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Sustainable coastal fisheries for nutritional security

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Abstract

Fisheries constitute the only sector, which offers animal protein to a broad economic cross-section of the society, thereby is in an advantageous position to ensure nutritional security. However, the scope for increasing coastal fish production, which contributes about 50% to the total fish production in India, appears to be limited. Reliable stock estimates, assessment of the efficacy of the existing fishing regulations, present economic status of fishing operations, formulation of key management interventions, and above all, allocation of adequate funds are a few major issues that demand immediate attention to ensure sustainability of marine fisheries.

Introduction

Nutritional security is the physical and economic access by all people at all times to the nutritionally adequate food they need. Therefore, it embodies stable, sustainable and predictable supply of nutritionally adequate food for life functions, and maintains equity through access for all with reference to the means of production and/or purchasing power (Williams, 1996). Fisheries sector is in an advantageous position to ensure nutritional security due to the following unique characteristics: (i) Fisheries constitute the only sector offering animal protein to a broad economic cross-section of the society from a price as low as Rs 10 kg^{-1} (e.g., the sardines) to as high as Rs 700 kg^{-1} (live spiny lobsters). (ii) The low valued resources like the sardines are not low in nutritional quality as their protein (65% dry weight) and energy (20 kj. g dry $weight^{-1}$) contents are equally high as that of the spiny lobsters (Radhakrishnan, 1989). For the economically weaker section, therefore, accessibility to the cheap but quality food could be achieved by sustaining/increasing fish production and by improving the physical accessibility through proper distribution. (iii) High fecundity (up to 1 million eggs) and fast growth rate (growth coefficient often > 1.0) of teleosts and crustaceans (Devaraj & Vivekanandan, 1999), probably have no parallel in other animal protein sources such as the livestock including poultry. These advantageous biological characteristics of aquatic organisms offer considerable scope for increasing production through aquaculture and for sustaining capture fisheries production, and thereby to find a solution to a greater extent in achieving nutritional security.

A steady increase in marine fish production from 0.5 million tonnes in 1950 to 2.4 m t in 1999 was possible solely through the catches from the natural stocks. The increase is comparable to the steady increase in the global fish production from 20 m t (1950) to 112 m t (1995) through the catches from the natural stocks, as well as from the recent growth in aquaculture. Compared to the temperate fish stocks such as the cod and haddock in the northwest Atlantic, which have drastically declined (Grainger & Garcia, 1996), most of the Indian marine fish stocks have not exhibited any alarmingly declining trend, although warning signals from several stocks have been recorded for their sustenance by adopting scientific management measures (Devaraj & Vivekanandan, 1999).

Among all the natural renewable resources, fisheries present perhaps the greatest challenge for effective management (Allsopp, 1985). The problems are the most difficult under tropical conditions. There are many interacting factors: a great variety of fish species, changing climatic and oceanographic conditions, level of exploitation, and social, political and economic pressures. In India, data have been systematically collected and analysed data since the 1940s to collate the necessary baseline data on the availability of species of fish, their abundance and catches, the effects of periodic environmental changes and the expected trends in their catches. Nonetheless, after centuries of fishing and with about 5 decades of concerted scientific and technical effort, fishery management has not emerged as an exact science, and it is not possible to claim success in the development of an effective, accepted and time-tested management system. However, concerted effort has made it possible to establish a few management regulations, which provide an insight into the critical needs for the future of capture fisheries. Reliable stock estimates, assessment of the efficacy of the existing fishing regulations, present economic status of fishing operations, formulation of key management interventions and above all, allocation of adequate funds are a few major issues that demand immediate attention to ensure sustainable marine fisheries.

Stock estimates

Biological management of fisheries resources involves proper assessment of fish stocks. Fish stock assessment may be described as the search for the exploitation level, which gives the maximum yield in weight from the fishery (Sparre & Venema, 1992). The main objectives of fish stock assessment are to (i) predict what will happen in terms of future yields, biomass levels and value of the catch, if the level of fishing effort remains the same or if it is changed in one way or another, and (ii) provide advice on the optimum exploitation.

Progress in stock assessment studies in India

Methods available for the assessment of fish stocks can be grouped under holistic models and analytical models. The holistic models consider a fish stock as a homogeneous biomass and use fewer population parameters than the analytical models. The analytical models are more demanding in terms of quality and quantity of input data but are believed to provide more reliable predictions. Though input data that are required for stock assessment, such as the landings, fishing effort and biological characteristics of the exploited stocks, are being collected for a number of fish stocks occurring along the Indian coast for the last 5 decades and stock assessment and prediction models were developed elsewhere as early as the 1930s, their application to the exploited Indian marine fish stocks has been made only in recent years. The first issue of the premier fisheries research journal, Indian Journal of Fisheries, which was published in 1954, dealt with essentially on the landings and biology of some of the major exploited stocks. Of the 127 research papers published in this journal during 1954-1959, most of them were on the characteristics of exploited stocks such as the landings (19.7%), and/or age & growth (16.5%), food & feeding (12.6%) and reproductive biology such as sex ratio, maturity, fecundity and spawning (12.6%) (Table 1). The emphasis in the 1950s was on understanding the nature of the stocks and not on quantifying the stocks. Consequently, the inadequacy/absence of the following information was a serious constraint in estimating the potential yield: (i) Most of the publications that reported the landings did not consider fishing effort, which is an important parameter for understanding the fishing trend and catch rate. (ii) For estimating age and growth, the progression of modes in the length frequency distribution and growth rings were traced through successive time periods, but there was hardly any attempt to estimate the growth coefficient values. (iii) Studies on the reproductive biology were on maturity and sex ratio, rather than on fecundity, which is an important parameter for assessing the reproductive capacity of the stocks.

Table 1. Coverage of different topics (% of papers published) by Indian Journal of Fisheries during two time periods

Topic	1954-1959	1996-1999
1. Occurrence		
New record	0.0	1.3
Distribution	5.5	4.6
2. Taxonomy		
Systematics	4.7	2.0
Morphometry	10.2	7.3
3. Egg & larval development	8.7	1.3
4. Environment		
Oceanography	6.3	1.3
Pollution	4.7	5.3
5. Plankton & productivity	6.3	3.3
6. Disease & parasites	0.0	4.6
7. Fisheries		
Methods	0.0	6.6
Landings	19.7	8.6
Food & feeding	12.6	6.6
Spawning	12.6	13.2
Growth	16.5	19.9
Mortality	0.0	8.6
Stock assessment	0.0	7.9
Craft & gear	4.7	0.7
Exploratory fishing	2.4	0.7
Marketing	1.6	0.7
8. Aquaculture		
Seed resource	0.0	0.7
Hatchery	3.1	6.0
Farming	4.7	8.6
Feed	0.8	7.3
Live transport	5.5	0.7
9. Physiology & Biochemistry	5.5	6.0
10. Processing	7.9	0.7
11. Others	3.1	4.6

(iv) Most of the studies on food and feeding were on the qualitative assessment of the feeding habits, and the quantitative estimates were inadequate and restricted to individual fishes rather than to the populations. Quantitative and qualitative estimates on feeding are essential for estimating the predation mortality. (v) There was no attempt to estimate fishing and natural mortality rates. The situation changed since the 1970s with the research emphasis gradually shifting towards the quantification of fish stocks. During 1996-1999, only 25% of the 239 papers published in the Indian Journal of Fisheries were on the exploited fisheries. However, the following significant improvements are discernable: (i) Most of the papers considered fishing effort and catch rate. (ii) The annual growth coefficient values were estimated (by nearly 20% of the papers) by tracing the

Table 2. Comparison of annual estimated stocks and yields for different species; yield[1] =annual landings during the period of study;yield[2] =landings during 1998; *represents Maximum Sustainable Yield

Species	Area	Year	Estimated stock (t)	Yield[1] (t)	Suggested status	Source	Yield[2] (t)
			ANALYTICAL METHODS				
Sardinella longiceps	SW coast	1958-67	440000	174356	Underexploited	Banerji,1973	97127
S.longiceps	SW coast	1965-76	484000	198440	Underexploited	Sekharan,1976	97127
S.longiceps	SW coast	1972-76	380000	134000	Underexploited	Devaraj *et al.*,1997	97127
S.longiceps	SW coast	1972-77	400000	136000	Underexploited	George *et al.*,1977	97127
S.longiceps	SW coast	1974	810000	210000	Underexploited	PFP,1976	97127
S.longiceps	W coast	1984-88	300000	117000	Optimally exploited	Annigeri *et al.*,1992	98209
S.longiceps	Karwar	1976-866	3632*	2450	Optimally exploited	Dhulkhed & Annigeri,1994	4184
S. gibbosa	Karwar	1979-83	2614	320	Underexploited	Annigeri,1985	2574
Lesser sardines	Karwar	1979-83	419*	272	Overexploited	Annigeri,1985	1610
Rastrelliger kanagurta	SW coast	1934-84	109229	62198	Underexploited	Devaraj *et al.*,1994	107709
R.kanagurta	SW coast	1958-67	90600	58781	Underexploited	Banerji,1973	107709
R.kanagurta	SW coast	1960-71	130000	65000	Underexploited	Sekharan,1976	107709
R.kanagurta	SW coast	1972-76	105000	68000	Underexploited	George *et al.*,1997	107709
R.kanagurta	SW coast	1972-73	450000	94000	Underexploited	PFP,1974	107709
R.kanagurta	W coast	1984-88	50700*	49800	Optimally exploited	Noble *et al.*,1992	143059
R.kanagurta	E coast	1984-88	25300*	23700	Optimally exploited	Noble *et al.*,1992	32554
R.kanagurta	Mangalore	1967-75	198870*	96541	Underexploited	Yohannan,1982	10794
Harpodon nehereus	NW coast	1947-86	189844*	80000	Underexploited	Fernandez & Devaraj,1996a	106066
H. nehereus	NW coast	1975-86	55000	57000	Overexploited	Kurian,1988	106066
H. nehereus	NW coast	1982-86	76893	52213	Overexploited	Kurian & Kurup,1992	106066
H. nehereus	Saurashtra	1974-84	108000	44064	Optimally exploited	Khan,1985	76945
H. nehereus	Nawabunder	1976-86	3918*	3561	Optimally exploited	Khan,1989	13006
Coilia dussumieri	NW coast	1960-85	24451*	17534	Optimally exploited	Fernandez & Devaraj,1996b	40389
Euthynnus affinis	Chennai	1981-86	27*	25	Optimally exploited	Srinivasarengan *et al.*,1994	214
Trichiurus lepturus	West	1984-88	65600*	23733	Underexploited	Thiagarajan *et al.*,1992	85000
T.lepturus	East	1984-88	20400*	21000	Overexploited	Thiagarajan *et al.*,1992	28000
Megalaspis cordyla	India	1985-89	14161*	6627	Underexploited	Reuben *et al.*,1992	25408
Nemipterus japonicus	Chennai	1980-83	2300	336	Underexploited	Vivekanandan & James,1986	570
N.japonicus	India	1984-88	51000*	48100	Optimally exploited	Murty *et al.*,1992	60000
N.japonicus	Mangalore	1988-95	3501*	3416	Optimally exploited	Zacharia,1998	
Penaeid prawns	Kakinada	1974-77	2589*	2029	Optimally exploited	Rao,1988	8711
Metapenaeus monoceros	Kakinada	1974-77	805	328	Underexploited	Rao,1994	2900
M. monoceros	Maharashtra	1986-88	6565*	5796	Underexploited	Smita,1990	2500
Parapenaeopsis stylifera	Maharashtra	1986-89	14709*	14818	Optimally exploited	Smita,1990	21000
Panulirus polyphagus	Mumbai	1976-86	80	109	Overexploited	Kagwade,1994	94
Loligo duvaucelii	India	1970-80	18203	5142	Underexploited	Silas *et al.*,1985	40000
L. duvaucelii	Mumbai	1980-84	2150	721	Underexploited	Vidyasagar & Deshmukh,1992	9881
			HOLISTIC METHODS				
Demersals	south Orissa - north Andhra	1961-70	41868		Optimally exploited	Krishnamoorthi,1977	70000
Demersals	south Andhra - north Tamilnadu	1974-83	22884		Underexploited	Vivekanandan & Krishnamoorthi, 1985	180000
Demersals	Saurashtra	1985-89	12370		Overexploited	Vivekanandan & Gopal,1991	400000

length frequency for several months (generally for > 36 months). (iii) There were estimates on mortality rates (8.6 % of the papers) and total stock and/or maximum sustainable yield (7.9 %) (Table 1). (iv) There were several studies, which attempted to predict the fisheries under different rates of exploitation.

Reliability of stock estimates

In spite of the improvements in the collection and analysis of data on the exploited fisheries, the attempts have not yielded, to a large extent, the desired results. Estimates on the stocks, yields and exploitation rates and the conclusions on the status of the fisheries remain an enigma even after several years of research. Most of the stock estimates suffer from one or more of the following defects: (i) Estimates on the stock size/MSY vary widely (Table 2). For instance, estimates on stock of the oil sardine *Sardinella longiceps* varied widely between 0.38 and 0.81 m t and that of the Indian mackerel *Rastrelliger kanagurta* between 0.10 and 0.45 m t along the southwest coast. (ii) Stock estimates were too high compared to the catches during the study period as well as during the later periods. For instance, the estimated stock of *S. longiceps* ranged from 0.4 to 0.8 mt along the southwest coast during 1958 -1977 but the yield ranged from 0.1 to 0.2 m t only during the study period and < 0.1 m t when the fishing intensity increased by several times in later years (1998). (iii) Stock estimates were too low compared to the catches during the study period as well as during the later periods. For instance, the estimated Maximum Sustainable Yield (MSY) of *R. kanagurta* was only 50,700 t along the west coast during 1984-1988 but the yield was substantially higher during the later years and reached 143,059 t in 1998. (iv) The status of the fisheries was wrongly assessed. For instance, (a) the yield from the supposedly underexploited fisheries did not increase even after an increase in exploitation over the years. For instance, the MSY and annual yield of *Metapenaeus monoceros* were 6565 t and 5796 t, respectively along the Maharashtra coast during 1986-1988 and the stock was concluded as underexploited. But the yield in the later years declined when the fishing intensity increased and reached 2500 t in 1998. (b) The yield from the supposedly overexploited fisheries increased with further increase in exploitation. For instance, the estimated stock and annual yield of the Bombayduck were 55,000 t and 57,000 t, respectively along the northwest coast during 1975-1986 and the stock was concluded as overexploited. But the yield in the later years increased with increasing fishing intensity and reached 106,066 t in 1998. (v) The exploitation rate (E = fishing mortality/total mortality) has been estimated and reported for 94 fish and crustacean stocks along the Indian coast through a number of publications and by the CMFRI (1997). Analysis of these estimates reveals that the E for 67 stocks was above 0.5 (Figure 1) during the 1980s and 1990s. In other words, 71% of the stocks along the Indian coast were assessed as overexploited for more than one decade. However, the yields from these "overexploited" stocks have not decreased, ten years later now, even after sustained increase in the fishing effort. (vi) Despite an increase in the fishing effort over the years, the E values estimated in the later years were lower than the estimates for the earlier years. For instance, the E for *R. kanagurta* was estimated as 0.66 along the SW coast during 1934-1983 (Devaraj *et al.,* 1994). The fishing effort increased by several times since then along the SW coast but the E was estimated to range between 0.2 and 0.5 only during 1997-98 (CMFRI, 1998). (vii) The analytical models are concerned with single species stock assessment. The E and stock estimates vary widely between the species in an ecosystem and hence, the management options on one species could not be applied to the other species exploited from the same ecosystem. For instance, the E for the carangids *Atropus atropus* and *Alepes kalla* were 0.82 (overexploitation) and 0.45 (underexploitation), respectively along the SW coast during 1984-1988 (Reuben *et al.,* 1992). The E for the females and males of the shark *Scoliodon laticaudus* were 0.63

(overexploitation) and 0.26 (underexploitation), respectively along the NW coast (Kasim, 1991). Under these situations, there is an uncertainty in suggesting suitable management measures.

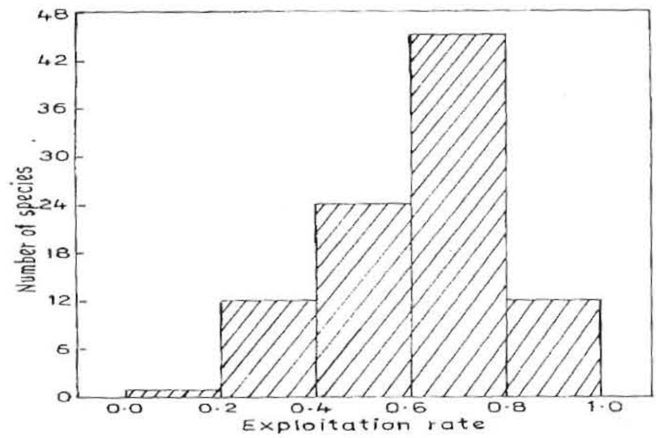

Figure 1. Frequency distribution of exploitation rate (E) of 94 fish and crustacean stocks along the Indian coast as reported by several publications and CMFRI (1997)

The uncertainties in the stock estimates could be linked to the resilience of the tropical fish stocks and the inadequacy of the existing stock assessment models in accommodating the resilience. (i) The tropical fisheries are characterized by a very large number of species (>800 species contribute to the major or minor fisheries in one region or another along the Indian coast) and majority of the stocks are continuous/frequent spawners with fast growth rate. Hence, the stocks are subjected to quick and large variations. Furthermore, the interactions between the trophic levels are too great that one could not expect consistence in the stocks and in the stock estimates as well, over the time-scale. All the existing models have been developed for temperate stocks but are being applied on tropical stocks without considering the dynamics of the tropical fish populations. (ii) There is little scope for the direct estimation of predation or natural mortality (M) in the existing models. The M is assumed as the leftover of the fishing mortality (F) from the total mortality (Z). Consequently, the M is often underestimated. Vivekanandan (2001) estimated that the quantity of prey ingested by the populations of two predators, viz., the threadfin bream *Nemipterus japonicus* and the lizardfish, *Saurida tumbil* off Veraval exceeded the annual landings of the corresponding prey. For instance, the two predator populations consumed 11,331 t of penaeid shrimps in one year whereas the annual landings of the shrimps was only 3,190 t. If the two predator populations could consume food higher than the landings in a well exploited fishery, and considering several other apex predators, the total biomass of shrimps lost due to predation must be several times higher than the mortality caused due to fishing. However, the conventional methods provided a natural mortality:fishing mortality estimate of 1:1.2, suggesting higher mortality of the shrimps due to fishing than the mortality due to predation. (iii) The models do not accomodate the reproductive capacity, which determines the recruitment. For instance, there is no scope to distinguish a high fecund species such as the tiger prawn, *Penaeus monodon* (about 1 million eggs.brood^{-1}; Rao *et al.*,

1995) from a low fecund species such as *S. laticaudus* (only 2 to 16 litters.brood^{-1}; Devadoss, 1998). (iv) The models ignore the impact of the environmental parameters such as temperature, upwelling and food availability on growth. (v) The holistic models do not consider the population parameters and consider all the stocks in a given area as a homogeneous mix. These models tend to underestimate the stock size and provide only an estimate of the availability of fish to the gear under operation. For instance, the demersal fish stocks were estimated as 12,370 t during 1985-1989 along the Saurashtra coast but the yield was as high as 4,00,000 t in 1998 (Table 2). The potential yield off Gujarat was estimated as 2,93,429 t in 1991 (Ministry of Agriculture, 1991) but the yield reached 7,03,105 t in 1998 (CMFRI, 1999). (vi) Stock estimates are made based on the fishing prevailing during the study period. The estimates will be upset when the fishing pattern changes. Along the Indian coast, there are continuous changes in the fishing pattern, by way of increase in the number and efficiency of craft and gears and extension of fishing grounds (Devaraj & Vivekanandan, 1999). There is no provision to incorporate these changes in the existing models, generally resulting in low estimates.

Need for departure from the current approach

The inadequacies in the stock estimates emphasise the necessity for a departure from the conventional single species approach. The need to account for the environmental and biological variables, and species interaction, particularly the functioning of the trophic food web in the ecosystem is becoming imminently clear. Application of ecosystem models such as the Ecopath (Polovina, 1984) involving energy, nutrients and trophodynamics to estimate the biomass of all the major species in an ecosystem appears to be a meaningful alternative. These ecosystem models are based on the assumption of biomass balance, i.e., balance of the flow to and from each group in an ecosystem (Christensen, 1998). In these models, the ecosystem is partitioned into trophic groups, and, given a set of parameters such as catch, consumption, assimilation, growth and reproduction, in addition to complementary estimates of fishing and natural mortalities from the conventional estimates as inputs, estimates of the annual biomass, annual biomass production and annual biomass consumption at each trophic level are made. Preliminary application of the ecosystem models to the southwest coast ecosystem revealed that these models could be developed as powerful tools not only for gaining proper insights into the functioning of an ecosystem but also for evolving fisheries management plans (CMFRI, 2000). The analysis revealed that the harvestable biomass of the plankton feeding pelagics such as the clupeids, Indian mackerel and scads is very high (14.6 t km^{-2}) compared to the annual average catches (6.7 t km^{-2}) along the SW coast and hence there is scope to increase the catches of the plankton feeders (7.9 t km^{-2}; Figure 2). On the other hand, the catches of several other ecogroups, especially the demersals (major perches, threadfin breams, goatfishes, sciaenids, flatfishes, whitefish etc) and the detritivores (penaeid shrimps) have exceeded the harvestable biomass by 0.1 to 2.2 t km^{-2}. The anaylsis provided the following important clues on the imbalance in the commercial operations along the southwest coast: (i) Gears employed for the exploitation of the demersal resources, particularly the bottom trawls are excessively used. The trawlable biomass appears to be overexploited and a reduction in the trawl effort is necessary. (ii) Gears employed for the exploitation of pelagic resources are either underutilised or are not utilised. Considering the scope for increasing the catches of the plankton feeders, which are pelagic, it has been suggested that pelagic/mid-water trawl, which is not commercially practised along the Indian coast, may be attempted.

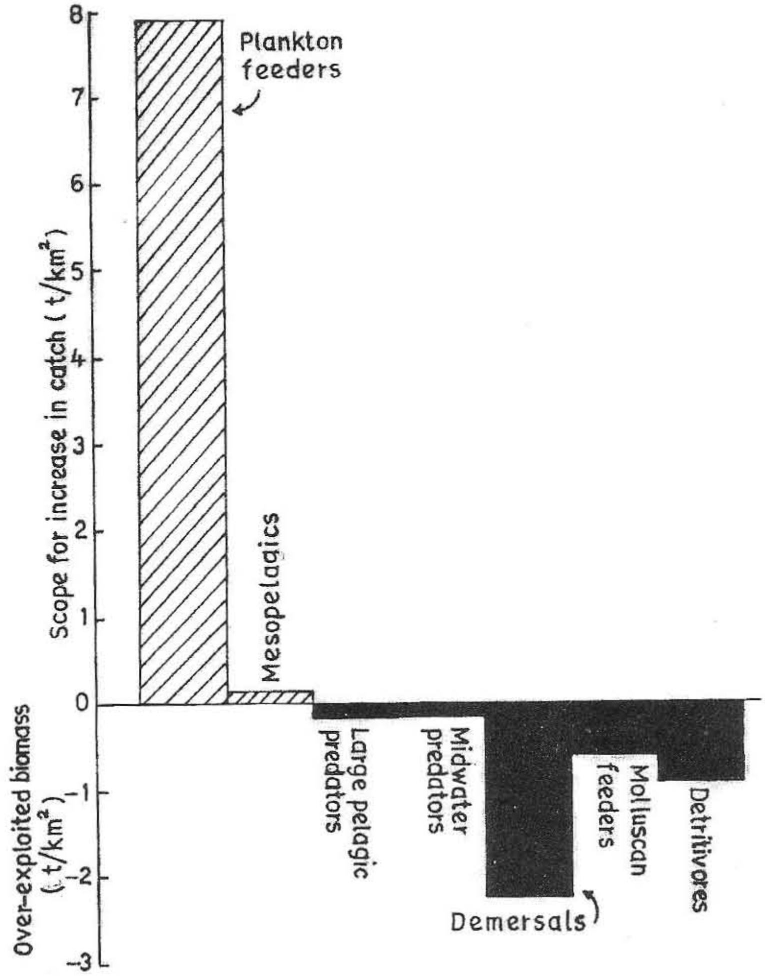

Figure 2. Status of exploitation of different ecogroups along the southwest coast as estimated by ecosystem model; the values are calculated from CMFRI (2000)

Preliminary application of the ecosystem model has demonstrated the capacity of the model in evolving fisheries management options through manipulating the craft and gears. However, these models are data demanding and their reliability depends on the quantitative and qualitative adequacies of the input data. Collection of input information on the fish stocks of different ecosystems is essential to assess the status of the fish stocks along the Indian coast and to evolve viable management options.

Fishing regulations

Fish is the largest living resource that is exploited from the nature. One of the most important characteristics of capture fisheries is that the resource is a common property, the access to which is free and open. The need to manage fisheries arises from two situations. 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 objectives of fisheries management are to provide wholesome food, maintain sustainability of the resources and ensure gainful employment and economic benefits.

Until the 1970s, the emphasis of coastal fisheries management in India was to increase fish production through improving and increasing the techniques and efficiency of fishing and by offering welfare measures to the fishers. These measures have, to a very large extent, paved the way for increasing the marine fish production from 0.5 m t (1950) to 2.4 m t (1999). In the 1980s and 1990s, however, there were serious concerns that the unrestricted growth of the fishing industry may become counterproductive (Devaraj & Vivekanandan, 1999). Consequently, there is a need to shift the management priority from increasing the fish production to sustaining the fisheries, and the maritime state governments have promulgated Marine Fisheries Regulation Acts (MFRA) in the 1980s. These acts concentrate on controlling the effort, gear and area of fishing. Though the contents vary between the states, the two major restrictions in the Acts are (i) regulation of mesh size and (ii) ban on inshore fishing by mechanised vessels. However, these two restrictions are found to be difficult to implement, and if implemented, may prove to be inefficient in replenishing the fish stocks.

Regulation of mesh size

Regulation of mesh size of gears is often emphasized to protect the young fish and to regulate the size of fish caught. It is 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 (Jones, 1976). Another purpose of controlling the mesh size is to permit the escape of juveniles hoping that their growth will increase the exploitable biomass, which might be available to the fishery later. The catch, on a later day, is expected not only to compensate the loss but also to become more valuable (Anderson, 1977). First, the total weight may be greater. Second, large-sized fish would have higher market price per unit. If both these conditions hold, then the value will surely go up in future. It is possible that an increase in unit value can even make up for a decrease, if any, in the catch.

The MFRAs insist that the mesh size in the codend of the trawls should not be below 30 mm (stretched from knot to knot). However, even after the promulgation of the MFRAs in the early 1980s, the codend mesh size (CEMS) of the trawls prevalent in the country is only 10 mm. The small meshes retain large quantities of low-valued small fish. Vivekanandan & Koya (2001) analysed the catches of an experimental trawler operating 30 mm and 15 mm CEMS, and the catches of the commercial trawlers operating 10 mm CEMS off Veraval. The low-valued by-catch fetched by the 30 mm CEMS was only 1.9 kg/h, whereas the 10 mm CEMS fetched 54.2 kg/h (Table 3). The by-catch was either discarded in the sea or sold for very low price. The by-catch of commercial trawlers comprised of the following 3 categories: category I: economically unimportant but large bodied groups such as pufferfishes, jellyfishes and stomatopods; category II: small bodied groups like the nonpenaeid shrimps, myctophids and a few species of crabs; and category III: juveniles of economically important groups. Among these, the landings of nonpenaeid shrimps (especially *Acetes* spp) and juveniles of economically important groups were very high (Table 3). It is estimated that the commercial trawlers of Veraval exploited 22,185 t of category III in one fishing season. Had the trawlers used nets with CEMS of 30 mm, the loss of juveniles would have been only 1,400 t.

However, the efficiency of larger CEMS is questionable. Larger CEMS allows non/under-exploitation of small-bodied adults such as nonpenaeid shrimps. For instance, larger CEMS (30 mm) allows the escape of all the nonpenaeid shrimps. Hence, a mesh large enough to allow one species to grow to optimal size may permit practically all of another species to escape permanently. Moreover, trawls with small CEMS of 10 mm fetch 2.5 times higher catch rate than those with 30 mm CEMS. The catch rate of penaeid shrimps was substantially higher (4.7 kg h^{-1}) in the trawls with 10 mm CEMS than that (0.1 kg h^{-1}) with 30 mm CEMS. As the immediate benefits of using small CEMS is high, the fishers are not prepared to use large meshes and wait for a possible but uncertain higher returns later. Furthermore, the larger mesh size erodes the economic returns, leading to difficulty in enforcing the Act.

Table 3. Catch rate (kg/h) of 3 categories of by-catch landed by trawlers that operated different codend meshes off Veraval

Category	Codend mesh size (mm)		
	10	15	30
I	0.2	0.6	0.1
II	27.3	4.1	0.1
III	26.7	17.3	1.7
Total	54.2	22.0	1.9

Regulation of fishing areas

To prevent the persistent conflicts between the artisanal and mechanised vessels in sharing the fishing areas, the MFRAs of the maritime states ban the mechanised fishing vessels from operating in the inshore waters (extending to a distance of 5 to 10 km from the shore and/or to a depth of 30 to 50 m), which have been exclusively assigned to the artisanal craft. As the density of fish biomass generally decreases with increasing distance from the shore and increasing depth, the mechanised craft are denied the opportunity to exploit richer fishing grounds of the inshore waters. For instance, biomass of the coastal small pelagics such as the oil sardine is dense in inshore waters, and hence, keeping the purseseines of Kerala, Karnataka and Goa outside the area of abundance of this stock is a disadvantage to them. Similar example is the abundance of penaeid shrimps in the shallow waters, which is deprived for the trawlers. Consequently, encroachment by the mechanised vessels into the areas demarcated for the artisanal craft continues, leading to frequent clashes between the two sectors.

Thus, the two regulatory measures in the MFRAs, viz., regulation of mesh size and fishing areas, remain largely unimplemented due to (i) uncertainties in their efficiency, (ii) non-compliance by the fishers, and (iii) absence of a surveillance system. The only restriction that is being enforced is to limit the fishing effort through seasonal closure of fishing by mechanised vessels.

Seasonal closure of fishing

The decisions on seasonal closure of fishing operation by the mechanised vessels are taken on a year-to-year basis by the maritime state governments, normally prior to or during the onset of southwest monsoon. On the west coast, Gujarat observes seasonal closure for about 140 days $year^{-1}$ during May-September for more than 25 years and Kerala for 45 to 60 days $year^{-1}$ during June-August for the last 12 years. The other states along the west coast also observe seasonal closure for 30 to 60 days. Along the east coast, Andhra Pradesh has initiated 45 days' closure during April-May since 1999. The objective of seasonal closure is to reduce the annual fishing effort of mechanized vessels, particularly the effort of the trawlers during the spawning season of fishes, and thereby replenish the stocks. The impact of seasonal closure on the annual fishing effort could be assessed by comparing the performance of two major landing centres, i.e., Veraval with regular seasonal closure every year for the last 25 years and Chennai, without closure. In Veraval, trawling is conducted, on an average, for only 215 days year^{-1}, while in Chennai, it is for almost 360 days year^{-1}. During the last 2 decades (1980-1999), the annual effort of Veraval trawlers increased by 1.8 times, from 3,75,000 h (1980) to 6,50,000 h (1999). In comparison, the effort of Chennai trawlers increased by nearly 4.5 times, from 2,50,000 h to 11,05,000 h (Figure 3). Though the effort of the Veraval

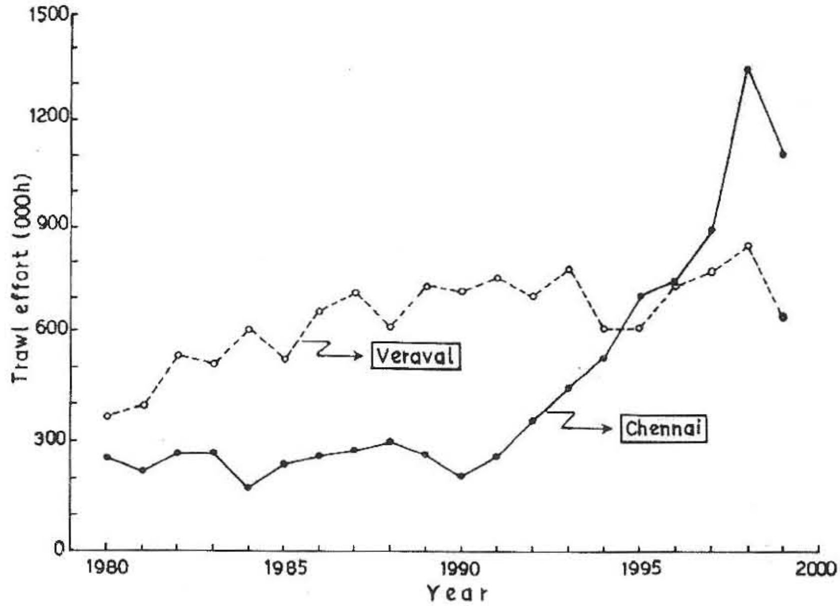

Figure 3. Comparison of fishing effort of trawlers based at Veraval and Chennai during 1980-1999

trawlers could not be maintained at a constant level in spite of the seasonal closure, the closure has helped in restricting the effort at a reasonable level in comparison to the uncontrolled increase in the effort of the Chennai trawlers. However, the number of trawlers increased very rapidly in Veraval. The number of trawlers increased by 2.2 times, from 560 to 1240 at Veraval (Table 4) compared to 1.7 times' increase at Chennai. More significantly, the trawl fleet at Veraval inducted larger and more efficient vessels. In 1998, about 85% of the Veraval trawlers were equipped with higher horsepower of 150 with an average length of >13 m. In comparison, 78% of the Chennai trawlers were large (OAL: > 13 m) with an average horsepower of 120 only. Consequently, the capacity of the trawl fleet in Veraval increased from 43,200 hp to 1,73,400 hp (Table 4), an increase of 4 times, compared to only 3 times' increase at Chennai. In terms of capacity, the catch rate realised by the Veraval (1.9 to 0.5 kg 000hp^{-1} h^{-1}) as well as Chennai (0.9 to 0.2 kg 000hp^{-1} h^{-1}) trawlers decreased equally by 75% during the last two decades. In other words, seasonal closure has helped in restricting the fishing hours but is inefficient in controlling the number and capacity of vessels and in arresting the declining catch rate. It is clear that to overcome the seasonal closure, the fishers of Veraval have expanded the parameters that are not subjected to restrictions. As the number of fishing days is restricted, the fishers have increased the fishing efficiency by investing in larger and more powerful vessels. In this process, there is a possibility of greater erosion of economic rent by the larger vessels, and only competing and wealthy fishers could survive. Those who could survive the competition, the potential economic benefits may ultimately dissipate, as they have to invest in larger vessels and in sophisticated fishing equipment.

Table 4. Increase in the capacity of trawl fleet operating from Veraval and Chennai Fisheries Harbours; OAL refers overall length of the trawlers

Fleet parameters	Veraval		Chennai	
	1980	1998	1980	1998
Number of trawlers				
<13 m OAL	320	180	370	150
>13 m OAL	240	1060	30	530
Total	560	1240	400	680
Trawl capacity (hp)				
<13 m OAL	19200	14400	22000	12000
>13 m OAL	24000	159000	3000	63600
Total	43200	173400	25000	75600
Catch rate (kg 000hp^{-1} h^{-1})	1.9	0.5	0.9	0.2

Had the seasonal closure year after year been effective in protecting the spawning stocks and increasing the recruitment, it should have been reflected in the catches. The annual catches off Gujarat (which follows closure for more than 25 years) increased by nearly 9 times in 28 years from 82,159 t (1971) to 7,03,105 t (1998) (Figure 4). The annual landings in Kerala, which fluctuated around 3,57,700 t during 1971 – 1987, increased after the introduction of seasonal closure in 1988 and the annual average landings was 5,69,825 t during 1988 – 1998. However, with the available information, it is not possible to prove that the increase in the landings at Gujarat and Kerala is solely due to the seasonal closure. The landings in Tamil Nadu, which does not follow seasonal closure, also increased from 1,60,619 t (1971) to 4,22,622 (1998) (Figure 4). During the 28 years, the increase in the landings in Tamil Nadu (2.6 times) was higher than that in Kerala (1.2 times). Irrespective of the seasonal closure, the following factors have played a dominant role in increasing the marine fish production along the Gujarat and Kerala as well as Tamil Nadu coasts during 1971–1998: (i) increase in the number and efficiency of mechanised vessels, especially the trawlers, (ii) extension of fishing grounds, along and off the coast (thereby exploiting the under-exploited areas up to 100 m depth), (iii) motorisation of artisanal craft, (iv) introduction of efficient gears such as ringseine and mini-trawl, (v) increase in the efficiency of trawlnets by increasing the mouth opening (thereby increasing the area of sweep of every haul), and decrease in the codend mesh size (thereby retaining the juveniles and thus resorting to bulk fishing). Due to these changes in the mechanised fishing sector, it is difficult to quantify the extra catches, if any, that would have been realised due to seasonal closure. The positive effects of seasonal closure can be ascertained by assessing the recruitment to the fishery, 3 to 6 months after commencement of every fishing season (Garcia, 1988).

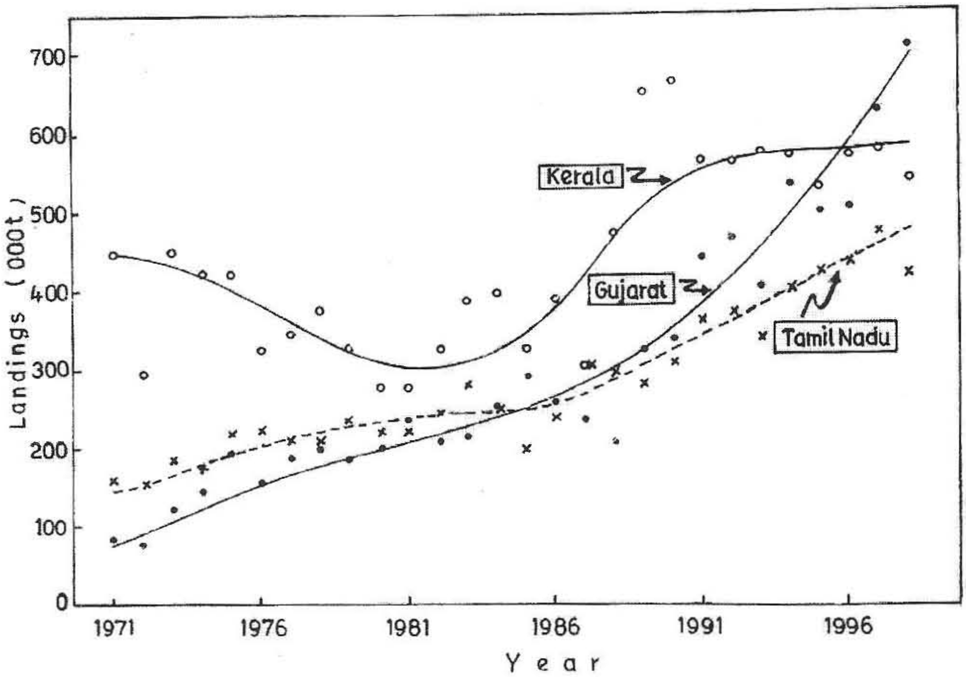

Figure 4. Comparison of marine fish production along Gujarat (•), Kerala (o) and Tamil Nadu (x) coasts during 1971-1998

Economic approach

The concept of fisheries management encompasses more than simple resource management as described above. Fisheries management, through the control of fishing activity, seeks not only obtaining maximum sustainable yield (MSY) but rather to achieve a maximum economic yield (MEY). Thus, the objectives of management are based not only on biological considerations but also on the socioeconomic aspects.

Uniqueness of fisheries economics

The basic nature of fisheries economics is unique compared to that of agricultural or industrial ventures. (i) It revolves around the focal theme that the resources are common property. The user need not pay for the right to exploit the resource, and he also does not have the right to prevent others from sharing it. (ii) In most industrial ventures, quality in end products could be achieved through high investments on infrastructure and machineries. The uniqueness of fisheries is that irrespective of the investment and modernization, quality of the product is the same. For instance````, a catamaran operating trammelnet with an investment of Rs 20,000 and a mechanised trawler with an investment of about Rs 8,00,000 exploit and land the same product, viz., the shrimps. Whereas the catamaran spends Rs 6 to produce one kilogram of shrimp, the trawler spends Rs 32 to produce the same end product (Sathiadhas *et al.,* 1995). The trawler is able to compensate the high fishing cost by (a) scouting and fishing in areas of abundance of high value resources, and (b) resorting to bulk fishing, thereby realising additional revenue. (iii) Another important feature of fisheries economics is that value of the products from a single operation varies widely. For instance,

Table 5. Price of different categories of fishery groups landed by trawlers at the Chennai Fisheries Harbour in January, 2000

Group	Landings (t)	Price (Rs kg^{-1})	Value (million Rs)
	Category I: Very high value		
Penaeid shrimps	185.3	20-450	27.8
Sand lobsters	1.0	20-150	0.1
Seerfishes	1.8	60-120	0.1
Pomfrets	49.4	40-120	3.2
Sub-total	237.5	20-450	31.2
	Category II: High value		
Sharks	9.3	20-80	0.5
Major perches	30.9	30-80	1.7
Carangids	107.0	20-70	4.0
Barracudas	16.1	30-60	0.7
Cephalopods	77.4	25-60	3.1
Sub-total	240.7	20-80	10.0
	Category III: Moderate value		
Rays	83.8	30-50	3.3
Eels	5.9	20-30	0.1
Clupeids	182.1	15-30	3.3
Lizardfish	15.2	30-40	0.5
Threadfin breams	91.2	20-50	3.2
Goatfishes	141.9	15-20	2.5
Sciaenids	124.9	15-30	2.8
Ribbonfishes	289.2	15-25	5.8
Indian mackerel	26.1	20-40	0.8
Flatfishes	16.8	15-70	0.7
Crabs	48.1	10-70	1.2
Others	50.9	10-50	1.3
Sub-total	1076.1	10-70	25.5
	Category IV: Low value		
Silverbellies	146.2	3-7	0.7
Stomatopods	3.9	3-7	0.02
Sub-total	150.1	3-7	0.7
Total	1704.4	3-450	67.4

the unit value of fishes exploited by the trawlers ranged from Rs 3 kg^{-1} (silverbellies) to Rs 450 kg^{-1} (penaeid shrimps) at Chennai Fisheries Harbour (Table 5). Moreover, there are wide differences in the price of same group or same species depending upon the size (or length) that is landed. For instance, the price of penaeid shrimps ranged from Rs 20 to 450 kg^{-1}, depending on size of the shrimp. Hence, low, moderate, high and very high valued fishes could be exploited without any difference in effort and expenditure. In other words, the fishing cost of the low and high valued products is the same. Expectedly, the trawlers target the very high and high valued groups. At Chennai, the very high and high valued groups contributed only 28% to the trawl landings in terms of quantity but 61.1% in terms of value. The moderate and low valued groups contributed 72.1% in terms of quantity but only 38.9% in terms of value.

These fundamental characters of fisheries economics induce the fishers, who invest on expensive craft and gears to keep increasing the fishing effort and search for high valued products. The fishers will increase the fishing effort so long as it is economical, irrespective of the reduction in the catch rate or even reduction in the catch (Anderson, 1977). With every increase in fishing effort, the fishing cost normally has a tendency to increase and the sale proceeds to go down.

Economic situation in an unmanaged fishery

An assessment of the state of economic health of fisheries cannot be confined to changes in physical outputs but must also include an evaluation of costs and revenues. The trawl situation prevailing in Chennai Fisheries Harbour provides the best representation between increase in the cost of fishing and decrease in the value of production in an unmanaged fishery. For this purpose, the data collected during 1980, 1988, 1994 and 1999 have been analysed. The fishing cost includes the fixed cost and the operational cost. The fixed cost includes the annual repayment of borrowed capital, interest, depreciation and investment, if any. The operational cost is the cost of fuel, labour and maintenance costs that were prevailing on the years when the data were collected. The value of production refers to the estimated market value at the landing centre. When the annual fishing effort increased by about 4 times from 2,50,000 h (1980) to 11,05,000 h (1999), the fishing cost also increased but by 14 times, i.e. from 42 million rupees to 551 million rupees.

The catch too increased from 5,822 t in 1980 to 42,649 t in 1994, but could not be sustained and declined sharply to 20,265 t in 1999 (Figure 5a). Consequently, the cost of production also showed parallel trend, i.e. an increase from 61 million rupees in 1980 to 874 million rupees in 1994 and subsequent decrease to 695 million rupees in 1999 (Figure 5b). To harvest a kilogram of fish, the cost of fishing increased from Rs 6.8 (1980) to Rs 27.2 (1999) (Figure 5c) and the ratio between the cost and value eroded from 1:1.6 (1980-1988) to 1:1.3 (1999). Figure 5 illustrates the gravity of the issue of excessive fishing effort off Chennai after 1994. The trawl effort exceeded what was required to harvest the highest catch of 42,649 t by more than two times in 5 years (see Figure 3). This implies dissipation of economic rent of 413 million rupees (additional fishing cost = 234 million rupees + reduction in the value of catch = 179 million rupees) in 1999 for the trawl fisheries. The coastal fisheries can ill afford the economic losses resulting from over-capitalisation and over-fishing.

Under this situation, the fishery management approach should involve rationalisation of capital investment on fishing. To avoid over-capitalisation 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 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 over-investment could be prevented, and at the same time, the

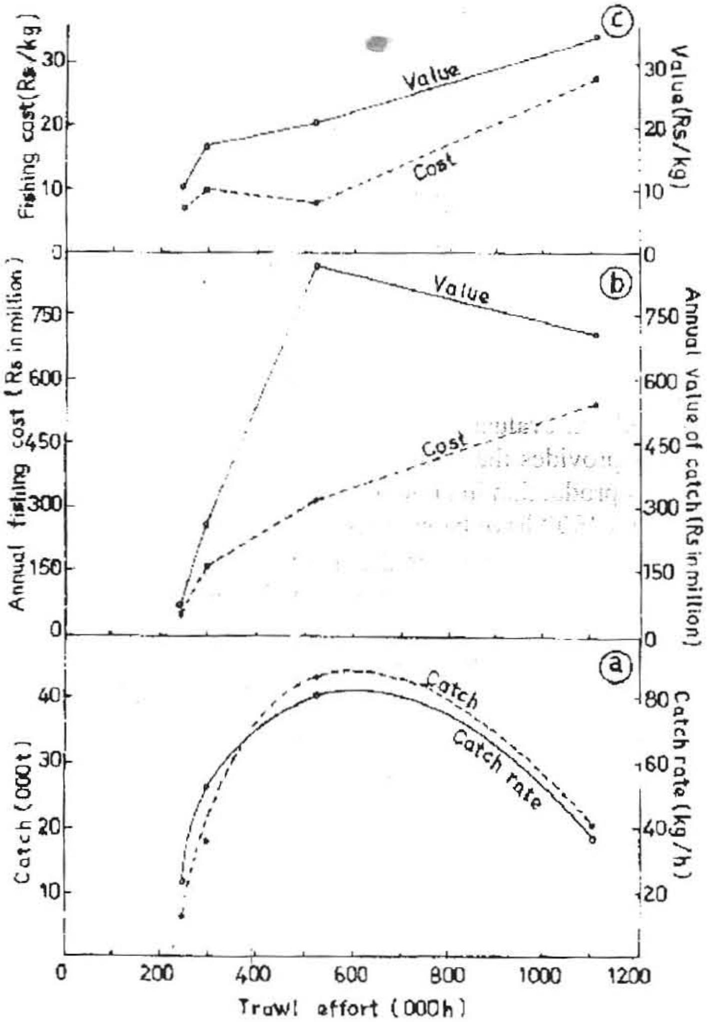

Figure 5. Impact of increase in trawl effort on the fishery economic parameters at Chennai Fisheries harbour during 1980-1999

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 over-capitalisation and regulating the fishing effort.

Key management interventions

Fisheries management is a dynamic resource allocation process where the ecological, economic and institutional resources of a fisheries exploitation system are distributed with value to society as the overall goal (Silvestre & Pauly, 1997). As the coastal fisheries is set in a variety of natural and human conditions, a wide diversity of specific objectives need to be pursued in its management. Devaraj & Vivekanandan (1999) identified the following major issues in coastal fisheries: increase in fishing intensity, declining stocks, conflict between fishing sectors, decreasing catch rate, decreasing recruitment, inappropriate exploitation pattern, habitat degradation and resource degradation. These multiplicities of issues could be summarized into generic categories of objectives

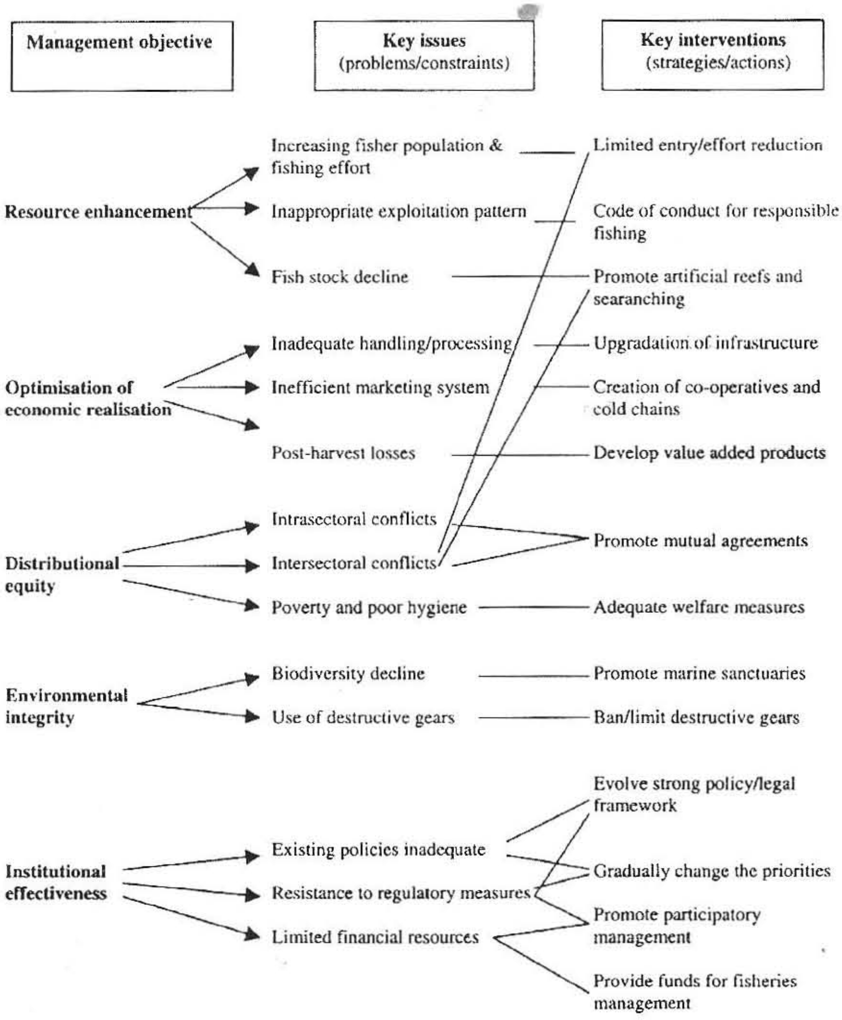

Figure 6. A system matrix of generic elements for formulating fisheries management options for India

such as resource enhancement, high economic realisation, distributional equity, environmental integrity and institutional effectiveness. Figure 6 presents a logical structuring of these objectives, issues and interventions and provides a systems matrix of generic elements that should be considered in advancing coastal fisheries management options. Fourteen key issues have been identified to affect the attainment of these objectives and the benefits derived from coastal fisheries. Fourteen key management interventions for the resolution or mitigation of these issues are also listed. The issues are interconnected and have cross-reinforcing tendencies, e.g. increasing fisher population leads to increase in fishing effort, over-fishing, conflicts between artisanal and mechanised sectors, leading to habitat and resource degradation. The management interventions are also interconnected, e.g. the limited entry of fishing vessels will result in effort reduction, stock enhancement and shift priorities in capture fisheries.

The management interventions outlined in Figure 6 shows scope for action at the community, maritime state and national levels. Much of the success will depend on institutional capabilities. The strengthening and upgrading of these capabilities and effective implementation of these interventions are dependent on the financial resources that can be mobilized for such purposes. Since the inception of the five- year plans by the Government of India in 1951, proper attention has been given to the development of fishing and allied industries in view of the high income and employment generating capacity of the sector. The outlay for fisheries (marine and freshwater) increased from 51 million rupees in the I five year plan (1951-1956) to 12,328 million rupees in the VIII plan (1992-1997) (Table 6; Ministry of Agriculture, 1996).

Table 6. Plan outlay for fisheries sector (source: Ministry of Agriculture, 1996)

Plan	Outlay (million Rs)
I	51
II	123
III	283
IV	827
V	1512
VI	3711
VII	5465
VIII	12328

The emphasis of the plan schemes thus far had been mostly on infrastructure development to facilitate increase in fish production. For instance, mechanization of the fishing fleets received the maximum thrust when there was necessity to expand the fishing areas beyond the range of the traditional craft, and to enable fishing for longer durations. Since the VII plan, the efficiency of the traditional sector has also increased due to motorisation of country craft. These developments were followed by appropriate measures to develop handling, processing and marketing infrastructure. During the VIII plan (1992-1997), the Government of India allocated 4,040 million rupees for central sector schemes and centrally sponsored schemes of fisheries development. Of this, major allocation was for fishermen welfare (16.6%), development of coastal fisheries (16.3%) and construction of major and minor fisheries harbours (25.0%) and only 350 million rupees (8.6%) was allocated for resource enhancement programmes and for enforcement of MFRA (Table 7).

As the emphasis in recent years is shifting from increasing the catches to sustaining them, adequate funds have to be mobilized for effective implementation of the interventions suggested in Figure 6. Higher allocation of funds, on par with the fisheries and fisher welfare programmes, is imperative for resource enhancement programmes such as searanching and seafarming and for effective implementation of fishing regulations.

Table 7. Allocation of funds for fisheries development during VIII plan (1992-97) by the Government of India (source: Ministry of Agriculture, 1996)

Schemes	Rupees (million)	%
1. Central sector schemes		
Central Inst.Fish.Nautical Engg. & Trg	150	3.7
Central Inst.Coastal Engg for Fish.	40	1.0
Integrated Fish. Proj.	100	2.5
Fisheries harbours	540	13.4
Training & Extension	20	0.5
Inland Fisheries Statistics	23	0.6
Central Fisheries Harbour Authority	50	1.2
2. Externally aided projects		
Shrimp & fish culture	77	1.9
3. Centrally sponsored schemes		
Minor fishery harbours	470	11.6
Freshwater aquaculture	600	14.9
Brackishwater farm development	250	6.2
Development of coastal fisheries (Motorization, introduction of plywood and intermediate craft & reimbursement of excise duty on HSD oil)	660	16.3
Fishermen welfare (Group accident insurance, Model Fishermen villages, Savings-cum-Relief Scheme)	670	16.6
Enforcement of MFRA	300	7.4
Resource enhancement through Artificial Reefs	50	1.2
4. New Schemes	40	1.0
Total	4040	

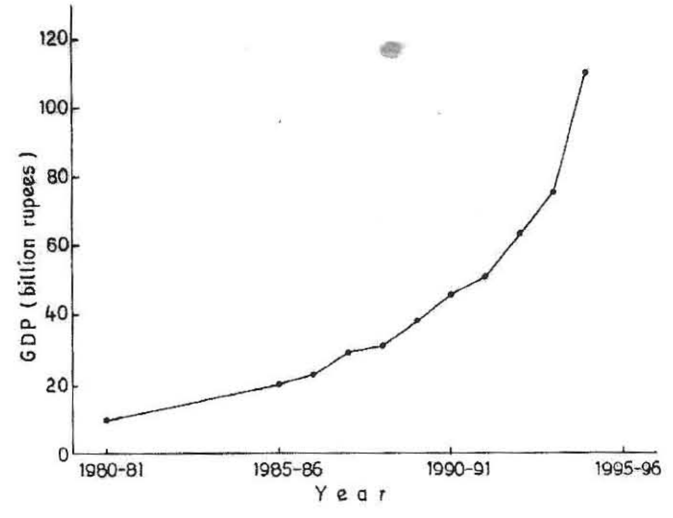

Figure 7. Gross Domestic Product of fisheries sector (marine and inland) (source: Ministry of Agriculture, Government of India, 1996)

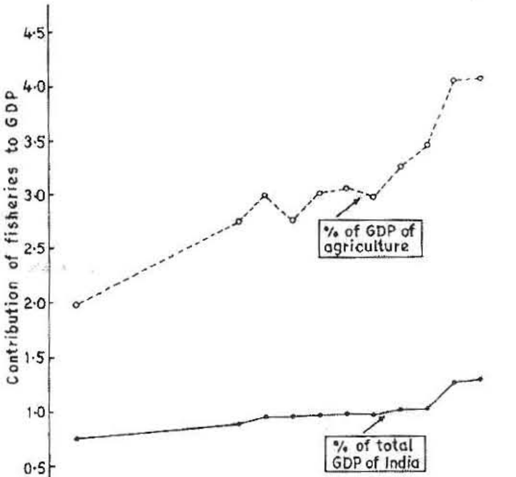

Figure 8. Contribution (%) of fisheries sector (marine and inland) to the GDP of India and the GDP of agriculture sector (source: Ministry of Agriculture, Government of India, 1996)

Marine fisheries sector is one of the largest foreign exchange earning sectors in India and the value of marine products export was 52 billion rupees during 1999-2000. The government has earned valuable foreign exchange without importing fish or materials/machineries (barring fuel for fishing vessels) required for export of fish. The Gross Domestic Product (GDP) of the fisheries sector (marine and inland) at current price level is steadily on the increase from 9.2 billion rupees in 1980-81 to 109.6 billion rupees in 1995-96 (Figure 7; Ministry of Agriculture, 1996). This implies that the resources (men, machineries and funds) of the fisheries sector are being efficiently utilized. The contribution of the fisheries sector to the GDP of India also increased from 0.75% to 1.30% (Figure 8), compared to the stagnation of the agriculture sector to the total GDP at 28.7%. Consequently, the contribution of the fisheries sector to the GDP of the agriculture sector substantially increased from 1.97% to 4.30%.

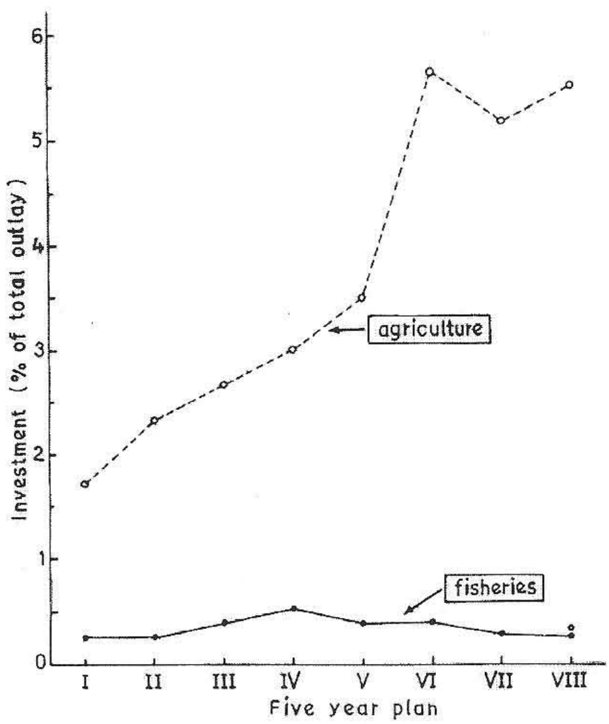

Figure 9. Investment on fisheries sector (marine and inland) through the five year plans; the values are percentage of total outlay and outlay for agriculture sector (source: Ministry of Agriculture, Government of India, 1996)

However, the government investment on the fisheries sector is stagnating around a mere 0.35% of the total plan outlay through the five year plans, compared to the substantial increase from 1.74% to 5.49% on the agriculture sector (Figure 9). The fisheries sector deserves better recognition for its growth and sustenance. Considering the livelihood of one million active fishers, the need for nutritional security and the potential for earning foreign exchange, it is imperative to invest on fisheries management for sustaining the coastal fisheries resources.

Recommendations

For sustenance of marine fisheries, the following major issues call for interventions:

(i) As the single species stock estimates are inadequate in properly assessing the status of the fish stocks, there are uncertainties in management interventions. Hence, multispecies, ecosystem models need to be applied for holistic assessment and prediction of the stocks and for evolving management plans.

(ii) There is need for a scientific introspection on the practicality and efficacy of the Marine Fishing Regulation Acts.

(iii) The priority of coastal fisheries development has to shift from increasing fish production to sustaining them by addressing the problems such as increasing fishing intensity, over-capitalisation, declining stocks, conflict between fishing sectors and habitat and resource degradation.

(iv) Considering the present marine fisheries situation, it is imperative to allot more funds for sustaining the coastal fish stocks and for resource enhancement programmes such as searanching and seafarming.

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