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THE INDIAN OIL SARDINE*

Introduction

The indian oil sardine, *Sardinella longiceps* Val. sustains one of the major pelagic fisheries of the country. Though the fish occurs all along the peninsular region in varying quantities, the highest abundance has been noticed off the Kerala and Karnataka coasts, especially between Alleppey and Karwar. The traditional fishing season commences by August and continues till March along this region. With the development of purse seine fishery, the season has been extended even up to June.

Wide fluctuations, from year to year, were noticeable in the magnitude of its catches. During 1961-68 the sardine catches ranged from 9.71 to 33.38% of the total marine fish landings of the country, the annual average being 2,10,376 tonnes. The all India annual average catch of the sardine during the subsequent ten years from 1969 to 1978 was 1,65,586 tonnes, though within that period the highest catch (2,26,997 tonnes) was in 1970, which formed 20.9% of the total marine landings.

Investigations conducted so far showed that the oil sardine shoals are confined mainly within the 15 km coastal belt, denser shoals being sighted frequently in the shallower nearshore waters, from where they are largely exploited in Kerala and Karnataka States. The fishery yield is largely from the commercial sizes ranging between 100 and 200 mm.

It is possible that the sardine harvest could be further increased by augmenting and deploying the fleet strength of purse seiners all along the Kerala and Karnataka coasts during the monsoon period also. Of course, its impact on the sardine stock has to be watched carefully and monitored from time to time for the benefit of the fishing industry.

Though the sardine fishing has been done till recent years principally by the indigenous gears and crafts, the advent of purse seiners has made tremendous improvements in its landings on the west coast, especially in the state of Karnataka. In that state, the proliferation of purse seining activity has effected a marked reduction of the sardine landings by the indigenous gears such as the Rampan (*Mar. Fish. Infor. Serv. T & E ser. 12, 1979*), "Kolibale", cast net and "Yendi". However, the impact of the purse seining conducted off the Karnataka region has not been seriously felt by the artisanal fishermen of the central and southern Kerala State.

All India oil sardine production

During the decade from 1969 to 1978, the highest all India oil sardine catch, was made in 1970. In the succeeding year also, the landing was very good. Thereafter the catch decreased. The landings during 1978 was estimated at 1,68,078 t. against 1,50,130 t. of the preceding year. The annual production during the years from 1974 to 1976, as shown in Table I revealed an increasing trend yielding 1,26,676, 1,59,240 and 1,69,262 t. respectively. In 1977, of the country's total oil-sardine catch, 78.17% came from Kerala State alone which had harvested the most lucrative sardine catches throughout the 1969-78 seasons.

Statewise production (Figs. 1 & 2)

Gujarat

No oil sardine landing occurred during the period 1970-1978, but for a small catch in 1969 (Table 1).

Maharashtra

The catches in the state though generally small, were above the average during 1972, 73, 75 and 76; it was only 108 t. in 1977, and no landings in 1978.

* Prepared by V. Balan and R. Reghu in consultation with K. V. N. Rao. The chapter on stock assessment is by K. Alagaraja. Basic data from centres other than Cochin were provided by V. S. Rengaswamy and N. G. Menon-Calicut, M. H. Dhulkhed-Mangalore and G. G. Annigeri-Karwar.

Table 1. Statewise oil sardine landings in tonnes during 1969-78

Year	W. Bengal & Orissa	Andhra-pradesh	Tamil Nadu	Pondi-cherry	Kerala	Karna-taka	Goa	Maha-rashtra	Gujarat	All-India Total
1969	247	—	18	—	1,39,983	33,580	—	399	23	1,74,250
1970	—	—	46	—	1,91,683	33,834	1,134	300	—	2,26,997
1971	2	—	45	—	1,94,977	11,836	1,994	407	—	2,09,261
1972	—	—	146	—	1,04,426	15,610	3,793	3,593	—	1,27,568
1973	38	125	45	—	1,22,783	15,495	3,426	2,483	—	1,44,395
1974	4	564	—	—	1,02,135	20,784	2,106	1,083	—	1,26,676
1975	—	131	—	—	97,183	52,701	7,526	1,699	—	1,59,240
1976	—	112	—	—	1,23,937	41,451	1,385	2,377	—	1,69,262
1977	—	—	714	—	1,17,356	31,145	807	108	—	1,50,130
1978	—	—	36	—	1,19,937	46,707	1,398	—	—	1,68,078
Average	29.1	93.2	105.0	—	131,440.0	3,0314.3	2,356.9	1,244.9	2.3	1,65,586

During 1974, 75 and 76, the landings obtained were 1,083, 1,699 and 2,377 t. respectively contributing about 1% in the all India catches.

Goa

Generally, the catches were small in magnitude in this state. However, they were above the state's average during the years 1972, 1973 and 1975. In 1978 a total of 1,398 t. was landed, whereas the catches were only 807 t. during the previous year. In 1974, the

landing was below the average. In 1975 and 1976, the catches were respectively 7,526 and 1,385 t. the highest being in 1975 for the state. In 1978 the best catch was during the final quarter, the purse seiners contributing the bulk of the catches.

Karnataka

The landings in Karnataka were below the average from 1971 to 1974. During the ten years viz., 1969-78, the highest catch was made in 1975, as in Goa, when

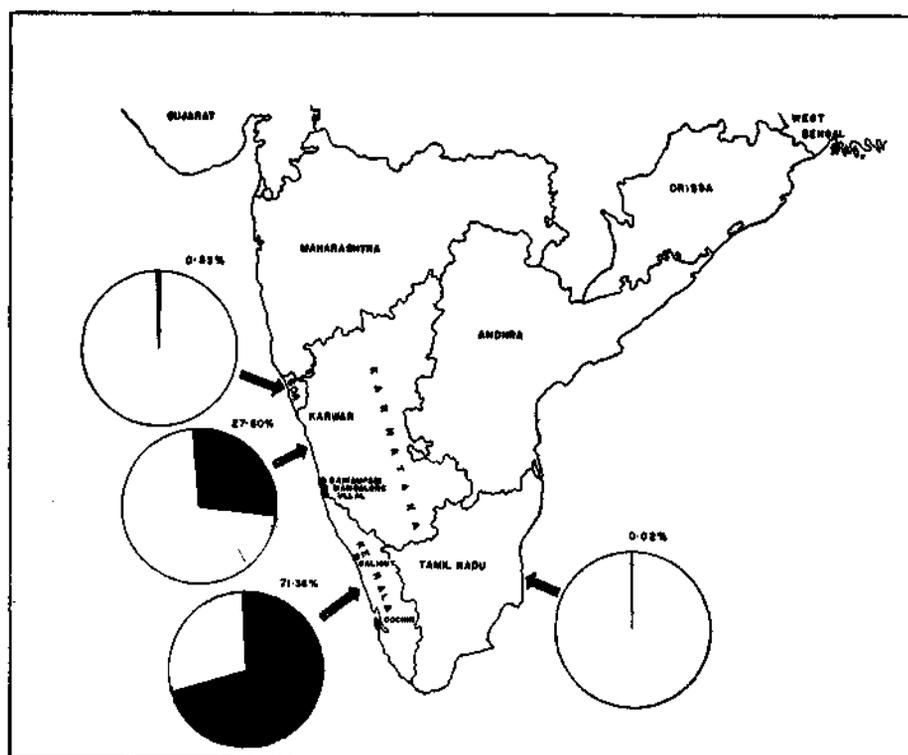


Fig. 1. Statewise annual oil sardine landings (percentage) in 1978

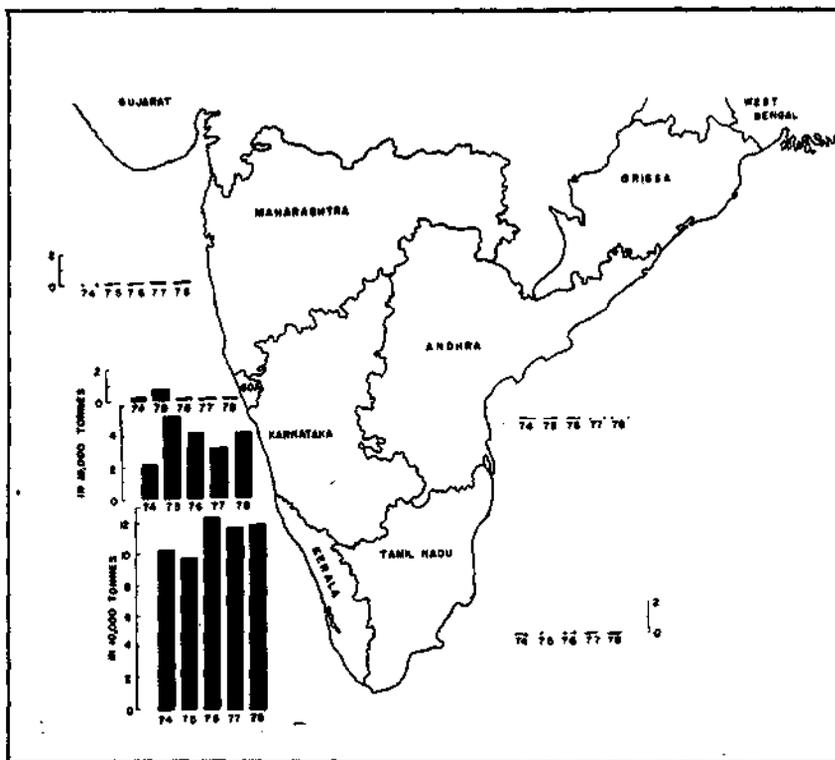


Fig. 2. Statewise annual oil sardine landings (tonnes) during 1974-78

it recorded 52,701 t. contributing 33.09% to the all India sardine landings. In the ensuing two years, the catches were almost average in magnitude. The landings improved tremendously and were the best during the last quarter (24,092 t.) of 1978, yielding a total of 46,707 t. for the year forming 27.78% of the all India sardine catches. The purse seiners at the Mangalore region solely boosted the state's catches during the 1978 season, their best catches being in September-October. Out of the annual total sardine catch of the entire Karnataka state in 1978, 80.17% was contributed by the purse seiners of the S. Karnataka region (Mangalore, Malpe and Ganguli centres). The corresponding contribution from the purse seiners of the N. Karnataka (Karwar) was only 0.05%. Viewing the magnitude of the catches on an overall basis, this state contributed the next highest catch compared to that of Kerala only.

Kerala

The major landings in the country during the decade came from this state alone. It is quite significant that in 1971, the highest sardine catch (1,94,977 t.) was made, contributing 93.17% to the all India oil sardine production. The state's annual average catch during

1969-78 was 1,31,440.0 t. In 1970, a very good landing of 1,91,683 t. was made. The landings during 1972-78 were below the average for the state. However, the catches in 1977 and 1978 formed 78.17 and 71.36% respectively in the total oil sardine yields of the country. It may be added that at Cochin, a catch of 333 t. was made by the purse seiners alone during 1978 (Fig. 3). During the final quarter of 1978, the state's highest

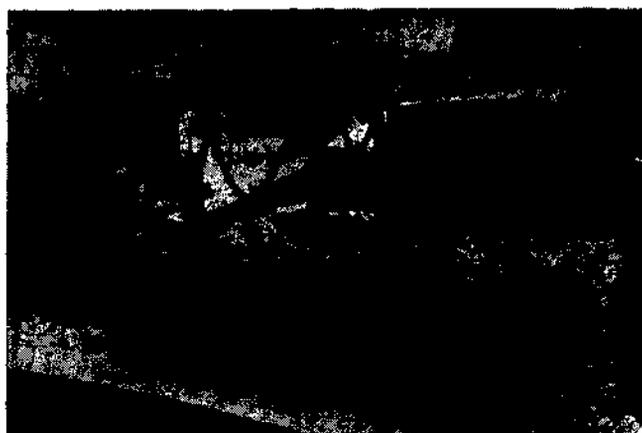


Fig. 3. Carrier boat with oil sardine catch from purse seiner at Cochin.

catch (75,595 t.) was made (forming 63.02% of the annual total); the smallest yield was during the second quarter, their general trend remaining the same as in the Karnataka and Goa States.

Tamil Nadu

The landings during the 1969-78 period were very poor for this state, the percentage contribution towards the all India sardine catches remaining very low. During the years from 1974 to 1976, there was no landing of oil sardine in this state. In 1978, the landing was remarkably poorer than that in 1977, the figures respectively being 36 and 714 t. In 1978, the catches were obtained only during the first and second quarters.

Andhra Pradesh

A small catch of 125 t. was landed during the years 1969-1973. The landings in 1974 amounted to 564 t. against only 131 t. of 1975. In 1976, only 112 t. was obtained, though there were no oil sardine landings in the succeeding two years in this state. Hence its percentage contribution to the all India production was relatively very small during the ten year period.

Orissa and West Bengal

The sardine landings were the smallest in these two states. A very meagre catch was made during 1969 and 1973 only. There was no landing of oil-sardine in these states after 1974.

Union Territories

There was no oil sardine landing in the Union Territories of Pondicherry, Andaman & Nicobar Islands and the Lakshadweep during the years from 1969 to 1978.

The oil sardine catch in relation to total marine fish landings

The total marine fish catch in the country during 1978 was estimated as 14,03,607 t. of which 11.97% was oil sardine. In 1977, 1976, 1975 and 1974 the percentage values respectively were 11.91, 12.51, 11.19 and 10.40. Thus, in the past five years, the annual percentage contribution of the oil sardine showed a range from 10.40 to 12.51 only.

Statewise, the oil sardine catches in Maharashtra formed only 0.01% of the total marine fish landings in

1977 against 0.18% in 1976. For 1975 and 1974, the corresponding percentages were 0.12 and 0.08 respectively.

In Goa, the percentages of oil sardine in the total marine fish catches for 1974 and 1975 were 0.17 and 0.53 respectively. In 1976, it was only 0.10%. In 1977 and 1978, the corresponding figures were 0.06 and 0.10 respectively.

In Karnataka, the corresponding percentages for 1974 and 1975 were 1.7 and 3.7 respectively. During 1976 and 1977, the values were 3.06 and 2.47. In 1978, however, the percentage rose to 3.32.

In the state of Kerala, the corresponding percentage values for 1974 and 1975 were high being 8.38 and 6.83 respectively. During 1976, the percentage rose to 9.16. In 1977 and 1978, the values were 9.31 and 8.54% respectively.

In Tamil Nadu during the years 1977 and 1978, their percentage contribution was less than 1.00. In Andhra Pradesh, the corresponding percentages were only less than 0.1 between the years 1974 and 1976.

Gears and catch per net

Observations on the various gears used and the catches per net were made at a few important centres. The bulk of the sardine catches at Cochin was made by the one-boat boat-seine "Thangu vala", its catch per net in 1978 being 280.0 kg. (Fig. 4a). This gear accounted for 78.5% of the total sardine catches there. For Ayila vala (gill net used for catching big sized sardine and mackerel) the percentage of the sardine catch was 9.3; its catch per net being 75.1 kg for 1978. In regard to the purse seine, the corresponding figures were 12.2% and 1120.5 kg per net during the year.

At Calicut (Fig. 4 b) Pattenkolli (boat seine) was the major gear accounting for 90.3% of the total sardine catch of 1978 season (6,292 t.), catching at a rate of 393.2 kg per net. Gill net Mathichala vala accounted for 9.6% of the catches, the catch rate being 116.8 kg per net. The cast net was also operated in September, landing 242.3 t.

Along the Karnataka coast during the second half of 1978, the increased purse seiner fleet landed heavy catches of oil sardine at Mangalore, Ganguli and Malpe centres (S. Karnataka), the total for the year being 37,449 t. against 31,145 t. of the previous year. At Mangalore alone 17,325 t. were landed

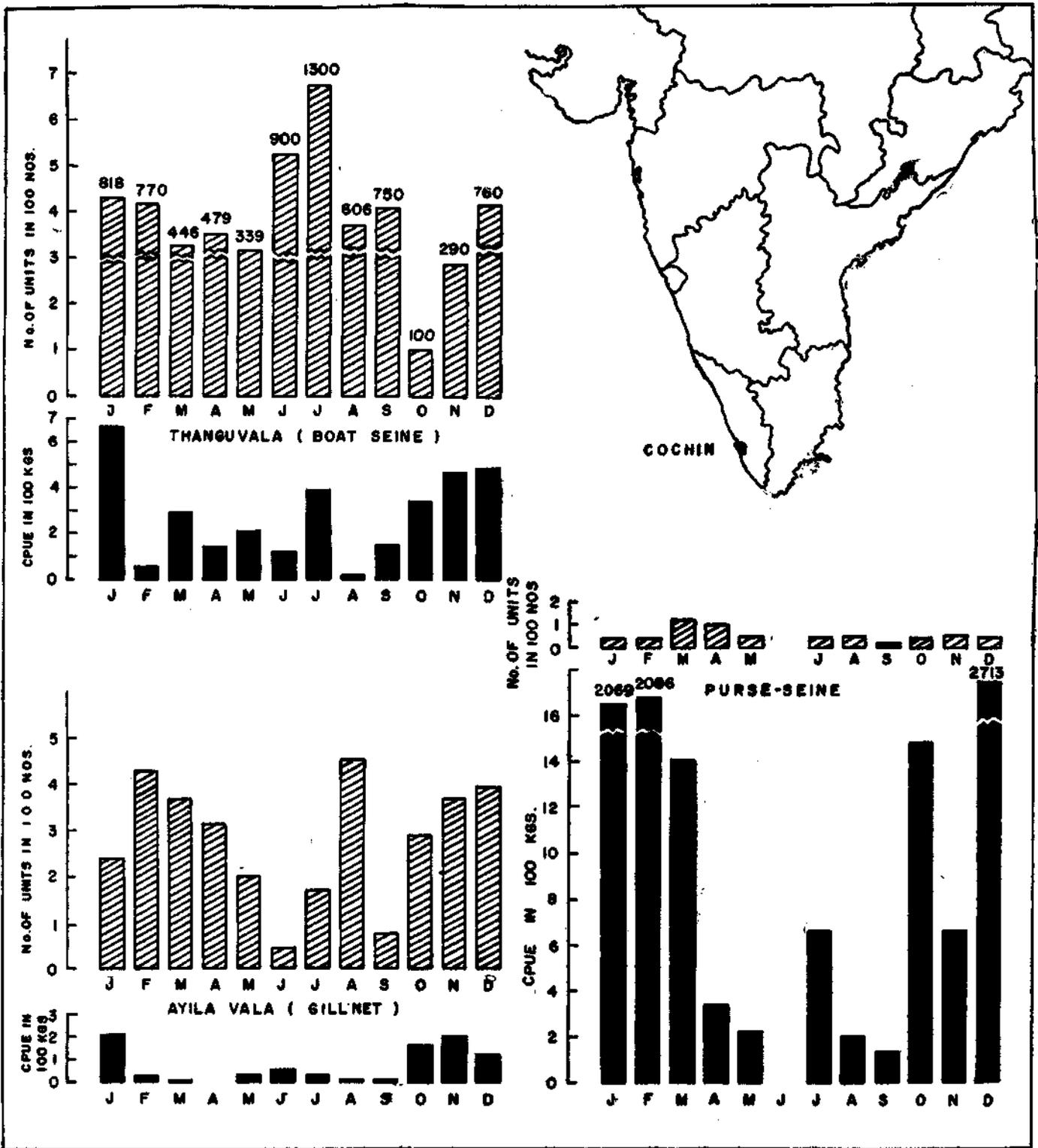


Fig. 4 a. No. of gears and monthly catch per net at Cochin during 1978

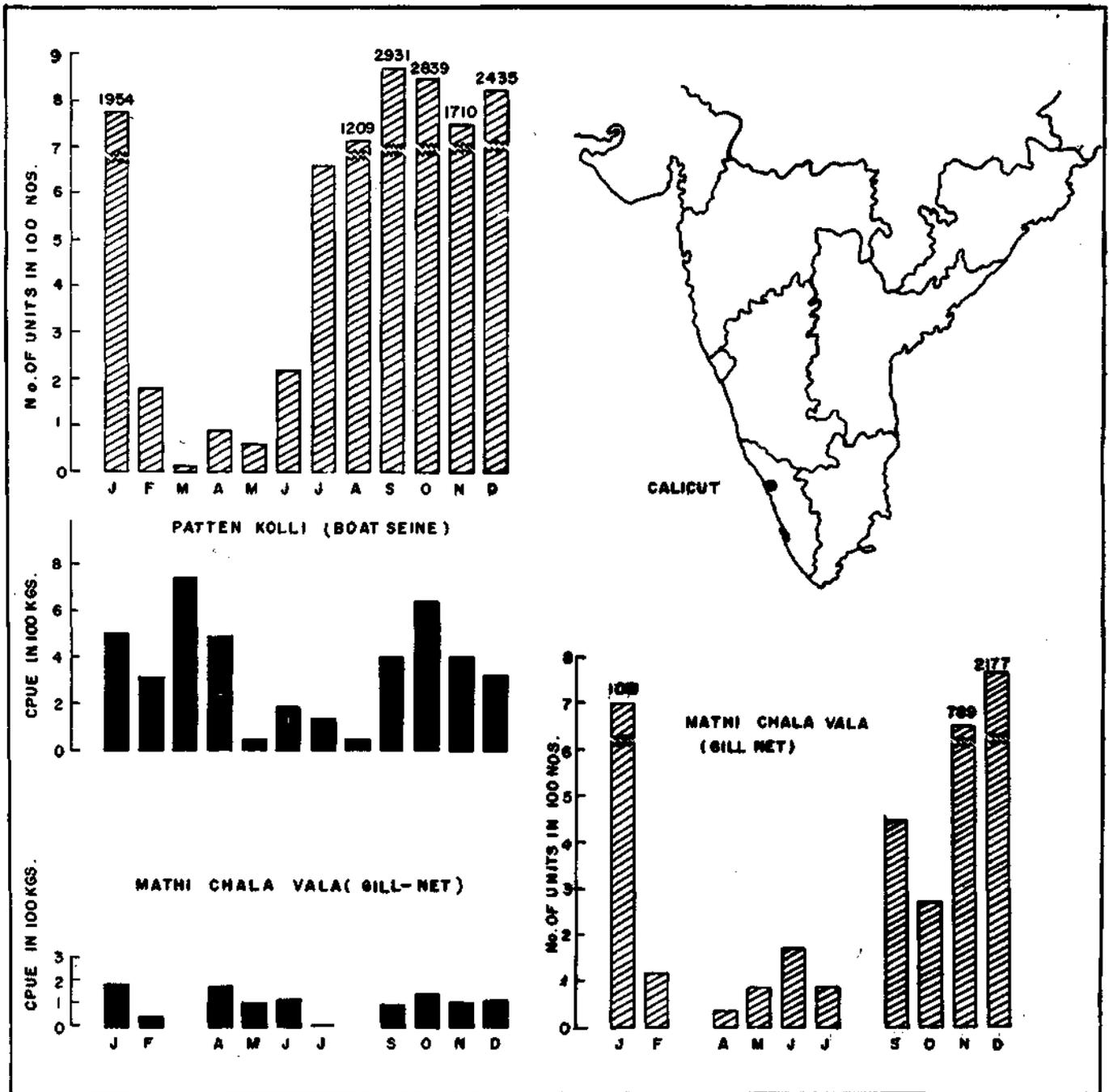


Fig. 4b. No. of gears and monthly catch per net at Calicut during 1978

against 1,938 t. in the previous year by purse seiners which formed 46.26% of the sardine catch for that region, at the high rate of 2,709.1 kg per seine during the year (Fig. 4 c). Among the various year-classes, the 0-year group alone formed 86.09% of the catch of purse seine. During the November-December period most of their catches were reduced to fish meal, consequent on glut conditions. It may be added that heavy concentrations of purse seine operations

in the Bolur-Suratkal area adversely affected the Rampan catches there. Consequently, indigenous gears at Ullal and Baikampady (neighbourhood of Mangalore) landed poor catches (16.7 and 48.6 t. respectively) during 1978.

At Karwar (Fig. 4 d) during 1978, the sardine catches in purse seine and indigenous gears accounted for 291 t. against 96 t. of the previous year. The

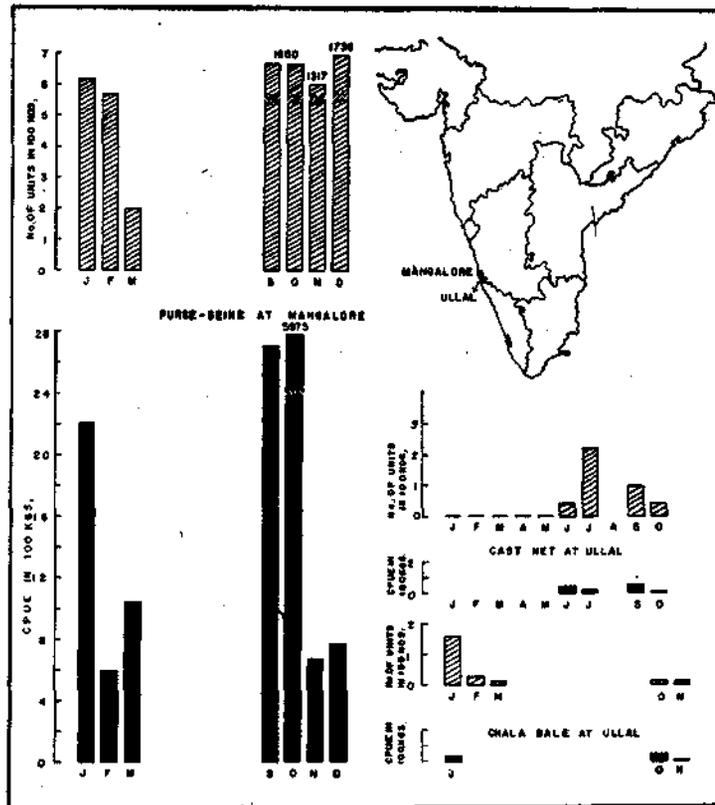


Fig. 4c. No. of gears and monthly catch per net at Ullal and Mangalore during 1978

percentages of the sardine contributions by Rampan, yendi, cast net and purse seine respectively were 11.82, 79.88, 0.09 and 8.21 in 1978. Their catches per net respectively for the year were 186.96, 273.55, 91.70 and 860.7 kg.

Seasonal distribution

The 1977 season persisted almost up to February of 1978 in the country; the fishery of 1978 season commenced in July. The landing was at its peak during August to October. The lean period for the sardine fishery was from March to June.

In the Cochin region, the fishery in 1977 lasted up to March of 1978. The fishery was rather protracted during the year. Though January 1978 had the highest catch (for all the gears combined), the poorest was in August, with only 14 t. Though the catch was lean between April and June period, it was above the average in July.

Along the Calicut coast, though the catches were poor from March to June, the bulk landings were obtained in September and October of 1978.

Relatively good catches were made in the Mangalore region between September and December of 1978 (augmented mainly by purse seiners). However, the catches were poor between February and May.

In the Karwar area, though the previous year's fishery persisted feebly up to February of 1978, the catches were very poor between March and June. The landing was much below the average in September, with further decline in the subsequent months.

Length distribution in 1978

The total length distribution as observed in a few selected centres in the Kerala and Karnataka states ranged between 50 and 215 mm, and this widest range was noticed at the Cochin centre in the Thangu vala catches. At Cochin, the youngest recruits (70 mm mode) started occurring in July. In September, the fast growing juveniles having the 100 and 105 mm modes occurred. The bigger fishes of mainly the 150, 165 and 180 mm modal groups entered the fishery in the subsequent months (Fig. 5 a).

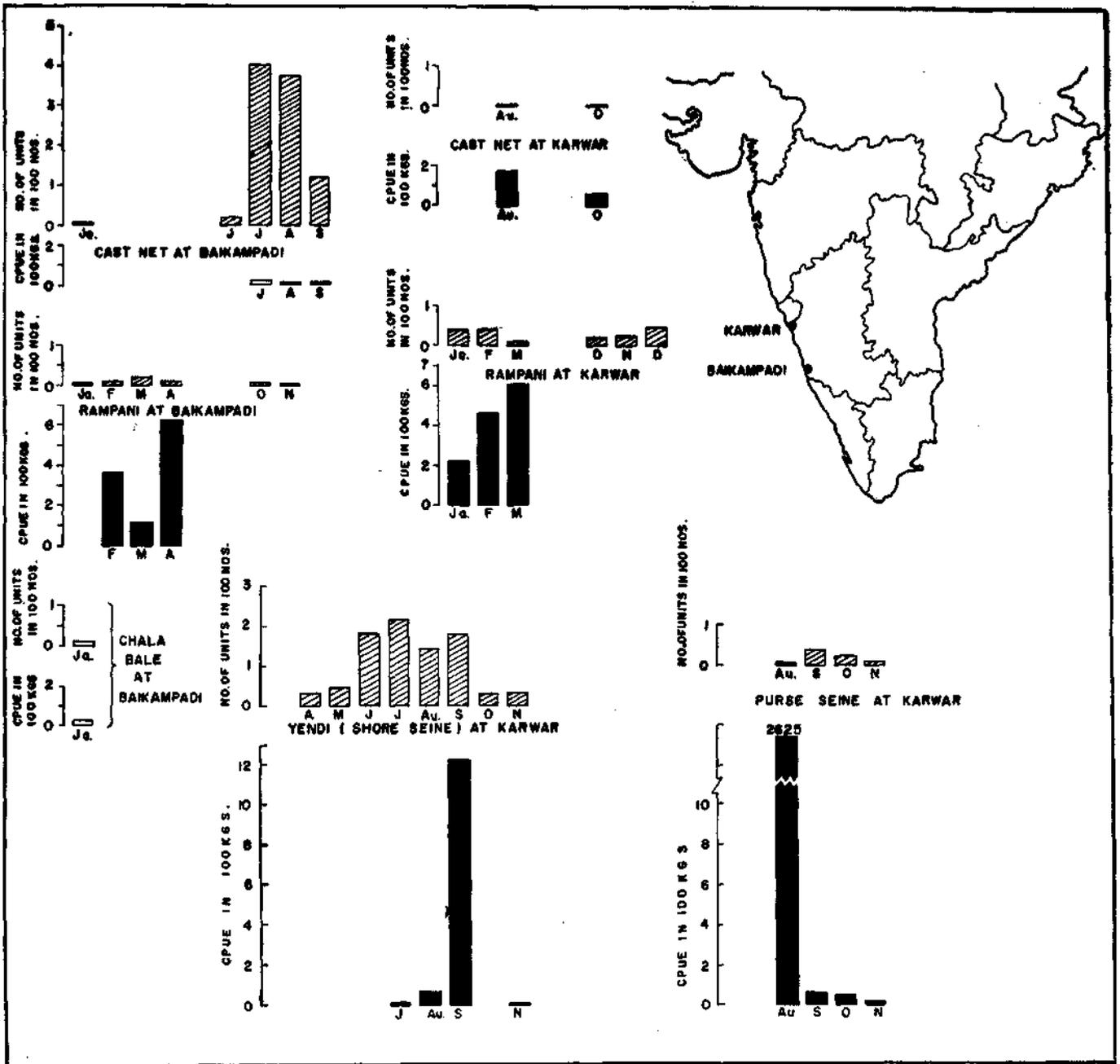


Fig. 4d. No. of gears and monthly catch per net at Baikampady and Karwar during 1978

At Calicut, the youngest recruits (65 mm total length) entered the commercial catches in August 1978. The 115, 125 and 110 mm modal sizes supported the catches from September to November. The juveniles having the 95 and 100 mm modal sizes were seen in January. These fishes were the fast growing 0-year group which were recruited towards the end of 1977. During the period from May to August and October

of 1978, there was a dominance of big-sized fish (having the 175 to 200 mm modal length range) also.

In the purse seine catches of Mangalore though the juvenile recruits having the 100 mm mode appeared in August, the fish having the modal ranges from 100 to 140 mm dominated during 1978. The bigger sized sardines whose modal lengths ranged from 160 to 195

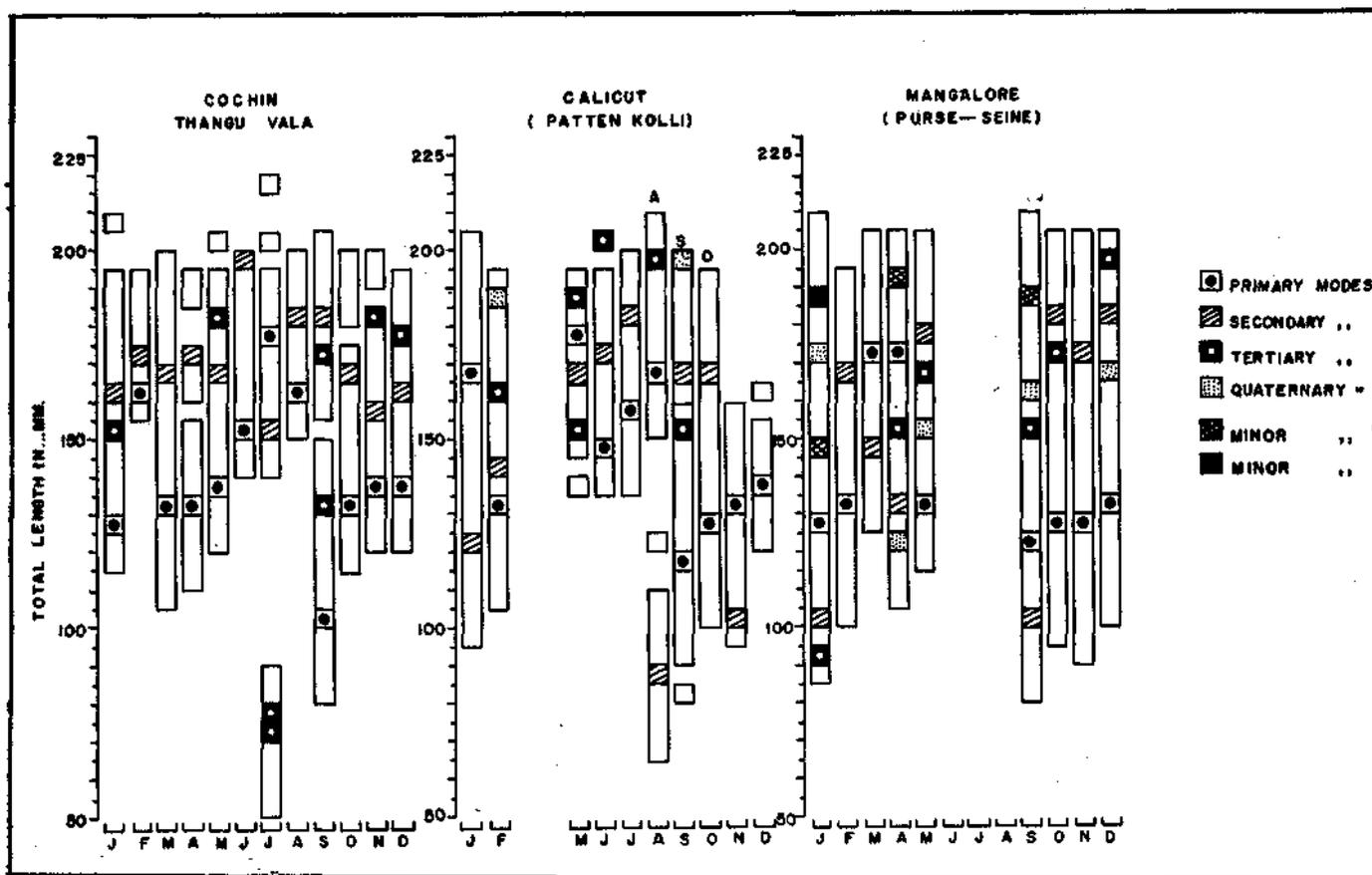


Fig. 5a. Monthly total length ranges and length modes during 1978 at Cochin, Calicut and Mangalore.

mm were also landed in appreciably good quantities. In the cast net catches, though the total length range was from 80 to 130 mm, the mode was at 100 mm. In the Rampan catches, in addition to the 100 mm, the 125 and 155 mm modes occurred. In the occasional trawl catches, the fish having the 135, 170 and 185 mm modes were obtained.

At the Karwar region, in purse seine catches, four dominant modal lengths, viz., 115, 125, 150 and 180 mm were noticed within the total length range of 75 to 195 mm (Fig. 5 b). In the cast net catches at various centres, the total lengths ranged from 80 to 150 and 165 to 210 mm, while the dominant modes were in the 95-135 mm sizes. In the Rampan catches, while the total length ranged from 75 to 205 mm, the prominent modal lengths were in the range 110 to 190 mm during the twelve months. In the yendi catches, though the total length ranged from 50 to 210 mm., the preponderant length modes were in 70-185 mm.

Growth

At Cochin the shifting of length modes from 70 to 135 mm from July to December period revealed a growth increment of 65 mm during the five months and this appears quite normal with the commercial sizes during that period of the year. The growth among the new recruits at Calicut also appears to be 50 mm in four months from August to December of 1978. In the Mangalore area, during the three months from September to December, the growth increase was 35 mm. The trend in growth among the 0-year class at Karwar region also was the same as that of Mangalore, being 35 mm (from 115 to 150 mm) during the August to November period.

Age composition

The size class structure in the commercial catches (based on length frequency studies) at selected observation centres, in the important gears used are given in Table 2. The commercial fishery consisted mainly of 0-year old fish during 1978 at the Cochin, Calicut,

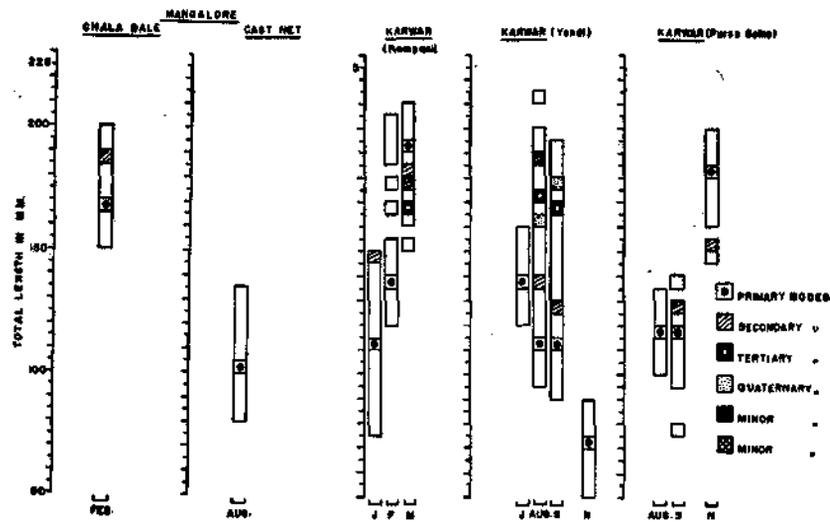


Fig. 5b. Monthly total length ranges and length modes at Mangalore and Karwar during 1978

Mangalore (Ullal and Baikampady) and Karwar centres. Whereas in 1977 the 0-year recruits dominated at Calicut and Baikampady, the 1+ year olds (145 to 170 mm) preponderated at Cochin. However, a marked dominance of the 2+ year and above fish (175 mm and above) was noticeable at Karwar in the Rampan catches.

Table 2. Catch in numbers, of the sardine, per net, in different size classes at selected observation centres.

Place (Net)	Years	0-yr 140 mm	1+ yr (145-170 mm)	2+ yrs & above above 170
Karwar (Rampan)	1978	8,517	487	552
	1977	83	1,509	4,860
Karwar (Yendi)	1978	1,544	53	6
	1977	—	—	—
Karwar (Purse seine)	1978	12,810	16	11
	1977	—	—	—
Karwar (Castnet)	1978	9,022	—	—
	1977	—	—	—
Ullal (Castnet)	1978	1,706	572	220
	1977	—	—	—
Baikampady (Rampan)	1978	32,891	397	—
	1977	44,727	17,601	14,413
Mangalore (Purse seine)	1978	97,796	10,651	5,149
	1977	—	—	—
Calicut (Pattenkolli)	1978	14,271	1,978	1,294
	1977	9,187	3,680	4,197
Cochin (Thangu vala)	1978	7,522	3,061	576
	1977	4,326	8,651	1,884

Age studies by scale method

Detailed age studies by means of scales carried out at Calicut centre indicated that the sardine having 148.5 mm mean length have completed one year, those

having the 170.8 mm mean length two years and those having the 195.2 mm mean length three years respectively during 1978. In the preceding year, the mean lengths corresponding to the 1+yr, 2+yr and 3+yr olds were 158.3, 180.8 and 194.6 mm respectively. During 1975 and 1976 the mean lengths for 1+, 2+ and 3+ years were 155.0 & 158.8, 179.2 & 180.0 and 192.0 & 187.6 mm respectively, closely agreeing with those of 1977 and 1978. It was also noticed that the growth was relatively rapid among the 0+yr and 1+yr old fish and that there were variations in growth rate during the different parts of the year.

Maturation and sex composition (Fig. 6)

At Cochin the stage I and spent-recovering fishes predominated in the first quarter of 1978, while stages III to V were dominant in the second quarter. Though in a large part of the third quarter, the "spent-recovering" stages were dominant, the "indeterminate" stage outnumbered the others during September. Appreciable quantities of stage I and "indeterminate" ones continued to occur during the rest of the year. The fish in oozing stage (VI) is generally not met with in the catches at Cochin. There was a striking preponderance of females throughout the year excepting in August (Fig. 6).

Among the young fish at Calicut the "indeterminate" stage and stage I dominated during the first quarter and from August to the end of the year. Due to the early spawning, the "partly-spent" stage preponderated in June, July, August and September (89.1,

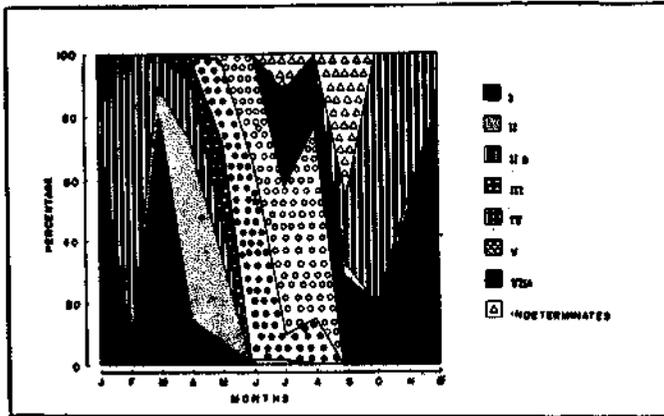


Fig. 6. Monthly percentages of maturity stages of oil sardine at Cochin during 1978.

90.2, 91.3 and 49.2% respectively). In October, the "spent" stage dominated (52.83%). Among the adult fish whose sexes could be determined, the females were predominant in February, July and December; whereas, the males were dominant in June only.

In the Mangalore area, the "partly-spent" stage dominated among the adults in January. From February to May stages I-IV were predominant. During the June-October period, the stage V and "partly-spent" ones outnumbered the rest. With the recruitment of the young fish in August and September, the "indeterminate" stage became predominant. The spent stage was dominant in December. The belated occurrence of the spent ones indicated a protracted nature of spawning in that area. Males outnumbered the females in January, May, June and from October to December.

The stage I was prominent in January, November and December at Karwar. Stages II and III were noticed during February and March. From August to September, the "indeterminate" stage, stage I and spent-recovering ones occurred in appreciable quantities. The partly-spent fish preponderated in July only. In the catches of most of the principal gears, a dominance of females was observed on pooling the entire sex data of 1978.

Vertebral studies

Systematic vertebral counts of the oil sardine made during 1977 and 1978 at Karwar from the Rampan catches indicated a range of 45 to 48, the peak frequency being at 47. The studies on the purse-seine catches also yielded the same results there.

Food

Studies on the food and feeding habits of the fish at Calicut and Cochin centres indicated that it feeds mainly on planktonic micro-organisms. The different items of plankton, either the phytoplankton or the zooplankton, predominated in its diet according to their abundance in its environment during the different periods of the year. Copepods, nauplii, crustacean remains, larval bivalves, tintinnids, dinoflagellates, *Fragilaria oceanica* and certain other diatoms were the major items noticed in the diet.

Assessment of mortality

Length frequency data obtained at Cochin and Calicut during 1976 to 1978 have been analysed. In the case of Calicut data for 1976 and 1978 monthly length frequency distributions indicated modal values repeated over three months successively. In addition, it was also observed that the distribution of modal values during January-March was found to be more or less repeated during July-September. In the case of Cochin for 1976-78, similar trend was noticed indicating the possibility of two distinct spawning seasons with a duration of three months each. Possibility of gear selectivity playing a role in this regard is ruled out as the gear concerned is *Pattenkolli vala*, a non-selective boat-seine.

When the length frequency data for Cochin for the years 1976-78 were analysed using probability paper method, five length groups with means at 67.5, 115.0, 140.0, 166.0 and 195.0 mm respectively were observed in the first year. In 1977 also, five groups were found with means at 106.0, 133.0, 157.0, 180.0 and 202.0 mm. However, in 1978, there were six groups with mean lengths at 66.5, 96.5, 106.5, 130.5, 157.5 and 186.5 mm respectively. In the case of data from Calicut during 1976, similar analysis indicated five groups with their mean lengths at 78.5, 94.0, 138.0, 168.0 and 182.5 mm respectively. From this it is clear that there is no uniformity in the mean length values of the groups.

Detailed age and growth studies by scales on this species as mentioned earlier, indicated three distinct age classes during 1978 with mean lengths at 148.5 mm, 170.8 mm and 195.2 mm respectively. Comparing these results, it may safely be said that the mean lengths of the first three age groups are at 140.0, 180.0 and 205.0 mm respectively. Using these values, the important growth parameters have been estimated.

Mortality rates

Resolving the multimodal curves into unimodal ones facilitates assigning the frequencies to individual unimodal groups. In the case of length frequency data from Cochin during 1976 and 1978, the group pertaining to the age three was not represented. However, in the 1977 data, this group was available but in very small quantities (0.6% of the total). Hence, in the present analysis, a broad classification having two groups only was made so that those coming under one-year group were all kept under the first group and the rest (above that size group) under the second group. The percentage contributions of these groups are given below:

Year	Ist year group %	Above Ist year group %	Cochin			Calicut	
			1976	1977	1978	1976	1978
Cochin 1976	92	8	\bar{l} 159.15	140.17	131.06	149.83	134.47
1977	21	79	l_c 87.5	52.5	52.5	52.5	67.5
1978	55	45	Z 0.68	0.57	0.57	0.46	0.78
Calicut 1976	58	42					

Here also there is no uniformity between years. However, percentage distributions of Cochin in 1978 and of Calicut in 1976 agreed well with each other. Inconsistencies in percentages between years in Cochin may be due to the pelagic nature of the stocks or insufficient sampling or both. At Cochin, the percentages of frequencies for the groups upto mean length at 157 mm and the rest for the years 1976 to 1978 were as follows:

Group/Year	Percentage			
	1976	1977	1978	Average
1. Upto 157 mm mean length	92.0	81.0	98.0	90.0
2. Above 157 mm	8.0	19.0	2.0	10.0

From the scale studies, the frequencies for 2+ year and 3+ year olds from the samples obtained at Calicut are presented below:

Age/year	Frequencies					
	1975	1976	1977	1978	Total	%
2 year	380	311	189	118	998	88.0
3 year	20	35	30	55	140	12.0

From the above, considering the three sets, viz., 81% & 19%; 90% & 10% and 88 & 12%, the corresponding total instantaneous mortality rates (Z) are 1.47, 2.21 and 1.97 respectively.

Beverton and Holt (*Rapp. p.v. Reun. Cons. perm. int. Explor. Mer.* 140 (1): 67-83, 1956) have indicated another method of obtaining estimates for "Z" using only the estimates of K, L_{max} , \bar{l} and l_c , where \bar{l} stands for the mean length caught, l_c for the length at first capture, L_{max} for maximum attainable length and K the growth parameter. Accordingly, the estimates of Z were obtained for comparisons as shown below:

The range of values for Z was found to be from 1.30 to 3.45 by several investigators in the fishery of different areas along the west coast. Here, we have two sets of Z values; one based on probability paper method and the other on Beverton and Holt's method (*op. cit.*) the ranges being 1.47-2.21 and 0.46-0.78 respectively. The last range does not come nearer to any of the other two. However, this range cannot be ignored for the following reasons. The other two ranges are based on age-length distribution study which is not an objective one to be free from personal bias. Many workers have attempted age-length distribution studies without coming to any final agreement. The values of Z obtained in the range 0.46-0.78 are based only on estimates of growth parameters and as such the reliability of these Z values may be relatively more. If that is the case, these Z values irrespective of the present level of indigenous fishing, clearly indicate that total mortality is comparatively less and would not have deleterious effect on the stocks. This has been corroborated by the sustained level of landings of this species for the past ten years. The ranges of survival rates for the corresponding ranges of Z values are given below for ready reference. (Range is indicated in the ascending order of values)

Instantaneous mortality rate	Ranges of values of Survival rate	Source	1.84	0.25	0.46	0.21	6,25,904	2,85,739
			0.50	0.92	0.42	3,15,952	1,42,870	
0.46-0.78	0.49-0.63	Present estimate based on Beverton and Holt's method.	0.75	1.38	0.63	2,08,635	95,246	
			0.90	1.66	0.76	1,72,947	79,181	
			1.00	1.84	0.84	1,56,476	71,435	

Y* = 1,31,440 tonnes, the average of ten years' (1969-78) landings estimates of oil sardine in Kerala State.

1.47-2.21	0.11-0.23	Present estimate based on probability paper method.
1.30-3.45	0.03-0.27	Previous investigations by different authors.

Assessment of stock

Considering $\frac{F}{Z}$ ie., $\frac{\text{Instantaneous fishing mortality}}{\text{Total instantaneous mortality}}$ as 0.25, 0.50, 0.75, 0.90 and 1.00, rough estimates of stock on the basis of average of ten years' catch estimates were obtained. Taking the rate of exploitation $U = \frac{F}{Z}(1 - e^{-Z})$ and Z values as 0.62 and 1.84, being the mid-values of the first two ranges mentioned earlier, average annual stock and average standing stock have been estimated as given below:

Z	$\frac{F}{Z}$	F	U	Y* (tonnes) \bar{U}	Y* (tonnes) $\frac{Y^*}{F}$
				Average annual stock	Average standing stock
0.62	0.25	0.16	0.12	10,95,333	8,21,500
	0.50	0.31	0.23	5,71,478	4,24,000
	0.75	0.46	0.34	3,86,588	2,85,739
	0.90	0.56	0.41	3,20,585	2,34,714
	1.00	0.62	0.46	2,85,739	2,12,000

During the last decade (1969-78), the maximum catch recorded was 1.95 lakh tonnes in 1971 in Kerala State. This clearly indicates that the average annual stock should be above 2.00 lakh tonnes. In the light of this, the values of F against Z=1.84 should be at the most 1.38. Stock estimates obtained by Pelagic Fisheries Project (FAO), Cochin earlier, indicated the stock level at about 4.00 lakh tonnes. This estimate is obtained when Z=0.62 and F=0.46. (In case of Z=1.84 the corresponding F value is estimated at 0.75). Hence, so far as indigenous effort is concerned it may safely be said that the present effort pressure will not have adverse effect on the sardine stocks. However, the recent proliferation of purse seiners off Karnataka State and the presence of a few off the Kerala State may have to be taken note of for detailed studies to see their impact on the stocks. Consequent on purse seining, marked decline in the landings of indigenous gears has already been reported recently along the Karnataka region.

Forecast

From the existing catch trends it is indicated that the sardine catches during the 1980 season would not be far from the average of the last decade. In the light of the stock assessment studies it may be mentioned that increase in fishing effort would result in better catches.

