Sustainable Management of Marine Fisheries of the Exclusive Economic Zone of India

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Introduction

India is one among the top ten fish producing countries in the world contributing over 5% (7.5 million t) of the world fish production. The marine fisheries sector contributes nearly 50% of the total fish production and the total export of seafood during 2008-09 was estimated at 6,02,835 t at a value of Rs. 8608 crores. The estimated manpower employed in the marine fisheries sector in 2005 has been 1.24 million and in addition an almost equal number has been reported to be involved in the harvest and post-harvest activities including marketing. In the last five decades, the technological advancements fostered by fisheries research in the harvest and post-harvest sectors have accelerated the process of transformation of a traditional, subsistence level marine fisheries sector into a market driven multi-crore rupee industry. The marine fish production has made great leaps through successive stages; first with a change in gear material from natural to synthetic fibers and concurrent introduction of mechanised trawlers in the fifties, second with the introduction of mass harvesting gear, the purse seine along the southwest coast in the 1970s followed by the introduction of motorisation (OBM) of country crafts and the subsequent proliferation of innovative gears like ring seines in the late 1980s. With the introduction of multiday fishing in the late 90s, the yield reached 2.7 million t in 1997, and remained almost static for nearly a decade before reaching a record production of 3.21 million t in 2008. The overall valuation at point of first sales also recorded an increase of 48% between 1995 (Rs. 74,090 million) and 2005 (Rs. 1,10,080 million). The marine fisheries sector has been largely depending upon inshore fisheries and with the production from the near-shore waters reaching asymptotic level, fishermen are slowly expanding their operations to deeper waters. The present scenario is characterized by declining yields from the coastal waters leading to conflicts between various sectors and ensuring sustainability has become an essential feature of any marine fishing policy. The increasing demand for fish in domestic and export markets means that even while increasing fish production remains the goal, sustainability has to be assured through effective natural resource management tools.

Status of Marine Fisheries

Resources

The availability and distribution pattern of marine fishery resources in India follow a pattern typical of tropical waters. The fishery resource is constituted by a large variety of species (nearly 1570 species of finfishes and about 1000 species of shellfishes) coexisting in the same fishing ground. The multi-species fishery comprises of over 200 commercially important finfish and shellfish species. The important varieties belong to the pelagic groups such as the sardines, anchovies, mackerel, carangids, Bombay duck, ribbonfishes, seerfishes, tunas; demersal finfish groups such as the sharks, rays, croakers (sciaenids), perches, silverbellies, lizardfishes, catfish; crustaceans such as the penaeid and non-penaeid shrimps, crabs and lobsters; and cephalopods *viz.*, squids and cuttlefishes. The abundance of these stocks varies from region to region and from season to season with large pelagics like tunas being more abundant around island territories and small pelagics like sardines and mackerel supporting a fishery of considerable magnitude along the southwest and southeast coasts. The Bombay duck and non-penaeid shrimps form a good fishery along the northwest coast, while perches are dominant in the southwest and southeast coasts, especially in the Gulf of Mannar, Palk Bay and Wadge Bank. Among this, species/groups contributing to more than one lakh tonnes a year are oil sardine, mackerel, Bombay duck, ribbonfishes, carangids, perches, croakers, shrimps and cephalopods. The annual catchable potential yield (of as many as 68 species/groups of fishes) in the Indian EEZ is validated by a Committee as 3.93 million t consisting of 2.02 million t of demersal, 1.67 million t of pelagic and 0.24 million t of oceanic resources (Anon, 2000) of which the present annual average production of about 2.72 million t forms 69.2%.

Mode of exploitation

The coastal fisheries exploit a large number of species using different craft and gears mostly in the depth range of 2 to 50 m (Pillai and Katiha, 2004). In recent years, the depth of fishing operations have extended upto about 800 m in some regions. Being a multigear fishery (gillnets, drift nets, hooks & line, pole & line, trawl line, bag nets, ringseines, purseseines, trawls, etc.), fishing practices vary between different regions, depending on the nature of the fishing grounds and the distribution of the fisheries resources.

Production trend

The marine fish production in the country progressively increased from 0.58 million t in 1950 to 2.73 million t in 1997 and 2.89 million t in 2007 (Fig. 1). The annual growth rate which was 6.5% during 1950-60 declined to 2.3% during 1960-70; increased to 4.3% (1970-80) and to 4.8% (1980-90) but subsequently declined to 1.9% during 1991-2000. The marine fish production plateaued since 1989 mainly because the fishing effort concentrated in the 2-100 m depth zone.

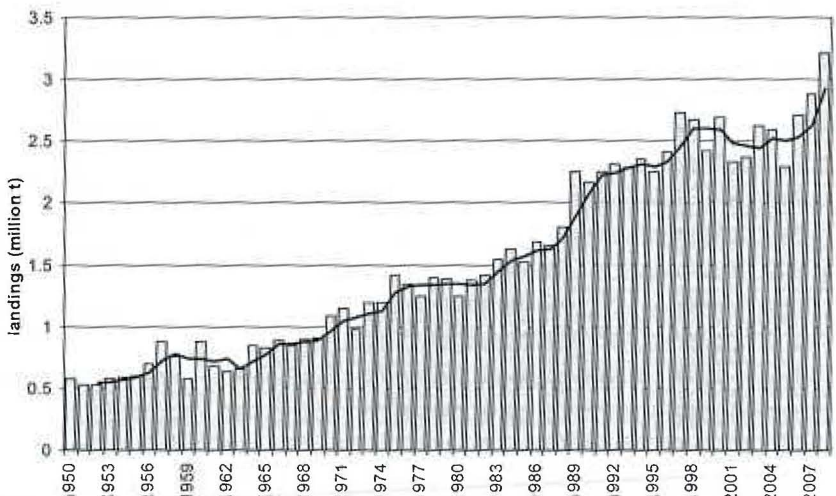

Fig. 1. All India marine fish landings (in million t) during 1950-2008 indicating a trend line of moving average (3 years)

The annual average landing during 2004-2008 was 2.72 million t against an annual catchable potential yield of 3.93 million t principally constituted by oil sardine (15%), penaeid prawns (6.8%), perches (7.2%), ribbonfishes (5.5%), non-penaeid prawns (5.4%), croakers (5.2 %), mackerel (5.1%), carangids (5%), cephalopods (4.4%), Bombay duck (4.2%) and anchovies (1.8%) (Table 1). During 2008, a production of 3.21 was reached of which the pelagic resources contributed 1.49 million t followed by demersal finfishes (0.69 m t), crustaceans (0.4 m t) and molluscs (0.12 m t) (Fig. 2). An analysis of the landing trend indicates that although the production from the pelagic resources in the country had a three-fold increase since 1961 its relative contribution to the total landings declined from about 71% in 1965 to 56% in 2003 and 54.8% in 2008 (CMFRI, 2009). The increase in landings of pelagics is mainly sustained by the increased production by oil sardine while several resources such as carangids, mackerel, lesser sardines and anchovies show a decline since mid 90s. Demersal fish production has shown an increase upto 2000 and thereafter declined marginally with resources such as flatfishes and croakers declining and perches and catfishes showing an improvement (Abdussamad and Pillai, 2009).

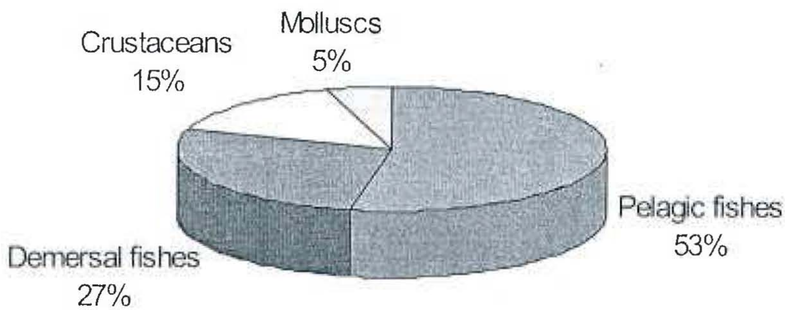

Fig. 2. Components of marine fish landings in India during 2008

Among the pelagics, about 60 species belonging to seven groups form major fisheries (Pillai, 2006) while demersal fisheries exploit around 65 species belonging to 21 major groups (Vivekanandan, 2006a). The marine fish production in the country by and large depends on the success or failure of oil sardine, mackerel, Bombay duck and shrimp fisheries (Devaraj *et al.,* 1997). The highly valued crustacean resources such as penaeid shrimps and lobsters are intensely exploited (Radhakrishnan *et al.,* 2007) while among molluscs, cephalopods are the most important group (Mohamed *et al.,* 2007)with an average annual production (2004 -08) of about 1.21 lakh t. The wide fluctuations in the annual yield of oil sardine and mackerel are well known and are generally due to factors such as spawning success and recruitment strength which are influenced by environmental factors (Krishnakumar *et al.,* 2008). However, in the case of the shrimp fishery, particularly the penaeid prawns, which are significant contrinbutor to the export trade, the landings have been fluctuating from year to year with no definite trend.

Table 1: Catch trends and potential yield estimates of different groups from coastal seas of India

Groups	Average catch (t)			Contribution (%)	Potential yield (t)
	1985-89	1999-2003	2004 -2008		
Elasmobranchs	54027	62799	49831	1.8	71408
Oil sardine	141831	319419	410498	15	294869
Other sardines	76541	101130	91286	3.3	101490
Anchovies	68630	115598	49544	1.8	141817
Other clupeoids	132626	43987	50711	1.9	78932
Bombay duck	93185	105601	114183	4.2	116227
Ribbonfishes	78384	172102	151465	5.5	193670
Carangids	111040	120608	137806	5	238148
Indian mackerel	123832	128430	149629	5.5	295040
Seerfishes	35171	48905	50983	1.9	61719
Coastal tunas	34185	50337	49028	1.8	65472
Barracudas	-	17125	17170	0.6	20849
Catfishes	50630	53711	62155	2.3	51255
Eels	6317	9637	10089	0.4	9081
Croakers	102934	141933	140743	5.2	273027
Perches	90083	189093	196138	7.2	226793
Flatfishes	29612	45482	38579	1.4	47304
Silverbellies	60766	53849	63196	2.3	67247
Pomfrets	37356	38378	45653	1.7	46088
Penaeid shrimps	143073	196464	185870	6.8	194192
Non-penaeid shrimps	48057	142929	146857	5.4	138711
Stomatopods	-	43663	27901	1.0	120351
Lobster	-	1938	1503	0.1	3874
Cephalopods	39799	107415	121443	4.4	101259
Others	40034	239327	367398	13.5	975594
Total	**1598113**	**549860**	**2729657**	**100**	**3934417**

Region-wise production trend

Catch trend during 2008 indicates that the southwest coast contributed 34% to the total marine fish production followed by northwest coast (30%), southeast coast (21%) and the remaining (15%) by northeast coast (CMFRI, 2009) (Table 2).

Sector-wise production trends

During 2008, the mechanised sector accounted for 74% of the total production, while contributed motorised sector 22% and artisanal sector

Table 2. Comparative output (in tonnes) of the primary marine fishing industry of different coastal States/Union Territories of India in 1985, 2000, 2003 and 2008

States/UTs	1985		2000		2003		2008 *	
	Output	Rank	Output	Rank	Output		Output	Rank
Andhra Pradesh	1,26,848	6	1,66,482	6	2,01,488	5	2,00,611	7
Gujarat	2,88,500	3	6,70,951	1	4,36,103	3	5,45,968	2
Goa	39,927	8	61,460	9	95,890	8	1,10,508	9
Karnataka	2,00,828	5	1,65,653	7	1,83,063	7	3,29,401	5
Kerala	2.95,339	2	5,75,500	2	6,05,523	1	7,25,487	1
Maharashtra	3,88,088	1	3,97,901	3	4,61,318	2	3,58,746	4
Orissa	49,205	7	84,622	8	68,857	9	1,64,421	8
Tamil Nadu	2,57,000	4	3,93,000	4	3,71,368	4	4,35,023	3
West Bengal	39,350	9	1,71,500	5	1,93,643	6	3,09,346	6
Andamans	6,304	11	28,147	11	30,060	10	NA	-
Lakshadweep	4,676	12	13,600	13	12,800	11	10,852	10
Pondicherry	19,913	10	38,620	10	11,752	12	14,331	11

* Fishery Resources Assessment Division (FRAD), CMFRI

4%. The contribution by the motorized sector was relatively high along the southwest and southeast regions while among the artisanal sector, contribution was higher on the southeast coast (Fig. 3) (CMFRI, 2009). As per the latest estimates, mechanised crafts account for 86% of the total investment in marine fisheries followed by motorized (9%) and non-mechanised crafts (5%) but the annual per capita production of active

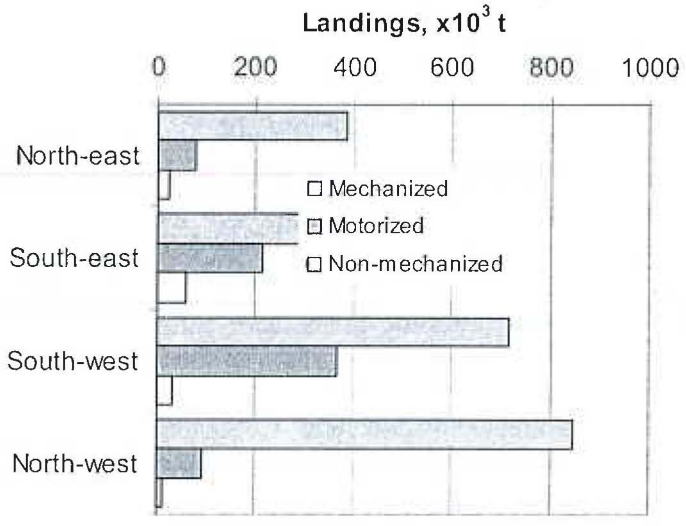

Fig. 3. Sector-wise fish landings in the various regions of India during 2008

fisherman in the mechanized sector has reduced from 5260 kg in 1980 to 3701 kg in 2005. The wide disparity in the estimated annual per capita catch of the fisherfolk in the motorized (1320 kg) and non-mechanised (408 kg) compared to the mechanized (3701 kg) indicates the marginalization of traditional fishing communities and the possibilities of frequent inter-sectoral conflicts (Sathiadas *et al.*, 2007) which will have to be addressed by policy makers by framing suitable management measures.

Recent developments

Coastal fisheries

Climate change induced species shifts in small pelagics

The relationship between changing climatic factors and fish distribution/abundance is complicated and in recent years subject to intense investigations and debate among scientists, policy makers as well as the primary stakeholders, the fishermen as these have impacts on the nature and value of the commercial fisheries. Studies indicate that the impact of global warming in the Arabian sea is the disruption of the natural decadal cycle in the sea surface temperature (SST) after 1995, followed by a secular increase in temperature which has resulted in decreased monsoon rainfall, progressively warmer winters and an increase in the phytoplankton biomass which has important implications in the marine food web and resulting fish abundance (Prasannakumar *et al.*, 2009). The oil sardine catches along the Indian coast have reached record landings of 4.9 lakh t in 2007 which was contributed mainly by the southwest coast. The species formed significant quantities along the southeast and northwest coasts also since 2000. Climate change induced distribution and abundance shifts in oil sardine and mackerel resources are thus becoming increasingly evident along the Indian coast (Vivekanandan *et al.*, 2008; Krishnakumar *et al.*, 2008). These are the resources which form nearly 20% of the total marine fish production of the country and sustain the livelihoods of a vast number of coastal fisherman as well as the nutritional security of the nation.

Offshore fishing

A general appraisal of the resources in the offshore and deep sea regions reveals that the species complex consists of a few highly valued species of oceanic tunas and pelagic sharks as well as several non-conventional species in the continental shelf area. At least a few of these non-conventional varieties are in demand in the export markets and with appropriate value addition are capable of realizing higher prices. There are also several highly valued squalid sharks in the continental shelf area which are highly valued for their oil (squalene) of great pharmaceutical importance and hence vulnerable to fishing. Morato *et al.*, (2006) reported that after 1986, there has been a steep increase at a rate of 22 m per decade in the average depth at which fishing is done in the Indian Ocean. Along the Indian coast, deep sea fishing activities are gaining momentum in many fishing centres with multi-day fishing voyages of 20-30 days targeting deep sea shrimp, oceanic sharks and tuna resources up to 600 -800 m depth. There is also considerable interest in developing fisheries for the oceanic squid.

Oceanic tuna resources

While considering the fact that tuna resources are migratory and straddling giving rise to seasonal fisheries, the estimated potential yield in the Indian EEZ is 2.14 lakh t (Anon, 2000) of which hardly 15 to 25 thousand tonnes are harvested annually at present. So far, a well equipped domestic tuna fishing fleet is conspicuously absent in India and tuna fishing by vessels operating under chartered, joint venture and LOP schemes have hardly yielded any tangible benefits to the nation in terms of increase foreign exchange, utilisation of processing facilities, employment generation and training for Indian fishermen. Constraints in fishing technology, post harvest processing and marketing bottlenecks are considered main reasons for the under-exploitation of this high value resource by an indigenous fishing fleet from the Indian EEZ in comparison to neighbouring countries such as Sri Lanka and Maldives which have well established tuna fishing and trade activities. However the annual exports of tuna from India have reached an estimated 16627 t valued at US$ 15.68 million during 2005-06 largely due to the interest in yellowfin tuna fishing by Indian fishermen. The MPEDA sponsored schemes started in 2002 for tuna longlining using modified shrimp trawlers (12 -18m OAL) have helped many idling shrimp trawlers to convert to tuna long liners. Since 2000, the traditional tuna fishing fleet using catamarans along the north east coast of India has also successfully exploited the yellowfin tuna resources with catches of 15 -20 t landed daily during the peak season of October to March which were used for processing into loins or canning (Rohit *et al.,* 2008). Development of floating FADs in the oceanic waters off Nagapattinam has also been reported to attract large number of tunas (Vivekanandan, 2006b).

Oceanic sharks

Targeted fishery for deep-sea sharks by select drift gillnet cum hooks and line units operating at depths beyond 400m has emerged lately at Cochin Fisheries Harbour and landing of these deep-sea fishing boats are specifically sharks, skates, rays and chimaeras (Joshi *et al.*, 2008; Akhilesh *et al.*, 2009). Certain deep sea trawlers are also carrying long line gear and depending on the seasons is used for fishing oceanic tunas where sharks are also landed as by-catch. Species landed include sharks (*Centrophorus* spp.), chimaeras (*Neoharriotta pinnata*), thresher sharks (*Alopias* spp.) and bramble shark (*Echinorhinus brucus*). The market value for oil sharks (*Centrophorus* spp.) can reach up to 300 Rs per kg and there are several occasions where deep-sea chondrichthyan landings exceeded two tonnes a day (Akhilesh *et al.*, 2009).

Deep sea shrimps

The deep-sea shrimp fishery is constituted by more than 10 species which is dominated by Pandalid shrimps constituting about 70% of total deep sea shrimps landings. *Plesionika spinipes* is the dominant species followed by *Heterocarpus woodmasoni*, *H. gibbosus*, *Plesionika martia* (Pandalidae); *Metapenaeopsis andamanensis* (Penaeidae), *Aristeus alcocki*(Aristeidae) and *Solenocera hextii* (Solenoceridae) are the major species contributing to the fishery (CMFRI, 2009).

Resource status

Until the 1970s, the emphasis of the Central and State government with regard to the marine fisheries development in India was to increase production through improved fishing technology, infrastructure (harbours, roads, processing and market facilities) development and incentives and subsidies to the fishermen. This has contributed much to the increase in the marine fish production from 0.5 in 1950 to 2.7 million tonnes in 1997. However, during the 1980s, concerns were expressed on the unrestricted growth of the fishing fleet and its possible adverse impact on different fish stocks (Murty and Rao, 1996). Studies indicate that about 90% of the resource groups are either in mature or senescent stage with little or no scope of enhanced yield (Srinath, 2003, 2006) and the scope for increasing coastal fish production in India is limited (Vivekanandan *et al.*, 2001). The substantial increase in the effort over the last 4 decades has resulted in decrease in the per capita area per active fisherman and per boat in the inshore fishing grounds, and also in the catch per unit effort giving rise to conflicts among different categories of fishermen, particularly between the artisanal and mechanised sectors. Ultimately the sustainability of many vulnerable resources in the coastal areas has been jeopardised by the incessant fishing pressure coupled with the impacts of pollution, and other anthropogenic causes. Such a critical situation warrants effective management of the exploited stocks in the coastal waters for sustaining the current production and to augment it further by focussing attention on the deep sea and oceanic sector.

Sustainability

Sustainable development is a globally accepted goal for natural resource management, identified at UNCED 1992. The basic principle that governs sustainable development of fisheries is that, it must be conducted in a manner that does not lead to over-fishing, or for those stocks that are over-fished; the fishery must be conducted such that there is a high degree of probability that the stock(s) will recover and also fishing operations should be managed to minimise their impact on the structure, productivity, function, and biological diversity of the ecosystem. The general stagnation in marine fish production during the last decade gives rise to concern about the sustainability of Indian fisheries.

The major issues that have to be addressed to overcome stagnation and decline in marine fish production in India are identified as:

- Unregulated open access fisheries
- Over capitalization and unwarranted capacity overload
- Excessive fishing pressure in the coastal areas up to about 50 m depth zone on target species resulting in declining trends in their catch and catch rates
- Decrease in area available in the coastal waters per active fisherman /boat for conducting fishing operations
- Lack of enthusiasm among the entrepreneurs for extension of fishing to the deeper waters
- Discards/indiscriminate exploitation of juveniles/sub-adults of many commercially important species by reducing the mesh size and resulting discards
- Damage to the benthos and benthic ecosystem by continuous sweeping of the same ground by shrimp trawlers, often destroying the food web of commercially exploitable species
- Inter and intra-sectoral conflicts among different categories of fishermen particularly between the artisanal and mechanised groups of fishermen and

also between those engaged in coastal artisanal fishing and coastal aquaculture

- Harvest and post-harvest losses
- Ecosystem degradation affecting the productivity and the carrying capacity
- Threats from climate changes and natural calamities
- Lack of Participatory Fisheries Management
- Lack of effective enforcement of MFRA
- Lack of implementation of Code of Conduct for Responsible Fisheries
- Absence of an informed management regime
- Global pressures on trade

Approaches for sustainable development

Of late, Indian marine fisheries have been facing the serious crisis of unsustainable development which is visible in various fronts of development, including ecological, economic and social fronts. In a multi species multi-gear marine fisheries where there are changing species ratios, changing exploitation patterns, changing predator-prey relationships, loss of biota and destruction of juveniles of almost all fish and shellfish species, increase of bycatch and discards, ensuring sustainability is a difficult but necessary task (Modayil, 2005). Towards this end, adoption of sustainable fishing practices, diversified multi-gear and resource specific fishing and complementary mariculture practices by traditional fishermen to supplement their income are being advocated. Some of the options are as follows.

Shift from Open-access to user rights

The policy measures likely to be most effective for resources management and protection of critical fish habitats in the aquatic environment are those which will shift from a free and open access system to a regulated fishery with the introduction of appropriate measures to allocate resources and establish user rights. Such measures, will *inter alia*, provide greater incentives to reduce excess fishing capacity/pressure one of the major factors responsible for overfishing and unsustainable development. In addition, the establishment of user rights is particularly important in protecting the interest of artisanal fishers from unequal competition with industrial vessels. The policy should aim to ensure socio-economic security for the artisanal fishermen whose livelihood depends solely on this avocation.

Reduction of fishing effort

Fishing effort is a composite of many parameters particularly fishing duration and fishing efficiency. In recent years, there has been significant increase of the motorized sector, especially the ring seine fishery and the mini-trawl fishery along the Kerala coast, causing concern for sustenance of some of the exploited stocks. There has also been dimensional changes in the gear giving wider coverage and efficient catchability. Similarly, the increase in the time spent for fishing in the mechanized sector by undertaking multiday voyages, use of high powered Chinese engines and use of sophisticated electronic devices for fish finding and communications has resulted in increased fishing efficiency. It is thus generally felt that the fishing effort in the Indian marine fisheries is on the higher side and there is need to reduce the effort in the mechanized sector.

In certain tropical demersal fisheries, the level of fishing effort may be so intense that long term changes in the composition of the catch will occur, resulting in high value finfish and crustacean species being replaced by low value finfish and invertebrates. Known as 'fishing down the food web' this phenomenon is evident in the Indian seas (Bhathal, 2005; Vivekanandan *et.al.*, 2005) However, the same can be avoided through effort reduction. A diminution of overall fishing effort will reduce pressure on the target stock(s) with a consequent reduction of effort on non-target species and discards. The restriction of fishing effort could be in various ways such as restriction on number of vessels, number of days at sea, fishing days/hours, engine power, fish hold capacity or length of nets etc. The fishery regulation through effort reduction that is in vogue in different maritime states today is chiefly aimed at the trawl fishery only but may have to be appropriately introduced for certain other gears such as purse seines and ring seines also so that effort rationalization occurs across all the sectors be it mechanized or motorized.

The CMFRI has determined the optimum fleet size for each maritime state during the period 1986-96 using the Surplus Production model (Table 3) and these estimates are under revision consequent to the national marine census carried out in 2005. The Revalidation Committee has already outlined some of the strategies for effort reduction and curbing over capitalization (Anon, 2000) which may be considered.

Licensing or quota regulation

The FAO Technical Guidelines for Responsible Fisheries No.4 Fisheries Management guideline 1.4 (11) states " It is in the interest of the users and the resource to maintain potential fishing capacity at a level that commensurates with the long term stock productivity". The issue of over-capitalization is normally associated with the open-access fisheries as in India. Concepts such as Total Allowable Catch (TAC) and Individual Transferable Quotas (ITQ) have been used in certain countries like Canada and Australia. However, in the Open – Access fisheries system prevalent in India, except for certain closed periods for fishing, there are few regulations on fishing effort and no practice of reporting the catch to any authority by any fishing vessel, mechanized or artisanal to enable fisheries management programmes. In this context, introduction of a single unified vessel registration and licensing scheme to help monitor fishing effort and optimisation of inputs is required. Mandatory registration and licensing of all motorized and mechanized boats and review of registration and licensing every five years is also required. Upward revision of the registration, licensing fees and berthing charges to discourage new entrants can also be considered.

Table 3: Existing and optimum fleet size (in number) in India

Fleet	Existing	Optimum	% Excess	% contribution to total catch (1996-97)
Mechanized	46918	20928	55.0	67.0
Motorized	31726	12832	60.0	20.0
Non-mechanized	159481	31059	81.0	13.0

Source : CMFRI (1997); Total catch : 2.41 million t (1996-'97)

Mesh-size regulation and curbs on destruction of fish juveniles

The fine meshes of gears like trawls and bag nets cause large-scale destruction of juveniles of many important commercial fishes. The codend mesh size of the trawls prevalent in India is very small (10-15 mm stretched mesh) while the prescribed trawl codend mesh size, for instance, in the state of Kerala is 35 mm. Central Marine Fisheries Research Institute (CMFRI) has recommended the Minimum Legal Size (MLS) for capture of four species of lobsters to ensure sustainable exploitation of the resource. Based on the recommendations of CMFRI, the Ministry of Commerce, Govt. of India has issued orders specifying the Minimum Legal Weight (MLW) fixed for *Panulirus homarus* is 200 g, *P. polyphagus* 300 g, *P. ornatus* 500 g and *Thenus orientalis* 150 g. Studies undertaken at CMFRI has also prescribed MLS (mantle length) for the major cephalopods which have high demand in the export market such as *Uroteuthis duvauceli*, *Sepia pharaonis* and *Octopus membranaceous* as 80, 115 and 45 mm respectively (Mohamed *et al.*, 2009). The exploitation of these cephalopod species has exceeded the revalidated potential yield estimate of 1.01 lakh t and these suggestions are to be considered by appropriate agencies such as MPEDA, which will ensure that stocks of highly valued marine resources are not overexploited. Implementation of MLS in a phased manner for all the major fishery resources is recommended (Table 4).

Table 4: Recommended Minimum Legal Size (MLS) and Minimum Legal Weight (MLW) of major finfish and shellfish resources

Species	Common name	MLS (cm)[a]	MLW (g)[a]
CEPHALOPODS[b]			
Uroteuthis duvauceli	Squid	8	25
Sepia pharaonis	Cuttlefish	11.5	150
Octopus membranaceous	Octopus	4.5	15
LOBSTERS			
Panulirus homarus	Rock Lobster	-	200
Panulirus polyphagus	Rock Lobster	-	300
Panulirus ornatus	Rock Lobster	-	500
Thenus orientalis	Sand lobster	-	150
FINFISHES			
Sardinella longiceps	Oil sardine	14	-
Rastrelliger kanagurta	Indian mackerel	16	-
Euthynnus affinis	Little tunny	40	-
Auxis thazard	Frigate tuna	30	-
Katsuwonus pelamis	Skipjack tuna	44	-
Thunnus albacares	Yellowfin tuna	70	-
Decapterus russelli	Scad	14	-
Megalaspis cordyla	Horse mackerel	22	-
Trichiurus lepturus	Ribbonfish	56	-
Scomberomorus commerson	King seer	75	-
Nemipterus japonicus	Threadfin bream	14	-
Nemipterus mesoprion	Threadfin bream	12	-
Cynoglossus macrostomus	Sole	11	-
Lactarius lactarius	Whitefish	13	-
Epinepheleus tauvina	Grouper	72	-
Parastromateus niger	Black pomfret	30	-
Pampus argenteus	Silver pomfret	-	200

[a] based on length-at-first maturity; [b] MLS of cephalopods is based on the smallest observed mantle length of mature specimens

Source: Pillai *et al.*, (2009)

The fishing for shrimp seed along the coastal waters of the east coast is another example of the destruction of valuable ichthyoplankton. For every shrimp seed collected, hundreds of other larvae and juveniles of commercially important species of finfishes and shellfishes are destroyed. This destruction of juvenile fishes should be stopped forthwith and immediate intervention is urgently required.

Alternative harvesting methods

The use of selective fishing methods can reduce bycatches and often limit mechanical damage to the catch. A good example would be preferring squid jigging to trawling for squids which can lead to reduction in bycatch as well as higher quality squid although the yield per unit fishing effort may not be as high as in trawling. A method of successional fishing whereby varieties of gear are used in space and time according to the biological characteristics of fishes with an aim of protecting their spawning stock and early juveniles has also been suggested for Indian fisheries (Yohannan *et al.*, 2001). During the spawning period, large meshed nets (above 80 mm) and hooks and line that exploit only larger fishes may be used while in the post spawning period nets with mesh above 40 mm may be employed. Trawling in inshore waters during May to September may also be controlled to protect spawners. FAD fishing has been suggested for development of offshore oceanic fisheries for tunas as well as small scale artisanal fisheries in coastal waters and a few experimental/ pilot projects are being implemented in the country by various state governments/NGOs. It has been observed that in several countries, FAD programmes failed to live up to the expectations not because of technical failure of the FADs but because insufficient consideration was given to social and economic conditions as well as marketing avenues for the fish caught (Vivekanandan, 2006b). Hence a well envisaged programme with selective deployment of FADs involving the fishing community at all stages and adequate monitoring of the fishery by research organizations can be put in place for the sustainable management of fisheries in India.

Closed season, closed area and Marine Protected Areas (MPAs)

Recognizing the necessity for ensuring sustainable yields from the exploited stocks, all maritime states have enacted fishery regulation acts enabling effort reduction, rebuilding of the stocks and ecosystem rejuvenation by closure of fishery for a specified period of time during monsoon with the objective of protecting the spawning stocks from capture by mechanised fishing vessels and allow natural replenishment of the fish stocks.

Areas of fish spawning and feeding as Marine Protected Areas (MPAs) in which fishing is prohibited, allow rapid build-up of fish spawning stock biomass. This is because the fish which are protected from fishing live longer, grow larger and produce an exponentially increasing number of eggs to help replenish adjacent fisheries. Studies by Mohamed *et al.* (2009a) have identified the fishing area of extreme South Kerala close to the Wadge Bank and the coral reef ecosystem off Bhatkal in Karnataka as biodiversity stressed fishing zones and emphasized the need for identifying part of these fishing zones as MPAs. Hence marine reserves in the Gulf of Mannar, Gulf of Kutch and Andamans are a right step and more action in this direction can be envisaged.

Diversification of vessels and targeting specific resources

To ease out fishing pressure in the inshore waters, the existing excess trawler vessels may be suitably upgraded/modified as multipurpose/ combination vessels to harvest the under tapped resources like carangids, ribbon fish, lizard fish, tunas, bill fishes and pelagic sharks available in the oceanic and deeper waters. However, while introducing innovative fishing gears, gear impact assessment studies before its massive introduction should be done. Encouraging the use of Bycatch Reduction Devices (BRDs) and Juvenile Fish Excluder cum Shrimp Sorting Device in trawls can also ensure the sustainability of the exploited fish stocks which should be preferably implemented by the Central / State Fisheries Development Agencies.

Optimum utilization of harvested resources

There are highly skilled deep sea fishermen hailing from Colachel, Kanyakumari district, operating hooks and line/drift gill nets for oceanic tunas who migrate following the tuna movements all along the Indian coast and adequate support for this group through facilitation of marketing can further increase tuna production and international trade earning valuable foreign exchange by enabling production of *sashimi* grade tuna. For this, provision of institutional support for small scale fishermen fishing for oceanic tunas using catamarans to upgrade their fishing crafts and acquire ice boxes/ fish preservation facilities for their traditional crafts which can enhance the economic yield from these fisheries has to be seriously considered.

Application of IT and remote sensing technologies

Satellite imageries, which provide continuous data on sea surface temperature and chlorophyll have been facilitated immensely consequent upon India launching her own remote sensing satellites *(Oceansat* I and II). This in turn has made possible mapping of potential fishing zones (PFZ) and fisheries forecast on short and long term basis. The PFZ validation undertaken by CMFRI by means of real time surveys for ground truth data reported significant correlation between the SST and the occurrence and/ or abundance of pelagic fish, as evidenced by increased catches in purse seine, ring seine and gill net units. Wider application of this tool can enable more efficient use of energy and time expended for fishing by the fishermen and needs to be developed further.

Fishing regulations for offshore and deep sea resources

In general the marine living resources exploited by deep-sea fisheries have biological characteristics that create specific challenges for their sustainable utilization and exploitation. These include: (i) maturation at relatively old ages; (ii) slow growth; (iii) long life expectancies; (iv) low natural mortality rates; (v) intermittent recruitment of successful year classes; and (vi) spawning that may not occur every year. As a result, they can sustain very low exploitation rates and if by chance these resources are depleted, recovery is expected to be long and not assured. The great depths at which marine living resources are caught by deep sea fisheries pose additional scientific and technical challenges in providing scientific support for management (FAO, 2008). This means that assessment and management have higher costs and are also subject to greater uncertainty and hence in 2007 International Guidelines for Sustainable Management of Deep-sea Fisheries in the High Seas which stressed a precautionary approach were developed (Anon, 2008). On a global scale while the exploitation of deep sea resources is comparatively low in the Indian EEZ, the trend for increasing deep sea fishing is evident in the Indian Ocean sector also (Morato *et al.*, 2006). Declining catches from coastal waters have encouraged a small group of fishermen for targeted deep sea fishing and catches include the highly vulnerable chondrichthyan resources such as oil sharks and chimaeras (Akilesh *et al.*, 2009). The oceanic tuna fishing conducted by distant water fishing nations under Letter of Permit (LoP) in the Indian EEZ, where, until recently, the resource was very little exploited by domestic fleet has also given rise to conflicts. Absence of any catch and effort data from the LoP vessels which is a mandatory requirement under the agreement is a cause of serious concern and a serious lacunae while making any estimates of the tuna stocks on a national or regional level. Adequate consideration to changing fishing patterns in the Indian EEZ for formulating precautionary management measures are worthy of consideration.

Establishment of Monitoring, Control and Surveillance (MCS) System

To date, considerable progress has been achieved in harvesting the inshore resources through emergence of a multiple fleet multiple gear fishery but along with this a host of problems such as excessive capitalization, inter-sectoral conflicts and uncontrolled fishing practices. This development is raising questions of sustainability and necessitating the need for a strong Monitoring, Control and Surveillance (MCS) system in India. In certain developed countries with a high capital–intensive fishing industry with fisheries management measures like catch quotas, restrictive licenses, seasonal closure and gear limitations, surveillance is a high-tech job done on shore and at sea using ships and aircraft. Although expensive, the system sustains itself through licensing with the fees paid as fine. In India, where fish stocks and fisheries within 12 nautical miles (nm) of territorial waters is the state subject and the national responsibility extends beyond 12 nm, the MCS machinery and requisite legislative instruments have to be improvised, strengthened and made compatible to meet the present and future challenges of management and conservation of fish stocks. Enforcing a system of Monitoring, Control and Surveillance (MCS) and a Vessel Monitoring System (VMS) to obtain real time operational data on catch composition, effort and fishing grounds which can be used as inputs in the periodical assessment of the fishery stocks for management purposes and formulating policy advisories is therefore worthy of serious consideration.

Participatory management

Management of fisheries can be made more effective if the principal stakeholders are involved in the decision making and its implementation. Fishermen cooperatives can be formed which can be vested with the responsibility of protecting the fisheries resources they harvest. They should be made aware of the biological and environmental basis for sustainability of fish stocks by constant interactions with the scientific community. Such interactions will be mutually beneficial to the fishermen, fishery scientists and the policy makers and make the implementation of the management measures/options smooth and effective. Awareness on benefits of conservation of fish stocks has to be created through extension services of Central and State Fisheries institutions/agencies with a participatory management approach.

Adoption of FAO Code of Conduct for Responsible Fisheries (CCRF)

The main objective of CCRF is to establish principles and standards applicable for responsible fishing and fisheries practices after taking into account relevant biological, technological, economic, social, environmental and commercial aspects. The Code of Conduct for Responsible Fisheries as a voluntary guide for all concerned with the fisheries was adopted by the FAO in 1995. The code provides necessary framework for national and international efforts to ensure sustainable exploitation of aquatic living resources in harmony with the environment and includes all aspects of fisheries – from the fishing ground to the final consumer. The BOBP and CMFRI have already translated CCRF into regional languages and popularized the need of its adoption by the stakeholders. The BOBP has highlighted several problems concerning the implementation of the Code in a large country like India and formulated various action plans for the implementation of the Code in Indian fisheries.

Ecosystem-based Fisheries Management (EBFM)

The term EBFM has been defined by the US National Research Council, (1998) as "an approach that takes major ecosystem components and services – both structural and functional - into account in managing fisheries. It values habitat, embraces a multi-species perspective, and is committed to understanding ecosystem process. Its goal is to rebuild and sustain populations, species, biological communities and marine ecosystems and high levels of productivity and biological diversity so as not to jeopardise a wide range of goods and services from marine ecosystems while providing food, revenues and recreation for human" (Garcia *et al.*, 2003). Worldwide, ecosystem models have been used to search for suitable policy options taking into account all possible tradeoffs among social, economic and ecological objectives. In India issues related to coastal zone degradation (due to pollution, excessive fishing pressure in inshore waters, negative impacts of excessive trawling on benthic biota, effective implementation of CRZ) are to be addressed preferably applying a ecosystem based approach which is expected to yield short-term and long-term benefits. To achieve this a scientifically planned protocol for implementation of EBFM is a necessity. CMFRI has already taken initiatives to find solution for issues in the fisheries sector based on EBFM with a beginning made by constructing a trophic model of the Arabian Sea ecosystem off Karnataka and simulation of fishery yields (Mohamed *et al.*, 2009).

Database on fish production

It has been now well recognized that the basic requirement for knowledge based fisheries management is availability of reliable and adequate data on the resources and their dynamics including economics of fishing. For this, an effective data acquisition mechanism is needed. The maritime states must develop mechanisms to generate reliable data on marine fish landings, fishing effort, economics of fishing and marketing, which could be used for understanding dynamics of the fisheries as well as for regulating their exploitation. The data on the marine fishermen population, craft, gear and other demographic parameters also require to be periodically updated through National Marine Fisheries Census Programmes which can serve as the base to formulate marine fisheries policies.

With regard to offshore fishing, many marine fisheries development agencies are promoting increased tuna production and trade and in this context adequate emphasis on sustainability of tuna fishing is also needed. Many countries in the Indian Ocean such as Sri Lanka and Maldives are already tapping the highly migratory oceanic yellowfin tuna in their respective EEZs and of late fishing is picking up in the Indian EEZ also. Hence it is imperative that considering the changes in fishing technology, intensification of fishing effort, climatic effects and fishery environment, periodic assessments of the stocks of oceanic tunas of the Indian EEZ are made based on resource surveys as well as commercial catches.

Certification

Seafood industry is going to face a major setback with the European Union bringing out a new regulation which intends to prevent, deter and eliminate illegal, unreported and unregulated (IUU) fishing. This regulation demands a 'Catch Certificate' by the Marine Products Export Development Authority (MPEDA) for all exports to the European Union since January, 2010. Hence a system to certify sustainable fishing methods and eco-label fish and fishery products by authorised agencies has to be developed. In addition, stakeholders have to be sensitized with regards to emerging non-tariff barriers (standard, testing, labelling and certification requirements) in global fish trade and need for adoption of sustainable fishing/ fish farming activities.

Climate change and its impact on marine ecosystem

Climatic aberrations affect coastal communities by causing cyclones, coastal erosion, loss of mandays at sea and also has an impact on the availability of fish resources by affecting their abundance and distribution patterns. Hence sensitisation of all stakeholders on the challenges likely to arise from climate change-induced sea level rise and other impacts on the fisheries sector should be done. Weather Watch groups for fisheries sector and development of contingency plans for weather related risks to the fishing communities are to be considered. Conservation of marine ecosystem should be promoted in the society at large and fishermen in particular. Energy efficient and fuel saving fishing technologies which will also reduce CO_2 emissions can also be promoted.

Conclusion

Marine fisheries in India, beset with problems of over capitalization, over capacity, increased operational expenses and reduced catch rates, is at cross roads seeking proper direction and guidance. In the context of globalization and challenges of global competition in trade and economics, there is urgent need for policy interventions at the state and national levels which will ensure sustainable exploitation of the marine resources as well as better livelihood opportunities for the fisherfolk. It is also necessary to encourage and facilitate resource management initiatives from within the fishermen communities themselves.

Fisheries management is a continuous and interactive process, where, economic, social and ecological costs and benefits are to be understood and interventions designed. According to Hillborn (2002), the key to successful fisheries management is not confined to better science, more reference points and precautionary approaches but rather in implementing better systems of marine governance which provides incentives for all the stakeholders (fishermen, scientists and managers) to make decisions that will be in their interest as well as contribute to societal goals. Co-operative research where scientific research is conducted in partnership with the industry is also gaining importance recently. Its direct benefits include increased quantity and quality of data, inclusion of fishers knowledge in science and management, improved relevance of research to fisheries management and reduced costs of science besides indirect benefits of improved relationships and trust between fishers and scientists (Johnson and Densen, 2007). In the Indian context, a comprehensive national fishing policy namely, *Marine Fishing Policy - 2004* has been released by the Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture, Govt. of India (Anon, 2004). Its policy objectives are: (i) to augment marine fish production of the country up to the sustainable level in a responsible manner so as to boost export of sea food from the country and also to increase per capita fish protein intake of the masses, (ii) to ensure socio-economic security of the artisanal fishermen whose livelihood solely depends on this vocation, (iii) to ensure sustainable development of marine fisheries with due concern for ecological integrity and biodiversity. In the policy, the need for a shift from the open access to the limited entry concept in the territorial waters besides enforcing stringent management measures for sustained production is stressed. A road map for ensuring sustainability, equitability, ecosystem conservation, eliminating destructive gears, reducing by-catch and discards and juvenile destruction, diversification of fishing into new areas, new resources, ensuring conservation of endangered and threatened species groups putting into practice the FAO Code of Conduct for Responsible Fisheries and ultimately evolving a working model for an informed participatory management of marine fisheries resources of the country is the need of the hour. This can be achieved only jointly by all the stakeholders including fishers, scientists, policy developers and implementers.

References

Abdussamad, E.M. and N.G.K. Pillai (2009). Significance of small pelagics in the marine ecosystem in sustaining the stock and fishery of Indian seas. In: Marine Ecosystems Challenges and Opportunities, Book of Abstracts, p. 106-107, Marine Biological Association of India, February 9 -12, Cochin

Akilesh, K.V., Ganga, U., Pillai, N.G.K. Manjebrayakath, H., Bineesh K.K. and Rajool Shanis, C.P. (2009) Deep sea Chondrichthyans – a study at Cochin Fisheries Harbour, Kerala, India, In: Marine Ecosystems Challenges and Opportunities, Book of Abstracts, p. 164, Marine Biological Association of India, February 9-12, Cochin

Anon (2000) Report of the Working Group for revalidating the Potential Fishery Resources in the Indian EEZ, Ministry of Agriculture, Govt. of India, 43 p.

Anon (2004) Comprehensive Marine Fishing Policy, Government of India, Ministry of Agriculture, Department of Animal Husbandry & Dairying, New Delhi: 26 p.

Anon (2008) Report of the Technical Consultation on the International Guidelines for the Management of Deep Sea Fisheries in the High Seas, Rome, 4-8 Feb and 25-29 August 2008: 16 p.

Bhathal, B. (2005) Historical reconstruction of Indian marine fisheries catches, 1950-2000, as a basis for testing the "Marine Trophic Index", Fisheries Centre, University of British Coloumbia, Vancouver, Canada

CMFRI (1997) Vision 2020-CMFRI Perspective Plan. (Murty, V.S., Ed.) Central Marine Fisheries Research Institute, Cochin: 70 p.

CMFRI (1997a) Status of Research in Marine Fisheries and Mariculture. CMFRI Spl. Publn., No. 67 : 35 p.

CMFRI (2009) Annual Report 2008-2009. Central Marine Fisheries Research Institute, Cochin: 122 p.

Devaraj, M., Kurup, K.N., Pillai, N.G.K. Balan, K., Vivekanandan, E. and Sathiadas, R. (1997) Status, prospects and management of small pelagic fisheries in India. In: Small Pelagic Resources and their Fisheries in the Asia – Pacific region (M. Devaraj and P. Martosubroto, Eds.), Proc. APFIC Working Party on Marine Fisheries, First Session, 13-16 May 1997, Bangkok, Thailand, RAP Publn. 1997/31: 91-197

FAO (2008) Report of the FAO Workshop on vulnerable ecosystems and destructive fishing in Deep sea fisheries, FAO Fish Rep. No. 829, FAO, Rome:18 p.

Garcia, S.M., Zerbi, A., Allaume, C., Do Chi, T. and Lasserre, G. (2003) The ecosystem approach to fisheries.I ssues, terminology, principles, institutional foundations, implementation and outlook, FAO Tech. Paper No. 443, Rome, FAO: 71 p.

Hillborn, R. (2002) The other side of reference points, Bull. Mar. Sci., 70(2): 403-408

Johnson, T.R. and van Densen, W.L.T. (2007) The benefits and organization of co-operative research for fisheries management, ICES J. Mar. Sci. 64: 834-840

Joshi, K. K., Balachandran, K., Raje, S.G. (2008) Changes in the shark fishery at Cochin, J. Mar. Biol. Ass. India 50 (1): 103-105

Krishnakumar, P.K., Mohamed, K.S., Asokan, P.K., Sathianandan, T.V. Zacharia, P.U., Abdurahiman, K.P Shettigar, V. and Durgekar, R.N. (2008). How environmental parameters influenced fluctuations in oil sardine and mackerel fishery during 1996 – 2005 along the south west coast of India. Mar. Fish. Infor. Serv., T& E Ser. 198: 1-4

Modayil, M.J. (2005) How do we ensure Sustainability in the open access marine fisheries of India? Souvenir Sustain Fish 2005, 16-18 March 2005, Cochin, India: 55-57

Mohamed, K.S., Joseph, M., Alloycious, P.S., Sasikumar, G., Laxmilatha, P. Asokan, K.P., Kripa, V., Venkatesan, V., Thomas, S., Sundaram, S. and Rao, G.S. (2009) Quantitative and qualitative assessment of exploitation of juvenile cephalopods from the Arabian Sea and Bay of Bengal and determination of minimum legal sizes, J. Mar.Biol.Ass.India, 51 (1): 98-106

Mohamed, K.S., Rao G.S. and Velayudhan, T.S. (2007) A century of molluscan fisheries research in India, In: Status and Perspectives in Marine Fisheries Research in India (Modayil, M.J and Pillai, N.G.K., Eds.), p. 173-195, CMFRI, Cochin

Mohamed, K.S., Sathianandan, T.V. Krishnakumar P.K., Zacharia, P.U., Asokan, P.K., Abdurahiman, K.P., Durgekar, R.N. and Shettigar, V. (2009a) Biodiversity stressed fishing zones in Kerala and Karnataka and identification of Marine Protected Areas, In: Marine Ecosystems Challenges and Opportunities, Book of Abstracts (Vivekanandan, E. et al., Eds.), p. 130-132, Marine Biological Association of India, February 9-12, Cochin

Mohamed, K.S., Zacharia, P.U., Muthiah, C. Abdurahiman, K.P. and Shettigar, V. (2009) Trophic Model of the Arabian Sea ecosystem off Karnataka and simulation of fishery yields, Bull. Cent. Mar. Fish Res. Inst. 51: 140 p.

Morato, T., Watson, R., Pitcher T.J. and Pauly, D. (2006) Fishing down the deep, Fish and Fisheries 7: 24-34

Murty, V.S. and Rao, P.V. (1996) Marine Fishery Resources of India – Present Status and Management Concerns. In: Marine Biodiversity Conservation and Management (Menon, N.G. and Pillai, C.S.G., Eds.), CMFRI, Cochin: 103-125

Pillai, N.G.K. (2006) Pelagic fisheries of India. Handbook of Fisheries and Aquaculture in India, Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research, New Delhi: 56-77

Pillai, N.G.K. and Katiha, P.K. (2004) Evolution of Fisheries and Aquaculture in India,Central Marine Fisheries Research Institute, Cochin: 240 p.

Pillai, N.G.K., Vivekanandan, E., Ganga, U. and Ramachandran, C. (2009) Marine Fisheries Policy Brief 1 (Kerala), Central Marine Fisheries Research Institute: 24 p.

Prasannakumar, S., Raj, P.R., Narvekar, J., DineshKumar and Vivekanandan, E. (2009) Is Arabian Sea responding to global warming and undergoing a climate shift? In: Marine Ecosystems Challenges and Opportunities, Book of Abstracts, Marine Biological Association of India, February 9 -12, Cochin: 248-249

Radhakrishnan, E.V.,.Manisseri, M.K. and Nandakumar, G. (2007) Status of research on crustacean resources In: Status and Perspectives in Marine Fisheries Research in India (Modayil, M.J and Pillai, N.G.K., Eds.), CMFRI, Cochin: 135-172

Rohit, P., Rao, G.S. and Rammohan, K. (2008) Yellowfin tuna fishery by traditional fishermen at Visakhapatnam, Andhra Pradesh, J. Mar .Biol. Ass. India 50 (1): 62-68

Sathiadas, R., Ramachandran, C., Vipinkumar, V.P. and Sangeetha Pratap, K. (2007) Status of fisheries economics and extension research in India - opportunities and challenges. In: Status and Perspectives in Marine Fisheries Research in India (Modayil, M.J. and Pillai, N.G.K., Eds.), p. 362-404, CMFRI, Cochin

Srinath, M. (2003) An appraisal of the exploited marine fishery resources of India, In: Status of Exploited Marine Fishery Resources of India, (Modayil, M.J and Pillai, N.G.K., Eds.), p. 60-65, CMFRI, Cochin

Srinath, M. (2006) Generalised Fishery Development Model (GFDM) approach for the analysis of marine fish landings in India, J. Mar. Biol. Ass. India: 48(1): 68-75

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

Vivekanandan, E. (2006a) Demersal fisheries of India., In: Handbook of Fisheries and Aquaculture in India, p. 78-92, Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research, New Delhi

Vivekanandan, E. (2006b) Oceanic and deep sea fisheries of India. Handbook of Fisheries and Aquaculture in India, p. 93-105, Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research, New Delhi

Vivekanandan, E., Pillai N.G.K., Rajagopalan, M. (2008) Adaptation of the oil sardine Sardinella longiceps to seawater warming along the Indian coast. In: Glimpses of Aquatic Biodiversity- Rajiv Gandhi Chair Spl. Pub., 7: 1-9

Vivekanandan, E., Srinath, M. and Somy Kuriakose (2005) Fishing the food web along the Indian coast, Fish. Res., 72: 241-252

Yohannan, T.M., P.N. Radhakrishnan Nair, N.G.K. Pillai and P.L. Ammini, (1999) Marine Fisheries in Kerala. Mar. Fish. Infor. Serv. T& E Ser., 160: 1-23