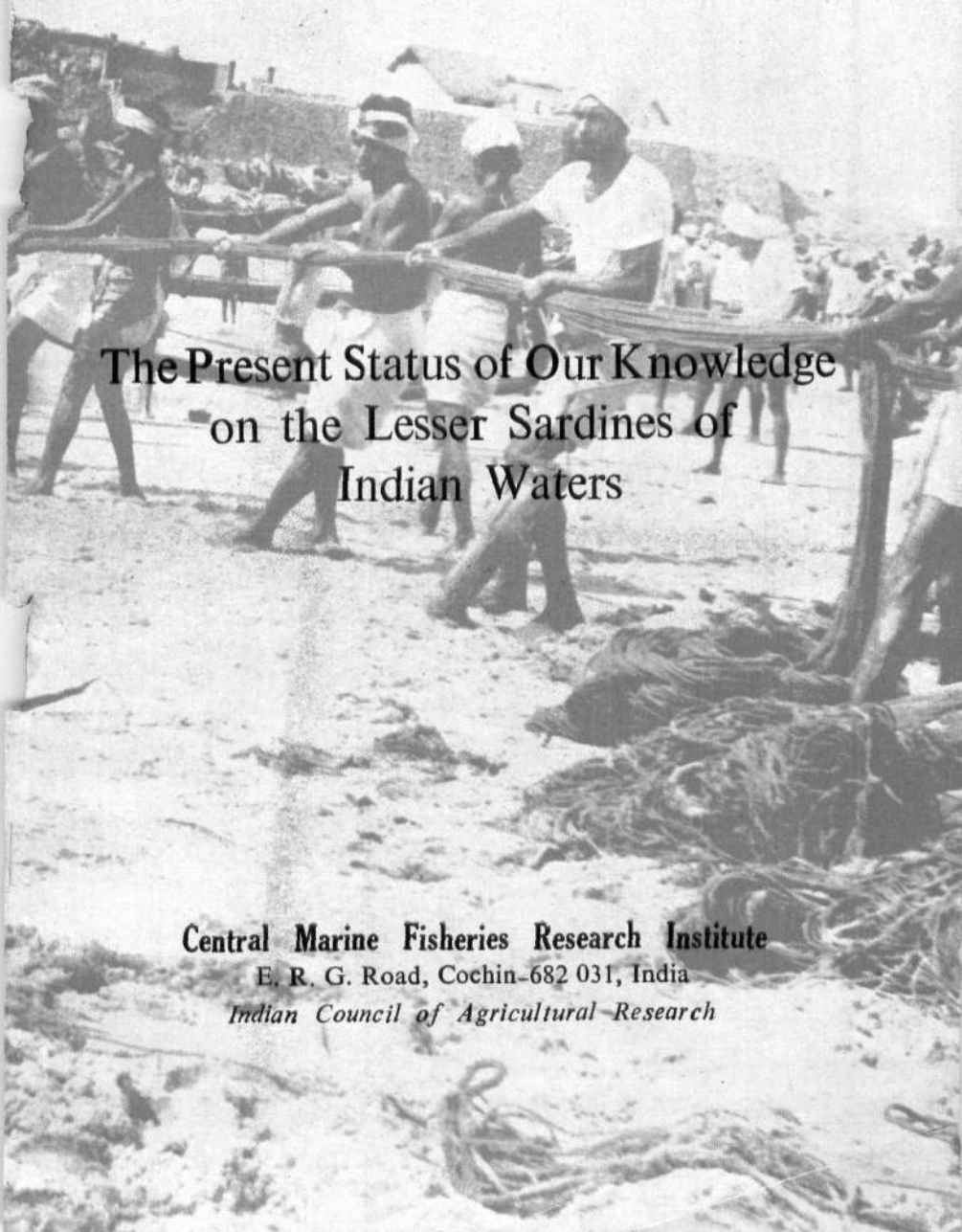


CMFRI Special Publication

Number 28



**The Present Status of Our Knowledge
on the Lesser Sardines of
Indian Waters**

Central Marine Fisheries Research Institute

E. R. G. Road, Cochin-682 031, India

Indian Council of Agricultural Research

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P R E F A C E

The lesser sardines, comprising the various species of *Sardinella* other than *Sardinella longiceps*, support lucrative fisheries along the coasts of Andhra Pradesh, Tamil Nadu and Kerala. The annual lesser sardine catch in recent years is in the order of 70,000 tonnes, accounting for about 4.5% of the total fish landings of the country. They are popular food fishes both in fresh and in cured states. Owing to their thin body and non-oily nature they are conveniently and rapidly beach-dried in large quantities and marketed to internal as well as external markets. Of the ten species that constitute the lesser sardine fishery in India, *Sardinella gibbosa*, *S. albella*, *S. fimbriata*, *S. sirm* and *S. dayi* are the most important species, forming as much as 80% of the total lesser sardine catch. Like those for the other marine pelagic fishes of India, the fishery for lesser sardine is subject to both annual and long term fluctuations.

The authors have put together in this account the available information on the fishery and biology of five important species of lesser sardines for the period 1958-78, and have also pointed out the gaps that exist in our knowledge of the biology, ecology and exploitation of this important resource.

I express my appreciation for the authors for carrying out the investigations and presenting the results in a comprehensive manner in this account. It is hoped that the information will be useful in further research on this resource as well as in the management of the fishery.

P. S. B. R. James
Director
CMFR Institute

PRESENT STATUS OF OUR KNOWLEDGE ON THE LESSER SARDINES OF INDIAN WATERS

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AND G. LUTHER

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ABSTRACT

The results of research carried out at Waltair, Mandapam, Tuticorin and Vizhinjam and at other centres on the lesser sardines over the past up till 1978 are reviewed in detail. In the twenty-year period from 1958 to 1978 there was an increasing trend of production of these fishes along the different coasts of India, the average annual landings nearly doubling from 36,000 t in 1958-67 to 70,000 t in 1968-78. The bulk of the catches came from Tamil Nadu, including Pondicherry, (32.6%), Kerala (32.2%) and Andhra Pradesh (26.5%). Fishing was mostly by the labour-intensive traditional methods in close-shore waters, better catches coming from 30-55 m depths. Shore seines, boat seines and gill nets were the principal gears employed in the fishery though gill nets were the most effective.

The species composition in the lesser sardine fishery varied from coast to coast: whereas *Sardinella gibbosa* and *S. fimbriata* were the dominant species along the northeast coast, *S. gibbosa*, *S. albella*, *S. dayi*, and *S. sirm* formed the dominant species along the southeast coast, and whereas *S. gibbosa*, *S. sirm*, *S. sindensis* and *S. dayi* formed the dominant species along the southwest coast, *S. fimbriata* and *S. albella* were dominant along the northwest coast.

The size composition in the fishery, as well as the size at first maturity, was different among different species. Fishes of 12-14 cm length in the case of *S. gibbosa*, *S. albella*, *S. dayi* and *S. fimbriata* and those of 14-21 cm length in the case of *S. sirm* formed the mainstay of the fishery. *S. gibbosa*, *S. albella*, *S. dayi* and *S. fimbriata* were about 12 cm at attainment of first maturity, as well as around the close of first year of life. But *S. sirm* was about 20 cm at attainment of maturity and about 16 cm around the close of first year of life.

Information is furnished on the catch per unit effort, size composition, maturity and spawning, food and feeding, as well as on the parasites and their effects on hosts, with regard to the important commercial species at observation centres. Gaps that exist in our knowledge on the biology, ecology and exploitation of these fishes are pointed out.

INTRODUCTION

In recent years, the lesser sardines, which comprise the various species of *Sardinella* other than *Sardinella longiceps*, have stimulated the interest of fishery biologists and administrators for their being in increasing demand. Lesser sardines form about 5.6% of the total marine fish production (average for 1968-1978), contributing to lucrative fisheries along the Indian coast (Fig. 1). Considerable employment potential is offered by this

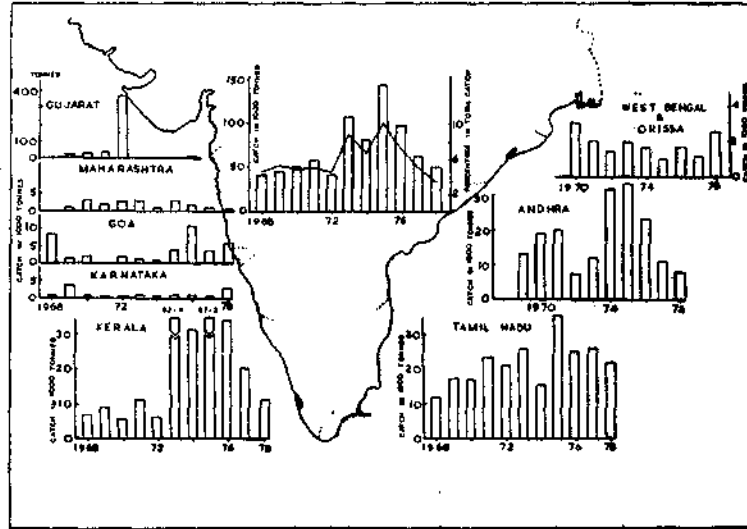


Fig:1 All-India and State-wise catches of lesser sardines from 1968 to 1978

fishery to the economically backward people, because the fishery is carried out mainly by the indigenous crafts and gears which are highly labour intensive. Because these fishes are cheap in terms of selling price, costly inputs in the form of mechanised vessels have not been introduced in their fishery, unlike in the case of shrimps and other quality-fishes. Since the recent past, however, great impetus has been given to the lesser sardine fishery by way of introducing improved gear made of synthetic yarn in place of cotton twine.

Information on the fishery and biology of the lesser sardines can chiefly be had from the studies carried out by Banerji (1973), Bennet (1961a, 1967), Bensam (1971), Chacko (1946), Dharmamba (1959), Dharmaraja and Varughese Philipose (1975), Dutt (1959, 1961, 1963), Ganapati and Rao (1957), Lazarus (1977a, 1984a), Nayar (1958), Radhakrishnan (1969, 1973) Rao (1981), Sekharan (1955, 1968, 1969, 1971), Sekharan et al (1969) and Vijayaraghavan (1953). Besides, several other scientific works and reviews also furnish information on the systematics of the group as well as of certain individual species (Chan, 1965; Day, 1878; Dutt, 1959, 1961, 1963; Lazarus, 1977b, 1983, 1984c; Losse, 1968; Menon and Talwar, 1975; Misra, 1953; Munro, 1955; Nair, 1954, 1973; Raja and Hiyama, 1969a, 1969b; Raja and Lazarus, 1975; Talwar, 1974 and Whitehead, 1972). Bensam (1973), Delsman (1926) and Lazarus (1984a) have described the eggs and early stages of some of the lesser sardines. Instances of gonadal abnormalities have been reported by Gnanamekaji (1962b) and Lazarus (1973). Bennet (1961b, 1964, 1974), Ganapati and Rao (1957) and Pillay (1962, 1964) have described some of the parasites found on lesser sardines. Predatory fishes known to chase sardine schools have been reported by Chacko (1946) and Nair (1959). Descriptions of the craft and gear used in the lesser sardine fishery are given by Chacko and Rajendran (1955), Bennet (1961a), James (1967), Lazarus (1984 b), Nayar (1958), Rao (1973) and Sekharan (1955).

Thus, a large amount of information has accumulated as a result of scientific studies carried out over the past several years at many centres of the Central Marine Fisheries Research Institute, at State Fisheries Research wings of Tamil Nadu and other maritime States, at Universities, and, recently, as a result of investigations by the Pelagic Fisheries Research Project of the UNDP/FAO. Salient features of these investigations carried out up to 1978 are briefly summed up in this account to focus attention on the present status of our knowledge of this important resource in order to furnish the much needed information to the fishing industry and to formulate future programmes of research work on the lesser sardines of the Indian seas.

2. LESSER SARDINE RESOURCES

2.1 Species Composition

The following ten species constitute the lesser sardine fishery of India: *Sardinella gibbosa* (Bleeker), *S. albella* (Valenciennes), *S. fimbriata* (Cuvier and Valenciennes), *S. dayi* Regan, *S. sirm* (Walbaum), *S. sindensis* (Day), *S. clupeioides* (Bleeker), *S. melanura* (Cuiver), *S. leiogaster* (Valenciennes) and *S. Jonesi* (Lazarus). The first seven species form the bulk of the fishery in the different centres, the other three occurring only sporadically and in stray numbers at certain centres.

2.2 Distribution

The lesser sardines are tropical in distribution and occur along the coasts of Arabia, Red sea, East Africa, Malagassy, India, Sri Lanka, Malaysia, Singapore, Philippines, Australia, China and the islands in the Oceania group.

Along the Indian coast, some of the species of lesser sardines exhibit a discontinuous and restricted distribution. A species that is well known and forming lucrative fishery in one State is often scarce in other States. This is depicted in Fig. 2.

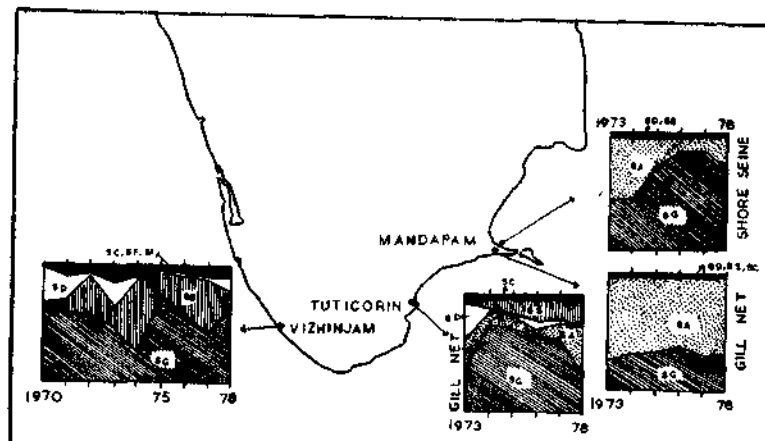


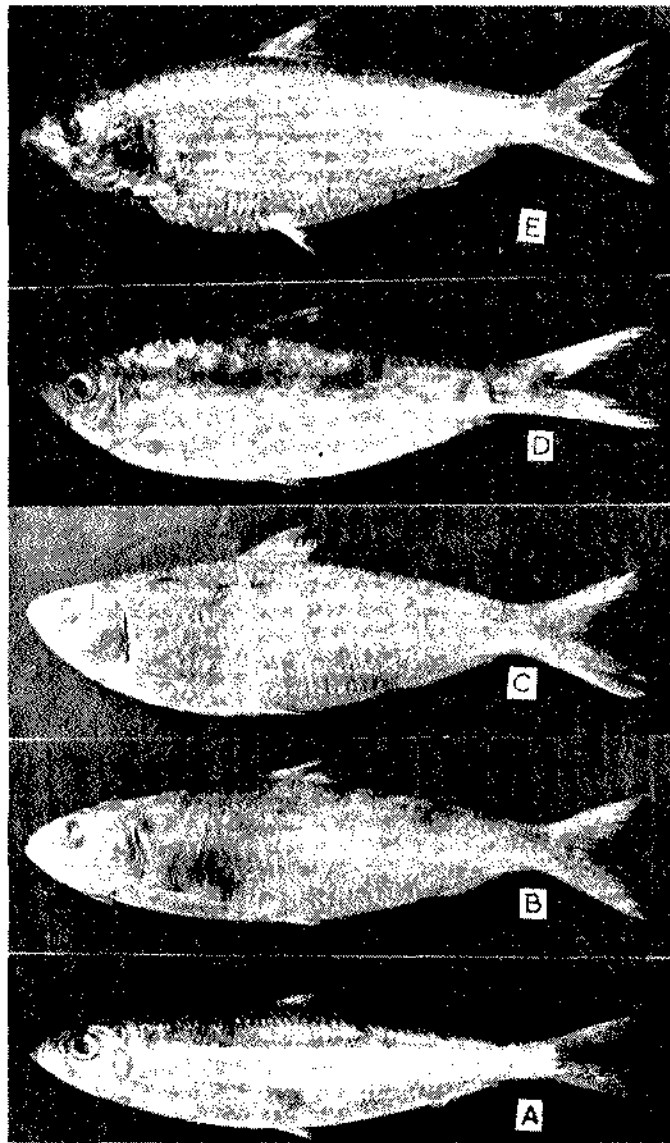
Fig. 2 : Lesser sardines : Species composition in percentage at observation centres : S. A. *Sardinella albella* : S. G. *S. gibbosa* : S. D. *S. dayi* : S. S. *S. sirm* : S. C. *S. clupeioides* : S. F. *S. fimbriata* : S. I. *S. sindensis*.

Along the coasts of West Bengal, Orissa and Andhra Pradesh, *S. fimbriata* and *S. gibbosa* support the sardine fishery. Regular concentrations appear along the Andhra coast. In the coastal waters of Tamil Nadu lesser sardines form an important fishery with *S. gibbosa*, *S. albella*, *S. dayi* and *S. sirm* forming the important components. Besides these, *S. clupeioides* occurs around the southernmost region (Bennet, 1965). *S. melanura* is also reported to occur in the Madras coast (Vijayaraghavan, 1953). All the lesser sardine species of India make their appearance at one time or other along the southwest coast, between Cape Comorin and Quilon; *S. gibbosa*, *S. sirm*, *S. sindensis* and *S. dayi* form good fishery in this region. In Karnataka and Goa, *S. gibbosa*, *S. fimbriata* and *S. dayi* constitute the fishery, but in Maharashtra and Gujarat *S. fimbriata* and *S. albella* occur in the fishery. In the Andaman waters *S. albella*, *S. dayi*, *S. melanura* and *S. sirm* are recorded by Luther (pers. Comn) and *S. leiogaster* is reported by Menon and Talwar (1975). From the Lakshadwip area *S. melanura* is reported by Jones and Kumaran (1959) and *S. clupeioides* and *S. fimbriata* by Jones (1969).

2.3 Yield

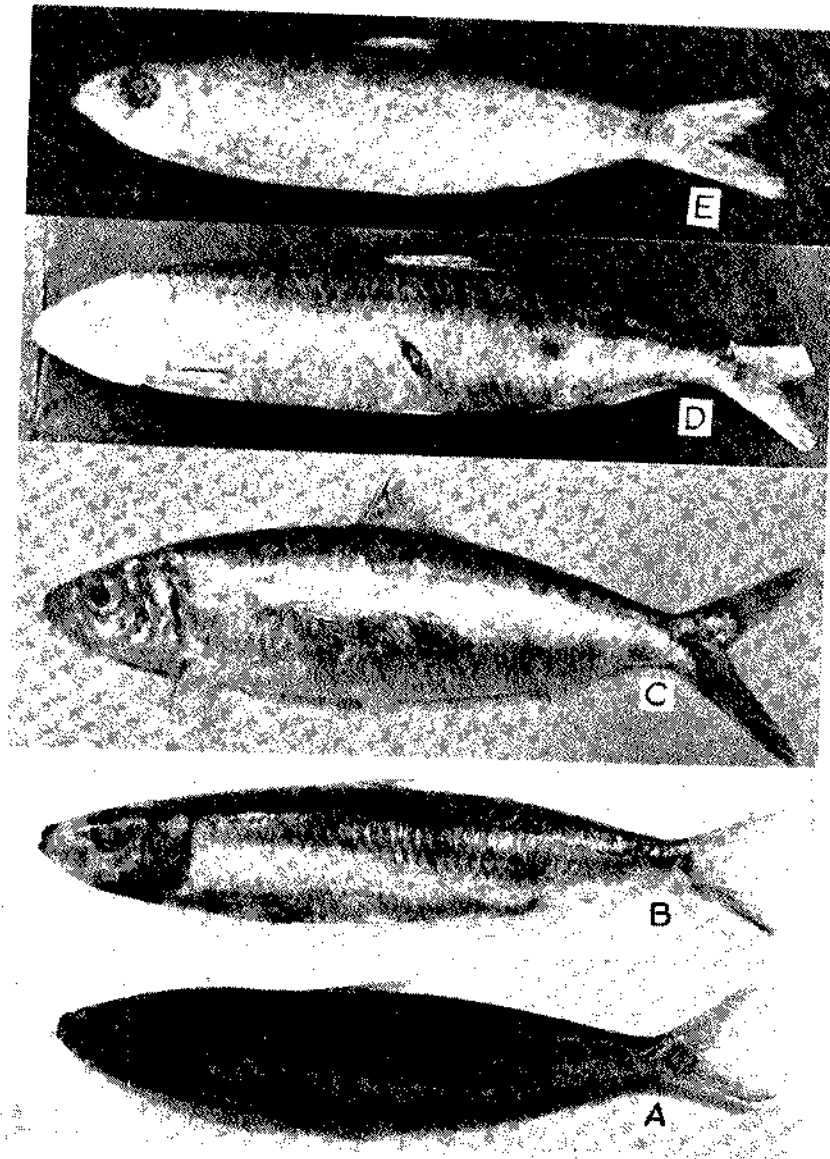
Annual yield of lesser sardines during the twenty-year period (1959-1978) ranges between 20,000 and 145,000 tonnes, with the average at 56,000 tonnes, forming 5.6% of the total marine fish catch. Bulk of the lesser sardine catch comes from three states, namely Andhra Pradesh, (26.5%), Tamil Nadu, including Pondicherry, (32.6%) and Kerala (32.2%), accounting respectively for 16.5%, 11.2% and 5.1% of the total fish catch (Fig. 1). Though the lesser sardine catches along the West Bengal-Orissa and Maharashtra-Goa coasts together account for less than 4% of the all India sardine catch, they form 9.2% and 6.2% of the total fish catch respectively in these two regions. Karnataka ranks low in the production of this fish, accounting for only about 1% of the total fish landings of the state. In Gujarat occurrence of lesser sardines is rare.

In a study of the trends in the yield of lesser sardines during 1952-72 along the east coast. Dharama Raja and Varughese Philipose (1975) records the production trends of the fish along the coasts of West Bengal and Orissa, Andhra



Lesser sardines.

- A. *Sardinella gibbosa* (Bleeker); B. *S. sindensis* (Day);
C. *S. fimbriata* (Cuvier of valenciennes); D. *S. dayi* Regan
E. *S. albella*. (Valenciennes).



Lesser sardines (Contd.):

A. *Sardinella sirm* (Walbaum); B. *S. Jonesi* Lazarus (After Lazarus, 1983); C. *S. clupeioides* (Bleeker); D. *S. leiogaster* (Valenciennes) After Lazarus, 1983); E. *S. melanura* (Cuvier).

Pradesh and Tamil Nadu as being different. Whereas a trend of catch declining from 1952 to 1961 and thereafter increasing is noticed in West Bengal and Orissa, the landings uniformly increases from 1952 to 1972 in Andhra Pradesh. For Tamil Nadu the production figures show a steady decreasing trend from 1952 to 1959 and uniformly increasing trend from 1960 onwards.

3. AVAILABILITY AND EXPLOITATION

Availability of the different species and the method of fishing them vary considerably according to the region and the season. Lesser sardines are typically schooling pelagic species, which, occurring in a band along the coast, mainly within 50 km from the shore, become available to shore-based fishery (Anon, 1976). This close-shore fishery is constituted mostly by juveniles, while majority of the adult stocks remain offshore. On account of this, better catches of lesser sardines are often obtained in depths between 30 and 55 m. In calm sea the schools of sardines tend to be in contact with the surface and so can easily be spotted by the eye. During rough weather the schools descend from the surface, and disperse. Sardines also occur as stray individuals in demersal trawl catches. In pelagic trawls sardines are most frequently caught from 20 m depth range (Anon, 1974).

3.1 *Craft and Gear Employed in the Fishery*

Indigenous craft and gear of various designs to suit local conditions are employed in the lesser sardine fishery. As fishing is carried out mainly in close-shore waters, very little development has taken place towards modernising the craft design or gear technology.

The crafts used are mainly the non-rigid catamarans, the masula and the Tuticorin-type and other plank-built boats on the east coast and southwest coast, and the dug-out canoes and large, rigid boats along the rest of west coast. In recent years a few mechanised boats have started operating off the south Kerala coast, using the traditional drift net for lesser sardines. Since very recently the use of out-board engines on catamarans and dug-out canoes, too, has become popular in this area, making it possible for the fishing to cover a vaster area. Illustrations of the common craft are given by Rao (1973). Fishing crafts used for fishing sardines along the Indian coasts are given in Table 1.

Table 1 Fishing Craft Employed In Lesser Sardine Fishery

West Bengal and Orissa	Andhra Pradesh	Tamil Nadu and Pondicherry	Kerala	Karnataka and Goa	Maharashtra	Gujarat
Carvel-built boat (<i>Chhandi</i>)	Masula boat	Masula boat (<i>Padagu</i>)	Dug-out canoe (<i>Vallom, Odam, Thoni</i>) with and without out-board engine	Outrigger (<i>Rampari</i> boat)	Satpati-type boat	Plank- built (<i>Madhwad</i> type) boat
	Pablo boat (<i>Kakinada nava</i>)	Pablo boat (Tuticorin type boat)	Pablo boat	pablo boat (plank-built) boat	Plank-built boat	
	Shoe dhoni	Dug-out canoe (<i>Odam, Thoni</i>)	Catamaran with and without out-board engine(<i>Maram</i>)	Mechanised boat	(<i>Machawa</i>) Out-rigger Canoe (<i>Rampani</i> boat)	
	Catamaran	Catamaran (<i>Maram, Chaluthadi</i>) Boat Catamaran				Mechanised boat

Table 2 Fishing Gear Employed In Lesser Sardine Fishery

West Bengal & Orissa	Andhra Pradesh	Tamil Nadu & Pondicherry	Kerala	Karnataka & Goa	Maharashtra	Gujarat
Drift nets <i>Chhandi-jal</i>	Gill net (<i>Kile vala</i> <i>Kavala vala</i>)	Gill net (<i>Chalai valai</i> , <i>Kavelai valai</i> , <i>Choodai vala</i>)	Gill net (<i>Chalai vala</i>)	Gill net (<i>Kantha bala</i> , <i>Kelta bale</i>)	Drift net (<i>Wawari</i>)	Drift net (<i>Jal</i> <i>Kendari</i>)
Shore seine (<i>Ber-Jal</i>)	Shore seine (<i>Pedda vala</i>)	Shore seine (<i>Karai valai</i> , <i>peria valai</i>)	Shore seine (<i>Kara vala</i> , <i>Kara madi</i> <i>Kamba vala</i>)	Shore seine (<i>Rampasi</i> , <i>Kai-Rampani</i>)	Shore seine (<i>Rampani</i>)	Bag net
	Boat seine (<i>Iragra vala</i>)	Boat seine (<i>Thuttu madi</i> , <i>Thurai valai</i> , <i>Madi valai</i> , <i>Mada valai</i>)	Boat seine (<i>Kolli vala</i> <i>Paithu vala</i> , <i>Thattum vala</i> , <i>Nethal vala</i> , <i>Thangu vala</i>)	Drift net (<i>Chala bala</i>)	Purse seine	
		Cast net (<i>Veechu valai</i>) "Torch" (<i>Soonthu</i>)	Cast net (<i>Veechu vala</i>) Hook and line (<i>Achil</i>)	Cast net (<i>Beesa bale</i>) Purse seine		

All types of gear used for the capture of small-sized pelagic shoaling fish such as shore seine boat seine, bag net, gill net, cast net and Rampany are used also for capturing lesser sardines. Hooks & lines (Achil) are also used, especially along the southwest coast (Lazarus, 1984b). Along the Rameswaram Island, "torch fishing" had been practised till early seventies for capturing younger sardines of 50-54 mm modal size (Sekharan, 1955; Bennet, 1961 a; and James 1967). At times good catches are landed by purse seines along some sections of Kerala, Karnataka, Goa and Maharashtra. Illustrations of common gears used in inshore waters are given by Rao (1973). In table 2 are listed the gears used for this fishery in the different maritime states. During the recruitment season, smaller sardines are caught by cast nets operated from smaller boats. The nets are made of synthetic yarn or cotton twine. Cast nets are used along the coasts of Kerala, Tamil Nadu and Karnataka. Usually juvenile sardines are caught in the shore seines. On account of this, though the fish caught by shore seines are more both in numbers and in total weight, the catches by boat seines and gill nets, as also by purse seines, fetch better returns.

3.2 *Catch Trends*

The fluctuations that are common to other major pelagic fisheries are noticeable with lesser sardine fishery as well. The trends of the lesser sardine catches along the Indian coast and their percentages in the total fish landings during the period 1950-78 are depicted in Fig. 3. During this period, there are only two years, 1973 and 1975, when the annual lesser sardine catches have crossed the hundred-thousand-tonne mark. The catches fluctuate between 19,551 tonnes in 1962 and 144, 722 tonnes in 1975, with the average at 51, 515 tonnes (Data Centre, CMFRI). Similarly, the percentage of lesser sardines in total marine fish catch also vary between 2.89% in 1961 and 12.96% in 1950. During the eleven-year period, 1968-1978, with

the exception of three years, 1968, 1969 and 1972, the annual catch is well above the average for the 29 - year period from 1950 to 1978.

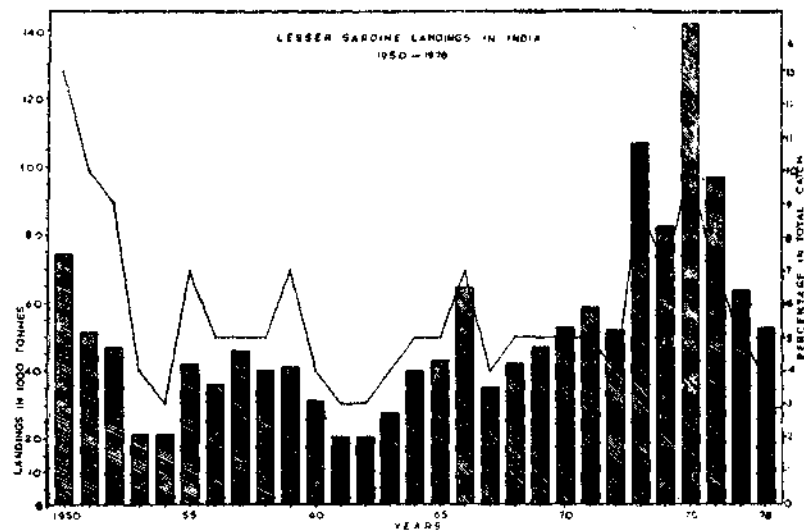


Fig. 3 : Lesser sardine landings in India from 1950 to 1978 and their percentage in total fish catch.

An index of the availability of fish in space and time is obtained from catch per unit. While the total landings reflect the total effort expended on the fishery, the catch per effort gives an indication of the density of fish in the fishing grounds. A rough measure of the changes in the fishery and availability of fish in the fishing grounds is obtained from a study of these catch rates. Earlier workers relied on the total fish landings as a measure of the changes in abundance (Sekharan, 1955, Nayar, 1958; Bennet 1967). Catch rates for the different gears were studied at Mandapan, Tuticorin, Vizhinjam and Visakhapatnam (Waltair) for a number of years. The trends of the fishery, the fishery seasons, species composition and catch rates for the lesser sardines vary from region to region and often within the same region. This aspect is dealt with here for each state with special reference to certain centres where the lesser sardines had been investigated (Fig. 4).

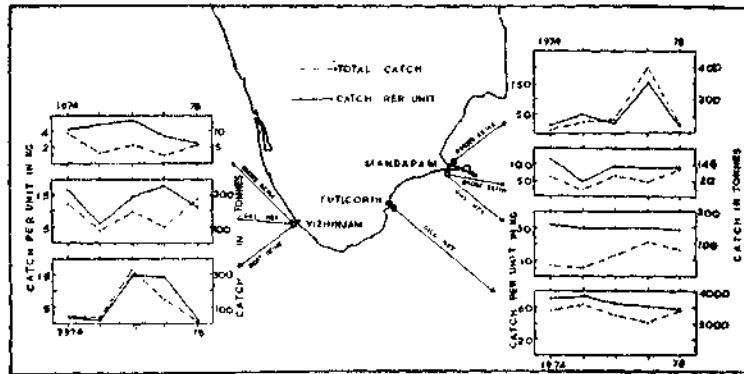


Fig 4 : Lesser sardine catch and catch per unit for important gears used in lesser sardine fishery at Mandapam, Tuticorin and Vizhinjam during 1974-'78.

West Bengal and Orissa

Though modest in quantity, the fishery accounts for 7.3% of marine fish landed in the two states between 1970 to 1978 (Fig. 1). Highest catch is in 1970 with 3,059 tonnes and the lowest catch is in 1975 with 957 tonnes. The average for the eight years is 1772 tonnes. Peak fishing season is from November to April-May. The most productive fishery is recorded in January 1973, when 675 tonnes of lesser sardines had been landed.

Andhra Pradesh

The lesser sardine fishery occupies an important place in the fisheries of Andhra Pradesh. Lesser sardines form 17.4% of the average total fish landings of 1969-1978. Average catch for the same period is 18,960 tonnes. The year 1975 is one of the good fishery years for lesser sardines in Andhra Pradesh, when 32,994 tonnes had been landed, forming 21.2% of the marine fish landed in the state. Lowest catch is in 1972, with 7,587 tonnes. The highest monthly catch of 9,884 tonnes is recorded in January 1976. Sizeable catches are obtained between November and May.

At Visakhapatnam the sardine fishery extends from October to June, with stray catches obtaining during the rest of the period. Peak fishery season lasts from January to May (Ganapati and Rao, 1957; Dutt, 1959, 1961, 1963; Rao, 1981). Gill net, shore seine and boat seine are the gears employed in the sardine fishery. However, gill net, accounting for about 95% of the sardine catch, is the most effective gear for catching sardines at Waltair and other places. The sardine component in the gill net catches is about 86%. Shore seine and boat seine account for only 4% and 1%, respectively, of the sardine landings, the sardine component in them being 5% and 2%, respectively (Anon, 1979). During the year 1968-76 the average annual lesser sardine catch is 73 t. The fishery shows a declining trend during 1968-72 and a variable trend during the remaining period. The annual catch rates are 12-33 kg in gill net, 1-8 kg in shore seine and 2 kg or less in boat seine with their averages at 24 kg, 3 kg and 0.7 kg, respectively. *S. fimbriata* and *S. gibbosa* occupy an important position in the artisan fisheries at Waltair, constituting 20-35% of the total clupeoid fishes and about 18% of the total fish landings. The fishery for *S. fimbriata* is from October/November to May/June whereas for *S. gibbosa* the period is shorter, being from February/March to June/July, sometimes commencing from October itself. The peak period of the sardine fishery is during February-March. Bulk of the sardine catch is represented by *S. fimbriata* during October-November and by *S. gibbosa* during April-May (Rao, 1981). *S. fimbriata*, however, is the dominant of the two species of the lesser sardines in the area (Rao, *et al*, 1980).

Tamil Nadu and Pondicherry

A good fishery for lesser sardines exists in Tamil Nadu. Annual landings fluctuate between 11,946 tonnes (1968) and 35,610 tonnes (1975) (Fig. 1.) During the period from 1968 to 1978, for which detailed data are available, lesser sardines account for an average yield of 21,963 tonnes or 11.8% of the average marine fish landed within the State.

At Tuticorin the fishery is active from about September till March, with *S. gibbosa* and *S. albella* dominating the fishery; the other species that occur being *S. sirm*, *S. dayi* and *S. clupeoides*. Here the catches are mostly landed by gill nets at an annual catch-per-net varying between 57 kg and 75 kg.

At Mandapam, the sardine fishery lasts from April to October in the Palk Bay with *S. albella* dominating the catch, and from November to March in the Gulf of Manner with *S. gibbosa* dominating. Both the species, however, occur in these two localities around Mandapam (Bennet, 1961 a). In the years subsequent to 1970, there has been a change in the species dominance in favour of *S. gibbosa* in both localities, especially in shore seine catches. But during the years 1977 and 1978 once again *S. gibbosa* is dominant in the Palk Bay and *S. albella* in the Gulf of Mannar. The annual catch rates show a range of 20-405 kg per shore seine operation in the Palk Bay, and 18-86 kg per shore seine and 29-30 kg per gill net in the Gulf of Manner. While shore seines account for all the landings in the Palk Bay, in Gulf of Mannar, though shore seines are also used, gill nets account for the bulk of the sardine catch.

Further north, along the coast of Madras city, according to Basheeruddin and Nayar (1961), sardines are caught mainly by shore seines, the main season being March-April with *S. fimbriata* and *S. sirm* supporting the fishery, and *S. gibbosa* and *S. albella* occurring in stray numbers. Further observations in recent years, however, have showed the fishery as being erratic, though the fish occur in the catches throughout the year. There has also been a shift in the fishery in subsequent years with gill nets landing bulk of the catch, *S. dayi*, *S. gibbosa* and *S. fimbriata* constituting the landings, with one or the other dominant in some part of the year.

Kerala

In the west coast, Kerala has produced the highest annual average of 25,701 tonnes of lesser sardine landings during the period from 1968 to 1978 (Fig. 1). The coastal waters south of Alleppey support very good fishery and, towards north, the fishery



Launching the boats for fishing (above) and operating a shore seine at Vizhinjam (below).



Gill-net landings (above) and sorting of a bumper catch of lesserxardines at Vizhinjam (below).

dwindles down to stray catches. Lesser sardines form only 7% of the total fish catch in Kerala. From 1968 to 1972 lesser sardine catch is more or less modest, averaging 8,262 tonnes. Immense increase in the commercial catch is noticed during 1973-1977 with average catch of 43,140 tonnes—a five-fold increase. Heavy catches of 67,302 tonnes in 1975 and 62,417 tonnes in 1973 have been obtained. Good fishery for lesser sardines occurs from August to December and the landings are generally poor during the first half of the year. At Vizhinjam, which is located in the central portion of the southern section, the fishery has two peak seasons, one during April-July and another from September-December, the two periods accounting for about 54% and 36%, respectively, of the annual catch. Gill nets, boat seines, shore seines and hooks and lines are the gears employed for the fishery, accounting for about 62%, 32%, 5% and 1% of the annual sardine catch in the area at a catch rate of about 2 kg, 8 kg, 17 kg, 4 kg, respectively (Lazarus, 1984 a). Dug-out canoes, plank-built boats and catamarans are the crafts used in the area. Gill net, wherein 80-90% of the catch is formed by sardines, is the principal gear for the fish. *S. gibbosa* (55%), *S. dayi* (19%) and *S. sirm* (15%) are the principal species at Vizhinjam, the first one being abundant during September-November, the second during July-December and the third during November-March. The other species met with in the catches in the order of their abundance are *S. fimbriata* (6%), *S. sindensis* (4%) and *S. cloupeoides* (1%).

Along the coast of Calicut the fishery lingers through out the post monsoon period with occasional periods of lull, the more important fishing season being September to February. Boat seines and shore seines are the main gear for the lesser sardine catches in the area (Venkataraman, 1960). Normally the fishery is constituted by *S. gibbosa*, *S. dayi* and *S. fimbriata*. The fishermen along this coast prefer to catch the lesser sardine, only next to mackerel and oil sardine.

Karnataka

Relatively small quantity of lesser sardines, averaging 992 tonnes, and amounting to 1.2% of the total fish catch, has been produced in Karnataka during the period 1968-78 (Fig. 1). Highest landings of 3,962 tonnes have been obtained in 1969 and the lowest in 1972, with 160 tonnes.

In the Karnataka area the lesser sardine fishery is erratic during most part of the year, September-November witnessing better landings. They are caught in shore seines, 'rampan', purse seines, cast nets and drift nets. *S. gibbosa*, *S. dayi* and *S. fimbriata* occur in the fishery.

Goa

There exists a good fishery for lesser sardines in Goa. Considering its small coastal stretch, and situated though between two poor sardine producing states, Karnataka and Maharashtra, Goa has an appreciable fishery, average annual yield for the 1968-'78 period amounting to 3,646 tonnes, which is 15.4% in the total fish catch (Fig. 1). Heavy landings totalling to 11,100 tonnes have been reported in 1976. But a very low catch of 72 tonnes is recorded in 1971. September-February is the best period for the fishery with highest landings in December. June and July are the lean months. *S. gibbosa* and *S. fimbriata* dominate the catches. Purse seines and shore seines are employed in the fishery.

Maharashtra

Production of lesser sardines in Maharashtra is uniformly low, the average catch for the 1969-78 period being 2,197 tonnes (Fig. 1). Highest annual yield is in 1970 with 3,404 tonnes, and the catch was lowest in 1978. Only a marginal support, of 0.9%, is given by the lesser sardines to the total fish production in the State. The lesser sardine catches are obtained during September-May. Bulk of the catches are available during December-April. *S. fimbriata* is the common species caught around Versova and the neighbouring fishing centres in shore seines and bag nets. At Malwan, according to Kaikini (1960), both *S. fimbriata* and *S. albella* dominate the catches of shore seines and gill nets.

Gujarat

Recent trends in the fish yield show no lesser sardine landings in Gujarat though small quantities had been recorded during 1968-1972. From 1968 to 1971 the annual landings averaged to a mere 20 t. But in 1972, unusually, 368 tonnes were landed. Except for an 8 tonnes recorded during 1976, no lesser sardine catch was recorded in the fishery between 1973 and 1978.

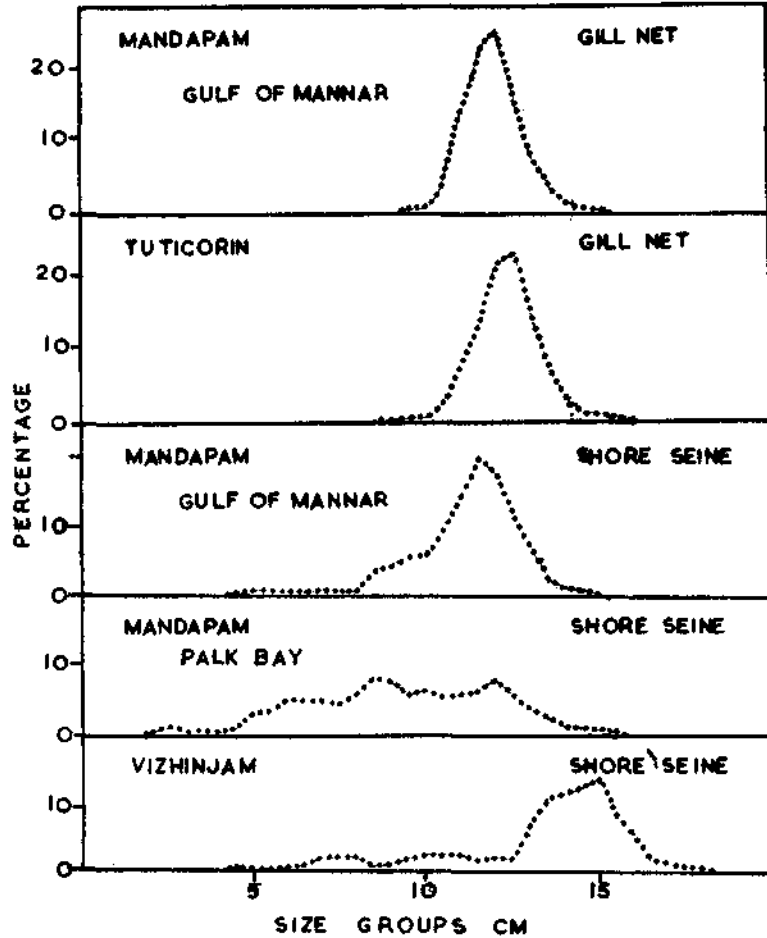


Fig. 5: Average percentage size composition of *Sardinella gibbosa* at observation centres: Mandapam, Tuticorin and Vizhinjam over the period 1973-'78.

4. BIOLOGICAL STUDIES

Results of studies made at selected centres on the biology of the different species of lesser sardines are presented here. They relate to size, age and sex compositions, state of maturity of fish in commercial landings, frequency and season of spawning, fecundity, spawning grounds, food habits, raciation, parasites and their effect on the host, and behaviour.

4.1 Size and age composition in the catches

Study of the size and age composition of commercial catches can lead to proper assessment of the potential size of the different year classes that support the fishery. A wide size range of fish occur in the commercial catches (Fig. 5-7). The

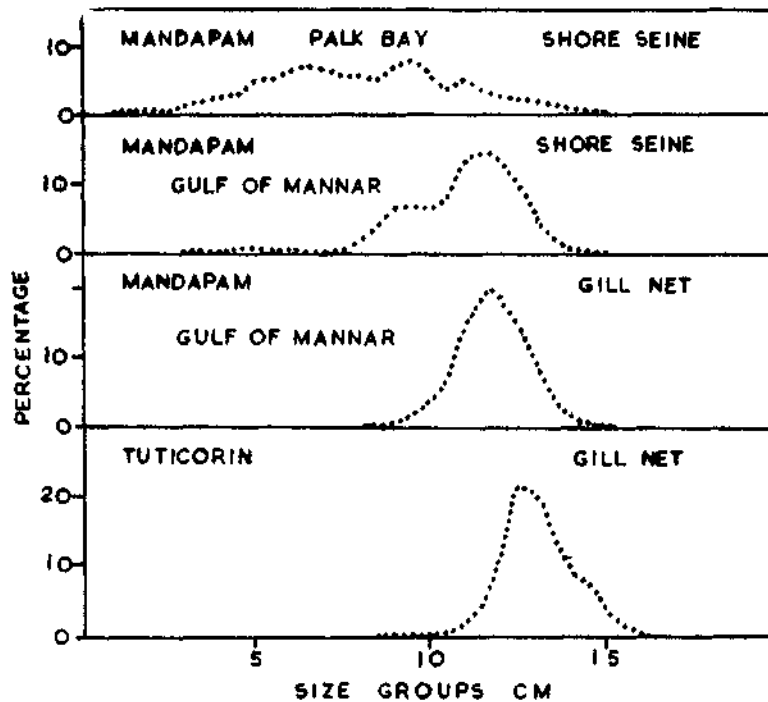


Fig 6: Average percentage size composition of *Sardinella albella* at observation centres : Mandapam and Tuticorin over the period 1973-'78.

smallest size of 2-3 cm total length were recorded for the four common species of lesser sardines, namely *S. fimbriata*, *S. gibbosa*, *S. albella* and *S. dayi*. The largest fish recorded of them varies between 16.5 cm and 21.3 cm. Bulk of the sardine catch from the coastal waters comprises medium sized fish of about 12-14 cm length, as gill nets of 2.5 cm mesh size are the main gear employed in the fishery. Though the whole size range of fish is available in the catches of shore seines, juveniles of the size below 12 cm are dominant in this gear. *S. sirm*, however, is observed in the size range of 6-23 cm with the dominant size between 14 cm and 21 cm (Figs. 5-7). As satisfactory age data from regular random samples for all the lesser sardine species were not available, only best approximates from length-frequency data of commercial landings could be drawn.

S. fimbriata: At Visakhapatnam (Waltar), according to Dutt (1959, 1961, 1963) and Rao (1981), *S. fimbriata* is recruited

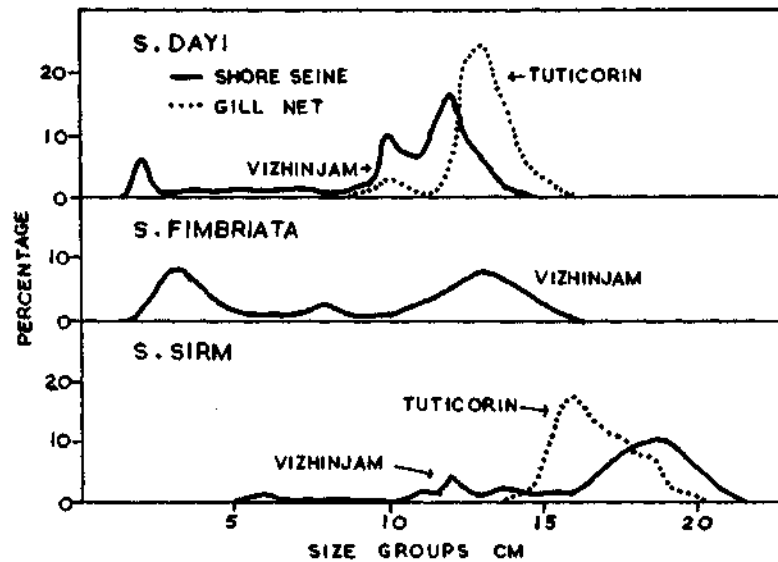


Fig. 7: Average percentage size composition of *Sardinella dayi*, *S. fimbriata* and *S. sirm* at observation centres: Tuticorin and Vizhinjam over the period 1973-78.

to the fishery with a modal size of 4-7 cm. Though maximum size recorded was 21.3 cm, fish beyond 19 cm length are rare. Juveniles of 5-10 cm length contribute to the bulk of the sardine catches in the early part of the season (October/November to March/April). The species has a growth rate of 1 cm per month while below 12 cm length. October-April is a period of rapid growth for the species. Late in the season (May-June), 1-year class represented by spent fish measuring 12-17 cm suddenly appear in the catches. Fish of 17-19 cm are at the end of 2nd year of life. But, the 0-year class fish in the size range of 5-12 cm support the fishery. From scale studies on *S. fimbriata* of Vizhinjam area Bennet (1967) found only one annulus in fish above 17 cm and came to the conclusion that fish of 17 cm length could belong to the 1 year class.

At Karwar, a study of the size at recruitment and the size groups in the different months for *S. fimbriata* revealed that, though fish 6 cm-18 cm length occur in the catches, the fishery is supported mainly by 10 cm-12.5 cm range of fish in the 0-year class. The fish grows to 12.5 cm length by the end of first year. Larger fish in the 1-year class appear between April and August (Radhakrishnan, 1964).

S. gibbosa: At Visakhapatnam (Waltair), *S. gibbosa* makes its first appearance in the season as juveniles (less than 12 cm length), dominant size ranging between 3 cm and 6 cm during October-December or February-April, or as adults of size range 12-18 cm during February-March. Unlike *S. fimbriata*, the occurrence of various size groups of *S. gibbosa* at Visakhapatnam does not conform to any particular pattern. Fish measuring 12-17 cm may be 1-year old (Ganapati and Rao 1957; Dutt, 1961, 1963 and Rao, 1981).

At Mandapam, *S. gibbosa* between 12 cm and 14 cm long form the dominant catch, though fish of size 2 cm-16.5 cm also occur in the catches. At this centre the fishery for *S. gibbosa* is supported up to 95% by juveniles of the 0-year class (Sekharan, 1955; Bennet, 1961a). In the Palk Bay some 1-year

and 2-year class fish also enter into the fishery, whereas in the Gulf of Manner fishery is supported by fish in 0-year class. *S. gibbosa* seems to grow to a length of 10 cm to 12 cm (standard length) in the first year. Sekharan (1968) has stated that *S. gibbosa* grows to 96 mm (standard length) in the first 6-7 months of life.

In the Tuticorin area *S. gibbosa* has been found to grow to 12 cm to 13 cm total length (10 to 12 cm standard length) in the first year. Thereafter growth is very slow. Fish above this length are very scarce. In the Vizhinjam area also almost the entire *S. gibbosa* fishery is supported by 0-year class fish. This species appears to grow faster in this area, attaining a total length of 14 cm by the end of first year of life. Juveniles that occur during January-May and August-October have been found to show differential growth rates.

S. albella: At Mandapam the size and age composition of *S. albella* in the commercial catches are more or less similar to those of *S. gibbosa* occurring there. It grows to 10-10.5 cm and to 14.0 cm standard length, respectively, by the end of first and second years of life. Sekharan (1968) has stated that this species grows to 8.2 cm standard length in the first 6-7 months of life. In the Tuticorin area this species has been found to grow to 11.2-13 cm total length (10-12 cm standard length) by the end of first year. Thereafter the growth rate is very slow, the fish attaining a modal length of 15 cm by the end of second year. Fish above this length are very scarce.

S. dayi: In the Tuticorin area *S. dayi* occurs in the length range of 9-17 cm, the dominant size group in the fishery being 13 cm. This species grows to 12.5-13.0 total length (10-12 cm standard length) in the first year. At Vizhinjam it occurs in the length range of 2.0-15.5 cm, but the fishery is supported mainly by fish in 12.5-14.0 length. Growth of 0-year class fish is rapid, the fish attaining a modal length of 14 cm by the end of first year. Fish of 15.5 cm modal length form the fishery during September-December period.

S. sirm: Landings of *S. sirm* at Tuticorin are restricted to the October-March period, with the fish ranging in total length

between 14 cm and 20.4 cm, the dominant size being around 16 cm. The species seems to have a higher growth rate. Gnana-mekalai (1962 a) has inferred that this species grows to 14 cm length in the first year. Studies made during 1972-77 have shown a modal growth of 15.5 to 17.5 cm total length in the first year with the average at 16 cm (14 cm standard length). *S. sirm* up to 20.5 cm length are belonging to the 1-year class are caught in the fishery. At Vizhinjam also this species has a restricted period of fishery. A wide range of size groups, from 6 cm to 23 cm enter the fishery. Definite progression of size groups has been traced. Well over 70% of the catch comprises 0-year class fish. Rest of the landings is formed by 1-year-old fish. The fish grows to 19.6 cm length during the first year and may reach to 21.7 cm in the second year (Lazarus, 1984a).

4.2 Sex composition

Previous works that give information on sex composition include Bennet (1961a, 1967), Dutt (1961), Ganapati and Rao 1957, and Rao (1981). Variations of a marked nature exist between the ratio of sexes during different years and within the same year (Table 3). From the predominance of males up to 15 cm length and of females in the length range 15.0-16.5 cm observed for *S. gibbosa*, Dutt (1961) has stated that females grow faster than males.

4.3 Maturity and spawning

Knowledge on the spawning habits and maturation cycle of the species is essential for understanding of its fishery as it throws much light on the periodic replenishment of the fishable stock. Studies made so far on the cycle of gonadal maturation and spawning habits as well as on the size at first maturity of lesser sardines are inadequate. Brief references have been made to the maturity of lessersardines in the contribution by Chacko (1946), Chidambaran and Venkatarman (1946), Dharmamba (1959), Ganapati and Rao (1957), Sekharan (1955) and Sekharan *et al.*, (1969).

Most of *S. gibbosa*, *S. albella*, *S. dayi* and *S. fimbriata*, below 10 cm total length are either indeterminate or immature, with gonads in stages I or II of maturity. Fish above 10 cm show varying degrees of sexual maturity. As the spawning season approaches, most of these fish above 10 cm become maturing and those above 12 cm length are mature. Studies conducted at Vizhinjam on *S. sirm* (Lazarus, 1984a) show that females attain sexual maturity at a larger size, of 20.7 cm, that, males, which mature at 19.7 cm. Stages of maturity in different months observed at some centres for *S. gibbosa*, *S. albella*, *S. dayi* and *S. sirm* are given in table 4-6.

S. gibbosa: In the Visakhapatnam (Waltair) area maturing and mature fish of *S. gibbosa* are observed from February to April/May (Ganapati and Rao, 1957; Dutt 1961 and 1963). Occurrence of adult fish with mature and ripe gonads as a dominant component of the catches is an important feature of the fishery of this species in this area. Sekharan *et al* (1969) have reported the spawning concentrations of *S. gibbosa* of 12.0-18.4 cm length as occurring during March-April along the north Andhra coast, from Machilipatnam to Palasa. From ova-diameter studies Dharmamaba (1959) has inferred that spawning of *S. gibbosa* is restricted to only once in each season. However, the ovadiameter -frequency distribution of mature and partly spent ovaries of this species as presented by Sekharan *et al.* (1969, p. 151, Fig.IA) indicates the possibility of an individual spawning for a second time in the same season. This explains the statement of Dutt (1961) of the possibility of there being two distinct spawning periods for *S. gibbosa*.

In the Mandapam area also the spawning season for *S. gibbosa* starts in February or March but extends till June or July (Sekharan, 1955). Percentages of mature males and females are highest in March and April. Young juveniles first appear in April.

In the Tuticorin area also, studies during 1972-1978 have indicated more or less the same spawning season for *S. gibbosa*, namely from February to July or August each year. The period of intensive spawning within this period has however not been

constant in the different years. Gravid females are seen during April. Spent fish enter the fishing grounds from February to August, with greater intensity during April-June. On the other hand, a spawning season extending from September to February has been reported for *S. gibbosa* by Chacko (1946). This season corresponds to the spawning season from July to February of the same species occurring off Vizhinjam as has been reported by Lazarus (1984a). Thus, spawning of *S. gibbosa* along the east coast takes place during February-July period, whereas along the west coast, as at Vizhinjam, it takes place during July-February period. From the report of Chacko (*Op. cit.*) it appears that mixing of the spawning populations of this species from the east and west coasts takes place along the southern region of the peninsula.

S. fimbriata: Unlike in the case of *S. gibbosa*, occurrence of maturing or mature *S. fimbriata* is very rare off Visakhapatnam (Dutt, 1959). On the other hand, Bennet (1967), basing on observations off Vizhinjam, has reported the spawning season of the species as August-February. From ova-diameter studies he has inferred that an individual spawns only once in the season. Further north, off Calicut, according to Chidambaram and Venkataraman (1946) this species spawns during April-June period. Still further north, off Karwar, according to Radhakrishnan (1964) *S. fimbriata* spawns during January-April. Ova diameter studies show that the spawning season is a short one

S. albella: Spawning season of *S. albella* in the Mandapam area is similar to that of *S. gibbosa*; that is, from February or March till June or July. The percentages of fish with mature gonads are highest in March and April (Sekharan, 1955). The trends of occurrence of gravid and spent fish off Tuticorin are similar to those noted at Mandapam.

S. dayi: The spawning season of *S. dayi* off Tuticorin is found to be more or less similar to that of *S. gibbosa* and *S. albella* occurring in the area; that is from February to July or August.

S. sirm: Although *S. sirm* with mature gonads are met with in the fishery during February-July, it is likely that the bulk of

Table 3 : Percentage Sex Composition of Lesser Sardines

Species and locality	Year	Male	Female	Indeterminate	Total sexed
<i>Sardinella gibbosa</i>					
Waltair (from Ganapati and Roa, 1957)	1953-55	52.50	26.10	21.40	—
Waltair (Dutt, 1961)	1956-57	62.00	38.00	—	1209
Mandapam	1970-71	45.25	51.88	2.87	2820
Tuticorin	1972-77	37.73	40.43	21.84	9250
Vizhinjam	1970-77	46.30	48.50	5.20	5046
<i>Sardinella albella</i>					
Mandapam	1970-71	43.38	46.91	9.71	3460
Tuticorin	1972-77	34.87	38.96	26.17	5085
<i>Sardinella dayi</i>					
Tuticorin	1972-77	46.84	45.27	7.89	1469
<i>Sardinella fimbriata</i>					
Vizhinjam (from Bennet, 1967)	1960-63	16.70	15.30	68.00	5019
<i>Sardinella sirm</i>					
Tuticorin	1972-77	43.45	41.06	15.49	962

Table 4: Maturity Stages of Lesser Sardines in Percent

Month	Indetermi- nate	Immature	Mature	Spent	Total sexed
<i>Sardinella gibbosa</i>					
Locality : Tuticorin (1972-77)			Species		
January	34.9	64.9	0.2	—	902
February	2.3	72.1	25.5	0.1	694
March	0.5	38.1	61.4	—	601
April	0.3	27.0	63.2	9.5	881
May	15.3	18.1	52.2	14.4	502
June	1.3	18.4	70.4	9.9	354
July	5.5	29.1	63.8	1.6	381
August	23.4	35.0	41.3	0.3	651
September	9.8	65.5	24.7	—	1028
October	31.2	62.4	4.4	—	895
November	61.3	38.5	0.2	—	576
December	40.6	59.4	—	—	372
Total	19.1	47.5	30.9	2.5	7837
<i>Sardinella albella</i>					
Locality : Tuticorin (1972-77)					
January	5.5	93.9	0.6	—	360
February	0.5	83.4	16.1	—	541
March	—	38.3	61.7	—	457
April	36.1	5.7	15.2	43.0	349
May	6.0	61.4	2.8	29.8	251
June	41.7	42.6	0.3	15.4	319
July	62.6	30.8	6.1	0.5	409
August	45.5	43.2	10.5	0.8	475
September	34.7	51.6	16.7	—	403
October	28.8	67.3	3.9	—	309
November	43.7	54.5	1.8	—	407
December	71.3	28.7	—	—	195
Total	29.4	51.4	13.0	6.2	4475

Table 4 : Contd.

Month	Indetermi- nate	Immature	Mature	Spent	Total sexed
<i>Sardinella dayi</i>					
Locality : Tuticorin (1972-77)					
January	8.9	79.7	11.4	—	246
February	—	75.1	24.9	—	177
March	0.4	65.5	33.3	0.8	240
April	—	27.8	48.9	23.3	237
May	9.9	82.6	4.1	3.4	172
June	51.6	48.4	—	—	126
July	21.0	72.0	7.0	—	143
August	38.1	58.1	3.8	—	105
September	17.1	80.0	2.9	—	70
October	59.6	40.4	—	—	161
November	29.9	69.7	0.4	—	241
December	16.4	83.6	—	—	55
Total	18.1	63.6	14.8	3.2	1973
<i>Sardinella sirm</i>					
Locality : Tuticorin (1972-77)					
January	3.0	95.5	1.5	—	132
February	—	76.7	23.3	—	60
March	No landings	—	—	—	—
April	No landings	—	—	—	—
May	No landings	—	—	—	—
June	No landings	—	—	—	—
July	21.2	51.5	27.3	—	66
August	28.6	61.6	9.8	—	112
September	7.9	87.3	4.8	—	63
October	17.6	76.6	5.5	—	182
November	19.7	79.8	0.5	—	188
December	17.7	80.9	1.4	—	147
Total	15.8	77.8	6.4	—	950

Table 4 : Contd.

Month	Indeterminate	Immature	Mature	Spent	Total sexed
<i>Sardinella gibbosa</i>					
Locality : Vizhinjam (1970-77)		Species			
January	—	95.2	4.8	—	42
February	—	60.5	39.5	—	119
March	22.4	37.1	37.6	2.9	210
April	0.5	50.9	37.4	11.2	410
May	10.2	30.4	57.7	1.7	591
June	4.4	9.9	84.6	1.1	91
July	—	67.2	27.7	5.1	119
August	49.2	29.2	21.6	—	199
September	—	59.6	40.4	—	151
October	—	85.8	12.8	1.4	351
November	3.8	88.6	5.7	1.9	261
December	—	98.9	1.1	—	88
Total	8.4	54.5	34.1	3.0	2632

the stock of mature fish move away from the inshore fishing grounds for spawning during March-June period. Mature fish occur in the fishery in appreciable quantities during February and July. Gnanamekalai (1962a) has stated that an individual of this spawns once in every three months during the spawning season.

From the foregoing observations it may be stated that though fish with mature gonads are met with in the inshore catches of most species of lesser sardines investigated, their proportion is relatively low (see Tables 4). Excluding the indeterminate fish from consideration, it may be seen from the Table 4 that immature fish dominate in the fishery to an extent of 59-92% of the catch (by number), details for the different species being: *S. gibbosa* 59-60%, *S. albella* 73%, *S. dayi* 78%, and *S. sirm* 92%. Fish with mature gonads for the above four species are in the order of only 37-38%, 18%, 18%

and 8%, respectively. Spent fish is also very low, being only 3-4% in each case except for *S. albella* with 9%. These observations indicate that bulk of the mature fish remain outside the inshore fishing zone of the artisan fisherman.

4.5 Fecundity

For this purpose, only the number of the most advanced group of ova in maturing or mature ovary has been estimated for individual fish. Fecundity of *S. gibbosa* has been found to vary between 12,786 and 41,326 and of *S. fimbriata* between 17,974 and 34,545 off Visakhapatnam (Roa, 1981); between 5,500 and 41,700 off Vizhinjam for *S. fimbriata* in the length range of 13.5-18.0 cm (Bennet, 1967.) Fecundity of *S. albella* off Karwar ranges between 10,000 and 13,500 eggs for fish in the length range of 14.6-15.5 cm (Radhakrishnan, 1961) and that of *S. sirm* of Vizhinjam between 21,500 and 132,900 (Lazarus, 1984a).

4.6 Food and Feeding

Studies indicate that the lesser sardines generally feed on a wide variety of items present in the plankton (Table 5.) Analysis of the stomach contents of sardines from different localities show similarity in the food consumed by the different species of lesser sardines. There is general agreement between the occurrence of items found in the sardine stomachs and in the plankton. Though *S. gibbosa* normally feeds on the organisms that are abundant in its environment, the presence of larger organisms such as fish larvae and prawn larvae in the stomach contents gives an impression that the species is selective in feeding to some extent. According to Chacko (1946), however, the food organisms found in the stomachs of *S. gibbosa* shows some fluctuations according to the paucity or profusion of such organisms in the plankton. Studies at Vizhinjam show that *S. gibbosa* feed mainly on copepods, *Lucifer* and diatoms. From a predominantly crustacean diet in the early stages, the fish seems to change to a diet consisting of crustaceans and phytoplankton with the attainment of about 80 mm length (Lazarus, 1977a). Adult *S. albella* seems to practise certain amount of surface filter feeding as well as particulate feeding of selective items like *Acetes*, *Mysis* and prawn larvae. On the other hand, post larval and immature forms of *S. albella* of Bombay waters

Table 5 : Important food components of lesser sardines

<i>S. gibbosa</i>	<i>S. albella</i>	<i>S. fimbriata</i>	<i>S. dayi</i>	<i>S. sirm</i>	<i>S. cueneoides</i>	<i>S. melanura</i>
<i>Eucalanus</i>	<i>Rhyncalanus</i>	<i>Acartia</i>	Calanid	Calanid	Calanid	<i>Pseudodiaptomus</i>
<i>Euterpina</i>	<i>Labidocera</i>	<i>Temora</i>	Metanauplius	<i>Euterpina</i>	<i>Euterpina</i>	<i>Paracalanus</i>
<i>Oncaea</i>	<i>Eucalanus</i>	<i>Pseudodiap-</i> <i>tomus</i>	<i>Labidocera</i>	Nauplii	<i>Acartia</i>	<i>Eucalanus</i>
<i>Corycaeus</i>	<i>Euterpina</i>	<i>Euterpina</i>	<i>Euterpina</i>	<i>Evadne</i>	<i>Mysis</i>	<i>Corycaeus</i>
<i>Acartia</i>	<i>Microsetella</i>	<i>Evadne</i>	Other	<i>Acetes</i>	Alima larva	Ostracods
<i>Macrosetella</i>	Other copepods	Copepod eggs	crustaceans	<i>Mysis</i>	Phyllosoma	Decapod larvae
<i>Pseudodiap-</i> <i>tomus</i>	<i>Lucifer</i>	<i>Lucifer</i>	Prawn larvae	Prawn larvae	larvae	Vegetable
Prawn larvae	<i>Acetes</i>	<i>Acetes</i>	<i>Acetes</i>	Fish larvae	<i>Porcellana</i>	matter
Megalopa larvae	<i>Mysis</i>	Other	Molluscan	Molluscan	<i>Thenus</i>	
<i>Lucifer</i>	Megalopa	crustaceans	larvae	larvae	<i>Acetes</i>	
<i>Mysis</i>	Bivalve larvae	Prawn larvae	Fish tissue		Fish tissue	
Crustacean	Tteropods	Molluscan	<i>Thalassiothrix</i>	<i>Coscinodiscus</i>	Bivalve larvae	
remains		larvae		<i>Trichodesmium</i>	<i>Coscinodiscus</i>	
Fish eggs	Fish larvae			<i>Ceratium</i>	<i>Trichodesmium</i>	
Fish larvae		<i>Coscinodiscus</i>	<i>Coscinodiscus</i>	<i>Peridinium</i>	<i>Ceratium</i>	
Molluscan	<i>Thalassiothrix</i>	<i>Fragilaria</i>	<i>Trichodesmium</i>	Forminifera	Forminifera	
larvae	<i>Bacteriastrum</i>	<i>Nitzschia</i>	<i>Rhizosolenia</i>			
<i>Trichodesmium</i>	<i>Triceratium</i>	<i>Ceratium</i>	Foraminifera			
<i>Coscinodiscus</i>	<i>Rhizosolenia</i>	<i>Bidduaphia</i>				
<i>Rhizosolenia</i>	<i>Pleurosigma</i>	<i>Trichodesmium</i>				
<i>Bacteriastrum</i>	<i>Trichodesmium</i>	<i>Navicula</i>				
<i>Chaetoceros</i>	<i>Coscinodiscus</i>	<i>Thalassiothrix</i>				
<i>Pleurosigma</i>	Forminifera	<i>Planktoniella</i>				
<i>Thalassiothrix</i>		<i>Pleurosigma</i>				

are found to feed mainly on smaller copepods particularly *Microsetella rosea*, zooplankton being eaten to a far greater extent than phytoplankton (Bapat and Bal, 1950). Phytoplankton (54.25%) constitute the main food while copepods (36.25%) rank next in importance for *S. albella* from Calicut area (Venkataraman, 1960). Rao (1981) has observed that the food of *S. fimbriata* below 6 cm length is mainly composed of the diatom *Cascinodiscus*. But he found both *S. fimbriata* and *S. gibbosa* of 5-15 cm length to feed mainly on copepods and to supplement their diet with other crustaceans such as mysids, megalopa and alima larvae, and occasionally with diatoms. He has met with the same type of food in *S. fimbriata* of 15-20 cm length but in *S. gibbosa* of the same size range the stomach contents comprise mainly of larvae of bivalves, gastropods and of prawns, and occasionally copepods. Ganapati and Rao (1957) state that *S. gibbosa* is predominantly a zooplankton feeder with an amount of selectivity in feeding. They were led to this conclusion as the stomach contents comprised more commonly the macroorganisms of the plankton such as young prawns, *Lucifer*, large crab zoea and post-larval fish which were much less abundant than the smaller entomostracans in the plankton samples.

According to Venkataraman (1960) *S. fimbriata* is a plankton feeder, phytoplankton and copepods forming the chief items. Minor food items encountered were small penaeids, larval bivalves, decapod and cirriped larvae, *Lucifer* and fish eggs. Bennet (1967) in the case of *S. fimbriata* found that copepods and other crustacean items were preferred by majority of the fish. Empty stomach was prevalent in adult fish with mature gonads. There were more number of fish with empty stomach in day samples than in night samples. It is likely that feeding is intense in the night and most of the food had passed on from stomach into the intestine when the fish were caught during the day.

The following food items were found to form the gut contents of *S. clupeioides*: Mysis, alima larva, phyllosoma larva, juvenile *Porcellana* spp, early stages of *Thenus*, *Acetes*, copepods and semi-digested fish tissue.

4.7 Length-Weight Relationship

Length-weight relationship of *S. fimbriata* and *S. gibbosa* of Visakhapatnam area was worked out by Rao (1981). Fishes of the length ranges of 30-200 mm and 50-200mm respectively were examined for the two species. A single equation was found adequate for males and females, immature and adult fish of each species. Sekharan (1968) worked on the length-weight relationship of *S. abella* and *S. gibbosa* of Mandapam area. In both the species the regression coefficients of the fishes of the 20-39 mm standard length were significantly higher than those of the fishes of the larger size groups. Ganapati and Rao (1957) have given the values of the condition coefficient of *S. gibbosa* of the Visakhapatnam area in relation to length of fish, and for the different months of an year.

4.8 Behaviour

Application of knowledge of fish behaviour in relation to environmental conditions is the most efficient and cheapest means of reducing the scouting and other wasted time, and improving the catch per effort. The reaction of schools, and, at times, of the entire stock of a given species of fish to the prevailing environmental conditions and their changes are revealed by types of group behaviour such as aggregation (schooling), dispersal, vertical migration, spawning and feeding migrations, passive transport by currents, etc (Laevastu and Hela, 1970). Though precise ecological data useful for forecasting the environment of fish is wanting for lesser sardines of the Indian seas, available information on some behavioural aspects of these fishes is reviewed here.

Certain organisms like medusae, *Sagitta*, *Oikopleura*, pteropods, polychaete larvae and *Noctiluca* are avoided by sardines (Sekharan, 1971). Prasad (1953) pointed out that *Noctiluca* blooms in the Mandapam area drive away sardine shoals from fishing grounds. A similar observation was made by Bhimachar and George (1952) from West Coast, where the so called "red water" caused by *Noctiluca* swarms cause setback to the pelagic fishery. On the other hand, swarms of copepods

commonly called "Karai" in the Gulf of Mannar indicate good fishery for lesser sardines which feed on the copepods. Closely connected with such behaviour of following favourite food items is the character of small juvenile sardines to move to the surface waters during darker nights. When near the surface, the small sardines are attracted by light. This behaviour of phototropism is exploited by fishermen by "torch fishing" (James, 1967). Wind direction and speed influence the movement of sardine shoals, Though the sardines move along the water currents they are known to move against the direction of the wind. But strong winds drive the sardines away from inshore waters (Bennet, 1961a).

Discussing the sardine fishery in relation to the biotic and abiotic environment, Dutt (1959) states : "The beginning of the sardine fishery (at Visakhapatnam) in October coincides with the minor plankton peak during this period (Ganapati and Rao, 1958), and the peak period of the sardine fishery itself coincides with the major phytoplankton peak. As the above authors point out, the hydrographical conditions are more favourable and stable during the northerly current system in the January-June period, when there is enrichment of the surface waters by upwelling of the sub-surface waters. The northerly current also brings in the enriched oceanic waters of the bottom Antarctic drift". The following observations were made by Dutt (1959 and 1963) on the sardine fishery of Visakhapatnam area : Although *S. gibbosa* and *S. fimbriata* occur in the same locality, their schools remain discrete, mixed species samples being very rare. These two species exhibit several contrasting behaviour patterns too. Whereas schools of *S. gibbosa* are constantly on the move, juvenile *S. fimbriata* after entering the coastal waters, evidently for feeding, in October-November, practically remain there until April. *S. fimbriata* with maturing and mature gonads do not occur in the catches, while spent fish make their appearance in May and June. On the other hand, adult *S. gibbosa* with mature gonads enter the inshore waters for spawning during February to April.

Radhakrishnan (1964), reporting on *S. fimbriata* from Karwar, states that only fish in maturity stages III-V and VII

occur in the inshore catches. This would suggest that either the spawning fish do not occur in the inshore waters or the duration of the stage VI ovary is so transient as to miss observation. It has been pointed out in an earlier section that occurrence of mature fish is very meagre in inshore catches whereas indeterminate and immature fish support bulk of the artisan fishery.

Differential distribution of eggs, juveniles and adult fish observed between Palk Bay and Gulf of Mannar near Mandapam suggests interesting behaviour of certain groups of fishes of this area. Bapat (1955) observed clupeid eggs (including those of *Sardinella*) to occur mostly in the waters of Gulf of Mannar than in the adjacent Palk Bay. Sekharan (1955) reported that he had not met with spawning fish of *Sardinella* spp in the sardine landing of the artisan fishery in Palk Bay. In recent years it has been observed that the fisheries for *S. albella* and *S. gibbosa* near Mandapam are dominated by juveniles of 62 mm and 42 mm average length, respectively, in Palk Bay and by adult fish of 123 mm and 128 mm average length, respectively, in Gulf of Mannar. These observations strongly point out that both the species of *Sardinella* prefer the oceanic deeper waters of Gulf of Mannar to the shallow enclosed waters of Palk Bay for their spawning grounds. This would in turn suggest that the young juveniles move into the Palk Bay for feeding and growth. Similar trend was observed in the case of the two species of *Chirocentrus* occurring in the same area by Luther (1985).

4.8 Racial studies

Very few attempts have been made to assess the homogeneity of lesser sardines occurring in Indian waters. The distribution of the various species along the coast is one of discontinuous nature. However, their occurrence in the fishery very often overlaps in the areas of abundance. Bennet (1961a) compared the morphometric characters of *S. albella* from the Palk Bay and the Gulf of Mannar by the method of regression analysis. Certain differences were observed. They were attributed to variations due to environment. However, inference arrived at after studying the incidence of *Peroderma cylindricum* (Heller), a parasitic copepod on the body of *S. albella*, indicate the existence of local stocks of this species around Mandapam.

Tagging experiments were conducted at Panjim (Hamre *et al.*, 1966) on *S. gibbosa*. The investigations did not proceed further than evolving suitable tags and techniques to be used on Indian fish.

4.10 Parasites

A number of parasites (Table 6) have been reported on lesser sardines (Bennet, 1961a, 1964, 1974; Ganapati and Rao, 1957; Pillay, 1962, 1964). The works also furnish information on the intensity of infection and effect of parasites on host fishes. Most of the parasites are host-specific in spite of the fact that different species of sardines mingle in the fishing grounds. One of the important effects of parasitic infection on the fish is the retardation of the maturation of gonads. The gonads do not grow to full maturity when parasites occur on the body. In all the cases of infection by parasitic copepods *Peroderma cylindricum* and *Bomolochus* the gonads always remained in immature state, while the other fishes in the same school had gonads in stages III and IV of maturity.

4.11 Predators

Sardines form food for many predatory fishes. Young sardines were found in the gut contents of *Chirocentrus* spp., *Otolithus ruber*, *Lactarius lactarius*, *Sphyræna obtusata*, *Euthynnus affinis affinis*, *Caranx ignobilis*, *Rastrelliger kanagurta* and *Carcharinus melanopterus*. Predatory fishes are known to follow sardine shoals (Chacko, 1946; Nair, 1959). Sardines are used as bait in the hook and line fishery particularly for scombroid fishes (Silas, 1962). Many sea birds also prey on sardines.

5. UTILIZATION

The lesser sardines, being available for a major part of the year, form an important source of animal protein food to the coastal people. Being relatively cheap, this fish in fresh state has good demand from the poorer sections of the coastal community. Inter-state trade of fresh fish is carried out by adding flaked ice to the fresh fish and transporting the same on fast-moving trucks. However, because of the small size of the fish, and of the price structure, this trade has serious limitations so far as the quantities that could be marketed in fresh state is concerned. Owing to this, the surplus catch is salted

Table 6 : Parasites of Lesser Sardines

Name of fish	Name of parasite	Mode of infection	Effect on host	Remarks
<i>Sardinella gibbosa</i>	<i>Aponnurus</i> sp	Stomach parasite	—	Entozoic, very common in
	<i>Heminurus</i> sp.	Stomach parasite	—	February Occasional only
	<i>Caligus</i> sp.	Buccal cavity	—	
<i>Sardinella albella</i>	<i>Cymothoa</i> sp.	Opercle, head	—	external parasite Very com-
	<i>Peroderma cylindricum</i>	Buried within the body of the host at lateral side.	Gonad retarded, never attain maturity	mon around Mandapam; each host specific; each host with one parasite.
	<i>Bomolochus sardinellae</i>	Eye parasite, on the eye ball,	Gonad development retarded	Host specific; male attached to the female, 10% of fish infected.
	<i>Pumilopsis sardinellae</i>	one parasite on each eye.		
<i>Sardinella sirm</i>	<i>Pumilopsis spathepedes</i>	On the eye ball, eye parasite.	Gonad retarded and never reach maturity	Host specific
<i>Sardinella fimbriata</i>	<i>Cymothoa</i> sp	Sides of the body		External parasite
	<i>Pseudopetahus fomicoides</i>	Buccal cavity		
	<i>Lernanthropus oblongus</i>	Gills		
	<i>Cymothoa</i> sp	Sides of the body		External parasite

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	<i>Cymothoa</i> sp.	Opercle, head	—	external parasite Very com-
<i>Sardinella albella</i>	<i>Peroderma cyliindricum</i>	Buried within the body of the host at lateral side.	Gonad retarded, never attain maturity	mon around Mandapam; each host specific; each host with one parasite.
	<i>Bomolochus sardinellae</i> <i>Pumillopsis sardinellae</i>	Eye parasite, on the eye ball, one parasite on each eye.	Gonad development retarded	Host specific; male attached to the female, 10% of fish infected.
<i>Sardinella sirm</i>	<i>Pumillopsis spathepedes</i>	On the eye ball, eye parasite.	Gonad retarded and never reach maturity	Host specific
<i>Sardinella fimbriata</i>	<i>Cymothoa</i> sp	Sides of the body		External parasite
	<i>Pseudopetalus fomicoides</i>	Buccal cavity		
	<i>Lernanthropus oblongus</i>	Gills		
	<i>Cymothoa</i> sp	Sides of the body		External parasite

and dried. A small quantity is pickled and canned, but this is still not in an industrial stage. Major portion of the dried sardines from the southern fishing centres is exported to Sri Lanka and the rest is sent either to the inland markets for human consumption or to the reduction plants for manufacturing dairy and poultry-feed.

6. CONCLUSIONS

From a critical assessment of the rate of exploitation for the lesser sardines during the period 1958-67 along the different maritime states of India, Banerji (1973) gives an encouraging picture of the potential yield of these fishes, especially for the Andhra Pradesh area. In fact, the average annual landings of these fishes in the country have doubled from 36,000 t during the period 1958-67 to 70,000 t during the period 1969-78. The increase that took place in many states was not only due to larger number of units in operation, but also to a large extent to the adoption of improved fishing methods. By and large, the gradual increase in the total landings from year to year, barring sporadic fluctuations, is a reflection of the increased efficiency of the gear as well as of the fishermen.

Though the lesser sardines are caught in several types of gear, the gill nets have proved to be most effective for catching these fishes. Therefore, development of this gear so as to catch by a single net the different size groups that may be available in a locality and extension of fishing activity to 30-50 depth zones in areas of their inshore fishery are worthy of consideration for increasing the catches of lesser sardines.

Four regional concentrations of lesser sardines could be identified. They are of the Andhra region, south Tamil Nadu region, south Kerala region and Goa region. As mentioned earlier, different species of *Sardinella*, other than the oil sardine, contribute to successful fisheries in these regions. Significant variations in hydrological parameters have been observed between east and west coasts of India (Panikkar, 1967; Panikkar and Jayaram, 1966, Murthy, 1967) These are associated with monsoon drifts and equatorial currents. It is likely that these differences in hydrological characters have a significant bearing on the regional variations in the production of lesser sardines.

The four common species of lesser sardines, namely, *S. fimbriata*, *S. gibbosa*, *S. albella* and *S. dayi* have more or less similar growth rate, the fish attaining 12-14 cm total length by the end of first year of life, and 17-19 cm total length by the end of second year. *S. sirm*, however, grows to about 16 cm length by the end of first year and to 21-22 cm length by the end of second year. The first four species are sexually mature by about 12 cm length and *S. sirm* is sexually mature by 19-21 cm length. For all these five species, fish with mature and ripe gonads form only a small fraction of the commercial landings as the bulk of which is formed by 0-year class fish.

Serious gaps exist in our knowledge of the biology and exploitation of the different species contributing to fisheries in the different regions. The inadequate information on the fishing effort expended for these fisheries is foremost among them. There is also no evidence to indicate that the fisheries for lesser sardines along the coasts of Andhra Pradesh, south Tamil Nadu, south Kerala and Goa are on limited localized populations or not. The highly seasonal occurrence of some species of sardines, for example, *S. sirm* and *S. clupeioides*, require detailed studies with special emphasis on their movements from and into the inshore fishing grounds. The distribution of the older size groups of fish as well as of fish with mature and ripe gonads in respect of all the above five species need to be investigated. Detailed investigations on the differential distribution of eggs, larvae, juveniles and adults of *S. gibbosa* and *S. albella* of the Palk Bay and Gulf of Mannar in relation to the various abiotic and biotic environmental parameters are likely to furnish an insight into the ecological requirements of the different ontogenic stages and for their movements between the two localities. Thus a great deal of information needs to be gathered on the different aspects of behaviour of each species in relation to the various environmental conditions for forecasting the amounts and areas of fishing.

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