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STATUS OF SARDINE FISHERY AT VISAKHAPATNAM

G. Luther

Visakhapatnam Research Centre of CMFRI, Visakhapatnam - 530 003

Introduction

Sardines (*Sardinella* spp.) are the single largest group of marine fishery resources along the coast of Andhra Pradesh forming 13% of the total marine fish landings in the state. Along the northern coastal districts of Srikakulam and Vizianagaram the sardines assume a greater importance forming 30-50% of the fish landings. At Visakhapatnam, however, these fishes account for 5-27% of the fish catches because of the greater contribution made by demersal groups caught by shrimp trawls. Further south, their contribution is still lower. They are being harvested from within 40 m depth zone of the inshore waters along the north Andhra coast almost entirely (98%) by the artisanal gear, and the rest by shrimp trawl. The present account gives detailed information on some aspects of the fishery and biology of sardines of the Visakhapatnam area carried out mainly during the period July 1983 to June 1989. The study brings to fore the declining trend in the lesser sardine landings in recent years in Andhra Pradesh, and the need to reduce fishing pressure on juvenile fish besides indicating the possible link between the seasonal trends in the pattern of the lesser sardine fishery and that of the physical and biological environment in the Bay of Bengal.

The sardine fishery along the coast of Andhra Pradesh in the past used to be constituted by the lesser sardines, *S. fimbriata* and *S.gibbosa* the occurence of oil sardine (*S. longiceps*) being rare and far between (Figs. 1-3). Since mid 1985, however, the oil sardine began to contribute significantly to the sardine landings (Luther, G., *Mar. Fish. Infor. Serv., T&E Ser.*, No. **88**, 1988). Recently, *Sardinella* (*Amblygaster*) *sirm* was also recorded at Visakhapatnam during November-December 1992 and March 1993 (personal communication from Mr. K.Vijayakumaran, CMFRI). At Visakhapatnam *S. fimbriata* accounts for about 60% of the total sardine landings followed by *S. longiceps* (23%) and *S. gibbosa* (17%).

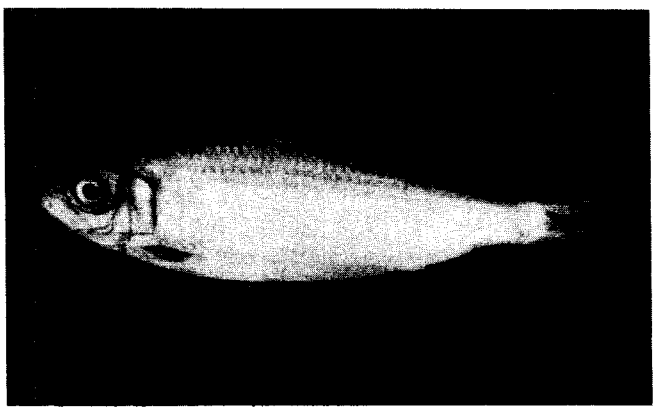

Fig. 1. *Sardinella fimbriata.*

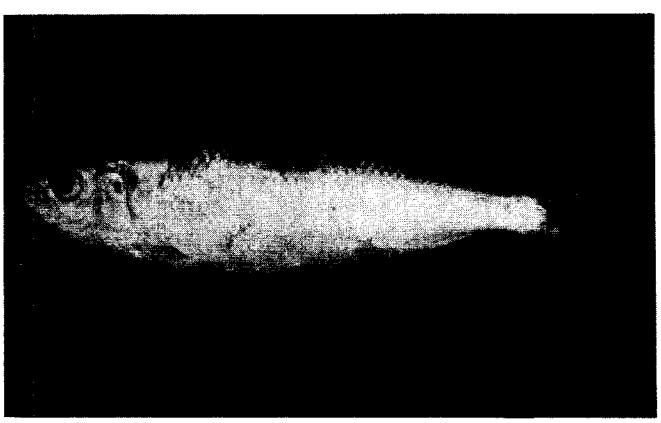

Fig. 2. *Sardinella gibbosa.*

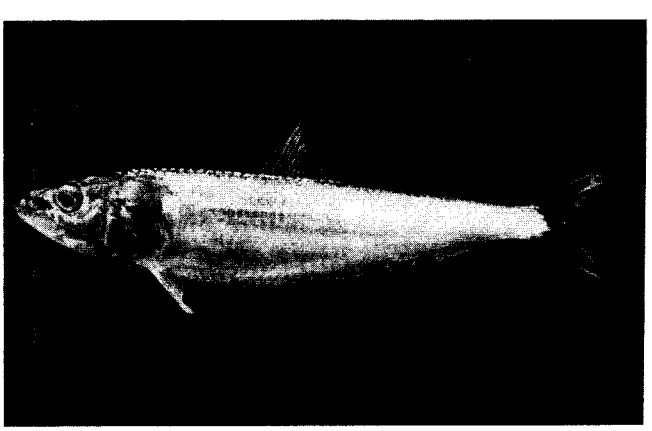

Fig. 3. *Sardinella longiceps.*

Trends in the gearwise sardine landings

Table 1 gives the catch details of lesser sardines and oil sardine landed by important artisanal gear at Lawson's Bay and Outer Harbour landing centres at Visakhapatnam during 1970-'85 and 1983-'89 respectively. At Lawson's Bay landing centre the lesser sardine landings by gillnet accounted for about 95% of the annual catch of this group followed by shore seine (3.5%) and boat seine (1.5%) during 1970-'78 (*Mar. Fish. Infor. Serv., T&E Ser.*, No. **6** , 1979). But during the period 1981-'85, gillnet contributed 91% followed by boat seine (5%) and shore seine (4%). At the Outer Harbour Centre during 1983-'85, however, the gillnet and boat seine emerged as the two principal gears landing sardines accounting for 71 and 29% of the total sardine catch comprising entirely of the lesser sardines. During 1985-'89, which period coincides with the period of the regular occurrence of the oil sardine at Visakhapatnam, the gillnet accounted for 60% of the lesser sardine catch and for 8% of the oil sardine catch. But the boat seine began to account for 40% of the lesser sardine catch and for most (92%) of the oil sardine catch. Shore seine's contribution to the exploitation of these resources has decreased considerably. Though both lesser sardines and oil sardines are captured by the shrimp trawl, their relative composition is quite low forming only 0.4% of the total catch. The annual sardine catch ranged between 3 and 75 t.

Although a variety of fish are caught in gillnet and boat seine landed at Outer Harbour, the lesser sardines and oil sardine constituted respectively 85 and 4% of the gillnet landings, and 30 and 20% of the boat seine catches. From these observations it may be pointed out that gillnet plays a vital role in the exploitation of lesser sardines and boat seine for the oil sardine at Visakhapatnam

Relative composition of the two species of lesser sardines in the two major gears

S. fimbriata forms the dominant catch over that of *S. gibbosa* both in gillnet and boat seine, their relative composition (by weight) being 67 : 33 and 91 : 9 respectively. Thus *S. gibbosa* is scarce in boat seine which is operated nearer to the coast and in the harbour channel than in gillnet which is operated 1-5 km away from the shore.

TABLE 1. *Catch details (annual averages) of lesser sardines at Lawson's Bay and outer harbour landing centres of Visakhapatnam during 1970-1989*

Gear	Effort (E)	Catch (kg) (C)	CPUE	% of sardines in the gear
Lesser sardines : 1970-'78 Lawsons Bay *				
Gillnet	3602	69,546	19.3	86.4
Boat seine	1472	736	0.5	1.7
Shore seine	1012	2,548	2.5	4.6
Lesser sardines : 1981-'85. Lawson's Bay				
Gillnet	3260	66,569	20.4	92.8
Boat seine	587	3,564	6.1	11.9
Shore seine	665	2,893	4.4	3.4
Lesser sardines : 1983-'84 & 1984-'85 Outer Harbour				
Gillnet	4484	178,640	39.8	89.3
Boat seine	4973	72,194	14.5	44.0
Lesser sardines : 1985-'86 to 1988-'89 Outer Harbour				
Gillnet	4561	104,362	22.9	84.7
Boat seine	5628	68,847	12.2	29.6
Oil sardine : 1985-'86 to 1988-'89. Outer Harbour				
Gillnet	4561	4,393	0.96	3.6
Boat seine	5628	47,500	8.4	20.4

* Source: *Mar. Fish. Infor. Serv., T&E Ser.*, No.**6**, 1979.

Fishing season

Both the lesser sardines and oil sardine occur in the artisanal landings almost throughout the year at Visakhapatnam their fishery seasons being different with some overlapping. The fishery season for the oil sardine is generally during June-December when about 90% of the annual catch is obtained. The fishery season for lesser sardines, on the other hand, is generally during October-April, the bulk of the annual catch (about 80%) being obtained during November-March (Fig. 4a, b)*.

Previous studies have shown November-May to be the period when sizeable catches of lesser sardines were landed in Andhra Pradesh.

*In the shrimp trawl prior to the regular occurrence of the oil sardine in the inshore catches at Visakhapatnam about 59% of the annual lesser sardine catch was obtained in March and another 13% in February. Similar trend continued for this group subsequently also. For the oil sardine, January accounted for about 54% of the annual shrimp trawl catch followed by February (16%). These trends indicate movement of lesser sardines and oil sardine to deeper waters during February-March and January-February respectively as also revealed by the diminishing catch rates of these groups in the gears operated in close shore waters during this period.

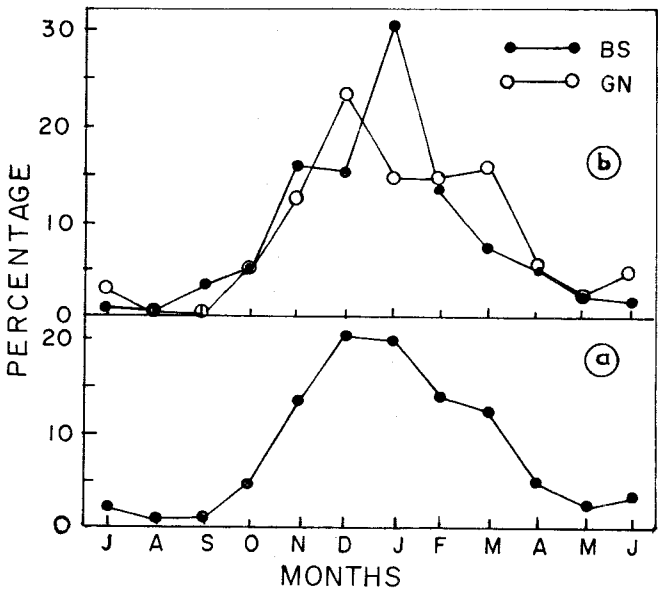

Fig. 4. Monthly variations in the landings of lesser sardines by boat seine and gillnet combined (a), and separately for each gear (b) at Outer Harbour, Visakhapatnam.

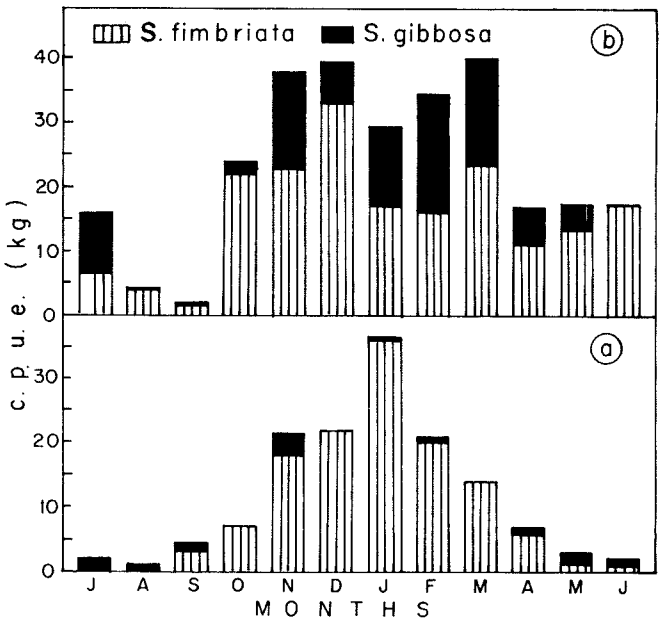

Fig. 5. Monthly variations in the catch per unit effort (kg) for boat seine (a), and gillnet (b) shown relatively for *S. fimbriata* and *S. gibbosa* landed at Outer Harbour, Visakhapatnam.

However, the fishery seasons for these resources showed year to year variations in their onset and duration. The possibility that this variation with respect to lesser sardines could be related to the corresponding variations in the seasonal pattern of sea surface circulation in the northern section of the Bay of Bengal, and the biomass production of zooplankton and secondary production in the continental shelf waters has been outlined in a later section.

The fishing effort by boat seine was nearly uniform throughout the year. However, good catches, exceeding annual catch per unit effort (catch during a single day's fishing trip by a unit of the fishing gear), of lesser sardines start occurring in this gear by September-December and last till February-April. Monthly cpue during the main season (November-March) varied between 14 and 36 kg (average 24 kg). During the rest of the period it varied between 1 kg and 7 kg (average 4 kg) (Fig. 5a). For the oil sardine, good catches start occurring in boat seine by May-July and last till December-February. Monthly cpue during the main season (June-December) varied between 7 and 22 kg (average 14 kg). During the rest of the period it reached upto 5 kg (average 2.4 kg) (Fig. 3).

The fishing effort by gillnet was generally poor or absent during August-September, moderate during October and May-July, and intense during November-April, the last one coinciding with the lesser sardine fishing season. Monthly cpue during the main season (November-March) varied between 30 and 40 kg (average 36 kg). During the rest of the period it varied between 2 and 17 kg poor cpue of 2-4 kg being met with during August-September (Fig.5b). Oil sardine catches by gillnet were quite insignificant and erratic with an average cpue of about 1 kg. Over the period of the present study this fish was met with in this gear during June-September (64%), December (23%), and March-April (13%). At other fish landing centres of Andra Pradesh the gillnet was reported to yield good cpue. The two species mainly constituting the lesser sardine fishery show slight variations between them in their seasonality and relative abundance (Figs. 5. 7 & 8). This is outlined below.

S. *fimbriata* : About 87% of the annual catch of this species was obtained during October-March, peak catches being obtained during December-January. In boat seine, good catches appear during September-December and last till February-April. Over the period, the cpue was high during November-March when 87% of the annual catch was landed with cpue varying between 14 and 36 kg (average 23 kg). In gillnet good catches started appearing during August-December and last till January-June. Over the period, good catches were obtained in this gear during October-March when 83% of the annual

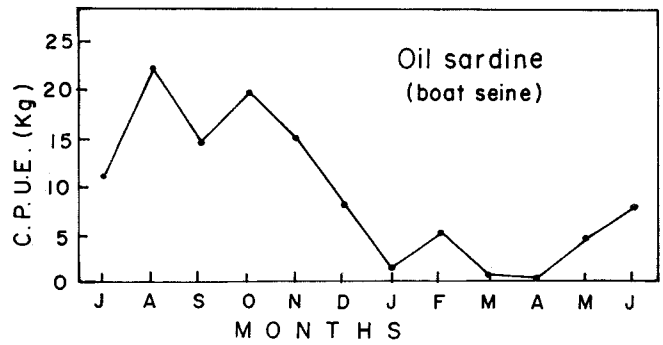

Fig. 6. Monthly variations in the catch per unit effort (kg) for *S. longiceps* landed by boat seine at Outer Harbour, Visakhapatnam.

catch was landed with cpue varying between 16 kg and 33 kg (average 23 kg). Fairly good catches were obtained during April-June also accounting for 14% of the annual catch with cpue varying between 11 kg and 17 kg (average 14 kg).

S. gibbosa : About 86% of the annual catch of this species was landed during November-April, peak catches being obtained around February. In boat seine, this species has no clearcut season of occurrence. However, over the six year period catches were moderate during April-September, November and February with an average cpue of 1 kg and accounting for 99% of the annual catch. In the gillnet, the catches were fairly good during

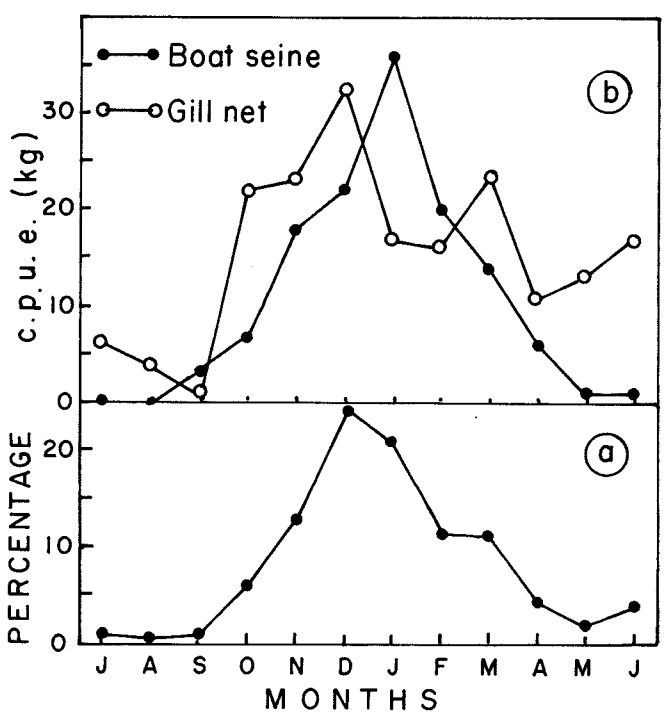

Fig. 7. Monthly variations in the catch by boat seine and gillnet (a), and catch per unit effort (b) for *S. fimbriata* landed at Outer Harbour, Visakhapatnam.

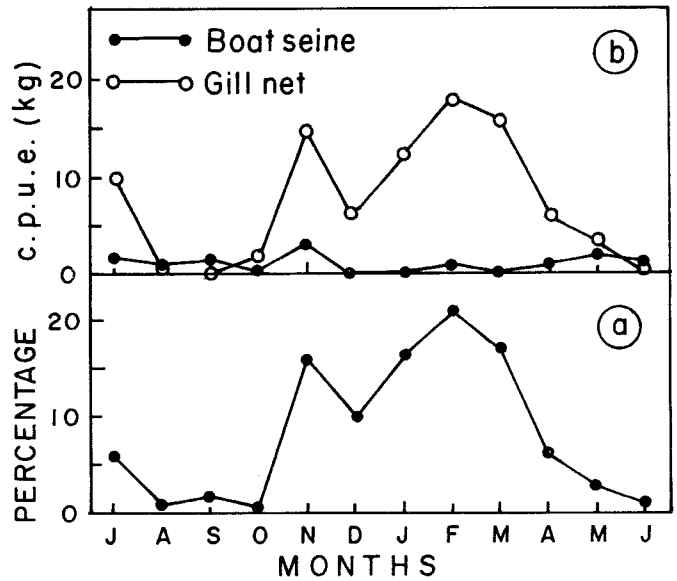

Fig. 8. Monthly variations in the catch by boat seine and gillnet (a), and in catch per unit effort (b) for *S. gibbosa* landed at Outer Harbour, Visakhapatnam.

November-March forming 87% of the annual catch with cpue varying between 6 and 18 kg (average 13 kg) over the period. April and July also witnessed good catches accounting for 10% of the annual catch with cpue of 6-10 kg. During the rest of the period the cpue was very poor.

The trend for the fishery of the oil sardine has been dealt with in the previous paragraphs.

Biological characteristics

The monthly ranges in length and modal sizes for the two common species of lesser sardines and oil sardine landed at Visakhapatnam over the periods of study are given in Fig. 9 and the overall size composition of the three species in boat seine and gillnet are given in Fig. 10. The size of fish mentioned in this account is the mid value of the length class interval. For example, fish of 52 and 67 mm length belong to 50-54 mm and 65-69 mm class intervals respectively. The estimated weights of fish at different lengths based on length weight relationships for the three species under reference, are given in Table 2. The salient features of the biology of these sardines are outlined below.

S. fimbriata : Fish of 35-196 mm total length occurred in the fishery. But the bulk of the catch was formed by juvenile fish below 127 mm length, 52-112 mm length in boat seine and 57-122 mm length in gillnet. Fish in these size groups accounted for 98 and 96% respectively of the total number of fish in cpue. In the stray catches

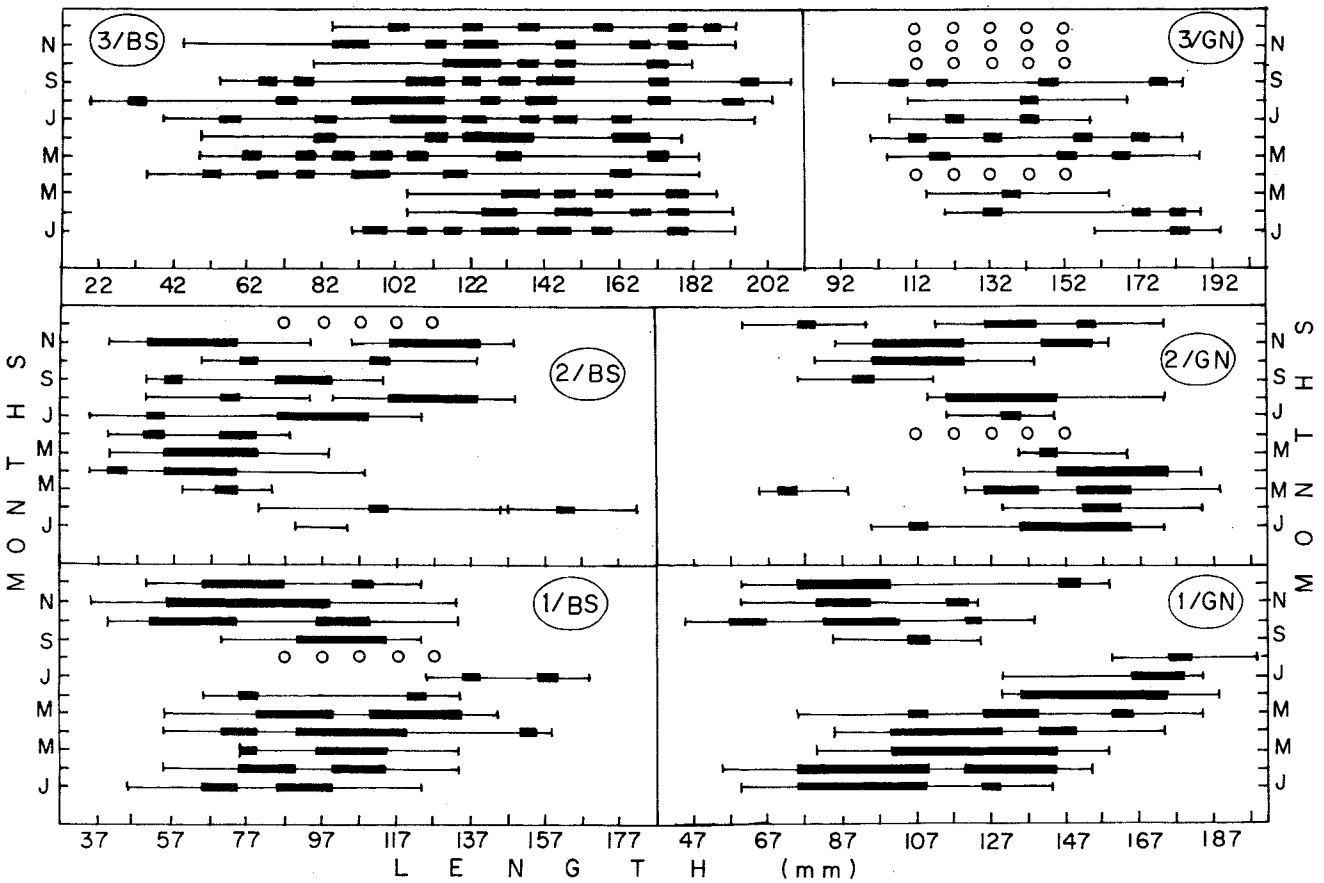

Fig. 9. Monthly ranges in length and modal sizes for *S. fimbriata* (1), *S. gibbosa* (2), and *S. longiceps* (3) landed by boat seine (BS) and gillnet (GN) at Outer Harbour, Visakhapatnam. Zero (O) indicates no sample for the month.

examined from other gears over the period, *S. fimbriata* occurred in the length range of 42-92 mm and 127-137 mm with dominant mode at 77 mm followed by other modes at 52 and 132 mm in shrimp trawl, and in length range of 32-112 mm with dominant mode at 72 mm followed by mode at 52 mm in shore seine, the catches comprising entirely of juvenile fish in both the gears. The size at first maturity has been estimated as 147 mm. From the length progression analysis this species was estimated to attain average lengths of 77 mm, 117 mm, 147 mm and 167 mm at completion of 3, 6, 9 and 12 months of life respectively. Thus mainly juveniles of this species, those below 7 months of age, are exploited by the fishery. Adult fish account for less than 0.5% of the catch (cpue) by boat seine and about 2% in gillnet. Although adults are encountered during February-August, fish with mature gonads are rare in the catches, they being met with only occasionally during July-August which is the off season for the fishery. During the rest of the period the adult fish had only spent - resting and developing gonads. Thus the spawning grounds of this species appear to lie beyond the present zone of fishing by gillnetters.

An attempt has been made to estimate the probable spawning season based on the period of entry of new broods and the growth rate of the fish. The youngest major brood entering the fishery had the modal size at 52 mm, the maximum size of fish in it being in the 77 mm size group. Though fish with modal size ranging between the above two size groups occurred during October-June, they were more common during October-December, with smaller peaks in January and April (Fig. 9). Fish of 77 mm length being 3 months of age, fish of this size (77 mm) occurring during October-December could be the result of spawning during July-September, and those of the same size range met with in January and April might be from the spawnings in October and January respectively. Thus, July-October appears to be the main spawning season followed by a minor spawning in January for *S. fimbriata* off Visakhapatnam. From the progression of the modal size groups in the

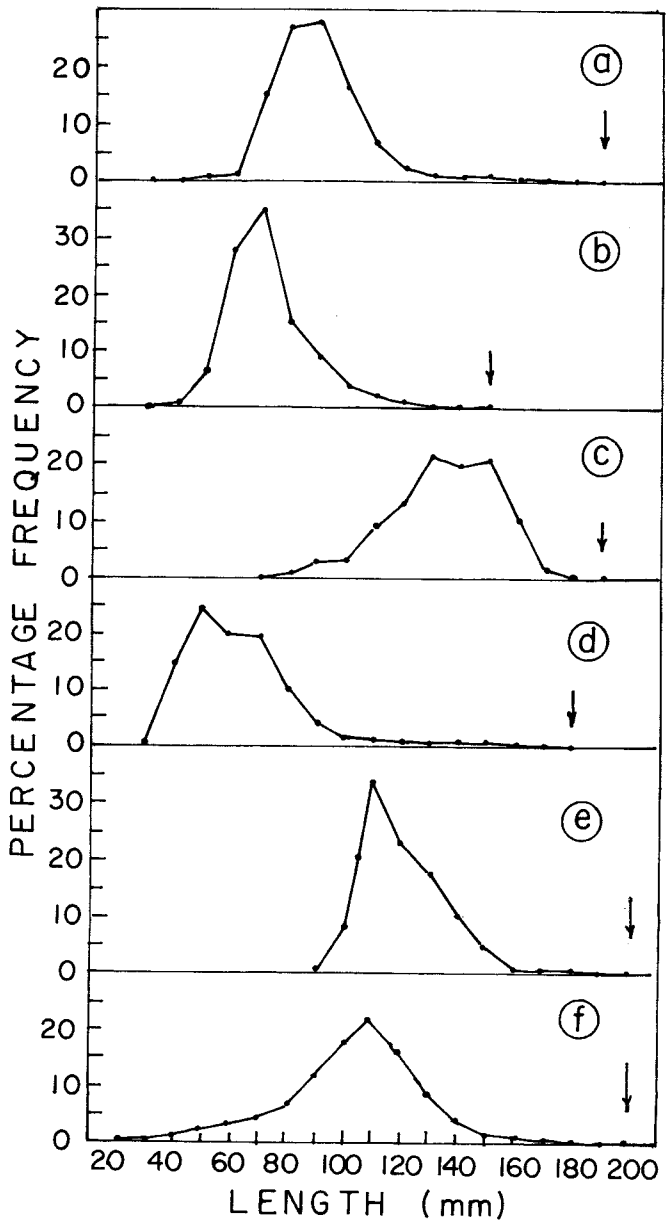

Fig. 10. Overall size composition of the three species of sardines landed by gillnet and boat seine at Outer Harbour, Visakhapatnam. *S. fimbriata* from gillnet (a), boat seine (b), *S. gibbosa* from gillnet (c), boat seine (d), *S. longiceps* from gillnet (e), boat seine (f). Arrows indicate location of the largest length group of fish.

successive months, it is noticed that a brood, after its entry into the fishing ground, sojourns there for 5-10 months, but usually for about 7 months.

Previous studies on this species at Visakhapatnam (Bennet P. S. *et al.*, *CMFRI Special Publ.*, No. **28**, 1986) have shown the recruitment of fish to take place at 4-7 cm length, fish of 5-12 cm length supporting the fishery. The maximum length recorded for the species was

TABLE 2. *Estimated weight (g) at different lengths and the length-weight relationships and the growth parameters for* S. fimbriata, S. gibbosa *and* S. longiceps

Length (TL, mm)	*S.fimbriata*	*S.gibbosa*	*S.longiceps*
40	0.5	0.5	0.6
50	1.0	1.0	1.2
60	1.8	1.7	2.2
70	2.8	2.7	3.6
80	4.1	4.1	5.4
90	5.8	5.9	7.9
100	7.9	8.1	11.0
110	10.4	10.8	14.9
120	13.4	14.1	19.7
130	16.9	18.0	25.4
140	20.9	22.6	32.1
150	25.6	28.0	40.0
160	30.9	34.1	49.1
170	36.8	41.0	59.6
180	43.5	48.9	71.4
190	50.9	57.7	84.8

21.3 cm, fish beyond 19 cm total length being rare. Fish of 17 cm length was considered to belong to the 1-year class and 17-19 cm length was considered to belong to the 1-year class and 17-19 cm being in the 2-year class. Occurrence of mature fish was rare. All the previous studies also have indicated the spawning ground of this species to be beyond the fishing zone of the gillnetters. The above observations bring to fore that though the dominant size of *S. fimbriata* exploited in the fishery in recent years continue to be the same as in the past, large fish beyond 196 mm length ceased to occur in the catches. This would indicate that *S. fimbriata* occurring along this coast is being subjected to overfishing.

S. gibbosa : Fish of 35-183 mm total length occurred in the fishery. But fish of the size ranges 42-97 mm in boat seine and 92-172 mm in gillnet accounted for 96 and 99% respectively of the total number of fish. The smallest modal size met with was at 52 mm size group in boat seine catches, and the smallest mature fish was at 125 mm length. In the stray catches examined from other gear over the period, *S. gibbosa* occurred in the length range of 107-182 mm with mode at 152 mm in shrimp trawl, and in the

length range of 32-152 mm with dominant mode at 72 mm followed by modes at 117 and 142 mm in shore seine. Thus 87% of the catch of this species examined from shrimp trawl comprised of adult fish whereas in shore seine 91% of the catch examined comprised of juveniles. The size at first maturity has been estimated as 142 mm length. Occurrence of adult fish was rare in boat seine forming only less than 1% of the catch whereas in gillnet it was as high as 52%. Although adults were encountered over the period of study during November-May and July-August, fish with mature gonads were met with only during January-April accounting for 54-99% of the adult fish. However, occurrence of both the adult fish and fish with mature gonads was highly erratic, they being encountered not in all the months as mentioned above in each year. During the course of spawning, an individual fish seem to release the ripe eggs in two batches at short interval of time, the first batch with 26,000-73,000 eggs and the second batch with 14,000-58,000 eggs. The available length data was inadequate to estimate growth in length for this species. But in terms of growth in weight (Table 2) it is seen that this species exhibits more or less similar increment as S. *fimbriata* upto 80 mm length. Thereafter it puts up more weight, though not quite markedly, upto 140 mm length. Assuming the growth rate of this species to be similar to that of *S. fimbriata* at least in the early juvenile stage an attempt has been made to estimate the extent of its spawning period based on the period of entry of the new broods into the fishery. Over the period of study fish below 77 mm length occurred during March-December but more commonly during April-June and November. Thus the brood that entered the fishery during the latter two periods could be the result of spawning during January-March and August, which is in accord with the record of occurrence of fish with ripe gonads during January-April, besides bringing to light the month of August as the likely minor spawning peak. Though the occurrence of this species is erratic, occasionally the schools after their entry seem to stay on the fishing ground for 2-4 months.

Previous studies on this species at Visakhapatnam (*op. cit., CMFRI Spl. Publ.*, No. **28:**1986) have also brought out its erratic occurrence on the fishing ground besides indicating February-April period as the spawning period and 17 cm size fish to be 1-year old. They also point out the species to make its first appearance in the season as juveniles with dominant size ranging between 3 and 6 cm during October-December or February-April or as adults of size range 12-18 cm during February-March. These results bear close agreement with those of the present study.

S. longiceps : Fish of 20-207 mm total length occurred in the landings. But the catch was formed mainly by fish of size range 57-147 mm in boat seine, 102-187 mm in gillnet, 72-175 mm in shrimp trawl and 92-187 mm in shore seine. The smallest modal size met with was at 32 mm in boat seine. This species was found to attain size at first maturity at 137 mm, and average lengths of 99 mm, 139.5 mm, 166.2 mm, 183.8 mm and 195.4 mm were estimated at completion of 3, 6, 9, 12 and 15 months of life respectively. Thus juveniles form the bulk of the catches of boat seine and shore seine but both juveniles and adults contribute to the catches of gillnet, shrimp trawl and shore seine. Fish with mature gonads were encountered without consistency as to their period of abundance in the three years of observations. The species appears to have a prolonged spawning period with intense spawning activity during December-February, April-June and August-October. However, only two groups of mature eggs are noticeable in mature ovaries, with a range of 12,432-130,459 eggs in the most mature group and 11,380 - 80,055 eggs in the less mature group.

General remarks

The lesser sardines constitute the major bulk (nearly 40%) of the clupeoid fish landings which, accounting for 30%, dominate the finfish catch in Andhra Pradesh. The lesser sardine landings of this state during 1969-1992 (Table 3) showed peaks in 1971 (19,949 t), 1975 (32,944 t), 1981 (15,719 t), 1985 (22,864 t) and 1989 (28,371 t). Treating the annual catch data by a moving average of three, however, three peak periods are noticeable ; one around 1975 (29,245 t) another around 1984 (20,485 t) and the third around 1989 (22,508 t) averaging to 24,079 t. Thus the level of exploitation of lesser sardine fishery resources of Andhra Pradesh according to the maximum contribution approach (Alagaraja, K. 1984, *Indian J. Fish.*, **31**(2): 177-208) could be between the average of the peak landings over the 24 year period of 24,079 t and the maximum annual landing of 32,944 t during 1969-'92.

It is also noticeable from Table 3 that the fluctuations in the lesser sardine landings closely

followed the pattern of the total marine fish landings from 1969 to 1987. Thereafter the trends of the two are more or less opposite to each other. Lesser sardine landings of the state during 1991 and 1992 averaged to 8791 t only as compared to 18,753 t during 1981-'90. Thus, there has been considerable decline in the lesser sardine landings in recent years. This calls for taking up remedial measures to arrest this declining trend by reducing the fishing pressure on juvenile fish.

Although the oil sardine takes a second rank in the sardine landings at Visakhapatnam, it is not only next to *S. fimbriata* and *S. gibbosa*, but far behind in the overall species composition of *Sardinella* in Andhra Pradesh. This is so because, as mentioned earlier, the distribution of the oil sardine is restricted to certain localities having rich production of phytoplankton which forms the main food of this species. The food of the two species of lesser sardines on the other hand, comprises essentially of planktonic copepods followed by other crustaceans and other zooplanktonic organisms from 50 mm length onwards. While the surface gillnets are the chief gear employed for catching the lesser sardines, the bagnet is the main gear for the oil sardine at Visakhapatnam as elsewhere along the Indian coast. While juvenile fish form most of *S. fimbriata* landed both by boat seine and gillnet, in the case of *S. gibbosa* juveniles form the dominant catch in boat seine and adults form sizeable quantity in gillnet. For the oil sardine, though juvenile fish form the dominant catch of both the gears, the proportion of adult fish is higher in gillnet. The three species also exhibit differences in their fishery and biological characters.

The Pattern of the sea surface circulation in the Bay of Bengal appears to influence the seasonal abundance of the lesser sardines (represented mainly by *S. fimbriata*) in the inshore waters of the north Andhra coast. The circulation pattern adopted for discussion here has been outlined by Ganapati, P. N. and D. V. R. Sarma (*Andhra University Memoirs in Oceanography*, Vol. II, 1958, p. 168-192, Fig. 1-12) and by Pillai, P. P. (*Proceedings of the First Workshop on Scientific Results of FORV Sagar Sampada*, 1990, p. 101-106, Fig. 5). During September-October (post S-W monsoon period) when the surface flow in the Bay of Bengal is predominantly northerly along the eastern side and southerly on the western (coastal) side,

TABLE 3. *Annual marine fish landings (in tonnes) and the lesser sardine landings in Andhra Pradesh during 1969-1992*

Year	Total fish landings	Lesser sardine landings	Year	Total fish landings	Lesser sardine landings
1969	77,526	13,371	1981	116,143	15,719
1970	74,459	19,047	1982	118,034	13,758
1971	84,010	19,949	1983	151,484	17,514
1972	84,480	7,587	1984	146,694	21,077
1973	99,544	11,928	1985	120,386	22,864
1974	158,818	31,520	1986	152,153	16,723
1975	155,638	32,994	1987	139,160	12,348
1976	131,321	23,220	1988	123,560	17,258
1977	100,756	10,972	1989	123,128	28,371
1978	82,116	7,685	1990	118,232	21,894
1979	91,426	6,180	1991	121,150	8,738
1980	116,013	13,930	1992	149,882	8,843

Source : Fishery Resources Assessment Division of CMFRI.

representing the counter clockwise circulation (Fig. 11a) the lesser sardine fishery makes its appearance in the coastal waters. This would suggest that the fish are brought to the coastal waters from the south-eastern parts of the Bay of Bengal. In the subsequent months (N-E monsoon period, Fig. 11b) the abundance of the fish in the coastal waters gets intensified on account of the predominantly west-drift of the surface currents, during November-January. However, with the onset of clock-wise circulation (that precedes the east-drift) during the succeeding period and its intensification during March-April, the surface water is deflected from the coast (Fig. 11c) and this coincides with the dwindling in the abundance of the lesser sardine in the coastal waters. During May-August, as the surface currents are essentially driven by the south-west monsoon, the flow takes an easterly direction, then south and south easterly (Fig. 11d) evidently transporting most of the adult stock of lesser sardine from along the northeast coast to the offshore waters coinciding with the end of the lesser sardine fishery season along the north Andhra coast.

This period (May-August) coincides in part with the main spawning period of *S. fimbriata* (July-October), and with the minor spawning period of *S. gibbosa* (August) supporting the view expressed in the earlier section that *S. fimbriata* mainly spawns in offshore waters. With the resumption of the northerly coastal surface circulation during September-October the lesser sardine fishery starts in the coastal waters supported mainly by younger juveniles (50-75 mm length) of *S. fimbriata*, and some older

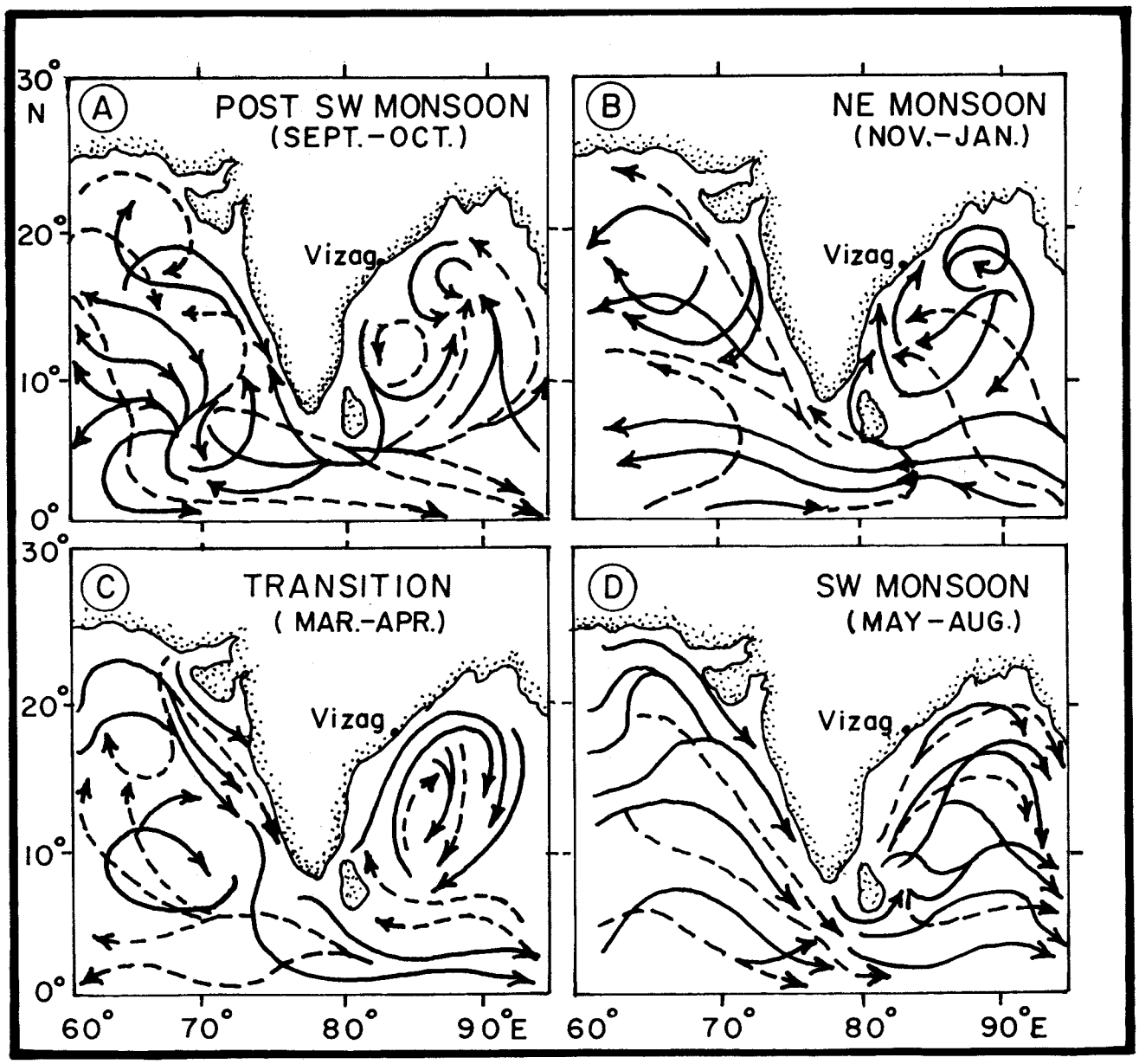

Fig. 11. Surface circulation patterns in the Bay of Bengal and Arabian Sea. (After P. Parameswaran Pillai, 1990; as adopted from Krey and Barbenard 1976 and Varadachari & Sharma 1966. Broken lines indicate the pattern of current during the former half of that period).

juveniles of both the species as well as adults of *S. gibbosa*. Stray specimens of *S. fimbriata* in advanced stages of maturity are also met with during this period. These sardines remain in the coastal waters till March-April. The intervening period coincides with the major spawning activity of *S. gibbosa*, indicating that this species spawns mainly in the coastal waters. With the onset of the clockwise circulation of the surface water, most of the lesser sardine stock available in the coastal waters is evidently carried away offshore to the eastern and southeastern sections of the Bay of Bengal, and the cycle is repeated each year. Examination of the seasonal trend of the oil sardine fishery as against the surface circulation pattern in the Arabian Sea and the Bay of Bengal during May-August (Fig. 11d) suggests the possibility of this species entering the Bay of Bengal from the southwest coast of India along with the surface currents driven by the SW monsoon during May-August (Fig. 6). This fish on its entry into the Bay of Bengal seems to hug the coast often entering the estuaries and brackish waters, and somehow not get carried

away by the east-southeast flowing currents that prevail in the Bay of Bengal during this period. The fish seems to maintain this coastal habitat till December, but seems to come early under the influence of the clockwise circulation that sets in towards the latter part of November-January period, and get carried off the coast in the subsequent period.

The lesser sardine fishery season along this coast also coincides with the period of the maximum biomass production of zooplankton and secondary production (November-February) along the northeast coast of India, and the off season of the fishery coincides with the SW monsoon period of occurrence of least biomass value of the above plankton group as revealed by the recent surveys (Mathew, K. J. *et al., Second Workshop on Scientific Results of FORV Sagar Sampada*, 1994 Abstract 55.) Thus there appears to be a close link between the pattern of sea surface circulation and the biomass production of zooplankton and secondary production on the one hand and the occurrence of the lesser sardine fishery on the other along the upper east coast of India.