# DIURNAL VARIATIONS IN THE DISTRIBUTION OF ZOOPLANKTON IN RELATION TO CURRENTS AND OTHER ECOLOGICAL PARAMETERS OF THE MUD BANK OF ALLEPPEY, KERALA

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Diurnal variations in the distribution of zooplankton biomass of the mud bank at Purakkad-Thottappally region south of Alleppey, Kerala have been investigated during May and August, 1975. Along with this, observations on currents, hydrography and phytoplankton productivity were also carried out and their effects upon the zooplankton of the mud bank region were studied.

During the two periods of diurnal observations, the ecological features of the mud bank presented totally contrasting pictures. In May, the flow was exclusively southerly, but it was rotatory in August. While the salinity and temperature of the water were high in May, they were very low in August due to the discharge of freshwater through the Thottappally spill-way. These changes in the environmental conditions influenced the occurrence, abundance and diurnal variation of the zooplankton of the mud bank region. The direct effect of freshwater influx on zooplankton was the absence of chaetognaths and appendicularians and lesser number of copepods in August while these forms were more common during May.

Despite the fact that light is the most important factor which governs the diurnal variations of the zooplankton, the effect of the current associated with the tidal variations upon the zooplankton was pronounced. In May the direction of the current was exclusively southerly, the velocity being fluctuated by the tidal effect. The increased or decreased velocity of the current flow over a diurnal period was found to influence the distribution of the zooplankters also which showed a simultaneous increase or decrease with the currents.

## INTRODUCTION

Our knowledge regarding the diurnal variations of the biological and hydrographical aspects from the Indian waters is mainly due to the works of Rengarajan (1958), Rao and Rao (1962), Shah (1967), Krishnamurty and Purushothaman (1971), Shynamma and Balakrishnan (1973) and Pillai and Pillai (1973).

With a view to understand the changes in the zooplankton distribution during a diurnal period at the mud bank region which presents physical, chemical and biological features totally different from the nearby areas, investigations were carried out during two seasons on the mud bank at Purakkad-Thottappally region, south of Alleppey. The present paper embodies the magnitude of the diurnal changes in the quantitative and qualitative distribution of zooplankton in relation to currents, hydrological properties and phytoplankton productivity.

## MATERIAL AND METHODS

Two diurnal observations were made on zooplankton biomass of the mud bank at Purakkad-Thottappally region. The first one was during the premonsoon season from 0900 hr on 16th to 0100 hr on 18th May, 1975 at Purakkad and the second one at the close of the SW monsoon from 1800 hr on 16th to 1900 hr on 17th August, 1975 at Chennankara, 3 km south of Purakkad. The mud bank which formed at Purakkad in 1975 had moved to Chennankara, near Thottappally during the SW monsoon in the same year.

The first set of observations were made on board R. V. CADALMIN-I, anchored 2 km off Purakkad at a depth of 4 m, and the second set of observations were made from a stable platform made of two canoes tied together and anchored at a depth of 4 m about 2 km away from the shore at Chennankara.

Zooplankton samples were collected once every 3 hr in May and every 2 hr in August, by vertical hauls from bottom to surface (4 to 0 m), using a 0.5 m nylon net of 0.4 mm mesh size. The plankton biomass was determined by displacement method. Groupwise analysis of the samples was made and enumerated. Simultaneous with the zooplankton sampling, seawater samples were collected from surface and bottom using Nansen reversing bottle. The estimations of dissolved oxygen, salinity and nutrients such as reactive phosphates, reactive silicates and nitrates were according to Strickland and Parsons (1968). The temperatures were also recorded. Seawater samples collected from surface and bottom by means of Van Dorn sampler were used for measuring the productivity by $^{14}C$ *in situ* experiments for 2 hr and 6 hr incubations. The qualitative and quantitative aspects of phytoplankton were done by settling method. Estimation of chlorophyll *a* was carried out following Strickland and Parsons (1968). The current measurements at 2 m depth were made using Ekman Current Meter at an interval of one hour.

## RESULTS

*Zooplankton biomass*:

Due to the comparatively large mesh size of the net (0.4 mm) used, relatively larger zooplankton only were obtained.

In May, (Fig. 1) the displacement volume of the plankton varied between 0.1 and 2.5 ml per sample. In general the biomass was high during night. The minimum was found from 0900 hr to 1800 hr on the first day and at 1200 hr on the second day. In August, the zooplankton biomass was much less when compared to that of May and therefore the volume could not be determined.

The pattern of diurnal variations of various groups of zooplankters are given in Fig. 2*a* and 2*b*, the relative abundance of zooplankters in each sample in Fig. 3*a* and 3*b* and the correlations of zooplankton with other environmental factors in Fig. 4*a* and 4*b*. A total of 11 groups each, were present in the collections of May and August. Copepods formed the major group in May (97%), while it decreased to 11% in August. The major group in August was the planktonic juveniles of *Barnea* sp., a bivalve mollusc (74.1%). The percentage composition of various other groups in May was chaetognaths, 7.76; decapod larvae, 2.21; appendicularians, 1.33; *Pleurobrachia*, 0.67; *Lucifer*, 0.55; polychaete larvae, 0.14; medusae, 0.13; *Acetes* sp., 0.13; fish larvae, 0.07 and 2 specimens of Amphipoda. In August the order of abundance was *Barnea* sp., 74.1; Copepoda,

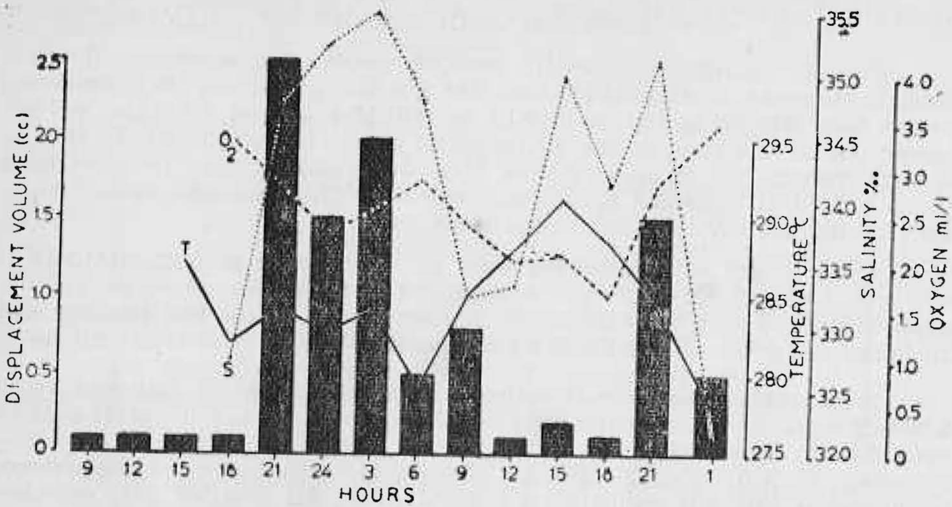


Fig. 1. Total biomass of zooplankters in relation to environmental parameters (May, 1975)

11.00; decapod larvae, 7.4; polychaete larvae, 4.10; fish eggs, 1.8; Amphipoda, 0.8; cladocerans, 0.40; fish larvae, 0.20; and cumaceans and medusae 0.10% each.

Copepods in various samples varied between 71.60 and 95.30% of the total in May and between 0.20 and 36.70% in August. They showed a marked diurnal change in both these months, being more in the night collections. In May, their number ranged between 532 and 2442 in the night samples while the day samples contained specimens between 82 and 1083. In August, their numerical abundance was between 7 and 24 in the day samples while it ranged between 1 and 205 in the night samples. The maximum of copepods was observed at 0300 hr on 18th May (2442) while it was at 1800 hr in August (205). The day time maximum was found at 0900 hr on 17th May (1083) while the same was at 0800 hr and 1200 hr in August (24).

The chaetognaths varied from 1.30 to 26.3% of the zooplankters during May and the maximum was observed at 2100 hr on both the nights and minimum at 1800 hr on 16th and 1200 hr on 17th May. These were totally absent in August.

The decapod larvae were of prawn and crab larvae. Their percentage distribution among other plankton varied between 1.00 and 7.50 in May, the maximum being in the first night at 2100 hr. In August the maximum was obtained at 2200 hr (54). In individual collections, their percentage varied from 0.50 at 0600 hr to 26.10 at 2000 hr. The prawn larvae were varying in their number in all the collections in August. Their total number was 134 in 7 night samples as against 70 in 6 day samples. Their percentage in the samples varied from 0.10 to 8.20, the maximum number being noticed at 2200 hr (54).

Appendicularians contributed to a low percentage ranging from 0.30 to 6.70 in the collections made in May and they were absent in the collections of August. They showed maximum at 2400 hr on 16th and 1800 hr on 17th May and were totally absent at 0100 hr on the second night.

*Pleurobrachia* was abundant in the night collections of 16th May with a

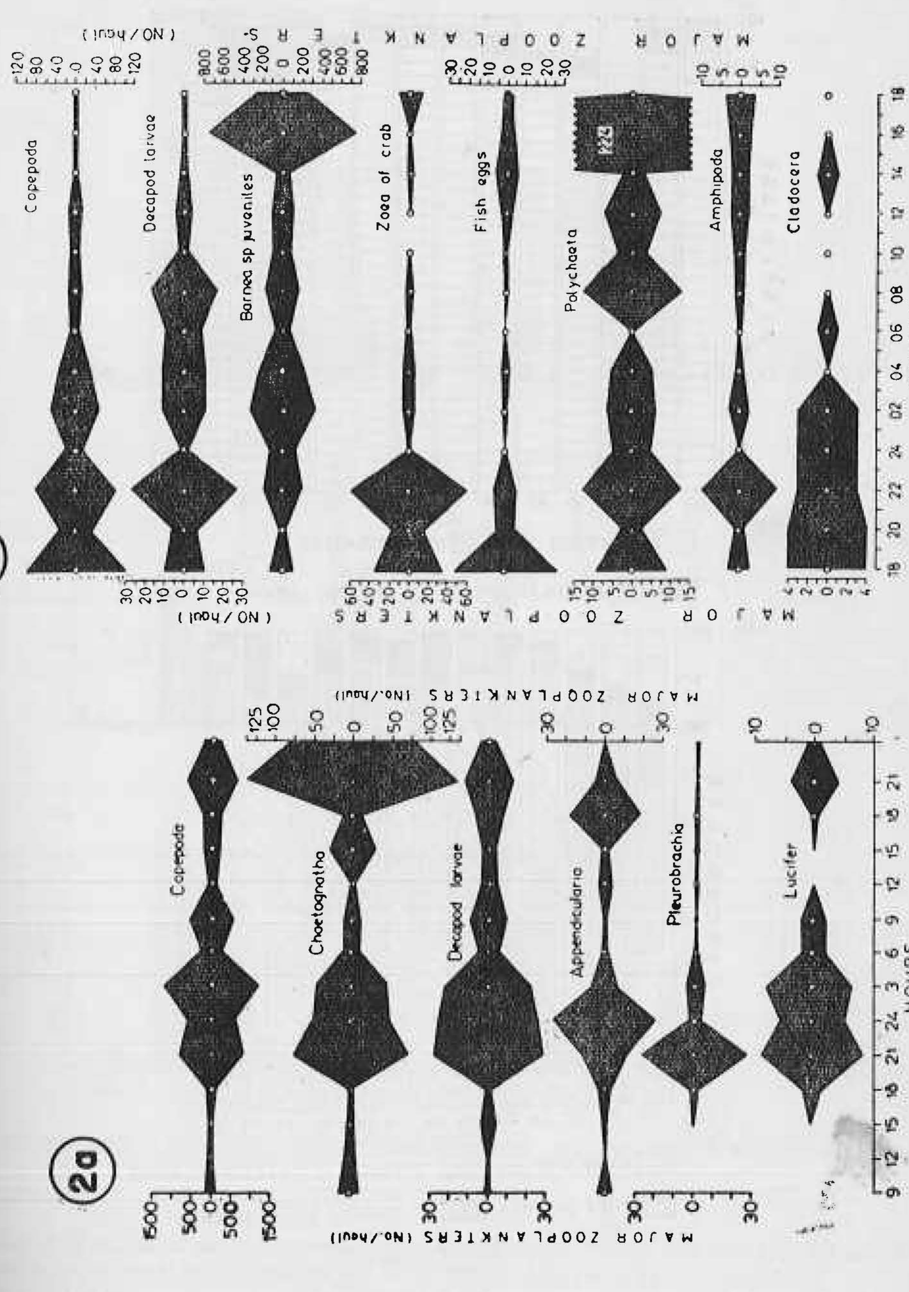


Fig. 2. Diurnal variations of major zooplankton groups a - May, 1975; b - August, 1975.

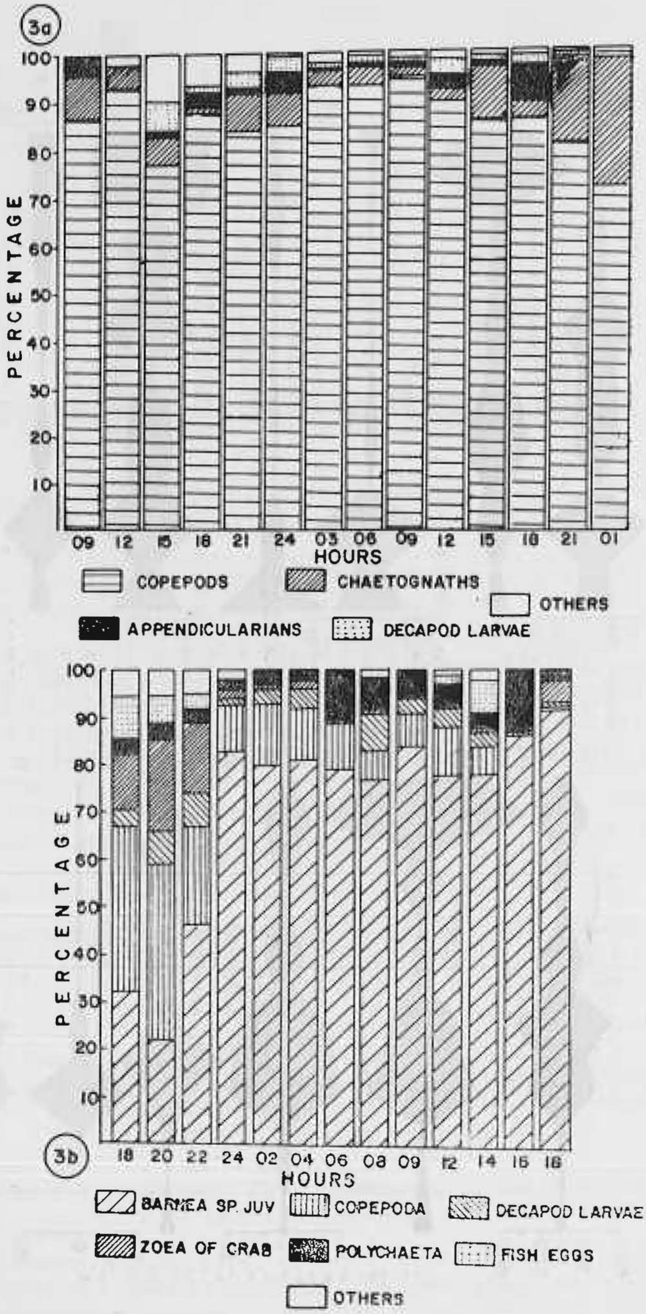


Fig. 3. Percentage abundance of important zooplankton groups
a - May, 1975: b - August, 1975

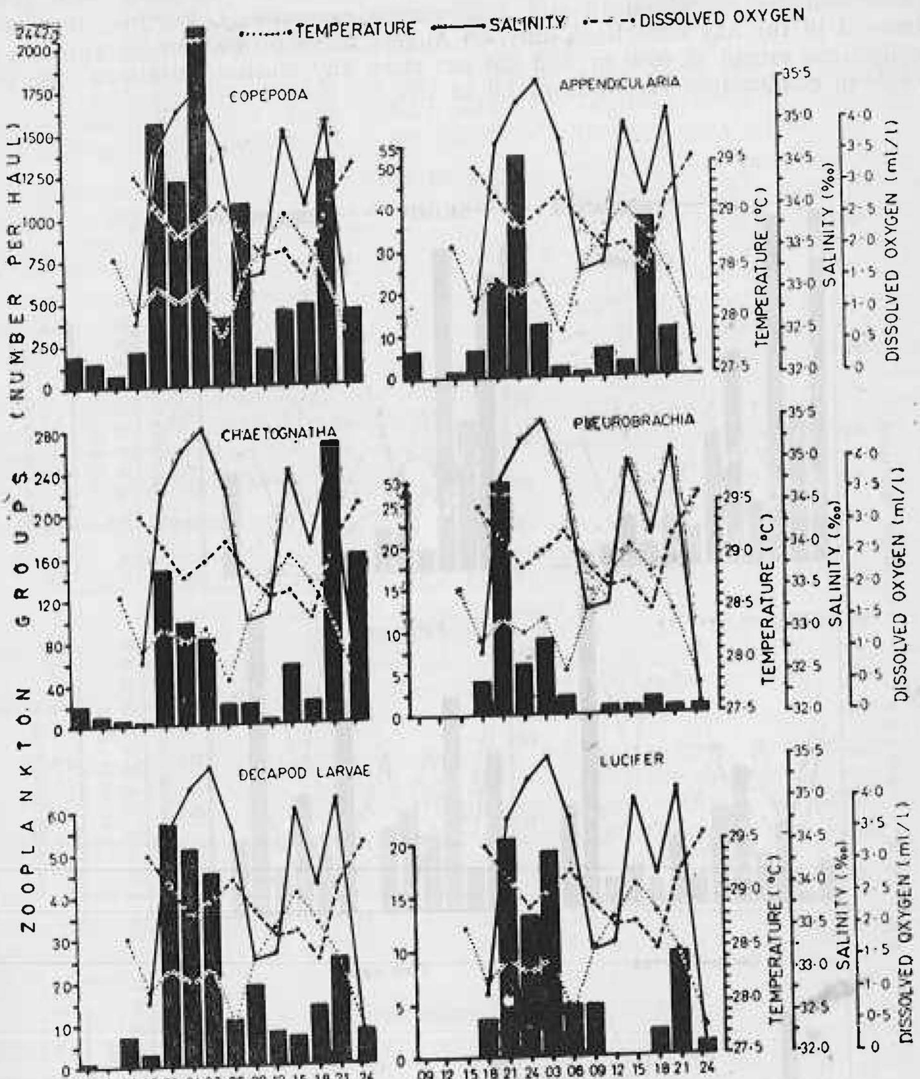


Fig. 4a. Abundance of major zooplankton in relation to environmental parameters (May, 1975)

peak at 2100 hr and their percentage ranged from 0.06 to 2.90. Like chaetognaths and appendicularians, these were also absent in the August collections.

*Lucifer* constituted only a low percentage (0.20 to 1.39) in May and were found only from 1800 hr to 0900 hr, the maximum being at 2100 hr and 0300 hr on 16th. Their number was less in the night collections on 17th May. This group was absent in the collections of August.

In the May collections, polychaete larvae were obtained only in traces and out of 14 collections 5 samples contained only one specimen each and 2 other samples contained 10 and 2 specimens respectively. Further, they were present in the day collections only. In August these forms were obtained in all collections except at 0600 hr and did not show any diurnal variations. The percentage composition varied from 1.8 to 12.9.

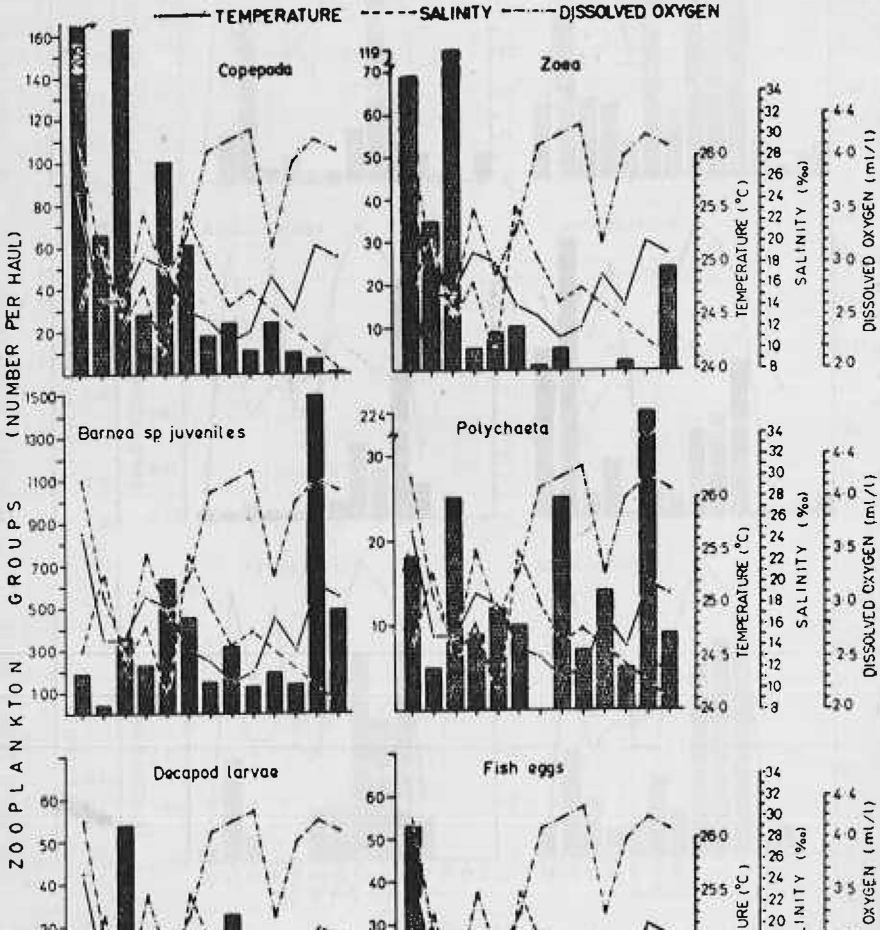


Fig. 4b. Abundance of major zooplankters in relation to environmental parameters (August, 1975)

The planktonic juveniles of *Barnea* sp. formed the major bulk in all the collections made in August. In each of the samples their percentage abundance among other plankters varied between 22.20 and 91.60 and their actual number ranged from 40 to 1500. No diurnal variation was noticed in their distribution. They were absent in the May samples.

Fish eggs were obtained in all the samples in August with their percentage ranging from 0.20 to 2.40. Their number was more in the collections from 1800 hr to 2200 hr. The maximum of 53 specimens was obtained at 1800 hr.

Medusae were represented only in 5 night collections in May and their occurrence was very poor. *Acetes* spp. were found only in 4 night collections in May. A total of 7 fish larvae were obtained in 3 collections in May. In August, they were present in 4 samples, out of which 3 were night collections. One specimen each of Amphipoda was found in 2 samples in May whereas they were present in moderate numbers in August in all except two samples. Their percentage composition in the collections of August varied from 0.20 to 2.40. However. they did not show any diurnal variation. Cladocerans, though present in a limited number of samples, showed marked diurnal changes in that they were found only in the night samples in August. However, a single specimen each was present in two day samples. A total of 6 cumaceans were also present in 4 night collections in August.

*Phytoplankton productivity*:

Incubations for the estimation of the primary production rates were conducted under constant light in simulated *in-situ* conditions. The production rates estimated by the $^{14}C$ technique in August showed gradual increase from 0600 hr and attained a maximum of 200 mgC/m$^3$/hr by 1000 hr, afterwards it decreased and a minimum of 11 mgC/m$^3$/hr was noticed in the evening. In May, the rate of production was comparatively less, the maximum being 106 mgC/m$^3$/hr at 1200 hr and by 1500 hr.

The diurnal variations of chlorophyll *a* for both surface and bottom are shown in Fig. 5 and 6. The chlorophyll *a* content at surface showed two maxima, one at 0900 hr (29.5 mg/m$^3$) on 16th and the other at 0300 hr on 17th (29.3 mg/m$^3$). The values at bottom also showed peaks at 1200 hr on 16th (22.4 mg/m$^3$) and at 0300 hr on 17th (26.7 mg/m$^3$). The minimum values of 6.4 mg/m$^3$ at surface and 10.6 mg/m$^3$ at bottom were found at 2100 hr on 16th May. In August, the maximum values of 100 mg/m$^3$ at surface and 80 mg/m$^3$ at bottom were observed at 1000 hr and minimum values of 5.6 mg/m$^3$ during night hours.

The total cell counts of phytoplankton from the surface and bottom for both the months are given in Fig. 5 and 6. In May, the surface values showed two peaks, one at 0900 hr and the other at 1000 hr on 16th while the bottom values showed maximum at 0900 hr and at 2100 hr on the same day. The phytoplankton cells were more in the morning and evening hours in May. In August, the maximum cell counts were obtained at 1000 hr after which there was a decrease and the minimum was found at 1800 hr. In general the variations in the cell counts were in proportion to the variations in the chlorophyll *a* values.

*Hydrographical conditions*:

The diurnal variations in the mean values of surface and bottom temperature in May and August are shown in Fig. 4a and 4b. The surface temperature varied from 27.50 to 29.70°C and was maximum at 1500 hr and minimum at 0600 hr on both days in May. The bottom temperatures were more or less uniform though a little higher values were noticed at mid night and at 0600 hr on 17th. In August the surface temperature varied between 24.90 and 27.20°C while at the bottom the variation was between 23.20 and 24.81°C.

The variations in the mean values of surface and bottom salinity in both the months are represented in Fig. 4a and 4b. The surface values were comparatively lower than the bottom values in May. The maximum was observed at 0300 hr and 1200 hr. The bottom values showed a maximum at 2400 hr and 1500 hr on 16th. In August the salinity values ranged between 5‰ and 27.05‰ and these low values were due to the freshwater incursion from the Thottappally spill-way which is very close to the place of observation.

The mean values of dissolved oxygen at surface and bottom in the two months are shown in Fig. 4a and 4b. In May and August the values were more or less steady throughout the period of observations.

The direction of the current in May was mainly between 150 and 180°, the major direction being at 160°, indicating the coast parallel southerly flow. The observed flow (maximum velocity: 36 cm/sec.) was confined to the littoral direction. The influence of the tidal system on the currents of the area was oscillatory. In August, the current pattern showed that the water movement was in all the directions during the course of the tidal period. Yet, the major currents were southerly. A northerly flow was observed for a short duration of about 3 hours from 0200 to 0500 hr. The mean southerly component during the tidal period in August was 24 cm/sec while the mean northerly component was only 5 cm/sec which was comparable with that during May.

## DISCUSSION

From the above results it is seen that the zooplankton showed an increase towards night in both the months. Despite the fact that light is the most important factor which governs the diurnal changes in the occurrence and abundance of the epipelagic plankters, the role of other ecological and biological factors cannot be ignored.

It is an established fact that the enrichment of waters by nutrients especially phosphates and nitrates associated with the sudden fall in temperature and salinity, results in the high production of phytoplankton (Subrahmanyan, 1959; Qasim *et al.*, 1969, 1972; Gopinathan, 1972). Qasim *et al.* (1969) and Gopinathan (1972) have shown that many phytoplankters bloom at exceptionally low salinity in the Cochin backwaters indicating that the water of low salinity favours a high rate of production. The present investigations in May revealed that even though high nutrient contents were noticed, the high salinity and temperature did not favour a high production. But in August a sudden fall in salinity with low values of nitrates and silicates and high phosphate concentration (Fig. 6) favoured a monospecific bloom of *Microcystis* sp. which was responsible for the high rate of primary production and chlorophyll *a*. Naturally such a condition should help in the congregation of zooplankton. But the observed fact is quite contrary to this. The observations on phytoplankton productivity during the two seasons and also the other environmental factors such as temperature, salinity, nutrients and currents have revealed that a high production rate alone is not enough to attract the zooplankton to a particular area. Thus, even though there was high concentration of phytoplankton in August, the zooplankton biomass was less in the mud bank area throughout the period of

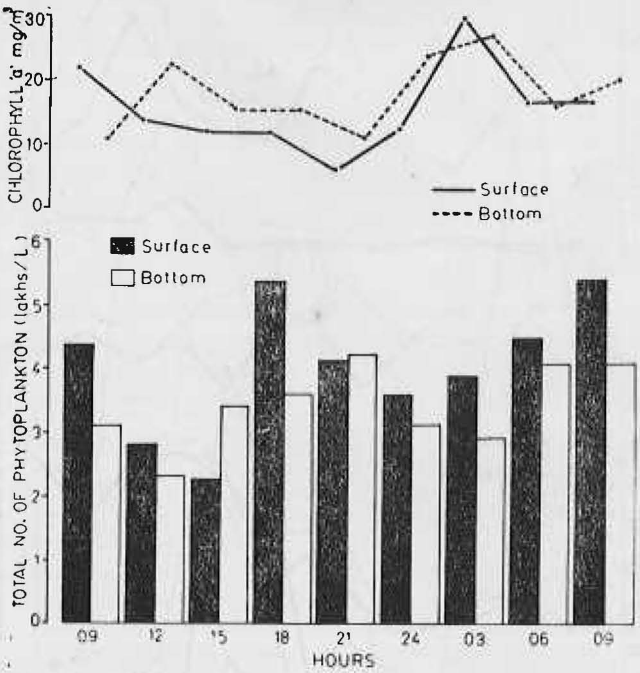


Fig. 5. Diurnal variations in the standing crop of phytoplankton, total cell counts and chlorophyll *a* (May, 1975)

observations and this is due to the effect of very low salinity resulted by the discharge of freshwater through the Thottappally spill-way. But during May even though the phytoplankton production was comparatively less the high abundance of the zooplankton may be attributed to the high temperature and salinity conditions.

In the night of 16th May, the salinity was at its maximum and the temperature was almost steady. This was the period of maximum abundance of zooplankton in general and the various groups in particular. But on 17th night the salinity showed greater fluctuations with minimum at 0100 hr and this resulted in the poor representation of zooplankton in the area of observation.

The zooplankton showed an increase towards night in May and this coincided with the increase in velocity of current flow. Fig. 7 shows the variations in the velocity of current in relation to the variations in the biomass of zooplankton. The fluctuations of the current is given over a mean value of 18 cm/sec while the zooplankton biomass fluctuations are presented over a mean value of about 0.7 cc. It is seen from Fig. 7 that both the parameters are almost varying in face with each other and indicate a high degree of correlation.

As the plankton samples were collected at regular intervals from the whole water column, the abundance of zooplankton in the night cannot be attributed to a strict vertical migration. There is every chance that this can be due to the migration from deeper water to the shallower region. Further the

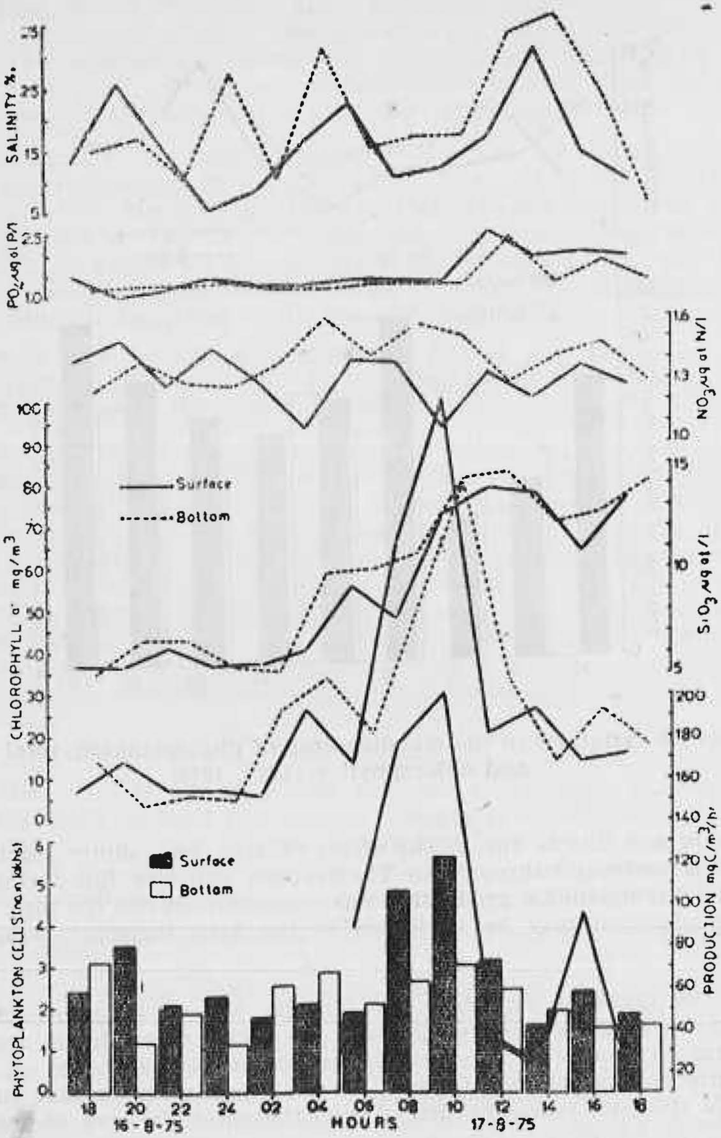


Fig. 6. Diurnal variations in the standing crop of phytoplankton, total cell counts and chlorophyll *a* in relation to salinity, nitrate and silicate

observed currents in the area were mainly southward which can induce the movement of deeper waters to the shallower region along the western coasts of continents (Defant, 1961).

While the current pattern in the month of May showed a steady trend, it presented a totally different picture in August. This changed pattern of current in August had a bearing upon the occurrence of zooplankton and their abundance. During 2300 hr and 2400 hr when the direction of current changed to offshore from inshore all planktonic groups except *Barnea* sp. showed a rapid

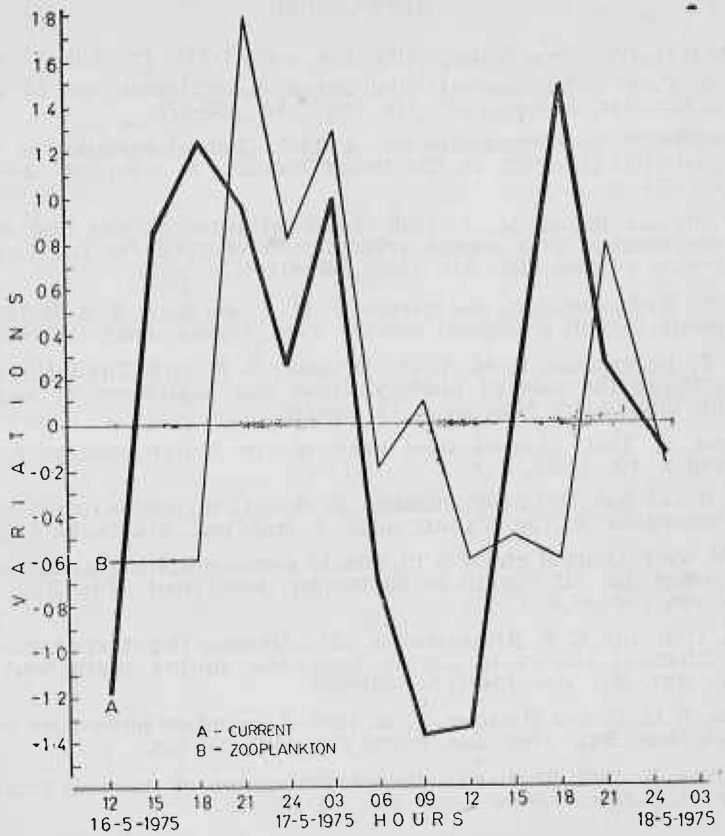


Fig. 7. Comparison between the variations in the velocity of current flow and zooplankton biomass (May, 1975)

decrease in their numbers. When the flow was northerly at about 0100 hr an increase in the population including the juveniles of *Barnea* sp. was observed. When the flow from 0300 hr to 0600 hr contained offshore components in it, the number of organisms were moderate. At 1600 hr, when the flow was shoreward an increase in polychaete larvae and juveniles of *Barnea* sp. was noted.

An inverse relationship between phytoplankton and zooplankton was observed. In May, the zooplankton dominated when the phytoplankton was less abundant whereas in August, phytoplankton was high in contrast to the zooplankton.

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## DISCUSSION

GRIFFITHS : Was there any evidence that the increase in zooplankton biomass and species abundance was due to the benthic animals migrating up (*i. e.,* benthic harpacticoids, cyclopoids, cumaceans etc) into the water column?

REGUNATHAN : I don't think so because we have been taking samples once in every two hours from the bottom to the surface and we could not find any animal migrating up. The high concentration may be due to horizontal migration of zooplankton towards the coast.

CHHAYA : Are you continuing this programme in 1976 also? If so, can you correlate your observations with the results of Dr. T. S. S. Rao that failure of monsoon has resulted in negligible or nil zooplankton in the northern regions?

REGUNATHAN : We have no plans of continuing this work. Dr. T. S. S. Rao's observations are from the backwater areas of Cochin. But the mud banks form a part of marine nearshore environment.

TIWARI : Since the southerly currents move day and night, how do you account for the abundance of zooplankters in your study area during night?

**Regunathan** : The currents were always (day and night) southerly during May. The variations in the abuandance of zooplankton, as per our observations, was closely associated with the strength of the current only but not with the direction of the current.