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Towards Ecosystem Based Management of Marine Fisheries – Building Mass Balance Trophic and Simulation Models

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Technical Notes

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PELAGIC FISHERIES RESOURCES OF INDIA

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Introduction

The marine fish production in India has progressively risen to the tune of 2.7 million t in 2000 due to the introduction of larger mechanized boats, motorisation of the country crafts, modernization in harvesting sector coupled with extension of fishing to deeper grounds since the late 1950s. The average annual marine fish production of India for the period 1985 to 2003 was 2.5 million t of which the pelagics contributed 1.4 million t accounting for 51% against a potential yield of 1.92 million t of this group from the Indian EEZ During the last decade pelagic resources contributed 46-56% (avg. 51%) of the total marine fish production. Almost 70% of the production was obtained from within the 50 m depth zone. As per the revalidation, annual potential yield from the EEZ of India is 3.9 million t, out of which 2.21 million t are from within the 50 m depth zone and 1.69 million t from beyond it (Anon, 1991). The current yield from 0-50m depth zone is at the optimum level, and hence does not offer any scope for increasing the yield and in fact this zone requires regulatory management for sustaining the yield. Therefore, the region beyond 50 m depth has to be the focus of expansion.

Exploitation of pelagic resources

The pelagics have been exploited by the conventional crafts and gears and as a consequence of modernization in the harvesting sector, new inboard/outboard engine fitted crafts and innovative gears such as ring seine, *matta vala* (disco net) etc. gradually replaced many of the traditional fishing gears. Mechanized fishing by trawls, purse seine, gillnets etc. also supported the growth of the pelagic fisheries.

Trend in production: The pelagic fisheries resources of India are largely of multispecies multisector fisheries. There are about 240 species contributing to the fishery(Table 1). A few species enjoy wide geographical distribution, while the others, such as the shads and the Bombayduck have rather restricted distribution.

Table 1. Major taxonomic categories of small pelagics and their species diversity

Family	Group/species	Number of species
I Clupeidae	1. Oil sardine*	1
	2. Lesser sardines* (including rainbow sardines)	14
	3. *Hilsa* spp. & other shad	15
	4. Whitebaits*	24
	5. *Thryssa* and *Thrissocles* spp.	10
	6. Wolf herrings	2

	7. Other clupeids	40
II Scombridae	1. Coastal tunas 2. Oceanic tunas 3. Seerfishes & wahoo 4. Mackerels*	5 2 5 3
III Trichiuridae	1. Ribbonfishes*	8
IV Carangidae*	1. Round scads 2. Golden scads 3. Hardtail scad (or horse mackerel) 4. Jacks 5. Black pomfret 6. Others	2 6 1 17 1 19
V Harpodontidae	1. Bombayduck	1
VI Stromateidae	1. Pomfrets	2
VII Coryphaenidae	1. Dolphinfishes	2
VIII Rachycentridae	1. Cobia	1
IX Mugildae	1. Mullets	22
X Sphyraenidae	1. Barracudas	7
XI Exocoetidae	1. Flyingfishes	10
XII Bregmacerotidae	1. Unicorn cod	1
XIII	Others	19
Total small pelagics		**240**

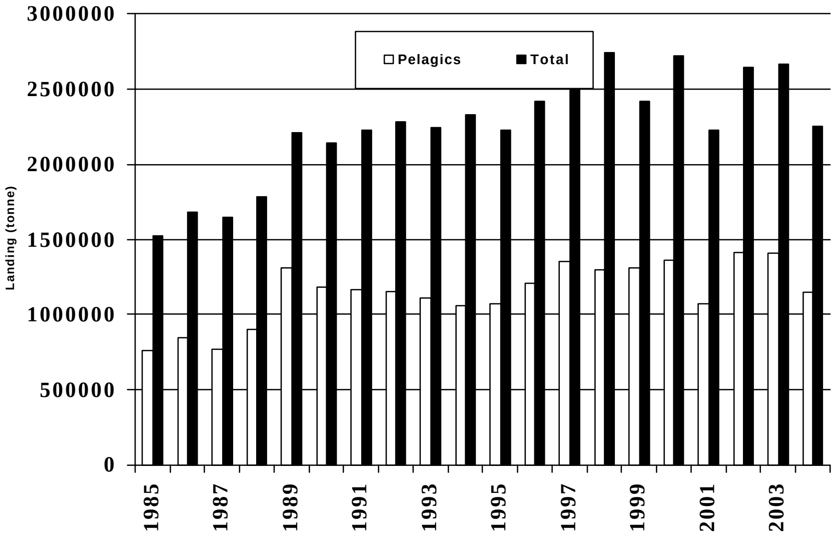
Srinath (1989), James and Alagarswami (1991) analysed the pattern of development of the pelagic fishery based on historical data relating to 1961-85 and 1979-85 respectively. Pillai (1992) has given a comprehensive account on the results of the stock assessment of the major pelagics. Devaraj et al (1997) has given an exhaustive account on status, prospects and management of the small pelagic fishes of India. Until the mid-seventies, the share of the pelagic stocks in the overall production remained very high with a consistently increasing trend from 54% in 1950 to 71% in 1960, and thereafter, at around 65% till the early seventies. The pelagic catches increased from 309,000 t in 1950 to the current 14,14,064 t (2002) registering over a fourfold increase. The growth in the production of the pelagics vis-à-vis the overall production could be gauged from Table 2 and Fig. 1.

Table 2: Growth in the average annual overall and pelagic fish production through the five decades from 1950 to 2003

Period	Production (t)		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
1996	1,243,424	2,422,043	+11	+7

The average annual landings of the major pelagics in the initial stages of mechanization (1961-65) to 1995-96 is given in Fig. 2. In the early years (in the development of marine fisheries) the growth rate in the production of pelagic fishes had been conspicuously higher than that of the overall production. This trend got reversed during 1970-79 because of the 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 the pelagic fish catches increased by 22%, the trend in the overall production was set by the demersal finfish and crustacean catches. The next decade (1980-89) witnessed a growth of 27% in the pelagic catches as well as in the overall production. During this decade there was rapid motorization of traditional fishing craft, particularly in the latter half of the eighties. As a result, the stagnation in marine fish production witnessed in the first half of the eighties gave way for accelerated production in the latter half. Intensive motorization of the traditional fishing crafts resulted in a remarkable increase in the annual production, especially of the total pelagics, which increased from 769,000 t in 1985, 1,313,000 t in 1989, registering a 71%increase (Fig. 1).

Fig.1 All India landing of total marine and pelagics during 1985-2003



Statewise contribution: The state-wise average contributions to the pelagic fish production showed that Kerala ranked first among the maritime States of India contributing about 31% of the total pelagic fish catch, followed by Gujarat and Tamil Nadu contributing 13.7% and 13.0% respectively. The contributions by other States were: Maharashtra 10.8%, Karnataka 10%, Goa 7.1%, Andhra Pradesh 6.9%, West Bengal 3.8%, Orissa 1.4%, Andaman and Nicobar Islands 1%, Pondicherry 0.8% and Lakshadweep 0.5%. Fig3. This shows that the southwest region comprising Goa, Karnataka and Kerala continued to be the highly productive area (36%) followed by northwest, southeast and northeast regions and the Island territories (Fig.4).

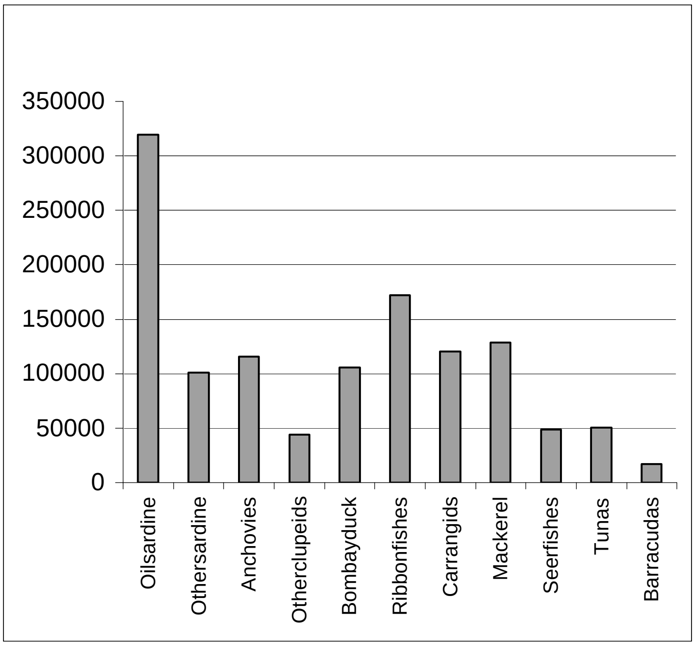


Fig.2 Landings of major groups of pelagic finfish (avg.) during 1999-2003

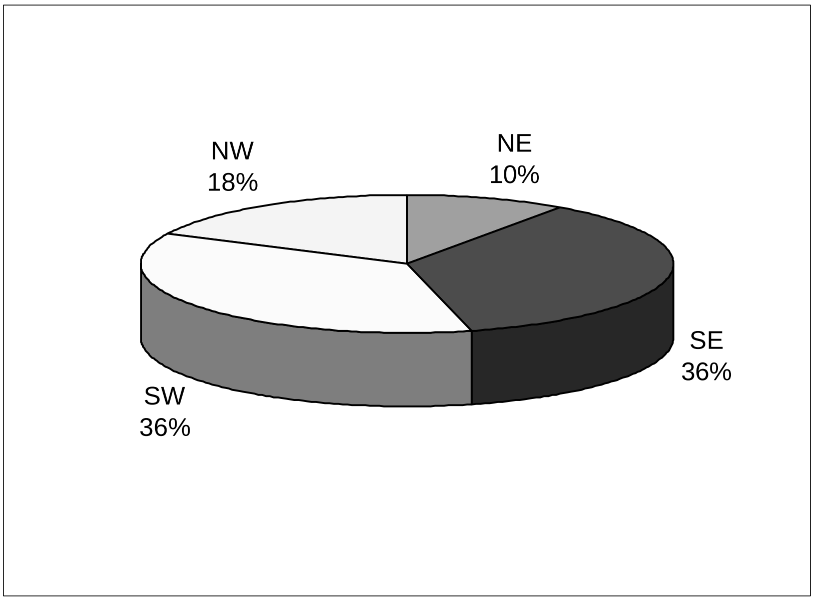


Fig. 4 Region-wise pelagic finfish landings during 2003

Major pelagic stocks: Out of the 240 species that contribute to the pelagic fisheries along the Indian coast, only about 60 species belonging to 7 groups viz., the oil sardine, lesser sardines, anchovies, Bombayduck, ribbonfishes, carangids and Indian mackerel form the major fisheries. The annual production of these groups during 2003 is 1.17 million t forming 85.4% of the pelagics and 43.98% of the total marine fish landings. The other pelagic groups which include the wolfherrings , shads, barracudas, unicorn cod, mullets, seerfishes and coastal tunas formed only 14.6% of the pelagic fish landings. The percentage contribution by the pelagic groups ranged from 1.0% in the case of barracudas to 14.0% by oilsardine. The groups, which exceeded one lakh t in production per year were mackerel, oil sardine, anchovies, carangids, ribbonfishes and Bombayduck. The oil sardine and ribbonfishes were the most predominant, contributing 14% and 6.8% respectively to the overall marine fish landings during 2003. Anchovies formed 4.8%, followed by the Bombayduck (4.9%), ribbonfishes (6.8%), lesser sardines (4.25%), wolfherring(0.57%), Hilsa shad (1.68%) and barracudas (0.62%) in the overall marine fish landings during this period. (Fig.5)

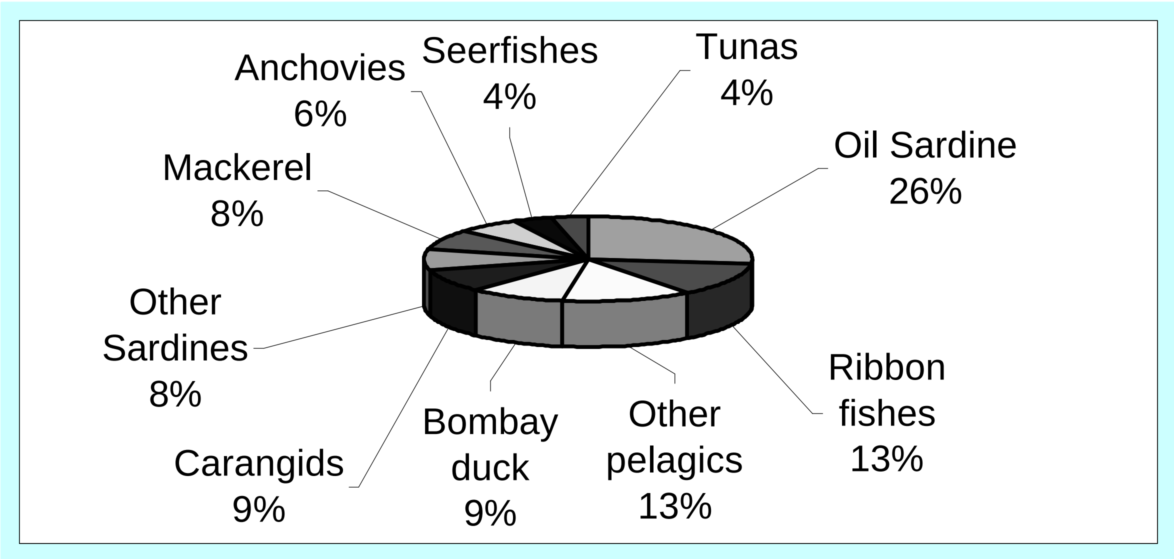


Fig. 5 Components of pelagic finfish landings in the total pelagics (2003)

The major single-species fisheries of the pelagic resources, the oil sardine (*Sardinella longiceps*), (Fig. 6.) the Indian mackerel (*Rastrelliger kanagurta)* and the Bombayduck (*Harpodon nehereus*) showed wide fluctuations in their availability for exploitation.

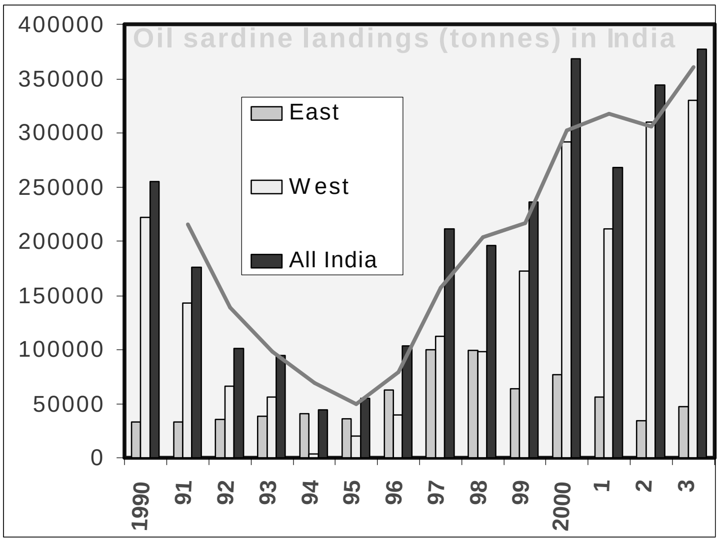


Fig. 6 Oil sardine landings in India

The Indian oil sardine is a very important pelagic fish species which contribute to about 15% of the total marine fish production in the country. The oil sardine fishery has been most strikingly characterized by wide fluctuations in the annual landings from the very early years of exploitation. There have been several periods of high abundance as well as major population crashes during this century. The variability in abundance of the oil sardine is cyclic.

During the last fifty years, the all –India production of the oil sardine ranged from 14,000 t in 1952 to all-time high of 3 lakh t in 1968 contributing 0.1% to 31.9% to the total marine fish landings in India. The oil sardine catch increased from 78,000 t in 1986 to 2,79,000 t in 1989, to decline again to 47,000 t in 1994. The resuscitation of the oil sardine stock after an ever-lowest landing of 47,000t in 1994 was manifest from the heavy recruitment that followed, which culminated to a highest production of 3.72 lakh tonnes in 2003(Fig.6). The average (1985 to 1996) annual landings of the oil sardine on the west coast were 128,282 t (86%) and the east coast 21,262 t (14%). Of late it has become an established fishery on the east coast (Luther,1988). 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. With the introduction of mass harvesting gears like purse seines in the late 70s and ring seines in the late 80s along with a steady rise in the motorization of the traditional fishing crafts, many of these traditional fishing methods have become redundant. Along the east coast mainly boat seines, gillnets and bag nets dominate. In Tamil Nadu coast, pair trawlers are also operated while ring seines have been recently introduced in the Palk Bay.

The lesser sardines comprise several species of *Sardinella* other than *S.longiceps* show wide distribution in the tropics and are one of the major pelagic fishery resources of our country. Though occurring in the landings of all the maritime states, they particularly contribute to a lucrative fishery along the southeast and southwest coasts. Of the 15 species of lesser sardines in the Indo-Pacific region, 12 occur in the Indian waters. The resource comprised 3-7% of the total annual marine fish production of the country during 1986-2000. During this fifteen year period the lesser sardine landings ranged from a low of 68,267 t in 1986 to a high of 1,28,021 t in 1995 (Fig.7).The east coast contributed 65% wuith an average annual production of 67,172 t during 1986-2000.The annual production along the west coast during this period was 35,449t.The dominant species contributing the fishery are *Sardinella albella, S. gibbosa S. fimbriata, S .sirm and S. dayi.* The traditional, motorized and mechanized crafts employ a variety of seines, gill nets and trawls to exploit the lesser sardines.

The whitebaits that comprise a group of small pelagic fishes belonging to the genus *Stolephorus* and *Encrasicholina* are widely distributed in our waters. This resource contributes on an average to 64,000 t(1991- 2003) forming 1.7-5.8% of the total marine fish landings in the country (Fig.8).Ten species of whitebaits have been found to occur in our seas. Among these species, *E.devisi*, *E.punctifer*, *S.waitei*, *S. commersonii* and *S.indicus* supported the fishery.Boat seine, shore seine, gill nets, ring seine and trawls are employed to exploit the resource in Andhra Pradesh, Tamil Nadu and Kerala coasts.

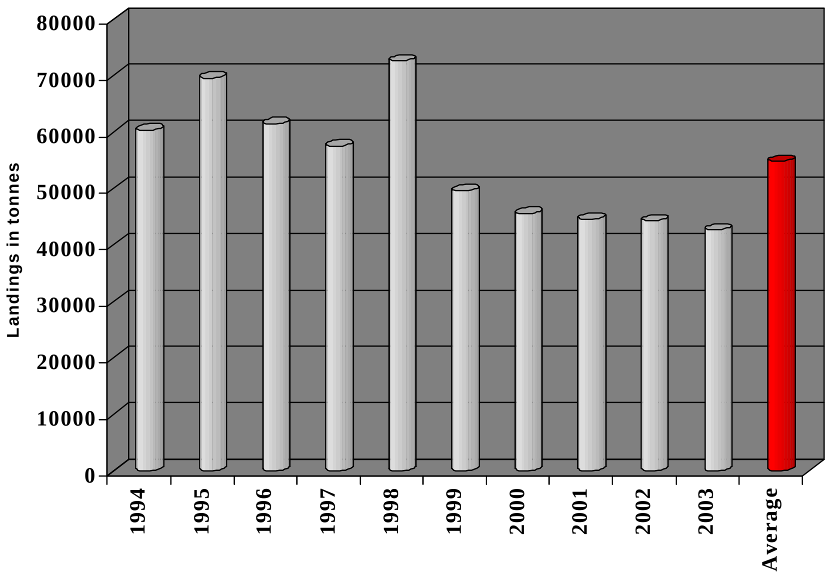


Fig. 8 Landings of Whitebaits during 1994-2003

The annual production of the Indian mackerel is also characterized by wide fluctuations as evident from the catch records of the past fifty years. During the last 20 years, the production ranged from 113,000 t in 1991 to 290,000 t in 1989.The mackerel fishery showed a declining trend from 1999(2.1 lak t in 1999 to 0.9 lakh t in 2001) and showed marginal improvements during 2002 and 2003 when the catch increased to 0.96 lakh t and 1.12 lakh t respectively (Fig.9).The large scale exploitation of the juveniles along the southwest coast is the key factor which limits the yield from the mackerel stock.Fishes below the size of 15 cm form about 42% of the catch from west coast. Increasing the size at first capture from 140 mm to 160mm by controlling exploitation during the 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.

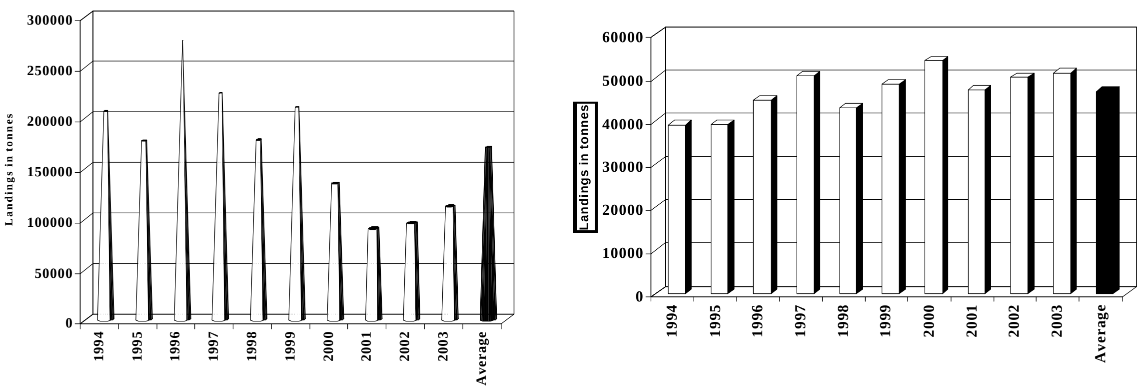


Fig. 9 Landings of Mackerel and tunas during 1994-2003

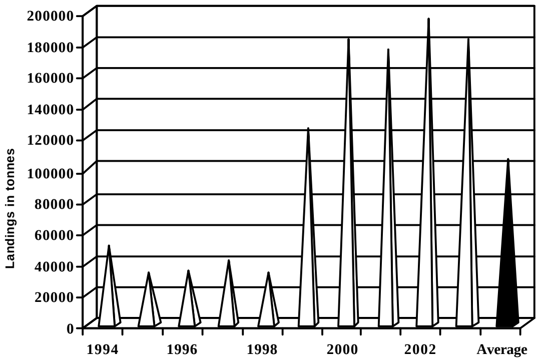
Tunas constitute one of the economically important marine fisheries resources and during, their production from Indian seas fluctuated between with an annual average production of forming 3.6% of the total pelagic fish production (Fig. 9). The tuna fishery in India is limited to the small-scale sector with negligible inputs from the industrial sector. The commonly occurring coastal tuna species in the small scale fisheries are *Euthynnus* *affinis* (little tuna), *Auxis thazard (*frigate tuna), *A.rochei* (bullet tuna), *Sarda orientalis* (striped bonito), *Thunnus tonggol* (long tail tuna) and oceanic species *Katsuwonus pelamis (*skipjack tuna),*T.albacares*(yellowfin tuna). *E. affinis* and *A. thazard* constituted the major species along both the coasts whereas *T.tonggol* and *T. albacares* along the northwest coast. . The drift gill net is operated all along the Indian coast, the purseseine southwest and the hooks and line off Vizhinjam. The pole and line and troll line are operated in Lakshadweep Island.

Tunas of the oceanic region largely remain under-exploited in the Indian EEZ.The Fishery Survey of India has been undertaking survey programmes to study spatial distgribution and abundance of these highly migratory species in the Indian EEZ by long line since 1983. Among the resources identified, the yellowfin tuna constituted the major species in all the regions.Big eye tuna was dominant in the equatorial region, while skipjack tuna was abundant in the northwestern region.

Seerfishes are one of the commercially important pelagic finfish resources of India of high commercial value.The seerfish catch of 50,376 t in 2000 which was just 1.85% of the marine fish production was valued at 4.03 billion rupees. Owing to their high unit value and economic returns, they support artisanal fisheries and is a major source of income for gill net and hooks and line fishermen of the country. Out of the four species viz., the king seer (*Scomberomorus commerson*), the spotted seer (*S.guttatus),* streaked seer (*S.lineatus)* and the Wahoo *(Acanthocybium solandri*), the fishery is sustained by the first two species. The king seer was dominant along the coasts of Orissa, Andhra Pradesh, Tamil Nadu, Kerala and Karnataka. The spotted seer is more abundant than the king seer along the coast of West Bengal, Maharashtra and Gujarat coasts.

Carangids occupy 9th position with a production of 1.11 lakh t, constituting 4.1% of the total marine fish production. The resources is comprised mainly of horse mackerel, round scads, queenfishes, trevallies, leatherjackets and pompanos and has emerged as one of the important pelagic fish resources especially in the mechanized sector. Carangids are extensively exploited by a multitude of gears like trawls, drift gill nets, bottom set gill nets, hooks and line, shore seine, ring seine purse seine etc.Many species support the the carangid fishery and the species composition in the catch depends on the selective properties of the gears employed. The non-selective trawls mostly exploited scads such as *Decapterus dayi, D.macrosoma, Selar crumenophthalmus,* horsemackerel *Megalaspis cordyla,* and trevally *Caranx para, C.carangus, Selaroides leptolepis.*

The ribbonfishes, also known as hair-tail or cutlass, form a major pelagic fishery resources of the Indian seas.The ribbonfishes landings has shown an increasing tren with considerable annual fluctuations.During the years from from 1956 to 2000, the landings fluctuated between 16,452 in 1963 to 1,82383 t in 2000 with an average landings of 63669t (Fig. 10).*Trichiurus lepturus* is the dominant species among ribbonfishes and supports a fishery all along the Indian coast. It forms more than 95% of the total ribbon fish landings. Other species noticed in the catches are *T.ruselli*, *Lepturocanthus saval, L.gangeticus, Euplurogrammus muticus and E.glassadon.* Ribbonfishes are exploited all along the coast and the bulk of the landings came from Gujarat and Maharashtra followed by Kerala, Tamil Nadu and Andhra Pradesh.



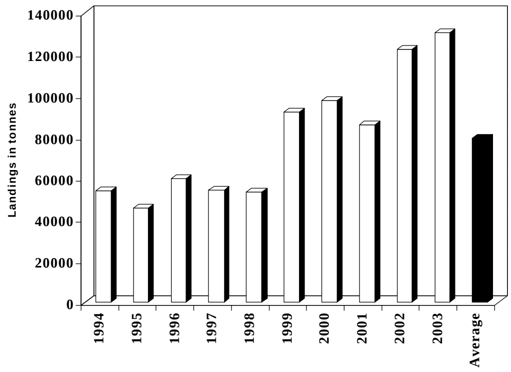


Fig.10 Landings of Ribbon fishes and Bombay duck during 1994-2003

As in the case of the oil sardine and the Indian mackerel, the Bombayduck along the northwest coast also exhibited wide annual fluctuations in production. The fishery is mostly supported by a single species, *Harpadon nehereus*, popularly known as Bombayduck . The landings of this species contribute about 5% of all India marine fish landings.The average annual catch of Bombayduck has been estimated at 1.1 lakh t by traditional and industrial sector (trawlers) along the northwest (88%) and northeast (12%) coasts of India. (Fig.10). The annual catchable potential yield is estimated as 1.16 lakh t (Anon.2000) .Fishing for Bombyduck is traditionally carried out by a stationary bag net called *dol* net worked entirely by the forces of tide along Maharashtra and Gujarat coasts.Though *Harpadon nehereus* was the sole contributor along the northwest coat, at Kakinada *H.squamosus* (195-214mm) accounted for 56% of the Bombayduck landings.

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 the stock. Numerous studies conducted 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. 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 CMFRI and feedback received indicated that considerable reduction in cost of fishing by saving time and fuel for locating fish shoals could be achieved. This technology requires further strengthening 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 could be developed.

Fish migration behaviour

Almost all marine fishes undertake some form of migration and pelagics are no exception. 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. Oceanic tunas undertake even longer migrations and stocks are frequently shared by many countries. Therefore understanding the migratory patterns of pelagics, especially highly valued large pelagics like tunas is crucial for planning a successful fishery and its management. Tagging is the best way to study migration and sophisticated acoustic and telemetric have been developed to allow continuous observations of the movements of a single fish. Tagging studies for small pelagics like oil sardine and mackerel has already been conducted in Indian waters. A collaborative mega project with external funding support is envisaged to undertake a tagging programme for the highly migratory and straddling stocks of oceanic tunas also.

Enhancement of fish production

Fish aggregating devices (FADs) are used to artificially 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 an FAD associated tuna fishery in Lakshadweep waters is being implemented. The project is expected to understand the aggregation dynamics of tunas and their feeding behaviour so that appropriate management measures can be formulated for the tuna fishery of the Lakshadweep islands.

Development of predictive models

Reliable estimation of stock size is required to formulate any fisheries management policies but pelagic fish stocks are notorious for their unpredictable catch fluctuations. Stock estimation using classical models have many limitations is being applied to pelagic fisheries as these fishes have highly variable recruitment pattern and environmental – biological interactions in these fisheries is extremely complex. 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 these fisheries through mathematical modelling of fishery dependant and independant 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 in other pelagic species also.

Resource conservation

Many of the world's greatest fisheries particularly for pelagics like sardines have collapsed owing to recruitment failure caused by high fishing pressure on the spawning stock emphasizing the need to study stock – recruitment relations. 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 the population is in place. Vessel based stripping of ripe spawners of mackerel captured in the nets and releasing the eggs in the fishing grounds itself 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. Increased capture of juveniles in ring seines has also to be avoided to prevent growth overfishing which causes huge economic loss. It is therefore vital to make periodic assessments of the pelagic stocks, the fishing practices adopted and the juvenile and spawner components of the 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 control (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.

Future prospects

Though a progressive trend is noticeable in production of most of the pelagics, many of them, especially the oil sardine, mackerel, Bombayduck,seerfishes, ribbonfishes and tunas have reached the optimum level of exploitation in the conventional fishing ground(Fig.15). 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 crossed the level of MSY and further increase in effort in the coastal sector would be detrimental to sustainable yield (James, 1992). The groups, which are expected to contribute significantly to the additional yield from beyond the 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 their potential resources from the 50-200 m depth area are extension of the operational range of crafts, introduction of combination vessels (drift gillnetting and longlining) for multiday fishing, widespread employment of 'light luring purseseiners', conversion of trawlers for offshore drift gillnet and tuna longline fishery, providing chilling and cold storage facility on board the vessel and implementation of suitable post-harvest technology for utilizing the products for internal as well as export market Besides the above groups, the deeper areas of the oceans contain huge mesopelagic resources, such as file fishes, lantern fishes etc. which can be converted into fish meal. According to a recent observation the 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 upto 100 million t per year. Similar populations, but of lesser magnitude, may be available in the Bay of Bengal also. Effective methods of their exploitation, handling, processing and utilization will have to be evolved. However, the fishing activities in the offshore and the high sea areas are at present restricted since such activities are capital-intensive and require offshore fishing vessels (longliners, purseseiners, midwater trawlers), infrastructures, shore facilities, expertise and skilled manpower. Development of the above for offshore fishing operations, coupled with value added product development, marketing and export would provide the necessary impetus for further development of pelagic fisheries in the country.

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