Handbook of
Fisheries and Aquaculture

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India has been one among the top 10 fish-producing countries of the world since 1960; with its position oscillating between the third and the sixth rank. Currently India occupies the third position, contributing about 4.81% (6.2 million tonnes including inland and marine production) to the world fish production of about 128.8 million tonnes. The marine fish production in India had reached 2.72 million tonnes in 1997 due to mechanization of crafts, motorization of country crafts, commencement of the stay-over fishing, and improvements in gears and related infrastructural facilities, which were introduced at different periods since late 1950s. Almost 90% of the fish production was obtained from within 70 m depth covering an estimated area of 100,000 km^2.

Among countries bordering Indian Ocean, India, endowed with 2.02 million km^2 of exclusive economic zone (EEZ) along a coastline of 8,129 km and 0.5 million km^2 of continental shelf with a catchable annual marine fishery potential of 3.93 million tonnes, occupies a unique position. Besides, there are vast brackishwater areas spread all along the coastline, which offer ideal sites for sea-farming and coastal mariculture. Among Asian countries, India ranks second in aquaculture and third in capture fisheries production, and is one of the leading nations in marine products export. The development of the Indian marine fisheries from a traditional subsistence-oriented one to industrial fisheries through Five-Year Plans has been phenomenal. However, the present scenario is characterized by declining yields from inshore waters, and increasing conflicts among different stakeholders, but the increasing demand for fish in domestic and export markets indicates good prospects for large-scale exploitation of oceanic and deep-sea resources. The production from capture fisheries is stagnating around 2.5 million tonnes per annum, threatening to decline, and warranting effective management of exploited stocks. The Indian experience with small-scale fisheries sector is similar to that of any other tropical developing countries. The multitude of species exploited by a large variety of fishing fleets make management of marine fisheries a difficult proposition. An attempt is made here to bring out historic and current status of pelagic fisheries and to focus attention on their sustained development through appropriate management plans.

The marine fisheries resources are mainly constituted by pelagic finfishes (all those fishes which live most part of their life in surface or subsurface waters), numbering about a dozen groups and species, demersal finfishes (those fishes which live most part of their life on bottom or sub-column layers) contributed by about 15 major groups and species, crustaceans comprising about 5 groups, and cuttlefishes and squids.

Pelagic fishery resources

Pelagic fishes are highly migratory and generally show shoaling behaviour. Pelagics comprise different taxonomic groups, which contribute to their rich species diversity and abundance. The important varieties belonging to pelagic group are clupeids, formed by wolf herring, oil sardine, lesser sardines, *Hilsa,* anchovies (*Coilia*, *Setipinna, Stolephorus, Thrissina, Thryssa*) and others; Bombay-duck, halfbeaks, and fullbeaks, flying fishes; ribbonfishes, carangids (horse mackerel, scads, leatherjackets), Indian mackerel, seerfishes, tunas, billfishes barracudas, mullets and unicorn cod. Among these, groups contributing to more than one lakh tonnes are oil sardine, lesser sardines, anchovies, mackerel, Bombay-duck, carangids and ribbonfishes. The increase or decrease in annual marine fish production of the country, by and large, depends on the success or failure of these groups. From available information on the distribution of marine fishes along the Indian coast, it could be inferred that there are 240 species of pelagics (Table 3.1). A few species of pelagics enjoy wide geographical distribution while others such as the shads (*Hilsa* spp.) and Bombay-duck (*Harpadon nehereus*) have restricted distribution.

Table 3.1 Major taxonomic categories of pelagics and their species diversity

Family	Group/species	Species number
Clupeidae	Oil sardine*	1
	Lesser sardines*(including rainbow sardines)	14
	Hilsa spp. and other shads	15
	Whitebaits*	24
	Thryssa and *Thrissocles* spp.	10
	Wolf herrings	2
	Other clupeids	40
Scombridae	Coastal tunas	5
	Oceanic tunas	2
	Seerfishes and wahoo	5
	Mackerels*	3
Trichiuridae	Ribbonfishes*	8
Carangidae*	Round scads	2
	Golden scads	6
	Hardtail scad (or horse mackerel)	1
	Jacks	17
	Black pomfret	1
	Others	19
Harpodontidae	Bombay-duck*	1
Stromateidae	Pomfrets	2
Coryphaenidae	Dolphinfishes	2
Rachycentridae	Cobia	1
Mugildae	Mullets	22
Sphyraenidae	Barracudas	7
Exocoetidae	Flyingfishes	10
Bregmacerotidae	Unicorn cod	1
	Others	19
	Total pelagics	240

* Major pelagics.

Crafts and gears

Conventional canoes, pablo-type boats and catamarans are fishing crafts used in exploitation of pelagic resources. They are navigated either manually or mechanically by fitting inboard/outboard engines. In addition to these, different sizes of trawlers and purseseiners are being engaged.

There is a wide array of gears employed in pelagic fisheries. The gears used are shoreseine, boatseine, gillnet, drift gillnet, hooks and line, pole and line, *dol* net, etc. Among these, shoreseine has gradually disappeared, and *Rampani* of Karnataka has been replaced by purseseine and ringseine.

Purseseine, ringseine, gillnet of various mesh sizes and pelagic-fish trawl were introduced later for pelagic resources exploitation. Over and above, considerable quantities of pelagic fishes are being landed in high-open trawl nets operated from shrimp trawlers. The introduction of purseseine in seventies and ringseine in eighties, and motorization of traditional crafts in early eighties had enhanced pelagic fish production from the currently exploited 0–50/100 m depth zones at different stages.

Trends in production

The annual average marine fish production of India for 1985 to 2005 was 2.3 million tonnes, of which the pelagics contributed 1.4 million tonnes against an annual catchable potential yield of 1.92 million tonnes from the Indian EEZ. During last decade pelagic finfish resources contributed 46–56% (average: 51%) of the total marine fish production. Almost 70% of the production was from within 50 m depth zone. As per the revalidation, annual potential yield from the EEZ of India is 3.9 million tonnes, out of which 2.21 million tonnes are from within 50-m depth zone and 1.69 million tonnes are from beyond this. The current yield from 0 to 50 m depth zone is at the optimum level, and hence does not offer any scope for increasing yield, and this zone requires regulatory management for sustaining yield. Therefore, the region beyond 50-m depth has to be the focus of expansion.

Comprehensive account on the pattern of development of pelagic fishery, based on historical data (the status, prospects and management of the small pelagic fishes) and results of stock assessment of major pelagics, is available. Until mid-seventies, the share of the pelagic groups in the overall production remained very high with a consistently increasing trend from 54% in 1950s to 71% in 1960s, and thereafter, at around 65% till early seventies. The pelagic catches increased from 309,000 tonnes in 1950 to 1,414,064 tonnes (2002); registering more than a fourfold increase.

In early years of development of marine fisheries, the growth rate of pelagic fishes production had been conspicuously higher than overall marine fish production. In 1970–79 this trend reversed due to rapid expansion of commercial trawling for shrimps for exports by the industrial sector. Commercial trawling resulted in significantly high production of demersal finfishes also, besides shrimps, crabs, lobsters and cephalopods. Although pelagic fish catches increased by 22%, the trend in the overall production was set by demersal finfish and crustacean catches. The next decade (1980–89) witnessed a growth of 27% in pelagic catches as well as in overall production (Table 3.2). During this decade there was rapid motorization of traditional fishing craft, particularly in latter half of the eighties. As the result, the stagnation in marine fish production witnessed in first half of eighties gave way for accelerated production

Table 3.2 Growth in average annual overall and 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
2000–2005	1,326,055	2,516,608	+19	+11

in later half. Intensive motorization of traditional fishing crafts resulted in a remarkable increase in annual production, especially of total pelagics, which increased from 769,000 tonnes in 1985 to 1,414,064 tonnes in 2002, registering a 71% increase.

Pelagics production in four geographical regions

State-wise contribution to pelagic fish production during 2005 showed that Kerala ranked first among maritime states of India, contributing about 24% to total pelagic fish catch, followed by Gujarat contributing to 18%. The contribution by Maharashtra and Tamil Nadu was 12% each, Karnataka was 10%, Goa was 3%, Andhra Pradesh was 7%, West Bengal was 9%, Pondicherry was 1% and Orissa was 4%. This shows that southwest region comprising Goa, Karnataka and Kerala continued to be the highly productive area (37%), followed by northwest, covering Gujarat and Maharashtra (30%), southeast, covering Tamil Nadu, Pondicherry and Andhra Pradesh (20%) and northeast, covering West Bengal and Orissa (13%).

Sector-wise landings

Mechanized sector contributed 49% to the total pelagics, followed by motorized (36%) and non-motorized (traditional) units (15%) (Table 3.3).

Table 3.3 Sector-wise effort, catch and catch/hr of pelagics in respect of different units in India during 1999–2003

	Mechanized	Motorized	Non-motorized (traditional)
Catch/hr (kg)	44	32	22
Total catch (tonne)	763,994	550,911	227,498
Effort(AFH) (hr)	17,435,308	17,697,995	10,961,736
Effort (units) (number)	1,076,745	4,102,995	3,015,025
Contribution (%)	49.5	35.7	14.8

A comparison of average annual production of major pelagic finfishes from initial stages of mechanization in 1960s to 1993–94, through early and late 1980s, showed an increasing trend with respect to all groups (Table 3.4). Substantial increase was noticed in anchovies, Bombay-duck and tunas and billfishes till 1992 and that of

Table 3.4 Average annual landings of major pelagic finfishes in initial stages of mechanization to 1998–2005 (catch in tonnes)

Major pelagics	1961–65	1981–85	1988–92	1993–97	1998–2003	2004–2005
Oil sardine	173,457	182,920	190,378	106,611	304,690	359,117
Lesser sardines	29,326	63,069	83,379	106,143	97,205	84,687
Anchovies	22,783	57,073	145,197	136,449	122,031	111,873
Bombay-duck	84,375	110,064	116,287	98,190	108,328	116,244
Ribbonfishes	24,153	50,056	82,910	116,043	156,811	121,592
Mackerel	38,622	40,595	165,504	226,535	136,423	125,833
Seerfishes	10,155	30,206	37,521	41,611	48,883	42,445
Tunas and billfishes	4,222	17,789	41,236	41,485	46,210	43,966
Carangids	22,027	48,769	152,142	150,509	150,903	139,089

ribbonfishes and mackerels till 1993–94. Compared to 1960s, in 1980s production almost doubled or even trebled for many groups, excepting oil sardine and mackerel; which showed only marginal increase. Increase in production in early eighties could be attributed mainly to purseseine fishing, while that of late eighties and nineties to motorization of country crafts, introduction of innovative gears like ringseine and commencement of stay-overfishing.

Major pelagic stocks

Out of 240 species that contribute to pelagic fisheries along the Indian coast, only 60 species belonging to 7 groups, oil sardine, lesser sardines, anchovies, Bombay-duck, ribbonfishes, carangids and Indian mackerel form major fisheries. Annual average production of these during 1990–2005 was 1.02 million tonnes; forming 82% of pelagics and 42% of total marine fish landings. The other pelagic groups, which include wolf herrings, shads, barracudas, unicorn cod, mullets, seerfishes and tunas, formed only 18% of pelagic fish landings. The groups, which exceeded one lakh tonnes in production per year, were mackerel (1.6), oil sardines (2.2), anchovies (1.2), carangids (1.4), ribbonfishes (1.3) and Bombay-duck (1.1). Oil sardine and mackerel were most predominant, contributing 10% and 6.8% to overall marine-fish landings. Carangids formed 6% followed by ribbonfishes (5.3%), anchovies (4.8%). Bombay-duck formed 4.5%, lesser sardines (4%), Tunas 1.9%, Seerfish 1.8%, Hilsa shad (1.1%), wolf-herrings and barracudas (0.6% each) in the overall marine fish landings during this period.

The percentage contribution of pelagics ranged from 1.1 of barracudas to 18.2 of oil sardine (Table 3.5).

Table 3.5 The average landings of pelagic finfishes (in tonnes) and their percentage contribution during 1990–2005

Groups	Catch (tonnes)	(%)
Oil sardine	224,655	18.2
Mackerel	163,832	13.1
Carangids	142,385	11.4
Ribbonfishes	129,540	10.4
Anchovies	116,098	9.3
Bombay-duck	110,696	8.9
Lesser sardines	97,306	7.8
Other clupeids	47,720	3.8
Tunas and bill fishes	45,950	3.7
Seerfishes	43,698	3.5
Hilsa shad	25,359	2.0
Wolf herrings	15,251	1.2
Barracudas	14,040	1.1
Other pelagics	70,372	5.6
Total pelagics	1,246,901	

The major single-species fisheries of pelagic resources, oil sardine (*Sardinella longiceps*), Indian mackerel (*Rastrelliger kanagurta*) and Bombay-duck (*Harpadon nehereus*) showed wide inter-annual fluctuations in their availability for exploitation. This fluctuation is due to fishery independent factors such as spawning success, recruitment strength and environmental factors, affecting resources. The distribution, production, biology, utilization and status of the stock of the major pelagics are summarized here.

Indian oil sardine

Distribution: This is a major inshore small pelagic, distributed in narrow belts extending to a distance of 3 to 20 km from the coast. Along Indian peninsula, there is greater concentration of oil sardine stock in Malabar upwelling zone along the southwest coast between 8° N and 16° N latitude. A fishery for this resource has emerged along the southeast coast from 1985. The oil sardine fishery has been most strikingly characterized by wide fluctuations in the annual landings; variability in abundance of oil sardine is cyclic.

Production trends: During the last fifty years, all-India production of oil sardine ranged from 14,000 tonnes in 1952 to an all-time high of 3.77 lakh tonnes in 2003; contributing 0.1% to 31.9% to total marine fish landings in India. The oil sardine catch increased from 78,000 tonnes in 1986 to 279,000 tonnes in 1989 but declined to 47,000 tonnes in 1994. The resuscitation of the oil sardine stock after an ever lowest landing in 1994 manifested from heavy recruitment that followed, which culminated in a highest production of 3.77 lakh tonnes in 2003. The average (1999 to 2003) annual landings of oil sardine along the west coast were 147,989 tonnes (73%) and were 53,984 tonnes (27%) along the east coast.

The oil sardine fishery success depends on rainfall, food availability, migratory pattern, survival of eggs and larvae, intensity of upwelling and availability and accessibility to gear in operation.

Means of exploitation: Till close of 1970s, mainly boat and beach seines, cast nets and small meshed gill-nets were major gears operated along the southwest coast. With introduction of mass-harvesting gears like purseseines in late 1970s and ringseines in late 1980s along with a steady rise in motorization of traditional fishing crafts, many of these traditional fishing methods became obsolete. Along the east coast mainly boat seines (*karavala, peddavala*), gill-nets (*chalavalai*) and bag-nets (*edavalai*) dominate. In Tamil Nadu coast, pair trawlers are operated at 12–60 m depth in Pampan-Rameswaram area while ringseines have been introduced in the Palk Bay.

Fishing season: Along the southwest coast, oil sardine fishery commences soon after outbreak of monsoon in June and continues till March–April. Along Kerala coast catches are fairly high throughout the year excepting during March–May, while in Karnataka–Goa belt, the season starts in September/October with peak fishing during October–January. On the southeast coast, the fishing season is from April to December with peak catches during April–June on Tamil Nadu coast and July–October along the Andhra Pradesh coast.

Biology: The success of oil sardine fishery along the southwest coast depends mainly on the recruitment strength of early juveniles of 80–100 mm during post-monsoon months. Juveniles appear in fishery in late August in southern region and form mainstay of the fishery whereas in northern region it appears in late September. The beginning of fishery is marked by the entry of the large-sized fish in the advanced stage of maturity, followed by the 0-year class. Commercial fishery is supported mainly by 0- and 1 year classes.

Oil sardine grows rapidly during first few months and matures early within its life span of about 2½ years. The age at first maturity occurs at less than one year, at about 150 mm size. Maturation is controlled by temperature and intensity of rainfall experienced by pre-spawners. On the west coast peak spawning occurs during June–August, and on the east coast, intense spawning activity has been observed during December–February, April–June and August–October. Through collections of spawners in oozing condition and planktonic eggs, spawning grounds have been located off Quilandy, near Kozhikode, Tanur-Tellicherry belt, Quilon and Mangalore at depths of 20–30 m and about 15 km from shore. Seasons of feeble or severe rainfall cause recruitment failure, while a daily rainfall of 20–30 mm during June–August along southwest coast indicates a good recruitment to fishery. As the success of commercial fishery for each season is determined by the number of juveniles recruited at the beginning of the same season, rainfall, which affects spawning success, has been used to forecast strength of juvenile brood entering fishery.

The oil sardine is a planktivore, and diatoms, dinoflagellates and copepods are the favoured food items. The abundance of diatom *Fragilaria oceanica* is said to indicate abundance of oil sardine in coastal waters. The optimum temperature and salinity ranges for distribution and abundance of oil sardine are 27–28°C and 22.8–33.5 ppt respectively, although occasionally they have been observed to enter estuaries along the southwest coast.

Utilization: Along the southwest coast, the fish has good demand in local and distant markets and fishery is fully 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.

Management: Fisheries of small pelagics like oil sardine is characterized by high inter-annual and decadal variability that makes their management difficult. There was an unprecedented failure of oil sardine fishery during forties which had disastrous effects on industries based on it, which provoked British administration to introduce restrictive legislation in 1943 to prevent capture of juveniles and spawners. Under Marine Fishing Regulation Act passed in 1980s by various maritime states, fishing by mechanized vessels, especially purseseines during monsoon is banned to protect spawners, but the implementation of the same is not uniform in all states. Moreover, traditional motorized crafts continue to engage in seining operations using extremely small meshed mass harvesting-nets like ringseine during this period, which destroy both spawners and young fish. Any fishery that allows uncontrolled exploitation of both juveniles and adults from a stock is likely to experience stock decline. Therefore it is imperative that destructive fishing practices using small meshed seines are effectively controlled by enforcing mesh-size regulation (minimum 18 mm), closed season and restricted fishing (June–September), besides strict licensing and optimum deployment of fishing units especially ringseines and purseseines.

Lesser sardines

Distribution: The lesser sardines, which comprise several species of *Sardinella* other than *S.longiceps* show wide distribution in tropics and are one of the major pelagic fishery resources of India. Though occurring in landings of all maritime states, they particularly contribute to a lucrative fishery along the southeast and the southwest coasts. Of the 15 species of lesser sardines in the Indo-Pacific region, 12 occur in Indian waters. The species that constitute fishery are *Sardinella albella, S. gibbosa, S.fimbriata, S. sirm, S. dayi, S. sindensis, S. melanura, S. clupeoides* and *S. jonesi*. The resource contributed 3–7% to the total annual marine fish production of the country during 1986–2003.

Production trends: During fifteen-year period, the lesser sardine landings ranged from a low of 68,267 tonnes in 1986 to a high of 128,021 tonnes in 1995. The east coast contributed 65% with an average annual production of 67,172 tonnes in 1986–2000. The annual production along the west coast was 35,449 tonnes comprising 35% of the total annual production. Tamil Nadu with an average landing of 42,263 tonnes, contributing 43% of the catch, stood first in lesser sardine production among maritime states.

Means of exploitation: Along the southeast coast, the small meshed gill-nets are effectively used to exploit lesser sardines. The seines (shore seines, boatseines and ringseines) are popular along the southwest coast. The canoes and plank-built crafts with outboard engines operate boat seines (*ranibale, mattubale, kotibale*) and ringseines at depths up to 30 m. The purseseines are operated from mechanized units at depths up to 60 m. The trawlers operating in the near-shore waters also land sardines in considerable quantities along the Karnataka coast.

Biology: The size at first maturity, spawning season and fecundity differ from species to species, but most of them become sexually mature before completion of 1 year and the commercial fishery is supported by 0 and 1+ year classes. *S. sirm, S. jonesi* and *S. clupeoides* grow to larger sizes compared to other species and 1 to 2 year classes dominate fishery.

Lesser sardines feed mainly on a variety of plankters. *S. gibbosa* feed on copepods, *Mysis, Lucifer*, larvae of prawns and crabs, fish eggs, *Acetes*, etc., while *S. albella* feed mainly on copepods, *Lucifer, Acetes, Mysis,* fish and bivalve larvae.

Utilization: Lesser sardines are a source of cheap protein for rural poor in coastal regions. They are consumed fresh in coastal regions and transported with ice to interior markets by road and train. Salted and sun-dried sardine products are sold in hinterland states in India. Smaller sardines are dried and used as important protein-mix in preparation of cattle, poultry and shrimp feeds.

Management: The total annual stock of lesser sardines is estimated at 280,000 tonnes comprising 20,000 tonnes in Andaman waters, 30,000 tonnes in northeast, 140,000 tonnes in the southeast, 80,000 tonnes in the southwest and 10,000 tonnes in the northwest coasts. The maximum sustainable yield (MSY) was estimated at 140,000 tonnes. The average annual production was 80,328 tonnes during 1986–90; 94,387 tonnes during 1991–95 and 122,243 tonnes during 1996–2000, and it is still below estimated MSY. Stock assessment on *S. gibbosa* indicated that its yield along the southwest coast is considerably lower than the MSY and hence there is further scope of increasing the catch from this region.

Anchovies

***Distribution*:** The anchovies are widely distributed along the Indian coast. The Indian anchovies include five genera *Stolephorus, Coilia, Setipinna, Thryssa* and *Thryssina* that constitute seasonal fisheries mostly along the coasts of Andhra Pradesh, Tamil Nadu, Kerala, Karnataka and Maharashtra.

***Production trends*:** The average annual catch during 1985–2003 was 1.31 lakh tonnes, constituting 11.2% of the total pelagic fish landings in India. The annual landings ranged from 1.05 lakh tonnes in 1987 to 1.66 lakh tonnes in 1991. Among anchovies, whitebaits were the most important with 1985–2003 average annual landings of 62,437 tonnes forming almost 48% of the overall anchovy production of 1.31 lakh tonnes, grenadier anchovy *Coilia dussumieri* formed 24%, *Thryssa* 26% and *Settipinna* 2%. The whitebaits formed 60% of the southeast coast and 80% of the southwest coast anchovy production. The grenadier anchovy dominated anchovy fishery in northwest and northeast regions with an average landings of 32,050 tonnes during 1985–2003.

Whitebaits

The whitebaits are dominant component of anchovy landings in India. The whitebaits that comprise a group of small pelagic fishes belonging to genus *Stolephorus* and *Encrasicholina* are widely distributed in Indian waters. This resource contributed on an average 64,000 tonnes (1991–2003) forming 1.7–5.8% of the total marine fish landings in the country. Ten species of whitebaits have been found to occur in our seas. They are *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 species, *E. devisi, E. punctifer, S. waitei, S. commersonii* and *S. indicus* support the fishery.

Means of exploitation: The major gears employed for exploiting whitebaits are boat seines, shore seines, bagnets and gill-nets operated mainly by catamarans and other small country crafts; many of them fitted with outboard motors. Purseseine, ringseine and trawl nets are also effectively used in fishery. In the southeast and southwest coasts, the most common gears exploiting whitebaits include boatseines (cod-end stretched mesh size: 10 mm) and shoreseines (cod-end stretched mesh 10–20 mm). On the southwest coast gill-net known as *netholivala* (mesh 15 mm), is specially employed for whitebaits during main fishing season. The purseseines (common stretched mesh at the bund, 14–18 mm) are operating in Karnataka and Kerala from mechanized boats since 1970s and ringseines (mini purseseines with a mesh of 8 mm) are operating from plank-built boats and dugout canoes fitted with outboard motors since mid-1980s in the southern Karnataka and northern Kerala. The operational depth of these gears ranges from 15 to 50 m.

The fishing season for whitebaits differs from place to place. It is October–March in Karnataka, July–December in Kerala, April–December in Tamil Nadu and October–March in Andhra Pradesh. They also exhibit seasonal migration along the west coast moving southwards in April–May and concentrate in the Gulf of Mannar during August–September.

Biology: The whitebaits fishery is supported by fishes of '0' year class and their mean age is 0.5 year. They also spawn at this age. They are multiple spawners with an extended spawning season starting from November and lasting till July. The distribution of their schools generally coincides with areas of high density of zooplankton, which is their major food item.

Utilization: Most of the whitebaits catch is consumed fresh except in times of glut when surplus is dried and sent to interior markets. A small fraction of fresh fish is used as baits in 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 could be ensured.

Management: Whitebaits are annually renewable resources and hence their periodic harvest during seasons of abundance is important to make full use of the fishery. Increasing fishing efforts during peak seasons of availability may be a practical option to enhance whitebaits' production in the country. Being a non-target species in most of the gears (except the *choodavala* operated by ringseine units), the effort required to obtain the MSY of whitebaits could be decided only in consideration with the stock position of the other resources caught in gears. A potential yield of 240,000 tonnes was estimated for whitebaits in the EEZ of India, of which the share of west coast, east coast and Andaman and Nicobar Islands is in the proportion of 69%, 29% and 2%. This indicates scope for a 3-fold increase over the present yield of whitebaits.

Golden anchovy

Distribution: The golden anchovy (*Coilia dussumieri*), like Bombay-duck, is an endemic resource in Maharashtra and Gujarat along the northwest coast of India. The species exhibits discontinuous distribution and constitutes a fishery in West Bengal and Orissa along with another species (*C. ramcarti*). It is an important pelagic resource found in association with the Bombay-duck and non-penaeid prawns.

Production trends: *C. dussumieri* landings ranged from 19,048 tonnes (1987) to 46,268 tonnes (1998) with an average of 32,050 tonnes. Analysis of gear-wise data indicates that prior to 1980, *dol* net was the sole gear that contributed to entire catch. The incursion of trawlers commenced in 1985 in *dol* net zone, and since then the contribution of trawl catch is on the increase. During 1986–90 trawl and *dol* contributed 38% and 60%, while during 1996–2000 contribution by the former increased to 70% of the total catch. Time series analysis of the data on the landings of golden anchovy during the last 15 years together with co-existing species like *H. nehereus* and non-penaeid prawns indicated that decline in landings of Bombay-duck coincided with that of *C. dussumieri*. However, the landings of non-penaeid prawns showed an increase during the same period.

Management: The management strategies of *C. dussumieri* cannot be considered in isolation. This species is one among the many components exploited by the *dol* net; the other resources being non-penaeid prawns, Bombay-duck, unicorn cod and juvenile pomfrets. In a multi-species fishery, it would be rather difficult to suggest optimum mesh size for each species. However the resource is currently underexploited and can sustain increased fishing effort.

Indian mackerel

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

Production trends: The annual production of the Indian mackerel is also characterized by wide fluctuations as evident from the catch records of past fifty years. During the last 20 years, the production ranged from 113,000 tonnes in 1991 to 290,000 tonnes in 1989. The mackerel fishery showed a declining trend from 1999 (2.1 lakh tonnes in 1999) to 2001 (0.9 lakh tonnes), and showed improvements during 2004 and 2005, when the catch increased to 1.26 lakh tonnes and 1.25 lakh tonnes, respectively.

Means of exploitation: The major fishing craft engaged in mackerel fishery include motorized and non-motorized catamarans, plank-built boats, dugout canoes, purseseiners and trawlers. The common gears employed include shoreseines, boatseines, gill-nets, hooks and lines, ringseines, purseseines and trawls.

Along the upwelling zone from where bulk of the catch is made, the exploitation is largely by large seines. Ringseines dominate in Kerala and purseseines in Karnataka–Maharashtra. These gears contribute 62% to the total mackerel catch in India. In other states, these gears are not operated and dominant gear is gill-net. Trawlnet is slowly emerging as an important gear in mackerel fishery.

Along the Kerala–Maharashtra area, the fishery season starts by August and lasts till December. Along the east coast where gill-nets are the major gear, exploitation starts by December and lasts till May with peak catches in March–April.

Biology: The Indian mackerel feeds primarily on zooplankton at the juvenile stages and mainly on the phytoplankton in adult stages. The most common food items are diatoms, dinoflagellates, copepods, cladocerans, mysids, etc. The intensity of feeding is very high in maturing and spent mackerel, but low in spawners.

The size at the first maturity ranges from 184 mm to 225 mm in total length, depending on the locations and annual variations in maturation. The intensive spawning of mackerel starts by April/May and continues till around July. Surveys by the UNDP/FAO Pelagic Fishery Project found mackerel larvae in great abundance during March–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 that spawning occurs along the entire coast.

The commercial catch depends mainly on 180–240 mm size fish and the bulk of it is formed by 0–1 year classes. Success of the fishery in a season depends on the recruitment of 0-year class into the fishery.

Utilization: A good quantity of mackerel is consumed fresh along the coastal and nearby areas. During glut, the surplus catch is salted, sun-dried and sent to interior markets. Export of frozen mackerel to Southeast Asian countries seems possible, considering surplus catches in certain years.

Management: There are no signs of any serious decline in mackerel catches in spite of constant increase in exploitation pressure. The large-scale exploitation of juveniles along the southwest coast is the key factor, which limits yield from mackerel stock. Fishes below 150 mm form about 42% of the catch from west coast. Increasing size at the first capture from 140 mm to 160 mm by controlling exploitation during the major recruitment period (July-September) or increasing mesh size of the larger seines to minimum of 35 mm can be employed to control growth overfishing.

Tunas

Tunas, being highly valued food fishes, are targeted by coastal as well as distant-water fishing nations throughout the Indian Ocean with varying intensity of exploitation. Tunas occur in coastal, neritic and oceanic waters and are caught using diverse types of crafts and gears. Tuna fishing and fisheries have become a focal point while addressing issues of development, utilization and management of fisheries in Indian Ocean in the light of EEZ regulations and other international conventions. In India, tuna-fishing is mainly an artisanal activity excepting for a brief phase of chartered and joint venture tuna fishing by longliners in1990s. However, tuna catches substantially improved by nearly 58% in 1990–2003 compared to early eighties, mainly due to motorization of traditional crafts, distant water multiday gill-net fishing, targeting oceanic tunas and adoption of progressive and innovative fishing techniques by mainland fishermen.

Production trends: Tuna production fluctuated between 30,285 tonnes (1987) and 54,007 tonnes (2000) with an annual average production of 41,443 tonnes forming 3.6% of the total pelagic fish production. Of the 8 major species of tunas occurring along the Indian coast, 5 are coastal and 3 are oceanic and migratory. The tuna fishery in India is limited to small-scale sector with negligible inputs from industrial sector. The commonly occurring coastal tuna species in small-scale fisheries are *Euthynnus affinis* (little tuna), *Auxis thazard* (frigate tuna), *A. rochei* (bullet tuna), *Sarda orientalis* (oriental bonito), *Thunnus tonggol* (long-tail tuna) and oceanic species *Katsuwonus pelamis* (skipjack tuna),*T. albacares* (yellowfin tuna). *E. affinis* and *A. thazard* constitute the major species along both the coasts and *T. tonggol* and *T. albacares* along the northwest coast.

Means of exploitation: The drift gill-net is operated all along the Indian coast, the purseseine in the southwest and the hooks and line off Vizhinjam. The pole and line and troll lines are operated in Lakshadweep Islands.

Biology: The size range of *Euthynnus affinis*, the dominant species in the fishery, is 10–78 cm, of *A. thazard* 16–52 cm, *A.rochei* 15–34 cm, *T. tonggol* 30–100 cm, *T. albacares* 50–150 cm and of *K. pelamis* 35–80 cm. The major length groups that support fishery are 30–56 cm, 34–42 cm, 22–26 cm, 46–108 cm and 48–60 cm, respectively.

Food and feeding: Tunas are carnivores and their major food items include crustaceans (larvae, juveniles and adults especially of shrimp and crabs), cephalopods (juveniles and adults), eggs, larvae and juveniles of fishes, whitebaits and other small pelagics.

Spawning periods of different species have been found to vary considerably. *E. affinis* spawns during pre-monsoon (April–May) and post-monsoon (October–November). The spawning period of *A. rochei* has been observed during post-monsoon period of September–October. A spawning peak in January–April has been observed for skipjack tuna.

Utilization: On an average about 74% of the total tunas landed are iced and marketed for fresh consumption. About 10% of the landings are utilized for *masmin* production;

9% are frozen, chilled and exported chiefly to Gulf countries; 4% utilized for canning and 3% are salt-dried for interior market.

Management: Tunas of oceanic region largely remain underexploited in the Indian EEZ. Since 1983, the Fishery Survey of India has undertaken longline surveys to study spatial distribution and abundance of these highly migratory species in Indian EEZ. Among resources identified, yellowfin tuna constitute major species in all regions. Bigeye tuna is dominant in equatorial region, while skipjack tuna is abundant in northwestern region. Extension of fishing to offshore and oceanic waters through multiday drift gill-netting, pole and lining, purseseining, longlining and intensification of troll lining and hand lining may help to augment tuna production from Indian waters.

Seerfishes

Seerfishes are one of the commercially most important pelagic finfish resources of India. The seerfish catch of 50,376 tonnes in 2000, which was just 1.85% of the marine fish production, was valued at 4.03 billion rupees. Owing to high unit value and economic returns, seerfishes support artisanal fisheries and are a major source of income for gill-net and hooks and line fishermen. Out of the four species, king seer (*Scomberomorus commerson*), spotted seer (*S. guttatus*), streaked seer (*S. lineolatus*) and wahoo (*Acanthocybium solandri*), fishery is sustained by the first 2 species. In 1985–2003, the all-India seerfish catch was constituted by kingseer (60%) and spotted seer (39%), and the rest by streaked seer and wahoo. The kingseer was dominant along the mid-eastern (Orissa, Andhra Pradesh), southeastern (Tamil Nadu), southwestern (Kerala) and mid-western (Karnataka, Goa) coasts. The spotted seer is more abundant than kingseer along northeast coast (West Bengal) and northwest coast (Maharashtra, Gujarat).

Production trends: The annual seerfish catch in 1985–2003 showed an increasing trend during past 5 decades with fluctuations ranging from mere 4,505 tonnes in 1953 to an all-time peak of 54,998 tonnes in 2003. Though production increased along both the coasts over the years, the increase along the west coast was remarkable.

Means of exploitation: Among a variety of gears employed for capture of seerfishes, gill-nets are the most popular along the east and west coasts. Presently, trawls are emerging as one of the important gears for juvenile seerfish exploitation. Gill-nets with larger mesh size of 120–170 mm have been found very efficient for seerfish exploitation. The gear contributed 65% to total seerfish catch of the country. Hooks and line are also found efficient and highly selective. Seerfishes are also taken along with other fishes by shoreseines, boatseines, long-lines and surface trolling. Purseseines along the west coast also land them as incidental catch.

In 1995–99, the production was highest during the first quarter in Andhra Pradesh, third quarter in West Bengal, Tamil Nadu and Pondicherry and fourth quarter in Orissa. Along the west coast, the fourth quarter was more productive in Kerala, Karnataka and Maharashtra, and the fourth and first in Gujarat.

Biology: In kingseer, juveniles (<17 cm), young fish (<35 cm) and virgin immature fish (<71 cm) formed 2.2%, 46.5% and 51.3% of the total estimated numbers of fish caught by all gears along the Indian coast. For spotted seer, juveniles (<9 cm), young fish (<18 cm) and virgin immature fish (<35 cm) accounted for 0.02%, 1.7% and 33.6%, respectively.

The length at the first maturity of *S. commerson* is 75 cm, 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. The frequency and time of brood releases is same for *S. guttatus* and *S. lineolatus* also. *S. commerson* is known to be a migratory species. The young ones, which are abundant in southwest coast during June to September, seem to move to southeast coast and afford a fishery. Spawning season of *S. guttatus* extends from January to August, and January to May is the spawning season for *S. lineolatus*.

The *S. commerson* feeds mainly on teleosts, *S. guttatus* feeds on teleosts, squids and prawns and *S. lineolatus* feeds exclusively on fishes such as sardines, anchovies and silverbellies.

Utilization: Seerfishes are the most sought after table-fish, on a par with pomfrets, and are in great demand all-over the country. They are relished mostly in fresh and to some extent in cured form (salt-dried). Because of their high quality meat value, they fetch high unit value.

Carangids

Carangids occupy a dominant position with a production of 1.33 lakh tonnes, constituting 4.1% of the total marine fish production. There are 46 species of carangids occurring along the Indian coast, but fisheries comprise mainly horse mackerels, round scads, selar scads, queenfishes, trevallies, leatherjackets and pompanos. Their distribution is confined mostly to shallow coastal waters up to a depth of 80 m. The resource has emerged as one of the important pelagic fish groups especially in mechanized sector.

Means of exploitation: Carangids are extensively exploited by a multitude of gears like trawls, drift gill-nets, bottom-set gill-nets, hooks and line, shore seine, ringseines, purseseine etc. The catamarans, plank-built boats and trawlers are major fishing crafts exploiting carangids.

Trends of production: The landings increased from a meagre 24,560 tonnes in 1969 to a phenomenal 1.97 lakh tonnes in 1995, but decreased to 1.11 lakh tonnes in 2000. The average annual production of carangids in 1985 to 2003 was 1.33 lakh tonnes, of which scads alone constituted 52,618 tonnes (39%), followed by horse mackerel (19,215 tonnes; 14%). Many species support carangid fishery, and the species composition in the catch depends on the selective properties of the gears employed. The non-selective trawls exploit scads such as *Decapterus dayi, D.macrosoma, Selar crumenophthalmus, Megalaspis cordyla,* and trevally *Caranx para, C.carangus, Selaroides leptolepis.* The peak season for scads along the Kerala coast is August–October, corresponding with monsoon and post-monsoon months.

***Biology*:** The carangids are carnivores, feeding predominantly on fishes and crustaceans. *Megalaspis cordyla* feeds mainly on clupeids and crustaceans. The young ones measuring about 8 cm in length feed on post-larval fish, juvenile prawns and other crustaceans. *Decapterus russelli* feeds on clupeids, diatoms, copepods and other crustaceans. The juveniles of 4 cm to 12 cm size feed on *Acetes*, copepods and other crustaceans.

M. cordyla size at first maturity is 250 mm. Its 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. In the northwest and southwest coasts, recruitment takes place in 2 different peaks. In northwest coast, there is a minor recruitment in October and a major one in January, while in southwest coast, the minor recruitment occurs in April and the major one in July. The spawning peak was found around July in northwest coast, while along southwest coast, the peak was in January.

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 production and consuming centres. During peak landings, surplus catch is deep-frozen and stored for lean season, which ensures steady price and supply. Larger species such as *C. malabaricus, C. melampygus, C. ignobilis, Atule mate* and *Alepes djedaba* are exported in frozen form.

Ribbonfishes

The ribbonfish, also known as hair-tail or cutlass is widely distributed along the Indian coast and form major pelagic fishery resources of Indian seas.

Production trends: The ribbonfish landings showed an increasing trend with considerable annual fluctuations. From 1956 to 2003, landings fluctuated between 16,452 tonnes in 1963 to 182,383 tonnes in 2000 with an average landing of 63,669 tonnes. The trend showed a 5-to-8 year cycle in landings. Ribbonfishes formed 2 to 6.7% (in 1960 and 2000, respectively) of the total fish landings and 4.6 to 13.4% (in 1970 and 2000, respectively) of total pelagic fish landings. On an average it formed 4.4% of the total fish landings and 9% of the pelagic landings (Table 3.6).

Table 3.6. The average annual landings of ribbonfishes in different decades with percentage of growth rate

Period	Average landings (tonnes)	Percentage growth
1956–60	30,741	–
1961–70	28,171	–8.4
1971–80	57,147	102.9
1981–90	65,360	14.4
1991–2000	120,461	84.3
2001–05	159,352	32.3

Trichiurus lepturus is the dominant species among ribbonfishes and supports fishery all along the Indian coast. It forms more than 95% of the total ribbonfish landings. Other species in catches are *T. russelli, Lepturacanthus savala, L. gangeticus, Eupleurogrammus muticus* and *E. glossodon*. Ribbonfishes are exploited all along the coast and bulk of the landings is from Gujarat and Maharashtra, followed by Kerala, Tamil Nadu and Andhra Pradesh.

Means of exploitation: The fleets employed in ribbonfish fishery include trawlers, motorized and non-motorized catamarans, plankbuilt boats and dugout canoes while the principal gears include trawls, boatseines, *dol* nets, shoreseines, hooks and line and gill-nets. Among major gears, trawls contributed 70% (68,051 tonnes), bagnets (including the *dol* nets of the northwest coast) 7%, gill-nets 3% and purseseines 2.2% to all India ribbonfish landings.

Biology: The ribbonfishes are carnivores, feeding predominantly on fishes and to a smaller extent on shrimps and other items. Selectivity in feeding was reported. While young ribbonfishes feed on smaller fishes and shrimps, adults prey upon much larger items. Huge shoals of ribbonfishes are commonly noticed in coastal areas, chasing sardines, anchovies and scads.

Ribbonfishes (*T. lepturus, L. savala, E. glossodon* and *E. muticus*) spawn more than once a year. Three batches of ova (immature, maturing and mature) are found in ovaries. The maturing and mature groups of ova are so sharply differentiated in mature ovaries of all species that their spawning seems to take place at short intervals of time in quick succession.

Utilization: Nearly 64% of ribbonfish landed annually in India are exported in frozen form to China, Japan and other Southeast Asian countries. Only undamaged fresh fish are considered for export. They are graded size-wise and are frozen intact without removing gut or fins. The local people consume large-size fresh fish while undersized are sun-dried.

Bombay-duck

Bombay-duck (*Harpadon nehereus*), which inhabits waters up to 50 m to 70 m isobath, forms a major single species fishery along the northwest coast from Ratnagiri in Maharashtra to Gulf of Kutch in Saurashtra coast. It forms a seasonal fishery along the coasts of West Bengal, Orissa and northern part of Andhra Pradesh. Bombay-duck is inconspicuous or totally absent in southwest and southeast coasts.

Production trends: As in oil sardine and Indian mackerel, the Bombay-duck along the northwest coast also exhibits wide annual fluctuations in production. The landings contribute about 5% of the all-India marine fish landings. Annual Bombay-duck production ranged from 67,392 tonnes in 1988 to 136,442 tonnes in 1991. The average annual catch of Bombay-duck was estimated at 105,087 tonnes by traditional and mechanized sector (trawlers) along the northwest (88%) and northeast (12%) coasts of India. The annual catchable potential yield along the northeast coast is estimated as 1.16 lakh tonnes. During 2005 catch from West Bengal (36,024 tonnes) had surpassed the catch from traditional Maharashtra coast (22,508 tonnes). Though *Harpadon nehereus* was the sole contributor along the northeast coast, another species, *H. squamosus* (195–214 mm, recently recorded at Kakinada) accounted for 56% of Bombay-duck landings at Kakinada. The fishing season shows two distinct phases of productivity: (*i*) September–January, which is more productive, with predominance of adults over juveniles, and (*ii*) February–March, which is less productive, with juveniles forming a major part of the catch.

Means of exploitation: Fishing of Bombay-duck is traditionally carried out by a stationary bag net called *dol* net along Maharashtra and Gujarat coasts. It is a traditional labour-intensive stationary bag net, made of synthetic filaments, highly specialized in design, working entirely by the forces of tide. Gill-nets, boat-seines and trawls are also employed in this fishery.

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

Management: In the past Bombay-duck stock had been exploited with a mix of success and failure. Large-scale landings of indeterminate and immature fish have been a source of concern since long. The only possible method by which age or size at first capture can be adjusted is by regulating mesh size at appropriate size. The *dol* net fishery is multi-species. The optimum mesh size for each species or group is different. Therefore it is not easy to evolve a new single optimum mesh size. The mesh size currently under operation with seasonal shifts appears to be most appropriate for maximization of yield.

Pomfrets

Pomfrets belonging to family Stromateidae, enjoy wide distribution at depth up to 150 m. They are highly relished table-fishes in internal and export markets and command high unit value. The annual average catch of 38,000 tonnes forming about 2% of all-India marine-fish landings, comprises silver pomfret (*Pampus argenteus*) and Chinese pomfret (*P. chinensis*). Most of their production is from Gujarat and Maharashtra in the northwest and Orissa in the northeast coasts. The principal gear exploiting adult pomfrets are drift gillnets of 140–155 mm mesh size while *dol* net exploits essentially juveniles in the northwest coast. The MSY of the silver pomfret (*P. argenteus*) in Indian waters has been estimated at 38,194 tonnes. As fishery had collapsed in the northwest coast during the 1990s, restriction of *dol* net operations to minimize recruitment overfishing and regulation of gill-nets to minimize growth overfishing have been prescribed as management measures.

Hilsa shad

Hilsa shad (*Hilsa* (=*Tenualosa*) *ilisha*) forms a prominent fishery in the northeast coast. It is known to spend most of its life in the inshore areas and migrates into estuaries and rivers for breeding. In 1999–2003, the annual catch of shad increased from 21,086 tonnes in 1999 to 44,734 tonnes in 2003; with an average production of 27,940 tonnes. *H. ilisha* alone contributed 70.9% (average: 19,831 tonnes). The gill-netters contributed bulk of shad catches in the northeast coast. The bulk of the fishery is constituted by fish in size range of 260 mm to 480 mm. The shads other than *Hilsa* shad form fisheries in all regions, particularly in the southeast and northwest regions.

Barracudas

Barracudas, otherwise known as sea-pikes of family Sphyraenidae, are important food and sport fishes of the tropical and subtropical waters, which are caught in sizable quantities along the Indian coast. Though they form shoals, the larger ones prefer to be solitary. The annual catch improved remarkably from a meagre 4,000 tonnes in 1986 to 18,576 tonnes in 2001. *Sphyraena obtusata, S. barracuda, S. jello* and *S. forsteri* constitute barracuda fishery in India, though more number of species occur in Indian waters. The larger fish are caught in hooks and line, bottom-set gill-nets and drift gill-nets, and smaller ones are caught in trawls in fairly good quantities. The barracudas are top predators, feeding voraciously on other pelagic fishes.

Flying fishes

The flying fish fishery is limited to Coromandel coast in Tamil Nadu. The average annual catch of flying fish was 4,217 tonnes in 1999–2003. The seasonal fishery is supported mainly by *Hirundichthys coramandelensis*. The annual catches are taken almost exclusively by scoop nets, and fluctuate considerably from year-to-year; contributing only about 0.1% to the total all-India landings.

Other clupeids

Among other clupeids, wolf-herring (*Chirocentrus dorab*) forms a fishery, and contributes about 0.7% to total all-India landings; of which about 50% comes from northwest coast. Clupeids consisting of species of *Dussumiera, Escualosa, Ilisha, Nematalosa, Opisthopterus, Pellona, Reconda, Dorosoma, Chanos*; together accounted for an annual average of 46,878 tonnes in 1985–2003; 1.6% of the total all-India landings.

Mullets

Among other pelagics, mullets form a fishery mainly in the northwest region, which contributed an annual average of 6,056 tonnes in 1999–2003.

Unicorn cod

The landings of unicorn cod (*Bregmaceros mclellandi*) is restricted to Maharashtra coast. The landings decreased from 6,880 tonnes per year in 1950–54 to 604 tonnes/year during 1999–2003.

Common features of pelagic fisheries

From foregoing account, it is clear that pelagic fisheries of India are characterized by: (*i*) dominance of Indian oil sardine, Indian mackerel and Bombay-duck; (*ii*) highly fluctuating nature of their fisheries; (*iii*) area-specific distribution of dominant species; (*iv*) crucial role of environment; and (*v*) unique biological characteristics. Interactions among these vital features determine abundance of pelagics.

Dominance of three species: Though over 200 species of pelagics occur along the Indian coast, only 3 species, the oil sardine (*S. longiceps*), Indian mackerel (*R. kanagurta*) and Bombay-duck (*H. nehereus*) play a very dominant role, not only in pelagic fisheries, but also in entire Indian marine fisheries. These three species together form 26.3% of the total marine fish landings (1999–2003). Adverse effects of any fishery dependent or independent factors on any of these three species would seriously affect landings of pelagics, which are, therefore, highly vulnerable and subject to fluctuations.

Highly fluctuating fisheries: The landing pattern of pelagics could be categorized as: (*i*) fisheries which have fluctuated very widely (oil sardine, Bombay-duck and Indian mackerel); (*ii*) fisheries which have increased landings fairly consistently (lesser sardines, *Hilsa* spp., whitebaits, *Thryssa* spp., *Coilia dussumieri*, carangids and ribbonfishes); and (*iii*) the only fishery which has declined (unicorn cod). The landings of unicorn cod (*Bregmaceros mclellandi*), which are restricted to the Maharashtra coast, decreased from 6,880 tonnes per year in 1950–54 to 604 tonnes per year in 1999–2003. In view of the consistently declining fishery, the unicorn cod may have to be listed as vulnerable, and strategies need to be devised to restore its population.

Area-specific distribution of the dominant species: Another important characteristic of pelagics is the area-specific abundance of dominant species. The fisheries for oil sardine, Bombay-duck, flyingfishes and unicorn cod are restricted to coastal waters of a single geographic zone, i.e. oil sardine to southwest coast between 8°N and 16°N latitudes (92.6% of the total oil sardine landings) and Bombay-duck to the northwest coast between 18°N and 22°N latitudes (90% of Bombay-duck landings), and their abundance in other coastal zones is quite meagre. Four groups/species (Indian mackerel, lesser sardines and whitebaits in the southwest and 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 zones.

A full understanding of reasons why distribution and abundance of a few species are restricted to certain well defined sea areas is yet to emerge. Differences in temperature, salinity and food regimes are thought to be important factors. However, thermal and salinity profiles in the coastal areas of the northern and southern latitudes are not very much different from each other. Even though these factors may be important, but these do not appear to be the basic factors that bind Bombay-duck to the northern latitudes. High tidal amplitudes of about 5 m are characteristic of the northern latitudes. Neither strictly pelagic nor demersal, the Bombay-duck effectively utilizes tidal oscillations for less energy demanding movement for foraging on sergestid shrimps and grenadier anchovy, which are also associated with the tidal oscillations. The reasons for abundance of 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 shoals and require huge quantities of food, find southwest coast as an ideal location to forage.

An inverse relationship between abundance of oil sardine and mackerel has often been reported along the southwest coast. The periods of maximum landings of oil sardine (e.g., 1995–2003: average annual yield = 2,43,526 tonnes) were periods of least abundance of mackerel (1995–2003: average annual yield = 166,166 tonnes). As both species are harvested by the same gears, the decadel variations may not be due to the effect of fishing effort expended.

Role of environment: Several environmental parameters are considered to be the determinants of abundance of oil sardine and mackerel. The onset and intensity of monsoon, sunspot activity, surface temperature, variations in pattern of coastal currents, sudden increase in salinity, dissolved oxygen, sinking of offshore waters, sea level and availability of nutrients in coastal waters are some of the causative factors believed to play crucial roles in determining abundance of oil sardine along the southwest coast.

Unique biological characteristics: Though represented by different taxonomic families, 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_∞ (at about 70% of L_∞). Most species of pelagics are either continuous spawners or have prolonged spawning periods with high fecundity. The pelagics such as sardines, whitebaits and mackerel feed mainly on plankton. Occupying a low trophic level, these groups are advantageously placed to get continuous food supply. The exploitation of pelagic resources has reached optimum/near optimum level and hence constant monitoring fisheries and evolving suitable management measures, preferably with a participatory approach is warranted.

Research priorities in the management of pelagic fisheries

Impact of environment on pelagic fisheries: Year after year, the success of pelagic fisheries is a delicate balance between physical oceanographic factors and effects of fishing on stock. Numerous studies conducted so far have confirmed that seawater temperature, dissolved oxygen levels, salinity, phytoplankton and zooplankton concentrations play a vital role in controlling distribution and abundance of pelagic fishery resources. 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*) using satellites are available from 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 the Central Marine Fisheries Research Institute (CMFRI), Kochi, for locating fish shoals and feedback received indicated considerable reduction in cost of fishing by saving time and fuel. This technology requires further strengthening through refinement and validation. Creation of maps indicating spatial and temporal distribution patterns of pelagic fishes and their prediction on a Geographical Information System (GIS) platform is another potentially powerful technology that can be developed.

Fish migration behaviour: Most of the pelagic finfish species move in large shoals and exhibit certain characteristic migratory patterns. While 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. Oceanic tunas undertake even longer migrations (transoceanic) and stocks are frequently shared by many countries. Therefore understanding migratory patterns of pelagics, especially high valued large pelagics like tunas is 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 observation of movement of a single fish. Tagging studies for small pelagics like oil sardine and mackerel have been conducted in Indian waters. A collaborative project with external funding support is envisaged by the CMFRI to undertake a tagging programme for highly migratory and straddling stocks of oceanic tunas.

Enhancement of fish production: Fish Aggregating Devices (FADs) are used to create special conditions where plenty of hiding sites and abundant forage are available for fishes and thereby attract them for feeding and even spawning. These have been found useful for aggregating oceanic tunas, and a project for evaluating FAD associated with tuna fishery in Lakshadweep waters is being implemented. The project is expected to provide an understanding on the aggregation dynamics of tunas and their feeding behaviour so that appropriate management strategies can be formulated for tuna fishery of the Lakshadweep islands.

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 interface between physics and biology will have to be developed. Already some attempts have been made to understand dynamics of these fisheries through mathematical modelling of fishery dependent and independent factors. Predictions for oil sardine fishery along the Indian coast based on sunspot activity, rainfall intensity, sea level change and duration and upwelling indices have proved successful and could be attempted for other pelagic species also.

Resource conservation

Many of the world's greatest fisheries particularly for pelagics like sardines have collapsed owing to recruitment failures caused by high fishing pressure on the spawning stock. Hence, there is a need to study stock-recruitment relationship. However, such studies are complicated due to the fact that there is significant influence of environment in determining recruitment success of pelagic species every year. Hence it is imperative that a precautionary approach whereby spawners are protected and allowed to replenish population is in place. Most of the pelagic species move in large shoals and exhibit certain characteristic migratory patterns to inshore, offshore or deeper areas for the purpose of feeding or breeding. In course of such migration, large schools enter coastal waters and constitute seasonal fishery along the coastal belt. 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 traditional fishing grounds resulting in an off-season for fishery. This emigrant part forms the brood-stock that contributes to new recruits to the coastal fishery in the subsequent years. Any attempt to exploit these brood-stocks from their protected areas, under the disguise of increasing production from the offshore may hamper inshore fishery in long-run. Therefore conservation of these brood-stocks is essential for a sustainable yield from inshore areas. Fishing-vessel-based stripping of ripe spawners of oil sardine and mackerel captured in nets and releasing eggs in the fishing grounds has been 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 by ringseine and purseseine causes over-fishing to stocks of oil sardine and mackerel, which cause huge economic losses, especially during monsoon period, when young recruits enter coastal waters. The mesh size of ringseine and purseseine is normally 14–18 mm and at times as small as 8-mm. Even though the 8 mm meshed net is meant for fishing whitebaits, young recruits of sardine and mackerel measuring 50–80 mm are also caught in large quantities. This negatively affects these fisheries in subsequent years, as these stocks are not allowed to grow, mature and reproduce. Similar is the case with *dol* net where mesh size is small (10–15 mm) and is employed in Bombay-duck fishery along the Maharashtra and Gujarat coast causing large-scale growth of over-fishing of the stock. So mesh size regulation with respect of ringseine, purseseine and *dol* net is inevitable, and the minimum size should be fixed as 20 mm. Fishery with 8 mm meshed ringseine should be restricted solely to exploit whitebaits (*Stolephorus* spp.) and not for any other pelagic fish stocks. Further proliferation of ringseiners needs to be checked urgently. It is therefore vital to make periodic assessments of pelagic stocks, fishing practices adopted and juvenile and spawners components of catches. Based on this, need-based management measures can be formulated either as input controls (restriction of fleet size, mesh size, closed season) or output controls (restriction on fishery for certain species, size of fish caught, etc.) Awareness creation among all stakeholders against non-sustainable fishing practices with a participatory management approach has become inevitable in fisheries management.

Though a progressive trend is noticed in production of most of the pelagics, many of them, especially oil sardine, mackerel, Bombay-duck, seerfishes, ribbonfishes and coastal tunas have reached optimum level of exploitation in conventional fishing ground. The stock assessment studies conducted for 19 species of exploited pelagic finfishes have showed that the present effort expanded is close to or in some cases has even exceeded level of MSY, and further increase in effort in the coastal sector would be detrimental to sustain yield. Under these circumstances, it is imperative to evolve suitable management measures for judicious exploitation so as to ensure a long-term sustainable yield from the 0–50/100 m depth zone. The groups, which are expected to contribute significantly to additional yield from beyond conventional belt, where the rate of exploitation is limited at present, are whitebaits, carangids, ribbonfishes, oceanic tunas and pelagic sharks. The options available for the exploitation of these potential resources from 50 to 200 m depth zone are extension of operational range of crafts, introduction of combination vessels (drift gillnetting and longlining) for multiday target fishing, widespread employment of light luring purse-seiners, conversion of trawlers for offshore drift gill-net and tuna longline fishery, providing chilling and cold storage facility on-board of the vessel and development of suitable post-harvest and value-addition technologies for utilizing products for domestic as well as export markets. The use of high-opening fish trawls beyond traditional grounds indicates good scope of enhancing production of carangids and ribbonfishes. Besides the above groups, the deeper areas of the oceans contain non-conventional mesopelagic resources, such as filefishes and lantern fishes that can be converted into fish-meal. According to a recent observation, mesopelagic fish fauna in the Arabian Sea is dominated by myctophid fishes. Among them, one species *Benthosema pterotum* is arguably the largest single species population of fish in the world, with stock estimates ranging up to 100 million tonnes per year. Similar populations, but of lesser magnitude, may be available in the Bay of Bengal also. Economically viable technologies could be developed for their commercial exploitation, handling, processing and utilization. However, the fishing activities in the offshore and in the high seas are at present limited since such activities are capital-intensive and require offshore fishing vessels (longliners, purseseiners, midwater trawlers), infrastructure, shore facilities, expertise and skilled manpower. Development of the above facilities for offshore fishing operations, coupled with value-added products development, marketing and export would provide necessary impetus for further development of pelagic fisheries in the country.