NOTES

TIDAL INFLUENCE ON THE DIEL VARIATIONS OF ZOOPLANKTON WITH SPECIAL REFERENCE TO COPEPODS IN THE COCHIN BACKWATER

ABSTRACT

Diel variations of hydrobiological characters were studied during a complete tidal cycle at a station in the fishing grounds at the lower reaches of Cochin Backwater during November, 1969. The tidal oscillations and the resultant tidal surface currents were found to exert profound influence on these properties. The temperature of the surface water fluctuated depending on solar radiation, whereas, the salinity variations showed a direct relationship with the tides, recording high values during flood tide. Variations in zooplankton biomass appear to be partly influenced by the diel rhythm of plankters, and the incoming tides contribute to their increase during day time. Three broad types of distribution patterns were observed for the different groups of zooplankters depending on their relationship with the tides and diel vertical migrations. Fluctuations in copepod population in the estuary evinced a complex pattern of distribution and the ingress of neritic waters and the diel rhythm were the causative factors for the diel variations in their distribution.

INFORMATION on the diel variation in the distribution of zooplankton in tropical waters is very meagre. Although studies on the diel variations of the hydrographical features have been carried out from Indian waters, todate only little emphasis has been given to investigate the magnitude of variations of the biological components in relation to changing physico-chemical features of the environment. What little is known is mainly due to the works of Rao and Rao, 1962 (Waltair Coast); Ramamurthy, 1954: Rangarajan, 1958: Seshaiyya, 1959: Krishnamoorthy and Purushothaman, 1972 (Vellar Estuary); Ummerkutty, 1966 (Gulf of Mannar) and Chandramohan and Rao, 1972 (Godavari Estuary).

In Cochin Backwater, tides are of a mixed type, predominantly semi-diurnal. It has been reported that the maximum range in tidal heights in this region occur during the post-monsoon months, when high spring tides having a range of 1.1 m and above are recorded, and during which period the changes in salinity of the surface and bottom waters were almost alike (Qasim and Gopinathan, 1969; Josanto, 1971). During the monsoon period the estuary becomes fresh water dominated and only during the post-monsoon months the entire water column gets well mixed, and brackish and marine conditions are gradually restored. Hence the month of November was chosen for diel variation observations, when the plankton fauna also was fairly rich and varied. The following report embodies the magnitude of the bi-hourly changes in the qualitative and quantitative distribution of zooplankters and hydrographical properties, namely temperature and salinity in relation to tidal variation in the estuarine waters of Cochin during one complete tidal cycle, extending over twentyfour hours in the post-monsoon month of November, 1969.

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Materials and Methods

Surface zooplankton and water samples were collected at bi-hourly intervals from one station in the tidal zone of Cochin Backwater (09° 58'N, 76° 15'E). Horizontal surface tows were made for 10 minutes with a conical net, which had a diameter of 0.5 m, with nylon gauze of 0.33 mm mesh width and an open area ratio of 5. The volume of water filtered was determined by a 'TSK-487' flow meter. Samples were preserved in 5% buffered solution of formaldehyde in sea water. Measurements of temperature and salinity were made from the same station along with the zooplankton samples. Collections were started at 1600 hrs on 11-11-1969 and continued till 1800 hrs on 12-11-1969.

Biomass of plankton collected on each tow was determined by displacement method. Individual groups were sorted out from a 50% aliqout of the sample and analysed numerically; total estimates were calculated from these data. Copepods were counted species-wise and the percentage distribution of 11 numerically dominant species of copepods calculated. The percentage composition of different groups of zooplankton were estimated for all thirteen samples collected.

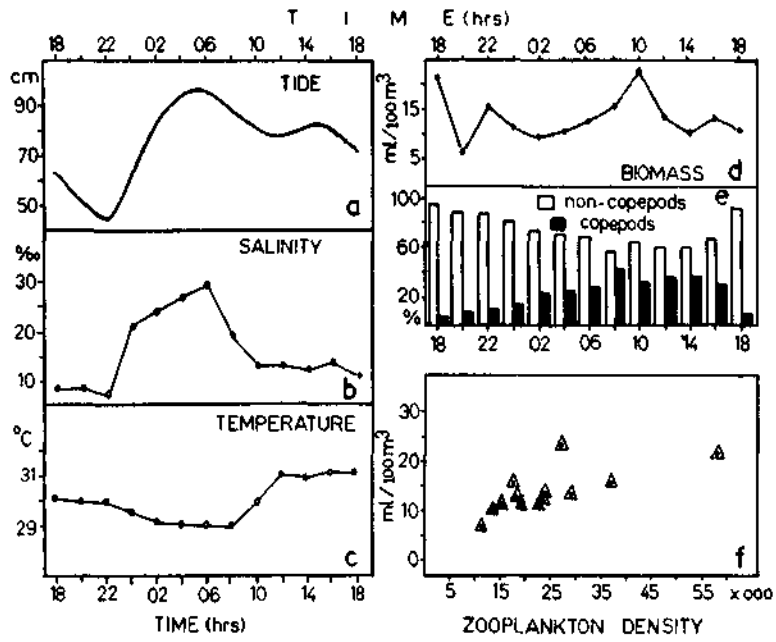

Fig. 1. Diel variations of (a) tide, (b) salinity, (c) temperature, (d) zooplankton biomass, (e) relation between copepods and non-copepod groups in the zooplankton and (f) relation between zooplankton biomass and number.

RESULTS

Tide (Table 1, Fig. 1a) : Tides in Cochin Backwater are of mixed, semi-diurnal type and two successive high and low waters appear each day, with substantial difference in range and time. The reversal of tidal current at the surface lags behind the tidal height by about two hours. A general picture of the outgoing and incoming tides in the backwaters has already been given by Qasim and

Gopinathan (1969). However, the analysis of tidal range for the year 1969 showed that maximum frequency was in the range of 0.8–0.9 m and lowest frequency in the range 1.1 and 1.2 m; maximum tidal range of 1.18 m has been recorded in December, 1969 (Josanto, 1971). Data pertaining to the height of the tide, dealt with in this report was collected from the Indian Tide Table (1969) and from the tidal records maintained by the Cochin Port.

Diel variations in temperature and salinity (Table 1, Fig. 1 b, c): The range of diel variation of surface temperature was 2.1°C. A gradual decline in temperature was noticed from 1800 hrs (30. 1°C) and this reached the minimum value in the early hours of the next day. From the lowest recorded temperature of 29.0°C at 0600 hrs, it increased to a maximum of 31.1°C for the day at 1800 hrs, mainly due to the drawing in of the water from the adjacent cooler inshore waters with the secondary flood. The warming up of the surface water by solar radiation thus substantially overshadows any such minor changes induced by the tides. Solar radiation thus seems to be the chief causative factor for inducing diel variations of temperature in the estuary.

George and Kartha (1963) have reported that there is practically no influence of tides on fluctuations in salinity. Qasim and Gopinathan (1969) have shown that tides profoundly influence the variations of salinity in the estuary. During the present study, it was observed that the influence of tides on the surface salinity of Cochin Backwater is considerable, and the salinity values showed a bimodal distribution with two peaks at 0600 hrs and 1600 hrs (29.90‰ and 14.49‰) respectively during the flood, and lowest salinity values recorded were 7.90‰ at 2200 hrs during the period of LLW. The range of variation was 22.00‰.

Fluctuations in zooplankton biomass (Table 1, Fig. 1 d): The depth of the station was only 8 m and the data on which conclusions are derived pertain to shallow waters. The biomass of the zooplankton appears to have partial relationship with the tide and tidal surface currents. At 1800 hrs, the standing crop was high in the estuary mainly due to the swarming of decapod larvae, including zoea after which a steep fall was observed associated with the ebb. The distinct rise in the volume during night at 2200 hrs, during the period of LLW seems to be associated with the vertical migration of the planktonic organisms to the surface. From midnight, a gradual increase in the biomass was noticeable and maximum value for the period of observation was recorded at 1000 hrs, which was mainly due to the inflow of neritic waters into the estuary during the high tide, which brought with it many marine organisms. The reversal of the tidal surface currents, as mentioned earlier, lags behind the tidal height by about two hours, and it is interesting to note that the rise and fall in the biomass were evident only by the setting in of such currents.

Density distribution of zooplankters (Fig. 1 f): During the period of observation, at 2200 hrs the number of zooplankters recorded maximum value (12% of the total), eventhough LLW persisted in the estuary. A gradual fall in their numbers was noted afterwards, and during the flood period at 1000 hours, when maximum biomass was recorded, the zooplankton number was only 9% of the total. Although a slight increase in the density of the zooplankton population was noted at 1600 hrs associated with the LHW, the percentage of population was only 10%. This suggest that during night time, irrespective of the state of the tide, many small organisms such as copepods, mysids, cumaceans and decapod larvae were present at the surface waters of the estuary.

TABLE 1. *Diel fluctuations in temperature, salinity, tide, zooplankton-biomass and constituent groups of copepods in Cochin Backwater*

Date	Time (hrs)	Temp. (°C)	Salinity (‰)	Nature of tide	Zoo-plankton biomass (ml/100m)³	Copepod groups-relative percentages		
						Calanoids	Cyclopoids	Harpacticoids
11.11.1969	1800	30.1	8.90	L	21.12	46	48	6
11.11.1969	2000	30.0	8.60	L	6.16	73	26	1
11.11.1969	2200	30.0	7.90	LLW	15.40	98	1	1
12.11.1969	0005	29.6	21.70	H	11.44	98	1	1
12.11.1969	0200	29.2	24.50	H	9.68	99	1	-
12.11.1969	0400	29.0	26.80	H	10.56	99	1	-
12.11.1969	0600	29.0	29.90	HHW	12.76	99	1	-
12.11.1969	0800	29.0	19.70	H	15.40	98	2	-
12.11.1969	1000	29.9	13.80	L	22.88	97	3	-
12.11.1969	1200	31.0	13.70	HLW	13.64	98	2	-
12.11.1969	1400	30.9	13.40	H	10.12	98	2	-
12.11.1969	1600	31.0	14.50	LHW	13.20	99	1	-
12.11.1969	1800	31.1	11.70	H	11.00	98	2	-

(L - Low water; LHW - Low high water; LLW - Low low water; H - High water; HLW - High low water; HHW - High high water)

Faunistic variations

Coelenterates: represented by siphonophores (40% each at 0200 hrs and 1200 hrs; 20% at 1400 hrs) and medusae (100% at 1200 hrs).

Annelids: Pelagic polychaetes were recorded during the high and low water periods in the estuary (25% each at 0200 hrs and 1000 hrs; 13% at 1200 hrs; 25% at 1600 hrs and 12% at 1800 hrs). Their concentration was particularly high during flood period.

Adult crustaceans: *Cladocerans* (Fig. 2): Present in all samples and high concentration was noticed after midnight. A clear relationship is evident between their abundance and the tide. *Ostracods*: Recorded only during the period of LHW when salinity showed a seconday peak (66% at 1400 hrs and 34% at 1800 hours). *Stomatopods*: Represented by *Alima* larva, the maximum of which was noticed during the HHW period (16% at 0005 hrs; 50% at 0600 hrs and 34% at 1800 hrs). *Mysids* (Fig. 2): were encountered in lesser numbers during night and were abundant during the flood water period of the day. A primary maximum shown by them at 2200 hrs irrespective of the ebb indicate their behaviour of vertical migration. *Cumaceans* (Fig.2): were met with in the night samples only. After dusk the distinct increase in population noticed during LLW at 2200 hrs was associated with their migrational behaviour. *Isopods*: appeared twice during the night collections. They first appeared in high concentration during the ebb period at 2000 hrs and 2200 hrs (20% and 40%) and in equal numbers (40%) in the flood period at 0600 hrs, former being associated with their vertical migration and latter due to the tide. *Amphipods* (Fig. 2): Although they were present in all the collections, their abundance, as for cumaceans was noticed in the night collections, a phenomenon associated with the vertical migration. *Lucifers* (Fig. 2): Low concentration was noticed at the surface at 2200 hrs and they were numerically dominant during the flood period.

Decapod larvae (Fig. 2): Occurred in all the collections and their pattern of distribution resembled that of amphipods. The maximum concentration was recorded at 1800 hrs, and they were numerically abundant during the LLW at 2200 hrs. They were less numerous till 0600 hrs and during the rest of the period they followed the distribution pattern of the tide of the day.

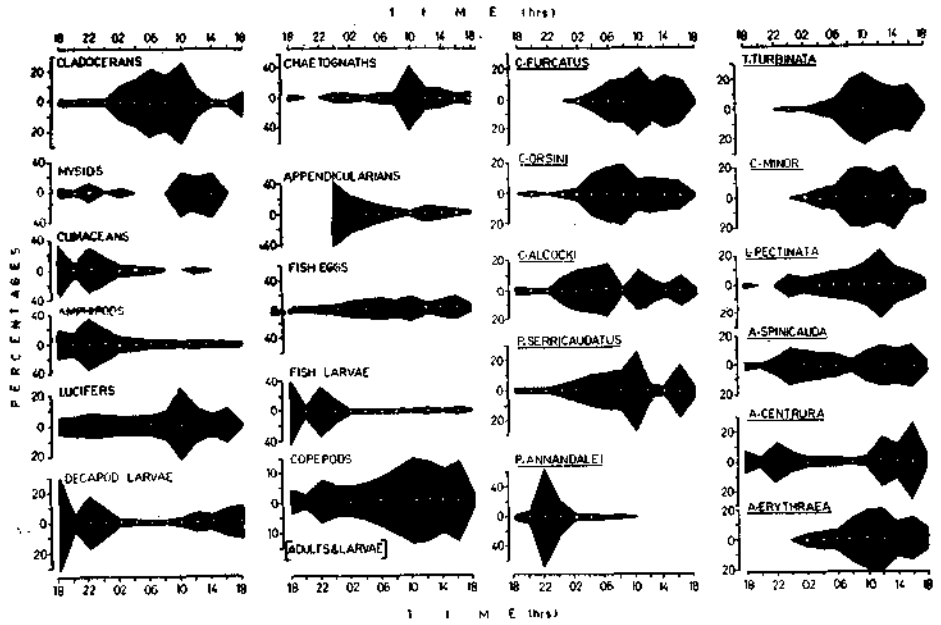

Fig. 2 Diel variations in the distribution of cladocerans, mysids, cumaceans, amphipods, lucifers, decapod larvae, chaetognaths, appendicularians, fish eggs, fish larvae, copepods (adults and larvae) and 11 calanoid copepods in Cochin Backwater.

Pelagic molluscs: Represented by heteropods which occurred only during the flood period at 0800 hrs. *Chaetognaths* (Fig. 2): Recorded maximum abundance during the flood tide of the day although they were present in the collections from midnight onwards; their distribution pattern has been found to be associated with the tidal surface currents. *Pelagic tunicates* (Fig. 2): Represented by appendicularians and *Doliolum* sp.; high concentration of the former was noticed at 0040 hrs when flood water set in the estuary. *Doliolum* sp. was recorded at 0800 hrs (100%) during the period of HHW.

Fish eggs and larvae (Fig. 2): There was not much fluctuation in the quantitative distribution of fish eggs. The variations in their concentration having been found to be associated with the tides. The concentration of the fish larvae was particularly high during night collections and they were less numerous during the day. The recorded abundance during the ebb at 2200 hrs seems to be associated with the vertical migration of this group.

Distribution of copepods (Figs. 1 e and 2)

Calanoids, cyclopoids and harpacticoids constituted the total adult population of copepods during the survey. Copepod population as a whole did not show

large scale variations in relation to the time of the day (Fig.2). The numerical analysis of copepods and non-copepods showed that the former constituted 30 -40% of the zooplankton component in the estuary at the morning hours, following the HHW (Fig. 1 e). A gradual increase in their percentage composition was noticed from dusk and the maximum was recorded at 1200 hrs in the period of flood water. Adult calanoid copepods constituted the major component of copepod population throughout the period of observation and their distribution was found to be associated with the tide. Cyclopoids also followed the same pattern and their maximum occurrence at 1800 hrs in the collection was due to the swarming of the species of *Oithona*. Harpacticoids were met with in the night collections only.

Quantitative estimates were made on 11 numerically dominant species of calanoid copepods (Fig.2). Different species reacted differently to the variations of the tide. Inshore marine species such as *Centropages furcatus, C. orsinii, Temora turbinata, Calanopia minor, Labidocera pectinata* and *Acartia erythraea* showed a positive relation with tides, being virtually absent during the period of ebb and numerically dominant during the period of flood. Species such as *Acartia centrura, A. spinicauda, Pseudodiaptomus serricaudatus* and *Centropages alcockii* were present throughout the collections, the two former species recorded maximum abundance during the midnight and towards dusk, while the distribution of the latter two species was associated with the tides. Typically estuarine species such as *Pseudodiaptomus annandalei* was practically absent during the day time and showed distinct numerical abundance at midnight, irrespective of the state of the tide, a phenomenon associated with vertical migration.

DISCUSSION

During the ebb freshwater is discharged into the estuary and similarly during the flood, sea water penetrates deep into the estuary. It was found that these water-movements exert profound influence on the hydrographic features and biological properties in the estuary. Salinity and temperature of the surface water showed distinct patterns of distribution. Temperature was found to be directly associated with the solar rediation and light penetration, while fluctuations in salinity values are controlled by the tides and tidal surface currents.

Broadly, three patterns of diel distributions can be recognised from the data. A pattern of distribution evinced by those forms dominating in the samples during night irrespective of the hydrographical conditions and the state of the tide, such as cumaceans, amphipods and fish larvae. A second pattern seen was by those with a primary maximum during night and a secondary one during flood period of the day in the estuary as in the case of pelagic polychaetes, mysids, isopods, lucifers and decapod larvae. The third type of distribution was evinced by typically neritic marine forms, and their fluctuations were closely associated with the state of tide, their maximum being recorded only during the flood period (e.g. coelenterates, cladocerans, ostracods, stomatopods, pelagic molluscs, chaetognaths, pelagic tunicates and fish eggs). The total population of copepods constituted by adults and larvae also belong to this group. However, an equable pattern of distribution was observed in the occurrence of flood water and neritic copepods in the estuary. Apart from the influence induced by the tides, the characteristic abundance of other groups at night in the surface waters of the estuary seems to be motivated by their behaviour of diurnal vertical migration.

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