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18 The Indian oil sardine

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ABSTRACT

The Indian oil sardine, Sardinella longiceps Val., supports a neritic pelagic fishery contributing 2 to 33 % of the annual marine fish production in India. Though distributed all along the Indian coast the species sustains a commercial fishery of high magnitude along the coasts of Kerala, Karnataka , Goa and southern part of Maharashtra. During the last fifty years the annual all India production oscillated between 14,000 t in 1952 to 3 lakh t during 1968. Presently the west coast indicates a declining trend compared to an ascending pattern along the east coast. The production from east coast surpassed that of the west coast contributing 52% of the all India production of 2.03 lakh t in 1998. The fishery along the west coast is known for its fluctuating nature. Further, the species indicates a cyclic pattern of abundance. A variety of traditional gears were engaged in exploiting the resource till the introduction of modern and sophisticated gear like the purse seines in the late seventies and the ring seines in the late eighties. In fact oil sardine is one among the few species that have ever remained a subject matter of intensive research. The focus of this compilation is to present a comprehenstve picture of the Indian oil sardine, its fishery, biology, stock, future prospects of exploitation and management measures needed for yield optimisation.

Introduction

The pelagic fisheries resource contributed 45-61% to the total marine fish production of 2.2 million tonnes during 1985-94. The clupeoids comprise a major group among the pelagic resource. Among the clupeoids, the Indian oil sardine (*Sardinella longiceps* Val.) known as *'Mathi/Nalla mathi'* in Malayalam, *'Boothai'* in Kannada, *'Tarli/Haid'* in Marathi, 'Noone-*kavallu*' in Telugu, *'Nonali/Paichalai'* in Tamil is the most predominant species that forms the mainstay of the pelagic fishes of India and its stock is probably the widespread in the Indo-Pacific region. The species supports a commercial

fishery extensively in the inshore waters of the west coast (8° N and 16° N) from Quilon to Ratnagiri. Its contribution to the total marine fish landings varied from 2 to 33 % during 1960 to 1995. In the recent past the highest landing of 3,00,000 tonnes was recorded in 1968 and a lowest of 47,000 t in 1994. The fish is much sought after as a favourite food item. During the early years and at times of glut it is also used for extraction of oil and as manure.

The large scale fluctuation in abundance, the population crashes and subsequent revival of the fishery have ever remained a subject of centre stage attraction from very early times. Many researchers from time to time have focused their attention to investigate a host of fishery independent and fishery dependent factors that influence the oil sardine abundance and came out with different suggesions. The discussion here attempts to bring out precisely the present status of our knowledge on the oil sardine, its fishery, biology, stock and identify areas which require further investigation for the optimum exploitation and management of the resource. Material for this discussion is based on the publications in literature. Details of the present exploitation is taken from the records of NMLRDC of CMFRI.

History at a glance

Pioneering works on the seasonal and annual migrations of oil sardine are those of Hornell (1910), Hornell and Nayudu (1924), Devanesan (1943) and Nair (1951 b ,1960) and Panikkar (1960).

The annual fluctuations encountered have been reported by Day as early as 1865 Thurston (1900) and Hornell (1910). Later, Nair and Chidambaram (1951), Nair (1960, 1973), Antony Raja (1972), Balan and Reghu (1979) and Balan (1984) have also dealt extensively on this aspect.

The fishery and biological aspects have been extensively described in the works of Annigeri (1969, 1987, 1992), Anon. (1947, 1960, 1969, 1972, 1973, 1974, 1975, 1976), Antony Raja (1973), Balan (1972, 1973, 1984), Balan and Reghu (1979), Balan and Nizar (1988), Bensam (1970), Chacko and Mathew (1956), Chakraborty *et al* (1975) , Devanesan (1943), Devanesan and Chidambaram (1953), Dhulkhed and Umakumari (1979), Dhulkhed *et al* (1982), Dhulkhed and Uma Bhat (1985), Foetadar and Savaria (1988), Jacob *et al* (1982), James (1981), Kaikini (1960), Kurup *et al* (1987), Nair and Prasanna Kumari (1973), Noble and Kutty (1978), Prabhu (1971), Prabhu

and Dhulkhed (1970), Radhakrishnan (1965), Rengasamy (1977), Sam Bennet (1965), Sekharan (1962), Sekharan and Dhulkhed (1963) and Sekharan and Nair (1976).

Significant contributions to the knowledge of spawning biology have been made by Antony Raja (1964, 1966, 1967, 1971), Balan (1965, 1972), Dhulkhed (1964, 1968), Dhutt (1968), Lazarus (1976, 1985) and Nair (1960, 1973).

Our knowledge on the spawning grounds and eggs and larvae of sardine is limited to the works of Anon. (1974, 1976), Devanesan and Chidambaram (1943), Devanesan (1943) and George (1976, 1980). The early life history has been described by Nair (1959).

Many workers while studying the fishery and biological aspects have dealt with the age and growth. But studies exclusively on age and growth have been made by Antony Raja (1970), Balan (1959, 1964), Bensam (1968), Dhulkhed (1977) and Gjosaetor *et al* (1984).

Studies on the food and feeding habits are those of Hornell (1910), Hornell and Nayudu (1924), Devanesan (1942, 1943), John and Menon (1942), Nair (1953 b), Nair and Subramanyan (1955), Chacko and Mathew (1956 b), Kuthalingam (1960, 1961), Dhulkhed (1962, 1970), Bensam (1964 c), Kagwade (1964) and Noble (1964). Results of the racial investigations are available from the works of Dhulkhed and Nagesh (1976) and Menezes (1975, 1980).

Accounts on the fishery and biology of oil sardine from the east coast have been reported by Gnanamuthu and Girijavallabhan (1984), Kumar and Balasubramanian (1987), Luther (1988, 1994), Mahadevan Pillai (1992), Marichamy *et al* (1992), Ramasomayajulu and Dhana Raju (1985) and Srinivasarangan and Chidambaram (1985). The phenomenal increase in the landings of oil sardine on the east coast in recent years awaits a serious study.

The Central Marine Fisheries Research Institute has published an annotated bibliography on oil sardine covering all literature upto 1989 (Girijakumari, 1990)

Distribution and variability

The general distribution of *Sardinella longiceps* is reported to be along the coast of Somaliland, Mombasa, Seychelles, Gulf of Aden, Red Sea, Gulf of

Oman, Persian Gulf, Pakistan, India, Sri Lanka, Andaman Sea, Malaysia, Indonesia, Philippines and Vietnam.

Studies on the variability of some morphometric and meristic characters of the species from different centres along the Indian coast, Aden, Muscat and Karachi indicated that there were no local racial or brood differences (Hornell and Nayudu, 1924). Devanesan and Chidambaram (1943) have expressed the possibility of the existence of different races. Those from some region of the Indian coast differed from those from Aden and Muscat. They have further observed that the oil sardine from Karwar seems to differ from that of the Malabar and Bombay - Karachi coasts in certain charactersistics of the head and tail.

Food and feeding

Large quantities of flocculent muddy unrecognisable matter was found in the stomach contents during October-December. It was observed that the fish fed on such muddy mass at the sea-floor, exhibiting preference for bottom feeding (Hornell and Nayudu, 1924). This muddy material was only a well digested form of diatoms and other planktonic organisms and that the bottom feeding habit could be only occasional due to unfavourable conditions near the surface (Devanesan, 1943). However, the movement of sardines towards the bottom is a common occurrence during October to January (Balan, 1962) and this may possibly explain the bottom feeding habits.

The fish is a plankton feeder and mainly feeds on diatoms, dinoflagellates, tintinnids and zooplankton. Among the diatoms, *Fragilaria oceanica*, *Pleurosigma*, *Coscinodiscus*, *Biddulphia* and *Trichodesmium thiebautii* were frequent. Those belonging to Dinophyceae consisted of *Procentrum*, *Ceratium*, *Peridinium*; and among zooplankton *Acrocalanus*, *Paracalanus*, *Oithona*, Harpacticoids, *Lucifer* and larval polychaetes have been noticed. The juveniles are carinivorous and post-larvae feed on diatoms and algae. The diatom *F.oceanica* is said to probably indicate abundance of oil sardine in coastal waters. During spawning, there seems to be a cessation of feeding activity. The observations of various researchers are summarised in Table 1.

Table 1. Observations on the food and feeding habits of *Sardinella longiceps*

Observation	Author & year
Juveniles are carnivorous, and adults feed on Phytoplankton. Indirect selection by their inefficient filtering mechanism in juveniles lead to carnivorous diet.	Bensam (1964)
Normally feed on fish eggs off Calicut. Also diatoms and dinoflagellates	Devanesan (1942, 1943)
Recorded 1) Diatoms: *Coscinodicus, Fragilaria oceanica, Biddulphia, Pleurosigma, Nitzchia, Rhizosolenia, Asterionella, Bacteriastrum, Ditylum, Hemidiscus, Planktoniella, Thalasiothrix* and *Triceratium*; 2) Dinophyceae: *Dinophysis, Procentrum, Cerethium, Peridinium, Pyrophacus* and *Ornithocercus*; 3) Tintinnids; 4) zooplanktons like *Aerocalanus, Paracalanus, Oithona and Harpacticoids*.	Dhulkhed (1962)
Food of juveniles (40-79 mm) were diatoms, dinoflagellates, copepods and bivalves. More dinoflagellates with increase in length	Dhulkhed (1970)
Feeding on flocculent muddy scum at sea bottom during October-December.	Hornell (1910)
Nearly 90% of the food consisted of greenish and brownish mud indicating preference for bottom feeding, recognisable matter consisted of diatoms and dinoflagellates.	Hornell & Nayudu (1924)
Mainly feeds on diatoms and dinoflagellates	John & Menon (1942)
Diatoms, dinoflagellates and zooplankton. The blue green algae *Trichodesmium thiebautti* was frequently observed.	Kagwade (1964)
Food of larvae consisted of diatoms and algae, compared to copepods,ostracods, *Lucifer*, larval	Kuthalingam (1960)

prawns, bivalves and polychaete larvae, sergestids, diatoms and algae in adults.	
Phytoplankton formed chief food item of juveniles and adults	Nair (1953 b)
Diatom *Fragilaria oceanica* can be an indicator species for sardine abundance	Nair and Subramanyan (1955)
Domination of diatoms in July-Sep. & Dec-Feb., copepods at other times, Even during blooms of *F.oceanica* catch was poor, hence ruled out the possibility of this diatom as indicator species.	Noble (1965)

Age and growth

Different views have been expressed by various experts about the age, growth rate and life span of this fish. On the basis of length frequency data Hornell and Nayudu (1924) have concluded that the fish grows to a length of 155-170 mm in one year and 190 mm in two years. They also postulated that spawning takes place at the end of the first and second years of its life. The life span was presumed to be 2.5 years. According to Chidambaram (1950) the fish attains 100, 145, 183 and 205 mm at the end of first to fourth year respectively. Nair (1953) after examining the rings on scales and otoliths came to almost the same conclusion as Chidambaram. Antony Raja (1969) is of the opinion that there is differential growth rate in the different broods arising out of early spawning and late spawning in the same season. The earlier brood spawned in June-July has a high rate of growth reaching 105 mm in eight weeks, whereas that spawned in July-August attains the same length in ten weeks. The maximum size group on record is 220-229 mm (Chidambaram, 1950; Rosa and Laevastu, 1960). The length frequency analysis (Annigeri *et al.*1992) showed that the fish attains 128 mm, 166 mm and 195 mm at the end of 1,2 and 3 years respectively. Results of observations on the age and growth of this species by different authors are summarised in Table 2.

Table 2 Results of the age and growth studies on *Sardinella longiceps*

Observations	Area	Author
Attains 117,172,192,210 mm at the end of 1 to 4 years. L_{oo} = 221 mm, K = 0.75 (annual) by VBG (1938); L_{oo} =231 mm,K=1.52 by	West coast	Annigeri *et al (1992)*

Bhatacharya method (1967); L_{oo} = 225 mm, K=0.73 by Wetheral *et al* (1987) method.		
Attains 95-110, 110-125, 125-140, 150-160 and 170-180 mm at the end of 2,3,6,12 and 24 months. Estimated value of L_{oo} =209.8mm, K=0.05 t_0 =13.42,normal life span 2.5 years.	Calicut 1961-62 to 65-67	Antony Raja (1973)
Scale studies- the fish attained 143, 164 & 184mm at the 1,2 &3 years respectively.	Calicut 1955-65	Balan (1959)
L_{oo} = 207 mm, K=0.53 (annual), t_0 = 1.33		Banerji (1973)
Attained 145-155 and 175 mm at the end of 1 & 2 years.	Cannannore 1936-42	Bensam (1964)
Attained 100, 145, 183 and 205 mm at the end of 1 to 4th year respectively. T_{max} 4 years.	Calicut	Chidambaram (1950)
Attains 140 mm at the end of one year.	Sri Lanka	Dayaratne & Gjosaeter (1986)
The average lengths at ages of 6,12,18 and 24 months were 87.9, 124.4, 156.9 & 172.7 mm respectively.	Mangalore	Dhulkhed (1977)
Attains 155-170 mm by Ist year and 190 mm by 2nd year.	Malabar	Hornell & Nayudu (1924)
By VBG method obtained a value of 147.72 mm, 172.53 mm and 187.7 mm for I,II and III year of life	Parangipettai	Kumar & Balasubramanian (1987)
100,145,183,205 mm at the end of I to IV year, growth rings seen in otoliths inferred to be annual		Nair (1949, 1953)
Attains 150,170, 190 mm at the end of 1 to 3 years	Calicut	Prabhu (1967)
Attains 100-110 during Ist year, 150-160 mm in 1lyear and 175-180 mm in the third year	Mangalore 1963-64 1967-68	Prabhu & Dhulkhed(1970)
Attains 125-130 mm, 165-175 mm and 180-190 mm at Calicut at the end of 1 to 3 years	Calicut 1970-71to1973-74 1967-68	Rengasamy (1977)

Av.length at age of Six, twelve,eighteen and twenty four months being 87.9,124.4,156.9 and 172.7 mm.	1960-73	Dhulkhed (1977)
128, 166, 195 mm at the end of I, II, III years.	West coast 1984-88	Kumaran *et al* (1992)
L_{oo} = 197.2 mm, K= 1.006 (annual)	West coast	Kurup *et al* (1987)

Length-weight relationship

Dhulkhed (1967 a) worked out the length-weight and volume relationship of the species from Mangalore and derived at the following equation:

Length-weight		Length-volume
Indetreminate	-7.6541 + 3.6169 log L	-7.6599 + 3.5940 log L
Female	-6.3420 + 3.2665 log L	-6.4108 + 3.5940 log L
Male	-6.7010 + 3.1086 log L	-6.6944 + 3.1091 log L
Pooled	-6.4662 + 3.2123 log L	-6.3439 + 3.2623 log L

Antony Raja (1967) also carried out an analysis of his data for five seasons and could not find a regular sequence of decreasing values of 'b' among the indeterminate, female and male fishes.

Reproduction

Sexes are separate. In spent and recovering fishes males could be distinguished by an externally visible muscular papilla in the cloaca and in females by the presence of a membranous papilla behind the anal opening.

Oil sardine attains sexual maturity at the age of one year at a length of 150 mm. Active spawners in the oozing condition measure 150 to 170 mm. Fecundity varies from 70,000 to 80,000 ova, but averages to 48,000 eggs. The fecundity is directly proportional to the weight of the ovary and is generally related to the size of the fish.

The sex ratio appear to vary. Some investigators found the females to predominate upto size at first maturity, but reduced segregation among ripe fish. A recent study by Annigeri *et al* (1992) indicated that the females dominated at all observation centres both on the east and west coast.

The spawning season is protracted with certain amount of interannual variations in its duration. In general, it extends from May to October with intense activity during June to August.According to Nair (1959) the fish spawns only once in its life but Antony Raja (1967) has pointed out the chances of spawning twice before the end of its fishable life-span. Dhulkhed (1967 b) is of the view that eggs are discharged in 3 to 4 batches during the spawning season, though Antony Raja (1967) disagrees with this observation. The spawning grounds have not been definitely located yet. It is supposed that spawning is found to take place at about 15 km from the shore at 30 m depth line in the surface and columnar strata from Quilon to Karwar. Isolated cases of spawning in the nearshore areas also have been observed off Kasaragod and at Cochin during July. Spawning usually takes place at night, a few days before and after new moon suggesting the influence of lunar periodicity (Devanesan and Chidambaram ,1943 and Antony Raja, 1969). A mean rainfall range of 20-30 mm for June-August may indicate good recruitment. It has been found that seasons of feeble or severe rainfall coincided with extensive *atresia* in the ovaries leading to reduction in spawning potential of the population (Antony Raja, 1973). The observations of various authors are summarised in Table 3.

The eggs in plankton were collected off Kerala coast and its early life history has been worked out (Nair and Subramayan, 1955). The eggs are pelagic, transparent, spherical about 1.4 mm in diameter with a wide perivitelline space. The yolk is colourless and has distinct segmentation. Generally only one but occasionally two and rarely three spherical oil globules have been observed (Nair, 1959).

Table 3. Spawning season, size at maturity of oil sardine along the west and east coast

Author	Year	Area	Period	Maturity, spawning, sex ratio, fecundity,eggs and larvae
1	2	3	4	5
West Coast				
Anon	(1974)	UNDP/FAO/PFP		Spawning in isolated local patches in nearshore waters (12m)off Kasaragod and Cochin
Anon	(1975)	UNDP/FAO/PFP		Young oil sardine observed during April-Aug. & Nov., February.

Anon	(1976)	UNDP/FAO/PFP		Spawning season April-August.
Annigeri	(1969)	Karwar	1964-65;	Spawning during July, August to November-December, size at maturity 140mm.
Antony Raja	(1964)	West coast	1959-63	Spawning season July-August.
Antony Raja	(1969)	Calicut	1959-60	Male matures earlier. No significant change in sex ratio
Antony Raja	(1971)			Average fecundity 37,000-38,000. Older fishes have higher values of fecundity.
Antony Raja	(1973)	West coast	1956-57 1972-73	25-35mm rainfall during June-July or 20-30mm for June-Aug. favours good recruitment. Feeble or excess rain leads to atresia, thereby reduction in spawning potential.
Balan	(1966)	Cochin	1959-63	Average fecundity 48,119. Females dominated during 1959, 60, 61, 62, 64 and 65 in the boat seines at Cochin.
Balan	(1972)	Cochin	1959-69	Spawning season June to August.
Balan	(1973)	Cochin	1969-71	No significant dominance of either sex in purse seine catches at Cochin during 1969-71.
Balan *et al*	(1979)	West coast		In 1978, females dominated at Calicut, Cochin and Karwar, but males at Mangalore.
Balan and Nizar	(1988)	Cochin	1980-85	Spawning june to August.
Bensam	(1970)	Cannanore	1961-63	Spawning April to August.
Chacko and Mathew	(1956)	West coast	1954-55	Mature and spent fishes occurred during April-August.
Chidambaram	(1950)			Females dominated above 200 mm size, equal proportions of sexes upto 200 mm.
Chidambaram and Venkataraman	(1946)	Calicut		Size at maturity 150mm.
Devanesan	(1943)	Malabar		Fecundity 70000-80000. Size at maturity 150mm. Active spawners and planktonic eggs during September-October.
Devanesan and Chidambaram	(1948)			Fecundity 70000, sex ratio equal below 200 mm length fishes.

				Spawning takes place at night, spawns few days before and after the new moon day.
Dhulkhed	(1964)			Malpe and Kasaragod Release eggs in 3-4 batches. Size at maturity 165-169mm.
Dhulkhed	(1968)	Mangalore	1960-67	Spawning time from June to September. Hardly any difference in sex ratio.
Dutt	(1968)			Different broods were noticed indicating extended spawning.
Hornell	(1910)	Malabar		Spawning during June to August and takes place earlier in north than in southern areas.
Hornell and Nayudu	(1923)			Dominance of females upto size at maturity, reduced sexual segregation among adult fishes.
George	(1976)	UNDP/FAO/PFP	1971-75	Peak spawning from April to August, close to shore in area 11 30'N.
George	(1980)	Ratnagiri	1971-75	From 1409 stations UNDP/FAO/PFP sporadic large collections of eggs during July and August.
Lazarus	(1976)	Vizhinjam		Spawners and spent fishes occur at Vizhinjam farther off the usual fishing grounds.
Lazarus	(1985)	Vizhinjam		Spawning and spent fishes occurred at Vizhinjam during May 1976 from farther off the usual fishing grounds.
Nair	(1959)			Spawning grounds beyond the present fishing zone.
Nair	(1960)			Fecundity 78000. Sex ratio equal among juveniles and spawners. The left ovary produced 40000 eggs and the right ovary 38000 eggs.
Nair	(1973)			Reviewed various aspects such as spawning, fecundity, development of eggs and larvae stages
Nair and Chidambaram	(1951)			Estimated fecundity 75000.
Prabhu	(1967)			Reviewed the biology. Spawning appeared to be

				protracted extending from July to October/ November. Spawning ground not far away from the fishing ground.
Radhakrishnan	(1965)	Karwar	1955-64	Observed the maturity and spawning
East Coast				
Gnanamuthu & Girijavallabhan	(1984)	Madras	1988	Mature fishes occurred during January-March. Males dominated.
Gnanamuthu & Thankaraj	(1989)	Madras	1987	Mature fishes occurred during January-March.
Gnanamuthu *et al*	(1989)	Madras		Protracted spawning along west coast, May-June to September- October.
Kuthalingam	(1960)	Madras		Described the larvae from hatching to 40th day.
Kumar & Balasubramaniam	(1987)	Parangipettai		Size at maturity 156mm for females and 158.5mm for males. Spawning during July to September.
Luther	(1988)	East coast	1961-86	Spawning during March-April. Juveniles 50-80mm occur by May at Visakhapatnam.
Marichamy *et al*	(1992)	Rameswaram Mandapam	1991-92	Females dominated during October to January. All specimens were in spent recovering stage.
Srinivasarangan & Chidambaram.	(1985)	Pondicherry	1983	Females dominated during November-December.

Embryonic development is rapid and completed in about 24 hours. The newly hatched larva about 2.75 mm in length floats in water with the help of the oil globule and yolk. The one-day old larva, measuring 3.35 mm in average length shows great reduction in the yolk and loss of oil globule. The two-day old larva becomes active in its movements and grows to about 3.7 mm in length. Most of the yolk is absorbed by the time the mouth is well developed. The three-day old larva shows no specific features except slight reduction in length due to complete absorbtion of yolk.

Shoaling and migration

Interesting observations on the different types of surface and bottom shoals have been described by Balan (1961). Shoals have been differentiated into flipping, pattering, rippling, coloured, luminiscent, bubbling and

odouriferous. Of these the first five types of shoals are generally seen at the surface and the last two at the bottom of the sea. The flipping shoals are reported to occur both during day and night, but more common in the morning and at night. The pattering shoals are found more during the day than at night producing sounds simultaneously or in succession. The rippling shoals produce ripples on the surface of water. Besides these, based on the behaviour patterns the shoals are further differentiated by the colour effects they produce as bluish and pinkish coloured shoals. There are also luminescent shoals easily caught during dark nights. The presence of a series of small air bubbles coming from below and bursting on the surface water are believed to be released by the fish while feeding on muddy bottom. This makes them an easy target to fishermen. Good concentration of fish is also indicated by the strong fishy odour. The size of the shoal may range from 2 to 25 m length and 1 to 20 m breadth. The shape of the shoals vary. They are roughly pointed in front and blunt behind. The pattering type of shoals are, however, reported to be oblong and the bluish ones somewhat narrow but long. The speed of the surface shoals is about 5 km per hour. The cruising capacity of the bluish and pinkish shoals is much lower than that of the rippling type.

The '0' year class migrate *en masse* from offshore to inshore areas simultaneously at all centres on the west coast by the end of southwest monsoon. The new recruits continue to get reinforced uniterruptedly in spite of heavy fishing pressure. With the warming up of water in summer, the shoal gradually move offshore first from the north and from south subsequently.

Tagging experiments

Large scale tagging of oil sardine was carried out by C.M.F.R.I from several centres on the east and west coast of India during 1967-69 (Prabhu and Venkataraman, 1970). Since the recoveries were limited, no definite conclusions could be drawn on the migration other than the local dispersal observed.

Fishery

Fishing areas

In India, oil sardine is found from Kathiawar to the Coramandal and Ganjam coast. But commercial concentration is predominant along the southwest coast between 8° N and 16° N latitudes. This covers Kerala, Karnataka,

Goa and southern part of Maharashtra. Of late, its emergence as an established new fishery along the east coast has been reported by Luther (1988). Along the west coast the fishing activity is restricted to the region about 3 to 20 km from the shore at depth range of 5 to 25 m. Dense shoals of this fish appear in the inshore areas along the Palk Bay during December to March period.

Fishing gear

Details of the traditional craft and gear engaged in oil sardine fishery have been documented by Nair (1973). The boat seine (*Mathikolli vala*) , the gillnet (*Mathichala vala*) and the shore seine (*Rampani*) were the important traditional gears. Several types of specialised nets like the boat seine (*Paithu vala ,Pattenkolli vala, Thattum vala, Thangu vala* and *Nethel vala)* and shore seines (*Kamba vala, Kairampani* and *Yendi*) with varying mesh size were also in use. The traditional gears progressively became out dated with the advent of efficient gear like purse seines in the late seventies (Dhulkhed and Bhatt, 1985). In Kerala and Karnataka the place of indigenous gear has been substituted by ringseine, a simulative purseseine.

Trends in production

The early part of the fishery from 1925-26 to 1968 has been reviewed by Nair and Chidambaram (1951) and Nair (1973). During the last fifty years the all India production of oil sardine ranged from 14,000 t in 1952 to an all time high of 3 lakh tonnes in 1968 (fig 1) contributing 0.1% to 31.9% to the total marine fish landings in the country. Average annual landings during 1985-93 on the west coast was 128,282 t (86%) and on east coast 21,262 t (14%). The annual landings in Kerala varied from 1554 t in 1994 to 184,879 t in 1989, in Karnataka 1631 t in 1994 to 45,900 t in 1988 and in Goa 2 t in 1994 to 22,186 t in 1991. State-wise average (1990-98) catch and percentage contribution on the west coast were, Kerala 6,7361t (47.6%), Karnataka 9,770 t (6.9 %), Goa 5,978 t (4.2%), Maharashtra 560 t (0.4%) and Gujarat 66 t (0.08%). Correspondingly, the landings on the east coast were, Tamil Nadu 42,656 t (30.2%), Pondicherry 4,454 t (3.1%), Andhra Pradesh 10,458 t (7.4%) and Orissa 130 t (0.12%).

Fishing season

The fishing season starts in June with the appearance of shoals of fish

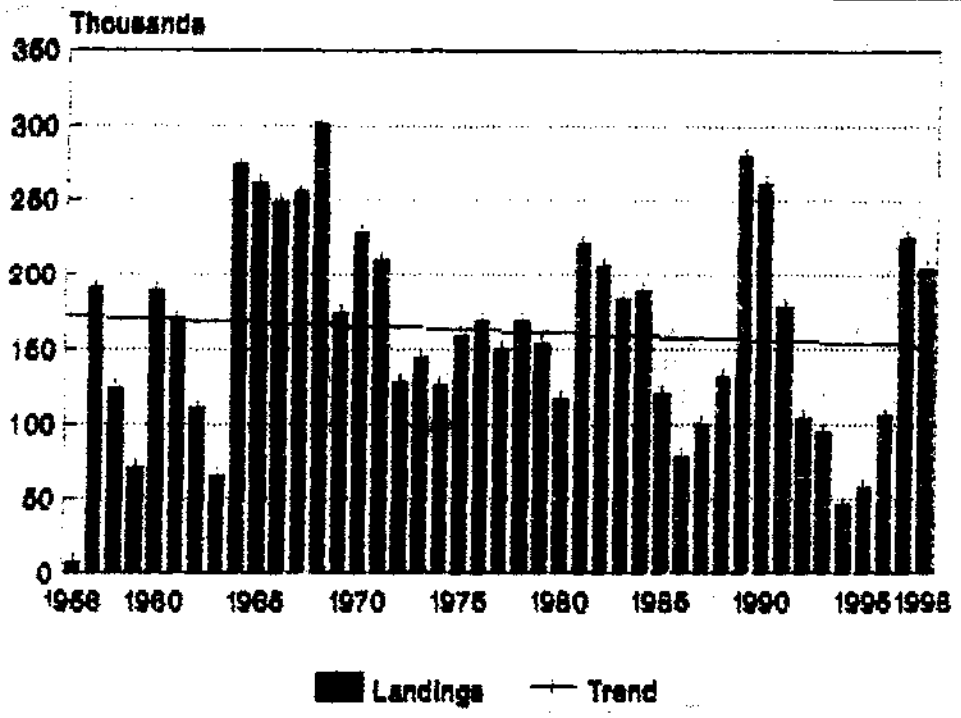


Fig. 1. All India oil sardine landings in tonnes

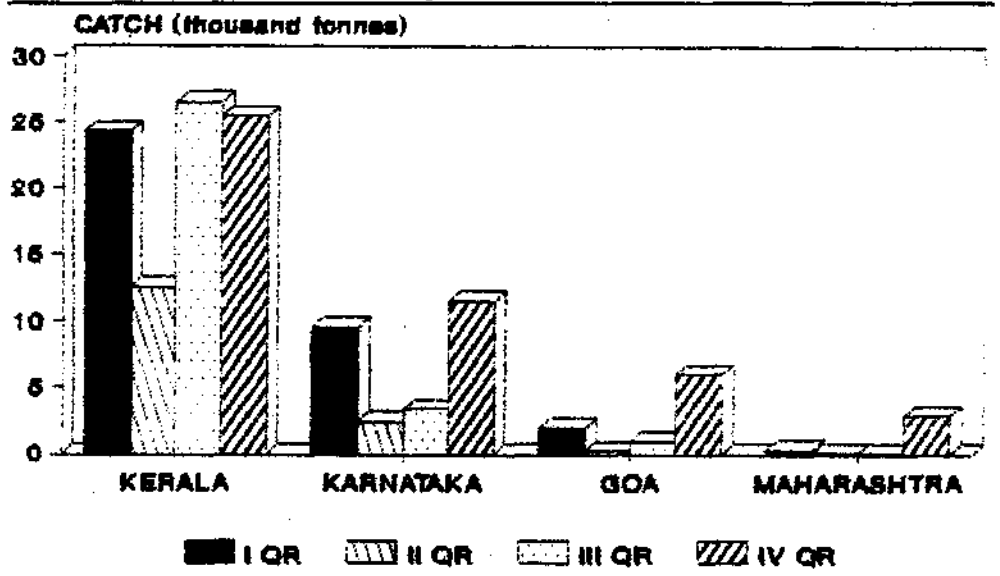
spawned in the previous year (Nair 1959, Antony Raja, 1969) at the southern end of the Malabar coast. These shoals further move northward and by the end of February progressively start withdrawing southward along with young recruits (Chidambaram 1950, Antony Raja 1969).

Quarter-wise production (Fig.2)

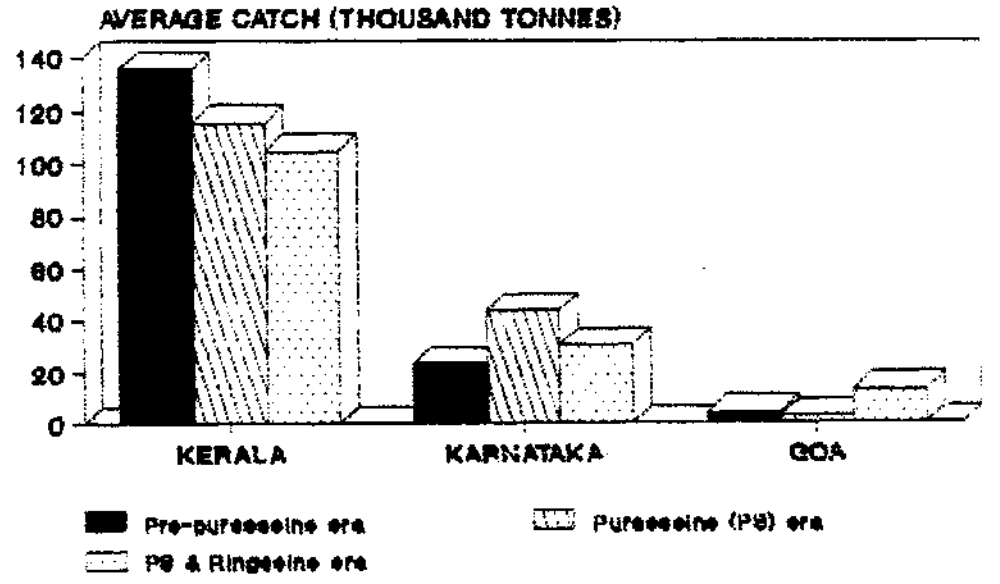
In Kerala, the peak catch of 26,513 t (Av.1985-93) was during the third quarter (July-September) followed by the fourth quarter (25,442), first quarter (24,255 t) and second quarter (12,596 t). In Karnataka, Goa and Maharashtra the fourth quarter followed by first quarter were productive. The landings during the last and first quarters respectively for these states were 11,600 t and 9,536 t; 6,021t and 1,950 t; and 2,879 t and 295 t.

Trends (Fig.3)

Trends of oil sardine landing in Kerala during the pre-purse seine period (1971-75), purse seine period (1976-81) and purse seine and ring seine



Fg.2. Quarter - wise production of oil sardine - statewise



Fg.3. Oil sardin landings (T) during different phases of development

period (1987-92) indicated no improvements in production despite the efficiency of the modern gear. In Karnataka, the landings increased during the second phase, but decreased subsequently. In Goa gradual increase was seen from the initial stage to the last phase.

Gear-wise contribution

In Kerala the average (1986-95) oil sardine landings by different gear was, purse seine 3,479 t (4.7%), ring seine 46,749 t (63.6%) , trawlers 677 t (1%) and other gears 22,587 t (30.7%). In Karnataka it was: purseseines 21,194 t (93.8%), trawlers 99 t (0.4%) and other gears 1,311 t (5.8%). In Goa on an average 6,548 t (98 %) were landed in purse seines and the rest in other gears. In Maharashtra the purse seines landed 870 t in 1995 and 140 t in 1993.

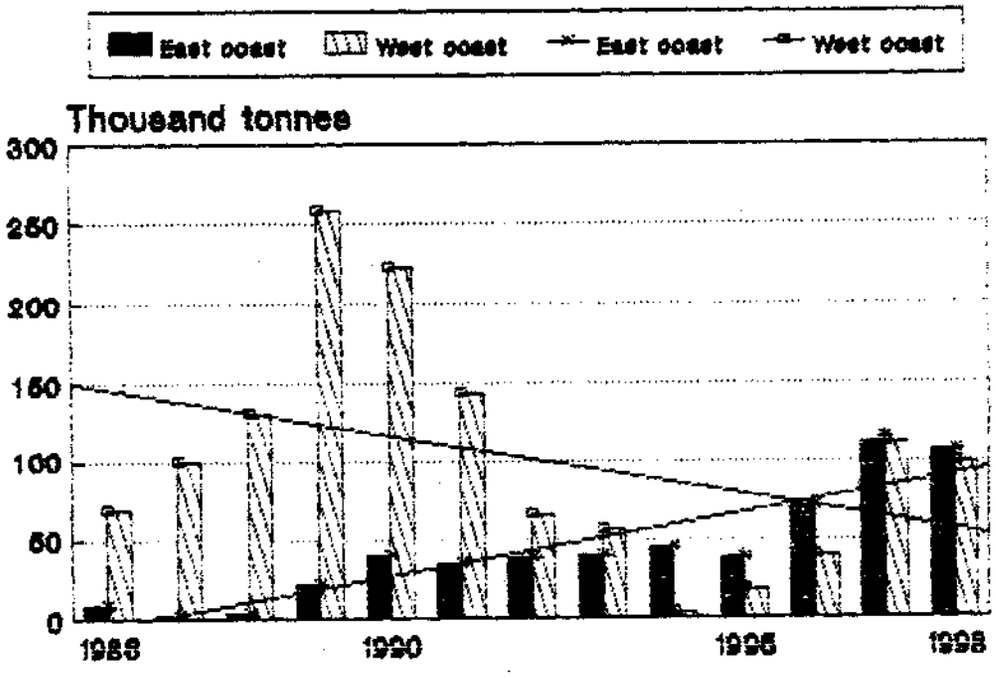
The purse seines realised an average c/e of 656 kg in Kerala compared to 459 kg in Karnataka and 138 kg in Goa . In Maharashtra it ranged from 8 kg in 1993 to 59 kg in 1995. The ring seines in Kerala realised an average c/e of 248 kg. Along the east coast a highest c/e of 2100 kg has been reported in the pair trawlers at Rameswaram (Marichamy *et al* 1992). This high c/e noticed at Rameswaram may not be a regular phenomenon.

The variability in abundance of oil sardine is cyclic. The decadal averages of all India production indicate a decreasing trend from 2,05,000 t in the seventies to 1,37,000 t in the first half of the nineties. In fact, when the traditional gears were in operation in the sixties the annual landings were better than that of late seventies. This period upto sixties represented a phase of high abundance, but the succeeding years appeared to represent a declining phase. The introduction of purse seines and later the ring seines coincided with the low abundance period and hence the total landings of oil sardine showed no increase despite the efficiency of these gears. On the contrary the indigenous gears during the premechanised era could realise 3 lakh tonnes in 1968.

Oil sardine - an emerging resource along east coast

The exploitation of oil sardine along the east coast till 1988 was sporadic and rare. But it appeared that there exists a variable stock of this resource along this coast also. Since there was no local consumer demand, the

stock was left to die a natural death until a time when the demand came from out side the state. The last decade, henceforth, witnessed large scale exploitation of the resource to meet the increased demand from Kerala. The production reached 21,500 t in 1989 and plateaued around 38,000 t till 1993. The landing was 43,600 t in 1994 and reached 70,500 t in 1996 and to an evertime high of 111,300 t in 1997 almost equalling 111,400 t realised from west coast. (Fig. 4). On an average (1990-98) the east coast contributed 40.8% and west coast the rest. Along the east coast 73.8% of the production was from Tamil Nadu, 18% from Andhra Pradesh, 7.7% Pondicherry, and the rest from West Bengal and Orissa. The production from this coast surpassed the trend along the west coast during 1998. During the year, the east coast contributed 52% to the all India production of 2.03 lakh tonnes. Interestingly the production in all the maritime states along the west coast indicated a decreasing pattern compared to an ascending trend discernible along the east coast. Trawls, pair trawls, gillnets, boatseines and shoreseines are engaged in exploiting the resource.



Fg.4. Oil eardine production East and West coast

Utilisation

Oil sardine is rich in oil and the history of the oil trade has been traced by Nair (1973). Nicholson (1915) introduced efficient methods of oil extraction. Of the two grades of oil produced the refined yellow oil was used in leather industry and in the arsenals and the inferior brown oil in the jute and steel industries. The oil stood very well in comparison with the Manhaden or Japanese sardine oil (Nicholson, 1922). The guano, the residue, was used as manure in coffee, tea, coconut, sugarcane and tobacco plantations. Similarly the fish-meal was another bye-product which was in great demand for feeding live stock. Sardines have been successfully canned in India from the early years but canning industry suffered setbacks from time to time due to severe technical and practical difficulties leading to the closure of the Chalayam cannery in 1933. Though there was a rivival of the canning industry the products were not so easily sold in international and domestic markets due to the high cost of cans (Antony Raja, 1969; Nair, 1973).

Presently, due to the increased demand for fresh fish from local and interior markets and easy availability of ice and quick transport facilities, the catch is now consumed fresh. But still the fishing industry has no infrastructure to meet the glut situation that occur at certain times as happened at Alleppey district during July to September 1999.

Fishery and environmental correlation

The literature is replete with correlation between oil sardine fishery and environmental conditions of the Malabar upwelling zone. Hornell (1910), Nair (1953) and Nair and Subramanyan (1955) have related the abundance of oil sardine to the diatom *Fragilaria (= Nitzschia) oceanica*. The two blooms of this diatom, one at the start of the monsoon and the other in September-October coincide with the arrival of oil sardine. Heavy blooms of it were noticed during 1949 and 1953 when the stock was resuscitating after the population crash of the forties. Overfishing and growth overfishing as causative factors for the fluctuation in abundance have been pointed out by Sundara Raj (1934, 1937), Devanesan (1943) and Devanesan and Chidambaram (1948). According to Sam Bennet (1968) a study of the strength of the new year class recruited and the strength of the subsequent year class may help in forecasting the fishery.

Temperature, salinity and availability of food as factors controlling oil sardine abundance have also been indicated by Chidambaram (1950), Annigeri (1969), Bensam (1970), Chandramohan and James (1977), Gopinathan (1974), Jadhaw *et al* (1989), James *et al* (1987), Mukundan (1967), Reghuvendra and Reddy (1985), Ramana *et al* (1988), Rao *et al* (1973) and Suresh and Reddy (1980).The influence of rainfall on oil sardine has been studied by Antony Raja (1972), Murty and Edelman (1971) and Kumaran *et al* (1992). Murty (1974) has suggested the relation of oil sardine landings to wind drift. Longhurst and Wooster (1990) have made a detailed study on the short term and long term abundance of oil sardine in relation to the oceanographic and meteorological conditions and the upwelling of the Malabar upwelling zone. Further, they opined that the unusually early remote force upwelling appears to inhibit subsequent recruitment of oil sardine. Recently Madhupratap *et al* (1992) discussed the influence of various factors of coastal oceanography on oil sardine fishery. Srinath (1998) made an exploratory analysis on the predictability of oil sardine landings in Kerala.

Most of these studies, except a few, were of short term nature spread over space and time and have neither taken into consideration the phases of variability in oil sardine stock nor attempted maximum parameter analyse. Hence different views have been expressed by many workers.

Sunspot activity and oil sardine abundance

The cyclic pattern in the abundance of oil sardine showed a striking similarity to the eleven year periodicity of the sunspot activity. Comparison of time series data on oil sardine landings and sunspot activity revealed good correspondence. Recently, the sun spot activity was the lowest during April 1994. It is interesting to note that the catch by all the gears operating along the west coast was either lowest or nil during 1994. Landings on the west coast dipped to 4000 tonnes in the same year, a major population crash in the recent history. The sunspot activity will be at its peak by the turn of this century when the oilsardine landings may be elevated to a satisfactory level and promising trends are already discerable since 1995. The production during 1997 has crossed 2,00,000 tonnes.

Sun being the ultimate source of energy has a bearing on the productivity of the environment. It appears that the various physical, oceanographical, meteorological factors, rainfall, upwelling and nutrient availability are tuned

in relation to the intensity of sunspot activity. Oil sardine is an immediate beneficiary of primary production by virtue of its position with a short food chain in the food web. Observations of Hornell (1910), Nair (1953) and Nair and Subramanyan (1955) about the relation between abundance of the fish and the diatoms assume importance in this context. However, lack of time series data on many of the environmental factors is a stumbling block in attmpting a correlation with the fishery for evolving meaningful fishery forecast models.

Stock assessment

Banerji (1973) estimated the total annual oil sardine stock as 4,40,000 t and the average standing crop as 2,10,000 t. The corresponding figures as estimated by Sekharan (1974) were 8,10,000 t and 3,90,000 t respectively. Balan *et al*; (1979) stated that the stock level should be about 4 lakh tonnes. This is in agreement with earlier (1972-76) estimates (Anon. 1976). Annigeri *et al* (1992) estimated the MSY as 1,50,000 t against a mean biomass of 1,07,000 t indicating scope for increasing production. Their studies indicated that increasing the fishing effort to the MSY level is not desirable in the present fishery as such a step would decrease considerably the returns per boat to an uneconomical level. Most of the stock assessment studies attempted in India on a number of fishes have always ended up issuing threatening notes to reduce effort level for avoiding overexploitation. These studies have taken into account the total effort in a multispecies fishery system. Any future studies should, therefore, take into account the effective effort rather than computing the total effort.

Suggestions for future work

1. Studies on the indescriminate destruction of juveniles and spawners, and consequent depletion of stock.
2. Effect of mesh size regulations to suggest optimum.
3. Effort rationalisation of purse seine and ring seine. Consideration of effective effort for stock assessment,
4. Effect of seasonal closure of fishing operations.
5. Studies on fecundity, recruitment, abundance of spawners, young fish and strength of the year class.

6. Abundance of oil sardine in relation to primary production and inter-annual variations in the productivity of the ecosystem.

7. Tagging of oil sardine from east and west coast of India.

8. Stock assessment of oil sardine from east coast.

9. Racial investigations using latest methods.

10. Collection of time series oceanographic data for correlation with the fishery to evolve forecast models.

11. Studies on the effect of global warming and rising sea level and *El Nino*. Maximum parameter analyses to develop fishery forecast models.

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