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TIDAL AND DIEL INFLUENCE ON ZOOPLANKTON OCCURRENCE IN THE MANDOVI ESTUARY, GOA

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ABSTRACT

Distribution and abundance of zooplankton over the tidal cycle were studied in the Mandovi estuary, Goa during August and December 1971 and May 1972. Tide induced salinity fluctuations were obvious with high values during spring tides. Salinity was low during August, apparently due to precipitation and land run off but increased subsequently. The mean biomass values for the day and night collections were 13.6 and 19.8 ml/100 m^3 respectively. Occurrence of most of the zooplankton taxa and species was related to diel rhythm and tidal oscillations. However, overall mean zooplankton standing stock at both the stations were same (16.3 ml/100m^3) indicating that estuarine zooplankton maintained their position during tidal exchanges. Variations in occurrence of common groups and species of zooplankton over the tidal cycle are discussed.

INTRODUCTION

Studies on distribution and abundance of estuarine zooplankton in relation to changing physico-chemical features over the tidal cycle are rather meagre (Chandramohan and Rao 1972; Pillai and Pillai, 1973; Madhupratap and Rao, 1979; Goswami, *et al.*, 1979 and Gajbhiye, *et al.*, 1984). Hence as a part of investigatins on the 'Ecology of Mndovi-Zuari estuarine system of Goa', studies were undertaken on the tidal and diel variations of zooplankton population in the Mandovi estuary and results are presented in this communication.

MATERIAL AND METHODS

Surface zooplankton samples were collected from two fixed stations located at the lower and mid-reaches of the Mandovi estuary (Fig. 1). The samples were taken at every three hour interval covering the entire tidal cycle during 16/17 August (monsoon) 1971; 2/3 December, 1971 (post monsoon) and 16/17 May,

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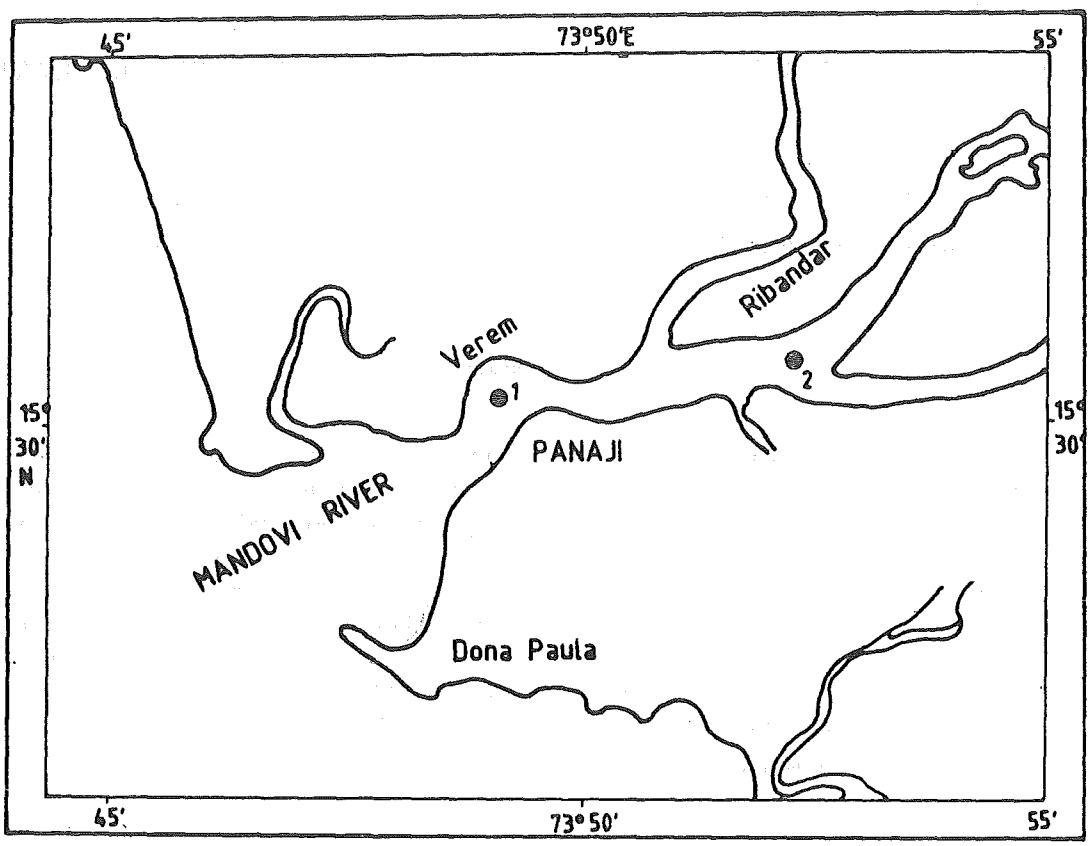

Fig. 1 : Location of the stations

1972 (pre monsoon). No collection was made at station 2 during August '71. The zooplanktoon sampling was done with a modified HT net (mouth area 0.25 m^2, mesh width 330 μ) fitted with a calibrated flowmeter. The zooplankton samples were preserved and analysed as per standard procedure. The water samples were also collected for determination of temperature and salinity. The latter was estimated as per standard method (Strickland and Parsons, 1968).

RESULTS AND DISCUSSION

The semi-diurnal tides of the Mandovi estuary, with the maximum tidal amplitude of about 2 m induce physico-chemical and biological variations. The maximum range of thermal variation over a tidal cycle was 2°C (28.0 - 30.0°C) recorded in May at station 1 (Fig. 2). Tides profoundly influenced salinity, the values being higher during spring tide than recorded at the low and ebb tides. This is in confirmation with the earlier reports (Rangarajan, 1958; Qasim and Gopinathan, 1969; Singbal 1973 and 1976 and Balakrishnan and Shynamma, 1976).

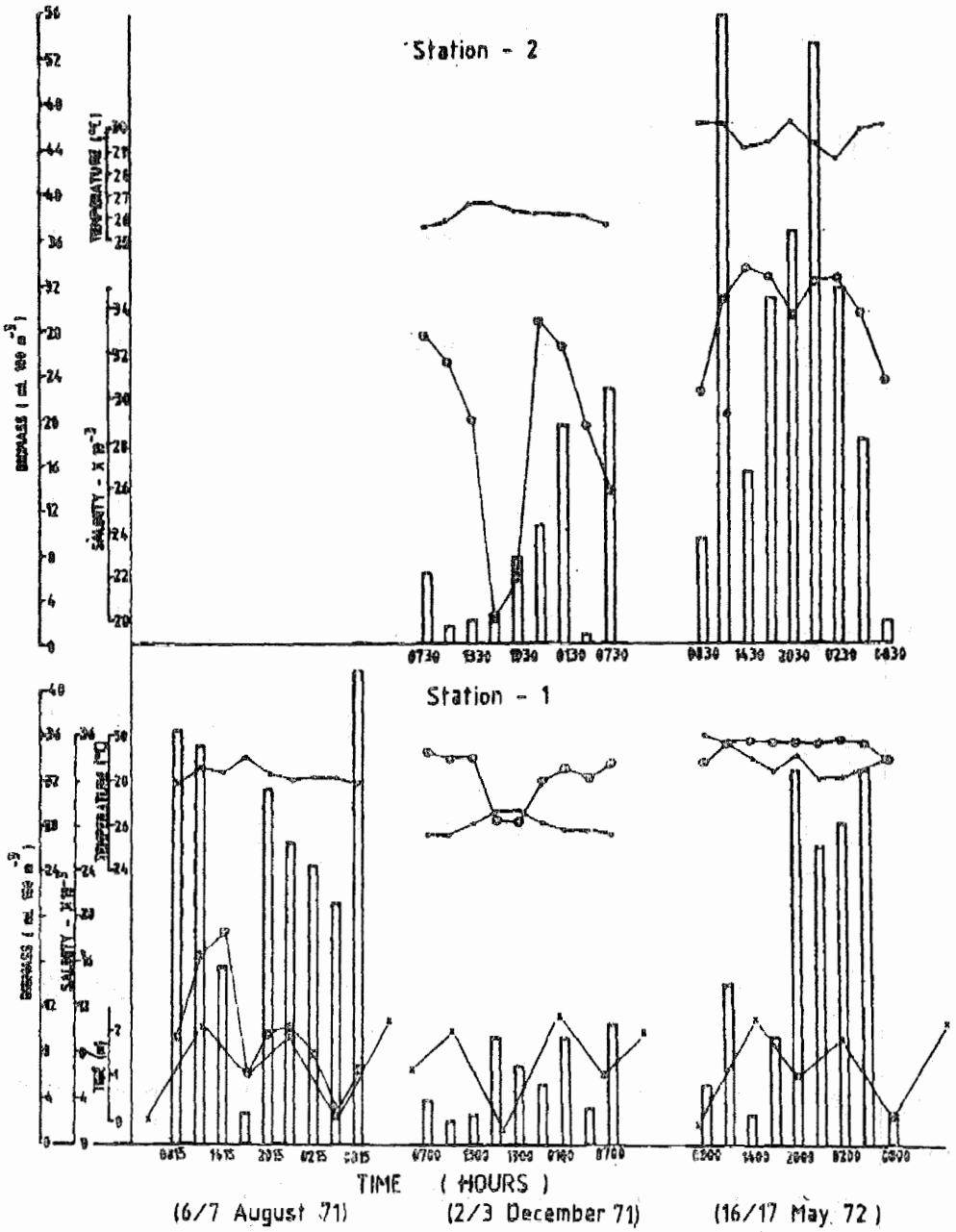

Fig. 2 : Tidal amplitude, temperature, salinity and zooplankton biomass values at two stations.

However, George and Kartha (1963) have reported that the tides have practically no influence on the salinity distribution. The maximum salinity fluctuations were observed in August (2.45 - 18.69‰), apparently due to monsoonal effects. In the remaining two months, salinity was more stable at station 1 than at station 2, situated at the mid-reaches of the estuary. Higher biomass values were obtained in May when the temperature and salinity values were also high. The biomass

Table 1 : Total copepod population (No/10 m³) and percentage occurrence of common copepod species in day (D) and night (N) and low and high tide (LT & HT) collections at stations 1 & 2 for different periods.

Species/ Total Population	Monsoon				Post monsoon				Pre monsoon			
	D	N	LT	HT	D	N	LT	HT	D	N	LT	HT
Total	936 (-)	1147 (-)	796 (-)	887 (-)	1173 (1044)	1493 (1161)	992 (864)	1074 (841)	1205 (1711)	1147 (1108)	923 (801)	1229 (1178)
Eucalanus Subcrassus	-	-	-	-	2.4 (0.7)	- -	0.5 (-)	1.7 (0.7)	4.9 (3.4)	2.7 (2.9)	2.3 (1.0)	5.0 (3.3)
Paracalanus parvus	-	-	-	-	2.4 (1.7)	1.0 (-)	11.0	2.3	-	-	-	-
Acrocalanus gracilis	-	-	-	-	15.0 (15.4)	4.2 (2.5)	3.6 (2.5)	6.4 (5.4)	3.4 (9.1)	16.8 (10.9)	7.7 (1.0)	13.6 (1.1)
Centropages tenuiremis	-	-	-	-	-	-	- -	-	17.3 (11.5)	14.2 (17.3)	13.9 (18.6)	7.7 (18.5)
C. dorsispinatus	-	-	-	-	1.2 (0.7)	1.0 (0.6)	4.0 (0.6)	1.2 (0.7)	-	-	-	-
C. trispinosus	-	-	-	-	4.6 (1.4)	1.0 (0.6)	2.1 (0.6)	4.1 (1.4)	16.3 (19.2)	12.2 (12.7)	16.4 (14.7)	19.9 (8.3)
Pseud. aurivilli	-	26.0 (-)	24.2 (-)	11.4 (-)	8.0 -	26.1 -	19.1 -	18.1 -	- -	- -	- -	- -
Heliodiaptomus cinctus	23.4 (-)	9.6 (-)	10.3 (-)	14.3 (-)	-	-	-	-	-	-	-	-
Temora turbinata	-	-	-	-	1.7 (0.7)	1.0 (-)	2.0 (-)	1.7 (0.7)	9.8 (8.6)	19.1 (16.9)	21.6 (19.7)	9.5 (9.4)
Labidocera vectinata	-	-	-	-	26.7 (31.3)	29.2 (26.4)	26.7 (27.9)	18.2 (29.6)	11.3 (20.9)	8.8 (7.3)	9.3 (5.9)	10.9 (11.7)

Acartia centrura	-	-	-	-	5.2 (3.4)	2.1 (1.9)	2.1 (2.5)	15.2 (2.7)	8.3 (10.3)	8.8 (10.0)	8.5 (18.7)	8.6 (20.5)
A. plumosa	17.0 (-)	6.6 (-)	6.7 (-)	7.1 (-)	17.4 (19.0)	22.9 (28.3)	21.9 (26.1)	18.7 (21.4)	-	-	-	-
A. southwelli	-	-	-	-	3.5 (-)	1.6 (-)	1.6 (-)	3.5 (-)	-	-	-	-
Acartiella sewelli	13.4 (-)	10.3 (-)	10.8 (-)	34.2 (-)	-	-	-	-	-	-	-	-
A. gravelyi	35.2 (-)	38.8 (-)	36.6 (-)	20,1 (-)	-	-	-	-	-	-	-	-
Euterpina acutifrons	-	-	-	-	-	-	-	-	2.9 (2.3)	2.0 (2.7)	2.3 (2.0)	2.7 (2.8)
Harpacticus sp.	4.4 (-)	2.9 (-)	3.6 (-)	7.2 (-)	-	-	-	-	-	-	-	-
Oithona rigida	-	-	-	-	6.4 (6.1)	4.7 (3.8)	3.6 (5.0)	5.8 (4.8)	11.8 (10.9)	12.2 (15.4)	13.9 (15.0)	18.9 (20.5)
O. brevicornis	-	-	-	-	-	-	-	-	11.5 (1.7)	1.3 (1.8)	1.9 (2.0)	1.3 (1.7)
Corycaeus sp.	-	-	-	-	0.6 (0.7)	0.0 (0.0)	0.6 (0.9)	0.6 (1.7)	0.5 (0.6)	0.5 (1.0)	1.0 (0.7)	0.4 (0.8)
Cyclops sp.	3.5 (-)	4.4 (-)	4.6 (-)	2.4 (-)	-	-	-	-	-	-	-	-
Others	3.1 (-)	1.3 (-)	3.2 (-)	3.3 (-)	4.8 (2.4)	5.2 (1.0)	1.2 (1.0)	2.5 (1.6)	2.0 (1.5)	1.4 (1.1)	1.2 (0.7)	1.5 (1.4)

* Values in parenthesis indicate percentage of species at station 2

Table II :Total cladoceran population (No/100 m³) and percentage occurrence of cladoceran species in day (D) and night (N) and low and high tide (LT & HT) collections at 2 stations for different periods.

Total population / species	Monsoon				Post monsoon				Pre monsoon			
	D	N	LT	HT	D	N	LT	HT	D	N	LT	HT
					Station 1							
Total population	65	56	46	75	159	115	130	144	41	43	47	37
E. tergestina	47.1	10.0	14.4	40.1	86.0	58.8	75.9	76.2	2.8	1.2	100.0	19.9
P. avirostris	1.5	14.0	11.3	4.3	10.2	39.4	19.8	21.7	87.2	98.8	-	80.1
Podon sp.	51.4	76.0	74.3	55.6	3.8	1.8	4.3	2.1	-	-	-	-
					Station 2							
Total population	-	-	-	-	88	67	79	76	22	33	26	29
E. tergestina	-	-	-	-	74.1	58.5	59.2	75.9	8.0	2.1	2.6	6.9
P. avirostris	-	-	-	-	3.4	5.5	6.3	1.5	92.0	97.9	97.4	93.1
Podon sp.	-	-	-	-	22.5	36.0	34.5	22.6	-	-	-	-

values fluctuated between 2.1 to 41.6 ml/100 m^3 at station 1 and 0.8 to 52.8 ml/100 m^3 at station 2 (Fig.2). However, average biomass values obtained at both the stations were the same (16.3 ml/100 m^3) indicating that zooplankton population maintained their position within the estuary during the tidal exchanges. The average biomass values for the day and night collections were 13.6 and 19.8 ml/100 m^3 respectively indicating day-night variability. This abundance of zooplankton has been assigned to the phenomenon of vertical migration (Chandramohan and Rao, 1972; Pillai and Pillai, 1973; Madhupratap and Rao, 1979 and Mathew *et al.*, 1977). The total average zooplankton population obtained in the day and night collections at stations 1 & 2 was 1452 and 1719/10 m^3 and 1078 and 1208/10 m^3 respectively. The fluctuations in the zooplankton counts were discernible during different tidal conditions. The maximum and minimum faunal and species diversity was noticed during spring and ebb tides respectively. The maximum zooplankton density was reported during ebb to flood tide in the Malad creek, Bombay (Gajbhiye *et al.*, 1984).

Copepods, cladocerans, chaetognaths and decapods including larvae of penaeid prawns were quite common in the zooplankton samples. The distribution of other groups viz. cirriped larvae, hydromedusae, siphonophores, polychaetes, ctenophores, isopods, stomatopods, sergestids, mysids, cumaceans, veliger larvae, pteropods, appendicularians, fish eggs and fish larvae depended on station location, tidal phase and time of collection. Mysids, polychaetes, veliger larvae and fish eggs were abundant in zooplankton samples collected at station 2 during night and ebb tide. Polychaetes, gastropods and mysids were reported to form the major portion of zooplankton collected during ebb tide from the polluted estuaries of Gujarat (Desai *et al.*, 1983). Siphonophores, ctenophores, appendicularians and fish larvae were more in samples taken at station 1 during spring tide and day as also recorded from the Zuari estuary (Goswami *et al.*, 1979). Pillai and Pillai (1973) obtained higher number of fish larvae in the zooplankton samples collected at night from Cochin Backwater

Copepods were the most dominant group. The copepod species showed a complex pattern of distribution. *Heliodiaptomus cinctus, Acartiella sewelli, A gravelyi, Harpacticus* sp. and *Cyclops* sp were obtained in collections taken during August (Table I). However, in addition to most of these species *Paracalanus parvus, Pseudodiaptomus aurivilli* and *Acartia plumosa* were the other copepod species obtained in the zooplankton collections taken during this period over the tidal cycle in the Zuari estuary (Goswami *et al.*, 1979). During the present investigations, these additional species were more in samples taken in December and

Table III : Total chaetognath population (No/10 m³) and percentage occurrence of chaetognath species in day (D) and night (N) and low and high tide (LT & HT) collections at 2 stations for different periods.

Total population/ species	Monsoon				Post monsoon				Pre monsoon			
	D	N	LT	HT	D	N	LT	HT	D	N	LT	HT
					Station 1							
Total population	2	1	0	3	25	23	25	23	52	46	46	52
Sagitta bedoti	100.0	100.0	-	100.0	71.6	78.8	77.6	73.0	72.3	79.3	70.3	78.6
S. enflata	-	-	-	-	26.8	21.2	22.4	26.0	23.5	19.6	28.6	17.2
S. pulchra	-	-	-	-	1.6	-	-	1.0	1.9	1.1	1.1	1.1
S. robusta	-	-	-	-	-	-	-	-	1.5	-	-	1.5
Krohnitta pacifica	-	-	-	-	-	-	-	-	0.8	-	-	0.8
					Station 2							
Total population	-	-	-	-	21	12	13	20	30	19	17	32
S. bedoti	-	-	-	-	84.1	92.8	83.6	88.0	77.5	94.1	86.1	80.9
S. enflata	-	-	-	-	15.9	7.2	6.4	12.0	21.2	5.9	13.9	17.7
S. pulchra	-	-	-	-	-	-	-	-	1.3	-	-	1.4

Table IV : Total decapod population (No/100 m³) and percentage occurrence of larval stages of penaeid prawns in day (D) and night (N) and low and high tide (LT & HT) collections at 2 stations for different periods.

Total population/ species	Monsoon				Post monsoon				Pre monsoon			
	D	N	LT	HT	D	N	LT	HT	D	N	LT	HT
					Station 1							
Decapod population	51	66	72	45	35	27	37	25	22	26	32	16
Penaeus merguiensis	20.4	17.8	19.6	17.6	41.5	42.7	48.3	36.9	26.7	45.5	46.4	25.3
Parapenaeopsis stylifera	-	-	-	-	-	-	-	-	2.6	4.4	3.3	3.1
Metapenaeus dobsoni	76.5	78.3	77.4	78.1	47.2	46.2	34.9	56.2	61.3	47.6	47.6	61.9
Metapenaeus spp.	3.1	3.9	3.0	4.3	11.3	11.1	16.8	6.9	9.4	2.5	2.7	9.7
					Station 2							
Decapod population	-	-	-	-	21	33	39	15	19	12	17	14
P. merguiensis	-	-	-	-	2.7	50.0	39.3	38.6	33.2	52.1	53.0	33.0
P. stylifera	-	-	-	-	-	-	-	-	-	-	-	1.0
M. dobsoni	-	-	-	-	75.7	43.3	46.4	53.5	51.9	42.7	41.5	51.5
Metapenaeus spp.	-	-	-	-	21.6	6.7	14.3	7.9	14.9	5.2	5.5	14.5

this may be due to salinity variations. *Acartia erythraea, Acrocalanus gibber* and *Centropages orsinii* showed positive correlation (r = 0.5) with tides and occurred in zooplankton collections taken at high tide and during the day. Pillai and Pillai (1973) also recorded *A. erythrea* and *C. orsinii* in zooplankton samples taken at high tide from Cochin Backwater. *Pseudodiaptomus aurivilli* and *P. binghami* were abundant in night collections (Pillai and Pillai, 1973 and Madhupratap and Rao, 1979). *Acrocalanus inermis, A. gracilis, Labidocera pectinata, Acartia plumosa* and *A. pacifica* were obtained only in night collections from the Malad creek, Bombay (Gajbhiye *et al.*, 1984).

Cladoceran population was represented by three species namely *Evadne tergestina, Penilia avirostris* and *Podon* sp. (Table II). *E. tergestina* being abundant in day collections while the remaining species in the night samples. The low saline species *(Podon sp.)* was absent in May collections at both the stations. The chaetognaths were represented by five species belonging to the genera *Sagitta* and *Krohnitta.* The highest and the lowest number of chaetognath species were recorded in May and August respectively. The chaetognath species viz. *S. bedoti, S. enflata, S. pulchra, S. robusta* and *K. pacifica* were present in day samples taken during high tide. The last two species were not observed in night collections and were not recorded from the zooplankton samples taken at station 2 (Table III). The highest incidence of chaetognaths was reported to be in night collections from Cochin Backwater (Mathew *et al.*, 1977). The decapods were quite common in the collection and the different species of penaeid represented are given in Table IV. The non penaeid prawn population was constituted by zoea and megalopa stages of Brachyurans, members of families Palaeomonidae, Alphaeidae and Acetidae. The sergestids *Lucifer hansani,* hydromedusae *(Eirene spp.)* and stomatopods (*Alima* spp.) were more during high tide but their abundance showed no correlation with diel rhythm. *L. hansani,* was reported to be the only species representing lucifers in Malad creek, Bombay (Gajbhiye *et al.*, 1984).

The present study indicates that tides exert profound influence on the hydrographical and biotic features of the Mandovi estuary. The high surface zooplankton population in the night collections is associated with the phenomenon of vertical migration of zooplankters.

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REFERENCES

Balakrishnan, K. P. and Shynamma, C.S. 1976. Diel variations in hydrographic conditions during different seasons in the Cochin Harbour (Cochin Backwater). *Indian J. Mar. Sci.* 5 : 190-195.

Chandramohan, P. and Rao, T.S.S. 1972. Tidal cycle studies in relation to zooplankton distribution in the Godavari estuary. *Proc. Indian Acad. Sci.* 75B : 23-31.

Desai, B. N., Gajbhiye, S. N., Jiyalal Ram, M. and Nair, V.R. 1983. Comparative account on zooplankton in polluted and unpolluted estuaries of Gujarat. *Mahasagar-Bull. Natn. Inst. Oceanogr.* 16 (3) : 281-291.

Gajbhiye, S. N., Nair, V. R. and Desai, B. N. 1984. Diurnal variation of zooplankton in Malad Creek, Bombay. *Indian J. Mar. Sci.* 13 : 75-79.

George, M. J. and Kartha, K. N. K. 1963. Surface salinity of Cochin Backwater with reference to tide. *J. mar. Biol. Ass. India.* 5 : 178-184.

Goswami, S. C., Selvakumar, R. A. and Goswami, U. 1979. Diel and tidal variations in zooplanktonic populations in the Zuari estuary, Goa. *Mahasagar-Bull. Natn. Inst. Oceanogr.* 12 : 247-258.

Madhupratap, M. and Rao, T.S.S. 1979. Tidal & diurnal influence on estuarine zooplankton. *Indian J. Mar. Sci.* 8 : 9-11.

Mathew, K. J., Gopinathan, C.P., Rao, D.S., Regunathan, A. and Murthy, A.V.S. 1977. Diurnal variations in the distribution of zooplankton in relation to currents and other ecological parameters of the mud bank of Alleppey, Kerala. *Proc. Warm Water Symp.Special Publication, NIO/UNESCO,* 250-263.

Pillai, P. P. and Pillai, M.A. 1973. Tidal influence on the diel variation of zooplankton with special reference to copepods in the Cochin Backwaters. *J. mar. Biol. Ass. India* 15 : 411-417.

Qasim, S. Z. and Gopinathan, C. K. 1969. Tidal cycle and the environmental features of Cochin Backwater. *Proc. Indian Acad. Sci.* 69 : 336-348.

Rangarajan, K. 1958. Diurnal tidal cycle in Vellar estuary. *J. Zool. Soc. India*. 10 : 54-67.

Singbal, S. Y. S. 1973. Diurnal variation of some physicochemical factors in the Zuari estuary, Goa. *Indian J. Mar. Sci.* 2 : 90-93.

Singbal, S. Y. S., 1976. Diurnal variation of some physicochemical factors in the Mandovi estuary of Goa. *Mahasagar-Bull. Natn. Inst. Oceanogr.* 9 : 27-34.

Strickland, J. D. H. and Parsons, T. R. 1968. A practical hand book of sea water analysis. *Fish. Res. Board Canada Bull.* No. 167 : 21-26.