CMFRI Diamond Jubilee Publication

Status and Perspectives in Marine Fisheries Research in India

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Status and scope of research on pelagic fisheries of India

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4.1 Introduction

Extensive and indiscriminate exploitation of marine natural resources, during the last three decades is leading to a situation where no more commercial fish stocks may be left in the sea by year 2050 unless ecosystems are protected and the biodiversity is revived, warns a new study cataloging the global collapse of marine ecosystems (Worm *et al.*, 2006). The task of understanding the dynamics of large marine ecosystems to offer effective and relevant scientific advice to develop management interventions is a difficult, complex, expensive and lengthy process. This is especially true in the Indian context where the country has an EEZ of 2.02 million km^2, which contributes nearly 40% of the total fish production from the Indian Ocean. Fishes have been mentioned in the ancient literature of India including the epics such as Ramayana and Mahabaratha. Excavations from Mohenjodaro and Harappa indicate that fishing with hooks and nets was common as back as 3000 B.C. and over the years fishing and fisheries in India have evolved at a rapid pace (Ayyappan *et al*., 2004). Marine fisheries is basically harnessing a natural resource and therefore its management must anchor on knowledge-based interventions generated through close monitoring of their distribution, abundance, exploitation, population dynamics and fluctuations of fish stocks in relation to natural factors and anthropogenic interventions. Against a scenario of an ever-increasing population and stagnant marine fish production in recent years, per capita seafood availability is a serious concern. The country is passing through a critical period of nutritional insecurity and consequently the necessity of exploring various fields of natural resources and augmenting production weigh heavily in long term planning. Trends in domestic and export markets, social and economic status of fisherfolk and impacts of changing scenario are to be analysed before conclusions are drawn for evolving a management regime to sustain and increase production. In this context, the role of Central Marine Fisheries Research Institute (CMFRI) assumes importance. CMFRI has been able to build up a massive database on exploited marine living resources of India through research and developmental activities in marine capture fisheries since the late 1940s. The database on the marine living resources has provided valuable information to planners, administrators, maritime State governments, other government agencies, universities, researchers and other stakeholders and also been of great value in planning fisheries development and in evolving management policies in India.

Though there are inherent problems related to the present open access system of the fisheries and socio-economic concerns such as over capitalization, excess fishing capacity and lack of responsible fishing practices, India could sustain marine fish production as against the collapse of fisheries in many developed countries in spite of their complex and rigid fisheries management regimes. CMFRI has also to meet the challenges ahead by suggesting practical measures and developing guidelines to make the fisheries biologically sustainable and economically viable. On the occasion of the Diamond Jubilee year, it is appropriate to document the status of research on the marine pelagic capture fisheries resources of the country and to indicate the prospects, challenges, strategies and measures to increase and sustain production to ensure food and nutritional security. The major events that took place over the years and the research work carried out on pelagic fisheries from time to time are reviewed here.

4.2 Pelagic fishery resources

The pelagic fishes live most part of their life in the surface or subsurface waters. This group exhibits rich species diversity and abundance in the Indian EEZ. Out of the 240 odd species available, only about 60 species belonging to 7 major groups support major and minor fisheries (Table 4.1). The Indian oil sardine, Indian mackerel and Bombay duck play dominant role in the Indian marine fisheries and together form about 26% of the total marine fish landings (1999-2003).

4.2.1 Unique biological characteristics

The pelagics (except pelagic sharks) are characterized by certain unique combination of biological features, which include formation of large schools, feeding on plankton or nekton, fast growth rate and short life span (2-4 years). Most of them are either continuous spawners or have prolonged spawning periods with high fecundity. Many of them are migratory and generally show shoaling behaviour.

Table 4.1 Details of major families of pelagic fishes and species/groups

Family	Group/species	Number of species
Clupeidae	Oil sardine*	1
	Lesser sardines* (including rainbow sardines)	14
	Hilsa spp. & other shad	15
	Whitebaits*	24
	Thryssa and *Thrissocles* spp.	10
	Wolf herrings	2
	Other clupeids	40
Scombridae	Coastal tunas	5
	Oceanic tunas	3
	Seerfishes & wahoo	5
	Mackerels*	3
Trichiuridae	Ribbonfishes*	8
Carangidae*	Round scads	2
	Golden scads	6
	Hardtail scad (or horse mackerel)	1
	Jacks	17
	Black pomfret	17
	Others	19

Harpadontidae	Bombay-duck*	2
Stromateidae	Pomfrets	2
Coryphaenidae	Dolphinfishes	2
Rachycentridae	Cobia	1
Mugildae	Mullets	22
Sphyraenidae	Barracudas	7
Exocoetidae	Flying fishes	10
Bregmacerotidae	Unicorn cod	1
	Others	19
	Total pelagics	242

**Annual catches exceed 1 lakh tonnes*

Area –specific distribution of dominant species: Certain species such as the shads (*Hilsa* spp.) Bombay-duck (*Harpadon nehereus*), grenadier anchovy (*Coilia dussummieri*), unicorn cod and flying fishes have a distribution specific to the various hydro-climatic zones (Fig. 4.1). The southwest coast is known for the commercial fishery of oil sardine and mackerel, though they are available and are exploited from east coast as well at present. The Bombay-duck fishery is characteristic of the northwest region comprising Maharashtra and Gujarat and along the east coast in the states of West Bengal and Orissa. The southeast coast of India is known for its commercial fisheries of a variety of lesser sardines (*choodai*). The whitebaits form an important multi-species fishery along both the coasts showing great variations in species composition and seasonal abundance from region to region. The carangids represented by nearly 45 species, of which 10-12 is commercially important, also evince regional variations in their fishery. Scombroids consisting of 15 genera and 49 species comprising of tunas, billfishes, seerfishes and mackerels are the dominant resources in the coastal as well as the oceanic realm. Tunas like skipjack, bigeye and yellowfin available in the oceanic waters and around the island territories still remain under-exploited. Though five species of seerfishes are available in Indian seas, mainly two species support the commercial fishery. Pelagic sharks also co-exist in the oceanic pelagic realm along with tunas and hence invariably form a major by-catch in gears set for larger scombroids (Pillai and Parakal, 2000; Jayaprakash *et al*., 2002, Bhargava *et al*., 2002).

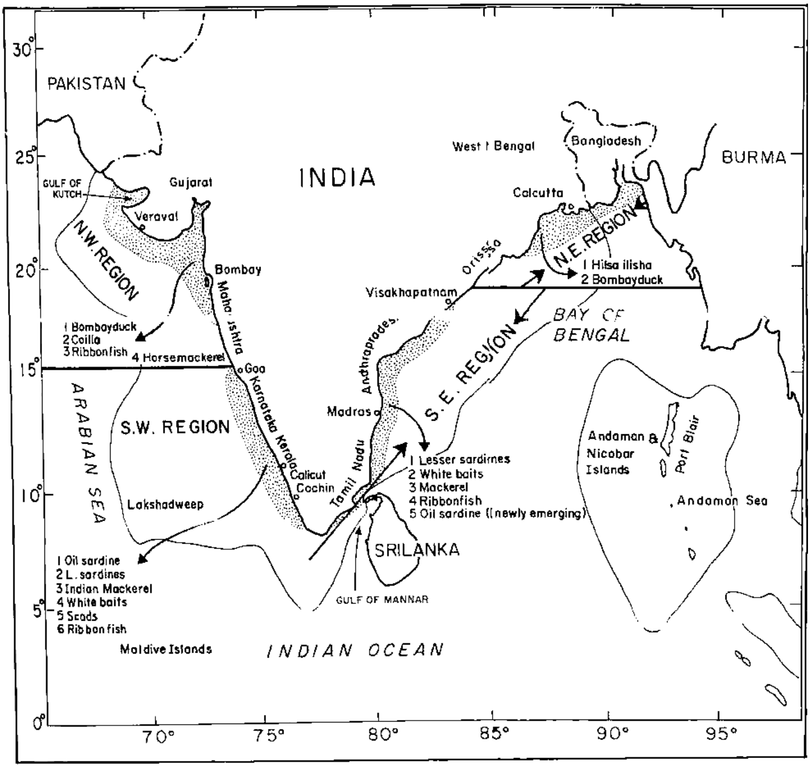


Fig. 4.1 Exclusive Economic Zone of India indicating the distribution of major pelagic fishery resources

4.3 Appraisal of the pelagic fisheries of India

India being a tropical country, the marine fisheries are multi-species and accessible to multi-gear, with varying fishing practices among different regions along the coast, depending on the nature of fishing grounds and distribution of fisheries resources. The pattern of development of the pelagic fisheries based on historical data has been reviewed in the past (Srinath, 1989; James and Alagarswami 1991; Devaraj *et. al* 1997; Nair *et al.*, 1998; Pillai and Pillai 2000). Until the late 1950s, pelagic finfishes especially the oil sardine, followed by mackerel and Bombay-duck formed the mainstay of small-scale traditional fisheries sector which had about one million active fishermen employing various indigenous crafts and gears. During the 1970s, a lucrative shrimp export market developed supported by a commercial trawling fleet which fished on shrimps, crabs, lobsters and finfishes leading to a situation where the trend in the overall production trend was governed by the demersal finfish and crustacean catches. The next decade (1980-89) witnessed intensive motorization of the traditional fishing crafts, which resulted in a remarkable increase in the annual production, and a growth of 27% in the pelagic catches as well as in overall production. During the last decade, pelagic finfishes contributed to 46-56% (average: 51%) of the total marine fish production, of which almost 70% was fished from within the 50 m depth zone (Table 4.2).

Table 4.2 Growth in pelagic fish production from 1950 to 2005

Period	Production (tonnes)		Relative growth (%)	
	Pelagics	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	+ 27
1980-89	819,093	1,579,836	+ 27	+ 27
1990-99	1,116,792	2,258,874	+ 36	+ 43
2000-05	1,326,055	2,516,608	+19	+11

Source: Pillai and Pillai (2000)

4.3.1 Mode of exploitation

Canoes, Pablo type boats, catamarans, trawlers and purseseiners are used in the exploitation of pelagic resources. The gears used are purse seine, shoreseine, boatseine, gillnet, drift gillnet, hooks & line, pole & line and *dol* net. Considerable quantities of pelagic fishes are also landed by pair trawls and high-opening trawl nets operated from the shrimp trawlers as well as gillnets of various mesh sizes operated from motorized/mechanized crafts. The introduction of gears like the purse seine in the late 70s and the ring seines in the 80s led to redundancy of traditional gears such as the boat-seine and gillnet (*mathikolli vala, mathichala vala, paithu vala*, *pattenkolli vala, thattum vala*, *thangu vala/ nethal vala*, *ayilachala vala)* off the Kerala coast and the giant shore seine, *rampani*, off the Karnataka coast which were widely used for fishing the pelagics (Pillai and Katiha, 2004; Pillai, 2006).

Vizhinjam landing centre

4.3.2 Fleet size

The growth of the fishing fleets (Table 4.3) shows that the artisanal fleet (including the motorized) increased by about 110% and the mechanized fleet by about 570% from the 1960s to the 1990s. This increase has resulted in an over-capacity of fleet operating in the inshore waters. Currently 2,251 traditional landing centres, 33 minor and six major fishing harbours serve as base for 1,04,270 units of traditional non-motorised crafts, 75,591 units of small scale beach landing motorized crafts, 58,911 units of mechanized crafts (mainly bottom trawlers, drift gill netters and purse seiners) and about 40 deep sea fishing vessels of 23-27m OAL. The development of harbours and landing jetties, motorization of artisanal crafts and rapid expansion of mechanized fishing have contributed towards significant increase in fish production, employment generation and revenue earnings.

Multiday gillnet/hooks and line units berthed at Mangalore fishing harbour

Table 4.3 Growth in fleet size during the period 1961-2005

Year	1961-62**	1973-77**	1980**	1993*	2005**
Motorized				26,171	75,591
Non-motorized	90,424	106,480	140,833	155,925	104,270
Mechanized boats		8,086	19,013	34,571	58,911
Trawlers		N.A.	11,316	N.A.	29,241

*Source: *Anon. (2000) Ministry of Agriculture, Govt. of India; ** CMFRI*

4.3.3 Production trends

The annual average marine fish production of India for the period 1985 to 2005 was 2.3 million tonnes (mt) of which the pelagics contributed 1.4 mt against an annual catchable potential yield of 1.92 mt from the Indian EEZ (Fig. 4.2). The major species were oil sardine, mackerel and Bombay duck. From 0.7 million t in 1985 to 1.4 million t in 2002, there has been a quantum leap in the pelagic fish production. A comparison of the average annual production of major pelagic finfish groups from the initial stages of mechanization in 1960s through the 80s to 1994, shows an increasing trend with respect to all the groups. Compared to 1960s, the production almost doubled or even trebled with respect to many groups in the 1980s, but since late 1990s catches have stabilized (Fig.4.3). The increased production in the early eighties could be attributed mainly to the introduction of purseseine fishing, while that of the late eighties and nineties to the motorisation of country crafts, introduction of innovative gears like ringseine and commencement of stay-over fishing. Substantial increase was noticed in the case of anchovies, Bombay-duck, tunas and billfishes till 1992 and that of ribbonfishes and mackerel till 1993-94 while oil sardine and mackerel showed only marginal increase.

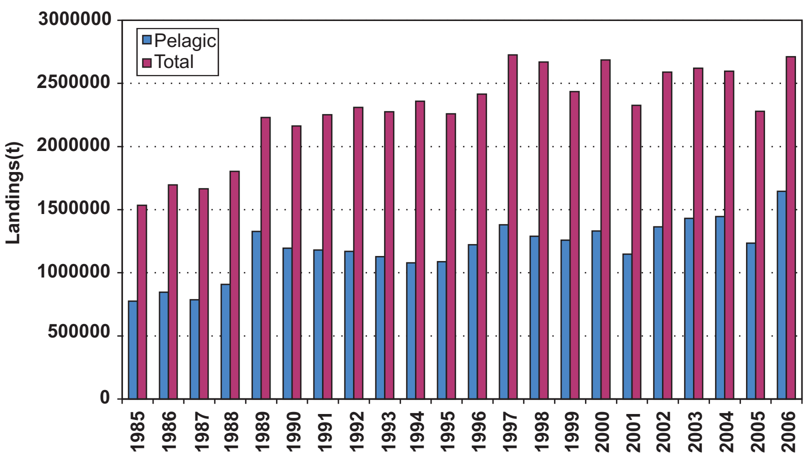


Fig. 4.2 All India landings of total marine and pelagics during 1985-2006

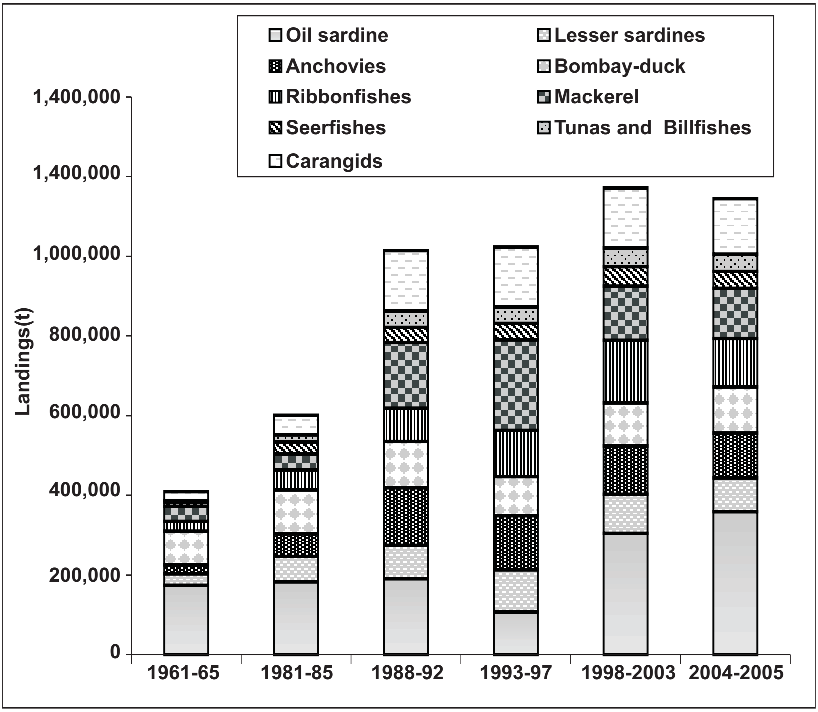


Fig. 4.3 Trend in major pelagic landings (in t) in India, 1961- 2005

The average annual pelagic fish landings (1990 –2005) is given in Table 4.4. Region wise, the southwest coast (Goa, Karnataka and Kerala) is most productive (41%) followed by the northwest (Gujarat and Maharashtra 25%), southeast (Tamil Nadu, Pondicherry and Andhra Pradesh 23%) and northeast (West Bengal and Orissa 11%). The trend of exploitation of pelagic stocks by the non-mechanised (traditional), motorised traditional and mechanised sectors is given in Table 4.5.

Table 4.4 Average landings of pelagic finfishes (in t) and their percentage contribution during 1990 – 2006.

Groups	Catch (t)	%
Oilsardine	236214	18.60
Mackerel	162540	12.80
Carangids	141169	11.11
Ribbonfish	135749	10.69

Anchovies	115013	9.05
Bombay duck	111302	8.76
Lesser sardine	96780	7.62
Other pelagic	77310	6.09
Other clupeids	47328	3.73
Tunas & billfishes	47271	3.72
Seerfish	44015	3.46
Hilsa	26066	2.05
Wolfherring	15284	1.20
Barracuda	14258	1.12
Total pelagics	1270299	

Source: CMFRI

Table 4.5 Sector- wise effort, catch & catch/hr of pelagic groups in respect of non-motorized (traditional), motorized and mechanised units in India during 1999-2005

	Mechanized	**Motorized**	**Non-motorized (traditional)**
Total catch (t)	763994	550911	227498
Effort (AFH)(hr)	17435308	17697995	10961736
Effort (Units)	1076745	4102995	3015025
% contribution	49.5	35.7	14.8
Catch/hour (kg)	44	32	22

Source: Pillai, 2006

4.4 Pelagic fisheries research programmes

Marine fisheries research in India really was set in motion during the early part of 1900s with James Hornell of the Fisheries Department of the Madras Province, who conducted a survey of the fishing methods and fishing cruises of the Madras Presidency (Hornell, 1908, 1910, 1916, 1927) and initiated studies to understand the fluctuations in the oil sardine fishery on the west coast (Hornell and Nayudu, 1923). Prior to 1947, the fisheries research activities in the country were carried out in universities and the Marine Biological Stations (at Krusadi, Calicut and Ennore) of the Madras Presidency. However, it was only after the establishment of the Central Marine Fisheries Research Institute, the scientific work was put on sound footing. During the pre and immediate post-independence period, the exploited resource was mostly dominated by pelagic finfishes like sardines, Bombay-duck and mackerel. This trend continued until the demersal fisheries developed with the introduction of bottom trawling by the erstwhile Indo-Norwegian Project in the late fifties. In tune with this scenario, initially the various research programmes of CMFRI were implemented on a regional and national basis under three divisions: Fishery Biology, Marine Biology & Oceanography and Fishery Survey. With the rapid growth of the fisheries sector and changing fishing patterns, during the V Five Year Plan, the Crustacean Fisheries Division and Molluscan Fisheries Division were created from the composite Division of Fishery Biology. Subsequently during the VI Five-Year Plan the Pelagic Fisheries Division was formed to implement the project programmes on pelagic fisheries resources. The overall objectives of the Division were:

- Collection of gear-wise catch, effort and species composition of pelagic resources exploited by different gears from various selected centres along the east and west coasts of India including Lakshadweep.
- To study the biology (food and feeding habits, maturation and spawning, growth and age) of various commercially important pelagic finfishes.
- Estimation of population parameters and assessment of various pelagic fish stocks for sustainable production and conservation of resources.
- Conduct mark-recovery studies on pelagic fishes to understand their growth and migration.
- Undertake extensive exploratory surveys of the EEZ to assess the potential of conventional resources such as tunas and related species and non-conventional resources of mesopelagics. Correlate the fishery with environmental data collected by the Fishery Environmental Management Division.

A summary of the research carried out on the pelagic resources since 1947 is presented below:

Period 1947 –1980

4.4.1 Fishery biology studies

Immediately after Independence, the research thrust of CMFRI was on taxonomy and fishery biology (distribution patterns, growth, food and feeding habits, maturation, spawning and fecundity) of major commercial species, which at that point of time was oil sardine and mackerel and to a certain extent penaeid prawns. Many of the classic work in fishery biology of Indian fishes published during the 50s to 70s period (Bapat and Bal, 1952; Bapat *et al*.,1952, Bapat, 1955; Sekharan, 1955; Prabhu, 1955,1956; Pradhan 1956; Jones and Pantulu,1958; Jones, 1957,1958, 1964; Kuthalingam,1960,1963; Jones and Silas, 1960,1962, 1962a; Balan,1964; Bensam,1964,1968; Jones and Kumaran, 1962; Rao,1962; Rao, 1962; Pradhan and Reddy, 1962; Antony Raja 1967,1969,1970, 1972 a,b,c; James, 1967; Qasim, 1972,1973,1973a) still remain models to be emulated in fishery biology work and could provide inspiration to the new and present genre of fishery biologists.

4.4.2 Resource surveys in inshore and offshore waters

The pioneering attempt by India to conduct exploratory longline fishery in the oceanic waters off the south west coast of India (5^{o} to 12^{o} N) was during 1964 –1965 period using the survey vessels "*M.T. Pratap*", "*Kalyani IV*" and "*Kalyani V*" of the erstwhile Deep Sea Fishing Station (presently Fishery Survey of India) which generated invaluable information and laid the foundation for more exploratory studies (Silas *et al*.,1985). During the 1960s and 1970s the research vessels of the Indo-Norwegian Project at Cochin particularly *R.V. Kalava* and *R.V. Varuna* and later the nine research vessels (*R.V. Cadalmin* series) owned by the Institute were extensively used in the pelagic fisheries research programmes (Silas, 1969; James, 1986). The Pelagic Fisheries project at Cochin, which was established with UNDP/FAO assistance in 1971 carried out extensive acoustic surveys with research vessels R.V. *Sardinella* and R.V. *Rastrelliger,* coupled with aerial surveys, for pelagic fish on the S.W. Coast. During these surveys fishing with pelagic trawls was also done. Dense concentrations of white baits, horse mackerel, scads, ribbonfish and catfishes were located along the S.W. Coast and estimates made of their standings stocks (Rao *et al.*, 1977; Anon, 1976, 1976 a). The existence of mackerel and oil sardine shoals outside the presently fished inshore zone was also brought to light. The Indo Polish industrial fishery survey in 1977 by M.V. *Murena* for pelagic resources along the northwest coast (15^o –24^o N lat.) yielded valuable information on the distribution and abundance of pomfrets as well as the existence of horse mackerel (*M. cordyla*) and ribbonfish stocks in depths between 50 –360 m depths (Bapat *et al*., 1982). These pioneering studies provided information on the nature and extent of distribution of various pelagic resources beyond the conventional and inshore fishing grounds. At the same time several changes were also taking place in the fishing industry mainly due to introduction of mechanized fishing and improvements to fishing craft and gear. Information generated could aid the development of targeted fishing for these resources. Today, ribbonfish and pomfrets are a significant contributor to the exports of fish from India while the horse mackerel is in good demand in the domestic market.

4.4.3 Studies on growth and migration

Tagging of fishes, despite its importance as means to elucidate interesting aspects of their biology such as migration, growth, recruitment, mortality, stock and racial composition, had not been attempted in India until the late 1950s. Mark release experiments were undertaken for the first time by tagging of *Hilsa* in the Hooghly Estuary and Grey mullets and certain brackish water fishes in the Chilka Lake. Tagging experiments on Indian mackerel and oil sardine were also conducted from Karwar, Mangalore, Calicut Cochin, Vizhinjam, Mandapam and Visakhapatnam during 1966-1969, using a variety of tags. Although the recovery for the mackerel and oil sardine was low (<1%) due to non-reporting/ shedding of tags, the studies could reasonably establish that the movement of these two pelagic fishes is parallel to the coast (Prabhu and Venkataraman, 1970).

4.4.4 Studies on high unit value resources

The scombroids are an economically important group comprising of tunas, seerfishes, billfishes and mackerel. The potential of this rich but untapped resource, especially tunas, was recognized as early as the 1960s. Investigations on tunas and billfishes were initiated chiefly through individual efforts during the late 1950s when two species of the genus *Auxis* were recorded from the west coast of India. In a pioneering study, detailed investigations of the tuna fishing industry in Minicoy Island in the Lakshadweep Sea were carried out using the 'Research Vessel' *KALAVA* functioning under the Indo-Norwegian Project (Jones and Kumaran, 1959; Jones 1958,1964; Thomas,1964). Pioneering works on the scombroid fishes of India including their taxonomic aspects (Jones and Silas, 1960), early life history (Jones and Kumaran, 1962) maturation and spawning (Raju 1962, 1962a) food and feeding (Kumaran, 1962, Thomas 1962) and behaviour (Silas, 1962) were published. The data on coastal tuna landings were also provided to the IPTP, Sri Lanka, which was the regional authority, concerned with the management of tuna resources of the Indo-Pacific region.

1981 -1990

4.4.5 Fishery biology studies

With the establishment of the Pelagic Fisheries Division in the early 1980s, research activities were centered around developing a valuable time series database on the resource (fishery) and biological characteristics (age, growth, maturity, spawning, fecundity, food and feeding habits, migration) of the major pelagic resources (oil sardine, lesser sardines, mackerel, Bombay-duck, tunas, billfishes, pomfrets, carangids, ribbonfishes, seerfishes and whitebaits) exploited in all the maritime states including UT of Lakshadweep. The extent and pattern of exploitation of pelagic fish resources of the west and east coasts of India were studied by monitoring the landings from the artisanal, drift-gillnet, trawl, purse-seine, ring-seine and pole and line fisheries employing a multi-stage stratified random sampling technique developed by the Fishery Resources Assessment Division. The impact of oceanographic parameters such as temperature and salinity, thermocline, areas of seasonal upwelling, convergence and divergence zones of the southwest coast continued to be studied for several pelagics (Pradhan and Reddy, 1962; Murthy, 1965,1974; Murty and Edelman, 1970; Rao *et al*., 1973; Murty *et al*., 1990; Pillai, 1991). Several long and short term studies of the tuna resources (skipjack and yellowfin) in the Lakshadweep Island ecosystem exploited by pole and line and troll lines were carried out and information on the fishery, distribution and abundance patterns, food and feeding habits, age and growth, maturity, spawning, fecundity, their population parameters and stock status were published (Silas and Pillai, 1982; Silas, 1985). Information on the distribution and abundance of tuna live-baits from Lakshadweep seas was also consolidated (Mohan and Kunhikoya 1985; Kumaran *et al*., 1989).

4.4.6 Resource surveys

Offshore resource surveys with respect to pelagic resources were continued and strengthened with the acquisition of the fishing vessel R.V. *Skipjack* (33 m OAL) in 1982. Valuable information on tuna, billfishes and sharks were also collected by participating in fishing trips conducted by tuna long-liners like M.F.V. *Prashiskhani* (of CIFNET), M.F.V. *Matsyavarshini* and M.F.V *Matsya Sugundhi* belonging to the Fishery Survey of India (Silas *et al*., 1985) and potential of various marine fishery resources were estimated (James *et al*., 1987; Joseph and John, 1987). Ichthyoplankton surveys were also conducted (George, 1989). During 1985 to 1989, scientists of the Division undertook extensive resource surveys in the Indian EEZ onboard the research vessel FORV *Sagar Sampada*, (James and Pillai, 1990) and papers on pelagic resources were published (James and Pillai, 1990a; Menon, 1990; Balachandran and Nizar, 1990; Raman and James, 1990; Murty *et al*., 1990).

1991 -2000

4.4.7 Fish stock assessment

With the introduction of the fish stock assessment tools and the training programmes by FAO/DANIDA in 1981, estimation of population parameters and stock of all the pelagic fish species became the major thrust of research programmes. A considerable database on the trends in production, seasonal distribution, fluctuations in abundance and migration pattern of many pelagic fishes and biological parameters of major pelagic resources has been generated which has been effectively applied in stock assessment studies (Annigeri *et al*., 1992; Bennet *et al*., 1992; James *et al*., 1992; Khan *et al*., 1992; Kurian and Kurup, 1992; Luther *et al*., 1992; Noble *et al*., 1992; Reuben *et al*., 1992, 1992a; Thiagarajan *et al*., 1992). Life history parameters and Biological Reference Points of some commercially important pelagic species are given in Table 4.6. Assessment of tuna live baits, crucial to success of pole and line fishing for tuna in the Lakshadweep, was also done (Gopakumar *et al*., 1991; Sivadas and Nasser, 2000).

4.4.8 Research vessel based sea truth data collection

The systematic exploration of the Indian EEZ both areawise and seasonwise using FORV *Sagar Sampada* was continued during the early 90s with the ultimate aim of locating and charting new fishing grounds for both exploited and underexploited varieties of fishes, crustaceans and cephalopods. Information on conventional pelagic resources as well as non-conventional mesopelagic resources collected during these cruises were published (Pillai *et al*.,1996; Jayaprakash, 1996; Sivakami *et al*., 1996; Menon *et al*., 1996, 1996a; Reghu *et al*., 1996; Nair *et al*., 1996).

4.4.9 Studies on monsoon fisheries

With the advancements in operational capabilities of the mechanized vessels during the 70s, fishing was extended to the monsoon months also which led to a series of developments culminating in conflicts and social tensions among the mechanized and artisanal sectors of fishermen. Monsoon plays a critical role in determining the success or failure of pelagic fisheries (Murty and Edelman, 1970; Longhurst and Wooster, 1990; Qasim, 1973) and management of monsoon fishery requires careful consideration by addressing the inherent socio-economic issues as well as ensuring sustainable exploitation of the resources (James, 1992). Based on previous studies conducted over a period of 45 years on oceanography, productivity of the eastern Arabian Sea and the fisheries and biological characteristics of the resources along the west coast of India during the different seasons, particularly the monsoon, the impact of monsoon fishing *vis-a vis* (i) the fishery resources (ii) interactions between artisanal and mechanized sectors exploiting the resource, (iii) complexities of multispecies multigear fisheries in inshore waters were studied. Results were published so as to enable the government formulate policies for rational exploitation and management of marine fisheries (Rao *et*

Table 4.6 Life history parameters and Biological Reference Points of some commercially important pelagics

Group/species	L_{max} (cm)	L_{inf} (cm)	K (yr^{-1})	$T_{max\ (years)}$	L_m (cm)	L_{opt} (cm)	L_c (cm)	L_r (cm)	Exploi-$^+$ tation rate E	Natural mortality M
Sardines **										
Sardinella longiceps	22	23.2	1.8	1.7	14	14	8	4	0.4	2.31
S.gibbosa	20	21.1	1.2	2.5	13	13	5	4	0.6	2.03
S.albella	23	24.2	1.2	2.5	15	15	5	4	0.5	2.03
S.fimbriata	21	22.1	1.3	2.3	14	13	5	4	0.5	2.08
S.sirm	22	23.2	1.2	2.3	14	14	7	6	0.2	2.03
S.dayii	18	19	1.3	2.5	12	11	10	9	0.2	2.08
Shads**										
Hilsa ilisha	60	62.2	0.5	6	34	39	24	15	0.6	1.71
Anchovies**										
Encrasicholina devisi	10	10.7	1.6	1.7	7	6	3	2	0.5	2.21
Stolephorus waitei	13	13.8	1.3	2.1	9	8	3	3	0.5	2.08
S.baganensis	8	8.6	1.5	2	6	5	3	3	0.4	2.17
S.commersonii	10	10.7	1.5	2	7	6	3	3	0.5	2.17
Coilia dussumieri	20	21.1	1.4	2.1	13	13	14	2	0.5	2.12

Bombay Duck**										
Harpadon nehereus	40	41.7	0.6	5	24	26	4	3	0.5	1.75
Ribbonfish**										
Trichiurus lepturus	130	133.1	0.6	5	68	87	20	10	0.7	1.75
Carangids**										
Megalaspis cordyla	40	41.7	1.4	2.1	24	26	25	20	0.7	2.12
Decapterus russelli	24	25.3	1.2	2.5	15	15	14	7	0.6	2.03
D.macrosoma	23	24.2	1.1	2.7	15	15	14	11	0.6	1.98
Caranx carangus	44	45.8	0.7	4.3	26	29	22	6	0.8	1.80
Atropus atropus	44	45.8	1	3	26	29	21	10	0.8	1.94
Alepes kalla	17	18	0.8	3.7	11	11	13	6	0.5	1.84
A.djedaba	33	35	0.6	5	20	22	20	20	0.8	1.75
Atule mate	34	36	0.9	3.3	21	22	17	10	0.7	1.89
Selaroides leptolepis	21	22.1	0.8	3.7	14	13	9	6	0.7	1.84
Selar crumenopthalmus	30	31.5	1.1	2.7	17	18	14	10	0.6	1.98
Mackerel**										
Rastrelliger kanagurta	30	31.5	1.7	1.8	18	19	14	9	0.7	2.26
Tunas *										

Euthynnus affinis	69	71.4	0.9	3.3	39	46	29	18	0.6	1.89
Auxis thazard	48	49.9	0.9	3.3	28	31	23	20	0.5	1.89
A.rochei	34	35.6	1.1	2.7	21	22	21	14	0.6	1.98
Thunnus.tonggol	98	100.8	0.6	5	53	65	38	28	0.6	1.75
K.pelamis	76	78.5	0.9	3.3	42	49	45	21	0.7	1.89
Bill fishes*										
Istiophorus platypterus	260	264	0.4	8	170	161	140	90		1.66
Seerfishes *										
S. commerson	140	143.2	0.9	3.3	72	94	20	20	0.8	1.89
S.guttatus	65	67.3	1	3	35	43	35	35	0.7	1.94
Pomfrets**										
Pampus argenteus	39	0.7	41	4.3	23	26	23	5	0.8	
Formio niger	56	58.1	0.7	4.1	31	35	25	15	0.8	1.80
Barracudas**										
Sphyraena obtusata	44	48.9	1	3	27	29	11	10	0.7	1.94
S.jello	153	156	0.4	8	78	86	35	17	0.5	1.66

**Length in Fork Length (FL)   **Length in Total Length (TL)*

+(Based on Data of 1985 –89 period)

Ref:Indian J.Fish., 39(3,4),(1992); Joseph and Jayaprakash (2003) *al*., 1992). Recommendations aimed at ensuring the sustainability of the fisheries included restrictions on ring seines and trawls in inshore waters during the monsoon period, which is peak spawning of most marine fishes (James, 1992a).

4.4.10 Studies on effect of major gears on exploited resources

In a multispecies multigear fisheries, to study the impact of various gears on the resources with a view to assess the maximum sustainable yield and effort levels and suggest effective conservation measures for the exploited resources, five projects, related to small mechanized trawlers (<14 m OAL), drift gill nets, *Dol* nets, purse seines and large trawlers (>14 m OAL) were initiated in 1989 and studies were published (Yohannan and Balasubramanian, 1989; Kasim and Khan, 1989; Luther *et al*., 1994, 1997).

2001 – 2007

4.4.11 Resource management inputs and advisories

By the dawn of the 21st century, fisheries of major commercial pelagic species were well developed and most of the marine resources were optimally exploited. A comprehensive publication containing papers on fishery, biological parameters, stock structure, processing and marketing of scombroid resources in Indian waters was published (Pillai *et al.*, 2002). A concise publication of the status of exploited marine fishery resources of India including pelagics was published for the benefit of planners, administrators, policy makers and the scientific community concerned with the sustainable development of the marine fisheries sector in the country (Joseph and Jayaprakash, 2003).

A time series database on oil sardine landings, their recruitment patterns and environmental parameters facilitated forecasts of oil sardine fishery (Jayaprakash, 2002). The migration pattern of oil sardine and ribbonfish was charted using the timeseries database of pelagic landings, which indicated the seasonal availability of various size groups occurring in a variety of gears operated at different depths in important fishery centres. While the adult stock of oil sardine along west coasts is observed to remain in the 30-40m-depth zone, the young sardines follow an anticlockwise circulatory path between Allepey and Calicut and off Mangalore, then move north following a clockwise circular path (Anon., 2003). Ribbonfishes also follow the seasonal current patterns along the Indian coast.

Realizing the scope for increasing marine fish production by tapping offshore resources, initiatives were taken as early as in the 80s to stimulate interest in tuna fishing and develop a national tuna fishery (Silas and Pillai, 1982; Silas 1985; James *et al.*,1989, 1989a, 1989b; James and Pillai, 1991). By 2004 considerable quantity of oceanic tunas (15,000 t) were being landed by artisanal crafts as well as a few shrimp trawlers diversified for longline fishing for tunas mainly on the southwest and northeast coasts. MPEDA reported exports of 16,627 t of tuna worth US$ 15.68 million during 2005-06. The Division continues to generate interest and support for tuna fishing and its optimum utilization among all stakeholders. With the growing importance accorded for developing an oceanic tuna fishery among the fisheries development agencies and planners, it was realized that more studies on this resource are required for sustainable exploitation. In 2005, a project to study the oceanic tuna stocks of skipjack and yellowfin in the Indian EEZ was taken up by the Division. Studies on migration patterns and population dynamics using length frequencies of the landings as well as morphometric and genetic studies were initiated. Also some baseline studies were conducted on FAD installation in the Lakshadweep seas and their impacts on tuna fisheries and fishing activities.

Tuna catches landed by multiday gillnet/hooks and line units at Mangalore fishing harbour

The fishery for yellowfin tuna has been progressing rapidly along the north east coast of India since 2005 and idling shrimp trawlers are being converted to longliners with subsidy from MPEDA. The initial success of this venture is very high with > 500 t of premium *sashimi* grade tuna being exported and it is expected to attract more fishing effort in the coming years. Worldwide there are some cases of declining tuna fisheries and the exact causes are hard to find, the abundance of this resource being overwhelmingly dependant on climatic parameters such as *El nino* and related hydrological parameters besides local currents and divergences. To sustain this rapidly developing and highly valuable fishery, scientific monitoring of the exploited resource by generating data on catch (by weight and numbers), hooking rates, bycatch and economics in addition to information on the size groups caught, their maturity stages and feeding behaviour is needed before the government starts subsidizing the conversion of more trawlers into tuna longliners. An understanding of their dynamics can also be an invaluable aid in formulation of guidelines for sustainable exploitation of the yellowfin tuna resources from the Indian EEZ. During the XI Plan Period the division also plans to take up studies on eggs and larvae of the diverse fish fauna in the Indian seas as also their biodiversity, spatio-temporal distribution patterns, relation to environmental variables and initiate steps for DNA barcoding of select commercial species. The spatio-temporal variations in the fishery resource distribution and abundance in the Indian EEZ by participating in vessel based resource surveys and its mapping on a GIS platform is another important programme envisaged during the same period.

4.5 Status of pelagic fishery resources

The oil sardine (*Sardinella longiceps),* Indian mackerel (*Rastrelliger kanagurta)* and the Bombay-duck (*Harpadon nehereus*) are major single-species fisheries sustaining the marine fish production in the country. The landing pattern of the pelagics can be categorized as follows: (a) fisheries which have fluctuated very widely (oil sardine, Bombay-duck and Indian mackerel); (b) fisheries which have increased the landings fairly consistently (lesser sardines, *Hilsa* spp., whitebaits, *Thryssa* spp. *Coilia dussumieri,* carangids and ribbonfishes); and (c) the only pelagic fishery which has declined (unicorn cod *Bregmaceros mclellandi*). The resource status is briefly summarized under:

4.5.1 Indian oil sardine

The Indian oil sardine supports a fishery of high magnitude along the southwest coast and in recent years has established itself as fishery along east coast also (Luther, 1988). In the history of marine fisheries research in India, never has a single species, as oil sardine (*Sardinella longiceps*), been a subject matter of intensive research by fishery scientists (Day,1865; Hornell, 1910; Hornell and Nayudu,1923; Devanesan 1943; Chidambaram,1950; Nair, 1952, 1959; Antony Raja, 1967, 1972, 1972a, 1972b, 1972c, 1973; Bensam, 1968; Longhurst and Wooster, 1990; Annigeri *et al.*, 1992; Srinath,1998; Jayaprakash, 2002) resulting in over 450 publications till date. The recorded history of the Indian oil sardine fishery dates back to 1896. The Monograph on Sardines (Nair, 1973). is an invaluable and authentic record of its fishery and exploitation in the pre-independence days regarding types of gear employed, resource utilization by extraction of oil and as manure in coconut, tobacco and sugar cane plantations as well as on various biological aspects such as age and growth, food and feeding, spawning, fecundity, eggs and larvae, etc. The optimum temperature and salinity ranges for distribution and abundance of oil sardine is 27-28^{o}C and 22.8-33.5 ppt respectively although occasionally they have been observed to enter the estuaries along the southwest coast. The oil sardine is a planktivore and diatoms, dinoflagellates and copepods are the favoured food items.

Till the close of 1970s, artisanal fishing gears mainly boat and beach seines, cast nets and small meshed gill nets were the major gears operated along the southwest coast. These were replaced in turn by purseseines during the mid 70s and ringseines during the 80s. The oil sardine fishery, supported mainly by 0 and 1 year classes, commences soon after the outbreak of monsoon in June and continues till April. The success of the oil sardine fishery depends mainly on the recruitment strength of early juveniles of the size 80-100 mm. The fishery commences during the post-monsoon months usually in late August in the southern region, and reaches the northern region in late September. Since the mid 1990s, a fishery for oil sardine has developed along the east coast also and the average (1999 to 2003) annual landings of the oil sardine was 201,973 t of which west coast contributed 73 % and the east coast 27%. Along the east coast mainly boat seines (*Karavala*, *Peddavala*), gillnets (*Chalavalai*) and bag nets (*Edavalai*) dominate. On Tamil Nadu coast, pair trawlers are operated at 12-60 m depth in Pamban–Rameswaram area while ringseines have been recently introduced in the Palk Bay. The fishing season is from April to December with peak catches during April-June on the Tamil Nadu coast and July-October along the Andhra Pradesh coast. Along the southwest coast, the fish has good demand in local and distant markets and the fishery is optimally exploited. On the east coast, demand for local consumption is low and most of the catch is marketed outside the state, particularly in Kerala. During periods of heavy landings, they are also sun-dried and supplied to manufacturers of poultry feed.

The large-scale fluctuations in abundance, the population crashes and a subsequent revival has remained a subject of great interest for long time and continues to be an enigma even today, making management decisions difficult. The oil sardine stock showed remarkable recovery after the population crash in the mid forties and after a most recent one in 1994 (from a lowest of 47,000 t in 1994 touched 4.04 lakh t in 2003), with no parallel example in the world itself (Fig.4.4). The abundance of the oil sardine along the southwest coast has been related to the onset of the monsoon (Panikkar and Rao, 1949;

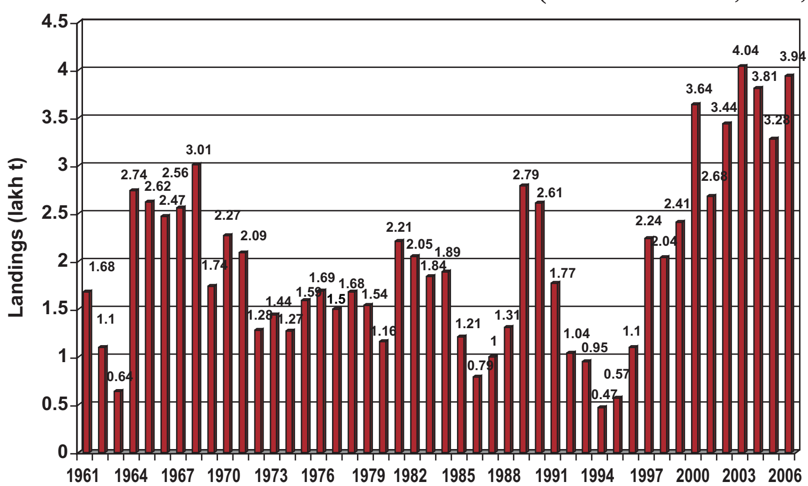


Fig. 4.4 All India oil sardine landings during 1990-2006

Longhurst and Wooster, 1990) and intensity of the monsoon (Pradhan and Reddy, 1962; Antony Raja, 1969; 1972a), sunspot activity (Srinath, 1998), surface temperature (Noble, 1972; Pillai, 1991), variations in the pattern of coastal currents (Murty, 1965, 1974,1993), 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). The unprecedented failure of the fishery in the 1940s which had disastrous effects on the industries based on it had the British Administration enforcing restrictive legislation on capture of juveniles and spawners in 1943. The Marine Fishing Regulation Acts of the various maritime states in India, ban fishing by mechanized vessels during the monsoon to protect spawners and new recruits. However, motorized boats continue to fish during the monsoon using extremely small meshed ring seines, which will be unsustainable in the long run and therefore has to be curbed. Minimum mesh size of 18 mm for ring seines, declaration of closed season during monsoon, reduction and optimization of the excessive fishing capacity of the ring seine/purse seine fleet are urgently required.

4.5.2 Lesser sardines

The species diversity of lesser sardines is gauged from the fact that, of the 15 species of lesser sardines in the Indo-Pacific region, 12 occur in the Indian waters. These include *Sardinella albella, S. gibbosa, S. fimbriata, S. sirm, S. dayi, S. sindensis, S. melanura, S. clupeoides* and *S. jonesi*. During 1986-2006 landings ranged from a low of 68,267 t in 1986 to 128,021 t in 1995 and the resource contributed about 5% to the total annual marine fish production of the country, with Tamil Nadu leading among the maritime states. The *Choodai* fishery of the east coast is the most important in the region between Dhanushkodi and Panaikulam in the Palk Bay (Sekharan, 1955). Results of the studies on the identification and bionomics (Nair, 1953; Lazarus 1977, 1977a, 1983), fishery and biological aspects (Bennet *et al.*,1986, Rohit and Bennet,2000) and stock assessment (Bennet *et al.*,1992) are available. The size at first maturity, spawning season and fecundity differ from species to species, but most of them become sexually mature before the completion of one year and the commercial fishery is supported by the 0 and 1+ year classes. *S. sirm, S. jonesi* and *S. clupeoides* grow to larger sizes compared to the other species and 1 to 2 year classes dominate the fishery. Along the southeast coast, the small meshed gill nets are operated while the seines (shore seines, boatseines and ringseines) are popular along the southwest coast. The purseseines operated from the mechanised units at depths upto 60 m and trawlers operating in the nearshore waters also land sardines in considerable quantities along the Karnataka coast. Being a source of cheap protein for the rural poor in the coastal regions, they are also used as raw material for the animal feed industry. The total annual stock of lesser sardines has been estimated at 280,000 t comprising 140,000 t in the southeast coast, 80,000 t in the southwest, 30,000 t in the northeast, 10,000 t in the northwest coast and 20,000 t in Andaman waters with a maximum sustainable yield (MSY) of 140,000 t (George *et al*., 1977). However, the average annual production during 1996 –2000 was much lower being only 122,243 t indicating that present exploitation rates are sustainable.

4.5.3 Anchovies

The anchovies constituted by five genera *viz. Stolephorus, Coilia, Setipinna, Thryssa* and *Thryssina* constitute seasonal fisheries mostly along the coasts of Andhra Pradesh, Tamil Nadu, Kerala, Karnataka and Maharashtra. The average annual catch during 1985-2003 was 1.31 lakh t forming 11.2% of the total pelagic fish landings in India and catches ranging from 1.05 lakh t (1987) to 1.66 lakh t (1991). Among anchovies, whitebaits (*Stolephorus* and *Encrasicholina* spp.) are dominant contributing 48% (average 1985 –2003) followed by *Coilia dussumieri* (24%), *Thryssa* (26%) and *Setipinna* (2%).

4.5.4 White baits

Species diversity of whitebaits in Indian seas include *Encrasicholina devisi, E. heterolobus, E. punctifer (Stolephorus buccaneeri), Stolephorus andhraensis, S. baganensis (S. macrops), S. commersonii, S. dubiosus, S. indicus, S. insularis* and *S. waitei* (*S. bataviensis*). Among these, *E.devisi, E.punctifer, S.waitei, S. commersonii* and *S. indicus* are the major components in the fishery. Boatseines, shoreseines, bagnets and gillnets operated from catamarans and other small country crafts, many of them fitted with outboard motors operated at depth ranges of 15-50m contribute to the landings. Purse seine, ring seine and trawl nets are also effectively used in the fishery. The fishes exhibits seasonal migration along the west coast, moving southward in April-May, concentrates in the Gulf of Mannar and Cape Comorin during southwest monsoon (June to August) and as soon as monsoon ceases spreads from Quilon in south to Ratnagiri in the north. The distribution of their schools generally coincides with areas of high density of zooplankton, which is their major food item. Being multiple spawners, they have an extended spawning season starting from November and lasting till July. Research on whitebaits eggs and larvae (George, 1989), biology and stock assessment (Luther, 1979; Luther *et al.*, 1992) have been well documented. A potential yield of 240,000 t was estimated for whitebaits in the EEZ of India of which the share of the west coast of India was estimated to be 69% (James, 1987). Whitebaits being 'annual crops' their periodic harvest during seasons of abundance is important and targeted fishing during peak season of availability is recommended. Most of the whitebaits catch is consumed fresh 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 dryers and canning in tomato sauce are some of the ways by which better utilization of anchovies can be ensured (Jayaprakash, 2003).

4.5.5 Golden anchovy

The golden anchovy (*Coilia dussumieri*), is an important pelagic resource found in association with the Bombay-duck and non-penaeid prawns on the northwest coast. *C.dussumieri* landings have ranged from 19,048 t (1987) to 46,268 t (1998). On the northeast coasts (West Bengal and Orissa) it occurs along with another species *C. ramcarti*. Prior to 1980, *dol* net was the sole gear employed for its fishing along the northwest coast but since1985 trawlers have started encroaching in *dol* net zone and the contribution by trawl gear is on the increase. During 1986-90 trawl and *dol* contributed 38% and 60% respectively, while during 1996-2000, 70% of the catch was by trawlers (Khan, 2003). The management strategies of *C. dussumieri* cannot be considered in isolation as it is one among the many components (non-penaeid prawns, Bombay-duck, unicorn cod and juvenile pomfrets) exploited by the *dol* net. However, the resource is currently underexploited and can sustain increased fishing effort (Khan, 2003).

4.5.6 The Indian mackerel

The Indian mackerel *Rastrelliger kanagurta* is an important fishery resource especially in the context of national food security, being next in importance only to the oil sardine. The mackerel fishery comprises a single species viz., *R.. kanagurta*. However, *R. brachysoma* and *R. faughni* also are reported to occur in the catches along the east coast. Valuable information on the fishery and biology of the species such as annual fluctuations in the fishery, age and growth, spawning habits and effect of environmental factors on the fishery, stock status has been compiled (George and Banerjee, 1968; Luther, 1973; Noble *et al*., 1992; Yohannan and Nair, 2002; Yohannan and Sivadas, 2003). 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) with the intensity of feeding being very high in maturing and spent mackerel, but low in the spawners. The size at first maturity ranges from 184 mm to 225 mm in total length, (Devanesan and John, 1940; Chidambaram and Venkataraman, 1946, Pradhan, 1956). Surveys conducted under UNDP/FAO Pelagic Fishery Project (Anon., 1976) have found mackerel larvae in great abundance during March-August along the southwest coast.

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 20 years, production ranged from 113,000 t (1991) to 290,000 t (1989) (Fig.4.5). Along the west coast the fishery season starts by August and lasts till December while on the east coast the exploitation starts by December and lasts till May with peak catches in March-April. In the upwelling zone of the southwest coast from where bulk of the catch is made, the exploitation is largely by ringseines and purseseines which contribute 62% to the total mackerel catch in India. Gill net is the dominant gear on the south east coast. Till the 1980s exploitation of the resource in the upwelling areas of the southwest coast of India was mainly restricted to the post-monsoon period by traditional crafts using small surface gears like shore-seine, boat-seine and gillnets made of cotton or hemp up to 20-m depth. With the introduction of motorization and purse seine and ring seines in the early eighties, the indigenous fishery has undergone a major upheaval with heavy catches of juveniles even during the monsoon period. Mackerel prefers to stay immediately above the thermocline and during the upwelling period, the concentration of the shoals in the surface waters is high because of the abundance of plankton and shallowness of the upper mixed layer. During sinking of the thermocline in summer, they migrate to deeper waters and lose the compactness of the shoal and are vulnerable to trawl nets (Yohannan and Nair, 2002). In recent years the increasing effort in the trawl fisheries has resulted in trawl net emerging as an important gear in mackerel fishery. The commercial catch is mainly constituted by 0 and 1-year classes (180-240 mm size fish) with fishes below the size of 150 mm forming about 42% of the catch from west coast. This large scale exploitation of the juveniles is the key factor which limits the yield from the mackerel stock. Increasing the size at first capture from 140 mm to 160 mm by controlling exploitation during the

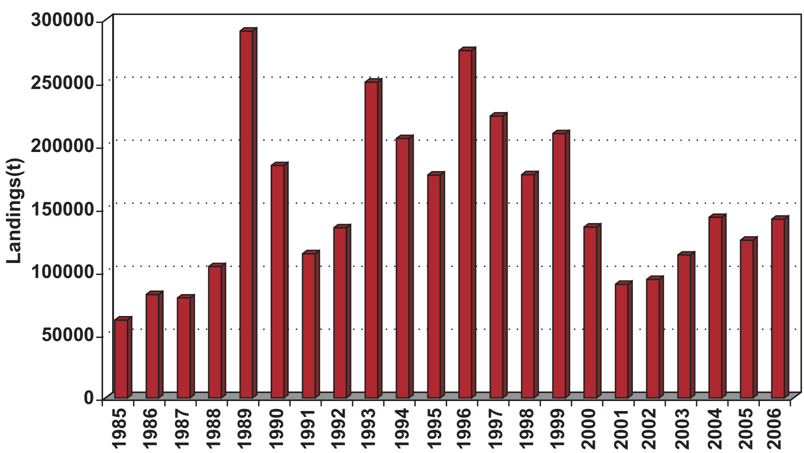


Fig.4.5 All India landings of mackerel during 1985-2006

major recruitment period (July-September) or increasing the mesh size of the larger seines to minimum of 35mm can be employed to control the growth overfishing (Yohannan and Sivadas, 2003). While the estimated potential yield of mackerel in the Indian EEZ is 2.9 lakh tonnes (Anon., 2000), annual yield show strong fluctuations due to variations in stock density, which is caused by fishery dependant and independent factors. Under the present length at first capture (140 mm), maximum sustainable yield from the resource is 2.2 lakh tonnes (Yohannan and Sivadas, 2003).

4.5.7 Tunas and bill fishes

Tunas, being highly valued food fishes are targeted fisheries worldwide. They occur in the coastal, neritic and oceanic waters and are caught using diverse types of crafts and gears. In the light of EEZ regulations and other international conventions, which require optimum utilization of marine resources by concerned maritime states, tuna fishing and fisheries have become a focal point while addressing issues of fisheries development, utilization and management. In India, tuna fishing was mainly an artisanal activity except for a brief phase of chartered and joint venture tuna fishing by longliners during the 1990s. However, of late interest in tuna fishing is picking up and tuna catches have substantially improved by nearly 58% during the 1990-2003 period compared to the early eighties. Motorization of traditional crafts, adoption of progressive and innovative fishing techniques by the mainland fishermen such as, distant water multiday gill net and hook and line fishing, conversion of idling shrimp trawling fleet for longlining and multi gear (longlining and deep sea trawling) operations, targeting oceanic tunas have been instrumental in giving a fillip to tuna fishing.

Of the 8 major species of tunas occurring along the Indian coast, five are coastal/neretic and three are oceanic and migratory. The commonly occurring coastal tuna species are *Euthynnus affinis* (little tuna), *Auxis thazard* (frigate tuna), *A.rochei* (bullet tuna), *Sarda orientalis* (oriental bonito), *Thunnus tonggol* (longtail tuna) while oceanic species include *Katsuwonus pelamis* (skipjack tuna),*T. albacares* (yellowfin tuna) and *T. obesus* (bigeye). The drift gill net is operated all along the Indian coast while the purseseine and the hooks and line are popular off southwest coast. The pole and line and troll lines are operated in Lakshadweep seas targeting skipjack and yellowfin tuna. Tuna production along the mainland coast fluctuated between 30,285 t (1987) and 54,007 t (2000) with an annual average production of 41,443t forming 3.6% of the total pelagic fish production. During 1985 –2002 period, landings on the mainland were dominated by *E. affinis* (51%) and *Auxis* spp. (21%). In the Lakshadweep seas, of the estimated 6,400 t, *K. pelamis* constituted (86%) followed by *T. albacares* (12%) and *E. affinis* (2%). Fishery biology and stock assessment of tunas and tuna live baits have been published (Silas and Pillai, 1982; Silas, 1985; James and Jayaprakash, 1991, Gopakumar *et al*., 1991; James and Pillai, 1991; James *et al*., 1992; Pillai *et al*., 2002, Yohannan *et al*., 1993).


Pole and line fishing in Lakshadweep seas

The revalidated potential yield of tunas from the Indian EEZ (Anon., 2000a) was estimated to be 278,000 t comprising 65,000 t of coastal tunas and 213,000 t of oceanic tunas. The average annual yield (1994 –2005) of coastal tunas was 46,000 t indicating moderate scope for enhancing production from the coastal fishery. However, the scope to exploit oceanic tunas is immense as only about 15,000 t are exploited currently against a potential of 2,13,000 t. Until recently about 90% of the total tuna landed was utilized in the domestic market or for '*masmin*' production while rest was exported chiefly to the Gulf countries in frozen/ chilled form. In recent years the volume of tunas exported as chilled/frozen and even of the high value *sashimi* grade has picked up due to the interest shown by the research organizations such as CMFRI, CIFT and FSI as well as export promotion agencies (MPEDA) and entrepreneurs in the fisheries sector.

Four genera of billfishes *Istiophorus*, *Makaira* and *Tetrapturus* (family Istiophoridae) and *Xiphias* (family Xiphilidae) occur in the Indian seas.

Production of billfishes in India increased considerably from 1,151t in 1991 to 4,448 t in 1997 with major species recorded being *Istiophorus platypterus*, *Makaria indica* and *Xiphias gladius* (Somvanshi *et al.*, 1998). Main sources of information on the sailfish catch in the Indian waters are data collected from the operators of chartered fishing vessels during the period 1988-94 and long line surveys of FSI which indicated appreciable catch rates of 39.4 kg/1000 hooks from the mainland and 45.76 kg/1000 hooks from Andaman and Nicobar waters. The sailfish *Istiophorus platypterus* is the most abundant species and are caught in drift gill nets, troll lines and pole & line in coastal waters and also occur as by-catch in long lines set for tunas in oceanic waters. Although a great deal of information on the distribution and abundance of this species in different areas is available, very little information is available on the biological characteristics (Silas and Rajagopalan, 1967; Balan, 1978; Siraimeetan, 1985, John *et al*., 1995, Somvanshi *et al*., 1998; Varghese *et al.*, 2004). Many of the large predatory pelagic species at the apex of the trophic level including swordfish, sailfish and marlins are considered vulnerable or endangered (Myers and Worm, 2003) and an ecosystem approach to resource conservation and management is vital for which basic biological characteristics of the various species like age, growth, food and breeding dynamics are required.

4.5.8 Seerfishes

The annual seerfish catch showed an increasing trend during the past five decades with fluctuations ranging from a mere 4505 t in 1953 to an all time peak of 54,998 t in 2003 with the increase along the west coast being remarkable. They contribute just 1.85% of the marine fish production but owing to high unit value are major sources of income for gill net and hooks and line fishermen. Out of the four species *viz*., the king seer (*Scomberomorus commerson*), the spotted seer (*S.guttatus)*, streaked seer (*S. lineolatus)* and the wahoo *(Acanthocybium solandri*), the fishery is sustained by the first two species. Kingseer is dominant (60%) in the landings followed by the spotted seer (39%). The spotted seer is more abundant than the king seer along northeast coast (West Bengal) and northwest coast (Maharashtra, Gujarat).


Seerfish landing at Mangalore Fisheries Harbour

Large mesh gillnets (120-170 mm) have been found very efficient and contribute about 65% to the total seerfish catch. Hooks and line are also found to be efficient and highly selective while purseseines along the west coast land seerfishes as incidental catch (Muthiah and Pillai, 2005). In recent years trawls are emerging as one of the important gears for juvenile seerfish exploitation, which is a destructive activity to be curbed.

Research on taxonomy, distribution, fishery and various biological aspects of seerfishes dates back to Day (1865) and detailed information on the age and growth, maturity, spawning and food and feeding habits are available (Devaraj 1977, 1981, 1983, 1986, 1987; Devaraj *et al.*, 1999; Muthiah *et al.*, 2003). The length at first maturity of *S. commerson* is 75 cm and the spawning season extends from January to September (Devaraj,1983). Spawning season of *S. guttatus* extends from January to August and for *S. lineolatus* from January to May (Devaraj, 1986, 1987).

Results of the assessment of seerfish stocks revealed that the king seer is exposed to higher fishing pressure along both coasts of India by all gears except by gillnet in Gujarat. The spotted seer is exposed to higher fishing pressure by trawl at Mangalore and Kakinada and by gillnet at Chennai and Kakinada. The gill nets of smaller mesh types like *'podivalai"* (70-100 mm) along the Tuticorin coast and the trawlers along both the coasts exclusively land small sized king seer resulting in recruitment over fishing, which is detrimental to the recoupment of the stock and therefore should be discouraged. The stock size of king seer is considerably reduced over a period of time due to continuous increase in exploitation by different gears and that of spotted seer is also reduced but not as critical as in the case of the king seer (Yohannan *et al.,* 1992; Pillai *et al.,* 1994; Devaraj *et al.*, 1999; Muthiah *et al.*, 2003).

4.5.9 Carangids

Carangids have emerged as one of the important pelagic fish groups landed by the mechanized sector and the average annual production (1985-2003) was 133,000 t which constituted 4% of the total marine fish production. Landings increased from a meagre 24,560 t (1969) to 197,000 t (1995) but declined to 110,000 t in 2000 (Fig. 4.6). There are 46 species of carangids occurring along the Indian coast but commercial fisheries comprise mainly of horse mackerel *(Megalaspis cordyla)*, round scads (*Decapterus dayi, D.macrosoma)*,, selar scads (*Selar crumenophthalmus*), queenfishes (*Carangoides* spp.), trevallies *(Caranx para, C.carangus, Selaroides leptolepis)*, leatherjackets (*Scomberoides* spp.) and pompanos (*Trachinotus* spp.). The fisheries are mostly seasonal coinciding with the monsoon and largely from 60–80 m depths along the mainland coast and 20 - 40 m in Andaman seas. Exploitation is done by a variety of gears such as trawl nets, drift and bottom-set gillnets, hooks and line, shore seines, ringseines and purseseines.

Most of the carangid species landed are only a by-catch in almost all the gears except small meshed drift gillnets, boat seines and shore seines and not subject to any increased fishing pressure. Among the 11 species, four of them *viz. S. leptolepis* at Tuticorin, *D. macrosoma* and *S. crumenophthalmus* at

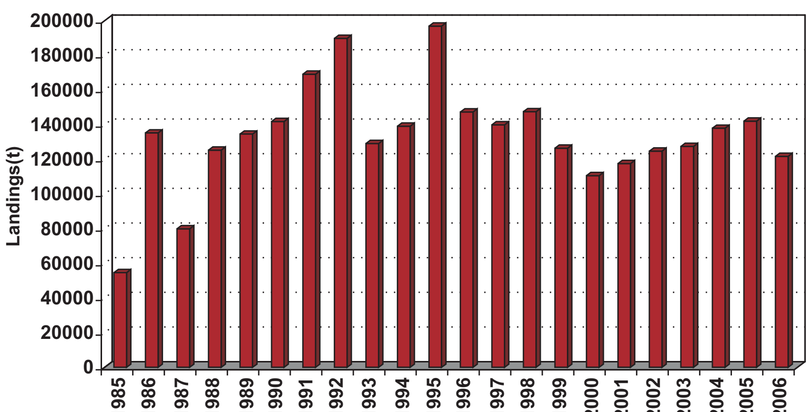


Fig. 4.6 All India landings of carangids during 1985-2006

Kakinada and *C. para* at Mangalore are underfished. *C. carangus* is underfished along the Tamil Nadu and Pondicherry coast and optimally fished off Tuticorin. *A. atropus* is optimally fished from northwest region. Species like *M. cordyla* is underfished along both east and west coasts. However, there appears to be overfishing of the species off Veraval and certain centres in the southwest region. *D. russelli* indicated overexploitation off Kakinada. Others like *A. kalla* along the southwest and *A.djedaba* and *Atule mate* along the Kerala coast are over fished. (Reuben *et al*., 1992a; Kasim, 2003). The carangids are in good demand in the domestic market and recently larger species such as *C. malabaricus, C. melampygus, C. ignobilis, Atule mate,* and *Alepes djedaba* are also being exported in frozen form.

4.5.10 Ribbonfishes

The ribbonfishes, (hair-tail or cutlass) are widely distributed along the Indian coast and form major pelagic fishery resources of the Indian seas. They constitute about 4% of the total marine fish landings of India. The average ribbonfish production in the 60s was 28,171 t, which increased to 65,360 t during the 80s to 120,461 t during 1990s. The average production during 2001-2005 was 159,352 t (Fig.4.7). *Trichiurus lepturus* is the dominant species (>95%) in the fishery. Species such as *T. russelli, Lepturacanthus savala, L.gangeticus, Eupleurogrammus muticus and E. glossodon* have also been

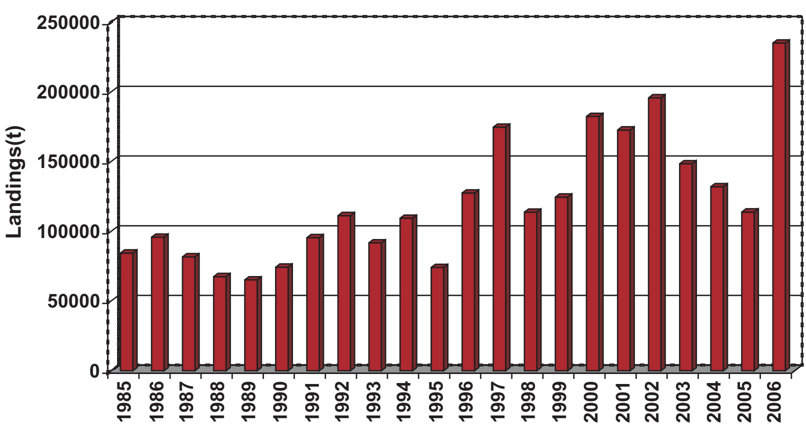


Fig. 4.7 All India landings of ribbonfishes during 1985-2006

recorded in the Indian waters. The major gears are trawls (70%) followed by the bagnets, gillnets and the purseseines. Considerable information on the fishery and biological aspects like age and growth, food and feeding, maturity, spawning, etc. of *Trichiurus lepturus, Lepturacanthus savala, Eupleurogrammus muticus* and *E.glassodon* is available (Venkataraman, 1944; Devanesan and Chidambaram, 1948; Jacob, 1949; Prabhu, 1955; James, 1967; James *et al.*, 1986; Narasimham, 1995). The ribbonfishes are carnivores, feeding predominantly on fishes, especially anchovies and to a smaller extent on shrimps and important in the marine food web as predators.

Nearly 64% of the ribbonfishes landed annually in India are exported in frozen form to China, Japan and other southeast Asian countries, the remaining being either routed for the domestic fresh fish market or sun-dried. The development of export market has led to targeted fishing for ribbonfishes and to a certain degree of unsustainable exploitation especially on the east coast, as evidenced from increasing component of juvenile ribbonfishes in trawl landings. This has created some stress on the stock inviting appropriate management interventions. It is suggested that in the present context a better and practical option would be to control the exploitation during the period of abundance when maximum removal of stock takes place, through limiting the fishing intensity. This may ensure maximum survival of broodstock and thereby help the resource to replenish by itself in due course (Nair and Prakasan, 2003).

Ribbonfish landing at Puthiyappa, Calicut

4.5.11 Bombay-duck

Bombay-duck constitutes a fishery of high magnitude along the northwest coast and are conspicuously absent on the southwest and southeast coasts. They form a seasonal fishery on the northeast coast (West Bengal, Orissa and the northern part of Andhra Pradesh). It is significant to note that during 2005, West Bengal (36,000 t) have surpassed production from the traditional coast of Maharastra (22,500t). They contribute about 5% of all India marine fish production with annual landings ranging from 67,392 t (1988) to 136,442 t (1991) (Fig.4.8). Studies on fishery biology and stock assessments have been made (Bapat *et al.*,1952; Bapat,1970; Khan *et al.*, 1992; Kurian,1989; Kurian and Kurup,1992; Fernandez and Devaraj, 1996). Fishing for Bombay duck is traditionally carried out by a stationary bag net called *dol* net along Maharashtra and Gujarat coasts. The gillnets, boatseines and trawls are also employed in this fishery. Though *Harpadon nehereus* was the sole contributor along the northwest coast, another species *H. squamosus* (195-214 mm) has been recently recorded off Kakinada on the northeast coast. The fishing season here shows two distinct phases of productivity: (i) September to January, which is more productive, with the predominance of adults over the juveniles, and (ii) February-March, which is less productive, with juveniles forming a major part of the catch. In the past, Bombay-duck stock has been exploited with a mix of success and failure. Large-scale landings of indeterminate and immature fish by *dol* nets and trawlers are a source of concern.

The Bombay-duck is highly perishable because of its high water content, and hence needs speedy disposal. The bulk of the catch is sun-dried and sold in the interior markets while a small portion is converted into manure. Laminated Bombay-duck are in good demand in some foreign markets.

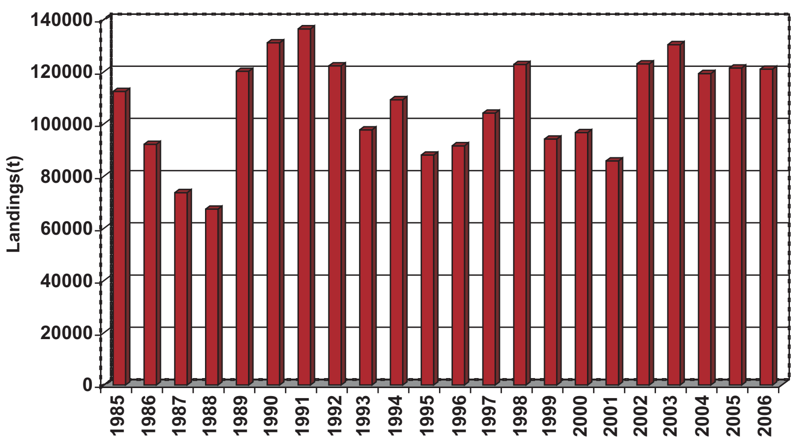


Fig. 4.8 All India landings of Bombay duck during 1985-2006

4.5.12 Pomfrets

Pomfrets belonging to the family Stromateidae, comprises silver pomfret (*Pampus argenteus*) and the Chinese pomfret (*P.chinensis*) which form about 2% of all India marine fish landings. They are highly relished table fishes and command high unit value in internal and export markets. Landings are mainly from Gujarat and Maharashtra on the northwest and Orissa on the northeast coasts. Landings increased from 13,600 t during the early 50s to around 47,200 t in the early 80s and was about 41,000 t during the late 90s (Khan, 2000). On the northwest coast the principal gear exploiting the adult pomfrets are drift gillnets (140-155 mm mesh size) while the *dol* net essentially exploits the juveniles. Studies on fishery biology (Kuthalingam, 1963; Pati,1980,1982) and stock assessment (Khan *et al.*, 1992) have been published. As the fishery on the northwest coast collapsed during the 1990s, restriction of *dol* net operations to minimise recruitment overfishing and regulation of gillnets to minimise growth overfishing were recommended as management measures to be urgently implemented (Khan, 2000). Recently, the CMFRI recommended minimum legal weight (MLW) of 300 g for export of pomfrets have been implemented by the Marine Products Export Development Authority (MPEDA), which can go a long way in ensuring the sustainability of the fishery.

4.5.13 Hilsa shad and other clupeids

The Hilsa shad (*Hilsa ilisha*) form a prominent fishery in the northeast coast. They are known to spend most of their life in the inshore areas and migrate into the estuaries and rivers for breeding. Two well marked migration of Hilsa shad into Hooghly river during post-monsoon (September-October) and winter (January-February) have been reported (Jones, 1957). The gillnetters contributed the bulk of the shad catches in the size range of 260 mm to 480 mm. The average annual catch of shad increased from 21,086 t in 1999 to 44,734 t in 2003 with an average production of 27,940 t, mainly comprising of the Hilsa shad only (71%). Stock has been assessed and several management measures recommended which include prevention of destruction of small fishes in seine nets and breeding fishes in gillnets during their migration to upstream (Reuben *et al*., 1992)

4.5.14 Barracudas

The barracudas (seapikes) of the family Sphyraenidae are top predators, feeding voraciously on other pelagic fishes and are caught in sizable quantities along the Indian coast. The annual catch improved remarkably from 4000t (1986) to 18,576 t (2001). Four species, *Sphyraena obtusata, S.barracuda, S.jello* and *S.forsteri* constitute the barracuda fishery in India (Kasim, 2000). Though they form shoals, the larger ones prefer to be solitary. Hence the larger fish are caught in hooks and line, bottom set gill nets and drift gill nets, while the smaller ones are caught by trawls in fairly good quantities.

4.5.15 Unicorn cod

The unicorn cod (*Bregmoceros mcclellandi*)forms a coastal fishery along the Gujarat and Maharashtra coast with only stray catches reported elsewhere (Rao, 1973).The fishery starts in the post-monsoon (October) and closes by March due to dwindling catches. It has been reported in good concentration in the Deep Scattering Layer (DSL) along the coast of Bombay-Ratnagiri area as well as on the southwest coast (10^o 29’ N- 75^o30’E) as well as in certain pockets in the Andaman seas (Reghu *et al.*, 1996). This fish is an important link in the food chain of many commercially important species such as sciaenids, polynemids and Bombay duck (Bapat and Bal, 1952; Suseelan and Nair, 1969). Larvae have been recorded on the southwest coast (Anon., 1975; 1976) and northeast coast (Jones and Pantulu, 1958). The landings have decreased from 6880 t per year during 1950-54 to 604 t/year during 1999-2005. In view of the consistently declining fishery, the unicorn cod may have to be listed as vulnerable, and strategies devised to restore the population.

4.5.16 Flying fishes

The flyingfish fishery is seasonal and limited to the Coromandel coast in Tamil Nadu supported mainly by the species *Hirundichthys coramandelensis*. The average (1999-2006) annual catch of 4,217 t was taken almost exclusively by the scoopnets.

4.5.17 Other pelagics

Clupeids such as the wolfherring (*Chirocentrus dorab*), Rainbow sardine (*Dussumiera* spp.), *Escualosa, Ilisha, Nematalosa, Opisthopterus, Pellona, Reconda, Dorosoma, Chanos* etc. together form about 1.6 % of the total all India landings. The mullets (*Mugil* spp.) form a fishery mainly in the northwest region, which contributed an annual average of 6,056 t during 1999-2006.

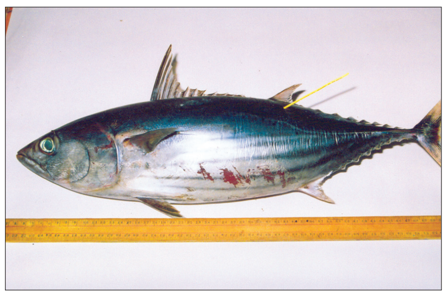
4.6 Research priorities in the management of pelagic fisheries

4.6.1 Impact of environment on pelagic fisheries

There is strong evidence that annual variations in the year class strength of pelagic fishes in upwelling areas are governed mainly by oceanographic factors such as upwelling intensity, offshore water transport and water column stability and each year the success of pelagic fisheries is a delicate balance between physical oceanographic factors and effects of fishing on the stock. Numerous studies conducted so far confirm that seawater temperature, dissolved oxygen levels, salinity, phytoplankton and zooplankton concentrations play a vital role in controlling the distribution and abundance of pelagic fishery resources. Also the global warming phenomenon caused mainly due to the anthropogenic emission of greenhouse gases by which earth's temperature regime is changing is seriously affecting the environment of the fish and its effect has to be studied with regards to the adaptability of fish to the changed environment, shifting areas and seasons of abundance and spawning. Thus, fishery environment data has become crucial to addressing productivity of fishing grounds, annual/long term fluctuations in fish catches and making fishery forecasts. Today, parameters like Sea Surface Temperature (SST) and phytoplankton pigments (Chlorophyll *a*) obtained from satellites are available with agencies like the Indian National Centre for Ocean Information Services (INCOIS) and are used in prediction of Potential Fishing Zones (PFZ). Dissemination of information of PFZ's among the fishermen in Kerala and Lakshadweep had been facilitated by Central Marine Fisheries Research Institute (CMFRI) and feedback received indicated that considerable reduction in cost of fishing by saving time and fuel for locating fish shoals could be achieved (Pillai *et al.*, 2000). This technology requires further strengthening through refinement and validation. Creation of maps indicating the spatial and temporal distribution patterns of pelagic fishes and their prediction on a Geographical Information System (GIS) platform is another potentially powerful technology that needs to be developed.

4.6.2 Fish migration

Most of the pelagic finfish species move in large shoals and exhibit certain characteristic migratory pattern. While the small pelagics like sardines and anchovies perform migrations along the coast, mackerels, scads and coastal tunas migrate fairly long distances between inshore and offshore waters. Therefore understanding the migratory patterns of pelagics, crucial for planning a successful fishery and its management. Tagging and recovery is the best way to study migration and growth of pelagic fishes and sophisticated acoustic and telemetric tags have been developed to allow continuous observations of the movements of a single fish. Tagging studies for oceanic tunas in collaboration with organizations such as Indian Ocean Tuna Commission (IOTC) Ministry of Earth Sciences (MOES) and Fishery Survey of India (FSI) is required to understand the dynamics of this important resource in the Indian EEZ.



Tagged skipjack tuna recovered from Minicoy

4.6.3 Role of FADs in enhancement of fish production

Fish Aggregating Devices (FADs) are used to create special conditions where plenty of hiding sites and abundant forage availability for fishes attract them for feeding and even spawning. FADs have been welcomed by many fishermen as it helps them reduce scouting time for shoals thereby saving on fuel costs. Oceanic tunas are found to gather around floating objects and logs in very large numbers. Large floating devices (*Payayos* type of Philippines) are reported in the Nagapattinam coast of Tamil Nadu while National Institute of Ocean Technology (NIOT) deployed 28 FADs in the Lakshadweep seas in 2006 which are reported to be attracting tunas. FAD associated tuna purse seine and longlining in the Indian EEZ (lat 12-16^0 N and 60-74^{0}E long.) has been suggested to augment production of oceanic fishes, especially tunas (Vivekanandan, 2006). However, the opinion on the utility of FADs is divided as mostly juvenile fishes aggregate near FADs, which in the long term may adversely impact the stocks. Hence studies are required on fish behaviour *vis-a vis* FADs and their impact on fisheries. Evaluating a FAD associated tuna fishery in Lakshadweep waters is a major program being implemented in a funded project entitled "Tuna resources of the Indian EEZ –their growth and migratory pattern". The project is expected to provide an understanding on the aggregation dynamics of tunas and their feeding behaviour around FADs so that appropriate management strategies can be formulated for the tuna fishery of the Lakshadweep islands.

4.6.4 Development of predictive models

Reliable estimation of stock size is required to formulate any fisheries management policy but pelagic fish stocks are known for their unpredictable catch fluctuations. Pelagic fish stock estimation using classical models have many limitations as these fishes have highly variable recruitment pattern and complex environmental – biological interactions. Therefore appropriate new stock assessment models using time series data on phytoplankton, zooplankton, fish catches, hydrography and climate data that will bridge the interface between physics and biology will have to be developed. Already some attempts have been made to understand the dynamics of pelagic fisheries through mathematical modeling of fishery dependent and independent factors (Srinath, 1998). Predictions for oil sardine fishery along the Indian coast based on sunspot activity, rainfall intensity, sea level change and duration and upwelling indices have been made (Jayaprakash, 2002) and this could be attempted for other pelagic species also.

4.6.5 Fish recruitment dynamics and modeling

Fluctuations in pelagic fish landings are partly due to recruitment variations. Many of the world's greatest fisheries particularly for pelagics like the sardines have collapsed owing to recruitment failure caused by high fishing pressure on the spawning stock. There is also a significant influence of environment in determining the recruitment success of pelagic species every year. Rational exploitation, conservation and management of resources require information on recruitment variations as well as the environmental factors involved in the process. A valuable database on recruitment variations is available from the time series database on length frequency, maturity and fecundity of about 19 pelagic species, as collected from commercial catch data. Strengthening of above database by including information collected from specific resource surveys for eggs and larvae of marine finfishes during the XI Plan period can aid fishery forecasts as well as serve as input for fixing of annual optimum fishing levels for sustainable management of pelagic fish stocks.

4.6.6 Conservation and management

Most of the pelagic species move in large shoals and exhibit certain characteristic migratory pattern to the inshore, offshore or deeper areas for the purpose of feeding or breeding. In the course of such migration, large schools enter the coastal waters and constitute a local and seasonal fishery. Towards the close of the season, a part of the stock that escapes from heavy fishing probably migrate away from the fishing ground to offshore or deeper areas and thus becomes unavailable in the traditional fishing grounds resulting in an offseason for the fishery. This emigrant part forms the broodstock that contributes to new recruits to the coastal fishery in the subsequent years and hence offshore fisheries development plans have to take this aspect also into consideration. This requires a sound knowledge base on the behaviour of spawners of different fish species as well as their fecundity variations, which can be obtained through specialized studies.

Fishing vessel based stripping of ripe spawners of oil sardine and mackerel captured in the nets and releasing the eggs in the fishing grounds has been

Ring seine - mass harvesting gear being cleaned after fishing by country craft fitted with 120 hp Leyland engine

tried on an experimental scale. Such programmes in addition to existing restrictions on fishing for spawners and in spawning grounds will have to be strengthened. Fishing for oil sardine and mackerel by ringseines and purseseines (8 -18 mm mesh size) and Bombay-duck using *dol* net (10-50 mm) has been observed to catch very small recruits of these fishes in the inshore waters especially during monsoon period, which cause huge economic loss and may eventually causes growth over fishing in these stocks. The potential detrimental effects on fish stocks due to large-scale deployment of ring seines off Kerala coast have been highlighted (James, 1992a; Yohannan and Sivadas,1993) but still gear remains popular among fishermen and there is huge increase in its fishing efficiency due to uncontrolled and unscientific increases in net dimensions and decrease in mesh size . Even though the 8 mm meshed ring seine net is meant for fishing the whitebaits, young recruits of sardine and mackerel measuring 40-80 mm are also caught in large quantities and hence these nets should be restricted solely to exploit whitebaits (*Stolephorus* spp.) by enacting suitable policy regulations. Further proliferation of ringseiners also needs to be checked urgently. Awareness creation among all stakeholders against non-sustainable fishing practices with a participatory management approach has become inevitable in fisheries management and the Pelagic Fisheries Division has been working in this direction by preparing and distributing pamphlets on juvenile oil sardine destruction along the Kerala coast (Anon., 2001). It is also vital to make periodic assessments of the pelagic stocks, the fishing practices adopted and the juvenile and spawner components of the catches (Luther and Sastry, 1993). Based on this, need based management measures can be formulated either as input controls (restriction of fleet size, mesh size, closed season) or output control (restriction on fishery for certain species, size of fish caught etc.).

4.7 Future prospects of pelagic fisheries

Marine fisheries resources of our country are dynamic and subject to fluctuations due to fishery dependant as well as fishery independent factors. Hence it has become necessary to periodically review the status of exploited resources and make critical assessment of the fishery potential as more data based on exploratory surveys as well as research on the various resources emerge. Estimates of annual Potential Yield (PY) in the Indian EEZ have been made based on the primary production in the Indian seas, exploratory surveys and the approximation based on the estimated production from exploited stocks (James *et al*., 1987) and has varied from 2 to 8.5 million t per year (Bapat *et al*., 1982). In the context of the declaration of EEZ in 1977 (George *et al*., 1977) made an estimate of annual potential yield as 4.47 million t. The revalidated marine fishery potential from the Indian EEZ was 3.93 million t (Anon., 2000a) of which the share of pelagic resources was 1.67 million t. Catch trends and potential yield estimates are given in Table 4.7.

Table 4.7 Catch trends and potential yield estimates of different groups

Group	Average catch (t) 1985-89	Average catch (t) 1999-2003	Max.landings (t) and the year in parentheses	Potential yield* (t)
Oil sardine	141831	319419	403952 (2003)	294869
Other sardines	76541	101130	128000 (1995)	101490
Anchovies	68630	115598	101000 (1988)	141817
Other clupeoids	132626	43987	195000 (1998)	78932
Bombay duck	93185	105601	138000 (1981)	116227
Ribbonfishes	78384	172102	235084 (2006)	193670
Carangids	111040	120608	197000 (1995)	238148
Indian mackerel	123832	128430	291000 (1989)	295040
Seerfishes	35171	48905	55000 (1998)	61719
Coastal tunas	34185	50337	52000 (1990)	65472
Oceanic tunas		12000	12000 (1998)	213000
Barracudas	-	17125	22000 (1998)	20849
Pomfrets	37356	38378	42000 (1983)	46088

Source: Modified Srinath and Balan, 2003 **Anon. , 2000a*

Recent instances of either species specific or location specific depletion of resources in the Indian marine coastal fisheries sector are emerging as evidences of unsustainable fishing pressure. The *Comprehensive Marine Fishing Policy* announced in 2004 therefore envisages a shift from the present 'open access fisheries' to a 'regulated access' system besides putting in a stringent management regime (Anon., 2004a). As regards pelagic resources, though a progressive trend is noticeable in production of some groups, many of them, especially the oil sardine, mackerel, Bombay-duck, seerfishes, ribbonfishes and coastal tunas have reached the optimum level of exploitation in the conventional inshore fishing grounds. The stock assessment studies conducted for 19 species of exploited pelagic finfishes have shown that the present effort expended is close to or in some cases even exceeded the level of MSY and further increase in effort in the coastal sector would be detrimental to sustain the yield (James, 1992b). There are also certain imbalances in pelagic fish landings *vis-a vis* their potential, especially on the north east coast of India where demersal fisheries especially shrimp trawling is given more importance (Sudarsan *et al*., 1991).

Since the potential from the 0 to 50m depth zone is estimated to be in 11.74 lakh t and the current production from the presently fished grounds is already 14.1 lakh t, 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 (James *et.al.*,1989).The groups, which are expected to contribute significantly to the additional yield from beyond the conventional fishery zone (outer shelf and oceanic waters) are the whitebaits, carangids, ribbonfishes, barracudas, oceanic tunas, billfishes and pelagic sharks (Joseph and John, 1987; James *et al*., 1987,1989; Pillai and Pillai, 2000). Of these, tunas are the most important being the third major fish commodity traded internationally after shrimps and groundfish. While the estimated resource potential of oceanic tuna in the Indian EEZ is 213,000 t. the landings are negligible forming only about 10% of the potential and strategies for better utilization of these resources have to be formulated. The options available are extension of the operational range of crafts, introduction of combination vessels (drift gillnetting and longlining) for multiday target fishing, introduction of 'light luring' purseseiners, conversion of idling shrimp trawlers for offshore tuna longlining and drift gillnet fishing, providing chilling and cold storage facilities on board the vessel and development of suitable post-harvest and value addition technologies for utilizing the products for domestic as well as export markets (James *et al*., 1989; Pillai and Pillai, 2000). During the last few years, harvesting of deep-sea tuna has increased due to the efforts of the MPEDA and DAHD&F (Ministry of Agriculture) in subsidizing the conversion of idling mechanized shrimp trawlers and deep-sea vessels to tuna long liners. As a result *sashimi* grade tuna could be exported to markets like Japan and USA leading to economic empowerment of the fishermen. Exploratory survey in areas between lat 13^0N and 21^0N upto 200 m depths on the north east coast using pelagic trawls, purse seines and high opening trawls have shown abundance of pelagic groups such as clupeids, carangids, mackerels, ribbonfishes, and barracudas and good potential for developing an offshore fishery for Indian mackerel and Indian drift fish *Ariomma indica* using high opening demersal trawls (Sudarsan *et al*., 1991) which needs to be evaluated further and if feasible, implemented.

Studies have also been conducted on the fish biomass in the deep scattering layers of the Indian EEZ and found to be constituted mainly by non-conventional mesopelagic and bathypelagic resources such as myctophids, gonostomids and stomiformes (Menon, 1990; Raman and James, 1990; Menon *et al*., 1996, 1996a; Jayaprakash, 1996). According to a recent observation, myctophid fishes dominate the mesopelagic fish fauna in the Arabian Sea, especially *Benthosema pterotum* with stock estimates ranging upto 100 million tonnes per year (US GLOBEC 1993). Myctophids are opportunistic feeders on zooplankton, prawns and small fishes and as part of the food web they are predators or prey at various trophic levels. They exhibit diurnal migration being in surface layers at night and between 800 –1000 m depths during daytime and serve as forage for large commercially valuable species such as tunas. They are also reported to be used by the fishmeal industry. Hence strategies for exploiting these resources based on the energetics of the ecosystem, wherein prey requirements of various predators as well as surplus production are assessed can be prepared.

The fishing activities in the offshore and the high seas are at present limited since such activities are capital-intensive and require offshore fishing vessels (longliners, purseseiners, midwater trawlers), infrastructures, shore facilities, expertise and skilled manpower. Further studies on availability and abundance of these deep sea resources and development of facilities for offshore fishing operations, value added product development, marketing and export would provide the necessary impetus for further development of pelagic fisheries in the country. In addition, existing fisheries should be sustained by developing management strategies based on the unique biological characteristics and self-renewal capacities of the major fishery resources, under an Ecosystem Based Fisheries Management (EBFM) module.

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