ON THE FLUCTUATIONS OF THE OIL SARDINE FISHERY AT CANNANORE DURING 1961—1964

P. BENSAM[1]

Central Marine Fisheries Research Institute; Unit, Cannanore

ABSTRACT

The decreasing trend in the catches of oil sardine at Cannanore from 1961-62 season leading to the total failure during 1963-64 and the remarkable recovery during 1964-65 are described. Information on the biology of the fish, based on the catches, such as maturity and feeding activities is briefly given. Observations on the behaviour of the fish in relation to certain environmental conditions have shown that temperature and salinity, perhaps, play a more significant role in the abundance of the population than factors like food or spawning. Juvenile oil sardine appear to have a narrower range of tolerance to temperature and salinity while the adults appear to have a wider range. Abudance of year-classes in relation to their individual contributions to the fishery during each season has shown that the success or failure of the fishery in a given season depends upon the abundance of the juveniles recruited during that season. The probable causes for the failure of the fishery during 1963-64 and for the recovery during 1964-65 are discussed in the light of the data available.

The widespread decline in the fishery for the Indian oil sardine, *Sardinella longiceps* Valenciennes, along the south-west coast of India from 1961 to 1963 followed by its recovery during 1964 (*vide:* Government of India Quarterly and Annual Scientific Reports of the Central Marine Fisheries Research Institute, 1961-1965), offered an opportunity for interpreting the probable causes influencing its yearly fluctuations. During the period 1961-1964 the catch and effort statistics of the oil sardine fishery recorded at Cannanore (a locality in the north sector of Kerala State), have been analysed with a view to understand the behaviour of the fish population in relation to the fishing conditions and environmental factors extant there. Necessary biological information have also been gathered to substantiate the probable causes underlying the fluctuations in the fishery.

1. The period of observation was only up to November 1964 during 1964-65.

1. Present address: Central Marine Fisheries Research Institute; Sub-station, Tuticorin

PROCEDURE

The total monthly landings were estimated by the formulae:

$$M_y = y_i \times \frac{n}{n_i}$$

$$\text{C. P. U. E.} = \frac{M_y}{\frac{n}{n_i} \times g_i}$$

where, M_y denotes the total monthly catches by a particular gear; y_i the actual landings of the gear on all days of observation in the month; n_i usually 6 per week; n the total number of fishing days in the month; and g_i the total number of the gear operated on observation days. The operation of a single net per day is taken as the unit of effort in the case of each type of gear. The catch per unit of effort (C.P.U.E.) is considered as an index of abundance of the population.

Length of the fish referred to in this paper denotes total length. Gonadial maturity stages have been determined based on the key used by the International Council for the Exploration of the Sea, as given by Lovern and Wood (1937). Quantitative as well as qualitative evaluation of the stomach contents have been made for judging the feeding intensities and food preferences, if any. Plankton abundance in the 6-fathom station off Cannanore has been assessed by displacement volumes of the total plankton. Salinity was determined by Oxner and Knudsen method given by Harvey (1945), using 10 ml samples.

PHYSICAL FEATURES OF FISHING GROUNDS

Fishing for oil sardine off Cannanore is mainly conducted at about 5 kilometres from the shore, within a depth range of 5-8 fathoms (Fig. 1), almost throughout the year, except for occasional interruptions during the south-west monsoon period. This area may be designated as the open sea, to distinguish it from another fishing ground for oil sardine located very close to the shore. The region within the depth range of 2-5 fathoms was not exploited at all for the oil sardine, during any part of the period under study. Fishermen have reported that this area is virtually devoid of oil sardine, though other fish like silverbellies and prawns are found there.

The other fishing ground for oil sardine is situated in the Cannanore Bay or Mopla Bay (Fig. 1). The depth of the bay is about 2m at a distance of about 1/2 km and 4 m at a distance of one km from the shore. The bottom within the 1-3m zone, is sandy or muddy.

METHODS OF CAPTURE

The principal gears used to capture oil sardine off Cannanore are *arakolli-vala* and *mathikolli-vala*, both boat-seines. Certain other gears, *ailakolli-vala*,

thattum-vala, *nethel-vala* (boat-seines) and *mathichala-vala* (gill-net) which operate rarely off Cannanore and bring in negligible catches of oil sardine are not considered for the purpose of the present study. The units of *arakolli-vala* are operated throughout the year irrespective of the availability or otherwise of the oil sardine and conduct fishing only in the open sea. The units of *mathikolli-vala* are used to capture only the oil sardine occurring inside the Bay.

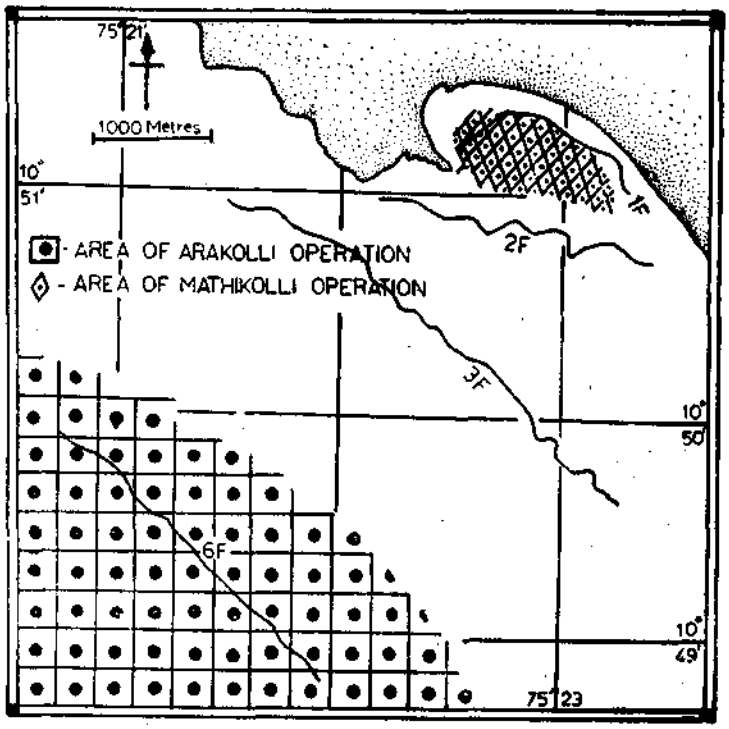

FIG. 1. Map of the sea adjoining Cannanore showing the fishing grounds of oil sardine, the open sea and Cannanore Bay, where *arakolli-vala* and *mathikolli-vala* respectively have been operated (Adapted from Admirality Chart).

TABLE 1. *Particulars of the total catches by* arakolli-vala *and* mathikolli-vala *during the fishing seasons of* 1961-1964 *period (in tonnes)*

	1961—62	1962—63	1963—64	1964—65
Catches by *arakolli-vala:*	1895.22	565.21	235.174	2242.26*
Catches by *mathikolli-vala*	997.67	1053.34	130.550	24.18*
Total catches:	2892.89	1618.55	365.724	2266.44**

* The *arakolli-vala* catches given include only those for the months July - November 1964 while the catches of *mathikolli-vala* include only those of November 1964, before which these units were not operated during 1964-65 season.

** Total catches include only those of July-November.

The total catches of oil sardine by the two gears during the different seasons of the period 1961-1964 are given in Table 1. From the table it appears as though the landings of *arakolli-vala* are generally higher than those of *mathikolli-vala*. This is beacause the period of *mathikolli-vala* operations is shorter than that of *arakolli-vala*. However, the trend of variations in the catches of the two gears during the months when both have been operated, depicted in Fig. 2 reveals that the monthly landings of *mathikolli-vala* are usually higher than those of *arakolli-vala*. A few exceptions to this are also observed such as during the months of December 1961 and March 1962. A study of the C.P.U.E. of the two gears represented in Fig. 3 shows that the C.P.U.E. of *mathikolli-vala* is generally more than that of *arakolli-vala*, usually double, increasing to as high as nine-fold as in November 1963. Even during months such as March 1962 when the catches of *arakolli-vala* are higher, the C.P.U.E. of *mathikolli-vala* is more than that of the former.

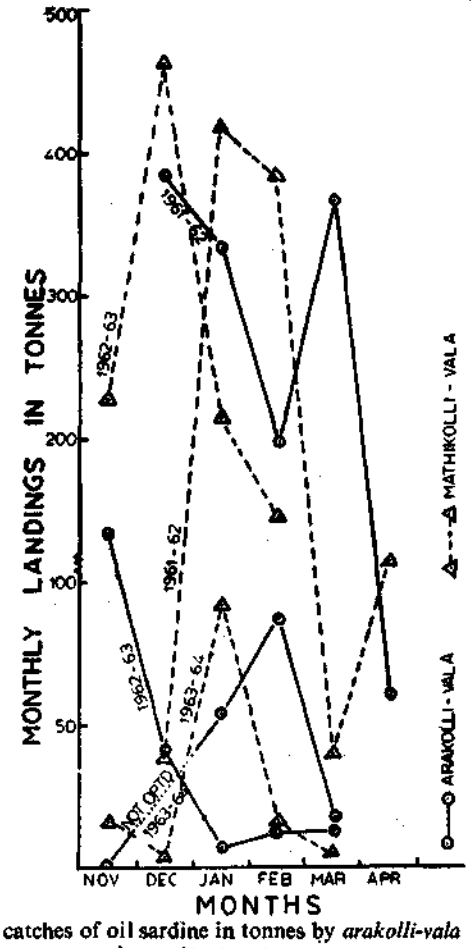

FIG. 2. Total monthly catches of oil sardine in tonnes by *arakolli-vala* and *mathikolli-vala* (from the open sea and the Bay respectively) during the months when both the gears were operated in the 1961-62, 1962-63 and 1963-64 seasons.

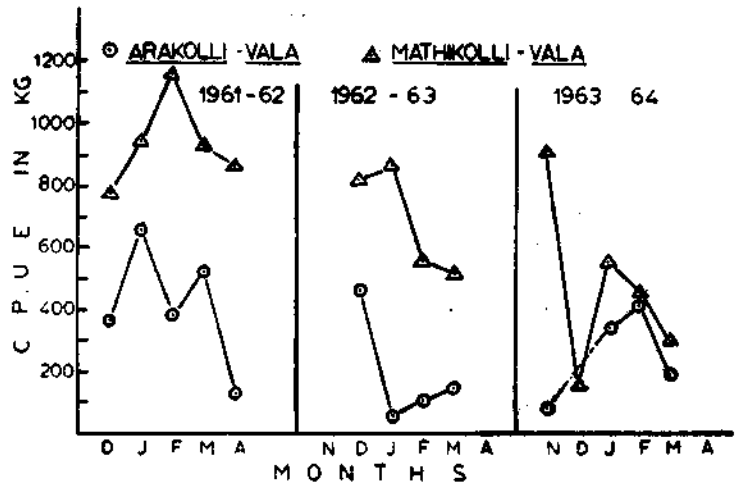

FIG. 3. Catch per unit of effort in kg in respect of *arakolli-vala* and *mathikolli-vala*, during the months when both the gears were operated in the 1961-62, 1962-63 and 1963-64 seasons.

CONTRIBUTION OF ADULTS AND JUVENILES TO THE LANDINGS

As observed by previous authors (Chidambaram, 1950; Nair, 1953), it is the spawners which appear earlier in the coastal waters of Malabar, by July or August. They are followed by the indeterminate and immature fish during September-October. These two groups are easily distinguishable from one another by differences in their size-ranges, dominant modes and maturity conditions. The spawners have sizes ranging between 130 and 194 mm, dominant modes varying from 145 to 175 mm and gonadial maturity ranging from mature, spawning, spent (stages III to VII) to recovering and recovered stages. This group has been recruited into the fishery as immature fish in the preceding season and continues to be present as spawners etc. during the season under study. The fish comprising this group are designated as adults. The other group is composed of oil sardine in the size-range of 51-145 mm, with dominant modes ranging from 105 to 135 mm and gonadial maturity attaining not more than stage II. This is recruited into the fishery during the season under study and the fish comprising the group are designated as juveniles.

The contributions of juveniles and adults to the catches of *arakolli-vala* and *mathikolli-vala* during the months when both have been operated are given in Table 2. The juveniles form the bulk of the landings. The contribution of adults to *mathikolli-vala* catches is even less than their proportion in the *arakolli-vala* landings. However, a study of the length-frequency distributions of juveniles and adults caught by the two gears has shown that the size-ranges and dominant modes of the two groups captured in one gear on a particular day are similar to those of the corresponding groups caught in the other gear, irrespective of the differences in their contribution. This is obviously due to the fact that, because of

TABLE 2. *Monthly contributions of juvenile and adult oil sardine (in tonnes) to* arakolli-vala *and* mathikolli-vala *catches in the course of* 1961-1964, *when both the gears were operated*

Name of gear	1961—62				1962—63				1963—64			
	Arakolli-vala		*Mathikolli-vala*		*Arakolli-vala*		*Mathikolli-vala*		*Arakolli-vala*		*Mathikolli-vala*	
Name of group	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults
Dominant mode (in mm.)	115; 125	115; 165	115; 125	155; 165	105; 115; 125	145; 155; 165; 175	105; 115; 125	145; 155; 165; 175	115; 125; 135	155; 165; 175	115; 125; 135	155; 165; 175
November	**		Not operated		132.08	2.69	224.86	4.58	0.170	0.004	16.00	0.25
December	375.05	9.20	39.25	Nil	41.30	Nil	462.50	0.45	Not operated		**	
January	179.20	154.70	419.30	Nil	6.00	1.50	172.40	43.10	44.760	7.520	85.00	7.82
February	197.71	1.78	384.00	Nil	3.42	9.24	139.93	5.52	75.080	12.500	15.44	1.50
March	284.20	83.00	40.00	Nil	**		Not operated		20.900	3.200	4.09	0.45
April	51.93	9.43	Nil	115.12	**		Not operated		Not operated		Not operated	
Total	1088.09	258.11	882.55	115.12	182.80	13.43	999.69	53.65	140.910	23.224	120.53	10.02

** Catches not included, as the other gear not operated.

their identical mesh-sizes both the gears exercise the same pattern of selectivity. It then follows that the smaller proportion of the adults in the catches of the *mathikolli-vala* units is only the result of their lesser abundance in the locality of their fishing.

Fluctuations in the fishery

The trend of the monthly landings of oil sardine at Cannanore during 1961-1964 is represented in Fig. 4. The fishery during the 1961-1962 season has been moderately good, with estimated total catches of 2884.89 tonnes. The peak landings of 753.20 tonnes appeared in the month of January 1962, after which the fishery gradually declined in the subsequent months. The total landings during the 1962-63 season were only 1618.49 tonnes. The highest monthly catch of 504.25 tonnes was obtained during the month of December 1962, which was earlier by one month when compared to 1961-62. The rate of decline after the peak in 1962-63 was the most rapid as compared to the previous and succeeding seasons. The landings during 1963-64 were the poorest recorded during the period under study and amounted to a meagre 365.72 tonnes. The monthly maximum of 145.10 tonnes, appearing in January 1964 was the lowest of the monthly peaks observed during 1961-64. The decline after the peak was gradual. The fishery of 1964-65 season recorded a sudden and remarkable recovery from the set-back

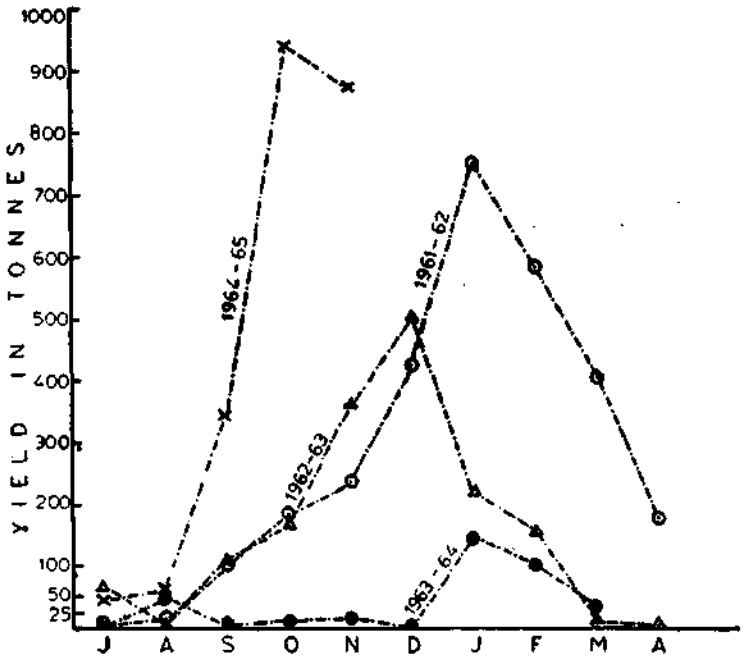

Fig. 4. Trend of monthly production of the oil sardine at Cannanore (caught by both *arakolli-vala* and *mathikolli-vala*) during 1961-62, 1962-63, 1963-64 and part of 1964-65 seasons.

observed during the previous season. The total landings of 4499.06 tonnes, (*vide* Government of India, Annual Scientific Report of the Central Marine Fisheries Research Institute for the period ending 31-3-1965)[1] were a record catch for the four seasons. The monthly peak of 939.80 tonnes, an yield of unequal magnitude when compared with the other peaks during 1961-1964, occurred during October 1964.

It is evident from the above that in spite of the set-back of the fishery during 1963-64, a remarkable revival has been registered in the succeeding season, indicating that the success of the fishery during a given season need not always depend upon the trend of the fishery of the preceding season. However, the gradual decline from 1961-62 to the poor catches during 1962-63 and total failure during 1963-64 points out that the failure during 1963-64 may have some relationship with the decline during the preceding season. Hence, to assess the probable causes for the failure of the fishery during 1963-64 and for the recovery during 1964-65, it becomes necessary to analyse the fluctuations in the strength of the population and the relationship, if any, of the strength of the year-classes with their contributions to the fishery.

Variations in population abundance

The C.P.U.E., an index of abundance of the population, in respect of the standard gear, *arakolli-vala*, is depicted in Fig. 5. From the figure it is evident that the density of the fish in 1961-62 increased gradually from July 1961 till January 1962, followed by a gradual decrease. The decrease from the peak month to the succeeding month, from 657.20 kg per unit to 380.70 kg per unit, is at a rate of about 43%. The corresponding figures during 1964-65 are from 1491.00 to 1127.00 kg per unit, at a rate of only 25%. During 1963-64, however, the C. P. U. E. from the month of maximum landings to the following month, has shown an increase from 337.10 to 407.30 kg, per unit, at a rate of about 20%. During 1962-63 season, on the other hand, a very unusual feature has been observed, in that, the C.P.U.E. registered a sudden and steep decrease from the maximum of 474.80 kg during December 1962 to 57.70 kg during January 1963, at an alarming rate of 88%. This is the steepest fall in abundance recorded during the four seasons and presents an abnormal pattern of behaviour of the population. However, this does not appear to have any perceptible adverse effect on the normal changes in the abundance of the population in the subsequent fishery, which indicates the independence of the population strength of the different seasons. However, the unusual fall in abundance of the population during 1962-63, followed by the total failure of the fishery during 1963-64, points out that the former might have played some role in causing the latter.

Changes in abundance of year-classes

The contribution of each year-class to the fishery, identified as A, B, C, etc., with the dominant modes and maturity conditions are given in Table 3. It

1. The period of observation was only upto November 1964 during 1964-65.

TABLE 3. *Monthly contribution of juveniles and adults (in tonnes) to the catches at Cannanore in each season during 1961-1964, named under year-classes A, B etc.*

	1961—62		1962—63		1963—64		1964—65	
	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles	Adults	Juveniles
Dominant modes in mm	155-165	115-125	145-175	105-125	155-175	115-135	175	105-125
Maturity	III-RII*	N-II**	III-RII	N-II	III-RII	N-II	III-RII	N-II
Name of year class	A	B	B	C	C	D	D	E
July	3.52		67.70		0.20		46.82	
August	12.90		7.50		50.60		47.60	13.14
September	99.10	4.30	2.60	106.90	6.20		13.70	332.50
October	6.16	176.74	43.30	126.60	0.30	10.00		939.80
November		238.30	7.27	356.90	0.25	16.17	24.18	848.70
December	9.20	414.30	0.45	503.80	1.10	2.64		
January	154.70	598.50	44.60	178.40	15.34	129.76		
February	1.78	581.71	14.76	143.35	14.00	90.52		
March	83.00	324.20	13.30		3.65	24.99		
April	124.55	51.93	1.06					
Total	494.91	2389.98	202.54	1415.95	91.64	274.08	132.30	2134.14 ***

* 'R' signifies recovered condition of gonads.

** 'N' signifies indeterminate condition of gonads.

*** The total catches given here include only those of the months of July - November 1964.

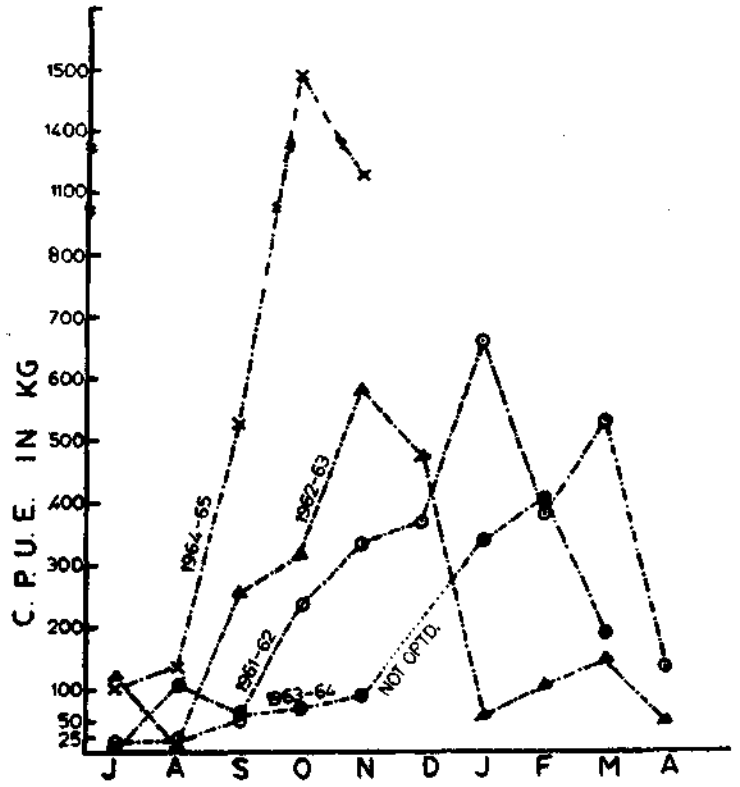

FIG. 5. Variations in the catch per unit of effort (C.P.U.E.) of oil sardine (in kg in respect of the standard gear *arakolli-vala*) during the different months in the 1961-62, 1962-63, 1963-64 and part of 1964-65 seasons.

is apparent from the table that during 1964-65, 1961-62 and 1962-63 the juveniles (E, B and C respectively) have contributed to the bulk of the catches while the adults (D, A and B respectively) formed only minor proportions of the landings. The contribution of juveniles during 1962-63 (C) has been good in the beginning. Since December 1962, however, this class has become scarce, resulting in very poor catches during January and February 1963 and completely absent during the remaining part of the season. The landings during March and April 1963 have been composed only of the adults (B). The poor fishery during 1963-64, as may be seen from the table, is due to the very poor representation of the juveniles recruited (D) which formed the smallest proportions of the landings when compared to the contributions of juveniles during 1961-62, 1962-63 and 1964-65 seasons (B, C and E respectively). It may also be noted that the sudden revival of the fishery during 1964-65 is due to the remarkably good catches of the juveniles recruited (E).

The importance of the juveniles in deciding the trend of the fishery during the season in which they are recruited, may be better assessed by a study of the

seasonal C. P. U. E. of the different year-classes in relation to the seasonal catches from them, depicted in Fig. 6. It can be seen that the good landings during 1964-65, 1961-62 and 1962-63 are largely due to the higher abundance of the juvenile classes recruited in those seasons (E, B and C respectively). During 1963-64, on the other hand, the juveniles recruited (D) have been very low in abundance and catches from them are also very small, in fact the smallest when compared with the abundance and landings of the juveniles during the other seasons. The adults have shown the highest level of abundance in 1963-64 (C); in spite of this the fishery during 1963-64 was a total failure, indicating that the role of the adults in ensuring the success or failure of the fishery is not so important as that of the juveniles. It is further substantiated by the fact that the low level of abundance of the adults during 1964-65 (D) did not reduce the population strength of the oil sardine, as the juveniles appeared in very high abundance during 1964-65. This study also points out that the abrupt fall in abundance of the juveniles from December 1962 to January 1963 (from 474.80 kg per unit to 46.10 kg per unit), a fall of unequal proportions for the juveniles during the period 1961-1964, is a reflection of some adversity suffered by them.

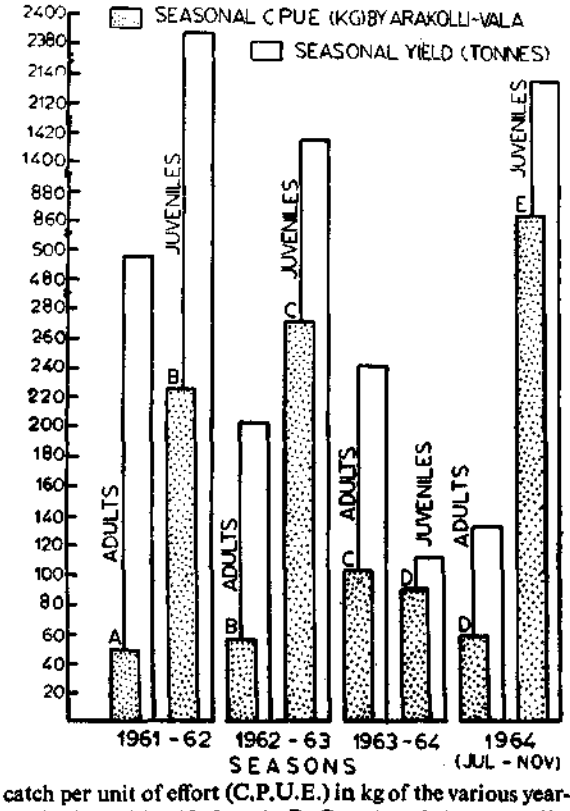

FIG. 6. Seasonal catch per unit of effort (C.P.U.E.) in kg of the various year-classes of oil sardine (juveniles and adults, identified as A, B, C etc.) and their contribution to the fishery in tonnes during 1961-62, 1962-63, 1963-64 and part of 1964-65 seasons.

FISHERY IN RELATION TO SOME ENVIRONMENTAL FACTORS

Plankton abundance

The qualitative and quantitative composition of the plankton off Cannanore was generally found to agree with that of the plankton off Kozhikode, a nearby centre (George, 1953; Subrahmanyan and Sarma, 1960). November - March is a period of low plankton abundance off Cannanore. This period coincides with the months of maximum exploitation of the oil sardine in the coastal waters. The monthly peak landings of oil sardine also usually occur in the course of this period.

Temperature and salinity

Variations in temperature and salinity observed during 1961-1964 are represented in Fig. 7. Temperature and salinity values have varied between 26.2 and 30.6°C,

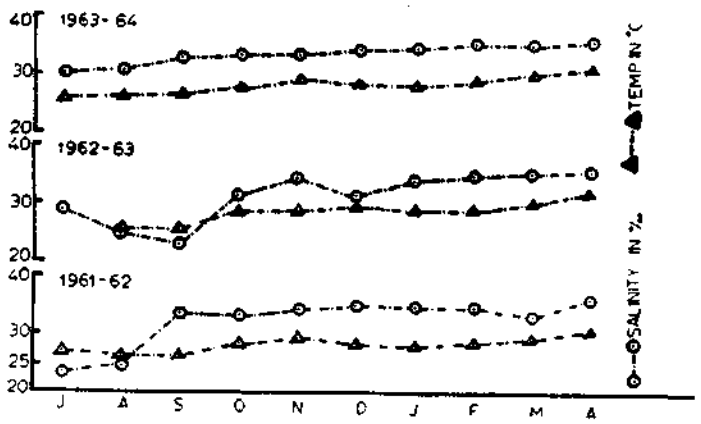

FIG. 7. Trend of monthly average variations of temperature and salinity in the 6-fathom station off Cannanore during 1961-62, 1962-63 and 1963-64 seasons.

and 23.5 and 36.3‰ respectively during the fishing season of 1961-62; between 25.5 and 30.8°C and 24.9 and 34.3‰ respectively during 1962-63; and between 25.9 and 30.9°C and 30.2 and 35.4‰ respectively during 1963-64. However, temperature and salinity during the months of higher abundance of oil sardine (November - March) fluctuated usually within 27 - 28°C, and 34-35‰. These limits are considered to be the optimum values for the fish in the coastal waters as observed by Chidambaram (1950) and Nair (1953). Temperature and salinity during July - September period, when catches of oil sardine are smaller, are generally lower and range within the values of 25.5 - 26.9°C and 22.8 - 33.5‰. The increases towards optimum conditions are observed only during September - October. Similarly, temperature and salinity values towards the end of the season, during March - May period, show increasing trends from the optimum conditions. Temperature and salinity during this period range between 29.1 and 30.8 °C and 34.3 and 36.3‰ respectively. During this period oil sardine landings also show a decreasing trend leading to total absence during May - June period.

The fishery in relation to the variations in temperature and salinity conditions prevailing during 1961 - 1964, given in Table IV. shows certain interesting features. During 1961-62 when temperature and salinity variations recorded average values of 0.70°C and 1.70‰ respectively the catches were fairly good and the C.P.U.E. showed normal increase and decrease. During 1962-63, on the other hand, temperature and salinity variations showed high fluctuations, the average values being 1.45°C and 2.67‰. The catches during this season became considerably smaller showing

TABLE 4. *Average variations of temperature and salinity of the surface waters in the 6-fathom area off Cannanore during* 1961-1964.

	Average temperature variations in °C	Average salinity variations in ‰	Total seasonal catches in tonnes
1961—62	00.70	01.70	2892.89
1962—63	01.45	02.67	1618.55
1963—64	00.85	00.73	365.72

a decrease of 43%; and concurrently the steepest fall in abundance of the population as a whole and juveniles in particular has taken place, as described earlier. During 1963-64 temperature and salinity have shown normal ranges of variations, the average values being 0.85°C and 0.73‰. But the total landings have decreased to a meagre quantity of 365.72 tonnes, recording a decrease of more than 75% from the previous season's catch. However, the trend of increase and decrease in the abundance of the population has shown a normal pattern, as seen before. It appears quite probable that this is due to the narrower range of variations of temperature and salinity prevalent during 1963-64. On the other hand, the widest range of variations observed during 1962-63 appears to have caused the abrupt fall in abundance of the population. It is also probable that the unusual variations recorded during 1962-63 might have had some effect on the fishery of the succeeding season.

DISCUSSION

Hornell and Nayudu (1924) have stated that the shoreward migration of the spawners and juveniles "is to feed upon the immense quantities of unicellular plants and animals which develop and concentrate in the sheltered coastal waters towards the close of the south-west monsoon". This is, obviously, based upon the commencement of the plankton abundance coinciding with the appearance of the fish in the inshore areas, which suggests that the former incident is followed by the latter. But the continued abundance of the spawners in the coastal regions during November - March period, despite the decline in plankton abundance, appears contradictory to the believed relationship of plankton abundance and migration of spawners. Nair

(1959), noting the empty stomachs of the spawners, believed that their shoreward migration is for "spawning only". It may be noted in this connection that oil sardine with fully ripe gonads as well as planktonic eggs and larvae of this fish have rarely been recorded from the Malabar coast. In fact the eggs and larvae have been reported from the Malabar coast only on two occasions so far, by Devanesan (1943) and Nair (1959). All this seems to indicate that the oil sardine does not spawn near the coastal areas, whereas, a few allied species that occur in much smaller abundance such as *Kowala coval, Anodontostoma chacunda, Opisthopterus tardoore, Sardinella jussieu, S. sirm, Anchoviella* spp and *Thrissocles* spp are observed to spawn near the shore as evidenced by the presence of spawners in the catches and eggs as well as larvae in the plankton. Hence, the primary cause for the appearance of the oil sardine spawners in the coastal areas does not seem to be related to feeding or spawning.

The juveniles enter the coastal waters well after the commencement of plankton abundance there. Their increasing abundance during November-March, when plankton abundance as well as feeding intensities are considerably lower, is noteworthy in this connection. While it may be inferred that the low plankton volumes are caused by the fish population grazing on them, as suggested by Subrahmanyan and Sarma (1960), the lower values of stomach contents indicating less feeding, and the increasing abundance of the juveniles in the coastal areas during November - March, without migrating to a better food environment elsewhere, appear quite contradictory to the accepted relationship. It is evident therefore that the migration of both juveniles and adults to the inshore waters is not principally controlled by food or spawning but by some other factors.

With regard to the behaviour of the oil sardine, juveniles as well as adults, to the varying conditions of temperature and salinity certain interesting observations have been made from the data collected. During April - June, the warmest part of the year, the higher temperature and salinity values coincide with the absence of the fish in the coastal waters, as recognised by earlier authors. The fish make their appearance in the inshore areas rather suddenly, soon after the commencement of the rains in July - August when temperature and salinity values are lowered. It is the adults that appear first. From July - September the exploited population is composed entirely of the adults and temperature and salinity during this period are usually below 26°C. and 30‰ respectively. The values of temperature and salinity approach the optimum (27 - 28°C and 34 - 35 ‰) in the months of September - October when the juveniles enter into the fishery, quite suddenly. It is improbable that they may not be vulnerable to the fishing efforts during July - September, if assumed to be present, because the gears, crafts and exploited grounds are the same before as well as subsequent to September - October period. Scarcity of food does not appear to be the cause for their absence, because plankton abundance has already commenced. It is evident therefore that the absence of juveniles in the inshore waters prior to September - October is due to the prevailing lower values of temperature and

salinity during July - September, which appear to be unfavourable for them and act as a barrier restricting them from entering the coastal areas. The presence of adults prior to September - October points out that the lower values of temperature and salinity are within the range of their tolerance.

The patterns of disappearance of the juvenile and adult oil sardine towards the end of the fishing season when temperature and salinity show increasing values also present certain differences. As observed during April 1962 and April 1963, when temperature and salinity have risen to 30.6°C and 36.2‰, and 30.8°C and 34.7‰ respectively, the catches of adults are 124.5 and 1.06 tonnes but the catches of juveniles are 51 tonnes and nil respectively. These show a more rapid rate of decrease of the juveniles, which have formed the mainstay of the landings not much before, than of the adults which have contributed only to a minor proportion of the catches before. It is obvious that the increasing temperature and salinity are felt by the juveniles rather immediately, while the adults which appear to have a higher range of tolerance, leave the coastal waters a little later. Pradhan and Reddy (1962) arrived at a similar conclusion for the Indian mackerel in that the younger fish are observed to have a narrower range of tolerance when compared with older fish.

From the above consideration it appears that the oil sardine abound in the inshore waters when temperature and salinity are most favourable during November-March period. Sekharan and Dhulkhed (1953) while dealing with the oil sardine fishery of Mangalore zone state that "the length of the fishing season apparently depends mainly on the duration of the period of intermediate values of temperature and salinity". As seen from the present studies also these factors appear to play a vital role on the appearance as well as disappearance of the fish in the coastal areas. Factors such as feeding and spawning impulses seem to play a role, if any, secondary to temperature and salinity in influencing the movements of the oil sardine.

It is difficult to formulate the magnitude of the set-back suffered by the juveniles recruited during 1963-64, resulting in the failure of the fishery, because the relationship between the parent stock and its progeny has not been elucidated in the case of the oil sardine. According to Hornell and Nayudu (1924) the juveniles recruited during a season are the products of the same year's spawning, implying that they are hardly 5-6 months old while entering the fishery and that the adults occurring along with them form part of their parent stock. However, Chidambaram (1950) and Nair (1953) have indicated that the juveniles recruited during a season are the products of the previous year's spawning, implying that they are about 1½ years old when entering the fishery and that the adults occurring along with them do not form part of their parent stock but give rise to the juveniles recruited during the succeeding season only. For instance, if the juveniles of 1963-64 (D) are considered 5—6 months old based on the first view they are the progeny of the adults of 1963-64 (C); whereas the same juveniles if considered 1½ years old, based on the second view, are to be taken as the progeny of the adults of 1962-63 (B).

Under these circumstances, to interpret the probable causes for the failure in the recuritment of a good juvenile class during 1963-64. it is necessary to examine whether the prevailing temperature and salinity conditions have been favourable or not during 1962-63 as well as 1963-64, as these are observed to have a profound effect on the population, particularly juveniles. From the data available it has been seen that temperature and salinity values showed the widest range of variations during 1962-63 and that it is reflected in the abrupt and steep fall in the abundance of juveniles (C) from December 1962 to January 1963. Besides, though the abundance of juveniles is less, the fishing effort has been considerably high during 1962-63, which might have also affected the stock by the time the fishing season has come to a close All these, quite probably, have contributed to the fall in abundance of the potential spawners during 1962-63 (C). The strength of the adults in the second year of their life in the fishery during 1962-63 (B) is apparently too small to compensate for the loss sustained by the juveniles (C). This might have led to the failure in giving rise to a substantially rich juvenile class during 1963-64 (D). However, giving credence to the second view, it follows that temperature and salinity during 1962-63, being unfavourable, would have caused unusual mortality of the eggs, larvae and juveniles, leading to the failure in producing a rich juvenile class during 1963-64. Thus, whatever view is taken into consideration, the role of temperature, salinity and probably the other links in the hydrographical chain on the oil sardine biology and fishery appears to be very significant.

Similarly the sudden recovery of the fishery during 1964-65, because of the success in the recruitment of a rich juvenile class (E), may be interpreted as either due to the success in the survival of the potential spawners during 1963-64 (D) or of the eggs and larvae under the prevailing conditions of normal ranges of temperature and salinity. The production of a rich juvenile class is naturally to be expected during 1964-65, thus causing the recovery.

The fishermen of Malabar are reported to have the belief that indiscriminate fishing with such a gear as *mathikolli-vala* is responsible for the scarcity of the fish in the succeeding years (Balan, 1961). It may be noted in this connection that the juveniles being responsible for the fluctuations in the fishery and the fish having a quick replenishing potential as observed from the present studies, it appears that the fishing mortality may not influence the future stock so much as the variations in the hydrographical conditions.

ACKNOWLEDGEMENTS

My deep gratitude is due to Dr. S. Jones, for the kind help and encouragement given in the course of my work and for the valuable discussions I had with him on some aspects dealt with in this paper. I am indebted to Mr. S.K. Banerji for critically going through the manuscript and for offering advice for its improvement. I am also grateful to Mr. P.C. George and Mr. K.V. Narayana Rao for the help given in the

course of the present studies and to Mr. K. Srinivasa Rao, for going through the manuscript and for the suggestions offered which had been of immense use in recasting the paper.

REFERENCES

BALAN, V. 1961. Some observations on the shoaling behaviour of the oil sardine, *Sardinella longiceps* Cuv. and Val. *Indian J. Fish.*, 8(1): 207-221.

CHIDAMBARAM, K. 1950. Studies on the length-frequency of the oil sardine, *Sardinella longiceps* Cuv. and Val. and on certain factors influencing their appearance on the Calicut coast of Madras Presidency. *Proc. Indian Acad. Sci.*, 31(5): 252-286.

DEVANESAN, D.W. 1943. A brief investigation into the causes of the fluctuation of the annual fishery of the oil sardine of Malabar, *Sardinella longiceps* Cuv. & Val., determination of its age and an account of the discovery of its eggs and spawning grounds. *Madras Fish. Bull.*, 28(1): 1-38.

GEORGE, P.C. 1953. The marine plankton of the coastal waters of Calicut with observations on the hydrological conditions. *J. zool. Soc. India*, 5: 76-107.

HARVEY, H.W. 1945. *Recent advances in the Chemistry and Biology of sea water*, Cambridge.

HORNELL, J. AND M.R. NAYUDU. 1924. A contribution to the life-history of the Indian oil sardine with notes on the plankton of the Malabar coast. *Madras Fish. Bull.*, 17(5): 129-197.

LOVERN, J.A. AND H. WOOD. 1937. Variations in the chemical composition of the herring. *J. mar. biol. Ass. U.K.*, 22: 281-293.

NAIR, R.V. 1953. Studies on the revival of the Indian oil sardine fishery. *Proc. Indo-Pac. Fish Coun.* 1953: 115-129.

NAIR, R.V. 1959. Notes on the spawning habits and early life-history of the oil sardine, *Sardinella longiceps* Cuv. & Val. *Indian. J. Fish.*, 6(2): 342-359.

PRADHAN, L.B. AND C.V.G. REDDY. 1962. Fluctuations in the mackerel landings at Calicut in relation to hydrographical factors. *Indian J. Fish.*, 9(1)A: 100-109.

SEKHARAN, K.V. AND M.H. DHULKHED. 1963. On the oil sardine fishery of the Mangalore zone during the years 1957-63. *Indian. J. Fish.*, 10 A (2): 601-626.

SUBRAHMANYAM, R. AND A.H.V. SARMA. 1960. Studies on the phytoplankton of the west coast of India, Pt. 3. *Indian J. Fish.*, 7: 307-336.