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Towards Ecosystem Based Management of Marine Fisheries – Building Mass Balance Trophic and Simulation Models

INFORMATION ONLY

Compiled and Edited by

Dr. K.S. Mohamed, Director, Winter School & Senior Scientist,
Central Marine Fisheries Research Institute [CMFRI],
PO Box 1603, Cochin – 682018, Kerala
ksmohamed@vsnl.com

Technical Notes

FISHERIES MANAGEMENT TECHNIQUES

E. VIVEKAKANADAN
RC of Central Marine Fisheries Research Institute, Chennai

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Introduction

Marine living resources are by no means inexhaustible, although some of them are extremely rich. In India, the production of marine fish increased by about 5.5 times in 55 years, from 0.5 million tonnes in 1948 to 2.7 m t in 2003. However, the catch rate is on the decline in many centers, and the scope for further increase in catch from the inshore waters is limited. To sustain marine fish production, a consistent fisheries management policy and implementation of management measures are needed. In recent years, considerable time and effort have been spent, discussing the need for and modalities of marine fisheries management involving the fisheries scientists, politicians, managers and fisherfolk.

Fisheries management is a dynamic resource allocation process where ecological, economic and institutional resources of a fisheries exploitation system are distributed with value to the society as the overall goal (Silvestre and Pauly, 1997). As the coastal fisheries are set in a variety of natural and human conditions, a wide diversity of specific objectives need to be pursued for their management. Multiplicities of issues confront the fisheries sector in achieving the management objectives. Devaraj and Vivekanandan (1999) identified the following major issues in coastal fisheries: increasing population of fisherfolk, increasing fishing intensity, inappropriate exploitation pattern, use of destructive gears, fish stock decline, biodiversity decline, inefficient marketing system, inadequate handling and processing of the produce, discards and postharvest losses, sectoral conflicts, poverty, illiteracy and poor hygiene among the artisanal fisherfolk, inadequate fisheries policies, resistance by the fisherfolk to follow fishing regulations, and low financial resource allocation for the fisheries sector.

Objectives of fisheries management

The need to manage fisheries arises from two conditions. First, there is a need to limit the harvest to what the fish stocks can sustain. Second, property rights to fish stocks are difficult to establish, leading to intersectoral conflicts. The central idea to keep in mind about the management of fisheries is that the problems encountered in fish production are unique compared to any other commercial sector industry. The limited but renewable nature of the resources and the ownership conflicts have no parallel in other sectors. When any other area of the economy collapses, there is a chance that it could be rebuilt, but if a fish stock depletes, it is a very difficult task, though not impossible, to rebuild.

Fisheries represent one of the best examples of the exploitation of the natural resources. One of the most important characteristics of capture fisheries is that the resources are a common property, the access to which is free and open. Irrespective of the type of exploiters: artisanal fishers or large fleet owners or joint venture operators, their operation will not be limited until the zero profitability threshold is reached. Hence, there is a need for a manager to intervene and regulate their activity.

The general objectives of fisheries management are to achieve nutritional security, maintain sustainability of the resources, and ensure gainful employment and economic benefits. To achieve this, a multidisciplinary approach involving biological, environmental, social, economic and administrative instruments is necessary (Silvestre and Pauly, 1997).

Principles of fisheries management

Management should be an integral part of any developmental activity. Fisheries development also should have effective management plans as integral part of the developmental strategy. The principle of fisheries management is to follow the model, which gives the best relationship between fishing effort and production. The generally observed relationship is that when the effort increases, the catch also increases initially almost proportionately. Later, the increase in catch slows compared to that of the effort (Fig. 1) with the result there is a progressive decrease in the catch rate (Fig. 2). If there is no management, the fishery will progress and reach the maximum yield and realise maximum value initially (point A in Fig. 3). It will progress further and reach point B, when the yield (or value) is equal to the cost of fishing. It is only at this stage, the need for management is felt, and the government compensates in the form of aids and subsidies and makes attempts to continue the profitability. Exhausting all other possibilities, the fishery will not progress beyond point C when only the running costs like fuel and labour are met with by both the fish yield value and the government aids (Gulland, 1972). Once arriving at this point of development, it is obvious that the crisis cannot be solved without stringent action, which may lead to socioeconomic upsets. Hence, it is preferable that management intervenes during the early phase itself in the development of a fishery. It is much easier to slow down expansion in the earlier phase than to reduce exploitation levels when the situation reaches a crisis.

The development of a fishery over the time scale can be categorised as (i) predevelopment phase, (ii) growth phase, (iii) full exploitation phase, (iv) overexploitation phase, and eventually (v) collapse phase, and may be, (vi) recovery phase (Csirke, 1984). In a well-planned fishery, effort is controlled during growth phase and catches are sustained at the level of full exploitation over a long period with no apparent risk of collapse, unless adverse environmental conditions occur. The principles and techniques of management vary during the different phases of a fishery. When the fishery is in the predeveloped phase, it has to be promoted; when it is in growth or fully exploited phase, it should be maintained; and when it is in an overexploited phase, attempts should be made to recover the fishery (Table 1).

In an uncontrolled fishery, on the other hand, the passage from the fully exploited phase to the overexploited phase occurs very rapidly, and if not controlled in time, leads to collapse. Coastal marine fisheries in India remained in a predeveloped phase till 1962 (premechanisation period; annual production: <0.8 m t) and on a prolonged growth phase till 1988 (mechanization period; increase in the number and efficiency of fishing vessels; annual production: 0.8 to1.8 m t); this is followed by the fully exploited phase, which lasted for 15 years till 2003 (exploitation of underexploited coastal areas and further increase in effort; annual production: 1.8 to 2.6 m t). The effort (in terms of fishing effort and fisher population) increased steadily throughout the three phases of development, more so in the fully exploited phase. Unless effective management measures are implemented, there may be a severe drop in the production in the future years.

The present fully exploited phase of the coastal fishery can be continued if the area of exploitable fishing grounds is increased in proportion to the increase in fisherfolk population and number of craft. Presently, only about 20% of the total fishing effort is in areas >50 m depth. Extending about 50% of the total fishing effort to 50-200 m depth may prolong the fully exploited phase.

Promoting an underdeveloped fishery

In most fisheries, their different constituents are usually in various stages of development. For instance, in spite of the transition of the Indian coastal fisheries entering the fully exploited phase, a few specific fishery groups like the pelagic sharks, tunas, bullseye, deepsea prawns and a few other deepsea fish stocks are still in the underexploited phase. The management for these stocks should aim at creating proper fishing opportunities in terms of appropriate fleets, postharvest value addition and training the interested groups of fisherfolks and entrepreneurs in the relevant technologies. There should be greater focus on investments in the types of craft and gear and equipments best suited for exploiting the identified stocks and processing them into products of demand. Prudent planning is extremely important to prevent risks of collapse, if the fishery becomes successful, but left without control.

Maintaining a developed fishery

The approach to maintain a developed fishery should be different from that of promoting an underdeveloped fishery. Information on the fish stock and the socioeconomic state of the fisherfolk is essential for managing this phase of the fishery. Based on this information, a decision has to taken, as the first step, whether to restrict or promote or just maintain the fishery. In case of a decision in favour of restrictions, proper methods of restriction have to be identified and adapted. Alternative fishing activities or occupations may have to be designed. The social acceptability of the restrictions and the socioeconomics of the fisherfolk have to be given priority at this stage. During this phase, the prospects of the stock in the future are more important than its current status. Today's Indian trawl fishery is a good example of a fishery in its developed phase.

Rebuilding a depleted fishery

For rebuilding a depleted fishery, the cause for depletion, environmental or fishing, should be investigated. If it is due to fishing, corrective action based on past experiences is necessary. The management approach could be either restriction of fishing or total ban depending on the severity of the problem. Alternative employment opportunities should be opened up for the fisherfolk well before imposing a ban. In many instances, depletion may not be wholesome, affecting all the constituent fisheries of a given area, but species-specific. For instance, the depletion of the stocks of the whitefish *Lactarias lactarias*, which is one among the many stocks, exploited by the trawl fishery (especially along the southeast coast), is a classical case of species-specific depletion. Management of the whitefish stock alone in a multispecies fishery becomes extremely difficult. In this type of depletion, the bionomic characteristics of the stock such as stock-recruitment and population fecundity should be closely monitored and steps (e.g., searanching) taken to prevent them from crossing danger levels.

Existing fishing regulations

Closure of fishing seasons

One of major problems in fisheries management is to regulate the fishing effort, which is increasing in spite of decline in the fish stocks. Fishing effort is a composite of many parameters, particularly fishing duration and fishing efficiency. The restriction of fishing effort could take various forms such as restriction on the number of vessels, number of days at sea, fishing days/hours, engine power, length of net (in the case of gillnet), fish holding capacity of vessels etc. Restriction of the number of days of fishing during the monsoon and fish spawning seasons is the most common method followed in India. The maritime state governments take year-to-year decision on the period and duration of closure of fishing operation by the mechanised vessels, normally prior to or during the onset of the southwest monsoon. On the west coast, Gujarat observes seasonal closure for 140 to 150 days/year during May-September for the last 25 years and Kerala for 45 to 60 days/year during June-August for the last 15 years. The other states along the west coast also observe seasonal closure for 30 to 60 days. Along the east coast, Andhra Pradesh and Tamil Nadu initiated 45 days' closure during April-May since 1999 and 2001, respectively. In addition to this, the government of Tamil Nadu has regulated the fishing activity in the Gulf of Mannar, wherein the mechanised vessels are permitted to undertake fishing three days/week (Mondays, Wednesdays and Fridays) and the artisanal craft on the other 4 days in a week. The objective of seasonal closure is to reduce the annual fishing effort of mechanised vessels, particularly the effort of the trawlers during the spawning season of fishes, and thereby replenish the stocks.

The positive effects of seasonal closure on the replenishment of fish stocks are yet to be proved. Seasonal closure of trawling/mechanised fishing is implemented with the general belief that most of the fishes, prawns and cephalopods undergo peak spawning during the monsoon seasons. Though tropical fishes spawn throughout the year with almost equal intensity, closure during the monsoon seasons helps the escape of the spawning population at least during the period of closure.

Demarcation of fishing areas for mechanised and artisanal sectors

In the context of persistent conflicts between the artisanal and mechanised vessels in the inshore waters, most of the maritime state governments promulgated their respective Marine Fishing Regulation Acts. Under these Acts, the areas of operation of the artisanal and mechanised vessels have been delineated. In general, the mechanised vessels have been banned from operating in the inshore areas (extending to a distance of 5 to10 km from the shore), which have been assigned exclusively to the artisanal craft. The mechanised vessels are classified according to the size of the vessels and the area/depth of operation is delineated accordingly. As the density of fish biomass is generally related to the depth of water, there are complaints of bias in demarcating the areas of fishing based on the distance from the shore. At a distance of 5 km from the shore, the depth may be only 20 m in certain areas like the Gulf of Mannar but 100 m in certain other areas (for e.g., off Cuddalore in the Coromandel coast). In order to remove this bias, some of the state governments incorporated the depth factor in their Acts in addition to distance from the shore. For instance, the Kerala Marine Fishing Regulation Act, 1980 divides the coastline into two sectors, a southern sector of 78 km coastal length and a northern sector of 512 km length. In the southern sector, distances from the shore up to the 32 m depth and in the northern sector distances from the shore up to the 16 m depth have been reserved exclusively for the artisanal craft. In the 32 to 40 m depth zone in the southern sector and the16 to 20 m depth zone in the northern sector, only motorised craft are permitted to operate. The small mechanised vessels (<25 GRT) are allowed to operate between 40 and 70 m depths in the southern sector and between 20 and 40 m depths in the northern sector. Larger vessels (>25 GRT) are supposed to operate beyond the 70 m and 40 m depths in the southern and northern sectors, respectively.

Regulation of mesh size

The purpose of controlling the mesh size, especially in the codend of the trawls, is to permit the escape of juveniles hoping that their growth would largely compensate the loss and increase the exploitable biomass, which might be available to the fishery later. Minimum mesh sizes are often emphasized as essential by the scientists as there is general agreement that protection of young fish is necessary. It is often argued that if fishing on immature fish is intense, the abundance of the species may be so reduced before it approaches maturity that there would be insufficient adult fish surviving even if there is no fishing on them. It is also postulated that long term yields would increase by permitting the faster growing immature fish to attain sexual maturity before exploitation, primarily because growth is most rapid in young fish. Under these assumptions, the biomass of a cohort maximizes at about the age at first maturity.

The codend mesh size (CEMS) of the trawls prevalent in India is uniformly very small (generally about 10 mm stretched knot to knot; but quite often, much less than this). Most fishery scientists have suggested a minimum stretched mesh size of 30 mm. Kalawar *et al*. (1985) advocated a compulsory mesh regulation by legally imposing a minimum stretched CEMS of 35 mm, that would help protect significant number of juvenile fishes as well as shrimps. According to Garcia and Le Reste (1981), mesh regulation would be useful for shrimps in the long term due to the following reasons: (i) Since shrimps have a short life span and rapid growth, the possible annual increase would be obtained before the completion of the first annual cycle. (ii) Increasing the mesh size leads to an increase in age and individual average weight and price/kg. The possible increase in value would be proportionately greater than the increase in tonnage.

Nevertheless, the regulation of CEMS is difficult to enforce. In countries where there are mesh size regulations, there is either noncompliance or the fishermen often get round the law by any of the following ways: (i) by lining the codend outside or inside with a finer mesh; (ii) by superimposing two layers of the legal mesh size so that the apertures are about half the original mesh size; (iii) by attaching a weight to the end of the codend so as to obtain maximum stretching of the net, thus decreasing the opening.

For a biological management system to be effective, monitoring, control and surveillance are necessary to enforce the regulations. This is one of the reasons why the biological management is considered to be very expensive. In Canada, where fisheries management includes quotas, restrictive licenses, seasonal closures and gear limitations, surveillance is done on the shore and at the sea by using ships and aircraft. The entire surveillance system is able to sustain itself financially through licensing and fines or through redistribution of funds from other sources. According to Arnasson (1994), the biological fishery management measures, although well suited for sustaining fish stocks, are useless from an economic point of view.

Prospective fishing regulations

Finding the existing fishing regulations inadequate to meet the increasing fishing intensity in the coastal waters, different government and non-government agencies have suggested various kinds of management measures for a sustainable fishery.

Overcapitalisation and limited entry

An assessment of the state of health of fisheries cannot be confined to changes in production but must also include an evaluation of costs and revenues. The coastal fisheries can ill afford the economic losses resulting from overcapitalisation and overfishing.

Under this situation, fishery management approach should involve the rationalisation of capital investment on fishing. To avoid overcapitalisation and dissipation of economic rent, the aggregate gross tonnage and/or horsepower of fishing vessels operating in an area should form the basis upon which the number of licensed vessels has to be regulated. In determining the number of vessels to be licensed, the total capital investment has to be evaluated and distributed by the size-class of vessel. Technical innovations could be permitted so long as the size of vessel remains unchanged. If the vessel size is to be enlarged, extra tonnage could be purchased only if a vessel is condemned. To ensure that the total operational efficiency of a fishery does not exceed the prescribed ceiling, plans for the enlargement of vessel size have to be carefully coordinated. In this way, the overall fishing effort could be controlled and overinvestment could be prevented, and at the same time, the fishing industry can improve the efficiency of the fleet. To implement this method of limited entry on the fishing capacity, a strict licensing system is required. At present, the mechanised vessels are licensed mainly for the purpose of revenue earning. The priority of licensing should be shifted from mere revenue earning to a system of preventing overcapitalisation and regulating the fishing effort (Vivekanandan, 2001).

Marine fisheries in India are common property, characterized by free access in almost every sense. There is no accountability of the effort expended and the catch realised. The only responsibility of the mechanised boats is to obtain licences from the state government authorities and observe the time-to-time restrictions, if and when imposed. There are several instances of vessels operating without any license and also not following the restrictions. There is no licensing for the artisanal craft. As there is no proper marketing system, the catch and the revenue realised are totally unaccounted. There should be a beginning to introduce logsheets for the fishing vessels and to insist on submitting details regarding fishing effort, catch, area of operation, sale proceedings etc. Predictably, the fishers will not provide reliable information. The mechanism of monitoring and verifying the declared information would not be impossible, but will be very expensive. Nevertheless a beginning should be made to inculcate responsible fishing among the fisherfolks.

Kalawar *et al.* (1985) suggested that the mechanised boats could be registered according to ports and prior permission of authorised officers made obligatory for vessel movement from one port to another. Licensing scheme could be extended to cover the entire fishing industry including the artisanal sector to help monitor fishing effort and optimisation of inputs. It is necessary to constitute scientific committees for resources estimation, prescription of total allowable catches and for rendering advice on various fisheries management issues. District level advisory committees with presidents of fishermen cooperative societies as members could be formed to help the government in framing or modifying rules governing fishing regulations. The revenue departments could also be involved in the enforcement of fishing regulations. A system in which the fisheries officer and the presidents of the fishermen cooperatives serve as the enforcement personnel, the tahsildar (administrative head of a tahsil or subdistrict) as the adjudicating officer and the district magistrate as the appellate board, would facilitate quick decisions on which the judgement given by the appellate board would be final.

Total allowable catch

The most common fisheries management method followed in many countries is to impose an upper limit on the total allowable catch (TAC). Setting an upper limit on how much can be caught, most fish stocks in the northeast Atlantic are now controlled. This is a typical biological management measure designed to protect fish stocks. If adhered to, the TAC restrictions are well suited for conserving the fish stocks. Under this system, the fishery biologists recommend the TAC for each stock for the ensuing fishing season. These recommendations are usually based on the criterion that fishing mortality should be at the level that allows MSY or related criteria. Once the TAC is set, it is divided among vessels, depending upon the type and efficiency of the vessels. For the purseseine fleet, for instance, the TAC for each of the pelagic stocks such as the herring, capelin and mackerel is divided on the basis of the licensed cargo capacity of the vessels. When the fishing capacity of the fleet is greater than the TAC, the activity of the fleet will have to be constrained to prevent its catches from exceeding the TAC. The catch of each vessel is reported to the concerned authorities through the fish marketing organisations. The TAC system is reported to be largely successful. In the case of Barents Sea capelin, the TAC system averted the collapse of the stock. The stock was severely depleted in the early 1980s and the TAC was introduced from 1986 to 1990. In 1991, the stock recovered sufficiently (Hannesson, 1994).

This example of successful management notwithstanding, the system also has shortcomings. Fishers and boat designers circumvent regulations on fishing vessels by increasing fishing capacity through new designs that satisfy the restrictive rules, and by including new fish finding devices and efficient gears. To overcome this, the US government amended the Fisheries Act of 1986, a regulatory device called individual transferable quota (ITQ), which is now being implemented in many countries. Under this device, the TAC quotas for each species and each vessel are transferable. The transferability ensures that the least efficient fishing vessels will not be used, as their quotas can be bought by the owners of more efficient vessels at a price that benefits both the buyer and the seller. If the ITQs are defined as shares of the TAC, the catch quotas of individual vessel will fluctuate in proportion to the TAC, and the boat owners will have to make a well educated guess as to how the TAC will fluctuate and how much they can expect to be allowed to fish in the future (Hannesson, 1994).

The debates on fisheries management around the world, and the novel methods being tried elsewhere, originate from the simple fact that open access is totally inadequate for managing marine fisheries resources. Open access is certain to lead to the depletion of stocks, possibly beyond recovery as evidenced in the case of many fisheries elsewhere. Access to fish resources must be limited by any of the restrictive methods though all of them have undesired side effects (Table 2).

In spite of the shortcomings, of all the fisheries management systems, it is believed that the TAC and the ITQs on catch are capable of biologically managing fisheries and deliver the full potential economic benefits of fisheries. In many countries, a consensus has emerged among the fishery economists that the ITQ system, because it essentially eliminates the basic common property problem of fisheries, offers the most promising general approach to managing marine fisheries. Unfortunately, the present marine fisheries management system in India could not adopt the TAC or the ITQ system, as there is no practice of reporting the catch to any authority by any commercial vessel, whether mechanised or artisanal. It is necessary, as the first step, to introduce reporting of the catch and revenue realised by the commercial mechanised vessels through logsheets.

Ecosystem-based fisheries management

As far back as half a century ago, the UN Technical Conference on the Conservation of the Living Resources of the Sea recognized the importance of an ecosystem approach to fisheries management in 1955. However, the impetus to this approach was given only in 1995 in the FAO Code of Conduct for Responsible Fisheries. Since then, several developed countries have begun the process of adopting the ecosystem-based fisheries management. Unlike the single species models in fisheries management, an ecosystem approach is an effective tool since it takes into account the complexity of the marine and coastal ecosystems and it is now believed that such an approach could provide a lasting solution to the problems of declining aquatic biodiversity and fish stock biomass. An ecosystem-based approach to fisheries management, according to the NMFS (1999), 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 the fish biology and ecosystem; (iii) the interactions 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 has 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 (NRC, 1999).

An ecosystem approach could help manage fisheries in the following ways (Mathew, 2001): (i) Conservation of fisheries resources, protection of fish habitats, and allocation to fishers are the three most important considerations in fisheries management. The vantage point to start from is the fishing gear group, because without its cooperation, it would not be possible to adopt effective conservation measures and protect fish habitats from fishery-related stress. The ecosystem models estimate the carrying capacity of the ecosystems and the biomass at each trophic level by taking into consideration the weather and hydrography of the ecosystem and fish biology. It also quantifies the number of craft and gears required for sustainable harvest from the given ecosystem. It helps bring about a greater control over large scale operations of nonselective fishing gears. (ii) The approach can facilitate a better understanding of the trophodynamics in an ecosystem, and also the impact of fishing gear selectivity on marine living resources. Programs designed to conserve marine mammals and turtles may become counterproductive when these resources multiply in large numbers and compete with fish stocks as well as fisheries. The fishermen of the Lakshadweep Islands complain about the proliferation of marine turtle population, which not only predate on fishes, but also cause damages to the fishing gears. Along the north Peru coast, squid jiggers complain about predation on squids by sea lions and dolphins. It is estimated that the annual damage caused by the sea lions is about 64 million US $ along the north Peru coast (Manuel, 1997). (iii) The ecosystem approach can be applied to understand and to prevent land-based sources of pollution that have an adverse impact on plankton, which constitute the mainstay of the food of the small pelagics. In addition, reduction of nursery grounds from destructive activities like construction and reclamation in coastal areas, mangrove deforestation, destruction of coral reefs, as well as the loss of marine biodiversity are the other vital issues that need to be dealt with seriously and effectively in the tropical waters. (iv) It would be helpful to understand the impact of the natural factors such as weather and hydrographic factors on fish stocks. In the Pulicat backwaters (southeast coast of India), for example, the mullet and shrimp stocks perish if the salinity exceeds that of the sea due to evaporation, zero exchange of water (as a result of mud formation at the mouth), and zero discharge into the lagoon from rivers (due to upstream dams). Under such conditions, conservation of the mullet and shrimp stocks is not possible just by refraining from fishing. The *padu* system, a system of rotational access to the fishers to shrimping grounds, practised in the Pulicat, does not mitigate the pressure on shrimp stocks because different groups, in a rotational basis, incessantly harvest the stocks.

The fisheries prevailing in about 150 marine ecosystems around the world have already been assessed based on ecosystem models. It appears that this approach may totally replace the dependence on the conventional single species stock models in the near future. Developing the ecosystem approach would be ideal for a country like India, which is characterized by multispecies, multigear and multicultural marine fisheries. However complex it might be, the ecosystems models need to be built up by knitting together all the relevant historic data, and involving in the process, the training and education of the fishermen towards the adoption of ecosystem approach to fishing.

No-fishing zones (Marine Protected Areas)

In the early 1990s, Canada's Atlantic cod fishery collapsed and thousands of people were put out of work. None of the conventional methods such as the (i) restrictions on the season's total catch, (ii) controls on the number of days or weeks of fishing, and (iii) regulations on the kind of craft and gear that can be used, did not have the desired effect on the stocks. Therefore, a group of scientists proposed a radical and surprising idea. If all forms of fishing in certain areas are banned altogether, the overall catch can be increased in a sustainable way. Since then, a plethora of studies have convincingly demonstrated that the creation of no-fishing reserves allows the rapid build-up of fish spawning stock biomass (Roberts and Polunin, 1991; Dugan and Davis, 1993; Allison *et al*., 1998). The idea behind reserves 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 ten 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 reserves showed average increases of 91% in the number of fish, 31% in the size of fish and 23% 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 areas in 1995. Within three years, commercially important fish stocks had doubled in the seas adjacent to the reserves.

No-fishing reserves will work well for migratory species also if the reserves are put in the right places. Reserves placed in nursery and spawning areas will protect the migratory species during critical life stages. For example, spawning haddock and groupers are protected in the Georges Bank and Virginia Islands, respectively as the spawning aggregations were fished to extinction. Some reserves will primarily benefit fisheries, some others conservation, but most will benefit both simultaneously.

There are strong evidences to suggest that reserves will work even better in the tropics. However, there is no direct experience of reserves in India barring the marine sanctuaries in the fragile coastal zones to protect coral reefs and mangroves. Considering that the concept of no-fishing zone is a good strategic tool, fisheries managers in India 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 fishing grounds. Recently the American Association for the Advancement of Science (AAAS), along with about one hundred scientists called for 20% of the world's oceans to be declared for no-fishing 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 or rotational reserves. Considering the location of fishing villages close to each other along the Indian coast, the selection of areas for no-fishing and the logistical, economic and social implications of dislocating and rehabilitating the fishers to fishing areas away from the reserves call for extreme care in planning.

Social issues

The components of fisheries management encompass more than resource management. Fisheries management, through the control of fishing activities, aims not merely to ensure the most favourable stock conditions for achieving the MSY or the maximum economic yield (MEY), but also on the social upliftment of the fisherfolks.

A review of the historical development of Indian fisheries reveals that in the earlier stages when the resources were abundant and management was not a serious concern, there was no dispute over the utilization of fishing grounds. The steady decline in the catch in the traditional sector has created great apprehension among the artisanal fisherfolk, who generally accuse the trawlers for the decline in the fish stocks. Competition for space is also believed to be a major factor for the setback in the catches in the artisanal sector. As a large number of trawlers crisscross the limited inshore waters (traditionally exploited by the artisanal fisherfolks), both day and night, there are complaints of stationary artisanal gears such as the gillnets and longlines getting damaged by them. Moreover, the artisanal fisherfolks are of the view that trawling is detrimental to the shrimp stocks.

Fisheries management deals with multiple stakeholders, and sustaining a fishery or fisheries requires the participation of all the stakeholders, who should discuss, agree upon and implement the management plans. The fishermen in India are generally organised through their cooperative societies. However, the societies are effective only in very few areas. In Gujarat, for example, these societies play a very important role in managing the fishery. They act as the managing agencies and take decisions on the suspension of trawling every year. Any violation of the decision by an individual fisher is dealt with seriously by the society/community. Representatives from the various levels of the societies are members of the local and regional fishery coordination bodies. This sort of democratisation greatly helps in improving the fishery or fisheries. Participatory and negotiated fisheries management is the most effective way to manage fisheries.

Other management options

For sustaining marine fish production, the management plan should explore the possibilities of (i) dispersing the existing fishing intensity in the inshore waters to the farsea, (ii) providing support to the fisherfolk by locating potential fishing zones through remote sensing, (iii) increasing the productivity of the coastal waters by installing artificial fish habitats and searanching, and (iv) providing alternate employment opportunities such as mariculture.

Thus there are multiplicities of issues with objectives such as resource enhancement, environmental integrity, distributional equity, economic realization and organizational effectiveness. All these generic elements should be considered in advancing marine fisheries management options for the resolution or mitigation of the issues. The issues are interconnected with cross-reinforcing tendencies, for example, increasing fishermen population leads to increase in fishing effort, overfishing, stock depletion, habitat degradation and conflicts within the fishing communities. The management interventions are also interconnected, for example, the limited entry of fishing vessels will result in effort reduction, stock enhancement and shift the priorities in capture fisheries. The management interventions call for biological, ecological, social, administrative, legal and political actions at the community, state and national levels. Much of the success depends on organizational capabilities for implementing the interventions to achieve the overall objective of sustainable marine fisheries development.

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Table 1. Management techniques for different phases of a fishery		
Pre-developed fishery	**Developed fishery**	**Depleted fishery**
Promote	Maintain	Recover
Identify the resources	Assess the stock status	Investigate the causes
Provide economic incentives	Decide on promotions/ restrictions	Correct the earlier mistakes
Develop suitable craft, gears & equipments	Consider socioeconomics of fishers	Stock-recruitment relationships to be closely monitored
Train the fishers	Future prospects of tocks to be given priority	Decide the levels of restrictions and strictly enforce them; Searanching may help; Alternate employment oppurtunities to be opened for fishers

Table 2. Methods of biological fisheries management		
Methods	**Desired effects**	**Undesired side effects**
Restriction on effort	To relieve fishing pressure on the stock	Fishers overcome restrictions by enhancing fishing efficiency; fishing becomes expensive; artisanal fishers affected.
Closed areas and/or seasons MPAs	Protection of spawning stocks	Fishing intensity increases outside closed areas/seasons; fishing cost increases.
Minimum mesh size	Protection of juveniles; increase in stock biomass	Instant decrease in catch not acceptable to fishers; uniform minimum mesh size not possible in multispecies fishery; effects could not be verified.
Total allowable catch	Decrease of fishing mortality; rebuild of stocks	Overcapacity of fleets; tendency to increase fishing efficiency.
Individual transferable quotas	Decrease of fishing mortality; rebuild of stocks	Favours a few large companies

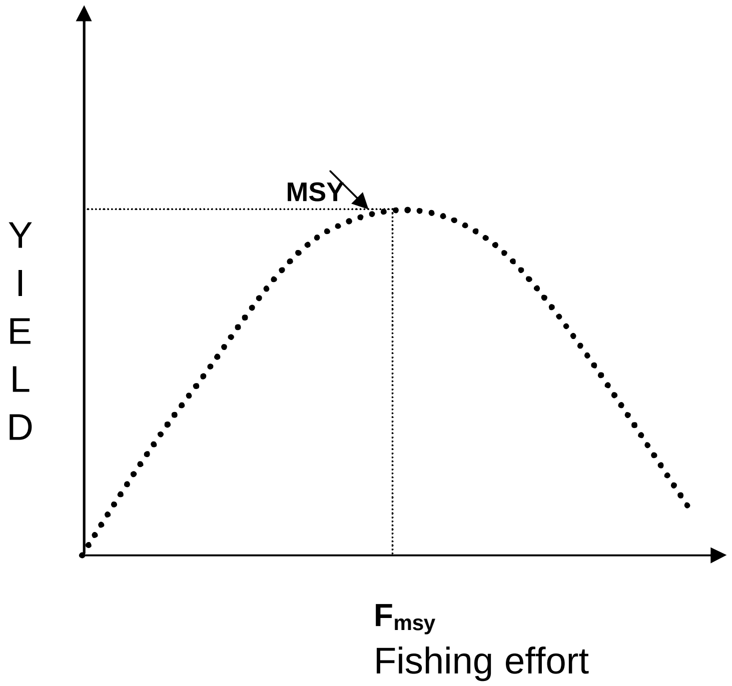

Fig. 1. Decrease in yield with increasing fishing effort

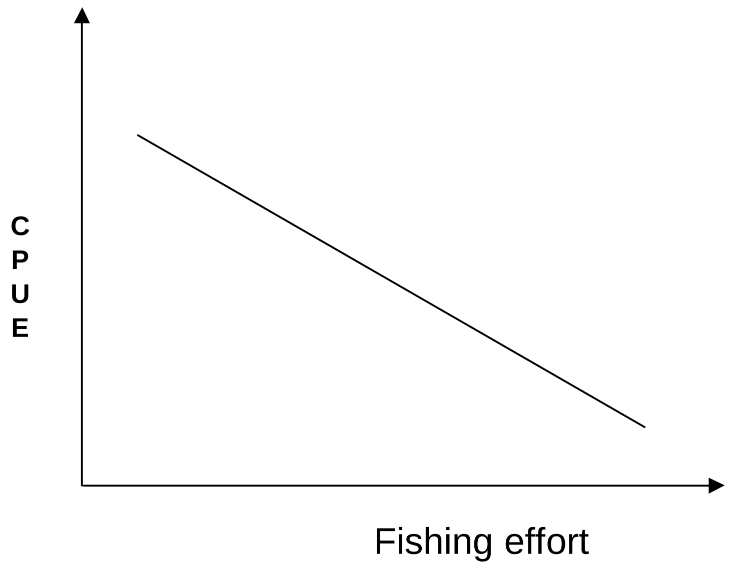

Fig. 2. Decrease in catch per unit effort (CPUE) with increasing effort

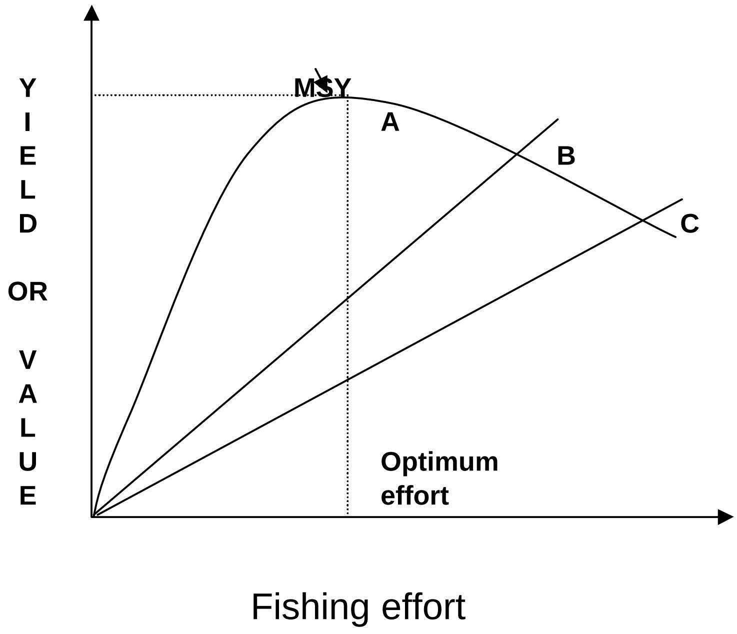

Fig. 3. Relationship between effort and yield/value; A : maximum yield/value; B : yield = cost of fishing; C : no further progress in fishery