

The Marine Plankton of the Coastal Waters of Calicut with Observations on the Hydrological Conditions *

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Introduction

The present paper is the outcome of regular plankton and hydrological investigations off West Hill, Calicut, for the three years 1948-51. There has been very little detailed work done on the plankton and hydrology of Indian coastal waters, especially along the West Coast of India except for the account of the seasonal fluctuations of the plankton of the Trivandrum Coast by Menon (1945) and notes on the plankton of the Malabar Coast by Hornell and Nayidu (1923) and of the Bombay Harbour by Bal and Pradhan (1945) and Gonzalves (1947). Chidambaram and Menon (1945) also attempted to correlate the quantity of fish landed on the Malabar Coast with the total plankton volumes, limiting the studies only to the post-monsoon months. On the East Coast plankton studies have been made by Menon (1931) and Aiyar, Menon and Menon (1936) and Subrahmanyam (1946) at Madras and by Chacko (1950) at the Krusadai Island in the Gulf of Manaar. Our knowledge of the hydrological conditions of the inshore waters is also very limited except for the investigations of Sewell (1928-29), Bal *et al* (1946) and Jayaraman (1950).

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The present studies do not claim to record an actual measure of plankton productivity but aim only to present a more or less complete picture of seasonal and annual variations in the composition of the more common planktonic groups and certain broad generalisation on the influence of the hydrological cycle on the coastal plankton.

Material and Methods

Plankton hauls were made from two stations off West Hill, Calicut ($70^{\circ} 46' E$ & $11^{\circ} 17' N$) one located two miles from the shore and the other in the 20 fathom area about ten miles away from the coast. Regular biweekly collections between 5 a.m. and 6 a.m. from the inshore station and weekly hauls from the offshore station were maintained except during the monsoon months when the offshore collections could not be made due to very stormy weather. A plankton net 75 cm. diameter of fine organdy cloth was used for collection. A vertical haul and two horizontal hauls, each of 15 minutes duration, one from the surface and the other from the bottom, were taken on all occasions. Quantitative data on the surface plankton from the 8 fathom area were made use of in the preparation of this paper and the offshore collections were purely qualitative.

Fresh plankton samples were brought to the laboratory in earthenware pots covered with wet cloth and an aliquot sample of each haul was examined under a low power microscope for a preliminary qualitative estimation. The relative abundance of the various groups in the various hauls was noted in the qualitative reports. The plankton was then fixed in 5 per cent seawater formalin and filtered through No. 60 bolting silk. After determining the total volume of the plankton by the displacement method, the material was kept apart for quantitative analysis.

The preserved sample was then made up to a known volume (generally 100 cc.) and an aliquot fraction (generally 1 cc.) was quickly removed by a graduated wide mouthed pipette to the counting slide and examined under a binocular microscope and all the organisms counted and the numbers entered in the quantitative statements. When large organisms such as larger chaetognaths and ctenophores were encountered in large numbers the entire sample was fractionated by means of a Lea-Gibbons sub-sampler and the total number of organisms in each sub-sample was counted.

The hydrological factors studied side by side with plankton investigations are surface temperature, salinity and phosphate content. Rain-fall data for Calicut were obtained from the Regional Meteorological Centre. Water samples were brought from the same locality from which plankton was hauled, in narrow-mouthed glass stoppered pyrex bottles of about 600 ml. capacity, covered with a black cloth. A casella bottle was used to obtain bottom water samples.

For recording temperature, sea water was collected in a vacuum flask further insulated within a wooden box plugged with cotton in the inter spaces. The readings were made with a centigrade thermometer as soon as the sample reached the laboratory. The vacuum flask was periodically tested to guard against possible deterioration in its efficiency.

Salinity of surface and bottom samples of water collected from the 8 fathom area and also from the 20 fathom area was determined. The simplified Oxner and Knudsen method as described by Harvey (1945) was followed using 10 ml. samples. Normal sea water of chlorinity 19.380‰ from Laboratoire Hydrographique, Copenhagen was used for comparison.

Phosphates were estimated by the method of Deniges as modified by Atkins (1923). Comparison of colour was made in daylight using Nessler's cylinders. The results have been expressed as $\mu\text{g.at.P/L}$. No correction has been made for salt error.

Seasonal Abundance of various Planktonic Groups

PROTOZOA

Only the more common Protozoa are enumerated, as no real estimate of the entire planktonic protozoa was possible with the methods employed. The most commonly represented group is the Flagellata while allied groups also are found in smaller numbers. The Tintinnoidea and Radiolaria do not bulk largely in the catches, but are present in the plankton almost throughout the year.

Rhizopoda

The foraminifera are represented by shells of species of *Globigerina* and *Polystomella* obtained in the hauls during monsoon months in July and August, obviously brought to the surface by currents. Single and colonial radiolarians occur in the post-monsoon months, the former common in the plankton collections from October to April and the latter during December and January. Menon (1945) has described *Acanthometron pellucidum*, as the more common acantharian of our coasts.

Flagellata

The flagellates are more commonly represented in the plankton by both the families of thecate flagellates (*Dinophysidae* and *Peridiniidae*) and the single genus, *Noctiluca* of the *Cystoflagellata*. The unarmoured flagellates make sporadic appearance in large numbers during certain days of intermittent sunshine in the latter part of the monsoon season. It has also been observed that flagellates and ciliates occur in myriads after the peak period of *Noctiluca* when the latter die and disintegrate.

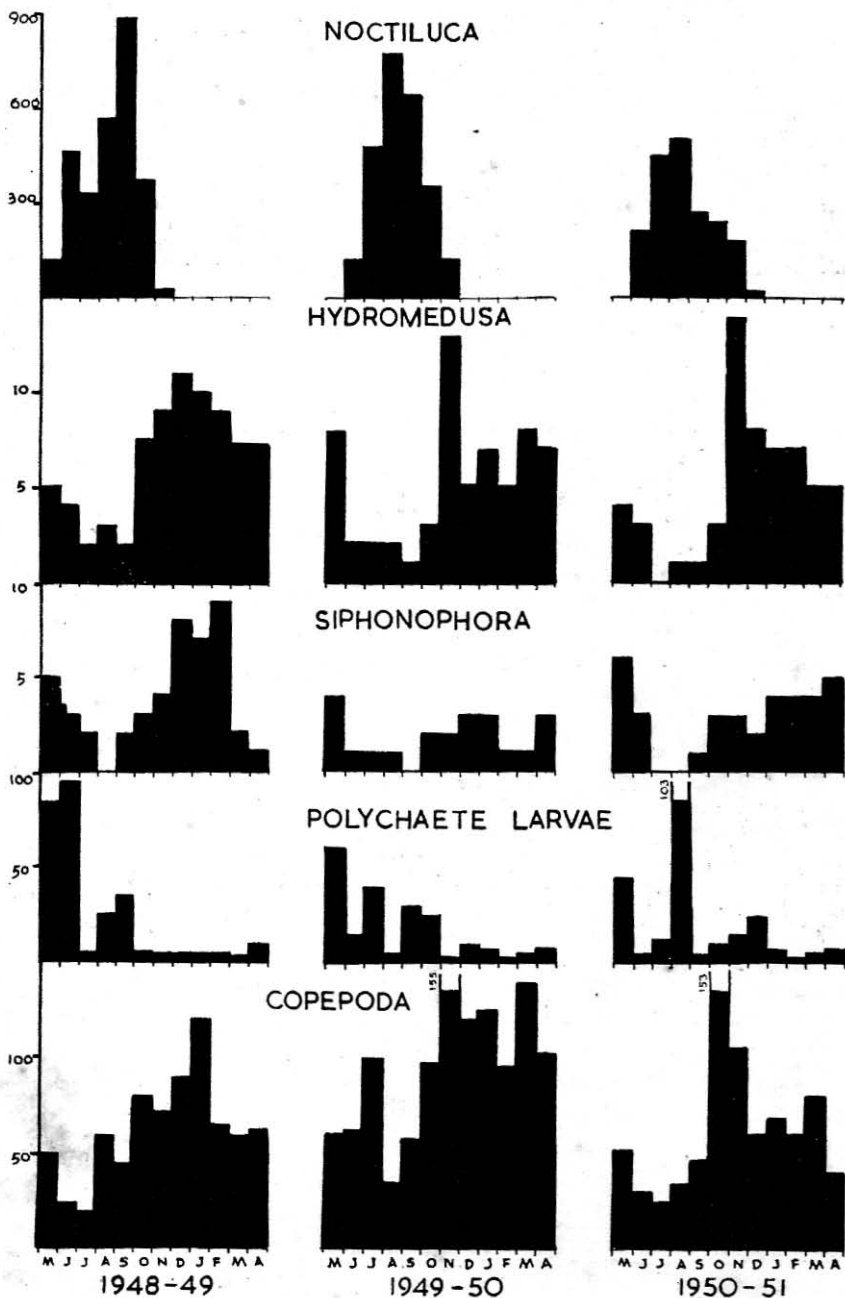


Fig. 1 (a)

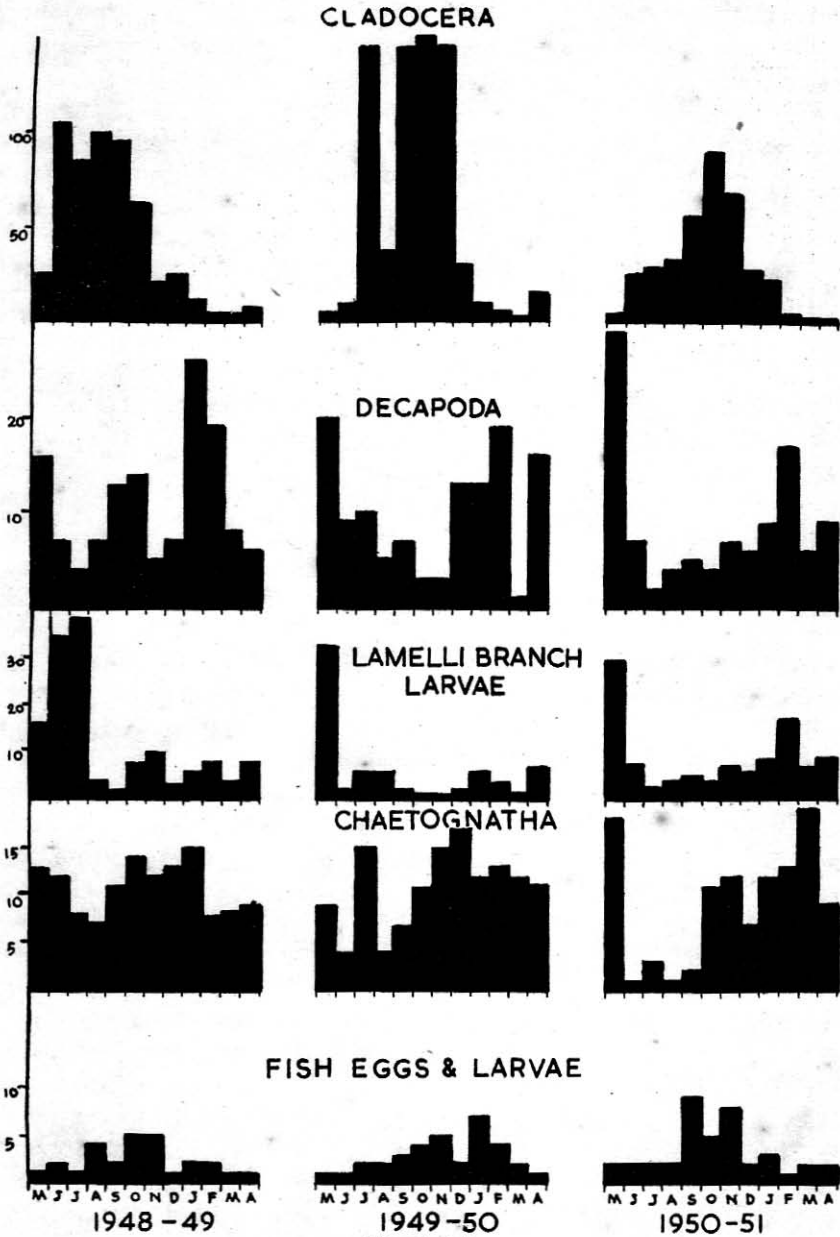


Fig. 1 (b)

During 1948-49, a peak in the occurrence of flagellates was observed in the middle of June when large numbers of *Ceratium massiliense* and *C. furca* occurred in the plankton. Species of *Acanthodinium* and *Procentrum* were also present in smaller numbers. This swarming of *Ceratium* lasted only a week. The next peak was observed in the middle of November when such forms as *Dinophysis miles*, *Pyrophacus horologium*, *Peridinium depressum* and *Ornithocercus magnificus* swarmed along with species of *Ceratium* and the peak lasted till the close of the month. *Ornithocercus* appeared in large numbers again during March.

During the second year, a peak was first observed in the middle of July when *Ceratium massiliense* and *Peridinium depressum* appeared in large numbers. The period of abundance lasted only for a week, but the forms continued to be present in the plankton in moderate numbers till the last week of August when huge numbers of unarmoured flagellates such as species of *Gymnodinium*, and ciliates appeared for a week in the inshore waters. *Dinophysis*, *Peridinium* and *Pyrophacus* continued to be present in moderate abundance till the first week of November. At the same time species of *Ceratium* and *Ornithocercus* occurred in abundance mixed with appreciable numbers of species of the other three genera mentioned above.

During 1950-51, in the first week of July swarms of species of *Ceratium* and *Peridinium* appeared. After this the *dinoflagellates* were not observed to occur in large numbers. In March a small peak was observed due to large scale appearance of *Ceratium massiliense*.

The cystoflagellate, *Noctiluca miliaris* Suriray, shows a definite period of abundance. A case of abrupt setback in fisheries of Malabar and Kanara Coasts due to the swarming and subsequent putrefaction of myriads of *Noctiluca* has been reported in an earlier paper (Bhimachar and George, 1950). *Noctiluca* starts appearing by the end of May and appears in swarms during June to September, its intensity in occurrence varying slightly in the different years. During 1948-49, the peak was observed in September although the organism was plentiful during June and July also and it remained so up to the middle of October, after which a short decline was noticed. During the second year the peak period of swarming was in August, and after September *Noctiluca* dwindled rapidly in numbers. The pattern of occurrence of *Noctiluca* in the plankton was more or less the same as of 1949-50 in the third year also, although the density of occurrence was less than that of the previous years. (Fig. 1a).

During the post-monsoon months, tintinnids form an important component of the plankton. The more common forms are *Tintinnopsis radix* and *Favella* sp. of which the former is more common in the inshore waters, particularly in the 4 fathom area. Both the species are abundant during October to January. Vorticellids attached to *Chaetoceros coarctatus* occur

in appreciable numbers during the monsoon months while *Zoothamnium* sp. was noticed in the plankton hauls obtained after the monsoon months.

COELENTERATA

Hydromedusae

Medusae form a major component of the macroplankton of this coast during the post-monsoon months and their seasonal occurrence is more or less regular. During May, the proportion of medusae is high, but soon after the onset of rains, they become scarce and almost disappear from the inshore area, till late August when they reappear in large numbers. The leptomedusae are the first to appear and are followed by the larger narcomedusae. From November to April these occur in appreciable numbers and are seen preying on copepods, cladocerans and *Sagitta*. The more common medusae of this coast are listed below :

1. *Obelia* sp. Commonest leptomedusa, occurring almost throughout the year, but never in swarms.
2. *Octocanna polynema* Haeckel. Common during September-December, appearing immediately after the monsoons.
3. *Aequorea pensile* (Modeer). Occurs in appreciable numbers during February to May. Larger specimens in the offshore hauls.
4. *Aequorea parva*, Browne. A more common species, but smaller than *A. pensile*. Observed in moderate abundance during November and December.
5. *Cytaeis tetrastyla*, Eschsholtz. Common during January to April.
6. *Leuckartiara* sp. In moderate abundance during January to March. The oval shaped knob on the top of the umbrella shrinks on preservation.
7. *Liriope tetraphylla* (Chamisso et Eysenhardt). Very common in November and again during March-April.
8. *Eucope* sp. is less common.
9. *Solmundella bitentaculata* (Quoy et Gaimard). Very common during October-November and again in March-April.

Scyphomedusae

The number of specimens of scyphomedusae collected were small. Although a large assemblage of species was expected to be collected, only a few species actually occurred in the collections. *Ephyrae* were seen in moderate numbers during the hot months, in the offshore hauls.

1. *Pelagia noctiluca*, Peron and Lesueur. Common during March and April.
2. *Nausithoe punctata*, Kolliker. Appears during January to March and is more common in the offshore hauls. Stray specimens, mostly young ones, observed during 1950-51 in August and September.
3. *Aurelia* sp. In small numbers during February and March in the offshore hauls.
4. *Netrostoma* sp. A single large specimen obtained on 26-10-49.

Siphonophora

Siphonophores occur in abundance from September to April and are found to follow more or less the same trend of seasonal abundance as the medusae. The larger species occur more commonly in the offshore hauls and they are scarce in the plankton during monsoon period, barring stray specimens of *Physophora*.

Sub-order Calycophorae

1. *Enneagonum hyalinum*. Quoy et Gaimard. = *Cuboides vitreus*, Bigelow 1919. Starts appearing in the plankton in October and continues to be common till December. Again in large numbers in the offshore hauls during January to March.

2. *Beselia bassensis* (Quoy et Gaimard). In moderate numbers during the summer months.

3. *Diphyes chamissonis* Huxley. The commonest siphonophore of the coast. Starts appearing in large numbers during November and continues to be present in appreciable numbers throughout the year, barring the periods of phytoplankton bloom.

4. *Diphyes dispar* Chamisso and Eysenhardt, occurs in small numbers along with *D. Chamissonis*.

Sub-order Physophorae

5. *Forskalia* sp. appears sporadically in the plankton. The preserved specimens agree in many respects with the figure of *Forskalia edwardsi* Koll. (Lens and Riemsdijk, 1908).

6. *Physophora hydrostatica* Forskal, occurs in small numbers along with *Forskalia*.

7. *Agalma* sp. Obtained during September and October. Broken bits of dactylozooids with tentacles are also met with in fresh plankton. The structure of the bract shows a close resemblance to that of *Agalma okeni* Eschsholtz. (Totton, 1932).

8. *Physalia utriculus* (La matiniere). Large numbers of small specimens washed ashore during July-August. One large specimen obtained on 15-2-50 from an offshore haul.

9. *Porpita pacifica* Lesson. Specimens obtained only from the offshore hauls during February and March.

10. *Velella* sp. Only a single small specimen with broken 'sail' was encountered during the course of the investigation.

Ctenophora

The cydippid ctenophores occur in large numbers in the inshore waters during March-April. Swarms of *Pleurobrachia* sp. were obtained in the collections from the four fathom area. Large numbers of ctenophore eggs were seen in the plankton in August in the first year, while in the succeeding two years, eggs were plentiful during November and December. Ctenophore eggs were also observed to occur sporadically in some collections obtained during the monsoon months.

1. *Pleurobrachia* sp. The commonest ctenophore of the coastal waters recorded in large numbers during February to May although they are present almost throughout the year.

2. *Ocyroe* sp. occurs from September to January and is less common thereafter.

3. *Beroe* sp. Appears in large numbers of varying sizes in the offshore hauls during March and April.

4. *Cestum* sp. A single specimen alone was encountered and it was from the 20 fathom area.

CHAETOGNATHA

The systematics and seasonal abundance of the *Chaetognatha* of Indian coastal waters have been described in detail, in earlier papers (George, 1949 and 1952). Three genera of Chaetognaths, viz., *Sagitta*,

Pterosagitta and *Krohnitta* occurred in the collections of which *Sagitta* is the commonest genus.

1. *Sagitta enflata*, Grassi. The most conspicuous arrow worm of this coast, appears in large numbers during the post monsoon months, particularly from November to January. The younger specimens more common during October and November. Scarce during monsoon months, except for occasional appearance in large numbers.

2. *S. bedoti*, Beranek. Very common from December to May, and in small numbers almost throughout the year.

3. *S. robusta*, Doncaster. A "robust" species which occurs more commonly from January to June.

4. *S. regularis*, Aida. A very small species which occurs in moderate numbers during November-December and again in March and April. More abundant in the offshore hauls.

5. *Pterosagitta draco* (Krohn). Rare in the collections and occurs during the hot months.

6. *Krohnitta pacifica*, Aida. In moderate numbers during December to May. More common in the offshore hauls.

ANNELIDA

The annelids in the plankton consists almost exclusively of larval polychaetes and such pelagic adult forms as *Tomopteris* and *Alciopa*.

The polychaete larvae appear at times in large numbers only to disappear in a few days' time. Their occurrence in the plankton is rather erratic when compared with other planktonic organisms especially during the post-monsoon months. The great bulk of the larvae obtained comprises larval spionids in different stages of development. The allied groups of larvae are represented only in moderate numbers. During 1948-49, larval polychaetes were recorded in huge numbers during May and June with a lower peak of abundance in August-September. (Fig. 1a). During 1949-50 the first peak was limited to May only while the second one was shifted to September-October. During the 3rd year the first peak was less intense, the major peak in occurrence falling in August and being limited to the month. It is of interest to note that the first peak in all the three years was almost exclusively due to swarming of larval spionids, while in the subsequent ones non-spionid larvae too contributed substantially to raise the polychaete fraction. A more or less clear layering of the planktonic groups has been noticed in the samples brought to the laboratory during May and June when myriads of *Noctiluca* distributed themselves into a pink patch at the top of the plankton trough, a green sediment at the bottom formed of diatoms and larval bivalves and an active column in between made almost exclusively of freely moving spionid larvae.

Spionidae

Large numbers during the monsoon months but less common during the rest of the year although exceptional cases of sudden outburst observed during the post-monsoon months. During 1948-49, spionids started appearing in appreciable numbers

during the second week of May and continued to be dominant during early June. Swarms again by the middle of August after which they were never observed in appreciable numbers. In 1949-50 swarms during July after which they dwindled, again swarming in the first week of September. 1950-51 data similar to 1948-49 with sporadic appearance in December.

Magelonidae

Second only to spionids in abundance. But unlike the spionids, they never appear continuously for a long period. The seasonal distribution is erratic, but they appear generally during June, again in August-September and in lesser numbers during February and March.

Terebellidae

Loima sp. Common in the collections obtained during November and December. Lesser numbers during the hot months.

Eunicidae

Larval Eunicids never very abundant in the plankton but appear in smaller numbers during October to January. Post-larvae and adults of *Lumbriconeris* occurred in the plankton during January 1951 on two occasions.

Chaetopteridae

Small numbers from October to January. No swarms observed.

Polynoidae

Large numbers in September and January and moderately abundant in the interval.

Nereidae

A few early larvae in summer, post-larvae during rainy seasons.

Tomopteridae

Tomopteris sp. Common during November to April in the inshore and offshore hauls. Never in large numbers.

Alciopidae

Alciopa sp. in small numbers along with *Tomopteris*. More common in offshore hauls of February to March.

CRUSTACEA

The crustacean fraction of the plankton is important in that it forms a regular component of the plankton throughout the year and also because plankton crustacea form an important food for the shoaling fishes and the major part of the 'edible' plankton in the coastal waters.

Cladocera

Although the group has not been recorded as of importance in the plankton of the east coast, cladocera form a major zooplanktonic element in the Malabar waters. The period of maximum also coincides with the peak fishery along this coast and the cladocerans have been observed

to form an important food of the shoaling fishes particularly of the Indian mackerel, *Rastrelliger canagurta* (Bhimachar and George, 1952). The common cladocerans of Malabar plankton are *Evadne tergestina* Claus and *Penilia avirostris* Dana. While *Evadne* occurs in the plankton quite abundantly and appears earlier than *Penilia*, the occurrence and seasonal abundance of the latter is also equally regular and marked. The genus *Penilia* has so far not been recorded from Indian coastal waters although it appears in the plankton of both the coasts. Menon (1931) and Aiyar and Menon and Menon (1936) from Madras, Chacko (1950) from the Gulf of Manaar and Menon (1945) from Trivandrum coast have reported that the dominant cladocera were *Evadne* and *Podon*, the latter less numerous than the former and that both show more or less similar seasonal distribution. Menon (1945) reports that these occur in "fairly good numbers along the Trivandrum coast with a period of maximum intensity during July and October". But from the collections made during the period under investigation on this coast, no specimens of *Podon* were obtained so far.

Except for very slight differences, the seasonal abundance of cladocerans in the plankton is regular during all the three years although the two forms showed slight changes as regards formation of peak and period of disappearance. During the year 1948-49 *Evadne* was the first to appear as early as May. By June *Penilia* had started appearing in small numbers when *Evadne* reached a peak in abundance. By August both the forms were equally abundant and the group showed a tendency to dwindle after September. During the second year, although cladocerans were represented in the plankton during May and June, they became abundant only in July and after a month they dwindled in numbers for a few weeks to appear again in large numbers during August lasting up to early November. The peak for the year was observed in October when both the forms swarmed after which *Penilia* showed a sharp decline and total disappearance while the other form continued to be present in smaller numbers. During 1950-51 cladocerans were not so abundant as had been noticed to be the case in the previous years, but followed more or less the same trend forming a peak in October, and dwindling in number by the end of November. During this year also *Penilia* appeared a month later and disappeared a few weeks earlier than *Evadne* from the inshore waters.

Copepoda

Copepods form the major component of the holoplankton of the coastal waters almost throughout the year except during the monsoon months when their numbers are greatly reduced. Jacob and Menon (1947) in an account of the Copepoda of the West Hill sea have attempted to describe the common copepods of this coast.

With the onset of the South-West monsoon in June, the copepods of the plankton which were moderately abundant till then, become scarce. They reappear in large numbers during September-October and thereafter the copepod fraction remains appreciable. During November to January copepoda form the most dominant fraction of the plankton. In the succeeding hot months they continue to occur in moderate abundance till May. Although copepods are scarce as a rule during the phytoplankton period during the monsoon months, at times they appear on certain days in large numbers along with appreciable numbers of chaetognaths and pteropods during this season also. This instance of sporadic appearance cannot be considered as a regular feature during the monsoon period. Copepod eggs, nauplii and copepodites are observed to occur in large numbers during October and November, and in certain years, in January also. A detailed account of the copepods is being prepared separately (Kasturirangan, unpublished).

Sub-order Calanoida

The calanoid copepods are present in the plankton almost throughout the year. Species of *Temora*, *Acartia*, *Pseudodiaptomus* and *Centropages* are plentiful during the post-monsoon months, the more common species being *T. turbinata* (Dana), *A. erythraea* (Giesbrecht), and *Centropages furcatus* (Dana). Species of *Paracalanus*, *Eucalanus* and *Labidocera* are more common during the summer, while *Euchaeta* sp. represented more in the offshore hauls. The genera, *Pontella*, *Candacia* and *Undinula* are less numerous when compared with others.

Sub-order Harpacticoida

These are less plentiful in the plankton than the calanoids, except for *Euterpina acutifrons* (Dana) which is one of the commonest copepods in the inshore hauls. Of the other two genera, *Macrosetella* and *Microsetella* that appear in appreciable numbers, the former is the more common.

Sub-order Cyclopoida

Oithona occurs almost throughout the year, the dominant species being *O. plumifera* Baird and *O. brevicornis* (Giesbrecht). Saphirinid copepods common in the offshore hauls during summer. *Corycaeus* sp. in moderate numbers along with *Oithona* and *Acartia* in the inshore plankton.

Sub-order Caligoida

Young specimens of *Caligus* sp. occurred in small numbers along with the other forms in the post-monsoon months, but was never abundant in the plankton.

Cirripedia

Cirripede nauplii occur almost throughout the year. In large numbers during the latter part of the south-west monsoon period, particularly during July with occasional swarms.

Amphipoda

In small numbers in the inshore plankton soon after the onset of the monsoon and only nominally represented thereafter. The more common forms belong to the family Hyperiidæ and these were seen to float on the surface of preserved samples.

Cumacea

On the whole few and very rare during monsoons. A few specimens of *Eocuma taprobanicum* Calman were obtained during January to March.

Ostracoda

Ostracods occur more in the offshore hauls during summer. They are rare at other parts of the year.

Decapoda

Decapod larvae* and such adult forms as *Lucifer* and *Acetes* are present in large numbers during the post-monsoon months. A good many of the forms recorded by Menon from Madras plankton (1933, 1937 and 1940) were obtained from the present collections also. Larval decapods particularly zoea and mysis stages of the macrurans are abundant in the inshore plankton during November to May.

Sub-order I—Natantia

Family *Penaeeidae*. Eggs and larval stages occur from November. Swarms of Penaeid eggs, mostly of *Metapenaeus dobsoni** appeared from 9th to 14th of November 1949 and were soon followed by early and advanced larval stages in moderate numbers. During 1950-51 their occurrence was less intense.

Family *Sergestidae*. The more common sergestids are *Acetes* and *Lucifer*. *Acetes dispar* (Kishinouye) swarms in the inshore waters during February to April and occurs less abundantly at other parts of the year. *Lucifer* sp. more or less equally common and has a peak period during March and April.

Family *Hippolytidae*. Larval Hippolysmatids occur during October and November. Advanced larvae of *Hippolysmata* sp. with the characteristic paddle-shaped penultimate joint in the fifth thoracic leg occurred in all the three years during this period both in the estuaries and in the inshore collections.

Family *Alpheidae*. Larvae of *Alpheus* sp. occurred in appreciable numbers along with larval hippolysmatids during October-December period.

Sub-order II—Reptantia

Family *Palinuridae*. *Phyllosoma* larvae were generally rare except for stray specimens during January to March.

Family *Hippidae*. Zoea of *Emerita* occurs during December and January, in small numbers till the onset of the rains.

Family *Albuneidae*. Less common than larvae of *Emerita* and along with them.

Family *Paguridae*. Advanced stages of larval hermit crabs in negligible numbers.

Family *Porcellanidae*. First zoea stage of *Porcellanella* sp. in the offshore hauls during October and again from February to April.

Family *Dorippidae*. Larvae of *Ethusa* sp. ranging from the first stage to the fourth stage in development (Menon, 1940) noticed in small numbers during November to February.

Family *Pinnotheridae*. Larvae of *Pinnotheres* sp. were collected in small numbers during January and February.

Division *Brachyura*. Zoea and megalopa stages of crabs, especially the former stage is common in the plankton after December especially during February and March.

Stomatopoda

Alima larva occurs regularly in small numbers from December to May. More common in offshore hauls. They completely disappear from the plankton during the rainy season.

* I am indebted to Mr. M. K. Menon for identification of the species.

MOLLUSCA

Larval bivalves, larval gastropods and certain pelagic molluscs appear regularly and in appreciable numbers.

Lamellibranchiata

Lamellibranch larvae* are common in the plankton almost throughout the year. These occurred in large numbers during May in all the three years. During 1948-49, they formed an important constituent till July. During the second and third years, they ceased to occur in abundance after June, but a minor peak was observed in February 1951. The larval bivalves observed in the plankton are mostly advanced stages. The more common Lamellibranch larvae observed in the plankton are :

1. *Mytilus* sp. Occur in very large numbers during May, June and July.
2. *Teredo* sp. In smaller numbers during February and March.
3. Venerid larvae. In fairly large numbers along with those of *Mytilus*.
4. *Ostrea* sp. In very small numbers during February and March.

Gastropoda

Veliger larvae are common during the hot months. Post-larval gastropods also occur in the plankton during this season. Pelagic molluscs appear in abundance during the post-monsoon months although large numbers of *Creseis* sp. appear sporadically on certain days during the monsoon season as well. Pelagic molluscs, along with larval bivalves enter the food of fishes.

Order *Heteropoda*. 1. *Atlanta* sp. in large numbers from October to March. Young stages frequently encountered during January to March. These occur in abundance in the offshore hauls also.

2. *Firoloida* sp. Less abundant and occurs very rarely in the inshore hauls. Female specimens with attached egg chains obtained during the hot months from the 20 fathom area.

3. *Carinaria* sp. in small numbers along with *Firoloida* in the offshore hauls.

Order *Pteropoda* (*Thecosomata*). 1. *Creseis acicula* Rang is the most common pteropod in the plankton and occurs in large numbers from September to April. Also observed to occur sporadically on certain days during the rainy season. Large numbers of *Creseis* in various stages of development along with the adults from November to January.

2. *Cavolinia* sp. Abundant in the offshore hauls and in smaller numbers in the inshore hauls.

ECHINODERMATA

Large numbers of dark green *Echinoplutei* occur in the plankton during March and April and are particularly prominent in the off shore hauls. Other larvae occur in small numbers during January to April. Small Echinoids and Ophiuroids have also been obtained.

* I am indebted to Mr. K. Virabhadra Rao for help in the identification of Lamelli branch larvae.

OTHER INVERTEBRATE LARVAE

1. *Actinotrocha*. Occurs in small numbers during October and November and rarely thereafter. Never very abundant in any season.
 2. *Pilidium*. Collected during November and again during February and March.
 3. *Cyphonautes*. In greater abundance during January to April and irregularly afterwards.
- Larval actinians. Irregularly in small numbers during the monsoon months.
- Tornaria*. Found during the post-monsoon months, October-December and are rare thereafter.

TUNICATA

The tunicates are represented by the orders *Salpida* and *Doliolida* in class *Thaliacea* and by the genera *Oikopleura* and *Fritillaria* in the class *Appendicularia*.

Salpida (*Hemimysaria*)

Salps occur in huge numbers during the closing part of the monsoon months. During 1948-49, large numbers of salpids appeared in the inshore waters in August for a couple of weeks after which they were observed to continue to be present in small numbers. Salps appeared in appreciable numbers again in January and were common till March. During the second year, a sudden appearance was noted in the last week of August and they remained dominant in the plankton till October after which they reappeared in large numbers from January to March. During 1950-51, they occurred in large numbers during the third week of August and this large scale occurrence lasted till the middle of September. As observed in the previous years the salpids were abundant during January and February. The more common forms observed in the plankton of this coast are listed below :

1. *Thalia democratica* Forskal. The commonest salpid of this coast. In large numbers by the close of the monsoon season and scarce thereafter till January after which it is abundant till April.
2. *Pegea confederata* (Forskal). Rare in the inshore waters except for a few specimens of both the solitary and aggregate forms during February-March.

Doliolidae (*Cyclomyaria*)

3. *Doliolum* sp. Common in August and September and in small numbers during January and February.

Appendicularia

4. *Oikopleura dioica* Fol. Almost throughout the year in the inshore and offshore waters, but never observed to appear in swarms. The commonest appendicularian of the coastal waters and appears in appreciable numbers from August to April and is more abundant during February and March.
5. *Oikopleura cophocerca* Gegenbaur. Occurs rarely in the offshore hauls during March-April.
6. *Fritillaria* sp. Very rare in the inshore hauls. Recorded from the collections obtained during March and April in the offshore hauls.

FISH EGGS AND FISH LARVAE

Fish eggs and larvae were not very abundant in the coastal waters for long periods and compared to other planktonic elements, they were numerically small in the plankton. But the seasonal abundance of fish eggs was more or less definite during the three years. During the monsoon months, eggs and larvae were scarce, but they started appearing in the plankton from September. Fish eggs have been observed to reach their numerical intensity along the Madras Coast during December and January (Nair 1952). October and November were the months in which fish eggs occurred in appreciable numbers along this coast and they were mostly of carangids and clupeids. Eggs continued to be present in moderate numbers till February after which they occurred only nominally and at random in the collections. Carangid and clupeid larvae occurred along with the eggs, the latter being more common during January and February.

Caranx sp. Eggs with single oil globule common from September.

Anchoviella sp. The oval shaped eggs more common during December and January, but in smaller numbers at other parts of the year.

Kowala sp. Eggs common during the September-November months, particularly during the latter half of the season.

**Sardinella longiceps*. Eggs obtained during August 1950 in the season of sardine fishery, when mature specimens touched this coast in shoals. The characteristic large round eggs of the oil sardine are rare in the plankton during other parts of the year.

PHYTOPLANKTON

In this section an attempt only is made to point out the peak periods of phytoplankton occurrence in the Malabar Coast and the common forms contributing to them. The seasons of abundance have been observed to vary from year to year, barring the monsoon months which were observed to be a period of phytoplankton dominance in all the three years.

During 1948-49 the peak of phytoplankton was observed in June. The dominant elements belonged to the *Diatomacea*, the more common forms being *Fragilaria oceanica* Cleve, *Coscinodiscus gigas* Ehrenberg var. *praetexta* Hustedt and species of *Rhizosolenia*, and *Chaetoceros*. Species of *Bacteriastrum*, *Skeletonema*, *Eucampia Ditylium* and *Asterionella* were also present. Early in September, *Coscinodiscus gigas* Ehrenberg var. *praetexta* Hustedt appeared again in very large numbers. A second peak was observed in the first week of December, the dominant elements in this bloom being *Nitzschia sigma* (Kutz) W. Smith var. *indica*, *Rhizosolenia setigera* Brightwell, *Chaetoceros curvisetus* Cleve and the blue green alga *Oscillatoria erythraeum*. This peak lasted only for about three weeks and afterwards the phytoplankton density declined. In April a minor

* I am indebted to Mr. R. V. Nair for the identification.

peak was observed which was composed wholly of species of *Pleurosigma*, *Lauderia*, *Chaetoceros* and *Biddulphia*.

During the second year, the monsoon bloom of phytoplankton started in the middle of June and lasted up to the second week of August, the diatoms forming the dominant flora. The major components of this peak were species of *Fragilaria*, *Thalassiothrix*, *Coscinodiscus* and *Chaetoceros*. During the second half of September, appreciable numbers of species of *Coscinodiscus*, *Chaetoceros* and *Rhizosolenia* appeared. A second peak occurred in the last week of December. The more common elements in the flora were species of *Rhizosolenia*, *Pleurosigma*, *Chaetoceros* and *Bacteriastrum*. In February, an abundance of *Pleurosigma Normanii* Ralf gave rise to a minor peak.

During 1950-51, the monsoon peak occurred by the first week of June and diatoms were plentiful up to the middle of September. The common genera observed in abundance were the same as those which appeared during the monsoon months of the previous year. *Oscillatoria erythraeum* also occurred in moderate abundance by the close of June. The second peak was noted in January unlike in December in the previous years and was composed mostly of species of *Chaetoceros*, *Rhizosolenia*, *Eucampia* and *Hemidiscus*. The small rise observed in April was due to swarming of *Pleurosigma* and *Biddulphia*.

The offshore plankton collected during the post-monsoon months always revealed a comparatively lower diatom proportion in the plankton. But from February to April both the species of *Oscillatoria*, *O. erythraeum* and *O. thiebauti* occurred in abundance, particularly the former species.

From a general survey of the seasonal composition of the phytoplanktonic elements during the different years, it appears that the occurrence of peak periods is not very regular year after year except the monsoon bloom of diatoms. The so-called autumn peak appeared in the first week of December during 1948-49. It reappeared late in December during the second year and during 1950-51 the peak was observed to have shifted to January.* Similarly the diatom rise observed during April in the first year appeared in February during 1949-50 and in the final year the peak occurred again in April. The seasonal abundance of the different genera and species is left undiscussed as the present observations could be regarded as not comprehensive enough to form the basis for such generalisations.

The Hydrological Conditions

TEMPERATURE

A high annual range in temperature has been met with in the different

* During 1951-52 this peak appeared only in early February.

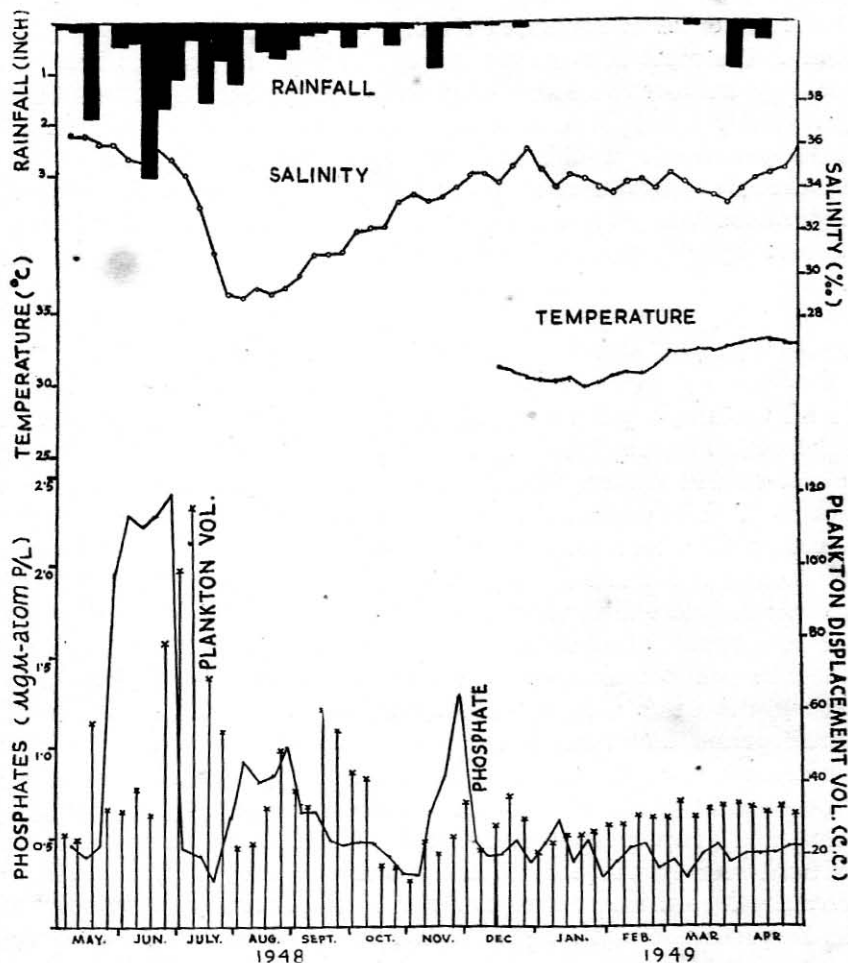


Fig. 2

seasons of the year and this has been observed to be more or less similar during the three years. During 1948-49 the highest temperature was observed in the second week of April, the value being 30.4°C . In the second year (1949-50) the highest reading was recorded in the last week of April the value remaining the same as of the previous year. During 1950-51 it was in the second week of May that the highest temperature was recorded when it rose to as high as 31.5°C . which is the highest record of water temperature for the three years (Appendices I, II and III). The lowest temperatures were observed always to be in July, when it was found to be as low as 23.2°C ., the dominant influence for this lowering being the active south-west monsoon.

As can be seen from Figs. 3 and 4, during the month of May, especially in the first half, the temperature remains very high but quickly

falls with the onset of rains and reaches the lowest values in July, when the monsoon is most active. By the end of August temperature steadily rises and by October the curve is on the ascent. The north-east monsoon was practically a failure along the west coast during all the three years, particularly during 1948-49 and hence it did not affect the continued rise in temperature during the season. During December and January, a fall in temperature was observed and by the second week of February, the values rose up and remained more or less steady till the onset of the rains.

SALINITY

In all the three years the salinity remained very high during April and May. 36.63‰, 36.70‰ and 36.65‰ were the highest values for the years 1948-49, 1949-50 and 1950-51 and these were recorded in the first week of May. The surface salinity in the 8 fathom area fell steadily with the onset of the rains and by July-August the values were as low as 28.8‰, 25.2‰ and 21.54‰ respectively. During the years 1948-49 and 1949-50, the lowest values were obtained in the second week of July, but in 1950-51 although the salinity values in July were comparable with those of the two previous years, the minimum reading was observed in August and the value obtained viz. 21.54‰, is the lowest recorded during the entire period under review. As can be seen from the bar diagrams for rain-fall the low record is directly due to heavy and widespread south-west monsoon of 1950. Soon after the monsoon the salinity values get steadier and by September-October salinity curves show an upward trend as has been seen in the case of temperature readings. The continuance of intermittent rain in October and November is likely to be responsible for the frequent rise and fall in the salinity curve for 1950-51. A steady but marked fall has also been observed during January and in the first half of February.

The salinity of the bottom water samples were more steady and less fluctuating than of the surface. The effect of intermittent rain on the bottom values was almost negligible and even during the monsoon, the salinity values were seldom lower than 32.0‰ in the 8 fathom area.

PHOSPHATES

The phosphate values obtained have been observed to be higher when compared with the records of Bombay (Bal *et al.*, 1946) and Madras (Jayaraman, 1951) coasts.

During the year 1948-49 low phosphates were observed in May. Soon after the onset of the monsoons very high phosphate values are observed during June and early July and is followed by erratic readings for the

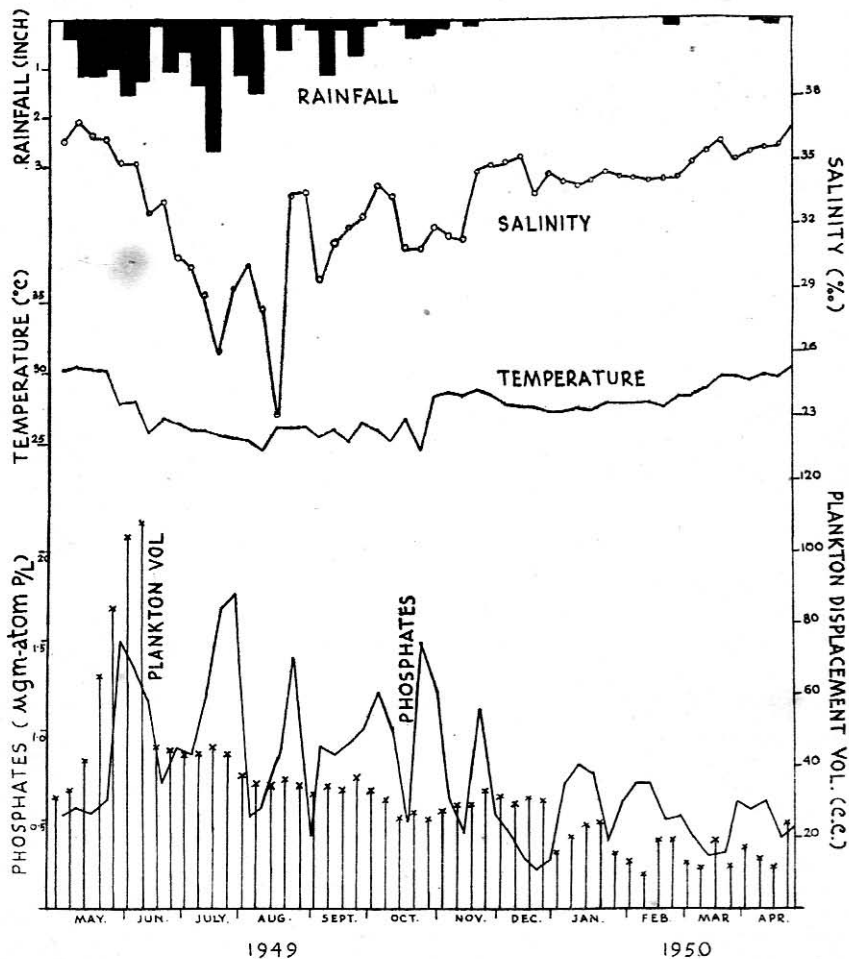


Fig. 3

rest of the monsoon months showing sharp ups and downs. This has been observed to be the same in the subsequent years as well. The heavy storms and large breakers practically churn the muddy bottom and the large volumes of fresh water brought in by the rivers consequent to heavy rains in the hills and surrounding places also exert marked influence on the hydrological conditions.

A sudden flowering of diatoms is also characteristic of this period. The fact that the phosphate content remains very high during this season of large scale production of phytoplankton shows that considerable quantities of phosphates still remain unutilised in the inshore waters during this period. A rise in the phosphate values was observed during the period of mud bank formations also during the latter half of the south-west monsoon period. The next large peak was found to be prior

to the second diatom bloom in November-December and it was followed by a trough. From January to May the values were moderately low, although minor peaks and troughs were observed prior to and subsequent to swarming of diatoms and dinophysids.

Although the fluctuations of phosphates follow the same pattern during the monsoon months in all the three years under review it shows large variations during the post-monsoon months in the different years, which are likely to be due to the influence of the periodic outburst of diatoms. The minor peaks in phosphates were observed in the last week of August and 1st week of November and also in January during the year 1948-49. In the second year the peaks were in August, October, early January and the last week of March. During 1950-51 the minor peaks were more prominent during November early January and in the last week of March.

The bottom samples invariably showed a high value throughout the year although the differences were more striking during the monsoon months and periods of formation of mud banks and were least during summer. The fall in the phosphates readings too was sharper and more striking in the surface samples.

Plankton Month by Month

A Plankton Calendar of the more frequent organisms of Calicut Coast

JANUARY—Sea moderately calm—cool mornings—water temperature falls steadily (tempr. range 28.2°C.-27.5°C.), surface salinity between 33.4‰ to 34.7‰.

Zooplankton—mostly copepods, Medusae and such Chaetognaths as *Sagitta enflata* and *Krohnitta*; Appendicularians, Salpids and Pelagic molluscs such as *Creseis* and *Atlantia* common; Outburst of single and colonial *Radiolaria* likely.

**Phytoplankton*—Diatoms common; *Rhizosolenia*, *Chaetoceros*, *Coscinodiscus* and *Biddulphia*.

FEBRUARY—Sea moderately calm—water temperature range 27.8°C.-29.4°C.; surface salinity range 34.0‰ to 34.8‰; Active breeze towards land in the afternoons.

Zooplankton—Copepods dominant, *Sagitta*, Pelagic molluscs, *Macrura* mysis stages, *Lucifer* and *Acetes*, stomatopod larvae, hydromedusa, appendicularians, ctenophores and clupeid fish larvae present. *Cyphonautes* larva and larval gastropods common.

Phytoplankton—The blue green alga, *Oscillatoria*, common; Diatoms mostly *Rhizosolenia*, *Skeletonema*, *Chaetoceros* and *Pleurosigma*.

MARCH—Sea calm, temperature range of water 28.5°C.-30.2°C.—Salinity range 33.7‰-35.10‰.

Zooplankton—Copepods dominant; post-larval stages and adults of *Acetes* and *Lucifer* abundant; *Sagitta enflata* and *S. bedoti* plenty, *Krohnitta* present; Hydromedusa, Pelagic molluscs and appendicularians common; *Pilidium* and *Cyphonautes* larvae frequent; *Beroe* and *Cestum* appears; *Porpita*, *Pegea* and green echinoderm larvae common in the offshore hauls.

Phytoplankton—Moderately present—diatoms mostly of *Rhizosolenia*, *Lauderia*, *Chaetoceros*, *Schroderella* and *Pleurosigma*.

APRIL—Sea calm—water temperature high, range 29.4°C.-30.4°C. Salinity high (34.5‰-36.4‰); hot days and warm nights—very active sea breeze.

Zooplankton—Chaetognaths dominant; mostly *Sagitta enflata*, *S. regularis* and

* The monthly variations of diatoms are less rigid and hence large scale occurrence of certain species are likely to be delayed or shifted to later months.

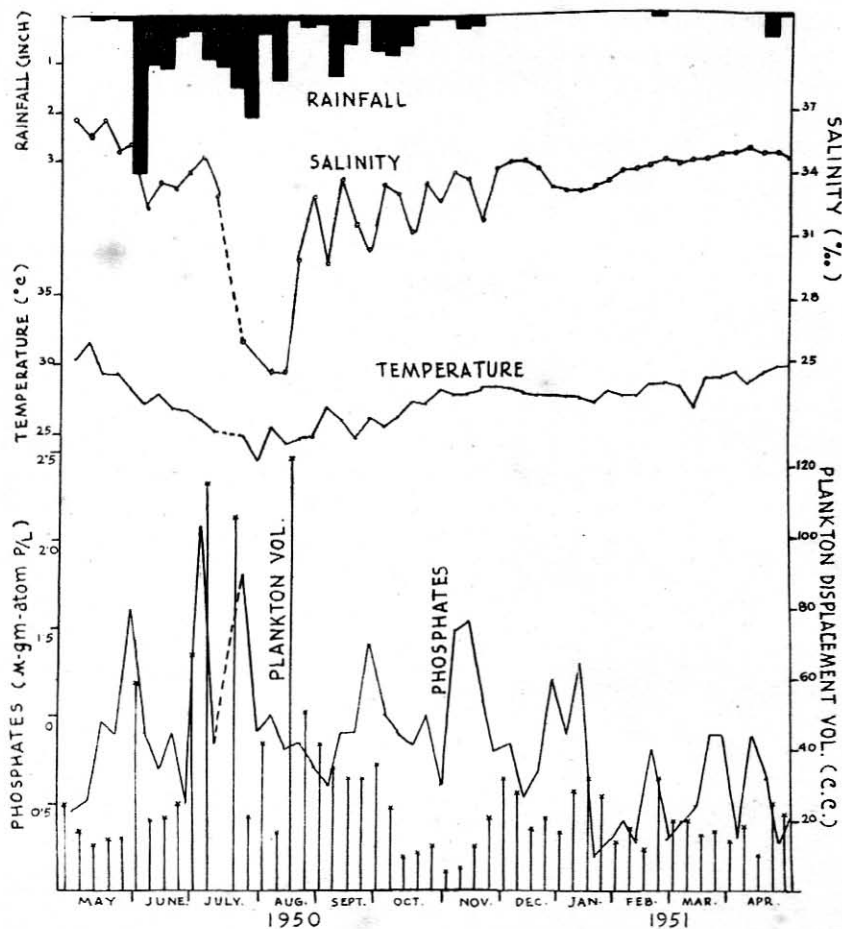


Fig. 4

Krohnitta pacifica; Copepods common; Lamellibranch larvae, Decapod larvae and plankton decapods, Hydromedusae and Magelonid polychaetes common. *Phytoplankton*—Mostly diatoms, *Pleurosigma* dominant.

MAY—Water temperature continues to be high till the middle of the month (31.5°C.-28.4°C.); salinity falls by the close of the month (36.6‰-35.4‰) due to occasional thunder showers. Sky clear in early May, overcast by the close of the month.

Zooplankton—Larger chaetognaths continue to be common; Copepods still dominant; *Acetes*, *Lucifer* and Crab zoea, continue to be numerous, Larval bivalves, spionid polychaete larvae and medusae common.

Phytoplankton—Moderate, mostly diatoms such as *Pleurosigma*, *Rhizosolenia* and *Coscinodiscus*.

JUNE—Monsoon breaks in the first half of the month, Temp. falls (28.0°C.-26.6°C.); Salinity declines (35.3‰-30.4‰); Moderate to heavy rains; Sea water turbid. *Zooplankton*—Polychaete spionid larvae in swarm conditions; *Mytilus* larva dominant; Copepods dwindled; Polyclads swarm and *Evadne* and *Noctiluca* reappear.

Phytoplankton—Very dominant; Total volume very high; Swarms of *Fragilaria*, *Coscinodiscus*, *Chaetoceros* and *Streptotheca*.

- JULY**—Monsoon active; Sea very rough—tempr. as low as 23.2°C.; Salinity falls up to 26.0‰ and to lower values in the inshore areas. Sea water very turbid. Mud bank formation likely.
Zooplankton—Copepods scarce; Spionids and *Noctiluca* in abundance; *Evadne* on the increase; *Penilia* reappear; Larval cirripedes and larval bivalves common.
Phytoplankton—Bloom of *Fragilaria*, *Coscinodiscus*, *Thalassiothrix Asterionella* and *Chaetoceros*; *Ceratium*, *Peridinium* and *Pyrophacus* also abundant.
- AUGUST**—Vigor of monsoon subsides, mud bank formation likely in the inshore waters, slusny mud thrown on the shore—intermittent sunshine—Tempr. varies between 24.4°C.-25.2°C.; Salinity goes up to 30.5‰.
Zooplankton—Moderate; Copepods still less abundant, *Noctiluca* in swarms; Cladocera on the increase; Dinoflagellates (Dinophysids and Peridinids) swarm in inshore area; Polychaete larvae decline; Invasion of Salps and Doliolids likely.
Phytoplankton—Unarmoured flagellates swarm in the inshore waters, diatoms mostly *Coscinodiscus*, *Fragilaria* and *Chaetoceros*.
- SEPTEMBER**—Rains intermittent—water tempr. rises (24.7°C.-26.5°C.); Salinity on the increase up to 33.3‰.
Zooplankton—Cladocerans more dominant than Copepoda, the latter reappear in large numbers; *Noctiluca* continues to be abundant; *Hydromedusa* such as *Solmundella* and *Liriope* reappear; *Thaliacea* continue in small numbers.
Phytoplankton—Moderately abundant; *Ceratium* dominant; diatoms mostly *Rhizosolenia*, *Chaetoceros*, *Biddulphia* and *Ditylium*.
- OCTOBER**—Tempr. on the rise—(25.2°C.-28.0°C.), salinity range is 30.8‰ to 33.7‰.
Zooplankton—Copepods dominant, Copepod nauplii present; Medusae, Siphonophores and larval invertebrates appear; Cydippid ctenophores and nonspionid larval polychaetes present; Fish eggs such as of *Caranx*, *Stolephorus* and *Kowala* are on the increase; Chaetognaths reappear in large numbers.
Phytoplankton—Diatoms moderate in abundance, mostly *Coscinodiscus*, *Chaetoceros*, *Biddulphia* and *Nitzschia*.
- NOVEMBER**—Tempr. on the increase (27.8°C.-28.6°C.)—Salinity values up but likely to be erratic due to occasional rains, the range being 31.1‰-34.9‰; period of north-east monsoon.
Zooplankton—Copepods and Chaetognaths more dominant; *Cladocera* on the decline particularly *Penilia*; Such medusae as *Octocanna*, *Liriope* and *Aequorea*, and such Siphonophores as *Diphyes* and *Enneagonum* present in appreciable numbers; Fish eggs particularly eggs of *Kowala* common; Liberation of Macruran eggs and larvae likely.
Phytoplankton—Diatoms mostly *Rhizosolenia*, *Chaetoceros* and *Coscinodiscus*; *Ceratium* and *Peridinium* in small numbers.
- DECEMBER**—Water tempr. more or less steady (27.0°C.-28.5°C.)—Night tempr. falls—Salinity between 33.6‰-35.1‰.
Zooplankton—Copepods and Chaetognaths dominant; Medusae, Siphonophores and Comb-jellies common; Pelagic molluscs mostly *Creseis*, *Atlanta* and *Cavolinia* present in moderate numbers; Fish eggs and various bottom invertebrate larvae appear.
Phytoplankton—Diatoms and Dinophysids on the increase, mostly *Rhizosolenia*, *Coscinodiscus* and *Chaetoceros* and also *Dinophysis*, *Ornithocercus* and *Ceratium*.

Total Plankton Displacement Volume

As can be seen from Figs. 2, 3, and 4 the displacement volumes increased many folds during the monsoon months in all the three years under review and these monsoon peaks have formed almost exclusively of phytoplankton.

During 1948-49 the total plankton volumes were moderately low in early May, but the volumes steadily increased with the onset of rains and by the last week of June the top value, 116 c.c. was obtained.

The volumes again increased in September after which the total displacement volumes remained low till December. During summer the volumes were never high but were steady owing to the occurrence in appreciable numbers of medusae, ctenophores, chaetognaths, and siphonophores. In 1949-50 the total volume began to rise in early June itself and the highest volume 108 cc. was recorded in the third week of June. The volumes ranged between 20 and 35 cc. from September to December and during February to April fairly low volumes were obtained when compared with those of the previous year. During 1950-51 unlike the previous two years the total plankton volumes were rather erratic although they followed the same trend in the fluctuations. Low volumes were obtained in May. Although a sudden rise was observed in the first week of June it was only by the middle of July that high volumes were obtained continuously and the highest volume recorded was 123 cc. (Fig. 4).

It is evident from the observations made during the three years under review that the total plankton volumes remained very high during the monsoon months, especially during the former half and that the dominant factor which was responsible for these high volumes is the swarming of diatoms and dinoflagellates. During the post-monsoon months, zooplanktonic elements reappear in large numbers, but they do not appreciably help to maintain the high volumes obtained during the monsoon months. A slight rise in the volume is noticed during February to April and it is due mainly to the domination of the plankton by the large species of ctenophores, siphonophores, *Sagitta* and tunicates.

Seasonal and Annual Variations

The studies on the seasonal distribution of the various planktonic groups reveal that with the onset of the rains in early June, a quick and marked change in the composition of the plankton takes place in the inshore waters. Hydromedusae, siphonophores, larger chaetognaths and copepods which dominate the plankton till then dwindle and almost disappear and they are replaced by swarms of diatoms such as species of *Fragilaria*, *Coscinodiscus*, *Rhizosolenia* and *Chaetoceros*. The cystoflagellate, *Noctiluca* also reappears in large numbers. The plankton is turned green or grey depending on the dominance of particular species. The zooplankton fraction is extremely low at this period except for the larval spionid polychaetes and larval bivalves. This dominance of diatoms lasts up to the close of August and during the latter half of the season, dinophysids and peridinids also occur in appreciable numbers.

From September onwards the phytoplankton dominance ceases and this period is characterised by the reappearance and swarming of cladocerans, copepods, medusae, siphonophores and chaetognaths. This season is different from the monsoon months in that both zoo and phytoplanktonic

species appear in appreciable numbers at the same time. During October and November, fish eggs, particularly carangoid eggs and eggs of *Kowala* occur in the plankton. The abundance of prawn eggs has also been observed to occur during this season and is followed by the appearance of macruran larve and post-larve. By the close of this season which lasts up to December or early January, a rise in the diatom proportion is also noticeable. Larvae of various bottom invertebrates such as *Actinotrocha*, *Pilidium* and *Cyphonautes* larvae are found to appear during the latter half of this period. *Tornaria* also appear at this part of the year.

From January onwards the larger forms particularly *Thalia*, *Sagitta*, larger copepods, Siphonophores and medusae dominate the plankton. The phytoplankton fraction is generally low, except for *Oscillatoria* which reappears during this season. Stomatopod larvae, larval brachyura and larger pteropods continue to be present till May. But for a slow rise in the proportion of diatoms due to swarming of *Pleurosigma*, the diatom proportion is negligible and Ostracods and Amphipods and *Krohintta* also increase in proportion during this period.

The annual variations in the plankton are not irregular in the three years under investigation as can be seen from Text Figs. 1a and 1b. The seasons of occurrence of the many forms do not appreciably change, but the intensity has been observed to vary in many groups. The *Noctiluca* dominance was most intense during 1948-49 while it became less in the two succeeding years. In the case of Cladocera the second year showed the maximum intensity in occurrence. As regards the annual variations in the composition of the larval bivalves, the group showed continuous swarming during May-June and July during 1948-49, while the second and third years this swarming period was limited to the month of May only. In the case of Chaetognaths, the proportion of abundance of the group in the monsoon months has diminished to a certain extent in the second and third years. The annual variations in the seasonal abundance of the polychaete larvae are also rather erratic (Fig. 1a) although their occurrence in swarms during the monsoon periods is marked and regular.

Plankton in Relation to Hydrological Conditions

As can be seen from the accounts of the seasonal abundance of plankton and the fluctuations in the hydrological conditions, the most important factor affecting them is the south-west monsoon which starts in early June and lasts up to August. The continuous rains accompanied by stormy weather conditions in the sea resulting in disturbances in the muddy bottom exert a profound influence on the fauna and flora of the coastal waters. The large amount of fresh water brought in by the rains and also by the two small rivers, *Beypore* and *Korapuzha* considerably

lowers the coastal salinities. Water temperature is also low during this period. Many planktonic forms such as the larger chaetognaths and siphonophores which are characteristic of the open sea dwindle and disappear except for stray appearance on certain days. The factors which bring about the swarming of diatoms during this season and the relative role of each have yet to be determined as we have no opportunity to study the offshore conditions during the monsoon season.

The phosphate values which normally ranged between 25 and 40 m. gms. of P_2O_5 per M^3 have shown substantially to increase during the monsoon season. These high phosphate values have also been observed to be more or less a regular annual feature in spite of the swarming of diatoms at this period.

During the post-monsoon period water temperature quickly returns to steadier conditions than salinity. Sverdrup (1942) points out that conditions of "relative warm water with some reduction in salinity" is ideal for neritic plankton to thrive. This perhaps explains the re-appearance of copepods, copepod eggs and nauplii and cladocerans and larval and post-larval decapods, during this season. The North-East monsoons would have brought in further ups and downs in the temperature salinity curves, but so far, the second monsoon was never active in any of the years under review and hence its influence on the general planktological and hydrological cycle was probably negligible.

A rapid depletion of phosphates in the surface waters during periods of phytoplankton abundance has been shown to be very marked in the temperate waters (Harvey 1928, Orr 1933 and Dakin and Colefax 1935 and 1940). But a similar phenomenon is absent in the Malabar waters during the monsoon period due to reasons already explained. Yet the phosphate values obtained during the rest of the year show more or less similar relationships. The so-called autumn peak of phytoplankton dominance and the slight rise noted in March-April have been represented by troughs in the phosphate curves. The summer months showed a generally low but steady phosphate content and the phytoplankton proportion during this period in all the years were noticeably poor especially when compared to the conditions at other seasons of the year.

Plankton in Relation to Fisheries

The present studies on the plankton and hydrological conditions show some interesting correlations with the fisheries of this coast, the more important of which are of the oil sardine, *Sardinella longiceps* and the Indian mackerel, *Rastrelliger canagurta*, both feeding exclusively on plankton. The principal season of the mackerel and sardine fisheries along this coast is from September to December. The plankton of this season is remarkable in that it is characterised by moderately abundant

phytoplankton and large numbers of reappearing copepods, cladocerans, decapod larvae, peridinians and other protozoans which are consumed as food by fishes particularly by the mackerel. This coincidence of the season of mackerel and sardine fishery with the period of abundance of edible planktonic forms is in accord with the view expressed by Panikkar (1949) that in tropical waters "a direct correlation between plankton and the abundance of pelagic fisheries composed of clupeids and mackerel should (therefore) be possible."

It is also indicated from this study that the abundance of plankton does not always mean proportional abundance in fish food since some planktonic elements such as medusae, ctenophores, siphonophores and *Noctiluca* do not appreciably contribute to the food of fishes although these forms when occurring in large numbers substantially increase the plankton volumes. Demarcation of planktonic species into the edible and non-edible groups is essential for purposes of evaluating the fluctuations of actual fish food. During the post-monsoon months from September to December, the edible plankton fraction is highest in the inshore waters while from February to May, the non-edible elements dominate the plankton.

The total plankton volumes have been observed to be highest during the monsoon months in all the three years and the readings obtained were much higher than those obtained during the other parts of the year, (Figs. 2, 3, and 4). This observation is not in agreement with the findings of Chidambaram and Menon (1945) that "the volume of plankton is at its maximum in the month of September." This is obviously due to the fact that the observations of these authors did not cover the monsoon months in any year of their studies.

The swarming and subsequent death and decay of *Noctiluca* followed by the appearance of ciliates and euglenoids have been observed to have a retarding influence on the fishery of the coastal waters, and since this phenomenon is generally not regular and when occurring is highly localised, it cannot be considered as an annual feature. The moderately low plankton volumes and the relatively high proportions of non-edible elements during the summer months will be evident from seasonal changes described. This may be the chief reason for the poor nature of the fisheries during summer months.

Summary

Seasonal and annual variations in the composition of the plankton off West Hill near Calicut, Malabar for the period 1948-51 were studied with special reference to the more important groups based on bi-weekly plankton hauls in the 8 fathom area. The studies reveal similar annual trends, with a few variations in details of the pattern in each year.

The salinity, water temperature, rainfall and phosphate content were also studied. The south-west monsoon which starts early in June has been observed to exert a

profound influence on the planktological and hydrological conditions of the coastal waters. A marked outburst of diatoms and dinoflagellates, high total plankton volumes, appreciable lowering of salinity and water temperature and high phosphates are characteristic of this period. The post-monsoon season during September to December is characterised by reappearance in large numbers of copepods, cladocerans, plankton decapods and fish eggs and larvae and moderate numbers of diatoms and dinophysids. This season has been observed to be a period of abundance of rich "edible plankton" in the coastal waters. The active fishery of the oil sardine and mackerel along this coast coincides with this period.

The north-east monsoon has been noted to be extremely feeble in all the three years under investigation. Hence its influence on the conditions of the coastal waters has been observed to be negligible.

Except for the monsoon bloom of diatoms which is a regular annual feature, the swarming of diatoms at other seasons has been observed to be less regular although two minor peaks can be expected, one during December-January and the other during March-April. No reduction in phosphate content has been noted during the monsoon bloom of phytoplankton although closer relationships were noticed during the minor diatom peaks.

The plankton obtained during the summer months, February to May, reveals larger medusae, salps, chaetognaths, siphonophores, larger copepods and *Oscillatoria*. High temperatures and salinities and moderately low phosphates are also characteristic of this period.

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APPENDIX I
1948-49

Hydrological data and total plankton volumes (weekly average), West Hill, Calicut

Week ending	Plankton displacement volume (in c.c.)	Surface Temperature (°C.)	Surface Salinity (‰)	Phosphates (μ.g.at.P/L.)
3. 5.1948	26	..	36.63	.423
10. 5.1948	25	..	36.54	.400
17. 5.1948	56	..	36.15	.423
24. 5.1948	32.8	..	36.02	1.99
31. 5.1948	32	..	35.41	2.25
7. 6.1948	38	..	35.27	2.20
14. 6.1948	31	..	35.91	2.25
21. 6.1948	79	..	35.36	2.37
28. 6.1948	99	..	34.60	.423
5. 7.1948	116	..	33.21	.409
12. 7.1948	69	..	31.06	.243
19. 7.1948	54	..	28.88	.634
26. 7.1948	22	..	29.03	.943
2. 8.1948	23	..	29.50	.809
9. 8.1948	33	..	29.25	.852
16. 8.1948	49	..	29.53	1.01
23. 8.1948	37.5	..	30.18	.739
30. 8.1948	34	..	31.00	.655
6. 9.1948	60	..	31.13	.517
13. 9.1948	55	..	31.20	.456
20. 9.1948	43.5	..	32.21	.482
27. 9.1948	41	..	33.27	.452
4.10.1948	17	..	33.27	.394
11.10.1948	16	..	33.40	.316
18.10.1948	13	..	33.74	.291
25.10.1948	24	..	33.41	.669
1.11.1948	20.2	..	33.58	.845
8.11.1948	25	..	34.11	1.35
15.11.1948	35	..	34.60	.479
22.11.1948	21.5	..	34.63	.394
29.11.1948	28	28.5	34.39	.418
6.12.1948	37	28.2	35.18	.479
13.12.1948	30	27.8	35.88	.366
20.12.1948	21	27.7	34.97	.493
27.12.1948	22.5	27.5	34.16	.597
3. 1.1949	25.5	27.8	34.70	.352
10. 1.1949	24.8	27.2	34.55	.479
17. 1.1949	26.0	27.5	34.07	.282
24. 1.1949	27	28.0	33.88	.363
31. 1.1949	29	28.2	34.27	.423
7. 2.1949	30.5	28.1	34.32	.442
14. 2.1949	30	28.7	34.17	.352
21. 2.1949	30	29.2	34.80	.380
28. 2.1949	32.5	29.2	34.30	.282
7. 3.1949	30	29.8	33.90	.409
14. 3.1949	32.5	29.7	33.70	.464
21. 3.1949	33.5	30.0	34.37	.387
28. 3.1949	34	30.2	34.10	.412
4. 4.1949	33	30.4	34.52	.401
11. 4.1949	31	30.4	34.69	.400
18. 4.1949	32.5	30.2	34.93	.399
25. 4.1949	31	30.2	35.90	.399

APPENDIX II

1949-50

Hydrological data and total plankton volumes (weekly average), West Hill, Calicut

Week ending	Plankton displacement volume (in c.c.)	Surface Temperature (°C.)	Surface Salinity (‰)	Phosphates (μ.g.at.P/L.)
2. 5.1949	31	30.3	35.90	.521
9. 5.1949	33	30.4	36.70	.563
16. 5.1949	41	30.2	36.10	.535
23. 5.1949	65	30.1	36.00	.591
30. 5.1949	84	27.8	34.80	1.48
6. 6.1949	104	28.0	34.82	1.32
13. 6.1949	108	25.8	32.50	1.25
20. 6.1949	45	26.8	33.00	.676
27. 6.1949	44.5	26.6	30.41	.873
4. 7.1949	43	26.0	30.04	.917
11. 7.1949	43	26.0	28.60	1.18
18. 7.1949	45	25.6	26.20	1.66
25. 7.1949	43	25.4	28.90	1.77
1. 8.1949	37	25.2	30.10	.501
8. 8.1949	35	24.6	28.02	.552
15. 8.1949	34	26.2	23.03	.845
22. 8.1949	36	26.0	30.30	1.39
29. 8.1949	34	26.0	33.51	.423
5. 9.1949	32	25.5	29.50	.869
12. 9.1949	34	26.0	31.40	.853
19. 9.1949	33.5	25.2	31.78	.938
26. 9.1949	36.5	26.5	32.22	1.03
3.10.1949	33	26.1	33.71	1.17
10.10.1949	30	25.2	33.28	1.03
17.10.1949	25	26.8	30.85	.601
24.10.1949	26.5	24.5	31.86	1.48
31.10.1949	25	28.2	31.40	1.17
7.11.1949	27.5	28.5	31.16	.571
14.11.1949	29	28.3	34.10	.441
21.11.1949	29.8	28.6	34.72	1.14
28.11.1949	33	28.4	34.99	.528
5.12.1949	31.5	27.6	35.20	.464
12.12.1949	29.5	27.5	34.04	.316
19.12.1949	30.5	27.5	34.35	.225
26.12.1949	30	27.2	33.90	.282
2. 1.1950	15	27.2	33.75	.691
9. 1.1950	20	27.4	34.00	.809
16. 1.1950	23	27.3	34.40	.774
23. 1.1950	24	27.8	34.18	.387
30. 1.1950	15.5	27.8	34.20	.612
6. 2.1950	12.5	27.8	34.00	.669
13. 2.1950	9.0	27.9	34.10	.669
20. 2.1950	19	27.5	34.10	.493
27. 2.1950	19.5	28.3	34.22	.521
6. 3.1950	12.5	28.5	34.90	.423
13. 3.1950	11.5	28.8	35.50	.316
20. 3.1950	19.0	29.6	35.80	.330
27. 3.1950	12	29.6	35.05	.634
3. 4.1950	16.5	29.5	35.45	.563
10. 4.1950	14	29.7	35.57	.634
17. 4.1950	11.5	29.6	35.59	.387
24. 4.1950	24	30.3	36.55	.456

APPENDIX III
1950-51

Hydrological data and total plankton volumes (weekly average), West Hill, Calicut

Week ending	Plankton displacement volume (in c.c.)	Surface Temperature (°C.)	Surface Salinity (‰)	Phosphates (µg.atP/L.)
1. 5.1950	24.5	30.4	36.65	.452
8. 5.1950	17.5	31.5	35.90	.521
15. 5.1950	13	29.3	36.65	.986
22. 5.1950	14	29.2	35.25	.917
29. 5.1950	15	28.3	35.50	1.60
5. 6.1950	59	27.2	32.48	.887
12. 6.1950	20	27.9	33.63	.747
19. 6.1950	21	26.8	33.50	.887
26. 6.1950	25	26.7	34.20	.521
3. 7.1950	67	26.0	34.95	2.21
10. 7.1950	118	25.3	33.03	.845
17. 7.1950
24. 7.1950	107	24.9	26.02	1.83
31. 7.1950	21	23.2	30.80	1.37
7. 8.1950	42	25.4	24.10	1.04
14. 8.1950	17	24.4	24.54	.831
21. 8.1950	123	24.6	29.90	.845
28. 8.1950	51	24.8	33.04	.704
4. 9.1950	42	26.9	29.75	.619
11. 9.1950	35	26.0	33.87	.917
18. 9.1950	32	24.7	31.67	1.34
25. 9.1950	32	26.1	30.51	1.42
2.10.1950	36	25.6	33.63	1.00
9.10.1950	24	26.3	33.20	.917
16.10.1950	10	27.2	30.31	.845
23.10.1950	11	27.1	33.63	1.00
30.10.1950	13	28.0	32.95	.634
6.11.1950	6.0	27.8	34.23	1.48
13.11.1950	7	27.8	33.93	1.57
20.11.1950	13	28.2	31.97	1.06
27.11.1950	21	28.3	34.42	.817
4.12.1950	32	28.2	34.61	.845
11.12.1950	28	27.9	34.71	.563
18.12.1950	18	27.8	34.47	.747
25.12.1950	21	27.8	33.60	1.21
1. 1.1951	17	27.7	33.40	.948
8. 1.1951	29	27.5	33.40	1.35
15. 1.1950	32	27.3	33.55	.225
22. 1.1951	27	28.2	33.80	.315
29. 1.1951	14	27.9	34.27	.422
5. 2.1951	18	27.9	34.30	.296
12. 2.1951	12	28.7	34.50	.786
19. 2.1951	32	28.8	34.80	.282
26. 2.1951	20	28.6	34.60	.423
5. 3.1951	22	27.0	34.70	.514
12. 3.1951	16	29.2	34.75	.891
19. 3.1951	17	29.2	35.00	.891
26. 3.1951	14	29.4	35.00	.317
2. 4.1951	18.5	28.6	35.23	.891
9. 4.1951	10	29.4	35.05	.647
16. 4.1951	25	29.8	35.00	.282
23. 4.1951	22	29.8	34.65	.408