A Profile of People, Technologies and Policies in Fisheries Sector in India

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Marine Fishing Practices and Coastal Aquaculture Technologies in India

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Marine Capture Fisheries

Introduction

Among the countries bordering the Indian Ocean, India, endowed with 2.02 million sq. km of EEZ along a coastline of 8129 km and 0.5 million sq. km of continental shelf with a catchable annual marine fishery potential of 3.93 million tonnes occupies a unique position. Besides, there are vast brackishwater spread areas along the coastline which offer ideal sites for seafarming and coastal mariculture. Among the Asian countries, India ranks second in culture and third in capture fisheries production and is one of the leading nations in marine products export. The development of Indian marine fisheries from a traditional subsistence-oriented to an industrial fisheries over different Five Year Plans has been phenomenal. However, the present scenario is characterized by declining yields from the inshore waters and increasing conflicts among different stakeholders, whereas the increasing demand for fish in domestic and export markets indicate good prospects for large scale seafarming and coastal mariculture.

Fishery Environment

The total area of EEZ of India is estimated at 2.02 million sq. km against its land area of about 3.2 million sq. km. The continental shelf area between 0 and 50 m depth is estimated at 191.97 thousand sq. km and that between 0 and 200 m depth as 452.06 thousand sq. km. There are general topo-hydrographical differences in the features of the coastline and adjacent seas, distribution and abundance pattern of the species and their fishery characteristics along the west and east coasts. The primary and secondary productivities are higher on the west coast compared to the east coast, mainly due to the strong upwelling process, which therefore supports a more abundant fishery. The northwest coast (15°-23°N latitude) has extensive fishing grounds and the sea bottom is generally muddy while the southwest coast (8°-15°N latitude) has a narrow continental shelf with less extensive fishing grounds. The southeast coast (10°-15° N latitude) is characterized by coral and rocky grounds while the sea bottom of the northeast coast (15°-21°N latitude) is predominantly muddy and suitable for bottom trawling (Figure 1).

The northern Indian Ocean, together with its two major bays, the Arabian Sea and the Bay of Bengal, is landlocked in the north by the Asian continent which separates the northern Indian Ocean from the deep-reaching vertical

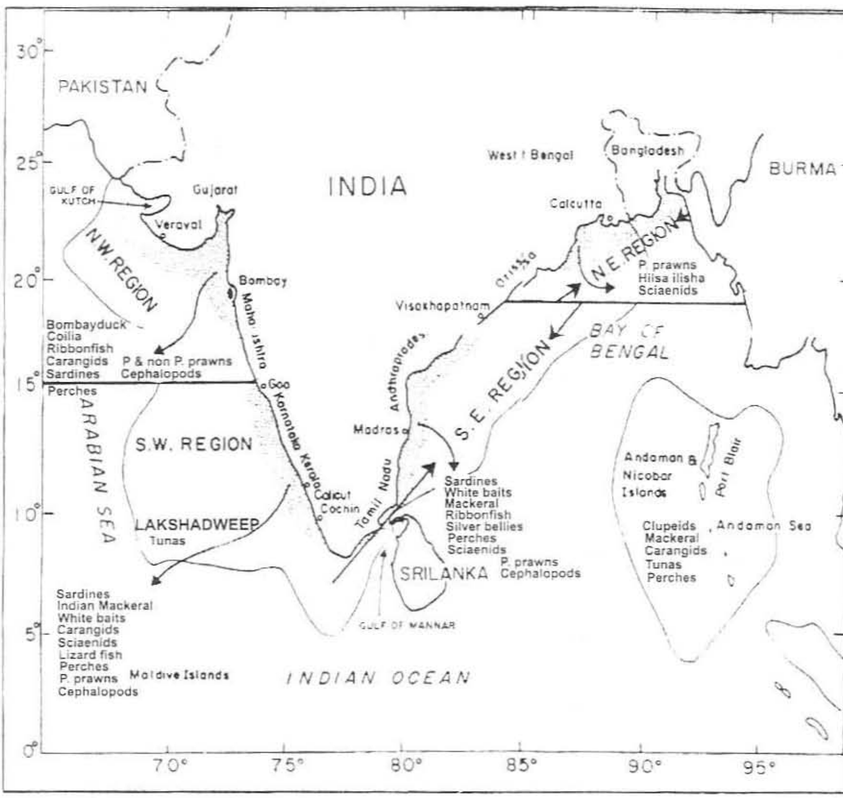

Figure 1. Exclusive economic zone of India

convection areas of the Arctic seas and the cold climate regions of the northern hemisphere. This geographic separation is a major factor, which determines the oceanographic conditions of the northern Indian Ocean. Circulation of waters in the Arabian Sea and Bay of Bengal is influenced by the pattern of winds associated with the summer and winter monsoons and comprise the monsoon current, the equatorial current and the equatorial counter current (Varadachari and Sharma 1967; Pillai *et al.* 1997). The monsoon current which is westerly during the northeast monsoon period (October-December) and easterly during the southwest monsoon season (May-October) has significant impact on the coastal fisheries. Average salinity value ranges between 34 and 37% in Arabian Sea and 30-34% in the Bay of Bengal. Both sea and land breezes are common in this area except during the southwest monsoon (along the west coast) and the northeast monsoon season (along the east coast).

In the Arabian Sea, temperature ranges between 23 and 29°C and in the Bay of Bengal, it is 27 to 29°C. With regards to vertical distribution of temperature in the Bay of Bengal, the thermocline is usually below 50-55 m, occasionally going down to 100-125 m, while in the Arabian sea, it fluctuates a great deal, showing definite seasonal trends (Rao 1973). Coastal upwelling occurs in varying intensities along the west and east coasts of India, corresponding with the southwest monsoon and determines the seasonal productivity patterns. During the months of strongest monsoon winds, coinciding with upwelling, linear banks of greenish, highly organic and mobile mud (*Chakara*) form inshore in many areas between latitudes 8 and 10° N (Bristow 1938) and support a seasonal fishery mainly consisting of sardines, whitebaits, mackerel and prawns.

Profile of Indian Marine Fisheries

The Indian marine fisheries sector is characteristically an open access one with free and common property rights. The multispecies fishery comprise over 200 commercially important finfish and shellfish species. Being a multigear fishery, fishing practices vary between different regions, depending on the nature of the fishing grounds and the distribution of the fisheries resources. Pelagic stocks like mackerel, sardines, whitebaits, ribbonfish, carangids, seerfishes, coastal and oceanic tunas; demersal groups like croakers, threadfin breams, silverbellies, catfish, lizard fish and goatfish; crustaceans like penaeid prawns, crabs, lobsters and stomatopods and cephalopods like squids and cuttlefish are common. The abundance of these stocks varies from region to region 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 Bombayduck (*Harpadon nehereus*) and non-penaeid prawns form a good fishery along the northwest coast, while perches (pigface breams, groupers and snappers) are dominant in the southwest and east coasts, especially in the Gulf of Mannar, Palk Bay and Wadge Bank areas.

Among gears, gillnets, drift nets and bag nets of varied mesh sizes are widely employed by traditional fishermen along both the coasts, while ring seines, purse seines and mechanized gillnets are confined to the southwest coast. Bottom trawls up to 13 m OAL are operated along the entire coast, while the second generation large trawlers 13-17m are operated from selected harbours along both the east and west coasts. Currently, 2251 traditional landing centres, 33 minor and six major fishing harbours serve as bases for 2,08,000 traditional non-motorized crafts, 55,000 small scale beach landing, motorized crafts, 51,500 mechanized crafts (mainly bottom trawlers, drift gillnetters and purse seiners) and 180 deep sea fishing vessels of 25 m OAL (Anonymous 2001).

The growth of the fleets shows that the artisanal fleet (including the motorized) increased by about 110 per cent from the 1960s to the 1990s and the mechanized fleet by about 570 per cent during the same period (CMFRI 1997) and has resulted in an overdeployed fleet operating in the inshore waters (Table 1). The pattern of marine fish landings in India during the past fifty years (Figures 2 and 3) clearly reveals that the contribution by the

Table 1. Optimum and existing fleet size, 1996-97 (in number)

Fleet	Existing (Number)	Optimum (Number)	Excess Percent	Contrtibution to total catch (Percent)
Mechanized	46918	20928	55.0	67.0
Motorized	31726	12832	60.0	20.0
Non-mechanized	159481	31059	81.0	13.0

Total catch: 2.41 million tonnes (1996-97)

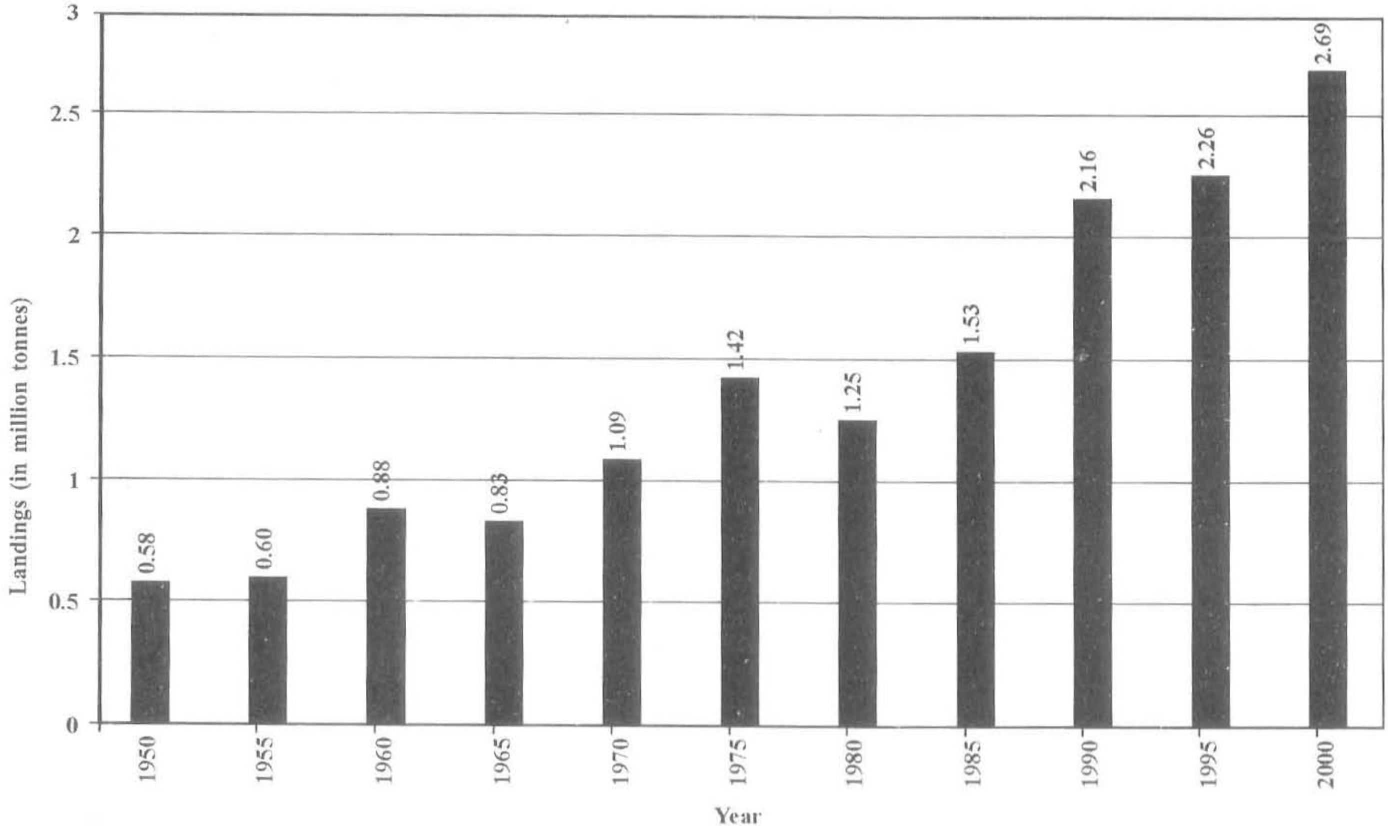

Figure 2 Total Marine fish landings (in million tonnes) in India 1950-2000

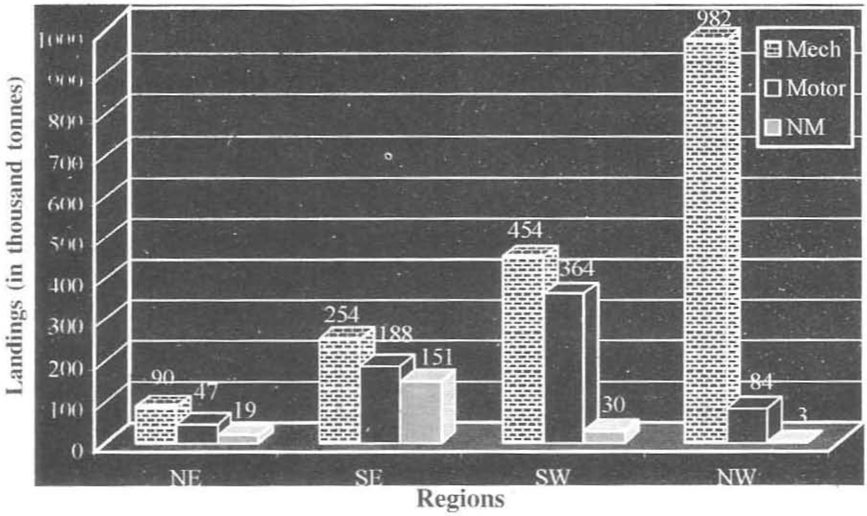

Figure 3 Sector-wise landings in different regions

artisanal sector to the total production was significant up to 1960s while presently, the contribution by the mechanized and motorized sector accounts for 91 per cent of the marine fish catch and the rest by artisanal gear (CMFRI 2000). The development of harbours and landing jetties, motorization of artisanal crafts and the rapid expansion of mechanized fishing have contributed towards a significant increase in fish production, employment generation and revenue earnings. However, as most of this fleet is engaged in coastal fisheries, where signs of decreasing CPUE are being reported, further expansion warrants stringent monitoring and adoption of sustainable fishing practices.

Socio-economic and Demographic Features

Currently, one million active fishermen are engaged in marine fishing in India, of which about 0.2 million are engaged in the mechanized sector, 0.17 million in the motorized sector and the rest in the artisanal sector. Among those engaged in the mechanized sector, 75 per cent work in trawl fisheries and 25 per cent in the fisheries operating gillnets, bag (*dol*) nets, purseseines and deep sea vessels. In the case of the motorized sector, 60 per cent are engaged in the ringseine fishery alone, which is predominant on the southwest coast and the rest in various other forms. In the artisanal sector, of the total 0.63 million active fishermen, 41 per cent are engaged in the operation of catamarans, 31 per cent in plankbuilt boats and the rest in the dugout canoes and others (Devaraj *et al.* 1998). Only 30 per cent of the fisherfolk possesses some sort of ownership of fishing implements, while a large number (70 per cent) of them work as labour force. The annual income of labourers working in a mechanized boat was estimated to be Rs. 34,200, while in motorized boat it has Rs. 15,200 and in artisanal unit Rs. 8,000 during 1995-96 (Table 2). This wide disparity in income between those engaged in the different subsectors results in clashes and conflicts (Sathiadhas 1996).

Fish Marketing System

The estimated first sale value of marine fish landings in the year 2000 was Rs. 102 thousand million with seafood exports earning Rs. 63 thousand million during 2000-01. The post-harvest fisheries including processing, product development, transport and marketing generate more employment than the harvesting sector, which, due to increasing demand and price of fish in both domestic and export markets, keeps growing. While the infrastructure for fish marketing is still principally oriented towards the export market, vast improvements in handling technologies and quick transportation facilities have led to increased market penetration of fresh iced fish to interior markets also. Currently, 50 per cent of fish is consumed fresh in and around producing centres, 43 per cent in centres up to 200 km interior to the coast and 5 per cent beyond 200 km limit (Sathiadhas *et al.* 1994). It is estimated that 44 per cent of fresh fish is auctioned off by fishermen themselves and the rest by involving intermediaries like wholesalers and retailers. Fisherman's share can be as high as 95 per cent in case of direct sale to the consumers (Devaraj 1987) and 30-68 per cent otherwise, with the wholesalers receiving 5-32 per cent and retailers 14-47 per cent of the consumer's rupee for different species of marine fish (Devaraj *et al.* 1998). Earlier, hardly 5 per cent of fish in the internal marketing system was marketed through co-operatives but the recent significant development of fisheries co-operatives has helped in reducing the high costs of marketing through integration of marketing and credit, establishing links with consumer co-operatives and introducing modern machinery and labour saving gadgets in all stages of marketing (Singh 2000). Fisheries associations are also coming up which will take up not only fishing but also direct selling of the catches to the consumers, thereby eliminating middlemen traders. At present, about 30 per cent of the total landings are processed after they become unsuitable for fresh consumption (Devaraj *et al.* 1998) and hygienically processed and

Table 2 . Sectorwise per capita investment, production, earnings and wages in Indian marine fisheries

Sectors (Rs. million)	Capital investment engaged	No. of fishermen per fishing (million)	Per capita investment production labour (Rs.)	Annual per capita of fishing of fishing labour (kg)	Per capita production per kg labour per working day (kg)	Av. value realised by fishing of fish (Rs.)	Income generated fishing labour/trip (Rs.)	Per capita earnings of of fishing labourer per trip (Rs.)	Annual wages* labourer (Rs.)
Mechanized	17,710	0.2	88,550	7,550	38	45	1,710	171	34,200
Motorized	3,380	0.17	19,888	2,588	13	35	455	76	15,200
Artisanal	8,810	0.65	13,440	437	2.4	25	60	40	8,000

(*Assuming 200 fishing days per annum)
Source: Sathiadhas *et al.* 1999

packed dried fish for domestic consumption in interior towns and canned fish in cities and defence establishments offer a good scope.

Fishing Regulations

Until 1970s, the emphasis of fisheries management in India was on increasing the fish production through improved fishing technology, infrastructure (harbours, roads, processing and market facilities) development and incentives and subsidies to the fishermen. These paved the way for increasing the marine fish production from 0.5 million tonne in 1950 to 2.7 million tonnes in 2000 (Figure 3). However, during the 1980s and 1990s, serious concerns were expressed that the unrestricted growth of the fishing industry might become counterproductive (Devaraj and Vivekanandan 1999) and therefore, the management strategy started aiming at sustaining the fisheries. Marine Fisheries Regulation Acts (MFRA) were promulgated in the 1980s with the focus on controlling the fishing area fishing gears, enforcing mesh size regulations and closed seasons.

Deep Sea Fishing Policy

To increase fisheries production from the outer continental shelf, the Govt. of India introduced the Deep Sea Fishing Policy (DSFP) in 1991, which allowed for chartered and leased vessels and joint ventures with foreign fishing vessels to operate in the Indian EEZ. But, due to protests from the fishery sector, this policy was scrapped and has adversely affected the exploitation of offshore resources. The lack of harvesting infrastructure and expertise on onboard processing of offshore resources is a serious bottleneck in developing the deep sea fishing sector.

Economic Evaluation

The total investment cost of fishing (Rs. 41.17 thousand million) by the marine fisheries sector (Table 3) and the estimated total value of the marine landings at about Rs. 102 thousand million indicate a fairly good profit ratio for the fishing industry as a whole (CMFRI 1997a). The economic feasibility of each fishing unit in the fishing industry, which is operating under nearly perfect competitive conditions depends on several factors like input and output prices, level of production and its functions (type and size of the vessel, age of the vessel, crew size and its skill, fishing time, fishing effort

Table 3. Capital investments, fixed cost and annual operating costs (Rs. in million) of the Indian marine fishing fleet during 1995

Fishing Fleet	Invest-ment	Fixed cost	Operating cost				Total cost	Fishing cost (Rupees/kg)
			Fuel cost	Labour	Others	Total		
1. Mechanized Sector								
(i) Medium trawlers (14-17m OAL)	8500	2550	2220	2330	1070	5620	8170	22.56
(ii) Small trawlers (10-13 m OAL)	20250	4500	6250	4100	2450	12800	17300	22.56
(iii) Dolnetters	300	90	60	120	40	220	310	2.95
(iv) Purseseiners	900	270	140	170	110	420	690	4.42
(v) Pablo & plank built boats	4340	1090	1050	2420	500	3970	5060	32.65
(vi) Others	200	60	30	60	20	110	170	3.40
Total	34490	8560	9750	9200	4190	23140	31700	19.87
2. Motorized Sector								
(i) Canoes	3750	750	470	1870	780	3120	3870	12.29
(ii) Catamarans	310	90	40	21	90	340	430	10.75
Total	4060	840	510	2080	870	3460	4300	12.11
3. Artisanal sector								
(i) Canoes, Catamarans & Plankbuilt boats	2620	660	-	11710	730	2440	3100	10.93
Total	2620	660	-	11710	730	2440	3100	10.93
Grand Total	41170	16000	10260	22990	5790	29040	39100	14.30

Source : CMFRI 1997a

and other inputs like fuel, food, insurance etc.) and above all, the marketing avenues and prospects (Sathiadas *et al.* 1995).

The rates of return for the deep sea vessels are less as compared to those of the fishing units (both mechanized and artisanal) operating in the inshore waters; because of the huge investment required for these vessels (Table 4). The tuna longliner fetches better rates of return as compared to the other deep sea vessels which concentrate mainly on prawns. Hence,

Table 4. Annual economic performance of different types of offshore vessels operating in the marine sector (1989-92)

Sl. No.	Economic parameters	Deep sea trawler (25 m OAL)	Deep sea multipurpose (26 m OAL)	Tuna long line (30 m OAL)
1.	Initial Investment (Rs. in million)	16.00	15.00	16.40
2.	Annual catch rate (tonnes)	46.00	76.00 (P-36, F-40)	91.00
3.	Value (Rs. in million)	7.82	6.83	10.10
4.	Operating cost (Rs. in million)	3.30	2.60	4.10
5.	Fixed cost (Rs. in million)	2.80	3.00	4.00
6.	Total cost (Rs. in million)	6.10	5.60	8.10
7.	Net operating income (Rs. in million)	4.52	4.23	6.00
8.	Net income (Rs. in million)	1.72	1.23	2.00
9.	Rate of return (%)	26	24	27
10.	Payback period (years)	7.6	7.6	4.7
11.	Value realised per kg of fish (Rs./kg)	170.00	90.00	11.00
12.	Average total cost per kg of fish (Rs./kg)	133.00	74.00	9.00
13.	Average operating cost per kg of fish (Rs./kg)	72.00	40.00	4.50

P – Prawns: F - Fishes

Source: Sathiadhas *et al.* 1995

the sustained development of deep sea fishing requires formulation and implementation of resource management policies that would ensure reduction in the fishing pressure on the penaeid shrimp and diversify fishing efforts to other resources.

Status of Exploitation

The coastal fisheries exploit a large number of species (Tables 5 and 6) using different crafts and gears, mostly in the depth range of 0 to 50 m. Although in recent years, this has been extended up to about 120 m in some regions. The annual average landing during the period 1995-99 was 2.5 million tonnes principally constituted by the Indian mackerel (8.5 per cent), penaeid prawns (7.7 per cent), croakers (6.8 per cent), oil sardine (6.7 per cent), carangids (6.1 per cent), perches (6.1 per cent), non-penaeid prawns (5.2 per cent), ribbonfishes (4.9 per cent), cephalopods (4.1 per cent), and others (10.7 per cent) (Table 5). Catch trend during the year 2000 indicates

Table 5. Catch trends and potential yield estimates of different species

Group	Average catch (t) 1985-89	Average catch (t) 1995-99	Group contribution (%)	Potential yield (t)
Elasmobranchs	54027	68861	2.8	71408
Oil sardine	141831	167123	6.7	294869
Other sardines	76541	116458	4.7	101490
Anchovies	68630	138080	5.5	141817
Other clupeids	132626	51868	2.1	78932
Bombay duck	93185	99714	4.0	116227
Ribbonfishes	78384	122805	4.9	193670
Carangids	111040	151601	6.1	238148
Indian mackerel	123832	212633	8.5	295040
Seerfishes	35171	45059	1.8	61719
Coastal tunas	34185	42786	1.7	65472
Barracudas	-	15717	0.6	20849
Catfishes	50630	43762	1.8	51255
Eels	6317	8317	0.3	9081
Croakers	102934	169643	6.8	273027
Perches	90083	152477	6.1	226793
Flatfishes	29612	44975	1.8	47304
Silverbellies	60766	60641	2.4	67247
Pomfrets	37356	41891	1.7	46088
Penaeid prawns	143073	192571	7.7	194192
Non-penaeid prawns	48057	130781	5.2	13874
Stomatopods	-	70758	2.8	120351
Lobster	-	2409	0.1	3874
Cuttlefish	-	52698	2.1	49989
Squids	39799	53185	2.1	49821
Others	40034	267135	10.7	
Total	1598113	2497342	100.0	3934417

Table 6. Status of exploitation of different species-stocks along the Indian coast in the 0-50 m depth zone

Species	State of exploitation		
	Full	Over	Under
Sardinella longiceps	All along	-	-
S. gibbosa	SW coast	-	West coast
Hilsa ilisha	NE coast	-	-
Encrassicolina devisi	-	-	All along
Stolephorus waitei	-	-	-
Rastrelliger kanagurta	All along	-	-
Scomberomorus commerson	-	SE&SW coast	-
Euthynnus affinis	All along	-	-
Thunnus tonggol	All along	-	-
Auxis rochei	-	-	All along
Katsuwonus pelamis	-	-	All along
Megalaspis cordyla	-	-	SW coast
Decapterus russelli	-	-	All along
Selaroides lepiolepis	SE coast	-	-
Atropus atropus	NW coast	-	-
Alepes kalla	SW coast	-	-
Atule mate	-	-	SW coast
Caranx carangus	SE coast	-	-
Parastromateus argenteus	-	West coast	-
Formio niger	-	SW coast	-
Trichiurus lepturus	-	East coast	West coast
Harpodon nehereus	NW coat	-	-
Nemipterus japonicus	All along	-	-
Nemipterus mesoprion	All along	-	-
Leiognathus bindus	East coast	-	-
L. dussumieri	Tamil Nadu	-	-
L. jonesi	Tamil Nadu	-	-
Secutor insidiator	East coast	-	-
Tachysurus tenuispinis	-	West coast	-
T. thalassinus	-	W&NE coast	-
Otolithus cuvieri	NW coast	-	-
Johnius macrorhynus	NW coast	-	-
J. vogleri	NW coast	-	-
J. sina	SW coast	-	-
J. carutta	SE coast	-	-
Penaeus monodon	East coast	-	-
P. indicus	-	East coast	-
P. semisulcatus	-	SE coast	-
Metapenaeus monoceros	All along	-	-
M. dobsoni	All along	-	-
Acetes indicus	NW coast	-	-
Panilurus polyphagus	-	NW coast	-
Loligo duvauceli	All along	-	-
Sepia aculeata	East coast	-	West coast
S. pharaonis	East coast	-	West coast

Source: Murty and Rao 1996

that the northwest coast contributed 40 per cent to the total marine fish production, followed by the southwest coast (32.0 per cent), southeast coast (22.0 per cent) and northeast coast (6.0 per cent) (Figure 4) (CMFRI 2000).

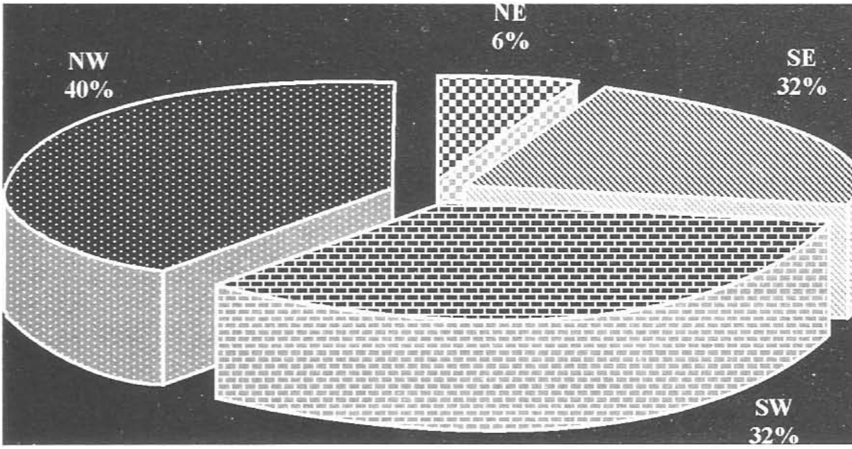

Figure 4. Region-wise contribution to all India production during 2000

Oceanic resources consist of tunas (*Thunnus albacares, T. obesus, Katsuwonus pelamis*), billfishes, myctophids (*Benthosema* spp., *Myctophum* spp. and *Diaphus* spp.) and oceanic squids (*Symplectoteuthis oualaniensis, Onychoteuthis banskii, Thysanoteuthis rhombus*). But there is no directed fishery for these species, except the marginal exploitation by chartered vessels, which operated under the deep sea fishing schemes during 1990s and which have since been suspended. Longline surveys conducted by Fishery Survey of India (FSI) has also revealed abundant resources of yellowfin tunas and pelagic sharks (Somavanshi 2001).

Ornamental Fish and Fisheries

Marine aquarium fish trade is gaining increasing popularity worldover with an estimated value of US $ 4.5 billion (Srivastava 1994). The Gulf of Mannar, Palk Bay, Gulf of Kutch, southwest coast and the Lakshadweep and Andaman group of islands are known to be rich in ornamental fishes (Murty 1969; Murty *et al.*1989). The wrasses, damselfish, surgeons, butterflyfish, moorish idol, squirrelfish, triggerfish, rabbitfish, parrotfish, angels, goatfish and pufferfish are the major aquarium fishes represented by nearly 180 species. Most of these fishes are abundant and offer scope for live fish export and development of home aquariculture in the country. The results of the survey and assessment of marine ornamental fishes of Lakshadweep (nine islands) implemented by the Central Marine Fisheries Research Institute (CMFRI) indicate an annual potential yield of 25 million fish consisting mainly of wrasses (38.0 per cent), damsel fishes (32.7 per cent), goat fish (8.4 per cent), parrot fish (7.4 per cent), squirrel fish (4.9 per cent), surgeon fish (4.8 per cent), butterfly fish (2.1 per cent), trigger fish (0.8 per cent) and others (1.7 per cent).

The seahorses or pipefishes are suitable for aquaria and are in great demand in Singapore and China for making soup and for medicinal purposes. In recent years, they are also being intensively exploited, particularly by divers from the southeast coast of India. A majority of these fishes are associated with coral reefs and those in great demand are not very abundant, their exploitation may disturb the habitats and result in depletion of stocks warranting restricted exploitation and monitoring and development of culture and hatchery technologies for the major species.

Issues

Declining CPUE and Idling Fleets

The annual growth rate of marine fisheries production increased from 4.3 per cent during 1970s to 4.8 per cent during 1980s and declined to 4.0 per cent during 1990s (CMFRI 1997a) and lowering down in growth rate is reflected in the annual catch attaining the optimum levels in the inshore fishing grounds up to a depth of 50 m of about 0.18×10^6 sq km area. The substantial increase in fishing effort since the 1970s has resulted in the decrease in per capita area per active fishermen and per boat in the inshore fishing grounds and also in the CPUE, which, in turn, has given rise to conflicts among different categories of fishermen, especially artisanal and mechanized sectors (Sathiadhas 1996). Technological improvements in capital intensive fishing implements have also rendered existing older units less economical or non-operational, leading to substantial idling of fleets and underemployment (Sathiadhas *et al.* 1999) .

Impact of Bottom Trawling on Sea Bottom and Its Benthic Biota

At present about 42,000 bottom trawlers operate (mainly targeting shrimps) in the entire coastal stretch, against the optimum number of 20,000. This kind of excessive bottom trawling is feared to have far reaching consequences, such as degradation of the sea-bed ecosystem and its biodiversity, as a large number of non-target groups comprising juveniles and sub-adults of economically important finfishes and shellfishes and also benthic organisms, most of them with little edible value but occupying key positions in the marine food web, are also destroyed (CMFRI 2000).

Discards

The discards in the Indian Ocean region account for 2.27 million tonnes, forming nearly 8.4 per cent of the total global discards (Alverson *et al.* 1994). Though there are no precise estimates of discards along the Indian coast, preliminary studies indicate that about 0.3 million tonnes is discarded by shrimp trawlers annually. The quantity of discards from trawlers may further increase in view of the rapid expansion of the multiday / distant water fishing. Therefore, there is an urgent need to devise suitable methods for onboard collection/preservation of discards and their value addition to prevent economic wastes.

Credit Facilities

With most of the traditional fishermen belonging to socio-economically weaker sections and adoption of advanced fishing methods becoming a necessity, availability of credit becomes crucial. Currently, only about 25 per cent of the active fishermen have ownership over fishing equipments and indebtedness is a serious issue in rural areas, where money lender and middlemen provide loans at exorbitant interest rates to purchase crafts and gear and almost confiscate the catches in return (BOBP 1983).

Coastal Aquaculture

Introduction

India is the second largest global aquaculture producer with a production of 2.03 million tonnes (1998), contributing 6.2 per cent to the global output.

Table 7. Open water fishery resources of India and their modes of fishery management

Resource	Unit	Size	Management Mode
Brackishwater	km	29000	Aquaculture
Rivers	ha	356000	Capture fisheries
Mangrove	ha	300000	Subsistence fisheries
Estuaries	ha	39600	Capture fisheries/Aquaculture
Estuarine wet lands	ha	190500	Aquaculture
Backwaters/lagoons	ha	1485557	Ranching
Reservoirs (small)	ha	202213	Culture-based fisheries
Flood plain wetlands	ha	2 million	Culture-based fisheries

Source : Pandian 2001

Coastal aquaculture is a significant contributor to this production, constituting mainly the shrimps like *Penaeus monodon* and *P. indicus*. However, vast water bodies highly suitable for aquaculture (Tables 7 and 8) and the varied biodiversity that has the potential to capture new markets with a wide range of seafood products, have prompted consideration of other candidate species like oysters, mussels, crabs, lobsters, scampi, seabass, groupers, seacucumber, ornamental fishes and seaweeds in the new aquaculture scenario in the country. Hatchery and rearing techniques have also been standardized for many of these organisms (Table 9).

Shrimp Farming

Shrimps being a highly valued export commodity, shrimp farming is considered a lucrative industry. Depending on the area of the pond; inputs like seed, feed; and management measures like predator control, water exchange through tidal effects or pumping, etc., farming systems have been classified into four groups: extensive, modified extensive, semi-intensive and intensive. According to Marine Products Export Development Authority (MPEDA), which is the main agency promoting shrimp farming through its various schemes and subsidies, during 2000-01, about 1,45,900 ha was under shrimp culture, with an average production of 0.7 tonne/ha/annum. Currently, 80 per cent of the shrimp production comes from small and marginal holdings, with farms of less than 2 ha constituting 49.2 per cent of the total area under culture, between 2-5 ha (15.8 per cent), 5-10 ha (13 per cent) and the

Table 8. Mariculture potential in India

Sl No.	Area	T.A. (million ha)	PCA (million ha)	CCA (million ha)	CAP (tonne)
1.	Coastal landbased	2.5	1.2	0.14	85,000 (mainly shrimps)
2.	Hinterland saline soil aquifer-based	8.5		100	200 (milkfish, mullets, pearlspot, shrimps, scampi)
Seafarming					
	(a) Open sea (EEZ)	202	1.8 (inshore 0-50 m depth)	20	1,500 (mussel)
	(b) Bays, coves and gulf	-	10,700	-	-
	(c) Estuaries and backwaters	-	2,050	5	800 (oysters)
	(d) Island lagoons/ lakes	-	35,000	-	-
Stock Enhancement Programme					
	(a) Searanching	18 (0-50 m depth)	18	Nominal	Nominal (shrimp, pearl oyster, clams, seacucumber)
	(b) Artificial fish habitat	-		50 reefs	10
	(c) Bottom artificial reefs/FAD	-		150 FAD	

TA = Total area; PCA = Potential cultivable area; CCA = Current cultivated area; CAP = Current Annual Production.
Source : Devaraj *et al.* 1999

rest >10 ha. Presently, there are about 200 operational shrimp hatcheries with a total annual production capacity of 10.8 billion seeds (PL 20), most of them located on the east coast, with state-of-the-art facilities. There are also 33 feed mills with a total installed capacity of 1,50,000 tonnes to cater to shrimp industry.

Table 9. Marine organisms of aquaculture importance in India

Species	Hatchery Techniques	Rearing Techniques
Fishes		
Mugil cephalus, *Liza parsia*, *L. macrolepis*, *Valamugil seheli*, *Chanos chanos*, *Etroplus suratensis*, *Epinephelus tauvina*, *E. dussumieri*, *Lethrinus* spp.,	X	X
Sillago sihama, *Anguilla bicolor* and *Siganus* spp. Anemone fish, *Chromis* sp. and *Lates calcarifer*	XX	XX
Crustaceans		
Penaeus monodon, *P. indicus* and *P. semisulcatus*	XXX	XXX
Scylla serrata	X	XXX
Portunus pelagicus	XX	XX
Panulirus homarus, *P. ornatus* *P. polyphagus* and *Thenus orientalis*	X	X
Molluscs		
Perna viridis, *P. indica*, *Pinctada fucata*, *Crassostrea madrasensis*, *Anadara granosa*, *Meretrix meretrix*, *M. casta* and *Paphia malabarica*	XXX	XXX
Trochus radiatus, *Xancus pyrum*, *Sepia pharaonis* and *Loligo duvaucelli*	X	X
Seaweeds		
Gracilaria edulis, *Gelidiella acerosa*, *Porphyra* sp., *Sargassum* spp., *Ulva* spp. and *Euchaemia* sp.	XX	XX
Seacucumber		
Holothuria scabra	XX	XX

x = Techniques under development
xx = Techniques developed
xxx = Techniques developed and commercialized

Fluctuating marine fish production combined with increased demand for shrimp in global market, successful demonstration of semi-intensive shrimp culture and establishment of commercial hatcheries along the east coast of India have led to rapid development of intensive/semi-intensive shrimp farms with a production of 5-10 tonnes/ha/crop in 4-5 months. Farmed shrimp production increased from 40,000 tonnes in 1991-92 to 82,850 tonnes in

1995-96 but subsequently, slumped to about 70,000 tonnes between 1995-97 (Table 10) as the fast pace of development failed to look at sustainability which resulted in disease outbreak, crop failures, environmental degradation and social tensions (Varghese 2001). Presently, most of the large farms run by corporate bodies have closed down due to disease problems, public litigations and protests by environmental groups over issues like salination of land and fresh water aquifers adjacent to shrimp farms, through seepage. The farming community has now become more responsive to the concepts of environment-friendliness and sustainable aquaculture. Disease problems are being overcome through adoption of closed system of farming (recirculation system, zero water exchange) in grow outs, application of probiotics, secondary aquaculture of selected fishes like mullets, milkfish, molluscs and seaweeds in reservoirs and drain canals, adoption of indigenous, good quality seed and feed and reduction in stocking density to 5-6 nos./sq. m in the farms. Preliminary trials of culture of *P. monodon* in freshwater

Table 10. Trend of shrimp exports and contribution by aquaculture

Year	Shrimp exports		Cultured shrimp			Per cent contribution	
	Quantity (mt)	Value (Indian Rupees. million)	Production (mt)	Export (mt)	Value (Indian Rupees million)	Shrimp export	Export value
1985	50349	3298.2					
1986	49203	3779.3					
1987	55736	4257.8					
1988	56835	4703.3	28000	18300	2293.0	33.00	48.78
1989	57819	4633.1	30000	19500	2597.0	33.72	58.57
1990	62395	6633.2	35500	23075	3764.0	36.98	56.77
1991	76107	9661.6	40000	26000	5447.6	34.16	55.81
1992	74393	11802.6	47000	30550	7662.5	41.06	64.93
1993	86541	17707.3	62000	40300	12889.3	47.14	72.79
1994	101751	25102.7	82850	53853	18662.3	52.92	74.35
1995	95724	23560.0	70573	47992	15316.9	50.96	64.09
1996	105426	27017.8	70686	45945	16425.6	43.58	60.80
1997	101318	31405.6	66868	43454	20860.0	42.90	66.42
1998	102484	33449.0	82634	53712	25110.0	52.41	75.07
1999	110275	36452.2	86000	54000	27820.0	48.96	76.32
2000	111874	44815.1	113700	65894	38700.0	58.90	86.35

Source: Ganapati and Viswakumar 2001

have shown fast growth and high production and have been adopted in many farms along the Andhra Pradesh and Kerala coasts. Advanced molecular techniques like Polymerase Chain Reaction (PCR) for early and rapid detection of viral pathogens, which cause disease outbreaks, are also being used to prevent disease problems in the growout system.

Socio-economic development through integrated farming systems and group farming experiments

In the coastal low lands (*Pokkali* fields in Kerala, *Khar* lands in Goa, *Khazans* in Karnataka State and *Bheri* in West Bengal) along the west coast of India, there is a traditional practice of shrimp farming in rice fields, which is done as a rotational crop after rice harvest giving production up to 0.5 tonne/ha/year. Fragmented holdings and poor socio-economic conditions of these small farmers, for whom the aquaculture is a livelihood activity, prevent the adoption of advanced technologies. Group farming approach, which relies on synchronized farming operations and collective management by the farmers of a locality is found to help increase production by improving the farmers' access to required inputs and reducing the cost of cultivation. As part of its action, research project on empowerment of rural communities through extension, the Central Marine Fisheries Research Institute (CMFRI) initiated group farming approach using shrimp (*P. indicus*) – rice rotation culture through its Institute-Village-Linkage Programmes (IVLP), designed to transfer technologies efficiently from lab to field and improve rural economy. Besides achieving social and economic gains for the farmers, it was especially useful in empowering women farmers, where women for the first time directly participated in an area entirely dominated by men and production of scientifically developed shrimp feed was taken up by women on a commercial basis (Krishna Srinath *et al.* 2000).

Unemployment is a serious issue, especially in rural areas of India. Consequent upon the establishment of shrimp farms , employment is reported to have increased by 2-15 per cent and the average income of farm labourers has increased by 6-22 per cent (CIBA 1997). The average labour requirement for paddy cultivation was found to be 180 labour days/crop/ha compared to shrimp farming where 2 crops were taken and labour requirement was 600 labour days/crop/ha (Rao and Ravichandran 2001). Ancillary industries like hatcheries, feed mills, processing and ice plants have also generated employment opportunities and boosted the rural economy (Patil and Krishnan 1998).

It has also helped in the development of indigenous technologies, especially with regard to feed and seed production. Imported shrimp feed is expensive and beyond the reach of small farmers and special low pollution diets which cost half the imported feeds and yet with an FCR of 1.5:1 has been developed indigenously and widely adopted by small farmers in improved extensive farming ventures. In addition, production of this scientifically formulated ecofriendly feed, *Mahima,* on a commercial basis, has been taken up by women in certain villages, which has also aided in empowering them.

In shrimp hatcheries, a regular supply of healthy broodstock is necessary. However, the supply of spawners from the wild is limited. Until recently, eyestalk ablation was the widely adopted method to induce rapid maturation and spawning. Presently, the technology has been developed to induce maturation and repetitive spawning using environmental and nutritional manipulation strategies in shrimps like *P. indicus* and *P. semisulcatus* (Pillai and Maheswarudu 2000).

Issues in shrimp farming

While extensive farming methods are sustainable and produce little waste, intensive operations discharge effluents carrying nitrogenous excretory waste, uneaten food, residues of chemicals and drugs that cause damage to the ecosystem. The quality of effluent water from different systems of shrimp farming in India (Table 11) is generally believed to be low without any serious impact on biodiversity (Kutty 2001). The Ministry of Agriculture (GOI) has prescribed standards for shrimp farm waste water (Table 12) which is in the interest of the aquaculturist to adhere and ensure sustainable production system. The MPEDA is also extending assistance for setting up effluent treatment units in shrimp farms of 5 ha or more water area, either singly or in a group.

Conversion of mangroves and agricultural lands are also serious reasons for conflicts arising out of competitive utilisation of limited natural resources, although such practices have been minimal (Rao and Ravichandran 2001) and mainly fallow and unproductive agricultural lands have been converted.

Table 11. **Quality of water from different systems of shrimp farming in India (Mg/l)**

Parameter	Extensive	Semi-intensive	Intensive
Phosphate P	0.05	0.12	0.11
Nitrate – N	0.15	0.04	0.22
NH_3 – N	0.007	0.02	0.013
Hydrogen sulphide	0.02	BDL*	BDL*

* Below detection level

Table 12. Standards for shrimp farm waste water

Sl. No.	Parameter	Guidelines issued by MoA**		Standards for discharge of pollutants* in marine coastal areas
		Coastal marine waters	Creeks	
1.	pH	6.0 – 8.5	6.0 – 8.5	5.5 – 9.0
2.	Suspended solids (mg/L)	100	100	100
3.	Dissolved oxygen (mg/L)	not less than 3	not less than 3	-
4.	Free ammonia (as NH_3 -N) (mg/L)	1.0	0.5	5
5.	Biochemical Oxygen Demand - BOD (5 days @ 20°C) (mg/L)	50	20	100
6.	Chemical Oxygen Demand -COD (mg/L)	100	75	250
7.	Dissolved phosphate (as P) (mg/L max)	0.4	0.2	-
8.	Total nitrogen (as N) (mg/L)	2.0	2.0	-

* Gazette Notification G.S.R. No. 422 (E) dated May19, 1993, General Standards for discharge of environmental pollutants Part-A: Effluents

** Ministry of Agriculture

There are also reports of salinization of ground water and agricultural land through seepage from aquaculture ponds (Patil and Krishnan 1998). Wild seed capture rampant before establishment of hatcheries and the blocking of access to sea by large farms were also causes for conflict with the capture fisheries sector, which has been resolved to a large extent now.

In view of the numerous conflicts that arose and litigations by environmental groups, the Coastal Regulation Zone (CRZ) notification, 1991 under the Environment (Protection) Act, 1986, restricts construction of shrimp farms a landward boundary up to 500 m from high tide line (HTL) and has put an end to the construction of coastal farms. While aquaculture development is controlled by local state governments, its overall supervision is done by the Central Ministry of Agriculture, which in 1995, issued guidelines for sustainable development and management of brackishwater aquaculture. It seeks to discourage conversion of agriculture lands, mangroves and other ecologically sensitive wetlands for aquaculture. Also, Environmental Monitoring and Management Programme (EMMP) and Environment Impact Assessment (EIA) have been made mandatory for shrimp farms of 10-40 ha and >40 ha, respectively, which require a 'No Objection Certificate' from the State Pollution Control Boards for all the qualifying aquaculture units.

A National Aquaculture Authority has also come into force, which consists of representatives of Pollution Control Boards, Revenue Authorities, Fisheries Departments, Developmental bodies and Research Institutions, who have been assigned the role of regulating shrimp culture in a sustainable manner in the country. The code of practices for shrimp hatcheries and farms are also being issued by MPEDA.

Shrimp farming being more economical and rewarding than any other agricultural farming (Table 13), suitable areas may be marked out for shrimp farming by an identified Integrated Coastal Area Management Authority and coastal aquaculture may be suitably integrated in an eco-friendly manner with other activities in the coastal region to reap maximum benefits. In general, there is a greater awareness of the need to adopt sustainable aquaculture methods like low stocking density, minimum usage of chemicals, and feeds and prevention of conflicts at most of the major shrimp farming centres. The apex shrimp farming associations and other stakeholders are coming together to discuss the common problems related to shrimp farming and evolve remedial measures for sustainable aquaculture practices.

Financing and supporting agencies

The National Bank for Agriculture and Rural Development (NABARD) extends help in fisheries development activities by assisting in pilot scale

Table 13. Economics of shrimp aquaculture/ hatchery units

Enterprise	Shrimp farm	Shrimp hatchery	Broodstock/ nauplii Facility
Area & production capacity	1 ha 1.0 – 2.0 t/ha/crop	0.3 ha 40 million PL20/year	0.1 ha 200 million nauplii/year
Species	*P. monodon*, *P. indicus*, *P. semisulcatus*	*P. monodon*, *P. indicus*, *P. semisulcatus*	*P. monodon*.
Farming method	Modified extensive	Broodstock develop-ment, induced maturation, larval and post-larval rearing	Indoor tanks
Duration	4-4$\frac{1}{2}$ months	30 days/run	15 days
Economics (in Rs.)			
Initial investment	18,000	7,60,000	38,500
Recurring cost	9,000	90,000	13,750
Total cost	27,000	3,80,000	52,250
Production	3.12 t (2 crops)	40 million PL 20/yr	200 million nauplii/yr
Revenue	97,500	2,62,500	50,000
Net profit	22,250	65,500	18,000

Source: ICAR 2000

demonstration of mariculture technologies under its Research and Development Grant Scheme and also encourages commercial scale projects through its refinance mechanism. Besides, the Brackishwater Fish Farmers' Development Agency and MPEDA also extend financial support/subsidies to farmers.

Lobster Farming/Fattening

There is great demand for live and whole cooked lobsters in the international market but in the absence of a viable hatchery technology and limited availability of juveniles and subadults from the wild, lobster farming has not yet picked up in the country. However, lobster fattening, which is carried out on a small scale, using the undersized lobster caught along with the commercial size lobsters from capture fisheries, is profitable. The spiny lobster, *Panulirus polyphagus*, is farmed in intertidal pits, provided with numerous shelters at a stocking density of 5 numbers/sq.m. Molluscan meat, trash fish and pelleted feed are used to grow the lobsters until they attain the weight of 125-150 g.

Crab Farming/Fattening

In view of the widespread disease problems in shrimp farming during 1990s, farmers started looking for alternate, more disease-resistant and economically important commercial fish species. Live mud crabs (*Scylla serrata*, *S. tranquebarica)* being a much sought export commodity, mud crab fattening was considered the best alternative. Seed stock consist of freshly moulted crabs (water crabs) of 550 g which are stocked in small brackishwater ponds at a stocking density of 1/sq. m or in individual cages for a period of 3-4 weeks while being fed thrice daily with trashfish @ 5-10 per cent of their biomass. Selective harvesting is done according to size, growth and demand and the venture is profitable (Table 14) because of low operating costs and fast turnover. Monoculture (with single size and multiple size stocking) and polyculture with milkfish and mullets are being carried out on a small scale, as the seed supply is still mainly from the wild. Experiments on breeding and seed production of *S. tranquebarica* have given 20 per cent survival rate from egg to first instar stage and attempts are on to improve the survival rate for an economically viable hatchery technology.

Table 14. Economics of three systems of mud crab farming

Culture Method	Monoculture	Polyculture	Fattening
Species	*Scylla tranquebarica* *S. serrata*	*S. tranquebarica* *S. serrata*	*S. tranquebarica* *S. serrata*
Culture period, days	120	138	30
Expenditure, Rs. (seed, feed, pond, preparation, labour)	43,860	48,400	56,200
Production, t crabs	0.78	1.14 and 0.7 tonne milkfish	0.56
Income, Rs.	1,57,200	2,61,200	1,22,850
Net profit/crop, Rs.	1,13,340	2,12,800	66,650

Source: ICAR 2000

Hatchery technology for breeding and seed production of the blue swimming crab, *Portunus pelagicus*, has also been developed and four generations of crabs have been produced by domestication. The hatchery seed is being mainly utilized for stock enhancement programmes along the east coast.

Molluscan Culture

Edible Oyster Farming

The first attempt to develop oyster culture in India dates back to 1910 by James Hornell. Since 1970s, the CMFRI has taken up R&D programmes on all aspects of oyster (*Crassostrea madrasensis*) culture and has produced a complete package of technology, which is presently being widely adopted by small scale farmers in shallow estuaries, bays and backwaters all along the coast.

In the adopted rack and ren method, a series of vertical poles are driven into the bottom in rows, on top of which horizontal bars are placed. Spat collection is done either from the wild or produced in hatcheries, on suitable cultch materials. Spat collectors consist of clean oyster shells (5-6 Nos.) suspended on a 3 mm nylon rope at spaced intervals of 15-20 cm and suspended from racks, close to natural oyster beds. Spat collection and further rearing is carried out at the same farm site and harvestable size of 80 mm is reached in 8-10 months. Harvesting is done manually with a production rate of 8-10 tonnes/ha. Oyster shells are also in demand by local cement and lime industry and culture production has increased to 800 tonnes in the year 2000.

Mussel (*Perna viridis, Perna indica*) Farming

Raft method (in bays, inshore waters), rack method (in brackishwater, estuaries) or longline method (open sea) are commonly adopted for mussel farming. Mussel seeds of 15-25 mm size collected from intertidal and subtidal beds are attached to coir/nylon ropes of 1-6 m length and enveloped by mosquito or cotton netting. Seeds get attached to rope within a few days while the netting disintegrates. The seeded ropes are hung from rafts, racks or longlines. A harvestable size of 70-80 mm is reached in 5-7 months and production of 12-14 kg mussel (shell on) per metre of rope can be obtained. Attempts to demonstrate the economic feasibility of mussel culture has led to the development of group farming activities in the coastal communities (especially rural women groups) with active support from local administration and developmental agencies like Brackishwater Fish Farmers Development Agency (BFFDA) and State Fisheries Department. Cultured mussel production has increased from 20 tonnes (1996) to 800 tonnes (2000) mainly through the rack system in estuarine area. Molluscan culture technologies and their economics are given in Table 15.

Pearl Oyster Farming and Pearl Production

In India, the marine pearls are obtained from the pearl oyster, *Pinctada fucata*. Success in the production of cultured pearls was achieved for the

Table 15. Molluscan culture technologies and economics

Technology	Edible oyster farming	Mussel farming	Pearl oyster culture
Species	*Crassostrea madrasensis*	*Perna viridis, P. indica*	*Pinctada fucata*
Farming method	Rack and Ren (30 x 10 m)	Raft (8 x 8 m)	Cages suspended from rafts/ racks
Culture period	8 months	5-7 months	12-15 months
Unit area	300 sq m	64 sq m	Open sea; 6 rafts and 600 box cages
Economics (US $)			
Initial investment	371	203	10,000
Recurring cost	139	357	4,419
Total cost	510	560	
Production	5.83 tonnes shell- on (0.48 tonne meat)	0.8 t shell on	
Revenue	736	934	Depends on percentage pearl production and market value of pearls
Profit	226	303	30% (at 25% pearl production)

Source: ICAR 2000

first time in 1973 by CMFRI. Raft culture and rack culture in nearshore areas are the two methods commonly adopted for rearing pearl oysters and recently attempts have been made to develop onshore culture methods.

Shell bead nucleus (3-8 mm) implantation is done in the gonads of the oyster through surgical incision while graft tissues are prepared from donor oysters of the same size and age group. Implanted oysters are kept under observation for 3-4 days in the labs, under flow through system and then shifted to the farm in suitable cages for rearing. Periodic monitoring is done and harvest is carried out after 3-12 months. Pearls are categorized into A, B and C types depending on colour, lustre and iridescence. 25 per cent pearl production has been successfully demonstrated in a series of farm trials at various locations along the Indian coast. Research is also directed towards development of a technology for *in vitro* pearl production using mantle tissue culture of pearl oyster.

The technology for mass production of pearl oyster seed and pearl production has paved the way for its emergence as a profitable coastal aquaculture activity at certain selected centres along the coast. Village level pearl oyster farming and pearl production, through direct involvement of small scale fishermen have been carried out successfully as part of technology transfer programme along the Valinokkam Bay on the east coast (Table 16). Pearl

Table 16. Economics of pearl culture programme at Valinokkam Bay – A group farming success

Number of oysters implanted	9414
Total expenditure incurred, US $	1571
Rate of Return, %	56.7
Total pearls harvested	1849
Revenue earned from sale of pearls, US $	2178
Pearls distributed to fishermen	250
Revenue earned from sale of pearls	US $ 2178

Expenditure incurred (as percentage of total)

Raft	Cages	Pearl oyster (for implantation)	Pearl oyster (for graft tissue)	Shellbead nuclei	Labour	Miscellaneous
24	18	24	2	17	6	9

Source: APAARI 2000

oyster farming has already generated income worth US $ 26,000 and several young women who are trained in pearl surgery in pearl farms are finding ready employment in this developing industry. The CMFRI also imparts training on pearl culture to trainees in neighbouring Asian countries, and various Memorandum of Understanding (MoU) have been signed with entrepreneurs, desirous of pearl culture since 1996.

Clam Culture

Package of clam culture practices has been developed for the blood clam *Anadara granosa* and *Paphia malabarica*, where production of 40 tonnes/ha/6 months and 15-25 tonnes/ha/4-5 months have been achieved in field trials. Induced spawning and larval rearing to setting of spat has been perfected for clams like *P. malabarica*, *Meretrix meretrix* and *Marcia opima*.

Sea Cucumber Culture

More than 200 species of sea cucumbers are found in Indian waters mainly in the Gulf of Mannar, Palk Bay and Andaman and Nicobar Islands. The most important commercial species is *Holothuria scabra*, whose continuous exploitation has led to depletion of natural population (James 1999). Seed of *H. scabra* was produced in the hatchery for the first time in India in 1988 through induced spawning using thermal stimulation (James 1989) and has been used widely since then to produce seed for stock enhancement programmes. Water quality is the most important parameter in hatcheries with ideal conditions being temperature, 27-29°C; salinity 26.2 – 32.7 ppt, dissolved oxygen 5-6 ml/l; pH, 6-9; and ammonia content, 70-430 mg/cubic metre (James 1999). Larvae require different diets at different developmental stages and algae like *Isochrysis galbana*, *Chaetoceros calcitrans*, *Tetraselmis chuii* and *Sargassum* are used. Seed produced in hatcheries are grown in velon screen cages (2 sq.m area), netlon cages (1.65 sq.m area, 5 mm mesh net), concrete rings (70 cm dia x 30 cm height) and also at the bottom of prawn farms. Artificial diets prepared with soyabean powder, rice bran and prawn head waste is used for feeding juveniles and results are encouraging. Juveniles have been stocked @ 30,000/ha and grown along with shrimps (*P. monodon*) in farms (James 1999). Sea cucumbers being detritus feeders, feed on waste shrimp feed and organic matter on the pond bottom, reducing the organic pollution load in the farm. Being an eco-friendly practice, which also provides an additional income to the farmer, it is expected to become popular among farmers who have been facing problems of shrimp disease outbreaks in the recent past.

Marine Finfish Culture

In the area of marine fish culture, the country is still in the experimental phase only. Attempts are being made to develop suitable hatchery and farming technology for mullets (*Mugil cephalus*, *Liza macrolepis*, *V. seheli*), groupers (*Epinephelus tauvina*), seabass (*Lates calcarifer*), milkfish (*Chanos chanos*) and pearlspot (*Etroplus suratensis*). The Central Institute of Brackishwater Aquaculture (CIBA) has developed an indigenous hatchery technology for seabass using captive broodstock which were stocked in large RCC tanks (12 x 6 x 2 m) with 70-80 per cent water exchange daily. Maturation process was accelerated using LHRH hormone injection and larvae were maintained with rotifers and *Artemia* nauplii. Cooked and minced fish meat is used for nursery rearing and survival rates up to 14 per cent in larval rearing phase and 84 per cent in the nursery phase have been recorded.

Ornamental Fish Culture

There are a wide variety of ornamental fishes in the vast water bodies and coral reef ecosystems along the Indian coast, which if judiciously used, can earn a sizeable foreign exchange. Hatchery technology for clownfish (*Amphiprion chrysogaster*), damsel fishes (*Pomacentrus caeruleus*, *Neopomacentrus nemurus* and *N. filamentosus*) and the sea horse (*Hippocampus kuda*) has been developed, which can be scaled up for mass production of these species.

Seaweed Culture

Around 60 species of commercially important seaweeds with a standing crop of one lakh tonne occur along the Indian coast (Table 17), from which, nearly 880 tonnes dry agarophytes and 3,600 tonnes dry alginophytes are exploited annually from the wild (Kaladharan and Kaliaperumal 1999).

Table 17. Commercially important Indian seaweeds and their standing crop

Sl No.	Group	Species	Standing crop (t)
1.	Agarophytes	*Gracilaria edulis, G. corticata, G. crassa, G. folifera, G. verrucosa, Gelidiella acerosa, Gelidium* spp., *Pterocladia* spp.	6,000
2.	Alginophytes	*Sargassum* spp., *Turbinaria* spp., *Laminaria* spp., *Undaria* spp., *Dictyota* spp., *Hormophysa* spp.	16,000
3.	Carageenophytes	*Hypnea* spp., *Chondrus* spp., *Eucheuma* spp.	8,000
4.	Edible	*Ulva* spp., *Enteromorpha, Caulerpa* spp., *Codium* spp., *Laurencia* spp., *Acanthophora* spp.	70,000

Seaweed products like agar, algin, carragenan and liquid fertiliser are in demand in global markets and some economically viable seaweed cultivation technologies have been developed in India by CMFRI and Central Salt and Marine Chemical Research Institute (CSMCRI). CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweeds collected from natural beds or spores (tetraspores/carpospores). It has the potential to develop in large productive coastal belts and also in onshore culture tanks, ponds and raceways. Carrageenan yielding seaweed, *Kappaphycus striatus*, was introduced from the Philippines by CSMCRI (Mairh *et al.* 1995) and presently this species is acclimatized and cultivated extensively along the Mandapam coast. To make the seaweed industry more economically viable, research aimed at improvement of strains of commercially important species by isolating viable protoplasts and somatic hybridization techniques, is being carried out. The rate of production of *Gelidiella acerosa* from culture amounts to 5 tonnes dry weight per hectare, while *Gracilaria edulis* and *Hypnea* production is about 15 tonnes dry weight per hectare (Gomkale *et al.* 2000).

Fish Processing Sector – Profile and Issues

The preservation and processing infrastructure include 372 freezing plants with capacity of 52.5 tonnes per day, 148 ice making plants with about 1,800 tonnes capacity per day, 450 cold storage having capacity of over 80,000 tonnes and 15 fish meal plants with about 330 tonnes capacity per day. There are also 900 registered prawn peeling sheds with a capacity of 2,684 tonnes, which form the pre-processing centres. The capacity utilization of the processing plants at present is hardly 25 per cent, mainly because of the shortage of raw materials. Most of the processing factories are old and only a few meet the criteria of the European Union Certification for imports to Europe.

The stringent import policies of many importing countries have also influenced the type and quality of products being exported. Out of the total marine fish landings, only about 15 per cent, including cephalopods and crustaceans, is exported. Finfishes constitute the single largest commodity in the seafood export market with major varieties as ribbonfish, pomfrets, seerfishes, mackerel, reef cod, snappers and tunas. The *surimi* based products, pasteurized crab meat and live fish (crabs, groupers, lobsters) also offer an immense scope for development (Table 18). Fresh and frozen farmed mussels and oysters have good demand in domestic market while mussels are also exported to countries like UAE, Germany and Republic of South Africa. Export to European countries requires certification of the water bodies used for mariculture and the appropriate authority issuing such certificate has to be decided. Production of value added fishery products is

Table 18. Item-wise exports of marine products from India

Item	1997-98		1999	
	Quantity, t	Value, million Indian Rupees	Quantity, t	Value, million Indian Rupees
Fr. Shrimp	100720	31341.5	103070	33623.8
Fr. Fish	188029	7267.3	126474	5257.8
Fr. Squid	35095	2708.9	34451	2878.1
Fr. Cuttle Fish	37258	3234.1	33771	2852.5
Fr. Lobsters	1289	477.9	1364	661.5
Chilled Items	3183	443.1	2793	360.1
Live Items	1700	293.4	1733	389.8
Dried Items	5669	334.5	5661	343.0
Others	12875	874.1	17887	207.3
Total	385818	46974.8	327205	47573.9

Source: MPEDA 2001 (Marine Products Export Development Authority) also being done although it is highly capital intensive and advanced processing and packaging technologies are currently insufficient in India.

Quality assurance in fishery products has been introduced since 1965 with pre-shipment inspection scheme (Export Quality Control and Inspection Act) and the In Process Quality Control (IPQC) was implemented in early 1978, prescribing the minimum requirements for raw materials, manufacturing processes, end product testing, preservation and packaging of final products. The Hazard Analysis Critical Control Point (HACCP) with stress on safety was introduced in 1995 and it is the responsibility of the processors to ensure proper hygienic conditions and observe the prescribed standards for seafood exports.

The steps taken by the Govt. of India to relax the policy on trade and convertibility of Indian rupee into foreign currencies have resulted in an increase of export of fish/fishery products. The MPEDA is also conducting numerous promotional efforts which have benefited exporters of fish and fishery products. In view of the rigorous quality requirements of the European countries, the quality vigilance and compliance to attain the required international standards are being stepped up. Irradiation process (Radurization) for the extension of shelf-life of fresh fishery products and improvement in microbial safety have been standardized in many countries, including India and would pave the way for the reduced post-harvest losses (Shamsundar 2001).

Conclusions

Indian fisheries sector is not only a source of valuable food and employment generation, but also contributes significantly to the national income also. In recent years, mariculture has gained importance and much research input has gone into the selection of candidate species, hatchery production of seed, farming/fattening, growout systems, genetics, nutrition, physiology and pathology of candidate species but lacuna still exist with regards to breeding and seed production techniques of certain edible finfishes and lobsters and seafarming technology requirements in diverse hydro-climatic conditions and the mariculture yield remains at less than 3 per cent of the total marine fish production. To develop fisheries sector further, a concerted effort by the stakeholders and policy makers is essential for formulating responsible and sustainable fishing practices and increase the productivity/production through artificial reefs, sea ranching programmes, aquaculture, reduced post-harvest losses along with a higher investment and allotment of funds for infrastructure and manpower training and technology development.

References

Alverson, D., Freberg, M., Murawski, S. and Pope, J.G. 1994. A global assessment of fisheries by catch and discards. *FAO Fish.Tech.Pap.*, 233 pp.

Anonymous, 2001. *Report of the Expert Group for Formulation of Comprehensive Marine Fisheries Policy*. Ministry of Agriculture, Dept. of Animal Husbandry and Dairying. New Delhi, 27 pp.

APAARI, 2000. Bivalve Mariculture in India – A success story in Coastal Ecosystem Development. *APAARI Publication*: 2000/1, 56 pp.

BOBP 1983. Marine Small Scale Fisheries of India : A General Discussion. *Bay of Bengal Programme, BOBP/INF/3(GCP/RAS/040/SWE)*, 69 pp.

Bristow R.C. 1938. *History of Mudbanks*. Govt. Press, Cochin, 37 pp.

CIBA, 1997. Final Report: *Comprehensive Survey of Impacts of Shrimp Farming in Nellore District*, Andhra Pradesh. Mimeo.

CMFRI, 1997. *Vision 2020-CMFRI Perspective Plan*. (ed. Murty, V.S) Central Marine Fisheries Research Institute (ICAR) Cochin, 70 pp.

CMFRI, 1997a. Status of Research in Marine Fisheries and Mariculture. *CMFRI Spl. Publn.*, No. 67 : 35 pp.

CMFRI, 2000. *Annual Report 1999-2000*. Central Marine Fisheries Research Institute, Cochin, 148 pp.

Devaraj, M. 1987. State of Act of Marine Fisheries in India. *Proc. Nat. Symp. Utilisation of Living Resources of the Indian Seas*. National Academy of Sciences of India : 101-114.

Devaraj, M., Murty, V.S.R., Sathiadhas, R. and Joshi, K.K. 1998. The New Economic Policy and Perspective for Marine Fisheries Research and Development in India. *Fishing Chimes* 18(5): 18-29.

Devaraj, M. and Vivekanandan, E. 1999. Marine capture fisheries of India: Challenges and opportunities. *Curr. Sci.*, 76(3): 314-332.

Devaraj, M., Pillai, V.K., Appukuttan, K.K., Suseelan, C., Murty, V.S.R., Kaladharan, P., Sudhakara Rao, G., Pillai, N.G.K., Pillai, N.N., Balan, K., Chandrika, V., George, K.C. and Sobhana, K.S. 1999. Packages of practices for sustainable, ecofriendly mariculture (land-based saline aquaculture and seafarming). *In: Aquaculture and the Environment*, (Mohan Joseph Modayil, ed.) Asian Fisheries Society, Indian Branch : 33-69.

Ganapathi, R. and Viswakumar, M. 2001. Present status and future prospects of coastal aquaculture in India. *In: Proc. International Workshop on Aquaculture and Environment*, (Menon, N.R., Kurup B.M. and Philip, R., eds.) 13-14 July 2001, Cochin, India. The Centre for Integrated Management of Coastal Zones and Cochin University of Science and Technology.

Gomkale S.D., Rama Rao, K., Subha Rao, P.V., Eswaran, K., Ganesan, M. and Mairh, O.P. 2000. Prospects of cultivation of seaweeds and its impact on sea weed industry. *In: Symposium of Ecofriendly Mariculture Technology packages – An Update* (Abstracts) 25-26th April, 2000. MBAI, CMFRI, Mandapam Camp.

ICAR, 2000. Technologies from ICAR (for industrial liasion) Indian Council of Agricultural Research, New Delhi, 350 pp.

James, D.B. 1989. Beche-de-mer- its resources, Fishery and Industry. *Mar. Fish. Infor. Serv., T & E.Ser.* 92: 1-34.

James, D.B. 1999. Hatchery and culture technology for the sea cucumber *Holothuria scabra* jaeger, in India. *NAGA, the ICLARM Quarterly*, 22 (4): 12-17.

Kaladharan, P. and Kaliaperumal, N. 1999. Seaweed industry in India. *NAGA, the ICLARM Quarterly*, 22 (1) : 11-14.

Krishna Srinath, Sridhar Manpal, Kartha, P.N.R. and Mohanan, A.N. 2000. Group farming for sustainable aquaculture. *Ocean and Coastal Management*, 43 (7): 557-571.

Kutty, M.N. 2001. Diversification of Aquaculture. *In: Sustainable Indian Fisheries*, (Pandian T.J. ed.) National Academy of Agricultural Sciences. pp. 169-212.

Mairh. O.P., Zodape, S.T., Tewari, A. and Rajyaguru, M.R. 1995. Culture of marine red alga *Kappaphycus striatum* (Schmitz) in the Saurashtra region. west Coast of India. *Indian J. Mar. Sci.*, 24: 24-31.

MPEDA 2001. Statistics of Marine Products Exports 1999. The Marine Products Export Development Authority, 328 pp.

Murty, V.S. 1969. Catalogue of fishes (excluding from the Laccadives) in the reference collections of the Central Marine Fisheries Research Institute. *Bull. Cent. Mar. Fish. Res. Inst.*, 10 : 36.

Murty, V.S., Kumaran, M. and Lal Mohan, R.S. 1989. Resource of ornamental fishes. *Bull. Cent. Mar. Fish. Res. Inst.*, 43: 46-64.

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

Pandian, T.J. 2001. A prelude for Indian Fisheries Policy *In*: *Sustainable Indian Fisheries*, (Pandian, T.J., ed.), National Academy of Agricultural Sciences, 321-327 pp.

Pandian T.J. 2001. Aquaculture in India: Problems and Prospects. *In*: *Proc. International Workshop on Aquaculture and Environment*, (Menon, N.R., Kurup B.M. and Philip, R., eds.) 13-14 July 2001, Cochin, India. The Centre for Integrated Management of Coastal Zones and Cochin University of Science and Technology : 170-183.

Patil, P.G. and Krishnan, M. 1998. Shrimp farming industry and its impact on rural economy. *Agricultural Economics Research Review*, 10(2) : 293-308.

Pillai N.N. and Maheswarudu, G. 2000. Broodstock development of Penaeid shrimp. *Symposium on Ecofriendly Mariculture Technology packages – an update* (Pillai,P.P., ed) (Abstracts) 25-26th April, 2000. MBAI, CMFRI, Mandapam Camp.

Pillai, V.N., Devaraj, M. and Vivekanandan, E. 1997. Fisheries environment in the APFIC region with particular emphasise on the northern Indian Ocean. *In:* Small Pelagic Resources and their Fisheries in the Asia – Pacific region. *Proc. Of the APFIC Working Party on* *marine Fisheries*, (Devaraj M and P. Martosubroto, eds.). First Session, 13-16 May 1997, Bangkok, Thailand. RAP Publn. 1997/31. pp. 381-424.

Rao G.R.M. and Ravichandran, P. 2001. Sustainable brackishwater Aquaculture. *In: Sustainable Indian Fisheries*, (Pandian T.J., ed.) National Academy of Agricultural Sciences pp. 134-151.

Sathiadhas, R. 1996. Economic evaluation of marine fisheries of India for sustainable production and coastal zone development. *Naga the ICLARM Quarterly*, 19(3): 54-56.

Sathiadhas, R., Narayanakumar, R. and Sehara, D.B.S. 1994. Exploitation of marine fisheries and their utilisation. *Proc. 4th Swadeshi Science Congress*, Swadeshi Science Movement, Kerala, Kochi, pp. 20-25.

Sathiadhas, R., Narayanakumar, R. and Reghu, R. 1995. Marine Fisheries Management for Sustainable Development. *Transfer of Technology Series*, CMFRI, pp 32.

Sathiadhas, R., Reghu, R. and Immanuel, Sheela 1999. Human resources utilization, productivity and earnings in Indian marine fisheries. *Seafood Export Journal*, XXX (4): 51-55.

Shamsundar B.A. 2001. Fish Processing. *In: Sustainable Indian Fisheries*, (Pandian, T.J. ed.) National Academy of Agricultural Sciences. pp. 250-271.

Singh, S.K. 2000. Role of fisheries co-operatives in reducing the high cost of marketing involved in fisheries sector. *In: Symposium of Ecofriendly Mariculture Technology packages – An update* (Pillai,P.P, ed.) (Abstracts) 25-26th April, 2000. MBAI, CMFRI, Mandapam Camp.

Somvanshi, V.S. 2001. Problems and prospects of deep sea and far sea fishing. *In: Sustainable Indian Fisheries*, (Pandian, T.J., ed.) National Academy of Agricultural Sciences, pp. 71-87.

Srivastava, L.S. 1994. Ornamental fish, New export opportunities. *Yojana*, Nov. 15 : 22.

Varadachari, V.V.R. and Sharma, G.S. 1967. Circulation of waters in the north Indian Ocean. *J. Indian Geophy*. 4(2): 61-73.

Varghese, P.U. 2001. Environmental impacts of coastal aquaculture with special reference to treatment protocol. *In*: *Proc. International Workshop on Aquaculture and Environment*, (Menon, N.R., Kurup B.M. and Philip, R., eds.) 13-14 July 2001, Cochin, India. The Centre for Integrated Management of Coastal Zones and Cochin University of Science and Technology : 114-120.

Virabhadra Rao, K. 1973. Distribution pattern of the major exploited marine fishery resources of India. Proc. Symposium on Living Resources of the Seas around India. *CMFRI Spl. Publn.* 11: 18-101.

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