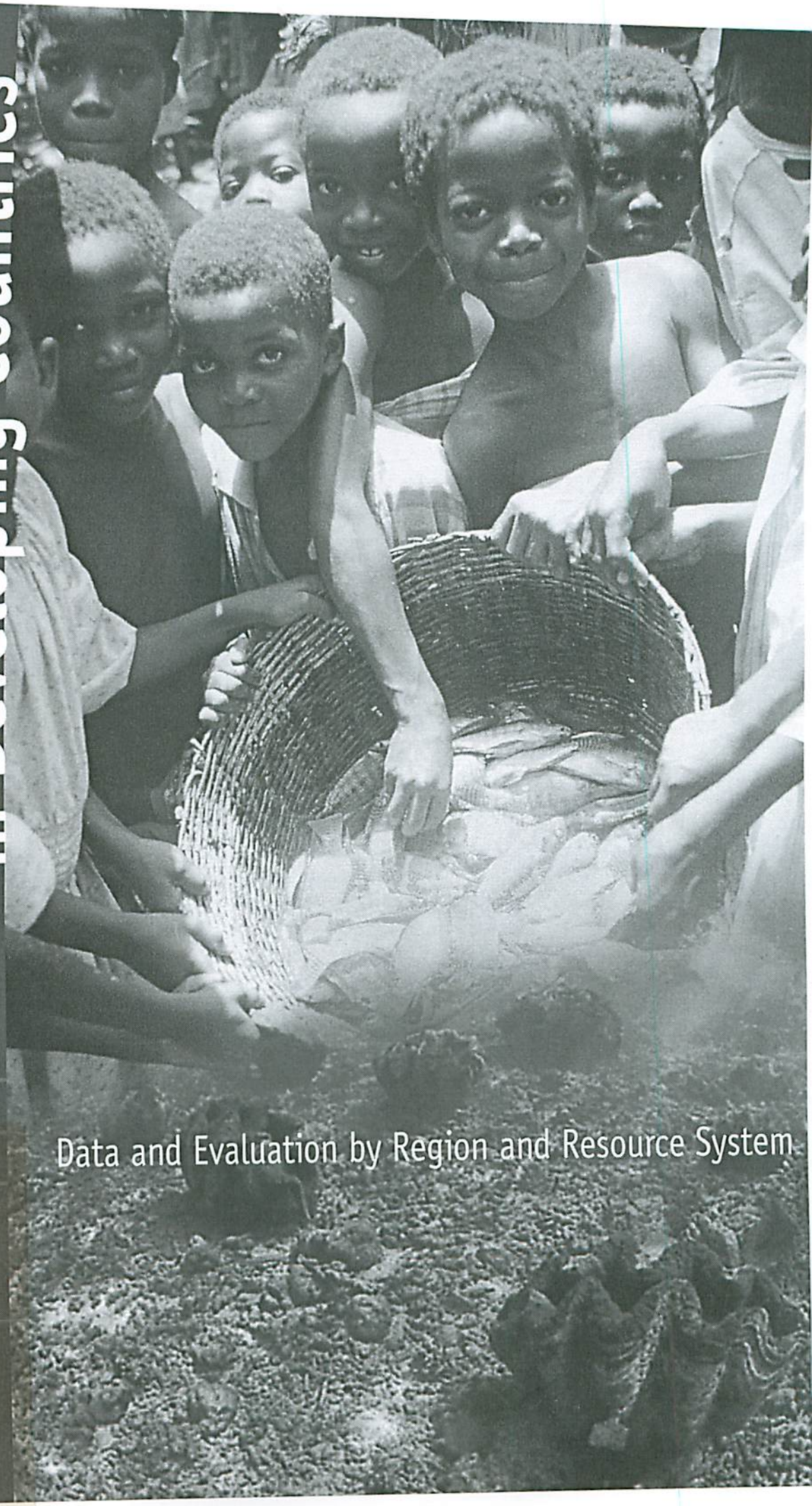
Aquatic Resources Research in Developing Countries



Supplement to the ICLARM Strategic Plan 2000-2020

Data and Evaluation by Region and Resource System

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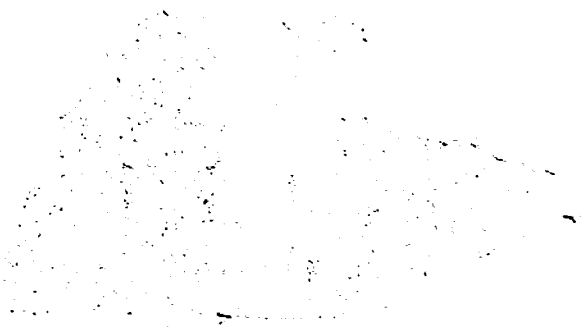

World fisheries and aquaculture outlook

A downturning global fisheries[1] production in the early 1990s brought about by overfishing and continuing environmental degradation generated public alarm and calls for improved management schemes and sustainable utilization of aquatic resource systems. Despite such crucial moves to improve stewardship of fisheries resources as the 1995 Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries, it is doubtful that global catches will recover and resume the fairly steady production increases which marked the period from the 1940s through the 1980s.

Over the next 25 years, the challenge in fisheries management will be to maintain present or near-present harvest levels while sustainably increasing aquaculture production to meet growing demands for fish and other living aquatic resources.

Moreover, there will be increased pressures to create new management regimes and to evolve cooperative or co-management regimes, particularly over coastal and inland fisheries. Opportunities for improved management will require research on the resources themselves, establishing historical levels and stock dynamics, and on the people who fish, consume the products and others who affect the quality of aquatic habitats. Opportunities exist to move from a species by species approach to an ecosystem approach that include people and their livelihood strategies.

ICLARM recognizes that better scientific knowledge is needed to arrest the overall state of stress in aquatic resource systems. Complex decision-making processes required for natural resources management are generally weakened by inadequate information and research inputs. The present state of knowledge of most aquatic resource systems, species and culture systems, however, lags far behind that of terrestrial agriculture and forestry systems. In the 21st century, we will continue to be at the forefront of research into alternative management options to relieve pressure on overfished and heavily degraded aquatic resource systems.

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Production, utilization and trade

Production

Capture fish production, or fish caught from natural stocks, has not been able to keep pace with the demand for fish. Looming shortfalls have been compensated, though not adequately, by better than expected increases in aquaculture production, which now contributes roughly 20% of the total world production of fish.

Global fish production in 1996 reached 130 million metric tons (mt), almost doubling the average per caput food fish supply from 8 kg in 1950 to over 15 kg currently[2]. Since 1985, the percentage of production from developing countries has steadily increased to roughly 70% (Fig. A). Worldwide, Asia dominates both fisheries and aquaculture production (Figs. B and C).

[1] The term 'fisheries' is often used broadly to include 'fisheries and aquaculture'; in the same manner, the generic term 'fish' is often used to refer to all aquatic resources, including finfish, mollusks, crustaceans and aquatic plants.
[2] Unless otherwise cited, fisheries statistics are based on recent FAO figures.

Food fish supply per caput in low-income food deficit countries (LIFDCs) is currently about half the world average. Currently, nearly 25% of food fish are from aquaculture.

Aquaculture has been growing at the extraordinary rate of 8.8% per year on average since 1986, compared to only 0.7% for capture fisheries (Fig. D) and 3% for livestock production (Williams and Bimbao 1998). The growth rate of aquaculture, despite significant setbacks from disease and environmental problems in some subsectors, has outstripped all other food production sectors in the last two decades.

Utilization

Fish is a source of high quality protein that can either be used directly as human food (food fish) or for other purposes (e.g., fishmeal). Fish and other aquatic organisms can also be used in a number of different ways, from ornaments to tourism.

Fig. A. Total fish production in developed and developing countries, 1950-1997.

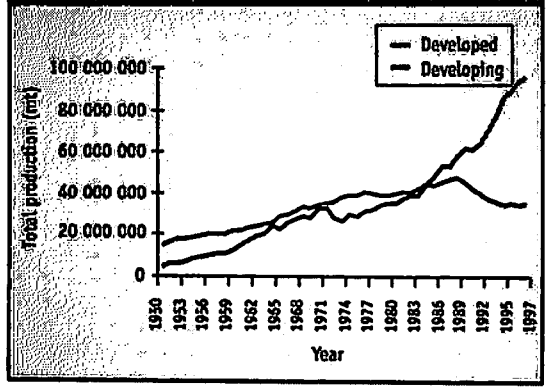


Fig. B. Fisheries production by continent, 1996.

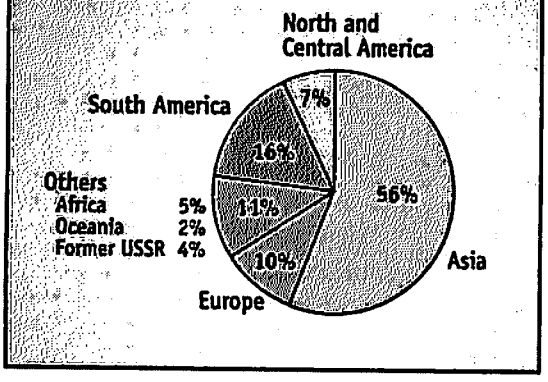


Fig. C. Aquaculture production by continent, 1996.

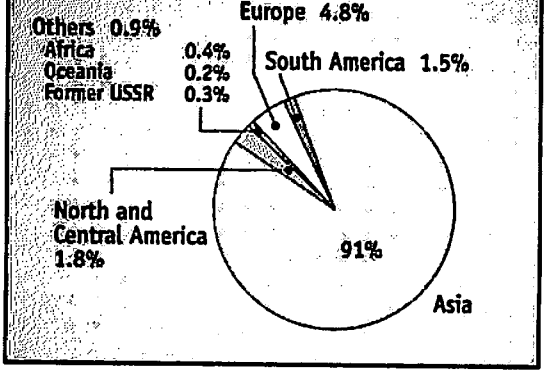


Fig. D. Capture fisheries production, 1950-1997.

Fish as food comprises about 16% and 6% of total animal protein and total protein consumed, respectively. In some regions of the developing world, most notably in the small island developing states (SIDS) of the Pacific and Indian Oceans and in the Caribbean, East Asia, Southeast Asia and parts of Africa, fish can make up much greater percentages of the protein intake.

Only 66% of capture fisheries production are used for human food directly; the remainder is used for other economic ends such as livestock and aquaculture feed, crop fertilizer, food and nonfood additives, or as bases for the production of industrial, medical and other chemicals through the application of biotechnology. Per capita fish consumption has reached a plateau of approximately 9 kg and 27 kg per person in developing and developed countries, respectively.

The demand for fish continues to rise worldwide, driven by growing populations, increasing affluence and greater awareness of its health benefits. More than half the present world fish catch is consumed in developing countries, but international trade is fast changing fish consumption patterns.

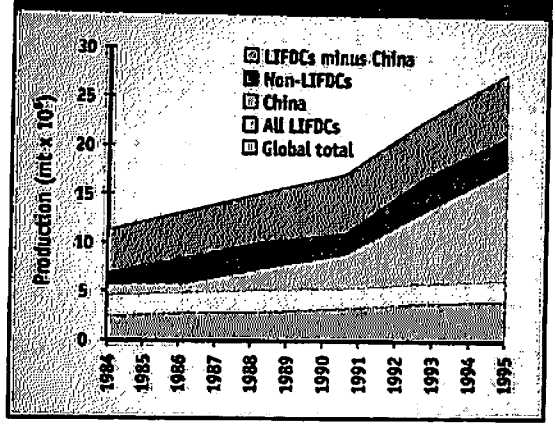
Trade

About 40% of the global fish production are currently traded internationally; developed countries are net importers. In 1995, the poorest countries (LIFDCs) have an excess of some US$ 8 billion of exports over imports of fish and shellfish worldwide.

The value of the global fish catch and international trade have all risen in recent times. These values are going up not only because more fish are produced but also because of the increasing price

developments in China, which accounts for 68% of global output in 1996 (Fig. E). The contribution of LIFDCs to world production has also increased sharply since 1990.

Fig. E. Annual global changes in total aquaculture production.



- In 1996, the total production of cultured finfish, shellfish and aquatic plants reached 34 million mt (valued at US$ 46.5 billion). Aquaculture contributed 14-62% to national aquatic production in the top 14 producing countries. Total aquaculture production from developing countries in East Asia alone amounted to 15.1 million mt in 1994; approximately 70% was derived from ponds.
- Three finfish species groups—carps, salmonids and tilapias—are the dominant aquaculture products, accounting for 82% of total finfish production in 1996. In terms of collective tonnage, carps are the major cultured aquatic organisms. Tilapia production doubled between 1988 and 1994 while carp production is suggested to have risen seven-fold. The major invertebrate products—mussels, oysters, clams and cockles—accounted for 73% of total invertebrate production. Shrimps and prawns provided another 15% (or 932,000 mt); the rate of expansion, however, decreased in 1990-1995 due to disease, environmental degradation and farm mismanagement.
- In terms of quantity, the output from freshwater environments expanded in 1990-1996 at 12% yearly; output from brackishwater environments (mainly shrimps) expanded at one third that of the freshwater environment, but was higher in terms of value. In contrast, output from the marine environments expanded at 15% per year and in 1996 accounted for half of the total world aquaculture output (Fig. F).
- Aquaculture accounted for about two thirds of total inland fishery production in 1996, with Asia being the most productive continent. Mariculture now accounts for more than half of marine mollusc production. Five of the world's top 13 species in 1996 were almost entirely derived from aquaculture.

Research in small-scale aquaculture can make fish more widely available and affordable to consumers. By increasing harvests and improving efficiency of production methods, fish farmers can profit and contribute to the household economy and rural development.

Viable strategies include small-scale integrated aquaculture-agriculture (IAA) practices, integrated approaches to coastal management, and genetic improvements in farmed species. Ways are needed, for instance, to integrate fish farming on resource-poor farms, not solely to produce more fish, but as part of a strategy to develop sustainable farming systems. Enhanced fish can also be consumed locally to increase productivity and ensure food and nutritional security, especially at the household level.

Community-based aquaculture schemes have the potential to reach many small-scale producers, including women. Planned intervention, however, is needed to help the poor share the benefits of aquaculture technology more equitably.

Further research needs to be directed at such key issues as ecosystem interactions, indicators of sustainability, resource valuation, extension methods for aquaculture, governance theory and influencing transnational management and equity. Participatory research tools should be developed to ensure that the target beneficiaries of such research are involved in critical stages of the research process.

Research should also address potential threats to the effective use of aquaculture that include the increasingly poor water quality and reduction in fresh water availability globally. Additional factors are land prices and alternative land use, feed costs for developing country practitioners, the competition between aquaculture and livestock feed markets, diseases, and labor costs.

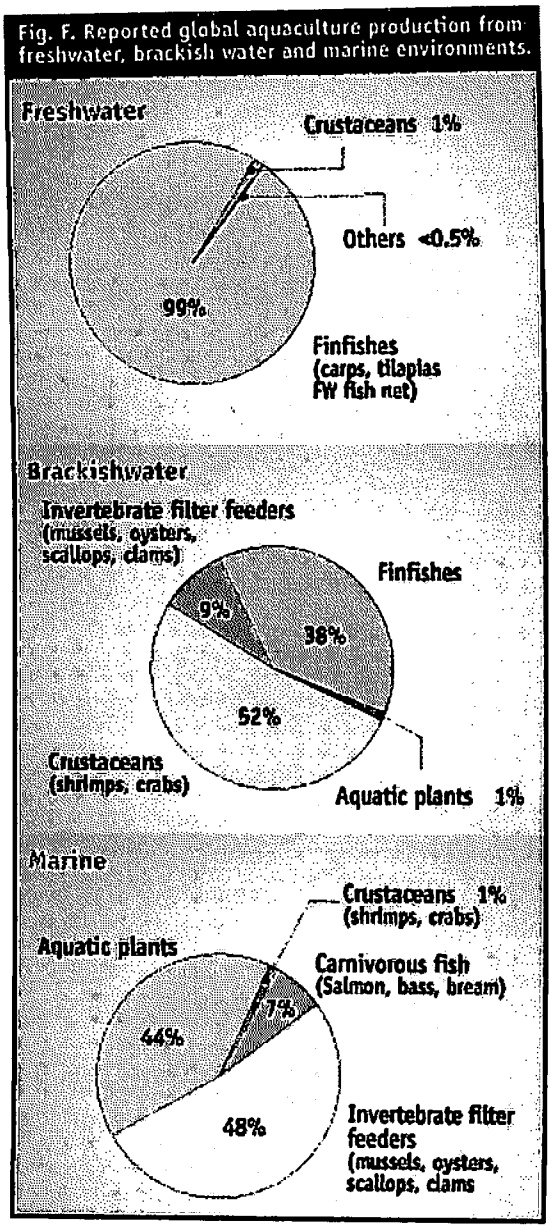


Fig. F. Reported global aquaculture production from freshwater, brackish water and marine environments.

The following are major trends and suggested directions for the growth of aquaculture:

- Freshwater aquaculture as a contributor to food security and rural development will become more important in the less developed countries of Asia. For instance, greater use of indigenous species may be practiced in the Mekong Basin countries.
- Environmental factors will continue to play a key role in aquaculture development throughout the East Asian region. China dominates fisheries statistics in the region, and has a concerted policy thrust to develop inland water aquaculture.
- The crisis in the shrimp culture industry has led either to the adoption of less resource dependent practices or diversification into other high value finfish species in Southeast Asia. These will likely remain beyond the means of the poor unless alternative feeding regimes can be developed.
- Aquaculture in South Asia will raise its profile still further as it provides relatively high returns compared with other agricultural products. With economic growth in the region generally increasing, the tradability and demand for both low and high value aquaculture produce will increase. Aquaculture is anticipated to grow with the adoption of new species, the use of polyculture and enhanced breeds, and the move to communal exploitation of water bodies and improved integrated farming practices.
- SIDS have few natural resources other than terrestrial and mangrove forests, and aquatic resources. There is a wide scope for enhancement of coral reef and marine aquaculture, which may have the dual role of protecting important high value species and generating food and income opportunities. Reef tourism, sports fishing, the aquarium industry and mollusk shell products (e.g., pearls) for export can be integrated into sustainable management regimes that evolved from existing cultural practices.
- The West Asia/North Africa (WANA) region is affected by perennial water shortages. Other human/agriculture pressures will mean that aquaculture development should involve the use of water for multiple purposes. Some of the major inland seas in the WANA region are catastrophically polluted and either dead to fishing or suffering major declines.
- Smallholder aquaculture in Africa, initially integrated with agriculture, will evolve toward partly or completely commercial systems as the demand for fish increases. Over the next 10 years, small-scale subsistence aquaculture will expand in suitable physical locations. Through participatory technology development and transfer, diverse and situation-specific smallholder farming systems will grow and become increasingly market-oriented, while maintaining a firm basis in efficient resource utilization.

- Aquaculture in mainland Latin America is highly commercial and not integrated into government structural policy frameworks that might target the poor. Some countries of the subcontinent have made major strides in aquaculture for exports largely of alien species (e.g., shrimp, salmon, and red tilapia).
- The number of SWBs and reservoirs brought into fisheries and aquaculture will increase along with pond aquaculture, as will the intensity of their management, as population continues to grow beyond the means of traditional extensive agriculture in developing countries. Methods for managing both the transition phase and the SWB fishery resources themselves are needed.

Emerging issues in aquatic resources management

Water covers 70% of Earth's surface and most (97.5%) of it is in the oceans, which produce food, wealth and numerous environmental services. The remaining 2.5% is freshwater; only a small part (0.7% of total global water) is in the earth's hydrological cycle and is vital to the terrestrial environment and to agriculture, fisheries, human, urban and industrial needs.

The exploitation of aquatic resources generates tension over such issues as trade, local and international market competition, demands for fisheries access by foreign fleets, illegal cross-border fishing, and management of shared stocks. Public alarm raised over genetic technologies and intellectual property rights (IPR), as well as global climate change, have added to the already complex issues.

Multifunctional uses of aquatic resource systems

Aquatic resource systems produce commodities, which provide nutritious food, income and livelihoods to many poor people in developing countries. They perform direct functions towards assuring food security, reducing poverty and sustaining the natural environment.

Food and nonfood products

High-protein food (fish, shellfish, seaweeds, etc.) and nonfood products are derived from aquatic resources. Nonfood products extracted by humans from aquatic resource systems include jewelry (pearls, mother-of-pearl), ornaments (shells), drugs and other pharmaceuticals, dyes, food additives (agar, carageenan), timber (from mangroves), limestone, sand and other structural materials (from reefs) and ornamental aquarium specimens.

Income and livelihoods

Many poor people live near, and depend on, aquatic resource systems such as coastal areas, lakes and rivers. ICLARM estimates that at least 50 million people in developing countries are directly involved in the harvesting and processing of fish and other aquatic resources; approximately 1 billion people rely on fish as a major source of food, income and/or livelihood. Poor people can also derive income from the collection or production of nonfood products and high value produce from aquaculture. Industrial concerns can gain additional value from the processing of low value fish into fishmeals and oil, which are utilized in livestock (and aquaculture) feeds. Few countries, however, record accurate employment statistics in the fisheries and aquaculture sectors. For instance, open access gathering and gleaning subsistence activities, mostly done by women and children, have been largely unrecorded but may add up to another 30-50% to the harvest. As more stocks become overexploited, the number of jobs and the average number of days spent fishing is probably declining. Diminishing resources can greatly affect households and communities as many onshore jobs are linked to fisheries catches. These include service jobs (e.g., net making, boat building, bait supply, fuel supply, etc.) and postharvest jobs (e.g., processing, marketing).

Valuable ecological services

Living aquatic resources are major components of natural ecosystems, which in their natural state, support high biodiversity, immense biological productivity and other natural functions (see Box 1). A total economic valuation of these ecological services was estimated at US$ 21 trillion. Our own analysis of coral reef ecosystems estimated a value of US$ 375 billion per year for seafood and coastal protection services alone. Fish production from coral reefs is higher than from any other natural fish production system, with reported yields of over 35 mt km^{-2} $year^{-1}$.

Nonfisheries-based uses

All aquatic resource systems (freshwater and marine) have many uses in agriculture, industry, household and other terrestrial activities. In recent years, a new 'ocean regime' has ushered in 'new ocean uses' apart from the traditionally dominant fisheries activities. These include shipping and navigation (e.g., ports and harbor construction), subsea mining (e.g., gas, oil), communications, industrial siting, waste disposal (e.g., industrial, sewage) zoning; offshore artificial island construction and recreation. These human activities create further challenges to the sustainable utilization and management of the coastal zone.

Increasing conflicts over multiple use

Relieving the anthropogenic threats to aquatic resource systems is the greatest challenge since up to one third of the world's population live in proximity to a coastline and the bulk of the population lives close to either freshwater or marine systems. Resource use conflicts will continue to arise due to rapidly modernizing and urbanizing societies, concomitant intersectoral use of the water and adjacent land resources, and a sectoral, rather than holistic, approach to governance. Furthermore, resource users and beneficiaries have differential access rights, based along sectoral, social, economic, political, ethnic, occupational and gender divides.

Box. 1. Ecological services from aquatic resource systems.

A recent study (Costanza et al. 1997) has indicated that about 83% of the global value of ecosystems services comes from marine waters, wetlands and lakes/rivers.

The important ecological services derived from these biomes include: habitat, refugia and nutrients for commercially important food and other useful species, protection oif adjacent and downstream land such as agricultral land and villages from erosion, siltation, storm damage, floods and droughts; nutrient cycling; tourism and recreational value; carbon sinks and greenhouse gas regulation; and stores of global climate records (e.g., some massive corals).

- Rapid developments in the coastal zone that result in altered environments for human uses present potential conflicts for its sustainable management. Many natural fish stocks are affected by land-based activities through downstream effects and the impacts of nutrients, sediments and other pollutants on aquatic ecosystems. Growing human populations increase all these pressures on the productivity of the coastal zone. Conflicts between large and small-scale fishers are also a major concern. ICLARM recognizes that integrated coastal management approaches will involve a large number of players including fishers, governments and private sector developers.
- Coral reef ecosystems abound in tropical seas; their sheltered waters and high pro ductivity have been an inducement to human settlement. Increasing population densitiesin developing countries and open access regimes in most countries to "walk-in", oftencompounded by landless fishers, are now leading to overexploita-tion and degradationof the reefs. Major issues include the overfishing of top predator fish and invertebrates. An opportunity exists for the appropriate placement and governance of MPAswithin sustainable management strategies for multiple species fisheries.
- Freshwater fishes are considered the most threatened group of vertebrates. They are heavily exploited and their habitats are stressed. The development of freshwater aquaculture is hampered by worsening water quality, reduced freshwater availability, particularly in South Asia and parts of Africa, alternative land and water uses (e.g., irrigation, dams, urban households/industries), and fish disease threats, demand for organ isms for culture/feed, and declining environmental quality. A growing perception of water as an economic good and tradable commodity will lead to higher prices for the resource as well as other social consequences. On the other hand, much potential

exists for IAA systems to provide multiple water uses and improve natural resource use generally. Production research needs to be complemented by increased capacity in intersectoral natural resource management.

- For SWBs, co-management has often been established without including fish production. Additional management issues include the integration of aquaculture amongst multiple uses. For large water bodies (reservoirs and lakes), management can be complicated by cross-border issues so that an ecosystem approach must be linked to sociopolitical considerations.

Increasing conflicts due to the multisectoral use of aquatic resources and other related developments have led ICLARM to choose co-management arrangements as the most appropriate governance option to aquatic resources. We intend to continue our research contributions in co-management and community-based methods, as well as the legal and institutional governance frameworks in developing countries. The equitable exploitation of aquatic resource systems, and the extension of the resource base for fisheries and aquaculture, depend upon access, tenure and governance arrangements.

Women in fisheries

ICLARM recognizes that women (and children) make highly significant but undervalued contribution to fisheries, aquaculture, fish processing, retailing and fisheries sector services. Our research shows that IAA technologies adopted by women's groups of poor rural households led to improved income and nutrition. Women have successfully adopted and developed many aquaculture production activities, including: raising fry to produce fingerlings for stocking ponds, providing water-replenishment services during the transport of fingerlings from the hatcheries to the farms, and growing fish in ponds. In developing assistance programs for women (e.g., training, microcredit, access to water bodies), there needs to be a greater understanding of gender roles and relations within the family or household and the institutional contexts within which these roles have evolved through time.

Aquatic genetic resources, biodiversity and intellectual property rights

Policymaking for aquatic biodiversity and genetic resources is far behind that for exploited plant species and terrestrial animals. Proprietary technology and IPR issues, however, will increasingly affect the poor's access to privately held knowledge in biotechnology, potentially denying them the benefits to be derived from such information.

Given the increasing private sector involvement in breed development and vaccine research, ICLARM in continuing its highly successful genetics research must work towards benefiting the smallholders and poorer sections of producers/consumers. ICLARM will place emphasis, for instance, on the genetic enhancement of carps and tilapias in Asia and Africa to produce better stocks. The introduction of genetically improved species, however, has raised new concerns about their possible impact on natural genetic diversity. Biotechnology activities must hence follow high standards of biosafety.

Another issue of general importance to enhanced fisheries is the potential loss of biodiversity as the makeup of the stocked fish can be governed by restricted genetic pools of fish selected for grow-out rates and survival in hatcheries. This is particularly true in South East Asian and East Asian countries, which have much more entrepreneurial attitudes towards the development of aquaculture of alien species, thus posing a threat to indigenous aquatic biodiversity. Furthermore, intensive exploitation of coral reef ecosystems has led to local extinction or severe losses of genetic diversity, particularly of vulnerable or high value species such as groupers, snappers and giant clams (e.g., in the Pacific SIDS).

Impacts of global climate change

Climate change will impact aquatic resources, and consequently those who depend on them through changes in precipitation patterns and in atmospheric carbon dioxide concentration; increase in

temperature/chemical reaction rates affecting aquatic production; changes in wind and ocean circulation patterns affecting fishing operations and the distribution and abundance of aquatic resources; rising sea levels and shifting coastlines; and increasing scarcity of freshwater. Many of these factors are researchable issues and will have as yet unpredictable impacts on aquatic resource systems.

Technology transfer, growing NARS capacity and the global knowledge system

There is a global trend towards greater participation in research processes by many different user groups. Increasingly, ICLARM will expand its collaboration with various stakeholders, including NARS partners. The need for greater knowledge to assist management and better use of resources entails: drawing upon all possible research resources and capacity; greater NARS capacity in developing countries, though often challenged by lack of operational funds; developed and developing countries' advanced scientific institutes (ASIs) increasingly heeding the call to tackle the critical issues of natural resources; greater collaboration with stakeholders in research; communication and sharing of knowledge; and recognizing an ever widening array of relevant scientific and indigenous knowledge systems to assist the management of living aquatic resources.

Changing development settings

All-encompassing issues in development, and potentially contentious issues, need to be factored into any strategic planning process. Trends towards a global economy and the increasing privatization of public goods and services are redefining the role and functions of the state towards less direct engagement in production activities and more active involvement in enabling regulatory frameworks and governance. These trends will probably continue well into the next century.

Fewer public resources, however, will translate into less financial resources and technical expertise or less ability to address equity and sustainable development concerns. More reliance on market mechanisms favors exploitation and production of high value species and not subsistence food species.

This is shown by macroeconomic and investment policies of most Asian countries that favor the culture of high-value, export-oriented species like shrimp. This policy bias has negative effects on the extensive and semi-extensive culture of important species like carp, tilapia and milkfish by small- or medium-scale farmers, and has led in many cases to damaging environmental consequences. Moreover, aquaculture has been initiated with government support for hatcheries in many countries. The tendency today, especially in countries in transition, is to privatize these services with potential concomitant lack of government control over breeding practices and quality of supply.

Fewer public subsidies also mean increased production costs, and hence weakened competitiveness in export markets, or consequent food insecurity. Rising incomes, coupled with higher prices on international markets, will expand the exports of high value wild and farmed fishery products; intraregional trade in fisheries will also prosper.

Technology transfer will become more linked to private investment and alliances will be forged between public and private sector agencies using biotechnology research.

Trade and the investments of the private sector now are larger than government expenditures and development assistance in most developing countries. The creation of the World Trade Organization and the emergence of regional trading blocs will mean further reductions to tariffs and other trade barriers. World trade in fish and related products will play an increasing role in fish food security. International agreements or regulations on export quality criteria may shape export industries of aquatic produce which may have to depend on high value species to overcome high transport costs, particularly in SIDS.

Economic recession increases unemployment and exacerbates poverty. It may cause more degradation of the aquatic resource base. Any persistent economic downturn will also slow down financial flows from overseas sources for fisheries investments, thus making domestic credit and investment facilities—

especially needed in a rapidly growing aquaculture industry—more important in the short term. Consumers, trading partners and the marketplace will become more discerning of product quality and quarantine, placing their own demands on governments and the aquaculture industry.

References

FAO. 1995. The Rome consensus on world fisheries adopted by the FAO Ministerial Meeting on Fisheries, Rome, 14-15 March. FAO, Rome.

Far Eastern Economic Review. March 1997.

Fisheries Department, FAO. 1996. The state of the world fisheries and aquaculture (SOFIA)-1996 Summary. Available: http://www.fao.org/WAICENT/FAOINFO/FISHERY/publ/sofia/soffiyef.htm.[March 1997].

Fisheries Department, FAO. 1997a. Aquaculture production statistics, 1986-1995. FAO Fish. Circ. 815, Rev. 9, 198 p.

Fisheries Department, FAO. 1997b. FAO Yearb. Fish. Stat. Commod. 81. Fish. Ser. 45, FAO Sat. Ser. 24, 163 p.

Fisheries Department, FAO. 1997c. Fisheries and aquaculture in the South Pacific: situation and outlook in 1996. FAO Fish. Circ. 907.

Fisheries Department, FAO. 1997d. Review of the state of world aquaculture. FAO, Rome. 163 p.

Fisheries Department, FAO. 1998a. Recent trends in global aquaculture production: 1984-1996. Available: http://www.fao.org/WAICENT/FAOINFO/FISHERY/trends/aqtrends/aqtrendf.htm. [December 1998].

Fisheries Department, FAO. 1998b. Recent trends in global fishery production. Available: http://www.fao.org/WAICENT/FAOINFO/FISHERY/trends/catch/catchf.htm. [December 1998].

Fisheries Department, FAO. 1998c. The FAO programme of fisheries assistance for small island developing states (SIDS). Available: http://www.fao.org./WAICENT/FAOINFO/FISHERY/sids/sidsf.htm.

Kapetsky, J.M. 1994. A strategic assessment of warm-water fish farming potential in Africa. FAO, CIFA Tech. Pap. 27, 67 p.

Kapetsky, J.M. 1995. A first look at the potential contribution of warm water fish farming to food security in Africa. *In* J.J. Symoens and J.C. Micha (eds.) The management of integrated freshwater agro-piscicultural systems in tropical areas. Technical Centre for Agricultural and Rural Cooperation, Wageningen, and Royal Academy of Overseas Sciences, Brussels.

McManus, J.W., C. van Zwol, L.R. Garces and D. Sadacharan, Editors. 1998. A framework for future training in marine and coastal protected area management. ICLARM Conf. Proc. 57, 54 p.

Nature. 1997. Fisheries science: all at sea when it comes to politics. Vol 386, March 1997.

Pauly, D. and V. Christensen. 1995. Primary production required to sustain global fisheries. Nature 374: 255-257.

Silvestre, G. 1996. Integrated management of coastal fisheries: lessons from initiatives in San Miguel Bay, Philippines. ICLARM, Manila, Philippines. 13 p.

Williams, M.J. and M.P. Bimbao. 1998. Aquaculture: the last frontier for sustainable food security? Dean D.K. Villaluz Memorial Lecture, 8 July, SEAFDEC Aquaculture Department, Tigbauan, Iloilo, Philippines.

Introduction to the Data Supplement

As a contribution to the Institute's strategic planning, ICLARM has assembled data on aquatic resources in developing countries and estimates of human population, poverty and environmental issues in the target countries. This document, which is an updated version of background data and information used at ICLARM's strategic planning workshop in June 1998, is provided as a supplement to ICLARM's draft strategic plan for the period 2000-2020.

The data is presented firstly on population, poverty and aquatic resource profiles of developing countries by regional groupings. The regional groupings chosen for this analysis are: South Asia, South East Asia, East Asia, mainland Latin America, Sub-Saharan Africa, West Asia/North Africa and the Small Island Developing States. The human population data is derived largely from FAO Agrostat figures for 1992-1994, World Bank Population Projections and the UNDP Human Development Report. Fisheries statistics are taken from FAO data for 1996. ICLARM's earlier strategic analysis (conducted in 1991-1992) utilized 1988 data, so production trends in this document have focused on the period 1988 to 1996, (but it should be noted that early FAO statistics, particularly in aquaculture, have recently been revised and these differences are reflected here).

ICLARM has adopted an aquatic resource system approach to evaluate issues and research priorities. Definitions and analytical profiles of the eight resource systems are given which include evaluations of research issues, ICLARM's capacity to conduct research for its beneficiary groups, and the probable outcomes and benefits of particular research paths. The text is augmented by catch and trade statistics for marine and inland fisheries and for aquaculture. Whilst the majority of the statistics are taken from the FAO data, ICLARM has inferred catches by resource system on the basis of proportional representation in a country's catch statistics following the approach developed by the Institute's 1992 planning exercise. Values for total production have been predicated on the basis of a country being a net importer or exporter of aquatic produce.

We believe that this novel approach, focusing directly on developing country and resource system issues provides more relevant material for analysis than global aggregates, or regional analyses based only on large continental groupings. For this reason we have also provided an additional analysis of the small island developing states (as an aggregate region, heavily dependent on aquatic resources from coastal, coral reef and off-shore resource systems). We believe that the general approach highlights several issues of resource valuation and the need to accurately determine catches by resource system (e.g., the catch of coral reef fish and invertebrates according to agreed reef area assessments) to refine the analytical process and raise awareness. These too are research questions for the future which ICLARM will pursue along with the major research outlined in ICLARM's strategic plan to improve the contribution of aquatic resources to food security and environmental sustainability in developing countries.

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Definitions

Resource systems

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 (including small water bodies)

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. Small water bodies are also lentic habitats less than 10 km^2 in surface area. Both lakes and small water bodies are usually considered common property and there may be free access for fishing or aquaculture sites. However, in some cases, rights are leased from the government or from other authorities, groups or individuals.

Floodplains, rivers and streams

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.

Coastal waters including 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 m depth are included here to encompass most fishing grounds of small-scale fishers. These areas are usually directly adjacent to soft-bottom shelves, leading to conflicts with the (trawl) fisheries operating there. Brackishwater ponds are included in this system. They are either natural or human-made; often the result of conversion of mangrove swamps. This resource system interfaces with terrestrial land use in the coastal zone and is often an area of intense intersectoral conflict over competing uses.

Coral reefs

CORAL REEFS are 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.

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Soft-bottom shelves

SOFT-BOTTOM SHELVES 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 SHELVES are regions of the continental shelf characterised by upwelling—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

OPEN OCEANS are defined as 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.

Regional groupings

South Asia

This grouping includes Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka and Myanmar.

East Asia

The region is confined to the Democratic People's Republic of Korea, Mongolia, China and the Republic of Korea.

South East Asia

The countries of South East Asia include Brunei, Indonesia, Malaysia, Philippines, Taiwan, Thailand, Kampuchea, Laos and Vietnam.

Sub-Saharan Africa

The region covers the African continent and Madagascar, except for the north African states bordering the Mediterranean (including Morocco).

West Asia/North Africa (WANA)

The region encompasses 19 states from Afghanistan in the east, Turkey in the north east, and the North African States to Morocco in the west.

Latin America

This grouping includes all countries of peninsular South America from Mexico southwards to Argentina.

Small Island Developing States (SIDS)

The SIDS is not a contiguous region but a collection of island states, largely from the Caribbean, and Indian and Pacific Oceans (although including Cape Verde and Cyprus).

Part 1

Population, poverty and aquatic resource profiles of developing countries by regional grouping

- Region: Sub-Saharan Africa
- Region: South Asia
- Region: East Asia
- Region: South East Asia
- Region: Latin America
- Region: West Asia/North Africa
- Region: Small Island Developing States

- Gauging the beneficiaries of aquatic resources research

- Tables for Part I
  - Summary population/poverty indicators by region.
  - Population and poverty indicators by country (for the seven developing country regions).
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Region: Sub-Saharan Africa

Description

This region of Sub-Saharan Africa (SSA) covers the African continent and Madagascar, except for the North African states bordering the Mediterranean (including Morocco). Marine fishing is concentrated in the eastern central Atlantic, the south east Atlantic and the western Indian Ocean.

Regional need

Poverty and food security in the region

The total population of SSA is estimated to be around 516 million (projected to grow over 1 billion by 2020). Recent figures from the Human Development Report, 1997, show that "income poverty runs deep in Sub-Saharan Africa and is a serious threat to economic and social stability. People in this region, along with South Asia, are among the poorest in the world. In 1992 about 45% of Sub-Saharan Africa's population was income-poor. In Gambia and Zambia nearly two-thirds of the people were income-poor; in Cameroon, in Guinea-Bissau and Uganda, more than half; and in Côte d'Ivoire, Kenya and Nigeria, more than a third. The poverty gap in Sub-Saharan Africa, at 15%, is nearly twice that in East Asia and South East Asia and the Pacific (excluding China), at 8%. About 170 million people (nearly a third of the region's population) do not get enough to eat. About 23 million children in the region are malnourished, and 16% of babies are underweight.

Given the modest gross domestic product (GDP) growth forecasts over the next 15 years, future prospects appear rather poor. Likely trends include further constraints on imports, increases in real fish prices, a continued demand for mainly low-value species and the continuing export of most demersal production. At the same time, lower public subsidies will increase production costs and weaken competitiveness on export markets in the process.

The implications for food security and supplies as well as for foreign exchange earnings are difficult to quantify, but might be a cause for concern in the future.

Environmental status of aquatic resources in the region

Several West African states have reported large increases in marine catches since 1988 particularly Namibia benefiting from the upwelling Benguela current) but more recently, catches in some important fishing nations are declining. Coastal population pressure and unregulated developments of the coastal zone potentially threaten artisanal fishing from reefs and inshore waters. The main characteristic of Sub-Saharan African freshwater fisheries potential is its annual variability. Systems that fluctuate seasonally and from year to year in surface area—reservoirs, swamps and river flood plains—account for almost 60% of the total water surface area and the biological and social management of such fisheries is particularly difficult. The Great Lakes are heavily exploited inland fisheries resources which have provided up to 10% of global inland fisheries catch. Because of reduced inflows with terrestrial-based pollution, species introduction and uncoordinated fishing practices, many of these lakes are in a state of rapid change. Similarly water availability and its quality will govern the projected growth of pond aquaculture and utilization of other small water bodies.

Importance of aquatic resources

Nutritional and cultural importance

Fisheries play an important role in many Sub-Saharan African countries as a major contributor to animal protein supplies, a foreign exchange earner and a generator of rural employment. An estimated 8 million people are directly or indirectly employed in the sector. Total production by the countries of the region amounted to 3.58 million mt in 1996. The estimates of the FAO suggest that food fish consumption has declined recently, from an average per caput supply of about 9 kg in 1990 to less than 7 kg in 1994 (live weight equivalent). However, fish play elevated roles in providing animal protein in the diets of coastal dwellers or communities gathered around the rivers and the Great Lakes of Africa.

Availability

Population growth rates project a human population of 700 million by the year 2000 in SSA and 915 million by 2010. At current levels of per caput food fish consumption, an increase of total supplies in the order of 2 million mt would be needed to meet demand in 2010.

The main future possibilities for increasing food fish supplies in the Sub-Saharan Africa region include productivity enhancement programs in small water bodies, the development and wider adoption of aquaculture, better utilization of small pelagic fish, relocalization of foreign fleets and increased imports. Further gains could be obtained by implementing sound fisheries management regimes, reducing discards from industrial fisheries and better postharvest handling practices and distribution networks.

Aquaculture production grew by about 113% in terms of volume between 1988 and 1996 and quadrupled in value.

Region: South Asia

Description

This grouping includes Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka and Myanmar. The countries thus encompass islands, large peninsular countries or countries with extensive coastlines, low lying, flood prone countries and high land-locked countries. It is clear that there will be large interregional differences in aquatic resource systems and their use.

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Regional need

Poverty and food security in the region

Approximately 1.2 billion people inhabit this region (1992-1994 average) with nearly 42% living below the poverty line. Malnourished children under 5 make up 7% (or nearly 85 million) of these population, and 600 million people overall suffer from chronic malnutrition. Regional population projections to the year 2020 suggest that there will be 1.8 billion people in the South Asian region. Fish and aquatic produce make important contributions to food security in Bangladesh, Sri Lanka and Myanmar and for selected populations in India.

Environmental status of aquatic resources in the region

The region depends upon the marine resources of the Arabian Sea, the northern Indian Ocean and the Bay of Bengal, with the latter being considered fully exploited. Artisanal fishing in near shore waters (all coastal states) or from coral reef areas (Sri Lanka, Southern India) is widely practiced and provides livelihoods for perhaps 10 million people. Resource use conflicts have arisen with commercial fishers. Degradation and pollution caused by the overexploitation of coastal aquaculture for shrimp has in some cases been addressed through legislation. A further issue in coastal management is that in South Asia about four million hectares of land are deforested annually.

All countries bordering the Bay of Bengal are abundantly supplied with monsoonal rainfall, and India and Bangladesh have major pond and floodplain freshwater aquaculture in which the Indian major carps predominate. Pollution, over intensification, increasing salinization of ground waters, and reduction of diversity amongst indigenous species through flood control are concerns. India has extensive reservoir fisheries. Here and elsewhere, hatchery management is key to biodiversity maintenance and longterm productivity. Appropriate community exploitation of common water bodies will determine future productivity from shared inland resources.

Importance of aquatic resources

Nutritional and cultural importance

In such a geographically disparate region, there are large differences in apparent fish consumption, with Myanmar and Sri Lanka consuming 15-16 kg caput^{-1} yr^{-1} (c.f. Nepal < 1 kg caput^{-1} yr^{-1}). India, whose marine catch grew to 2.8 million mt in 1996, and obtained over 2.3 million mt from inland waters and aquaculture production, apparently only consumes 4.4 kg caput^{-1} yr^{-1}. This figure masks large differences caused by religious and cultural practices (e.g., most religious communities in the coastal state of Kerala eat fish while some groups in other fish-rich states do not include fish in their vegetarian diets). In Bangladesh, fish is the primary source of animal protein and while marine catch for this country rose modestly, by about 34,000 mt between 1988 and 1996, catches from inland waters rose by about one-third and aqua-

Region: East Asia

Description

For the purposes of this evaluation, the region is confined to the Democratic People's Republic of Korea, Mongolia, China and the Republic of Korea and does not consider Japan or the eastern coastal states of the Russian Federation.

contents

Regional need

Poverty and food security in the region

China dominates the statistics of the region. The human population of China was recorded at 1.17 billion in 1994 and is anticipated to rise to 1.43 billion by 2020. Currently 11% of the population are considered to exist below the poverty line with as many as 24 million malnourished children under the age of five years. In the developed states of the region, 79% of the population is expected to be urban by 2000 and contributing to the large demand for fisheries produce in this region in which fish is a traditional food source. The further development of China's coastal cities into the next century is anticipated to exacerbate this trend. Fish consumption is generally high, exceeding meat consumption in some of the countries; annual food fish supply amounts to 28 kg caput^{-1} on average (live weight equivalent). The region is an active trading partner on the international market and a net importer (in both volume and value).

Environmental status of aquatic resources in the region

The East China Sea, the Yellow Sea, the Sea of Japan and the eastern offshore waters of Japan are among the most intensively fished waters in the world. The Gulf of Tongkin and the South China Sea are considered fully exploited and it is unlikely that future demand can be met from these resources. Environmental factors continue to play a key role in aquaculture development throughout the region. For example, shrimp farmers in China recently suffered dramatic losses in production owing to disease outbreaks from poor water and soil conditions in their ponds. Intensification trends in resource use and production are increasingly apparent in Chinese freshwater aquaculture, raising concerns over the impending release of wastes.

Environmental problems with coastal aquaculture practices in the Republic of Korea (and shared with Japan) concern mainly high densities of cages and rafts in water bodies with limited water exchange. Many aquafarmers in the region are being affected by increasing aquatic pollution from other activities. Shellfish farmers in the Republic of Korea have suffered recurrent harmful algal blooms, sometimes resulting in anoxic bottom waters and toxin contamination of their products. The increasing pollution of rivers, lakes and reservoirs in China is causing considerable economic losses to aquafarmers and fishermen. Chinese requirements for water and hydroelectricity may affect downstream habitats in adjacent regions (e.g., the Mekong Basin) and their species diversity. Another issue of general importance to enhanced reservoir fisheries is the potential loss of biodiversity as the makeup of the stocked fish can be governed by restricted genetic pools of fish selected for grow out rates and survival in hatcheries.

Importance of aquatic resources

Nutritional and cultural importance

Fish plays a major role in the diets of the people of all but Mongolia in this region. Fish provides the focus of seasonal observances and

culture more than doubled in the same period. Relatively large populations are involved in fishing and processing activities in these countries, and with fry production for aquaculture. Shrimp farming is often viewed as a commercial enterprise with the produce for export. Aquaculture can be expected to raise its profile still further as it provides relatively high returns compared with other agricultural practices and produce. Other aquatic resources are exploited more locally, e.g., fossil reef excavation for construction purposes in Sri Lanka.

Availability

While the Indian Ocean coastal and offshore resources remain relatively abundant, most of the pelagic fish, crustaceans and demersal species in coastal fishing grounds in the Bay of Bengal have been fully exploited or depleted. Increasing pressure on coastal resources and the exploitative shrimp aquaculture practices of the past will have to be managed to ensure continued productivity. For South and South East Asia combined, fish supplies will need to increase by 6 million mt even to maintain current per caput consumption levels. With economic growth in the region generally increasing, the tradeability and demand for both low- and high-value aquaculture produce will increase. Aquaculture is anticipated to grow with the adoption of new species, the use of polyculture and enhanced breeds, and the move to communal exploitation of water bodies and improved integrated farming practices.

Region: South East Asia

Description

The countries of South East Asia considered in this evaluation include Brunei, Indonesia, Malaysia, Philippines, Taiwan, Thailand, Kampuchea, Laos and Vietnam. Many of these peninsular or archipelagic island states share common aquatic resource issues with the small island developing states of the Indo-Pacific generally.

contents

Regional need

Poverty and food security in the region

The population of the countries totals approximately 443 million of whom 30% live below the poverty line. Currently nearly 18 million children below the age of five years are considered malnourished. The population of the region is suggested to reach 633 million by the year 2020. The average fish consumption for the region is a relatively high 24.9 kg caput^{-1} yr^{-1} and in some countries and coastal communities fish provide the principal source of animal protein.

Environmental status of aquatic resources in the region

The region is bordered by the Andaman Sea to the west, the Pacific Ocean to the east and the Indian Ocean to the south. However, other gulfs and seas of the region (the Gulf of Thailand, the Gulf of Tongking and the South China Sea) are degraded or fished to their maximum extent. Indonesia and the Philippines have very extensive coast lines. The Philippines marks the center of species diversity of coral reef species but both countries presently suffer from unsustainable or destructive fishing practices for many coral reef species. Thailand has led aquaculture production for the region in terms of value creating substantial foreign exchange earnings, particularly through shrimp culture. However, in 1995, production in Thailand decreased by 10% due to environmental consequences (pollution and shrimp diseases) of over exploitation. The countries of the Mekong Basin are heavily dependent upon the floodplain fisheries of the Mekong but production is now falling because of degradation of the environment, reduction in water flow, etc. Such habitat alterations also threaten species diversity. Intensive aquaculture operations in existing lakes and reservoirs, e.g., in the Philippines, suffer from seasonal water inversions limiting productivity. South East Asian (and East Asian) countries currently have a much more entrepreneurial attitude to the development of aquaculture with alien species and this may threaten indigenous aquatic biodiversity with time.

Importance of aquatic resources

Nutritional and cultural importance

The contribution of fish to total animal protein consumption in Indonesia and the Philippines was over 50% in 1993. In Thailand, Cambodia and Vietnam, this contribution was more than 35%. Despite Indonesia's major harvests from marine and freshwater capture fisheries and from aquaculture, population pressure keeps consumption at 17.1 kg caput^{-1}yr^{-1}, while in Malaysia, it rises as high as 54.5 kg caput^{-1}yr^{-1}. Freshwater fish dominate southeast Asian aquaculture but aquatic produce including crustaceans (24% by weight and 30% value in 1995) and aquatic plants (24% by weight and 10% by value in 1995) contribute substantially with molluscs and diadromous fish accounting for 13% and 9% by weight, respectively. Other species such as snails, eels and frogs are widely utilized from wetland fisheries in the

celebratory banquets for many Chinese people. Aquaculture has been a traditional practice in the Yangtze and Pearl River basins of China. However there has been something of an aquatic explosion with China and the Republic of Korea both being in the top four aquaculture producing countries. China alone produced 17.6 million mt or 63.4 % of world aquaculture production in 1995. Aquaculture development in inland waters is part of government policy for development. Chinese populations on the mainland, but also in the wealthy countries of the diaspora, provide high demand for all types of aquatic produce (mostly from SE Asian countries and the states of the Pacific) raising concerns for the sustainability of supply (e.g., for some species of sea cucumbers, and live reef fish). Japan with a per caput supply of 67.8 kg exerts strong market forces on the region also. Marine and diadromous fish are likely to contribute to the aquaculture sector in the future to cater for some of this demand, water quality permitting.

Availability

Fish production is an important economic activity in the East Asian coastal states generally. The region is one of the world's largest fish-producing areas with a total production (including Japan) of 36.6 million mt in 1994 of which 25.2 million mt was produced by the developing states considered here. The marine and inland catch rates as well as aquaculture production showed large increases for the East Asian region between 1988 and 1996 and it seems unlikely that the rates of growth, certainly from the marine sector can be maintained. Advanced technologies for marine species in the more developed nations of the broader East Asian region and a conscious policy thrust in China to develop inland water aquaculture will continue the impetus, but this may be countered by limits to intensification and water quality issues. Some apparent increases in aquaculture production in China result from a reclassification of statistics by the FAO for this country. Fish consumption in the region should stay high and even increase further in some areas (in both volume and per caput levels) along with population growth and improved consumer purchasing power.

Region: Latin America

Description

This grouping includes all countries of peninsular South America from Mexico southwards to Argentina. It should be noted that the island nations of the Caribbean are not included here but are grouped with other small island states in the tropics as the small islands developing states (SIDS).

contents

Regional need

Poverty and food security in the region

There were approximately 432 million people in mainland central and south America in 1994. One hundred and sixty three million or 38% of these are poor but only approximately 1% of children under five years are considered malnourished. The population is suggested to reach 617 million by the year 2020 with substantial numbers of urban dwellers in some countries.

Environmental status of aquatic resources in the region

The most productive upwelling fisheries off Peru and Chile have been affected previously by overfishing and El Ñino events. Coastal (artisanal) fisheries are threatened by the unregulated growth of coastal urban, industrial and other uses. Three particular problems relate to bycatch and discards in the Latin American region: bycatches of groundfish and of turtles during shrimp fishing and bycatches of dolphins during tuna fishing. US legislation and international conservation programs for dolphins are reducing unwanted effects on these by-catch species. Shrimp fisheries in Brazil and Mexico have altered fishing practices to address this problem. Nevertheless, traditional trawling persists in inshore fisheries, where the by-catch is used for human consumption.

Latin America has made major strides in aquaculture for export, largely of alien species (shrimp, salmon and red tilapia). Shrimp culture, as elsewhere, has experienced environmental problems and increased disease incidence. Culture intensification and mangrove clearing have caused loss of larvae for capture fisheries in some regions. Utilizing low priced fishmeal from the Chilean anchoveta fishery, these successful industries can depress new inland aquaculture industries or the production from capture fisheries becomes underpriced. Aquaculture is highly commercial and not integrated into government structure and policy frameworks which might target the poor.

Importance of aquatic resources

Nutritional and cultural importance

Latin America and Caribbean fish production reached record levels in 1994 of 24 million mt, representing 22% of the world total. Small pelagic marine fish make up about 75% of the total catch. The contribution of the sector to the economy is highly concentrated in coastal rural areas where it is the key—and often only—source of employment and income. Internally, it plays a minor role. Food fish consumption has been less than the global average at a per caput supply of about 9 kg annually (live weight equivalent). Latin American countries are major exporting countries of fish and fishery products and account for 11% of world exports, with Chile as the main net exporter. Shrimp and fish meal are the main exports. The export-oriented aquaculture industry is expected to rise from a production of 330,000 mt in 1995 to about 690,000 mt for all farmed species by the year 2000.

Mekong Basin countries. Generally, marine fish contribute little to present overall aquaculture production in South East Asia, but there is increased interest in the culture of carnivorous fish species like grouper which, however, are likely to remain beyond the reach of the poor. Political commentaries in the Philippines often allude to classes and costs of marketed fish as indicators of societal groups and purchasing power.

Availability

The increasing marine fish catches noted for the region between 1988 and 1996 are unlikely to be continued and since 1995 some fisheries/ecosystems may be in decline. Enforceable management regimes, e.g., including no-fishing marine protected areas, will be required to sustain coral reef environments and promote the food and nonfood uses (e.g., tourism and aquarium industry for alternative livelihoods). In aquaculture, the crises in the shrimp culture industry has led either to the adoption of more realistic practices or the diversification into other high value fin fish species. However, these are likely to remain beyond the means of the poor unless alternative feeding regimes (lowering the present percentage contribution of fishmeal or including presently discarded bycatch) can be found. Freshwater aquaculture as a contribution to food security and rural development will become more important in the less-developed countries of the region. Greater use of indigenous species may be practiced in the Mekong Basin countries. More than 13% of total production of the subregion is used to produce fishmeal, oil and other nonfood products, and there may be opportunities to convert this sector from the nonfood to the food sector.

Availability

Fish consumption in Latin America and the Caribbean has been increasing gradually over the last 20 years and will probably continue to increase in the future. Taking population and economic growth into account, it is estimated that demand will increase by about 2 million to 3 million mt by 2010.

Commercially exploited marine species are generally in an advanced state of exploitation and existing stocks will need better management to meet future demand. In addition, fish production in Latin America will fluctuate according to the variability in abundance of small pelagic stocks. Increased supplies could come from the reduction of discards and postharvest losses. The increased utilization of small pelagics for direct human consumption could be exploited but such exploitation will need to be based on economic, technological and marketing feasibility.

Current inland fisheries production trends will probably become more pronounced in the future. In the south—Argentina, Chile and parts of Brazil—trends to close fisheries to commercial exploitation and to reserve them for recreational and subsistence activities will continue. In the central part of the region, commercial fisheries on rivers and reservoirs will continue at generally low productivity levels. In the north, and in particular in the drought polygon of Brazil, in Cuba and Mexico, the intensified management of reservoirs through stocking and species introduction is expected to continue. Given these trends, increased production will be possible subject to careful management and the enhancement of Latin American reservoirs.

Region: West Asia/North Africa

Description

This region of West Asia/North Africa (WANA) encompasses 19 states from Afghanistan in the east, Turkey in the north east, and the north African states to Morocco in the west.

contents

Regional need

Poverty and food security in the region

The population of this region is approximately 345 million people, 26% of whom are considered to be below the poverty line. Both relatively rich and poor countries are included in this region but on average the number of malnourished children under five is suggested to be about 9.6 million or 3% of the total population. By the year 2020, the population is expected to grow to approximately 604 million.

Environmental status of aquatic resources in the region

The region is bounded largely by the Mediterranean Sea, the Red Sea and Persian Gulf. Morocco's marine waters extend into the Atlantic Ocean. Some of the major inland seas are catastrophically polluted and either dead to fishing or suffering major declines. The Black Sea has become polluted and overfished and subject to overgrowth by invertebrate species without commercial value. The Caspian Sea is suffering from severe pollution and environmental problems which threaten the biological marine resources. Fish resources have also been affected by heavy fishing and sturgeon stocks are particularly damaged. The Aral Sea has been subject to dessication due to a series of dry years in the 1970s and the diversion of water from its two feeder rivers for irrigation. Introduction of irrigated agriculture has led to salinity levels increasing drastically in rivers and water storage reservoirs.

The Red Sea remains relatively intact and a haven for coral reef habitat and species typical of the region. While Egypt has established a major aquaculture industry, this is essentially confined to the Nile delta. Reduced flow of the Nile for irrigation and other uses reduces the likely expansion of aquaculture outside this zone. A major issue for the whole region is that it is considered to be in water shortage and other human and agricultural pressures will mean that if aquaculture is to be developed it will involve the use of water put to multiple purposes.

Importance of aquatic resources

Nutritional and cultural importance

No country in the Near East and North Africa region depends substantially on fish and fishery products as a mainstay of its economy. Fisheries are diversified, ranging from those based on relatively abundant resources off the Atlantic coast of Morocco, to coastal and inland water fisheries with relatively poor resources. Total production reached some 2.57 million mt in 1996, of which Moroccan landings represented more than one-quarter. Food fish consumption varies widely throughout the region and is low relative to meat. In Yemen, supply reaches 40 kg caput^{-1}, while Afghanistan has the lowest per caput consumption at 0.1 kg (live weight equivalent). Egypt has made substantial gains in both marine catches and aquaculture production (1988-1996) but still

imports 173,000 mt of fisheries products at an annual cost (1996) of US$89 million. In general, the region is not a substantial contributor to international trade in fisheries.

Availability

Total fish production grew modestly between 1988 and 1996 and apparent fish consumption is below the world average but has risen recently to 9 kg caput^{-1}yr^{-1}. Assuming that fish consumption in the region remains relatively low by world standards, it would seem reasonable to expect that, at least until 2010, a slight increase in demand could be met from higher regional landings of fish if these are not diverted for export. Factors contributing to possible increased consumption in some North African countries include economic expansion and the development of tourism. Morocco will probably show a high increase in fish consumption as the economy and fisheries sector expand. There may be opportunity to exploit Mediterranean coastal areas for the culture of marine species but the tendency will be for export-oriented development. Fish consumption in Near Eastern countries is expected to remain relatively modest. The fish supply does not play, and is not expected to play, any substantial role in the food security of the subregion, but fish nonetheless constitutes an important alternative food source.

Region: Small Island Developing States

Description

The small island developing states (SIDS) is not a contiguous region but a collection of approximately 40 states, largely from the Caribbean, Indian and Pacific (although including Cape Verde and Cyprus), which share similar aquatic resource issues by virtue of being islands. Most are members of the informal political grouping of AOSIS (Alliance of Small Island Developing States).

contents

Regional need

Poverty and food security in the region

Approximately 43 million people live in the SIDS listed in Table 1.8, with 44% living in poverty (although we have not accumulated data for all states). Malnourished children under the age of five years make up 5% of the total in Pacific island states such as Papua New Guinea. However, the collective population of the SIDS is expected to rise to well over 57 million people in 2020—a growth of at least 32% in a highly restricted surface area. With few natural resources other than terrestrial and mangrove forests, aquatic resources are heavily exploited in the cultural traditions of these islands for subsistence (80% of production), livelihood and income generation. Annual consumption of fish in the Federated States of Micronesia is said to reach 63 kg and an astonishing 125 kg caput^{-1} yr^{-1} in the Maldives. Some states are already dependent upon the import of canned fish to meet demand. As a collection of island or archipelagic states, they have very long coastlines and large Exclusive Economic Zones (EEZs) in relation to their surface areas. For example, the combined area of the EEZs of island member states of the Secretariat of the Pacific Community (SPC) is nearly 30 million km^2. The selling of tuna licenses for fishing rights in their EEZs to overseas fleets is a major form of national income generation.

Environment status of aquatic resources in the region

With the possible exceptions of Cuba, the Dominican Republic and Jamaica, which have inland aquaculture potential, most SIDS are dependent upon coastal, coral reef and offshore aquatic reserves.

High population densities and inappropriate land use practices (e.g., logging) threaten the continued quality of the coastal zones. Overfishing of coral reef species, particularly invertebrates such as trochus, green snail, giant clams and sea cucumbers have reached such proportion as to making these species endangered or even locally extinct in some states. The Indo-Pacific states generally show high species diversity which diminishes eastwards. In the Caribbean, the same functional groups are represented by fewer species. Sustained fishing pressure from artisanal fishermen in most areas, or more recent exploitation of fish for the live reef fish trade in the Indo-Pacific, threaten to alter coral reef community structure irreversibly and bring fishermen into conflict with other coastal users, such as tourism industries. Climatic disturbances (hurricanes, monsoons, periodic or global warming) can have exacerbating effects on coastal and coral reef resources already stressed by terrestrial runoff and overexploitation. Coral reef bleaching in the Caribbean has been noted increasingly. Deep slope reef and sea mount fisheries were developed rapidly and then quickly over exploited in the 1980s in the Pacific and have collapsed.

Catches of tuna in offshore waters is restricted by official quotas but often the small island states have insufficient infrastructure and human resources to oversee actual catches and therefore monitor their offshore resources.

Importance of aquatic resources

Nutritional and cultural importance

Fish and aquatic produce are essential to the livelihoods and well being of island populations. Consumption, where recorded, is often well over 20 kg caput^{-1} yr^{-1} and serves as the major source of animal protein. Traditional fishing practices and terrestrial rights exist in some of the Pacific Islands on which devolved management arrangements could be based. Mollusc shell products provide income generating opportunities (pearls, mother of pearls for buttons, inlay) or are used in other ways (e. g., giant clam shells for money in the Solomon Islands). The reliance on aquatic resources and their products is heightened in states which lack alternative resources, and other means of income generation. The Pacific Island states are suggested to reap as little as 6.5% of the value of tuna caught in their waters (approximately US $1.46 billion in 1996).

Availability

The high rate of population growth coupled with the lack of substantial alternative livelihood generation will increase pressure on coastal and coral reef resources and to out migration, perhaps of skilled individuals. However, if sustainable management regimes can be evolved on the basis of existing cultural practices, luxury, recreational, food and subsistence markets exist for products at different international, regional and national levels. Adequate protection and sustainable exploitation practices for existing biodiversity can provide alternative income generation from reef tourism, sports fishing and the aquarium industry. There is wide scope for the enhancement of coral reef and marine aquaculture which may have the dual role of protecting important high-value species and generating food and income opportunities. Chinese and other Asian markets for bêche-de-mer and live reef fish, and Japanese and other international markets for tuna will ensure high demand into the foreseeable future. International agreements (such as CITES) or regulations governing export quality criteria (e.g., HACCP) may play roles in shaping export industries of aquatic produce which will have to depend on high-value species to overcome high transport costs.

Gauging the beneficiaries of aquatic resources research

With ICLARM's aquatic resource system approach to setting research priorities, the benefits of conducting aquatic resources management research in different regions were initially assessed using human population statistics for developing countries with additional poverty and nutritional indicators (see the foregoing regional profiles).

Available data sets on human population, which are largely available divisible by country, were used. However, human population numbers and poverty indices aggregated at the country or regional level (effective in evaluating impacts of land-based agricultural activities) do not always adequately define who will benefit from aquatic resources research. In small island states, we can be assured that "populations" and "beneficiaries" are fairly congruent. In developing countries, the poor beneficiaries of increased fish production are likely to be clustered around aquatic habitats—lakes, river basins, wetlands, and coasts as, at a subsistence level, fish is a perishable commodity subject to distribution and postharvest constraints. We thus need to evolve better estimates of beneficiary populations, preferably at the individual resource system level. This sort of data is not generally available from the published literature, and to add value to the estimates any such study would have to be augmented by detailed knowledge of trade and consumption patterns. These too are not yet widely developed at a resource system level in individual countries. Instead, therefore, we have tried to utilize human populations located in proximity to the major aquatic systems (inland watersheds and coasts) as surrogate values for the beneficiaries from aquatic resources research. Alternative, average global measures of coastal populations (Cohen et al. 1997) seem to be undifferentiated for our planning purpose, and proxy measures—such as number of fishing families—only includes one set of the possible beneficiaries.

We have therefore sought to define the proportion of developing country populations likely to be directly influenced, through enhanced production or consumption of aquatic produce or through improvement in aquatic environments. We have conducted a study to provide estimates of developing country populations encompassed by the major watersheds of the world or living within 60 km of the coast.

Methodology for estimating coastal populations and populations within major watershed areas

The basemap used was the Digital Chart of the World (DCW) which is a set of digital GIS layers with a scale of 1:1 million. The coastal population was then computed by extracting from the global population database all the points that lie within the 60 km buffer from the coast. The 60 km buffer was used to coincide with the measure used by the Reefs at Risk report (Bryant et al. 1998) in identifying human populations dependent upon coral reefs.

We used human population data contained in the Global Demography Project of the National Center for Geographic Information and Analysis (Global Demography Project, Tech. Rep. TR-95-6). The report contains population figures taken from the latest available census of each country. The 1994 global population was therefore estimated using a standard growth model based on average annual growth rates by country as provided by the United Nations. The database is for 217 countries using a 5×5 min grid. The database's total population was 5,617,519,139 allocated to 19,032 points. The database was plotted to the basemap using ARCView. The results of this analysis are given in Tables 1.10-1.16 as the 1994

coastal population per country in actual numbers and are summarized in Table 1.9 as a percent of total. For the purposes of the Strategic Plan, only the developing country data are shown.

To determine the population within the watershed area, digital data for major watersheds of the world was obtained from the GlobalARC GIS Database. The digital data contained in the CD-ROM was displayed as maps of the world's watersheds and overlaid with the 1994 population data (5×5 min) using ARCView in order to locate the population inside the watershed area per country. Furthermore, the coastal population estimates produced earlier were also overlaid to find out how many of the population located in the coast can also be found inside the areas of the watershed(s). The output of this matrix is a table showing, for 1994, human population estimates inside watershed areas and coastal populations overlapping the watersheds for each country (also given in summary in Table 1.9 and in detail by region in Tables 1.10-1.16).

Outcomes of the analysis of "potential beneficiaries"

The major results apparent from Tables 1.9-1.16 are that the peninsular and archipelagic countries of South East Asia have a high proportion of their populations living in coastal environments. As anticipated, the SIDS have almost their entire populations dependent upon the coastal zone. These concentrations of the human populations, and similarity of aquatic environments lead to shared coastal issues within these two regional groupings most heavily dependent on fish and aquatic produce. Research focused on coastal fisheries and marine aquaculture, and sustainable management of the coastal zone resources including coral reefs, will have the largest relative impacts in these regions and provides high probability of spillover effects of the research from one region to the other.

In terms of total populations, greater numbers of people in East Asia, South Asia and Sub-Saharan Africa live in proximity to large river and freshwater lake systems than to coastal environments. Based on potential beneficiaries, (and without a poverty weighting), research on inland waters and floodplains and the promotion of freshwater aquaculture should therefore be pursued as of most benefit to these regions. However, each region still has substantial numbers of people living in coastal regions and marine catches contribute to the nutritional support of their populations. As an example, an examination of the countries of the West African coast extending from Cameroon to Senegal, shows that, on average, 25% of the population of these countries (and over 50% in five countries)—substantially more than the continental average—live in the coastal zone where they are known to profit from artisinal coastal fisheries.

Overall, 50% of the total developing country population live within watersheds and approximately 24% live in the coastal zone. This is close to the global percentage when the estimate is conducted on a 60 km buffer zone. As anticipated, this contrasts with the published global estimate of 37% of the world's population living within 100 km of the coast (Cohen et al. 1997). Our country and regional level analyses highlight significant regional differences within the global average and enhancethe priority-setting process.

Improving the evaluation of beneficiaries

As has been seen, even these refined regional estimates of potential beneficiaries do not guarantee the potential for exploitation or improved consumption by these populations. In the case of India, one of the most populous countries on earth, there are large differences in consumption patterns—in Kerala, for instance, most religious and ethnic groups eat fish which makes important nutritional and financial contributions to the human welfare and economy of the state. Elsewhere in India, however, strict

vegetarian observances will not necessarily translate opportunity to consume aquatic produce into practice Similar differences between opportunity and consumption are likely to occur in other continents.

It must be stated that although the approach identifies potential beneficiary populations for ICLARM's work, it is not yet equivalent to poverty mapping, as the distribution of poor people within the coastal and wetland populations remains to be determined. ICLARM intends to continue this analysis (with for example, other CGIAR centers). At this finer level of discrimination, it will also be important to recognize the difference between countries in which only local benefits accrue from aquatic resource use and those in which available transport and infrastructure allow the servicing of distant urban markets (e.g., in another example from India, carp produced by aquaculture in Andhra Pradesh being shipped to Calcutta in around 8 hours).

By adding more discriminating environmental risk criteria (e.g., to be developed for coral reefs through ICLARM's collaboration with the Regional Reefs at Risk Study for South East Asia, or for terrestrial aquaculture opportunities, through the adoption of the methods of Kapetsky) (see References), there is also the possibility of analyzing areas where high-priority natural resource management research as well as production research should be focused. Combining data on poverty and environmental degradation will provide analyses equivalent to the CGIAR Study on Marginal Lands conducted for terrestrial, agricultural ecosystems. ICLARM intends to continue such research into research priority setting as one of its contributions to the aquatic resources sector through generic research.

However, we believe that this approach is already a useful addition to determining the distribution of populations most likely to benefit from research in different regions and on different aquatic resource systems. For instance, this analysis further highlights the special attention that should be paid to aquatic resource issues in the SIDS and demonstrates the likely spillover effects to other specific regions. The SIDS are a group of beneficiaries highlighted for support in several international fora because of their high dependence on aquatic resources, but not recipients of specific research support approaches by the majority of CGIAR centers.

References

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. Reefs at risk: a map-based indicator of threats to the world's coral reefs. World Resources Institute, ICLARM, World Conservation Monitoring Center and UNEP. 56 p.

Cohen, J.E., C. Small, A. Mellinger, J. Gallup and J. Sachs. 1997. Estimates of coastal populations. Science 278 (14 November 1997):1211-1212.

GlobalARC GIS Database produced by the Center for Remote Sensing and Spatial Analysis and US Army Corps of Engineers Construction Engineering Research Laboratory (CERL). Available: http://deathstar.rutgers.edu/global/arccd1list.html

Global Demography Project of NCGIA, Tech. Rep. TR-95-6. Available: http://www.ncgia.ucsb.edu/pubs/gdp/pop.html#Global

Kapetsky, J.M. 1994. A strategic assessment of warm-water fish farming potential in Africa. CIFA Tech. Pap. 27. FAO, Rome, Italy.

Tables for Part I

Summary population/poverty indicators by region.

Table 1.1. Summary population/poverty indicators by region.

	Population (000) 1992-1994 ave. (FAO-Agrostat 1994-1995 Projections)	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000,1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
SS Africa	517 855	275 977	53%	1 034 361	28 130	5%
South Asia	1 234 597	515 864	42%	1 832 487	89 055	7%
East Asia	1 244 948	138 139	11%	1 522 725	24 315	2%
South East Asia	440 021	130 798	30%	633 233	17527	4%
Latin America	433 582	164 322	38%	618 759	5 122	1%
WANA	345 105	88 725	26%	604 560	9 681	3%
SIDS	42 791	18 668	44%	57 173	700	2%

Population and poverty indicators by country (for the seven developing country regions).

Table 1.2. Population and poverty indicators—Sub-Saharan Africa.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000;1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
Angola	10 279	5 503	54%	22 713	641	6%
Benin	5 088	2 443	48%	9 882	212	4%
Botswana	1 401	676	48%	2 548	57	4%
Burkina Faso	9 773	7 675	79%	21 336	444	5%
Burundi	6 027	5 014	83%	12 233	300	5%
Cameroon	12 526	3 695	30%	25 476	335	3%
Central African Republic	3 156	1 819	58%	6 542	na	na
Chad	6 013	2 836	47%	12 261	296	5%
Congo	2 443	1 365	56%	5 623	113	5%
Côte d'Ivoire	13 319	6 705	50%	30 683	297	2%
Djibouti	556	162	29%	1 199	na	na
Equatorial Guinea	379	254	67%	774	na	na
Ethiopia	52 981	30 592	58%	122 556	3 810	7%
Gabon	1 248	403	32%	2 643	26	2%
Gambia	1 042	730	70%	2 094	27	3%
Ghana	16 450	6 925	42%	32 769	733	4%
Guinea Bissau	1 028	663	65%	1 790	37	4%
Guinea	6 308	3 607	57%	13 054	268	4%
Kenya	26 388	11 545	44%	44 404	782	3%
Lesotho	1 943	1 048	54%	3 202	48	2%
Liberia	2 845	648	23%	4 372	95	3%
Madagascar	13 858	5 924	43%	24 129	834	6%
Malawi	10 508	8 638	82%	18 995	466	4%
Mali	10 137	5 246	52%	21 265	390	4%
Mauritania	2 162	1 109	51%	4 500	58	3%
Mozambique	15 121	8 695	58%	35 647	1 195	8%

Table 1.2, continued.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000';1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
Namibia	1 461	771	53%	2 865	75	5%
Niger	8 553	2 791	33%	20 396	676	8%
Reunion	634	143	23%	840	na	na
Rwanda	7 555	6 528	86%	12 121	457	6%
Senegal	7 904	3 995	51%	15 089	259	3%
Sierra Leone	4 298	2 228	52%	9 007	196	5%
Somalia	8 965	4 787	53%	18 392	656	7%
Sudan	26 647	18 823	71%	52 502	1 525	6%
Swaziland	809	393	49%	1 985	11	1%
Tanzania	28 023	13 731	49%	53 438	1 220	4%
Togo	3 886	1 082	28%	8 636	119	3%
Uganda	19 941	14 578	73%	39 273	896	4%
Zaire	41 241	29 050	70%	87 007	2 425	6%
Zambia	8 935	5 910	66%	15 834	419	5%
Zimbabwe	10 737	5 236	49%	16 567	252	2%
Total	**517 855**	**275 977**	**53%**	**1 036 151**	**28 130**	**5%**

Table 1.3. Population and poverty indicators—South Asia.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000';1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
Bangladesh	115 233	84 910	74%	172 900	11 480	10%
Bhutan	1 597	1 379	86%	2 771	93	6%
India	901 485	357 529	40%	1 304 263	69 345	8%
Nepal	20 816	12 448	60%	35 731	1 665	8%
Myanmar	44 601	15 341	34%	69 073	1 985	4%
Pakistan	132 967	37 244	28%	224 826	3 725	3%
Sri Lanka	17 898	7 012	39%	22 923	762	4%
Total	**1 234 597**	**515 864**	**42%**	**1 832 487**	**89 055**	**7%**

Table 1.4. Population and poverty indicators—East Asia.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections ('000) Year 2020 (World Bank)	Malnourished children <5 (000';1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
China	1 175 449	131 415	11%	1 434 383	24 315	2%
Mongolia	2 318	563	24%	4 137	na	na
North Korea	23 049	4 281	19%	32 133	na	na
South Korea	44 132	1 880	4%	52 072	na	na
Total	**1 244 948**	**138 139**	**11%**	**1 522 725**	**24 315**	**2%**

Table 1.5. Population and poverty indicators—South East Asia.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000;'1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
Brunei	274	48	18%	455	na	na
Indonesia	191 675	47 727	25%	254 627	8 660	5%
Malaysia	19 246	3 022	16%	28 843	459	2%
Philippines	64 805	16 153	25%	108 236	3 045	5%
Taiwan	20 823	3 662	18%	24 919	na	na
Thailand	57 580	17 326	30%	78 091	726	1%
Kampuchea	9 683	2 820	29%	14 718	522	5%
Laos	4 605	3 293	72%	9 088	255	6%
Vietnam	71 330	36 747	52%	110 202	3 860	5%
Total	**440 021**	**130 798**	**30%**	**633 233**	**17 527**	**4%**

Table 1.6. Population and poverty indicators—Latin America.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000;'1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
Argentina	33 780	5 287	16	42 048	39	0.1%
Bolivia	7 065	4 019	57	13 066	125	2%
Brazil	156 483	72 060	46	214 951	1 250	0.8%
Chile	13 822	4 107	30	18 260	30	0.2%
Colombia	33 985	14 087	41	46 819	387	1%
Costa Rica	3 270	955	29	4 828	33	1%
Ecuador	10 981	5 545	51	17 005	193	2%
El Salvador	5 518	2 773	50	8 372	153	3%
French Guyana	135	41	31	1 006	na	na
Guatemala	10 032	7 103	71	18 952	402	4%
Guyana	816	408	50	1 006	17	2%
Honduras	5 336	1 950	37	10 305	173	3%
Mexico	90 024	27 259	30	128 455	1 585	2%
Nicaragua	4 115	832	20	7 139	128	3%
Panama	2 538	1 074	42	3 651	33	1%
Paraguay	4 701	1 636	35	8 791	28	0.6%
Peru	22 888	7 091	31	33 791	373	2%
Puerto Rico	3 618	1 105	31	4 287	na	na
Suriname	414	189	46	514	na	na
Uruguay	3 149	381	12	3 683	25	0.8%
Venezuela	20 912	6 420	31	31 830	148	0.7%
Total	**433 582**	**164 322**	**38%**	**618 759**	**5 122**	**1%**

Table 1.7. Population and poverty indicators—WANA.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000;1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
Afghanistan	17 731	9 224	52	46 114	1 195	7%
Algeria	26 724	5 973	22	44 255	470	2%
Bahrain	535	115	22	903	na	na
Egypt	60 314	14 017	23	81 718	759	1%
Iran	64 145	16 107	25	116 676	4 145	6%
Iraq	19 464	4 641	24	40 534	373	2%
Jordan	4 079	609	15	8 085	87	2%
Kuwait	1 782	391	22	2 617	15	1%
Lebanon	2 807	578	21	5 485	31	1%
Libya	5 050	1 163	23	11 575	33	1%
Morocco	25 945	9 602	37	40 752	453	2%
Oman	1 993	154	8	4 506	na	na
Qatar	529	124	23	769	na	na
Saudi Arabia	17 131	4 099	24	38 780	309	2%
Syria	13 700	5 132	37	30 375	294	2%
Tunisia	8 570	1 530	18	13 434	92	1%
Turkey	59 598	11 231	19	83 442	768	1%
United Arab Emirates	1 815	421	23	2 636	12	1%
Yemen	13 193	3 613	27	31 904	645	5%
Total	**345 10 5**	**88 725**	**26%**	**604 560**	**9 681**	**3%**

Table 1.8. Population and poverty indicators—SIDS.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000;1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
American Samoa *	47	na	na	na	na	na
Barbados *	260	69	26	294	na	na
Belize *	204	97	47	349	na	na
Cape Verde *	370	129	35%	676	na	na
Comoros *	607	255	42%	1 215	na	na
Cook Islands *	19	na	na	na	na	na
Cuba *	10 874	3 443	32	12 454	75	0.7%
Cyprus *	726	115	16	890	5	0.7%
Dominican Republic *	7 542	4 110	55	10 455	118	2%
Federal State of Micronesia *	106	na	na	201	na	na
Fiji *	773	na	na	969	na	na
French Polynesia	220	na	na	na	na	na
Guam *	133	na	na	205	na	na
Guadeloupe	413	126	31	526	na	na
Haiti	6 894	5 205	76	9 984	241	3%
Jamaica *	2 411	1 285	53	2 836	20	0.8%
Kiribati *	77	na	na	110	na	na
Marshall Islands *	43	na	na	na	na	na
Martinique	371	113	31	447	na	na
Maldives *	251	na	na	292	na	na
Mauritius *	1 091	178	16%	1 410	17	2%

Table 1.8, continued.

	Population (000) 1992-1994 ave (FAO-Agrostat/ World Bank 1994-1995 Projections	Country's population below poverty line (Total poor) (FAO-Agrostat)	Percentage below poverty line (Total) (FAO-Agrostat)	Population projections (000) Year 2020 (World Bank)	Malnourished children <5 (000;1992) (FAO-Agrostat)	Malnourished children <5; % of population (FAO-Agrostat)
Nauru *	10	na	na	na	na	na
New Caledonia	197	na	na	242	na	na
Northern Mariana Is.	59	na	na	na	na	na
Niue *	2	na	na	na	na	na
Palau	17	na	na	na	na	na
Papua New Guinea *	4 110	2 655	65%	6 777	210	5%
Pitcairn Islands	47	na	na	na	na	na
Samoa *	161	na	na	na	na	na
Singapore *	2 792	419	15%	3 812	na	na
Solomon Islands *	285	na	na	720	na	na
St. Lucia *	138	42	31	234	na	na
Tokelau	1	na	na	na	na	na
Tonga *	97	na	na	113	na	na
Trinidad and Tobago *	1 278	427	33	1 671	14	1%
Tuvalu *	9	na	na	na	na	na
Vanuatu *	142	na	na	291	na	na
Wallis and Futuna	14	na	na	na	na	na
Total	**42 791**	**18 668**	**44%**	**57 173**	**700**	**2%**

* Members or observers of the Alliance of Small Island Developing States (or AOSIS). Other AOSIS members are not included because of lack of equivalent available data.

Summary table of human populations by region including total potential beneficiary percentages found in watersheds or within 60 km of the coast (1994).

Table 1.9. Coastal and watershed population by region.

Developing country regions	Population	% Watersheds	% Coastal	Total beneficiaries*
SS Africa	515 070 813	63	14	456 784 551
South Asia	1 224 969 216	68	14	987 642 526
East Asia	1 252 723 855	54	16	903 322 540
South East Asia	440 090 772	20	70	380 598 612
Latin America	433 222 620	36	28	266 888 354
WANA	350 147 522	24	31	194 294 138
SIDS	43 218 714		95	41 437 175
Grand total for developing** countries	4 327 117 628	51	24	3 158 570 747
Grand total for all countries	**5 617 519 139**	**50**	**25**	

* The 'potential total beneficiary' populations were determined by the addition of the watershed and coastal populations, and subtracting the overlapping populations from the two areas.

** Actual total numbers derived from Table 1.10–1.16 are:
Grand Total: 1994 Total population=4 327 117 628, population within watershed=2 212 241 871 1994, coastal population=1 043 132 915, coastal population within watershed=96 804 039

Table 1.10. Sub-Saharan Africa.

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
Angola	11 527 258	2 931 568	3 980 315	
Benin	5 175 394	745 117	2 781 741	
Botswana	1 446 623	1 343 666		
Burkina Faso	10 164 692	9 845 680		
Burundi	6 011 039	5 982 965		
Cameroon	13 218 483	4 841 274	1 285 276	
Central African Republic	3 149 545	2 853 773		
Chad	6 308 708	6 308 708		
Congo	2 318 276	435 071	405 787	
Djibouti	450 751		450 751	
Equatorial Guinea	386 373	122 744	180 143	
Ethiopia	53 142 980	39 699 866		
Gabon	1 561 195	902 477	608 787	23 853
Gambia	936 026		537 762	
Ghana	16 698 087	7 205 704	4 549 554	116 178
Guinea	6 242 070	2 315 636	1 946 352	
Guinea Bissau	1 085 777		778 656	
Ivory Coast	13 498 862	658 602	4 290 026	
Kenya	25 835 246	14 166 871	1 767 060	
Lesotho	1 928 269	1 928 269	123 020	123 020
Liberia	2 902 441		1 541 099	
Madagascar	13 046 689	1 885 099	5 232 405	57 108
Malawi	10 660 484	8 429 390		
Mali	9 744 733	8 680 451		
Mauritania	2 204 077	1 397 010	45 543	
Mozambique	16 604 659	7 319 052	6 490 745	3 413 533
Namibia	1 550 917	680 299	41 914	
Niger	8 797 739	8 797 739		
Nigeria	97 228 747	62 803 890	16 013 631	4 376 068
Reunion	644 000		644 000	
Rwanda	7 934 396	7 934 396		
Senegal	8 116 554	3 448 999	6 004 940	3 448 999
Sierra Leone	4 551 746		1 997 029	
Somalia	9 951 515	4 140 958	4 404 227	2 000 409
Sudan	27 713 419	26 632 004	425 278	
Swaziland	842 766			
Tanzania	28 386 267	8 820 985	4 322 598	
Togo	4 048 365	1 076 813	1 548 510	
Uganda	18 144 363	15 801 627		
Zaire	41 025 915	39 058 280		
Zambia	8 778 681	8 778 681		
Zimbabwe	11 106 686	7 575 757		
Subtotal	**515 070 813**	**325 549 421**	**72 397 149**	**13 559 168**

Table 1.11. South Asia.

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
Bangladesh	120 732 218	97 257 625	15 688 994	
Bhutan	1 586 631	1 586 631		
India	894 608 580	580 011 421	123 450 210	24 330 579
Myanmar	43 099 620	30 348 375	12 229 551	2 766 180
Nepal	19 927 275	19 927 275		
Pakistan	126 692 967	111 940 585	9 778 250	1 144 983
Sri Lanka	18 321 925		13 665 351	
Subtotal	**1 224 969 216**	**841 071 912**	**174 812 356**	**28 241 742**

Table 1.12. East Asia.

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
China	1 252 723 855	712 639 510	163 853 467	25 584 771
Mongolia	2 228 222	1 427 397		
North Korea	22 034 992	1 318 586	15 366 778	
South Korea	43 410 902		34 301 573	
Subtotal	**1 320 397 971**	**715 385 493**	**213 521 818**	**25 584 771**

Table 1.13. Southeast Asia.

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
Brunei	281 614		281 614	
Cambodia	9 129 576	7 300 119	516 280	
Indonesia	189 331 169	3 198 932	153 544 478	1 035 261
Laos	4 722 773	4 165 554		
Malaysia	19 626 381		17 111 805	
Philippines	65 981 121		59 299 005	
Taiwan	22 479 146		22 479 146	
Thailand	57 323 791	42 805 731	17 567 583	6 792 830
Vietnam	71 215 201	31 821 551	37 766 256	9 431 351
Subtotal	**440 090 772**	**89 291 887**	**308 566 167**	**17 259 442**

Table 1.14. Latin America.

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
Argentina	33 796 870	11 388 192	71 882	
Bolivia	7 648 315	7 648 315		
Brazil	151 896 627	47 062 201	29 597 477	41 169
Chile	13 772 705		5 298 345	
Colombia	34 414 593	30 491 869	7 749 947	6 189 085
Costa Rica	3 319 438		3 319 438	
Ecuador	10 541 816	1 399 653	5 252 634	
El Salvador	5 752 470		4 645 717	
French Guiana	130 219		130 219	
Guatemala	10 321 266	1 700 489	3 060 499	
Guyana	754 931			
Honduras	5 367 067		2 188 997	
Mexico	92 380 840	35 722 726	20 861 884	2 659 674
Nicaragua	4 275 103		2 655 205	
Panama	2 562 045		2 562 045	
Paraguay	4 773 464	4 773 464		
Peru	24 496 400	9 006 900	15 489 500	
Puerto Rico	3 647 931		3 647 931	
Suriname	428 026		321 321	
Uruguay	3 084 641	676 192	2 059 723	
Venezuela	19 857 853	6 870 862	12 933 817	2 809 162
Subtotal	**433 222 620**	**156 740 863**	**121 846 581**	**11 699 090**

Table 1.15.West Asia/North Africa (WANA).

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
Afghanistan	17 250 388	10 721 538		
Algeria	27 459 229	82 585	14 773 864	
Bahrain	575 814		575 814	
Egypt	56 133 439	20 615 218	22 219 269	
Iran	64 193 453	7 652 142	8 925 376	
Iraq	20 941 718	19 865 011		
Jordan	3 950 283			
Kuwait	1 639 000		1 639 000	
Lebanon	2 942 959		2 942 959	
Libya	5 245 515		3 316 553	
Morocco	27 767 919	304 028	14 690 296	
Oman	2 090 308			
Qatar	478 000		478 000	
Saudi Arabia	18 099 992		3 537 468	
Syria	14 045 467	7 167 674	1 549 734	
Tunisia	8 620 181		6 026 626	
Turkey	61 300 938	17 794 099	28 676 784	459 826
United Arab Emirates	2 061 800		1 199 926	
Yemen	15 351 119			
Subtotal	**350 147 522**	**84 202 295**	**110 551 669**	**459 826**

Table 1.16. Small Island Developing States (SIDS).

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
American Samoa	53 000		53 000	
Barbados	260 627		260 627	
Belize	207 586		88 698	
Cape Verde	413 573		413 573	
Comoros	634 656		634 656	
Cook Islands	17 000		17 000	
Cuba	11 102 280		11 102 280	
Cyprus	739 027		739 027	
Dominican Republic	7 759 957		6 097 306	
Fiji	755 000		755 000	
French Polynesia	217 000		217 000	
Guadeloupe	410 638		410 638	
Guam	143 173		143 173	
Haiti	7 044 890		7 044 890	
Jamaica	2 407 607		2 407 607	
Kiribati	77 000		77 000	
Maldives	11 511		11 511	
Martinique	374 574		374 574	
Mauritius	1 097 234		1 097 234	
Micronesia	111 607		111 607	
Nauru	10 000		10 000	
New Caledonia	178 000		178 000	
Northern Island Marianas	60 963		60 963	
Nuie	2 000		2 000	
Palau Islands	16 411		16 411	
Papua New Guinea	4 039 033		4 039 033	
Pitcairn				
Singapore	2 824 024		2 824 024	

Table 1.16, continued.

Country	1994 Total population	Population within watershed	1994 Coastal population	Coastal population within watershed
Solomon Islands	366 000		366 000	
St. Lucia	141 743		141 743	
Tokelau	1 600		1 600	
Tonga	98 000		98 000	
Trinidad	1 292 000		1 292 000	
Tuvalu	13 000		13 000	
Vanuatu	165 000		165 000	
Wallis and Futuna	14 000		14 000	
Western Samoa	159 000		159 000	
Subtotal	**43 218 714**		**41 437 175**	

Part II

Summary data by aquatic resource systems

- Resource system 1: Ponds
- Resource system 2: Reservoirs and lakes (including small water bodies)
- Resource system 3: Floodplains, rivers and streams
- Resource system 4: Coastal waters (including estuaries and lagoons)
- Resource system 5: Coral reefs
- Resource system 6: Soft-bottom shelves
- Resource system 7: Upwelling shelves
- Resource system 8: Open oceans
- Resource considerations of the Small Island Developing States

- Tables for Part II
  - Summaries of fish production, estimated total values marine and inland catches, aquaculture, total value of aquaculture, apparent fish consumption and trade statistics by region, 1988-1996.
  - Trends (1988-1996) in total production and estimated total value by developing country.
  - Trends (1988-1996) in marine catch, inland catch and aquaculture by developing country.
  - Trends (1988-1996) in total value of aquaculture and apparent fish consumption by developing country.
  - Trade statistics (1988-1996) by developing country.

contents Part I Part III ?

Resource system 1: Ponds

Description

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

Artificial ponds are usually earthen, however, in some cases they are concrete lined or can be small concrete tanks. The water source can either be rain runoff, irrigation or groundwater. Ponds are either drainable or undrainable, and are harvested by seining, trapping, draining or combinations of these three procedures. The water management in these ponds can be stagnant or flow-through. Most ponds can be utilized at all times, but some may be seasonal.

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Resource system analysis

Trends and forecast

Total aquaculture production from tropical developing countries and East Asia in 1996 amounted to 23 million mt with a value in excess of US$30 billion.

Production from freshwater aquaculture in developing countries rose from an estimated 2.4 million mt in 1988 to 12 million mt in 1996. Production of tilapia rose four-fold in this period, and carp production is stated to have more than doubled. It is probable that tilapia and other species will continue to grow in production and the potential for continued increase (particularly in Asia with the use of more intensive systems and improved strains, and by new adoptees in Africa) is great. Much of the production of Latin America and the Caribbean countries goes to the US export market.

Central and South America, East Asia and the South East and the Pacific regions each exported more than US$2.5 billion worth of aquaculture produce in 1996. While these figures will include shrimp, they underscore the scope for international trade in aquaculture produce and benefits to developing countries. In contrast, Sub-Saharan Africa gained just US$863,000 from exports of aquaculture produce in 1996 while importing aquaculture products to the value of US$375,000. The WANA region imported more aquaculture produce more than it exported although the value of the fisheries exports was almost four times the import value. All forms of aquaculture yield produce valued at US$747 billion in this region.

The number of producers/users has not been estimated. Statistics do not disaggregate fishers concerned in inland fisheries into the component resource systems. However, the numbers are clearly high in all Asian subregions and proportionately less in drier continents or where aquaculture is not currently widely developed (wider Africa region).

Resource system characteristics

Ponds are used either for the culture of a single species of fish (monoculture) or for fish species in various proportions (polyculture) to maximise feeding niches and nutrient cycling. Pond aquaculture integrated with farms can use farm plant or household residues or manure to feed/fertilize the ponds appropriate to farmers' resources. Higher productivity is normally derived from the use of more costly formulated feeds. Production efficiency also depends upon factors such as temperature, species, genotype, age and size of fingerlings at stocking, water depth, oxygenation etc. Ponds provide additional aquatic habitat for aquatic organisms including phytoplankton, zooplankton, insects, aquatic animals, birds and mammals. Pond

aquaculture can damage biodiversity by the accidental release of exotic species, and theoretically, but not proven, the release of detrimental, nonnative, conspecific genotypes. Other ecological impacts can sometimes include the alteration of natural habitat in the construction of ponds (particularly in the case of deciduous forest or mangroves), although, in some cases this alteration of previously damaged habitat can actually increase the area of wetlands and beneficial habitat for wildlife.

Another potentially damaging ecological impact is the release of excess nutrients from ponds into the natural environment. However, this can be turned into a positive impact by utilizing these nutrients in a productive manner through irrigation, fertilization, etc. Ponds have a potentially positive impact as deterrents to soil erosion. Aquaculture production has the potential to alleviate pressure on natural fisheries.

Government policy and regulation

Macropolicy

Macroeconomic and investment policies of most of the Asian countries favor the culture of high value export oriented species like shrimp. This policy bias has negative effects on the extensive and semi-extensive culture of important species like carp, tilapia and milkfish by small or medium farmers, and has led in some cases to damaging environmental consequences.

Feed policy

Feed cost comprises about 70% of the production cost of semi-intensive and intensive aquaculture. Many countries use imported feed and/or use foreign ingredients in locally formulated food. The high cost of feed is one of the major constraints to the adoption of aquaculture technology by poor farmers.

In many countries aquaculture has been initiated with government support for hatcheries. In several countries, especially for countries in economic transition, the tendency is to privatise these services with potential concomitant lack of government control over breeding practices and quality of supply.

Some countries have "agriculture first" rights over water use which impinges on water quality for aquaculture and its subsequent efficiency.

Resource system SWOT

Strengths

The system is controllable; it is ownership driven; has a high range of potential with many different types of systems—ranging from the simple to the complex—that can be used; the system is durable and can be amortized and depreciated over a long period of time; it is relatively simple for communities used to the management of water in agriculture; the produce is less likely to be contaminated by pollution compared to lake capture fisheries, it can be diversified to reduce economic risk and the production system and species utilized can be rapidly changed to adapt to tastes or changing market trends. It provides opportunity to harvest, conserve and store water resources while deriving other benefits. Pond aquaculture has been used to protect and propagate endangered aquatic species and genotypes, and could be used to a greater extent to accomplish this goal.

Weaknesses

Aquaculture is dependent upon a reliable supply of clean water and water management experience of the farmer plays an important role in success. Not all soils are appropriate and depending on geographic location, crops can be lost from flooding. Another weakness is the knowledge and capital required to enter. Extensive systems are less productive, intensive systems carry higher risk to productivity and sustainability.

Opportunities

There is a huge unexploited potential for expansion worldwide, not only for area of production, but production per area. Pond aquaculture provides nutritionally high quality products which can contribute to human protein intake and income through the sale of fish. There are many potentially valuable species in developing countries that have not been evaluated.

Threats

Threats include increasingly poor water quality and reduction in fresh water availability globally. Land prices and alternative land use, feed costs for developing country practitioners, the competition between aquaculture and livestock feed markets, diseases, and labor costs.

Research issues, trends, prospects

Issues

How to intensify aquaculture or increase productivity without environmental consequences. How to ensure equity of benefits to smallholder/poor sector of society as productivity drive turns aquaculture "industry" towards market exploitation (cash) and away from subsistence (food) imperatives. How to overcome adoption failures (in Africa especially) and how best to structure input supply and markets. How best to integrate aquaculture with multipurpose use of water. Production of quarantine guidelines, and codes of practice governing transfer of aquatic germplasm to conform with national wishes and to husband existing biodiversity.

Research needs and opportunities

- Economic, market and impact analysis for identification of optimal species and technologies for developing countries
- Aquaculture systems development, including documentation of genetic resources, elucidation of population genetics mechanisms and evaluation of new species, and integration of systems including polyculture
- Genetic enhancement of aquaculture species, including improved knowledge of molecular genetics for this purpose
- Determination of the genetic impact of genetically enhanced and domesticated fish on native genotypes
- Development of hatchery management and fingerling distribution systems
- Determination of nutrient requirements of target species both from a growth and health perspective, leading to development of low-cost but nutritionally complete feeds
- Control of water quality in pond effluents
- Development of disease control mechanisms
- Development of predator control systems
- Development of safe post harvest treatments, marketing, processing and distribution systems
- Development of effective technology dissemination practices

Core research disciplines relevant to this resource system

- Genetics
- Nutrition
- Fish diseases
- Socioeconomics—economics
- Water quality management
- General aquaculture
- Hatchery management
- Reproductive physiology

Trends and prospects

In general, the international research effort in this area is nominal compared to other branches of agriculture and is highly competitive. However, there appears to be a gradual increase in effort in this area. This is reflected by the ever increasing number of journal articles and the gradual increase in the number of journals devoted to aquaculture research. ICLARM has many new resources in this area (methods, collaborators in national programs, ASIs and commercial companies, germplasm, new facilities in Egypt) and needs to use them effectively. There is always the threat of other priorities but, in general, pond aquaculture is economically attractive compared to much of other agriculture. Aquaculture knowledge and practices have spillovers to lake and reservoir systems, and to stock enhancement schemes in these and other water bodies including to some aspects of marine aquaculture. Aquaculture development is continuously under threat from other sorts of landuse or labor markets.

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ICLARM role and position

ICLARM is a major resource provider in the fields of genetics, integrated aquaculture, invertebrate mariculture and socioeconomics. ICLARM collaborates with numerous NARS and advanced institutions. Our major customers are targetted to be poor fish farmers and poor consumers. Major donors for aquaculture projects have been ADB, UNDP, Japan and various European donors. Competition is difficult to identify because many or all of our competitors, which include all major advanced aquaculture research institutions, are also potential collaborators. ICLARM has built its program in a unique way—as a facilitator with minimal facilities of our own—which has provided a unique niche. Now we have our own facilities in Egypt and opportunities through the GIFT Foundation in the Philippines and partners in Malaysia and we must learn to use them for strategic research purposes. This gives ICLARM the advantage of having access to two worlds of basic and applied research facilities and our role as a facilitator. ICLARM's expertise in farm level integrated aquaculture is much in demand.

The major weakness has been lack of facilities and laboratories, and lack of long term funding to support new phases of genetics research.

Additional reference

Tacon, A.G.J. 1996. Global trends in aquaculture and aquafeed production, p. 90-108. *In* International milling directory 1996. Uxbridge, Turret-RA1.

Ponds

contents

Potential benefits

Currently, the harvests of natural fish populations from capture fisheries, considered globally, is at a probable maximum: further substantial increases in ocean productivity are not anticipated under the current access and management regimes. As a consequence, future demands for aquatic protein must be met through the development of aquaculture-based production systems. In 1993, approximately 16 million mt of aquacultured animal protein was produced, representing some 13% of the total aquatic animal protein harvested or produced (Tacon 1996). Per capita fish consumption has doubled over the past 30 years. The production of aquacultured animal protein has been increasing at a rate of over 10% annually since the mid 1980s, compared to the more modest growth of terrestrial meat production which ranges from 0.7% (beef) to 5.2% (poultry). The most rapid growth of aquacultured finfish production is occurring in developing (11.5% annually) rather than developed (4.0% annually) countries (Tacon 1996). However, smallholder aquaculture suffers from low yields due to lack of appropriate management methods and the high costs of feed inputs. Intensification can be accompanied by increases in disease incidence and inequity in the distribution of benefits. Low rates of adoption hinder the wider dissemination of integrated agriculture aquaculture practices. The percentage of aquaculture supply from ponds will increase relative to other aquaculture systems.

Thus, pond aquaculture research through increasing production and improving efficiency of production methods can make fish more widely available and more affordable to consumers. Increased harvests can produce profits and income for the farmer and thus assist rural development. The wider adoption of pond aquaculture can add to the diversification of agriculture and produce a range of products from food staples to high value food or ornamental species for income generation. There is good potential to provide livelihood opportunities for women through aquaculture. Focus on efficient and productive species can assist the generation of wild stocks by taking pressure off over-exploited natural resources. Conducting research in-country with national partners ensures the development of appropriate breeds and practices and enhances NARS research and development capacity for aquaculture.

Ability to utilize

In humid Asian countries, traditional aquaculture and water management practices exist. Some countries (e.g., China, Fiji) have national plans for the development of aquaculture.

In many other developing countries, the fisheries extension system is very weak or does not exist. Weak fisheries extension systems or lack of coordination between research and extension are hindering the use/adoption of research results by farmers or potential farmers. However, the situation is improving in many countries, NGOs are now playing an important role in disseminating research results. Introduction of pond aquaculture to new entrant farmers will be most challenging in dry areas or regions of seasonal rainfall, as water management, input and marketing issues are integral parts of the research. However, new technologies are relatively quickly adopted if they are within the means of the farmer. Interest in applied genetics is high in most aquaculture-practicing regions. The ICLARM-coordinated International Network for Genetics in Aquaculture (INGA) is linked to the general improvement of genetic analysis capacity in several national aquaculture institutes in developing countries. However, genetic

expertise is not yet widespread and individual institutes become overburdened with international projects.

Research results show that the adoption of aquaculture technology is higher in single ownership ponds than for jointly owned ponds. Lease arrangements also alter the aims of the short term lease holder. Policy research to enhance government's structural approach to the sector is required to balance commercial approaches with the needs of poor producers and consumers.

Science potential

The opportunity for scientific advancement is enormous particularly in the field of genetics. In the case of general aquaculture, there is great opportunity for advancement in utilizing food pathways, identifying low-cost food inputs with high impact output, and developing high value crops for poor farmers that will generate income. Research on extension and the micro- and macroeconomic conditions which facilitate the adoption of small scale aquaculture are required.

In genetics there is the opportunity to tune research for the small holder and poorer sections of producers/consumers by placing emphasis on genetic enhancement of carps and tilapias in Asia and Africa to produce better breeds. Traits for improvement will vary depending upon the species and situation, but may include growth rate, feed conversion, reproduction, survival, disease resistance, tolerance of stress factors such as poor water quality and water characteristics such as temperature and salinity, harvestability, sex ratio, and carcass characteristics, and by focusing on aquaculture in three basic environments, pond culture, cages, and deepwater rice-fish culture.

There are major needs and opportunities to increase documentation of genetic resources. Genetic improvement in fish can take place through a number of techniques including, selective breeding, monosex approaches, gene transfer, and combined genetic enhancement programs. The majority of these techniques are available and have been applied to fish species or to livestock systems.

There is concern about the potential effects of domestic, genetically enhanced and transgenic fish on natural populations and natural gene pools. Disease and environmental issues are open to investigation with new science coupled with appropriate legislation on quarantine and fish introductions. Environmental risk assessment research is critical for full implementation and impact of the genetically enhanced fish as well as responsible protection of natural genetic resources and biodiversity.

Opportunities exist to conduct this type of research with developing country scientist partners. Collaboration with advanced genetics institutions can assist technological inputs and strengthen developing country partners through educational programs (such as the ADB scholarship program, INGA).

R&A capacity

In the area of general aquaculture and integrated aquaculture, ICLARM had a major stake which has been diminished because of a decline in critical mass. Our advantage is the focus on poverty alleviation and the systems approach to aquaculture and agriculture. Our gaps in skills include expertise in nutritive flows and soil science, nutrition, diseases and nutritive flow-economics and human nutrition. ICLARM has farm-based aquaculture experience and socioeconomic expertise to conduct the complementary extension and implementation research and to determine impact.

ICLARM's international standing in genetics is moderate to good through the linear development of the GIFT project. There is an excellent opportunity to improve that substantially through wider collaboration. An excellent network of collaborative teams has been established in developing countries (through INGA and the DEGITA project). Our advantage is the clear focus on aquatic resources appropriate to poverty alleviation, leadership of a motivated strong network with substantial pond facilities.

ICLARM currently lacks its own laboratories and hatcheries in Asia and long term funding for genetic development programs which are weaknesses.

For socioeconomic and policy research

ICLARM has high international standing in *applied* socioeconomic and policy research in the field of fisheries and aquaculture. ICLARM's main advantage in the socioeconomic research are the interdisciplinary nature of research approaches and good collaborative arrangements with national teams.

SUMMARY DATA

Resource system 2: Reservoirs and lakes (including small water bodies)

Description

A lake is a large body of water surrounded by land. A reservoir is a natural or artificial lake used as a source of water supply. These are lentic habitats, that is, inland standing waters >2 ha. Most large reservoirs have multipurpose functions. These include drinking water supply, irrigation, power generation, power plant cooling, and flood control. Both lakes and reservoirs are normally utilized for fish production through capture fisheries or aquaculture or both. Lakes and reservoirs are normally, with several exceptions, markedly different in respect to features such as basin shape, water exchange rates, extent of water fluctuations, thermocline depth and species composition. The characteristics of reservoirs will be influenced by age.

The distribution and size of lakes and reservoirs in the tropics shows considerable variation between continents. Among developing countries, most of the largest lakes are found in Africa. Large lakes are uncommon in South America. Asia has approximately 28.55 million ha of natural lakes (with substantial surface areas in Indonesia, China, and Bangladesh) and 5.5 million ha of reservoirs (largely in India, China and Thailand). However, reservoirs form integral parts of community life and fisheries productivity in smaller countries of the region also (e.g., Sri Lanka). The Government of India classifies reservoirs as large (>5 000 ha), medium (1,000-5,000 ha) and small (< 1,000 ha). Water bodies less than 200 ha are not considered in this classification but still provide opportunities for further fisheries exploitation in all regions. The FAO definition of a small water body is anything up to 10 km^2.

Surface water area along with catchment are the key features affecting management options for increasing fish productivity:

- Large lakes/reservoirs are managed through existing capture fishery models and large-scale cage aquaculture. Affected by problems of managing stocks which are shared by communities and/or countries. Not feasible to fertilize or privatize.
- Small waterbodies (SWBs)—These can be managed more as individual community or private resources. Fertilization, intensive stocking and use of cages for aquaculture are feasible.

Other different sets of categories could be based on biodiversity, origin, fisheries yield, water volume or irrigative capacity (for reservoirs). For example, Lake Chad and Lake Victoria are similar in terms of formation and management strategy, but widely different in terms of biodiversity, ecosystem structure and hydrology. Similarly, both of these lakes are substantially different in terms of ecosystem function from the Rift Lakes. Through intensive cage culture operations Philippine reservoirs (only 19,000 ha total surface area) are reputed to yield 576 kg $ha^{-1}yr^{-1}$ of fish (De Silva and Amarasinghe 1996).

Resource system analysis

Trends and forecast

Gross value of production is difficult to estimate as FAO's 1995 figures do not divide inland capture fisheries and aquaculture. Our estimate for tropical developing countries is that this resource system produces approximately 2.95 million mt.

Laë (1997) compiled data on 65 African lakes. Using his figures, (which are more conservative than official statistics) ICLARM (Brummett unpublished) calculated that these waterbodies collectively produce about 600,000 mt annually and directly support some 200,000 fishers.

Using country-level estimates for potential from FAO (adjusted downward on the basis of local consensus), it appears that overall African Inland fish production could rise from the current 1 million mt to reach 1.3-1.8 million t per annum. If the 65 lakes used in this analysis are the major producers, then rivers and floodplains are producing about 400,000 mt per annum.

ALCOM have suggested that there are 50,000-100,000 smaller waterbodies in east and southern Africa alone. The majority of these are located far from main population centers and are underexploited. Their number is expected to grow as watershed management and small scale irrigation schemes increase in number and diversity. These will require increasingly intensive management to meet the needs of increasing rural populations.

In Asia, reservoir fisheries have high potential (estimated to be 500-2,000 kg ha^{-1} yr^{-1}). Presently, productivity is only about 45-90 kg ha^{-1} for indigenous species, approximately 250 kg ha^{-1} for carp production in China and 100-800 kg ha^{-1} in countries in which self-feeding tilapias are stocked as a component of the system. The use of "cove culture" in the water inlets to reservoirs in China brings productivity of these areas up to the level of pond aquaculture, approximately 4,500-5,000 kg ha^{-1}. Advances of this sort, coupled with enhanced stocking regimes are expected to enhance productivity from these systems and a range of SWBs (e.g., in Bangladesh) in the future. Cooperative management and privatization issues may dictate the pace of development rather than biotechnical research.

Resource system characteristics

As mentioned above, reservoirs, lakes and SWBs need to be dealt with separately in terms of ecosystem. The main production basis of lakes is autochthonous. Nutrients are made available for primary production mainly through sediment and water interchange, upwelling (vertical mixing) and inflows. Natural African lakes are home to some of the most diverse species flocks in the world and have highly complex ecologies. Reservoirs depend on nutrients brought in by afferent rivers and streams. The processes are still not fully understood. The patterns observed in the ecology of these systems are complex as they result from the interaction of many factors. These patterns can be observed over a wide range of temporal and spatial scales. For example in Lake Tanganyika, water residence time is about 500 years. In this time there would be $\times 10^5$ generations of phytoplankters compared to 250 generations of a top predator such as *Lates stappersii*. SWBs and reservoirs, on the other hand, often feature either very impoverished species diversity (often based on stocking of sport fishes or a few species for weed control and/or foodfish production) or adapted riverine amalgamations.

Natural lakes in Africa are mostly very old and stable. However, some natural lakes with large shallow areas undergo extensive seasonal and inter-annual variation in water level. Whereas reservoirs and SWBs are highly variable from season to season and year to year in terms of water level, nutrient density and recruitment. Many SWBs have perpetually unbalanced predator:prey ratios as a result.

There are many published reports concerning tropical lake ecology, but many of these are incomplete and there is room for more integrative work in this area.

African lakes have the greatest diversity especially in some families such as cichlids. Of the more common groups, characoids, cichlids, cyprinoids and siluroids occur in Africa, characoids, cichlids and siluroids in South America and

cyprinoids, siluroids and only a few cichlids in Asia. The species composition can be severely altered by the introduction of exotic fish.

Reservoir fish species are normally riverine in origin except those that have been introduced. In the formation of a reservoir some lotic fish adapt to the lentic habitat but others, such as the large Indian carps, do not. Many of these fish require river flood conditions to spawn.

Natural lakes also differ from reservoirs and SWBs in their management and exploitation. Natural lakes generally have a long history of exploitation which is often associated with traditional management strategies (although many of these have been lost through the years of political upheaval). In contrast, many of the communities which surround SWBs and reservoirs are not comprised of fishers and have no tradition of managing aquatic resources. Approaches to these different user-groups will necessarily be different.

Government policy and regulation

Most governments have policies and regulations to manage their inland fisheries. In China, there has been a policy to expand the types of water body used for aquaculture. About 1.5 million ha of reservoirs have been exploited for this purpose (FAO 1997). In smaller developing countries, government responsibility for hatchery and stocking programs have varied causing instability in production (e.g., Sri Lanka). In most SSA countries, plans for stock enhancement and cage aquaculture have been in existence since the early 1980s, but little has so far been achieved. However many of the national staff appointed to undertake this work are inadequately trained. The greatest proportion of the fishing effort is artisanal and governments have little success in implementing policy. There are often national conflicts of interest, for example between irrigation and fisheries. There are many examples of lack of control of pollution, eutrophication and the introduction of exotic organisms (plants and animals). Many large lakes and reservoirs are bordered by more than one state and the mobile fish resources are shared. The process of information exchange between the riparian countries has so far had little success as have attempts to form international commissions to formulate overall management policy.

Also important will be watershed management efforts for which policy (particularly in regard to land-holding patterns) is still in a formative stage. Systems of communal land allocation by traditional authorities will prove a major obstacle to changes in landuse and watershed management.

Resource system SWOT

Strengths

Systems are multi-purpose and provide support for many people living around their shores and beyond. For example about 7 to 10 million people live in the catchment area of Lake Tanganyika and depend on it for their livelihood and well being.

Weaknesses

The dynamics of the systems are poorly understood. Many of the organisms have not been identified. This particularly applies to the fish species in the African Great Lakes. Management is not usually successful in obtaining the optimum benefits and rationally exploiting the system. This may be due to a number of factors (economic, political, training, access to the resource, knowledge, etc.)

Opportunities

Sustainable production of fish at affordable prices. Yield from capture fisheries is unlikely to increase although there may be some opportunities to exploit vacant niches that are stocked, (e.g., by the introduction of small pelagics into reservoirs). Fish production may also be increased by aquaculture development through the use of cage culture, etc.

Threats

Pollution, eutrophication, waterborne disease, siltation (turbidity) overfishing, conflicts of interest (for water usage), poaching, introduction of exotics.

Research issues, trends, prospects

Issues

- Population versus resources—leading to overexploitation of fish stocks and fishing down the food chain
- Inadequate technology to permit smallscale fishers to access pelagic stocks
- Poor agricultural practices and watershed management leading to soil erosion, siltation and increased turbidity of receiving waterbodies
- Low productivity of many African surface waters suggested (average of less than 60 kg ha^{-1} yr^{-1} in lakes)
- Increasing problems with aquatic weeds as a result of pollution and exotic fish species introductions
- Bilharzia and other water-related public health concerns
- Integrated management approaches to remedy: lack of ecological data and reliable catch statistics, appropriate inventories and determination of fisheries potential on which to base exploitation rates If data are available, the means of analysis are often inadequate
- Lack of suitable monitoring programs and modelling capacities
- Lack of simple keys for identification of organisms
- Lack of suitable trained national staff. Many fisheries officers do not have the capacity to estimate benefits from inland fisheries
- Lack of information exchange between scientists or at the level of national agencies or riparian states
- Lack of cooperation within the resource users
- Lack of suitable harvesting, processing, transportation and marketing methods

Research needs and opportunities

Identify present knowledge and available data on the ecosystem and state of the fish stocks. Perform research on those parts of the ecology of the resource system that are required for modelling and for making quantitative predictions. Put into place suitable techniques for monitoring the resources including the collection of catch statistics.

Specific items of research might include the development of suitable models on which to base resource management; effect of climate change on fish yield; reproductive requirements (low fish biomass may result from poor recruitment due to reproduction problems); suitability of introductions into small (and large?) reservoirs in Africa (as is carried out periodically in Asia); appropriate development of aquaculture practices (e.g., feeding for cage culture; fertilization for SWBs) the effectiveness of reserves or sanctuaries; and the development of suitable methods (technology) of fish handling, processing and marketing. Develop integrated management schemes taking into account biological, economic and socio-political exigencies.

Core disciplines

- Capture fisheries management and stock assessment
- Fish hatchery management and stock enhancement
- Cage aquaculture
- Aquaculture
- Ecology (limnology and terrestrial)
- Economics
- Fisheries biology and modelling (statistics and mathematics)
- Geography and geology
- Community-based natural resource management methods and policy
- Hydrology
- Sociology
- Taxonomy
- Water quality and fertilization management
- Integrated smallscale irrigation management

Trends and prospects

The number of SWBs and reservoirs brought into fisheries and aquaculture will increase, as will the intensity of their management, as population continues to grow beyond the means of traditional extensive agriculture. Methods for managing both the transition phase (from seasonal pond farming

to reservoir-fed irrigation systems) and the SWB fishery resources themselves are needed.

FAO is developing strategies for managing SWB and associated watersheds and aquaculture and other players in the management of lakes and reservoirs are mentioned below. ICLARM has the possibility of providing detailed Ecosystem modelling to groups working in this area.

The African Rift Lakes are probably receiving adequate biological attention through large scale GEF and other international activities. Much work has been done on the species diversity of certain fish groups. However, governmental will to adopt effective management strategies is lacking. Despite policies which support increased utilization of these resources, very little money from the various national budgets is allocated to their development.

Watershed management is a clear area where ICLARM skills in IAA and co-management could be combined to develop new approaches to productivity and natural resource management. Effective watershed management will involve not only soil conservation measures, but will also require changes in the way water moves through the agro-ecosystem. Irrigation will be used to mitigate losses of arable land to reservoir and SWB formation. Opportunities exist here for case studies and the elucidation of new management strategies (and ICLARM has developed a research approach for the improved management of Lake Nasser).

ICLARM role and position

Virtually all African countries have substantial lake, reservoir and/or SWB resources which could benefit from improved study and management. Policy in these countries is largely favorable to ICLARM's involvement. Natural lakes are receiving particular attention of the Scandinavian countries. Lakes Victoria, Malawi and Tanganyika are probably oversubscribed in terms of research projects. Kariba has several management entities which might be receptive to collaboration with ICLARM but this would have to be very much a NARS-led activity. In Asia, there is relatively advanced national capacity for the development of stocking and enhanced fisheries but less experience in social and political management issues.

ICLARM has contacts through the community based management work in Bangladesh and contributions to co-management studies in Asia and Africa. Substantial links to Malawi which may be site of further work on SWB.

The major customers for ICLARM's work would be the fisheries and management authorities for these resource systems and their users

SWBs are the focus of ALCOM, but they have very little expertise and could benefit from collaborative relationship. The CTA is involved in study and management of Sudano-Sahelian reservoirs and could be a collaborator.

Alternative suppliers of research knowledge are the FAO, Chinese, Indian, etc. national programs. ICLARM has many collaborators through co-management and ecosystem modelling research.

ICLARM's strengths and weaknesses in relation to this system

- Managing lakes and large fisheries in major reservoirs can be done through usual capture fisheries approaches and ICLARM would only have to refocus from an emphasis on marine systems to effectively deal with them.
- Reservoirs and SWB's will require a multi-disciplinary approach and a lot more experimentation to define useful methods. The disciplinary divisions between "fisheries" and "aquaculture" and "social science" may persist unless an integrated approach is adopted dealing effectively with these ecosystems.
- The African lakes proposal allows for collaborative research within ICLARM and with national institutes. It would be an opportunity for ICLARM in appropriate partnerships to build on the information gained by a number of recent large aid projects in the region. There have been many capture fisheries research projects carried out in the region which have had specific objectives in ecological, sociological and or economical areas. Rarely have these areas of research been integrated to formulate a common management policy for a shared fishery and moreover, rarely have ecological considerations been integrated with the social and economic structures in which they are embedded.

Additional references

De Silva S.S. and U.W. Amarasinghe. 1996. Reservoir fisheries in Asia, p. 189-216. *In* S.S. de Silva (ed.) Perspectives in Asian fisheries: a volume to commemorate the 10th anniversary of the Asian Fisheries Society. Asian Fisheries Society, Manila.

Laë, R. 1997. Estimation des rendements de pêche des lacs africains an moyen de modéles empiriques, Aquat. Living. Resour. 10: p. 83-92.

Rana, K.J. 1997. China, p. 91-97. *In* Review of the state of world aquaculture. FAO Fish. Cir. 886-Rev. 1. FAO, Rome.

EVALUATION DATA

Reservoirs and lakes (including small water bodies)

contents

Potential benefits

We estimate that lakes and reservoirs in developing countries produced in 1996 approximately 2.95 million mt representing about a third of the inland freshwater catch and relatively small percentage of total aquaculture. However, with the inclusion of small water bodies (SWBs) this resource system has been identified as a key area for possible expansion both in extent and productivity in developing countries. China has intentionally expanded aquaculture or stock enhanced fisheries technologies to reservoirs, with an apparent large increase in productivity. Managed expansion of water use and the introduction of management regimes to assist local communities in access and benefit sharing could h ave major effects on food security and livelihood for these communities. Impacts on national systems are likely to be high; either through increased fish supply, and efficient water and resource management or through the development of cooperative management schemes at village or community level in countries that have traditionally exploited reservoirs for human and agricultural uses. Key users will be African nations with large lake areas, southern and western Africa for the exploitation of the "new resource" of SWBs, and many Asian countries having extensive reservoir and SWB systems. The principal outcome in large lakes will be cooperative management schemes; with SWBs the extension of the resource and increased productivity, and with reservoir fisheries, appropriate aquaculture techniques for improved production and sustainability.

Ability to utilize

Asian countries are already tackling the technical improvements in stocking and management of freshwater bodies but will gain from the integration of new technologies into community management schemes. In Africa, there is extensive use of the Great Lakes but shared management regimes across borders are required. Exploitation of the continent's small water bodies may require assistance at all stages of research (e.g., management fertilization, harvest techniques, species mix, ecosystem modification) to avoid the disappointing adoption and success rates that have accompanied many pond and lagoon aquaculture schemes previously.

The outputs would be advice on species choice and stocking regimes, analyses and advice on optimal community management or co-management regimes and economic feasibility assessments for species and resource system exploitation.

Science potential

Most stock enhancement methods for these purposes are known. Establishing optimal species compositions will vary with the trophic/environmental conditions. Ecosystem modelling and simulation technologies are available. Different management regimes may need to be developed depending upon government, private, or community ownership and the size of the water body in question. Prospects for socioeconomic improvement of these systems based on adaptive technology development are high. Adoption may be easier to obtain in countries with longer history of water body management for fisheries production.

R&A capacity

ICLARM has the potential to develop integrated management schemes based on better ecosystem modelling capacity. Managing lakes and large fisheries in major reservoirs can be done through usual capture fisheries approaches and ICLARM would only have to refocus from an emphasis on marine systems to effectively deal with them. Reservoirs and SWB's will require a multi-disciplinary approach and a lot more experimentation to define useful methods. The division between "fisheries" and "aquaculture" and "social science" will be an obstacle to overcome to deal effectively with these ecosystems. ICLARM's development of an approach for work on lake Nasser, effectively a large reservoir, combines many of the issues into a holistic framework and collaborative research approach for use, with modifications, elsewhere. There is donor interest in SWB work in southern Africa and Bangladesh as this is one means of productively extending the resource system. Work in these areas may become a substantial (in dollar terms) proportion of ICLARM's research portfolio. Logistical and infrastructural support is in place or being developed in Bangladesh, Malawi and Egypt. Contacts with many other sites through collaborators to co-management projects.

SUMMARY DATA

Resource system 3: Floodplains, rivers and streams

Description

This resource system represents inland waterbodies that are already in use or have potential for use for capture fisheries, culture-based/enhanced fisheries and various forms of aquaculture. Floodplains, rivers and streams often become parts of a single fishery production system during the rainy season, streams and rivers and floodplains have quite different biophysical characteristics and property rights regimes.

Streams and rivers

This subresource system includes all running rivers and streams. It is, however, important to note that rivers are dynamic systems and that their courses and flows are constantly changing due to natural (e.g., sediment deposition, erosion, scouring of river bed, tremors, earthquakes, etc.) and human-made reasons (e.g., construction of dams). These are different ecosystems, and the human population living around them is continuously adapting to the many changes (opportunities and challenges) brought by the development, including shifts in reliance on the type and extent of fishing practices.

Floodplains

The lands along both sides of a river channel formed by layers of river alluvium, containing the meanders or braided reaches of a river and periodically inundated at times of high river discharge, constitute its floodplain. Floodplain resource systems also includes various types of depressions or former river channels (e.g., oxbow lake) of different origins and sizes that are periodically or perennially flooded. Floodplains can be classified in several ways. Based on the level of inundation, floodplains can be categorized as perennially or seasonally flooded with correlated differences in sediment deposition. They can also be divided into: (1) vegetation (e.g., flooded forests) and swamp zone, and (2) areas within the agricultural zone. The first type is ecologically very important, and it has much greater significance for biodiversity. Development and agricultural encroachment, and sedimentation and siltation continue to reduce and alter the size and ecology of this type of floodplain. On the other hand, areas within the agricultural zones have also been subjected to changes such as controlled flooding and loss of links with rivers and streams.

Major river and floodplain systems are very important to Asian countries. China has several major river systems and the Ganges watershed covers over 1 million km^2, 18% of which is wetlands and encompasses 82 large cities. The Mekong watershed encompasses an area of approximately 800,000 km^2, involving four countries; 9% of the area is wetlands. There are a large number of endemic fish species some of which are threatened by dam building and degradation of habitat. In Africa, major watersheds are the Congo, Niger, Lake Chad, Nile, Okavango Swamp and Zambesi. Apart from the Nile, the major Asian watersheds support a human population density 10-100 times greater than the African systems.

Resource system analysis

Trends and forecast

Our analysis suggests that total productivity from the resource system in the developing countries increased from approximately 3.5 million mt in 1988 to 4.58 million mt in 1996. However, it is widely accepted that the prior production figures may have been large underestimates, leaving out the subsistence catch which is only now being taken account of and analyzed. Production from some river systems e.g., in the Mekong Basin countries, is falling due to degradation of the environment, reduction in water flow, etc. Research is required therefore not on production per se but on environmental management and biodiversity protection.

Resource system characteristics

Floodplains

Floodplains are highly seasonal and variable in terms of level of flood waters. Ponds, borrow pits, swamps and shallow lakes get filled up during the rainy season. Flora and fauna are complex due to high variability of flood and water regimes. According to the water depth flora can be submergent, emergent and floating. The fish fauna can also be either resident or migrant. Many fish species move from upstream areas for breeding and nursing. Juveniles of fish and shellfish find food and protection in the aquatic plant communities. Water birds (resident and migrant) are attracted by the rich food base in the swamp and forested part of the floodplains. The timing and duration of flooding in the floodplain are highly variable, which affect growth and survival of fish greatly. Rapid flood recession strands and desiccates juvenile stages of fish and disrupts their food chains, while the anaerobic conditions and lethal pH changes of prolonged flooding cause mortality. Thus, most dominant fish of the floodplains are adapted to periodic oxygen depletion and the prolonged dry season, either by possessing accessory breathing organs, or by having special behavioral patterns for avoiding these unfavorable conditions. Fish productivity in riverine systems is enormously enhanced through floodplain ecosystems. These also provide habitats for breeding of fish normally resident in stagnant waterbodies as well as for feeding grounds for their offspring.

During the dry season, land ownership in floodplains, particularly in land used for agricultural purposes, is fixed according to tenure arrangement. During floods in the wet (rainy) season and where land is not bounded, fish are a community property granting community members access to fish in all the communities' areas.

Rivers and streams

A river's annual or mean discharge rate is probably the most relevant measure of its size—certainly the periodicity and seasonal flow pattern is one of the important characteristics from a fisheries point of view. In terms of average discharge, the Amazon (180,000 $m^{-3}s^{-1}$), Congo (41,000 $m^{-3}s^{-1}$) and the Ganges-Brahmaputra river (India/Bangladesh/Nepal) (38,000 $m^{-3}s^{-1}$) are the three largest in the world. Unlike the Amazon and Congo in the equatorial belt, which have a constant discharge and a low to moderate sediment lead, the Asian rivers have high seasonal discharges causing extensive flooding during the rainy (monsoon) season. In China, the total inland water area (rivers and floodplains) is 5.25 million ha. Seventy nine rivers have drainage areas that exceed 10,000 km^2. Fish movement and migration in the Asian rivers are upstream or downstream during the greater part of the year and laterally out onto the inundated floodplains during the rainy (flood) season. The inundated floodplains provide a wide range of habitats congenial for fish reproduction and early developmental growth. Dry season flow can reduce to a barely minimum flow. Dry river beds are used for all sorts of agriculture and land-based activities. During peak or wet season flows extend to adjacent lowlands, swamps, canals, grass lands and forests. These areas often support a large diversity of flora and fauna, including fish.

Rivers and streams are largely common property and normally have open access. In some cases, however, these resources are the property of government which claim and exercise sole jurisdiction.

Government policy and regulation

- Several government agencies control the resources of river, streams and floodplains. This multi-institutional involvement often leads to the formulation of conflicting policies.
- Licensing and leasing of waterbodies (rivers, streams and some floodplains like oxbow lake) to commercial fishers often prohibit small fishers from using these resources. Small fishers, in most cases, cannot lease these resources, as they do not have access to credit and government institutions.
- Land and water use policies are complex, often provide incentives for maximizing private benefits and generate social and environmental costs.
- Intersectoral use of the land, water and resources of rivers, streams and floodplains are governed by several agencies (e.g., land authority, forest authority, and authorities for crop agriculture, industry, tourism and transport). Users and beneficiaries have differential access rights, based along sectoral, social, economic, political, ethnic, occupational and gender divides.
- Macro and national priorities often overlook what is best for local and sectoral benefits, and are responsible for causing dislocation and disruptions among various local users and uses.

Floodplains

Most land is under private or limited communal use. Water, in general, is considered a free resource, but at times it can be scarce and subject to control by government authorities or individuals. Ownership and access to fish resources vary across type of flood lands. For instance, fishing is tenure-free on privately owned flooded rice fields during the rainy season, whereas low lying areas where fish aggregate during the dry season can be held as private reserves.

Rivers and streams

Commercial fishing is regulated by licensing and leasing. But lack of information and enforcement have made sustainable management an unachievable objective through these instruments. On the other hand, distributional equity and integration of natural resource management into overall development is not addressed by policies and regulation in most countries.

Resource system SWOT

Strengths

Use by poor people and, thus, there are strong equity implications; highly productive and resilient systems despite severe fluctuations, many continue to exist; most people live along and around rivers and floodplains. Fish and aquatic products provide essential nutrition and buffer food security.

Weaknesses

Lack of appropriate policies and local institutions (e.g., co-management arrangement) regarding the utilization of these resources; subject to upstream impacts such as sedimentation and siltation, particularly floodplains; a disperse resource. River fisheries especially are only useful for supplying the local community; fisheries statistics on production, species and value are poor.

Opportunities

- To make better measurement of contribution of fish to productivity/food security. Wider use of resource evaluation techniques. Increasing and sustaining the productivity of these resource systems through appropriate technical and institutional interventions.
- Integrated natural resource management through application of new technology, knowledge and improved governance.
- Development of accurate ecological footprints of development activities

Threats

- Inappropriate use of these resource systems by other sectors is polluting the environment and thereby reducing the productivity.
- Persistent disregard for environmental and ecological cost, lack of accounting for environmental and natural resources and their values continue to generate inappropriate priorities and policies. Indeed policies and interventions made by outside sectors are major threats to the environment and ecology.

- Human pressure in densely populated regions and weak institutions are responsible for overexploitation, extinction and loss of biodiversity.
- Industrial pollution contributes both to fish mortality and high metal levels in fish (e.g., China). Potential threat to human health and more broadly to public perception of role of fish in diet.
- Loss of wetland areas in the same regions due to drainage for agriculture.

Research issues, trends, prospects

Issues

- Reduction in catch and loss of aquatic biodiversity in rivers and floodplains. These effects, however, are not due only to overfishing but to large scale degradation of environment and ecology through pollution and physical changes to the ecosystem.
- Lack of access to resources (natural resource, capital and other inputs, etc.) for poor fishers. The lack of political power in the lower socioeconomic groups constrains their demand for equitable access to many resources, including fish.
- Inappropriate policy and weak institutional support for poor fishers, and a lack of analysis of the impact of major policy changes.
- Sustaining and improving production and benefits.
- Equity-competitive and fair access to resources and means of production.
- Policy and institutional support to build capacity of fishers and farmers for expansion of production, enhancement of stock and restoration of habitat.

Research needs and opportunities

- Modelling of ecosystem for sustainable resource management, taking into account the multisectoral use of water bodies. Models are needed that can combine information on the physical and natural environment and the ecology of species with the socioeconomics of human intervention in exploiting and managing various subresource systems (floodplains, rivers, etc.)
- Research on alternative technical options (e.g., stock enhancement, habitat restoration, rice-fish farming in floodplains, etc.) for increasing and sustaining the productivity of various subresource systems
- Research on institutional and legal policy issues
- Research on community-based management (e.g., advantages and limitations of different systems of use rights in relation to the biophysical, socioeconomic, administrative and legal characteristics of various subresource systems
- Analysis of sectoral and macroeconomic policies affecting rivers and floodplains, and their users/beneficiaries
- Valuation and bioeconomic modelling
- Land and water resources policies and intersectoral resource allocation

Core disciplines relevant to this resource system

- Aquaculture/stock enhancement technology
- Resource economics
- Ecosystem analysis/modelling/biodiversity indicators/population genetics
- Policy and institutional analysis

Trends and prospects

The total international effort applied to this system is variable. This resource system was not a priority resource system in the 1992 strategic planning exercise. FAO is doing/sponsoring some research in this resource system. Awareness is increasing about the sector's role in poverty alleviation and food security (e.g., DFID, UK, and USAID's major projects on inland fisheries in Bangladesh). Biodiversity, wetland and conservation groups (especially IUCN) are putting emphasis on protection and rehabilitation from environmental point of view. ICLARM, ORSTOM, TRAFFIC and WWF are now planning a collaborative program on small-scale fisheries. Peoples' needs and requirement should to be integrated into the overall management

framework. There is new emphasis by Sweden on wetlands, e.g., RAMSAR.

Publications are promoted by FAO, IUCN, ICLARM and Wetland International.

ICLARM resources devoted to this system:

- Bangladesh inland fisheries policy and community based fisheries management work
- Deepwater Rice-fish Project in Bangladesh and Vietnam
- Legal and institutional policy and co-management work
- Forthcoming project on policy and valuation of aquatic wetland in the Mekong Basin

Spillover to other resource systems

Lakes/reservoir fisheries part of the continuum of inland waters and fisheries exploitation in many countries. Strong similarities with coastal (e.g., estuaries, lagoons) and in-shore fisheries management, in terms of community involvement, decentralized management, legal and institutional analysis and resource valuation.

Threats from other water or land use priorities

- Intensive use of agricultural land with application of chemical fertilizer and pesticides is polluting floodplains and to some extent, rivers.
- Construction of dams and flood control systems is negatively affecting rivers and floodplains
- Urbanization

ICLARM role and position

Although ICLARM is not a major provider to this resource system, it has a number of important projects dealing with this resource system, more particularly the floodplain sub-resource system.

- Co-management Project
- Legal and institutional work of PRIAP
- Deepwater Rice-fish Project of IAASP
- Ford-sponsored projects in Bangladesh
- Resource valuation in Mekong Basin countries
- Fishes for the Future proposal (inventory and action plans for freshwater fishes)

ICLARM has a number of memoranda with partner institutes in connection with the implementation of research projects on these resource systems.

- Good links with MRC/Mekong countries and Bangladesh.
- Opportunities to catalyze work with CGIAR and other centers concerned with water and habitat use.

Major customers for ICLARM's work

- Government agencies/departments (in development and environment)
- NGO and local community groups
- Policymakers
- Floodplain fishers and rice farmers
- Alternative suppliers: No direct competitors, Wetlands International, NRI (UK), OXFAM, seeking collaborative arrangements

ICLARM's strengths and weaknesses in relation to this system

Strengths

- Our strong linkages with partner institutes in Asia, e.g., Bangladesh, Mekong Basin countries, (GOs and NGOs), in-house capacity in fisheries/biological science and in modelling, co-management and socioeconomic issues, and interdisciplinary research approach of ICLARM.
- Ability to deliver methods for widescale application in this resource system

Weaknesses

- Lack of resource databases and required staff to develop and distribute these
- Current lack of coordination of biodiversity, resource valuation and social and legal analysis approaches in individual cases

Additional reference

Revenga, C., S. Murray, J. Abramoritz and A. Hammond. 1998. Watersheds of the world. Ecological value and vulnerability. World Resources Institute and Worldwater Institute. 164 p.

Floodplains, rivers and streams

contents

Potential benefits

Growth

Research on streams and rivers is expected to reverse the present downward trend in fish production of this resource system. It is possible to maintain the present level of production through the adoption of research results (both technological and management). But in floodplains, fish production can be increased substantially. For example, it has optimistically been suggested that over 10 million ha of deepwater ricefields can be brought under fish culture, and an average production of 1 mt ha^{-1} could be achieved through the adoption of appropriate technology and suitable institutional management.

Beside direct benefits (e.g., production or income) substantial benefits will come through systems improvements and offsite impacts. Since the system is part of a continuum, both natural and propagated fisheries will have to integrate with agriculture, forestry, agro-forestry and tourism.

Benefits will spill across multiple users and stakeholders (local communities, policymakers, NARS, NGOs). Some benefits may be observed offsite or after a long period of time. Many of the benefits will be in the form of production diversification, product transformation and market creation. Reduced cost, declining rate of degradation, diverse livelihood options—all of them combined will be necessary to provide a buffer to current insecurities of food, income and livelihoods. Focusing on flood plain issues, major relevance will be to South Asia and the Mekong Basin countries.

Environmental impact

Rivers and floodplains are under threat from industrial and agricultural pollution, interference from other land use projects. Evaluation of current biodiversity and environmental complexity is a resource research issue. Management schemes that provide means of stabilizing or improving the state of rivers and wetlands would have positive effects.

Social and cultural impact

Cooperative systems to manage common property are expected to have major effects at several levels of society, including equitable distribution of benefits and sustainability of the resource for future generations. These affect food security, institutional balance and sustainability.

As the rivers and floodplains are harvested mostly by small scale fisheries, they will be the key beneficiaries of the research on these resource systems. Key users are expected to be governments, NGOs and local communities in countries having inundated or floodplain systems.

Ability to utilize

In the past, very little use was made of research results. On the other hand, very little knowledge could be made available to the beneficiaries. Traditional government agencies that are responsible for delivery of the knowledge have been weak. But decentralization and democratization are expected to create a policy and institutional environment in which NGOs and communities will provide an improved climate for the extension and delivery of research results to the beneficiaries. There is increasing interest by various

government and local leaders to take steps to operationalize the concept of co-management in fisheries planning and management. Biodiversity issues are being appreciated with increased habit disruption (e.g., in the Mekong Basin, through flood barriers in Bangladesh).

The nature of output will be: 1) ecological and economic assessments and models; 2) action plans for conservation of aquatic biodiversity; 3) implications for changing land and water use and management; 4) alternative institutional models for resource governance; and 5) general policy and institutional framework and guidelines.

Science potential

Significant scientific advances have been made in relevant fields (e.g., ecosystem modeling, research on co-management, policy and institutional analysis). Stock enhancement techniques are known in general but production increases depend both on biotechnical knowledge (e.g., exploitation of all available niches in sub-system) and economic (cost of hatchery, fish inputs) and social (cooperative harvesting and benefit sharing) factors being put in place. Interdisciplinary research with application of these research tools has very high prospects in solving many problems of these resource systems. Collaboration with national institutions and NGOs will ensure appropriate balance between basic and applied research.

The health and condition of the resource itself will be factors in determining the rate of change. On the other hand, the status of the ecosystem health will depend on human action—the importance given to it by the stakeholders (government and community or users). Information and technologies for varied intervention on the resource-base (land, water, soil and vegetation) are becoming available and ICLARM's research will have the opportunity to make use of these (e.g., GIS, land-use planning). This means, we can expect a greater rate of success than in the past. In the context of fisheries and aquaculture both quantity and quality of ground- and surface-water will be a key factor for policy and technology choices.

Scientific advances can be made in the area of least harmful technologies and use practices through development of models providing ecological and economic integration of the resource system.

Research needs to be strategic, but application and adaptation for local level changes will require policy and institutional changes that may be site-specific. These too will require research inputs and training.

R&A capacity

ICLARM can take a lead in the resource evaluation and equitable management and exploitation of floodplains. It has already acquired experience and credibility by providing research guidance as well as analysing institutional and legal policies issues. Requires to enhance resource evaluation techniques and experience and to activate biodiversity analysis and action planning for specific regions. ICLARM has high international standing, skilled manpower and very good collaborative arrangements with national government and NGOs to implement research programme/projects effectively in these resource systems (principally in Bangladesh and Mekong Basin countries).

Future research approach must be integrative and multidisciplinary. The approach should also be at the basin/watershed/wetland level. Rivers and streams are clearly components of these but will not themselves be the research focus.

Research will require additional and substantial resources to be able to make a difference. National capacity and partnership building are essential. Most national institutions lack both integrative management approach and capacity, so that constant capacity building from the governance to the science of biodiversity issues will be necessary.

Resource system 4: Coastal waters (including estuaries and lagoons)

contents

Description

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 m depth are included here to encompass most fishing grounds of small-scale fishers. These areas are usually directly adjacent to soft-bottom shelves, leading to conflicts with the (trawl) fisheries operating there. Brackishwater ponds are included in this system. They are either natural or human-made; often the result of conversion of mangrove swamps. This resource system is often an area of intense intersectoral conflict (e.g., among fisheries, aquaculture, marine transport, urban development, tourism, and coastal forestry/agriculture). It is subject to downstream impacts of many land activities (e.g., agriculture, industry, forestry, mining).

Resource system analysis

Trends and forecast

Gross value of production

Estuaries/lagoons has been estimated to contribute about 17% of the total fish catch and 34% of the aquaculture production (ICLARM Strategic Plan 1992). In 1996, fisheries production from these coastal waters is about 11.16 million mt (noting that the contribution of marine aquaculture production is included under this resource system, even when it includes coral reef organisms).

Growth rate and forecasts

Continued high exploitation by fisheries is anticipated with increased coastal aquaculture and cross sectoral impacts.

Trade statistics: Not calculated

Number of producers/users

Not known, but very substantial. Includes most of the 10 million fishers in Asia.

Resource system characteristics

Estuaries and lagoons

Estuaries and lagoons are coastal embayments that have a greater or lesser degree of connection with the sea but whose waters are diluted by freshwater draining from the river system. Tidal actions in the sea areas also push saltwater upriver to some extent, depending on the strength of the tide, geologic formations, the offshore currents, and the quantity of freshwater entering the system via rivers. Hence, estuaries are characterized by the instability of the system. The environment changes constantly with the concentration of and dilution of chemicals (i.e., salt), deposition and erosion of sediments, and the coming and going of plants and animals. The entire system is maintained by a complex pattern of water circulation which among other things, replenishes nutrients, removes waste products, and propels plankton. The specific pattern of water movement is the result of a combination of runoff volume, flow velocity, tidal action, and winds.

Lagoons compared to estuaries have limited freshwater supply and are characterized by high salinity. The rate of evaporation and the rate of salt influx combined with runoff volume determines the salinity of the water body.

Areas of particularly extensive lagoon/estuarine environment include Brazil, West Africa, the Bay of Bengal shores of India and Bangladesh, and the Atlantic and Gulf of Mexico coasts of the USA (Clark 1992).

Both estuaries and lagoons maintain exceptionally high levels of biological productivity being greater than either the marine (offshore) or freshwater systems. The key to its productivity are: 1) the existence of a fresh and marine water "sink" providing nutrients, organic material and oxygen; 2) high solar energy input resulting from the usual shallowness of the estuarine waters; and 3) the high mixing rates which assist gaseous exchange, nutrient circulation and waste disposal.

Estuaries and lagoons also play important ecological roles including: 1) "exporting" nutrients and organic materials to outside waters throughout tidal circulation; 2) providing habitat for a number of commercially or recreationally valuable fish species; and 3) serving the needs of migratory nearshore and oceanic species which require shallow, protected habitats for breeding and/or sanctuary for their young (nursery areas). Recent work on estimating the global value of ecosystem services of various resource systems suggested that estuaries, with an estimated area (global) of 180 million hectares, are valued at US$22,000 ha^{-1} $year^{-1}$. (Costanza et al. 1997) Their functions in nutrient cycling as well as food production are the most important ecosystem services this system provides.

Estuary and lagoon ecosystems play a role in the life cycles of economically important finfish and shellfish species by providing feeding, breeding, and nursery habitat. For example, over 90% of all fish caught in the Gulf of Mexico are reported to be estuary dependent to some degree (Clark 1992). The Gulf of Thailand, which is characterized by a two-layer shallow estuary with lower salinity surface water, has a primary productivity of 2.49 $gC\ m^{-2}day^{-1}$. In 1992, catches from the Gulf of Thailand contributed 75% (1.9 million mt) of the total marine catches of the country.

Because of their sheltered nature, estuaries and lagoons have been highly valued as sites for ports and harbors, and the subsequent siting for industry and residential development. They have also wrongly been regarded as ideal dumping grounds for domestic and industrial wastes. Lagoons and estuaries are also favored as sites for recreation (tourism activities). Fisheries, shell fisheries and mariculture are frequently based on these resource systems. In Thailand, coastal aquaculture contributed to about 3% (62,155 mt) of the total marine catch in 1985. This production came from shrimp (40.8 thousand ha), molluscs (3.4 thousand ha) and fish (107.7 thousand ha) culture activities. In 1994, marine aquaculture produced about 3.9 million mt, of this shrimps and prawns contributed to 909 thousand mt while abalone, oysters, scallops and clams collectively accounted for 2.7 million mt.

Estuaries and lagoons are largely common property and normally have open access.

Mangrove areas

Mangroves are holophytic (salt-tolerant), seed-bearing, woody plants of which there are more than 50 species present in Asia. They thrive along sheltered intertidal coastlines on soft saline sediments that are often anaerobic and sometimes acidic. Some 24 million hectares of mangrove forests occur in coastal areas of subtropical and tropical areas of the world. Mangrove forest help control flooding, preserve water quality, and protect shorelines from storms and erosions. They are essential support system for tropical marine life providing nursery and breeding ground for finfish and crustaceans, and vital habitat for other organisms. The global value of ecosystem services provided by mangroves is suggested to total US$ 9,990 ha^{-1} $year^{-1}$. (Costanza et al. 1997). Of this, 85% is attributed to their functions in waste treatment and disturbance regulation.

A prominent feature is the production of leaf litter and detrital matter which is exported to lagoons and nearshore coastal environments. The organic matter exported from the mangrove habitat is utilized in one form or another by the inhabitants of estuaries/lagoons, seagrasses, coral reefs and nearshore waters which may occur in the area. Most tropical commercial shrimps and

fish species are supported by this food source. Over 30% of the fisheries of Peninsular Malaysia (about 200,000 mt) are reported to have some association with the mangrove system. Mangrove forest in Peninsular Malaysia is estimated at 103,000 ha. However, the threat to Malaysia's mangrove lies in land conversion or deforestation for agriculture, industry and aquaculture. The mangroves in the Philippines have declined from 450,000 ha in the 1920s to only 140,000 ha by the mid-1980s. Sixty percent of this decrease was due to conversion of the coastal land into fishponds for milkfish and shrimp. Mangrove forests are largely the property of the national government. In some cases, areas are leased to private individuals/corporations for fishpond development.

Government policy and regulation

- Planning for use and management of the resources involves several government agencies. Lack of coordination among these institutions often results in formulation of conflicting policies for conservation and development.
- Fishing licenses are secured from fisheries agencies at the national or subnational level. In some countries such as in the Philippines, fishing licenses for small-scale fishers can be secured at the local government due to devolution of authority to local level.
- Leasing of mangrove areas for aquaculture development is given by the national agency, however, some countries have stopped giving fishpond lease agreements due to negative impacts of mangrove conversion to other uses.
- Most countries have strict laws on environmental protection and management, however, compliance on waste water quality is sometimes a problem.
- There are traditional rights over the use of lagoon systems and sea bed resources in Pacific island countries.

Resource system SWOT

Strengths

- Apart from fisheries, these coastal water bodies sustain human settlements and support a multitude of uses including mariculture, waste disposal, shipping, recreation and residential development.
- Open access areas are used by poor people and, thus, there are strong equity implications to resource use.
- Maintain exceptionally high levels of biological productivity and biodiversity, and play important ecological roles.
- Ability of the estuarine system to efficiently utilize nutrients and with relatively good absorptive capacity for pollutants
- Provide sheltered environments for the development of marine aquaculture of many high value invertebrate and finfish species

Weaknesses

- Lack of coordination among agencies concerned in the planning and management of the resources. In most cases, appropriate policies and institutions are present, however, strict implementation of policies is a problem.
- The resource system is subjected to upstream impacts (e.g., siltation and sedimentation) and pollution (waste water) from lowlands
- Inadequacy of information and research inputs to the complex decision-making process that constitutes coastal management.
- Fisheries statistics (for production, species and value) need further refinement and major improvements are required on collection of data especially from artisanal use.

Opportunities

- The complexity of the problems can best be addressed through an integrated coastal fisheries management (ICFM) or integrated coastal management (ICM) approach to attain proper coordination of actions among agencies involved in resource management
- Develop indicators for management of various sectoral activities and evaluation of the environmental carrying capacity of the resource system.
- Develop/establish viable systems of rights and regulated access to limit entry into coastal fisheries (i.e., improvement of licensing schemes, gear/area/temporal restrictions).

- Development of coastal aquaculture technologies which are economically feasible, environment-friendly and which are sufficiently simple as to aid adoption.

Threats

- The multisectoral use of the system has created a variety of environmental impacts and severe losses (short- and long-term) of estuarine and lagoonal natural resources.
- Major source of degradation of shallow embayments (i.e., estuaries) is their continued use as pollutant discharge areas (both domestic and industrial waste water). Pollution has also become a pressing problem caused by coastal aquaculture development (as a result of intensive activities).
- High levels of fishing effort on coastal fish stocks particularly in nearshore fishing grounds. Conflicts between large- and small-scale fisheries are also a major concern. Collection of fish/shrimp seeds to sustain aquaculture production is becoming a biodiversity and resource threat in many areas

Research issues, trends, prospects

Issues

- Lack of institutional coordination and integrated policies/actions emanating from sectoral management approach
- High levels of fishing effort and overfishing on coastal fish stocks, particularly in nearshore (mostly estuarine) traditional fishing grounds. This has resulted in a leveling-off (if not decline) in landings; reduced catch rates, incomes and rents; and intense competition and conflict among fishers
- Increase in aquaculture/mariculture activities to maintain current fish production or sustain current demand for fish. In the past, mangrove areas have been converted for use in shrimp/fish pond culture.
- Increased stress on coastal environments (i.e., estuaries, lagoons and mangroves) due to fishing and other economic activities. Degradation of shallow embayments (i.e., estuaries) due to pollution from both domestic and industrial waste water. Pollution also poses problems for coastal aquaculture
- In most situations, there is inadequacy of information and research inputs to decision-making process in coastal zone management. The appropriateness of the scope, elements, timeliness and accuracy has been questioned
- Improvements in fisheries statistics and databases to make real-time management of coastal fisheries feasible
- Inadequacies in the policy and legal framework; limited personnel and technical capabilities; shortage of resources/funding; inadequate or overlapping mandates and functions; and lack of institutional collaboration/coordination
- Constraints in technical development of aquaculture technologies (i.e., limitations of seed production, high cost of artificial feeds, problems in technology transfer)

Research needs and opportunities

Pilot/case studies comparative work and training in the area of integrated coastal fisheries management in situations where fisheries is the main activity in the resource system. Further work in ICZM for situations where intense multisectoral activities bear on the resource system. Based on a recently concluded meeting at ICLARM (Workshop on New Directions for Integrated Coastal Zone Management Research), the research topics identified as important and relevant as research initiatives for ICLARM were (most important to the least important):

- Legal and institutional analysis of ICZM
- Determination of criteria and indicators for change in habitat and biodiversity
- Economic evaluation of natural resources
- Development of a framework for ICZM research
- Limits of sustainable use due to the high pressure on resources

- Quantification and impact analysis of erosion and sedimentation on the coastal resources and environment
- Analysis of equitable use of and access to natural resources with regard to legal framework
- Rehabilitation of degraded coastal habitat and fisheries
- Aquaculture focused on food security
- Fishers mobility and relocation due to degradation of coastal habitat and fisheries
- Environmental impact studies

Core research disciplines

- Ecosystem analysis/modeling
- Fisheries and marine ecology/biology
- Aquaculture and stock enhancement technology
- Policy and institutional analysis
- Resource and ecological economics
- Marine and pollution chemistry
- Physical oceanography
- Soils research

Trends and prospects

- The total international effort devoted to research for this resource system would be substantial if integrated projects matched rhetoric. There are many new international projects on ICZM including many players, though difficult to generate frameworks and extract general results. Said to be new focus of IADB program for Latin America.
- Sophisticated marine aquaculture technology from Japan, North America, France, etc.
- UNDP Train-Sea-Coast training methods; French research in West African Lagoon system, etc.
- Publication record and trends: FAO, ICLARM, Japan, France, many others on component research
- ICLARM resources devoted to the resource system:
  - Modeling of multispecies fisheries—the coastal fisheries management project in Asia
  - Tropical fish stock assessment and earlier long term studies of San Miguel Bay
  - Programs of the CAC focused on coastal aquaculture and stock enhancement, and new initiatives in ICZM
  - Ecological economics for sustainable use of aquatic resources—legal and institutional analysis of coastal resources; co-management; institutional capacity building for community-based fisheries management in Bangladesh
  - Impact of aquatic resources research: methods and assessment
  - Impact of giant clam productivity enhancement research
  - Policy analysis of the contribution of fisheries to food security
  - Coastal management training program in the Philippines

Ex-ante cost benefit analyses

ICLARM's work on the benefits of aquaculture research just starting

Spillover to other resource systems

Coral reefs, soft-bottom and upwelling shelves are part of the continuum of coastal areas. Management and conservation of estuaries/lagoons and mangroves would perhaps have spillover effects in these adjacent resource systems. The integrated approach noted for the floodplains areas is similar to that required in the coastal zone, with a large number of nonfisheries users.

Threats from other water or land use priorities

Siltation and pollution of coastal waters from land-based activities (e.g., logging, agricultural, industrial) intensification of economic activities (i.e., industries, ports and harbors, urban and tourism development) which would create a variety of environmental impacts and severe losses in coastal resources.

ICLARM role and position

There are many international research providers to the resource system including many ASIs and international organizations. ICLARM has major role, however, in strategic research areas involving fisheries. ICLARM has links to South and South Eastn nations for coastal fisheries and co-management and, for aquaculture, to Solomon Islands and other Pacific Islands.

The major customers for any ICLARM work in this resource system would be multiple from

the Development banks through a range of coastal issues including fishers and fishing cooperative.

ICLARM has major role, however, in provision of strategic research results involving fisheries to fisheries agencies and management consortia.

ICFM and ICZM is a field with many players. In aquaculture many players wish to collaborate with activities of CAC (Australia, New Zealand, Canada, etc.)

ICLARM's strengths and weaknesses in relation to this system

Strengths

- Ability to apply methods/software developed at ICLARM for coastal fisheries management
- Track record in multidisciplinary and multisectoral ICFM approach (e.g., San Miguel Bay)
- Strong linkages with partner institutes in Asia and South Pacific, e.g., Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand, Vietnam, Solomon Islands
- Ability to develop resource information database for use in coastal fisheries resource management
- Catalytic role in the introduction of the integrated coastal zone management concept and case studies through the ASEAN-US Coastal Resources Management (1986-1992)
- Specialist knowledge in coastal aquaculture for developing countries

Weaknesses

- Recent lack of lead person/scientist required to undertake coastal zone management work
- Competition for staff time with other integrated and disciplinary approaches

Additional references

Clark. 1992. Integrated management of coastal zones. FAO Fish. Tech. Pap. 327, 167 p. FAO, Rome.

Costanza, R., R. d'Arge, R. de Groot, S. Faber, M. Grasso, B. Hannon, K. Limbrug, S. Naeem, R.V. O'Neill, J. Paruelo, R. Raskin, P. Sutton and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Pauly, D. and V. Christensen. 1995. Primary production required to sustain global fisheries. Nature 374:255-257.

Coastal waters (including estuaries and lagoons)

contents

Potential benefits

The physical extent of the resource system cannot be enlarged but intensification of use of coastal zone and its fisheries is likely. Maintaining productivity and diversity in the face of population and multisectoral development pressures will be a challenge. If water quality problems and challenge from land-based activities can be avoided, mariculture can benefit from increasing biological research and technological sophistication. However, effective management in the coastal zone rests on social, institutional and legal issues and cooperation. Useful products would therefore be frameworks for conceptualizing research problem hierarchies or identifying key individual biophysical constraints for further research. The former would be difficult to relate to specific impacts whereas the second might have major benefits more locally (e.g., areas having estuarine mangrove forests, shrimp pond aquaculture, etc.). Key research beneficiaries are likely to be NARS, NGOs and development agencies/banks in Asia and the Pacific where ICLARM has most contacts.

Ability to utilize

As mentioned, conceptual frameworks for research may well aim at development agencies, ASIs, etc., but develop little tangible attributable impact. ICLARM's work on San Miguel Bay is widely quoted and provided an action plan of continuing local relevance but with unknown spillover effects. The Philippines is very interested in coastal zone management and co-management issues, most developing countries have interest in bay/inshore fisheries and many coastal and island states wish to develop aquaculture to offset stagnation in capture fisheries and protect threatened biodiversity. Indeed, frameworks for coastal management are most likely to succeed in countries having devolved governance regimes. The outputs could be various, from problem identification, economic valuation of resources and alternative use, rehabilitation strategies to appropriate mariculture technologies for developing countries.

Science potential

ICLARM has a substantial track record in the area of integrated coastal fisheries management (ICFM). Further work on the ICFM framework, case and comparative studies, and training approaches/methods hold considerable potential. ICZM is a burgeoning field, but more training in methods and approaches is needed until developing countries can conduct a sufficient number of the specialties and synthesis to run national program. Scientific awareness of coastal zone degradation and threats. Good land based and ocean based research capabilities but few institutes capitalizing on bringing issues together to analyze effects on marine environment. Intensive mariculture a success in some developed nations, and with growth potential and support for future development in developing countries in the Indo-Pacific.

R&A capacity

- Ability to apply methods/software developed at ICLARM for coastal fisheries management and track record in ICFM
- Strong linkages with partner institutes in Asia and South Pacific, e.g., Bangladesh, Brunei Darussalam, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand, Vietnam and Solomon Islands
- Ability to develop resource information database for use in coastal fisheries resource management
- Have had catalytic role in the introduction of the integrated coastal zone management concept and case-studies through the ASEAN-US Coastal Resources Management (1986-1992)
- Lead role in marine aquaculture for developing countries
- Lack of lead person/scientist required to undertake coastal zone management work
- Little current biophysical work directly focused on problems of bays, lagoons or estuaries
- Staff numbers to commit to a large range of activities too small to make a difference without reorganizing research effort
- CAC well placed to expand focus from mariculture to more general influences of CZM on the coastal aquatic activities with relevance to Pacific Island states, some parts of SE Asia and the Caribbean
- Brackishwater aquaculture, relevant to the lagoons of West Africa and elsewhere is not yet being attempted or targeted, although genetic improvement research is appropriate to this system

Resource system 5: Coral reefs

Description

Coral reef ecosystems dominate tropical seas, except in upwelling zones and areas which receive heavy freshwater inputs. Defined as encompassing those areas within the euphotic (sunlit) zone, in which reef-building corals are able to colonize solid surfaces on stable sediments. The reef crests are the most prominent part of a coral reef system but in terms of the resources 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 sheltered waters created by the reef systems, combined with the high productivity of the coral reefs, has been an inducement to human settlement. But high population densities in developing countries are now leading to overexploitation and degradation of the reef systems in many areas and consequently threatening the productive base on which many of the communities were founded.

The productivity of coral reef systems is extraordinarily high, by virtue of the symbiosis which exists between symbiotic dinoflagellate algae (zooxanthellae) and reef-building corals. This is further enhanced by the nitrogen-fixing abilities of many algae and even further enhanced 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. Populations of algae, invertebrates and fish may be largely "self-recruiting" on isolated coral atolls, but there is great connectivity among such populations within and among countries where distances between reefs are relatively small. 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.

Coral outcrops makes the use of trawls and most other modern industrial fishing gears infeasible. Coral reef systems are therefore the domain of the artisanal fisher, using a wide variety of small-scale fishing gears.

The global extent of this area has been earlier estimated to total about 620,000 km^2 but models under development based on likelihood give estimates of 1.6 to 2.6 million km^2.

Resource system analysis

Trends and forecast

The precise yields from coral reef systems are poorly known but the available information suggests that current global harvests of reef fish and invertebrates are about 4-6 million mt annually. Fish production from coral reefs is higher than from any other natural fish production system, with reported yields ranging to over 35 mt km^{-2} year^{-1}. An estimate of 8 mt km^{-2} year^{-1} has been suggested as the average potential for reef production. However, there is debate over the base area and the mean catch/area estimate, as well as over global catches and potential catches. Recent evidence indicates that at least in heavily exploited reefs of South East and the South Pacific, catches are much higher (8-37 mt 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.

There is considerable evidence that reef catches in many areas have declined substantially

with heavy fishing pressure and also as a result of degradation of reef systems.

Gross value of production

The value of production is unknown, and given the disparate economies of the countries involved, this is not a very meaningful statistic. However, if a nominal value of US$0.50/kg is assigned, gross value would be $2-3 billion.

Growth rate and forecasts

Static or declining in Indian Ocean, SE Asia, Caribbean and Eastern Pacific and near to major towns in South Pacific. Increasing in remote areas/islands of South Pacific in parallel with population increases. Disperate and sometimes niche markets for giant clams, trochus, green snail, pearl oyster, grouper, spiny lobster exist and could be differently developed.

Trade statistics

Live reef fish trade lucrative for exporters of aquarium/live food fish: annual volume of Asian trade in live food fish is 20-25,000 mt worth approximately $US 1 billion. The Philippines exported 6 milllion aquarium fish in 1996. Currently, many harvested by illegal, unsustainable means.

Number of producers/users

the number of people relying on coral reefs for food and livelihood may be estimated by assuming an average catch of 1 mt fisher^{-1}year^{-1}. If the global catch is 6 million mt, there must be about 6 million fishers and their families who are dependent upon the resources. Obviously, the lower catches of part-time and subsistence fishers is offset by the high catches that may still be obtained in some relatively pristine areas. However the extent of artisanal use is probably only poorly reflected at these higher levels of aggregation.

Resource system characteristics

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.

Government policy and regulation

In general, there is a lack of clear government policy pertaining to coral reef resource systems. Some countries have a limit on exports of reef species. Enforcement of existing regulations is seldom pursued. Thus fisheries in almost all developing countries are unregulated. The large number of species involved, the multiplicity of fishing gears and the widely dispersed landing sites make conventional management extremely difficult. There is little coordinated regulation of external factors (e.g., logging) which affect reefs.

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 systems of tenure, recent experience indicates that community-based management is possible, mainly by the creation of fishery reserves or marine protected areas.

International regulations such as CITES may have increasing effect on coral reef "industries" with time.

Resource system SWOT

Strengths

- Coral reefs occur in many countries of the Indo-Pacific and Caribbean.
- They are resilient due to great connectivity between reefs, i.e. if one part is damaged (e.g., by crown-of-thorns) then replenishment by corals, fish and invertebrates can occur within a decade due to pelagic dispersal of larvae. Reefs isolated by great distances from others are not in this category.
- Very high potential value per unit area. High potential equity of benefit distribution, low capital needed for entry /use of the resource system.
- Coral reefs provide a wide range of high-value export products, and subsistence food.

- Many scientists worldwide have a thorough knowledge of coral reef ecosystems.
- Coral reefs have a high profile with public. As a result, large areas are now in MPAs (e.g., GBR marine park).
- Exploitable natural resource for (relatively) non degrading functions like tourism

Weaknesses

- Subject to damage by storms, crown-of-thorns: Very susceptible to overfishing and nutrient overload (causing a shift from coral to fleshy algae).
- It is difficult to enforce management regulations for reefs in isolated areas.
- There is virtually no scope to increase the extent of the resource because it is limited to hard substrate in shallow, clear, warm seas.
- Many fisheries species associated with coral reefs are long-lived and slow-growing, and so have limited production and are vulnerable to over-exploitation.
- Desirable, valuable, old, fishes with high growth coefficients and large asymptotic sizes are progressively replaced by less desirable and less valuable fishes, with small maximum sizes at lower levels in the food chain.
- Even unfished stocks are likely to be below maximum productivity due to recruitment limitation.
- It is often difficult to market fresh products from coral reefs because countries are remote, have little infrastructure and are poorly serviced by airfreight/shipping.

Opportunities

- There are good indications that the productivity of heavily exploited coral reefs can be improved several times, particularly through the establishment of properly managed reserves or protected areas.
- Different systems of tenure, ownership or access to coral reef resources have evolved, 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.
- Networks of marine protected areas (fisheries reserves) can be used to protect spawning aggregations (sources and recruitment areas or sinks) to maintain productivity of important species
- Productivity of several species can be increased over "natural" levels by aquaculture and stock enhancement.
- Coastal communities can be educated to understand the function and connectivity of coral reefs to promote their wise use.
- Proper management could substantially improve quality of life of half a billion people.

Threats

- Coral reefs are relatively fragile ecosystems and are easily degraded by siltation, eutrophication, contamination by pollutants, physical damage and over-exploitation, all of which will have a negative effect on productivity.
- High fishing pressure (especially on reefs of the Caribbean, Indian Ocean and Indo-Pacific)
- Intensive exploitation has led to local extinctions or severe losses of genetic diversity, particularly of vulnerable or highly-valued species, such as groupers and snappers or giant clams.
- Destructive fishing methods such as explosives and poisons, are a severe problem in many areas.
- Reclamation projects/use of sand for construction
- Water pollution, siltation (runoff, industrial, agricultural)
- Rising water temperatures (coral bleaching)
- Excessive visitation by tourists (damage by divers, anchors etc)
- Coral disease epidemics
- MPAs are declared but not managed or fishing bans implemented.

contents

Research issues, trends, prospects

Issues

From an international perspective, the major threats to coral reef resource systems relate to overexploitation, sedimentation and eutrophication, resulting in degradation of the reef system, lowered production and loss of biodiversity. This is clearly documented. The solution to the last two items lies in the implementation of integrated coastal area management. If this is properly implemented, documenting resilience and recovery of the reefs is the chief task.

The fisheries in coral reef systems in most of the densely populated areas of South East and South Asia, East Africa and the Caribbean are, in general, yielding substantially less than their potential. This results from the absence of management systems and, more pertinently, the absence of well-validated bioeconomic models upon which management decisions can be based. It is also clearly established that where management systems are imposed by outside authority, their chances of success are minimal. In contrast, community-based systems, in which regulatory measures are imposed by coastal communities on their fellow fishers, have been shown to be effective in the South Pacific and Japan, where a variety of customary or community-based marine tenure systems have existed for many centuries. There are strong indications that many coastal communities would be willing to adopt systems which would empower them to manage "their" resources.

Overexploitation can be countered by effective management of the fishery, including the use of stock enhancement techniques and by the development of marine fishery reserves or marine protected areas.

Management of a fishery requires an understanding of the impacts of the fishery on ecosystem structure as a whole. For most fisheries the basic fishery parameters for the important species are little known and catch statistics are lacking. Recent developments of the Ecopath model have simplified data requirements to a large degree but the need remains for the development of cost-effective data acquisition systems. This will lead to the management of fisheries as an integral part of the ecosystem.

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 are making fisheries enhancement systems eminently feasible, but such developments must be accompanied by community-based management systems, failing which efforts in fisheries enhancement will simply be negated by overfishing of the enhanced stocks.

There is increasing attention to the need to project the effects of increases in sea level and water temperatures on coral reefs and dependent people. The impact of increased runoff from catchments (due to logging or other changes in land use) on coral reefs should be determined, including investigation of the nature of the multi-disease epidemic affecting many Caribbean reefs and how soon and in what ways will it affect the Indo-Pacific.

Research needs and opportunities (*current activity)

- Large-scale studies of trophic relationships on coral reefs in Pacific and Indian Oceans and in the Caribbean
- Development of data acquisition systems which deliver data upon which management decisions can be based and which do not require intensive deployment of highly skilled staff and large expenditures by national fishery agencies
- Studies of the feasibility of increasing sustainable yields from coral reef systems by the cultivation of desirable species or by enhancing natural recruitment by the release of hatchery-reared juveniles
- Development of collection systems for pelagic larvae, probably using light traps or crest nets, as an alternative to cultivation of larvae in hatcheries

- Determination of replenishment rates and effects of fishing on mariculture on biodiversity and genetic structure
- Genetic improvement of successful species where the biotechnical aspects of aquaculture have been shown to be economically feasible.
- Combination of biotechnical work and bioeconomic modelling with social, cultural and legal aspects for successful development of viable farming systems for coral reef species.
- Development of ReefBase, for storing all available quantitative and categorical information on coral reefs. This would provide the basis for addressing questions such as:
  - Where are the reefs? How much area do they cover? What is their value to people? How much destruction is occurring at what rates, how and where? What constitutes a healthy reef (from several approaches including ecosystem, community, complexity theory/dynamics, indicator species, biogeochemical, pathological)? How does this vary under different environmental conditions?
  - What are sustainable levels of wild harvests? What is the connectivity between coral reefs in different nations within one biogeographic area? What are the effects of reef changes downstream on reefs and their management upstream?
- Management practices to ensure reef health and sustainable use
- What approaches to MPA development should be recommended in various situations and what benefits can be expected?
- Development of FishBase, for storing and compiling data on the ecology, population dynamics and reproduction of the world's fishes.
- Further development of ECOPATH ver. 4, with EcoSim and EcoSpace, which will enable a series of steady-state trophic models of coral reefs to be elaborated. This will lead to an understanding of biomass and energy flows in various types of coral reefs, including the results of supplementing natural recruitment by the release of hatchery-reared juveniles.
- Research on the practicality and effectiveness of marine fishery reserves, of various sizes and in various locations, 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. *
- Improving resource management through the development of data acquisition systems, bioeconomic models and community-based management systems
- Bioeconomic modelling of reef resources 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 various gears on all exploited species and on their food base and the evaluation of management options, including the use and valuation 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.
- 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 is 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. Identification of tools and training methods for optimal management.

Core disciplines relevant to this resource system

- Reef ecology/trophic functioning/population genetics/invertebrate pathology/taxonomy
- Mapping GIS/modelling, physical sciences
- Stock assessment
- Aquacultural techniques for stock enhancement
- Economics (including resource economics)
- Quantitative anthropology (legal analysis)
- Integrated coastal zone management

Trends and prospects

- Total international effort devoted to research for this resource system very large, but diffuse

- Publication record and trends: increasing interest and publications, particularly in MPAs and in the "sustainability" of reef fisheries
- ICLARM resources devoted to the resource system: Coastal Aquaculture Center, ReefBase, parts of FishBase, Caribbean projects
- Ex ante cost benefit analyses (where available) Some analyses of mariculture and economic evaluation of reefs just starting
- Spillover to other resource systems, fisheries techniques, shelf fisheries, other community-based studies, biodiversity conservation
- Threats from other water or land use priorities, multiple threats from sedimentation and pollution from land
- Apparent threats enhanced by temporary or more permanent thermal/climactic alterations

ICLARM role and position

- Major research providers to the resource system: ACIAR, Netherlands, DfID, IDB
- Number of collaborative arrangements:
  - CAC: donors, Solomon Islands, SPC, other countries of Asia/Pacific, AIMS, James Cook University, etc.
  - Caribbean: Two Memoranda of Agreement with states of the region
  - ReefBase: Formal: WCMC, WRI, URI, GCRMN, Netherlands (informal hundreds)
  - PISCES: Indonesia, Malaysia, Taiwan, Vietnam (ICLARM Solomons)
  - MPA activity: Formal: Netherlands Coastal Management Center
  - Coastal training: Formal: IIRR, Haribon, PCAMRRD, DENR, DA, local governments
  - Major customers: beneficiaries: coastal dwellers around the world
  - Clients: researchers, managers, NGOs and GOs, students, divers, writers and conservationists
  - Major customers for ICLARMs work: Fisheries departments, NGOs and conservation agencies, universities and colleges, coastal dwellers in coral reef areas
  - Major competitors (other suppliers): AIMS, USA, France and other European universities

ICLARM's strengths and weaknesses in relation to this system

Strengths

CAC is recognized as one of the major aquaculture research facilities in coral reefs, ReefBase, past record and reputation, field bases in Asia, Pacific and the Caribbean.

Weaknesses

Minimal number of field projects (two in the Caribbean, none elsewhere) dealing with exploitation and management. Insufficient staff, limited number of senior staff to supervise projects, lack of funding for major projects.

Additional references

Barber, C.V. and V.R. Pratt. 1997. Sullied seas: strategies for combating cyanide fishing in South East Asia and beyond. World Resources Institute and International Marine Life Alliance. 57 p.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. Reefs at risk: a map-based indicator of threats to the world's coral reefs. World Resources Institute, ICLARM, World Conservation Monitoring Center and UNEP. 52 p.

Coral reefs

contents

Potential benefits

Over the next decade, research should be undertaken which can be expected to lead to the following:

- Verification of the magnitude of harvests which potentially can be taken 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 fishery reserves or protected areas and 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 utilisation and valuation and consequently improved bioeconomic models of exploited coral reef resource systems and direct benefits to low income users.
- Improvement in management methods for capture fisheries, including enhanced fisheries, as a result of the development of community-based management of coral reef resource systems, leading to substantial increases in harvests from these systems.
- Increased harvests of around 2 million t 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.

Major beneficiaries will be countries which depend on reef resources, such as the SIDS of the Caribbean and Indo-Pacific. East Africa and South East Asian countries will expect to have high spillover effects. Some outputs can be used to shape political awareness and appropriate action for protection of the environment by regional bodies and global NGOs. Many of the outputs are geared to fisheries and coastal managers but populations dependent for their livelihood on coral reefs will benefit directly.

Ability to utilize

- Past performance: Rapid adoption of advances by ASIs. Less so by LDC NARS.
- Strength of national systems: Little improvement in past twenty years and declines in many cases. NGOs have interest in MPAs but need scientific advice.
- Impediments and inducements to uptake: Poor career structure in many NARs, political interference, lack of management schemes and legal enforcement.
- Nature of outputs: Scientific knowledge, culture technologies, management technologies, policy advice on management, data available through electronic, globally accessible data bases. Restoration of fish and invertebrate biomass and harvests in managed areas.

Science potential

- Rate of change in relevant fields: Rapid especially in assessment methodologies, capture and culture methods and integrated resource system approaches.
- Prospects for scientific advances: Excellent. Appropriate partnerships between local government, international agencies, scientists and users could bring full range of scientific disciplines and deployment methods to bear for better management.

R&A capacity

ICLARM's international standing:

- Collaborative teams: Cross-institute expertise but geographically remote. Local sets of collaborators in the SIDS in which projects formulated.
- Share of expenditure: Unknown, ICLARM spent approximately $1.3 million on coral reef research in 1997 (including data base, coastal aquaculture and field research).
- Significant advantages and gaps in skills: Few advantages compared with ASIs, but CAC is a recognized center for conduct of activities geared to developing countries and ICLARM has staff with broad experience of reef areas globally. Coastal zone management issues high profile in the Philippines. Need to develop skills/experience in resource economics.
- Quality of infrastructure and support: Poor infrastructure, except CAC. Technical/scientific levels high throughout ICLARM, less sophisticated in centers of operation.

Resource system 6: Soft-bottom shelves

Description

Soft-bottom shelves 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

contents

Resource system analysis

Trends and forecast

Gross value of production

The analysis by resource system estimates that approximately 24.4 million mt was produced from soft-bottom shelves in developing countries in 1996. The catch is highly diverse covering 21 ISSCAP groups.

Growth rate and forecasts

The shelf area of Asian developing countries excluding China approximates 4.6 million km^2. All marine catches in Asia (the bulk from these shelf areas) contributed 13.3 million t and US$ 9 billion of fisheries exports. However, in Asia, several major fishing grounds (Manila Bay, Gulf of Thailand, and the Java Sea) are heavily fished with the abundance of stocks as low as 10-15% of unexploited levels. Coastal fisheries employed roughly 8 million fishers in India.

Resource system characteristics

The coastal shelves represent an extremely diverse system with large numbers of species ranging from very small to extremely large. Most of the soft-bottom shelves are trawlable and hence most species accessible to fishing gear. Without refuges being readily available, there is a massive change in resource system structure caused by fishing, and globally marine catches are unlikely to recover substantially without reduction in fishing pressure.

Presently the shelves support major valuable fisheries, including for shrimps, which causes a major discarding problem of unwanted species.

Government policy and regulation

Regulation has placed emphasis on avoiding conflict and keeping trawlers away from the coast, i.e., preventing overlap of near-shore small-scale fishery with offshore industrial trawl fishing. Research generally leading to mesh size regulations with strong difficulties in enforcement.

Trawl industry tends to benefit from government support to detriment of small-scale fishing even though these provide work and income for otherwise poor families.

Resource system SWOT

Strengths

Well studied. Provides large proportion of fish catch and protein in diet for coastal developing countries. Substantial employment for coastal dwellers and their families (e.g., Ghana, marine catch is 85 percent of total fisheries production of nearly 477,173 mt. Fish provides 60% of animal protein in diet. There are an estimated 130,000 artisanal fishers in an industry of 580,000 people).

Weaknesses

Gross catch levels appear to be sustained over time but masking massive underlying change in species composition and ecosystem degradation. Enforcement of regulatory instruments difficult. Catches stagnant or declining. Few areas which can be further exploited. Trawls and species-

specific fishing (e.g., for shrimp) affects juveniles/populations of other commercial species and mitigates against recovery of the general resource.

Opportunities

Move from single-species based approaches to interest in ecosystems. Develop ecosystem-based management before overfishing degrades parts of resource system irrevocably.

Threats

Continued overfishing; coastal fisheries not integrated into coastal zone management and suffer from poor land use. Development of trawling and increase in small-scale fishery leads to depletion of larger species in exploited systems and massive change in species composition.

Research issues, trends, prospects

Issues

- Local populations of large predatory fish are driven to extinction. This process can be halted only by marine protected areas whose locations, size and implementation are now major research issues.
- Development of appropriate fisheries management reference points.
- Political conflict between industrial and artisanal fishers over access and exploitation. Need to maintain and enhance coordination of regional fisheries. Many other management issues affecting these fisheries relate to legislation and national and international enforcement, not so much to research.
- Socioeconomic analysis of the effects of declining catches and competition (displacement of artisanal fishers).
- Need to identify and develop policy for economic use of by catch.

Research needs and opportunities

- The development of minimum data sets effective for fisheries management.
- Development of ecosystem approaches to management of coastal fisheries and interacting systems.
- Major need for research is to develop generic approaches for studying the local size, impacts of marine protected areas and fit this component into actual communities to generate acceptance of marine protected areas.
- Dovetail fisheries management on shelves to coastal zone management including alternative livelihoods.

Core disciplines relevant to this resource system

Modelling, stock enhancement/assessment; socioeconomic and anthropological studies on impact of marine protected areas on fishers and coastal communities.

Trends and prospects

Total international effort devoted to research for this resource system. Most nations have relatively good knowledge of their own coastal fisheries and extensive trawl data. Less effective analysis and translation into effective management.

Publication record and trends

Most studies in growth/mortality are devoted to mesh size regulations.

ICLARM resources devoted to the resource system (*ex ante* cost benefit analyses)

Trawl base project; Ecopath modelling, about one-third of Fishbase is relevant here.

Spillover to other resource systems

Fisheries biology and ecosystem management methods widely applicable largely due to similarity of growth mortality patterns and of methods to study them. Integral activity in coastal zone management.

Threats from other water or land use priorities
The coastal systems interact with and are affected by mangrove, coral reef, sea grass and coastal ecosystem degradation; removal of lagoons, etc.

ICLARM role and position

- Major research providers are scientists working with the resource system in NARS of countries with large shelves
- Number of collaborative arrangements—memoranda with ADB and collaborating countries in South and South East Asia; memoranda with fisheries centers and FishBase collaborating institutes
- Major customers for ICLARM's work are NARS Fisheries Management Institutes
- Major competitors are institutes in developed countries like USA and Australia

ICLARM's strengths and weaknesses in relation to this system

- Traditionally strong, given location and previous connections with NARS and South East Asia. Stock assessment methods developed for tropical assemblages, continuing focus on data collection and analysis methods.

Additional reference

Silvestre, G and D. Pauly, Editors. 1997. Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, 208 p.

EVALUATION DATA

Soft-bottom shelves

contents

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Potential benefits

Soft bottomed shelves provide approximately 30% of total marine catch in developing countries. Relatively few areas of the world are left for exploitation, most are over exploited. Total catch is largely stagnant although monetary value may continue to appreciate. Remains important food and livelihood reserve for millions of people in developing countries but resource degradation and structural alteration threaten current return. Political conflict and displacement of coastal fishers are issues only partly resolvable by research. With regional cooperation and legal enforcement, the implementation of nationally important marine protected areas may serve to sustain and/or increase catch levels. Benefits would depend upon the access and distribution of benefits accorded to fishers in national waters. Benefits may be shared by governments, industrial and artisanal fishers.

Ability to utilize

There will be a need to develop capacity and devolve authority for stock assessment and management (at least for inshore waters) to coastal management groups. This is part under way in Asia, and is governed by some traditional tenure rights in the Pacific. Provision of alternative livelihood opportunities may be required to reduce fishing pressure so that the larger community can be trained to manage the resource. Outputs include knowledge of stock dynamics in response to fishing, management guidelines, identification of effects of coastal use on resource health/sustainability. Economic evaluation of resource in relation to food markets. Scientific knowledge of resources and management options can be readily absorbed through capacity building exercises. However, implementation requires cooperative political support.

Science potential

There is much general and specific knowledge of coastal fisheries. Need to treat resources within whole ecosystem and investigate the appropriate use of marine protected areas (MPAs) and coastal zone management or resource exploitation. Technologies to conduct research to hand but require government/community based implementation. Basic strategies to conduct research on large MPAs needed. Socio-economic research should be applied to means for implementation of management.

R&A capacity

ICLARM is well respected in the stock assessment field. The ADB project will provide clear knowledge of stock dynamics and fishing management recommendations for the coastal fisheries of Asian countries. ICLARM has current projects in coastal fisheries, co-management and marine protected areas. Need to match technology with development of legal instruments/government negotiations and agreements to test implementation.

Resource system 7: Upwelling shelves

Description

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.

contents

Resource system analysis

Trends and forecast

Gross value of production

Estimated to be 30.8 million mt in 1996 or 42% of total developing country marine catch

Growth rate and forecasts

Unlikely to grow substantially—although value may appreciate with shortfall from other means of supply. Can suffer larger interseasonal or other periodic variation due to fishing pressure, El Niño oscillations and unknown influences on decadal time frame.

Trade statistics

Upwelling catches dominate the output in marine catch statistics by region: in 1994 Chile and Peru together caught 19.3 million mt for a total value of US$ 41.6 billion against a country average for Latin American countries of 1.13 million mt and US$ 2.4 billion. The combined output dropped to 16.2 million mt in 1996. For Namibia and Angola, total combined fish production in 1994 was 378,500 mt of which the exported portion was worth US$ 102 million, whereas the average value of fisheries exports from Sub-Saharan African countries was just US$7.9 million. In 1996, the combined total was slightly less at 340,750 mt but the export value was still US$104 million.

Number of producers/users

Substantially exploited by industrial fishers. The system is used to produce human food and inputs into livestock and marine aquaculture feeds.

Resource system characteristics

Highly productive systems, primary productivity estimated at 973 gC m^{-2} $year^{-1}$ and catch at 22.2 gC m^{-2} $year^{-1}$ (compared with values for other tropical shelves of 103, and 0.01). However, production is vary variable and limited in space (0.8 million km^{-2}).

Biodiversity is low, the system is dominated by schooling species such as anchovies and sardines which can oscillate as the preponderant species according to fishing pressure and time. Mackerel, horse mackerel, bonito and hake are predators and can themselves provide large biomass (suggested to be 1.6-2.0 million mt of horse mackerel in the Peruvian upwelling in the early 1980s).

Government policy and regulation

Except for US (California), there is no effective regulation; it is "catch as catch can" and there is little translation of research into management. An overriding research problem to be resolved, that of predicting recruitment of the key species, maybe intractable.

The fisheries are highly industrialized, with products providing a substantial export trade. A proportion is turned into fish meal and is of

little benefit to the producing countries (except for US).

Resource system SWOT

Strengths

Highly productive producing large quantities of fish protein/oil for human and animal (including aquaculture) food/feeds. Contribute to fish catches and protein source in poorer countries, especially of West Africa (Angola, Namibia; Ghana, Cote d'Ivoire, Cameroon, Senegal and Nigeria).

Weaknesses

Impossible to modify this naturally variable resource system. Subject to collapse through exploitative policy and fishing pressure. Size of systems paradoxically likely to increase due to global warming but subject to increased occurrence of disruptive events due to El Niño, etc.

Opportunities

Increase percentage of catch to be converted for human use by protein substitution techniques for animal feed.

Threat

Unregulated overfishing

Research issues, trends, prospects

Issues

There is a need to implement policies to regulate over fishing. There is insufficient understanding of interacting biological and physical processes to predict stock dynamics. Research to reduce use of fish meat for aquaculture (and other livestock feeding systems) and provide competition for fish meal use with soybean and other vegetable protein derivatives. Global warming is a threat to the system and, conversely, the system may provide indication of such events.

Research needs and opportunities

- More refined data on reproductive biology and modelling of the effects of temperature oscillation on biophysical processes
- Fish technology research to enhance use of fish for human consumption

Core discipline relevant to this resource system

- Fisheries science, ecology, biological oceanography and fish technology

Trends and prospects

Total international effort devoted to research for this resource system is high, mainly from South Africa, USA and European Union. Very high investment in boats and gears from local and licensed fishing nations.

Publication record and trends

ICLARM resources devoted to the resource system were considerable in mid to late 80s; presently low.

- Numerous publications worldwide but tending to tackle species-specific problems rather than ecosystem dynamics
- Biophysical modelling may receive boost from renewed interest and analysis of El Niño/climate change

Ex ante cost-benefit analyses (where available)

Done for the Peruvian system. Suggested net benefit of approximately US$ 173 million per year from a total catch of 3.5 million mt. Annual returns of US$371 million were estimated,but fleet costs are approximately US$ 200 million (Aguerro, using 1982 prices).

Spillover to other resource systems

- Population effects interact with other shelf areas
- Global effects on markets, use of fish products, aquaculture feeds industry.

Threats from other water or land use priorities

None except for the impact of global warming

ICLARM role and position

- Major research providers to the resource system
- Number of collaborative arrangements—memoranda : Contacts with fisheries scientists, few active contacts to the scientists working in the system except through ecopath users.
- Major customers for ICLARM'S work: fisheries scientists
- Alternative suppliers: Countries with direct interest in exploitation

ICLARM's strengths and weaknesses in relation to this system

Strengths

- Earlier detailed biological/mathematical evaluation of productivity of the Peruvian ecosystem;
- Ecopath, general fisheries market economics in relation to world food model

Weakness

No present involvement

Additional references

Durand M.H., P. Cury, R. Mendelssohn, C. Roy, A. Bakun and D. Pauly, Editors. 1998. Global versus local changes in upwelling systems. ORSTOM, France.

Pauly D. and V. Christensen. 1995. Primary production required to sustain global fisheries. Nature 374:255-257.

Upwelling shelves

contents

Potential benefits

The upwelling systems of the world are highly productive producing fish for export markets for human consumption, and feed inputs for livestock industry and aquaculture. Provide large incomes to adjacent centers and/or licensed exploiters. Needs heavy capitalization and difficult to alter efficiency or equity distribution of the products. Long term growth of marine culture industry of some carnivorous finfish may be affected by the continued erratic nature of the catch and/or by global warming. Relatively small ability to channel benefits of research results to ICLARM's target clients but can provide assistance to global fisheries science. Therefore, the provision of information on different aspects of upwellings and their catches to the global community may have benefit as an integrative function.

Ability to utilize

- Data intensive biophysical modelling may be needed to advance research further. Unclear whether research results could be utilized in current legal framework for exploitation of the resource. Upwelling systems benefit adjacent countries but benefit may not be widely shared.
- Economic evaluations of the role of the upwelling catches on fisheries market prices may have some *ex ante* value in determining exploitation in other systems.
- Efficiency of product use will be key to countries with established fish meal consuming industries. However, alternative products likely to be developed in/for developed countries.

Science potential

- Cooperative international efforts needed (probably with only partnership role for developing countries) in basic/strategic research (uncertain application). In the end there may be limited payoff for developing country applicability.
- Economic evaluation and food/feeds research do not have to be conducted directly on the resource system *per se*.

R&A capacity

ICLARM has past knowledge and fisheries and ecosystem modelling to offer to international efforts. Economic evaluation which can be undertaken as part of continent wide supply/demand analyses can be combined with global view of developing country fisheries and food security. Within this, FAO and others involved with marine aquaculture may address livestock/aquaculture feeds question on competition to human use.

Resource system 8: Open oceans

Description

This resource system is the residue of the offshore ocean systems after the resource systems inshore of land masses and/or not defined by other features such as upwelling systems are accounted for. By spatial area and volume this represents the majority of the world's oceans but, in fisheries and primary productivity terms, is the least productive of all systems. For example, the primary productivity and catch for the open oceans (in gC $m^{-2}year^{-1}$) has been estimated as 103 and 0.01 respectively, compared with values of 310 and 2.2 for tropical shelves.

The depth of the open oceans is from about 200 m deep (the nominal edge of continential shelves) to over 11.5 km deep in the deepest trenches (the Mariana trench between the Philippines and Japan).

The three major types of open ocean fisheries are: (i) surface and subsurface fisheries for large pelagic and highly migratory fish species such as the scombrids (tunas, marlins, large mackerels), (ii) demersal fisheries for fish, scampi and deepwater shrimps, and (iii) mid-water fisheries for smaller pelagics such as squid, jack mackerels, migratory salmons and species such as Alaskan pollock. Although almost finished, high seas whaling was also practiced in many parts of the open oceans until the international whaling moratorium of the 1980s.

Until recent decades, the open oceans were also thought to have the lowest biodiversity. However, exploration of the deep ocean floor, particularly around such features as undersea hydrothermal vents, deep ocean troughs and seamounts, have revealed a vast number of invertebrate species in many different phyla.

Although once thought to be the aquatic equivalent of a featureless desert, over the last 3 decades, detailed oceanography, geomorphology, biology and climate research, especially that aided by satellites, large, well-equipped ocean going (civilian and naval) research ships and submersibles which have almost plumbed the deepest parts of the oceans, have revealed not just the underlying structure of the earth's crust and its movements by plate tectonics, but also some of the complexities of ocean temperatures regimes, current systems, mass transfers, the ocean's role in climate and weather, the recent geologic history of the oceans and the biology of deepsea communities.

For surface and midwater species such as tunas and small pelagics, the depth and position of oceanic thermoclines are usually crucial to fish distributions and thus fishing patterns. Large-scale climate events such as the El Niño phenomena have major effects on the distribution and abundance of fish and the success of fishing.

Many developing countries have extensive open ocean areas under their control. For the countries located on major continents (Asia, Africa, South America), these vary in size and extent and may be limited by demarcation rules with neighbors. In some areas, such as the South China Sea, such demarcation arrangements are the cause of severe territorial disputes among several countries. In the small island countries such as those of the Pacific and Indian oceans and the Caribbean, territorial waters which enclose open ocean territory are the major resource base of the countries which usually have little land territory. Inshore and open ocean marine resources are the major resources of these nations. Therefore, the income derived from fishing access fees and some oceanic catch from domestic fleets is the dominant source of national income for most countries.

Resource system analysis

Trends and forecast

Highly migratory species

Since 1970, catches of tunas, billfish and swordfish have doubled from about 1.5 million mt to about 3 million mt in the 1990s. These species are all valuable on the world markets, most are subject to fishing by distant water fishing fleets and the catch is highly traded. The species vary from smaller and faster growing types such as skipjack and yellowfin tuna which generally appear to be able to sustain current exploitation levels, to larger, longer lived species such as the 3 bluefin tuna species which are in various stages of serious overexploitation.

Most fisheries for tuna are controlled by international agreements within various national EEZs (under the provisions of the UN Convention on the Law of the Sea) and in international waters under the new UN Convention on Highly Migratory Species and Straddling Stocks. Following the 1982 UNCLOS and declaration of EEZs by many countries, the distant water fishing nations (chiefly Japan, Taiwan and South Korea) had to negotiate access arrangements with many nations to obtain rights to fish tuna. During the late 1970s and 1980s, these fishing nations were joined by the USA, China, Indonesia, Thailand and other more minor countries in fishing in the waters of other countries. However, as many countries, especially those newly industrializing countries of Asia, developed their own capacity to take tuna stocks, access to distant waters was reduced and countries such as Japan bought more and more of their tunas and similar species as direct imports.

Many tuna fisheries on the open ocean share stocks with inshore even artisinal fisheries, especially in such areas as the central and western Pacific and around the Maldives in the Indian Ocean.

Production in the larger scale fisheries is from pole and line (now only practiced on a limited basis), longline and purse seine. Longline fish are the most valuable. These fish are usually sold as high value sashimi, fetching the highest prices on the discerning Japanese market (nearly US$6-7,000/mt for yellowfin tuna in 1994). Most fish caught by purse seine and pole and line are canned.

Sharks are a small but important bycatch of many tuna fisheries, especially the longline fisheries. Usually only the fins are retained for use in sharkfin soup and the gelatinous threads so used fetch very high prices on some Asian markets. Since most sharks are long lived and slow growing, most oceanic (and even inshore) shark stocks are overexploited. Efforts have been made to list some of the species on endangered and threatened species lists.

In the late 1980s and early 1990s, large oceanic fisheries for (mainly) albacore tuna developed in the Pacific Ocean, using long (over 100 km) and deep monofilament gillnets. Much of this fishing was done in the non-territorial seas. A worldwide public outcry by conservation groups and others led to the swift phasing out of this indiscriminate method of fishing due to very high bycatches of marine birds and mammals, and to the existence of "ghost nets" drifting in the oceans.

Demersal fisheries

Open ocean demersal fisheries are a phenomena of the late 70s onwards. High value but low productivity species such as orange roughy (*Hoplostethus atlanticus*), dories, various rockfish (*Sebastes* spp.), high latitude species such as the Antarctic frost fishes, and scampi (*Nephrops* and *Metanephrops* spp.) and carid shrimps have been caught in deeper waters (down to 1.5 km) in various oceans of the world. In deeper waters, some species, such as orange roughy, occur in all oceans. Many of the deepwater fishes produce excellent quality white fish products but grow so slowly (some are found to live for well over 100 years) that they have very low sustainable catches.

Small numbers of large, well-equipped industrial trawlers are used to catch these species. Some stocks were overexploited within a few years of the discovery of their fisheries and before relevant fisheries biology could show the limited extent of the fisheries.

Midwater fisheries

Some of these fisheries produce large volume of low value product but are nevertheless very valuable on the world market for process fish (surimi products, canned fish, etc.). Most of the major species exhibit apparent decadal patterns of changes in abundance, thought to be related to major ocean climate influences but also modifiable by heavy fishing patterns. For example, Alaskan pollock, one of the biggest fisheries in the world, produced 4 million mt of catch in 1970, rising to nearly 7 million mt in the mid 1980s and falling to just under 5 million mt in the 1990s. Large industrial fishing fleets are the main form of capture. Most of the fisheries are based on straddling stocks.

Oceanic squid fisheries, such as the important ones in the Atlantic ocean and those off New Zealand, are annual stocks and annual catches can be highly variable. Approximately 2 million mt of squid are caught each year in the open oceans.

Resource system characteristics

The open oceans are less productive per liter of water than most other systems but by virtue of their vast extent and/or the structuring features of the systems (thermoclines, upwellings, ocean features such as seamounts, etc.) productivity is large in aggregate and often concentrated in space and time by the structuring features.

Little research has been conducted except with tuna and knowledge of oceanology is relatively limited.

Biodiversity may also be surprisingly high. Although not directly relevant to the main form of fisheries production, some of this biodiversity is proving interesting for the bioactive products being discovered. For example, special forms of bacteria which live in hydrothermal vents at hundreds of degrees centigrade may have uses in industrial processes, including the production of bioproteins.

Governmental policy and regulation

All R&D is the preserve of wealthy countries with the capacity to exploit and explore the open oceans. Among the developed countries, the USA, Japan and various other OECD members are at the forefront. Among developing countries, only China and India appear to have a direct capacity to take part in these efforts. However, countries such as Indonesia, Thailand and the Philippines may have some capacity through their own research ships (often donated by overseas assistance) or through joint ventures. Territories (e.g., Pacific territories of France) and former territories in the Pacific and Indian Oceans may also gain some access to the resources in their open oceans through arrangements with industrialized partners.

Internationally, UNCLOS and the new UN Convention on Highly Migratory Species and Straddling Stocks govern most of the policies and management actions. Interactions with local fisheries policies and regulations are also important for many countries in which local populations share the resource, e.g., in the Pacific islands states. Enforcement of the agreed Economic Zone regulations is difficult and has been done mainly through commissions regulating the catches of tuna and bill fish. Most governments tend to favor export oriented or at least foreign exchange earning activities.

Increasingly, conservation arrangements such as marine mammals conventions and attempts to list several key fish species are interacting with the exploitation of open ocean resources.

Resource system SWOT

Strengths

- Relatively free from pollution effects and somewhat protected from exploitation by the offshore nature of the resource
- Some species are very valuable

Weaknesses

- Difficult systems to study and manage sustainably because of their vast, offshore nature and the difficulty of applying good monitoring, control and surveillance
- Expensive to fish economically because of the scale of fishing vessels needed
- Large-scale fishing operations can overexploit some types of species in just a few years if let to run unchecked

- Emphasis on tuna for export implies little benefit for poor segments of society

Opportunity

Small island countries could capture more of the benefits for themselves as distant water fleets reduce

Threats

- Developing countries do not have their own capacity to take full advantage of the present fisheries resources nor the biotechnology opportunities of the biodiversity or their open ocean resources
- Several species of tuna/billfish will go extinct in the next decade

Research issues, trends, prospects

Issues

Gaining good estimates of fish populations, population dynamics and ecosystem functioning of the open ocean requires major research resources and capacity. Nevertheless, great progress has been made in the last 20 years using high technology, including remote sensing (from above and in the ocean) technologies. Almost all research issues also require international cooperation and coordination.

Preventing extinction of top predators and developing novel methods (e.g., large scale marine protected areas) to ensure sustainability of the ocean catch is a major issue.

Feasibility studies need to be extended on large scale open ocean ranching and ocean fertilization (e.g., iron seeding).

Most of the oceans have major tuna commissions which undertake a range of research, management and monitoring activities, as well as serve as the secretariats for management commissions. These include: the Inter American Tropical Tuna Commission and the International Commission for the Conservation of Atlantic Tuna. A western Pacific tuna body is being contemplated although at this stage western Pacific Tuna are studied and monitored through regional bodies such as the South Pacific Commission and the Forum Fisheries Agency.

Research needs and opportunities

- For small-scale fisheries in developing countries, the interaction of the offshore and more inshore fisheries for the same species need to be better understood. Socioeconomic as well as biological research is important here.
- More generally, none of the tuna commissions pays much heed to the international socioeconomic dimensions of the resource exploitation, leaving such studies as do get done to national governments alone.
- Research opportunities in marine biotechnology for the deep ocean biodiversity abound.
- Scaling up the concepts of marine protected areas to the levels of the open ocean.

Core disciplines

- Fisheries science, ecosystem modelling, economics, political science, oceanography, marine biotechnology.

Trends and prospects

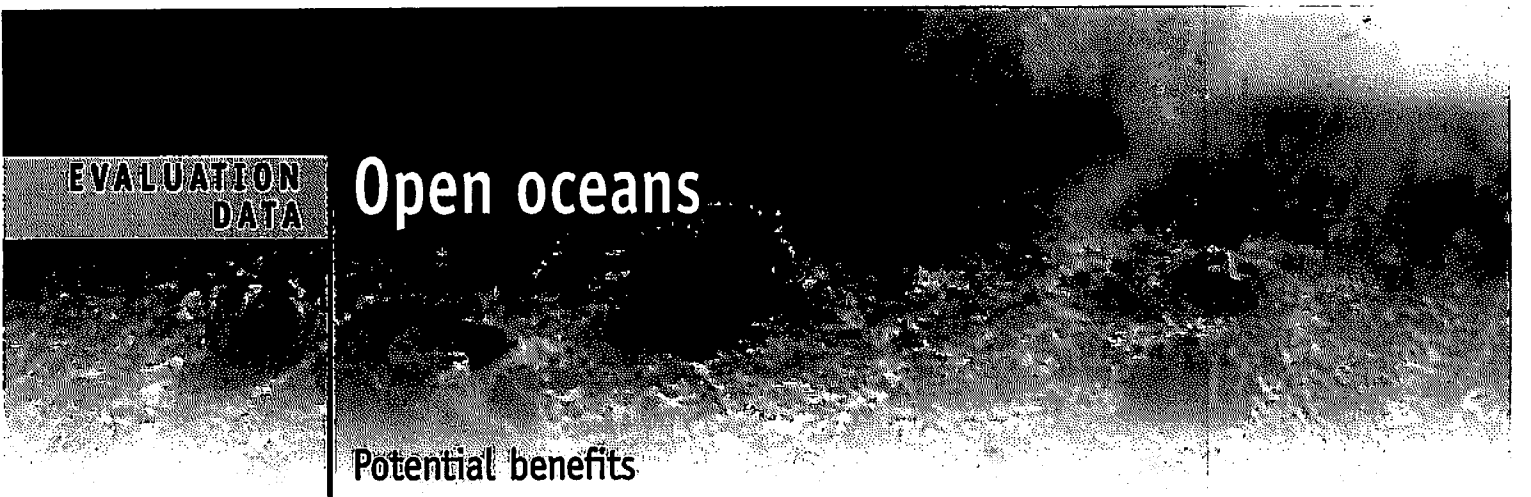
ICLARM has almost no research devoted to this resource system. Global studies including FishBase and various ecosystem modelling studies have, however, included work and information on this system.

Much direct or first hand research on the system will require massive resources, well beyond ICLARM's capacity and the results will return little direct benefit to the poor in developing countries. ICLARM, however, should maintain a currency with the general trends in the development of knowledge of the open ocean systems, especially where they reveal interactions with resources in our more mainstream systems.

ICLARM role and position

Watching brief and occasional inclusion of the system in global studies.

Open oceans



contents

Potential benefits

Benefits to developing countries come from access fees for use of resources by distant water fishing nations, increasing capacity for countries to fish own resources, good capacity for continued good catches of the faster growing tunas.

Ability to utilize

National systems in many countries weak in their own right (e.g., Pacific islands) but strengthened in effect by regional agencies and assistance from distant water fishing nations as part of the general assistance packages. Few countries will develop or need to develop substantial national capacity to perform much of the research required.

Science potential

Scientific knowledge critical for continued sustainability of the valuable open ocean fisheries (all types). However, most science interest in the open ocean is likely to be of a more fundamental nature in future and related to the gaining of basic knowledge (oceanography, geology, climatology) or high technology exploitation of the biological and other resources (some fisheries, biotechnology, ocean thermal power, undersea minerals, etc.).

R&A capacity

ICLARM has little capacity to work in most of the areas of science mentioned and would require large resources to acquire the skills and equipment to enter many of the necessary fields.

SUMMARY DATA

Resource considerations of the Small Island Developing States[1]

contents

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Description

The majority of Small Island Developing States (SIDS) are found in tropical latitudes in the Pacific and Indian Oceans and in the Caribbean. They are comprised of high islands and atolls, with some states being archipelagos or having archipelagos of smaller islands. In consequence they have very long coastlines and large Exclusive Economic Zones (EEZs) in relation to their surface areas. For example, with the introduction of the 200 mile EEZs, the combined area of the EEZs of island members of the Secretariat of the Pacific Community (SPC) is nearly 30 million km^2. With few natural resources other than terrestrial and mangroves forests, aquatic resources are heavily exploited in the cultural traditions of these islands and for subsistence (80% of production), livelihood and income generation. Pelagic offshore fisheries, deep reef slope and reef and lagoonal fisheries are all of importance so that finfish and invertebrate species and their products are widely exploited. Although land mass and total human population numbers are low, population growth rates have rapidly increased population densities so that in some cases, human outmigration has resulted. Terrestrial and coastal degradation is an issue in many states. The number of trained professionals in many cases is low. The Alliance of Small Island Developing States (AOSIS) is an informal political grouping of these small island states.

Resource system analysis

Trends and forecast

Dalzell et al. (1996) suggest that approximately 100,000 mt yr^{-1} is caught from coastal fisheries in the South Pacific region with a nominal value of US$262 million. Total tuna catches from the region for the same year were 991,000 mt, worth approximately US$1.46 billion. These are higher estimates than recorded in official FAO statistics (1994). However, 80% of catches from coastal and reef fishing enter the subsistence eco-nomy and go unrecorded. The island states gain revenue from granting tuna fishing licenses to vessels of other nations but sometimes have only theoretical control over actual catches and much of the value remits to developed nations. It is likely that improved data collection and surveillance would increase national knowledge of the resource and both subsequent management and remuneration. Sport(s) fishing and tourism based on coral reefs and coastal amenities are important emerging industries, as is the potential to supply the aqua-rium trade. Deep slope reef and sea mount fisheries were developed rapidly and then quickly overexploited in the 1980s in the Pacific and have collapsed. However, there are major export trades (after tuna) in reef fish (food, live food fish trade, aquarium industry); crustacea (crabs, lobsters and shrimp), although the latter are harvested from relatively few island states in commercial quantities (e.g., Gulf of Papua fishery produces 1,000-1,300 mt of shrimp annually); and molluscs which are heavily exploited for food and for the export value of pearls and for mother-of-pearl (trochus,

[1] It is recognized that the SIDS can be considered both as a dispersed regional grouping and as countries which focus aquatic issues on resource systems 5-8, as previously defined. Summary data have therefore been compiled for both regional and resource system formats.

green snail, black lipped and gold-lipped oyster shells). Markets for shell products are steady but green snail, exploited for most of the century, is becoming rare. The 1997 production of pearls in French Polynesia was worth over US$140 million. In the Cook Islands, pearl farming is the second largest earner of foreign exchange after tourism and was worth US$6 million in 1997.

The principal importing countries (Hongkong, Singapore and Taiwan) for beche-de-mer imported 9,000 mt from all sources in 1988 (equivalent to a preprocessed weight of approximately 90,000 mt sea cucumbers) with an approximate value of US$27 million. In the early 1990s, individual fisheries for sea cucumbers exceeding 500 mt could be found in the Maldives, Fiji and the Solomon Islands. Middlemen will presently pay US$20 per kg for first quality beche-de-mer to fishermen. There is no sign of market decline but there are severe reductions in availability of some species. There has been widespread replacement of high value species by lower value species.

There are (1992-94 average) approximately 43 million people in the SIDS for which we have data, a large number of whom are poor, (often in excess of 30% not including countries like Cyprus), and reaching 55-65% of the island's population in, for example, Haiti, Jamaica, Dominican Republic, Dominica, Sao Tome and Principe, the Comoros and Solomon Islands and Vanuatu. By 2020, the populations of the SIDS listed in Table 1 are anticipated to have grown by 57 million. Despite the high poverty level, the high rates of consumption of fish and aquatic produce (average fish consumption per caput rising to as high as 63 kg for Micronesia) has kept the percentage of malnourished children below 4% in most cases. In 1996, official statistics suggest that over 700,000 mt of fish was produced in the SIDS but this is likely to be a large underestimate given the extent of subsistence consumption.

Resource system characteristics

The small island states encompass all the coastal, lagoonal, reef, shelf and offshore pelagic resource systems described specifically earlier (see resource system profiles 5-8). There are, however, quite different means and rates of exploitation between resource systems, which are exploitable to different degrees because of the climatic and biogeographical differences between island states. In general, island states in the Indian Ocean and Caribbean are more subject to currents and weather patterns affecting the large continental land masses than are the Pacific Islands. The Indian Ocean is in general less productive than the Pacific but the interaction of strong monsoonal events with relatively fast moving continental currents (like the Somali current) give rise to upwellings. Anchovy (*Stolephorus* spp.) and sardine (*Sardinella*, particularly *S. longiceps*) are caught in large numbers in the western Indian Ocean and elsewhere in the same ocean large pelagic fish make up 35% of the catch. The Indo-Pacific islands have very high species diversity. Although this decreases eastwards of 120°W, 250 species of aquarium fishes are traded from Guam. Typically, catches contain 200-300 different fish species. Over 1,000 species of shell-bearing molluscs are eaten, or their shells utilized by South Pacific islanders.

In the Caribbean, many of the same families and guilds of fishes occur although species diversity is less than in the IndoPacific. There is very heavy exploitation of reefs in most islands. In Jamaica, total marine catches have been static for many years, despite expansion of the exploited area to include remote oceanic banks. In nearshore waters, a combination of overfishing, loss of herbivores and hurricane damage have served to reduce coral cover and fish abundance. Increased observation of coral bleaching may be attributable to increased reef stresses including temperature fluctuations. Water quality and terrestrial runoff are concerns.

Government policy and regulation

The small island developing states are a mix of newly independent (from the 1960s and 1970s) former colonies, overseas territories of major European and Pacific rim powers and trust territories.

The majority of the Pacific Islands are grouped together into the Pacific Community whose Fisheries Program has conducted research and development on tuna and coastal fisheries. The South Pacific Fisheries Forum Agency is concerned with managing access by distant water fishing nations to the region's tuna stocks. Present commercial catches of tuna are made predominantly by vessels from Pacific rim countries such as Japan, Taiwan, USA, China, Korea and the Philippines.

The Indian Ocean Marine Affairs Cooperation Conference (IOMAC) provides a transsectoral instrument for integrated ocean management. There are western ocean groupings which include coastal African states and the large Island State of Madagascar for regional discussion and management although nation states enact their own fisheries regulations.

Apart from the Association of Eastern Caribbean States, which has a fisheries secretariat and harmonized fisheries legislation, there is no regional fisheries organization in the Caribbean. Problems are compounded by the multiplicity of independent or self-governing states and of languages.

Many islands, particularly in the ethnically diverse cultures of the South Pacific have traditional laws governing tenure, fishing rights and practices. In some cases, these are infringed by new migrant communities and fishers from outside the traditional group (both artisanal and commercial). Over exploitation is often counteracted by temporary (e.g., trochus) or permanent bans on fishing/exploration. However, bans and other laws are often difficult to implement in archipelagic countries or in countries with small numbers of supervisory services (police, fisheries scientists, coastguards, etc.). The development of marine protected areas has been advocated in many parts of the world but observance of fishing bans has been difficult to maintain either because of economic hardship, lack of alternative livelihood, or insufficient management. Data collection methods and management schemes will have to be made appropriate to the conditions of the small island states.

Resource system SWOT

Strengths

- The major and immediate importance of aquatic resources to the livelihoods and well-being of the generally poor populations of these islands
- States have large coastline to land mass ratios with productive and biodiverse coral reef and other coastal and marine resources.
- Luxury, recreational, food and subsistence markets exist for products at different international, regional and national levels
- Many tenurial rights systems and traditional fishing practices exist which could form the basis of devolved, national fisheries management
- High similarity of habitats with other tropical islands, including those which are components of archipelagic or continental coastal countries, ensures wide research applicability and spillover
- Regional cooperation is usually strong thus facilitating international legal agreements and arrangements for regional research and training

Weaknesses

- Small, culturally diverse island states often separated, even within the same ocean, by large distances. Brings high communication, transport and travel costs
- Small human populations with correspondingly small NARS so that few are self sufficient in all fields of research and have low numbers of trained fisheries managers or resource specialists
- Difficulties in enforcing (nontraditional) laws and regulations
- States often under pressure from other developed nations and commercial fishers wishing to exploit offshore and reef resources
- Population pressure retards development, increases aquatic and terrestrial degradation and leads to human population migration (e.g., overturning rights regimes in other states through migratory fishers)
- Free access regimes have increased fishing pressure in some states to the point of endangering some aquatic species
- Little agricultural land and dependence upon fish and aquatic produce mean that islands only

have similar items for inter-island trade and must look outward for markets

Opportunities

- Improved management would bring major effects for human populations and genetic resources protection in these otherwise resource-poor states.
- Collectively, island states exercise control over vast areas of the world's oceans and are therefore extremely important in global fisheries management and policy development
- Research conducted in island states can have direct effects in these nations and methods and results are usually directly applicable to coastal states bordering the same oceans and therefore impacting their large coastal human populations
- To prevent the extinction of rare and valuable marine, coral reef, sea grass, mangrove and other coastal aquatic species
- To establish regulated fisheries and collection rates for high value species to provide both food and additional income and livelihoods to the human population
- To develop aquaculture (especially of high value food and non-food species for export), tourism and other sustainable means of exploiting natural resources to generate personal and national incomes

Threats

- Unregulated exploitation of island state's resources by "walk-in" fishers and the commercial pressure of other nation fishers or aquatic produce middlemen
- Overpopulation, with terrestrial resource use leading to eutrophication, and degradation of marine and coastal habitats
- Overfishing
- Traditional fisheries and coastal management practices under threat from societal change
- Climatic (hurricane, monsoon, periodic or global warming, sea level rise) events damage resources or economic changes make products unattractive to continental markets.
- Political and resource limitations to collective action by SIDS and to enforcement of international legal agreements
- Neglect by the global economy

Research issues, trends, prospects

Issues

Major issues are the development of appropriate means to collect data from artisanal fishers to properly estimate resource exploitation. Biodiversity inventories and protection of endangered species (through active husbandry and use, where possible, as well as the introduction of carefully-sited aquatic protected areas) is extremely important as several high-value species have been overfished to the point of extinction (e.g., the giant clam *Tridacna gigas* in Melanesia). Carrying capacity for reefs in different areas should be determined and appropriate offtake levels set for artisanal use, commercial food sources, licensed live food fish or aquarium species collections for export. Legal and policy analysis to formulate and govern coastal management plans, including the elaboration of MPAs, should be pursued utilizing participatory and traditional models where appropriate. Ecological evaluation techniques should be developed for aquatic/coastal resources so that aquatic resource use is properly entered into national, coastal zone management plans and so limit effects of terrestrial activities on aquatic resource use. Market analyses for aquatic resource based industries need to be carried out to balance conservation, artisanal food supply, leisure and high value export industries. Through active research conducted in and for small island states of the different oceans, methods for and solutions to fisheries issues shared by large islands and tropical coastal states boarding these oceans will be derived.

Population growth and unregulated access to island's natural resources, both coastal and off-

shore, threaten the sustainability of island resources and human development and the major contribution of these states to global industries in aquatic produce. Aquatic biodiversity in these key tropical habitats is under threat from overexploitation.

Research needs and opportunities

- Large-scale studies of trophic relationships on coral reefs in Pacific and Indian Oceans and in the Caribbean to establish species interdependencies
- Development of data acquisition systems which deliver data upon which management decisions can be based and which do not require intensive deployment of highly skilled staff and large expenditures by national fishery agencies
- Studies of the feasibility of increasing sustainable yields from coral reef systems by the cultivation of desirable species or by enhancing natural recruitment by the release of hatchery-reared juveniles
- With appropriate safeguards on exploitation rates, development of collection systems for pelagic larvae, probably using light traps or crest nets, as an alternative to cultivation of larvae in hatcheries
- Determination of replenishment rates and effects of fishing and mariculture on biodiversity and genetic structure
- Genetic improvement of successful species where the biotechnical aspects of aquaculture have been shown to be economically feasible
- Combination of biotechnical work and bioeconomic modelling with social, cultural and legal aspects for successful development of viable farming systems for coral reef species
- Management practices to ensure reef health and sustainable use
- Devising approaches to MPA development for recommendations in various situations and determination of benefits
- Research on the practicality and effectiveness of marine fishery reserves, of various sizes and in various locations, 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
- Improving resource management through the development of data acquisition systems, bioeconomic models and community-based management systems
- Bioeconomic modelling of aquatic resource systems in respect of fisheries (including recreational and sport fisheries), aquaculture and fisheries enhancement, tourism and the social costs of nonconservation. Such models will allow quantification of the effects of various gears on all exploited species and on their food base and the evaluation of management options, including the use and valuation of reefs for various non-extractive uses such as tourism. The models will also provide indicators for optimization of fishing and other uses of coral reefs. Mechanisms to verify and refine the parameters of these models will be devised at selected sites.
- 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 is 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. Identification of tools and training methods for optimal management.

Core disciplines relevant to this resource system

- Reef ecology/trophic functioning/population genetics/invertebrate pathology/taxonomy
- Mapping GIS/modeling, physical sciences
- Stock assessment
- Aquacultural techniques for stock enhancement
- Economics (including resource economics, trade and development economics)
- Quantitative anthropology (legal analysis)
- Integrated coastal zone management
- Modeling stock enhancement/assessment
- Socioeconomic and anthropological studies on impact of marine protected areas, fishers and coastal communities.

Trends and prospects

Many small island states are highly unlikely to achieve a fully self-sufficient status, but every available resource is crucial to lessening dependencies. In the case of aquatic resources, addressing the particular needs of small island states is a priority because of their high dependency on these resources in general. Specific consideration of the SIDS has also been expressly detailed in recent international fora such as Agenda 21, by the FAO and within the CGIAR (focused previously on the agriculture of small nation states including the Caribbean islands). However, integrated research approaches are few although substantial amounts of management and biological research have been conducted on the different aquatic habitats separately. There are large international efforts to research and manage tuna stocks and regulate catches. There is a substantial body of coral reef literature on biological interactions, often focused on single species. There is a large body of collected knowledge about the Pacific Island states but few integrated management schemes integrating coastal aquaculture and the newer high-value potential of industries based on aquatic resources. Few integrated studies relating to terrestrial and aquatic resource issues in small island states exist and whilst traditional rights and practice regimes are well described, few studies have attempted to integrate these into modern, devolved coastal management schemes for small island states.

ICLARM conducts research on coastal aquaculture in the Pacific, on the scientific basis for the use of MPAs in the Caribbean and the Pacific, and holds the world's major data base on factors affecting coral reefs. ICLARM presently spends $1.3 million or approximately 10% of its total program research directly on these activities. ICLARM also has a program in coastal fisheries data management and in co-management approaches to fisheries. New research will focus on effects of forestry practices on aquatic resource systems.

Insufficient data are available on a global scale, and economic evaluation insufficiently well developed (although it should be part of the research approach) to appropriately make *ex ante* evaluations about the returns to research. However, in natural resource conservation, biodiversity, fish harvest and human welfare spillovers, the effects are anticipated to be large. The work would have impact on tropical coastal communities in all continents dependent upon the same types of aquatic resources. For example, research on reef fisheries and aquaculture in the Pacific has many spillovers to South East Asia.

ICLARM role and position

- ICLARM has a major thrust in coral reef, coastal and related research.
- Development of ReefBase, for storing all available quantitative and categorical information on coral reefs
- Basis for addressing questions such as:
  - Where are the reefs? How much area do they cover? What is their value to people? How much destruction is occurring at what rates, how and where? What constitutes a healthy reef (from several approaches including ecosystem, community, complexity theory/dynamics, indicator species, biogeochemical, pathological)? How does this vary under different environmental conditions?
  - What are sustainable levels of wild harvests? What is the connectivity between coral reefs in different nations within one biogeographic area? What are the effects of reef changes downstream on reefs and their management upstream?
- ICLARM's Coastal Aquaculture Centre (CAC) conducts work on coastal aquaculture for developing countries and can expand from prior work on coral reef invertebrate species.
- ICLARM has MPA evaluation and monitoring work in the Caribbean and Solomon Islands and is well placed to contribute to global debates and research on exploitation of MPAs.
- Development of FishBase, for storing and compiling data on the ecology, population dynamics and reproduction of the world's fishes.
- Further development of Ecopath ver. 4, with EcoSim and EcoSpace, which will enable a series of steady-state trophic models of coral reefs to be elaborated. This will lead to an understanding of

biomass and energy flows in various types of coral reefs, including the results of supplementing natural recruitment by the release of hatchery-reared juveniles.

ICLARM's strengths and weaknesses in relation to this system

Strengths

CAC is recognized as one of the major aquaculture research facilities in coral reefs; ReefBase; past record and reputation; senior staff capable of answering all questions outlined under 3.1; and field bases in Asia, Pacific and Caribbean.

Weaknesses

- Minimal number of field projects (two in Caribbean, none elsewhere) dealing with exploitation and management; insufficient staff; limited number of senior staff to supervise projects, and lack of funding for major projects.
- Major customers for ICLARM's work fisheries departments, NGOs and conservation agencies, universities and colleges, coastal dwellers in coral reef areas
- Alternative suppliers: AIMS, USA, Japanese and European universities, IUCN, WWF, SPC

Additional references

Adams, T.J.H. 1998. Coastal fisheries and marine development issues for small islands. *In* M.J. Williams (ed.) A roadmap for the future for fisheries and conservation. ICLARM Conf. Proc. 56, 58 p.

Belles, W., P. d'Ayala P. Hein. 1990. Sustainable development and environmental management of small islands. *In* Man and the biosphere. Vol 5. UNESCO and Parthenon Publishing. 419 p.

Dalzell P., T.J.H. Adams and N.V.C. Polunin. 1996. Coastal fisheries in the Pacific Islands. Oceanogr. Mar. Bio. Ann. Rev. 34:395-531.

Fisheries Department, FAO. 1997. Fisheries and aquaculture in the South Pacific: situation and outlook in 1996. FAO Fish. Circ. 907 FIP/C907. FAO, Rome.

Fisheries Department, FAO. 1998. The FAO programme of fisheries assistance for small island developing states (SIDS). Available: http://www.fao.org./WAICENT/FAOINFO/FISHERY/sids/sidsf.htm

Small Island Developing States

contents

Potential benefits

Agricultural land is so restricted in small island states that the populations depend upon forestry (terrestrial and mangrove) and aquatic resources as the only exploitable natural resources. There is thus an exceptionally high dependence on fish and other aquatic produce for food, livelihood and income generation in these states. The subsistence catch is estimated at 80% of the total. Very high species diversity in fish and invertebrates is utilized for food, sale and cultural exploitation. High population pressure has led to degradation of terrestrial and coastal reef habitats. The development of appropriate means to collect data from artisanal fishers will give much needed estimates of true resource exploitation. Aquatic biodiversity inventories and protection of endangered species (through the appropriate siting of aquatic protected areas) will prevent threatened extinctions and maintain resources for future exploitation e.g., giant clams, or reefs for tourism and leisure exploitation.

Determination of the carrying capacity of reefs in different areas will allow recommendations of appropriate offtake levels for artisanal use, commercial food sources, and increased income generation through licensed live food fish or aquarium species collected for export. This should be complemented by market studies to direct these industries for the benefit of island nations. Training in all aspects of coastal and fisheries management will place greater knowledge and authority in the hands of island states to monitor and regulate licensed fishing activities of other nations in the EEZs and therefore to control the state's major source of income.

Legal and policy analysis will help in the formulation and governance of coastal management plans for the participatory exploitation of common resources. Active research conducted in and for small island states will benefit almost the entire populations of the SIDS and have direct applicability and spill over to similar coastal environments found throughout tropical developing countries in all regions.

Coastal dwellers, both men and women, fishers and the majority of inhabitants in small island states will derive sustainable food harvests and alternative income generating opportunities. The nation states will derive sustained and improved income from the appropriate exploitation of reef and coastal resources and offshore pelagic fish stocks. Coastal aquaculture enterprises will similarly enhance individual and national food and income generation, as well as wellbeing in these states and elsewhere, particularly in Asia.

Ability to utilize

Most SIDS have a large proportion of their population engaged in fishing and exploitation of coastal or marine resources. Training will be an important element of improved approaches to resource management as academic and legal expertise is not widespread. Many islands, particularly in the Pacific have traditional tenurial rights and fishing practices on which devolved management schemes could be based. Biodiversity is still relatively high and hundreds of species of finfish and invertebrates are exploited so that systems in the Indo-Pacific generally remain resilient. There have been long running projects for the aquaculture or stock enhancement of some species with demonstrable success. Successful examples of

marine protected areas need to be demonstrated more widely and the philosophical and research basis of these methods spread between island states themselves.

Threats come from population pressure, overfishing of the resource and the pressure from commercial incentives to continue bad practices because of the high price for some aquatic resources in external markets. Management schemes and legal enforcement are presently lacking.

Outputs will be coastal and fisheries management schemes based on reliable data, environmentally sensitive aquaculture industries, alternative livelihoods and income generation for displaced fishers and other coastal users, protection schemes for threatened aquatic biodiversity. Methods and approaches widely applicable to coastal regions in poor developing, tropical countries.

Science potential

Substantial knowledge of coral reef dynamics and tuna stock enhancement. ICLARM itself leads in coastal aquaculture for developing countries and knowledge of marine protected area implementation for protection of coral reef fish and invertebrates. Many stock assessment groups are moving to consideration of "minimum data" approaches to fisheries and biodiversity management. Knowledge of traditional fishing and tenure rights is quite high, but there is less experience of translating these into sustainable, modern, devolved methods of management. SIDS are microcosms of many areas in tropical coastal countries with respect to upland-lowland-coastal management but have greater vulnerability and reduced resilience. Prospects for dovetailing existing biological and socio-legal knowledge into management methods applicable for tropical countries is high. Indigenous research capacity is often limited so tripartite, or regional arrangements for the conduct of research will be required with continuous training and project experience.

R&A capacity

ICLARM's international standing

ICLARM has a strong research interest and expertise in coral reefs and aquaculture - although the effort is distributed. ICLARM spent approximately US$1.3 million of its resources on this aspect in 1997. The Institute has the ability to construct teams including socio-economic and legal expertise and to apply experiences in co-management from other parts of the world. Linkages have been established to several regional bodies and appropriate collaborating ASIs and donors for such an approach.

Tables for Part II

contents ?

Key to the derivation of the total production by resource system

The resource systems have been analyzed by FAO geographic areas covering tropical developing countries for ISSCAAP groups of species.

The analysis is based on that given in Table 2 of the Appendix to ICLARM's strategy document of 1992. In the current analysis, 1988 figures are compared with those from 1996.

The resource system totals have been derived using FAO statistics for 1996 for freshwater aquaculture, marine aquaculture, freshwater fisheries catches and marine catches.

Freshwater aquaculture figures have been allotted to Ponds:Lakes and Reservoirs:Streams, Floodplains and Rivers in the ratio 10.0:0.6:0.1*
(For China, 73% of freshwater aquaculture production is derived from ponds**: for Africa, approximately 95% of aquaculture production has been estimated to come from ponds***).

Table 2.1.Total production by resource system.

ISSCAAP Code	Group of species	Total production (mt)		Aquaculture (mt)		Capture (mt)	
		1988	1996	1988	1996	1988	1996
11	Carps, barbels and cyprinids	5 155 847	11 873 421	4 697 031	1 255 902	458 816	617 519
12	Tilapias and other cichlids	631 919	1 199 798	162 184	666 987	469 735	532 811
13	Misc. freshwater fishes	3 464 346	3 878 319	91 998	122 838	3 372 348	3 755 481
41	Freshwater crustaceans	166 442	488 721	25 758	30 245	140 684	458 476
2	Diadromous fishes[1]	1 195 689	1 615 820	427 544	771 934	768 145	843 886
51	Freshwater molluscs	328 283	569 008	10 736	11 806	317 547	557 202
Subtotal		**10 942 526**	**19 625 087**	**5 415 251**	**12 859 712**	**5 527 275**	**6 765 375**
31	Flatfish	83 761	111 915	-	-	83 761	111 915
33	Basses, groupers, snappers, etc.	2 457 481	3 437 986	287	61 682	2 457 194	3 376 304
34	Jacks, mullets, sauries, etc.	4 779 320	7 478 084	4 973	20 310	4 774 347	7 457 774
38	Sharks, rays, chlameras, etc.	464 493	542 910	-	-	464 493	542 910
42	Sea-spiders, crabs, etc.	387 297	704 115	8 756	15 383	378 541	688 732
43-44	Lobsters, etc.	851 790	1 247 025	8 756	15 383	843 034	1 231 642
45	Shrimps, prawns, etc.	2 012 499	2 807 555	518 807	891 321	1 493 692	1 916 234
47	Other marine crusteans	407 155	1 026 333	2 901	7 265	404 254	1 019 068
52	Abalones, winkles, etc.	53 585	36 529	110	7	53 475	36 522
53-54	Oysters and mussels	460 740	1 062 862	3 011	7 272	457 729	1 055 590
55	Scallops	266 216	1 029 438	123 100	1 009 753	143 116	19 685
56	Clams, cockles, etc.	641 262	1 895 844	319 899	1 519 104	321 363	376 740
57	Squids, cuttlefishes, octopuses	1 269 292	1 771 547	-	-	1 269 292	1 771 547
58	Misc. marine molluscs	987 108	2 184 764	173 736	1 187 983	813 372	996 781
7	Misc. invertebrates[2]	400 447	1 335 334	1 564	4 784	398 883	1 330 550
Subtotal		**15 522 446**	**26 672 241**	**1 165 900**	**4 740 247**	**14 356 546**	**21 931 994**
32	Gadoids	1 351 151	1 904 640	-	-	1 351 151	1 904 640
35	Sardines, anchovies, etc.	14 026 771	15 345 969	-	-	14 026 771	15 345 969
Subtotal		**15 377 922**	**17 250 609**	**-**	**-**	**15 377 921**	**17 250 609**
36	Tunas, bonitos, etc.	14 026 771	15 345 969	-	-	14 026 771	15 345 969
37	Mackerels, etc.	14 026 771	15 345 969	-	-	14 026 771	15 345 969
39	Misc. marine fishes	6 391 423	9 597 499	32 682	182 171	6 358 741	9 415 328
Subtotal		**34 444 965**	**40 289 437**	**32 682**	**182 171**	**34 412 283**	**40 107 266**
TOTAL							
	Production	**76 287 859**	**103 837 374**	**6 613 833**	**17 782 130**	**69 674 026**	**86 055 244**
	Freshwater aquaculture			**5 415 251**	**12 859 712**		
	Marine aquaculture			**1 198 582**	**4 922 418**		
	Freshwater capture					**5 527 275**	**6 765 375**
	Marine capture					**64 146 751**	**79 289 869**

Freshwater catch has been divided between Lakes and Reservoirs: Streams, Floodplains and Rivers in the ratio 1:2 as described earlier. ****

Productivity from Coral Reefs is highly variable and catch per reef is still a subject for analysis. However, we have adopted the same total production of 6 million metric tons as described earlier.****

Subtracting the total coral reef production from total marine catches, the remainder has been distributed across Estuaries and Lagoons: Soft bottom shelves: Upwelling shelves: Open oceans in the same ratio as derived earlier, i.e., 5.1:11.1:14.0:3.1****

Marine aquaculture has been added to the total production of Estuaries and Lagoons noting the land associated nature of much of this type of aquaculture, even though this includes the cultivation of coral reef organisms.

Ponds Freshwater aquaculture)	Lakes, reservoirs	Floodplains, rivers	Estuaries, lagoons	Coral reefs	Soft-bottom shelves	Upwelling shelves	Open oceans
12 017 400	2 954 004	4 584 742	16 143 096	6 000 000	24 429 953	30 812 556	6 822 773

Summaries of fish production, estimated total values marine and inland catches, aquaculture, total value of aquaculture, apparent fish consumption and trade statistics by region, 1988-1996.

Table 2.2a. Summary of fish production and apparent fish consumption.

	Total fish production[2] (mt)		Total value[2] (US$'000)		Apparent fish consumption (kg/yr/person) (Ave.1993-1995)
	1988	1996	1988	1996	
SS Africa	2 953 652	3 582 691	3 632 992	6 735 459	9.8
South Asia	5 316 553	8 208 025	7 230 512	17 975 575	8.5
East Asia	15 830 250	36 508 879	28 177 845	65 715 982	28.5
Southeast Asia	8 598 787	13 804 587	17 541 525	20 154 697	24.9
Central and South America	16 150 271	21 936 781	23 417 893	46 286 608	12.3
WANA	2 409 073	2 576 082	8 865 389	5 255 207	9.1
SIDS *	568 845	504 567	1 496 062	1 175 641	31.4

Table 2.2b. Marine and inland catches.

	Marine catch (mt)		Inland catch (mt)	
	1988	1996	1988	1996
SS Africa	1 386 319	1 907 555	1 552 138	1 642 727
South Asia	3 099 638	4 361 216	1 145 419	1 583 928
East Asia	8 834 165	16 487 138	842 774	1 874 168
Southeast Asia	6 280 913	10 742 635	848 058	953 091
Central and South America	15 463 401	20 944 248	494 662	463 407
WANA	2 057 567	2 072 143	256 704	347 671
SIDS*	525 716	439 413	21 783	25 882

Table 2.2c. Aquaculture and total value of aquaculture.

	Aquaculture (mt)		Total value of aquaculture US$'000)	
	1988	1996	1988	1996
SS Africa	15 195	32 409	21 074	88 529
South Asia	1 071 496	2 262 881	1 271 254	3 546 386
East Asia	6 153 311	18 147 573	7 817 380	18 818 717
Southeast Asia	1 469 816	2 108 861	3 628 551	6 964 596
Central and South America	192 208	529 126	855 862	2 146 885
WANA	94 802	156 268	423 283	747 343
SIDS *	21 346	39 272	34 293	74 421

Table 2.2d. Trade statistics.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
SS Africa	901 381	587 354	215 968	290 497	505 179	375 796	435 122	863 184
South Asia	57	2 018	27 452	52 143	2 858	3 958	130 567	183 437
East Asia	452 055	877 778	782 016	982 065	368 583	1 434 003	2 386 756	2 771 639
Southeast Asia	587 466	1 032 489	603 044	1 695 711	644 373	1 199 197	1 976 782	4 481 003
Central and South America	84 327	337 705	699 647	1 413 953	67 523	371 912	1 873 697	4 074 130
WANA	147 166	280 194	192 850	228 324	125 618	241 286	530 915	851 953
SIDS *	196 898	269 451	201 533	191 454	343 239	597 380	547 168	676 606

Sources:
FAO. 1998. Fishery statistics: Commodities. FAO Yearbook. Vol. 83. FAO, Rome.
FAO. 1998. Fishery statistics: capture production. FAO Yearbook Vol. 82. FAO, Rome.
FAO. 1998. Aquaculture production statistics. FAO Fish. Circ. 815, Rev. 10.

Notes:
[1] Total production includes nominal catches of fish, crustaceans, molluscs and other aquatic animals, residues and plants taken for all purposes (commercial, industrial and subsistence) operating both in inland, fresh and brackish water areas, and in inshore, offshore and high seas fishing areas. Statistics for mariculture, aqyaculture and other kinds of fish farming are included.
[2] Fish production price was estimated using the average regional export/import/aquaculture price.
* Based on AOSIS countries, the informal grouping of small island states.

Trends (1988-1996) in total production and estimated total value by developing country.

Table 2.3a. Sub-Saharan Africa.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Angola	101 783	72 841	125 193	136 941
Benin	37 267	42 000	45 838	78 960
Botswana	1 900	2 100	2 337	3 948
Burkina Faso	7 916	7 500	9 737	14 100
Burundi	11 701	10 000	14 392	18 800
Cameroon	70 696	84 039	86 956	157 993
Central African Republic	13 079	13 000	16 087	24 440
Chad	58 000	100 000	71 340	188 000
Congo Democratic Republic	162 000	163 011	199 260	306 461
Congo Republic	41 977	33 790	51 632	63 525
Côte d'Ivoire	89 506	71 000	110 092	133 480
Djibouti	454	360	558	677
Equatorial Guinea	4 000	2 306	4 920	4 335
Ethiopia	4 067	8 855	5 002	16 647
Gabon	22 093	45 180	27 174	84 938
Gambia	13 852	31 525	17 038	59 267
Ghana	362 351	477 173	445 692	897 085
Guinea	38 001	64 584	46 741	121 418
Guinea Bissau	4 690	7 000	5 769	13 160
Kenya	138 350	178 959	170 171	336 443
Lesotho	30	42	37	79
Liberia	16 076	7 232	19 773	13 596
Madagascar	101 118	118 090	124 375	222 009
Malawi	78 817	63 804	96 945	119 952
Mali	55 875	111 970	68 726	210 504
Mauritania	97 600	85 000	120 048	159 800

Table 2.3a. Sub-Saharan Africa, continued.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Mozambique	35 457	34 952	43 612	65 710
Namibia	33 395	267 916	41 076	503 682
Niger	2 504	4 156	3 080	7 813
Nigeria	279 514	254 230	343 802	477 952
Reunion	2 053	5 199	2 525	9 774
Rwanda	1 328	3 050	1 633	5 734
Senegal	260 769	436 337	320 746	820 314
Sierra Leone	52 293	61 360	64 320	115 357
Somalia	18 227	15 000	22 419	28 200
Sudan	29 245	48 915	35 971	91 960
Swaziland	110	153	135	288
Tanzania	392 958	356 817	483 338	670 816
Togo	15 469	15 119	19 027	28 424
Uganda	214 325	195 298	263 620	367 160
Zambia	60 584	66 332	74 518	124 704
Zimbabwe	22 222	16 486	27 333	31 012
Total	**2 953 652**	**3 582 691**	**3 632 992**	**6 735 459**

Table 2.3b. South Asia.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Bangladesh	829 929	1 264 435	1 128 703	2 769 113
Bhutan	315	330	428	723
India	3 125 962	5 260 420	4 251 308	11 520 320
Nepal	12 100	21 879	16 456	47 915
Myanmar	704 547	872 972	958 184	1 911 809
Pakistan	445 495	555 489	605 873	1 216 521
Sri Lanka	198 205	232 500	269 559	509 175
Total	**5 316 553**	**8 208 025**	**7 230 512**	**17 975 575**

Table 2.3c. East Asia.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
China	11 379 604	31 936 876	20 255 695	57 486 377
Mongolia	281	231	500	416
North Korea	1 718 000	1 800 000	3 058 040	3 240 000
South Korea	2 732 365	2 771 772	4 863 610	4 989 190
Total	**15 830 250**	**36 508 879**	**28 177 845**	**65 715 982**

Table 2.3d. South East Asia.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Brunei	2 042	7 524	4 166	10 985
Indonesia	2 795 208	4 401 940	5 702 224	6 426 832
Malaysia	873 584	1 239 691	1 782 111	1 809 949
Philippines	2 010 363	2 133 063	4 101 141	3 114 272
Taiwan	1 353 520	1 229 759	2 761 181	1 795 448
Thailand	549 270	3 647 900	1 120 511	5 325 934
Kampuchea	86 800	104 310	177 072	152 293
Laos	28 000	40 400	57 120	58 984
Vietnam	900 000	1 000 000	1 836 000	1 460 000
Total	**8 598 787**	**13 804 587**	**17 541 525**	**20 154 697**

Table 2.3e. Central and South America.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Argentina	493 517	1 238 974	715 600	2 614 235
Bolivia	4 427	6 368	6 419	13 436
Brazil	830 122	850 000	1 203 677	1 793 500
Chile	5 209 844	6 910 556	7 554 274	14 581 273
Colombia	89 927	159 651	130 394	336 864
Costa Rica	17 069	31 189	24 750	65 809
Ecuador	876 024	793 891	1 270 235	1 675 110
El Salvador	11 733	13 224	17 013	27 903
French Guyana	5 540	7 977	8 033	16 831
Guatemala	3 725	11 074	5 401	23 366
Guyana	36 523	45 000	52 958	94 950
Honduras	19 951	24 119	28 929	50 891
Mexico	1 372 595	1 499 403	1 990 263	3 163 740
Nicaragua	4 728	18 010	6 856	38 001
Panama	123 682	144 235	179 339	304 336
Paraguay	10 054	22 000	14 578	46 420
Peru	6 641 894	9 531 960	9 630 746	20 112 436
Puerto Rico	1 697	2 424	2 461	5 115
Suriname	3 684	13 150	5 342	27 747
Uruguay	107 348	123 382	155 655	260 336
Venezuela	286 187	490 194	414 971	1 034 309
Total	**16 150 271**	**21 936 781**	**23 417 893**	**46 286 608**

Table 2.3f. WANA.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Afghanistan	1 000	1 300	3 680	2 652
Algeria	106 744	100 000	392 818	204 000
Bahrain	6 736	12 940	24 788	26 398
Egypt	284 247	341 033	1 046 029	695 707
Iran	235 005	381 700	864 818	778 668
Iraq	28 545	12 000	105 046	24 480

Table 2.3f. WANA, continued.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Jordan	372	533	1 369	1 087
Kuwait	10 796	8 253	39 729	16 836
Lebanon	1 800	4 485	6 624	9 149
Libya	21 682	33 832	79 790	69 017
Morocco	551 862	640 093	2 030 852	1 305 790
Oman	165 676	121 616	609 688	248 097
Qatar	3 086	4 740	11 356	9 670
Saudi Arabia	46 064	50 782	169 516	103 595
Syria	5 533	12 128	20 361	24 741
Tunisia	103 056	85 048	379 246	173 498
Turkey	674 207	554 856	2 481 082	1 131 906
United Arab Emirates	89 506	107 000	329 382	218 280
Yemen	73 156	103 743	269 214	211 636
Total	**2 409 073**	**2 576 082**	**8 865 389**	**5 255 207**

Table 2.3g. SIDS.

	Total fish production[1] (mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
American Samoa	99	259	260	603
Barbados *	9 097	3 439	23 925	8 013
Belize *	1 498	1 981	3 940	4 616
Cape Verde *	6 276	9 187	16 506	21 406
Comoros *	5 700	13 000	14 991	30 290
Cook Island *	1 100	1 010	2 893	2 353
Cuba *	231 250	108 701	608 188	253 273
Cyprus *	2 555	3 104	6 720	7 232
Dominican Republic	12 912	14 600	33 959	34 018
Federal State of Micronesia	2 634	9 341	6 927	21 765
Fiji *	32 455	31 682	85 357	73 819
French Polynesia	2 859	9 977	7 519	23 246
Guam *	572	341	1 504	795
Guadeloupe	8 233	9 600	21 653	22 368
Haiti	5 500	6 000	14 465	13 980
Jamaica *	10 305	15 943	27 102	37 147
Kiribati *	23 222	25 000	61 074	58 250
Marshall Island	190	270	500	629
Martinique	3 053	3 324	8 029	7 745
Maldives *	71 483	105 558	188 000	245 950
Mauritius *	17 154	12 544	45 115	29 228
Nauru *	170	400	447	932
New Caledonia	3 684	3 528	9 689	8 220
Northern Marianas	201	225	529	524
Niue *	115	113	302	263
Palau	1 507	1 300	3 963	3 029
Papua New Guinea	25 971	26 200	68 304	61 046
Pitcaim Island	4	8	11	19
Samoa *	2 500	698	6 575	1 626
Singapore *	15 250	13 510	40 108	31 478
Solomon Is *	55 141	53 286	145 021	124 156
St. Lucia *	782	1 273	2 057	2 966
Tokelau	200	210	526	489
Tonga *	2 717	2 841	7 146	6 620

Table 2.3g. SIDS, continued.

	Total fish production[1]/(mt)		Total value of fish production (US$'000)	
	1988	1996	1988	1996
Trinidad and Tobago	7 587	12 805	19 954	29 836
Tuvalu *	1 409	400	3 706	932
Vanuatu *	3 360	2 729	8 837	6 359
Wallis and Futuna	100	180	263	419
Total	**569 077**	**702 972**	**1 496 062**	**1 175 641**

Sources:

[1] FAO Yearbook Vol. 82. FAO, Rome and FAO. 1998. Aquaculture production statistics. FAO Fish. Circ. 815, Rev. 10.

* Members or observers of the Alliance of Small Island Developing States (or AOSIS). Other AOSIS members are not included because of lack of equivalent available data.

Trends (1988-1996) in marine catch, inland catch and aquaculture by developing country.

Table 2.4a. Sub-Saharan Africa.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2] (mt)	
	1988	1996	1988	1996	1988	1996
Angola	93 783	66 841	8 000	6 000	—	—
Benin	8 668	7 000	28 541	35 000	58	—
Botswana	—	—	1 900	2 100	—	—
Burkina Faso	—	—	7 909	7 500	7	0
Burundi	—	—	11 677	9 990	24	10
Cameroon	50 529	63 984	20 000	20 000	167	55
Central African Republic	—	—	13 000	12 650	79	350
Chad	—	—	58 000	100 000	—	—
Congo Democratic Republic	2 000	3 973	159 241	158 288	759	750
Congo Republic	22 377	15 285	19 423	18 500	177	5
Côte d'Ivoire	60 936	59 000	28 400	11 650	170	350
Djibouti	454	360	0	0	—	—
Equatorial Guinea	3 600	1 906	400	400	—	—
Ethiopia	723	—	3 343	8 770	1	85
Gabon	20 191	35 768	1 900	9 409	2	3
Gambia	11 152	29 021	2 700	2 500	—	4
Ghana	304 294	403 043	57 630	73 580	427	550
Guinea	35 000	60 580	3 000	4 000	1	4
Guinea Bissau	4 540	6 750	150	250	—	—
Kenya	7 970	5 688	129 819	172 666	561	605
Lesotho	—	—	0	28	30	14
Liberia	12 074	3 232	4 000	4 000	2	0
Madagascar	61 116	83 015	39 771	30 000	231	5 075
Malawi	—	—	78 602	63 569	215	235
Mali	—	—	55 858	111 910	17	60
Mauritania	91 600	79 000	6 000	6 000	—	—
Mozambique	32 185	29 341	3 248	5 574	24	37
Namibia	32 416	265 785	979	1 195 —		936
Niger	—	—	2 479	4 135	25	21
Nigeria	168 611	169 817	100 272	67 794	10 631	16 619
Reunion	2 020	5 195	0	0	33	4

Table 2.4a. Sub-Saharan Africa, continued.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
Rwanda	—	—	1 290	3 000	38	50
Senegal	243 726	388 759	17 000	47 500	43	78
Sierra Leone	36 273	46 830	16 000	14 500	20	30
Somalia	17 727	14 750	500	250	—	—
Sudan	1 200	4 348	28 000	43 567	45	1 000
Swaziland	—	—	90	60	20	93
Tanzania	49 199	48 186	343 722	308 431	37	200
Togo	11 955	10 098	3 509	5 000	5	21
Uganda	—	—	214 291	195 088	34	210
Zambia	—	—	59 437	61 562	1 147	4 770
Total	**1 386 319**	**1 907 555**	**1 530 081**	**1 626 416**	**15 030**	**32 224**

Table 2.4b. South Asia.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
Bangladesh	244 853	279 170	430 242	595 177	154 834	390 088
Bhutan	—	—	300	300	15	30
India	1 786 637	2 840 919	445 995	651 079	893 330	1 768 422
Nepal	—	—	6 975	11 230	5 125	10 649
Myanmar	559 727	635 537	139 147	169 300	5 673	68 135
Pakistan	348 897	395 340	89 748	142 092	6 850	18 057
Sri Lanka	159 524	210 250	33 012	14 750	5 669	7 500
Total	**3 099 638**	**4 361 216**	**1 145 419**	**1 583 928**	**1 071 496**	**2 262 881**

Table 2.4c. East Asia.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
China	5 028 048	12 459 446	721 102	1 762 860	5 630 454	17 714 570
Mongolia	—	—	281	231	—	—
North Korea	1 560 200	1 622 000	92 000	103 000	65 800	75 000
South Korea	2 245 917	2 405 692	29 391	8 077	457 057	358 003
Total	**8 834 165**	**16 487 138**	**842 774**	**1 874 168**	**6 153 311**	**18 147 573**

Table 2.4d. South East Asia.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
Brunei	1 934	7 390	106	15	2	119
Indonesia	2 083 596	3 385 440	298 460	344 370	413 152	672 130
Malaysia	825 631	1 126 689	996	4 000	46 957	109 002
Philippines	1 435 475	1 606 240	231 829	184 145	343 059	342 678

Table 2.4d. South East Asia, continued.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
Taiwan	1 056 322	967 076	2 853	407	294 345	262 276
Thailand	233 555	2 934 600	96 614	203 644	219 101	509 656
Kampuchea	21 000	31 200	61 200	63 510	4 600	9 600
Laos	—	—	21 000	26 000	7 000	14 400
Vietnam	623 400	684 000	135 000	127 000	141 600	189 000
TOTAL	**6 280 913**	**10 742 635**	**848 058**	**953 091**	**1 469 816**	**2 108 861**

Table 2.4e. Central and South America.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
Argentina	482 569	1 225 960	10 595	11 682	353	1 332
Bolivia	—	—	4 332	5 988	95	380
Brazil	623 997	620 719	190 566	178 000	15 559	51 281
Chile	5 200 595	6 692 653	9	—	9 240	217 903
Colombia	37 928	106 600	48 685	23 061	3 314	29 990
Costa Rica	16 370	22 075	300	2 128	399	6 986
Ecuador	799 815	684 506	578	300	75 631	109 085
El Salvador	10 312	9 338	703	2 742	718	1 144
French Guyana	5 477	7 977	0	0	63	—
Guatemala	2 332	3 653	473	4 000	920	3 421
Guyana	35 680	44 110	800	700	43	190
Honduras	17 056	13 956	50	98	2 845	10 065
Mexico	1 142 737	1 305 615	156 906	117 153	72 952	76 635
Nicaragua	4 540	14 300	114	1 137	74	2 573
Panama	119 458	139 076	37	80	4 187	5 079
Paraguay	—	—	10 000	21 650	54	350
Peru	6 597 459	9 486 158	39 477	38 890	4 958	6 912
Puerto Rico	1 611	2 311	0	0	86	113
Suriname	3 558	12 999	126	150	0	1
Uruguay	107 142	122 763	201	598	5	21
Venezuela	254 765	429 479	30 710	55 050	712	5 665
TOTAL	**15 463 401**	**20 944 248**	**494 662**	**463 407**	**192 208**	**529 126**

Table 2.4f. WANA.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
Afghanistan	—	—	1 000	1 300	—	—
Algeria	106 434	99 665	88	13	222	322
Bahrain	6 736	12 940	0	0	—	—
Egypt	64 266	93 101	167 781	172 095	52 200	75 837
Iran	188 515	242 437	20 090	109 286	26 400	29 977
Iraq	5 000	2 000	16 461	7 000	7 084	3 000
Jordan	2	2	300	350	70	181

Table 2.4f. WANA, continued.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
Kuwait	10 788	8 163	0	0	8	90
Lebanon	1 700	4 115	0	20	100	350
Libya	21 652	33 732	0	0	30	100
Morocco	550 461	636 293	1 243	1 500	158	2 300
Oman	165 676	121 616	0	0	0	—
Qatar	3 086	4 739	0	0	—	1
Saudi Arabia	45 733	47 709	0	0	331	3 073
Syria	1 251	2 670	1 242	3 103	3 040	6 355
Tunisia	102 003	82 861	0	706	1 053	1 481
Turkey	621 608	472 055	48 499	49 600	4 100	33 201
United Arab Emirates	89 500	107 000	0	0	6	0
Yemen	73 156	101 045	—	2 698	—	—
Total	**2 057 567**	**2 072 143**	**256 704**	**347 671**	**94 802**	**156 268**

Table 2.4g. SIDS.

	Marine capture[1] (mt)		Inland capture[1] (mt)		Aquaculture[2**] (mt)	
	1988	1996	1988	1996	1988	1996
American Samoa	99	259	0	0	—	—
Barbados *	9 097	3 439	0	0	—	—
Belize *	1 497	977	1	—	—	1 004
Cape Verde *	6 276	9 187	0	0	—	—
Comoros *	5 700	13 000	0	0	—	—
Cook Is *	1 100	1 000	0	10	0	0
Cuba *	214 528	73 472	842	6 762	15 880	28 467
Cyprus *	2 495	2 575	1	64	59	465
Dominican Republic	11 435	12 606	1 200	1 205	277	789
Fed State of Micronesia	2 631	9 336	3	5	0	0
Fiji *	27 999	28 413	4 444	3 034	12	235
French Polynesia	2 794	9 910	0	0	65	67
Guam *	367	121	7	0	198	220
Guadeloupe	8 170	9 570	21	0	42	30
Haiti	5 200	5 500	300	500	—	—
Jamaica *	7 531	12 133	332	710	2 442	3 100
Kiribati *	23 190	24 948	—	—	32	52
Marshall Island	190	270	0	0	—	—
Martinique	3 000	3 266	0	0	53	58
Maldives *	71 483	105 558	0	0	—	—
Mauritius *	17 079	12 379	2	—	73	165
Nauru *	170	400	0	0	—	—
New Caledonia	3 452	2 523	0	0	232	1 005
Northern Mariana Island	201	225	0	—	—	—
Niue *	115	113	0	0	—	—
Palau	1 507	1 300	0	0	—	—
Papua New Guinea	11 464	12 585	14 500	13 592	7	23
Pitcairn Island	4	8	0	0	—	—
Samoa *	2 500	698	0	0	—	0
Singapore *	13 151	9 943	130	—	1 969	3 567
Solomon Island *	55 136	53 275	0	0	5	11
St. Lucia *	782	1 271	0	0	0	2
Tokelau	200	210	0	0	—	—
Tonga *	2 717	2 841	0	0	—	—

Table 2.4g, continued.

	Marine capture (mt)		Inland capture (mt)		Aquaculture** (mt)	
	1988	1996	1988	1996	1988	1996
Trinidad and Tobago	7 587	12 793	0	0	—	12
Tuvalu *	1 409	400	0	0	—	—
Vanuatu *	3 360	2 729	0	0	—	—
Wallis and Futuna	100	180	0	0	—	—
Total	**525 716**	**439 413**	**21 783**	**25 882**	**21 346**	**39 272**

Sources:
[1] FAO. 1998. Fishery statistics: capture production. FAO Yearbook Vol. 82.
[2] FAO. 1998. Aquaculture production statistics. FAO Fish. Circ. 815 Rev. 10.
* Members or observers of the Alliance of Small Island Developing States (or AOSIS). Other AOSIS members are not included because of lack of equivalent available data.
** Aquaculture includes fish and shellfish only.

Trends (1988-1996) in total value of aquaculture and apparent fish consumption by developing country.

Table 2.5a. Sub-Saharan Africa.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave. 1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Angola	—	—	8.6	88 399
Benin	205	—	10.6	53 933
Botswana	—	—	5.6	7 846
Burkina Faso	21	0	1.3	12 705
Burundi	121	15	3.7	22 300
Cameroon	283	173	8.9	111 481
Central African Repepublic	267	880	4.4	13 886
Chad	—	—	6.3	37 882
Congo Democratic Republic	1 217	825	6.7	
Congo Republic	145	15	25.9	63 274
Cote d'Ivoire	447	792	12.2	162 492
Djibouti	—	—	1.8	1 001
Equatorial Guinea	—	—	22.8	8 641
Ethiopia	3	204	0.1	5 298
Gabon	8	11	37.0	46 176
Gambia	—	2	17.9	18 652
Ghana	462	960	21.1	347 095
Guinea	5	16	9.9	62 449
Guinea Bissau	—	—	5.0	5 140
Kenya	1 530	1 373	5.9	155 689
Lesotho	38	29	2.7	5 246
Liberia	5	0	4.5	12 803
Madagascar	244	16 233	6.5	90 077
Malawi	220	219	6.3	66 200
Mali	21	63	8.4	85 151
Mauritania	—	—	17.4	37 619
Mozambique	31	59	1.9	28 730
Namibia	—	421	11.2	16 363
Niger	79	54	0.5	4 277
Nigeria	13 219	42 884	5.8	610 665
Reunion	349	70	27.3	17 308
Rwanda	86	78	0.7	5 289

Table 2.5a, continued.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave. 1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Senegal	116	376	27.8	219 731
Sierra Leone	6	33	14.9	64 040
Somalia	—	—	1.3	11 655
Sudan	23	1 200	1.7	
Swaziland	40	178	0.2	5 329
Tanzania	26	344	10.7	8 656
Togo	11	41	12.0	336 276
Uganda	7	210	10.2	39 637
Zambia	1 092	20 038	9.0	179 469
Total	**20 327**	**87 796**	**9.9**	

Table 2.5b. South Asia.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave. 1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Bangladesh	213 199	806 451	9.1	1 048 620
Bhutan	15	38	—	—
India	1 023 411	1 979 604	4.4	3 966 534
Nepal	7 031	10 870	0.8	16 653
Myanmar	12 954	704 440	15.9	709 156
Pakistan	6 795	13 408	2.1	279 231
Sri Lanka	7 849	31 575	18.9	338 272
Total	**1 271 254**	**3 546 386**	**8.5**	

Table 2.5c. East Asia.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave. 1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
China	7 277 932	17 886 099	19.1	22 451 076
Mongolia	—	—	0.7	1 623
North Korea	220 900	247 000	46.5	1 071 779
South Korea	318 548	685 618	47.7	2 105 096
Total	**7 817 380**	**18 818 717**	**28.5**	

Table 2.5d. South East Asia.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave.1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Brunei	10	977	26.5	7 261
Indonesia	943 217	2 020 197	17.1	3 277 643
Malaysia	36 989	159 954	54.5	1 048 907
Philippines	695 982	1 195 661	33.8	2 190 409
Taiwan	1 195 668	177 528	38.2	795 439
Thailand	501 429	1 836 725	25.9	1 491 322
Kampuchea	9 356	23 254	8.5	82 306
Laos	10 500	36 000	6.6	30 393
Vietnam	235 400	514 300	13.4	955 822
Total	**3 628 551**	**6 964 596**	**24.9**	

Table 2.5e. Central and South America.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave.1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Argentina	527	9 067	10.1	341 178
Bolivia	215	1 092	1.5	10 598
Brazil	71 249	226 908	6.4	1 001 491
Chile	48 911	787 102	28.4	392 545
Colombia	20 312	137 862	3.9	132 542
Costa Rica	2 125	35 979	6.0	19 620
Ecuador	578 745	649 947	7.2	79 063
El Salvador	2 778	3 250	2.3	12 691
French Guyana	636	—	33.7	4 550
Guatemala	5 328	14 512	1.1	11 035
Guyana	130	475	42.1	34 354
Honduras	15 267	69 289	1.1	5 870
Mexico	54 799	87 089	11.0	990 264
Nicaragua	480	10 287	1.4	5 761
Panama	27 333	32 099	16.4	41 623
Paraguay	38	350	3.8	17 864
Peru	25 141	53 590	23.8	544 734
Puerto Rico	622	377	—	—
Suriname	0	2	19.2	7 949
Uruguay	17	145	8.2	25 822
Venezuela	1 209	27 463	17.6	368 051
Total	**855 862**	**2 146 885**	**12.3**	

Table 2.5f. WANA.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave.1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Afghanistan	—	—	0.1	1 773
Algeria	918	861	4.2	112 241
Bahrain	—	—	16.8	8 988
Egypt	68 660	167 567	7.3	440 292
Iran	230 250	306 625	5.2	333 554
Iraq	85 178	30 000	0.9	17 518

Table 2.5f. WANA, continued.

	Total value of aquaculture[1] US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave. 1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Jordan	339	809	3.7	15 092
Kuwait	100	585	11.4	20 315
Lebanon	308	1 750	4.1	11 509
Libya	30	150	6.6	33 330
Morocco	599	13 430	8.1	210 155
Oman	0	—	22.1	44 045
Qatar	—	6	18.4	9 734
Saudi Arabia	1 257	10 804	6.0	102 786
Syria	18 468	28 987	0.8	10 960
Tunisia	2 341	7 494	9.0	77 130
Turkey	14 818	178 275	8.4	500 623
United Arab Em	17	0	24.5	44 468
Yemen	—	—	6.1	80 477
Total	**423 283**	**747 343**	**9.1**	

Table 2.5g . SIDS.

	Total value of aquaculture[1] (US$'000)		Apparent fish consumption[2] (kg/yr/person) (Ave. 1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
American Samoa	—	—	—	—
Barbados *	—	—	27.1	7 046
Belize *	—	6 310	6.8	1 387
Cape Verde *	—	—	17.4	6 438
Comoros *	—	—	22.7	13 779
Cook Is *	0	0	61.6	1 170
Cuba *	13 051	21 575	11.4	123 964
Cyprus *	605	4 518	18.2	13 213
Dominican Republic	4 195	2 950	7.2	54 302
Fed State of Micronesia	0	0	—	—
Fiji *	68	982	33.4	25 818
French Polyne	301	478	37.6	8 272
Guam *	497	756	—	—
Guadeloupe	1 131	704	41.5	17 140
Haiti	—	—	2.3	15 856
Jamaica *	4 452	9 387	16.1	38 817
Kiribati *	59	97	73.3	5 644
Marshall Island	—	—	—	—
Martinique	1 100	1 064	48.4	17 956
Maldives *	—	139.8		
Mauritius *	550	1 481	27.1	29 566
Nauru *	—	—	—	—
New Caledonia	3 265	10 737	19.9	3 920
Northern Mariana Island	—	—	—	—
Niue *	—	—	—	—
Palau	—	—	—	—
Papua New Guinea	20	66	13.2	54 252
Pitcairn Island	—	—	—	—
Samoa *	—	0	45.7	7 358
Singapore *	4 924	13 087	31.8	88 786
Solomon Island*	75	154	33.5	9 548
St. Lucia *	0	15	21.4	2 953
Tokelau	—	—	—	—
Tonga *	—	—	25.8	2 503

Table 2.5g. SIDS, continued.

	Total value of aquaculture[2] (US$'000)		Apparent fish consumption[3] (kg/yr/person) (Ave. 1993-1995)	Apparent fish consumption (mt/yr) (weighted)
	1988	1996		
Trinidad and Tobago	—	60	8.3	10 607
Tuvalu *	—	—	—	—
Vanuatu *	—	—	24.8	3 522
Wallis and Futuna	—	—	—	—
Total	**34 293**	**74 421**	**31.4**	

[1] FAO. 1998. Aquaculture production statistics. FAO Fish. Circ. 815 Rev. 10.

[2] FAO. 1998. Fishery statistics: Commodities. FAO Yearbook. Vol. 83.

* Members or observers of the Alliance of Small Island Developing States (or AOSIS). Other AOSIS members are not included because of lack of equivalent available data.

Trade statistics[1] (1988-1996) by developing country.

Table 2.6a. Sub-Saharan Africa.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
Angola	108 315	57	3 128	1 848	53 760	358	6 296	4 060
Benin	4 908	12 686	—	166	1 614	6 486	—	1 259
Botswana	1 481	1 168	219	10	2 066	1 927	749	32
Burkina Faso	5 782	1 200	—	161	3 854	1 406	—	170
Burundi	—	0	—	4	—	1	—	150
Cameroon	63 600	41 112	812	366	43 713	12 936	5 993	1 235
Central African Republic	161	54	—	—	164	27	—	—
Chad	—	—	—	—	—	—	—	—
Congo	24 098	18 693	9	49	14 484	9 359	74	604
Comoros	80	461	—	—	250	226	—	—
Côte d'Ivoire	206 370	182 485	32 179	1 155	133 830	131 654	36 376	6 299
Djibouti	95	27	19	10	540	235	73	81
Equatorial Guinea	1 205	1 336	—	476	570	1 410	—	2 878
Ethiopia	—	—	6	—	—	1	1	—
Gabon	3 227	5 107	1 390	877	3 535	4 024	5 390	4 907
Gambia	6 794	111	4 961	798	4 800	73	2 133	2 145
Ghana	33 120	20 435	25 235	12 056	26 500	14 689	20 801	17 690
Guinea	7 000	62	—	4 688	3 400	78	—	16 051
Guinea Bissau	—	—	460	5 173	—	28	1 400	9 642
Kenya	1	3 123	5 034	16 144	4	6 168	9 768	50 389
Lesotho	—	—	—	—	—	—	—	—
Liberia	11 000	2 410	500	202	5 000	2 019	0	601
Madagascar	—	12 488	5 549	9 912	—	11 643	35 483	68 817
Malawi	19	—	42	20	46	—	284	450
Mali	1 300	400	—	—	850	370	—	—
Mauritania	—	—	79 564	44 036	—	—	169 509	149 387
Mozambique	10 907	4 276	—	7 585	4 200	573	—	35 470
Namibia	—	682	—	66 414	—	1 629	—	102 163
Niger	143	1 009	—	97	178	291	—	221
Nigeria	270 833	229 438	3 010	6 295	103 792	114 772	7 596	40 973
Reunion	3 095	2 695	307	1 110	14 279	13 739	4 707	12 782
Rwanda	—	85	—	—	—	80	—	—
Senegal	34 508	14 676	48 060	80 029	36 185	10 264	110 902	253 455
Sierra Leone	2 700	1 800	1 513	7 216	805	2 601	8 220	16 502
Somalia	—	26	3 016	2 971	—	71	7 800	7 349
Sudan	—	30	—	0	—	27	—	16
Swaziland	—	—	—	—	—	—	—	—

[1] Sum of fish, crustaceans and molluscs (fresh, chilled or frozen).

Table 2.6a. Sub-Saharan Africa, continued.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
Tanzania	—	6	—	11 553	—	18	—	21 038
Togo	20 692	15 848	276	181	11 081	6 671	1 192	1 299
Uganda	—	—	—	8 021	—	—	—	33 943
Zambia	18	60	676	103	64	50	355	399
Zimbabwe	200	13 308	3	771	430	19 892	20	727
Total	**821 652**	**587 354**	**215 968**	**290 497**	**469 994**	**375 796**	**435 122**	**863 184**

Table 2.6b. South Asia.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
Bangladesh	—	1	25 831	32 474	—	7	154 118	240 887
Bhutan	—	—	—	—	—	—	—	—
India	—	450	94 607	289 153	—	790	410 843	968 750
Nepal	—	1	—	0	—	15	—	1
Myanmar	—	—	2 900	17 916	—	—	8 503	97 920
Pakistan	9	1	26 780	45 480	94	6	105 617	120 229
Sri Lanka	48	2 017	672	6 663	2 764	3 952	24 950	63 208
Total	**57**	**2 018**	**27 452**	**52 143**	**2 858**	**3 958**	**130 567**	**183 437**

Table 2.6c. East Asia.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
China	107 813	457 910	263 095	620 325	77 309	561 759	922 870	1 648 509
Mongolia	—	1	—	195	—	3	—	134
North Korea	—	1 274	79 485	44 251	—	3 186	82 850	56 512
South Korea	344 242	418 593	439 436	317 294	291 274	869 055	1 381 036	1 066 484
Total	**452 055**	**877 778**	**782 016**	**982 065**	**368 583**	**1 434 003**	**2 386 756**	**2 771 639**

Table 2.6d. South East Asia.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
Brunei	1 263	1 914	—	0	3 509	4 249	—	29
Indonesia	4 514	15 020	141 046	466 784	2 810	16 883	619 844	1 488 355
Malaysia	164 385	241 267	113 169	175 127	83 144	291 198	115 154	216 330
Philippines	113 881	171 661	48 910	74 668	32 775	80 014	305 325	292 295
Taiwan China	—	90 173	—	577 418	—	302 394	—	1 627 939
Thailand	303 423	510 467	262 127	314 656	522 135	500 772	757 285	405 332
Kampuchea	—	—	—	—	—	—	—	—
Laos	—	575	—	46	—	224	—	171
Vietnam	—	1 412	37 792	87 012	—	3 463	179 174	450 552
Total	**587 466**	**1 032 489**	**603 044**	**1 695 711**	**644 373**	**1 199 197**	**1 976 782**	**4 481 003**

Table 2.6e. Central and South America.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
Argentina	15 337	8 105	193 911	510 421	12 901	19 437	249 011	759 519
Bolivia	36	2 634	134	10	76	997	58	4
Brazil	49 911	238 408	43 353	21 143	29 280	219 639	179 261	120 704
Chile	—	4 162	90 696	219 198	—	17 720	226 625	844 529
Colombia	1 518	19 108	19 771	65 640	2 544	28 039	62 310	165 772
Costa Rica	8 730	24 455	10 131	23 592	9 167	25 499	47 675	123 547
Ecuador	—	17 696	82 348	128 126	0	15 456	373 512	718 769
El Salvador	659	128	3 594	5 921	500	226	17 217	41 723
French Guyana	528	1 425	3 524	1 721	1 239	3 214	30 937	41 360
Guatemala	377	154	1 788	5 784	272	414	14 265	37 565
Guyana	—	1	3 070	5 733	—	22	16 795	19 251
Honduras	—	517	13 423	10 779	110	3 087	51 158	63 284
Mexico	6 846	11 121	126 679	154 450	10 753	27 191	411 655	625 583
Nicaragua	—	18	1 130	9 524	—	105	9 579	74 718
Panama	40	322	11 073	20 320	247	1 291	71 515	107 884
Paraguay	54	340	28	17	47	856	15	31
Peru	10	2 232	26 594	96 731	55	1 701	35 036	163 466
Puerto Rico	—	—	—	—	—	—	—	—
Suriname	80	24	703	2 974	100	87	2 940	10 136
Uruguay	195	1 070	58 741	91 509	198	1 717	61 669	89 049
Venezuela	6	5 785	8 956	40 360	34	5 214	12 464	67 236
Total	**84 327**	**337 705**	**699 647**	**1 413 953**	**67 523**	**371 912**	**1 873 697**	**4 074 130**

Table 2.6f. WANA.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
Afghanistan	—	—	—	—	—	—	—	—
Algeria	2 798	1 001	76	651	4 142	1 719	305	3 264
Bahrain	657	1 656	578	5 713	2 173	3 319	1 889	9 647
Egypt	100 245	173 357	975	1 601	44 498	89 403	3 371	2 654
Iran	15	10 087	750	6 318	86	7 221	5 189	22 654
Iraq	—	—	—	—	—	—	—	2
Jordan	3 252	9 194	134	1 178	3 801	14 687	121	2 314
Kuwait	8 703	5 165	1 610	499	23 903	13 079	14 794	5 769
Lebanon	—	6 300	—	—	—	10 500	—	—
Libya	200	1 171	—	5 549	160	2 355	520	31 169
Morocco	1 378	1 992	113 821	121 165	1 361	2 222	297 234	559 788
Oman	371	1 404	34 146	55 292	1 210	2 219	48 118	58 635
Qatar	232	705	—	0	781	1 948	—	5
Saudi Arabia	23 728	32 206	1 442	159	31 751	38 407	3 656	1 105
Syria	12	20	52	0	207	276	77	1
Tunisia	871	1 829	16 586	12 436	1 168	3 205	102 129	87 598
Turkey	2 235	29 211	17 944	11 455	1 470	32 238	38 930	47 226
United Arab Em	2 469	4 896	1 888	3 836	8 907	18 488	3 912	12 488
Yemen	—	—	2 848	2 472	—	—	10 670	7 634
Total	**147 166**	**280 194**	**192 850**	**228 324**	**125 618**	**241 286**	**530 915**	**851 953**

Table 2.6g. SIDS.

	Imported quantity (mt)		Exported quantity (mt)		Import value (US$'000)		Export value (US$'000)	
	1988	1996	1988	1996	1988	1996	1988	1996
American Samoa	—	—	—	—	—	—	—	—
Barbados *	301	794	62	113	1 505	3 411	216	549
Belize *	—	—	751	1 148	—	—	6 237	12 427
Cape Verde *	—	4	1 077	208	—	22	1 420	1 201
Comoros *	—	461	—	—	—	226	—	—
Cook Is *	—	58	—	186	—	99	—	494
Cuba	—	19 579	23 934	8 169	—	8 441	144 856	84 553
Dominican Republic	581	1 012	916	90	990	2 353	1 106	611
Fed State of Micronesia	9	—	—	63	25	—	—	342
Fiji *	19 449	14 188	2 735	7 994	17 432	18 505	5 782	26 329
French Polynesia	537	822	—	—	3 117	1 816	—	—
Guam *	—	—	—	—	—	—	—	—
Guadeloupe	2 020	2 496	5	51	8 610	13 318	88	184
Haiti	—	2 375	—	57	—	924	4 320	1 238
Jamaica *	3 567	21 875	297	3 725	4 955	17 461	2 179	25 617
Kiribati *	—	—	—	673	—	—	—	1 865
Marshall Is *	7	25	—	526	20	63	—	1 490
Martinique	3 386	1 625	98	27	12 806	14 460	957	150
Maldives *	—	—	20 264	15 065	—	—	17 727	21 616
Mauritius *	3 081	28 106	553	360	4 484	35 806	2 535	1 612
Nauru *	—	—	—	—	—	—	—	—
New Caledonia	325	591	1 311	1 455	1 528	2 689	3 080	9 048
Northern Maria	—	—	—	—	—	—	—	—
Niue *	—	—	—	—	—	—	—	—
Palau	—	794	—	44	—	1 918	—	241
Papua New Guinea	810	9 559	1 206	1 165	1 105	6 453	10 041	9 315
Pitcairn	—	—	—	—	—	—	—	—
Samoa *	—	—	—	99	—	—	—	384
Singapore *	162 195	164 956	110 979	120 644	285 235	468 855	307 659	448 607
Solomon Island	—	—	35 810	23 285	—	—	32 719	14 694
St. Lucia *	197	—	37	—	737	102	139	—
Tokelau	—	—	—	—	—	—	—	—
Tonga *	14	17	457	312	31	64	1 852	1 602
Trinidad and Tobago	410	114	1 041	5 504	593	390	4 222	11 661
Tuvalu *	—	—	—	260	—	—	—	391
Vanuatu *	9	—	—	231	66	4	33	385
Wallis and Futuna	—	—	—	—	—	—	—	—
Total	**196 898**	**269 451**	**201 533**	**191 454**	**343 239**	**597 380**	**547 168**	**676 606**

Sources:
FAO. 1998. Fishery statistics: Commodities. FAO Yearbook. Vol. 83.
FAO. 1991. Fishery statistics: Commodities. FAO Yearbook. Vol. 73.
* Members or observers of the Alliance of Small Island Developing States (or AOSIS). Other AOSIS members are not included because of lack of equivalent available data.

Part III

Setting priorities

- The resource system approach
- ICLARM's earlier Strategic Plan
- A review of priorities
- Definition of regions and determining regional priorities
- Adjustments in regional groupings
- Outcomes and directions for ICLARM's Strategic Plan
- Lessons learned from the resource system approach

contents Part I Part III ?

This section describes the approach taken to ICLARM's research priority setting which utilized the contributory data included in this book.

The resource system approach

ICLARM[1] has set its research priorities based on aquatic resource systems which are defined as "the zone of convergence of the resources, their aquatic environment and the human resources". The aquatic resources in this case are fish and other useable aquatic biota in an aquatic habitat and the uses considered are for food, other economic purposes such as recreation, ornament, culture and environmental services. This definition makes an aquatic resource system analogous to an agroecosystem or forest system.

ICLARM's earlier Strategic Plan

ICLARM's previous strategic plan, which has governed the operations of the Institute since 1992, was written in preparation for the Center to join the CGIAR. The earlier plan premised its analysis on a global view of fisheries and aquaculture deduced from the Center's experience and the official statistics of the FAO for 1988. It introduced the concept of resource systems, slightly modified in the current analysis. The earlier procedure analyzed resource systems in terms of productivity, which was modified by potential for increases in production leading to a subsequent ranking of resource systems in terms of importance. This ranking was further modified by such values as threats to sustainability and equity. In the case of regional priorities, quantity of production was modified by numbers of poor people and apparent requirements for NARS strengthening. While this mechanistic method had the benefit of being transparent, the actual values given to the various modifiers were subjective and in one case, have been disputed[2]. However, the outcomes of the plan: a focus on pond aquaculture, coastal resource systems and coral reefs, largely have not been challenged. Indeed, ICLARM's analysis was one of the early attempts to gauge priorities for the application of research in aquatic resources for the benefit of poor people.

Since that time, there has been a considerable change in the global perception of the sustainability of capture fisheries and an increase in knowledge and methodologies for natural resource management research. There has also been a major revolution in aquaculture, in which developing countries figure strongly, which has increased both in terms of total production, and value, and has provided opportunities for foreign exchange earning at the national level and food security, livelihood and income generating opportunities at the farm and community level[2]. Thus, eight years after the initial priority setting, ICLARM has sought to reevaluate these strategic research directions. A reassessment of its comparative advantage in the changing world of fisheries globally has been included encompassing new opportunities provided by growth and the attainment of new facilities.

In ICLARM's current review of future strategic directions for research, eight main types of resource systems in marine and inland environments have been categorized and evaluated for their importance to poor people. These are defined (see earlier section on definitions) as: (1) farm ponds; (2) reservoirs, lakes and small water bodies; (3) floodplains, rivers and streams; (4) coastal waters—including estuaries and

[1] ICLARM. 1992. ICLARM's strategy for international research on living aquatic resources management. 79 p. with Annex.

[2] De Silva, S.S. 1995. A case for a higher priority for reservoir-lake system research. Naga, ICLARM Q. 18:10-14.

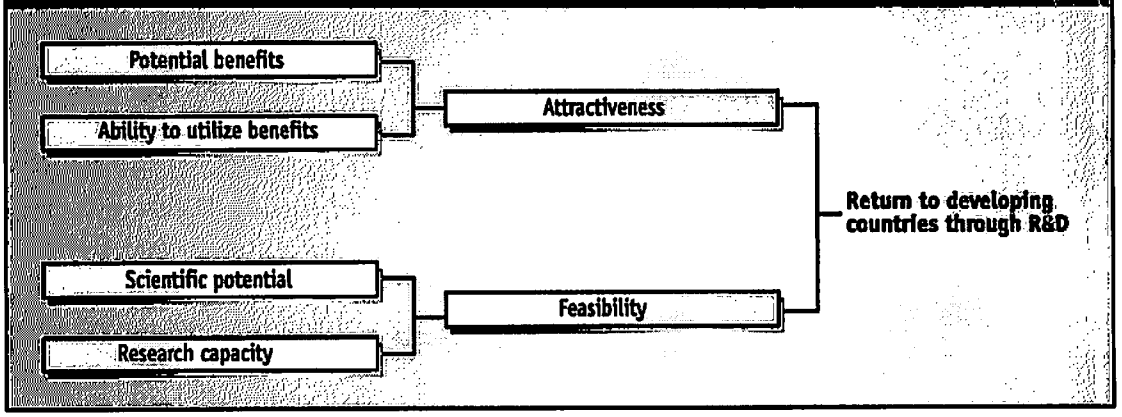
lagoons; (5) coral reefs; 6) soft-bottom shelves; (7) upwelling shelves; and (8) open oceans. In the analysis for the current plan, a ninth grouping, small island developing states (SIDS) were analyzed as a regional grouping and as nations which have particular dependence on resource systems 4, 5 and 8.

A review of priorities

In the current review, and benefiting from continuity with the previous approach, more recent fisheries and aquaculture production statistics (1996 figures from the FAO[3]) have been allotted by resource system. Data were collected on total production, growth rate and forecasts, and trade statistics and an estimate of the numbers of producers and users. Resource systems were evaluated in terms of ecology and biodiversity. Government policies and regulations, which would affect the potential growth and utility of its resource system, were listed. The resource system was analyzed by a SWOT test to determine major opportunities for production and major risks to the exploitation of the resource system, particularly for ICLARM's target clientele. For each resource system, the research issues were defined and ICLARM's role and position with respect to the different research possibilities was evaluated. Data were presented (this vol., Part II) as evaluation sheets listing potential benefits of research, the ability to utilize the outcomes of research, existing or anticipated science potential to answer the key problems, and research and adoption capacity of the intended recipients.

The planning process centered on the conceptual framework shown in Fig. 3.1. Parameters governing research choices were scored separately and in combination. Then each resource system was scored for attractiveness (a measure of the potential benefits from conducting research, and the ability to utilize the outcomes in the region) against feasibility (a measure of the scientific potential to provide solutions to aquatic resource issues and ICLARM's research capacity to undertake the research alone or in partnership).

Fig. 3.1. Conceptual framework for establishing priorities.



[3] Complete production and trade statistics for 1996 only became available after the planning workshop described below so that the data considered by the planning workshop participants were complete to 1994, and trends were based on 1988 to 1994 values. The most recent FAO statistics have shown apparent, major increases in production, particularly in aquaculture and in the national figures for China. Also some revision of previously published figures means that the current data set (kindly provided by the FAO as FishStat on diskette) does not always allow comparison with the 1988 data used in the 1992 Strategic Plan.

Definition of regions and determining regional priorities

For the evaluation of research priorities by region, and to avoid confounding developed country statistics included in the regions of the world defined by the FAO, ICLARM initially divided the developing world into Sub-Saharan Africa, South Asia, the Mekong Basin countries, East Asia, South East Asia and the Pacific, Latin America and the Caribbean, and West Asia and North Africa. Data were developed on human populations at the country level and for these regional aggregations, and World Bank population projections were included to 2020. The indicators of poverty that were used were the percentage of a country's population below the poverty line, and the numbers of the malnourished children under the age of five years (see Tables in Section 1).

The Strategic Planning meeting adopted, on the basis of the agreed data, a delphi approach to the determination of priority. All participants scored regions in terms of poverty and nutritional need and with a single indicator for environmental need. Regions were also scored for the nutritional and cultural importance of aquatic resources and their products, and resource availability (a measure of the importance of particular resource systems in different regions). The groups compared scores and discussed outliers, if any, to produce agreed rankings.

In terms of regional needs assessment, when poverty and nutritional need were plotted against environmental need, South Asia was identified as the highest priority region. Sub-Sarahan Africa and the Mekong Basin countries were considered to have high poverty and nutritional needs but, in the case of Sub-Saharan Africa, the environmental problems for aquatic resources can be severe in certain localities, but are not as acute or widespread at the subcontinental level as they are in South East and East Asia. In Asia, current population levels and existing threats to aquatic resource systems provide an immediate imperative for research. Aquatic resources were considered to have a more reduced role in the alleviation of poverty and food security in WANA and LAC. When regional needs were plotted against the parameter of resource importance, South East Asia and the Pacific scored highest followed by East Asia, the Mekong Basin countries and South Asia. For the parameter of regional needs, South Asia again scored highest. The resource importance for ICLARM's stakeholders was considered to be lowest in LAC and WANA.

Adjustments in regional groupings

During the planning workshop, it was agreed that the linking of the small island states of the Indo-Pacific with other Asian regions, or the Caribbean island states with continental Latin America, obscure the key importance of aquatic resources to the SIDS for food security, livelihoods and income, and the critical requirement for natural resources management research in these islands to protect these resources for the future. Thus, in terms of natural resource management research, the SIDS were given an equivalent ranking to South East Asia recognizing that this overall priority is subject to two conflicting measures (i) they have small total populations when judged against other regional groupings, but (ii) they are critically dependent upon the sustainability of coastal, coral reef and offshore fishery resources.

Further, the separation of the Mekong Basin countries, in which some countries are highly dependent upon the resources of the Mekong and its floodplains, was not considered appropriate when other aquatic resource issues were considered or other potential floodplains of the world. ICLARM has subsequently considered the Mekong Basin countries within South East Asia. However, with around 45 to 88% of the populations of the four principal countries living within the Mekong watershed, any floodplain research to be undertaken by ICLARM within the planning period should be focused on this area of South East Asia (and on the floodplain regions of South Asia). The final strategic decisions were therefore developed on the basis of the seven regional groupings outlined in Part I. Further data on the

"potential beneficiary populations" in these regions were determined by estimating human populations resident in inland watersheds or in coastal areas (see Tables 1.9-1.16).

Outcomes and directions for ICLARM's Strategic Plan

A general outcome of the evaluation was that, in the order of resource systems given above, aquaculture in ponds provided the most tractable system in terms of both research and capture of the potential benefits, with open oceans providing the least tractable system because of their vast expanse and the number of climatic, and geophysical effects which are beyond the means of research to alter. Thus, the derived order for the "feasibility of conducting research" tended to be from ponds down to open oceans. An exception to this linear relationship was the coral reef resource system. The reefs exist as a discrete ecosystem for which ICLARM has a broad comparative advantage to undertake research, it has high importance to fishers in the tropics with no alternative means of income, and the high premium placed on the maintenance or improvement of its environmental status in order for reefs to continue to provide benefits to coastal communities.

In contrast, a further resource system showing an anomalous placement was lakes and reservoirs. The "attractiveness" for research improvements in lakes and reservoirs (a grouping which includes small water bodies) was considered high, but ICLARM's comparative advantage was currently low and would have to be established with time and more resources to undertake research, principally in Africa, on this resource system.

In a series of iterative discussions, the Workshop identified and agreed on priority resource system research, and regions which would profit most from the conduct of the research. It should be noted that ICLARM will continue to underpin its regional research activities by generic research and the provision of information globally.

As can be seen from the resource system priorities (see Table 3.1) and discussed in ICLARM's Strategic Plan), this has resulted in ICLARM slightly expanding its research focus over the 1992 plan for the coming decades from the focus on ponds to also include additional freshwater systems, namely floodplains, small waterbodies and lakes. Given a likely optimal size for ICLARM (smaller rather than larger) and working in appropriate partnerships with fishing communities, NARS, NGOs, ASIs, development agencies and the private sector, the Center does not believe it can also extend global coverage to all aspects of its research.

ICLARM will therefore continue to focus on Asia, the major producers and consumers of aquatic produce and with burgeoning populations at greatest risk from damaging the environmental base on which sustained productivity depends. The additional focus on floodplains follows from the heightened awareness of the subsistence use of these regions to the poor countries of the region (e.g., Bangladesh and eastern India, and the Mekong Basin countries). These regions are 10-100 times more densely populated than equivalent wetland areas in, for instance, Africa.

ICLARM will, as a priority, extend its work on the development of aquaculture to assist food security in Africa as, in the next century, human population growth rates will swell the numbers of poor people. On this continent, there are new opportunities to introduce aquaculture and to exploit small water bodies. ICLARM will seek to apply its existing knowledge to develop integrated, holistic management approaches to different key resource systems with time, beginning with lakes/large reservoirs, small water bodies and coral reef systems. Capacity building will also be a key activity.

ICLARM has considered the small island states (largely the nations and territories of the Caribbean and Indo-Pacific) worthy of special attention because of their near complete reliance on aquatic resources for food security, livelihood and income generation (see Resource consideration of the Small Islands Developing States, Part II). ICLARM intends to focus its coral reef studies and aspects of its

Table 3.1. ICLARM aquatic resource system research priorities.

Aquatic resource system	Priority status	Research thrusts	Geographical location
Ponds	Very high	• Introduction of integrated aquaculture systems and impact analysis • Genetic enhancement techniques	Asia, SSA
Small water bodies reservoirs and lakes	Medium	• Develop knowledge base • Enhance productivity • Integrate manamgement	SSA
Floodplains, streams and rivers	High	• Enhance yields • Develop appropriate research methods and data to evaluate the resources and improve policy decisions and institutional framework	Mekong Basin, South Asia
Coastal waters (including estuaries and lagoons)	High	• Co-management of coastal and fisheries resources • Planning for integrated resource use • Introduction of sustainable coastal aquaculture and stock enhancement	South East Asia (including Mekong Basin), SSA, SIDS
Coral reefs	Very high	• Integration of data on coral reefs to determine parameters of reef health • Better management in the context of coastal zone management • Sustainable exploitation of coral reef resources through aquaculture and marine protected areas (MPAs)	SIDS (Pacific, Caribbean), South East Asia, East Africa
Soft-bottom shelves	Medium	• Analysis and policy implications of changes in coastal fisheries	Asia, Africa
Upwelling shelves	Low	• Watching brief on productivity and influences of catch on trade and other aquaculture development	—
Open oceans	Low	• Monitor world catch statistics and trade	—

coastal management research on the SIDS for these reasons. ICLARM is confident from past experience that the results and experiences from these studies will be directly applicable to similar habitats in other countries, particularly to regions of South East Asia.

Mainland Latin America will not be a principal focus for ICLARM's research as both offshore fisheries and the rapidly emerging aquaculture are highly commercialized industries often akin to these in developed countries. ICLARM will however seek to extend its generic technologies (e.g., trawl data analysis, ecosystem models and integrated aquaculture/agriculture technology) to NARS of the region as appropriate. ICLARM will seek to carry out fish and seafood demand/supply studies in all regions of the world to obtain the best predictive viewpoint on behalf of developing countries.

Countries of the WANA region will be generally restricted in water availability in the next century and fish production will be but one of the multipurpose uses of fresh water in a region which is not highly dependent upon fish. However, ICLARM's presence in the Egyptian delta will ensure that the results of ICLARM's aquaculture enhancement research will be rapidly made available to countries of the region able to exploit such approaches. It will be important to continue to monitor opportunities for increasing food production for poor people from marine aquaculture in this region or whether this will be undertaken as export directed industries. ICLARM aims to be a source of fisheries, biodiversity and holistic management advice for the whole African region, drawing on its new infrastructure in Egypt.

Lessons learned from the resource system approach

ICLARM's approach to strategic planning has focused on developing countries, largely situated in the tropical regions of the world. The approach has utilized FAO fisheries statistics, (the best, presently available global data set divisible by country and fisheries species groups) to gauge the importance of aquatic resources to these regions and countries. Removing the influence of some developed countries from regional statistics has the effect of (a) placing more emphasis on country statistics in which there may be inadequacies in reporting country data unevenly distributed through the data set; and (b) relying on the official sector for reporting catches whereas the importance for many poor people in developing countries is in the open access, subsistence use of aquatic resources which goes largely unrecorded. For instance, the Mekong River Commission has suggested that inclusion of the actual subsistence use of wetlands in the Mekong Basin countries will greatly increase the preciously reported catch statistics for these countries. Such resource evaluation questions are critical to future optimization of resource use and policy formulation and are themselves researchable questions.

Secondly, ICLARM has inferred in some cases, on a best assumption basis, the catch per resource system (e.g., catch per reef) as available data are collected differently. However, as above, the development of reliable estimates, ground truthed by contemporary empirical case studies, is an active area of research which will benefit from joint approaches of ICLARM with the FAO and other partners in the future.

Thirdly and most importantly, to resolve in future planning refinements, the adoption of the resource system approach (even considering freshwater and coastal systems) does not easily yield a single environmental risk parameter to enter into regional assessments at the continental level. It is therefore more useful to consider the importance of any resource system to a particular region and to determine the future environmental constraints on the sustainable exploitation of that resource system in that region rather than inferring general principles across regions.

Finally, priority setting based on present and projected production levels disregards the possibility of assisting a region (for instance, Sub-Saharan Africa) to *develop* particular aquatic resource systems such as farm ponds and small water bodies. Reliable weighting measures that deal with the issue of *current* production and importance versus *potential* opportunities to affect food security have not been developed. For this reason, it is felt important that potentials for research in areas of Asia and Sub-Saharan Africa be treated separately. ICLARM has therefore relied on experience and expert opinion and intends to balance its research portfolio between generic issues (approximately 25% of total research funds) and with increased activities in Africa (reaching not more than one third of the portfolio in 2005). The remaining regional research will be conducted in South and South East Asia and in the SIDS of the Caribbean and Indo-Pacific.

As part of the strategic planning process, ICLARM has also reinforced its vision for the coming two decades and considered its current attributes (people, skills and facilities) and skills it will need to acquire to tackle the somewhat expanded portfolio of research. It has considered its present and future partners and their likely strengths. Potential needs and constraints on implementation, and the requirements to work with donors in an increasingly synergistic way were also evaluated. As many of these interactions are dynamic, as are the developing fields of aquaculture and fisheries themselves, ICLARM undertakes to keep its Strategic Plan under review—particularly in those areas subject to rapid change. These reviews will be aided by the development of refined regional poverty and resource system data.