IO2001/D1/03

INTERNATIONAL COLLECTIVE IN SUPPORT OF FISHWORKERS (ICSF)
INTERNATIONAL OCEAN INSTITUTE (IOI), INDIA

FORGING UNITY
Coastal Communities and the Indian Ocean's Future

Conference Organized at IIT Madras
Chennai, India, 9 – 13 October 2001

Ecosystem Considerations for Managing Marine Fisheries in the Indian Ocean

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Abstract

Fisheries management approach of several countries, including those in the Indian Ocean region, has been generally on a species-to-species basis. It has been realized now that this approach has severe limitations, especially for the tropical, multispecies fisheries. While the understanding that fish and other living aquatic living resources are integral part of their ecosystems is not new, this idea has not been put into practice in managing stocks, especially for the marine fish. Reshaping the management strategies by involving all the stakeholders in such an ecosystem approach is expected to yield short-term and long-term benefits

Fisheries in the ecosystem context[1]

Fish stock assessment models provide scope for determining maximum sustainable yields so that management options can be advocated for removing *surplus* production. Surplus production is the total weight of fish that can be removed by fishing without changing the size of the population. Several surplus production models have been advanced in the last century for the temperate fish stocks (for e.g., Schaefer, 1954; Thompson and Bell, 1934), and with a few modifications for the tropical fish stocks (for e.g., Pauly, 1979; Sparre and Venema, 1992) to determine the species biomass and the maximum yields, and to evolve fisheries management options. However, when fishing is examined in an ecosystem context, the rationale for harvesting *surplus* production is ambiguous (National Marine Fisheries Service, 1998). Marine ecosystems are compact and are effective in capturing energy, cycling nutrients and producing biomass. Several researchers argue whether any of the biomass is truly *surplus* to an ecosystem, for e.g., Hilborn and Walters, 1992).

Fishing induces ecological and biological changes on the prey-predator interactions, growth, mortality and reproduction among the fish stocks. In short, fishing alters the structure and function of marine ecosystems (Dayton, 1998). In turn, fish stocks could not be understood and quantified fully without a thorough knowledge of their associates in the sea, especially of their prey and predators, their habitat, and also of the dynamics of physical and chemical oceanography. The understanding that the fish and other living aquatic living resources are integral part of their ecosystems is not new. However, this idea has not been put into practice, especially for the marine fish stocks.

The management approach of several countries, including those in the Indian Ocean region, to a very large extent, has concentrated on a species-to-species basis. It has been realized now that the traditional management approach has severe limitations, especially for the tropical, multispecies fisheries. Most of the developing countries in the western Indian Ocean and eastern Indian Ocean experience constraints in effectively managing their marine fisheries (Devaraj and Vivekanandan, 1997); concentration on species-by-species management approach in the multispecies environment and weak implementation instruments have severely restricted effective management of the resources (Vivekanandan, 2001). Nevertheless, fisheries have continued because they provide food, livelihood and economic benefits to the communities and contribute to the balance of payment to several countries bordering the Indian Ocean.

Unlike the situation that existed two decades ago, the present day computer technologies make it possible to quantify the functions of the ecosystem and adopt a better approach for the management of exploitation on an ecosystem-by-ecosystem basis. What is required now is a holistic view of fishery exploitation and management as a real and integral part of the marine ecosystem (Langton and Haedrich, 1997).

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[1] **The views presented here by the author are purely personal and they need not necessarily reflect the views of the organization he represents**

Uniqueness of the environment of the Indian Ocean

The relationship between the environment of the Indian Ocean and fisheries in the region is determined primarily by the uniqueness of the northern Indian Ocean. The northern Indian Ocean, together with its two major bays, the Arabian Sea and the Bay of Bengal, is landlocked in the north due to the existence of the Asian continent. This morphological uniqueness of the Indian Ocean is primarily responsible for the differences in the geological, physical, chemical and climatic conditions of the ecosystems compared to those of the other oceans in similar latitudes, as outlined below:

(i) The Asian continent separates the northern Indian Ocean from the deep reaching vertical convection areas of the Arctic Seas and the cold climate regions of the northern hemisphere.

(ii) The continent is large enough to affect the ocean climatologically by causing the seasonally changing monsoons, the southwest and northeast monsoons.

(iii) The seasonally changing monsoons in turn reverse the oceanic circulation over the northern part.

(iv) Connected with this seasonally changing circulation are various upwelling areas, which operate only during one season, the southwest monsoon season, which is in contrast to all the other major upwelling areas in the world (Wyrtki, 1973).

(v) The northern Indian Ocean areas are the largest regions with the lowest oxygen concentration in the entire open oceans of the world.

(vi) Another outgrowth is the formation of high salinity waters in the Arabian Sea from the even more highly saline Red Sea and Persian Gulf.

These factors influence large differences in the behaviour and functions of the ecosystems of the Indian Ocean from those of the other oceans; and between the ecosystems within the Indian Ocean. A succession of dynamic links in the food chain between the phytoplankton, zooplankton, plankton feeders and carnivores takes place. It is important to estimate the efficiency of transfer of energy from primary production to tertiary production and understand at which trophic level one is harvesting the various ecosystems of the Indian Ocean.

Trophic interactions: a key consideration for ecosystem management

When stress is applied to an ecosystem, it is initially difficult to notice the changes in its structure and behaviour. However, beyond a critical threshold, the system begins to deteriorate rapidly and the impact becomes conspicuous (Holling and Meffe, 1996). Fishing is perhaps the earliest stress applied to the marine ecosystem. The oldest fishing implements so far identified are harpoons, found in the territory of the Congo (ex-Zaire), and dated 90,000 years (Stringer and McKie, 1996). For centuries of early stages of development, fisheries tended to use highly selective gears and their effect on ecosystems probably resembled the effect of natural predation (Stergiou, 1999). The fishing pressure exerted by modern industrial fleets differs radically from natural predation and has detrimental effects on the trophic web (the network that represents the predator-prey interactions of an ecosystem).

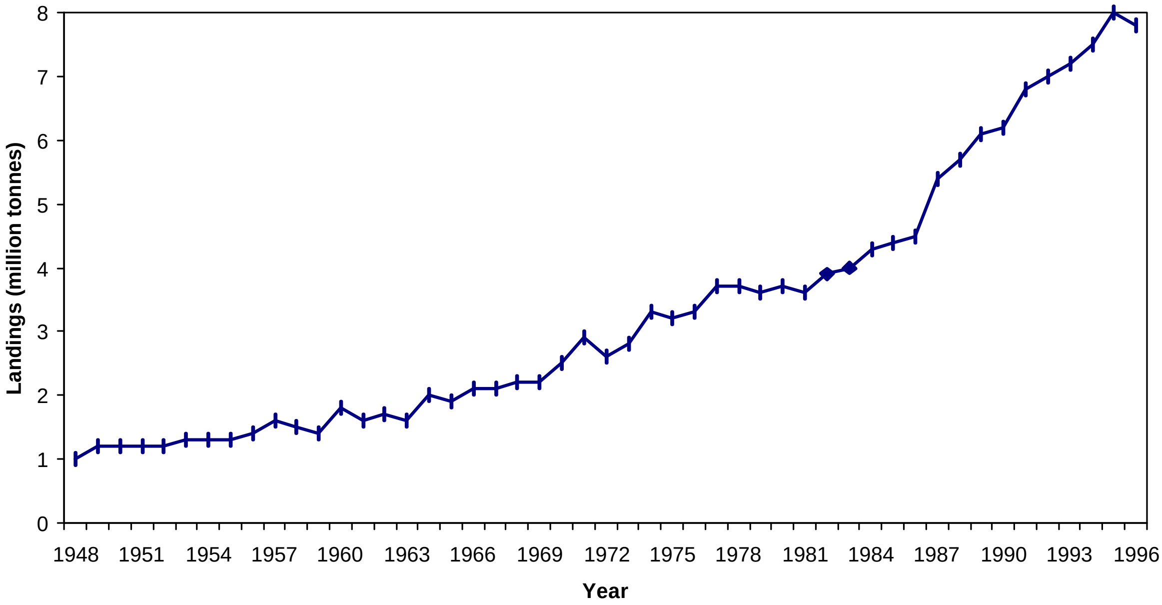
The effects are detrimental mainly for long-lived, late maturing species (Parrish, 1998), leading to the phenomenon now known as "fishing down marine food webs". Pauly *et al*. (1998) and Pauly (1999) have shown that landings from global fisheries have shifted from large piscivorous fishes toward small invertebrates and planktivorous fishes in the last five decades, especially in the northern hemisphere. They demonstrated that the networks of flows of matter (=biomass) are affected directly by fishing, which removes predatory fish, or competes with them for their preys, in either case affecting the marine food webs. The results on the analysis of global data are striking: there is a gradual decline in the mean trophic level of fish landings of about 0.1 per decade (from 3.3 in 1950 to 3.1 in 1994). Fishing down food webs also occurs in the Antarctica and the freshwater systems around the world, where the catch has strongly reduced nearly to herbivore level. In the tropical belt also, a similar trend was observed in the Gulf of Thailand (Christensen, 1998). Initially, fishing down the food web yields higher catches, but below a certain trophic level, which may vary between ecosystems, further decline in the trophic levels leads to decreasing catches. This trend is generally perceived as indicating a serious problem and the present trend would lead to widespread fisheries collapses.

There are extensive studies on the stomach content of fishes in the Indian Ocean region, where hundreds of fish of many species have been sampled over several decades. Some multispecies predator-prey models have been developed, but generally these models are better at explaining the effects that trophic relationships might have had, rather than predicting future patterns and variations. One such evidence on the effect of trawling on the trophodynamics has been obtained for the Bombayduck *Harpodon nehereus* along the northwest coast of India. In the 1950s, prior to the introduction of trawlers, the major diets of the Bombayduck were the penaeid and nonpenaeid prawns and cannibalism was insignificant (Bapat *et al*., 1952). With the intensification of trawling, the abundance of prawns reduced and the Bombayduck has resorted to cannibalism. In the 1980s and 1990s, the smaller Bombayduck contributed 30% to the diet of the larger ones (Devaraj and Vivekanandan, MS).

Components of ecosystem-based approach to fisheries management

According to the National Marine Fisheries Service (1998) of the USA, an ecosystem-based approach should take into account the following four aspects: (i) the interaction of a targeted fish stock with its predators, competitors and prey species; (ii) the effects of weather and hydrography on fish biology and ecosystem; (iii) the interaction between fish and their habitats; and (iv) the effects of fishing on fish stocks and their habitats, especially how the harvesting of one species might have an impact upon the other species in the ecosystem. The National Research Council of the USA (National Research Council, 1999) advocated one more aspect to this approach, i.e. recognizing humans as components of the ecosystems they inhabit and use, thereby incorporating the users of the ecosystem in the approach.

Fig. 1. Marine fish landings in the Indian Ocean region



Rationale for application of ecosystem approach for managing fisheries in the Indian Ocean

The marine fish landings in the Indian Ocean region increased from about 1 million tonne in 1948 to nearly 8 million tonnes in 1996 (Fig. 1). However, the 8-fold increase masks a series of problems, which the fisheries in the Indian Ocean region are facing today. Fisheries in the Indian Ocean are perhaps the most poorly managed compared with those of the other oceans. The reasons are biological, social and economic complexities. In the tropical belt of the Indian Ocean, the fisheries exploit hundreds of species, and the landings in major landing centers regularly include about 200 species belonging to about 50 groups every day – though a few, sometimes only 2 or 3, may contribute 50% of the catch (e.g. the oil sardine along the southwest coast of India, the round scad in the Gulf of Thailand). Each of these 50 groups is unique in the marine ecosystem and also in the fisheries. Viviparity, low fecundity, slow growth, long life span of sharks; schooling, high fecundity, fast growth, short life span of clupeids; transoceanic migration of tunas; sex transformation by groupers; amphibiotic estuarine and marine habitation, high fecundity, fast growth, short life span of penaeid prawns; semelparity in a few cephalopods are examples of a few diverse life pattern strategies adopted by the economically important fish groups. Fisheries in the tropical oceans exploit these groups regardless of their uniqueness. It is common that several of these diverse groups are landed in a single trawl haul. A single trawl haul in the tropical belt of the Indian Ocean land, on an average, lands 40 to 60 species; some of them are in a state of overexploitation, some others are in an underexploited state and the rest are optimally exploited. Now the question is how to manage these diverse fish stocks, which are in different states of exploitation? Should the management option concentrate on the dominant species, and hope that the ecosystem will somehow adjust to management measures aiming to generate high catches of that species? Or should the option try to consider "ecological redundancies", i.e. group the fishes into guild of similar species or similar states of exploitation and try to manage the guilds as if they were single species? These uncertainties are an enigma for evolving effective management priorities for the multispecies fisheries. It is believed that ecosystem-based fisheries management will not be ambiguous in providing answers for these questions.

Plan for ecosystem-based fisheries management

As fisheries management expands its focus from target fish stock to ecosystem, the main implication of the ecosystem-based fisheries management is the need to cater to the well being of ecosystem as well as communities. While it is a major conceptual advancement, the practical problems raised by this recognition are immense. There is still uncertainty as to how to implement an effective ecosystem-based management system in practice. Nevertheless, there are pragmatic ways to begin implementation of ecosystem-based fisheries management and to deal with complex interaction of human institutions and societies.

Amongst the immediate steps that should be taken by the countries bordering the Indian Ocean in moving towards ecosystem-based fisheries management are the following:

(i) Ecosystem classification and zonation

The ecosystems supporting fisheries in the Indian Ocean region vary markedly, and the status of exploitation in each ecosystem and the way in which fisheries are managed within them will also vary according to their individual characteristics. Hence, the management options such as optimizing craft and gear combinations should be different for these two diverse zones. The structure, function and processes that occur between as well as within the ecosystems should be considered for delineating the ecosystems. The delineation should consider human/institutional components and their interactions too. Zonation of the coastal areas into smaller and manageable levels may be useful for effective implementation. An indicative outlay of the zonation along the 8129 km coastline India could be as follows: (a) Gulf of Kutch ecosystem, (b) Saurashtra coast, (c) South Gujarat coast, (d) North Maharashtra coast, (e) South Maharashtra coast, (f) Konkan coast, (g) North Kanara coast, (h) South Kanara coast, (i) Calicut-Cochin coast, (j) Cochin-Kanyakumari coast, (k) Wadge Bank, (l) Gulf of Mannar, (m) Palk Bay, (n) Coromandel coast, (o) Pulicat Lake (p) North Andhra-south Orissa coast, (q) Chilka Lake, (r) Bhitarkanika, (s) North Orissa-West Bengal coast, (t) Sunderbans, (u) Andaman & Nicobar Islands and (v) Lakshadweep Islands.

(ii) Develop ecosystem modeling

Modeling is an essential scientific tool in developing ecosystem approaches for fisheries management. Food-web based model could examine factors that affect primary productivity and their interaction with all components of the ecosystem. As a measure of the state of exploitation of the world’s aquatic ecosystem, Pauly and Christensen (1995) estimated how much primary production was required to sustain the global fisheries in 1988-1991. The results showed that, globally, some 8% of aquatic primary production was appropriated by the fisheries, and that there was considerable variation between resource system types: for open ocean fisheries, only

2% was required, while upwelling, shelves and freshwater systems required in the order of 25 to 35% primary production. For sustaining the coastal fisheries, it is suggested that only one third of the total primary production could be used since a good part of it (over half) can be expected to fall out to the sediment (Christensen, 1999). It may be concluded that the 'available' primary production of the oceans, especially in the coastal waters is fully utilized by humans.

Models such as ECOPATH (Polovina, 1984; Pauly and Christensen, 1995) have provided insight into some fundamental ecosystem questions. ECOPATH with the recently incorporated ECOSIM software system is designed to describe the tropic fluxes and variables in ecosystems. By using this software, more than a hundred ecosystem models have been published, and another fifty are in progress. Considering the need to gain an insight into the functioning of the trophic food web for the Indian fish stocks, Vivekanandan *et al.* (2001) gathered the available information and constructed a biomass budget for the southwest coast of India for the years 1994-1996 by using the ECOPATH. For this purpose, the ecosystem along the SW coast was categorized into 11 ecogroups based on the feeding habits and ecological niche of the species/groups: large predators, medium predators, large zoobenthic feeders, demersal feeders, mesopelagic feeders, molluscan feeders, zooplankton feeders, phytoplankton feeders, zooplankton, phytoplankton, detritivores and detritus. The analysis resulted in the following conclusions: (i) The annual average catch of the large and medium predators, demersal feeders and detritivores exceeded the respective estimated harvestable biomass, and hence, the exploitation of these groups should be restricted. (ii) There is scope for increasing the catches of large zoobenthic feeders and the plankton feeders. (iii) Gears employed for the exploitation of demersal resources are being used excessively. (iv) Gears employed for the exploitation of pelagic resources, such as the pelagic and midwater trawls are underutilized or unutilized. (v) Though the ecosystem analysis demands large number of input parameters, the analysis is useful for understanding the ecosystem and for evolving suitable management options (Vivekanandan, 2001).

Table: Considerations for Ecosystem Management

Type of ecosystem	Components	Management options	Type of fishing regulation
I Critical Ecosystem	Coral reefs; Sponges; Mangroves	Marine protected area; Coral rebuilding; Mangrove afforestation	Fishing ban altogether
II Vulnerable ecosystem	Declining fish stocks; Concentration of vulnerable/endangered species	No-fishing zone; Resource enhancement programs like sea-ranching	Fishing ban altogether; Alternative livelihoods like mariculture
III Polluted ecosystem	Bioaccumulation of pollutants	Ecowatch; Evolve standards for waste discharge; Implement polluter-pays principle	Fishing and marketing of fish with pollutant loads to be prevented
IV Estuaries, lagoons & backwaters	Nurseries; Closure of barmouth	Seasonal closure of fishing	Ban on all forms of fishing during seasons of spawner & juvenile abundance and closure of bar mouth; Regulate mesh size
V Open coastal waters	Combination of under & overexploited stocks	Seasonal closure of mechanised fishing; Area demarcation for mechanized & traditional craft; Limited entry; Part of area as no-fishing zone either on rotation or permanently	Regular but controlled fishing; Precautionary approach; Alternate livelihoods like mariculture
VI Farsea/ deepsea	Mostly under & unexploited stocks	Atlas on areas of resource abundance; Devise economically viable craft & gear; Regional cooperation	No restriction for the present; Local fishing communities deserve encouragement

(iii) Setting objectives and options for each ecosystem

In consultation with all legitimate stakeholders and interest groups, objectives must be agreed upon for each ecosystem. Objectves should include both long-term and short-term goals to increase the biodiversity as well as the biomass and should cover biological, ecological, economic, social and institutional issues. Some of the considerations for ecosystem-based fisheries management are given in Table 1. For instance,

(a) the short-term objective of a coral reef ecosystem should be protection of the reef and its dependent fauna and flora, and, the long–term objective should be to rebuild and extend the reef area.

(b) The objective of the mangrove ecosystem is to protect the plants, the nurseries, and, if required, launching afforestation programmes. Some of these ecosystems in the Indian Ocean region have already been declared as marine protected areas (MPAs), but the present system do not look so great. Less than 0.3% of the area in the Indian Ocean region lies with in ‘marine protected areas’, but a much smaller fraction of that is currently protected from fishing.

(c) The objectives for an urbanized/industrialized ecosystem should be to set standards for the effluent discharge, regularly monitor the pollutant load in the coastal waters and in the body components of the organisms

(d) The objectives for sustaining the ecosystem of open waters should encompass a combination of technical measures, closed areas and seasons, input and/or output controls, and a suitable system of access rights for all users. The system and functioning of the coastal openwater ecosystem differ between one zone to the other. For instance, the Kerala coast (southwest coast of India) experiences upwelling during the southwest monsoon (June to September), abundant supply of phytoplankton and zooplankton, and consequently, the fishery is dominated by the small pelagics (49.7% of the landings) such as the sardines, whitebaits and Indian mackerel. On the other hand, the Saurashtra coast (northwest coast of India) experiences winter cooling and sinking during November-February, and consequently, the fishery is dominated by the demersals (57.2% of the landings) such as the sciaenids, flatfishes, ribbonfishes etc.

The concept of no-fishing zone in the open waters is gaining important in several regions. The idea behind no-fishing zone is to ban altogether all forms of fishing in select areas. The concept behind this idea is simple. If the fish are protected from fishing, they live longer, grow larger and produce an exponentially increasing number of eggs. It is observed that adult fishes tend to remain in the protected areas while their larvae help replenish adjacent fisheries. Overall (multispecies) levels of biomass per unit area can double in two years and quadruple in the years of closure. In the Californian reserves, reproductive output of two rockfish species was estimated to be two to three times as great as in the fished areas. On the west coast of the USA, the reproductive output of the longcod in a reserve in Puget Sound was 20 times greater than outside, and for the copper rockfish 100 times greater (Palsson, 1998). These no-fishing zones showed average increases of 91% in the number of fish species present (Roberts, 1999). These increases occurred within two years of starting the protection scheme. Crucially, the beneficial effects spilled over into areas where fishing was still permitted. In St.Lucia, for example, a third of the country’s fishing grounds were designated no-fishing area in 1995. Within three years, commercially important fish stocks had doubled in the seas adjacent to the reserves.

There are strong evidences to suggest that reserves will work even better in the tropics. However, there is no direct experience of reserves in the tropical regions of the Indian Ocean barring marine sanctuaries to protect coral reefs and mangroves. Considering that the concept of no-fishing zone is a good strategic tool, fisheries managers in the countries bordering the Indian Ocean should start working on the questions about how much of the fishing grounds should be placed in reserves, how many are needed, and where should they be. There seem to be three principles, which govern no-fishing zones. According to the first principle, both biological and economic benefits can be maximized through closures ranging between 20 and 40% of the fishing grounds. Recently the American Association for the Advancement of

Science, along with about one hundred scientists called for 20% of the world's oceans to be declared as no- fishing zone by the year 2020 (Roberts, 1999). The second principle is based on the expectation of maximization and equitable distribution of benefits through a subdivision of the 20% reserve area to represent both biogeographic and ecological diversities within the reserves. The third principle stems from the question whether the derivation of maximum benefits is from the permanent reserves or from rotational reserves. Considering the location of fishing villages in close proximity to each other in the countries bordering the Indian Ocean, the selection of areas for no-fishing, and the logistical, economic, political and social implications of dislocating and rehabilitating the fishers to fishing areas away from the reserves call for extreme care in planning. Perhaps alternate livelihood in the form of ecofriendly mariculture in the no-fishing zone could be considered.

(e) Resource enhancement programs such as sea ranching or installation of artificial reefs may be implemented in a few specific ecosystems.

The fishing communities are dispersed all along the coastline in the countries bordering the Indian Ocean and they are dependent on marine ecosystems that are close to them. The nature of the ecosystems is an important determinant of many cultural characteristics, including the social and economic organization and the fishing gear and technologies that are utilized. They develop intimate, detailed and function-oriented knowledge about the marine ecosystems. They are also easily vulnerable to resource depletions. The question is how are the countries prepared to adopt ecosystem-based fisheries management. The ecological considerations do not expect the halt of traditional, locally-based management systems. However, the traditional community-based approach will have to be re-invented, within the specific cultural, social and economic constraints of each country. Foremost among these is the requirement to involve all stakeholders.

Conclusion

Reshaping the management strategies by involving all the stakeholders in an ecosystem approach is expected to yield short-term and long-term benefits. Some of the decisions like no-fishing zone may demand rehabilitation of the communities to alternate sites or livelihood opportunities. A carefully planned protocol and implementation of ecosystem-based fisheries management within a logistic timeframe is expected to contribute to the protection of marine biodiversity and fisheries.

References

Bapat,S.V., Banerji,S.K., and Bal,D.V. (1952). Observations on the biology of *Harpodon nehereus*. *J.Zool.Soc.India* **3**, 341-356.

Christensen,V. (1998). Fishery-induced changes in a marine ecosystem: insight from models of the Gulf of Thailand. *J.Fish Biol*. **53**, 128-142.

Christensen,V. (1999). Ecosystem modeling and the challenge of ecosystem-based management. *ACP-EU Fish.Rep*. **5**, 25-29.

Dayton,P.K. (1998). Reversals of the burden of proof in fisheries management. *Science* **279**, 821-822.

Devaraj,M., and Vivekanandan,E. (2001). Marine Fisheries of India: Principles and Practices (MS).

Hilborn,R., and Walters,C.J. (1992). Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. Chapman and Hall, New York.

Holling,C.S., and Meffe,G.K. (1996). Command and control, and the pathology of natural resource management. Conservation Biology 10, 328-337.

Langton,R.W., and Haedrich,R.L. (1997). Ecosystem-based management. In " Northwest Atlantic Groundfish: Perspectives on a Fishery Collapse". (J.Boreman, B.S.Nakashima, J.A.Wilson, and R.L.Kendall, eds.), American Fisheries Society, Maryland, 153-158 p.

National Marine Fisheries Service (1998). Ecosystem-based fishery management: a report to the US Congress by the Ecosystem Principles Advisory Panel. *http.//www.nmfs.noaa.gov/sfa/reports.htm*.

National Research Council (1999). Sustaining Marine Fisheries. National Academy Press, Washington D.C., 177 pp.

Parrish,R.H. (1998). Life history strategies for marine fishes in the late Holocene. In "Global versus local change in upwelling areas" (M.H.Durand, P.Cury, R.Mendelssohn, A.Bakun, C.Roy,, and D.Pauly, eds.), Serie Colloques et Seminaires. ORSTOM, Paris, 525-535 p.

Pauly,D. (1979). Theory and management of tropical multispecies stocks: a review with emphasis on Southeast Asian demersal fisheries. *ICLARM Stud.Rev*. **1**, 35 pp.

Pauly,D. (1999). Fishing down marine food webs, as an integrative concept. *ACP-EU Fish.Res.Rep*. **5**, 4-6.

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

Pauly,D., Christensen,V., Dalsgaard,J., Froese,R., and Torres Jr.F. (1998). Fishing down marine food webs. *Science* **279**, 860-863.

Polovina,J.J. (1984). Model of a coral reef ecosystem. I. The ECOPATH model and its application to French Frigate shoals. *Coral Reefs* **3**, 1-11.

Roberts,C.M. (1999). Marine protected areas as strategic tools. *ACP-EU Fish.Res.Rep*. **5**, 37-43.

Schaefer,M.B. (1954). Some aspects of the dynamics of population important to the management of commercial marine fisheries. *Bull.IATTC* **1**, 26-56.

Sparre,P., and Venema,S.C. (1992). Introduction to tropical fish stock assessment. *FAO Fish.Tech.Pap.* **306**, 376 pp.

Stergiou,K. (1999). Fisheries impacts on marine ecosystems. *ACP-EU Fish.Res.Rep*. **5**, 29-30.

Stringer,C., and McKie,R. (1996). African exodus: the origins of modern humanity. Henry Holt, New York, 282 p.

Thompson,W.F., and Bell,H. (1934). Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield, and yield per unit gear. *Rep.Internat.Fish.Comm*. **8**, 48 pp.

Vivekanandan,E. (2001). Sustainable coastal fisheries for nutritional security. In "Sustainable Indian Fisheries", (T.J.Pandian, Ed.), National Academy of Agricultural Sciences, New Delhi, 19-42 p.

Vivekanandan,E., Pillai,V.N., Srinath,M., and Kurup,K.N. (2001). Ecosystem analysis of fish biomass along the southwest coast of India. Report for the ADB RETA 5766 Project, ICLARM, Penang.

Wyrtki,K. (1973). Physical oceanography of the Indian Ocean. In "Biology of the Indian Ocean" (T.Zeitzschel, ed.). Chapman and Hall, London. 18-36 p.