STATUS, PROSPECTS AND MANAGEMENT OF SMALL PELAGIC FISHERIES IN INDIA

by

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Abstract

The annual small pelagic fish production increased from 0.30 million mt during 1950-54 to 1.24 million mt during 1996 along the Indian coast. The 4 fold increase was possible due to several technological advancements. The potential yield from the pelagic resources of the EEZ is estimated to be 2.2 million mt. As there is no further scope for increasing the production from the inshore waters, there is need to bring the outer shelf and oceanic waters into increasing levels of exploitation. During 1991-95, the northwest, southwest, southeast and northeast coasts contributed 28.3%, 40.4%, 24.8% and 6.6% to the small pelagic landings, respectively. Following the motorization of the traditional craft, the effort of the motorised craft increased from 0.71 million boatdays (1985) to 3.72 million boatdays (1996), resulting in a sharp decline in the CPUE from 163 kg/boatday to 98 kg/boatday. However, the CPUE in repsect of the small pelagics from the nonmortorized and mechanized sectors increased. The major gears in the fisheries include the trawl, pursesiene, ringseine and gillnets. During 1991-95, the Indian mackerel, anchovies, Bombayduck, oil sardine and other sardines constituted 15.4%, 12.5%, 10.0%, 8.2% amd 8.1% to the landings of the small pelagics. The fluctuations in the landings of the Indian mackerel, oil sardine and the biological characteristics and stock assessments of major species of small pelagics are discussed in the paper. The economic performance of the different sectors engaged in the fisheries for the small pelagics has been analyzed. The total value of the small pelagics landed during 1995 was Rs 22 157 million. For sustaining the small pelagic fisheries, suitable management measures have suggested.

INTRODUCTION

Among the various littoral states of the Asia-Pacific countries (Fig. 1), India enjoys a prominent position in marine fish production. The Indian coastline is 8 129 km long and the exclusive economic zone 2.02 million sq.km, including the continental shelf of 0.452 million sq. km. The shelf is narrow (32 km) at 15° N. Lat. on the southeast coast and wide (174.6 km) at 20° N .Lat. on the northwest coast (Fig.2). The current exploited shelf area (upto the 60 to 80 m depth line) covers hardly 5% of the EEZ, and yields annually 2.4 million tonnes of marine fish (1996). India is among the top ten fish producing countries of the world, contributing about 3% to the world marine fish production of about 85 million mt.

About 5 million fisherfolk inhabiting the coastal areas pursue fishing and allied activities for their livelihood. About 180 000 nonmotorized traditional fishing craft, 32 000 motorized traditional craft and 47 000 mechanized vessels are deployed in the marine fisheries sector. The nonmotorized and motorized craft operate essentially for the small pelagics which make considerable impact on the socioeconomics of the coastal communities. The development of fisheries, therefore, sans the development of the small pelagic fisheries, does not have much relevance in today's India. Consequently, small scale fisheries have been receiving comparatively high priorities in the successive five year plans, particularly for infrastructure development.

The Indian experience with the small scale fisheries sector is similar to that in any other tropical developing country. The multitude of species exploited by a large variety of fishing fleets makes the management of marine fisheries a difficult proposition. An attempt is made here to bring out the historic and current status of the small pelagic fisheries and to focus attention on their sustained development through appropriate plans of actions.

The Central Marine Fisheries Research Institute (CMFRI), established in 1947, is the premier organization for marine fisheries research in India. This institute is under the administrative control of the Indian Council of Agricultural Research (ICAR), an autonomous apex body pioneering and monitoring research in agriculture, animal husbandry and fisheries. Since its establishment, the institute began to acquire authentic statistics of marine fish production and to use it as the basis for planning various research and development programmes in the marine fisheries sector. For this purpose, the institute deploys a multistage stratified random sampling design for the estimation of marine fish production, fishing effort, cost and earnings. Authentic statistics of specieswise marine fish production, fishing effort, and their regional and seasonal variations are available since 1950. The material for this paper was drawn from the databank built up by the institute through this survey. Information on various aspects of marine fisheries is disseminated from this databank on a regular basis through a well developed computerized information system.

GROWTH PROFILE OF MARINE FISHERIES

Marine fisheries operations in the preindependence days used to be carried out at a subsistence level, almost exclusively by the traditional fishermen. Today, this sector has attained the status of a capital intensive industry, warranting close monitoring and management for sustained development. In the course of the past five decades, the annual marine fish production increased from about 0.6 million mt in the fifties to the current level of 2.4 million mt (Fig. 3). This phenomenal increase has been possible largely due to the R & D efforts initiated by the central and state governments through the successive five year plans. Considering the importance of fisheries as a source of protein, employment and foreign exchange, development of fisheries became a focal theme among the five year plan priorities set by the governments.

Introduction of mechanized fishing vessels and modern gear materials during the I & II five year plans (1951-1960); increase in the use of synthetic gear materials during the III five year plan (1961-1965); introduction of purseseining during the V five year plan (1974-1978); motorization of artisanal craft in 1979; and the substantial growth in the motorized artisanal fleet operating ringseines during 1985-1996 are the major reasons for the significant increase, not only in the marine fish production, but in the pelagic fish production as well (Table 1).

Table 1. Development thrusts in the marine fisheries sector through the plan periods from 1951 to 1996.

Plan period	Duration	Major developments	Average annual catch
I five year plan II five year plan	1951 to 1955 1956 to 1960	1. Mechanization of indigenous artisanal fishing craft 2. Introduction of mechanized fishing vessels 3. Introduction of modern gear materials 4. Infrastructure for preservation, processing, storage and transportation	P = 309168 mt (54.68%) D = 256244 mt (45.32%) T = 565412 mt P = 477607 mt (65.36%) D = 253092 mt (34.64%) T = 730699 mt
III five year plan Three annual plans	1961 to 1965 1966 to 1968	1. Substantial increase in the use of synthetic gear materials 2. Export trade	P = 465606 mt (63.78%) D = 264455 mt (36.22%) T = 730061 mt P = 58864 mt (65.09%) D = 315714 mt (34.91%) T = 904355 mt
IV five year plan	1969 to 1973	1. Imports of trawlers for deepsea fishing 2. Indigenous construction of deepsea trawlers 3. Fishing harbours at major & minor ports 4. Intensification of exploratory fishery surveys 5. Expansion of export trade	P = 618272 mt (57.77%) D = 451992 mt (42.23%) T = 1070264 mt
V five year plan	1974 to 1978	1. Diversification of fishing, introduction of purseseining	P = 641498 mt (48.36%) D = 684910 mt (51.64%) T = 1326408 mt
One annual plan	1979	2. Diversification of products 3. Motorization of artisanal craft	P = 693590 mt (50.78%) D = 672149 mt (49.22%) T = 1365739 mt
VI five year plan	1980 to 1984	4. Exploratory surveys in offshore grounds 5. Declaration of EEZ in 1977 6. MZI Act 1981 for regulation of foreign fishing vessels 7. Deepsea fishing through licensing, chartering and joint venture vessels	P = 716005 mt (49.90%) D = 718909 mt (50.10%) T = 1434914 mt
VII five year plan Two annual plans	1985 to 1989 1990 to 1991	1. New chartering policy of 1989 2. Development of deepsea fishing 3. Substantial growth in motorized artisanal fleet of ringseiners 4. Coastal shrimp aquaculture	P = 999127 mt (56.5%) D = 769913 mt (43.5%) T = 1769040 mt P = 1177719 mt (53.96%) D = 1004693 mt (46.04%) T = 2182412 mt
VIII five year plan	1992 to 1996	1. Deepsea fishing by joint venture 2. Development of coastal aquaculture 3. Substantial growth in motorized artisanal fleet of ringseiners 4. Export trade changes from a resource-based to food engineering-based industry	P = 1129807 mt (49.21%) D = 1166082 mt (50.79%) T = 2295889 mt

P = pelagic; D = demersal; T = total.

The annual small pelagic fish production increased from 0.3 million mt during 1950-1954 to about 1.24 million mt during 1996 (Table 2). The contribution of the small pelagics to the total production ranged from 46.6% to 63.5% during the five decades with an average of 51.4%.

Ample support provided by the R&D institutions, coupled with the investments by the private sector interested in export trade, supplemented the government efforts in expanding the growth of the sector. Production of pelagics and total fish registered significant increase during the decade of 1960-69, with a relative growth rate of 45% for the pelagics(Table 3), which was largely due to the expansion of the mechanized fleet. In the following decades (1970-79 and 1980-89), although there was an overall upward trend in production, the annual growth was only 22 to 27%, indicating optimum level of exploitation of all the resources in the inshore waters, upto about the 50 m isobath.

Table 2. Annual average landings of small pelagics, large pelagics and total marine fish landings in India during 1950-96 in mt.

Year	Small pelagics	Large pelagics	Total pelagics	Total Catch	% of pelagics in total	% of small pelagics in total	% of small pelagics in pelagics
1950-54	298935	8306	307242	561604	54.71	53.23	97.30
1955-59	407598	10257	417855	675413	61.87	60.35	97.55
1960-64	459462	14851	474313	738008	64.27	62.26	96.87
1965-69	565897	14213	580110	891435	65.08	63.48	97.55
1970-74	593981	23808	617788	1130788	54.63	52.53	96.15
1975-79	631586	36910	668496	1356626	49.28	46.56	94.48
1980-84	678796	47821	716005	1434914	49.90	47.31	94.80
1985-89	964148	34978	999127	1769040	56.48	54.50	96.50
1990-94	1184624	44081	1228705	2242412	54.79	52.83	96.41
1995	1126485	53554	1180039	2225028	53.03	50.63	95.46
1996	1242454	44359	1286813	2388239	53.88	52.02	96.55
1950-96	638974	33970	671815	1242406	54.07	51.43	95.11

Rapid motorization of the traditional craft gave fillip to production during 1990-95, enhancing the relative growth to 43%. However, production from the conventional grounds within the 50 m depth zone seems to have reached the optimum level consequent on the intensive operation of ringseines from the motorized craft as evident from the sharp decline in the relative growth (11%) during 1996. Perhaps, further increase in the growth rate could be achieved only through another technological advancement such as the extension of the fishing grounds beyond the 50 m isobath significantly.

In the case of the major pelagic stocks of oil sardine, Indian mackerel, tunas, seerfishes, pomfrets and Bombayduck, exploitation has already crossed or reached the MSY levels. The stocks of lesser sardines, whitebaits, carangids and ribbonfishes offer marginal scope of increased yields in the inshore grounds within the 50 m depth. Certain remarkable changes in the composition of the catches have been observed over the years along the east coast. For example, in recent years, the oil sardine has been emerging as an important fishery all along the east coast where it was practically absent till the mid eighties. The Indian mackerel became relatively more significant in Andhrapradesh and Orissa in recent years than in the past.

Table 3. Growth in the average annual overall and pelagic fish production through five decades from 1950 to 1996.

Period	Production (MT)		Relative growth (%)	
	Pelagic	Overall	Pelagics	Overall
1950-59	362,548	618,501	-	-
1960-69	527,211	814,721	+45	+31
1970-79	643,142	1,243,707	+22	+53
1980-89	819,093	1,579,836	+27	+27
1990-95 (6 years)	1,174,934	2,239,514	+43	+42
1996	1,286,813	2,388,239	+11	+7

The stagnation in marine fish production at 2 to 2.4 million mt per year in recent years necessitated investigations to reassess the potential yield from the EEZ. A Working Group on the Revalidation of Potential Marine Fisheries of the Indian EEZ (1991) estimated the potential yield of the Indian EEZ to be 3.9 million mt of fish annually, comprising 2.2 million mt from the 0 to 50 m depth zone and 1.7 million mt from the region beyond. The current yield from the 0 to 50 m depth zone is at the optimum level, and hence, does not offer any scope of increasing the yield. Therefore, the region beyond the 50 m depth has to be the focus of expansion. At the rate of 11 kg fish required per year per capita, India requires about 7.2 million mt of fish by 2025 AD for its fish-eating population of about 700 million. Out of this, the marine sector will have to provide about 4.3 million mt from both capture fisheries and mariculture.

The Working Group on the Revalidation of Potential Marine Fisheries of the Indian EEZ (1991) indicated the potential yield from the pelagic resources of the EEZ to be 2 211 000 mt, comprising 461 000 mt from the northwest region, 834 000 mt from the southwest region, 241 000 mt from the southeast region, 178 000 mt from the northeast region and 497 000 mt from the other areas including the Andaman & Nicobar islands, Lakshadweep and the oceanic region. However, the current production of pelagics includes 310 000 mt from the northwest region, 460 000 mt from the southwest region, 278 000 mt from the southeast region and 69 000 mt from the northeast region. Thus, there is a gap of 597 000 mt from the EEZ of mainland India alone. Since the potential from the 0 to 50m depth zone is estimated to be 1 174 000 mt and the current production is already 1 117 000 mt, there is not much scope of further increase in production from this inshore zone, and hence, the need to bring the outer shelf and oceanic waters into increasing levels of exploitation. The major stocks holding good potential in the outer shelf include the anchovies, carangids, ribbonfishes, tunas and sharks.

TRENDS IN PRODUCTION

Small pelagics

The small pelagics are defined as the pelagics excluding the highsea or oceanic tunas (skipjack & *Thunnus* spp.), billfishes and sharks. They comprise different taxonomic groups, which contribute to their rich species diversity, abundance and fisheries. From the available information on the distribution of marine fishes along the Indian coast (Fischer and Bianchi,1984; Smith and Heemstra,1986), it could be inferred that there are about 240 species of small pelagics (Table 4).

A few species of small pelagics enjoy wide geographical distribution while the others such as the shads and the Bombayduck have rather restricted distribution (Table 5, prepared in the APFIC Working Party Meeting during 13-16 May, 1997 at Bangkok). There is no strict body size-based dividing line that separates the small pelagics from the large pelagics. Species such as the Bombayduck which reach 390 mm total length are generally considered small pelagics. However, in this report, a few species of carangids, which are larger in body size (600-750 mm) than the Bombayduck, are, as a group, included in the small pelagics, together with several species of carangids such as the scads and others of smaller and intermediate sizes, which form sparse schools in almost the entire water column in the neritic region. With the same reasoning, the ribbonfishes, barracudas, dolphinfishes, cobia, seerfishes, coastal tunas etc. are also treated under the small pelagics. In addition to the differences in their body size and epipelagic habitat, there are several other characteristics which are unique to the small pelagics. Shoaling behaviour, planktonic or nektonic feeding, localised movement or short range migration and very high numerical abundance are a few characteristics, which distinguish the small pelagics from the rather long migratory, highly predatory and numerically less abundant large pelagics (highsea tunas, billfishes and sharks). Surprisingly, all the small pelagics that form fisheries are finfishes and the crustaceans and the cephalopods, which form about 20% of the total marine fisheries of India, are not represented in the catches of the small pelagics. However, a few species of squids, which migrate to the surface during nights, and the larvae of several species of crustaceans, which lead planktonic lives are represented in the catches in the finfish-dominated small pelagic fisheries.

Table 4. Major taxonomic categories of small pelagics and their species diversity.

Family	Group/Species	Number of species
I Clupeidae		
	1. Oil sardine*	1
	2. Lesser sardines* (including rainbow sardines)	14
	3. *Hilsa* spp. & other shads	15
	4. Whitebaits*	24
	5. *Thryssa* and *Thrissocles* spp.	10
	6. Wolf herrings	2
	7. Other clupeids	40
II Scombridae		
	1. Coastal tunas	7
	2. Seerfishes & wahoo	5
	3. Mackerels*	3
III Trichiuridae		
	1. Ribbonfishes*	8
IV Carangidae*		
	1. Round scads	2
	2. Golden scads	6
	3. Hardtail scad (or horse mackerel)	1
	4. Jacks	17
	5. Black pomfret	1
	6. Others	19
V Harpodontidae		
	1. Bombayduck	1
VI Stromateidae		
	1. Pomfrets	2
VII Coryphaenidae		
	1. Dolphinfishes	2
VIII Rachycentridae		
	1. Cobia	1
IX Mugildae		
	1. Mullets	22
X Sphyraenidae		
	1. Barracudas	7
XI Exocoetidae		
	1. Flyingfishes	10
XII Bregmacerotidae		
	1. Unicorn cod	1
XIII	Others	19
	Total small pelagics	240

* Major small pelagics

Table 5. Major small pelagic resources in the APFIC Region (as prepared in the APFIC Working Party Meeting during 13 - 16 May 1997 at Bangkok).

	FAO Fishing Area	51	57		71				61	
	Subregional Area	1	2	3	4	5	6	7	8	9
No	Species Group	Western Indian Ocean	Eastern Indian Ocean	Malacca Strait	Gulf of Thailand	South China Sea	Celebes Sea (Sulawesi Sea)	Australia (Northern)	East China Sea	Sea of Japan
1.	Mackerels: - *Rastrelliger* spp. - *Scomber japonicus*	 xx 	 xx 	 xx 	 xx 	 xx 	 xx 	 - 	 - xx	 - xx
2.	Scads (*Decapterus* spp., *Selar* spp., *Atule* spp.)	xx	x	xx	xx	xx	xx	-	xx	xx
3.	Torpedo Scad (*Megalaspis cordyla*)	xx	x	xx	xx	xx	xx	-	x	-
4.	Sardines - *Sardinella* spp. - *Dussumieria* spp. - *Sardinops*	 xx 	 xx 	 xx 	 xx 	 xx 	 xx 	 -	 xx	 xx
5.	Jacks - *Caranx* spp. - *Trachurus* spp.	 xx 	 xx 	 xx 	 xx 	 xx 	 xx 	 x 	 - xx	 - x
6.	Seerfishes (*Scomberomorus* spp.)	xx	xx	xx	xx	xx	xx	-	xx	x
7.	Small tunas (*Auxis* spp.,*Euthunus* spp., *Thunustonggol, Sarda* spp.)	xx	x	xx	xx	xx	xx	-	x	-
8.	Anchovies (*Stolephorus* spp.)	x	x	x	x	x	x	-	xx	xx
9.	Bombayduck (*Harpadon nehereus*)	x	xx	-	-	x	-	-	-	-
10.	Hairtails (*Trichiurus* spp.)	xx	xx	x	x	x	x	-	x	x
11.	Shads (*Hilsa* spp.)	x	xx	-	x	-	-	-	-	-
12.	Wolf-herring (*hirocentrus* spp.)	x	xx	xx	x	x	x	-	-	-
13.	Barracudas (*Sphyraena* spp.)	xx	xx	x	x	x	x	-	x	x
14.	Pomfrets (*Formio niger*, *Stromateus* spp.)	x	xx	x	x	x	x	-	xx	-
15.	Flyingfishes (*Hirundichthus* spp.)	xx	xx	-	-	x	x	-	x	x
16.	Mullets (*Mugil* spp., *Liza* spp.)	xx	x	x	x	x	-	x	x	x
17.	Dolphinfish (*Coryphaena* spp.)	-	x	x	x	x	x	x	x	x
18.	*Rachycentron canadus*	x	x	x	x	x	x	x	x	x

x : Being exploited by coastal states; xx: Potential transboundary pelagic stocks

Production trends: pelagics in relation to overall

Over the past five decades, marine fish production in India (Fig. 2) has been increasing progressively, though interspersed with years of stagnation, in between. From 0.6 million mt in 1950, production increased steadily to the current (1996) 2.42 million mt, registering a fourfold increase (Fig. 3). Until the mid seventies, the share of the pelagic stocks in the overall production remained very high with a consistently increasing trend from 54% in 1950 to 71% in 1960, and thereafter, at around 65% till the early seventies. The pelagic catches increased from 309 000 mt in 1950 to the current (1996) 1 286 813 mt (Table 3), registering nearly a fourfold increase. The growth in the production of the pelagics vis-a-vis the overall production could be gauged from the data in Table 3 and Fig. 4.

In the early years in the development of marine fisheries, the growth rate in the production of pelagic fisheries has been conspicuously higher than that of the overall production. Expectedly, this ought to have been the trend, as the development emphasis during the early plan periods upto 1969 has been on improving the traditional sector, which had the wherewithal only for exploiting the essentially pelagic stocks in the nearshore areas. This trend got reversed in the immediate decade of 1970-79 because of the rapid expansion of commercial trawling for shrimps for exports by the industrial sector, under initial subsidy support extended by the governments. Commercial trawling resulted in significantly high production of demersal finfishes also, besides shrimps and lobsters. Although the pelagic catches increased by 22 %, the trend in the overall production was set by the demersal finfish and crustacean catches. The next decade (1980-89) witnessed a growth of 27% in the pelagic catches as well as in the overall production. During this decade, there was rapid motorization of the traditional fishing craft, particularly in the latter half of the eighties. As a result, the stagnation in marine fish production witnessed in the first half of the eighties was replaced by accelerated production in the latter half, with the annual catch touching the 2 million mt mark in 1989. Since then, the annual production has been stagnating around 2.2 to 2.4 million mt, perhaps waiting for another technological change for a further take off from the present level. Intensive motorization of the traditional fishing craft resulted in a remarkable increase in the annual production, especially of the total pelagics, which increased from 835 000 mt in 1985, to 1 313 000 mt in 1989, registering a 71% growth; the small pelagics production showed an increase of about 74% during this period.

Production trends: small pelagics in relation to pelagics and overall

During 1991-95 the small pelagics constituted about 96% of the total pelagic catches, with the larger pelagics (mainly sharks, highsea tunas and billfishes) forming the remaining 4%. The larger pelagics formed about 2.2% of the overall fish production during this period (1991-95). Among the small pelagics, the sardines, mackerel, anehovies, carangids, Bombayduck and ribbonfishes together contributed 39.01% to the overall production; 73.3% to the total pelagics production and, 76.5% to the small pelagics production during 1991-95 (Table 6). The other small pelagics which include mainly the wolf herrings, shads, other clupeids, barracudas, unicorn cod, pomfrets, seerfishes, coastal tunas and mullets, formed the remaining 23.49 % of the small pelagic catches.

Table 6. Average annual production (mt) of the major small pelagics (msp) through the successive 5-year periods during 1981-1995.

	1981-85	1986-90	1991-95	1996
Oil sardine	182,920	169,800	95,957	110,346
Lesser sardines	63,069	78,554	93,725	103,732
Anchovies	100,901	126,222	145,088	133,891
Bombayduck	110,064	96,918	110,771	85,766
Ribbonfishes	50,056	77,122	97,444	126,994
Carangids	48,794	122,461	163,285	145,860
Indian mackerel	40,595	147,503	174,922	274,135
Total	596,399	818,580	881,192	980,724
Total of pelagics	760,975	1,076,031	1,200,810	1,286,813
% of msp in pelagics	78.4	76.0	73.3	76.2
% of msp in small pelagics	84.3	78.7	76.5	78.9
% of msp in overall production	40.0	43.2	39.0	41.0

The small pelagics have been the mainstay of the pelagic catches consistently. Although the share of the larger pelagics (highsea tunas, billfishes and sharks) in the total pelagics has been increasing rather significantly, their contribution remains insignificant, relative to the smaller pelagics. The share of the small pelagics in the total pelagics has, over the years, seen only a marginal decrease, from 97.4% in the fifties to 95.9% currently. Therefore, in the ultimate analysis, the pelagics would mean basically the small pelagics only. The small pelagics of commercial bearing are mainly the oil sardine, lesser sardines, anchovies, Bombayduck, ribbonfishes, carangids and Indian mackerel. The trends in their average annual production through the successive 5 year periods in the past 15 years are dealt with in Table 6.

Except the oil sardine and the Bombayduck, catches of the other small pelagics have been increasing progressively from 1981 to 1995. While the Malabar upwelling extending from the Ratnagiri coast (Maharashtra state) to the Gulf of Mannar (Tamilnadu State) is the major area inhabited by the oil sardine stock, bulk of the Bombayduck stock is found in the northern Maharashtra to the southern Gujarat coast. Although the oil sardine catches have been decreasing in recent years, fisheries for this species have emerged all along the east coast from the mid eighties onwards. Whether the decreasing trend in the landings of the oil sardine is due to overexploitation by the purseseine and ringseine fleets in the major stock area is yet to be established. The revival of the fishery in 1995 and 1996 may, however, prove the decreasing trend observed since the early nineties to be only a phase within a rhythmic cycle of about 11 years. The Bombayduck fishery has been maintaining an annual production of around 100 000 mt almost consistently over the last two decades. While the northwest coast contributes 86%, the northeast coast contributes 13% to the annual landings of the Bombayduck. The production of mackerel which used to be very high in the earlier years upto the 1970s, reached extremely low levels in the early eighties; however, it recovered rapidly from 28 000 mt in 1982 to 290 000 mt in 1989. The overall increase in the landings of the ribbonfishes is attributable mainly to their increase in the northwest region, in recent years.

Stock assessment of small pelagics

Assessment of stocks is esential for deciding guidelines for the rational exploitation and management of fisheries. The stocks and their levels of exploitation in respect of a number of species of small pelagics in the Indian seas have been determined on the basis of effort and catch data, biological parameters and primary production. The data presented in Table 24, which pertain to different time periods, have been effectively utilised as guidelines from time to time for evolving management options for the small pelagics fisheries.

Though 240 species constitute the fisheries along the Indian coast, it is only about 60 species belonging to 7 groups of small pelagics, viz., the oil sardine, lesser sardines, anchovies, Bombayduck, ribbonfishes, carangids and Indian mackerel that form the major small pelagics fisheries. The annual production of these 7 groups was 1 million mt in 1996, forming 76.2% of the small pelagics and 41.0% of the total marine landings (Table 6). The other small pelagics which include the wolfherrings, shads, barracudas, unicorn cod, mullets, seerfishes and coastal tunas formed only 23.8% of the small pelagics landings.

Pelagics production in relation to total marine fish production

During 1985-96, the production of the pelagics increased from 0.83 million mt in 1985 to 1.40 million mt in 1989 and declined subsequently and reached 1.29 million mt in 1996 (Fig. 4). The total marine fish production sharply increased from 1.6 million mt in 1985 to 2.2 million mt in 1989 and sustained at that level till 1995, but it increased further to 2.42 million mt in 1996. Consequently, the contribution of the pelagics to the total production increased from 58.4% in 1985 to 63.6% in 1989 and declined subsequently to 53.9% in 1996. The contribution of the pelagics to the total production, which showed an increasing trend consequent on the combined effect of motorization and the expansion of the ringseine fleet especially in the southwest coast, could make an impact upto 1989. The effect of this technological advancement could not be realized after 1989, though the advancements in other craft and gears such as the trawlers for the exploitation of the demersal stocks sustained the annual production around 2.2 million mt during 1989-1995 and increased it to 2.42 million mt in 1996.

Small pelagics production in relation to pelagics and total production

During 1985-96, the production of small pelagics increased from 0.80 million mt in 1985 to 1.24 million mt in 1996. However, the relative growth of the small pelagics production drastically declined from 30.7% during 1986- 90 (compared to 1985) to 11.4% during 1991- 95 and to 8.3% in 1996 (Table 7).

Table 7. Landings of pelagics in India during 1985 to 1996 (mt).

Name of fish	1985	Avg(86-90)	Avg(91-95)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	17650	14347	16007	13992
Oil sardine	120575	169800	95957	110346
Other sardines	59427	78554	93725	103732
Hilsa shad	9051	7862	25132	25648
Other shads	11824	11626	13507	6477
Anchovies	13	325	209	0
Coilia	26021	26632	33694	32093
Setipinna	1547	2290	2167	2316
Stolephorus	54367	69158	72224	60010
Thrissina	0	131	4	146
Thryssa	27710	27686	36790	36753
Other clupeids	34280	43270	50853	60670
II. Bombayduck	112453	96918	110771	85766
III. Halfbeaks and fullbeaks	1977	2251	2736	3360
IV. Flyingfishes	1235	4167	3273	965
V. Ribbonfishes	84341	77122	98808	126994
VI. Carangids				
Horse mackerel	3447	14497	20108	17652
Scads	7861	46768	86387	66790
Leather jackets	8665	4215	4965	5179
Other carangids	34523	56981	51825	56239
VII. Pomfrets				
Black pomfret	10166	13200	14213	12375
Silver pomfret	22660	24816	25253	22857
Chinese pomfret	99	326	595	515
VIII. Mackerels				
Indian mackerel	61230	147414	174896	274118
Other mackerels	0	89	26	17
IX. Seerfishes	33699	33874	41134	36633
X. Tunnies				
E. affinis	16582	21163	17107	14778
Auxis spp.	3076	6662	6352	11119
Others	6434	3477	3724	2834
XI. Barracudas	3116	7126	11700	13548
XII. Mullets	5088	5658	5737	5272
XIII. Unicorn cod	734	641	835	297
XIV. Miscellaneous	18353	23771	41851	32963

Table 7 cont'd

Name of fish	1985	Avg(86-90)	Avg(91-95)	1996
B. Large pelagics				
I. Sharks	33093	30243	40919	34075
II. Tunnies				
K. pelamis	85	318	182	458
T. tonggol	1086	728	3806	4058
III. Billfishes	877	892	1225	3514
IV. Miscellaneous	1652	1034	1822	2254
Small pelagics (t)	798204	1042816	1162565	1242454
Large pelagics (t)	36793	33215	47955	44359
Pelagics (t)	834997	1076031	1210520	1286813
Others (t)	687520	817048	1048355	1101426
Total (t)	1522517	1893080	2258875	2388239
% of pelagics in total	54.84	56.84	53.59	53.88
% of small pelagics in total	52.43	55.09	51.47	52.02
% of small pelagics in pelagics	95.59	96.91	96.04	96.55
Relative growth				
Small pelagics (%)		30.65	11.48	8.29
Large pelagics (%)		-9.72	44.38	-15.61
Pelagics (%)		28.87	12.50	7.25
Others (%)		18.84	28.31	4.01
Total (%)		24.34	19.32	5.73

The contribution of the small pelagics to the total production ranged from 51% to 55%; and to the pelagics production from 95.6% to 96.9% during 1985-96. The larger pelagics (highsea tunas, billfishes and sharks) formed only 3.1% to 4.4% of the pelagics landings.

Small pelagics production in the 4 geographical regions

During 1991-95, the northwest, southwest, southeast and northeast coasts contributed 28.3%, 40.4%, 24.8% and 6.6% to the small pelagics landings, respectively (Table 8). In other words, the west coast contributed 68.7% of the small pelagics landings. Most of the small pelagics fishery groups are dominant in one coastal region or another. For instance, the oil sardine (99.4%), lesser sardines (91.0%), whitebaits (98.7%) and Indian mackerel (87.7%) were dominant in the southwest and southeast coasts; the horse mackerel (90.6%) in the southwest and northwest coasts; the scads (89.2%) in the southwest coast; the Bombayduck (86.3%) and Coilia (83.7%) in the northwest coast; the flyingfishes in the southeast coast (90.2%); and the unicorn cod (99.7%) in the northwest coast (Table 8).

Table 8. Annual average (1991-95) landings (in tonnes) of pelagics in the 4 geographical regions of India and their percentage contribution.

Name of fish	Average 1991 - 1995 (in MT)					Contribution from different regions (%)			
	NE	SE	SW	NW	Total	NE	SE	SW	NW
A. Small pelagics									
I. Clupeids									
Wolf herrings	2002	4213	1836	7956	16007	12.51	26.32	11.47	49.70
Oil sardine	52	38536	56849	520	95956	0.05	40.16	59.24	0.54
Other sardines	1906	48362	36911	6547	93725	2.03	51.60	39.38	6.99
Hilsa shad	23181	782	183	986	25132	92.24	3.11	0.73	3.92
Other shads	136	9329	297	3746	13508	1.01	69.07	2.20	27.73
Anchovies	0	9	34	166	208	0.00	4.22	16.31	79.46
Coilia	3930	1538	126	28100	33694	11.66	4.56	0.37	83.40
Setipinna	1844	317	6	0	2167	85.12	14.62	0.26	0.00
Stolephorus	942	19524	51726	33	72224	1.30	27.03	71.62	0.05
Thrissina	0	2	1	0	3	6.25	62.50	31.25	0.00
Thryssa	1672	11083	12635	11399	36790	4.55	30.13	34.34	30.98
Other clupeids	3817	18227	19395	9414	50854	7.51	35.84	38.14	18.51
II. Bombayduck	14104	1095	3	95568	110771	12.73	0.99	0.00	86.28
III Halfbeaks and Fullbeaks	7	1216	1407	108	2737	0.24	44.42	51.40	3.94
IV. Flyingfishes	1	2953	297	22	3273	0.04	90.23	9.07	0.66
V. Ribbonfishes	4824	17313	12793	63878	97444	4.95	17.77	13.13	65.55
VI. Carangids									
Horse mackerel	789	1089	9692	8538	20108	3.92	5.42	48.20	42.46
Scads	109	4911	77068	4299	86388	0.13	5.69	89.21	4.98
Leather jackets	429	1850	1083	1603	4964	8.64	37.26	21.81	32.29
Other carangids	982	19492	24392	6959	51825	1.89	37.61	47.07	13.43
VII. Pomfrets									
Black pomfret	2135	2578	3913	5586	14212	15.02	18.14	27.54	39.30
Silver pomfret	5835	4110	1313	13995	25253	23.11	16.27	5.20	55.42
Chinese pomfret	102	18	374	101	595	17.08	3.03	62.95	16.95
VIII. Mackerels									
Indian mackerel	749	39524	113847	20775	174896	0.43	22.60	65.09	11.88
Other mackerels	5	6	13	3	27	17.91	23.88	47.01	11.19
IX. Seerfishes	3291	10503	9600	17740	41134	8.00	25.53	23.34	43.13
X. Tunnies									
E. affinis	121	3281	10629	3076	17107	0.71	19.18	62.13	17.98
Auxis spp.	3	451	5279	619	6352	0.05	7.11	83.10	9.75
Others	20	358	869	2477	3725	0.55	9.62	23.33	66.50
XI. Barracudas	39	5608	4502	1550	11699	0.34	47.93	38.48	13.25
XII. Mullets	830	1971	392	2544	5737	14.46	34.36	6.83	44.35
XIII. Unicorn cod	0	1	1	833	836	0.00	0.12	0.14	99.74
XIV. Miscellaneous	2623	18790	11432	9006	41851	6.27	44.90	27.32	21.52
B. Large pelagics									
I. Sharks	2825	9633	3891	24570	40919	6.90	23.54	9.51	60.05
II. Tunnies									
K. pelamis	0	148	23	11	1546	0.00	9.60	1.47	0.72
T. tonggol	0	243	463	3100	3806	0.01	6.37	12.17	81.45
III. Billfishes	18	391	209	607	1225	1.50	31.88	17.07	49.54
IV. Miscellaneous	102	805	117	798	1822	5.60	44.18	6.41	43.81
Small pelagics (mt)	76481	289041	468897	319670	1161201	6.59	24.89	40.38	27.53
Large pelagics (mt)	2945	11220	4703	29086	49319	5.97	22.75	9.54	58.98
Pelagics (mt)	79426	300261	473600	348757	1210520	6.56	24.80	39.12	28.81
Others (mt)	44138	240154	316966	455572	1048355	4.21	22.91	30.23	43.46
Total (mt)	123564	540415	790566	804329	2258875	5.47	23.92	35.00	35.61

Small pelagics production from different fishing sectors

The small pelagics are exploited by the nonmotorized traditional, motorized traditional and mechanized sectors. The annual total effort of all the three sectors decreased from 13.8 million boatdays in 1985 to 12.0 million boatdays during 1991-95 and to 11.7 million boatdays in 1996 (Table 9). As the small pelagics production increased during this period by 66%, the CPUE increased from 58 kg/boatday in 1985 to 96 kg/boatday during 1991-95 and 106 kg during 1996. Though the relative growth of small pelagics production declined from 30.7% during 1986-90 to 11.4% in 1991-95 and to 7.0% in 1996, the relative growth in the CPUE declined only marginally from 32.8% to 24.5% between 1986-90 and 1991-95, but significantly to 10.9% from 1991-95 to 1996. The CPUE of total fish production also registered a 69% increase during this period (Table 9).

Table 9. All sector landings of pelagics in India during 1985-96.

	1985	1986-90 (Avg)	1991-95 (Avg)	1996
Absolute values (mt)				
Small pelagics (mt)	798204	1042816	1162565	1242454
Large pelagics (mt)	36793	33215	47955	44359
Pelagics (mt)	834997	1076031	1210520	1286813
Others (mt)	687520	817048	1048355	1101426
Total (mt)	1522517	1893080	2258875	2388239
Effort in boatdays	13816050	13588487	12158065	11733576
Percentage				
Pelagics in total(%)	54.84	56.84	53.59	53.88
Small pelagics in total(%)	52.43	55.09	51.47	52.02
Small pelagics in total pelagics(%)	95.59	96.91	96.04	96.55
CPUE (kg)				
Small pelagics	58	77	96	106
Large pelagics	3	2	4	4
Total pelagics	60	79	100	110
Others	50	60	86	94
Total	110	139	186	204
Relative growth (%)				
Small pelagics		30.65	11.48	6.87
Large pelagics		-9.72	44.38	-7.50
Pelagics		28.87	12.50	6.30
Others		18.84	28.31	5.06
Total		24.34	19.32	5.73
Effort		-1.65	-10.53	-3.49
CPUE				
Small pelagics		32.83	24.60	10.74
Large pelagics		-8.21	61.36	-4.15
Total pelagics		31.02	25.73	10.15
Others		20.83	43.41	8.86
Total		26.42	33.36	9.55

Table 10. Non-mortorized sector landings of pelagics in India during 1985-1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	8506	5643	3302	1797
Oil sardine	18119	24616	26070	32894
Other sardines	48683	48562	28707	33668
Hilsa shad	653	1052	1160	739
Other shads	6066	5644	5254	1649
Anchovies	0	0	9	0
Coilia	6068	6383	9169	8364
Setipinna	460	868	415	198
Stolephorus	17737	29850	21764	14823
Thrissina	0	118	1	62
Thryssa	10246	7611	8263	6983
Other clupeids	20119	14116	11383	11185
II. Bombayduck	18551	19454	19584	16039
III. Halfbeaks and fullbeaks	1395	1377	1141	1642
IV. Flyingfishes	1234	4046	2716	49
V. Ribbonfishes	34444	17729	13354	7868
VI. Carangids				
Horse mackerel	936	1961	1768	3124
Scads	3574	5660	3922	5912
Leather jackets	4273	1534	948	648
Other carangids	15800	12983	11746	6466
VII. Pomfrets				
Black pomfret	2631	1766	1293	728
Silver pomfret	3673	4529	3630	1817
Chinese pomfret	10	30	31	65
VIII. Mackerels				
Indian mackerel	21380	29883	31502	13929
Other mackerels	0	42	3	0
IX. Seerfishes	10952	9014	6053	3895
X. Tunnies				
E. affinis	3421	3629	2352	2217
Auxis spp.	549	728	385	212
Others	435	157	57	65
XI. Barracudas	1653	2459	1230	1340
XII. Mullets	4609	5173	4776	4181
XIII. Unicorn cod	3	38	3	0
XIV. Miscellaneous	13114	11564	9714	6453
B. Large pelagics				
I. Sharks	12597	7833	5369	5035
II. Tunnies				
K. pelamis	0	15	71	0
T. tonggol	0	14	47	241
III. Billfishes	485	220	109	222
IV. Miscellaneous	645	351	306	194
Small pelagics (mt)	279294	278218	231705	189012
Large pelagics (mt)	13727	8433	5903	5692
Pelagics (mt)	293021	286651	237608	194705
Others (mt)	96144	93035	88152	85275
Total (mt)	389165	379686	325759	279980
Effort in boatdays	10216950	8905205	6425388	4678579

(i) Small pelagics production from the nonmotorized sector: Of the three sectors exploiting the small pelagics, the effort and catches of the nonmotorized sector alone declined during 1985-96. The effort declined from 10.2 million boatdays to 4.7 million boatdays and the small pelagics landings from 0.28 million mt to 0.19 million mt (Table 10).

The relative growth in the effort and catches also declined during this period. However, the CPUE of the small pelagics from the nonmotorized sector increased from 27 kg/boatday to 40 kg/boatday (Table 11). Following the reduction in effort and catches, the contribution of the nonmotorized sector to the production of small pelagics declined significantly from 48.8% to 15.2%. It is clear that the nonmotorised sector is giving way to the motorized and mechanized sectors in the production of small pelagics, and to the total fish production as well.

Table 11. Non-mortized sector landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	279294	278218	231705	189012
Large pelagics (mt)	13727	8433	5903	5692
Pelagics (mt)	293021	286651	237608	194705
Others (mt)	96144	93035	88152	85275
Total (mt)	389165	379686	325759	279980
Effort in boatdays	10216950	8905205	6425388	4678579
Percentage				
Pelagics in total(%)	75.29	75.50	72.94	69.54
Small pelagics in total(%)	71.77	73.28	71.13	67.51
Small pelagics in total pelagics(%)	95.32	97.06	97.52	97.08
CPUE (kg)				
Small pelagics	27	31	36	40
Large pelagics	1	1	1	1
Total pelagics	29	32	37	42
Others	9	10	14	18
Total	38	43	51	60
Relative growth (%)				
Small pelagics		-0.39	-16.72	-18.43
Large pelagics		-38.56	-30.00	-3.57
Pelagics		-2.17	-17.11	-18.06
Others		-3.23	-5.25	-3.26
Total		-2.44	-14.20	-14.05
Effort		-12.84	-27.85	-27.19
CPUE				
Small pelagics		14.29	15.42	12.03
Large pelagics		-29.51	-2.99	32.43
Total pelagics		12.24	14.88	12.54
Others		11.02	31.32	32.86
Total		11.94	18.91	18.04

(ii) *Small pelagics production from the motorized sector*: Fishing effort by the traditional craft fitted with outboard motor increased substantially from 0.71 million boatdays in 1985 to 3.72 million boatdays in 1996. As a result, the small pelagics landings by this sector increased from 0.12 million mt to 0.36 million mt and its contribution to the small pelagics landings increased from 11.5.% to 29.3% from 1985 to 1996. However, the CPUE, which increased from 163 kg/boatday in 1985 to 199 kg/boatday during 1986-90, declined sharply to 98 kg/boatday in 1996. The decline in the relative growth of the CPUE was quite pronounced, mainly due to the low CPUE realized from the motorized gillnet fleet in the southeast coast, where this fleet expanded only in the 1990s. On the contrary, the motorized ringseine fleet operations in the southwest coast realized very high CPUE (Tables 12 & 13).

Table 12. Motorized sector landings of pelagics in India during 1985 to 1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	193	1023	3845	3441
Oil sardine	61861	95880	44337	57482
Other sardines	1120	9368	29311	26226
Hilsa shad	5	151	538	643
Other shads	0	229	4397	1737
Anchovies	0	0	0	0
Coilia	0	0	266	39
Setipinna	0	0	8	4
Stolephorus	26167	18768	26038	20724
Thrissina	0	0	1	105
Thryssa	352	2109	4908	7554
Other clupeids	1277	7324	15977	22967
II. Bombayduck	0	2	1305	280
III. Halfbeaks and fullbeaks	155	476	484	822
IV. Flyingfishes	0	16	43	899
V. Ribbonfishes	2307	2834	3630	10568
VI. Carangids				
Horse mackerel	79	3448	5635	3587
Scads	1022	17206	39251	14985
Leather jackets	162	387	1140	1303
Other carangids	3399	12817	7957	13344
VII. Pomfrets				
Black pomfret	367	1496	2261	2337
Silver pomfret	136	713	3149	3337
Chinese pomfret	4	43	126	10
VIII. Mackerels				
Indian mackerel	6213	44565	69574	134051
Other mackerels	0	4	0	1
IX. Seerfishes	4671	5662	17442	11834
X. Tunnies				
E. affinis	2753	9030	9343	7941
Auxis spp.	1644	3808	4428	10192
Others	426	1351	2782	2154
XI. Barracudas	206	541	1334	1706
XII. Mullets	88	134	313	317
XIII. Unicorn cod	0	0	42	0
XIV. Miscellaneous	563	1498	2894	3601

Table 12. Cont'd.

	Name of fish		1985	1986- 90 (Average)	1991-95 (Average)	1996
B.	Large pelagics					
	I. Sharks		1725	2340	9103	4152
	II. Tunnies					
		K. pelamis	44	202	39	394
		T. tonggol	341	139	2735	2501
	III. Billfishes		13	118	709	1339
	IV. Miscellaneous		10	48	253	84
	Small pelagics (mt)		115170	240884	302759	364191
	Large pelagics (mt)		2133	2846	12838	8470
	Pelagics (mt)		117303	243730	315597	372661
	Others (mt)		10325	35255	56609	71163
	Total (mt)		127628	278985	372207	443824
	Effort in boatdays		708165	1208091	2348112	3715571

Table 13. Motorized sector landings of pelagics and others in India during 1985 - 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	115170	240884	302759	364191
Large pelagics (mt)	2133	2846	12838	8470
Pelagics (mt)	117303	243730	315597	372661
Others (mt)	10325	35255	56609	71163
Total (mt)	127628	278985	372207	443824
Effort in boatdays	708165	1208091	2348112	3715571
Percentage				
Pelagics in total(%)	91.91	87.36	84.79	83.97
Small pelagics in total(%)	90.24	86.34	81.34	82.06
Small pelagics in total pelagics(%)	98.18	98.83	95.93	97.73
CPUE (kg)				
Small pelagics	163	199	129	98
Large pelagics	3	2	5	2
Total pelagics	166	202	134	100
Others	15	29	24	19
Total	180	231	159	119
Relative growth (%)				
Small pelagics		109.16	25.69	20.29
Large pelagics		33.40	351.09	-34.03
Pelagics		107.78	29.49	18.08
Others		241.47	60.57	25.71
Total		118.59	33.41	19.24
Effort		70.59	94.37	58.24
CPUE				
Small pelagics		22.60	-35.33	-23.98
Large pelagics		-21.80	132.08	-58.31
Total pelagics		21.80	-33.38	-25.38
Others		100.16	-17.39	-20.56
Total		28.14	-31.36	-24.64

Table 14. Mechanized sector landings of pelagics in India during 1985 to 96 (in mt.)

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	8951	7681	8860	8501
Oil sardine	40595	49304	25550	19968
Other sardines	9624	20624	35707	43838
Hilsa shad	8393	6659	23434	24204
Other shads	5758	5753	3856	3060
Anchovies	13	325	200	0
Coilia	19953	20249	24259	23680
Setipinna	1087	1422	1744	2120
Stolephorus	10463	20540	24422	24457
Thrissina	0	13	2	41
Thryssa	17112	17966	23619	22111
Other clupeids	12884	21830	23493	25259
II. Bombayduck	93902	77462	89882	69427
III. Halfbeaks and fullbeaks	427	398	1111	868
IV. Flyingfishes	1	105	514	17
V. Ribbonfishes	47590	56559	81824	108536
VI. Carangids				
Horse mackerel	2432	9088	12705	10732
Scads	3265	23902	43214	45893
Leather jackets	4230	2294	2877	3351
Other carangids	14824	31181	32122	36133
VII. Pomfrets				
Black pomfret	7168	9938	10659	9231
Silver pomfret	18851	19574	18474	16716
Chinese pomfret	85	253	438	429
VIII. Mackerels				
Indian mackerel	33637	72966	73820	125317
Other mackerels	0	43	23	16
IX. Seerfishes	18076	19198	17639	18383
X. Tunnies				
E. affinis	10408	8504	5412	4205
Auxis spp.	883	2126	1539	595
Others	5573	1969	885	604
XI. Barracudas	1257	4126	9136	10496
XII. Mullets	391	351	648	774
XIII. Unicorn cod	731	603	790	297
XIV. Miscellaneous	21119	10709	19750	37262
B. Large pelagics				
I. Sharks	18771	20070	26446	24207
II. Tunnies				
K. pelamis	41	101	73	64
T. tonggol	745	575	1024	1277
III. Billfishes	379	554	407	1729
IV. Miscellaneous	1056	635	1046	1542
Small pelagics (mt)	419683	523714	618609	696521
Large pelagics (mt)	20992	21935	28996	28819
Pelagics (mt)	440675	545650	647605	725340
Others (mt)	565049	688758	913304	928413
Total (mt)	1005724	1234408	1560909	1653753
Effort in boatdays	2890935	3475191	3384564	3339426

Table 15. Mechanized sector landings of pelagics and others in India during 1985 - 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	419683	523714	618609	696521
Large pelagics (mt)	20992	21935	28996	28819
Pelagics (mt)	440675	545650	647605	725340
Others (mt)	565049	688758	913304	928413
Total (mt)	1005724	1234408	1560909	1653753
Effort in boatdays	2890935	3475191	3384564	3339426
Percentage				
Pelagics in total(%)	43.82	44.20	41.49	43.86
Small pelagics in total(%)	41.73	42.43	39.63	42.12
Small pelagics in total pelagics(%)	95.24	95.98	95.52	96.03
CPUE (kg)				
Small pelagics	145	151	183	209
Large pelagics	7	6	9	9
Total pelagics	152	157	191	217
Others	195	198	270	278
Total	348	355	461	495
Relative growth (%)				
Small pelagics		24.79	18.12	12.59
Large pelagics		4.49	32.19	-0.61
Pelagics		23.82	18.69	12.00
Others		21.89	32.60	1.65
Total		22.74	26.45	5.95
Effort		20.21	-2.61	-1.33
CPUE				
Small pelagics		3.81	21.28	14.12
Large pelagics		-13.08	35.73	0.73
Total pelagics		3.00	21.86	13.52
Others		1.40	36.15	3.03
Total		2.10	29.84	7.38

(iii) *Small pelagics production from the mechanized sector*: Fishing effort by the mechanized craft increased from 2.9 million boatdays in 1985 to 3.3 million boatdays in 1996, resulting in the increase in the landings of the small pelagics by 66% and the CPUE from 145 kg/boatday to 209 kg/boatday. The contribution of the mechanized sector to the small pelagics production increased from 52.6% to 56.1%. However, the relative growth in production, which was 24.8% during 1986-90 gradually declined to 12.6% in 1996 (Tables 14 & 15).

Gearwise production of small pelagics

There is a wide array of gears employed in the small pelagic fisheries. The major gears include the purseseine and trawl operated from the mechanized vessels, ringseine operated from the motorized craft and gillnets operated from the nonmotorized, motorized and mechanized craft. The purseseines are operated along the southwest coast, where the small pelagics contribute more than 91% to their landings. Purseseine effort almost doubled from 56 000 boatdays in 1985 to 101 000 boatdays in 1996, but the small pelagics landings by the purseseiners declined from the maximum of 0.17 million mt per year during 1986-90 to 0.15 million mt in 1996 and the CPUE from 2038 kg/boatday during 1986-90 to 1454 kg/boatday in 1996 (Tables 16 & 17).

Table 16. Purseseine landings of pelagics in India during 1985 to 1996 (in mt).

Name of fish	1985	1986-90 (Av.)	1991-95 (Av.)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	23	13	23	27
Oil sardine	40074	46404	12812	7162
Other sardines	5097	9136	16779	11340
Hilsa shad	3	60	88	8
Other shads	8	19	39	0
Anchovies	0	12	1	0
Coilia	5	1	94	0
Setipinna	0	0	6	0
Stolephorus	5427	10693	7813	2461
Thrissina	0	0	0	0
Thryssa	817	2844	3785	415
Other clupeids	794	2550	2025	1500
II. Bombayduck	0	0	0	2
III. Halfbeaks and fullbeaks	71	123	120	164
IV. Flyingfishes	0	0	0	0
V. Ribbonfishes	358	957	2184	13
VI. Carangids				
Horse mackerel	631	5333	6110	3987
Scads	1457	11673	17466	9058
Leather jackets	94	378	680	458
Other carangids	7285	11540	6347	4194
VII. Pomfrets				
Black pomfret	1303	1603	3615	2685
Silver pomfret	65	114	55	49
Chinese pomfret	0	10	8	0
VIII. Mackerels				
Indian mackerel	32140	66042	59415	100586
Other mackerels	0	0	0	0
IX. Seerfishes	148	344	289	1502
X. Tunnies				
E. affinis	2043	2669	2282	387
Auxis spp.	585	1081	1191	2
Others	81	74	20	14
XI. Barracudas	12	21	36	228
XII. Mullets	30	7	3	0
XIII. Unicorn cod	0	0	0	0
XIV. Miscellaneous	249	238	169	133
B. Large pelagics				
I. Sharks	83	102	40	0
II. Tunnies				
K. pelamis	0	26	0	0
T. tonggol	624	367	230	0
III. Billfishes	1	0	0	24
IV. Miscellaneous	2	1	0	0
Small pelagics (mt)	98800	173939	143455	146375
Large pelagics (mt)	710	496	270	24
Pelagics (mt)	99510	174435	143725	146400
Others (mt)	3588	8763	7342	2726
Total (mt)	103098	183198	151067	149126
Effort in boatdays	56121	85336	85765	100655

Table 17. Purseseine landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	98800	173939	143455	146375
Large pelagics (mt)	710	496	270	24
Pelagics (mt)	99510	174435	143725	146400
Others (mt)	3588	8763	7342	2726
Total (mt)	103098	183198	151067	149126
Effort in boatdays	56121	85336	85765	100655
Percentage				
Pelagics in total(%)	96.52	95.22	95.14	98.17
Small pelagics in total(%)	95.83	94.95	94.96	98.16
Small pelagics in total pelagics(%)	99.29	99.72	99.81	99.98
CPUE (kg)				
Small pelagics	1760	2038	1673	1454
Large pelagics	13	6	3	0
Total pelagics	1773	2044	1676	1454
Others	64	103	86	27
Total	1837	2147	1761	1482
Relative growth (%)				
Small pelagics		76.05	-17.53	2.04
Large pelagics		-30.16	-45.46	-91.11
Pelagics		75.29	-17.61	1.86
Others		144.22	-16.22	-62.86
Total		77.69	-17.54	-1.28
Effort		52.06	0.50	17.36
CPUE				
Small pelagics		15.78	-17.94	-13.06
Large pelagics		-54.07	-45.73	-92.43
Total pelagics		15.28	-18.02	-13.21
Others		60.61	-16.64	-68.36
Total		16.86	-17.95	-15.89

The ringseines, which are operated along the Kerala coast, increased their effort from 0.17 million boatdays in 1985 to 0.24 million boatdays in 1996. The small pelagics which contribute about 90% to the landings of the ringseines, increased from 0.13 million mt during 1986-90 to 0.18 million mt during 1991-95,but decreased to 0.16 million mt in 1996. The ringseine CPUE for the small pelagics and the total catch also declined, particularly in 1996, mainly due to the drastic reduction in the oil sardine catch (Tables 18 & 19).

The operation of gillnets decreased from the annual average of 1.1 million boatdays during 1986-90 to 0.9 million boatdays in 1996 while the production of small pelagics increased from 0.73 million mt in 1985 to the annual average of 0.9 million mt during 1991- 95 and declined to 0.84 million mt in 1996. The average CPUE ranged from 80 kg/boatday during 1986- 90 to 89 kg/boatday in 1996 (Tables 20 & 21).

Table 18. Ringseine landings of pelagics in India during 1986 to 1996 (in mt).

Name of fish	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics			
I. Clupeids			
Wolf herrings	9	25	0
Oil sardine	62320	38033	21977
Other sardines	5971	18652	3363
Hilsa shad	38	11	0
Other shads	15	103	0
Anchovies	0	0	0
Coilia	0	0	3
Setipinna	0	0	0
Stolephorus	8778	20650	18048
Thrissina	0	0	0
Thryssa	531	2629	3939
Other clupeids	3218	8593	14868
II. Bombayduck	0	0	0
III. Halfbeaks and fullbeaks	222	125	108
IV. Flyingfishes	0	0	0
V. Ribbonfishes	31	88	20
VI. Carangids			
Horse mackerel	2469	620	309
Scads	8109	36885	9929
Leather jackets	131	77	37
Other carangids	3170	2195	2253
VII. Pomfrets			
Black pomfret	113	613	1321
Silver pomfret	108	90	750
Chinese pomfret	0	73	0
VIII. Mackerels			
Indian mackerel	28725	48731	86091
Other mackerels	0	0	0
IX. Seerfishes	92	122	8
X. Tunnies			
E. affinis	2960	600	11
Auxis spp.	481	1107	1
Others	0	11	2
XI. Barracudas	161	108	9
XII. Mullets	50	92	9
XIII. Unicorn cod	0	0	0
XIV. Miscellaneous	450	632	446
B. Large pelagics			
I. Sharks	17	68	14
II. Tunnies			
K. pelamis	90	4	0
T. tonggol	0	0	0
III. Billfishes	0	8	7
IV. Miscellaneous	0	0	0
Small pelagics (mt)	128154	180868	163502
Large pelagics (mt)	108	80	21
Pelagics (mt)	128262	180948	163523
Others (mt)	9562	13319	20359
Total (mt)	137825	194267	183882
Effort in boatdays	167564	251973	240277

Table 19. Ringseine landings of pelagics and others in India during 1985 to 1996.

	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)			
Small pelagics (mt)	128154	180868	163502
Large pelagics (mt)	108	80	21
Pelagics (mt)	128262	180948	163523
Others (mt)	9562	13319	20359
Total (mt)	137825	194267	183882
Effort in boatdays	167564	251973	240277
Percentage			
Pelagics in total(%)	93.06	93.14	88.93
Small pelagics in total(%)	92.98	93.10	88.92
Small pelagics in total pelagics(%)	99.92	99.96	99.99
CPUE (kg)			
Small pelagics	765	718	680
Large pelagics	1	0	0
Total pelagics	765	718	681
Others	57	53	85
Total	823	771	765
Relative growth (%)			
Small pelagics		41.13	-9.60
Large pelagics		-25.89	-73.64
Pelagics		41.08	-9.63
Others		39.29	52.85
Total		40.95	-5.35
Effort		50.37	-4.64
CPUE			
Small pelagics		-6.15	-5.20
Large pelagics		-50.71	-72.36
Total pelagics		-6.18	-5.23
Others		-7.37	60.29
Total		-6.27	-0.74

The operation of gillnets decreased from the annual average of 1.1 million boatdays during 1986-90 to 0.9 million boatdays in 1996 while the production of small pelagics increased from 0.73 million mt in 1985 to the annual average of 0.9 million mt during 1991- 95 and declined to 0.84 million mt in 1996. The average CPUE ranged from 80 kg/boatday during 1986- 90 to 89 kg/boatday in 1996 (Tables 20 & 21).

Though the trawls are operated as bottom trawls, they land substantial quantities of small pelagics, which increased from 90 455 mt in 1985 to 356 698 mt in 1996 and the CPUE substantially from 63 kg/boatday in 1995 to 192 kg/boatday in 1996. The increase during 1991-96 was due to the substantial increase in the ribbonfishes and *Coilia dussumieri* along the northwest coast. The contribution of the small pelagics to the total trawl landings increased from 16.2% in 1985 to 29.1% in 1996 (Tables 22 & 23).

Table 20. Gillnet landings of pelagics in India during 1985 to 1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	4363	4620	3287	2669
Oil sardine	177	279	2110	464
Other sardines	2302	7765	8306	11758
Hilsa shad	2632	6046	22410	24089
Other shads	5024	3849	2348	1956
Anchovies	0	9	1	0
Coilia	29	100	93	17
Setipinna	2	30	21	81
Stolephorus	0	31	427	1018
Thrissina	0	0	0	0
Thryssa	320	356	1322	1066
Other clupeids	2646	6084	4861	3183
II. Bombayduck	95	132	721	868
III. Halfbeaks and fullbeaks	166	209	235	491
IV. Flyingfishes	1	10	142	7
V. Ribbonfishes	2684	4364	2915	1606
VI. Carangids				
Horse mackerel	1148	1697	1358	1154
Scads	19	35	56	63
Leather jackets	2846	1312	1123	1090
Other carangids	1050	1611	2291	2465
VII. Pomfrets				
Black pomfret	5001	6940	3902	2568
Silver pomfret	12327	12826	10158	6758
Chinese pomfret	68	118	110	209
VIII. Mackerels				
Indian mackerel	836	1376	5053	4610
Other mackerels	0	36	6	0
IX. Seerfishes	14889	14000	10428	9740
X. Tunnies				
E. affinis	7468	4624	2443	2986
Auxis spp.	297	917	296	554
Others	5328	1694	613	319
XI. Barracudas	305	571	579	658
XII. Mullets	14	91	314	101
XIII. Unicorn cod	0	0	0	2
XIV. Miscellaneous	790	1631	2420	1509
B. Large pelagics				
I. Sharks	11848	8762	5863	7067
II. Tunnies				
K. pelamis	28	70	52	61
T. tonggol	78	177	708	1234
III. Billfishes	336	529	312	1467
IV. Miscellaneous	135	190	191	180
Small pelagics (mt)	72827	83365	90349	84059
Large pelagics (mt)	12425	9729	7126	10009
Pelagics (mt)	85251	93094	97475	94068
Others (mt)	22640	22189	20443	21490
Total (mt)	107891	115283	117919	115558
Effort in boatdays	774835	1044456	910058	946643

Table 21. Gillnet landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Avg)	1991-95 (Avg)	1996
Absolute values (t)				
Small pelagics (t)	72827	83365	90349	84059
Large pelagics (t)	12425	9729	7126	10009
Pelagics (t)	85251	93094	97475	94068
Others (t)	22640	22189	20443	21490
Total (t)	107891	115283	117919	115558
Effort in boatdays	774835	1044456	910058	946643
Percentage				
Pelagics in total(%)	79.02	80.75	82.66	81.40
Small pelagics in total(%)	67.50	72.31	76.62	72.74
Small pelagics in total pelagics(%)	85.43	89.55	92.69	89.36
CPUE (kg)				
Small pelagics	94	80	99	89
Large pelagics	16	9	8	11
Total pelagics	110	89	107	99
Others	29	21	22	23
Total	139	110	130	122
Relative growth (%)				
Small pelagics		14.47	8.38	-6.96
Large pelagics		-21.69	-26.75	40.45
Pelagics		9.20	4.71	-3.50
Others		-1.99	-7.87	5.12
Total		6.85	2.29	-2.00
Effort		34.80	-12.87	4.02
CPUE				
Small pelagics		-15.08	24.38	-10.56
Large pelagics		-41.91	-15.94	35.02
Total pelagics		-18.99	20.17	-7.23
Others		-27.29	5.74	1.06
Total		-20.73	17.39	-5.79

Table 22. Trawl landings of pelagics in India during 1985-1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	2799	2516	4893	5180
Oil sardine	277	2405	10088	7442
Other sardines	2177	3421	10016	19769
Hilsa shad	115	107	347	102
Other shads	547	1617	1350	1099
Anchovies	0	169	196	0
Coilia	4930	8449	9530	12129
Setipinna	804	1024	1015	1469
Stolephorus	4957	9552	16110	20879
Thrissina	0	11	2	0
Thryssa	15681	14125	17280	19499
Other clupeids	7647	11820	15392	19343
II. Bombayduck	1160	4033	6402	12666
III. Halfbeaks and fullbeaks	0	64	742	110
IV. Flyingfishes	0	2	355	10
V. Ribbonfishes	28284	43425	68051	100158

Table 22 Cont'd.

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
VI. Carangids				
Horse mackerel	635	1918	4979	5415
Scads	1789	11917	25691	36699
Leather jackets	1117	515	967	1679
Other carangids	5626	17020	22832	28872
VII. Pomfrets				
Black pomfret	673	1035	2859	3870
Silver pomfret	1971	3685	5608	7943
Chinese pomfret	17	124	313	182
VIII. Mackerels				
Indian mackerel	622	5290	9082	19990
Other mackerels	0	6	17	16
IX. Seerfishes	2222	2966	6030	6694
X. Tunnies				
E. affinis	874	343	594	655
Auxis spp.	0	15	38	31
Others	150	173	230	268
XI. Barracudas	937	3436	8235	9439
XII. Mullets	255	168	295	666
XIII. Unicorn cod	0	41	3	0
XIV. Miscellaneous	4189	6762	14145	14424
B. Large pelagics				
I. Sharks	5967	7044	11892	12294
II. Tunnies				
K. pelamis	13	4	11	1
T. tonggol	43	1	81	36
III. Billfishes	41	20	59	182
IV. Miscellaneous	294	316	683	527
Small pelagics (mt)	90455	158154	263690	356698
Large pelagics (mt)	6358	7385	12725	13040
Pelagics (mt)	96814	165538	276415	369738
Others (mt)	459757	582419	817729	856292
Total (mt)	556571	747957	1094145	1226030
Effort in boatdays	1444604	1818617	1980276	1853567

Groupwise production of small pelagics

The gearwise production of individual fisheries (specieswise or groupwise) has undergone considerable changes during 1985-96. For example, the purseseine landing of the Indian mackerel was only 32 140 mt in 1985, but increased by 3 times to 100 586 mt in 1996 (Table 16). On the contrary, the purseseine landings of the oil sardine drastically reduced from 40 074 mt in 1985 to 7 162 mt in 1996. The Indian mackerel, which formed 31% of the purseseine landings in 1985, increased to 67% in 1996 while the oil sardine, which formed 39% of the purseseine landings in 1985, decreased to a mere 5% in 1996. The other important fisheries in the purseseine sector include the lesser sardines, carangids and whitebaits (Table 16).

The ringseine landings of the Indian mackerel increased substantially from 28 725 mt in 1985 to 86 091 mt in 1996 while the landings of the oil sardine declined from 62 320 mt to 21 977 mt (Table 18). The other important constituents of the ringseine landings include the whitebaits and carangids (Table 18). The gillnet landings of the hilsa shad increased considerably from 2 632 mt in 1985 to 24 089 mt in 1996 (Table 20), mainly due to the heavy landings in the northeast coast, where a special type of gillnet promoted by the Bay of Bengal Programme is being operated in the current decade of the 1990s. The landings of the lesser sardines and the Indian mackerel also increased, especially along the Tamilnadu coast (Table 20).

Table 23. Trawl landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Avg)	1991-95 (Avg)	1996
Absolute values (mt)				
Small pelagics (mt)	90455	158154	263690	356698
Large pelagics (mt)	6358	7385	12725	13040
Pelagics (mt)	96814	165538	276415	369738
Others (mt)	459757	582419	817729	856292
Total (mt)	556571	747957	1094145	1226030
Effort in boatdays	1444604	1818617	1980276	1853567
Percentage				
Pelagics in total(%)	17.39	22.13	25.26	30.16
Small pelagics in total(%)	16.25	21.14	24.10	29.09
Small pelagics in total pelagics(%)	93.43	95.54	95.40	96.47
CPUE (kg)				
Small pelagics	62.62	86.96	133	192.44
Large pelagics	4.40	4.06	6	7.04
Total pelagics	67.02	91.02	140	199.47
Others	318.26	320.25	413	461.97
Total	385.28	411.28	553	661.44
Relative growth (%)				
Small pelagics		74.84	66.73	34.41
Large pelagics		16.14	72.32	1.13
Pelagics		70.99	66.98	32.86
Others		26.68	40.40	3.76
Total		34.39	46.28	11.10
Effort		25.89	8.89	-6.46
CPUE				
Small pelagics		38.88	53.12	43.69
Large pelagics		-7.75	58.25	8.11
Total pelagics		35.82	53.35	42.04
Others		0.63	28.94	10.93
Total		6.75	34.34	18.77

The bottom trawls exploit the small pelagics also as many of them undertake diurnal vertical migration. The trawl landings of ribbonfish increased from 28 284 mt to 100 158 mt, the carangids from 9 167 mt to 72 665 mt, the whitebaits from 4 957 mt to 20 879 mt, the lesser sardines from 2 177 mt to 19 769 mt, and the Indian mackerel from 622 mt to 19 990 mt from 1985 to 1996 (Table 22).

Regionwise production of small pelagics

On the basis of the general physical and topographical features of the sea and the sea bottom, and the distribution pattern of various fish stocks and their fisheries, the Indian coast could be broadly divided into the west coast and the east coast. The continental shelf of the northwest coast comprising the maritime states of Gujarat and Maharashtra is very wide with extensive fishing grounds where the sea bottom is generally muddy. The continental shelf of the southwest coast covering the states of Goa, Karnataka, Kerala and the west coast portion of Tamilnadu is rather narrow, and hence, the fishing grounds are less extensive. The sea bottom in the inshore fishing grounds of the southwest shelf is muddy. Some of the most productive grounds which support rich fisheries for stocks like the Indian mackerel, oil sardine, whitebaits and shrimps are located in the inner shelf of the southwest coast. The southeast coast comprising Tamilnadu, Pondicherry and Andhrapradesh is characterized by coral and rocky grounds interspersed with even grounds in the Gulf of Mannar and muddy bottom in the other regions. The sea bottom of the northeast coast (Orissa and West Bengal) which is mainly muddy in the depth range of 25 m to 100 m, is quite suitable for bottom trawling; the continental shelf between 100 m and 140 m depths and some regions beyond, are generally of uneven bottom.

It could be seen from Table 8 that during 1991-95 the west coast accounted for 70.6% of the total small pelagics landings and the east coast 29.4%.

(i) Northeast coast: The northeast coast produced only 5.5% of the total small pelagics during 1991-95 (Table 8). The average annual landing of the small pelagics was 58 519 mt during 1985-'96 which formed 57.2% of the total landings. The total landings of this region including the landings of the large pelagics and the small pelagics reached the maximum in 1993, but declined subsequently (Figs 5 & 6).

(ii) Southeast coast: In the southeast coast, the average annual small pelagics landings during 1985-96 reached 259 138 mt, forming 53.6% of the total landings. The total landings, total pelagics and small pelagics gradually increased and reached the highest of 618 539 mt, 358 964 mt and 349 590 mt, respectively in 1996 (Figs 7 & 8). The fleet of motorized catamarans keeps expanding in the southeast coast since the early 1990s, resulting in almost a continuous increase in the landings of the small pelagics.

(iii) Southwest coast: The production of total fish, pelagics and small pelagics was the maximum in the southwest coast compared to the other regions, except in 1996. During 1985-96 the average annual total landings reached 762 704 mt, the pelagics 475 495 mt and the small pelagics 469 897 mt (Figs 9 & 10). The southwest coast contributed 44.3% to the total small pelagics landings in the country. The production of small pelagics, which was maximum in 1989 (0.7 million mt), gradually declined to 0.47 million mt in 1996. Obviously, the benefits of the adoption of the ringseines operating from the motorized traditional craft in the 1980s seem to have culminated in the 1990s.

(iv) Northwest coast: Unlike in the southwest coast, the total fish landings in the northwest coast increased consistently during 1985-96 (Fig. 11). The landings of the small pelagics (304 792 mt), which formed only 42.7% of the total landings in the northwest coast compared to 61.6% in the southwest coast, did not decrease during 1985-96. After the increase in the small pelagics landings in 1989, the production stabilized around 350 000 mt in the subsequent years (Fig. 12). Though the ringseines do not exist and the extent of motorization of the traditional craft is comparatively less in the northwest coast than in the southwest coast, intensive fishing operations by multiday trawlers beyond the 50 m isobath and the traditional dolnet fishing land very high catches of ribbonfishes and the grenadier anchovy *Coilia dussumieri* along the northwest coast, as observed during 1985-96. On account of these reasons, the total landings in the northwest coast (0.85 million mt) could surpass that in the southwest coast (0.79 million mt) in 1996.

Estimates of total stock and MSY of small pelagics

Assessment of stocks is essential for deciding the guidelines for the rational exploitation and management of fisheries. The status of the exploited stocks and their levels of exploitation for a number of small pelagics stocks in the Indian seas have been determined on the basis of the data on effort and catch, biological parameters and primary production pertaining to different time periods, and the results are being used as the basis for the management of the small pelagics fisheries (Table 24).

For estimating the MSY and the optimum effort, the Schaefer (1954) model was fitted for the time series data on catch and standardized effort. For standardizing the fishing effort, the catch per boatday realized by the purseseiners and the ringseiners, which are the major craft-gear systems employed in the fisheries for the small pelagics along the southwest coast, was used. On this basis, a weighted average CPUE was calculated and was used to standardize the fishing effort on the all-India level. The standard units, converted to different operating units, have been used for determining the optimum fleet size of the mechanized sector. The MSY and the optimum fleet thus calculated revealed that the number of trawlers presently under operation (30 200) has exceeded the optimum number (10 638) (Table 25). Similarly, the number of purseseiners (980) has also exceeded the optimum fleet (736). However, there is scope for increasing the fleet of gillnetters and bagnetters in the northeast, southeast and northwest coasts (Table 25).

Table 24. Assessment of stocks of small pelagics in different regions of the Indian seas by various researchers.

Species	Area	Period	Annual stock (mt)	Standing crop (mt)	MSY (mt)	Yield * (mt)	Exploita-tion level	1996 catch (mt)	Reference
S. longiceps	SW	1958-67	440,000	210,000	212,304	174,356	Under	110,346	Banerji, 1973
- do-	SW	1965-76	484,000	-	290,000	198,440	Under	(all India)	Sekharan, 1976
- do-	SW	1974	810,000	390,000	-	210,000	Under		ANON, 1976
- do-	SW	1972-77	400,000	-	-	136,000	Under		George *et al.*, 1997
- do-	SW	1972-76	-	-	195,000	134,000	Under		
-do-	West	1984-88	-	-	150,000	117,000	Optimum		Annigeri *et al.*,1992
Lesser sardines	Andaman	1976	20,000	-	-	-	-	-	George *et al.*, 1997
- do-	NE	- do-	30,000	-	-	-	-	-	
- do-	SE	- do-	140,000	-	-	-	-	-	- do-
- do-	SW	- do-	80,000	-	-	-	-	-	- do-
- do-	NW	- do-	10,000	-	-	-	-	-	- do-
- do-	All India	- do-	280,000	-	-	-	Under	103,732	- do-
S.gibbosa	Goa- Karnataka	1984-88	-	-	4,600	4,100	Under	(all India)	Sam Bannet *et al.*,
- do-	Tamil Nadu	- do-	-	-	20,600	20,000	Optimum		1992
- do-	Andhra Pradesh	- do-	-	-	5,000	5,000	Optimum	Lesser	- do-
								sardine)	

Table 24 Cont'd

Species	Area	Period	Annual stock (mt)	Standing crop (mt)	MSY (mt)	Yield * (mt)	Exploitation level	1996 catch (mt)	Reference
Stolephorus devisi	East coast	1984-88	-	-	12,300	11,400	Under		Luther *et al.*, 1992
-do-	West	-do-	-	-	25,200	19,100	Under		-do-
S. bataviensis	East	1984-88	-	-	9,900	9,400	Under		Luther *et al.*, 1992
-do-	West	-do-	-	-	14,100	14,100	Optimum		-do
R. kanagurta	Southwest	1958-67	-	-	90,600	58,781	Under	-	Banerji, 1973
-do-	-do-	1960-71	130,000	-	87,000	65,000	Under	-	Sekharan, 1976
-do-	-do-	1972-76	-	-	105,000	68,000	Under	-	George *et al.*, 1997
-do-	-do-	1972-73	-	450,000	-	94,000	Under	-	ANON, 1974
-do-	East	1984-88	-	-	25,300	23,700	Optimum	275,677	Noble *et al.*, 1992
-do-	West	-do-	-	-	50,700	49,800	Optimum	(all India)	-do-
-do-	Southwest	1934-73	-	-	70,788	62,198	Optimum		Devaraj *et al.*, 1994
T. lepturus	East	1984-88	-	-	20,400	-	Over	126,994	Thiagarajan *et al.*,
-do-	West	-do-	-	-	65,600	23,733	Under	(all India)	1972
M.cordyla	All India	1985-89	-	-	14,161	6,627	Under	17,652	Reuben *et al.*, 1992

Table 24 Cont'd

Species	Area	Period	Annual stock (mt)	Standing crop (mt)	MSY (mt)	Yield * (mt)	Exploitation level	1996 catch (mt)	Reference
D. russelli	All India	1985-89	-	-	28,707	19,055	Under	66,790 (all scads)	Reuben *et al.*, 1992
C. carangus	Tamil Nadu	1985-89	-	-	2,600	2,314	Under	-	-do-
S. leptolepis	Tamil Nadu	1985-89	-	-	6,583	5,726	Under	-	-do-
A. atropus	Tamil Nadu	1985-89	-	-	953	977	Over	-	-do-
A. kalla	Kerala	1985-89	-	-	15,700	14,264	Optimum	-	-do-
A. djeddaba	Kerala	1985-89	-	-	11,420	4,297	Under	-	-do-
A. mate	Kerala	1985-89	-	-	4,305	3364	Under	-	-do-
H. nehereus	Northwest	1982-86	76,893	-	54,631	52,213	Over	85,766	Kurian & Kurup, 1992
-do-	-do-	1975-86	-	-	55,000	57,000	Over		Kurian, 1988
-do-	-do-	1956-83	189,844	-	-	-	Over		Fernandez & Devaraj, 1996a.

* Annual yield during the respective study period

Table 25. Optimum fleet size under the mechanized sector against MSY (mt).

	MTN*	MPS**	MGN***	MBN****
I Northeast				
Total MSY	35668	Nil	48923	18782
Effort MSY (in boatdays)	94914	Nil	213720	28459
Vessels required (number)	509	Nil	1450	192
Vessels in operation	1600	Nil	120	120
II Southeast				
Total MSY	280538	Nil	34883	919
Effort MSY (in boatdays)	669427	Nil	509405	1276
Vessels required (number)	3599	Nil	3471	9
Vessels in operation	8300	Nil	650	175
III Southwest				
Total MSY	354626	111718	2348	Nil
Effort MSY (in boatdays)	801705	70547	18325	Nil
Vessels required (number)	4283	607	124	Nil
Vessels in-operation	9500	850	1100	190
IV Northwest				
Total MSY	437644	40816	28641	2111
Effort MSY (in boatdays)	419463	15106	165618	22171
Vessels required (number)	2247	129	1110	147
Vessels in operation	10800	130	1250	1110
V All India				
Total MSY	1108476	152534	114795	21812
Effort MSY (in boatdays)	1985509	85653	907068	51906
Vessels required (number)	10638	736	6155	348
Vessels in operation	30200	980	3400	1495

* @180 Fishing days per year (Trawler)
** @120 fishing days per year (Purseseiner)
*** @150 fishing days per year (Gillnetter)
**** @150 fishing days per year (Bagnetter

MAJOR SMALL PELAGIC STOCKS

The pelagics occupy an important position in India's marine fisheries. They constituted about 54% of the total landings during 1996. Among the pelagics, the small pelagics were predominant, contributing about 96% to the total landings of the pelagics. Among the small pelagics, the Indian mackerel and the carangids were the most predominant, contributing 7.74% and 7.22% respectively to the overall marine fish landings during 1991-95. Among the other small pelagics, the anchovies formed 6.41%, followed by the Bombayduck (4.9%), ribbonfishes (4.31%), oil sardine (4.25%), lesser sardines (4.15%), other clupeids (2.25%), hilsa shad (1.11%) and barracudas (0.52%) in the overall marine fish landings during this period (Table 8). The distribution, production, biology and trade aspects of the major small pelagics are summarized below.

Oil sardine

Distribution: In the world average annual production of around 280 000 mt of Indian oil sardine *(Sardinella longiceps)* during 1988-92, the Indian contribution of 190 000 mt formed 67.7%. The oil sardine are a major inshore small pelagic, distributed in narrow belts extending to a distance of 3 km to 20 km from the coast. Their geographic distribution extends widely from Seychelles through Somalia, Africa, Pakistan, India and Indonesia to the Philippines. Along the Indian peninsula, there is greater concentration of the oil sardine stock in the Malabar upwelling zone along the southwest coast between 8°N and 16°N latitudes, although in recent years a new fishery for this species has emerged along the east coast as well.

Means of exploitation: Till the close of the 1970s, various artisanal fishing craft operating gears like the shoreseines, boatseines, castnets, *rampanies* (huge shoreseines) and small meshed gillnets used to be engaged in the oil sardine fishery along the southwest coast. With the advent of purseseining in the late 1970s, first in Goa and then in Karnataka and to a limited scale in Kerala, the traditional fishing systems began to lose their importance in the fisheries for the small pelagics in these states. The situation got further aggravated in the 1980s with the popularization of the ringseines in Kerala and *Mattabala* (a variant of the ringseine) in Karnataka, coupled with the steady growth of motorized fleets of traditional fishing craft in these states. The purseseines and the ringseines have almost replaced the *rampanies* (yendi) in Karnataka and the boatseines in Kerala.

Fishing season : The oil sardine fishery commences along the southwest coast soon after the outbreak of the southwest monsoon (June) and continues till March-April. Usually the fishery starts first in the south (9°N latitude, i.e., Quilon) and progresses to the north (17°N latitude, i.e., Ratnagiri), probably in sequence with the early upwelling in the southern area. The above cycle of events is repeated every year. The beginning of the fishery is marked by the entry of large sized fish in the advanced stages of maturity followed by the 0 yearclass. The commercial fishery is supported by the 0 and 1 yearclass fish. The success of the oil sardine fishery along the southwest coast depends mainly on the recruitment strength of the early juveniles of the size 5 cm to 10 cm during the postmonsoon months. The juveniles begin to appear in the fishery from late August and form the mainstay of the fishery in the southern region, whereas in the northern region they begin to appear from late September onwards. The oil sardine always move in shoals, the size of the individual shoals being generally 2 m to 25m long and 1 m to 20m wide. The oil sardine shoals move at a speed of about 5km per hour and are known to descend to subsurface depths during daytime.

All India production: The Indian oil sardine production in the recent 10-year period (1986-95) reveals two phases : one of increasing trend in the first 5-year period (1986-90) followed by a decreasing trend in the second 5-year period (1991-95). From 78 000 mt in 1986, the production rose to 279 000 mt in 1989 and 261 000 mt in 1990, but subsequently suffered a steep fall to 47 000 mt in 1994 (Fig. 13). The oil sardine catch of 110 000 mt in 1996 shows an improvement by 15% over the average annual landings of 96 000 mt of 1991-95. The average annual catch in the southwest coast in the second half (1991-95) was only 57 000 mt compared to 150 000 mt during the first 5-year period (1986-90). However, a redeeming feature with the fishery was the phenomenal improvement in its landings in the southeast coast (Tamilnadu) in recent years where it did not form a conspicuous fishery in the earlier years. The average annual landings in the southeast coast increased from 15 000 mt during 1986-90 (42% of all India catch) to 39 000 mt during 1991-95, which is very significant, both biologically and commercially. The emergence of the oil sardine fishery along the southeast coast warrants further investigations to establish the causative factors responsible for its geographic expansion. The fishery has also newly emerged along the northeast coast (Orissa and West Bengal) during the last 5 years, from a position of almost no landings during 1986-90 to 52 mt during 1991-95. However, the qualitative change that has occurred in the southeast and northeast region is very important and warrants investigations as to the causes, on the following aspects.

(i) The landings of the oil sardine have increased in the southeast coast *viz-a-vis* the decline in the southwest coast during the same period. The possibility of migration between these two regions needs to be examined through tagging experiments. (ii) If the shift in the fishery is due to migration, the causes for the migration would require to be elucidated. (iii) A major development along the southeast coast since 1990 is the emergence of large number of shrimp farms along the coastal areas. About 120 000 ha of coastal area has been converted into shrimp farms (mainly along the east coast), which discharge huge quantities of organically very rich wastewater into the sea, inducing planktonic bloom which the oil sardine are able to utilize effectively. Congregation of marine fishes in the areas of wastewater discharge is well known.

Regionwise production: The oil sardine formed 4.25% of the overall marine fish production in the country during 1991-95 against 9.0% during 1986-90. During 1991-95 the share of the oil sardine in the overall marine fish production in the northeast region was only 0.04% in the annual average of 124 000 mt, in the southeast region it was 7.1% in the annual average of 540 000 mt, in the southwest region it formed 7.2% in the annual average of 791 000 mt, and in the northwest region it formed only 0.06% in the annual average of 804 000 mt. The share of the different regions in the overall all-India production of oil sardine varied from 0.05% for the northeast region to 59.24% for the southwest region, the southeast and the northwest regions forming 40.16% and 0.54% respectively. A major share of the landings of the oil sardine in the southeast region was contributed by the nonmechanized traditional gears which, at the current (average for 1991-95) level, was about of 25 000 mt, forming 52.6 % of the total oil sardine catch in this region.

Gearwise production: The major gears that exploit the oil sardine stock are the purseseines and the ringseines operated from the motorized (outboard) traditional craft in the southwest region and gillnets in the southeast region. During 1991-95, the purseseine fleet in the southwest region contributed an annual average of 13% to the overall production of oil sardine in the country, while the same fleet contributed 0.3% from the southern part of the northwest region (Ratnagiri area) to the national oil sardine catch, heralding the beginning of commercial purseseining in the Ratnagiri area of the northwest region. During 1986-90, the boatseines, purseseines and ringseines from the southwest coast contributed 77% to the overall landings of the oil sardine, while during 1991-95, these gears contributed only 54% to the oil sardine landings. The purseseine fleet contribution reduced from 27.23% to 13.06%, while the ringseine fleet contribution improved marginally from 36.74% during 1986-90 to 39.65% during 1991-95 along the southwest coast. During 1991-95, the traditional gears operated by the nonmotorised craft landed an annual average of 25 000 mt forming 63.8% of the oil sardine catch of the southeast coast.

Factors influencing fluctuations: The oil sardine fishery is known for its highly erratic and fluctuating behaviour. Hornell (1910) attributed the fluctuations to the changes in the production of diatoms, food availability to the fry and the prevalence or absence of favourable hydrological conditions. There is also a view that the fluctuations are related to the shifts in the migratory path of the fish, causing variations in the vulnerability of the stocks to fishing, owing to the limited range of the traditional fishing operations. Devanesan (1943) attributed the low catches to the overfishing of the immature fish, while Nair (1952) and Nair and Subrahmanian (1955) attributed the changes to the availability and abundance of the diatom *Fragilaria oceanica* in the inshore waters. Murty and Edelman (1970) stated that the intensity of the monsoon along the west coast of India above a critical value would be favourable for the enrichment of the sea not only with nutrients, but also with dissolved oxygen. Sam Bennet (1973) expressed the view that the total number of fish in the population would not exceed the limits determined by the food resources and the rate of reproduction; if the numerical strength of a particular generation was large enough to utilize almost completely the food resources, the successive generations would become progressively weak in numbers, till the most dominant generation got reduced in its strength.

As observed by Sekharan and Dhulkhed (1963), the success of a given year's fishery was found to be determined by the abundance of the 0-yearclass. However, this was not always true. For example, the 1-year old fish dominated the catch of 124 000 mt in 1958-59. Although generally the 1-year old fish were next in abundance to the 0-yearclass, the 2-year old fish were more abundant than the 1-year old in some years, for instance, in 1955-56, 1956-57 and 1964-65. Such dominance of the older groups over the younger ones could be attributed to the changes in the availability and poor recruitment into the fishery. Since rainfall during the spawning season has been found to determine spawning success, rainfall data could be used to differentiate changes in recruitment from changes in availability.

For spawning to be a success, the average rainfall per day during the peak spawning season (mostly June to August) should be 30 mm. Spawning takes place around the new moon, and its success depends on whether optimum rainfall prevails a week before and after the new moon day. In the 1963 and 1965 spawning seasons, the average daily rainfall was much below the optimum: 13 mm and 18.3 mm respectively, which led to large scale preovulation follicular breakdown, called atresia. As a result, the 1963 catch declined to a mere 64 000 mt from the previous year's 110 000 mt, when the rainfall was 31.6 mm/day (Antony Raja, 1967). However, the 1965 catch (262 000 mt) did not slump as it was constituted mainly by 1 year old fish (150-160 mm size group) (Sam Bennet, 1968; Antony Raja, 1972) resulting from the 1964 spawning when the rainfall was 29.2 mm/day. If the 1964 spawning success restored the 1965 fishery, the same should hold for the 1964-65 situation, but it did not. Therefore, a number of factors in interaction with each other seems to determine the success of the fishery. The important factors include rainfall, availability and accessibility to the gear in operation, migratory pattern, survival of the eggs and larvae, and the intensity of upwelling.

Food and feeding habits: The adult oil sardine feed mainly on the diatoms, dinoflagellates, tintinnids and zooplankton. Among the diatoms, *Fragilaria oceanica, Pluerosigma, Coscinodiscus* and *Biddulphia,* and among the bluegreen algae *Trichodesmium thiebautii* are frequently met with in the diet The dinophyceae consist of *Procentrum, Ceratium* and *Perdinium.* Among the zooplankton, *Acrocalanus, Paracalanus, Oithona, Harpacticoids, Lucifer* and larval polychaetes are common. The juveniles are carnivorous while the postlarvae feed mainly on the diatoms. *F. oceanica* seems to be a good indicator of the abundance of the oil sardine stock in the coastal waters. During actual spawning, there seems to be cessation in feeding activity.

Age & growth and age composition: Divergent findings made by various authors about the age, growth rate and life span of the oil sardine reveal two distinctly different sets of results (Table 26) . The differences between the two sets are very sharp in the first year of age, but progressively narrow down at the 2 and 3 years of age. At the age of 4 years, the results agree each other very closely. A reanalysis of the length frequency data from Sekharan and Dhulkhed (1963) by means of the scatter diagram method of length frequency analysis (Devaraj, 1983b) confirms the second category results (1 year= 146 mm, 2 year=171 mm, 3 year=186 mm and 4 year = 194 mm) to be the correct estimate of length at age in years, which also implies growth to be very rapid in the first year, but very slow subsequently.

Considering the bagnet (*mathikollivala*) in Kerala as the standard gear, the age composition of the oil sardine catch was computed for the southwest coast. The average number of fish caught in one unit of *mathikollivala* per year for the 12-year period 1954-55 to 1965-66 was 24 983 comprising 77%, 17%, 5% and 1% of 0,1, 2 and 3 year old fish respectively. During this period, the 0-year group dominated in all the years except in 1958-59, it was comparatively poor in 1955-56 and 1963-64 (4 000 fish/unit), fairly good in 1956-57 and 1958-59 (8 000 /unit), improved further in 1954-55, 1957-58, 1959-60, 1962-63 and 1965-66 (20 000/unit), still better in 1960-61 and 1961-62 (30 000/unit), and most abundant in 1964-65 (45 000/unit).

Table 26. The length-at-age in respect of the oil sardine determined by various authors.

	Author	Age in years and total length in mm				Remarks
		1	2	3	4	
1.	Hornell & Nayudu, 1924	150 170	-	-	-	SL given by the authors has been converted to TL.
2.	Chidambaram, 1950	100	145	183	205	The authors supposed that even fish of 150 mm
3.	Nair, 1952	100	150	190	210	length were immature on
4.	Sekharan, 1965	100	-	-	-	the basis of
5.	Balan, 1968	143	164	186		growth rings on
6.	Bensam, 1968	145-175	175	-	-	scales.
7.	Sekharan & Dhulkhed, 1963	100	150	-	-	
8.	Sam Bennet, 1968	100	150	175	190	
9.	Antony Raja, 1970	150-160	170-180	-	-	
10.	Prabhu & Dhulkhed, 1970	100-110	150-160	175-180	-	
11.	Banerji, 1973	146	171	186	194	On the basis of von Betalanffy growth eq. applied to length at-age data.
12.	Devaraj, MS	146	171	186	-	By reanalysing the data in Sekharan & Dhulkhed (1963) by means of a scatter diagram of modal lengths against time in months.

(1) to (12) results fall in 2 sets shown below:

Age in years	1	2	3	4
Set (1)	100-110	145-160	175-183	190-210
Set (2)	143-160	164-180	186	194
Banerji's estimates within category (2)	146	171	186	194

Size at maturity, fecundity, spawning and broods per yearclass: The oil sardine attain sexual maturity at the age of one year at a length of 150 mm. The active spawners in the oozing condition measure 150 to 170 mm. The sexes are separate. In spent and recovering fish, the males could be distinguished by an externally visible muscular papilla in the cloaca while the females could be identified by the presence of a membranous papilla behind the anal opening. The sex ratio appears to vary. Some investigators found the females to be predominant upto the size at first maturity, but a reduction in sexwise segregation among the ripe fish, and equal representation of sex among the juveniles and spawners. A recent study by Annigeri *et al.* (1992) indicated the dominance of the females in all the observation centres along the east and west coasts during 1984-88. The relative fecundity varies from 70 000 to 80 000 ova in the 1 to 2 year old fish (the left ovary produces on an average 40 000 eggs and the right ovary 38 000 eggs), but on an average a female produces 48 000 eggs per batch. Fecundity is directly proportional to the weight of the ovary, which in turn is generally related to the size of the fish.

Gravid and spent fish and juveniles occur in the nearshore waters off Kerala and Karnataka during June to August. Spawning has been observed at a distance of about 15 km from the shore along the 30 m isobath in the surface and column from Quilon to Karwar. Isolated cases of spawning in the nearshore areas have been observed off Kasargod and off Cochin during July. Spawning usually takes place at night, a few days before and after the new moon days. According to Antony Raja (1973), a daily rainfall of 20 to 30 mm during June to August may indicate good recruitment. Seasons of feeble or severe rainfall coincide with extensive atresia in the ovaries that may lead to a reduction in the spawning potential of the population, and consequent recruitment failures (Antony Raja, 1973)

Although the spawning season is generally held to extend from June to October, there is reason to believe that spawning may commence in January and last till October, but the main spawning seems to last for only 3 to 6 months or exceptionally it may be over in just one month. The commencement and the duration of spawning seem to vary from year to year, as evident from the time of origin of the broods, traced from the analysis of the 1957-63 length frequency data for Mangalore. The spawning season as traced back from this analysis for the 1957-62 period is given in Table 27.

Table 27. The spawning season of the oil sardine as traced from the 1957-63 length frequency data for Mangalore.

Year	Spawning season	Duration in months	No. of broods
1957	Mid March to mid June	4	1
1958	June	1	1
1959	Mid January to mid June	6	1
1960	January to March	3	1
1961	Mid May to August	4	1
1962	March to July	5	1

Thus, within the total duration of spawning, whether it is one month or up to 6 months, spawning intensity is found to be more or less uniform without a definite break or peak. As a result of uniform spawning, only one brood is released during each spawning season. The longer the duration of spawning, the wider is the distribution of the modal lengths for the younger size groups of a given brood in the scatter diagram of modal analysis. As the brood grows to complete about one year of age, the scatter values tend to become narrower in distribution. Such a change in the nature of the distribution of the scatter values seems to result from two reasons: (1) faster growth of that section of the brood that is still in the 0-yearclass; (2) abrupt fall in the growth rate of fish of the same brood, which have attained 1-year of age.

Contrary to this finding of the existence of only a single brood per yearclass, earlier studies seem to suggest each yearclass to be comprising more than one brood. Sekharan (1965) recognized two broods per yearclass in the length frequency data for Calicut. On the basis of the monthly length frequency curves for several years from commercial samples collected from 5 centres along the west coast, Banerji (1973) recognized two broods per yearclass corresponding to the two spawnings, one in June to July and the other in July to August. Antony Raja (1967) observed the spawning season off Calicut to be June to October within which he surmised two major spawnings, one in late June - early July and the other in late July to early August, giving rise to two broods. He further contended that the first brood released in June to July faced less competition for food and space, and hence, grew much faster than the second one. In order to reconcile these differences, the data in Table 28 taken from Antony Raja (1972), were critically examined.

Table 28. Frequency of broods per yearclass of oil sardine based on the length frequency data for Calicut.

Year	Month	Spurts in spawning	Modal length (mm)	Product of spawning in	Age in months
1961	October	1	115	July	3
	November	2	110	August	3
1962	November	1	65	July-August	1-2
1963	September	1	110	July	3
	October	2	95	August	2
	October	3	70	September	1
1964	August	1	115	June	2
	August	2	80	July	1.5
1965	August	1	105	June-July	1-2
	August	2	35	July-August	0.5 -1

The 5th column in Table 28 indicates that within each spawning season, spawning takes place mostly in spurts (1961, 1964 & 1965) at an interval of a month. During some years, there is only a single spurt (1962) and in others three spurts (1963) at an interval of one month. Spawning is centred around the newmoon day and the spurts represent group spawning by the spawning section of the population, not necessarily representing the number of batches of ova spawned per fish. While it is true that the modal lengths representing the products of the spawning spurts are distinctly recognizable in the length frequency data, so long as their distribution pattern in the length frequency data does not produce distinct alignments into separate broods, they cannot be treated as representing distinct broods. Thus, the 2 or more spawning spurts within a given spawning season seem to give rise only to a single brood comprising a yearclass.

Shoaling and migration: Different types of surface and bottom shoals have been described by Balan (1961). The 0-yearclass migrate *en masse* from the offshore to the inshore areas simultaneously all over the sardine centres along the southwest coast towards the end of the southwest monsoon. The new recruits, after reaching the inshore areas, continue to get reinforced uninterruptedly through the entry of fresh recruits, inspite of heavy fishing pressure. With the warming up of the surface waters and the deepening of the thermocline in summer (March to May), the shoals gradually move back to the offshore areas, vacating first from the north and then from the southern centres, every year. Large scale tagging of oil sardine was carried out by the CMFRI from several centres on the east and west coasts of India during 1967-68 and 1968-69 (Prabhu and Venkataraman, 1970). The recoveries were limited. Hence no definite conclusions could be drawn regarding the migration of this fish, but the limited recoveries revealed only local dispersal. A programme of intensive tagging of oil sardine is essential in view of the recent emergence of this species along the east coast in commercial terms.

Stock assessment and management: Banerji (1973) estimated the total annual oil sardine stock in the southwest coast for the 1958-67 period to be 440 000 mt, the average standing crop 210 000 mt , and the MSY 212 304 mt for the optimum effort of 64.065 million manhours as against the average annual yield of 174 356 mt for the effort of 55.195 million manhours. Sekharan (1976) estimated the total annual stock to be 810 000 mt and the standing stock 390 000 mt. Based on acoustic and aereal surveys coupled with test fishing, the UNDP Pelagic Fisheries Project at Cochin estimated the annual standing stocks for the period 1972-77 to be 400 000 mt. Balan and Reghu (1979) also estimated the stock size to be about 400 000 mt. Annigeri *et al.* (1992), however, estimated the MSY to be 150 000 mt against a mean biomass of 107 000 mt, indicating scope for increasing production, but they also stated that increasing the fishing effort to the MSY level was not desirable as it would decrease the returns per boat considerably to uneconomic levels.

The recorded history of the Indian oil sardine fishery dates back to 1896. During the 60 years from 1896 to 1956, the entire catch was a mere 200 000 mt, the average annual catch being about 3 000 mt during these six decades; nearly 100 000 mt or 50% was landed in 1908, 1922 and 1923. However, commencing from 1957, a new phase began in the fishery for the oil sardine. Three distinct trends could be recognised in the post 1957 fishery.

(1) 1957-1963, when the average annual catch was 130 000 mt at an average effort of about 55 million manhours.

(2) 1964-1971, when the annual catch nearly doubled to 255 000 mt at an annual effort of about 65 million manhours.

(3) 1972-1977, when the catch per year was 145 000 mt at an annual effort of 60 million manhours, thus registering a reversal to the 1957- 63 peirod, with no corresponding decline in effort.

The doubling of the catch during the 1964-71 period does not seem to have led to the decline in the biomass during 1972-77; the annual stock has remained virtually the same at 400 000 mt in the 1958-77 periods. The slight decline in the effort during 1972-77 could not have resulted in such a major slump in the catch. Changes in the availability of the stock to the inshore fishery, seem to have set the changing trends in the catch. Only a small part of the stock seems to have been available to the inshore fishery of the 1972-77 period, a major part of the stock having remained in grounds beyond the reach of the traditional inshore gear. Such setbacks to the fishery paved the way for the growth of the purseseine fleet, since 1976. It is, however, very important to limit the growth of the purseseine fleet to prevent stock depletion and diminishing returns. It has been estimated that the oil sardine and mackerel stocks alone could support a fleet of 425 purseseiners including 235 for Kerala, 135 for Karnataka and 55 for Goa. Such a deployment would sustain the 1978 catch per unit effort of 5 mt per boat per day either oil sardine or mackerel, or both at the rate of 120 fishing days per year. Besides causing social concerns, the purseseines may cause considerable damage to the stocks, particularly in the context of an array of ringseine fleets operating in Kerala and Karnataka. The entire biomass of the oil sardine and mackerel is distributed in a total of 61 000 schools (25 000 oil sardine and 36 000 mackerel schools) covering an area of 4 800 sq.km along the southwest coast (Anon., 1976). The average biomass per school of oil sardine is 16 mt and mackerel 12.5 mt. The purseseine catches, on occasions, are as high as 40 mt per day per boat, equivalent to about 2 to 3 times the school size. Such decimating power of the purseseiner provides enough warning for stringent checks on the growth of this fleet, as well as of the ringseiners.

Utilization: Owing to the increasing demand for fresh fish from the local and the interior markets and easy availability of ice and quick transportation facilities, a good amount of oil sardine catch is now consumed in fresh condition. However, during periods of glut, a portion of the catch is cured with salt and sundried. Although sardines have been successfully canned in India since the British days, the canning industry suffered serious problems from time to time owing to several technical and practical difficulties. The oil sardine are rich in oil which is extracted for various industrial uses. After the extraction of the oil, the residue forms the guano which is used as a valuable manure in plantation crops because of the high nitrogen and phosphate content. Sardine fishmeal is in great demand in the livestock and shrimp feed industry.

Lesser sardines

Species:The species of *Sardinella* other than *S. longiceps* (oil sardine) and the rainbow sardines (*Dussumieria acuta* and *D. hasselti*) constitute the lesser sardines, which support lucrative fisheries especially along the southeast and Kerala coasts. Out of the 15 species of *Sardinella* in the Indo-Pacific region, 12 occur in the Indian Ocean. The sardines are typical shoaling fish occurring within the 50 m isobath in the coastal waters. The species that constitute the major lesser sardine fisheries include *Sardinella albella, S. gibbosa, S. fimbriata, S. sirm, S. dayi, S. sindensis, S. melanura, S. clupeoides* and *S. jonesi*.

Distribution: The lesser sardines are tropical, occurring along the coasts of Arabia, Red Sea, Madagascar, India, Sri Lanka, Malaysia, Singapore, Philippines, Australia and China. Along the Indian coast, while a few species are dominant in one region, a few other species are dominant in the other. In the Goa-Karnataka region (Konkan coast) , *S. gibbosa, S.dayi, S.fimbriata* and *S. albella* are quite abundant. In Kerala, *S. gibbosa, S. sindensis* and *S. sirm* dominate the lesser sardines, while the lesser known species such as *S. clupeiodes, S.fimbriata, S. melanura* and *S. jonesi* occur occasionally. *S. albella* and *S. gibbosa* are dominant in the Palk Bay and the Gulf of Mannar while *S. sirm* are limited to the peninsular tip between Vizhinjam and Tuticorin. *S. gibbosa, S. albella, S. dayi, S. sirm, S. clupeoides, S. fimbriata* and *S. gibbosa* are abundant in the central region of the east coast.

Means of exploitation: The traditional nonmotorized and motorized craft as well as the mechanized craft are employed in the lesser sardine fisheries. While the dugout and plankbuilt craft are used in the inshore waters, the purseseiners, gillnetters and trawlers are employed in the grounds extending upto the 42 m to 60 m isobath. The most widely used gears in the southwest coast include the boatseines, ringseines, purseseines and gillnets. The purseseines, which replaced the rampani in Karnataka, enhanced the lesser sardine catch in this state considerably. The trawlers operating in the nearshore grounds upto the 40 m isobath also land sardines in considerable quantities along the Karnataka coast. Small meshed gillnet is the main gear for the lesser sardine fisheries in the southeast coast.

All India production: The lesser sardines constituted 8.4% of the landings of the pelagics during 1986- 90 and 4.2 % during 1991-95. The average annual yield was 78 553 mt during 1986-90 and 93 725 mt during 1991-95 (Table 8), registering an increase of 19% (Fig. 14). During 1986-95 the landings ranged from 68 000 mt in 1986 to 125 000 mt in 1995, but declined slightly to 104 000 mt during 1996.

Regionwise production: During 1991-95, the lesser sardines formed 1.5% of the overall marine fish landings in the northeast region, 9% in the southeast region, 4.7% in the southwest region and 0.8% in the northwest region. The southeast region contributed the maximum of 51.6% (Table 8) to the total lesser sardine production, followed by the southwest region (39.4%), the northwest region (7%) and the northeast region (2%).

Gearwise production: The major gear employed in the fishery is the gillnet (especially along the southeast region), which contributed 9.7% to the total lesser sardine landings in India during 1986-90 and 10.2% during 1991-95 (Tables 20 & 21). The purseseiner fleet accounted for 10.1% and 12.3% of the lesser sardine landings during 1986-90 and 1991-95 respectively, while the ringseiner fleet accounted for 7.6% and 19.9% during 1986-90 and 1991-95 respectively in the southwest coast. Besides the gillnets, a variety of other traditional gears also contribute substantially to the landings of the lesser sardines in the southeast region. Out of the average annual landings of 48 362 mt in the southeast region during 1991-95 the share of the nonmechanized fleet was 24 000 mt (49.8%).

Food and feeding habits: The lesser sardines generally feed on a wide variety of plankton. There is considerable similarity in the food consumed by the different species, and general agreement between the items found in the gut and in the plankton. *S. gibbosa* feed on copepods, *Mysis*, *Lucifer*, prawn and crab larvae, fish eggs and larvae, *Acetes* etc., while *S. albella* feed mainly on copepods, *Lucifer*, *Acetes*, *Mysis*, fish larvae, bivalve larvae etc. Both phytoplankton and copepods form the main food of *S. fimbriata,* while prawn and other crustacean larvae, *Acetes*, molluscan larvae etc. form the major food of *S. dayi*. The minor food items found in the lesser sardine diet include small penaeids, larval bivalves, decapod larvae, *Lucifer* and fish eggs.

In all the species of sardines, the gillrakers increase in number with size. For example, *S. albella* and *S. gibbosa* of 35 mm length possess only 45 and 44 gillrakers respectively, while at 164 mm, they possess 98 and 89 gillrakers respectively. *S. fimbriata* possess 43 and 81 gillrakers respectively, at the above lengths while *S. sirm* and *S. clupeoides* have only 26 and 42 gillrakers respectively at comparable lengths. Only *S. longiceps* possess the largest number of 145 and 258 gillrakers in the juvenile and adult stages respectively. A distinct relation is discernible between the number of gillrakers and the stock size, with species possessing large number of gillrakers developing into high volume stocks, particularly in upwelling areas taking advantage of the immense phytoplankton filtration capabilities. The only exception to this relation is that the oil sardine stock could not establish into a major stock in the Arabian upwelling area as most of the phytoplankton is lost into the mesopelagic realm where they support immense stocks of lantern fishes.

Size at maturity, fecundity and spawning: *S. gibbosa, S. albella, S. fimbriata* and *S. dayi* below 100 mm in total length are either indeterminate or immature with gonads in stage I or II of maturity. Fish measuring above 100 mm in length show varying degrees of sexual maturity. As the spawning season approaches, most of them in the length range of 100 mm to 120 mm attain maturing conditions, while those measuring above 120 mm in length become fully mature. The minimum size of *S. gibbosa* at maturity is 115 mm, but it varied from centre to centre, as in some localities it was found to be 139 mm. *S. fimbriata* attain sexual maturity at a length of 135 mm to 185 mm (Sam Bennet *et al.*, 1992), while *S. dayi* attain first maturity around 140 mm. The relative fecundity of *S. gibbosa* varied from 12 786 to 41 326

The lesser sardines exhibit considerable variations in their spawning seasons depending on the species and regions. Although there is protracted spawning almost throughout year, peaks are evident, but individual fish seems to spawn only once in the case of *S. albella, S. gibbosa* and *S. fimbriata,* twice in the case of *S. longiceps* and thrice in the case of *S. sirm* within the same spawing season. Unlike the oil sardine, the lesser sardines seem to release 3 to 4 broods per year (Table 29).

<u>Population parametres, stock assessment and management</u>**:** The length at age of 1 year is 125 mm to 135mm in the case of *S. albella*, *S. gibbosa* and *S. fimbriata*, 146 mm for *S. longiceps* and 170 mm for *S. sirm*. Based on the values of K, M and t_{max}, the growth of these sardines in relation to their life span is the fastest (K= 1 or more) in the first three species with a shorter life span of 2 years, but slow (K=0.53) in the last two species where the life span is three to four years. The direct relation between K and M is also obvious in these sardines (Table 30). The high values of M for the stocks of *S. albella, S. gibbosa* and *S. fimbriata* are in tune with their fast growth in the first year of life and their role as the main forage (over 90%) of all epipelagic predators such as the seerfishes, dorabs and leather jackets in the Palk Bay and the seerfishes, tunas, billfishes and sharks in the Gulf of Mannar.

Table 29. Spawning frequency & season and broods per yearclass in respect of the lesser sardines in the Indian seas in relation to the oil sardine.

Species	Area	Spawning		No. of broods per yearclass
		Season	Frequency per year	
	Palk Bay	Feb.-Mar. to Jun.-July		
S. albella	Gulf of Mannar	Mar. to June	One	-
	Malabar	Sept. to May with peak in March to May		
	Palk Bay & Gulf of Mannar	Feb.-Mar. to June-July		
S. gibbosa	Lawson's Bay	Feb. to May	One	-
	Malabar	Jan. to May		
S. fimbriata	Tuticorin (Gulf of Mannar)	Oct. to Nov.		
	Vizhinjam	Throughout with peak in May-June, Aug. and Oct.-Nov.	One(2 in Java Sea)	3 to 4
S.sirm	Tuticorin (Gulf of Mannar)	Nov. to Dec. Feb. to March May to June	Three	4
D. hasselti	Southwest coast	Premonsoon & monsoon (March to September	-	-
S. longiceps	Southwest coast	June to Oct.	Two	1

Table 30. Lengths (mm) at age (years) and population parameters of lesser sardines in relation to *S.longiceps* in the Indian seas.

Species	Length (mm) at age (years)					Population parameters				
	1	2	3	4	L_{max}	L_∞	K	l_m	l_m/l_∞	M
S. albella	125	145	-	-	145	152	1.41	103	0.72	3.10
S. gibbosa	135	160	-	-	168	171	1.44	102	0.60	3.20
S. fimbriata	128	185	-	-	185	220	0.98	120	0.66	2.16
S .sirm	170	240	292	-	300	380	0.53	140	0.47	1.16
D. hasselti	130	180	-	-	190	-	-	-	-	-
S. longiceps	146	171	186	194	225	207	0.53	155	0.70	1.17

The bulk of the lesser sardine catch consisted of the 0 yearclass (90 %) particularly before 1965 in the Palk Bay and the Gulf of Mannar because of torch fishing with handnets of 8.5 mm mesh, boatseine with 16.5 mm mesh and shoreseines of 9 mm mesh (used during March to April for the new recruits), 12 mm (mesh used during May to June for the fast growing postrecruits) and 14 mm mesh (during July for the near adults). In locations like the Konkan, North Canara and Vizhinjam coasts, where gillnets (26 mm mesh) are also used, the 0 and 1 yearclasses are present in equal proportions in the catches. In locations like Tuticorin and Malabar where the gillnets constitute the major gear, nearly 95% of the catches are of 1 yearclass and the remaining 5 % are 0 yearclass (Table 31). As torch fishing and boatseining are not practised in the Palk Bay and the Gulf of Mannar after 1965, recruitment overfishing seems to have minimised in these regions.

Table 31. Age composition (%) of lesser sardines in relation to *S.longiceps* in the Indian seas (*Torch fishing in vogue till 1965 in PB & GM was responsible for the predominance of zero year fish).

Species	Area	Age in years				Fishing season
		0	1	2	3	
S. albella	Palk Bay (PB) * & Gulf of Mannar (GM)	95	5	-	-	March to Sept.(PB) Oct. to April (GM)
	Malabar (1950s)	10	90	-	-	Jan. to May
S. gibbosa	Palk Bay (PB) Gulf of Mannar (GM) Lawson's Bay (LB)	95	5	-	-	Mar. to Sept. (PB) Oct. to April (GM) Nov. to April (LB)
S. fimbriata	Konkan (K) North Canara (NC) Vizhinjam (V)	50	50	-	-	Throughout the year with peak in Oct. to Dec. (K & NC) April to June (V)
	Malabar	10	90	-	-	
S. sirm	Tuticorin (Gulf of Mannar)	12	88	0.1	-	Nov. to March
S. longiceps	Quilon to Ratnagiri (southwest coast)	77	17	5	4	June-July to March-April

According to George *et al.* (1977), the total annual stock of the lesser sardines is 280 000 mt comprising 20 000 mt in the Andamans, 30 000 mt in the northeast coast, 140 000 mt in the southeast coast, 80 000 mt in the southwest coast and 10 000 mt in the northwest coast and the MSY is 140 000 mt (50% of the annual stock). However, according to Banerji (1973), the MSY for the 1958-67 period was only 53 000 mt. The average annual catch of 78 553 mt during 1986-90 and 93 725 mt during 1991-95 (Table 8) and the annual catch of 125 000 mt during 1995 match well with the MSY estimate of 140,000 mt made by George *et al.* (1977).

According to the UNDP-PFP, Cochin (Anon., 1974), the lesser sardines formed one of the many items comprising the biomass of the so called 'shallow water mix' together with the golden scad (*Caranx kalla*), silverbellies, glass perch (*Ambassis* spp.), whitefish (*Lactarius lactarius*) etc. along the southwest coast of India during 1972-73. The shallow water mix biomass was 142 000 mt (17% of the total pelagic biomass) during June-July 1972-73 along the 13° to 14° N latitude coast, 125 000 mt during November, 1972 along the 14° to 15° N latitude coast and 109 000 mt in January to February 1973 along the 14° to 15° N latitude coast while in the other months (March/April, April, May/June & July/Aug) it was 25 000 mt to 88 000 mt. With the approach of the southwest monsoon in May-June, the shallow water mix which is usually distributed near the bottom, changes to a more pelagic way of life and comes to the surface, obviously because of the emergence of the low oxygen layer towards the surface. They are not fully recorded by the echosounder, but might be sighted on or near the surface as schools. After the southwest monsoon, they return to their original habitats (subsurface) with the deepening of the thermocline and are well located by the echosounder.

Specific lesser sardine or rainbow sardine type of recordings have proved to be very scarce and erratic, being most frequently mixed with the shallow water mix as well as the whitebaits. The type of recordings recognized as the lesser sardines were often made in the area between 20m and 40m bottom depth. Fishing with pelagic trawls usually gave small catches, mainly of *S. fimbriata* and *D. hasselti* and occasionally *S. albella*. Seasonal southward migration of *S. fimbriata* and *S. albella* is evident from abundance shifting from the tip of the southwest coast (7°N latitude) in June-July to the east of Cape Comorin in the Gulf of Mannar (8°N latitude) in July-August. Similarly, *D. hasselti* move southwards from the Kasargode area (12°N latitude) in January to March through the (9° to 12°N latitude) and in May-June to the east of Cape Comorin (8°N latitude) in the Gulf of Mannar during July-August (Anon., 1974).

Utilization: The lesser sardines are a source of cheap protein for the rural poor in the coastal regions. The steep decline in the catches of the oil sardine in recent years has resulted in the increased demand for the lesser sardines. The sardines are consumed fresh in the coastal regions and transported with ice to the interior markets by road and train. Salted and sundried sardine products are sold in the hinterland states in India and also in countries like Sri Lanka and Hongkong. Smaller sardines are dried and used as important protein mix in the preparation of cattle, poultry, and shrimp feeds.

Table 26. The length-at-age in respect of the oil sardine determined by various authors.

	Author	Age in years and total length in mm				Remarks
		1	2	3	4	
1.	Hornell & Nayudu, 1924	150 170	-	-	-	SL given by the authors has been converted to TL.
2.	Chidambaram, 1950	100	145	183	205	The authors supposed that even fish of 150 mm length were immature on the basis of growth rings on scales.
3.	Nair, 1952	100	150	190	210	
4.	Sekharan, 1965	100	-	-	-	
5.	Balan, 1968	143	164	186		
6.	Bensam, 1968	145-175	175	-	-	
7.	Sekharan & Dhulkhed, 1963	100	150	-	-	
8.	Sam Bennet, 1968	100	150	175	190	
9.	Antony Raja, 1970	150-160	170-180	-	-	
10.	Prabhu & Dhulkhed, 1970	100-110	150-160	175-180	-	
11.	Banerji, 1973	146	171	186	194	On the basis of von Betalanffy growth eq. applied to length at-age data.
12.	Devaraj, MS	146	171	186	-	By reanalysing the data in Sekharan & Dhulkhed (1963) by means of a scatter diagram of modal lengths against time in months.

(1) to (12) results fall in 2 sets shown below:

Age in years	**1**	**2**	**3**	**4**
Set (1)	100-110	145-160	175-183	190-210
Set (2)	143-160	164-180	186	194
Banerji's estimates within category (2)	146	171	186	194

Anchovies

Species: The anchovies including the whitebaits in the Indian seas belong to five genera, viz., *Stolephorus, Coilia, Setipinna, Thryssa* and *Thrissina*. The whitebaits are the dominant component of the anchovy landings in India. The whitebait fishery comprises 10 species. They are *Stolephorus devisi, S. bataviensis, S. heterolobus, S. buccaneeri, S. andhraensis, S. baganensis, S. commersoni, S. indicus, S. insularis* and *S. dubiosus*. In the global marine fish production, the share of the anchovies during 1992 was 11%. The Indian contribution to the world anchovy production, during this period was 2%.

Distribution: The anchovies are widely distributed in the Indo-Pacific region. Considerable knowledge on the fishery potential and the biology of the whitebaits (*Stolephorus*) has been generated by the investigations of the FAO/UNDP Pelagic Fisheries Project (1971-75) along the southwest coast of India extending from Ratnagiri on the west coast (17°N) to Tuticorin (8° 14'N) on the east coast mainly within 50 m depth. Whereas *S. devisi, S.bataviensis, S. heterolobus, S. baganensis* and *S. buccaneeri* form the fishery in the area between Ratnagiri and the Gulf of Mannar, *S. commersoni* and *S. indicus* form the fishery in Palk Bay and further north in the Bay of Bengal. The grenadier anchovy, *Coilia dussumieri* are limited to the northwest coast, and to a limited extent, to the northeast coast.

Means of exploitation: The exploitation of the anvhovies does not pose much problem as they are easily amenable to different kinds of fishing. The major gears employed in the fishery are the boatseines, shoreseines, bagnets and gillnets, operated mainly by the catamarans and plankbuilt boats, most of them fitted with outboard engines. The purseseines, ringseines and bottom trawls also land good quantities of anchovies. In the southeast and the southwest coasts, the most common gears exploiting the whitebaits include the boatseines (codend stretched mesh 10 mm) and the shoreseines (codend stretched mesh 10 to 20 mm). On the southwest coast south of Quilon, gillnets, known as *netholivala* (mesh 15 mm), are specially employed for the whitebaits during the main fishing season. In Kerala these gears are mainly operated from the catamarans and small plankbuilt boats, fitted with outboard motors. In Andhra Pradesh, however, large plankbuilt boats, known as *masula* boats, are employed in operating large shoreseines for the anchovies and other small pelagics. During October-March, when the shoals are distributed all along the coast in shallow waters at 15 m to 30 m depth, they can be effectively fished with high opening midwater trawls (codend mesh size: 15 mm). The purseseines (common stretched mesh at the bunt, 14 to 18 mm) are operating in Karnataka and Kerala from mechanized boats since the seventies and the ringseines (mini purseseines with a mesh of 8 mm) are operating from plankbuilt boats and dugout canoes fitted with outboard motors, since the mid eighties in southern Karnataka and northern Kerala. The operational depth of these gears ranges from 15 m to 50 m. Dispersed whitebait shoals can easily be aggregated by light attraction at night and caught by small purseseines.

All India production: Among the anchovies, the whitebaits are the most important, with current (1991-95) average annual landings of 72 000 mt (Fig. 15; Table 8), forming almost 50% of the overall anchovy production of 145 000 mt. The grenadier anchovy *C.dussumieri* form 23%, *Thryssa* 25.3% and *Setipinna* 1.5% of the current anchovy landings (Table 8). The whitebaits form 60% in the southeast coast and 80% in the southwest coast of the total anchovy production in these regions. The grenadier anchovy dominate the anchovy fishery in the northwest and northeast regions, which contributed an annual average of 28 100 mt (27.4%) and 3 930 mt (5.7%) to the annual landings of anchovies of 39 698 mt and 8 328 mt respectively during 1991-95 in these regions. The national average annual catch of 126 624 mt of anchovies during 1986-90 increased to 145 086 mt during 1991-95, registering a growth of 15%. Currently, anchovies form 12% of the total catch of the pelagics. The anchovy landings have been showing an increasing trend during the last 10 years, as indicated above . This increase is mainly due to a 33% increase in *Thryssa,* 27% increase in *Coilia* and 4% increase in the whitebaits. The annual production of whitebaits varied from 51 000 mt to 100 000 mt during 1986-1995, with a remarkable increase from 51 000 mt in 1987 to 100 000 mt in 1988, but during the remaining period, it fluctuated from 54 000 mt in 1985 to 84 000 mt in 1991. Compared to the average annual landings of about 145 000 mt during 1991-95, the catch of anchovies during 1996 registered a fall of 9% to 131 000 mt. The whitebaits registered a fall of about 12 000 mt from 72 000 mt to 60 000 mt during the corresponding period.

Regionwise production: During 1991-95 the anchovies formed about 10.6% of the total landings of the pelagics in the northeast region, 10.8% in the southeast, 13.6% in the southwest and 11.1% in the northwest regions. About 72% of the landings of whitebaits occurred in the southwest region and 27% in the southeast region. About 83% of the landings of the grenadier anchovy came from the northwest region and 12% from the northeast region (Table 8).

Gearwise production: In Andhra Pradesh, 82% of the whitebait catch was obtained in the shoreseines, followed by the trawls (13%), boatseines (4%) and gillnets (1%). In Tamil Nadu, the gillnets, boatseines and shoreseines combinedly accounted for 83% of the annual whitebait catch, followed by the trawls (17%). In Karnataka, the purseseines contributed the highest (93%), followed by the trawls (6%) and others (1%) to the whitebait catch. In Kerala, on the other hand, the boatseines landed the bulk (65%) of the whitebait catch, followed by the gillnets (11%), trawls (11%), shoreseines (9%), ringseines (motorized units) (3%) and others (1%).

Food and feeding: The whitebaits feed mainly on copepods, small bivalves and crustaceans. *S. devisi* occasionally feed on phytoplankton such as *Coscinodiscus*. The grenadier anchovy feed on *Acetes*, fish larvae, copepods, ostracods and prawn juveniles. *Thryssa* spp. feed on prawns, *Acetes*, polychaetes and fishes (Menon and George, 1975).

Size at maturity, fecundity and spawning: The spawning of the whitebaits occurs for about 10 months a year. However, there are periods of peak spawning for every species. *S. devisi* are a multiple spawner, with spawning extending from November to July with peak intensity during October-February off Mangalore (Table 32). The size at first maturity is around 62 mm (Table 33). The total number of ripe ova in the mature ovaries of *S. devisi* varies from 670 to 3 166 (Rao, 1988a). Along the southwest coast, the peak spawning of *S. bataviensis* takes place during February. The minimum size at first maturity is around 77 mm. The total number of ripe ova in the mature ovaries ranges from 972 to 2 571 (Rao, 1988b). The fecundities of the other whitebaits are: *S. heterolobus*: 1 000 to 2 500; *S. bataviensis*: 5 000 to 10 000; *S. buccaneeri*: 7 000 to 11 000; *S. indicus*: 9 000 to 14 000. The grenadier anchovy spawn once in their life time, with peak spawning during April-June. The size at first maturity is 186 mm (Table 33).

Migration: The whitebaits undertake seasonal migration along the southwest coast and the Gulf of Mannar in 4 distinct phases: (i) In October, when the northeast monsoon sets in, the shoals are discontinuously distributed in a narrow elongated band along the southwest coast from Mangalore to Cape Comorin (Fig. 16). (ii) During November to February, the shoals form a continuous wide belt with a disruption between 11°N and 12°N. (iii) During March-April, the shoals break up and begin their southward migration, which continues till July. (iv) In August, the southward migration culminates, with the bulk of the stock migrating towards north in the east coast and piling up between Cape Comorin and the central Gulf of Mannar in the east coast. The migration of the whitebaits follows the surface currents of the northeast and the southwest monsoons. During the southwest monsoon, the currents flow southwards along the west coast; and north and northeastwards in the Gulf of Mannar; during the northeast monsoon, the current flows in the reverse direction.

Table 32. Spawning frequency & season and broods per yearclass in respect of the anchovies in the Indian seas.

Species	Area	Spawning	
		Season	Frequency per year
S. devisi	Mangalore	Oct. to Feb.	Multiple
	Visakhapatnam	Feb. to Mar.; July	Two
	Madras	Apr. to June	One
	Cochin	Oct. to Nov.; Feb.	Two
	Vizhinjam	Mar.to May; Nov. to Dec.	Two
S. bataviensis	Visakhapatnam	Feb. to Mar.; June to July	Two
	Madras	Apr.; June to Aug.	Two
	Cochin	February	Two
C. dussumieri	Northwest coast	Apr. to June.	One
C. ramcarati	Hooghly estuaries	Dec. to Mar.; Aug.	Two
T. mystax	Calicut	Nov. to Mar.	Multiple

Population parameters, stock assessment and management: Stock assessment indicates that the increase in the production of the whitebaits from the present level will be marginal except in the case of *S. devisi* which is poorly exploited in both the coasts. A three-fold increase in effort along the east coast and six-fold increase in effort along the west coast would be required to realise the coresponding MSYs by increasing the landings by 7.4% and 31.9% respectively. However, in multispecies, multigear fisheries, such projections could be only tentative, as there is no exclusive fishery for the whitebaits alone (Luther *et al.*,1992). While developing the anchovy fisheries further, the following fishing practices could be introduced: (1) high opening midwater trawls for the grounds in the 15 m to 30 m depth during October to March, which is the major fishing season (Table 34); (2) midwater trawls for the stocks that aggregate in the Gulf of Mannar during August to September; and (3) chumming the shoals using light luring devices and catching them with small purseseines.

Table 33. Lengths (mm) at age (years) and population parameters of anchovies in the Indian seas.

Species	Length (mm) at age (years)				Population parameters					
	1	2	3	4	L_{max}	L_∞	K	l_m	l_m/l_∞	M
S. devisi	101	113	-	-	105	113	2.04	62	0.55	2.61
S. bataviensis	101	115	-	-	-	116	2.03	77	0.66	2.61
-do-	85	120	133	-	-	135	1.40	75	0.56	2.25
C. dussumieri	163 to 185	-	-	-	205	265	1.07	186	0.70	2.02 to 2.46
C. ramcarati	83	128	163	188	-	265	0.29	123	0.46	-
T. mystax	120	185	205	-	205	-	-	145	0.70	-

Utilization: Most of the anchovy catch is consumed in the fresh state except in times of glut when the surplus is dried and sent to interior markets. A small fraction of the fresh fish is used as baits in the hooks and line fishery. Improvements in cold storage facilities, introduction of artificial driers and canning in tomato sauce are some of the ways by which better utilization of anchovies could be ensured.

Indian mackerel

Distribution: The Indian mackerel, *Rastrelliger kanagurta,* distributed widely in the entire Indo-Pacific region, constitute the mainstay of the mackerel fishery in this region. In India, *R. kanagurta* are widely distributed along both the coasts, with very high concentrations along the southwest coast. *R. brachysoma*, occurring in the Andaman waters contribute very little to the fishery while *R. faughni* has been reported to occur only very rarely along the southeast coast of India. Nearly 90% of the world production of the Indian mackerel (*R. kanagurta*) is contributed by India. About 77% of the annual catch of the Indian mackerel comes from the west coast and 23% from the east coast.

Table 34. Age composition (%) of anchovies in the Indian seas.

Species	Area	Age in years				Fishing season
		0	1	2	3	
S. devisi	Mangalore	97	3	-	-	Oct. to Dec.; Jan. to Mar.
S. bataviensis	Mangalore	95	5	-	-	Oct. to Dec.; Jan. to Mar.
Coilia dussumieri	Northwest coast	76	24	-	-	Throughout the year
C. ramcarati	Hooghly estuaries	15	23	29	33	-

Means of exploitation: The major fishing craft engaged in the mackerel fishery include the motorized and nonmotorized catamarans, plankbuilt boats, dugout canoes, purseseiners and trawlers. The common gears employed include the shoreseines, boatseines, gillnets, hooks & lines, ringseines, purseseines and trawls.

All India production: The annual production of the Indian mackerel is characterized by wide fluctuations as evident from the catch records of the past fifty years. During the last 10 years, the production ranged from 113 000 mt in 1991 to 290 000 mt in 1989 (Fig. 17). Relatively higher landings were observed in the 5 year period from 1991 to 1995 (Table 8), when the production registered an increase of 19% over the production of the preceding 5 year period of 1986-90 (147 000 mt). The contribution of the mackerel to the total marine fish production remained at 7.8% during 1986-90 as well as during 1991-95. Compared to the average annual landings of 174 896 mt of 1991-95, the landings of mackerel showed a substantial growth in 1996 when the fishery yielded 274 118 mt.

Regionwise production: The Indian mackerel contributed 14.4% to the annual marine fish production in the southwest region and 7.3% in the southeast region during 1991-95 (Table 8). In recent years (1991-95), the contribution of the mackerel to the annual marine fish production in the northwest region increased significantly to 2.6%. At the current level (1991-95), the southwest region accounts for 65.1% of the total yield of mackerel in the country while the southeast region accounts for 22.6% and the northwest region 11.9% (Table 8). In the southeast region, the production during 1991-95 registered a conspicuous 68% increase over the average annual production of 24 000 mt for the 1986-90 period. Along this coast, the annual catch increased substantially from 21 000 mt in 1991 to 60 000 mt in 1992 and continued to sustain at moderately high levels thereafter. A similar trend could be observed in the northwest region as well, where there was more than twofold increase in the catch during 1991-95 from 9 000 mt per year during 1986-90; during 1991-95, the production registered a steep increase from 12 000 mt in 1992 to 29 000 mt in 1993 and sustained at this high level since then.

Gearwise production: Among the major gears that exploit the mackerel, purseseines and ringseines together contribute 62% to the overall production of mackerel in the southwest coast. The contribution of the purseseines, however, declined to 6.8% during 1991-95 compared to 44.8% during 1986-90 (Tables 16, 17, 18 & 19).

Food and feeding: The Indian mackerel feed primarily on the zooplankton at the juvenile stages and mainly on the phytoplankton in the adult stages (Chacko, 1949; Pradhan, 1956; Venkataraman, 1961; Noble, 1965). The most common food items are the diatoms, dinoflagellates, copepods, cladocerans, mysids etc. The intensity of feeding is very high in maturing and spent mackerel, but low in the spawners. Along certain areas off the west coast, two feeding maxima have been observed: one in October to December and the other in March to April when the fat content also increases appreciably. It is noteworthy that the feeding maxima are followed by the periods of brood release in January to February and April to May respectively.

Size at maturity, fecundity and spawning: The size at first maturity ranges from 184 mm to 225 mm in total length, depending on the locations and the annual variations in maturation (Devanesan and John, 1940; Chidambaram and Venkataraman, 1946; Pradhan, 1956) (Table 35).

Along the southwest coast, spawning is protracted, with definite peaks in different localities within the extended season of February to September. Surveys by the Pelagic Fisheries Project (Anon., 1976) found mackerel larvae in great abundance during March to August along the southwest coast. Along the east coast, spawning extends from October-November to April-May. The occurrence of mackerel larvae all along the Indian coast suggests spawning along the entire coast. The PFP (Anon., 1976) findings also corroborate spawning all along the coast. Observations by Pradhan (1956), Sekharan (1958), Radhakrishnan (1965), Vijayaraghavan (1965) and Rao (1967) reveal that the Indian mackerel spawn in succession, releasing the eggs in batches. According to Devanesan and John (1940) and Vijayaraghavan (1965) spawning of mackerel takes place mostly in the night. The ripe ovary has two distinct batches of ova, the maturing and ripe ones. During each spawning season, an individual mackerel spawns two batches of eggs in quick succession . However, the number of broods per yearclass of the west coast stock is limited in most of the years to just one (February to May) and rarely to two (February to May and October to November). Therefore, the two distinct batches of ova per fish cannot be directly related to the number of broods, separated from each other by a long duration of over five months. Instead, the number of broods may be related to the number of spawning peaks within a spawning season, each peak giving rise to a brood.

Devanesan and John (1940) estimated an average fecundity of 94 000 eggs. Rao (1967) found the absolute fecundity to be 110 000 eggs in 3 successive size groups in mackerel of 228 mm to 232 mm total length. Mackerel larvae and postlarvae have been collected along the southwest coast between 7°N and 12°N latitude at depths ranging from 10 to 200 metres. Evidently, the spawning takes place in the same grounds where the adults are distributed.

Population parameters, stock assessment and management: The values of growth parameters of the mackerel vary widely between different areas (Table 35), possibly due to the variations in the biotic and abiotic factors. Nevertheless, the growth coefficients have been found to be quite high for all the locations studied. It appears that the mackerel becomes (Table 36) physiologically old at 1.5 to 2 years (Table 36). In spite of the variations in the basic input data used by different authors during different time periods, there is a surprising uniformity in the conclusions arrived at regarding the stock size and the optimum yield. Analysing the mackerel fishery of the southwest coast for the years 1934-73, Devaraj *et al.* (1994) observed that the average catch was only 16.58% less than the MSY, with slight annual variations to the left or the right limb of the yield curve. Fishing at the F_{msy} has to be considered with utmost caution. Theoretically, exceeding the F_{msy} may result in wide fluctuations in the stock, and the return time to equilibrium may increase markedly. At present, the number of purseseiners has stabilized at about 500, comprising 90 in Kerala, 300 in Karnataka, 66 in Goa and 40 in southern Maharashtra, owing to poor fluctuations in the stock, and the return time to equilibrium may increase markedly. At present, the number of purseseiners has stabilized at about 500, comprising 90 in Kerala, 300 in Karnataka, 66 in Goa and 40 in southern Maharashtra, owing to poor returns on investment. In the context of the same inshore fishing grounds, being exploited by various other fleets as well, the purseseine fishery has no prospect of expansion any further. According to Haywood (1982), the optimum number of purseseiners for Karnataka is 230 while according to Devaraj (1979), it is 275 in the absence of any major artisanal fishery, such as beachseining, which has been replaced by purseseining.

Table 35. Lengths (mm) at age (years) and population parameters of Indian mackerel.

Area	Length (mm) at age (years)				Population parameters				
	1	2	3	4	L_∞	K	l_m	l_m/l_∞	Reference
Karwar	100	180	-	-	-	-	-	-	Pradhan, 1956
Southwest coast	195	235	252	-	266	0.83	-	-	Udupa & Bhat, 1984
- do -	226	-	-	-	238	2.84	184	0.77	Devaraj *et. al.*, 1994
- do -	245	-	-	-	265	2.60 - 3.80	-	-	Biradar, 1985
South Kanara	120 to 150	210 to 230	-	-	-	-	-	-	Sekharan, 1958
Mangalore	150	225	266	289	316	0.60	-	-	Rao et al., 1965
- do -	140 to 160	220	-	-	-	-	-	-	Yohannan, 1977
Cochin	220	240	-	-	228	3.60	-	-	George & Banerji, 1968
Orissa	130	225	260	260	272	0.66	-	-	Pati, 1982
Andaman	148	218	265	265	390	0.74	255	0.65	Luther, 1973

<u>Utilization</u>: A good quantity of mackerel is consumed in fresh conditions along the coastal and nearby areas. During glut conditions the surplus catch is salted, sundried and sent to the interior markets. Export of frozen mackerel to the South East Asian countries seems possible, considering the surplus catches in certain years.

Table 36. Age composition (%) of Indian mackerel in different gears (Devaraj *et al.* 1994).

Gear	Area	Age in years				Period
		0	1	2	3	
Beachseine	Karwar	79	21	-	-	1948-59
- do -	Mangalore	90	10	-	-	1957-73
Gillnet	Calicut	75	25	-	-	1934-41
- do -	Cochin	98	2	-	-	1957-64
Pelagic trawl	Southwest	90	10	-	-	1972-75

Ribbonfishes

Species: The major species include *Trichiurus lepturus, Lepturacanthus, L. savala, Eupleurogrammus glossodon* and *R. muticus*.

Distribution: Ribbonfishes are widely distributed in the Indo-Pacific and the Atlantic. Six species constitute the commercial fishery in several areas along the Indian coast, but only *Trichiurus lepturus* and *Lepturacanthus savala* are the most abundant throughout the Indian coast while *E. intermedius* form a seasonal fishery in some major fishing centres, *E. muticus* along the northwest and northeast coast and *E. glossodon* and *T. auriga* (caught in small quantities) along the east coast. The landings of ribbonfishes in 1996 recorded 127 000 mt, registering a growth of 30% over the average annual catch of 97 000 mt during 1991-95.

Means of exploitation: The fleets employed in the ribbonfish fishery include the trawlers, motorized and nonmotorized catamarans, plankbuilt boats and dugout canoes while the principal gears include the trawls, boatseines, dolnets, shoreseines, hooks & line and gillnets.

All-India production: During 1983-90, the average annual world production of ribbonfishes was 688 312 mt, of which 14.2% was contributed by India. During 1991-95, the average annual ribbonfish catch of 97 444 mt was 26% higher than that for 1986-90 and formed 8.4% of the small pelagic catches and 4.3% of the total marine fish production in India (Fig. 18).

Regionwise production: During 1991-95, about 79% of the average annual catch was landed from the west coast and 21% from the east coast. The major share (65.5%) of the annual landings was obtained from the northwest region, followed by 16.4% from the southeast, 13.1% from the southwest and the rest 50% from the northeast region. The ribbonfish formed 7.9%, 1.6%, 3.0% and 3.9% of the total marine fish landings in the northwest, southwest, southeast and northeast regions respectively (Table 8).

Gearwise production: Among the major gears, the trawls contributed 70% (68 051 mt), the bagnets (including the dolnets of the northwest coast) 7%, the gillnets 3% and the purseseines 2.2% to the all India ribbonfishes during 1991-95.

Food and feeding: The ribbonfishes are carnivores, feeding predominantly on fishes and to a smaller extent on shrimps and other items (Venkataraman, 1944; Jacob, 1949; Devanesan and Chidambaram, 1948). Selectivity in feeding was reported by James (1967) and Prabhu (1955). While young ribbonfishes feed on smaller fishes and shrimps, the adults prey upon much larger items. Huge shoals of ribbonfishes are commonly noticed in coastal areas, chasing shoals of sardines, anchovies and scads.

Size at maturity, fecundity and spawning: The ribbonfishes (*T. lepturus*, *L. savala, E. glossodon* and *E. muticus)* spawn more than once a year (Table 37). Three batches of ova (immature, maturing and mature) are found in the ovaries. The maturing and mature groups of ova are so sharply differentiated in the mature ovaries of all the four species that their spawning seems to take place at short intervals of time in quick succession. Although Prabhu (1955) indicated a short and definite spawning once a year in June for *T. lepturus* off Mandapam, subsequent observations clearly indicate prolonged spawning almost throughout the year, with two peaks. Prabhu (1955) estimated the relative fecundity of *T. lepturus* to be 16 000 ova while James *et* al. (1983) estimated the absolute fecundity to be 134 000 ova. Big shoals of *T. lepturus* are seen in the inshore waters after June in many locations along the Indian coast. Since the majority of the fish in such schools are above 45 cm in length (45 cm to 47 cm is the size at first maturity) and in just spent and spent recovering stages, it is possible that this schooling in the nearshore grounds is associated with spawning as well as active postspawning feeding on the youngones of other small pelagics during the peak monsoon season. Spawning in *L. savala, E. muticus* and *E. glossodon* is quite prolonged, taking place almost throughout the year, evidently because of the release of successive batches of eggs by individual fishes (James, 1967; Narasimham, 1976).

Table 37. Spawning frequency and season in respect of the ribbonfishes in the Indian seas.

Species	Area	Spawning	
		Season	Frequency per year
T. lepturus	Kakinada	Feb. to June	Two
	West coast	Apr. to June	One
	Madras	May to June; Nov. to Dec.	Two
	Mandapam	June	One
L. savala	Mandapam	Feb. to May	Two
E. glossodon	Kakinada	June to Aug.; Oct. to Jan.	Two
E. intermedius	Mandapam	May to Sep.	Multiple

Population parameters, stock assessment and management: The age and growth of *T. lepturus, L. savala* and *E. intermedius* from the Indian waters indicate a life span of 3 to 4 years (Table 38). Narasimham (1978) and James *et al.* (1983) reported that *T. lepturus* grow at a faster rate than the other ribbonfish species. The largest specimen of *T. lepturus* (115 cm in total length) found in the commercial catches at Kakinada (Andhra Pradesh) was considered to be 5 years old (Narasimham, 1978). The occurrence of *E. intermedius* of more than 43 cm in length indicates a life span of at least 4 years (James, 1967).

There is overfishing of the stock of *T. lepturus* along the east coast where the effort should be reduced by 33% (Thiagarajan *et al.,* 1992). Although the exploitation rates are high, there is scope for increasing the catch by extending the fishing areas, considering the large biomass recorded in experimental fishing (Somvanshi and Joseph, 1989). Along the west coast there is good scope of increasing the present effort, as the present yield of 77 000 mt (1991-95) is not even 50% of the estimated biomass of 223 773 mt.

Table 38. Lengths (mm) at age (years) and population parameters in respect of the ribbonfishes in the Indian seas.

Species	Length (mm) at age (years)				Population parameters				
	1	2	3	4	L_∞	K	l_m	l_m/l_∞	Reference
T. lepturus	391	587	708	828	-	-	470	-	James *et al.*, 1983
- do -	427	686	879	1024	1454	0.29	450	0.31	Narasimham, 1983
- do -	512	825	1010	-	1297	0.50	-	-	Chakraborty, 1990
- do -	550	870	1050	1150	1290	0.56	-	-	Thiagarajan *et al.*, 1992
- do -	400	670	860	980	1260	0.38	610	-	- do -
E.intermedius	210	330	430	-	-	-	380	-	James, 1967

Utilization: The ribbonfishes are consumed fresh locally, and the surplus, if any, is salt cured or sundried. The good export market that once existed for Indian cured fish in Sri Lanka and Malaysia has now declined, but a new market for Indian deep frozen ribbonfish has emerged recently in the UAE, Singapore and Hong Kong. Following this, the ribbonfish, once considered a cheap fish, has become a high value commodity in the domestic market. Baits of ribbonfish are used in longlining and trolling for larger pelagics and larger demersals like the seerfishes, tunas, eels, sharks, catfishes and jewfishes.

Carangids

Species: There are 46 species of carangids occurring along the Indian coast, but the fisheries consist mainly of the horse mackerels, round scads, selar scads, queenfishes, trevallies, jacks and pompanos. The queenfishes and jacks attain large sizes, whereas the others are small, but form big schools. In recent years there has been a significant increase in the production of the carangids, which currently form about 7.2% of the total marine fish landings in India.

Distribution: Out of the 46 species of carangids, *Megalaspis cordyla, Decapterus russelli, Alepes kalla, Atropus atropus, Alepes djedaba, Atule mate, Caranx carangus* and *Selaroides leptolepis* contribute significantly to the carangid fisheries, which extend up to a depth of about 100m. While *M. cordyla* and *D. russelli* are quite important in the fishery all along the Indian coast, *A. kalla* and *A. atropus* form good fisheries along the southwest and northwest coasts respectively. The fishing for *A. djedaba* and *A. mate* is confined mainly to Kerala and that for *C. carangus* and *S. leptolepis* is limited to the southeast coast.

Means of exploitation: The catamarans, plankbuilt boats and trawlers which form the major fishing craft all along the Indian coast land good quantities of carangids. Gillnets (25 mm to 40 mm mesh), drift gillnets (50 mm to 80 mm & 80 mm to 120 mm mesh) made of nylon or garfil, boatseines (10 mm to 15 mm mesh), trawls (15 mm to 20 mm mesh), seinenets called *kachal* (25 mm to 30 mm mesh) and *jangal* (35 mm to 40 mm mesh) in the northeast coast and purseseines and ringseines(10 mm to 12 mm mesh) in the southwest coast, and hooks & line are principally used in the exploitation of the carangids, among others. Although the carangids are not the target fisheries in any of these gears, they form a good component in the catches of these gears.

All-India Production: The average annual production of carangids during 1991-95 was 163 285 mt of which the scads alone formed 86 000 mt (52.9%) (Fig. 19). The carangids formed 7.2% of the total marine fish production in the country during 1991-95 (Table 8).

Regionwise production: During 1991-95, the average annual yields of *M. cordyla* and *D. russelli* were 20 000 mt and 86 000 mt respectively, which formed 0.9 and 3.8% of the total marine fish production in the country. In the southwest region, the carangids formed 14.2% of the total production during 1991-95. The average annual production of 163 285 mt during 1991-95 consisted of 112 000 mt from the southwest region (69%), 27 000 mt from the southeast region (17%), 21 000 mt from the northwest region (13%) and 2 000 mt from the northeast region (1%). *D. russelli* formed about 10% of the total landings in the southwest region, while in the other regions it formed only less than 1%. The southwest region contributed 48.2% of the landings of horse mackerel, while 42% came from the northwest region. However, 89% of the scad landings came from the southwest region (Table 8).

Gearwise production: A major portion of the landings came from the purseseines and ringseines in the southwest region. These two gears contributed 43% to the total carangid production in the country during 1991-95 (Tables 16, 17, 18 & 19). About 33% of the national production was contributed by the trawls, especially from the southern states (Tables 22 & 23).

Food and feeding: The carangids are carnivores, feeding predominantly on fishes and crustaceans. *Megalaspis cordyla* feed mainly on clupeids and crustaceans. The young ones measuring about 8 cm in length feed on postlarval fish, juvenile prawns and other crustaceans (Basheeruddin and Nayar, 1961). *Decapterus russelli* feed on clupeids, diatoms, copepods and other crustaceans. The juveniles of 4 cm to 12 cm size feed on *Acetes*, copepods and other crustaceans.

Table 39. Lengths (mm) at age (years) and population parameters of carangids in the Indian seas.

Species	Length (mm) at age (years)				Population parameters					
	1	2	3	4	L_{max}	L_∞	K	l_m	l_m/l_∞	M
Caranx carangus	288	390	450	-	-	444	0.65	220	0.50	0.95
C. leptolepis	166	210	-	-	-	213	1.43	-	-	2.19
Megalaspis cordyla	358	485	510	-	-	554	1.03	250	0.45	0.93
Decapterus russelli	160	208	224	-	-	232	1.08	137	0.59	1.90
Atropus atropus	321	412	440	-	-	440	1.00	210	0.48	1.26
Selaroides leptolepis	158	170	198	-	-	202	0.82	88	0.44	1.35
Alepes kalla	101	142	160	-	-	171	0.83	129	0.75	1.40
A. djeddaba	185	236	289	-	-	326	0.61	189	0.58	0.99
Atule mate	205	278	315	-	-	340	0.85	172	0.51	1.22

Maturity and spawning: The size of *M. cordyla* at first maturity is 250 mm (Table 39). The spawning is prolonged, resulting in recruitment almost round the year. In the east coast, peak spawning occurs during March to May, followed by peak recruitment in April-May (Table 40). In the northwest and the southwest coasts, recruitment takes place in two different peaks. In the northwest coast, there is a minor recruitment in October and a major one in January, while in the southwest coast, the minor recruitment occurs in April and the major one in July. The spawning peak was found to be around July in the northwest coast, while along the southwest coast, the peak was in January.

Table 40. Spawning frequency and season in respect of the carangids in the Indian seas.

Species	Area	Spawning		No. of broods per yearclass
		Season	Frequency per year	
Megalaspis cordyla	East coast Northwest Southwest	March to May July January	Two One One	-
Decapterus russelli	East coast Northwest Southwest	April, August December, August August, January	Multiple Multiple Multiple	-
Selaroides leptolepis	East coast	October	One	-

The length of *D. russelli* at first maturity is 137 mm. Two batches of eggs are released in each spawning season. Spawning and recruitment are prolonged and almost continuous, but two peaks have been discerned in all the regions, with only minor variations. In the east coast, recruitment is quite pronounced around July, followed by a less pronounced one in November. Spawning is intense in April, but less intense in August. Along the northwest coast, recruitment is continuous, with peaks in June and January, due to the peak spawning in December and August respectively. Along the southwest coast, recruitment is highly pronounced in January and feeble in July. The size of *S. leptolepis* at first maturity varies from 88 mm to 101 mm. Major recruitment occurs in January, corresponding to intense spawning in October. Almost the entire catch along the Tamilnadu coast is comprised by the 0-yearclass (Table 41).

Stock assessment and management: The average annual catch of *M. cordyla* during 1985-89 was estimated to be 6 627 mt *vis-a-vis* the MSY of 14 161 mt comprising 1 056 mt for the east coast, 4 727 mt for the northwest and 8 378 mt for the southwest coast. In the southwest coast, the fishing effort should be increased by 81% to obtain the MSY.

The estimated average annual catch of the scad *D. russelli* during 1985-89 was 19 055 mt *vis-a-vis* the MSY of 28 707 mt comprising 2 799 mt for the east coast, 3 700 mt for the northeast coast and 22 208 mt for the southwest coast. The MSY was 5.7% more than the current annual catch for the east coast, 17% more for the northwest and 2% more for the southwest coast. The fishing effort on and the catch of *M.cordyla* and *D.russelli* have increased substantially in the subsequent years due to the expansion the fishing area.

Table 41. Age composition (%) of carangids in the Indian seas.

Species	Area	Age in years				Fishing season
		0	1	2	3	
Decapterus russelli	East coast	89	10	1	-	Throughout year
	Northwest	62	35	3	-	Oct. to March
	Southwest	54	45	1	-	Oct., Apr. to June
Caranx carangus	Tamilnadu	99	1	0	-	Throughout year
Selaroides leptolepis	Tamilnadu	99	1	0	-	Throughout year
Alepes kalla	Southwest	98	1	1	-	Nov. to Jan.; Apr. to June
Alepes djeddaba	Kerala	85	9	6	-	Jan., June, Nov.
Atule mate	Kerala	33	64	3	-	Nov. to May

C. carangus form a fishery along the Tamilnadu-Pondicherry coast, where the average annual production during 1985-89 was 2 720 mt, taken mainly by the trawlers. The current annual production of 2 314 mt is 13.5% lower than the MSY. Reduction in the current fishing effort by the trawlers is recommended to increase the yield to the level of the MSY.

S. leptolepis form a fishery only along the Tamilnadu coast, where the average annual landing during 1985-89 was 5 726 mt, taken mainly by the trawlers, *vis-a-vis* the MSY of 6 583 mt which is 9.5% higher than the present production. Reduction in fishing effort by about 39% is recommended to increase the yield to the MSY level.

A. atropus form a fishery along the northwest coast of India, where the average annual catch during 1985-89 was estimated to be 977 mt, of which 67.5% came from Maharashtra and the rest from Gujarat. The MSY is estimated to be 953 mt.

A. kalla form a fishery along the southwest coast where the average annual catch during 1985-89 was estimated to be 14 264 mt, of which 61% was from Kerala. The MSY is 1.36% more than the present yield, but the 41% increase from the current effort required to attain the MSY would not be economically viable.

A. djeddaba constitute a fishery only in Kerala where the average annual catch during 1985-89 was 4 297 mt. The stock is grossly underexploited, and hence it requires to increase the present effort by 221% to attain the MSY.

A. mate fishery is also limited to Kerala, where it is carried out mainly by hooks & lines and drift gillnets. The average annual catch during 1985-89 was estimated to be 3 364 mt against the MSY of 4 305 mt.

A detailed study on the stocks of the carangids by Reuben *et. al.* (1992) indicated underexploitation of *M. cordyla* along the southwest coast, *D. russelli* along the northeast and southeast coasts and *A. djeddaba* and *A. mate* along the southwest coast during 1985-89. However, the virgin biomass of these stocks has declined to critical levels at the F_{msy}, leading possibly to recruitment overfishing. Reuben *et. al.* (1992) reported that larger individuals of *M. cordyla* (>205mm), *D. russelli* (>170mm) and *A. mate* (>210mm) were exposed to intensive exploitation by the gillnets, trawls and hooks & line, respectively. *C. carangus* and *S. leptolepis* are also overexploited along the southeast coast. Since the carangids are not the targets of these three major gears, the demand for any reduction in the effort by these gears from the present level cannot be justified unless the actual targets of these gears also exhibit signs of overexploitation.

Utilization: The carangids are high quality table fish in great demand and marketed mostly in fresh or iced condition because of the quick transportation facilities that exist in most places between the production and consuming centres. During peak landings, the surplus catch is deep frozen and stored for the lean season, which ensures steady prices and supplies. Since recently, larger species such as *C. malabaricus, C. melampygus, C. ignobilis, S. mate,* and *S. djeddaba* are being exported in frozen form.

Bombayduck

Distribution: The Bombayduck (*Harpodon nehereus*), which inhabit the waters upto the 50 m to 70 m isobath, form a major single species fishery along the northwest coast from Ratnagiri in Maharashtra to the Gulf of Kutch in the Saurashtra coast. They afford a seasonal fishery along the coasts of West Bengal, Orissa and the northern part of Andhra Pradesh. Bombayduck are inconspicuous or totally absent in the southwest and southeast coasts.

Means of exploitation:The dolnet operated by the plankbuilt boats is the primary gear used in the Bombayduck fishery along the northwest coast. It is a traditional labour-intensive stationary bagnet, made of synthetic filaments, highly specialized in design, working entirely by the forces of tide. The gillnets, boatseines and trawls are also employed in this fishery.

All India production: The average annual catch of Bombayduck was about 111 000 mt during 1986-95 when it ranged from 74 000 mt in 1987 to 136 000 mt in 1991 (Table 8; Fig. 20). The average catch during 1991-95 increased by 14% from the 1986-90 level, and formed 4.9% of the total marine fish landings in India. In 1996, the catch of 86 000 mt indicated a decline of 23% from the 1991- 95 average.

Regionwise production: Nearly 87% of the annual landings during 1991-95 came from the northwest coast and the rest from the northeast coast. Along the northwest coast, the fishing season begins by April with high catch rates, which dwindle with the progress of the season, recording the lowest values in February to March. The fishing season shows two distinct phases of productivity: (1) September to January, which is more productive, with the predominance of adults over the juveniles; (2) February to March, which is less productive, with juveniles forming a major part of the catch.

Saurashtra - Gulf of Cambay region (Fig. 21). The existence of the Gulf of Cambay, which serves as ideal nursery grounds appears to be the second most important factor, next to the tidal amplitude, responsible for the emergence of Bombayduck as a major stock along the northwest coast.

Table 43. Age composition (%) of Bombayduck in the Indian seas.

Area	Age in years				Period
	0	1	2	3	
Gujarat	59	21	20	-	1979
Maharashtra	21	29	50	-	1979
Saurashtra	75	18	7	-	1980-84
Northwest caost	44	52	3	1	1947-86

Population parameters, stock assessment and management: The annual growth coefficient (K) of the Bombayduck varies from 0.29 to 0.77 in the northwest coast. The K value for the Saurashtra coast is higher than that for the Maharashtra coast because of the predominance of the 0 yearclass in the former and the predominance of 1 and 2 yearclasses in the latter.

Fernandez and Devaraj (1996 a,b) reported that the mean Y_W/R for 1956-83 (5.95g) in relation to the MSY/R (11.88g) indicated an overexploitation of the Bombayduck stock by 17.6% in the northwest coast. By reducing the mean annual fishing effort by 8%, the average annual yield could be increased to the MSY of 189 844 mt. Since dolnetting is the major means of exploiting the Bombayduck fishery, the existing fleet of 2 428 (2 102 in Maharashtra and 326 in Gujarat) dolnetters could be reduced to the optimum of 2001 dolnetters to help maximise the yield of Bombayduck. Two more regulatory measures suggested to increase the yield are: (a) change over to 25 mm to 27 mm mesh at the codend of the dolnet, and (b) closing of fishing season during February to May, which should form the basic management strategy in future for the sustained development of this fishery.

Utilization: The Bombayduck are a very soft fish of low quality and highly perishable because of the high water content, and hence require to be disposed quickly for consumption in fresh condition. The bulk of the catch is sundried and sold in the interior markets while a small portion is converted into manure. Laminated Bombayduck are in good demand in some foreign markets.

Seerfishes

The seerfishes are one of the most valued fishes and hence form the target of drift gillnet and hooks & line fisheries. *Scomberomorus commerson, S. guttatus* and *S. lineolatus* occur along the Indian coast in addition to the wahoo, *Acanthocybium solandri*. *S. commerson* form about 56% of the seerfish landings. The annual seerfish production which ranged from 29 101 mt to 45 143 mt during 1985-96 formed 1.8% of the total marine fish landings. The northwest coast contributed 43.1% to the all-India seerfish landings followed by the southeast (25.5%) and the southwest coasts (23.3%). The major gear used in the fishery is the drift gillnet of 7 cm to 17 cm mesh sizes which effectively exploit the commercial size groups through both gilling as well as entangling.

The seerfishes are exploited by hooks & lines, troll lines and trawls also. The growth parameters of the seerfishes have been studied in detail (Table 44). The length at first maturity of *S.commerson* is 750 mm and the spawning season extends from January to September during which a weak brood is released during January-February, a strong brood during April-May and another weak brood in July-August (Devaraj, 1983a). The same frequency and time of brood release is true with *S. guttatus* (Devaraj, 1987a) and *S.lineolatus* (Devaraj, 1986) also. *S. commerson* are known to be a migratory species. The young ones which are abundant in the southwest coast during June to September seem to move to the southwest coast and afford a fishery

Table 44. Length (mm) at age (years) and population parameters of seerfishes.

	Length (mm) at age (years)				Population parameters					
Species	1	2	3	4	L_∞	K	l_m	l_m/l_∞	M	Reference
Scomberomorus commerson	402	726	995	1186	2081	0.81	750	0.36	0.79	Devaraj, 1983a
- do -	-	-	-	-	1270 to 1768	0.50 to 0.66	-	-	0.71 to 0.90	Devaraj *et. al.*, MS
S. lineolatus	350	713	835	965	1683	0.18	700	0.42	-	Devaraj, 1983a
- do -	-	-	-	-	1268	0.86	-	-	-	Devaraj *et. al.*, MS
S. guttatus	315	650	725	859	1278	-	400	0.31	-	Devaraj, 1987a
- do -	-	-	-	-	680 to 1092	0.72 to 0.85	-	-	-	Devaraj, *et al.*, MS

The spawning season of *S. guttatus* extends from January to August, releasing a weak brood during January-February, a strong brood from March to July and another weak brood in August. The spawning season of *S.lineolatus* extends from January to May, releasing a weak brood in January and February, succeeded by a strong brood from March to May.

Along the southeast coast, the young ones of about 450 mm length form 91% of the catch. As exccessive exploitation of the stock before the size at first maturity may affect the spawning stock and recruitment, exploitation by small meshed gillnets along the southeast coast should be discouraged so as to ensure a good spawning stock and also to improve the catch along the southwest coast (Yohannan *et. al.*, 1992). *S. commerson* stock is being overexploited as the current level of effort is 80% more than the optimum along the east coast and 60% more than the optimum along the west coast. Operation of hooks & lines and gillnets of 150 mm to 200 mm mesh size may be encouraged for sustaining the seerfish fishery.

Coastal tunas

Of the 8 major species of tunas occurring along the Indian coast, 5 are coastal and 3 highsea and migratory. The coastal tunas are the kawakawa (*Euthynnus affinis*), the frigate tuna (*Auxis thazard),* the bullet tuna (*A. rochei*), the oriental bonito (*Sarda orientalis)* and the longtail tuna (*Thunnus tonggol*). The annual tuna catch during 1985-96 ranged from 23 544 mt to 45 868 mt, of which about 70% was formed by the coastal tunas. The southwest coast contributed about 53% to the tuna landings, followed by the northwest coast (29%) and the southeast coast (18%). The coastal tunas are exploited by drift gillnets, hooks & lines and purseseines. The drift gillnets are more popular as they guarantee good returns. The gillnets contributed 54%, hooks & lines 27%, purseseines 17% and other gears 2% to the tuna production.

The coastal tunas are migratory and they appear in shoals in the southern part of the southwest coast in the premonsoon period (October to April). A part of this stock seems to migrate into the southeast coast, but a major portion of the stock migrates northward along the southwest coast, forming a peak fishery off Cochin during May to August and off Mangalore in October.

The studies conducted by James *et al.* (1992) for the period 1984-88 indicate that the exploitation of tunas, especially the coastal tunas from the traditional fishing grounds, has almost reached the optimum. Based on the population parameters (Table 45) and the stock estimates for the period 1984-88, the coastal tunas have been found to be exploited at the optimum level (James *et al.*, 1992). However, in the case of *E. affinis*, 66% decrease in the current effort has been suggested to optimise the fishery, while in the case of *A. thazard, A. rochei* and *T. tonggol,* increase in the current effort would increase the yield only marginally. The dwindling tuna catches at certain centres along the west coast suggests that indiscriminate motorization of the artisanal fleets may lead to overexploitation (James *et al.,* 1992). Extension of fishing to the offshore shelf through multiday drift gillnetting and purseseining, and intensification of troll-lining and handlining during the monsoon season may help augment the tuna catches from the west coast of India (James *et al.*, 1992).

Table 45. Length (mm) at age (years) and population parameters of coastal tunas.

Species	Length at age				Population parameters					Reference
	1	2	3	4	L_∞	K	l_m	l_m/l_∞	M	
Euthynnus affinis	314	466	571	644	810	0.37	430	0.53	0.62	Srinivasarangan *et al.*, 1944
Auxis thazard	292	422	503	550	630	0.49	305	0.48	1.02	Silas *et al.*, 1985a
A. rochei	160	280	340	-	370	0.64	-	-	1.02	James *et al.*, 1992
Thunnus tonggol	423	619	740	813	930	0.49	-	-	0.66	Silas *et al.*, 1985a
Sarda orientalis	447	580	630	650	660	1.01	-	-	-	Silas *et al.*, 1985b

Pomfrets

Among the small pelagics, the pomfrets are highly priced and consist of the silver pomfret (*Pampus argenteus*) and the Chinese pomfret (*P. chinensis*). The annual landings of 25 848 mt during 1991-95 comprised essentially the silver pomfret (25 253 mt or 97.7%). The length of the silver pomfret at first maturity is 240 mm and the L_∞ 395 mm in the northwest coast (Khan *et al.,* 1992b). The spawning season is prolonged with peaks in April and August along the east coast (Pati, 1982) and February-August along the west coast (Gopalan, 1967). The area between the 55 m and 90 m depths off Cambay in the northwest coast and the sandheads area in the northeast coast form the breeding grounds of the silver pomfret (Khan, 1982). The northwest coast accounts for the maximum landings. The principal gear exploiting the adult pomfret is the drift gillnets while the dolnet exploits essentially the juveniles in the northwest coast. The MSY of the silver pomfret in Indian waters has been estimated to be 38 194 mt (Khan MS). As the fishery has collapsed in the northwest coast during the 1990s, restriction of dolnet operations to minimise recruitment overfishing and regulation of gillnets to minimise growth overfishing have been prescribed as management measures (Khan, MS).

Hilsa shad

The hilsa shad (*Hilsa ilisha*) form a prominent fishery in the northeast coast region. They are known to spend most of their life in the inshore areas and migrate into the estuaries and rivers for breeding. During 1986-95, the annual catch has been generally increasing, from 2 000 mt in 1988 to 30 000 mt in 1993. The hilsa shad formed 18.8% (25 133 mt) of the total fish landings during 1991-95 (annual average) in the northeast coast, which contributed 92% to the shad fishery of India. The gillnetters alone accounted for 87.7% of the shad catches landed during 1991-95 in the northeast coast. Recruitment to the fishery takes place at the minimum size of 150 mm and maximum size of 370 mm. The bulk of the fishery is constituted by fish in the size range of 260 mm to 480 mm. The hilsa shad attain maturity at a size of 350 mm to 370 mm and release only a single batch of ova each spawning season. Fecundity ranges from 467 100 to 1 369 500 eggs in fish in the size range of 370 mm to 540 mm. The shads other than the hilsa shad form fisheries in all the regions, particularly in the southeast and the northwest regions which accounted for 13 500 mt and 9 300 mt respectively in the average annual catch during 1991-95.

Barracudas

The barracudas, otherwise known as the seapikes of the family *Sphyraenidae,* are caught in sizeable quantities along the Indian coast. They are distributed in all tropical waters in depths of 1 m to 40 m. Though they form shoals, the larger ones prefer to be solitary. The barracudas are vigorous predators, feeding voraciously on other pelagic fishes. The larger fish are caught in hooks & lines, bottomset gillnets and drift gillnets, while the smaller ones are caught in trawls in fairly good quantities. The annual catch improved remarkably in recent years from a meagre 4 000 mt in 1986 to 14 000 mt in 1995. The barracudas may spawn more than once each season. The number of eggs released per batch increases with the age and ranges from 42 000 to 484 000 eggs.

Flyingfishes

The flyingfish fishery is limited to the coramandal coast in Tamilnadu. The seasonal fishery is supported mainly by *Hirundichthys coromandelensis*. The fishery commences by the middle of May and lasts till the middle of July, though occasionally it extends up to the middle of August. The flyingfishes seldom appear in discoloured water, and hence, early onset of monsoon conditions resulting in the discolouration of the seawater with silt from the river discharges, forces the fish to migrate away from the inshore grounds, and the fishing season comes to an abrupt end. The annual catches taken almost exclusively by the scoopnets, vary considerably from year to year contributing only about 0.1% to the total all India landings. The fish attain maturity at a size of 350 mm to 370 mm and spawn only a single batch of ova each season. The fecundity varies from 467 100 eggs to 1 369 500 eggs for fish in the size range of 370 mm to 540 mm.

Other clupeids

Among the other clupeids, the wolf herring (*Chirocentrus dorab*) form a fishery, and contribute about 0.7% to the total all India landings, of which about 50% comes from the northwest coast. Clupeids consisting of species of *Dussumieria, Escualosa*, *Ilisha*, *Nematalosa*, *Opisthopterus*, *Pellona*, *Reconda*, *Dorosoma*, *Chanos* etc together accounted for an annual average of 50 853 mt during 1991-95, forming 2.3% of the total all India landings. The northeast coast contributed 7.5%, the southeast 35.9%, the southwest 38.1% and the northwest 18.5% to the all India catch of these clupeids.

Mullets

Among the other small pelagics, the mullets form a fishery mainly in the northwest region, which contributed 44% to the annual average landings of 5 700 mt in 1991-95 followed by the southeast coast which contributed 34%.

Unicorn cod

During 1991-95 Maharashtra state landed 836 mt of unicorn cod.

Other small pelagic mix

The miscellaneous small pelagics mix yielded during 1991-95 an annual average of 42 000 mt which included 3 000 mt from the northeast region, 19 000 mt from the southeast region, 11 000 mt from the southwest region and 9 000 mt from the northwest region.

A SYNTHETIC ANALYSIS OF THE SMALL PELAGIC FISHERIES IN INDIA

Common features of small pelagics fisheries

From the foregoing account, it is clear that the small pelagics fisheries are characterised by the following features: (i) dominance of three species; (ii) highly fluctuating nature of their fisheries; (iii) area specific distribution of the dominant species; (iv) crucial role of the environment; and (v) unique biological characteristics. Interactions among these vital features determine the abundance of the small pelagics.

Dominance of three species: Though there are over 200 species of small pelagics along the Indian coast, only 3 species, namely, the oil sardine (*S. longiceps*), the Indian mackerel (*R.. kanagurta*) and the Bombayduck (*H. nehereus*) play a very dominant role, not only in the small pelagics fisheries, but also in the entire Indian marine fisheries. These three species together form 26.3% of the total marine fish landings (1950-1995). Adverse effects of any fishery dependent or independent factors on any of these 3 species would seriously affect the landings of the small pelagics, which are, therefore, highly vulnerable and subject to fluctuations. The great fishery of the Peruvian anchovy (*Engraulis ringens*) in the 1960s reached an estimated annual production of 12 million mt and subsequently collapsed due to the biological consequences of *El Nino,* also called the Southern Oscillation. This event is a classical example to demonstrate how a fishery based on a single species succumbs to an adverse natural phenomenon. This kind of situation is contrary to the one prevailing in the fisheries for the demersals, where the fishery is not dependent exclusively on any particular species and there are numerous species that play equally dominant roles.

Highly fluctuating fisheries: The landing pattern of the small pelagics could be categorized as follows: (a) fisheries which have fluctuated very widely (oil sardine, Bombayduck and Indian mackerel); (b) fisheries which have increased the landings fairly consistently (other sardines, *Hilsa* spp., whitebaits, *Thryssa* spp. *Coilia dussumieri*, carangids and ribbonfishes); and (c) the only fishery which has declined (unicorn cod). The landings of the unicorn cod (*Bregmaceros meclellandi),* which are restricted to the Maharashtra coast, have decreased from 6 880 mt per year during 1950-54 to 836 mt per year during 1991-95. In view of the consistently declining fishery, the unicorn cod may have to be listed as vulnerable or endangered, and strategies devised to restore the population.

It is now widely understood that the high latitude clupeid and small pelagics stocks are more variable on a decadal scale than the demersal stocks (Longhurst and Pauly, 1987). However, this trend does not hold good for all the clupeids or for all the small pelagics. Within the small pelagics, the catches of the 3 dominant species alone fluctuated. For instance, the deviation from the mean landings for the mackerel fluctuated from -48% (1965-69) to 28% (1970-74), then to -51% (1980-84) and subsequently to 103% (Fig. 22). On the other hand, the landings of *Thryssa* spp. consistently increased from -67% (1950-54) to 132% (1990-95) (Fig. 23).

Notwithstanding the overall increasing trend in marine fisheries production, the landings of the 3 species fluctuated widely from the average catches and were below the long-term mean values as late as 1980-1984 (mackerel and Bombayduck) and 1985-1995 (oil sardine). Hence, the most dominant species are the most fluctuating ones.

Area specific distribution of the dominant species

Another important characteristic of the small pelagics is the area specific abundance of the dominant species. The fisheries for the oil sardine, Bombayduck, flyingfishes and unicorn cod are restricted to the coastal waters of a single geographic zone, i.e., oil sardine to the southwest coast between 8^{o}N and 16^{o}N latitudes (92.6% of the total oil sardine landings) and the Bombayduck to the northwest coast between 18^{o}N and 22^{o}N latitudes (>90% of the Bombayduck landings), while their abundance in the other coastal zones is quite meagre. Similarly, the flyingfishes are restricted to the southeast coast and the unicorn cod to the northwest coast. Four groups/species (Indian mackerel, lesser sardines and whitebaits in the southwest and the southeast coasts; and the grenadier anchovy in the northwest and northeast coasts) form fisheries in two zones. The remaining groups exhibit much wider range and form fisheries in all the zones.

A full understanding of the reasons why the distribution and abundance of a few species are restricted to certain well defined sea areas is yet to emerge. There are considerable ecological variations, including ichthyofaunal, between adjacent sea areas inspite of their geographic continuity. If the populations of Bombayduck are restricted to the northern latitudes, especially along the northwest coast and to a limited extent along the northeast coast and the populations of the oil sardine and the mackerel restricted to the southern latitudes, there must be some key factors, which are distinctly different between the northern and southern coasts. Differences in temperature, salinity and food regimes are thought to be important factors. However, the thermal and salinity profiles in the coastal areas of the northern and southern latitudes are not very much different from each other. Devaraj (1987b) considered that these factors may be important, but do not appear to be the basic factors that bind the Bombayduck to the northern latitudes. High tidal amplitudes of about 5 m are characteristic of the northern latitudes. Neither strictly pelagic nor demersal, the Bombayduck effectively utilize the tidal oscillations for less energy-demanding movement for foraging on the sergestid shrimps and the grenadier anchovy, which are also associated with the tidal oscillations (Devaraj, 1987b). The reasons for the abundance of the oil sardine and mackerel populations in the southwest coast are fairly clear. Regular upwelling along the southwest coast leads to dense plankton blooms. Being plankton feeders, the oil sardine and mackerel, which form large shóals and require huge quantities of food, find the southwest coast an ideal location to forage.

In the long Indian coastline, it is only along the southwest coast, two of the three most dominant fisheries and another major fishery, the whitebaits, coexist. It is estimated that, on an average, 137 925 mt of oil sardine (92.6% of the total all-India oil sardine landings) and 78 816 mt of mackerel (76.7% of the total all-India mackerel landings) were contributed by the southwest coast during 1970-1995. An inverse relationship between the abundance of the oil sardine and the mackerel has often been reported along the southwest coast. The periods of maximum landings of the oil sardine (for example, 1965-1969: average annual yield =229 833 mt) were the periods of least abundance of the mackerel and the periods of maximum abundance of the mackerel (1970-1974: aay =93 009 mt; 1990-1995: aay =117 722 mt) were the years of least abundance of the oil sardine (Fig. 24). As both the species are exploited by the same gears, the decadal variations may not be due to the effect of fishing. Longhurst and Wooster (1990) considered that the landings of the small pelagics reflected their relative abundance, and hence, it is likely that the fluctuations in the landings were due to the fluctuations in their abundance. Hornell (1910) and Antony Raja (1969) suggested a density dependent inverse relationship between the oil sardine and the mackerel populations on a year to year basis. However, Longhurst and Wooster (1990) and Madhupratap *et al.*(1994) did not find such an inverse correlation between the annual landings of the two stocks. In the present study, comparison of the pooled data for every 5 year periods has revealed an inverse correlation (r = -0.818) between the landings of the two species. Hence, the density dependent inverse relationship may not be evident on a yearly basis, but relevant on a longer time scale.

Crucial role of the environment: Several environmental parameters are considered to be determinants of the abundance of the oil sardine and the mackerel. The onset of the monsoon (Panikkar, 1949; Longhurst and Wooster, 1990) and the intensity of the monsoon (Pradhan and Reddy, 1962; Antony Raja,1969; 1972), sunspot activity (Srinath,MS), surface temperature (Noble, 1972; Pillai, 1991), variations in the pattern of coastal currents (Murty,1965), sudden increase in salinity (Rao *et al.*,1973; Pillai,1991), dissolved oxygen (Pillai, 1993), sinking of the offshore waters (Ramamirtham and Jayaraman,1961), sea level (Longhurst and Wooster,1990), and the availability of nutrients in the coastal waters (Madhupratap *et al.*,1994) are some of the causative factors considered to play crucial roles in determining the abundance of the oil sardine along the southwest coast.

The date of onset of the southwest monsoon over the Kerala coast appears to play a crucial role in determining the oil sardine abundance. The monsoon normally sets by June 1 and spreads northward towards Karnataka. Correlating the date of onset of the monsoon and the oil sardine abundance for 1900-1986, Longhurst and Wooster (1990) observed that the major periods of high oil sardine abundance were the ones when the monsoon onset was tending towards earlier, rather than late onset dates. The period of the southwest monsoon onset is the period of the lowest sea level (580 mm) while the period of the northeast monsoon is the period of the highest sea level (720 mm). The above average sea level in March-April (>650 mm) is associated with high landings while the below average sea level (<600 mm) is associated with low landings. Longhurst and Wooster (1990) concluded that low sea level during March-April implied either early wind-driven upwelling or early intensification of the equatorward coastal current, which had the greatest influence on the size of the oil sardine stock in the subsequent fishing season.

Antony Raja (1972) opined that the success of sardine recruitment could be predicted by the intensity of rainfall during the weeks of spawning. He found a significant correlation between rainfall and the subsequent abundance of 0-group oil sardine. However, the relationship between rainfall and abundance has been questioned by several authors. Perhaps, an appropriate combination of the onset, duration and intensity of the monsoon is necessary for successful recruitment of the oil sardine. The sardine take advantage of the situation and time their spawning to coincide with the appropriate conditions during the southwest monsoon. Delays in the onset of the monsoon or weak/failure of the monsoon and a weak upwelling would ultimately affect the spawning, recruitment and the fishery. This is evident from the poor recruitment of youngones to the fishery whenever the rainfall during the spawning season is poor. However, Fernandez and Devaraj (1996 a,b) have reported distinctly different pattern of relationship between monsoon and spawning of the Indian mackerel and the Bombayduck.

The interannual pattern of oil sardine abundance showed a striking similarity to the 11 year cycle of the sunspot activity. Recently, the sunspot activity was the lowest in April, 1994. Interestingly, the oil sardine catch by all the gears operating along the west coast of India was the lowest (4 000 mt) in 1994, which was a major crash in the recent history of this fishery (Fig. 25). Sunspot activity will be again at its peak by the turn of this century when the oil sardine landings are expected to revive to a significant level, and promising trends are already discernible since 1995. Sun is the ultimate source of energy, which determines, *inter alia*, the productivity of the bioshpere. The various physical, oceanographic and meteorological factors including the rainfall, upwelling and nutrient seem to be influenced by the intensity of sunspot activity, directly or indirectly. Thus, there is no unanimity over the factor(s) determining the abundance. The consensus among most researchers is that the abundance is related to upwelling and the consequent abundance of the planktonic food. The chain of events - physical, chemical and biological, leading to upwelling and the consequent high productivity, seem to constitute the factors directly influencing the abundance of the stock (Fig.26).

Unique biological characteristics: Though represented by different taxonomic families, the small pelagics, as a group, are characterized by certain unique combination of biological features which include formation of large schools, feeding on plankton or nekton, fast growth rate, short longevity and late maturation in relation to $L\infty$ (at about 70% of $L\infty$). Based on the von Bertalanffy growth parameters for 15 species of small pelagics, 14 species of large pelagics and 25 species of demersal finfishes occurring along the Indian coast, Devaraj and Vivekanandan (MS) concluded that the annual growth coefficient (K) of the small pelagics (1.12) is considerably higher than that of the large pelagics (0.27) and the demersals (0.64). The small pelagics such as the sardines, whitebaits and mackerel feed mainly on plankton (Table 46). Occupying a low trophic level, these groups are advantageously placed to get continuous food supply. The growth and abundance of the pelagics are associated with the blooms of phytoplankton, dominated by the diatoms. Moreover, the pelagic stocks occupy mainly the epipelagic zone which is generally eutrophic, particularly in the organically rich upwelling areas.

Table 46. Main food of a few small pelagics.

Species	Main food
Sardinella longiceps	
Adults	Diatoms, dinoflagellates, tintinnids
Juveniles	Zooplankton
Postlarvae	Diatoms, other microalgae
S. gibbosa	Zooplankton
S. albella	Zooplankton
S. fimbriata	Zooplankton, phytoplankton
S. dayi	Crustacean & molluscan larvae, *Acetes*
Stolephorus devisi	Zooplankton, occasionally phytoplankton
S. bataviensis	Zooplankton
Coilia dussumieri	Zooplankton, *Acetes*
Rastrelliger kanagurta	
Adults	Zooplankton, phytoplankton
Juveniles	Zooplankton
Harpodon nehereus	Juveniles of Bombayduck, clupeids, prawns, *Squilla*

Devaraj and Vivekanandan (MS) observed that the small pelagics attain, on an average, 60% of their $L\infty$ at the end of I year of age and reach the maximum length in 2 years, whereas many large pelagics attain only about 28% of their $L\infty$ at the end of the I year of their life and the maximum length in 8 years. The main difference between the small pelagics and other groups is that the small pelagics are short lived and fast growing and are therefore subjected to severe recruitment fluctuations (Devaraj *et al.*,1994; Fernandez and Devaraj,1996a,b). The small pelagics attain maturity at a very late stage of their life (length at first maturity at 70% of L_∞) compared to that of the large pelagics and demersals (length at first maturity at 40% of L_∞). Most small pelagics including the oil sardine and the Indian mackerel delay their maturation in order to prolong their body growth for a comparatively longer duration in their life, than the large pelagics and the demersals.

Most species of small pelagics are either continuous spawners or have prolonged spawning periods, a typical characteristic of tropical fishes. While the peak spawning of the oil sardine takes place during the southwest monsoon season, that of the Indian mackerel, whitebaits, Bombayduck and the grenadier anchovy does not take place during the southwest monsoon months. The mackerel reproduce intermittently throughout the year along the southwest coast (Blindheim and Monstad,1976) and the larvae occur in all the months, but the broods released in the premonsoon season only become successful and enter the fishery (Devaraj *et al.*,1994). The whitebaits tend to congregate south of the region of the oil sardine fishery and pile up in the central Gulf of Mannar during the peak southwest monsoon (July-August), and then migrate back northwards along the entire Kerala coast (Anon.,1976). Due to these reasons, it appears that spawning of the mackerel and the whitebaits is not influenced by the monsoon and upwelling, in the same way as that of the oil sardine.

Causes for the increasing production trend

Notwithstanding their natural fluctuations, the production of the small pelagics in India has shown an increasing trend over the past five decades, primarily because of the introduction of new fishing technologies and diversification of fishing operations, for example, the steady growth of the purseseiner and ringseiner fleets and the popularization of motorization of the indigenous fishing craft, particularly along the southwest coast. As a result, not only the small pelagics in the grounds upto the 50 m isobath came to be optimally exploited, but the carangid stocks in grounds beyond the 50 m isobath began to be well exploited. The spurt in the development activities since the late eighties in the states of Gujarat and Maharashtra in the northwest and West Bengal and Orissa in the northeast also resulted in increasing production of small pelagics, besides others. While the development of infrastructure started quite early in the southern states, it started rather late in the northern states. The basic differences in the social perceptions and the traditional ethos of the coastal inhabitants also contributed to this delay in the development of infrastructure in the northern states.

Although commercial purseseining, which commenced in the southwest region in the latter half of the 1970's, rapidly increased the production of the small pelagics, it was at the expense of the very versatile gear *rampani*, traditionally used by most of the fishermen in Karnataka. The purseseine fishery resulted in the redeployment of labour, as the owners of the rampani, lured by the prospects of higher wages in mechanized fishing, enrolled themselves as labourers in the purseseiner fleet As the *rampanis* are shore- based in operation, they got deprived of the incoming shoals of small pelagics, obstructed by the purseseiners. Consequently, the rampani operators were forced to close down their entire fleet, to reconcile with the changed dispensation, albeit, with remonstrance and intersectoral conflicts. However, the shift from the traditional boatseine to the modern ringseine fishery in the southwest states of Kerala and Karnataka has been quite smooth as both are essentially in the hands of the small scale traditional fishermen. Some of the ringseines are one km long and they are operated mainly from the traditional motorized craft. Compared to the boatseines, the ringseines are more efficient, and there are complaints of mass destruction of juveniles of small pelagics, as the escapement is virtually negligible unlike the boatseine where it is about 50%. Therefore, ringseine operation is banned legally in some states (e.g., Kerala), but not yet implemented effectively. The enormity of the gear could be gauged from the proportion of the landings taken by this net in the southwest region alone in recent years. During 1991-95 it contributed 9% to the total marine fish production in the country, and 23 % to the total production in the southwest region. The emergence of the carangids in the ringseine fishery as a major item was possible because of the extension of fishing into distant grounds by the motorized boats. Small meshed (8 mm) ringseines enhanced the catches of whitebaits significantly. As a result, both carangid and whitebait catches became very prominent in the recent years.

The most obvious facts emerging from the foregoing analysis are summarized below:

(1) The current production of the small pelagics seems quite optimum, offering little scope for any conspicuous increase. After a certain level of fishing effort, the catch of small pelagics does not seem to bear any significant relation with effort, and therefore, the appropriate manipulation of fishing effort becomes a function of fisheries economics. As the small pelagic fisheries are already well developed, management measures could be left to the economics of the fishery for sustaining the catches on a long term basis. Development of suitable technologies for pelagic finfish breeding and seafarming assumes long term significance in the context of current plateauing of catches.

(2) The intrinsic nature of the annual fluctuations seems to be rooted in the interplay of the various fishery independent factors. The intractability of the nature and outcome of this interplay makes prediction unreliable. The fishery independent factors, believed to influence the production of the small pelagics, include sea surface level pressure and sunspot activity. A prediction model using sunspot activity and catch data in respect of the oil sardine and other small pelagics seems to be of great promise as a tool to forecast the yields in advance and thereby facilitate fleet deployment decisions.

(3) There are many instances of extreme gluts in the production of some of the small pelagics surpassing all predictions. On such occasions, fish move instantly from the sellers' markets to the sellers' yard with no buyers for want of proper infrastructure and logistics to process and store the surplus. This situation results in considerable withdrawal of fishing effort, with attendant starvation in the midst of plenty. Not only infrastructure for immediate transportation to the interior markets, but also networks of cold storages in the hinterlands as well as for conversion into value added products could alleviate this mysery, and offer atleast the minimum incentives for continuing the fishing operations. Although infrastructure in these sectors is much better developed today than in the past, there are still missing gaps requiring urgent steps.

(4) Motorization of traditional fishing craft coupled with the adoption of ringseining and purseseining has undoubtedly resulted in the uplifit of the social and economic status of fisherfolk considerably in recent years along the southwest coast. However, the indiscriminate increase in the size of the ringseiner and purseseiner fleets deploying very big seines with extremely small mesh sizes has resulted in the mass destruction of the prerecruits of small pelagics. Legal ban imposed on such nets is not implemented effectively owing mostly to social and political reasons. Use of multimesh nets with legal restriction on the mesh size may minimise this problem.

(5) The use of high opening fish trawls beyond the traditional fishing grounds indicates good scope of enhancing the production of carangids and ribbonfishes.

(6) The small pelagics stocks experience high rates of natural mortality, especially in the juvenile stages. It is, therefore, important to determine their stock-recruitment relationships to help formulate measures to ensure optimum spawning stocks.

(7) Management options based on stock assessments may differ from one stock to the other, and hence, their concurrent implementation is difficult in the multispecies small pelagics fisheries. Economic and social compulsions may also make inplementation of the recommended measures difficult. This situation calls for management objectives that would help maximise benefits from atleast the major individual stocks.

ECONOMIC PERFORMANCE OF FISHING UNITS ENGAGED IN PELAGIC FISHERIES

For the purpose of economic evaluation of the fishing units engaged in pelagic fishing, the small scale marine fisheries sector in India has been classified into three groups, viz., (1) the nonmotorized artisanal sector using indigenous (traditional) craft with traditional gears, (2) the motorized sector using indigenous (traditional) craft with outboard engines of <50 HP, and (3) the mechanized sector using inboard engines of 50 to 120 HP. The average initial investment in these fishing units has been worked out on the basis of the data collected for the sample units operating at selected centres in each region. Most of the outboard boats were old and their values were considered to be their resale values at the time of the observation. The gross investment on fishing equipments at current (1995) price thus calculated worked out to Rs 41 170 million comprising Rs 9 230 million in the artisanal sector, Rs 4 560 million in the motorized sector, Rs 23 880 million in the mechanized sector and Rs 3 500 million in the deepsea vessels. The manpower employed in active fishing alone was estimated as 1 million in marine fisheries. In the small scale fisheries sector, the average annual catch per unit ranged from 0.3 mt for a nonmechanized unit in the northwest coast to 280 mt for a purseseiner in the southwest coast.

Artisanal sector

The catamarans and the canoes are the most widely used traditional craft. The catamarans are in operation all along the Indian coast except in the northwest region. They require only low initial investment. The investment requirement of the catamarans operating gillnets varied from Rs 23 000 in the northeast to Rs 40 000 in the southeast regions (Table 47). The average annual catch of a catamaran unit with gillnet varies from 7 mt to 15 mt with gross earnings ranging from Rs 30 000 in the northeast coast to Rs 82 000 in the southwest coast (Table 48). The net profit ranged from Rs 4 000 to Rs 7 000 and the rate of return ranged from 23% to 35 %.

The economic performance of the nonmechanized plankbuilt canoes operating gillnets in the different coastal areas is given in Table 48. The average initial investment ranged from Rs 37 000 in the northwest coast to Rs 75 000 in the southwest coast, fetching annual gross earnings of Rs 48 000 to Rs 80 000. The net profit ranged from Rs 6 000 to Rs 10 000 with a rate of return of 25% to 32 %.

Table 47. Economic performance of traditional catamaran units operating gillnets in the different coastal areas of India during 1995.

Economic parameters	Catamaran with gillnets		
	Southwest	Southeast	Northeast
1. Average initial investment (Rs)	34,000	24,000	23,000
2. Average annual catch (mt)	15	13	7
3. Gross earnings (Rs)	82,000	60,000	30,000
4. Operating costs (Rs)	64,000	45,000	20,000
5. Fixed cost (Rs)	11,000	10,000	6,000
6. Total cost (Rs)	75,000	55,000	26,000
7. Net operating income (Rs)	18,000	15,000	10,000
8. Net profit (Rs)	7,000	5,000	4,000
9. Rate of return (%)	35	31	23
10. Payback period (years)	2.6	3.9	3.3

Table 48. Economic performance of nonmechanized plankbuilt canoes operating gillnets in the different coastal areas of India during 1995.

Economic parameters	Northwest	Southwest	Southeast	Northeast
1. Average initial investment (Rs)	45,000	75,000	60,000	37,000
2. Average annual catch (mt)	15	17.5	14.0	10
3. Gross earnings (Rs)	60,000	80,000	66,000	48,000
4. Operating costs (Rs)	38,000	50,000	40,000	28,000
5. Fixed cost (Rs)	16,000	20,000	20,000	14,000
6. Total cost (Rs)	54,000	70,000	60,000	42,000
7. Net operating income (Rs)	22,000	30,000	26,000	20,000
8. Net profit (Rs)	6,000	10,000	6,000	6,000
9. Rate of return (%)	30	27	25	32
10. Payback period (years)	3.1	3.8	3.5	2.7

Motorized sector

The economic performance of different types of motorized fishing units operating along the Indian coast is given in Table 49. The average initial investment of a motorized canoe operating gillnets in the northwest coast was about Rs 120 000. The annual gross earnings was Rs 150 000 as against the expenditure of Rs 135 000. The rate of return worked out to 28% and the payback period was 4.1 years. In the southwest coast, the ringseiners required the maximum investment of Rs 600 000 as against Rs 75 000 for the motorized canoes operating hooks & lines. The net profit (Rs 97 000) of the ringseiners was very high, which is reason enough for the proliferation of the ringseiners in the southwest coast. The operations of the motorized catamarans with gillnets, hooks & lines and canoes with gillnets in the southeast coast also indicated reasonably good profits. For these units, the rate of return ranged from 33% to 39% and the payback period of initial investment from 2.1 to 3.6 years. The average initial investment on a canoe with gillnet in the northeast coast was Rs 160 000, the rate of returns was 20% and the payback period of capital investment 6.7 years.

Table 49. Economic performance of motorized fishing units in different regions during 1995.

Economic parameters	North-west coast	Southwest coast			Southeast coast			North east coast
	Canoe + GN	Canoe + RS	Canoe + GN	Canoe + H&L	Catamaran GN	Catamaran H&L	Canoe + GN	Canoe + GN
1. Average initial investment(Rs x 10^3)	120	600	100	75	50	35	85	160
2. Annual catch (mt)	16.95	200	21	18.4	16.5	14.5	29	17
3. Gross eranings (Rs x 10^3)	150	675	108	150	76	82	138	118
4. Operating cost (Rs x 10^3)	115	402	69	109	54	65	84	70
5. Fixed cost (Rs x 10^3)	20	176	26	25	13	9	34	40
6. Total cost (Rs x 10^3)	135	578	95	134	67	74	118	110
7. Net operating income (Rs x 10^3)	35	273	39	41	22	17	54	48
8. Net profit (Rs x 10^3)	15	97	13	16	9	8	20	8
9. Rate of return (Rs x 10^3)	28	31	28	36	33	38	39	20
10. Payback period (years)	4.1	3.3	4.4	3.2	3.6	3	2.1	6.7

All major types of fishing units in the artisanal and motorized sectors are working on profit, not because of the higher levels of catch, but because of the good price. The nonmechanized fishing units are mostly operated as family enterprise in India. About 60% of the revenue is paid as wages to the crew or workers and most of them are owner-operators. Hence, the fishing income received by the owners is the net income plus the wages shared by the family labourers.

Mechanized sector

The operations of gillnetters are carried out all along the Indian coast whereas the operations of the dolnetters, purseseiners and pair trawlers are confined to certain regions. The purseseiners are operated only along the southwest coast, the dolnetters along the northwest coast and the pair trawlers along the coasts of the Gulf of Mannar and the Palk Bay in Tamilnadu.

The key economic indicators of mechanized boats operating gillnets in different coastal areas are given in Table 50. The average initial investment ranged from Rs 330 000 to Rs 450 000, fetching gross earnings of Rs 336 000 to Rs 520 000. The annual net profit ranged from Rs 34 000 to Rs 70 000 and the rate of return ranged from 28% to 38 %.

Table 50. Economic performance of mechanized gillnet units in the different regions of India during 1995.

Economic parameters	Northwest	Southwest	Southeast	Northeast
1. Average initial investment (Rs x 10^6)	0.330	0.450	0.350	0.400
2. Annual catch (mt)	22	18.0	23	29
3. Gross earnings (Rs x 10^6)	0.336	0.520	0.438	0.435
4. Annual operating cost (Rs x 10^6)	0.202	0.312	0.263	0.258
5. Fixed cost (Rs x 10^6)	0.100	0.138	0.105	0.125
6. Total cost (Rs x 10^6)	0.302	0.450	0.368	0.383
7. Net operating income (Rs x 10^6)	0.134	0.208	0.175	0.177
8. Annual net profit (Rs x 10^6)	0.034	0.070	0.70	0.052
9. Rate of return (%)	28	31	38	28
10. Payback period (years)	4.5	3.2	3.1	3.4

Dolnetters operating along the northwest coast of India required an average initial investment of Rs 320 000 (Table 51). The average annual revenue was Rs 454 000 and the annual net profit Rs 63 000. The rate of return worked out to 38 % and the payback period 3.2 years. The average investment of a purseseiner was about Rs 1 million and the average annual catch 280 t which realized a gross revenue of Rs 1.2 million. The operating cost was about Rs 580 000 and the fixed cost Rs 306 000, realizing a net earning of Rs 314 000 per year. The net income and the rate of return were high at Rs 314 000 and 46%, respectively (Table 51). The annual average gross earning of a pair trawler worked out to Rs 1.3 million as against the total annual cost of Rs 1.10 million, with a net profit of Rs 195 000 per year while the net income was Rs 195 000 and the rate of return 37 % (Table 51).

Table 51. Economic performance of mechanized boats operating purseseines, dolnets and pair trawls in different regions during 1995.

Economic parameters	Northwest	Southwest	Southeast
	Dolnetters	Purse seiners	Pair trawlers
1. Average initial investment (Rs x 10^3)	320	1000	900
2. Annual catch (mt)	51	280	150
3. Gross earnings (Rs x 10^3)	454	1200	1300
4. Operating cost (Rs x 10^3)	295	580	880
5. Fixed cost (Rs x 10^3)	96	306	225
6. Total cost (Rs x 10^3)	391	886	1105
7. Net operating income (Rs x 10^3)	159	620	420
8. Net income (Rs x 10^3)	63	314	195
9. Rate of return (%)	38	46	37
10. Payback period (years)	3.2	2.4	3.2

Gross earnings from small pelagics

The gross earnings from the small pelagics landings were estimated by conducting surveys in different landing centres along the Indian coast during 1995. It was estimated that the gross earnings amounted to Rs 22,157 million from 1 090 809 mt, at an average price of Rs 20/kg (Table 52). Though the small pelagics formed 48.1% of the total landings in 1995, the earnings accounted for only 30.0% of the total gross earnings. As the demersals included the high value penaeid shrimps, cephalopods and perches, the average price of the demersals was Rs 44/kg.

Table 52. Catch and gross earnings from the small pelagics in India during 1995.

(at landing centre level)

Group	Price (Rs/kg)	Total catch (mt)	Value (Rs in millions)
Clupeids	9	419865	3778.8
Bombayduck	11	92687	1019.6
Flyingfishes	22	4090	90.0
Ribbonfishes	11	73743	811.2
Carangids	46	196832	9054.3
Pomfrets	50	44593	2229.7
Mackerel	11	176830	1945.1
Seerfishes	55	45853	2521.9
Coastal tunas	10	15000	150.0
Barracudas	28	14679	411.0
Mullets	22	6498	143.0
Unicorn cod	17	139	2.4
Total small pelagics	20	1090809	22157.0
Total large pelagics	24	24177	586.0
Demersals	44	1152142	51257.0
Total marine landings	33	2267128	74000.0

MANAGEMENT

The basic feature of marine fisheries in India is the free access to the resources. Fisheries management in India is broadly governed by the Indian Fisheries Act 1897, The Marine Fishing (Regulation) Bill 1978 formulated after the Exclusive Economic Zone Act 1977 and the various maritime state Marine Fishing (Regulation) Acts enacted in the 1980s. While marine fisheries in the 12 nm territorial sea are within the direct governance of the respective states, those outside fall under the jurisdiction of the central government. The regulatory measures formulated under the above Acts include prohibition of destruction of fish stocks by explosives, poisons and certain gears; regulation of fishing in the nursery areas; control of indiscriminate fishing of broodstocks in their migratory phase; and, leasing or licensing of fishing rights, particularly in the inland waters. The competition for the resources, especially in the nearshore areas obligated the maritime state governments to intervene and formulate regulatory measures through legislation.

The management measures imposed at present by the maritime state governments fall under two categories: (i) seasonal closure of operation, and (ii) restriction of fishing areas. These are aimed mainly at safeguarding the interests of the small scale and medium scale fisheries. Presently, the operations of the mechanized vessels are suspended for 1 to 2 months in the west coast during the southwest monsoon season. Considering the influence of the monsoon in determining the abundance of the stocks of the small pelagics, suspension of purseseining and ringseining operated from the mechanized and motorized vessels is most relevant. The seasonal closure of fishing by the mechanized vessels is in vogue in the west coast for the past few years and such a measure has been introduced very recently in some areas in the east coast also. The decision on the closure is taken on a year-to-year basis by the maritime state governments, prior to or during the southwest monsoon season. Unlike the demersal fisheries, the fisheries for the small pelagics, even now, are mainly the activity of the artisanal fishers, operating nonmechanized or motorized craft. Considering the poor socioeconomic conditions of the artisanal fishers, the state governments have not imposed any restrictions on their fishing activities. Under the Marine Fishing Regulation Acts, promulgated by the maritime state governments, the areas of exclusive operation of the artisanal and mechanized vessels have been delineated. In general, the mechanized vessels are banned from operating in the inshore areas (extending to a distance of 5 to 10 km from the shore, earmarked exclusively for the artisanal craft). These Acts relating to the demarcation of the fishing areas, are beset with inherent weaknesses. First, there is no adequate surveillance system available with any state government to monitor the infringement of the rules of operations. Encroachment by the mechanized vessels in the areas demarcated for the artisanal fishers continues for more than a decade after the promulgation of the Acts. Second, demarcation of the fishing areas is basically meant for the protection of the interests of the artisanal fishers. In the process, the fishers operating the mechanized craft are at a disadvantage as they are denied exploitation of the much richer fishing grounds in the inshore waters. For instance, the biomass of the oil sardine is dense in the inshore waters, and hence, keeping the purseseine operators of Kerala and Karnataka outside the area of abundance of this stock is a disadvantage to them. It may, therefore, be necessary to modify the present regulations based on the feedbacks from various sectors so that all the stakeholders are benefited and the resources are exploited judiciously. Besides, regulations are imposed on fishing gears used in juvenile fisheries in the backwaters, estuaries and shallow inshore waters through licensing, mesh size regulation and minimum legal length at first capture. Among these, although the licensing of fishing gear engaged in the juvenile fisheries is in force in Kerala, its implementation has not been successful mainly owing to socioeconomic constraints, particularly the absence of alternative employment opportunities for the fishermen. Similarly, mesh size regulation could not be enforced due to the multispecies, multigear nature of marine fisheries and the socioeconomic reasons.

Some of these problems could be mitigated by a proper orientation of the management strategies. For example, (i) the rich whitebait, ribbonfish and carangid stocks along the southwest coast could be used as the basis for forcing the surplus purseseiners and midwater trawlers to operate in the offshore grounds beyond the 50 m isobath. (2) Some of the surplus shrimp trawlers using small codend mesh in the shallow grounds could be converted into fish trawlers with large meshes in much deeper grounds, both for the demersals and the pelagics. Others could be used in line or trap fisheries for the larger demersals in specific banks like the Kori Great Bank off Gujarat, Angiria Bank off Ratnagiri, Quilon Bank off Quilon, Wadge Bank off Kanyakumari and Pedro Bank in the Coromandel coast.

The small pelagic fisheries have reached a stage where, in addition to the regulation of fishing activity, it requires assistance from the governments for sustaining production. Satellite observations of the sea surface have progressed immensely consequent on India launching her own remote sensing satellites. The application of remote sensing for locating the areas of fish abundance has started in right earnest, which if proved to be successful, would be a great boon to the fishers. The satellite imageries provide continuous data on parameters such as sea surface temperature, chlorophyll, phytoplankton, sedimentation, coastal currents changes, etc. covering most of the EEZ. These data have several applications including mapping potential fishing zones (PFZs) and fisheries forecast on a short term as well as long term basis. Application of remote sensing for locating potential fishing zones will be extremely useful, particularly for the small pelagics fisheries. The National Remote Sensing Agency, Hyderabad is regularly receiving the imageries from the Indian satellites. These imageries are used to derive the SST values for the Indian seas, which are further interpreted to identify the PFZs. These identified PFZs are informed to the fishermen on a day-to-day basis through newspapers, television and radios by the maritime state governments and the Central Marine Fisheries Research Institute network of 13 research centres and 28 field centres. Groundtruth surveys and feedback information are very important components of remote sensing to verify the forecast. The CMFRI has reported substantial increase in fish catch in the PFZs when compared to the non PFZs. The abundance of the oil sardine is related to high SST and high dissolved oxygen concentration. The forecasts of the PFZs have been found to be more valid in the case of small pelagic stocks than of the demersal stocks. Although only a beginning has been made, the results do indicate the possible future applications of satellite derived chlorophyll and SST distribution for the purpose of directing and controlling fishing effort. There are still several intricacies that need to be addressed immediately for the meaningful application of remote sensing to marine fisheries: (i) There is considerable delay in data processing and distribution to the endusers, namely, the fishermen. (ii) The fishers contend that the information on the PFZs would be useful only if names of the dominant fish groups in the PFZs are known. Though identification of fish groups in the PFZs is not possible with the help of the present satellite imageries, the technology is being further upgraded to cater to these specific needs. (iii) An intricate question is the confidence the fishers seek to ensure lucrative yield from the PFZs. The solution shall depend on how fast the algorithm of prediction will be perfected.

The unpredictable nature of the major stocks of the small pelagics has made their markets highly vulnerable to price fluctuations. Most of the small pelagics are considered to be low value fish. The price of oil sardine, lesser sardines, *Thryssa* spp, whitebaits, grenadier anchovy and Bombayduck is Rs 10/kg in the landing centres. However, the price varies according to regional preferences. *Hilsa* spp are a delicacy in West Bengal and fetch more than Rs 70/kg. The Indian mackerel are preferred in the southwest coast, where they are priced at around Rs 25/kg. The sardines, whitebaits and Indian mackerel together with rice form the staple food of the coastal population in Kerala, Karnataka and Goa. The Bombayduck and grenadier anchovy form a regular item in the food of the coastal population in Maharashtra. The dependence of a large number of artisanal fishers and the coastal population on the small pelagics underlines the socioeconomic importance of these low value fishes. However, the absence of a proper distribution system and the lack of optimum holding facilities at the landing sites are the major hurdles in the proper utilization of these fisheries. In most instances, the catch should be sold immediately, for whatever price offered, or risk a total loss. The only other option is to turn it into low value dried products. Major quantities of small pelagics are consumed fresh and on days of glut, the surplus is cured and sundried. Almost the entire landings of the small pelagics are consumed by the coastal population and due to their low value and high transportation cost, they seldom reach the interior parts of India. The maritime state governments should render assistance in channelling their distribution by identifying centres where demand could be stimulated, undertake physical improvements to wholesale and retail outlets and design mobile retail equipments. Considerable knowledge exists in the country on product development for the affluent markets. Small processing plants could be established in specific locations. High priority should be given to reduce postharvest losses and work in this direction should include the use of low cost energy sources in fish processing (for e.g., wind-driven ice plants, improved solar driers etc). The existing networks of fishers' cooperatives should be strengthened as a means of meeting the fishermen's economic needs of supplies and credits at low cost and profitable market outlets for their products.

RECOMMENDATIONS

1. The most prominent feature of the pelagic fisheries in general and the small pelagics in particular is their extreme annual fluctuations. The causative factors need to be identified through real time oceanographic data collected in relation to catches and the application of mathematical models to such data to attempt prediction.

2. Spawning of the various species of the small pelagics as a whole is intense throughout the year: some of them spawn intensely during the immediate premonsoon, some during the monsoon periods and others during the postmonsoon season. Therefore, spawning season cannot be used as the basis for banning fishing in any part of the year. However, fishing could be suspended in part or in full during the southwest monsoon season as is in vogue in states like Maharashtra, Karnataka and Kerala, as a means of reducing fishing effort to attain near optimum to optimum levels.

3. Further proliferation of ringseiners needs to be checked urgently.

4. As the small pelagic fisheries constitute the mainstay of the economy of the small fishermen, the areas close to the shore upto a distance of 5 km should be exclusively earmarked for fishing by the artisanal fishermen

5. Surveys of spawning population and stock-recruitment relationships need to beundertaken to bridge the gaps in our knowledge of the biology of the small pelagics.

6. Tagging and recovery studies on the oil sardine and the mackerel need to be undertaken on a regular basis.

7. Infrastructure facilities for storage and transportation of the catches to the interior markets require further strengthening to handle surplus catches of small pelagics.

8. Close monitoring of domestic, agriculture and industrial discharges into the nearshore areas is essential to safeguard the inshore stocks from pollution.

9. The maps giving predictions of the potential fishing zones based on remote sensing of sea surface features need to reach the active fishermen well in time to assist them in their fishing operations.

10. Reassessment of the marine fishery potential needs to be carried out on a regular quinquennial basis to determine changes in stock sizes.

REFERENCES

Anon. 1974. Survey results. 1972/73. *UNDP/FAO Pelagic Fishery Project* (IND 69/593) *Progress Report*, No. 6, 141 pp.

Anon. 1976. FAO/UNDP Pelagic Fishery Project Report No. 18. Plankton, fish eggs and larval studies. p. 1-22.

Annigeri, G.G., K. Narayana Kurup, M. Kumaran, G. Madan Mohan, Luther, P.N. Radhakrishnan Nair, Prathibha Rohit, G.M. Kulkarni, J.C. Gnanamuthu and K.V. Narayana Rao. 1992. Stock assessment of oil sardine, *Sardinella longiceps* Val., off west coast of India. *Indian J. Fish.*, 39(3,4): 125-135.

Antony Raja, B.T. 1967. Length weight relationship in the oil sardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 14(1&2): 150-170.

Antony Raja, B.T. 1969. The Indian oil sardine. *Bull. Cent. Mar. Fish. Res. Inst.*, 16: 1-128.

Antony Raja, B.T. 1970. Estimation of age and growth of the Indian oil sardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 17: 26-42.

Antony Raja, B.T. 1972. A forecast for the ensuing oil sardine fishery. *Seafood Exp. J.*, 4(10): 27-33.

Antony Raja, B.T. 1973. Forecasting the oil sardine fishery. *Indian J. Fish.*, 20(2): 599-609.

Balan, V. 1961. Some observations on the shoaling behaviour of the oil sardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 8(1): 207-221.

Balan, V. 1968. Studies on the age and growth of the oil sardine *Sardinella longiceps* Val. by means of scales. *Indian J. Fish.*, 11A (2) (1964): 663-686.

Balan, V. and R. Reghu. 1979. The Indian oil sardine. *Mar. Fish. Infor. Serv. T&E Ser.* No. 14, p. 7-13.

Banerji, S.K. 1973. An assessment of the exploited pelagic fisheries of the Indian Seas. *Proc. Symp. Liv. Res. Seas around India,* Central Marine Fisheries Research Institute, Cochin, p. 114-135.

Bapat, S.V., S.K. Banergi and D.V. Bal. 1952. Observations on the biology of *Harpodon nehereus* (Hamilton). *J. Zool. Soc. India*, 3(2): 341-356.

Bapat, S.V. 1970. The Bombay Duck *Harpodon nehereus* (Ham.). *Bull. Cent. Mar. Fish. Res. Inst.*, 21: 1-66.

Basheeruddin, S. and K.N. Nayar. 1961. A preliminary study of the juvenile fishes of the coastal waters off Madras city. *Indian J. Fish.*, 8: 169.

Bensam, P. 1968. Growth variations in the Indian oil sardine *Sardinella longiceps* Valenciennes. *Indian J. Fish.*, 11A (2) (1964): 699-708.

Biradar, R.S. 1985. Population dynamics of Indian oil sardine and Indian mackerel off the southwest coast of India. *Dissertation Univ. of Bergen*, Norway, 42 pp.

Biradar, R.S. 1989. Stock assessment of Bombay duck (*Harpodon nehereus*) off Maharashtra, India. *Papers prepared by participants at FAO/DANIDA/ICR national follow-up Training Course in Fish stock assessment, Cochin, India,* from 2 to 28 November, 1987. FI: GCP/INT/392/DEN/1 1989.

Blindheim, J. and T. Monstad. 1976. A synopsis of the information pelagic resources off the southwest coast of India. *UNDP Pelagic Fish. Proj. Prog. Rep.* 18: 1-31.

Chacko, P.I. 1949. Food and feeding habits of the fishes of the Gulf of Mannar. *Proc. Indian Acad. Sci.* 29 : 83.

Chakraborty, S.K. 1990. Fishery, age, growth and mortality estimates of *Trichiurus lepturus* Linnaeus from Bombay waters. *Indian J. Fish.*, 37(1): 1-7.

Chidambaram, K. and R.S. Venkataraman. 1946. Tabular statements on the natural history of certain marine food fishes of the Madras Presidency - West coast. Govt. Press, Madras: 1-26.

Chidambaram, K. 1950. Studies on length frequency of the oil sardine, *Sardinella longiceps* Cuv. & Val. and on certain factors influencing their appearance on the Calicut coast of Madras Presidency. *Proc. Indian Acad. Sci.* 31 B. pp. 252-286.

Deshmukh and A. Kurian.1980. The Bombay Duck. *Mar. Fish. Infor. Serv. T&E Ser.*, No. 20: 1-9.

Devanesan, D.W. and V. John. 1940. On the natural history of *Rastrelliger kanagurta* (Russell) with special reference to its spawning season and eggs. *Curr. Sci.*, 9(10): 462-464.

Devanesan, D.W. 1943. A brief investigation into the causes of the fluctuations of the annual fishery of the oil sardine of Malabar, *Sardinella longiceps*, determination of its age and an account of the discovery of its eggs and spawning ground. *Madras Fish. Bull.* No. 28 (Report No. 1), p. 1-24.

Devanesan, D.W. and K. Chidambaram 1948. The common food fishes of Madras Presidency, Govt. Press, Madras.

Devaraj, M. 1979. Management problems in Indian mackerel and Indian oil sardine fisheries on the southwest coast of India. *Workshop on Ocean Management, Central Institute of Fisheries Education.* 4-5th April 1979, Bombay, India. *Abstract in* : India Today and Tomorrow.

Devaraj, M. 1983a. Maturity, spawning and fecundity of the king seer, *Scomberomorus commerson* (Lacepede) in the seas around Indian Peninsula. *Indian J. Fish.*, 30 (2): 203-230.

Devaraj, M. 1983b. Fish population dynamics, Course manual. *Bulletin of the Central Institute of Fisheries Education*, Bombay, No. 3(10) 83, 98 pp.

Devaraj, M. 1986. Maturity, spawning and fecundity of the streaked seer, *Scomberomorus lineolatus* (Cuvier & Valenciennes) in the Gulf of Mannar and Palk Bay. *Indian J. Fish.*, 33(3): 293-319.

Devaraj, M. 1987a. Maturity, spawning and fecundity of the spotted seer, *Scomberomorus guttatus* in the Gulf of Mannar and Palk Bay. *Indian J. Fish.*, 34(1): 48-77.

Devaraj, M. 1987b. The natural cause and effect theory of fish abundance as the basis for human intervention in Indian marine fisheries. In: Advances in aquatic biology and fisheries, Prof. N.B. Nair felicitation volume, 251-256.

Devaraj, M., I. Fernandez and S.S. Kamat. 1994. Dynamics of the exploited Indian mackerel *Rastrelliger kanagurta* stock along the southwest coast of India. *J. mar. biol. Ass. India,* 36(1&2): 110-151.

Fernandez, I. and M. Devaraj. 1996a. Dynamics of the Bombayduck (*Harpodon nehereus*) stock along the northwest coast of India. *Indian J. Fish.*, 43(1): 1-11.

Fernandez, I. and M. Devaraj. 1996b. Dynamics of the gold-spotted grenadier anchovy (*Coilia dussumieri*) stock along the northwest coast of India. *Indian J. Fish.*, 43(1): 27-38.

Fischer, W. and G. Bianchi. 1984. FAO species identification sheets for fishing purposes. FAO, Rome, 335 pp.

George, K.C. and S.K. Banerji. 1968. Age and growth studies on the Indian mackerel *Rastrelliger kanagurta* with special reference to length frequency data collected from Cochin. *Indian J. Fish.*, 11(2): 621-638.

George, P.C., B.T. Antony Raja and K.C. George. 1977. Fishery resources of the Indian Economic Zone. *Souvenir*, Silver Jubilee, Integrated Fisheries Project, Cochin, India, Oct., 1977: 79-116.

Gopalan, U.K. 1967. Studies on the maturity and spawning of silver pomfret, *Pampus argenteus* in the Arabian Sea. *Bull. National Inst. Sci., India,* 38: 785-796.

Haywood, K. 1982. Purse seiners at Karnataka. Microcomputers employed to study the options at a fishery. *Fishing News International, September 1982*, 21(9): 26-27.

Hornell, J. 1910. Report on the results of a fishery cruise along the Malabar coast and to the Laccadive Islands in 1908. *Madras Fish. Bull.* 4 : 71.

Hornell, J. and M.R. Nayudu. 1924. A contribution to the life history of the Indian oil sardine with notes on the plankton of the Malabar coast. *Madras Fish. Bull.* XVII. No.5, pp. 129-197.

Jacob, P.K. 1949. The bionomics of ribbonfishes (*Trichiurus* spp.) and their fishery on the west coast of Madras Province. *J. Bombay Nat. Hist. Soc.*, 46(2): 261-264.

James, P.S.B.R. 1967. The ribbonfishes of the family Trichiuridae of India. *Mar. biol. Ass. India, Memoir I.* 226 pp.

James, P.S.B.R., T.R. Chandrasekhara Gupta and S.L. Shanbhogue 1983. Some aspects of the biology of the ribbonfish *Trichiurus lepturus* Linnaeus (1978). *J. Mar. Biol. Ass. India*, 20(1&2): 120-137.

James, P.S.B.R., P.P. Pillai, A.A. Jayaprakash and N.G.K. Pillai 1992. Tunas and billfishes. In: Monsoon fisheries of the west coast of India. *CMFRI Bulletin*, 45: 56-84.

Khan, M.Z. 1982. A probable nursery ground of silver pomfret *Pampus argenteus* off Nawabunder (Gujarat). *Indian J. Fish.*, 29: 257-261.

Khan, M.Z. 1985. Observations on the fishery of Bombayduck, *Harpodon nehereus* (Hamilton) along the Saurashtra coast. *Indian J. Fish.*, 32(4): 431-438.

Khan, M.Z., K.N. Kurup and A.P. Lipton. 1992. Status of Bombay duck *Harpodon nehereus* (Ham.) resource off Saurashtra coast. *Indian J. Fish.*, 39(3,4): 235-242.

Khan, M.Z., M. Kumaran, A.A. Jayaprakash, K.S. Scariah, V.M. Deshmukh and M.H. Dhulkhed. 1992. Stock assessment of pomfrets off west coast of India. *Indian J. Fish.*, 39: 249-259.

Kurian, A. 1988. Equilibrium state of the fishery for the Bombayduck *Harpodon nehereus* (Ham). An outcome of production ecology and exploitation interactions. *Proc. Symp. on living resources of Indian seas*, 225-234.

Kurian, A. 1989. Application of synthetic models for the assessment of Bombayduck, *Harpodon nehereus* (Ham.) stock off the Maharashtra coast. *Indian J. Fish.*, 36(4): 275-283.

Kurian, A. and K.N. Kurup. 1992. Stock assessment of Bombay duck *Harpodon nehereus* (Ham.) off Maharashtra coast. *Indian J. Fish.*, 39(3,4): 243-248.

Longhurst, A.R. and D. pauly. 1987. Ecology of tropical oceans. Academic Press, San Diego, 407 pp.

Longhurst, A.R. and W.S. Wooster. 1990. Abundance of oil sardine (*Sardinella longiceps*) and upwelling on the southwest coast of India. *Can. J. Fish. Aquat. Sci.*, 47: 2407-2419.

Luther, G. 1973. Observation on the biology and fishery of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier) from Andaman Islands. *Indian J. Fish.*, 20(2): 425-447.

Luther, G., K.V. Narayana Rao, G. Gopakumar, C. Muthiah, N. Gopalakrishna Pillai, Prathibha Rohit, K. Narayana Kurup, S. Reuben, P. Devadoss, G. Syda Rao, P. Sam Bennet and N.S. Radhakrishnan. 1992. Resource characteristics and stock assessment of whitebaits. *Indian J. Fish.*, 39(3,4): 152-168.

Madhupratap, M., S.R. Shetye, K.N.V. Nair and R. Sreekumaran Nair. 1994. Oilsardine and Indian mackerel: Their fishery problems and coastal oceanography. *Curr. Sci.*, 66(5) : 340-348.

Menon, M.D. and K.C. George. 1975. White-bait resources of the southwest coast of India. *Sea food export Journal*, 7(1): 1- 14.

Murty, A.V.S. 1965. Studies on the surface mixed layer and its associated thermocline off the west coast of India and the inferences thereby for working out a prediction system of the pelagic fisheries of the region. *Indian J. Fish.*, 12(1): 118-135.

Murty, A.V.S. and M.S. Edelman. 1970. On the relation between the intensity of the southwest monsoon and the oil sardine fishery of India. *Indian J. Fish.* 13: 142-149.

Nair, R.V. 1952. Studies on the revival of the Indian oil sardine fishery. *Proc. Indo-Pacif. Fish. Coun.*, 4: 115-129.

Nair, R.V. and R. Subrahmanyan. 1955. The diatom *Fragilaria oceanica* Cleve, an indicator of abundance of the oil sardine *Sardinella longiceps* Cuv. & Val. *Curr. Sci.* 24 : 41.

Narasimham, K.A. 1976. Some observations on the biology of the ribbonfish *Eupleurogrammus muticus* (Gray). *Indian J. Fish.* (1974), 21(2): 479-494.

Narasimham, K.A. 1978. Age and growth of the ribbonfish *Trichiurus lepturus* Linnaeus. *Indian J. Fish.*, 23(1&2): 174-183.

Narasimham, K.A. 1983. On the fishery, mortality rates and yield per recruit of the ribbonfish *Trichiurus lepturus* Linnaeus. *Indian J. Fish.*, 30(1): 99-109.

Noble, A. 1965. The food and feeding habits of the Indian oil sardine *Sardinella longiceps* Valenciennes at Karwar. *Indian J. Fish.,* 12 A (1): 77-86.

Noble, A. 1972. Surface temperature and its relation to the duration of mackerel fishery at Karwar. *Indian J. Fish.*, 19: 167-170.

Noble, A., G. Gopakumar, N. Gopalakrishna Pillai, G.M. Kulkarni, K. Narayana Kurup, S.Ruben, M. Sivadas and T.M. Yohannan. 1992. Assessment of mackerel stock along the Indian coast. *Indian J. Fish.*, 39(3,4): 119-124.

Panikkar, N.K. 1949. A survey of the pelagic fisheries of the world. The biology of pelagic fishes. *Proc. IPFC,* 1: 123-132.

Pati, S. 1982. Studies on the maturation, spawning and migration of silver pomfret, *Pampus argenteus* (Euphrasen) from Bay of Bengal. *Matsya*, 8: 12-22.

Pillai, V.N. 1991. Salinity and thermal characteristics of the coastal waters off southwest coast of India and their relation to major pelagic fisheries of the region. *J. Mar. Biol. Ass. India*, 33 (1&2): 115-133.

Pillai, V.N. 1993. Variations in dissolved oxygen content of coastal waters along southwest coast of India in space and time. *Indian J. Mar. Sci.*, 22 : 279-282.

Prabhu, M.S. 1955. Some aspects of the biology of the ribbonfish, *Trichiurus haumela* (Forskal). *Indian J. Fish.*, 2(1): 132-163.

Prabhu, M.S. and M.H. Dhulkhed. 1970. The oil sardine fishery of the Mangalore zone during the season 1963-64 to 1967-68. *Indian J. Fish.*, 17: 57-75.

Prabhu, M.S. and G. Venkataraman. 1970. Mackerel and oil sardine tagging programme 1966-67 to 1968-69. *Bull. Cent. Mar. Fish. Res. Inst.*, No. 17, 38 pp.

Pradhan, L.B. 1956. Mackerel fishery of Karwar. *Indian J. Fish.*, 3(1): 141-185.

Pradhan, L.B. and C.V.G. Reddy. 1962. Fluctuations in mackerel landings at Calicut in relation to hydrographical factors. *Indian J. Fish.*, 9(1): 200-209.

Radhakrishnan, N. 1965. Oil sardine investigations at Karwar. *Indian J. Fish.*, 12A (1): 99-117.

Ramamirtham, C.P. and R. Jayaraman. 1961. Hydrographic features of the continental shelf waters off Cochin during 1958 and 1959. *J. mar. biol. Ass. India*, 2(2): 199-207.

Rao, D.S., C.P. Ramamirtham and T.S. Krishnan 1973. Oceanographic features and abundance of the pelagic fisheries along the west coast of India. *Proc. Symp. Living Resources of the Seas around India, CMFRI Spl. Publ.*, 400-413.

Rao, G.S. 1988a. Some aspects of biology of *Stolephorus devisi* (Whitley) from Mangalore area, Dakshina Kannada. *J. mar. biol. Ass. India*, 30: 28-36.

Rao, G.S. 1988b. Some aspects of biology of *Stolephorus bataviensis* from Mangalore area, Dakshina Kannada. *J. mar. biol. Ass. India*, 30: 107-113.

Rao, K.S. 1967. Food and feeding habits of fishes from trawl catches in the Bay of Bengal with observation on diurnal variation in the nature of the food. *Indian J. Fish.*, 11(1): 277-314.

Rao, K.V., K.V. Sekharan and M.J. Pradhan. 1965. On the mackerel fishery of the Mangalore area during the period 1957-1961. *Indian J. Fish.*, 9(2): 653-678.

Reuben, S., H.M. Kasim, S. Sivakami, P.N. Radhakrishnan Nair, K.N. Kurup, M. Sivadas, A. Noble, K.V. Somasekharan Nair and S.G. Raje. 1992. Fishery, biology and stock assessment of carangid resources from the Indian seas. *Indian J. Fish.*, 39(3,4): 195-234.

Sam Bennet, P. 1968. A method for predicting the Indian oil sardine fishery. *Symposium on the Living Resources of the Seas around India.* Abstracts, 8.

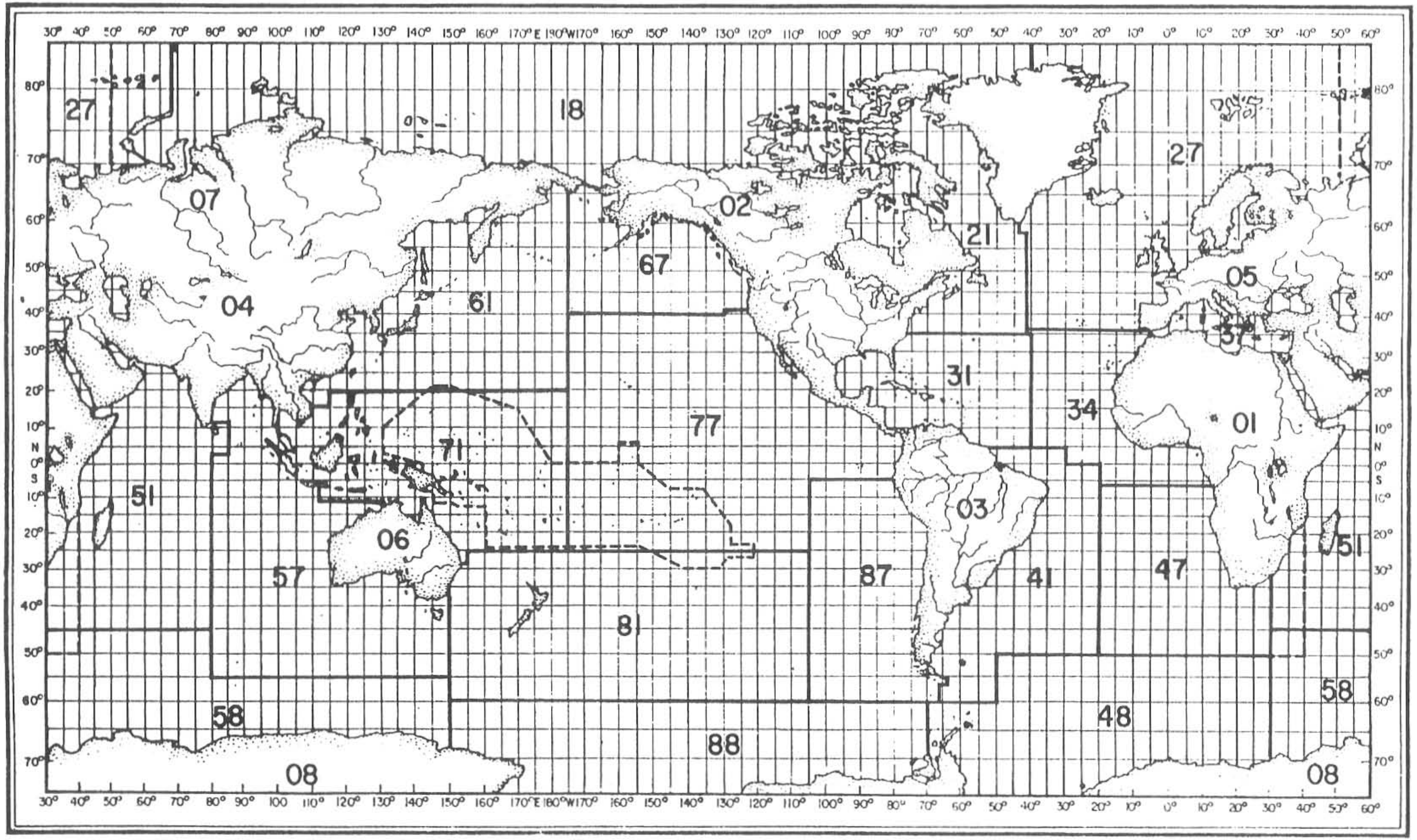


Fig. 1. Major fishing areas for statistical purposes.

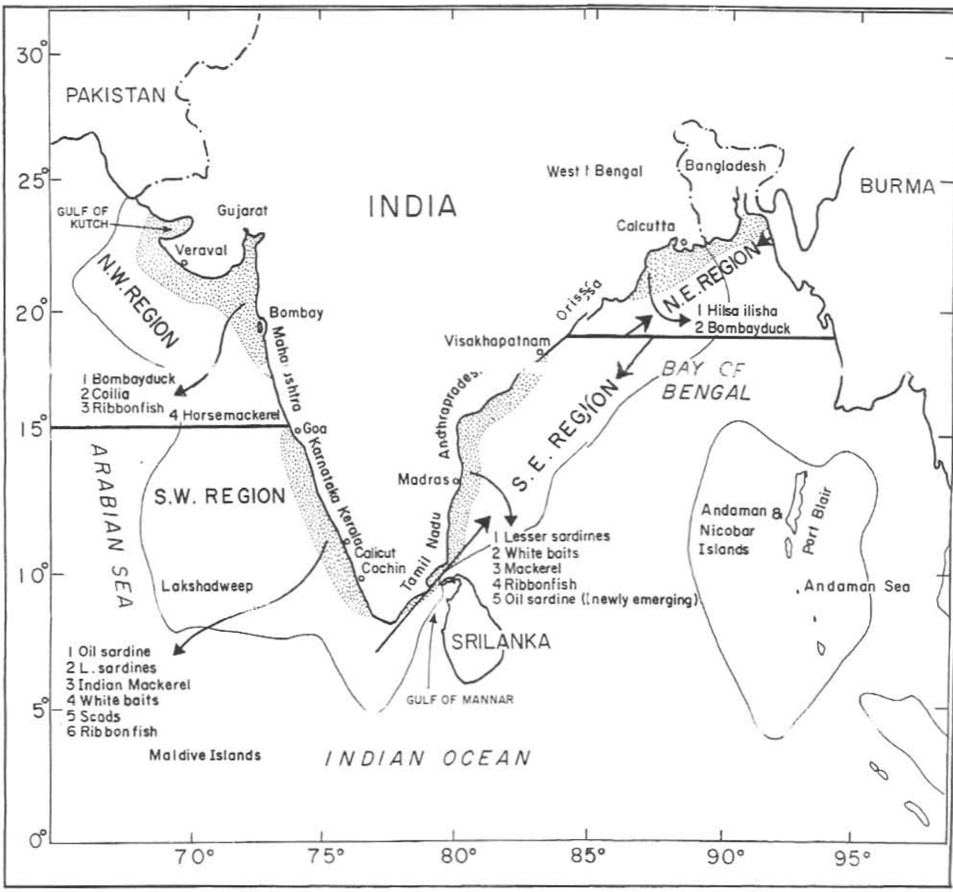


Fig. 2. Exclusive Economic Zone of India.

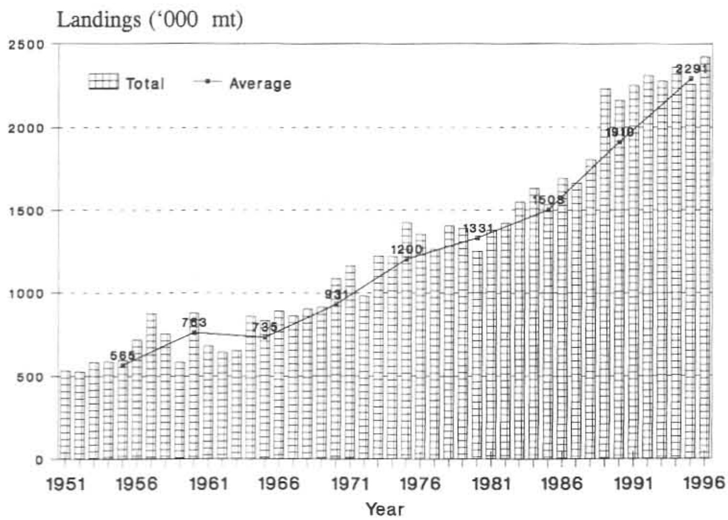
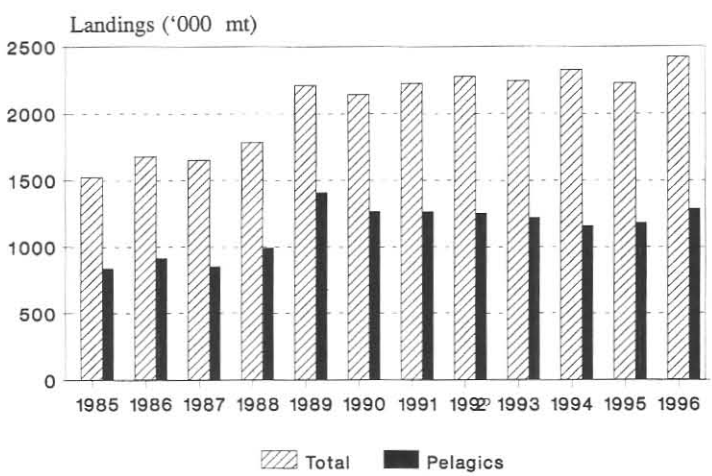
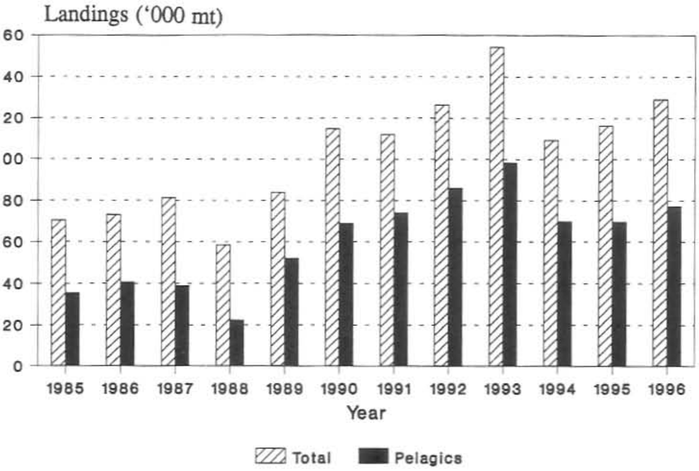


Fig. 3. All India marine fish landings: total & 5 year average during 1951-1996.



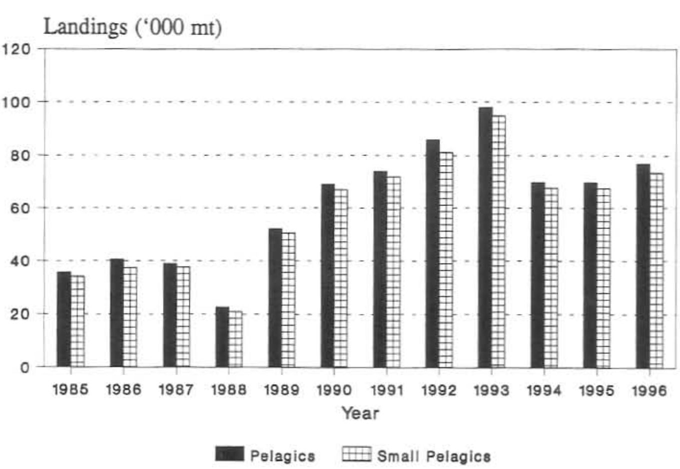
Avg. An. total = 2,058,695 mt
Avg. An. pelegic = 1,133,237 (55% of total)

Fig. 4. All India landings of total marine and pelagics during 1985-1996.



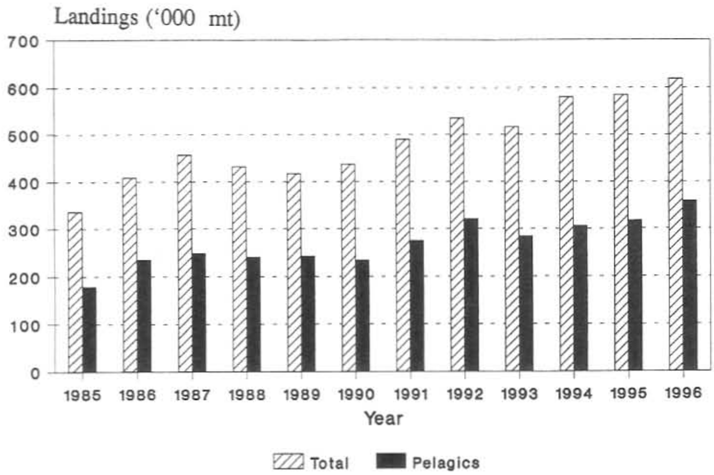
Avg. An. total= 102,339 mt
Avg. An. pelagic= 60,976 mt (59.6% of total)

Fig. 5. Northeast landings of total marine and pelagic during 1985-1996.



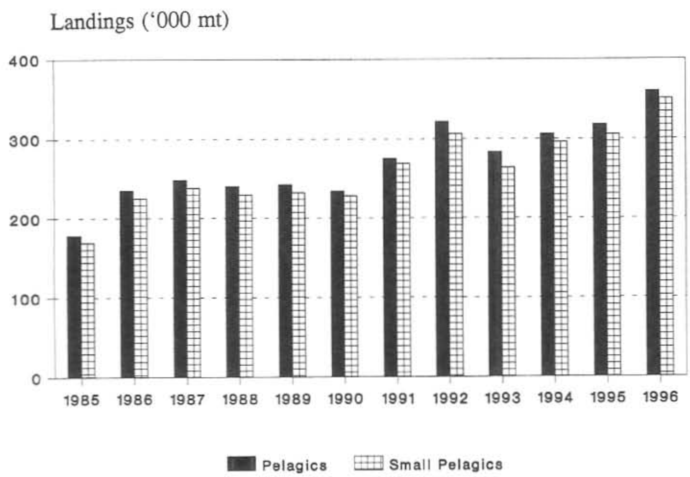
Avg. An. pel=60,976 mt
Avg. An. small pelagic= 58,519 mt (96% of total)

Fig. 6. Northeast landings of pelagics and small pelagics during 1985-1996.



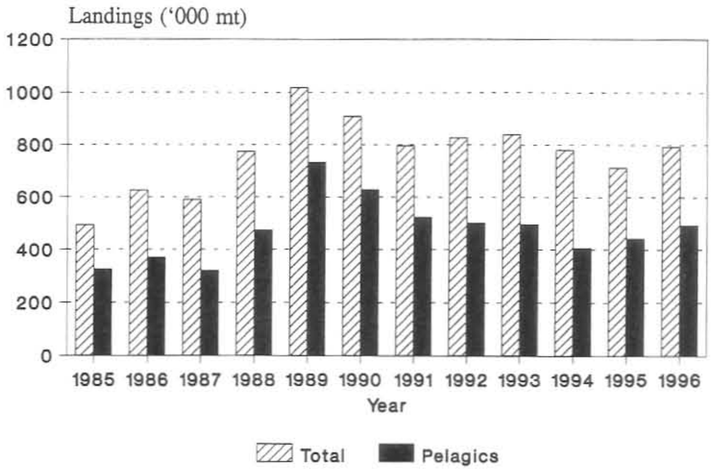
Avg. An. total= 483,911 mt
Avg. An. pelagic= 269,690 mt (55.7% of total)

Fig. 7. Southeast landings of total marine and pelagics during 1985-1996.



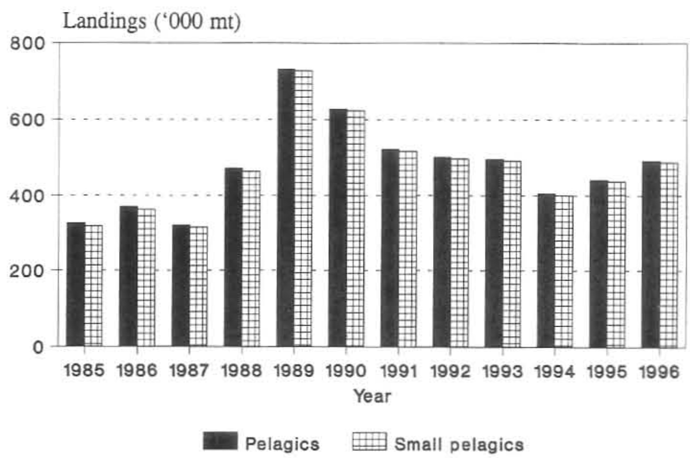
Avg. An. total= 269,690 mt
Avg. An. pelagic= 259,138 mt (96.1% of total)

Fig. 8. Southeast landings of pelagics and small pelagics during 1985-1996.



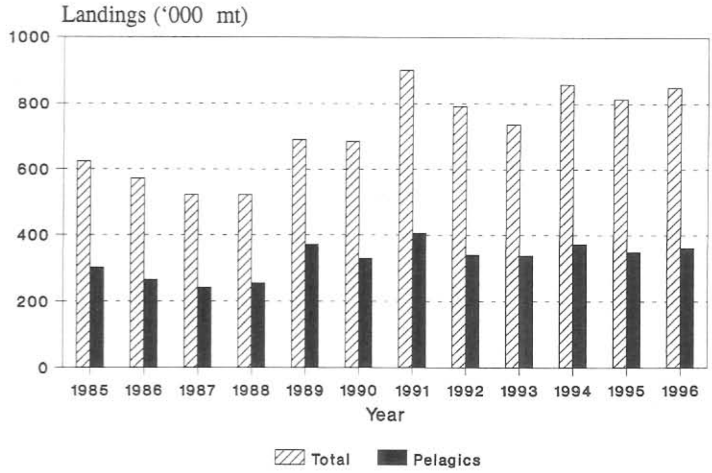
Avg. An. total= 762,704 mt
Avg. An. pelagic= 475,495 mt (562.3% of total)

Fig. 9. Southwest landings of total marine and pelagics during 1985-1996.



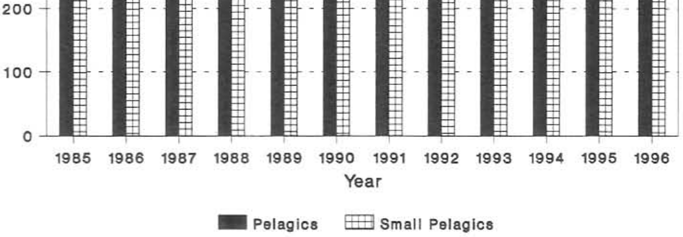
Avg. An. pelagic= 475,495 mt
Avg. An. small pelagic= 469,897 mt (98.8% of total)

Fig. 10. Southwest landings of pelagics and small pelagics during 1985-1996.



Avg. An. total= 713,199 mt
Avg. An. pelagic= 327,348 mt (45.9% of total)

Fig. 11. Northwest landings of total marine and pelagics during 1985-1996.



Avg. An. pelagic= 327,348 mt
Avg. An. small pelagic= 304,792 mt (93.1% of pelagic)

Fig. 12. Northwest landings of pelagics and small pelagics during 1985-1996.

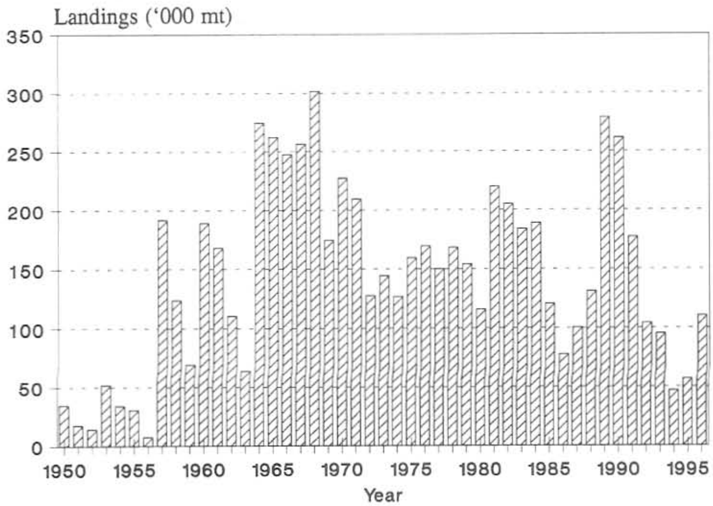


Fig. 13. All India oilsardine landings during 1950-1996.

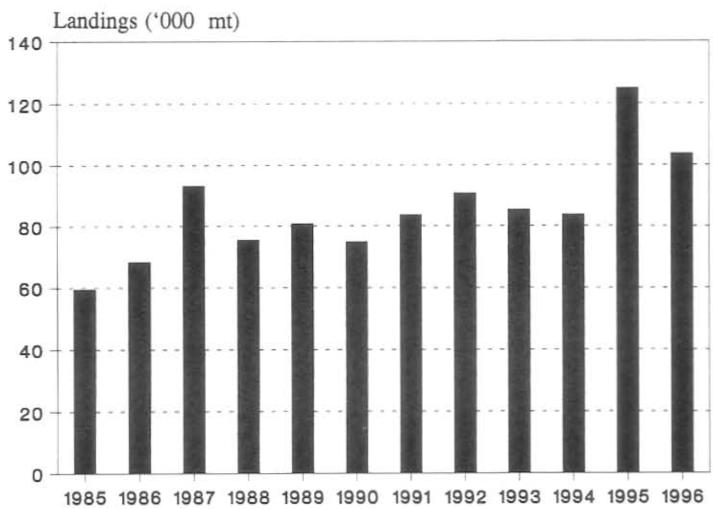


Fig. 14. All India lesser sardine landings during 1985-1996.

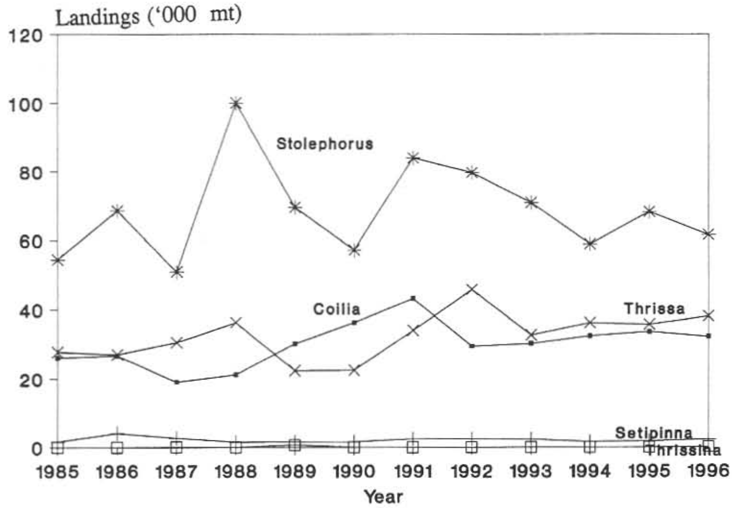


Fig. 15. All India landings of anchovies during 1985-1996.

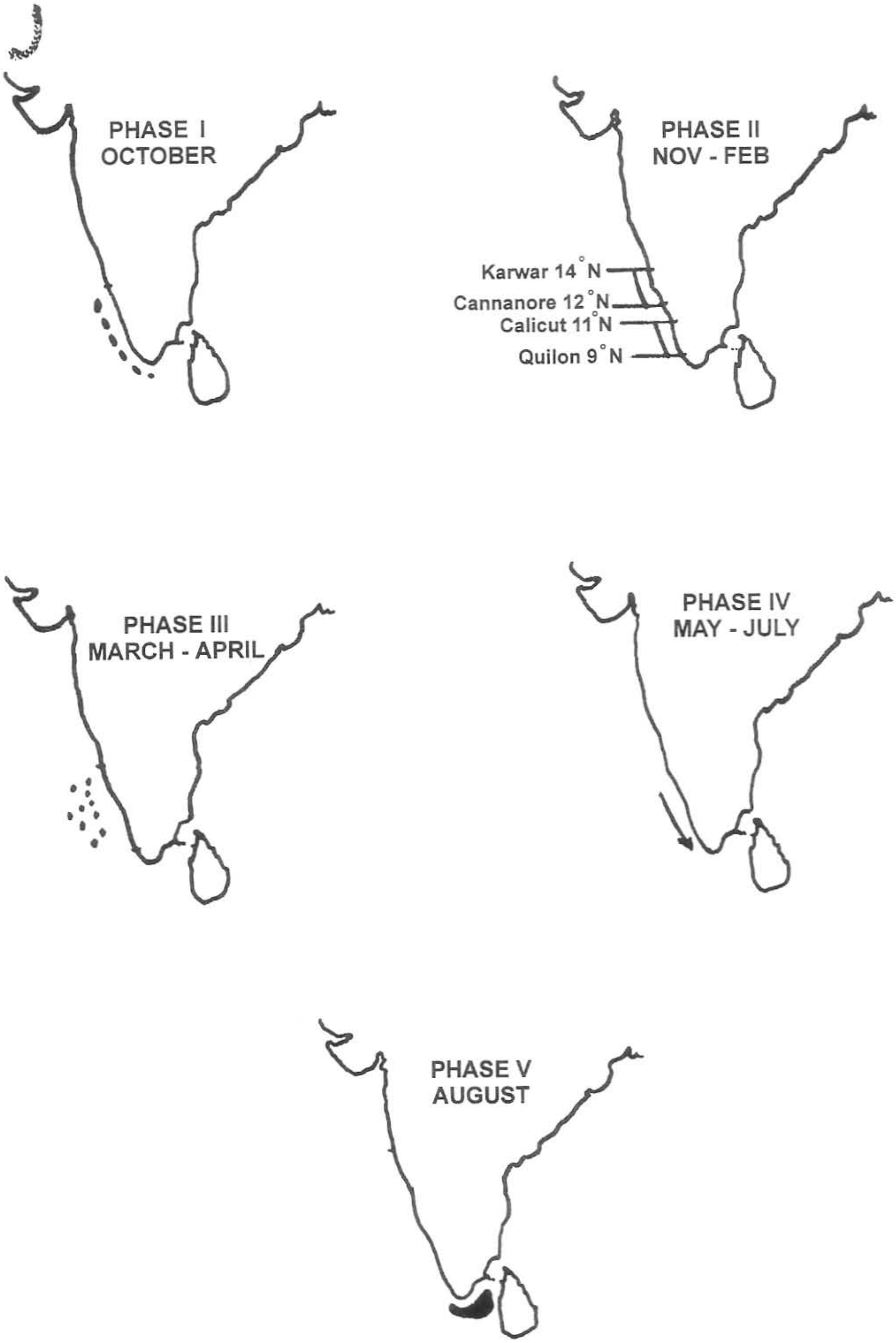


Fig. 16. Seasonal migration of whitebaits.

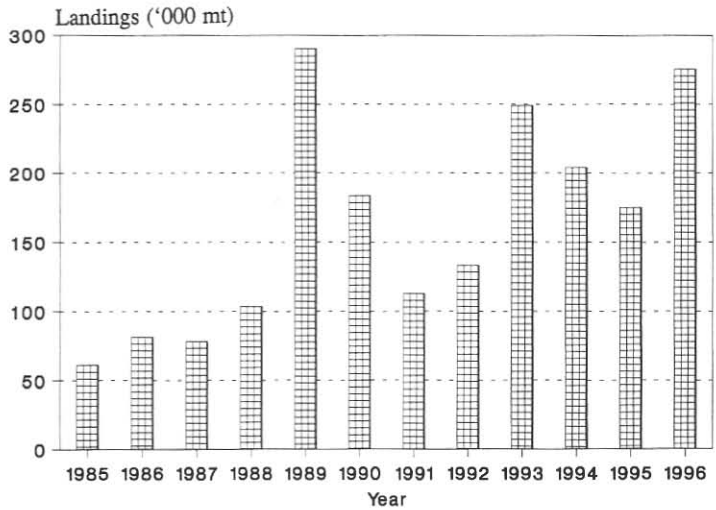


Fig. 17. All India landings of mackerel during 1985-1996.

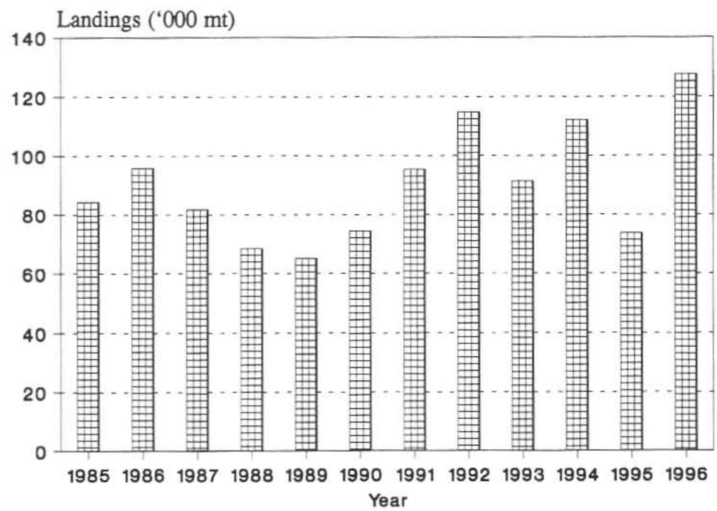


Fig. 18. All India landings of ribbonfishes during 1985-1996.

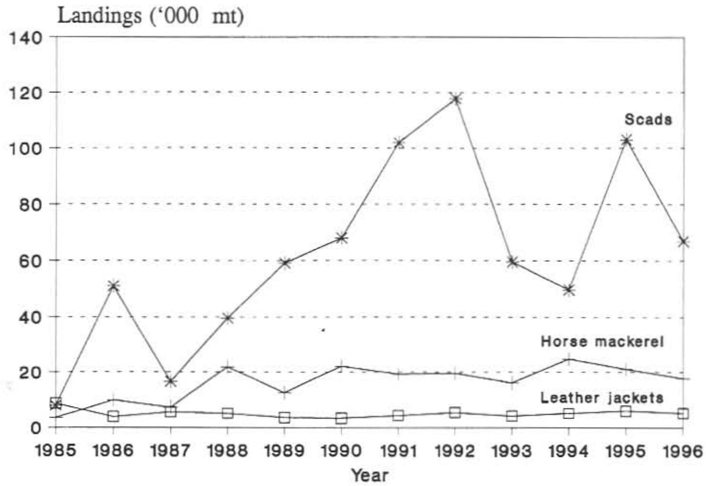


Fig. 19. All India landings of carangids during 1985-1996.

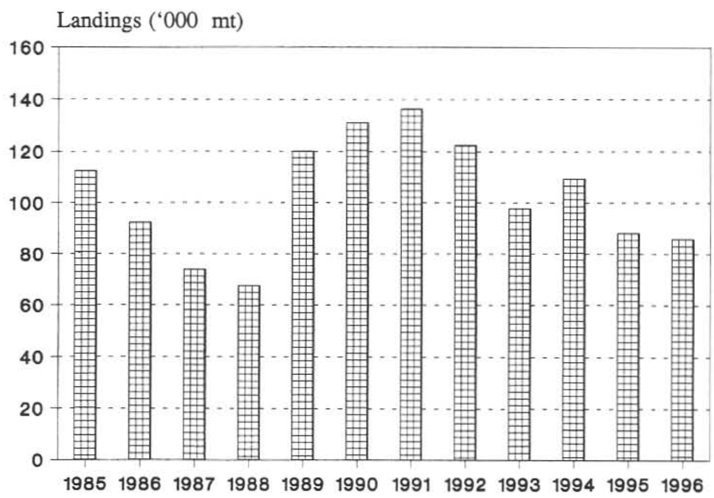


Fig. 20. All India landings of Bombayduck during 1985-1996.

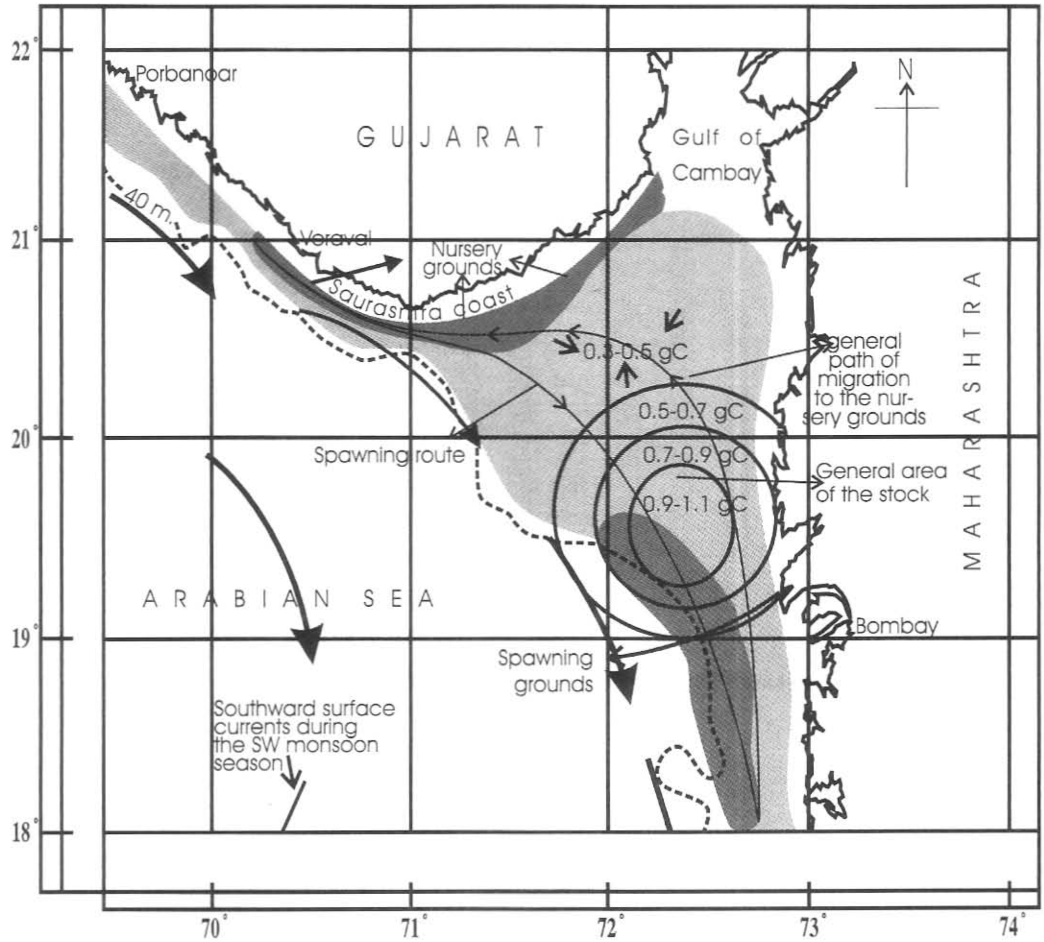


Fig.21 Migration of Bombayduck

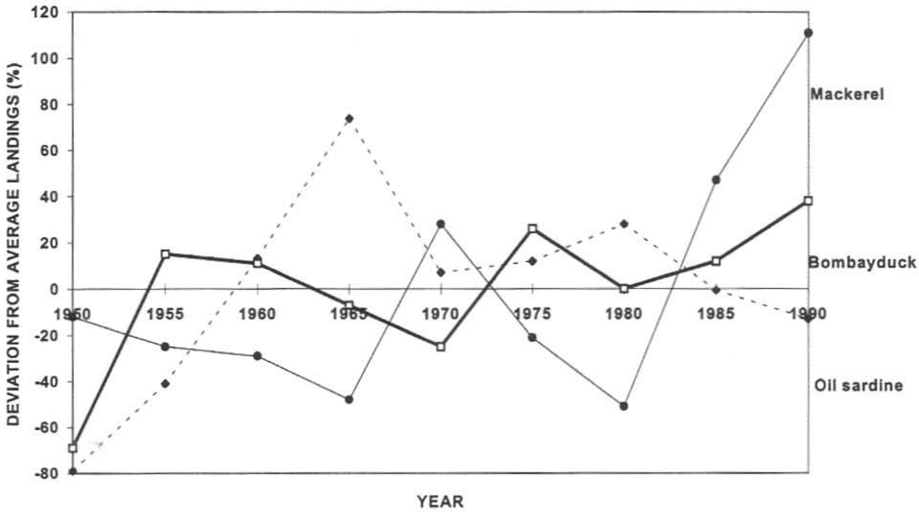


Fig. 22. All India landings of oil sardines, mackerel and Bombayduck expressed as deviations from the respective long term (1950-1995) mean values.

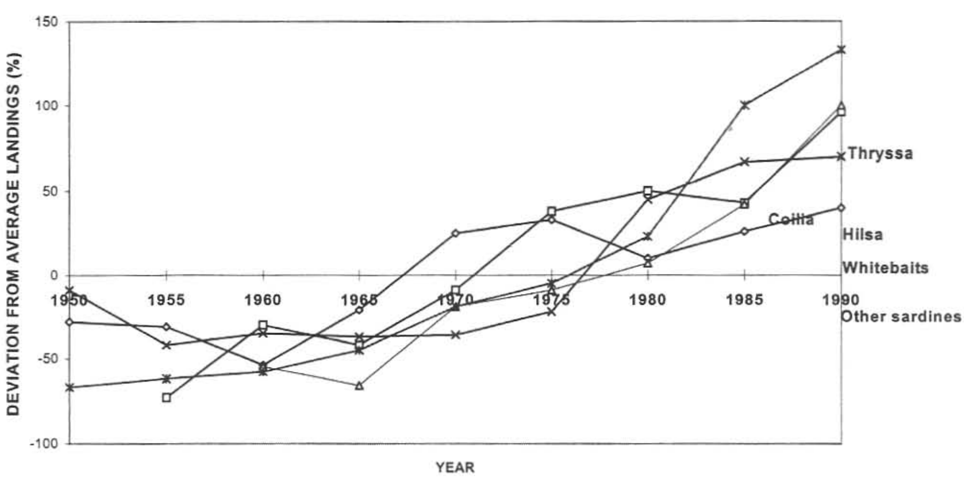


Fig. 23 All India landings of other small pelagics expressed as deviations from the respective long term (1950-1995) mean values.

Fig. 24. Annual catch of oil sardine and Indian mackerel from the SW coast of India

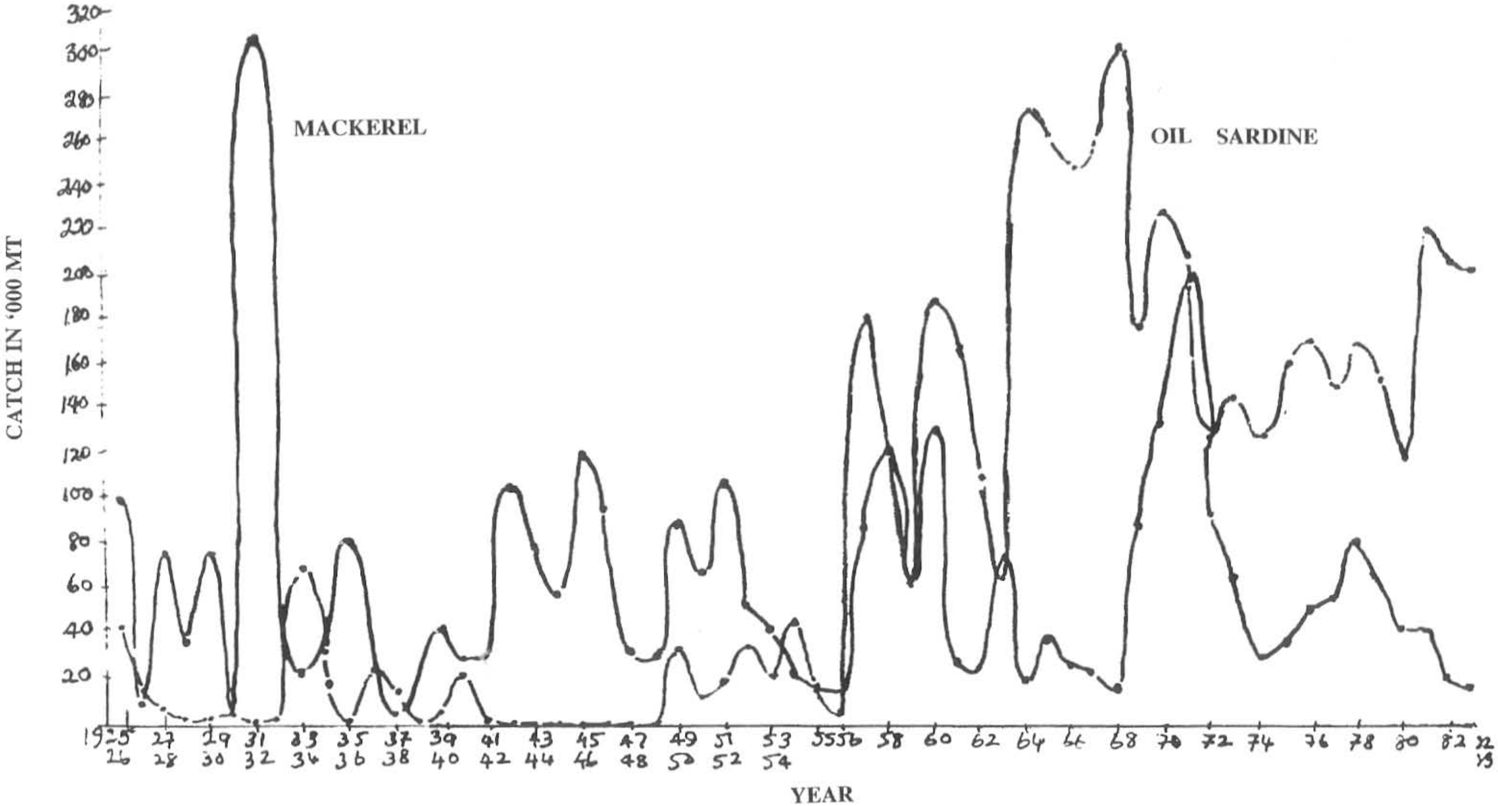


Fig. 24. Annual catch of oil sardine and Indian mackerel from the SW coast of India.

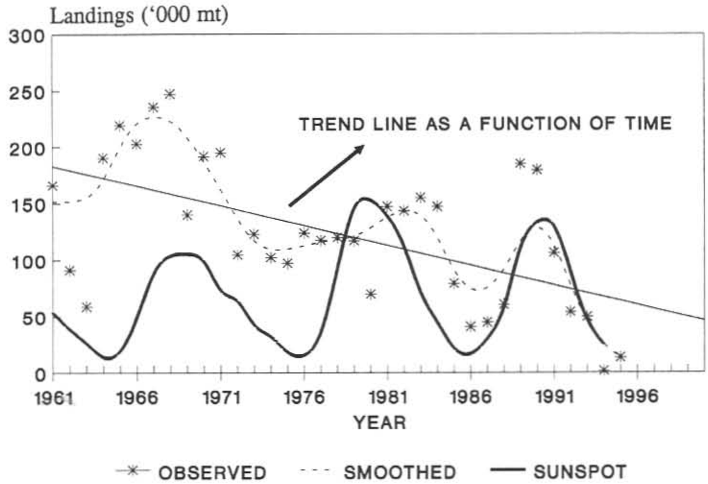


Fig. 25. Oilsardine landings in relation to solar activity in Kerala.

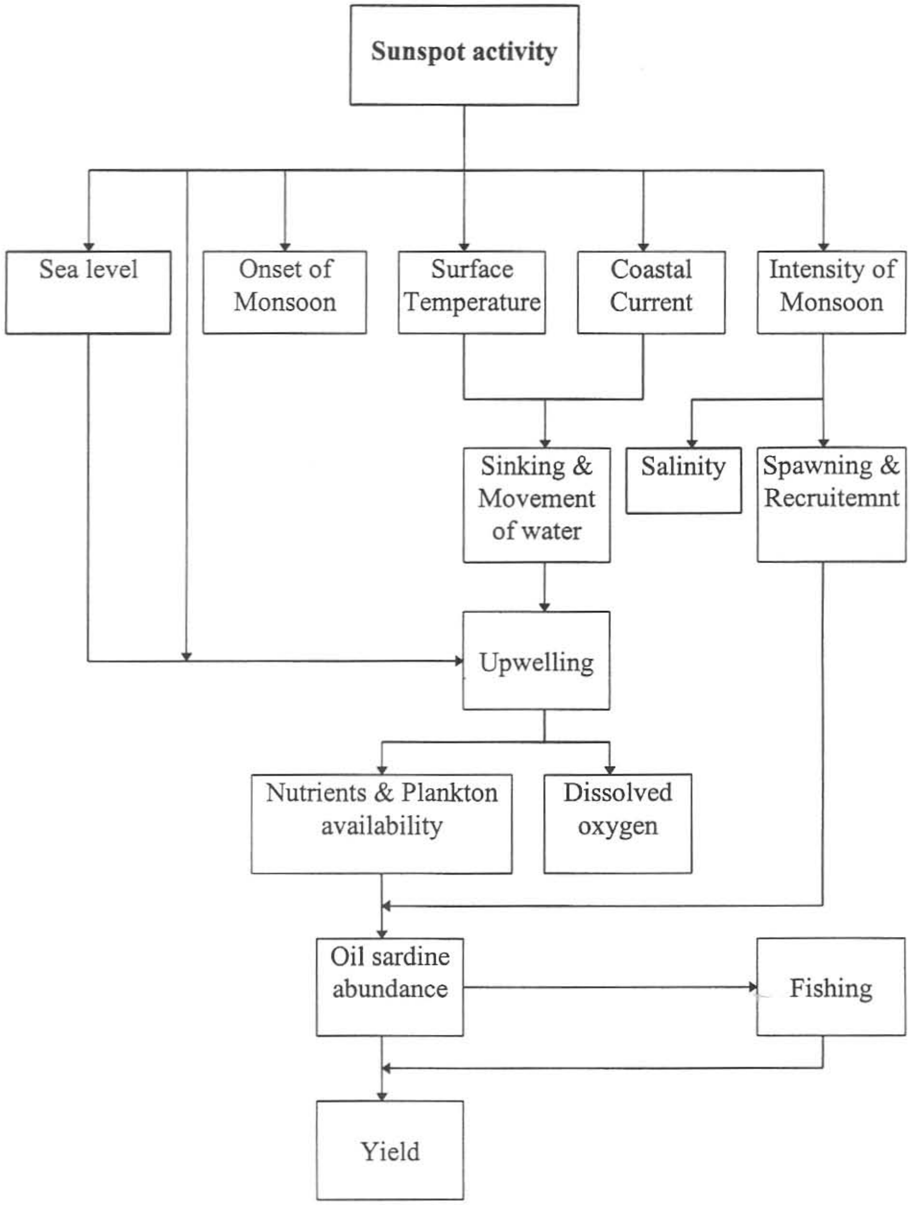


Fig. 26. Factors influencing oil sardine yield.