in Spanish.

In Malawi, there was a general expectation that ICLARM would continue collaborative research and training in aquaculture and act in an advisory capacity in broader research areas.

In the South Pacific meeting, issues raised were coral reef conservation, the importance of educational/training linkages and information dissemination.

A meeting was held in August with 16 senior representatives of Philippine institutions to discuss collaboration, general assistance and training. Collaboration would ensure that ICLARM will not "overshadow" NARS; assistance ("a pool of experts") was needed to fill present gaps in NARS capacity, and training would develop that capacity. Specific research that ICLARM could address included sustainable development and other policy issues.

At the meeting in Hong Kong of senior NARS officials on managing fisheries in the South China Sea, the strong need for more socioeconomic information on a regional basis was voiced. ICLARM was seen as a research instrument and partner in international aspects of the fisheries and a major provider of information and training.

In summary, NARS agree with the contents of the draft strategic plan as far as it goes. The overwhelming viewpoint of the NARS was that ICLARM should involve them in more collaborative research and undertake training to develop their own expertise. However, some continue to view ICLARM as a source of expertise to tap on an *ad hoc* basis. ICLARM's information dissemination activity was seen by a number of NARS as one of its most useful roles and one that should be continued.

Resource Systems

Using the concept of resource systems described on p. 17, the aquatic sector can be divided into a number of large-scale resource systems, similar to but not directly comparable with agroecosystems used by the CGIAR for agricultural research. Nine resource systems were identified. Two systems were excluded: the uplands, which are generally insignificant for capture fisheries and unfavorable for aquaculture, and the high seas because a CGIAR institute has little comparative advantage in industrial-scale fisheries.

The remaining seven resource systems: Ponds; Reservoirs and lakes; Streams, rivers and floodplains; Estuaries and lagoons; Coral reefs; Soft bottom shelves; and Upwelling shelves, are described in Box 3.

The starting point for priority setting was the FAO fisheries statistics, which are comprehensive in geographic coverage and species breakdown. There are nearly 1,000 aquatic species harvested and these are arranged by FAO into fifty-one groups. These data are less reliable than agricultural statistics for major agricultural crops. Many developing countries do not have the necessary infrastructure to collect accurate statistics on resources that involve millions of widely dispersed fishers, are marketed through many channels and are made up of a large number of species. Even in the large-scale industrial fisheries, the data are often biased by under-reporting, nonrecording of discards and by-catch and reporting at landing ports rather than areas of fish capture. In the small-scale fisheries, often no routine data are collected and a high proportion of the catch may go, unrecorded, to home consumption. It will be important that the future ICLARM work closely with FAO to develop rapid and simple techniques to supplement the official statistics for the small-scale sector. Accurate fisheries data are essential not only for decisions on strategic research but for management of the fisheries themselves.

The ICLARM priority setting exercise started with the quantity of production as the baseline. The FAO data (which while imperfect are the only available data) disaggregated by resource system formed this baseline. The details of the approach and the assumptions are presented in the Appendix. This was different from the TAC approach which used value of production and poverty and land-use indicators. These indicators were either not applicable or unavailable for the relevant fisheries resource systems. The same applied to the modifiers which TAC used.

The next step was to obtain an index of potential gain. This was then modified by indices reflecting equity and sustainability concerns. The results and the various assumptions made are presented in Table 2.1.

ICLARM has used these outputs as indications of priority but has not used them to allocate resources to the priority resource systems.

While there may be debate on some of the assumptions, this type of priority setting is transparent and also indicates information gaps. This approach will be refined and used during future medium-term planning.

The resource systems which receive the highest priority for research by the future ICLARM are coral reefs, ponds and estuaries and lagoons.

The resource system which currently has the highest production is that of upwelling shelves. However, this system is normally fished by large-scale

Box 3
Resource Systems

Uplands: Terrain with steep gradients at the higher elevations of catchments, where little or no fishery or aquaculture is possible.
Ponds: Ponds are small freshwater bodies, usually artificial, occasionally natural, in rainfed and irrigated areas where aquaculture, particularly integrated with agriculture is possible. Flooded rice fields are hence considered as ponds. Ponds are normally characterized as being under private individual or group ownerships or leasing arrangements.
Reservoirs and lakes: Reservoirs are natural or artificial waterbodies, primarily used for irrigation, hydroelectric power and domestic water supply. Lakes are natural waterbodies. Both are usually freshwater and have high potential for aquaculture and conventional or enhanced capture fisheries. They are usually considered common property and there may be free access to fishing or aquaculture sites. However, in some cases, rights are leased from the government or from other authorities, groups or individuals.
Streams, rivers and floodplains: Streams and rivers are flowing waters while floodplains are the lowland areas, adjacent to watercourses that are subject to periodic or near-permanent inundation and sediment deposition. Streams, rivers and floodplains support substantial inland fisheries and have potential for enhanced fisheries. Normally all these systems are common property and have open access, except where access and/or ownership attached to surrounding lands restricts this.
Estuaries and lagoons: Estuaries are semi-enclosed coastal waterbodies with free connection to the open sea and within which seawater is diluted with freshwater from land drainage (i.e., brackishwater). Lagoons are shallow waterbodies resembling ponds or lakes, which usually have one or more shallow restricted outlets to the sea. This grouping includes the key habitats, such as mangrove, that support coastal fisheries. It also has potential for aquaculture and for enhanced fisheries. Coastal waters out to 10 meters depth are included here to encompass most fishing grounds of small-scale fishers. These areas are usually directly adjacent to soft-bottom shelves (see below), leading to conflicts with the (trawl) fisheries operating there. Brackishwater ponds are included in this system. They are either natural or man-made; often the result of conversion of mangrove swamps. This resource system is often an area of intense intersectoral conflict over competing uses.
Coral reefs: Areas of continental and island shelves in tropical oceans in which reef-building corals are dominant features, forming scattered patch reefs, fringing reefs or barrier reefs and usually large areas of shallow coraline enclosed waters. The latter have potential for aquaculture. This is often an area of intensive fishing and gleaning. There may be traditional use rights but reefs are often considered open access.
Soft-bottom shelves: These are the relatively shallow (up to 10-200 m deep) productive areas surrounding continents. In the tropics, it is mainly the upper, nearshore parts (10-50 m) of the shelves which sustain marine fisheries. There are strong interactions (and conflicts) between nearshore small-scale fisheries and large-scale commercial operations.
Upwelling shelves: Upwelling is the process in which cold, nutrient-rich water is brought to the surface of the sea from deeper layers. This process mainly occurs on the eastern side of oceans, driven by the interaction of strong and steady winds directed towards the equator and the earth's rotation. The upwelled water fertilizes the sea, enabling the support of large populations of a few species of small (anchovies and sardines) and large (bonitos, mackerels) pelagic fishes. These areas also support large populations of sea birds and sea mammals. In addition to the four major upwelling areas (off Peru, California, North West Africa and Angola/Namibia), scattered smaller upwellings occur throughout the tropics, e.g., in the Arabian Sea and in Indonesia. In most cases, upwellings are fished by medium- to large-scale industrial fishing vessels.
Open oceans: The open seas beyond 200 m depth, where mainly oceanic resources such as tuna and large squid are fished by commercial or large-scale enterprises.

Table 2.1. Priority setting for the balance of effort of the future ICLARM, by aquatic resource system, based on fish production, potential for increase, threats to sustainability and equity.

Criteria	Resource systems: Ponds	Reservoirs, lakes	Streams, rivers, floodplains	Estuaries, lagoons	Coral reefs	Soft-bottom shelves	Upwelling shelves
Fish catch (t x 10^6)[a]	-	1.8	3.5	7.1	4.0[i]	11.1	14.0
Aquaculture production (t x 10^6)[b]	5.0	0.2	0.1	3.0	0.5	0.0	0.0
Potential to increase production[c]							
Capture fisheries	0	2	0	1	2[i]	1	1
Aquaculture	2	2	1	1	1	0	0
Index of potential gain[d]							
Fishery	0.0	3.6	0.0	7.1	8.0	11.1	14.0
Aquaculture	10.0	0.6	0.1	3.0	0.5	0.0	0.0
Combined	10.0	4.2	0.1	1.1	8.5	11.1	14.0
Combined priority[e]	4	2	1	5	3	6	7
<u>Modifiers</u>							
Threats to sustainability[f]	2	2	3	4	4	2	1
Equity[g]	4	3	4	3	4	2	1
Modified index	30.0	10.5	0.4	35.4	34.0	22.2	14
Modified priority[h]	5	2	1	7	6	4	3

[a]As derived from the Appendix.
[b]Distribution of production as estimated by ICLARM from FAO aggregate data.
[c]Scale is 0-4. Estimate based on an analysis of potential, constraints and feasibility. Information for capture fisheries is summarized in the Appendix. Aquaculture potential for ponds is based on early successes of expansion of semi-intensive aquaculture in SE Asia, Bangladesh and preliminary results from Malawi all with new entrants; for reservoirs and ponds, see Costa-Pierce and Soemarwoto 1990 (Reservoir Fisheries and Aquaculture Development for Resettlement in Indonesia, 378 pp. ICLARM, Manila). Estuaries and lagoons have recently shown considerable increase in aquaculture production. However, these are considerable socioeconomic constraints in addition to equity issues and pollution which limit the potential.
[d]Derived by multiplying current fish catch/aquaculture production by potential.
[e]High number indicates high priority.
[f]This index acknowledges the downstream cumulative effect of unsustainable practices. Thus, estuaries and lagoons and coral reefs receive the effect of all the unsustainable agriculture, and forestry practices plus the impact from industrialization and urbanization. In addition they are subject to conflicting resource use and habitat destruction (e.g., conversion of mangroves and destructive fishing).
[g]This index interprets the contribution of the production to the livelihood of the poor and the availability of the production of food to the poor. For example in upwelling shelves, the fishery is carried out by industrialized fleets often from developed countries while the catch is converted to nonhuman food, contrasted to ponds where production is carried out largely by small-scale producers who either consume the products or sell them in local markets.
[h]Derived from combined index of potential gain modified by sustainability and equity, assuming equal weight. High number indicates high priority.
[i]Conservative figures used for these indexes to reflect the concerns raised by the External Review Panel. The following changes were made (numbers in parentheses reflect numbers presented to the Panel): Fish catch in Estuaries, lagoons 7.1 (5.1); Coral reefs 4.0 (6.0), Potential to increase production - Capture fisheries in Coral reefs 2(3).

industrial fleets, often from developed countries, and at least thirty per cent of the catch is reduced to oil and meal for livestock feeds. Thus, this system has a low equity indicator (i.e., low access and benefits to the poor). This system, while showing periodic large-scale fluctuations (due to climate influences) experiences much lower stress from human-induced environmental change than the other systems. Thus, the index of threats to sustainability is low. The modifiers for sustainability and equity lower the priority of the upwelling shelves, which therefore will not be a priority research area for ICLARM.

While upwelling systems have been excluded as a priority research area for the future ICLARM, they are very important systems and produce 27% of the fish production in developing countries. Coordinated research in these systems is needed and should be carried out by NARS in cooperation with FAO, international and regional fisheries commisions and ASIs. The area of commodity conversion (usually termed postharvest technology in fisheries, discussed in next section) may in the future result in higher priority being given to upwellings as it has the potential for producing increased food to the poor.

The soft-bottom shelves are also an important resource system for fisheries. However, their research priority is lowered by sustainability and equity considerations. Nevertheless, they constitute an area where major interactions occur between small-scale and large-scale fisheries. This interaction will form part of the research addressed in the estuaries and lagoons resource system.

Regions

The priority by region was determined by creating a baseline using quantity of production and number of poor in a similar manner to TAC. The baseline was then modified by NARS strengthening needs. The results (Table 2.2a) indicate the highest priority for Asia, then SSA followed by LAC and WANA.

The calculations were repeated after removing upwelling catches. The results (Table 2.2b) do not change the priority ranking but they do indicate a higher priority for Asia and lower for LAC than when upwelling systems are included.

Research in Asia will focus on all three priority systems. In Africa, freshwater fisheries account for 54% of the total catch and production. It is even higher (64%) if upwelling fisheries are excluded. Therefore, a special case can be made for a focus on the freshwater resource systems which have previously been excluded from the global research agenda - reservoirs and lakes, and streams, rivers and floodplains - to address specifically the special African conditions. These issues will be addressed as the mid-term planning proceeds and the results of exploratory research in Africa become clearer.

In LAC, a minor focus on coral reefs and coastal systems is warranted.

Choice of Researchable Issues

The critical issues that should be addressed by international research were listed in Chapter 1. The choice of researchable issues for the future ICLARM was made on the basis of those which were not being addressed adequately by other organizations, and in which ICLARM would have a comparative advantage.

Table 2.2a. Values used in assessing regional priorities for international fisheries research.

	Weights	Asia/ Pacific	SubSaharan Africa	Latin America/ Caribbean	WANA
Quantity of production %[a]	(0.5)	62.5	5.0	28.4	4.0
No. of poor %[b]	(0.5)	72.1	16.2	6.3	5.4
Weighted baseline %		67.1	10.6	17.4	4.7
NARs strengthening needs %[c]	(0.25)	12.5	50.0	25.0	12.5
Final weighted baseline %		49	24	20	8
Priorities[d]		4	3	2	1

Table 2.2b. Values used in assessing regional priorities for international fisheries research with upwelling catches removed.

	Weights	Asia/ Pacific	SubSaharan Africa	Latin America/ Caribbean	WANA
Quantity of production %[a] (excluding upwelling)	(0.5)	82.3	3.7	10.3	3.7
No. of poor %[b]	(0.5)	72.1	16.2	6.3	5.4
Weighted baseline %		76.9	10.3	8.3	4.6
NARs strengthening needs %[c]	(0.25)	12.5	50.0	25.0	12.5
Final weighted baseline %		55	24	14	7
Priorities[d]		4	3	2	1

[a]Derived by ICLARM from FAO aggregate data.
[b]Based on TAC 1991 (A Review of CGIAR Priorities, Part I Advanced Working Draft), p. 133.
[c]Index derived from TAC 1991 (A Review of CGIAR Priorities, Part I Advanced Working Draft), p. 145-146.
[d]High number indicates high priority.

Although there is large potential for gains through postharvest research, much of the needs are for adaptive and industrial research and extension of current technology (see SIFR). ICLARM has little comparative advantage in postharvest research. ICLARM's priority setting exercise determined that upwelling systems had lower priority than other resource systems. In addition, TAC has identified research on offshore fisheries resources as being outside the scope of a CGIAR institute. Therefore, the following issues are excluded:

- Prevention of postharvest losses and food conversion
- Improved management of fisheries in upwelling areas
- Development of fisheries for currently underexploited offshore resources, e.g., tunas and squids

Thus, there are seven issues that could be addressed by the future ICLARM:

- Sustainability of coastal fisheries systems
- Improved management of coral reef fisheries
- Improved fish productivity through genetics and husbandry
- Removal of socioeconomic and environmental constraints to aquaculture growth
- Development of farming systems
- Assessing and developing the potential for enhanced fisheries
- Strengthening of national research systems

Activity Types

In the preceding sections, ICLARM's approach to research priority setting was outlined in the context of selected pressing global problems and opportunities. It was concluded that they should be addressed on the basis of the resource systems, to which priority was allocated according to aquatic production and potential by region.

The translation of research issues into research activities was made using the research activity types of TAC ("A Possible Expansion of the CGIAR") with some modifications, as they applied to the aquatic sector. Those which were judged to match the seven outstanding issues to be addressed were:

Resource conservation and management
Fish productivity
Commodity conversion and utilization
Human linkages
Socioeconomics and policy
Institution building and research-related activities

One of the activities, "commodity conversion and utilization", was excluded from research during the priority setting of researchable issues. Table 2.3 shows the proportions of research activity types, together with the allocation for institution building or strengthening.

Table 2.3. Balance of resources for research and strengthening activities for a future ICLARM.

Activity	% of resources
Resource conservation and management	35
Fish productivity	25
Social sciences (Human linkages, Socioeconomics and Policy)	20
Institution building	20

A detailed analysis of research activities and subactivities by resource system was carried out by ICLARM during the planning process described earlier. The results of analyses are presented in Fig. 2.1.

Fig. 2.1. Areas of emphasis of research by resource system and detailed activitiy categories. Amount of shading reflects degree of involvement of the institute.

Activities / Resource Systems	Ponds	Reservoirs, lakes	Streams, rivers, floodplains	Estuaries, lagoons	Coral reefs	Shelves soft bottom	Shelves upwelling areas
RESOURCE CONSERVATION AND MANAGEMENT							
1. Global Environment	○	○	○	◒	◒	◒	◒
2. Ecological Characterization	○	○	○	○	○	○	○
3. Habitat Conservation	○	◔	○	●	●	●	
4. Aquatic Use Management	○	◔	○	●	◒	○	
5. Germplasm Conservation	◔	○	○	○	○	○	○
6. Fisheries Ecology and Management	○	◒	◔	●	●	●	○
7. Fishing/Farming Systems	●	◔	◔	●	●	●	
FISH PRODUCTIVITY							
1. Germplasm Enhancement, Breeding	●	○	○	○	○		
2. Fish Production Systems							
a) Pond Dynamics	●		○	○			
b) Recruitment Enhancement	◔	◒	○	○	◔		
3. Husbandry	◒	◔	○	○	◔		
HUMAN LINKAGES							
1. Gender Issues	○	○	○	○	○	○	
2. Sociocultural Organizations	◒	○	○	●	●	○	
3. Intersectoral Linkages and Externalities	◒	○	○	●	●	○	
4. Institutional and Organizational Arrangements	◔	○	○	◒	◒		
SOCIOECONOMICS AND POLICY							
1. Microeconomics and Social Science	◒	○	○	◒	◒	◒	
2. Market	◒	○	○	◒	◒	◒	○
3. Policy	◒	○	○	◒	◒	◒	◒
4. Research on Research	○	○	○	○	○	○	○

The priority areas in Fig. 2.1 cover a wide array of resource systems. Since one research organization could not cover them all, the relative priorities were aggregated to determine priorities amongst the activities as well as to confirm the priorities for the resource systems.

The future ICLARM's priorities are to undertake these research activities, to address the critical international research issues of managing fisheries in developing countries, assessing their potential for enhanced fisheries, removing socioeconomic and environmental constraints and developing fish breeds, husbandry and farming systems for aquaculture growth. ICLARM will also increase its activities in institution building for stronger national programs.

All these activities will be oriented to address problems and opportunities in three resource systems: ponds, estuaries and lagoons, and coral reefs. Research and institution building activities will continue to focus on the Asia/Pacific region. SubSaharan Africa will receive less attention until its needs are better understood. Other regions will be included through ICLARM's global initiatives. How these priorities for activity, resource systems and regions are put into programs of work is the subject of the next chapter.

CHAPTER 3
Programs

This chapter describes the future ICLARM's programs for research and related activities. Each program description is prefaced with a reminder of both the critical international research issue and the ICLARM objectives, relative to the issues, to be addressed. Programs are described by objectives, rationale, strategy, and potential impact. Program strategy consists of a statement referring to the whole program followed by a detailed elaboration of the scope and mode of research for each thrust identified in the strategy. However, before providing these detailed descriptions, it is necessary to establish a basis for building programs.

Regions were rejected as a basis for programs because the levels of activity between them are so different. The difficulty of using commodities as a basis for program development was noted earlier. Activity type fails as a basis for program building because it does not force interdisciplinary scientific effort towards the all important interaction shown in the Venn diagram of resource systems (Chapter 2). Similarly, a disciplinary basis for programming would raise barriers to interdisciplinary work. Conversely, building programs on resource systems would not only foster the kinds of research approaches needed to deal with the critical international issues identified, i.e., bring together biological and social scientists to work on the management of aquatic resources, but also build on the strengths of ICLARM and its goal and objectives.

Thus, the future ICLARM's research programs are built on three resource systems: ponds, estuaries and lagoons, and coral reefs. The recognition of a need for strengthening national programs as a critical international issue and in ICLARM's objectives provides a basis for program building in this area.

The major research issues that will be addressed concern resource management which shows a natural separation into inland and coastal areas. The resource management needs of the former deal more with farm management while those in the latter concern mainly management of common property resources.

The marine area includes a heterogeneous group of ecosystems - estuaries, bays, lagoons, mangroves, seagrass and reefs making up the broad coastal resource system.

The future ICLARM will take a systems approach to coastal problems although there will be a focus on estuaries and lagoons. However, coral reefs were identified as having a high potential for increasing yields and in many locations they form a discrete resource and ecosystem. Also, due to their great faunal and structural similarity around the circumtropical belt, there is particularly high transferability of results from one area to another, justifying a separate program (see Coral Reef program description for additional justification).

Based then on the resource systems and strengthening needs, the future ICLARM will have four programs:

- Inland Aquatic Systems
- Coastal Resource Systems
- Coral Reef Resource Systems
- National Research Support

This program structure allows a high degree of integration and thus efficiency. While there are clear discrete thrusts in each program, all have some common elements which bind them. Each program will need to understand, describe and analyze the resource system, then identify and verify ways to improve the system, and finally to implement and evaluate the impact of the improvements. This will require common approaches and methodologies across programs, e.g., databases, modeling and participation of users. One common research theme that binds all three research programs is farming/fishing systems.

This approach which builds on the previous 20 years of experience in farming systems will be applied to farms but also expand this concept of a holistic, systems-oriented, multidisciplinary and user perspective to fishing communities.

Likewise the National Research Support Program is closely linked to the other research programs as it will often rely on their research output as the direct vehicle for NARS strengthening.

The integration of programs described will be further reinforced in the way ICLARM will manage its research. Three divisions - ecology and biology, farming/fishing systems and social science - will bring together the common elements exemplified above.

Having established the basis of the programs, a description of each is presented. Three of the programs, Coastal Resource Systems, Coral Reef Resource Systems and National Research Support will be further developed during the ICLARM mid-term planning in 1992; for example, the Coral Reef Resource Systems Program benefitted from an international meeting in Townsville, Australia, in March 1992.

Inland Aquatic Systems Program

This program is designed to address the following critical international research issues:

- Improved fish productivity through genetic gain and better husbandry
- Development of integrated agriculture-aquaculture farming systems
- Removal of socioeconomic and environmental constraints to aquaculture growth

and to contribute to ICLARM's objective to devise and improve production systems that will provide increasing yet sustainable yields.

Objective

The program's objective is to foster the adoption of sustainable inland aquaculture by resource-poor, small-scale producers and thereby to increase fish production and income.

Rationale

Inland aquatic resource systems include small waterbodies (ponds and rice field floodwaters), larger waterbodies (lakes and reservoirs) and floodplains and watercourses (including streams and rivers). Estuaries are considered part of coastal resource systems. The priority inland aquatic resource system for the future ICLARM is that of freshwater ponds and rice field floodwaters in irrigated and rainfed cropland agroecosystems, here termed collectively 'ponds'.

As in coastal areas, rapid population growth in the agricultural heartlands of developing countries and the cities that they feed is creating increasing demand for aquatic produce that inland capture fisheries will be unable to meet. Moreover, increasing demands are being made on small-scale farmers to raise the productivity and profitability of their operations, from resources that are becoming increasingly stretched.

One attractive solution is to produce more food and profits by aquaculture and enhanced fisheries from waters managed for agriculture, domestic consumption, forestry, power generation and waste treatment. Better aquatic management can yield huge benefits. Fish are highly nutritious and profitable produce.

Aquaculture is defined as the farming of aquatic organisms, almost exclusively finfish in inland areas. Farming implies interventions in the rearing process such as captive breeding, feeding and protection from predators and explicitly involves clear individual or group ownership of the fish until harvested. Aquaculture can be usefully classified as extensive, having no fertilizer or feed inputs; semi-intensive, having limited fertilizer and/or feed inputs; and intensive, largely or totally reliant on feed inputs.

Enhanced fisheries are akin to aquatic ranching, where waters are stocked with juveniles raised in hatcheries; the fish then exploit natural productivity and are harvested, with appropriate fisheries management, ownership and access arrangements. Enhancement of inland fisheries in large waterbodies such as lakes, reservoirs and floodplains probably also has great potential but this is less proven than for aquaculture *per se* and its development will require an exploratory long-term approach.

Inland pond aquaculture is ripe for expansion. Most developing countries have almost no fish farmers. Even in the few Asian countries with long aquaculture traditions, less than 1% of the total farming population is involved in aquaculture. The basis for significant expansion of inland aquaculture will therefore be adoption of aquaculture enterprises by new entrants. These new entrants can and should be the millions of resource-poor, small-scale farmers of the developing world. They could benefit greatly if they adopt sustainable, profitable, equitable, environmentally-compatible and safe inland aquaculture systems, tailored to their available resources, sociocultural circumstances, institutional factors and market opportunities. They already manage water for agriculture and the opportunities afforded by the new frontier of aquaculture should be theirs, not primarily occupied instead by larger corporate interests.

What kind of aquaculture should be developed? It should be *semi-intensive* and integrated synergistically with other farming enterprises and homestead activities. Semi-intensive aquaculture comprises low-input, low-cost systems that are relatively nonpolluting and have few disease problems. They are also more compatible with the skills and sometimes the indigenous knowledge of small-scale farmers and also have wide variety and scope for improvement.

Intensive systems, especially 'stand-alone' fish farms, are more capital intensive, often create environmental problems because of their wastes, have high management requirements and can be very risky. They are usually inappropriate for small-scale resource-poor producers.

Extensive systems have relatively low yields and are often dependent on common property resources, especially waters, that are becoming overexploited.

Synergism between semi-intensive aquaculture and other farming enterprises is already well-proven. The key is to develop small fishponds on cereal crop-based and mixed farms and to produce fish in flooded rice fields. The pond itself can be a longlasting water store for agriculture: this is particularly useful in rainfed areas. Agricultural residues and by-products are good feeds and fertilizers for fishponds and pond mud can increase soil fertility for vegetable and fruit production. The most widespread and valuable interactions are between crop, vegetable and fish enterprises, since most farms are cereal crop-based and poor farmers have few or no livestock.

Rice fields are excellent nursery systems for fish and small pond refuges that, coupled to or decoupled from rice fields, can facilitate very flexible integrated rice-fish farming systems. This holistic approach elevates rice-fish culture from the conventional narrow approach ('fish in rice fields'), which is usually extensive and low yielding, to a semi-intensive systems approach of full integration with other farm enterprises. Fish can be an integral part of Integrated Pest Management (IPM) in crop-fish integrated farming systems and can help to cut down the use of chemicals. Fish can also increase soil fertility and raise crop yields.

There are many other mutually beneficial interactions that are possible between aquaculture and other enterprises: trees, livestock and homestead activities.

Semi-intensive aquaculture enterprises on small-scale mixed farms can provide highly profitable produce, better cash flow and reduced risk through diversification of enterprises from part-time labor: often an opportunity for women, similar to backyard poultry raising. They are also a means of linking on-farm resource utilization and integrating farm enterprises, thereby increasing efficiency and sustainability.

What is preventing expansion of this kind of inland aquaculture? The short answer is reluctance and risk perception, stemming from a basic lack of knowledge of how such systems work and how they can be optimized. With so few fish farmers in most developing countries, adoption of inland aquaculture is widely perceived as complex, strange and risky and *is* in fact so because of the shortcomings of the aquaculture systems currently available for adoption. Better systems are needed that will be appropriate to the attitudes, resources and calendars of activity of farmers and that can integrate new knowledge with their indigenous knowledge.

How to optimize the integration of aquaculture enterprises with others on small-scale farms is not well-known. The fishpond itself is like a black box: knowledge of its nutrient dynamics is very limited. Most farmed fish breeds perform like wildtypes or worse, because no sustained attempts have been made to improve them, ignorance of the consequences of poor broodstock management has brought widespread inbreeding depression and indirect negative selection on existing fish farms.

ICLARM's comparative advantage to help solve these problems derives from its history of work in Asia and Africa, conceptualizing and executing collaborative research towards superior fish breeds for better low input integrated farming systems. ICLARM's existing Aquaculture Program concentrates on these themes and the new research agenda proposed here will have continuity with ongoing activities and will capitalize on the Center's strengths. The Center has led in the identification of the key research issues for these improvements and has worldwide and well-developed working relationships with NARS and ASIs that are prominent in this field, particularly with the Asian Institute of Technology (AIT), Bangkok (where a professional team has been working on small-scale integrated farming systems for about 13 years), and major projects in Bangladesh, Malawi and the Philippines. ICLARM also has a leading position in the organization and execution of collaborative research on genetic improvement of freshwater finfish - from documentation of wild and farmed fish genetic resources to their evaluation and use in national breeding programs - and in the formation of networks, including an international Integrated Rice Fish Research Group in collaboration with IRRI, part of the Asian Rice Farming Systems Network.

The Program will address key constraints - lack of good fish breeds and reliable integrated farming systems and reluctance of potential entrants to adopt inland aquaculture - by interdisciplinary research on sustainable inland aquaculture systems. It will undertake genetic, other biological component research and socioeconomic, institutional and policy studies within a research framework that can be termed 'better breeds for better systems'.

The program's component research will be driven by outputs from farming systems research, principally user and potential-user perspectives. It will develop fish breeds that feed low in the foodchain, largely on protein- and micronutrient-rich natural foods, generated *in situ*, and supplemental energy-rich feeds, all derived from low-value resources available on farms or from adjacent enterprises. This work will concentrate on a few species of wide strategic importance among the African tilapias and Asian carps.

Combinations of selective breeding and genetic management (for example, gene transfer and other biotechnology currently under investigation in several ASIs) promise huge advances but the technology is at a very early stage of development. ICLARM will work closely with such ASIs and will provide opportunities for advancing this field of work on tropical species and systems.

Much of the results of the program's work on breed and system development will be widely transferable because the species of tilapias and carps, on which ICLARM and collaborators will work, are farmed throughout the tropics; the pond microorganisms and other biota that drive freshwater aquatic foodchains are similar in all tropical developing regions. In addition, wider adoption of inland aquaculture will greatly encourage, indeed necessitate, better water management. This will have positive effects on soil conservation and will help efforts to mitigate the degradation of catchment areas, many of which have similar environmental problems to coastal areas.

The chances of success are high, particularly in Asia. ICLARM's experience is that small ponds, with current unimproved breeds and farming systems, already return over US$1,200/ha in 5-10 months for new adopters in Bangladesh (40% of whom are women) and produce 2.5-6.0 t fish/ha/year for about 300 new small-scale integrated farmers in Malawi. Moreover, the work of ICLARM and its collaborators on genetic improvement has recently shown in the Philippines that a new synthetic base population of Nile tilapia, upon which selection still has to be started, grows 30-60% better than breeds in current use.

Despite these benefits and a high chance of success, the constraints to adoption of inland aquaculture will not be overcome easily, especially in Africa. Adoption of new enterprises by new entrants faces many difficulties. There is a need to identify and understand the socioeconomic and institutional factors which promote or retard adoption. In Asia, lack of a tradition of aquaculture in, for example, Laos and Nepal, has not prevented its recent expansion. Throughout the Asian humid tropics, especially in IndoChina, expansion of inland aquaculture can be rapid. In Africa, a different agricultural history, a greater reliance on inland capture fisheries and a lack of a recent tradition of fish husbandry in most countries could pose special problems. There are, however, hopeful signs in a few countries, notably Malawi.

The program will also explore and catalyze research on other inland aquatic systems, such as the reservoirs, lakes, floodplains and wastewaters that might support inland aquaculture and enhanced fisheries.

Strategy

Better small-scale integrated farming systems that incorporate semi-intensive aquaculture and appropriate breeds of fish *must* be developed *together* and with a clear understanding of the perspectives of existing and potential new entrant farmers and consumers and environmental consequences (positive and negative). Thus, research on all aspects must be interactive and done in parallel.

Breeding research will provide methodologies to develop improved breeds tailored to various farming systems and markets. The program will catalyze and help to guide the development of national fish breeding programs. In the medium to long term, it will be these national programs that will develop better breeds and conserve germplasm of a wide range of farmed fish species.

The future ICLARM will, in collaboration with NARS and ASIs, develop improved germplasm of a few widely used African tilapia and Asian carp species for low-input, semi-intensive systems, with associated germplasm banking and regional testing.

It is a relatively new approach in aquaculture research to propose genetic improvement of fish and scientifically-based management of aquatic foodchains for such systems. Previously, it was generally felt that breed improvement should apply only to intensive aquaculture.

Husbandry research will focus on pond dynamics to understand and optimize the management of nutrient flows. This will provide key information for farming systems research, which is defined here very broadly as interdisciplinary research on whole farm systems, involving biologists, ecologists and social scientists. The farming systems research will develop management strategies for integrating aquaculture into small-scale crop-based farming systems.

The 'Farmer First' approach will be used and a major emphasis will be given to understanding the perspectives of potential new adopters of aquaculture and the reasons for adoption or rejection. This approach recognizes that successful adoption will depend upon the participation of potential new entrants in the research and that the farming system must be compatible with the social, economic and institutional circumstances of their households and communities. This is an innovative approach in aquaculture research. Most aquaculture research to date has focused on the relatively small numbers of existing fish farmers (who are often atypical of the farming community) and attempted to improve their production and has neglected the vast numbers of potential new entrants who could benefit from adoption of aquaculture, and whose entry would add up to millions of tonnes more production per year, even when derived from small, semi-intensive ponds and rice field floodwaters giving modest fish yields.

The program's work to produce fish breeds and systems that are attractive to resource-poor new entrants will require a centralized interdisciplinary team based at a headquarters equipped with experimental ponds, tanks and laboratories. However, maximum use will be made of collaborative research networks, other partnerships and contracts to make sure that the strengths of ASIs, IARCs and NARS are tapped to advance the work, especially where they can provide the use of dedicated research facilities or opportunities for strengthening these cost-effectively. The key requirement is that facilities be available for sustained research. In many NARS, aquaculture research facilities often undergo a change of use, mainly for seed production, once some expansion of aquaculture has started and thereafter become unavailable for answering research questions.

The interactive core research thrusts proposed are aimed at: improved fish productivity through genetic gain and better husbandry, development of integrated agriculture-aquaculture farming systems, and removal of socioeconomic and environmental constraints to aquaculture growth.

Exploratory research on enhanced inland fisheries will be done through commissioned reviews and collaborative projects.

The scope and mode of research for the three core thrusts now follow.

Thrust 1:
Improved Fish Productivity Through Genetic Gain and Better Husbandry

SCOPE OF RESEARCH

Germplasm/Breeding. Research methods and strategies will be devised and implemented to develop improved carp and tilapia germplasm for farmers operating low-input, inland aquaculture systems and will help to initiate and thereafter interface with national breeding programs. There will be parallel studies on user (farmer and consumer) perspectives and the economic, social and environmental impacts of improved fish breeds. Strain registries and records of wild and captive fish genetic resources will be kept in the multipurpose relational database (FISHBASE) at headquarters.

Nutrient Flow Modeling/Pond Dynamics. The husbandry focus will be on flows of major nutrients (e.g., N, P, protein, energy) within the foodweb of small ponds and flooded rice fields receiving low value inputs in integrated farming systems. Flows will be elucidated by pond dynamics research, including consideration of the impacts of new improved fish breeds. The results will be channelled into bioeconomic and ecological modeling work (see below) to determine the possibilities for synergism among aquatic and other farming enterprises and to assist the evolution of management guidelines for sustainable integrated farming systems.

MODE OF RESEARCH

Genetic gain will depend upon germplasm improvement and breeding programs. Genetic research methods and breeding strategies, consonant with the conservation of biodiversity, and germplasm improvement and banking (live fish collections and sperm cryopreservation) for species of wide importance will be done through a collaborative research network, and other partnerships and contracts with NARS and ASIs. Headquarters facilities will be established for further research on the documentation and evaluation of tilapia and carp genetic resources and germplasm improvement and banking, with three core research specialists: a quantitative geneticist, a population geneticist and a network coordinator. Training, related to this research, will be a major feature and will assist the development of national breeding programs.

The work will be largely centralized at headquarters, with networking in Asia and Africa and substantial long-term collaborative partnerships where development of national breeding programs has already been stimulated [e.g., India (carps), Philippines (tilapias)] or is likely [e.g., Thailand (carps and tilapias)]. Collaboration in Africa will also be through networking wherever the needs of NARS and aquaculture development suggest that the Center has a comparative advantage to help. There will be close collaboration with ASIs that are prominent in fish genetic research and with the increasing numbers of genetic research projects, genetic resources bureaux and networks among NARS and ASIs.

Pond dynamics research and nutrient flow modeling will be done in close collaboration with AIT, with parallel linkages to the USAID-Pond Dynamics CRSP, NARS, IARCs and ASIs. Networking will be pursued as a means of maximizing cost-effectiveness of data gathering and analysis. These collaborations, which will be largely concerned with pond systems research on-campus and on working farms, will be complemented by in-house component research at ICLARM's headquarters, which will require tank and laboratory facilities for simulating pond components and studying nutrient flows by sophisticated biochemical techniques.

While these facilities are awaited, the work will be largely decentralized with data generated mainly from collaboration with NARs and ASIs and from the Center's integrated farming projects in Africa and Asia. Ultimately, the balance between headquarters and decentralized work will be about 50:50. The work will require three core staff based at headquarters: a pond biologist/ecologist, a pond dynamics expert/nutrient modeler and a fish husbandry specialist.

Thrust 2: Development of Integrated Agriculture-Aquaculture Farming Systems

Scope of Research

There will be two interdependent activities: 1. bioeconomic and ecological modeling, 2. integrated agriculture-aquaculture management strategies.

Bioeconomic and Ecological Modeling. The bioresource and cash flows and the social and environmental impacts of integrated farming systems will be modeled at whole farm (including the homestead), community and agroecosystem levels, emphasizing sustainability, productivity, profitability, stability and equity including gender, nutrition and public health issues. Ecological processes will be modeled using steady state, i.e., ECOPATH, and dynamic modeling programs. These models will be used to understand the dynamics of integrated farming systems and will themselves help to drive further research. Software and guidelines will be developed for researchers, especially for quantifying impacts on people and the environment and to assist training and extension.

Integrated Agriculture-Aquaculture Management Strategies. Management strategies will be developed for sustainable, equitable, environmentally compatible, and safe integrated farming systems. Key research and information gaps will be identified through farmer participatory research and resource flow modeling for integrated farms and other inland aquaculture and aquaculture-based enhanced fisheries. A relational database (FARMBASE) will collate information going to and coming from nutrient flow and bioeconomic modeling work and will become a global resource for integrated farming systems research, training and information.

Mode of Research

This work will be coordinated from headquarters but will involve a large measure of collaborative research with NARS, community level NGOs, ASIs and IARCs through a combination of key sites and networks. Long-term collaboration will be sought with ASIs having particular strengths in modeling and farming systems research. Key sites in Asia and Africa will be selected on the basis of agroecosystem type, local institutional support and human pressure on the resource system. Examples are irrigated and rainfed ricelands in IndoChina and the Philippines and maizebased/dambo systems in southern Africa. The general principles of integrated agriculture-aquaculture will apply across a wide range of systems.

Modeling and database work at headquarters will draw upon the results of this collaborative research and partnerships. The models will also help to 'drive' research as they evolve. The core group of staff required will comprise a modeling specialist, three farming systems specialists (one with specific responsibility for outreach to Africa) and a database expert.

Thrust 3: Removal of Socioeconomic and Environmental Constraints

SCOPE OF RESEARCH

Inland aquaculture will not be adopted by small-scale farmers unless the systems available for adoption are compatible with the social, economic, institutional and physical circumstances of their households and communities. The research proposed will consider all these factors and also the complexity, risks and management requirements of new systems. In addition, resource requirements (land, labor, capital), returns and attitudes to innovation will be carefully evaluated with respect to culture, use conflicts, resource access and property rights. Costs, returns and cash flows of the system will also be evaluated and marketing infrastructure (credit, markets and input availability) investigated. Extension services (training, research and technical asistance) and legal and organizational structures to support adoption of the systems will also be considered.

Aquaculture development and innovations (and indeed interventions of any kind in the agrarian systems of developing countries) must not cause equity shifts or changes in access to resources that will disturb or threaten basic household nutritional requirements. There is, of course, potential to improve the nutrition of farming families through aquaculture: they can consume 'spare', small or otherwise less marketable produce - as in agriculture. However, new technology is never neutral and policymakers and planners must assess the possibility of negative effects.

Many families in existing and potential fish farming areas in developing countries are extremely poor and are on the margin with respect to protein-energy malnutrition. The increasing acceptance of the 'Farmer First' approach, rather than top-down technology transfer will help to avoid interventions that could threaten the nutrition and health of farming families. Farmers will be asked for *their* perspectives on food production for livelihood and for family food security. For example, where land holdings are very limited (a common situation in developing countries) it may be inappropriate to try to persuade farmers to build ponds and thereby eliminate or reduce the capacity to grow crops for the families' own security. There is little or no margin for error here, especially where climatic and other uncertainties threaten family food security, as in SubSaharan Africa. Adoption of new farming systems can therefore pose high risks. An interactive combination of on-station and on-farm research, emphasizing the involvement of farmers at all stages of conceptualization and testing will help to ensure that new developments avoid negative effects.

The public health aspects and the environmental impacts of aquaculture will be considered as part of the *total resource system* of which aquaculture, its policymakers and practitioners (effectors), its beneficiaries and other affected persons form parts: in other words, a holistic, ecological approach will be taken.

MODE OF RESEARCH

This research agenda will be accomplished largely by catalyzing wider studies in collaborating NARS, IARCs and ASIs and helping to collate and interpret the results and by collaborative studies at key work sites. The work will be closely linked with the future ICLARM's farming systems research in Africa and Asia and the NARS strengthening activities of the Asian Fisheries Social Science Research Network. The future ICLARM's main role will be in exploring these constraints and working with others towards their further elucidation and, where possible, mitigation or removal. This work will be led and coordinated by a social scientist based at headquarters.

Potential Impact

As emphasized in the rationale, the research thrusts needed to expand inland pond aquaculture are all interdependent. The impacts of their results are also interdependent. Better breeds and better farming systems can increase the productivity and profitability of existing fish farms, but these would give only marginal increases in most developing countries. Large gains for the benefit of large numbers of small-scale producers can only come by new entrants adopting inland aquaculture. For example, adoption of rice-fish culture yielding only 200 kg of fish/ha/year (double the current lowest estimates for yields using unimproved breeds and systems) by only 10% of rice-based farmers in tropical Asia would probably yield about 1 million tonnes of fish per year, worth at least 1.5 billion US dollars.

Because genetic gain, better integrated farming systems *and* adoption by new entrants are all essential ingredients for a major impact, the expectations for each are now summarized, before forecasting an overall impact.

Very rapid initial genetic gains will come from adoption by small-scale farmers and hatchery operators of broodstock management that will avoid genetic deterioration in their fish. Moreover, genetic gain in growth rates of about 10% per generation is expected from selective breeding: i.e., up to 15% per year for tilapias and about 5% per year for carps, having longer generation times. The impacts of combining biotechnology and selective breeding could be very much greater still with significant gains, yet to be quantified, in many commercial traits related to breeding and product quality.

The initiation of self-sustaining national breeding programs for carps and tilapias in at least five Asian countries and planning for the same in at least three African countries is anticipated within ten years, with reliable guidelines for strategic decisionmaking on cross- and pure-breeding, how to combine biotechnology with selective breeding, use of exotic and native species, quarantine and fish health, technical support, assessment of the social and environmental impacts of adoption of improved breeds, and policies for conservation of genetic resources of farmed fish.

Within five to ten years, there will also be reliable guidelines for sustainable, synergistic, integrated agriculture-aquaculture systems involving fish as a component of IPM strategies; and as an aid to improve aquatic and soil fertility and increase yields of crops, vegetables and trees; and as a cash crop raised from on-farm by-products. This is expected to at least double the fish yields and overall profitability of systems in current use, based on theoretical assumptions of improved aquatic productivity in small ponds and rice field floodwaters by management of foodchains.

Given that there are no unforeseen insurmountable constraints, which is probable for South and Southeast Asia, and possible for some SubSaharan African countries with adequate water resources, it is anticipated that there *will* be widespread adoption of the new breeds and systems developed. For the individual farm household, this will increase farm profitability.

Overall, it is anticipated that the proposed work could result in a doubling of developing-country inland aquaculture production from 5 to 10 million tonnes within 10-15 years and a wide recognition of fish as *routine* produce from small integrated farms in developing countries.

Coastal Resource Systems Program

This program is designed to address the critical international research issue of sustainability of coastal resource systems. This includes understanding the dynamics of the aquatic resources themselves, the fishers that exploit them and the broad intersectoral forces which impact on them, including pollution, other economic activities and the institutional and policy environment. In order to do this, the program will have to deal with conflicts both within the fisheries sector and between sectors. Overall, the program will contribute to ICLARM's goal of improving the biological, socioeconomic and institutional management mechanisms for sustainable use of coastal resource systems with primary emphasis on living aquatic resources (i.e., the fish resource). The following presents the overall framework which will be further developed during the medium-term plan.

Objectives

The objectives of the program are:

i) to understand the dynamics of the aquatic resources of coastal resource systems such that management interventions leading to high yet sustainable catches can be identified and implemented;

ii) to understand the dynamics of the living aquatic resource use sector, the fishers including their economic and social behavior, the fishing communities, markets and policies such that appropriate management interventions can be designed which will be implementable at the community, local government and national levels;

iii) to describe and understand the effects on living aquatic resources of intersectoral factors affecting coastal areas, thereby assist ICLARM's client countries in the formulation of coherent policies for sustaining or developing their living aquatic resources through integrated development and management of their coastal areas.

Rationale

Throughout the tropics, coastal fisheries are under threat. The resource base upon which they depend is much reduced in terms of biomass and biodiversity, with valuable, large species rare on many fishing grounds and the harvests often dominated by low value and seasonally variable small fish. The coastal fisheries suffer from excessive numbers of new entrants: not only new family members in fishing households, but often the landless to whom fishing has become an occupation of last resort.

Given the finite nature of the resource, these new entrants reduce the harvests of existing fishers - a repeat of the "tragedy of the commons". Fishing communities, faced with reduced harvests have increasingly tolerated destructive fishing "gears" such as explosives and poisons, seriously depleting the resources; a process now called "Malthusian overfishing".

At the regional and national levels, export-oriented policies and subsidies encourage urban-based, industrial fisheries also exploiting coastal fisheries resources, in direct competition with small-scale fisheries. Also encouraged are development schemes, notably the aquaculture of shrimps in coastal wetlands which further reduces the habitats from which young fish are recruited into coastal fisheries.

Inland, deforestation, mining and urbanization generate millions of tonnes of silt, tailings and wastewaters that are flushed through estuaries and coastal lagoons, further reducing the extent and quality of critical fisheries habitats.

Not all facets of this bleak picture occur along all developing-country coastlines - indeed, some countries still have vibrant coastal fisheries. Yet, throughout the tropics and especially in Asia, most fishers belong to the "poorest of the poor", and the fisheries trends and intersectoral conflicts alluded to above all apply, gravely threatening the sustainability of what are still major productive systems.

Given appropriate knowledge, clear policies and enforcement, these trends can be arrested and fisheries rehabilitated. Here are two examples:

- In Cyprus, a subtropical country with a coastal trawl fishery similar to those in much of Asia, research identified the crucial "window" in space and time during which young fish were particularly vulnerable to excess fishing. A small shift of the existing closed season led to a 40% increase in catches in the first year, and a similar increase the next. This response, now referred to as the "Cyprus effect" in the fisheries literature[a] also helped establish a dialogue between fishers and scientists, which later enabled other management measures (increased mesh sizes, fishing in deeper waters) to be implemented, thus reversing a trend that appeared inexorable.
- In Tunisia and other western Mediterranean countries, a system called "bordigue"[b] has been perfected which fully utilizes the growth potential of the young fish which penetrate into coastal lagoons. This system leads to sustainable catches 3 to 5 times higher than in lagoons lacking bordigues. The principal obstacles to the adoption of this system outside of its area of origin are cultural; a high level of consensus and cooperation is required from the fishers jointly exploiting a lagoon fitted with a bordigue.

The two examples illustrate positive interventions of a technical nature, within a largely unchanged management and resource allocation framework. Fewer examples exist of positive interventions which changed the patterns of allocation of coastal resources. One such example is the ban on trawling in western Indonesia, promulgated in 1980, which allocated to the small-scale sector all those coastal fisheries resources, previously and inequitably shared between a small number of relatively wealthy trawl operators and hundreds of thousands of poor small-scale fishers. Although this ban was not closely monitored, sufficient studies exist to demonstrate that this intervention resulted in coastal resources rapidly "bouncing back" and hence in increased incomes among coastal fishers[c]. However, the transferability of this approach to other countries

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[a] Garcia, S. and A. Demetropoulos. 1986. Management of Cyprus fisheries. FAO Fish. Tech. Pap. 250, Rome, 40 p.
[b] Chauvet, C. 1988. Manuel sur l'aménagement des pêches dans les lagunes côtières: la bordigue méditerranéene. FAO Doc. Techn. Pêches (290), Rome, 77 p.
[c] Bailey, C., A. Dwiponggo and F. Marahudin. 1987. Indonesian marine capture fisheries. ICLARM Studies and Reviews 10, 196 p.

beset with problems similar to those faced by Indonesia has never been studied. Moreover, in many developing coastal nations where multiple resource use conflicts are greatly aggravated by poverty and population growth, resolution to the issue of overfishing becomes more complicated and management measures more difficult to implement. Understanding the dynamics of the coastal resource systems and their response to different sectoral users are essential elements for designing management options.

Studies of tropical fisheries which take account of this are rare; the ASEAN/US Coastal Resources Management Project executed by ICLARM has been one of the few activities in this area. The project was successful in drawing attention to the number of intersectoral impacts which, in the ASEAN region, affect coastal fisheries and in formulating appropriate fisheries management strategies within the framework of integrated coastal zone management plans. These have been incorporated into the regional or national economic development plans of the various state/provincial or central governments.

Fig. 3.1 shows the nested hierarchical structure of and the interlinkages between the above-mentioned levels of description and/or intervention. The outer ring, the "ECOREGION" refers to those issues related to the maintenance of the environmental processes that control the health and productivity of the coastal ecosystems sustaining fish populations. Many of these intersectoral factors that harm these ecosystems and the fisheries activities therein are beyond the control of the fishery sector. For example, deforestation of watersheds increases flooding and siltation with strong negative impacts for lagoon fisheries, while landlessness produces numerous new "entrants" into fisheries that already suffer from excess fishing effort. Resolution of these wider problems requires cooperation across all sectors involved, as well as the planning agencies which guide them and the funding agencies which support them.

The next "level" of Fig. 3.1 is shared between two interacting elements, the FISHERY and the ECOSYSTEM. The FISHERY refers to all human activities concerned with the catching, landing and marketing of fish. This includes a large number of researchable issues ranging from the behavior of fleets in space and time, and the way they adjust themselves to the spatial and temporal behavior of the fish resources, the investments in fisheries, their bioeconomics, the sharing arrangements within crews and between labor and capital, the markets, the factors regulating entry into and exit from fishing, the intrasectoral conflicts (e.g., between small-scale fishers' communities and industrial fishing) and the related issue of equity, the issue of community management *vs* central allocation and management systems, etc. Work in this area requires, for any fishery, detailed and accurate data on the catches (composition, value) extracted from the "FISH RESOURCE" element of Fig. 3.1.

The ECOSYSTEM element of Fig. 3.1 refers to both the biotic and abiotic factors impacting fish populations - including interactions between populations. Issues include the spatial distribution of different coastal habitats and their responses to human activities, the impact of expected global changes (of sea levels, sea surface temperatures, current flow patterns), the (trophic) interactions of fish populations, and their impact on fish production and hence the yields available to a fishery.

The inner ring refers to the FISH RESOURCES, i.e., the genetics of the species fished, their biology, ecology, life cycles, population dynamics; and, at the level of individual countries, to the detailed distributional information generated by the fisheries. The knowledge on tropical fishes is considerable, but widely scattered, often not available in the libraries of most NARS, an issue that must be addressed if tropical fisheries management is to progress.

All elements of Fig. 3.1 are closely interrelated and must be treated as such, i.e., by making optimal use of synergisms between disciplines and of information cutting across levels. This applies especially to catch data whose size composition and distribution in time and space allow for inferences on the biology of the FISH RESOURCE species, on among-species interactions within an ECOSYSTEM context, on the value of the catch and hence fishers' incomes within each FISHERY and, as longer time series, on intersectoral impacts within the ECOREGION.

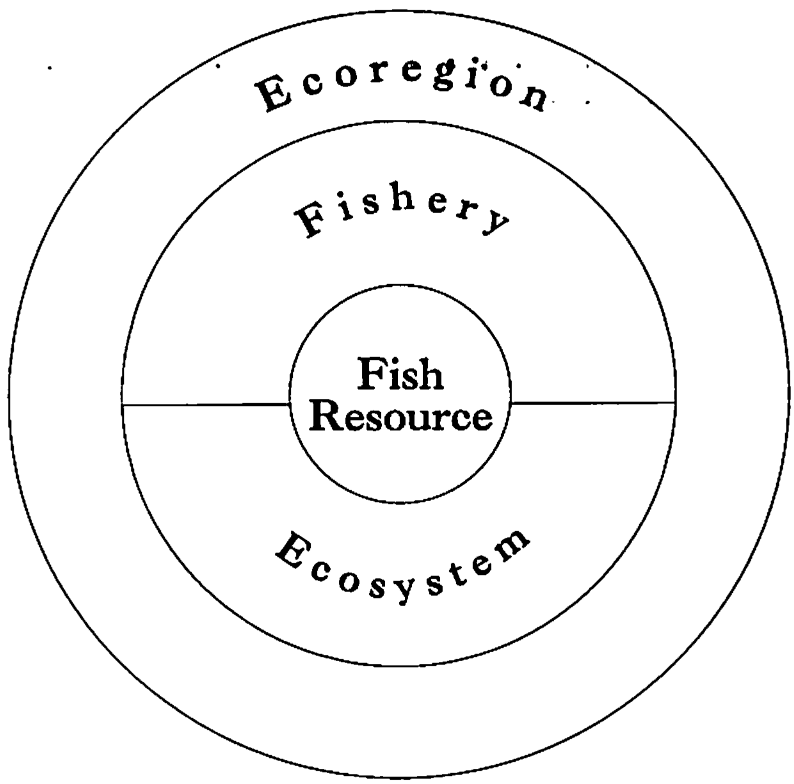

Fig. 3.1. Schematic representation of the nested hierarchies of issues in coastal systems research. The strategy proposed here involves three interconnected "Thrusts", devoted to (1) the FISH RESOURCE and the ECOSYSTEM; (2) the FISHERY; and (3) the ECOREGION.

Strategy

The Coastal Resource Systems Program will operate through three research thrusts described below. All of these will be considered in a collaborative mode and include a mixture of on-site research, "in-country" projects and research based at headquarters.

Program staff at headquarters will:

a) interact with NARS and ASIs for the joint development of methodologies for analysis of coastal resources and tropical multispecies fisheries and their management;

b) conduct regular consultations with selected NARS concerned with fisheries and related coastal sectors, identify institutional, environmental or other policy issues of general interest, prepare joint reviews of these, and communicate recent research advances;

c) interact with all interested NARS on the further development of databases, train national users in these databases and make these widely available;

Outposted staff in a few countries will:

d) help NARS in setting up computerized systems for acquiring, storing and analyzing/interpreting fisheries and related data and train NARS scientists in formulating fisheries management options, based on such information and analyses;

e) assist NARS in the development of methodologies to collect and analyze. data through case and pilot study;

f) where possible, also become involved at selected sites in designing, implementing, monitoring and documenting the impact of alternative management regimes, and in assisting NARS in transferring positive experiences to other sites.

Throughout, emphasis will be on excellence of research including assistance to NARS scientists in publishing their results in primary journals - and in transferability of experiences and methodologies to assist implementation. This transferability will be achieved both conceptually, by stressing common aspects of aquatic resource uses and management throughout the intertropical belt (e.g., the specific features of open access resources) and technically, by making the methodologies to be developed widely published in reports and papers and available as generic, user-friendly software for personal computers.

Although closely interrelated, these activities will be implemented via three thrusts:

i) Understanding the dynamics of tropical fish resources, which will provide the biological basis for management interventions and which combines the "ECOSYSTEM" part of Fig. 3.1 with those aspects of the "FISH RESOURCE" that are relevant to understanding their dynamics (growth and mortality rates, recruitment and biomass fluctuations, etc.);

ii) Management strategies for coastal fisheries, which will study coastal fisheries systems from the household and the community level, to the national policy level, with emphasis on identifying and removing sociocultural, economic and institutional constraints to improved management and sustainable fisheries;

iii) Integrated management strategies for coastal aquatic resources, which will draw together knowledge on all those aspects of coastal development and national policies impacting on the coastal zone and its fisheries and synthesize this in rigorous fashion to derive generalizable management options and policy recommendations for development compatible with sustainable coastal aquatic resources.

Thrust 1: Understanding the Dynamics of Tropical Fish Resources

Scope of Research

Fish are usually not seen, counted or weighed before they are caught, and hence, fisheries research has from the very onset, depended on indirect inferences (mathematical and statistical) for quantifying vital statistics of fish populations needed for management.

Thus, some of the earliest applications of mathematics and statistics (outside of the physical sciences) are those of fisheries biologists. A similar situation occurred with computers, which fisheries biologists have tended to use earlier than other biologists. Models and modeling are used routinely in the context of describing, understanding and managing fisheries resources.

Thus, fisheries biologists often tend to build complex and/or data-intensive models. The reason for this is not only the need to estimate indirectly the size of exploited populations, but also for two additional, interrelated reasons:

i) fisheries biologists usually have easy access to large amounts of fishery-generated field data with which to parameterize and test their models; and

ii) because of the common property nature of fishery resources, these must be managed by public agencies which also generate publicly available data.

The most important step in the development of fisheries biology as a quantitative science came through the development of basic concepts of single-species fisheries stock assessment described by R. Beverton and S. Holt in the 1950s.

This single-species approach has been very successful. However, it can be applied only to populations suffering limited fishing pressure and only if the management options that are considered do not strongly change the trophic interactions between populations. For tropical fisheries which suffer from extremely high fishing pressure or with a high interaction with other populations, the use of single-species models is problematic.

To circumvent these problems, various extensions of the Beverton and Holt model have been suggested. The most advanced of these is the multispecies virtual population analysis (MSVPA) model recently developed for the North Sea.

This model conclusively demonstrates that management advice based on MSVPA will differ radically from advice based on single-species assessment.

An example: single-species assessment suggests that mesh size for North Sea cod should be increased and would lead to increased cod yields. MSVPA predicts, on the other hand, that the increasing cod size and biomass resulting from the mesh size increase would lead to increased predation on the young of several other important species and that their yields would decline. Not even for cod would there be a gain as the more numerous large cod would increase predation on the codlings.

This type of analysis can be transferred from temperate to tropical areas. Tropical fisheries exploit what in temperate areas would be considered "problem stocks", i.e., stocks with very high fishing pressure and strong species interactions. Thus single-species methodologies in the tropics may be even more misleading than they have been in temperate areas.

The research issue is: how can multispecies models be implemented and used in tropical situations and what characteristics should such models have? Most VPA-based models require annual catch-at-age data, and this makes the existing form of MSVPA impossible to implement in most tropical situations because of (a) the difficulty in obtaining current catch statistics in (nearly) real time as required, and (b) the difficulty in routinely ageing tropical fish.

There are, however, two trends in marine biology and marine fisheries research which make implementation of multispecies models possible also for the tropics. They are (a) "phalanx analysis" in which the catch-at-age data required for MSVPA are replaced by catch-at-length data, and (b) "particle-size" theory in which the abundance of organisms ranging in size from bacteria to whales is predicted to follow certain patterns.

ICLARM has a clear comparative advantage for work in these areas, i.e., for developing, in cooperation with scientists from advanced institutions and selected NARS, a size-structured theory of fishing suitable for implementation in developing countries. This comparative advantage is mainly due to previous development at ICLARM of length-based stock assessment methods and of various, now widely distributed software implementing this methodology, as well as through the development of a tool for straightforward construction of ecosystem models, the ECOPATH II program, now also widely used by NARS scientists throughout the world.

Another asset here is the existence of FISHBASE, a database on fish developed at ICLARM and which contains for a large number of species, the bulk of the (published) information required for their incorporation into multispecies models, i.e., distribution, growth rate, diet composition, etc.

Mode of Research

The development of generic MSVPA and related models for analysis of tropical coastal fisheries will be shared between ICLARM staff and the staff of selected ASIs with experience in this area. Their development will involve close interactions with the staff of selected NARS.

The description, understanding and eventual management of selected fisheries to be undertaken in Thrust 2 (see p. 47) jointly with selected NARS will not only be supported by MSVPA and FISHBASE. Rather, this will also involve the elaboration, also in Thrust 1, of site-specific models combining general features of the fish resources concerned with locally important features.

An increasing number of NARS and ASI scientists will be involved in ensuring that FISHBASE includes not only information available from the internationally published literature, but also information extracted from the national, and/or grey literature. This will involve setting up national FISHBASE modules for a limited period in various strategic NARS and ensuring donor support for a wide dissemination of annually updated CD ROM (laser) disks containing FISHBASE, and of the required disk readers.

FISHBASE will encourage south-south transfer of knowledge on tropical fish, and will provide a standard and an outlet for "component research" on the fish resources by the national researchers. FISHBASE will also help avoid duplication of research.

Thrust 2: Management Strategies for Coastal Fisheries

SCOPE OF RESEARCH

Current coastal fisheries management strategies have, for the most part, not been successful in reversing the trend of resource degradation. There are many reasons for these failures including the open access/common property nature of the resource, lack of knowledge about the behavior, organization and social and economic structure of fishers and fishing communities, and poor planning and administration of management programs.

A wide range of information is needed for the development of effective and appropriate coastal fisheries management strategies. Essentially, this means gaining an understanding of human utilization of, and impact on, the aquatic resource system and an understanding of the nature of aquatic resource systems and their response to human uses and impacts. In addition, an understanding of both traditional and contempoary management practices of coastal aquatic resources is required.

Thus, the interaction between coastal aquatic resources and the people who use the resources is a critically important issue in fisheries research. This is largely a social science topic (economics, sociology, anthropology, political science) and includes issues of economic and social analysis of fisheries, sociocultural organization, gender and equity, enterprise and industrial organization, markets, institutional arrangements and policy analysis. A major challenge is to link social science research with biological and technological research in a mutually supporting union.

This can be achieved through the design, field testing and implementation of computerized data acquisition systems flexible enough to accommodate entry of both biological and economic (i.e., costs, price) data from the fisheries, and the output of files to software for bioeconomical analysis and interpretation of such data; as well as the training of NARS scientists in the use of such systems and in formulation of management advice emerging from the analysis of the data they contain.

While a considerable amount of information on coastal fisheries and fishers is available, it is widely scattered and often anecdotal. A systematic review of this information, including of long time-series of catch and effort data, is needed to document individual fisheries and draw out generalizations, trends and analytical tools of wider applicability nationally, regionally and globally. An early component of the research on coastal resources will be to take stock of the information and make it available.

A variety of tools/methodologies will be developed and/or standardized for coastal resource system analysis and planning/management. These include both discipline specific (economic, sociological, anthropological, political science) and interdisciplinary (rapid appraisal, GIS) tools/methodologies.

Computerized data acquistion systems, flexible enough to accommodate entry of both biological and social science data from the fisheries, will support the program's research and that of its NARS partners. This will include the training of NARS scientists in the use of such systems and in formulation of management advice emerging from such analyses.

MODE OF RESEARCH

Collaboration with selected international, national (NARS, government ministries), and local (NGOs, community groups, local government) agencies and organizations is expected to assess alternative methodological and management approaches. Case and pilot studies of selected fisheries will allow incorporation of varying social, political, cultural and economic conditions in developing appropriate tools, methods and approaches to coastal fisheries management.

The above-mentioned computerized data acquisition systems will produce outputs to be used as inputs to bioeconomic and mathematical programming models through which various fisheries management options will be quantified and evaluated. Every effort will be made to ensure the integration of the data systems in the routine activity of the concerned NARS to ensure their use past the duration of the projects and hence the continuation of model-driven data collection schemes.

Headquarters backup for these activities will include training courses and stages for scientists from cooperating NARS and publication of reviews in which the lessons learned from site- and country-specific activities will be interpreted in a global context.

Thrust 3: Integrated Management Strategies for Coastal Aquatic Resources

SCOPE OF RESEARCH

The institutions within which groups operate include not only relevant administrative and judicial organizations but also, for example, property rights systems, formal and informal political processes, economic rules and organizations, dispute settlement machinery, the bureaucratic structure, communication systems, fiscal arrangements, and other rule-based systems. Fisheries management policies in developing countries are shaped through the convergence of institutional interests between local, national and international agencies. Those concerned with reorienting fisheries management to promote socially sound and sustainable policies need to recognize this convergence of interests if they are to restructure them effectively.

On one hand, the role of national and the influence of international agencies in shaping the direction of fisheries management must be understood. The actual linkages and the policies, programs and laws which allow for management and coastal use rights must be identified. On the other hand, community groups have definite ideas about why their resources are being depleted and damaged, and about what can be done. But these perspectives are often lost because development workers and researchers addressing resource depletion do not have practical and effective ways to work with resource-user groups, learn from them, understand gender roles in resource use, or share information and new techniques.

This perspective acknowledges that the greatest barrier to sustainable aquatic resource use is the lack of knowledge about involving people - women, men, children, community groups and communities as a whole - in management of these resources. To achieve sustainable management, research in coastal areas must involve community groups in research techniques that recognize and are sensitive to their roles and responsibilities and use the results to identify problems affecting or perceived by community groups.

Evaluation of trade-offs among competing resource uses and consideration of the needs of different user groups are keys to sustainable development. For example, pollution from industrial or agricultural chemicals can affect aquaculture production and coastal fisheries. These issues are of great importance also in fisheries management and studies on intersectoral linkages will also have to understand and predict the flow of labor. There is a large intersectoral component to the overfishing problems in small-scale fisheries. In many cases, the excessive fishing effort stems from large amounts of excess labor pushed out of other economic activities into open access activities such as fisheries. This process exacerbates problems of overexploitation and greatly complicates resource management. The aim here will be to resolve intersectoral conflicts and formulate policy guidelines for reconciling multiple use of the coastal areas and coastal management plans that ensure sustainability of the fisheries. This work will include information gathered in Thrusts 1 and 2 and integrate these with information from other sectors which impact on fisheries and/or the ecosystems that support them.

Mode of Research

This thrust will be implemented as a headquarters activity with regard to the development of appropriate methodologies and the consolidation, through analyzing and synthesizing, of the results and experiences of the ASEAN/US Coastal Resources Management Project and other systematic reviews. This will be used to derive new knowledge, concepts and methodologies which can be used to improve present utilization of coastal renewable resources and effective implementation of results on new advances generated by fisheries and aquaculture research. Headquarters methodology development to be conducted in cooperation with other IARCs, ASIs and selected NARS will concentrate on testing the suitability of a variety of tools and methodologies, including mathematical programming, decision analysis, hierarchic process analysis, benefit-cost analysis and related methods for evaluating intersectoral impacts and management options and for valuating open access resources including fisheries and their externalities. This will be supported by approaches involving intertemporal cost accounting to deal with long-term aquatic resources depletion, i.e., with the sustainability of fisheries "development" and the general issue of intergenerational equity.

Support is to be provided by this thrust to site- and country-specific activities but will generally concentrate on evaluating the direct and indirect impacts of various national policies concerning natural resources allocation on fisheries management and the impacts of other coastal developments on the suitability of coastal fisheries and aquaculture. This part of the work will require use of GIS, and should lead to an improved appreciation of the general applicability and limitations of this tool for management and planning in the fisheries and related sectors.

ICLARM will continue its catalytic role in developing holistic approaches to coastal fisheries management (in collaboration with NARS), by developing case studies at carefully selected pilot sites with varying social, political, cultural and economic conditions. This will allow field testing, refining and sharing of tools and methodologies developed by the Center and elsewhere as well as providing opportunities to identify new research areas.

This thrust will also contribute to and use the ICLARM database on country-specific information mentioned in conjunction with Thrust 2. This database will be used for "globalization" of some quantitative results of Thrust 3. However, it is expected that the bulk of these results will be disseminated through published reviews and, more importantly, through training of NARS scientists and planners and policymakers.

Potential Impact

Over the next decade, these thrusts are expected to:

- demonstrate convincingly that many fishing communities can, if empowered to do so, manage coastal fisheries resources in sustainable fashion and thereby in many cases increase both their catch and standard of living;
- strengthen a number of NARS to follow up on the results from cooperative pilot projects and to implement similar schemes in a large number of communities;
- provide, through NARS implementation, sustainable fish catches and other benefits such as greater biodiversity for the relevant sites;
- influence the perception of policymakers and resource managers with respect to the development of environmentally sound and socially equitable policies, and the formulation of management and development plans for coastal areas.

Coral Reef Resource Systems Program

This program is designed to address critical international research issues related to the potential productivity of coral reef fisheries and the scope for increasing sustainable harvests by the development of aquaculture and fisheries enhancement systems. Additionally, a variety of management systems for coral reef fisheries need to be examined, including the role of marine protected areas in sustaining production and conservation of biodiversity. These activities invariably have complex social and economic settings which must be understood before effective management systems can be devised for coral reef resource systems.

Objectives

The Program's objectives are to:

i) improve income-earning opportunities and available foods for coastal villages through the development of village-based aquaculture and fisheries enhancement systems in coral reef environments;

ii) improve management of coral reef resource systems as a result of effective synthesis of information on the coral reef ecosystem and the human interactions, the creation of sustainable fisheries management models and the development of effective community-based management systems.

Rationale

Coral reef systems dominate tropical seas, except in upwelling zones and areas which receive heavy freshwater inputs. The coral reef system can be defined as encompassing those areas within the sunlit zone, in which reef-building corals are able to colonize solid surfaces on stable sediments. The global extent of this area has been estimated at about 620,000 km^2.

The reef crests are the most prominent part of a coral reef part of a coral reef system but in terms of the resource it is the environment which the reef creates which is the most important: namely the sheltered lagoon systems, back reef areas, reef flats and coralline shelves. Reefs can take the form of barrier reefs, fringing reefs, patch reefs or atolls, but the most extensive habitats are wide areas of shelf or lagoon floor which are studded with outcrops of coral, with intervening areas of sand, silt or seagrasses. The shores of coral reef systems are often fringed with narrow stands of mangroves, but never with the vast mangrove forests which occur in deltaic areas.

The productivity of coral reef systems is very high, by virtue of the symbiosis which exists between symbiotic algae and reef-building corals. This is further enhanced by the nitrogen-fixing abilities of many algae and by the filter-feeding activities of countless reef animals, which capture phyto- and zooplankton from the passing ocean currents and thus concentrate energy within the reef system.

The precise levels of yields from coral reef systems are poorly known but the available information suggests that current harvests of the order of 4 million tonnes globally are underestimated (see Box 4) and this would add to the importance of this resource system.

Box 4
Coral Reefs

Primary Production

Primary production in coral reefs is commonly 10 to 100 times higher than in open ocean waters and comparable to the highest values reported from terrestrial ecosystems.[1]

Fish production

Fish production from coral reefs is higher than from any other natural fish production system, with reported yields ranging to over 35 tonnes $km^2 year^{-1}$. An estimate of 8 tonnes has been suggested as an average potential for reef production based on work by J.L. Munro in the Caribbean.[2]

There is controversy over the base area and the mean catch/area estimate, as well as over global catches and potential catches. Recent evidence[3] indicates that at least in heavily exploited reefs of Southeast Asia and the South Pacific, catches are much higher (8-37 $km^2 year^{-1}$) than previously assumed. Moreover, gathering/gleaning has not usually been included, although it may add another 30-50% to the catches of fish.[4,5,6]

There is considerable evidence that reef catches worldwide decline substantially with heavy fishing pressure. There is also evidence, especially from Southeast Asia and Australia, that reef recovery is quite rapid when the exploitative or destructive pressure is removed.[3]

Reef Area

The best available estimate of the coral reef area in the world is 617,000 km^2, shared by over 100 countries - many of them small island states in the (Western) Atlantic, Indian and (South) Pacific Oceans, or populous archipelagic states (Indonesia, Philippines).

Diversity

The biodiversity of coral reefs is very high - rivalling that of tropical rainforests. Species diversity is highest in the western Indo-Pacific (2,000 fish species) and lowest in the Atlantic (200 species in the Caribbean). Reef species in the Caribbean differ from but are relatives of those in the Indo-Pacific and occupy similar niches, thus allowing transferability of results.

Coral Reef Fishers

The number of people relying on coral reefs for food and livelihood is hard to estimate but could be 4 million fishers, assuming a global catch of 4 million tonnes, and an annual catch rate of 1 t per person.

Sustainability

The highly fished reef areas of the Caribbean Indian Ocean and Indo-Pacific are under considerable threat, as high fishing pressure is often combined with land-based pollution (siltation, increased organic loading); destructive fishing techniques (explosives, poisons, etc.); climate change (with increased sea surface temperatures leading to coral bleaching, sea level rise); and natural disasters (typhoons/hurricanes, volcanic ash).

Management

In the islands and atolls of the Pacific where coastal populations have traditionally relied on coral reef resources, many complex traditional (usually community-based) management systems have evolved and in some cases have been incorporated into formal fisheries regulations with beneficial results. Even in the absence of traditional system of tenure, recent experience in the Philippines indicates that community-based management is possible, mainly via unfished reserves which substantially increase fish diversity, fish biomass and catch. Alternative management regimes will have to be identified that are suitable for the specific conditions of the Caribbean, an area which lacks traditional management regimes, and where in addition to small-scale fishers, leisure fishers and SCUBA-diving tourists strongly shape the patterns of reef uses.

[1]Longhurst, A.R. and D. Pauly. 1987. Ecology of tropical oceans. Academic Press, San Diego.
[2]Smith, S.V. 1978. Coral reef area and the contributions of reefs to processes of resources of the world oceans. Nature 273:225-226.
[3]Russ, G. 1991. Coral reef fisheries: effects and yields, p. 601-635, *In* P.F. Sale (ed.) The ecology of fishes on coral reefs. Academic Press, New York.
[4]Savina, G.C. and A. White. The tale of two islands: some lessons. Environ. Cons. 13(2):104-112.
[5]Chapman, D. 1987. Women's fishing in Oceania. Human Ecology 15(3):267-288.
[6]McManus, L. 1989. The gleaners of Northwest Lingayen Gulf, Philippines. Naga, the ICLARM Quarterly 12(2):13.

Coral reef fisheries have a feature which separates them from all other fisheries: the presence of coral outcrops makes the use of modern industrial fishing gears (e.g., trawls) unfeasible and coral reef systems are therefore the domain of the artisanal fisher, using a wide variety of small-scale fishing gears. The sheltered waters and the high productivity created by the reef systems have been an inducement to human settlement. High population densities are now leading to overexploitation and degradation of the reef systems in many areas.

There are over 100 countries bordering tropical waters that possess coral reefs. In Southeast Asia they are very extensive in the nearshore areas and for the majority of small island states in the Caribbean, the Indian Ocean and the Western Pacific Ocean, coral reefs are the principal aquatic resource system.

Coral reefs are fragile ecosystems and are easily degraded by siltation, eutrophication, contamination by pollutants, physical damage and overexploitation, all of which will have a negative effect on productivity. They do, however, appear to be resilient and often recover rapidly. The status of coral reefs ranges from the near-pristine reefs of remote oceanic atolls to the heavily degraded reefs adjacent to areas of high population, often further stressed by siltation from deforestation, mining and poor land use practices.

Intensive exploitation has led to local extinctions or severe losses of genetic diversity, particularly of vulnerable or highly-valued species. In addition, degradation of reef systems by the use of destructive fishing techniques, such as explosives and poisons, severely decreases the productive capacity of the reef.

The productivity of heavily exploited coral reefs can be improved several fold, particularly through the establishment of properly managed reserves or protected areas. Different systems of tenure, ownership or access to coral reef resources have evolved, often leading to sustainable management. However, in many areas they have broken down under population pressure, leading to a wide range of problems in conserving and managing the resources. Gender and age-related issues are important, particularly where degradation of reef systems leads to a major loss of food and income derived from gleaning shallow reef areas, which is normally undertaken by women and children.

The fisheries in coral reef systems in most of the densely populated areas of Southeast and South Asia, East Africa and the Caribbean are, in general, yielding substantially less than their potential owing to the absence of management systems and models. Proper management requires an understanding of the biological basis of production and of the amounts which can be harvested on a sustainable basis. Some areas of reefs may need to be fully protected to ensure that there is minimal loss of biodiversity and that there are sufficient breeding stocks of organisms there to maintain the fisheries and the reefs themselves. On other reefs, some species may be recruitment limited, either as a result of unfavorable dispersal of larvae or because spawning stocks of particularly desirable species have been severely reduced by overexploitation. In such cases, productivity could be enhanced by stocking systems. Additionally, the shallow areas adjacent to coral reefs are favorable sites for mariculture.

It is also clearly established that where management systems are imposed by outside authority, their chances of success are minimal, whereas community-based systems, in which regulatory measures are imposed by coastal communities on their fellow fishers, have been shown to be effective in Southeast Asia, the South Pacific and Japan. In some cases a variety of customary or community-based marine tenure systems have existed for many centuries whereas in other areas coastal communities have recently adopted resource management systems.

Additionally, there is much scope for the development of aquaculture systems within coral reef lagoons leading to the movement of small-scale fishers from the exploitation of common-property resources to dependence on farming systems. Concurrently, biotechnical advances could make fisheries enhancement systems feasible, but such developments must be integrated with community-based management systems. The integration of aquaculture and enhanced fisheries with community-based management will follow a similar approach to that used in the integration of freshwater aquaculture into the farming systems.

Strategy

The strategy for implementation is to address critical gaps in knowledge, while concurrently maintaining momentum in established research areas in aquaculture and fisheries enhancement. Secondly the program will seek to learn the full biological potential of coral reefs for sustainable exploitation and to develop ways to realize that potential for maximum benefit of small-scale users. Additionally, new research areas will be opened up in relation to a web of interconnected topics such as community-based management systems, fisheries management models and methods for habitat conservation and resource rehabilitation.

Some issues of a general nature, such as interactions with other sectors and the resolution of conflicts that arise from such interactions between sectors are treated in more depth in the Coastal Resource Systems Program.

This research strategy can conveniently be encapsulated into three major thrusts:

- improving productivity;
- improving ecosystem management; and
- improving resource management.

The mode of research will be through networking with participating NARS and ASIs, by the development of international research groups addressing specific topics and by establishing collaborative research projects with individual NARS and ASIs for the verification of specific hypotheses or the acquisition of required data sets.

Thrust 1: Improving Productivity

Scope of Research

It is feasible to increase sustainable yields from coral reef systems by the cultivation of desirable species or by enhancing natural recruitment by the release of hatchery-reared juveniles.

In keeping with ICLARM's focus on small-scale producers, the emphasis will be on the development of village-based farming systems for various species of coral reef organisms, such as giant clams, oysters, various crustaceans, and coral reef fishes. Development of collection systems for pelagic larvae is an alternative to cultivation of larvae in hatcheries. Genetic improvement of successful species is a logical activity where the biotechnical aspects have been shown to be economically feasible. Combination of the biotechnical work and bioeconomic modeling with social, cultural and legal aspects is essential for successful development of viable farming systems.

In the case of fisheries enhancement the initial step will be to review successful experiences in Japan and elsewhere. This will lead to a review of potential species including high-valued species which feed low in the food chain. Important considerations include the carrying capacity of reefs, the periodicity of recruitment to coral reef systems, the feasibility and desirability of gathering postlarval or juvenile fish or invertebrates for ongrowing, the degree to which outmigration of stock takes place on coral reefs and the social and economic context.

Mode of Research

Coral reef aquaculture and fisheries enhancement will be investigated within pristine and overexploited reef systems. The former will be studied at ICLARM's Coastal Aquaculture Centre (CAC) in the Solomon Islands, with networking concentrated in the Asia-Pacific region, but with contacts with interested groups in the Caribbean and East Africa. This will facilitate the identification of research needs and opportunities, the catalysis of research efforts to investigate promising species and systems and the showing of ideas and results. The networking will be coordinated from ICLARM headquarters in the Philippines.

ICLARM's current work on farming systems for phototrophic giant clams is a successful example of this mode of operation. The biotechnical work is now being extended to Southeast Asia's more populous and stressed reef systems. Future research will be done on germplasm enhancement of giant clams. The aquaculture potential of other highly productive species and their potential role in fisheries enhancement will also be investigated. Opportunities for impoverished, small-scale producers in hatchery, nursery and growout operations will be emphasized.

A balanced approach between work at the CAC, networking, and work led and coordinated from ICLARM headquarters will be followed for future work in aquaculture and enhanced fisheries research. There will be close collaboration with NARS and ASIs and opportunities will be sought for contracting research to ASIs with particular comparative advantages in areas such as detailed studies on the physiology and biochemistry of reef organisms. NARS strengthening, through collaborative research and training, will receive particular attention.

The farming systems research approach being developed through the Inland Aquatic Systems Program can serve as a model for both research and extension.

Thrust 2: Improving Ecosystem Management

Scope of Research

Improving catches and ensuring that they are sustainable are key issues for the large number of beneficiaries dependent on coral reef systems. Progress relative to these issues is hampered by the lack of reliable information and generalizations relative to the nature of the biological production system and to plausible biotechnical intervention mechanisms.

Work in this thrust will synthesize existing data, develop models from which to draw global conclusions and examine methods for maximizing yields and/or enhancing recovery of degraded reef fisheries, including the role of marine reserves and habitat rehabilitation.

A global relational database of coral reefs (REEFBASE), including their characteristics, resource and yields is in an advanced planning stage and will provide a major resource for this work. REEFBASE will contain quantitative and categorical information on coral reefs. In addition to general information, such as yields by reef type and the global distribution of reefs by type and status, the database will link with GIS software to accommodate original space-structured time-series data collected in cooperation with a large number of cooperating NARS. The program will also cooperate extensively with ASIs which have expertise in coral reef studies and with regional and global organizations (notably UNEP and IUCN) which have similar interests.

REEFBASE will draw heavily on existing databases in the initial stages (particularly the 3-volume "Coral Reefs of the World" edited by S.M. Wells for IUCN and UNDP). A separate database (FISHBASE), currently being developed at ICLARM, includes data on coral reef fishes and will provide researchers with other data needed for quantitative work on coral reef fisheries systems.

Coral reefs are complex ecosystems which are difficult to manage. Modeling provides insights into the structure of the system and the critical factors which control it. A series of trophic models of coral reefs will be elaborated. An understanding of, and generalizations on, biomass and energy flows in various types of coral reefs, including the results of supplementing natural recruitment by the release of hatchery-reared juveniles, will emerge from this work.

Research is required on the practicality and effectiveness of marine reserves for the conservation of biodiversity and of spawning stocks, and the degree to which they can serve as a source of recruits to fisheries in surrounding areas. Questions on the effective sizes of reserves and of ways of influencing, developing or improving policies for coral reef conservation or rehabilitation must also be addressed. There will be a scope for a comparative geographic approach.

MODE OF RESEARCH

This thrust will be executed in close cooperation with ASIs, NARS and NGOs.

Cooperation with ASIs of developed countries with coral reefs (particularly in Australia) will be sought with regard to the thrust's modeling requirements, which may be met, at least in part, by adapting for use in developing-country situations, various models produced by ASIs. The ASIs will also cooperate with ICLARM by contributing to relevant databases.

Cooperation with NARS, with NGOs and with various regional programs will be sought with regard to parameterization, verification and implementation of models of coral reef resource systems. Also, linkages with a large number of NARS and/or NGOs will be established and maintained to ensure entry, verification, dissemination and use of the field data entered in REEFBASE.

Thrust 3:
Improving Resource Management

SCOPE OF RESEARCH

Cost-effective methods needed to acquire data for multispecies, multigear coral reef fisheries will be developed. However, the minimum biological, economic and ecological data requirements to model the multispecies stocks have not yet been defined, nor have models been developed which can be based only on elementary data. It is therefore necessary to develop and test cost-effective data acquisition systems in collaboration with NARS and subsequently to develop and test fisheries management models based on these data.

Additionally, improved management of reef resource systems is hampered by the lack of analytical and decision tools and relevant generalizations which incorporate the mix of important biological, economic and social factors.

Bioeconomic modeling of reef resources will be carried out in respect of aquaculture, fisheries and fisheries enhancement, industrialization, tourism and the social costs of nonconservation. Such models will allow quantification of the effects of fishing on all species and on their food base and the evaluation of management options, including the use of reefs for various nonextractive uses such as tourism. The models will also provide indicators for optimization of fishing systems on coral reefs. Mechanisms to verify and refine the parameters of these models will be devised at selected sites.

The sociocultural aspects of community-based management systems and various alternatives will be addressed on a comparative basis. Knowledge on enabling mechanisms (particularly on the legal, institutional and sociocultural aspects) to effect optimum strategies are also notably lacking. Methods for the resolution of resource use conflicts and for influencing the adoption of appropriate resource management strategies are of particular importance.

MODE OF RESEARCH

Development, field-testing and refinement of models and data acquisition systems will be done in close collaboration with selected international and national agencies. For studies of management systems, the collaboration of NARS and of local NGOs, community groups or local government agencies will be sought in a diverse array of countries to permit the refinement of experimental management approaches under varying social, political, cultural, economic and environmental conditions.

Potential Impact

Over the next decade these thrusts are expected to lead to:

- verification of the sustainable harvests from coral reef resource systems and guidance on the management strategies which are necessary in order to realize high sustainable yields;

- development of technologies for aquaculture and fisheries enhancement in coral reef systems which are relevant to the needs of small-scale producers;
- availability of detailed assessments of the status of the world's coral reef ecosystems;
- synthesis and validation of models of biomass and energy flows in coral reef ecosystems;
- development of methods for identifying and managing coral reef reserves or protected areas for assessing their likely impact in terms of improved recruitment to adjacent areas and the conservation of biodiversity;
- improvement in the availability of quantitative data on resource utilization and valuation and consequently improved bioeconomic models of exploited coral reef resource systems, leading to substantial increase in harvests from these systems; and
- increased harvests of around 2 million tonnes can reasonably be expected from improved management of coral reef fisheries plus substantial gains, particularly in terms of income to coastal communities, from developments in aquaculture and fisheries enhancement.

National Research Support Program

This program is designed to address the critical international issue of strengthening of NARS such that they can respond to the challenges of better management of their living aquatic resources in order to improve and sustain the capture fisheries and increase the production from aquaculture and enhanced fisheries. It will contribute to ICLARM's own objective in the same area. An additional function this program will play is to ensure effective feedback between the NARS and the future ICLARM.

Objectives

The objectives of this program are:

- to strengthen national program scientists;
- to strengthen networking between NARS including NGOs; and
- to assist NARS in strengthening their research policies and research management related to fisheries research.

Rationale

ICLARM can only have widespread impact if national programs are able to utilize, implement or adapt the outputs in their conditions. The National Aquatic Research Systems in many countries often fall within an agricultural department. Thus, we use the term NARS (National Agricultural Research System(s) as used by other centers), although in some cases it may be a separate National Aquatic Research System.

In general, fisheries research at the national level is less important, lower in status, more poorly funded and has fewer qualified personnel than that in agriculture.

The SIFR task force which examined "the organization and conduct of fisheries research at a national level in the Asian region" concluded:

> "The responsibility for the organization and conduct of research in fisheries varies from one country to another. However, in all cases, whether responsible for research or not, the fisheries departments come under the Ministry of Agriculture. This predominance of agriculture, and the attempted application of agricultural production models to fisheries has constrained the development and particularly the management of fisheries. As a small and often neglected part of a large ministry, fisheries professionals, both in research and administration, have had difficulty in making their voices heard."

TAC (1991) indicates that many national systems have yet to achieve critical mass of researchers in fisheries. One of the major conclusions of the SIFR study was the need to strengthen national programs in order to carry out effective fisheries management.

The potential client NARS number over 100, each with a unique blend of institutions, research groups, individual scientists and different research needs and opportunities.

The NARS in Asia are the most highly developed (with the exception of Myanmar, Laos, Cambodia, Vietnam and the South Pacific where the NARS are very weak or nonexistent). In some cases the stronger national programs can assist in strengthening the weaker NARS.

In most of Africa there is a dual problem of lack of trained personnel, particularly at the Ph.D. level, and a scarcity of national funding for research. Fisheries research activities are often donor-driven and fragmented.

In Latin America and the Caribbean, there is a good supply of well trained and committed researchers. However, their research is often crippled by the overall economic difficulties of the region resulting in few research funds and low salaries.

There are additional special needs to support fisheries research at both the institutional and national research policy level. This is particularly so as they are often weak sisters of agricultural institutions. There is an additional need for strengthening Fisheries Social Science, an area critical for improvement in fisheries management but lacking or weak in most NARS.

In addition to the formal NARS there is an increasing role of an informal "system", the NGOs. In many cases they are actively involved at the community level, both in community organization and implementation of development activities. They may also be involved in research where they are sometimes at the forefront (e.g., participatory research and sustainable development). NGOs offer a unique opportunity to link with this research and with communities and other user groups. They are also often involved in national, regional and international networking.

Support to NARS can occur at three different levels: at the senior policymaking level where research policy is often determined; at the institutional level; and with the individual researchers. Previous ICLARM activities have focused on the individual researcher involving them in collaborative research and supporting them with information and training. In a few cases, via special projects, ICLARM has strengthened national institutions (e.g., Bangladesh, Malawi and Philippines).

Most developing-country fisheries researchers are isolated from the current literature and developments. This is often reflected in the lack of relevance of some research, the poor quality of resulting manuscripts and predominance of inaccessible grey literature. ICLARM has addressed these problems previously by information networks (the Network of Tropical Fisheries Scientists and the Network of Tropical Aquaculture Scientists), publishing a quarterly magazine (Naga) which includes topical articles and a current awareness service and several newsletters, production of databases (e.g., FISHBASE), organizing conferences and workshops, and publishing proceedings and other research documents.

There is a large number of national educational facilities in fisheries. There are over 400 relevant institutions listed in ICLARM's education and training database. A few training courses and workshops are offered on a regional level such as those offered in Asia by SEAFDEC and NACA. International training activities are few. The annual international courses in stock assessment methodology conducted jointly by FAO and DANIDA, with ICLARM involvement, are unique.

ICLARM's comparative advantage in strengthening NARS is based on its previous strong track record in strengthening developing-country fisheries researchers through collaborative research, training, networking in social science, aquaculture, capture fisheries and coastal area management, and a strong information program. ICLARM has considerable experience working with a broad range of national institutions in interagency and interdisciplinary activities.

As ICLARM will be one of the few resource management and the only fisheries management institute in the CGIAR, there will be additional demands to supply fisheries and resource management expertise to NARS strengthening activities carried out by ISNAR.

Strategy

The strengthening of NARS is a dual function of this program and the three research programs. There will have to be a close coordination between them. In most cases the strengthening, via information and training, will be a direct output of the research programs. The specific details of this program can only emerge as the result of considerable consultation with NARS and ISNAR. This will occur during the preparation of the mid-term planning. The following serves as an outline of the proposed approach.

There will be thrusts in:

- information,
- training, and
- NARS research policies and management.

Thrust 1: Information

Scope of Work

The functions of information management in the institute should include (i) establishing and maintaining an adequate scientific information base for the Center's researchers; (ii) disseminating in various forms the research findings of the Center to clients and beneficiaries; (iii) more general scientific information for developing-country fisheries scientists (clients); (iv) public awareness activities; and (v) linking closely with others involved in fisheries information.

An additional function is to assist in measuring the effectiveness of the institute's work primarily by citation analysis. This contributes to the research on research and is an important part of the internal research management system.

Dissemination of ICLARM's research results will be through a balance of primary literature and institute publications. There will be a need to produce material at a variety of levels to suit the needs of client (and beneficiary) groups and to serve a public awareness function.

Conferences and workshops are very useful for information dissemination and for increasing contact among fisheries scientists who are often isolated. These will be organized around major research issues and major outputs of the ICLARM research programs. They are particularly useful to assist in summarizing knowledge prior to embarking on new research activities and in identifying policy issues. The policy of editing and publishing conference proceedings also assists NARS scientists in moving their information from unpublished reports (grey literature) to the cited literature.

Mode of Operation

The information work should be dynamic: seeking to improve efficiency in dissemination using new technologies and media where appropriate; responding to needs for translation of material in various languages; and helping to overcome bottlenecks in the quality and quantity of information flow, which cause duplication of research and rejection by leading journals of research manuscripts from developing-country fisheries scientists.

The program will work with existing networks where possible and strengthen existing ICLARM networks (e.g., AFSSRN) by linking information to the networks.

Thrust 2: Training

Scope of Work

The development of human resources is an important function of an institute supported by the CGIAR. Training will be a very important activity. The overall training needs of institutions engaged in fisheries research in developing countries are very large, and other organizations are often better placed to respond to many of these needs. The future ICLARM will, therefore, build its training program on a selective basis, confining itself to areas closely related to its research and to training functions where it has a clear comparative advantage, as well as cooperating closely with other organizations involved in training.

Training will focus on strengthening researchers. The emphasis should be international or regional, rather than national and focus on methodologies and other new knowledge generated by the Center.

Mode of Operation

A number of modes will be used in training, including direct training, on-the-job training of visiting scientists, training of trainers, publication of training materials, distance learning and the use of audiovisual products, expert systems, or merely user-friendly interfaces built into software. The Center will make the most cost-effective choice in each case, based on an understanding of the values and efficiency of different approaches, and the capacity of other organizations that might collaborate in training activities. For example, networking is an important and cost-effective mechanism for training.

The formal training will be done in a number of modes: (i) solely by the Center, ii) in collaboration with NARS, ASIs, IARCs and NGOs, (iii) solely by other institutions with ICLARM's input being training materials. All ICLARM training courses would be evaluated for efficiency and impact.

In addition, the future ICLARM will continue to maintain a global directory of educational and training opportunities especially for developing-country scientists.

Thrust 3:
NARS Research Policy and Research Management

SCOPE OF WORK

This thrust will address research policy and management at the national and institutional levels. It will build on ISNAR's experience and methodologies in working with national agricultural systems. ICLARM's role will be to supply the specific fisheries expertise in research priority setting and management. In addition, this thrust will assist in liaison with NARS and NGOs and ensuring that their priorities and concerns enter into the program planning process.

MODE OF OPERATION

The strengthening of research policy and management will be carried out as an initial experiment to test the approach and only in a very few countries. This would have to be a joint ICLARM-ISNAR activity and link closely with FAO.

The liaison function of this thrust will be primarily to ensure that adequate feedback exists between ICLARM and NARS. This thrust will rely on workshops, training and informal networking. Our experience indicates that in resource management there is a much larger number of institutions and researchers involved, imposing additional demands on networking.

Potential Impact

The expected impact of this program will be:

- larger number of NARS scientists trained and capable of undertaking research relevant to biological, systems and socioeconomic dimensions of living aquatic resource management;
- improved information flows to scientists in national programs and increased outlets for publication and dissemination of scientific findings;
- increase capacity in NARS to collaborate effectively with other institutions and sectors in the sustainable management of aquatic resource systems;
- a greater number of linkages between NARS and NGOs such that research outputs are rapidly deployed to their intended beneficiaries;
- research policies more closely directed to effect the wise management of aquatic resources;
- greater exchange of knowledge and methodologies relevant to research on aquatic resources management within and between national and international research and development institutions; and
- increased relevance and focus in the future ICLARM's research programs.

CHAPTER 4
Implementation, Management, Organization and Resource Allocation

ICLARM will implement the research and related programs described in Chapter 3 through a balanced, flexible blend of centralized and outreach activities; independent and collaborative work; with NARS, IARCs, advanced scientific institutions (ASIs) and other groups. Balance will tend to favor decentralized activities in which NARS, IARCs and ASIs collaborate.

This chapter indicates how ICLARM intends to implement the four programs elaborated in the previous chapter through descriptions of 1) mechanisms for undertaking the research and related activities, 2) management matrices for the research activities, 3) organizational principles and structures for the whole Center, and 4) physical, human and financial resources required and their allocation.

In considering how these activities should be implemented, the choices were guided by consideration of the guiding principles (see Chapter 2) and additional considerations of service to clients, a commitment to excellence, accountability and transparency.

Mechanisms for Research and Related Activities

Independent and Collaborative Research

The institute will conduct independent, high-level research for the development of innovative approaches when it is the most cost-effective means of achieving research objectives. This is likely to apply to about 25% of the institute's total research program, the remainder being undertaken by means of collaborative research partnerships and networks. This independent research will be applied particularly to areas where there is the need for critical mass or where there is a need to develop and test methodologies and generate independent data.

Collaborative research partnerships and networks will be the major mechanism for achieving research objectives. An example of a proposed collaborative research network is shown in Box 5. Partners will be sought either on an activity-by-activity basis, or as longer-term collaborators, from a wide range of institutions and individuals in developing and developed countries. These are categorized as follows: FAO; other United Nations organizations; other international centers; intergovernmental fisheries organizations; regional research and development organizations; ASIs; NARS; environmental conservation organizations; educational institutions; and nongovernmental organizations.

The possibilities for collaboration are numerous but partnerships will be sought only when appropriate and when they assist the research objectives and institution strengthening. In addition to substantial collaborative research, the Center will play a catalytic role, supplying ideas, data, methods and expertise to stimulate and strengthen research by other groups.

Box 5
An Example of a Network

An international finfish genetics network is seen as an appropriate mechanism for achieving research objectives in germplasm conservation, enhancement and breeding.

Objectives:

- to document and evaluate fish germplasm of key species;
- to provide scientific support for efforts to conserve such germplasm *in situ* through conservation of habitats;
- to stimulate national fish breeding programs;
- to strengthen NARS by providing related training and information to participating groups.

For germplasm conservation the network will document for various species the *in situ* status, performance and all other available genetic information using methods similar to those used by the IBPGR for plants. The resulting database will be maintained and its contents published from headquarters, and made widely available to interested users.

For germplasm evaluation, enhancement and breeding, the network will establish interregional research activities on fish genetic research and training, focused initially on carps and tilapias because of their utility as test species and their importance as sources of food and livelihood for disadvantaged populations in a number of countries. The hub of the network will be at ICLARM's headquarters. From here, the network will be coordinated and research assistance given to national programs, including assistance in establishing collaborative linkages with advanced scientific institutions and specialized training.

Network participants will be from NARS in Africa and Asia and from other international centers and advanced laboratories. The size of the network will be limited initially to participants from those few developing countries where genetic research has high priority and can make a substantial contribution to the expansion of aquaculture.

Other countries with significant interest in aquaculture genetics will participate in workshops, information exchange and training and are potential future network members.

ICLARM will cooperate closely with other CGIAR-supported institutions. There will be close interaction with ISNAR on support to NARS and close interaction with IFPRI on policy. Ideally, there should be a fisheries policy unit located in ICLARM with strong links to IFPRI, possibly with an outposted senior IFPRI researcher located and working with the unit. This, however, will require additional resources.

Relationships with other centers will be in areas of farming systems, integration of fisheries and agriculture, and aquatic use management. There should also be close linkages to ICRAF and the new forestry institute as they share many of the same resource management issues - including the management of common property.

Centralized and Outreach Activities

One of the primary requirements in order to achieve the objectives of the future ICLARM will be a critical mass of well qualified, highly motivated professional staff.

The synergism that could be generated from a core group from different disciplines will only occur if they are located in one facility and work closely together. The output from such a group will be research findings of broad potential application, methodologies, software and generalized management models as well as training and information. When there is a need for site-specific information, validation and testing will be achieved by networks and outreach sites. The biotechnical research (fish breeding and improved husbandry) will produce improved germplasm and husbandry techniques for specific sites. However, these are considered to be pilot studies which will also emphasize the general processes of "how to improve aquatic germplasm".

Regional outreach not only provides a vehicle for research, information and training activities, but also provides a mechanism for feedback on the needs of clients and beneficiaries.

There will also be a need for key sites for a number of the research activities. These sites will allow for both site-specific adaptation of research and cross site comparisons. These will be particularly important for the modeling activities, farming/fishing systems, and common property activities. These sites will often be components of collaborative networks with partnership institutions but will also be sites of other ICLARM project activities where appropriate.

SubSaharan Africa is a region of special needs and opportunities in fisheries research, as in agriculture and forestry. For fish production systems, this region has:

- a need to implement sustainable management of the freshwater and marine fisheries;
- theoretical opportunities for enhanced fisheries, particularly in coastal lagoons; farm dams and other reservoirs and lakes; and
- a perceived potential (though unproven) for aquaculture development, chiefly in freshwater.

A cautious approach is proposed to research in SubSaharan Africa. Initially existing projects will form the basis to better understanding of the needs and opportunities both in research and strengthening so that future efforts will be cost-effective and likely to achieve rapid impact. Africa should have the first priority for an outreach office once the research and strengthening needs are established.

The SubSaharan Africa Office will initiate and manage collaborative research projects, engage in NARS strengthening activities, and explore needs and opportunities for establishing future networks. It will conduct in-depth studies of the special research needs and likely scope for growth or improvement of African aquaculture and fisheries. These studies will emphasize inland waters.

As the constraints to the development of African fisheries and aquaculture will be largely sociocultural and resource-related, this regional office should be staffed initially by a small multidisciplinary team including social scientists, working closely with headquarters and with project and NARS staff and consultants when required. It will accomplish its work through collaborative projects and networks with related NARS strengthening, information and training activities, conducted mainly in French and English.

Latin America and the Caribbean constitute a large and diverse region. It includes the world's most productive marine capture fisheries, inland aquatic resource systems, coastal lagoons, mangrove areas and coral reefs. Overall, the greatest need in fisheries research for development is for better management of marine capture fisheries.

(However, the fisheries in the upwelling systems are excluded from ICLARM's research). Needs and opportunities for coastal and inland enhanced fisheries and aquaculture are less apparent, though there are some significant indications of potentials and problems.

A Latin America/Caribbean Regional Office would have low priority. A liaison officer in headquarters initially would assist in linking collaborative projects and networks conducted with strong involvement of headquarters staff. NARS strengthening will be accomplished by collaborative projects, networks, training and information. The ICLARM Headquarters would need to establish information capabilities for materials in Spanish.

The West Asia/North Africa region is characterized mainly by arid or semi-arid coastal states in which scope for small-scale inland aquaculture and fisheries is limited. The most important fish production systems are the fisheries in the upwelling areas on the Atlantic coast of western North Africa and to the south of the Arabian peninsula. Elsewhere there are scattered areas of potential for coastal and inland enhanced fisheries and aquaculture, especially in Egypt which dominates the freshwater production of the region. No regional office or physical facility is planned.

ICLARM will manage its research in a matrix of problem-oriented programs and science-based divisions (Fig. 4.1). The research programs are: Inland Aquatic Systems; Coastal Resource Systems; and Coral Reef Systems. The divisions are: Ecology and Biology; Farming/Fishing Systems and Social Sciences. Each research program will be overseen by a Program Director and will undertake projects, managed by Project Leaders, staffed by project research teams. Each research division will have an appointed Head of Division, selected from among the scientific staff. This could be a rotational appointment among programs.

This matrix arrangement will maximize interaction and complementarity among programs. The research divisions are crucial elements. They will be, in effect, across-program scientific working groups composed of researchers with common perspectives, disciplines and needs. They will comprise the disciplinary critical masses needed for scientific interaction while the programs and their interactions will be the means of interdisciplinary work. Thus, for example, a Sociologist working in a project in the Inland Aquatic Systems Program contributing to work on gender issues will belong to the Social Science Division and will interact with colleagues working on similar issues in coral reef and coastal fishing villages and feel part of a social science team.

The research divisions will also be crucial in strengthening ICLARM's scientific capabilities and credibility. Much of the proposed research agenda is innovative and some, for example the focus on better breeds of fish, better farming systems and new adopters in the Inland Aquatic Systems Program, represent paradigm shifts away from previous thinking. Such agenda are exciting, but new thinking will require great cohesion among the future ICLARM's staff and collaborators in other institutions who share the same views, read and contribute to the same scientific literature and thereby can promote a new paradigm.

Division	Programs			
	Inland Aquatic Systems	Coastal Resource Systems	Coral Reef Resources	National Research Support
Biology/Ecology				
Fishing/Farming Systems				
Social Sciences				

Fig. 4.1. The Program/Division structure of the future ICLARM.

Structures

Organizational Structure

The Center's proposed organizational structure is presented in Fig. 4.2. The focal point of the structure will be the Center's research projects and institution building activities.

Governance over the Center's activities and resources will be the primary responsibility of the ICLARM Board of Trustees. The determination of Center policy will be the Board's major mechanism for exercising this governance responsibility. Other responsibilities of the ICLARM Board will include the appointment/dismissal of the Center's Director General and providing oversight of the administration of the Center.

Board operations are not expected to change very much from the manner in which the ICLARM Board of Trustees currently operates. Board membership, except for the Director General who will continue to be an ex-officio trustee, will be composed of individuals chosen for their technical knowledge, management experience and skills, stature in the scientific community and/or understanding of the problems of developing-country research institutions.

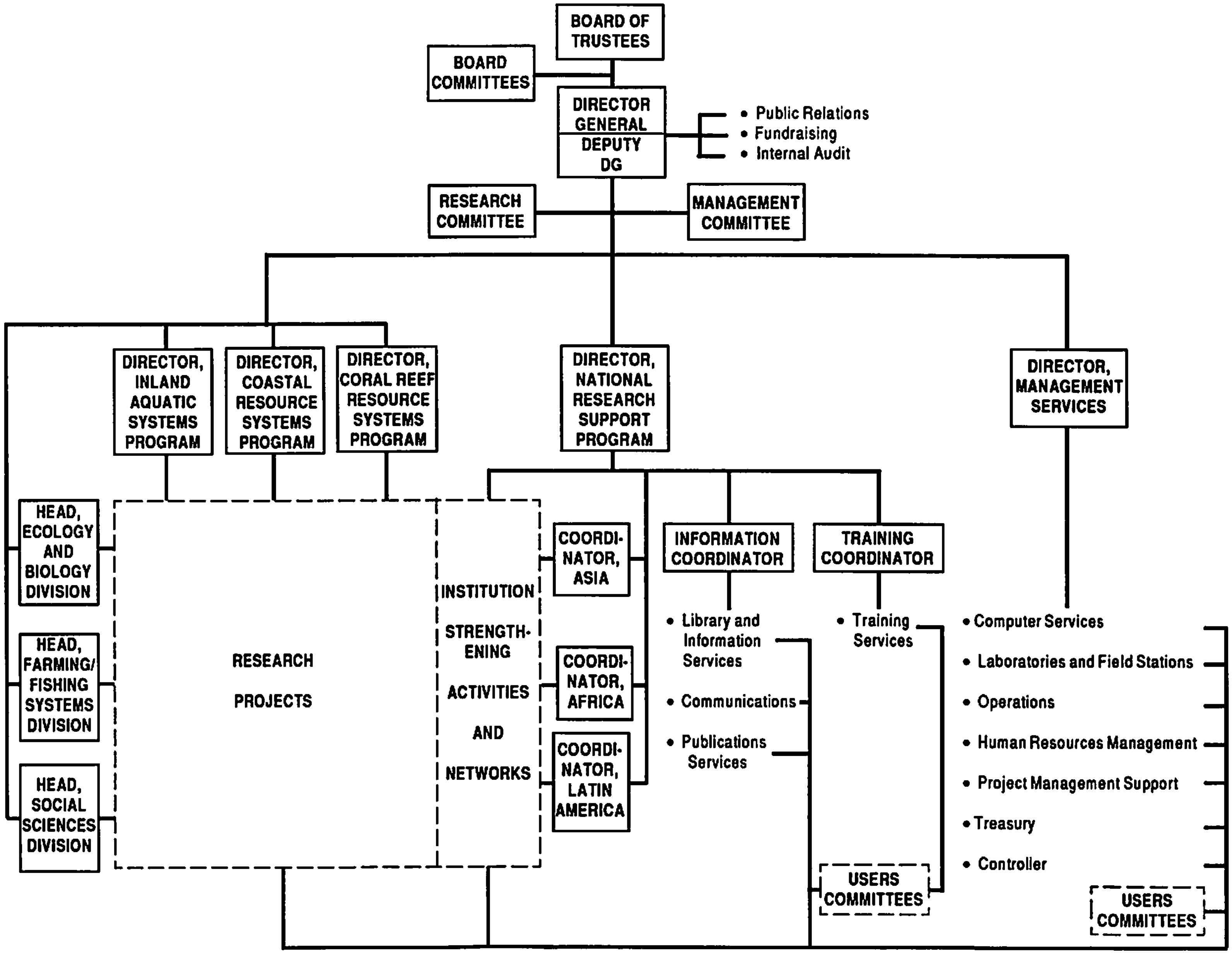

Fig. 4.2. Proposed organization structure of the future ICLARM.

Administrative responsibility over the Center belongs to the Director General who will be accountable to the Board of Trustees. The Director General will be assisted by a Deputy Director General. A Management Committee will also be established to oversee the formulation and implementation of operating policies and procedures.

Overall program management will be undertaken by the Research Committee which will be composed of the Research Division Heads, the Program Directors and the Director for Management Services and chaired by the Deputy Director General. The Research Committee will review and approve new projects as well as project plans and budgets. The Committee will also serve as an effective mechanism to operate the Center's priorities framework as well as to monitor and evaluate progress and results. The Center will develop and establish management protocols and information systems that will support the activities of the Research Committee. A publications subcommittee will operate the Publications Policy that the Center will eventually establish as well as oversee the quality of materials for publication.

The coordination of training and information services will fall under the responsibility of the National Research Support Program, the primary user of these services. These will include the Library and Information Service, Communications, Publications Service and Training Service Units.

The research support required by the Center's programs will be delivered by the Management Services Department, to be overseen by a Director for Management Services. This department will establish and maintain users' committees for each of its key support functions which will include computer services and laboratory facilities. These users' committees will operationalize the "Service to Programs" philosophy that this Department will maintain.

In addition to operating research support services, the Management Services Department will also be directly responsible for the human resources, operations and financial management functions of the Center. Each of these functions will be headed by professional managers.

The staff complement is considered a minimum to implement the strategy. It may not be possible to cover all activities from core funds. Additional positions will be sought from complementary sources. In addition the staff complement will be strengthened through a strategic use of interns, graduate students, postdoctoral fellows, visiting scientists, associate experts, and key linkages with ASIs.

Resource Requirements and Allocation

Staff Requirements and Allocation. A proposed allocation of staff to divisions and programs is presented in Table 4.1. This is based on what is considered to be a minimum critical mass to carry out the strategy.

Table 4.1. Program thrusts, expressed as research activities, showing person years required.

Program thrusts	Senior Core Person Years	Activity Type	Division**
Inland Aquatic Systems Program	(11)		
Improved Fish Productivity			
• Genetics/breeding	3.5	Germplasm/breeding	A
• Nutrient flow modeling	2.5	Pond dynamics	A

continued

Table 4.1. (continued)

Program thrusts	Senior Core Person Years	Activity Type	Division**
Development of Integrated Farming Systems			
• Development of databases	1	Farming/fishing systems	B
• Bioeconomic and ecological modeling	1	Farming/fishing systems	B
• Integrated management strategies	1	Farming/fishing systems	B
Removal of constraints	2	Sociocultural organization	C
Coral Reef Management Program	(7)		
Maximum Sustainable Yields			
• Database	*		
• Resource modeling	1	Fisheries ecology and management	A
• Protected areas	1	Fisheries ecology and management	A
Management Methods			
• Bioeconomic modeling	1	Farming/fishing systems	B
• Community management	1	Sociocultural organization	C
• Policy issues	0.5	Socioeconomics, policy	C
Development of Aquaculture Systems			
• Biotechnology	1	Fisheries ecology and management	A
• Coastal aquaculture systems	1	Farming/Fishing systems	B
• Fisheries enhancement	0.5	Fisheries ecology and management	A
Coastal Resources Management Program	(8)		
Understanding Dynamics			
• Resource system modeling	2	Fisheries ecology and management	A
• Ecology of coastal systems	0.5	Fisheries ecology and management	A
• Economics of coastal resources	0.5	Economics	C
Management Strategies			
• Bioeconomic modeling	1	Fisheries ecology and management	A
• Community level research	1	Farming/fishing systems	B
• Sociocultural aspects	0.5	Sociocultural organization	C
Integrated Management Strategies			
• Database and GIS	1	Fisheries ecology and management	A
• Aquatic use management	1	Fisheries ecology and management	A
• Macro Policy	0.5	Policy	C
National Research Support Program	(7)		
• Research policy and management	0.5	Research management	
• Information	2	Information science supported by midlevel professional staff including librarian and editor	
• Training, conferences and workshops	1.0	Coordinator	
• Networking and liaison	1.5	Network coordinator (NARS strengthening component only) e.g., AFSSRN	
• Liaison	2.0	Asia/Pacific, Africa, Latin America	

*Database development will be part of the responsibility of various program staff.

**Divisions:		
	A Ecology, biology	15 persons
	B Farming systems	6
	C Socioeconomics	5

Facilities. The headquarters of the future ICLARM will be in Asia, the region of greatest fisheries production, population and potential for improving the welfare of the target beneficiaries. Such a headquarters should be located adjacent to a large Asian city which has appropriate communication, infrastructural and educational facilities in order to attract internationally recruited staff. The main headquarters building would need offices for systems researchers to carry out modeling and software development. This would include an information facility including library and in-house publication capabilities, a small training facility and administration offices.

Adjacent to headquarters, laboratories and facilities for the biotechnical research are needed. The highest priority will be for freshwater facilities which include ponds, cages, hatcheries and wet laboratories. Additional facilities for reservoir and marine research at the same location would be desirable. However, collaborative arrangements may have to be established with NARS for some of these facilities. Coral reef research has specific site requirements: pristine or near pristine environments for component research and heavily exploited reefs for fisheries management research. The current ICLARM facility in the Solomon Islands offers the pristine site. This would be used for comparative studies in reef management and component research work on giant clams and other cultivable species.

The headquarters building and its associated laboratory facilities will serve as research facilities for global and Asia-Pacific oriented studies. Outreach offices will be needed for site-specific tests and NARS strengthening but will be located within national institutions and will not require any capital outlay.

The subsequent construction of a substantial regional research and training facility for SubSaharan Africa is envisaged once regional research needs and opportunities are better defined. This would supplement national research facilities. Once these facilities are built, the SubSaharan Africa Regional Office will become, if resources permit, an African Regional Headquarters, with laboratories and ponds, its own information services system (in English and French) and an expanded complement of professional staff in the biological and social sciences.

Resources. The future resource requirements are outlined in Table 4.2. In order to implement the strategy, there is a need for a considerable increase in current resources. There is, however, also a need to increase the proportion of unrestricted core funding from its current level of 30% of total resources to give ICLARM the resource flexibility required to undertake the activities required to achieve its strategic objectives.

Table 4.2. ICLARM's projected operating requirements (US$Million).

	Core Programs		Complementary			
	SSYs	US$	SSYs	US$	Administration	Total
1991	15	$3.4	1	$0.2	$0.7	$4.3
1992	19	4.0	3	0.8	1.2	6.0
1996	33	8.3	5	1.5	2.2	11.6

There will be a requirement for capital expenditures for improvements in the Solomon Island facilities, equipment, headquarters building and facilities, and an African office. These projected requirements are shown in Table 4.3.

Table 4.3. ICLARM's projected capital requirements (US$Million).

	1992	1993	1994	1995	Total required 1992-95
Headquarters	0.15	1.10	5.25	4.50	11.00
Africa	0.00	0.05	0.60	2.20	2.85
Solomon Islands	0.10	0.50	0.10	0.10	0.80
TOTAL	0.25	1.65	5.95	6.80	14.65

CHAPTER 5
Transition

It is expected that the transition from the present size and structure to those of the future ICLARM could begin in 1993 but would require three further years (1994-1996), given adequate funding, to accomplish.

The three research programs have been designed to build on the present ICLARM's strengths. This will be accomplished by continuation of some projects into the core of the future ICLARM, while phasing out others. In some cases, the staff from concluding projects will transfer into core activities to take advantage of the expertise they have gained with the Center.

One of the proposed programs - Inland Aquatic Systems - is largely based on the present Aquaculture program in ICLARM, with the addition of a pond dynamics activity. The other two programs are basically new in content. The Coral Reef Management activities have few equivalents in the present ICLARM, while the Coastal Resources Management program includes elements of both the existing Coastal Area Management program and Capture Fisheries Management program with an additional social science component. Thus, extensive changes are required in the transition process. Staffing the (new) programs will be done stepwise over 3-4 years.

The present ICLARM also has facilities and project assets which have provided it with a comparative advantage in some research areas. These need to be accommodated in the future ICLARM.

Staffing

The Inland Aquatic Systems program will begin in 1993. The research requires that genetics/breeding, farming systems research and work on constraints to adoption of aquaculture proceed in parallel. Both need to be near full strength in the first year. The husbandry (pond dynamics) work, although urgent, in part will await construction of facilities, although some work will be done through decentralized activities before ICLARM's facilities are ready.

The first decade of the program's research agenda is, therefore, divided into two periods:

- 1993-1995 - largely a continuation and modest expansion of ongoing research collaboration in integrated farming systems and germplasm/breeding, with recruitment of additional staff, and establishment of wider collaboration and networking arrangements with NARS, IARCs and ASIs, especially AIT.
- 1996-2003 - achievement of strong in-house research capacity linking closely with networks, other collaborative research arrangements, and training activities.

The Coral Reef Management program requires new staff and will require three years to become fully operational. This program will begin late in 1992 with appointment of a Director to initiate the program; and the hiring of farming/fishing systems scientists; social scientists; a biologist in 1993; and an additional biologist in

1994. The policy component is added in 1995. Two of these positions will be based at the Solomon Islands and one will be OIC of the activities undertaken in ICLARM's facilities there.

The Coastal Resource Systems program will begin in 1993, after the major project of the existing Coastal Area Management program is completed. In 1992 preliminary activities (in existing projects) will be initiated by both the Coastal Area Management Program and Coastal Fisheries Management Program. The details of the integration of these two existing programs will be worked out as part of the mid-term planning in 1992. A social science component will be added in 1993 and 1994.

The National Research Support program should begin in 1993 also. This program contains some activities not previously carried out by ICLARM. Some of the functions will be carried out by research program personnel but there will be a need for parallel development of the support program.

The Management Services Department must develop quickly in response to the increased staff size as well as to assume various responsibilities not undertaken in the present ICLARM.

The Directors for all of the above organizational units will be appointed by early January 1993 in order to implement the new programs in 1993. The Directors of the programs will spend 50% of their time on research.

A research divisional structure is planned to emerge as the new programs become staffed. Staffing should be sufficiently advanced by 1994 to allow selection of heads of the three proposed divisions (Biology/ecology, Farming/fishing systems and Social sciences) at the beginning of 1994. Thus the matrix research management will be fully implemented in that year.

The process of transition is summarized in Table 5.1.

A Research Committee to oversee development of the research programs has already commenced. A Publications Committee will be formed during 1993.

A research support group will be formed during 1993 within the Management Services Department to assume responsibility for various facilities and activities.

Facilities

The present headquarters, rented office space, will be used while new premises are being sought. Apart from enlargement of the existing office, computer and library facilities, the new headquarters will require adjacent laboratories and ponds. A search committee will assess possible sites in Asia and make a firm decision on headquarters by early 1993.

New International-Center and host-country agreements are already being sought to facilitate the setting up of a new headquarters.

It will take up to three years (1993-1995) to establish a new headquarters with modest in-house facilities (covering about 4-5 hectares) for research on inland aquaculture systems - principally experimental ponds and tanks, a small experimental hatchery, analytical and physiological laboratories, a quarantine unit, a cryopreservation unit and a reference collection of live fish of selected strategic species.

Table 5.1. Process of transition.

Existing program/project	Transition events	Planned program personnel needs by research division including present staff
Aquaculture	**New program begins in 1993**	**Inland Aquatic Systems** 1993 Director, 0.5 year research
• Genetics/breeding	Continues with project funding until 1996; needs early appointment of core geneticists and collaborative coordination of programs in Asia and research network coordinator	1993 Biologist 1993 Biologist 1994 Biologist
• Rice-Fish	Continue integrated rice-fish research group as core activity requiring a coordinator	1994 Farming/Fishing Systems scientist (0.5)
• Malawi	Research continues to 1994 on project funds; thereafter provide basis for expansion of core research in Africa	1994 Farming/Fishing Systems scientist
• Bangladesh	Research continues with three projects to 1994 and thereafter on the basis of new projects	
• Ghana	Research continues to 1993 on project funds and phased out	
• FARMBASE	Development work continues on core and project funds to 1994 thereafter as core activity	1993 Farming/Fishing Systems scientist
-	New activity - team to undertake exploratory activities in Africa, freshwater	1993 Farming/Fishing Systems scientist (0.5)
-	New activity - bioeconomic modeling	1994 Social scientist
-	New activity - husbandry research/ pond dynamics	1993 Ecologist
-	Start up-1993; full complement delayed pending facilities construction in 1995	1995 Biologists (1.5)
-	New activity - removal of constraints to aquaculture growth	1993 Social scientist
Aquaculture		**Coral Reef Resource Systems** 1993 Director, 0.5 year research
• Giant clam culture	Continues, partly with project funding, to 1995. Genetics component starts 1992	1993 - Biologist/OIC Coastal Aquaculture Centre
• Reef fish ranching	Continues at low level through 1992, followed by major exploratory research in enhanced fisheries	1993, Activity of Director

continued

Table 5.1. (continued)

Existing program/project	Transition events	Planned program personnel needs by research division, including present staff
-	New activity Protected areas	1993 Ecologist
-	Coastal aquaculture systems	1993 Farming/Fishing Systems scientist
-	New activity - biological models of reef resource systems	1993 Ecologist
-	New activity - farming/fishing systems and bioeconomic modeling	1994 Farming/Fishing Systems scientist
-	New activity - tenure systems for community-based fisheries management	1993 Social scientist
-	New activity - fisheries policy	1994 Social scientist (0.5)
Capture Fisheries Management	**Several projects end in 1992; most of remainder transferred to new program beginning 1993.**	**Coastal Resource Systems** **1993 Director, 0.5 year research**
• FISHBASE	Ongoing; transfer in 1993	1993 Biologist (with Network of Tropical Fisheries Scientists)
• Network of Tropical Fisheries Scientists	Ongoing, with transition towards a collaborative research network	
• Management-oriented Fisheries Project	Project concludes at end of 1992	
• The ICLARM Software Project	Development of tropical stock assessment methodology, incorporates software project in 1993.	1993 Biologist (with Tropical Fish Stock Assessment Project)
• Tropical Fish Stock Assessment Project	Incorporated into Development of tropical stock assessment methodology in 1993.	
-	New activity - multispecies resource modeling	1994 Biologist (with Global Comparisons of ecosystems/ECOPATH)
• Global Comparisons of ecosystems/ECOPATH	New activity - Ecology of coastal systems, incorporates ECOPATH in 1994	
-	New activity - Bioeconomics of coastal fisheries	1993 Social scientist (0.5) (with Economic valuation of coastal resources)
• Economic valuation of coastal resources (Latin America)	Project ends in mid-1992. Becomes: Valuation of coastal resources (general)	
Coastal Area Management	**Closes at end of current projects; end of 1993. Staff absorbed into new program**	
• ASEAN Coastal Resources Management	Project concludes at end of 1992. New activity - Aquatic use management	1993 Biologist
• GISCAM	Project concludes at end of 1993.	-

continued

Table 5.1. (continued)

Existing program/project	Transition events	Planned program personnel needs by research division, including present staff
-	New activity - Participatory research for identification of constraints to community improvement	1993 Farming/Fishing systems scientist
-	New activity - Field testing of new management schemes/approaches	
• San Miguel Bay Management	Project concludes in mid-1993. Becomes basis of new activity	1993 Biologist
-	New activity - intersectoral linkages and common property issues	1993 Social scientist (0.5)
	New activity policy	1995 Social scientist (0.5)
Information	New program with new activities begins 1993.	**National Research Support** Director (0.5)
	Information	1993 Coordinator 1994 Editorial support
	Training, conferences and workshops	1993 Coordinator
	Research policy and management	1994 (0.5)
	Networking	1993 (0.5), 1994 (1,
	Liaison Asia/Pacific	1993 (0.5)
	Africa	1994 (1.0)
	Latin America	1994 (0.5)

The Coastal Aquaculture Centre, ICLARM's facility in the Solomon Islands, will become a focus of fieldwork in the Coral Reef Resource Systems program. Apart from ongoing and planned aquaculture research, the site is ideal for case studies on farming/fishing systems, community management and conservation areas, as well as for coral reef systems work which the Center may undertake itself and/or contract out. This facility offers opportunities for work on topics which have a high degree of transferability to heavily exploited coral reefs elsewhere. The facilities will, however, be upgraded in 1993 to accommodate additional staff and activities.

Supply of Resources

The achievement of ICLARM's objectives as outlined in the strategy will depend on the resources outlined in Table 4.2. being made available. The transition process suggests that the activities will be phased in over a four-year period (1993-96). If adequate resources are not available, the hiring of core staff will be delayed and the implementation of the plan will be slower.

Other Assets

Table 5.1 shows how the present ICLARM projects will be incorporated into the proposed research and related programs. The future ICLARM will build on the strengths of the present Center in this way, phasing out peripheral activities over the years 1992-1994.

Important project "assets" that will be maintained include the databases currently under development (FISHBASE, FARMBASE), the advances in genetics research and ecosystem modeling, the advances in integrated farming systems, and the implications of successful national projects in Malawi and Bangladesh.

The project in Malawi has established a significant national presence there. Malawi is the lead country for aquaculture and fisheries for the SADCC subregion. It is possible that useful regional advances can be made from Malawi. However, the project assets (library, offices and ponds) will revert to the national system by 1995 and the scope of future work in Africa will depend on the outcome of planned future analyses of the potential of aquaculture and enhanced capture fisheries in Africa. Based on the present analysis there is an anticipated requirement of about $3 million to fund an African Office.

APPENDIX

Catch and Potential of Major Fisheries Resource Systems in Tropical and Subtropical Areas*

* Compiled by Villy Christensen, Abbie Trinidad-Cruz, James Paw, Jun Torres, and Daniel Pauly, ICLARM, Manila, April 1991. Revised January 1992.

I. Introduction

The need for fish for food is increasing rapidly in the developing parts of the world. Over the past decades the catches have managed to approximately balance the population increase (Fig. 1), but whether this can continue is far from certain. The present status of the fisheries indicates that in major parts of the developing world, high population densities have already led to overfishing. Further, the potential for increased catches *with the present management strategies* lies mainly in offshore fisheries and in fisheries off less populated areas. The potential from non-traditional fisheries is very limited in the more populated areas, where the stocks are already heavily exploited. To expand the catches in these areas new strategies must be introduced.

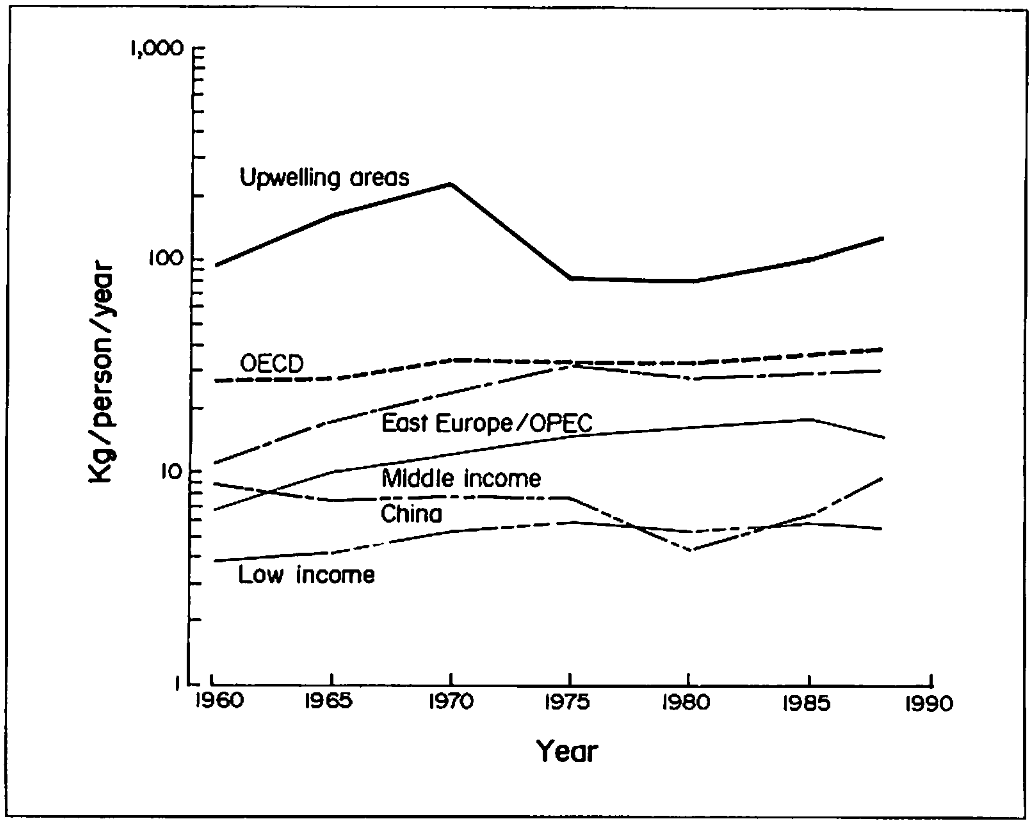

Fig. 1. Per caput fish production by country groupings over the period 1960-1988. The countries with major upwelling areas include Peru, Chile, Morocco, Mauretania, Sénégal, Angola and Namibia.

The guidelines for how to proceed are clear: ways must be found to reduce the fishing pressure and to protect the juvenile fish. This is simple advice but unfortunately of a kind that one cannot expect, under present circumstances, to see successfully implemented anywhere. The major reason for this has been lack of understanding of the sociological and biological implications of the proposed measures. This situation can only be improved through research on how fish and fisher populations interact and how fishers plan and conduct their activities.

The potential for increasing the fish production differs between resource systems. This will be described further in Section V.

The present account was compiled in an attempt to evaluate, in terms of production and potential, the relative importance of the major aquatic resource systems of special interest for international fisheries research. The resource systems are described further in Section III.

II. Methodology

The term 'fish' as we use it here includes, in addition to finfish, aquatic invertebrates and a small number of reptiles. Seaweeds (annual production about 1.6 million tonnes in 1988) are not included; they are treated as aquaculture produce. Marine mammals are also excluded. The terms demersal(s) and pelagic(s) are used to represent types of finfish which occur at or near the sea floor and in the midwater or upper layers of the sea, respectively. This usage follows FAO and excludes invertebrates such as crustaceans (e.g., shrimp) and molluscs (e.g., mussels, squid).

The information used for this compilation mainly comes from FAO catch statistics complemented by data specific to various resource systems. The FAO statistics are based on geographical regions and as such are difficult to use in a resource system context. This will invariably lead to error in the results; we have reason to hope, however, that these errors will not severely influence the general conclusions.

Estimates of catch potential or maximum sustainable yield (MSY) can be obtained in several ways. Two often-used methods are *1)* for lightly exploited systems to assume the MSY to equal half the virgin biomass times the natural mortality of the population (Gulland 1971); and *2)* for heavily exploited systems to plot time series of yield *versus* fishing effort and, from the scatter plot, estimate the MSY.

A major drawback of the latter method is that the effort data, especially for small-scale fisheries, are of a very poor quality. Further, this method is based on the existing fishing pattern. Most or all of the intensive fisheries in developing countries are characterized by application of excess effort and by use of fine meshed gear. Changing the fishing pattern by, e.g., introduction of sanctuaries, larger mesh sizes and increased use of passive gears instead of trawls, have in many cases led to catches higher than would have been the MSY, as estimated using yield *vs* effort plots.

The present analysis describes aspects of fisheries in developing areas of the world. As the FAO summary statistics are based on FAO geographical regions we have where needed used the regions in Table 1 as representative for the developing countries. This is an approximation, and the results will only be comparable to, not identical with, results from analysis explicitly incorporating developing countries only.

Table 1. FAO areas included in tabulations of tropical and subtropical areas.

FAO Region	Area
1	Africa
4	Asia
23	South America
31	Atlantic, WC
34	Atlantic, EC
41	Atlantic, SW
47	Atlantic, SE
51	Indian Ocean, W
57	Indian Ocean, E
71	Pacific Ocean, WC
77	Pacific Ocean, EC
87	Pacific Ocean, SE
	Mexico
	China

III. The Resource Systems

The resource systems considered here are

a) Uplands

b) Ponds, including small water bodies

c) Reservoirs and lakes

d) Rivers, floodplains and swamps

e) Estuaries and lagoons

f) Coral reefs

g) Shelves with soft bottom

h) Shelves with upwelling

i) Open oceans

The resource systems are defined as follows:

a) Uplands: Terrain with steep gradients at the higher elevations of catchments, where little or no fishery or aquaculture is possible.

b) Ponds: Ponds are small freshwater bodies, usually artificial, occasionally natural, in rainfed and irrigated areas where aquaculture, particularly integrated with agriculture is possible. Flooded rice fields are hence considered as ponds. Ponds are normally characterized as being under private individual or group ownerships or leasing arrangements.

c) Reservoirs and lakes: Reservoirs are natural or artificial waterbodies, primarily used for irrigation, hydroelectric power and domestic water supply. Lakes are natural waterbodies. Both are usually freshwater and have high potential for aquaculture and conventional or enhanced capture fisheries. They are usually considered common property and there may be free access to fishing or aquaculture sites.

However, in some cases, rights are leased from the government or from other authorities, groups or individuals.

d) Streams, rivers and floodplains: Streams and rivers are flowing waters while floodplains are the lowland areas, adjacent to watercourses that are subject to periodic or near-permanent inundation and sediment deposition. Streams, rivers and floodplains support substantial inland fisheries and have potential for enhanced fisheries. Normally all these systems are common property and have open access, except where access and/or ownership, attached to surrounding lands, restricts this.

e) Estuaries and lagoons: Estuaries are semi-enclosed coastal waterbodies with free connection to the open sea and within which seawater is diluted with freshwater from land drainage (e.g., brackishwater). Lagoons are shallow waterbodies resembling ponds or lakes, which usually have one or more shallow restricted outlets to the sea. This grouping includes the key habitats, such as mangrove, that support coastal fisheries. It also has potential for aquaculture and for enhanced fisheries. Coastal waters out to 10 meters depth are included here to encompass most of fishing grounds by small-scale fishers. These areas are usually directly adjacent to soft-bottom shelves (see below), leading to conflicts with the (trawl) fisheries operating there. Brackishwater ponds are included in this system. They are either natural or man-made; often the result of conversion of mangrove swamps. This resource system is often an area of intense intersectoral conflict over competing uses.

f) Coral reefs: Areas of continental and island shelves in tropical oceans in which reef-building corals are dominant features, forming scattered patch reefs, fringing reefs or barrier reefs and usually large areas of shallow coraline enclosed waters. The latter have potential for aquaculture. This is often an area of intensive fishing and gleaning. There may be traditional use rights but reefs are often considered open access.

g) Soft-bottom shelves: These are the relatively shallow (up to 10-200 m deep) productive areas surrounding continents. In the tropics, it is mainly the upper, nearshore parts (10-50 m) of the shelves which sustain marine fisheries. There are strong interactions (and conflicts) between nearshore small-scale fisheries and large-scale commercial operations.

h) Upwelling shelves: Upwelling is the process in which cold, nutrient-rich water is brought to the surface of the sea from deeper layers. This process mainly occurs on the eastern side of oceans, driven by the interaction of strong and steady winds directed towards the equator and the earth's rotation. The upwelled water fertilizes the sea, enabling the support of large populations of a few species of small (anchovies and sardines) and large (bonitos, mackerels) pelagic fishes. These areas also support large populations of sea birds and sea mammals. In addition to the four major upwelling areas (off Peru, California, North West Africa and Angola/Namibia), scattered smaller upwellings occur throughout the tropics, e.g., in the Arabian Sea and in Indonesia. In most cases, upwellings are fished by medium- to large-scale industrial fishing vessels.

i) Open oceans: The open seas beyond 200 m depth, where mainly oceanic resources such as tuna and large squid are fished by commercial or large-scale enterprises.

IV. Occurrence of Fish Groups in Resource Systems

Fisheries commodities are defined using the format used by FAO. FAO provides annual catch data for 950 individual species or group of species, regrouped in 51 clusters. The groupings are based on the FAO 'International Standard Statistical Classification of Aquatic Animals and Plants' or ISSCAAP (FAO 1990).

For the present analysis we have grouped the data into 26 commodity groups and indicated in which of the considered resource systems the major catches are taken (Table 2). The commodity groups consist of clusters of related species.

The main conclusion that can be drawn from Table 2 is that the importance of the different commodities varies between resource systems.

The importance of the commodities also shows regional differences. Fearn and Davies (1991) presented a comprehensive analysis of potential regional benefits from fisheries commodity research for the major commodities. They defined regional benefits as direct and spillover benefits to all countries in the

Table 2. Distribution of catches (million tonnes per year) in tropical and subtropical areas by ISSCAAP groups. Stars indicate where major parts of catches occur in the resource systems. Aquaculture production is not included.

ISSCAAP Code	Group of species	Total[a)] catch	Up-lands	Ponds	Lakes, reserv.	Floodpl. rivers	Est. lag. bays	Coral reefs	Shelves A	Shelves B	High seas
11	Carps and other cyprinids	0.59		*	*	*					
12	Tilapias and other cyprinids	0.31		*	*	*					
13	Misc. freshwater fishes	4.01	*	*	*	*					
41	Freshwater crustaceans	0.18		*	*	*					
2	Diadromous fishes	1.11			*	*	*				
51	Freshwater molluscs	0.26			*	*					
31	Flatfish	0.10					*		*		
33	Bashes, congers, etc.	2.49					*	*	*		
34	Jacks, mullets, etc.	6.14					*	*	*		
38	Sharks, rays, etc.	0.42							*		
42	Crabs, etc.	0.65					*				
43-44	Lobsters, etc.	0.09					*	*	*		
45	Shrimps, prawns, etc.	0.99					*		*		
47	Other marine crustaceans	0.07					*	*	*		
52	Abalones, winkles, etc.	0.05					*		*		
53-54	Oysters and mussels	0.10					*		*		
55	Scallops	0.04					*		*		
56	Clams, cockles, etc.	0.20					*	*	*		
57	Squids, cuttlefishes, etch.	1.30					*		*		
58	Misc. marine molluscs	0.16					*	*	*		
7	Misc. invertebrates	0.19					*	*	*		
32	Gadoids	1.73					*		*	*	
35	Sardines, anchovies, etc.	13.07					*		*	*	
36	Tunas, bonitos, etc.	2.25							*	*	*
37	Mackerels, etc.	2.12					*		*	*	*
39	Misc. marine fishes	6.09					*	*	*	*	*
Total		44.69	-	-	1.8	3.5	5.1	6.0	11.1	14.0	3.1

[a)] FAO Statistics, 1988 for FAO geographic areas 1, 3, 4, 31, 34, 41, 47, 51, 57, 71, 77, 87 and China.

geographic region where the research is being undertaken and found the dominant financial benefits to come from prawns and shrimps in South East Asia, from clams in South Asia, carps in China, tuna in the South Pacific, small pelagics in West and North Africa, and miscellaneous diadromous fish (fish which migrate from the sea to freshwater or *vice versa*) in other parts of Africa (Table 3).

Table 3. Potential regional benefits from fishery commodity research. (Source: Fearn and Davis 1991)

South East Asia		South Asia		China	
Commodity	Regional benefits ($US x 10^6)	Commodity ranking	Regional benefits ($US x 10^6)	Commodity ranking	Regional benefits ($US x 10^6)
Prawns/shrimps	21.9	Clams	61.3	Carps	335.1
Demersal/pelagics	12.0	Misc. diadromous	40.6	Prawns/shrimps	28.9
Herrings & others	6.6	Prawns/shrimps	25.9	Demersal/pelagics	7.3
Tilapia	2.7	Carps	23.8	Mussels	5.2
Lobsters	0.8	Demersal/pelagics	23.0	Mackerels & others	4.3
Mackerels & others	0.8	Tilapia	9.4	Tuna & others	2.5
Tuna & others	0.5	Oysters	6.1	Herrings & others	0.2
Carps	0.1	Mussels	4.9	Oysters	0.0
Misc. diadromous	0.1	Tuna & others	3.7	Tilapia	0.0
Clams	0.0	Herrings & others	3.6	Misc. diadromous	0.0
Oysters	0.0	Lobsters	3.5	Lobsters	0.0
Mussels	0.0	Mackerels & others	3.5	Clams	0.0

South Pacific and Papua New Guinea		Africa		West Asia North Africa	
Commodity ranking	Regional benefits ($US x 10^6)	Commodity ranking	Regional benefits ($US x 10^6)	Commodity ranking	Regional benefits ($US x 10^6)
Tuna & others	4.4	Misc. diadromous	20.6	Herrings & others	9.5
Demersal/pelagics	0.5	Carps	8.1	Carps	2.8
Lobsters	0.2	Lobsters	4.8	Demersal/pelagics	1.6
Prawns/shrimps	0.1	Tilapia	4.1	Mackerels & others	1.2
Clams	0.1	Herrings & others	1.4	Prawns/shrimps	0.6
Misc. diadromous	0.1	Demersal/pelagics	1.0	Lobsters	0.6
Tilapia	0.1	Oysters	0.3	Tuna & others	0.3
Carps	0.0	Tuna & others	0.2	Mussels	0.1
Oysters	0.0	Prawns/shrimps	0.2	Oysters	0.0
Herrings & others	0.0	Mackerels & others	0.1	Misc. diadromous	0.0
Mackerels & others	0.0	Clams	0.0	Tilapia	0.0
Mussels	0.0	Mussels	0.0	Clams	0.0

V. Catch and Potentials by Resource Systems

a) Uplands

Very little fishing takes places in this resource system and the system offers very little potential. We have for these reasons opted to discuss neither status nor potential for the uplands.

b) Ponds

In ponds only negligible catches are taken, and the area does not offer any noteworthy potential for increases of the capture fisheries. Research effort in these areas should concentrate on aquaculture production.

(c) **Reservoirs and Lakes**

Lakes are to a large extent a temperate phenomenon. In the tropics and subtropics, only Africa has large natural lakes. The three largest (Victoria, Malawi and Tanganyika) cover a combined area of 134,000 km^2. Only few large natural lakes are found in the tropics outside Africa. Indonesia has three that can be considered large - Lakes Toba (Sumatra), Towuti and Poso (Sulawesi). Very few natural lakes are found in South and Central America.

Artificial lakes, i.e., reservoirs comprise the greatest areas of stable standing waters in the tropics. In the 56 countries and associated islands of Africa, there are 320 major dams and reservoirs occupying a total of 41,000 km^2 (total maximum surface area).

Reservoir fisheries in Africa contribute roughly 10% or 150,000 tonnes annually to inland fisheries yield. Yet, the full biological and economic potential of reservoir fisheries has rarely been realized. This is primarily because reservoirs were established for purposes other than fisheries; little is known about how to manage reservoir fisheries.

In Asia, reservoir fisheries play a significant role in India and in Sri Lanka. The latter has the highest relative proportion of small reservoirs in the world.

The distinction between lakes and reservoirs may seem academic - after all a reservoir is a lake that was just more recently dry land or a river. However, due to the brief history of the reservoirs they do not possess the variety of life forms that characterizes a lake. This raises a need for careful consideration as all ecological niches may not be filled, something that often results in inefficient transfer from primary production to fish yield. As an example, introduction of sardines to the artificial Lake Kariba resulted in a niche being filled and in sustainable catches of over 20,000 tonnes annually. This indicates that management based on understanding of ecological interactions raises potential for enhancing the fish productivity.

The productivity of tropical lakes is related to their topography. Shallow lakes generally have a higher productivity than deeper ones. This is related to a higher shallow water primary production and to generally shorter food webs in shallow areas. Reservoirs, usually being more dendritic and thus with longer shorelines than lakes, have a potentially higher productivity than lakes - once their various niches are occupied. Fig. 2 shows the relationship between fish yield and primary productivity for tropical lakes and reservoirs.

Small lakes tend to be fully exploited, while larger lakes often are less utilized in the offshore areas. The relationship between fish catches and effort for a number of African lakes is given in Fig. 3. As this figure includes yields (not maximum sustainable yields) from a number of lakes, it can only be concluded that the yields of African lakes do not increase when there are more than two fishers per square kilometer.

Total catches from lakes and reservoirs are difficult to estimate from the statistics where they are grouped with production from river systems and from freshwater aquaculture. Total freshwater production in the developing world was some 10.8 million tonnes in 1988. Of these, 5.5 million tonnes can be attributed to aquaculture (mainly in ponds), leaving 5.3 million tonnes for capture fisheries. The breakdown of the catches between the two main freshwater resource systems is uncertain. We only know of qualitative

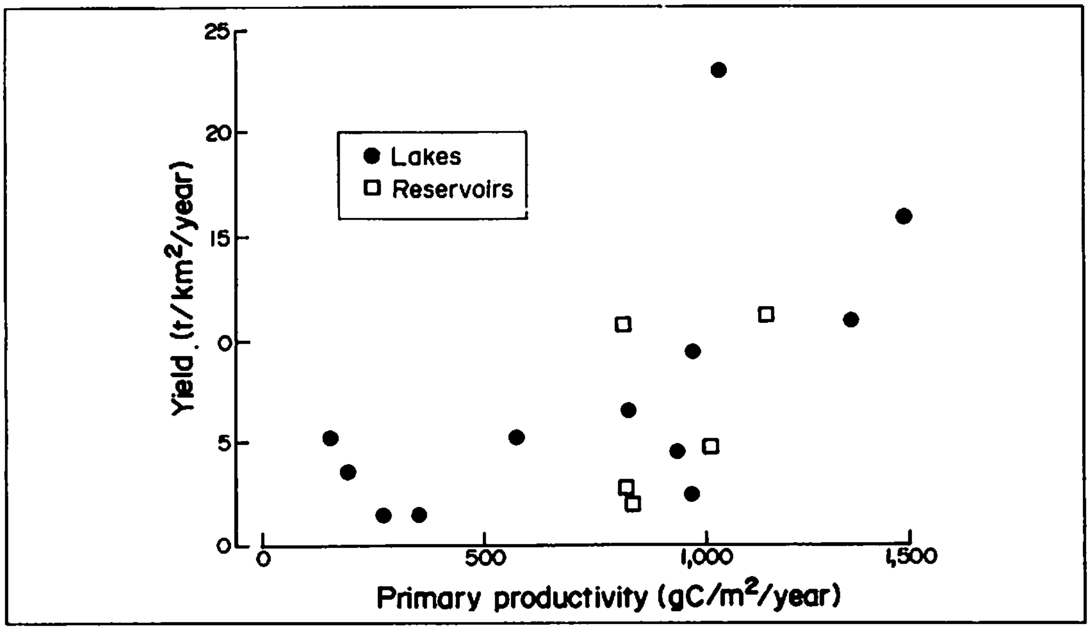

Fig. 2. Fish yields and primary productivity in tropical lakes and reservoirs. (Source: Marten and Polovina 1982)

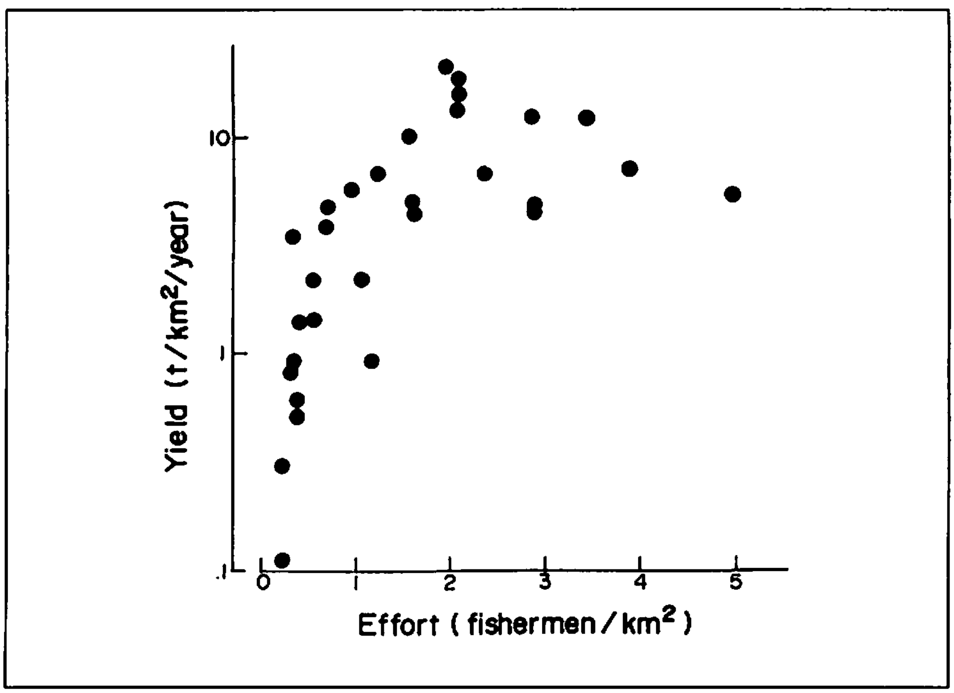

Fig. 3. Fish yields and fishing effort on African lakes. (Source: Henderson and Welcomme 1974)

evidence suggesting that most catches are taken in floodplains, rivers and swamps. We have therefore allocated 1/3 of the catches to lakes and reservoirs, and 2/3 to floodplains, rivers and swamps. This results in an estimate of annual catch in lakes and reservoirs of 1.8 million tonnes.

(d) Floodplains, rivers and swamps

The bulk of the world's freshwater fish catch is taken from running waters and their seasonal flood zones - fringing floodplains (lateral flood zones), internal deltas and coastal deltas. Of these, the coastal deltas of rivers are subsumed under "estuaries and lagoons" and are discussed further below.

The mean catch rates for tropical rivers and floodplains in Africa, Central and South America, and Asia have been estimated at 5.2 tonnes km^{-2} $year^{-1}$ (Wellcome 1985). It was not possible, due to the considerable variations in the catch rates, to identify any differences between the three continents.

The catch rates from rivers vary more than for lakes. Low productivity occurs in headwaters in areas of highly weathered soils where the primary productivity is low. Contrarily, high productivity can often be attributed to input of nutrients and organic material from watershed areas including sewage from cities. Further, a good part of the fish catches in rivers comes from fish passing through on feeding or breeding migrations. This leads to catches in excess of what can be supported by primary production.

Total catches from all rivers, floodplains and swamps are not known. As explained in the section above a first, crude estimate of total production in the resource system is 3.5 million tonnes annually. The potential for considerable increases in the catches seems limited.

The total production of tropical rivers and floodplains amounts to some 4% of global fish production. As such it may seem unimportant, but as the rivers and floodplains are harvested almost exclusively by small-scale fishers for local consumption, it constitutes an important food source in otherwise impoverished areas. It also should be noted that the statistics for this type of small-scale fishery rarely receive much attention from the responsible authorities. Therefore, the actual catches may be underestimated.

When the number of fishers in a river system increases, the catches per unit area decrease. This is illustrated in Fig. 4 where a regression between catch per unit effort (CPUE) and effort shows a clear negative correlation (Wellcome 1985). The trends are the same in Fig. 5, where a time series of catch/effort data from the Nile downstream of the Aswan Dam is summarized (Wellcome 1985). Here, the development from an under- to an over-exploited fishery is clearly demonstrated. Over a ten-year period, the area yielded a more or less constant catch of 8,000 tonnes per year despite a threefold increase in effort.

Data on fisherfolk populations and effort are often difficult to obtain. This sort of information is, however, badly needed to develop realistic management models.

(e) Estuaries and lagoons

This resource system covers non-reef coastal areas and includes coastal deltas, estuaries and other nearshore areas down to approximately 10 meters depth. The depth limit is set mainly to include most of the catches by coastal small-scale fisherfolks in the category.

The total area of this resource system is difficult to estimate, as a detailed database is not available. From information in Gulland (1971) the total shelf area (0-200 m depth) can be estimated at 10.9 million km^2 for developing countries. Of these 0.7 million km^2 are attributed to upwelling areas. One-quarter of the total area is assumed to be within 0-50 meters deep, where the vast majority of the catches are taken. This

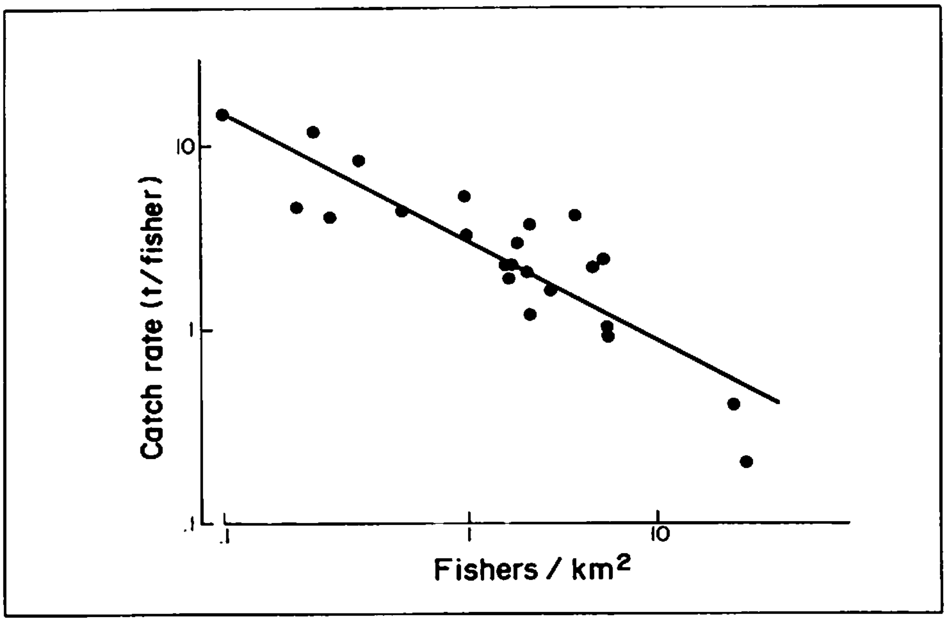

Fig. 4 Catch per unit effort as a function of effort for 17 rivers; CPUE = 2.92 * (Fisheries/km^2)$^{-0.5}$. (Source: Welcomme 1985).

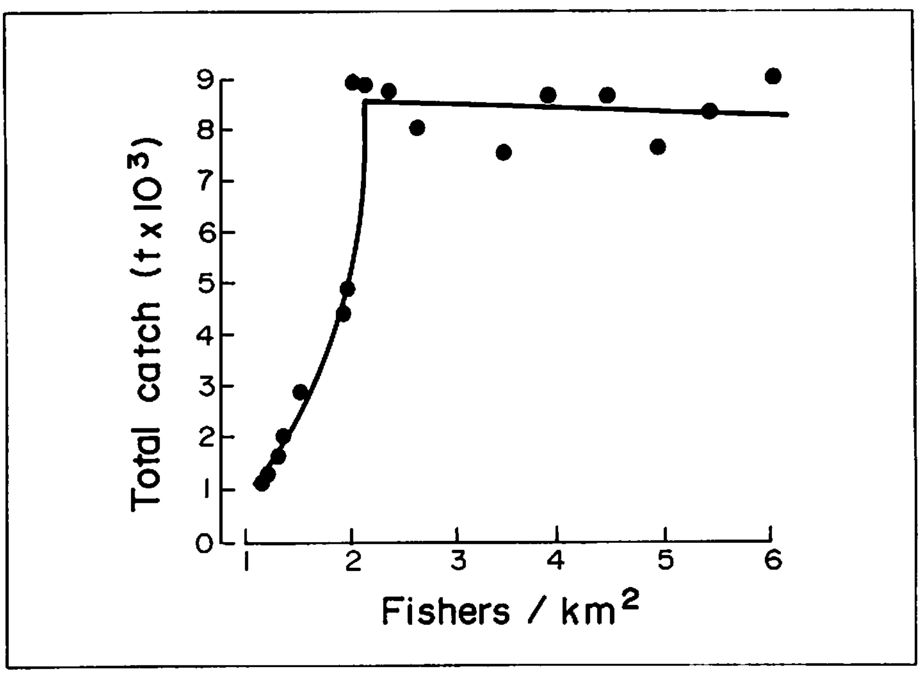

Fig. 5. Plot of total catch against the number of fishers for the Nile south of the Aswan Dam. (Source: Welcomme 1985).

corresponds to 2.7 million km², of which 0.6 can be attributed to coral reefs (see below). The remainder is assumed to be distributed between estuaries and lagoons, and softbottom shelves in proportion to the estimated catches in the systems, i.e., as 5.1 to 11.1. This corresponds to 0.7 and 1.5 million km² respectively.

Overall, it is a heterogeneous area, characterized by *(i)* high productivity, attributable to mangrove litterfall and substantial import of nutrients from river runoff; and *(ii)* being an important nursery area for fish and penaeid shrimp. The systems are exploited mainly by small-scale fishers. In recent years, this use has led to conflicts with expanding coastal aquaculture operations. Governments tend to support export-oriented, capital-intensive shrimp culture, often at the expense of small-scale fishing opportunities.

Total catches from the resource system are difficult to estimate. We have used an indirect estimation procedure. The proportions of the catches taken by small-scale and large-scale fisheries in the considered region are estimated to be approximately the same (Thompson 1980; Pauly and Christensen *in press*). Using a 1:1 ratio we estimate the total production for the coastal water resource systems to be 11.1 million tonnes per year. The catches from coraline areas amount to some 6 million tonnes annually (Smith 1978). Therefore, the catches from estuaries, bays and lagoons can be approximated to 5.1 million tonnes annually.

The fisheries in the tropical coastal areas are characterized by growth overfishing throughout. The high fishing pressure forces fishers to use mesh sizes far below the optimal. The fisheries, therefore, become highly opportunistic and dependent on seasonal pulses of new recruits.

(f) Coral reefs

Smith (1978) attempted to estimate the proportion of the ocean surface area that can be attributed to coral reefs. His estimates lead to an estimate of 617,000 km^2 of coral reefs for the entire world.

Based on work done in Jamaica by J.L. Munro, Smith (1978) assumed a fisheries yield of 8 tonnes km^{-2} year^{-1} for coral reefs and adjacent reef areas; this led to an estimated annual yield (potential or realized) of 6 million tonnes annually for the entire coral reef regions of the world.

However, yield per coral reef surface area appears to be extremely variable both for natural reasons and due to different levels of exploitation or reef degradation. A high figure of 32 tonnes km^{-2} year^{-1} is obtained from a well managed Philippine reef, of which the catch sold was 11.3 tonnes, catch consumed 10.7 tonnes and local drying 11.7 tonnes (White and Savina 1987). The above figure of 8 tonnes, which may be a reasonable estimate of the "mean yield", could well be increased given improved management or decreased, if overfishing and coral reef destruction continue unabated.

The potential fish yield from coraline areas is high, perhaps much higher than until now assumed. Fig. 6 shows the relationship between yield from coral reefs and fishing effort. The figure does not show any levelling off due to increased effort; reefs seem to be able to sustain considerable fishing pressure if administered wisely. Noteworthy also are some community-based management initiatives from several intensively fished Philippine reefs, as mentioned above, where increases in catches by a factor of 2 to 3 have been experienced mainly through abolishing destructive fishing and introducing community-based enforcement of fish sanctuaries, (Fig. 7).

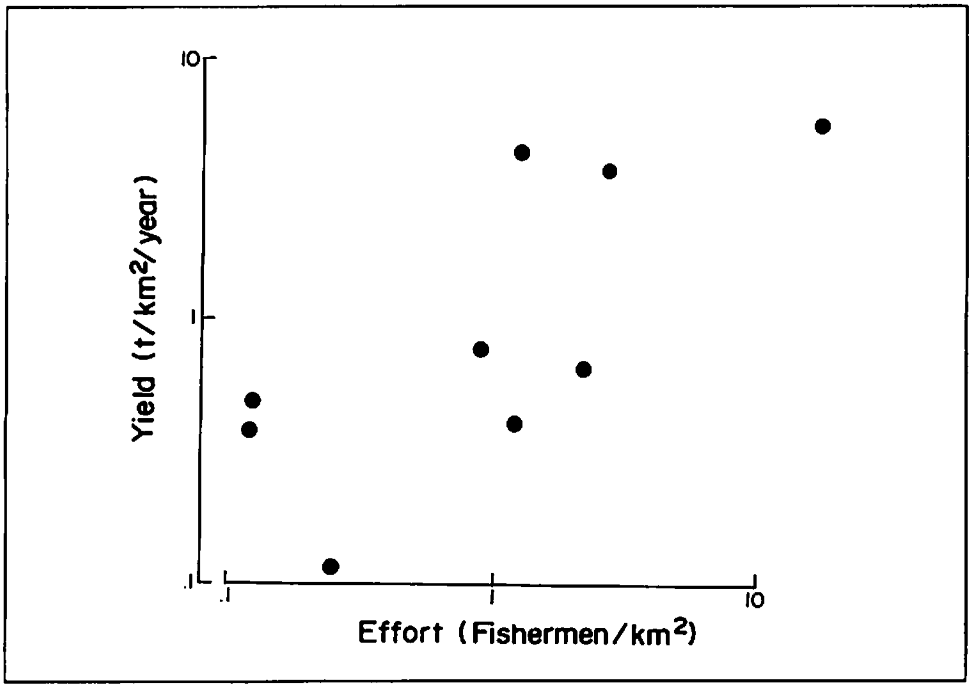

Fig. 6. Fish yields *vs* fishing effort in coral reefs. (Source: Marten and Polovina 1982)

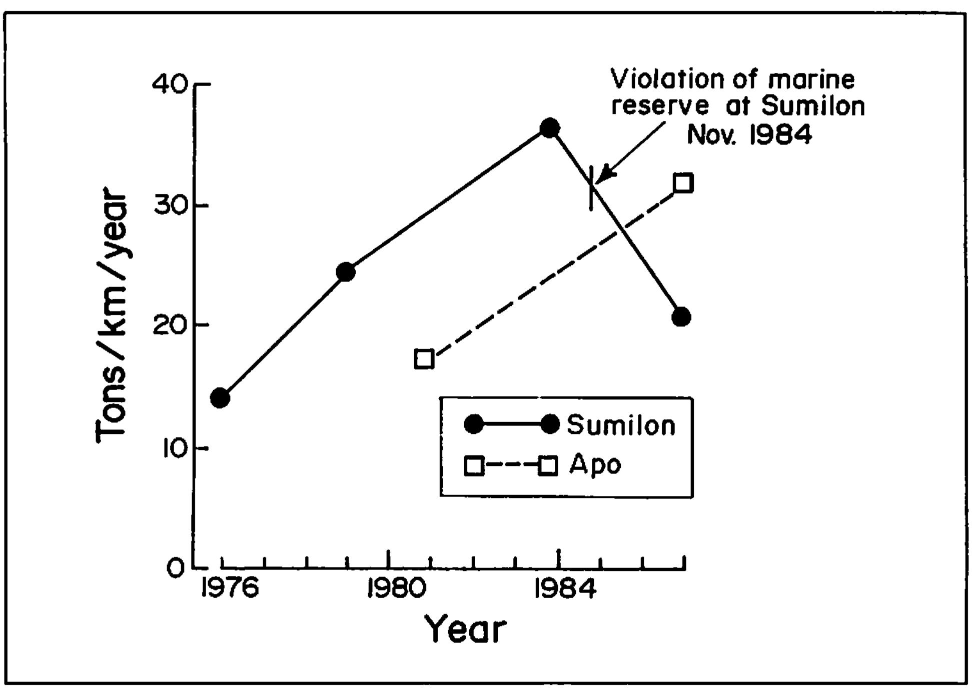

Fig. 7. Change in fish yield reported for Sumilon and Apo Islands, reflecting the effects of different management schemes. (Source: White and Savina 1987)

(g) Shelves with soft bottom

The total area of soft-bottom shelves (10-50 m depth) was estimated above to be some 1.5 million km^2. The potential maximum sustainable yield (MSY) of tropical demersal and pelagic marine fisheries varies considerably. The ranges in MSY for tropical continental shelf areas in different geographical regions are given in Table 4, where similar ranges for upwelling areas are included for comparison.

Table 4. Estimated maximum sustainable yields (t/km^2/year) for tropical continental shelf areas. (Source: Marten and Polovina 1982)

	Minimum			Maximum		
Region	Pelagic	Demersal	Total	Pelagic	Demersal	Total
NE Atlantic	0.8	0.6	1.4	7.3	8.0	15.3
NW Atlantic	1.8	1.8	3.6	7.0	7.0	14.0
NW Pacific	0.6	1.7	2.3	8.5	4.0	12.5
Indian Ocean	0.7	1.4	2.1	4.3	5.5	9.8
E Central Atlantic	4.0	1.2	5.2	5.0	2.5	7.5
South China Sea	0.2	0.8	1.0	2.4	4.3	6.7
W Central Atlantic	0.7	0.2	0.9	3.2	2.5	5.7
		Upwelling				
SW Atlantic	1.5	6.0	7.5	17.5	10.0	27.5
Peru	-	-	-	1.0	21.9	22.9

The MSY of the continental shelf demersal fisheries is strongly negatively correlated with the mean depth on the shelf (Fig. 8). On the other hand, the MSY shows a clear relationship with primary productivity, as illustrated in Fig. 9 for tropical pelagic fisheries.

Total catches from the soft-bottom shelf areas of developing countries are difficult to estimate directly due to lack of suitably compiled data. Indirectly the catches can be estimated by first taking the difference between the total fish catches in the regions considered (Table 1), and the catches in freshwater, in upwelling areas and in the open oceans. This difference gives the total catches in coastal and soft-bottom shelf areas, which are split between the systems in a 1:1 ratio, as discussed earlier. The results from these manipulations are shown in Table 5, where total catches for the soft-bottom shelf areas are estimated at some 11.1 million tonnes for 1988. The catches from soft-bottom shelf areas are thus approximately as large as (and much more valuable than) those from upwelling fisheries.

A few decades ago only few of these regions were more than lightly exploited. Since then the introduction of industrialized fisheries has rapidly changed the status of most shelves from potential to overfished fishing areas. The result of this is mainly waste of resources through deployment of excessively large fleets and depletion of the more valuable stocks, with lower-valued short-lived species now dominating.

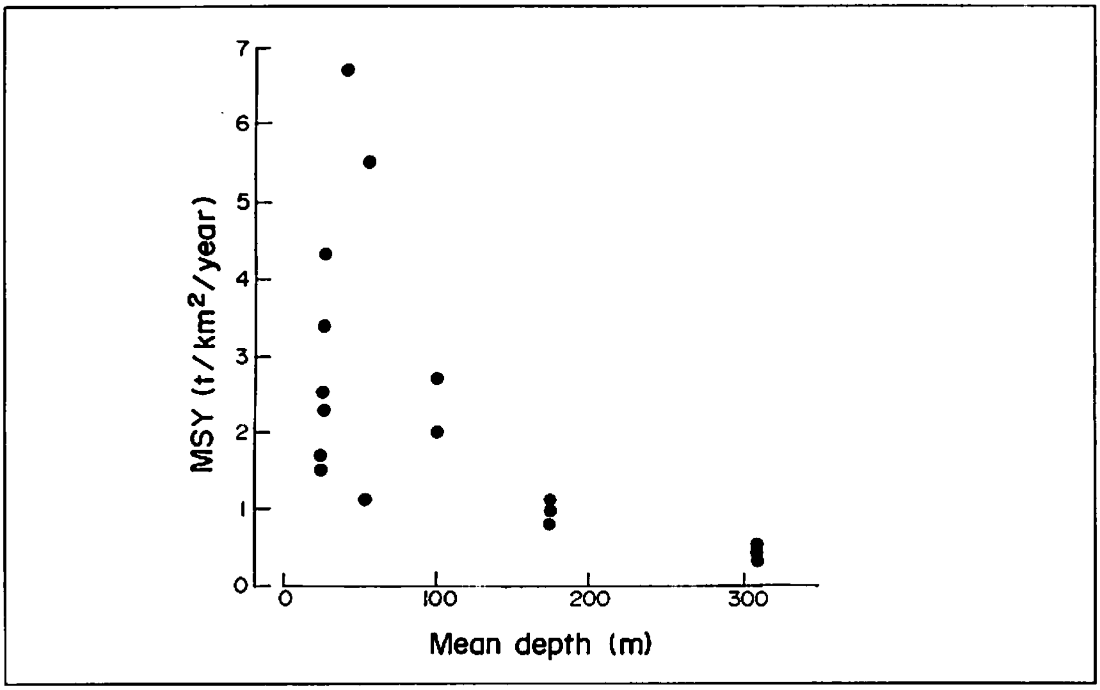

Fig. 8. Maximum sustainable yields (MSY) and depth of continental shelf demersal fisheries, based on Table 7. (Source: Marten and Polovina 1982)

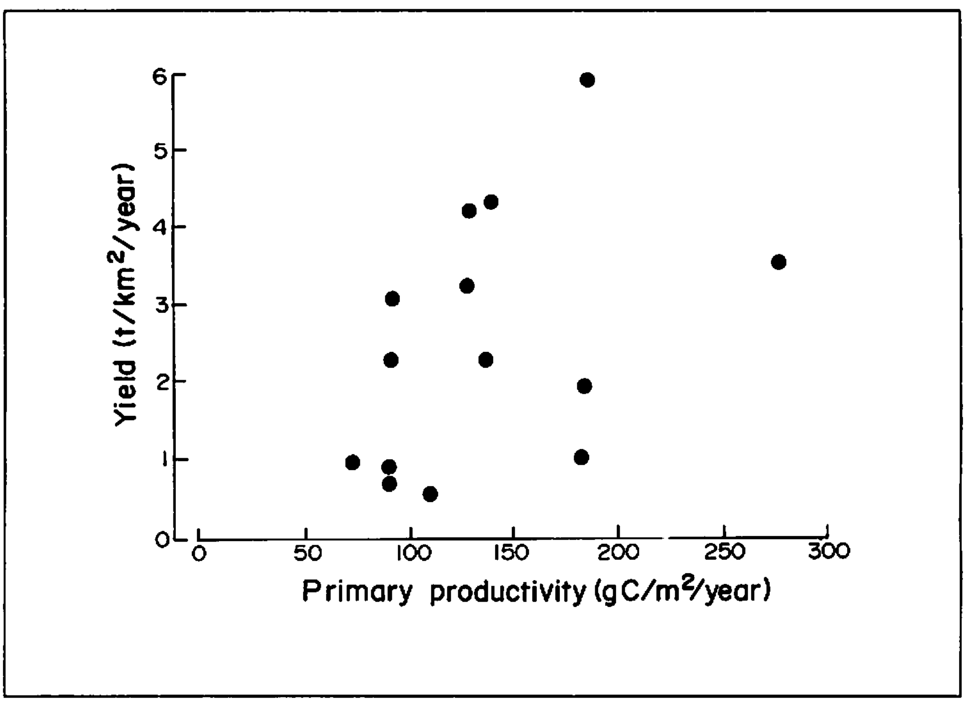

Fig. 9. Maximum sustainable yield and primary productivity of continental shelf pelagic fisheries, based on Table 13. (Source: Marten and Polovina 1982)

Due to the present nearly total lack of management of trawl fisheries in the developing world and their subsequent overexploitation, it is likely that catches can be increased by proper management. To do so it is essential to introduce new management strategies.

Table 5. Summary of estimated catches for the major resource systems for tropical and subtropical fisheries (excluding aquaculture production). Catches are in million tonnes per year. Areas in million km², and production in t·km⁻²·year⁻¹.

	Catch	Area	Production	Comment	Assessment of potential for increases[b]
Uplands	-	-	-	Catches insignificant	-
Ponds	-	-	-	Catches insignificant	-
Reservoirs, lakes	1.8	0.3	6.0	1/3 of total freshwater catch	+
Floodplains, rivers, swamps	3.5	0.6	5.8	2/3 of total freshwater catch	-
Estuaries, bays, lagoons	5.1[a]	0.7	7.7		+
Coral reefs	6.0	0.6	10.0	From Smith (1978)	++
Shelves, softbottom	11.1[a]	1.5	7.7		+
Shelves, upwelling areas	14.0	0.7	20.0	FAO statistics	+
High seas	3.1	-	-	FAO statistics	+
Total	44.7			FAO statistics	

[a] Catches for estuaries, etc. and softbottom shelves are estimated as the difference between total catches and the catches in the other resource systems, attributing 50% of the difference to softbottom shelves and 50% to estuaries, etc. and coral reefs.
[b] - = no significant increase possible; + = small increases possible; ++ = moderate increases possible.

(h) Shelves with upwelling

Based on data in Gulland (1971), the total area of shelves with upwellings has been estimated to be 0.7 million km². The MSYs for two upwelling fisheries are given in Table 4. The productivity of these systems is very high, comparable to the most productive aquatic systems. Due to the large areas over which upwelling takes place this makes upwelling fisheries the most productive overall.

The fish stocks in the upwelling areas are very much affected by environmental conditions. This has, for all the major stocks in upwelling areas, led to total collapses of the fisheries, and not always in combination with severe overfishing.

The upwelling fisheries are described in more detailed in the regional descriptions (Section V).

(i) Open oceans

The open oceans are fished by few developing countries (most notably Thailand), mainly for tunas. The resources of tunas and squids in the oceans are large, and expansion of these fisheries seems possible. The catch possibilities are discussed further in section VI.

(j) Generalizations

A summary of the estimated catches for the major resource systems in tropical and sub-tropical areas is given in Table 5. Ranked by total catches, the shelves with upwelling are highest, closely followed by shelves with soft bottom, and coral reefs, coastal areas, open ocean and freshwater systems following.

The yield of a resource system is related to the magnitude of the primary production. This is shown in Fig. 10 where the range and modal values of fish yield are presented as a function of the primary productivity. The yield is also influenced by other factors, e.g., the structure of the food web.

The effectivity in transfer of matter from the primary producers to the catches differs between resource systems. This is shown in Table 6. The geometric means of the observed ranges vary by a factor of 180 from the most to the least efficient.

Table 6. Ratio of fish yields to primary productivity. (Source: Modified after Marten and Polovina 1982)

Ecosystems	Range			Geometric mean	Ratio
Coastal upwelling	.005	-	.013	0.0081	180
Rivers	.005	-	.01	0.0071	150
Ponds	.001	-	.01	0.0032	71
Lagoons and estuaries	.0008	-	.01	0.0028	62
Continental shelf	.0003	-	.003	0.00095	21
Lakes	.0004	-	.0016	0.00080	18
Reservoirs	.0002	-	.002	0.00063	14
Coral reefs	.0002	-	.0008	0.00040	9
Open ocean	.00001	-	.0002	0.000045	1

The proportion of primary production that is eventually harvested is to a large extent a function of the number of trophic levels in the systems. A factor of 180 corresponds more or less to two steps up the food chain. In the most efficient system, the coastal upwelling system, the fishery is mainly based on catching small pelagic fish that feed on the primary producers directly or on herbivores. In the least efficient system, the open oceans, the fisheries are predominantly based on the top predators. This fact offers some possibilities for increasing the catches; changing the fishing pattern can increase the amounts landed considerably.

It is difficult to quantify the potential increases in fish catches by resource systems. A major reason for this is that few before us have used the resource system approach; also that the traditional fish stock assessment models cannot cope with radically changed fishing regimes. Following the traditional approach - unchanged fishing patterns in exploited areas - the potentials can be quantified, albeit roughly. We will discuss this further in Section VI, dealing with *regional* catch trends and potential on a global scale.

VI. Global Trends in Regional Fish Catches

The global production of fish has been increasing steadily over the last 25 years (Fig. 11), in what appears to be three stages: Increasing catches in the 1960s due to increased exploitation of upwelling and

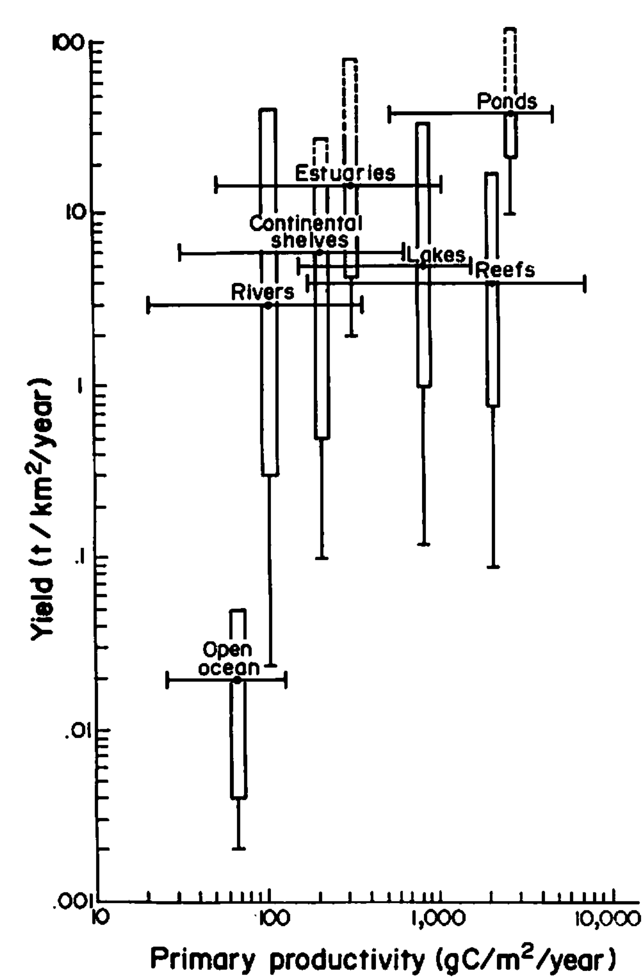

Fig. 10. Ranges of fish yields and primary productivities in various tropical ecosystems. Dots at the intersection of ranges represent modal values. Solid portions of the bars represent the range of maximum sustainable yields. Dashed projections at the top of the ranges for estuaries and ponds represent elevated yields from aquaculture with fertilization (but not supplemental feeding). The dashed projection for continental shelves represents higher yields which occur in areas of upwelling. (Source: Marten and Polovina 1982).

coastal fisheries. Stagnation in the 1970s when the Peruvian anchovy collapsed, and a gradual increase in the 1980s mainly due to increased catches of shoaling pelagic species (FAO 1990).

The bulk of the fish catches is taken from continental shelves (i.e., from water depths of less than 200 meters, generally at depths of less than 50 meters). Most of this production comes from the highly productive temperate and subpolar continental shelves in the northern hemisphere and in upwelling areas (Table 7).

The world catches are approximately evenly distributed between developed and developing countries (Table 8). Developments from 1978 to 1988, however, show a trend toward increasing production in developing countries. Total annual fish production in these countries rose 57% over the decade. The share of the total catches taken by developing countries increased in this period from 46% to 53%. The major

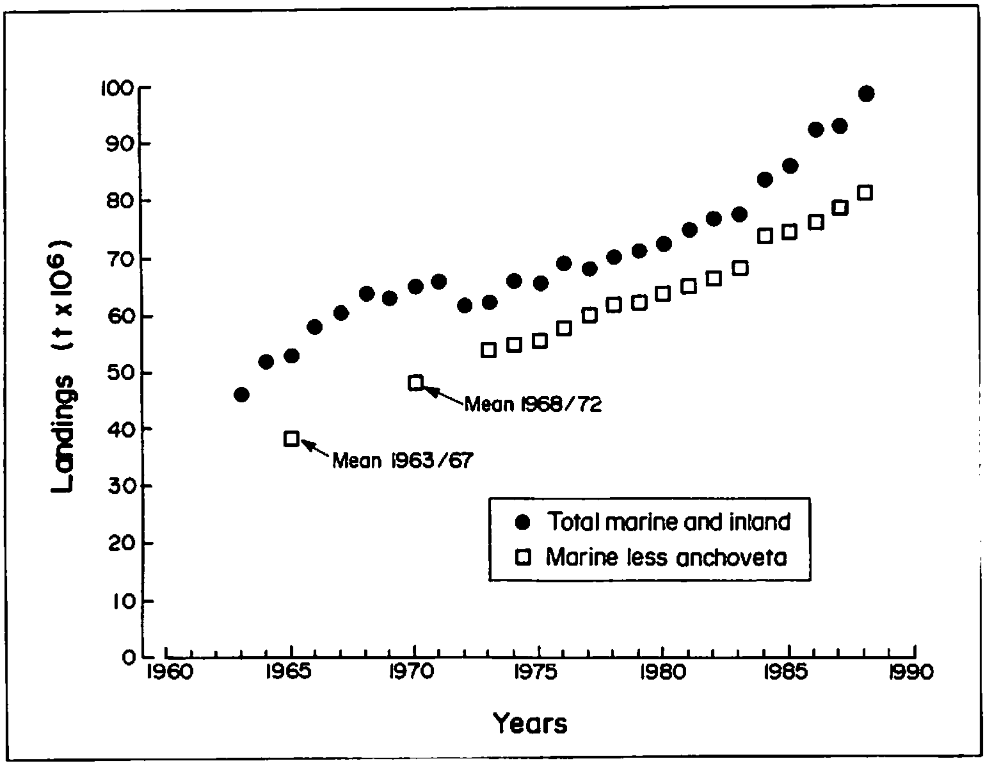

Fig. 11. Annual world landings of aquatic resources (excluding mammals and plants). (Source: FAO 1990)

Table 7. Fisheries yield (10^3 tonnes), by continent, 1978 and 1988. Aquaculture production is included.

	Inland		Marine	
	1978	1988	1978	1988
Africa	1,467	1,802	2,831	3,508
America, North	152	564	6,121	9,004
America, South	213	368	7,063	14,045
Asia	4,509	9,188	27,115	34,414
Europe	295	484	12,336	12,391
Oceania	25	24	311	863
USSR	733	996	8,197	10,336
Other	-	-	1,011	-
Total	7,394	13,426	64,985	84,561

[a]From FAO statistical yearbook.

Table 8. Nominal marine and inland water fish catches (million tonnes per year) by FAO regions, 1978 and 1988. Aquaculture production is included. (Source: FAO yearbooks)

Region	1978	1988
Northwestern Africa	0.4	0.8
Western Africa	1.5	1.4
Central Africa	0.4	0.5
Eastern Africa	0.8	1.1
Southern Africa	0.4	0.0
Northern America	0.1	0.2
Central America	0.9	1.5
Caribbean	0.3	0.3
South America, Pacific	5.5	12.6
South America, Other	1.7	1.8
Near-East (Africa)	0.1	0.3
Near-East (Asia)	0.7	1.2
Southern Asia	3.5	4.7
East & Southeast Asia	9.3	12.8
China	4.7	10.4
Asia, Other	2.7	2.6
Oceania	0.1	0.2
Developing countries	33.2	52.3
Developed countries	38.1	45.7
World total	72.4	98.0

proportion of the increased catches in the developing countries can, however, be attributed to the upwelling fisheries (Peru/Chile; Morroco/Mauritania/Senegal; and Angola/Namibia) and to a doubling of the nominal Chinese production.

A separation of the global production of the eight major fish commodity groups is presented in Fig. 12 for 1978 and 1988. The increases in catches over the decades seem to be distributed over nearly all commodity groups, though predominantly for freshwater fishes, small pelagics and invertebrates.

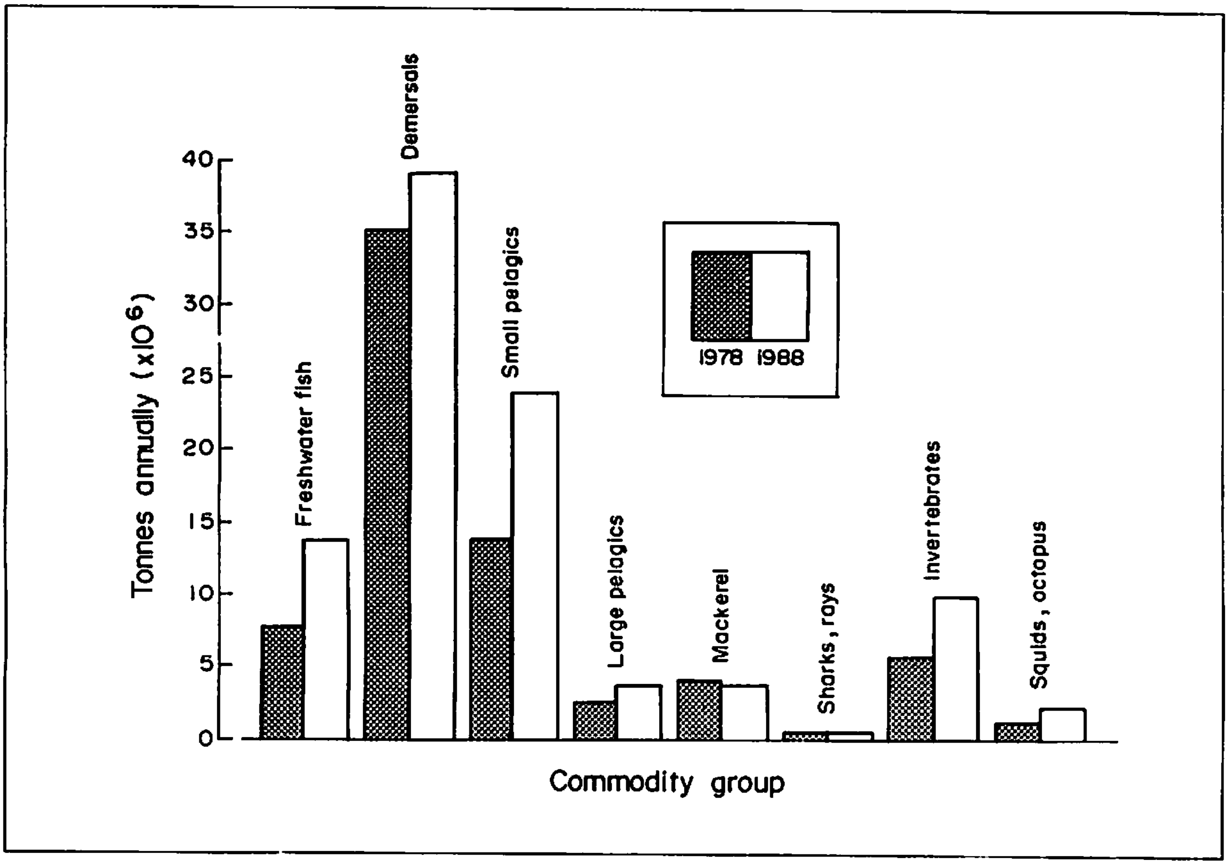

Fig. 12. Global fish production in 1978 and 1988 by major commodity groups. Aquaculture production is included. Expressed in million tonnes.

The major fishing nations among the developed countries can be arranged in three groups: *(i)* the nations bordering the North Atlantic, mainly fishing within their respective EEZ boundaries; *(ii)* the East European countries, with large, but now rapidly diminishing distant-water fisheries; and *(iii)* Japan, whose large regional fishery is supplemented by huge overseas catches taken worldwide.

The developed fishing nations previously took a large proportion of the potential catches off the coasts of developing countries. This pattern is now changing through the introduction and subsequent enforcement of 200-nautical-mile (nm) EEZs. The developing countries with the potential for large offshore fisheries will need substantial management support to utilize their offshore resources optimally.

The fisheries of developing countries can also be categorized into three groups: *(i)* the upwelling fisheries, mainly west of South America, and Northwest and Southwest Africa where there is a large potential for increased catches through improved management; *(ii)* local commercial fisheries within EEZ areas; and *(iii)* small-scale fisheries whose catches are predominantly for local use. In addition, South Korea and Taiwan have taken up the Japanese practice of fishing overseas and operate large distant water fleets.

The best (most comprehensive) sources of catch information are the FAO fishery statistics yearbooks. The quality of the data contained therein is variable, especially for the small-scale fisheries of developing countries. Fortunately, this has improved over the last decades, and a larger proportion of catches is now reported or otherwise estimated. These improvements in the quality of the catch statistics make it difficult to assess global trends in fish production.

In the following we will give a brief overview of the fisheries in the major FAO regions of the world (Fig. 13).

North Atlantic (FAO Regions 21 and 27)

These regions support some of the highest fish production globally, being that part of the world with the most developed traditions for large-scale fisheries. A large proportion used to be taken by high-sea fleets fishing mainly for cod. With the introduction of 200-nm EEZs this tradition has been broken and national fisheries are now dominating.

For the North West Atlantic, FAO (1981) estimated the total potential for demersal fisheries to be 2.5 to 3.5 million tonnes per year, and for pelagic fisheries some 2.0 million tonnes. The present catches are 3.8 and 0.6 million tonnes per year, respectively. This seems to suggest some basis for expansion of the pelagic fisheries, the traditional demersal stocks being fully utilized. Additionally, there may lie possibility of an expansion in fisheries for less traditional resources as redfish and silver hake by fishing deeper. FAO (1990) reports the Atlantic mackerel to be underexploited, the present catches being only 25 % of those 20 years ago.

All the major (traditional) stocks in the North East Atlantic region are fully exploited or overexploited. The potential for the region is suggested by FAO (1981) to be some 16 million tonnes annually. The difference between potential catches (which may be over-optimistic) and present catches (10.5 million tonnes) is due to nonconventional stocks, which are difficult to exploit, and to depleted stocks, which are presently nonproductive. This is indicated by the catch trends over the last decade, which have dropped from 11.9 million tonnes in 1978 to 10.5 million tonnes in 1988. This stresses the need for better management even in this area, the cradle of fisheries biology.

Western Central Atlantic (FAO region 31)

The best known fisheries in this region are the penaeid shrimp fisheries in the Gulf of Mexico and the Atlantic/Gulf menhaden fishery. Of these the shrimp play an important economic role, while the substantial (US) catches of menhaden are mainly used for reduction, and thus are of less economic importance. The overall fish production is low and the two countries concerned (USA, Mexico) are not to

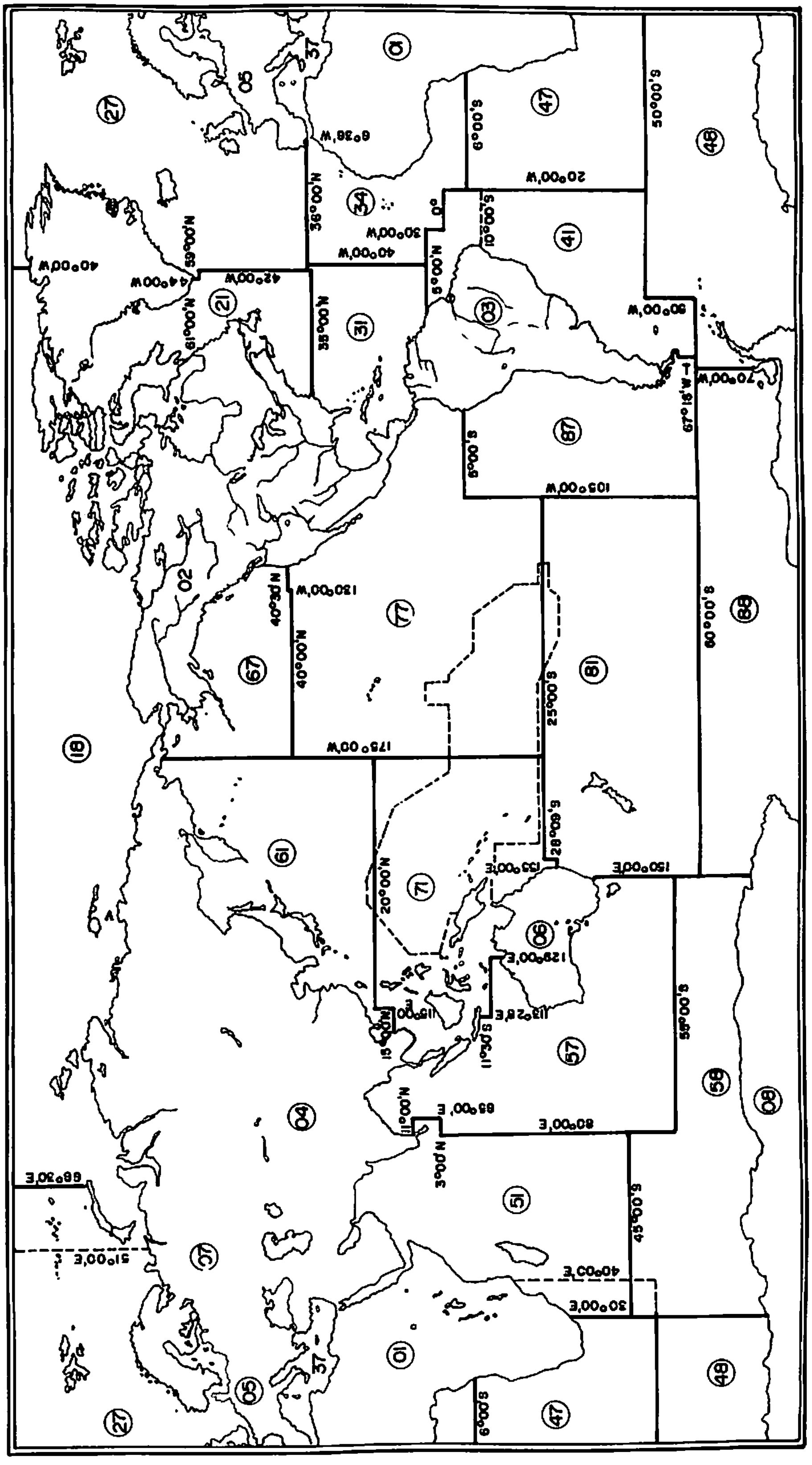

Fig. 13. Geographic boundaries of the major fishing FAO areas. (Source: FAO 1990)

any large extent dependent on these fisheries.

The potential for demersal catches in the region is estimated by FAO (1981) to be 2.5 to 3.5 million tonnes annually, comprising a variety of species, to which should be added a potential of 2.0-3.5 million tonnes of pelagic fishes and some 0.4 million tonnes of invertebrates annually. The corresponding catches are presently around 0.4, 0.7, and 0.5 millions tonnes, respectively, indicating a potential for increased catches of especially the demersals. Newer FAO reports (1990), however, conclude that the demersal stocks are fully exploited and that any substantial increases must come from fisheries on small pelagics, the largest migratory oceanic pelagics, and cephalopods. The catches from the region have remained stable at around 2 million tonnes annually over the last decade.

The region is to some extent dominated by a massive American presence. A sign of this is that sport fisheries contribute up to 20 % by weight of the total landings in the region (Couper 1983). The sport fisheries are an influential factor for management, forcing managers to maintain a large stock of apex predators (tuna, billfish, etc.) in contrast to the aim of management in most other areas.

East Central Atlantic (FAO region 34)

The traditional fisheries in this area have been small-scale coastal fisheries. The rich offshore fishing grounds, especially off West Africa, have so far been exploited by industrialized nations, mainly from East Europe and Spain. This is now gradually changing and especially Morocco and Senegal now take a good part of their resources. The main resources are located within the 200-nm EEZ, but several of the nations in the region have their offshore-derived income mainly from fishing licenses.

The largest resources are pelagic stocks - sardine and European pilchard. The total catches of pelagics are around 2 million tonnes annually, below the potential of 3.5-4.0 million tonnes suggested by FAO (1981). The present catches of demersal fish in the region are of the order of 1.0 million tonnes annually, corresponding to the potential suggested by FAO (1981). The total catches from the region have increased from 3.0 to 3.6 million tonnes annually over the last decade.

The northern part of the region illustrates the effect of lack of proper management. FAO (1990) gives catches and estimated potentials for stocks in the region (Table 9) together with an evaluation of the state of the stock. The table includes all stocks where both potential and catch are quantified. The stocks are all considered overexploited, and yet the catches are a fraction of the potential. A phased decrease of overall fishing pressure, especially on juveniles, imposition of closed seasons, changes in the mixture of deployed gears, etc., would help rebuild the stocks, from which far greater catches could then be extracted.

Mediterranean and Black Sea (FAO region 37)

The total fish production in this region amounts to around 2 million tonnes annually, including aquaculture production. The potential seem nearly fully exploited, and FAO (1990) reports that potential

Table 9. Annual capture fisheries yields and potentials of various fish stocks off northwestern Africa. (Source: FAO 1990)

Area: East Central Atlantic, Northern part

Stock	Catch	Estimated potential	Catch potential	State of exploitation
Octopus	42	100-135	0.31-0.42	Grossly overexploited
Cuttlefish	10	30-40	0.25-0.33	Overexploited
Squids	2	20-40	0.05-0.10	Overexploited
European pilchard	320	1,000 (variable)	0.32	Possibly fully exploited
Sardinellas	153	600 (variable)	0.26	Intensively exploited, locally overfished
Horse mackerel	58	400 (variable)	0.14	Possibly fully exploited
Mackerels	12	6-12	0.12	Fully exploited
Hakes	6	6-12	0.5-1.0	Grossly overexploited
Sea breams	23	150 (?)	0.15	Probably overexploited

increases would be mainly for small pelagics. The total production from the region has over the last decade increased from 1.2 to 2.0 million tonnes annually.

South West Atlantic (FAO region 41)

This region includes Brazil, Uruguay, and Argentina. It is not a major fishing area; the catches though increasing total only some 2.2 million tonnes annually. The fisheries take place within the EEZs, and the catches by noncoastal states in the region are negligible.

The main demersal species in the area is Patagonian hake for which the potential catches are reported by FAO (1981) to be within the wide range of 0.5 to 1.8 million tonnes annually, indicating the need for additional research. The total potential for demersal resources in the area is estimated at 2.5 million tonnes annually, while the present catches are of the order of 1.1 million tonnes. The pelagic fishes in the region are mainly anchovy and sardine, the potential catches of which are estimated to be 1.2 million tonnes annually. The present fishery harvests less than 1/10 of this potential. The population dynamics of the other pelagic stocks in the SW Atlantic are unknown, and the potential catches have not been estimated.

The fishery in the region increased over the last decade from 1.4 to 2.2 million tonnes annually. It seems that the region offers substantial potential for expansion of the marine fisheries.

South East Atlantic (FAO region 47)

The region includes Angola, Namibia and South Africa. The commercial fishery in South Africa was initiated at the turn of the century and was then based on Cape hake. There are some small-scale and sport fisheries along the coastlines.

The fishery in the area shows fluctuations between years, mainly the result of dependence on a few species with variable recruitment, notably anchovy and Cape horse mackerel. These two species, together with hakes and sardinellas made up 85% of the total catches in 1988.

The region contains highly productive areas off the western coast. The resources were previously utilized mainly by distant fleets, especially from Eastern Europe and Spain. The pattern has now changed as in most parts of the world, and the local nations are now dominating the catches, taking 57% of the catches (FAO 1990). Fishing by distant-water fleets in the 200-nm EEZ off Namibia has since ceased completely.

The potential catch of demersal resources (predominantly Cape hake) in the SE Atlantic is estimated at 1.0-1.4 million tonnes annually, of which the majority is presently taken. The pelagic fishery off South Africa is based on catches of anchovy, horse mackerels and sardinellas. The previously important pilchard fishery has now collapsed. The total potential for pelagics is estimated at 2.5 million tonnes (FAO 1981) of which presently only half is taken.

The total fishery in the region is reported to have decreased from 3.3 to 2.5 million tonnes annually over the last decade. Expansion of the pelagic fishery is dependent on improved management, based on biological and environmental information.

Western Indian Ocean (FAO region 51)

This is the second largest FAO region, comprising more than 30 million km^2. The fishery throughout the region is of a small-scale character. Overseas fleets are limited to tuna vessels from South Korea and increasingly, Europe and Japan.

The potential catch of demersal resources in the West Indian Ocean is estimated by FAO (1981) to be more than 2.6 million tonnes annually. The present catches are around half the potential, indicating possibilities for expansion. For the pelagic groups, the estimates of potential resources are very uncertain as estimates are missing for several important areas. The potential seems, however, to be of the order of 3 million tonnes annually. The pelagic catches now are around 1 million tonnes, a large proportion of which is tunas. The total catches have increased from 2.3 to 2.9 million tonnes over the last decade.

Overall the FAO statistics points at potential additional catches of perhaps more than 3 million tonnes annually. Most of this potential occurs in coastal areas of less than 70 meters depth. Additional large unexploited resources of mesopelagic fish have been detected, but no economically viable way of harvesting these resources has been developed.

Eastern Indian Ocean (FAO region 57)

The countries in this region constitute a very diverse group. In the northern part of the region the fishery is mainly small-scale, while in the south there are highly industrialized fisheries. The fishery by overseas fleets in the region is small.

Only very limited information is available on the stock sizes in the region. Tentatively, the potential can be estimated at 2 million tonnes of demersals and 1-2 million tonnes of pelagics annually. The present catches are around 1.5 million tonnes of demersal finfish, and 0.6 million tonnes of pelagic finfish. The total catches have gone up over the last decade, from around 1.3 to 2.7 million tonnes annually.

The additional catches that can be added to the present ones seem to be of the order of 1-1.5 million tonnes annually. This estimate is, however, highly uncertain due to the generally low level of assessment and management of fish resources in the area. Many coastal pelagic stocks, both small and large species, seem to be lightly exploited in the northern part of the region (FAO 1990).

North West Pacific (FAO region 61)

This is the most productive region of the world, with catches amounting to more than 1/4 of the world total.

The large fisheries of Japan and China are well established, and have more recently been supplemented by a large Soviet and Polish fishery in the region. China, Taiwan, Vietnam and the Korean states together make up the most important small-scale fisheries in the world. The traditional fishing pattern in China is in marked contrast to the highly developed fishery conducted by Japan, which operates the largest commercial fishing industry in the world, fishing the seven seas. The Japanese development has been followed by South Korea and Taiwan.

Total fish production in the area has increased from 18.9 to 26.7 million tonnes annually over the last decade. This substantial increase is mainly caused by an increase of nearly 6 million tonnes annually in the Chinese production.

Serious overfishing is seen in many demersal stocks in the southern part of the area, including the Yellow Sea and East China Sea. The stocks of commercially valuable demersal stocks here are now estimated to be one-tenth to one-fi... of their previous levels (FAO 1990). Some offshore stocks offer potential for increased catches, most other stocks in the area are considered nearly fully exploited. Higher catches will require improved management.

North East Pacific (FAO region 67)

The fisheries in this region developed within the last century. The possibility of exporting fish to the large markets in the eastern USA quickly led to overexploitation of some of the more vulnerable fish species. Consequently the International Halibut Commission was established in 1924 and it became the first international body to regulate a fishery with some success.

The potential catches of demersal fish in the region are estimated by FAO (1990) to be only a few hundred thousand tonnes higher than the present catches of some 2.7 million tonnes annually. The demersal resources consist mainly of Alaska pollack, pacific cod, yellowfin sole and rock sole.

For the pelagics, the only notable possibility of increased catches seems to come from the herrings, where perhaps an additional few hundred thousands tonnes can be caught annually (FAO 1981). The pelagic catches are now just over 400 thousand tonnes annually, most being salmon.

The total catches have increased from 1.8 to 3.3 million tonnes annually over the last decade, mainly due to increase in the demersal catches.

Western Central Pacific (FAO region 71)

This area is characterized by high productivity of the ocean, a high number of small-scale fishers and rather steady catches over the last decade (6.1 to 6.5 million tonnes).

The potential demersal catches are estimated by FAO (1981) at 4-5 million tonnes annually while the catches presently amount to 3.2 million tonnes. The coastal areas are overexploited throughout the region, while the pelagic stocks are probably underutilized, especially in Eastern Indonesia. FAO's (1981) estimate is a potential production of 4-5 million tonnes annually, or around twice the level of the present catches of some 2.3 million tonnes per year. The shrimp fishery in the region takes around 400 thousand tonnes annually (and hundreds of thousands of tonnes of bycatch which are mainly discarded), while some 180,000 tonnes of cephalopods are caught annually. The cephalopod stocks are considered only slightly to moderately exploited (FAO 1990).

Fishing by distant water fleets is a feature of the region. Several South Pacific and Asian countries have joint venture or access agreements with distant water fleets, especially from Japan and the USA.

In the shallower areas increased catches can only be expected if the management is improved. The need for reduced fishing effort, mesh size regulations, and closed seasons is emphasized (FAO 1990).

The demand for fish for the local markets is steadily increasing as a result of growth in populations. The consequences are likely to be coastal stocks that are even more overexploited, and expansion of the industrialized fisheries.

Eastern Central Pacific (FAO region 77)

This region includes an eastern ocean boundary that supported a major fishery for Californian sardine with peak catches of over 1 million tonnes annually in the 1930s. The fishery collapsed in the 1950s, but since the 1970s gradually increased to close to 500,000 tonnes annually. While depleted, the niche of the sardines was taken over by lower valued anchovies, as also seen in other areas.

FAO (1981) reported the potential yield of the demersal resources in the region at some 1 million tonnes annually, mainly of coastal hake. The catches in the late 1980s were around 1/4 of this estimate, suggesting possibilities for increased yields. For the pelagic stocks (excluding tunas) the estimates of potential yield amount to 2.0-2.5 million tonnes annually. The present catches are some 1.3 million tonnes per year. Noting previous catches of 1.0 million tonnes of sardines annually, and the close connection between climate and pelagic stocks in this region, it needs to be stressed that proper management is essential to maintain and/or increase the catches.

Potential increases of perhaps 300-400 thousand tonnes annually of catches of skipjack tuna and albacore seems possible (FAO 1990). The total tuna catches are currently around 500,000 tonnes per year.

The cephalopod catches in the region are estimated to have a potential of around 1.0 million tonnes annually, mainly of jumbo squid. The catches are now over 100,000 tonnes annually and increasing - by a factor of five over the last decade. FAO (1990) indicates that there are also potential (US) catches of half a million tonnes annually of unexploited stocks of crabs.

The catches by distant fleets in the area are limited to offshore tuna and squid fisheries.

In summary the catches from the Eastern Central Pacific offer a potential for expansion. The last decade has shown an increase from 1.7 to 2.4 million tonnes annually. To continue the increase good management is essential; especially for the small pelagics. The offshore exploration of tunas, mackerels and squids is probably the only viable way of utilizing the gigantic quantities of mesopelagics in this area, the largest FAO region.

South West Pacific (FAO region 81)

The major fisheries (in bulk) in the region are carried out by the highly industrialized Australian and New Zealand fleets. On the small Pacific islands, artisanal fisheries are of major importance for the subsistence of the local populations. On many islands, community-based management has been successful in maintaining the predominantly reef-based fisheries in a healthy state.

The demersal fisheries in this region are suggested by FAO (1981) to have a potential of around 1.0 million tonnes per year. The total catch of demersal fish presently is estimated to be around 3/4 of this, indicating slight possibilities for increase.

For the small pelagics, the potential is estimated at another million tonnes annually; present catches are small (1/10 of the estimated potential). Additional potentials of other pelagics have not been estimated. The present catches are of less than a hundred thousand tonnes annually.

Catches of cephalopods have been around 100,000 tonnes per year for the last decade. As the cephalopod stocks are considered only lightly exploited, possibilities of expansion exist, especially in the offshore areas (FAO 1990).

The past decade has seen a major increase in catches, from some 0.3 million tonnes annually up to a million tonnes.

South East Pacific (FAO region 87)

The upwelling fisheries off Peru and Chile are famous for high production and bad management. The catches of the Peruvian anchovy have in recent decades gone from over 15 million tonnes annually down to less than 1 million. In 1988 they were around 3.6 million tonnes of anchovy, up from some 2 million tonnes the previous year, but still far less than their potential.

The fishery for pelagics off the western South American coast is the only one among the world's upwelling fisheries that is and has been conducted exclusively by developing countries.

The potential for the pelagic stocks is estimated at 4 to 12 million tonnes annually while the present catches are around 8.6 million tonnes and, as mentioned, highly varying.

The demersal stocks in the region are substantial with catches of 3.8 million tonnes in 1988, up from 1.7 million tonnes a decade before. The total catches have more than doubled over the decade, from 5.2 to 12.9 million tonnes annually.

The conclusion for the South East Pacific is that without proper management, the highly opportunistic and intensive fishing pattern one has seen in the region over the last four decades will prevent the potential from being realized.

VII. Discussion

Table 10 gives a summary of present and potential production by FAO area. Overall potential is suggested to be around 25 million tonnes, noting that the estimates of potential production need to be updated and that potential for increasing invertebrate production is hardly discussed.

Assuming that half of the potential in regions where developed and developing countries share the resources (regions 31, 34, 47, 57, 71 and 77), and all of the potential in areas where the catches are dominated

Table 10. Potential and actual catches in the major marine FAO regions of the world. Potential catches are from FAO (1981, 1990) or set equal to present catches where these exceed the potential.

FAO region	Area	Catches (10^3 t) Present	Potential	Potential increase Total	%
21	North West Atlantic	4,400	5,200	800	18
27	North East Atlantic	10,500	16,000	5,500	52
31	Western Central Atlantic	1,900	6,400	4,500	236
34	Eastern Central Atlantic	3,600	5,000	1,400	38
37	Mediterranean/Black Sea	2,000	2,000	0	0
41	South West Atlantic	2,200	3,700	1,500	68
47	South East Atlantic	2,500	3,900	1,400	56
51	Western Indian Ocean	2,900	5,600	2,700	93
57	Eastern Indian Ocean	2,700	3,500	800	29
61	North West Pacific	26,700	26,700	0	0
67	North East Pacific	3,300	3,900	600	18
71	Western Central Pacific	6,500	9,600	3,100	47
77	Eastern Central Pacific	2,400	4,800	2,400	100
81	South West Pacific	1,000	2,000	1,000	100
87	South East Pacific	13,000	13,000	0	0
	Total			25,700	30

by developing countries (regions 41 and 51) can be attributed to potential catches for developing countries this suggests a potential increase of some 11 million tonnes for the marine fisheries of the developing world, not including any nonconventional resources.

How can this increase be realized? We believe this can be achieved only if each country:

- manages all its important fish stocks such that it produces something close to maximum sustainable yields (MSY);
- conserves the critical habitats that contribute to the recruitment of the stocks, i.e., the mangroves, bays, seagrasses and other nearshore nurseries on which these stocks depend; and
- conserves coral reefs and increases their production through judicious location of sanctuaries (for natural recruitment enhancement).

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