PLANKTON OF CALICUT INSHORE WATERS AND ITS RELATIONSHIP WITH COASTAL PELAGIC FISHERIES

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Studies on the inshore plankton of Calicut waters and on the related hydrological featuıes have been made in earlier years, and there have been attempts, in general terms or specifically, at correlating these with the fisheries of the area. From Hornell and Nayudu (1924) who suggested that the oil sardine might be coming into the inshore waters to feed on the plankton there, various workers have followed this view. Particular mention may be made, in this regard, of the observations of Chidambaram and Menon (1945) who arrived at a positive correlation between the plankton and the pelagic fisheries of this area during the post-monsoon period; of George (1953) who demarcated the inshore plankton as "edible" and "non-edible" from the point of view of fish food and marked the fact that the fishery season along the coast coincided with the period of abundance of "edible plankton", suggesting close relationship between the two; of Subrahmanyan (1959) who discussed the relationship of plankton production with fluctuations of oil sardine and mackerel landings on a month-to-month basis, finding broad correlation between standing crop of the plankton and total quantity of fish landed. A specific food-relationship between the juveniles of the oil sardine and the diatom *Fragilaria Oceanica* was suggested by Nair and Subrahmanyan (1955) with a possible effect on the sardine fishery of the area. Subrahmanyan (1959) while confirming this, found no such relationship between the mackerel and any other specific factor.

The present study which formed part of the continuing research programmes in marine biology of the Institute consists of observations on the inshore plankton (with a slant on the zooplanktonic elements) during 1957-65 and was carried out, for part of its time, with a concurrent study on the food of the mackerel (Mukundan, MS).

MATERIAL AND METHODS

The study was based on weekly hauls at a 20 m (inshore) and a 40 m (offshore) station off Calicut coast. Though hauls with bolting silk net as well as organdie net were taken, for this study the colleotions with No. 2 bolting

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silk net were used, except for 1963 and early part of 1964 when collections were made with the organdie net alone. Thus this part of the observations may not strictly be comparable with the rest in matters of detail. Still these data have been considered here for the sake of the over-all picture of the relative fluctuation patterns within the period concerned. The main difference found was in the matter of phytoplankton. The organdie net gave higher plankton volumes during the monsoon period (because of the higher phytoplankton content of the hauls) than the larger-meshed bolting silk used to give. This also makes clear why this study has for the most part shown higher volumes of plankton for the post-monsoon period, whereas the earlier studies (George, 1953; Subrahmanyan, 1959) recorded maximum values for the monsoon time coinciding with the phytoplankton primary blooms.

Both horizontal surface hauls and vertical hauls were taken at each of the stations. The vertical hauls were used for quantitative assessments, while the observations on the horizontal haul samples were sometimes used to complement the picture of the qualitative composition of the plankton of the area.

In this account, concerned as it is with the correlation of the plankton to the main pelagic fisheries of the locality, no attempt is made to treat the constituents species by species. The results of a concurrent study on the food of mackerel from the same area (Mukundan, MS), as also the present knowledge of the food of both sardine and mackerel entering the coastal fisheries (*vide* later section under 'Discussion') showed that the fishes do not feed on selected species and within the groups that are consumed the composition of the gut contents generally reflected that of the plankton available. The stress, therefore, has been placed on the major planktonic groups that have distinct bearing as food or have marked periods of fluctuation.

It is also true that, unlike in temperate waters, no single zooplankton species here has been observed to dominate its own group or the sample for any period so as to make a specific study of selected species necessary for its evaluation in respect of the fisheries.

The total plankton volumes were measured by displacement and counts were made from 1 ml subsamples.

The impossibility of sampling the stations with the country craft available during the height of the monsoon disturbances continued to be a disadvantage. Whereas samples from the 20 m-station could be taken once the extreme roughness of the sea and the wind had subsided, the offshore station could not often be worked for weeks together. Because of this, as also because the commercial exploitation of the plankton-feeding fisheries of sardine and mackerel takes place during the season from the inshore areas only, the data from the inshore station have been used for the study of the fluctuations of the zooplankters as well as for over-all correlation with fish landings.

The data on the landings of the oil sardine *Sardinella longiceps* and mackerel *Rastrelliger kanagurta* at Calicut, as also on the salinity and temperature fluctuation in the inshore waters, have been taken from the departmental records. Since, in the widely and quickly changing patterns of marine biological and hydrological conditions in the inshore areas during the monsoon months, any effect of these environmental factors on the fish is likely to be immediate and quick-changing, these data have been calculated on a week-to-week basis for correlation with weekly landing figures for the fishes.

SEASONAL FLUCTUATIONS OF THE PLANKTON

a) Total plankton volumes—The highest monthly average volumes for 1957-58 occurred in August (2.4 ml) and October (2.8 ml) and values from 1 to 1.5 ml were obtained from January to April. In most of the other months the volume was less than 1 ml in average, though individual collections occasionally were richer.

During the next year the zooplankton was richest in October-November, averaging a volume of 4.5 ml, the start of this increase in abundance being in August. May-June and again December and January had the lowest volumes (less than 0.5 ml).

In 1959-60, August samples averaged the highest figures (15.1 ml) though the unusually steep figure for the month was mainly due to the swarms of cladocerans and siphonophores in one week's samples. October, marking the re-emergence of the zooplankton in strength, had an average of 3.3 ml, while the swarms of medusae pushed up the figures for January-March (8 ml to 14 ml). The March sample gave an unusually high value of nearly 9 ml, but this was mainly due to the phytoplankton bloom consequent on the early monsoon conditions that year.

During the year 1960-61, September (7.6 ml) marked the post-monsoon abundance of zooplankton while October recorded 4.6 ml. The highest figures were reached in April (9 ml), the samples then being made up mostly of (besides copepods and *Sagitta*) siphonophores, medusae and salps.

The July samples in the year 1961-62 had high volumes (4 ml) owing mainly to phytoplankton abundance; the zooplanktonic abundance is shown by the smaller volumes of 1.6 to 2 ml in October-December and in the ensuing summer months when the bulk was made up, more than usual, by medusae and salps.

In 1962-63 the peak season for zooplankton was September-October (2.8-3 ml). The volumes were again generally high in January, last week of March and towards close of April (1.5 to 3 ml). The volumes were unusually low in December, rarely going above 1 ml.

The plankton volumes in 1963-64 were highest in May-June (up to 5 ml), October (over 9 ml), December (3.6 ml), and in some samples in February. The high May figures were due to continuing abundance of the summer zooplankton because of delayed monsoon, the higher values of June being due to the phytoplankton blooms.

For the year 1964-65 higher values were obtained in August (2.4 ml) and November (3.8 ml). The revival of zooplankton abundance after monsoon started as late as in the second half of October and continued in a subdued way for the rest of the year. Except for some samples in February-April rarely did the weekly hauls go beyond 1 ml in total volumes.

b) *The main zooplankton groups*

Consideration here is limited to the fluctuations of the group as a whole, except in instances where only one or two species make up the group in the plankton.

Copepods— Copepods form the single consistently dominant zooplankton group in the Calicut inshore plankton. Other groups such as the cladocerans or siphonophores or medusae may on occasions prove more numerous, often swarming to the virtual exclusion of most others. But these are of extremely limited duration. Taken for the year as a whole the copepods remain the most abundant.

The only time when copepods are found to be meagre in the inshore plankton is the south-west monsoon time. Until the outbreak of the monsoon (sometimes even surviving the first few weeks) the copepods retain their strength. Then they decline sometimes gradually, often abruptly and remain so till the peak of the monsoon is past. Then there is an equally quick recovery and the copepods often reach their own peak occurrence by October-December. And this abundance is retained, with slight variations until the next year's monsoon. The monthly pattern of copepod abundance for the various years is shown in Fig. 1.

Cladocerans— The cladocerans were obtained in inshore samples in almost all the months (except at the height of the SW monsoon). But the period of their peak occurrence was the immediate post-monsoon months, July-October: when their swarms are characteristic features of the samples. The commencement of the swarming is often as sudden as the tapering off. In general, of the two species that go to make up this group in the Calicut plankton, *Evadne* swarms appear a few weeks before *Penilia* swarms. The latter also usually outlasts the former. Fig. 2 shows the pattern of occurrence of these two forms.

Decapods and their larvae— The important adult decapods found in the inshore waters were the two species of *Lucifer*. Both occur intermingled,

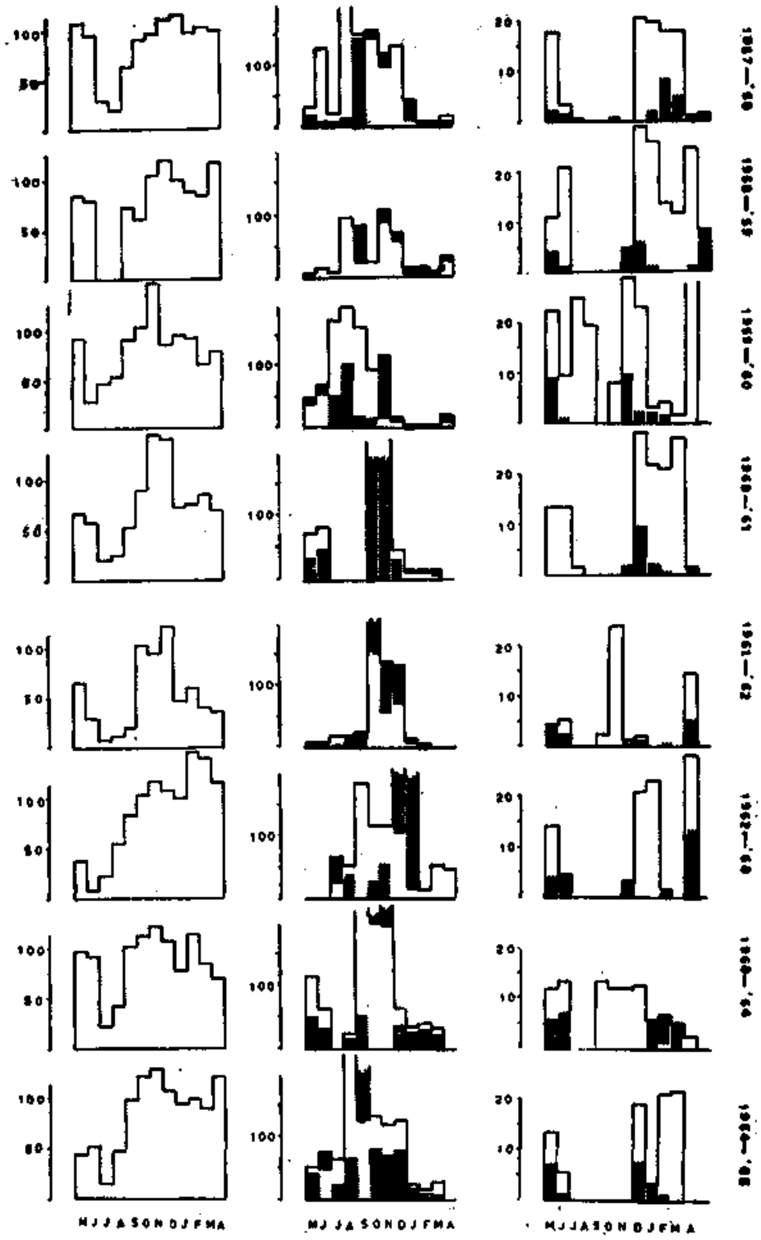


FIG. 1 FIG. 2 FIG. 3

Fluctuations in abundance of zooplankton groups.
1. Copepods. 2. *Evadne* and *Penilia* (shaded).
3. Decapods (shaded) and their larvae.

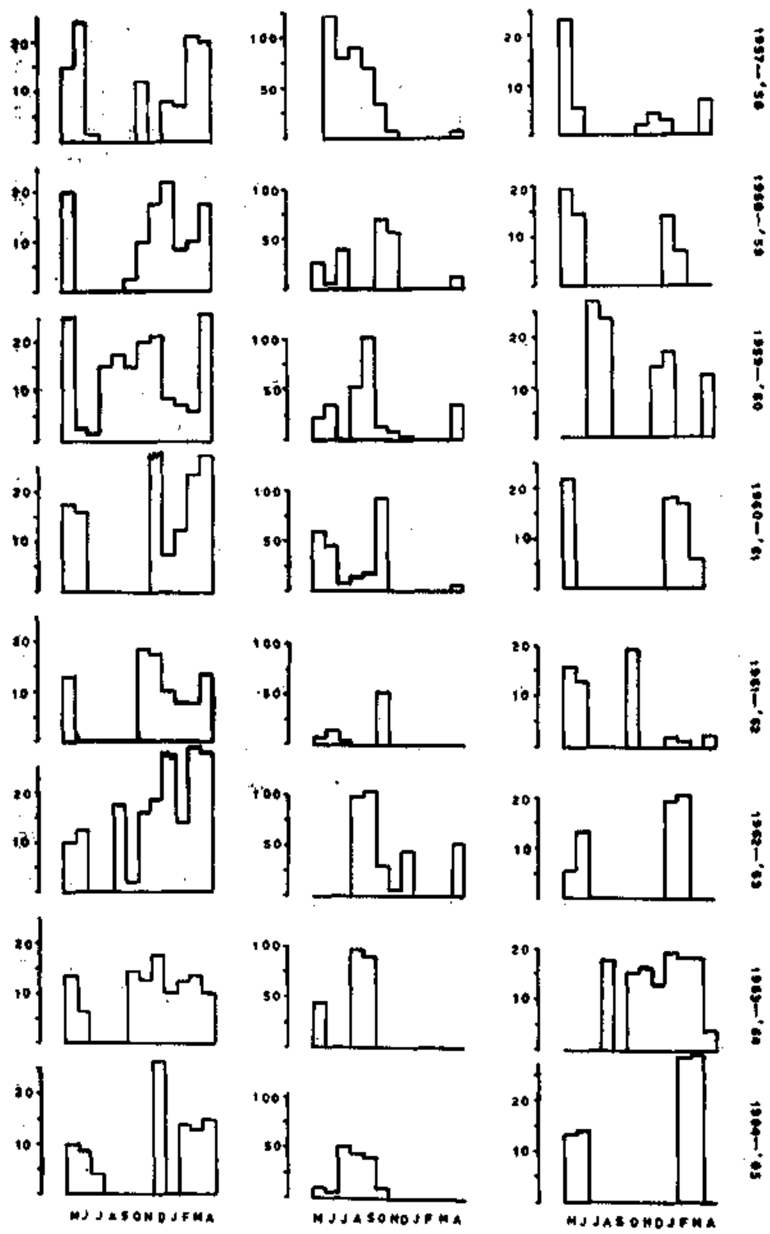


FIG. 4 FIG. 5 FIG. 6

Fluctuations in abundance of zooplankton groups.
4. Chaetognaths. 5. Polychaete larvae. 6. Molluscan larvae.

L. hanseni being commoner. The period of abundance is the post-monsoon months November-January, often extending in less strength to March or April. The commonest decapod larvae available in the inshore waters were the penaeid and sergestid nauplii and zoea. Good numbers of brachyuran zoea were also obtained infrequently and rarely other (alpheid etc.) larvae too occurred. But the bulk of the group was invariably made up of the first two. The period of abundance was the post-monsoon months of November-February, though in some years it had extended well to May-June, or started early by September (vide Fig. 3).

Chaetognaths— The common chaetognath in the inshore plankton has been *Sagitta enflata* though two more species of this, as well as *Krohnitta* spp. are also less frequently available. The pattern of occurrenc of the group as a whole is given in Fig. 4.

Except for the monsoon months the chaetognaths are available in most samples during the year, coming in larger numbers by October-November, usually abundant by December and continuing in good strength through the summer months.

Polychaete larvae— The inshore plankton of Calicut has usually a very rich but seasonal crop of polychaete larvae. Starting when the peak of the monsoon is over it lasts for about three to four months.

Quantitatively the bulk of the group is usually made up of spionid larvae. Polynoid, chaetopterid, nereid and magelonid larvae too are commonly included. Usually the season begins with large numbers of polynoid larvae and trochophores, followed by more advanced trochophores, phyllochaetopterids and magelonids. Then large swarms of spionid larvae come in and these often last till the season of abundance is over. The over-all pattern of occurrence is shown in Fig. 5.

Molluscan larvae—Both gastropod and bivalve larvae are well represented, though seasonally, in inshore plankton. The bivalve larvae were numerically more and generally occurred from November to February. Gastropod larvae, too, had a similar pattern and are generally abundant in the summer months. The pattern of occurrence is shown in Fig. 6.

Pelagic gastropods— The pelagic gastropods available seasonally in the inshore samples comprise pteropods and heteropods; *Creseis* is the main genus of pteropod available, the commonest form is *Creseis acicula*. Besides this, *Diacria quadridentata* and *Cavolinia* are also found occasionally. The heteropods belong mainly to *Atlanta*, though occasionally *Oxygyrus* spp. also are observed. Both pteropods and heteropods show some abundance often occurring together, though the former is by far the more abundant. Their combined seasonal variations are given in Fig. 7.

Medusae— The medusae available in the Calicut inshore plankton comprised both hydromedusae and scyphomedusae. The main representatives of the first were species of *Obelia,Aequorea, Leuckartiara, Liriope*, while *Nausithoe* was the commonest of scyphomedusae. The medusae start appearing after the monsoon season. Usually *Obelia* medusae and smaller forms like *Leuckartiara* and *Phialidium* are obtained earlier, and these continue up to about December though some may extend further. By November-December the larger and oceanic forms like *Liriope* and *Nausithoe* are more common. This has been the basic pattern of distribution and abundance for these, as shown in Fig. 8.

Siphonophores— The siphonophores in the inshore plankton mainly comprised calycophoran forms like *Diphyes, Chelophys, Bassia, Euncagonum* and physophorans like *Agalma* and *Forskalia*. The siphonophores appear in the post-monsoon months and continue in their highest abundance in the summer months up to the onset of the monsoon. Thus they have a pattern of availability similar to that of medusae. The pattern is marked in Fig. 9.

Tunicates— The tunicates form qualitatively a significa nt part of the inshore plankton in the late post-monsoon months and summer months. They include thaliaceans like *Pegea confoederata, Thalia democratica, Dolilium* spp. etc. and appendicularians like *Oikopleura* and *Fritillaria*. The pattern of abundance of these is shown in Fig. 10.

Fish eggs and larvae— A large number (but fewer types) of fish eggs and larvae were available in the plankton. Carangoid and clupeoid eggs made up the bulk. Others included significant numbers of sole eggs. None could be identified as sardine or mackerel eggs or larvae. Though the eggs and larvae are observed in plankton in different months, the significant abundance is from August to December. (Fig. 11).

Noctiluca— The swarming of the pink *Noctiluca* in inshore area has been a consistent feature of the inshore waters. It starts with the south-west monsoon rains and extends for varying periods of four to six months. Often extensive patches of water discoloured by these swarms are observed. The samples are often tinted pink or brown, with the layer of the *Noctiluca* forming a surface film often a cm or more thick. The seasonal variations of this form is shown in Fig. 12.

PATTERN OF VARIATION OF HYDROLOGICAL FACTORS FROM YEAR TO YEAR

The two hydrological factors of salinity and temperature have been found to be immediately and more or less sharply affected during the monsoon and post-monsoon months. From the high values in May both showed sharp decline in the inshore area with the onset of rains and this level is maintained usually till about July in case of salinity and September-October in case of temperature. Thereafter there is a gradual rise. In some years this is interrupted by a lesser fall in November-January and the higher values are normally reached again by March-April.

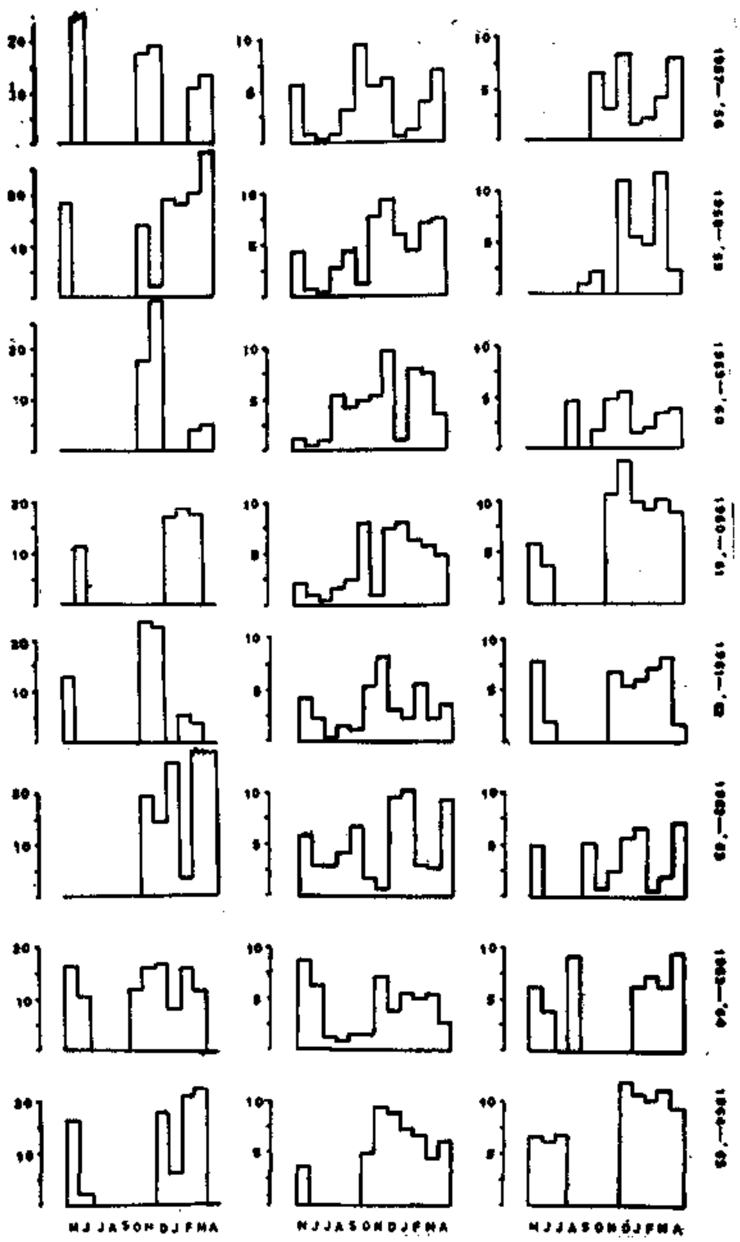


FIG. 7 FIG. 8 FIG 9.

Fluctuations in abundance of zooplankton groups
7. Pelagic gastropods. 8. Medusae. 9. Siphonophores.

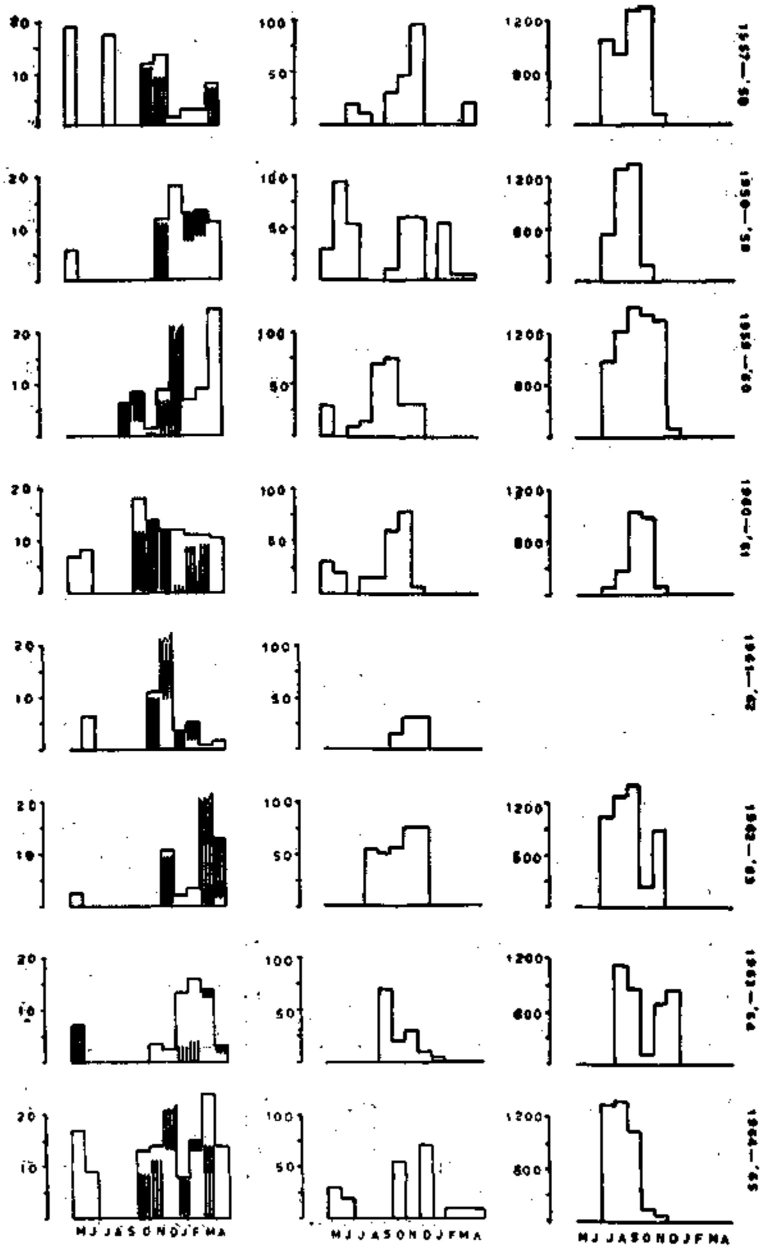


FIG. 10 FIG. 11 FIG. 12

Fluctuations in abundance of zooplankton groups
10. Thaliaceae and appendicularians (shaded). 11. Fish eggs. 12. *Noctiluca*.

The trends for the different years are shown in (Figs. 13-20). It is often noticed that during the post-monsoon period, low values for temperature and high ones for salinity are obtained in the same month.

Magnitude of the Mackerel and Oil Sardine Landings at Calicut

To see whether variations in the plankton and hydrological factors like salinity and temperature particularly in the immediate post-monsoon months have any direct impact on the presence and movement of shoals in inshore fishing waters, the fluctuations in the commercial landings of these two fishes were studied. The values calculated on a week-by-week basis are indicated in Figs. 16-20.

The mackerel landings have been poorer than of oil sardines for these years. The bulk of the mackerel catches had been in the four-five months following the peak of monsoon, and in none of these years had it extended to any marked degree beyond January. In 1960-61, the last week of August, the second week of October, the last week of November and the first two weeks of December brought in good catches, while the maximum landings were in last week of December. In the next year the landings were much poorer, and only the first and third weeks of October and first week of November had any appreciable landings. In 1962-63 the total landings were slightly improved, the last week of August and first two weeks of October having somewhat better landings. The year 1963-64 had good landings of mackerel only in the latter half of September, August-September showing some above-average catches in the concluding weeks. Similar was the pattern for 1964-65 too. Only in the second week of September, first week of October and in the last week of November did mackerel landings show anything more than the barest minimum.

As regards the oil sardine the picture was much better. In 1960-61 August, September, October and December-February all had heavy landings, October third and fourth weeks recording the highest figures. There were also good catches during the last week of January. In 1961-62 too, the landings were well-spaced almost up to March. The first week of August, last week of September, last week of October and almost whole of December-February had heavy landings of oil sardine, the highest figures being in August-October and December-January. During the next year, July 1962 had heavy landings particularly in the second week; thereafter sizeable catches were obtained only in November (third week) and January 1963 (last week). The local oil sardine langings were relatively much poorer in 1963-64.

Discussion

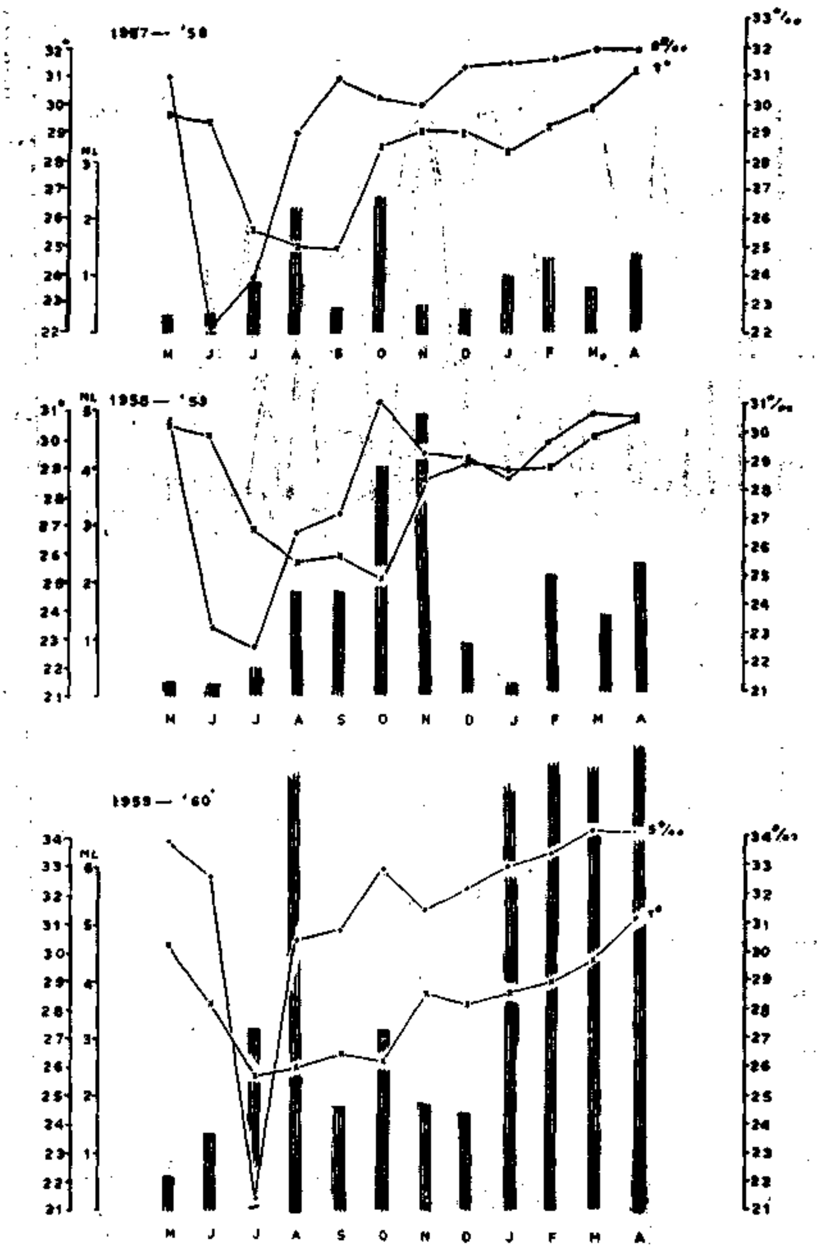
The trends of change in the salinity and temperature values indicate that both fall with the onset of the rains and, with minor ups and downs, remain at a relatively low level for a month or two—May-June or June-July usually. Then they rise, often extending over the August-December period, and reach their highest values in the summer months. The variations in temperature in these inshore waters are relatively more steady and sustained (though with sporadic exceptional values) than those of salinity. The values for salinity often fluctuate widely from week to week particularly in the September-December period but attain a steadiness in the high summer values. The lowest values for salinity were recorded in the previous years in May-June, though exceptionally low values were obtained twice in 1962 in August and October. June 1960 recorded the lowest value of 17.3‰ for the period of the report.

Viewing the pattern in the fluctuations of abundance of the main groups of zooplankters in the inshore waters it is seen that these fall into two main types. The first one, which includes most of the groups, shows sharp decline with the onset of rains and the lowering of salinity and temperature, and their numbers remain low for the duration of the monsoon. The revival starts by August-September, the different groups attaining their peak abundance in different months.

The second type comprises mainly the cladocerans, *Evadne* and *Penilia*, and the dinoflagellate *Noctiluca*, and their occurrence pattern in most years is the reverse of the former. They swarm during the monsoon months and occasionally extend into the immediate post-monsoon months but rarely are they found in any swarms in the months of higher salinity and temperature. This group's appearance and disappearance from the inshore plankton are abrupt.

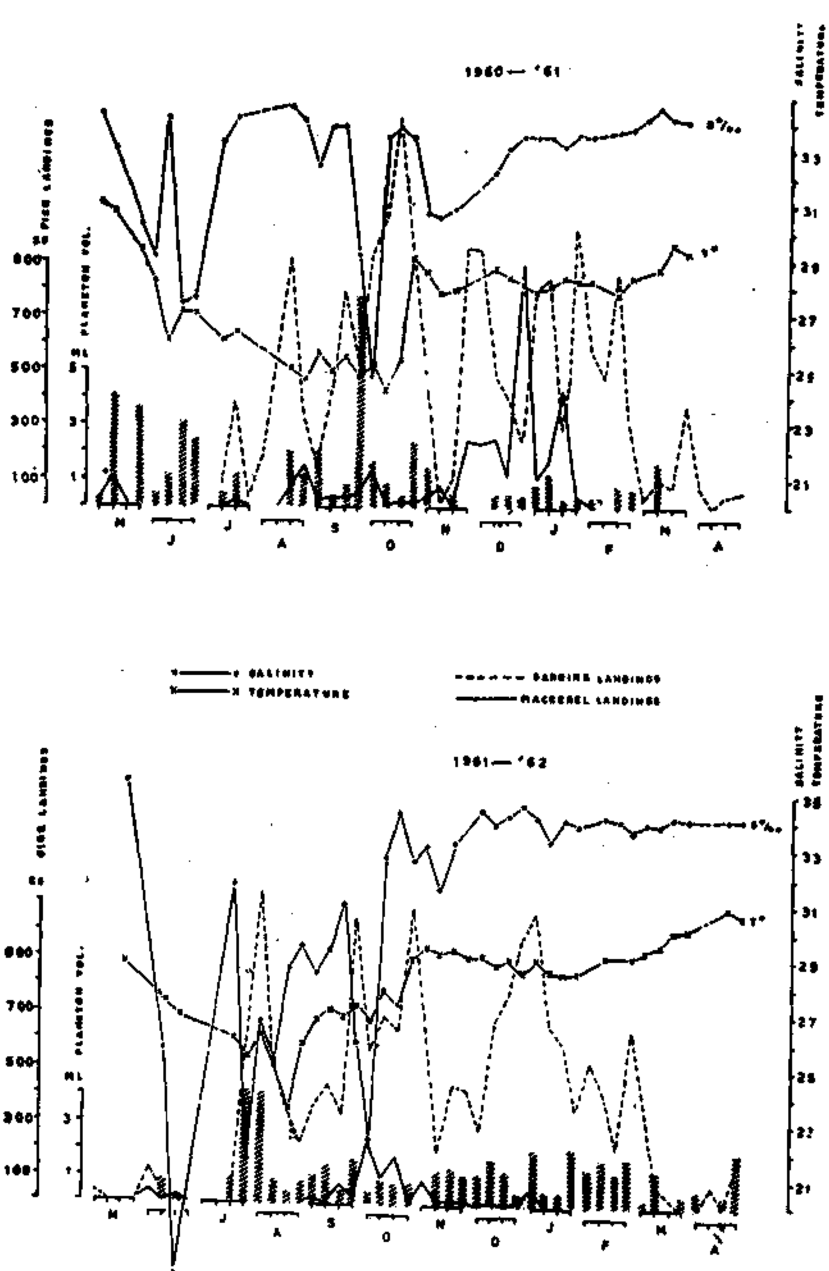
The significance of the inshore plankton in Calicut waters from the fisheries point of view arises from the fact that the two main exploited fisheries of the area are of the plankton-feeders (oil sardine and mackerel) and the exploitation takes place mainly when the fish shoals enter the coastal waters. The point has long been stressed in that there is a correlation thus between plankton and the fishery. Many earlier workers, as pointed out in the introduction, have also traced a direct cause-and-effect relationship between the two.

The sardine and mackerel are voracious feeders on the plankton, particularly in the adolescent stages at which they enter the inshore waters and the fishery every year. The food of the oil sardine has been studied from different centres, though mostly from commercial catches obtained from inshore areas (Chidambaram, 1950; Dhulkhed, 1962; Nair, 1952; Venkataraman, 1960; Kagwade, 1964; Noble, 1965) and the picture emerging is consistent that it is a plankton feeder. Whereas the earlier workers had felt that it is a predominently phytoplankton feeder some of the later workers tended to view this as largely caused by differences in availability of food items and that the oil sardine does consume good quantities of zooplankton. As the abundance of oil sardine in the inshore waters is during the post-monsoon months, well past the phytoplankton bloom, this is not in any way surprising. The food of mackerel was similarly studied



FIGS. 13 - 15

Fluctuations of plankton volumes, temperature and salinity values and fish landings. (Monthly values). 13. 1957-58 14. 1958-59 14. 1959-60.



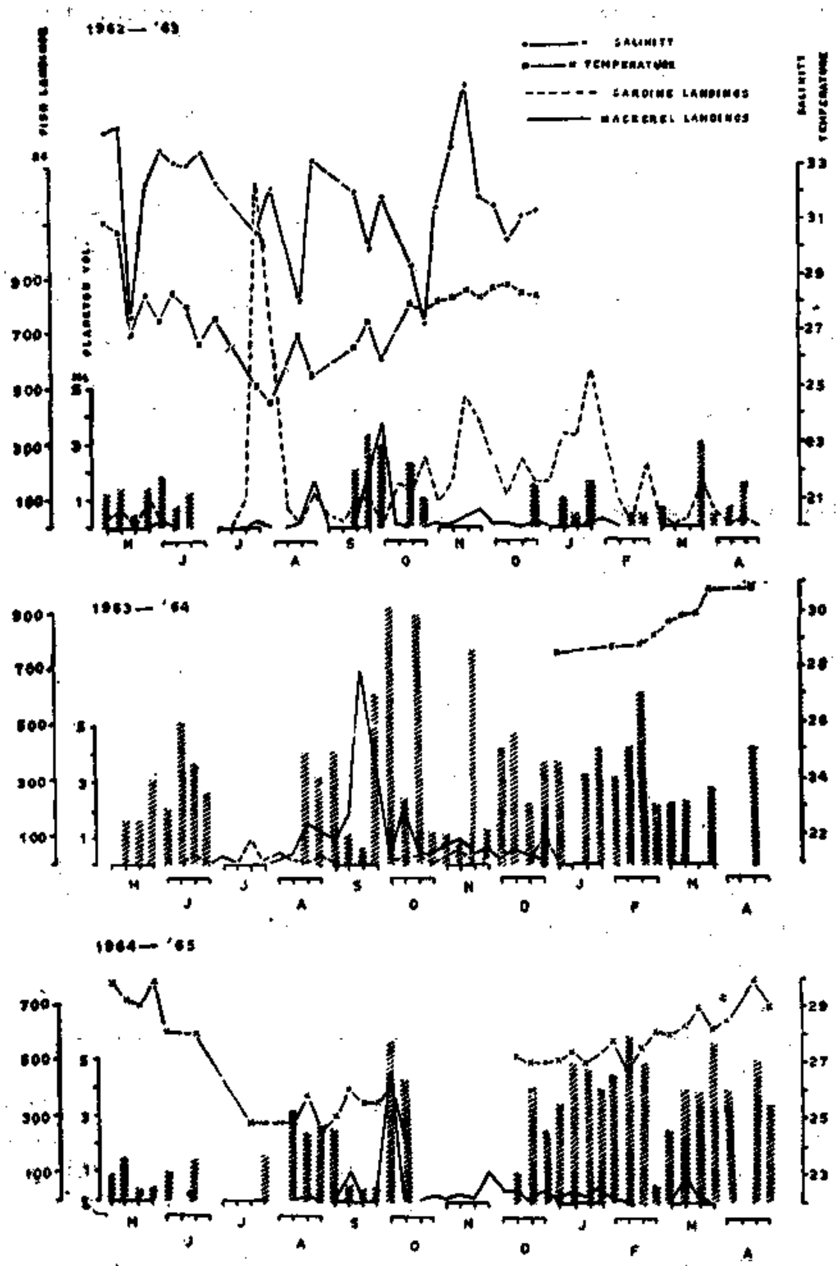
FIGS. 16 - 17

Fluctuations of plankton volumes, temperature and salinity values and fish landings. (Weekly values). 16. 1960-61 17. 1961-62.

from different centres (vide George, 1964; Rao, 1962; Noble 1962) and here again with the exception of Rao (1962) the samples have been from the inshore areas. The mackerel also is understood to be a plankton feeder, but with limited discrimination, as the gut contents were, generally, seen to reflect the composition of the plankton. The phytoplankton blooms appearing with the onset of rains are soon followed by a richness of zooplankton and the immediate post-monsoon months form thus the time of extreme abundance of what has been described as "edible" plankton (the abunddnce in summer months being that of "non-edible" types). On this has rested the assum ption that the plankton in the form of food is the prime factor that draws the fish shoals into these waters.

In this connection, however, it is to be noted that this concept of the food of the mackerel is based mainly on the study of the size groups entering the commercial fishery along the coastal stretch and that the food of the juveniles, as well as the larger sizes, have not figured prominently in many of those studies on food. The observations of Rao (1962) who studied large-sized mackerel from deeper waters suggest that the so-called "non-edible" type of plankton could be consumed by the mackerel in large quantities. Similarly it is generally held that there is no difference in the diet of the juvenile and adult mackerel (vide George, 1964), though Rao and Rao (1957) and Kuthalingam (1956) have shown a different diet for the juveniles. Though the concurrent study on the food of the mackerel from the same locality as the present one largely confirmed the findings of Bhimachar and George (1952) to the extent that only maturing (post-juvenile) and adult fishes were available for examination during this period, the stomach contents of some juveniles obtained later showed a decided difference (published separately elsewhere). So the widely held view on the food, particularly of the mackerel, appear to be applicable in its entirety only for the size groups entering the close-shore fishing areas, and is but partially valid for fishes that are out of these grounds.

A point which has to be borne in mind in this regard is that whereas weekly collections of plankton and hydrological data have been from fixed stations of 20 and 40 m depths on fixed days, the fish catches were from areas varying between 4 and 25 m even during the season, and wider afield out of the season. So the area and the whole week can be held to have been representatively sampled within but wide limits. However, a comparison is still worthwhile inasmuch as a practical approach would have been made to know whether from a study of the variability of the plankton and associated factors from a collection centre, some indication can be had about the abundance or otherwise of the sardine and mackerel fishery. The pattern shows some general trends of correlation, but does not give any more precise picture of positive or negative influence of one over the other, which is only to be expected in view of the limitations outlined above.



FIGS. 18-20

Fluctuations of plankton volumes, temperature and salinity values and fish landings. (Weekly values). 18. 1962-63 19. 1963-64 20. 1964-65.

As the fluctuation of environmental factors would be at its peak during the monsoon disturbances (when data on fish shoals or movements are lacking) and as commercial fish landings (which are sought to be correlated) start mainly by August-September, any correlation observed would necessarily be of a limited nature in that only relationships that exist within the duration of the main fishery season in the post-monsoon months would be indicated by this. The total volume of plankton was, for reasons indicated earlier, taken as an index of available food abundance. This, along with salinity and temperature values, were plotted against landing figures.

In 1960, for example, the high values for plankton were generally accompanied by high sardine and mackerel figures within the same week or sometimes by margin of one week. But the data for the first and last weeks of September and the first two weeks of December show a different picture. In 1961 the sardine landings in August-September followed the same pattern of accompanying the weekly plankton values or following it by one week, but the landing figures thereafter do not keep to this. Similar is the case in the following year too.

That presence of plankton as food is essential for a good fishery is clearly borne out. The relative poverty of plankton in the inshore areas in 1961-62 post-monsoon seasons was accompanied by an acutely poor fishery for both mackerel and sardine locally. But the reverse does not appear to hold good. The last two quarters of 1964-65, to take another instance, had abundant plankton in inshore areas, but the local fishery remained poor. The difficulty in linking the fish abundance solely with food in inshore waters is also clear from the fact that even in years when mackerel had failed (most of the recent years with possible exemption of 1960 and 1963) the sardine had shown extreme abundance. Both being plankton feeders, factors other than availability of plankton alone, have obviously influenced.

The fluctuations in the environmental factors like salinity and temperature are obviously significant in this respect. The fishery starts by about August-September when, after the fall in values during the monsoon, temperature and salinity start showing an upward trend and the season generally terminates before the highest values are reached in summer. The shoals in 1960-61 (to take a year when both sardine and mackerel fisheries were successful in the Calicut area) appeared to enter the inshore area when the temperature (weekly value) was 26.3°C and salinity 34.1‰. In the two succeeding years the corresponding figures were 26.2°C and 25°C for temperature and 26.7‰ and 30.5‰ for salinity. If the T-S factors are influencing the entry of fishes into the area it seems possible, from the above, that temperature is the more significant factor, as the salinity values at the time of entry appear to offer a wider latitude in the years concerned.

During 1960-61 the range of weekly temperature values during the fishery season, was 24.6°C—29°C and for salinity 30.5‰—34.5‰. Similarly the range in the next two years was 26.2 - 28°C and 24.4 - 28.7°C for temperature and 26.2—34.3‰ and 30.5—35.8‰ for salinity. The relatively limited range in temperature is evident here too.

Considering the weekly peaks in landings it is seen that in 1960-61 season the highest sardine landings were recorded in weeks that ranged 25°C to 28.2°C in temperature and 31.6‰ to 34.5‰ in salinity. In the next two years the corresponding ranges for temperature were 26.2°-30.7°C and 25°-28.5°C and for salinity 25.9—34.1‰ and 27.2—35.7‰. As for mackerel the weekly peaks were, during the 1960-61 season, in the range of 24.6-28.3°C and 30.5-34‰. In the succeeding years the corresponding values were 26.6°-29.3°C and 25.4-28.5°C for temperature and 33-34.3‰ and 27.2-35.7‰ for salinity.

When the individual major weekly peaks are considered against the T-S values it is seen that the higher sardine catches in 1960-61 followed by one or two weeks a sudden lowering of salinity from the prevailing levels (often to a point between 27.5‰ and 33‰), when the temperature remained in the 25°-29°C range. The peaks in the third week of August and the first two weeks of January, however, did not correspond to this pattern. A broadly similar trend could be made out next year also when most of the weekly peaks were preceded by a dip in the salinity curve, though exceptions are evident here too. And it has to be mentioned that fishes, particularly in the later post-monsoon months of these seasons, were mostly caught farther from the shore and the T-S conditions in the fishing grounds might have varied from these average figures from the inshore stations.

Taking all this together it could be seen that within the confines of the inshore fishing grounds the landings of sardine and mackerel show a pattern of variation in abundance corresponding to fluctuations in total plankton and salinity and temperature. With plankton available in sufficient quantity, the peak landing for both species appear to be within the range of 26.5° to 28.5°C of temperature and 28.5‰ to 33.5‰ of salinity.

Pradhan and Reddy (1962), examining the mackerel landings at Calicut against fluctuations in temperature and salinity (in monthly average values) had found the average values of 29.1°C and 33.27‰ as proximal optimum and suggested a good mackerel season when the degree of variations of T-S during the season was least. These optimum values come within the optimum range found during the present study here, though the range of fluctuations, especially when observed in weekly values, is much larger even in a successful year like 1960-61.

There can thus be little doubt of a general and positive correlation existing between plankton and the other environmental factors like temperature and salinity and the pelagic fisheries of the area. The point here to be considered is the extent to which these relationships affect the commercial fishery. If the shoals enter the coastal waters every season to feed on the rich plankton crop of the post-monsoon months, how does one reconcile the erratic fluctuations and often complete failures of the fisheries with concurrent abundance of plankton in inshore waters?

There could be more than one possibility for this. The failure of a fishery could be caused by changes in the populations concerned, by basic alterations in the recruitment, survival etc. Though such a depletion or revival of whole populations would, in a multi-year class fishery, be a gradual one, our sardine and mackerel fisheries being based on one age-group (or at best two) it is not improbable that such changes could be reflected in the abrupt set-backs and equally sudden revivals that are so characteristic of these fisheries.

Provided these inherent factors in the populations remain more or less unchanged, the obvious explanation for the immigration of the shoals shoreward would be to assume relative advantages offered by the inshore environment. In the absence of information about the conditions that prevail in the offshore waters during this time it is difficult to determine what these values could be. The presence of food, no doubt, is one of them. Prasad (1966) has shown an ascending gradient of standing crop of plankton from the offshore areas towards the shore along the south-west coast (the sardine-mackerel zone), and it is possible the fishes follow this gradient. From observasions within the inshore area, an optimum range of salinity and temperature appears to favour large-scale movement of fish into these waters. Since both sardine and mackerel, as shown earlier, seem to indicate more or less similar range of preferences in these, the causes for the failure of one fishery and the success of the other in the same year, may not lie in the inshore environment, but in the inherent factors of the populations concerned.

It is also to be noted in this connection that our present knowledge of the sardine or mackerel shoals in our waters is based on observations on only a part of the population of limited size-range, that enters the narrow coastal belt for a part of the year, and we have little information about these when they are out of these grounds. So when we speak of the "failure" of a fishery it may mean no more than that the shoals, for some reason, failed to enter our fishing grounds.

The reports of local failures of the fishery even when the plankton and T-S factors in the inshore area appear favourable and the overall picture of the fishery indicates no large-scale structural changes in the populations, prompt a consideration of the possibility that entry into coastal waters becomes necessary for the fish only when conditions in the offshore areas (as, for instance, grazing pressure) necessitate it. All available evidence now indicates that the juvenile fish as well as the spawners occur in offshore regions beyond the commercial fishing limits, and it is the maturing fish that come shoreward during the post-monsoon months. It is clear also that, notwithstanding the plankton gradient, the richness of plankton along the west coast extends far wider than the commercial fishing areas and "productivity in the coastal regions of Indian waters is high practically anywhere on the shelf" (Prasad, *loc. cit.*) This could indicate the possibility that moderate shoals in the offshore regions may be able to feed well without entering the coastal waters, and success in recruitment and survival above a point may create the level of grazing pressure that is needed to send the more competitive older fish spreading shoreward into the fishing areas.

It is quite possible that the grazing relationship between the fishes and plankton is more actively exploitable as in the case of the herring (Cushing, 1955; Savage, 1931) where the exploitation is based on following the shoals as they concentrate to feed on the plankton patches. But to take similar advantage of this from the fisherman's point of view, one needs to go after the fish and catch them. In such instances the presence of plankton in a given area becomes an important factor in the concentration of the fish. But as at present, in the context of our commercial fisheries that exploit only that part of the population that comes near the shore, the presence of abundant plankton in these inshore waters does not automatically auger for a successful fishery.

All this is when consideration is of the two factors, the plankton and the fish. In the larger context of the movement of the shoals in the waters off the west coast, the influence of other environmental factors, especially temperature, may be decisive. These have been considered, as already discussed in sections above, by some of the earlier workers: Chidambaram (1950) suggested the movement of sardine shoals in inshore waters may be largely controlled by changes in hydrological conditions; Subrahmanyan (1959) indicated a parallel relationship between fluctuations in the phosphate contents and mackerel landings and an inverse relationship for oil sardine; Pradhan and Reddy (1962) suggested a possible correlation between a good mackerel season and an optimal and narrow range of temperature and salinity, while Murty (1965) indicated possible predictions about the pelagic fisheries from observations of the patterns of coastal currents. The present study tends to place relative stress on temperature. A more reliable picture seems likely to emerge only when the range of distribution of these pelagic shoals is determined and observations cover representative parts of the populations in space and time.

SUMMARY

The fluctuations in the total volume of plankton and the abundance of major zooplanktonic groups in the inshore area off Calicut have been observed and studied in relation to changes in the environmental conditions of salinity and temperature. The relationship between these values in the inshore area and the major pelagic fisheries for the oil sardine and the mackerel has been considered with special reference to seasonal immigration of shoals into coastal waters. Apart from the possible failure of the fishery as a whole on account of basic changes in population parameters, circumstances that could bring about a local

failure of the inshore fishery when the over-all fishery is moderately successful are indicated. It is suggested that, in addition to favourable plankton and temperature conditions, a level of grazing pressure in the offshore regions may create the conditions that send the more competitive post-juvenile fish spreading out into the coastal waters to enter the fishery in the post-monsoon months. The possibilities of other evnironmental factors influencing the over-all movement of pelagic shoals in these waters are indicated.

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