

## DIEL AND TIDAL VARIATIONS IN ZOOPLANKTONIC POPULATIONS IN THE ZUARI ESTUARY, GOA

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### ABSTRACT

Zooplankton distribution was studied at two stations in the Zuari estuary, Goa, over the entire tidal cycle and during different seasons. The highest value of zooplankton standing crop (biomass) was obtained during the period of low salinity regime. Variations in the occurrence and abundance of major planktonic groups and their species were influenced by diel rhythm, tidal oscillations and seasons. Nocturnal abundance of zooplankters was seen at both the stations. During flood tide of the day, neritic organisms were transported by tidal currents into the estuarine region. A few limnetic species were also observed in the zooplankton samples collected during monsoon period at a station located in the mid-reaches of the estuary. Spatial and temporal variations of dominant zooplanktonic groups and common species are discussed.

### INTRODUCTION

Diel variations in the distribution of zooplankton in relation to changing physico-chemical conditions have been studied by Chandramohan and Rao (1972) from Godavari estuary; Seshaiya (1959) and Vijayalakshmi and Venugopalan (1973) from Vellar estuary; Ummerkutty (1966) from Gulf of Mannar; Pillai and Pillai (1973); Mathew, Gopinathan, Rao, Regunathan and Murthy (1977) and Madhupratap and Rao (1979) from Cochin backwaters.

Singbal (1973) and Bhargava and Dwivedi (1974) have described diurnal variations in physico-chemical parameters and phytoplankton pigments respectively from the Zuari estuary, Goa. Present paper deals with the qualitative and quantitative variations in the distribution of zooplankton in the Zuari estuary in relation to diel rhythm, tides and seasons.

### MATERIAL AND METHODS

Surface zooplankton samples were collected from two fixed stations located at the lower and mid-reaches of the estuary (Fig. 1), during monsoon, post-monsoon and premonsoon seasons (August, 1971; February and April 1972 respectively). Zooplankton and water samples for environmental parameters were taken at 3 hourly interval covering the entire tidal cycle. The zooplankton were collected using a modified HT net (mouth area 0.25m<sup>2</sup> and mesh width 0.3 mm) fitted with a calibrated flowmeter. The net was towed for about 5 minutes and the samples were fixed in 5% buffered formaldehyde. The biomass was determined by displacement method. Various planktonic

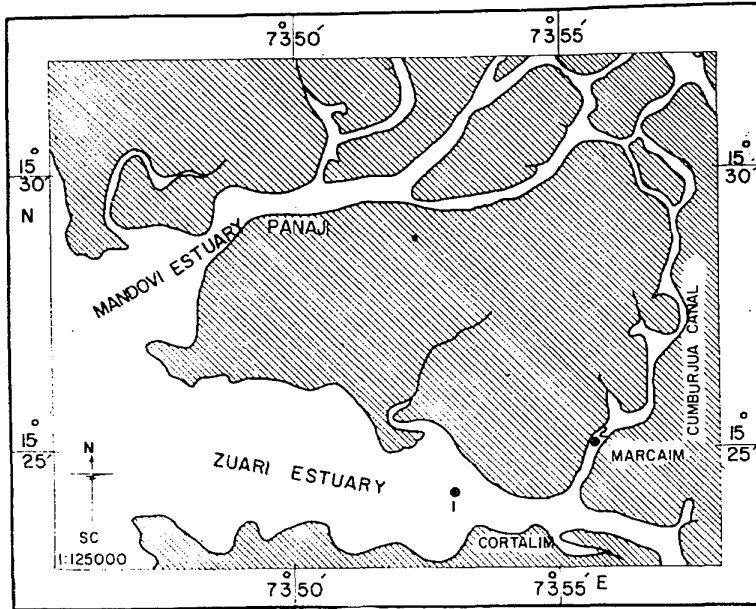


Fig. 1. Location of worked out stations,

groups and their species were enumerated by examining 4–10% of the subsample and the number of organisms computed per  $m^3$ . The salinity was estimated by standard method (Strickland and Parsons, 1968).

## RESULTS

### Zooplankton biomass

The zooplankton biomass was higher for the samples taken between dusk and early morning and thereafter the values started decreasing. The biomass values at both the stations ranged from 15 to 1425 ml/1000  $m^3$ , the highest and the lowest values were recorded in night and day samples respectively (Fig. 2). Average value for the night and day samples was 360 and 202 ml/1000  $m^3$  respectively. The biomass was also dependent upon the tidal incursions. The values at both the stations were higher for samples taken at high tide in the months of August and April (Table I).

Zooplankton standing crop was also influenced by seasons. The biomass values were quite high during monsoon when the temperature and salinity values were low (Table II). The average biomass during monsoon, postmonsoon and premonsoon at Station I was 513, 221 and 177 ml/1000  $m^3$  and the corresponding values at station 2 were 468, 169 and 91 ml/1000  $m^3$  respectively. Spatial variations in the abundance of zooplankton were also observed. The average biomass values were higher at station 1 (330 ml/1000  $m^3$ ) than at station 2 (242 ml/1000  $m^3$ ). The higher values at station 1 were due to the ingress of neritic organisms.

Table I. Average biomass (ml/1000m<sup>3</sup>) in the day and night collections and for samples taken at high and low tides.

Location	August (Monsoon)		Months/Seasons February (Postmonsoon)		April (Premonsoon)	
	Day	Night	Day	Night	Day	Night
Station 1	423	624	115	353	87	288
Station 2	445	497	97	257	47	145
Tide	HT	LT	HT	LT	HT	LT
Station 1	682	301	135	228	189	161
Station 2	557	354	166	172	79	107

HT = High tide; LT = Low tide.

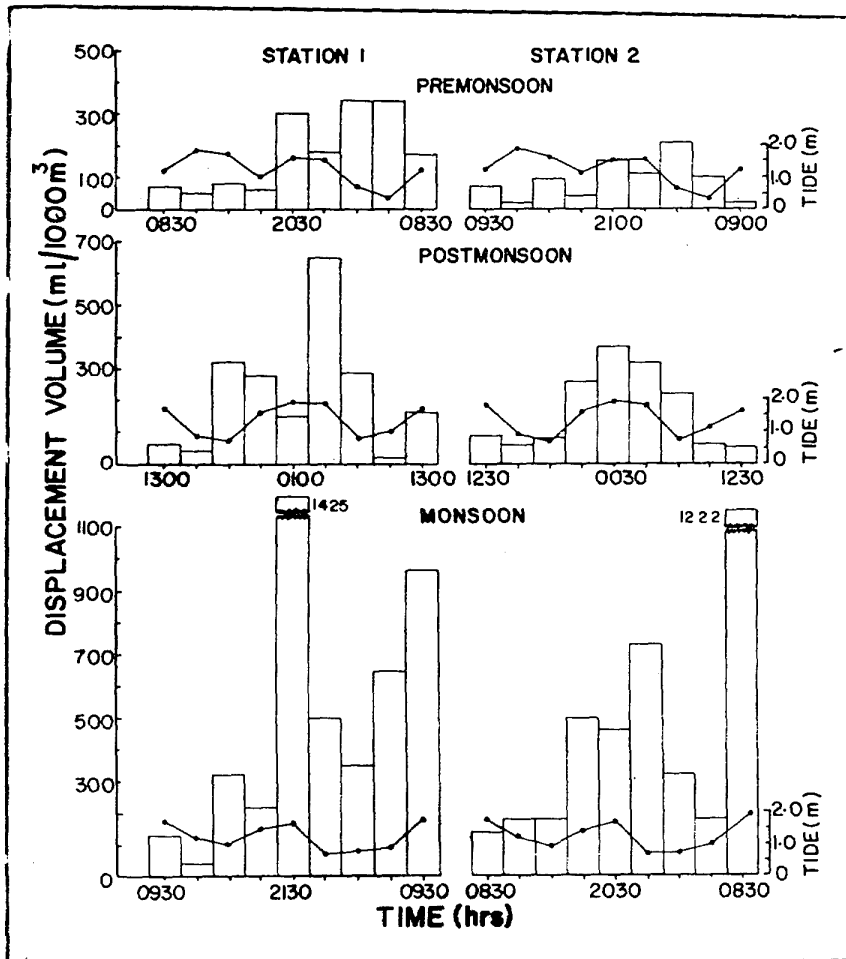


Fig. 2. Displacement volume of zooplankton and tide level for 2 stations during the period of observation.

*Faunistic composition*

Sixteen major zooplankton groups were recorded in the samples from both the stations. Diurnal variations in the occurrence of seven planktonic taxa are shown in Fig. 3. Siphonophores, ctenophores, lucifers, copepods, cladocerans, cirriped larvae, chaetognaths and fish larvae were in greater numbers in day samples while polychaete larvae, decapod larvae, veligers, cumaceans, amphipods, isopods, mysids and fish eggs were more in the night collections. In addition to such a diel variations, seasonal and tidal differences in their distributions were also discernible. Ctenophores, lucifers, chaetognaths, pelagic tunicates were common during the flood tide of the premonsoon season. Similarly, decapod larvae comprising mostly of crab zoea, cumaceans, cirriped larvae etc. were abundant during the ebb tide of monsoon and premonsoon seasons. The distribution of some of the major groups and their species in the order of abundance is given below. The taxa which constitute less than 1% of the total zooplankton population have been grouped together as 'other groups'.

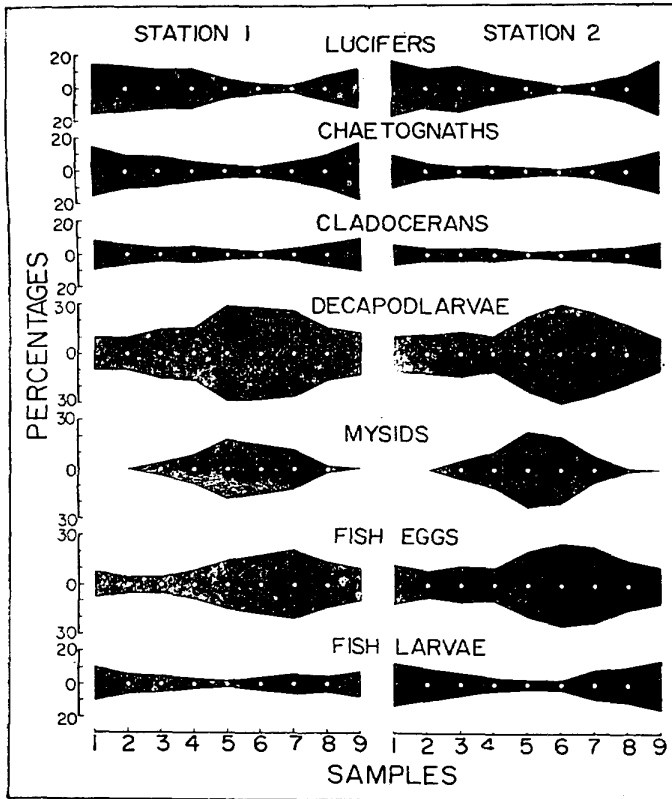


Fig. 3. Kite diagram showing the distribution of seven zooplankton taxa at stations 1 and 2.

## Copepoda

Copepods formed a major component of the zooplankton (53.0 to 82.8%) in all the samples collected from both the stations over the tidal cycle during the monsoon. In other seasons also, copepods occurred in large numbers but were not always dominant. The percentage occurrence of copepod population and other zooplankters during different seasons are shown in Fig. 4.

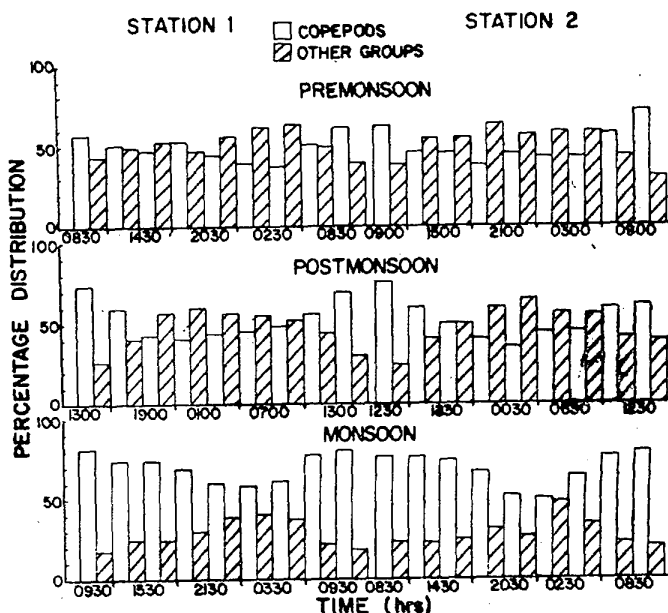


Fig. 4. Percentage distribution of copepods and other zooplanktonic groups at 2 stations.

Qualitative and quantitative difference in the distribution of copepods were observed at both the stations. The total number of copepods and their species were more at station 1 than at station 2. The neritic species, viz. *Canthocalanus pauper*, *Eucalanus crassus*, *Acrocalanus gibber*, *Centropages furcatus*, *Temora turbinata*, *Pontella danae*, *P. spinipes* and *Corycaeus gibbulus* were recorded only at Station 1 while *Pseudodiaptomus annandalei* and *Mesocyclops* sp. were observed in the plankton samples taken from station 2. Tidal incursions too, appear to cause variations in the numerical abundance of copepod species. The stenohaline forms, viz. *Paracalanus aculeatus*, *Centropages orsinii*, *Acartia erythraea* and *Tortanus forcipatus* were obtained in greater numbers in the samples collected during high tide while *Heliodyptomus cinctus* and *Acartiella gravelyi* were more during low tide. A few limnetic forms such as *Cyclops* sp., *Mesocyclops* sp. and *Diaptomus* sp. were recorded at station 2 during the ebb tide of monsoon.

Seasons seem to influence the distribution of copepods in this estuarine system. In addition to the occurrence of above mentioned species, 24 copepod species were invariably present in the samples collected from both the stations. Eight of these species were abundant in the samples taken during the monsoon while 5 and 6 species

Table II. Diurnal variations of temperature (°C) and salinity (‰) at two stations in the Zuari estuary during different seasons.

Sample No.	M O N S O O N			P O S T M O N S O O N			P R E M O N S O O N											
	Station 1		Station 2	Station 1		Station 2	Station 1		Station 2									
	Time (hrs)	°C	‰	Time (hrs)	°C	‰	Time (hrs)	°C	‰									
1	0930	28.0	9.47	0830	28.0	4.67	1300	27.7	32.27	1230	27.0	31.92	0830	30.7	36.29	0900	30.7	36.36
2	1230	29.0	10.41	1130	28.2	9.49	1600	28.8	32.63	1530	27.0	31.65	1130	31.1	36.56	1200	31.0	36.20
3	1530	28.9	7.63	1430	28.8	7.27	1900	27.5	31.38	1830	27.2	31.24	14.0	31.4	36.40	1500	31.5	36.14
4	1830	28.6	6.71	1730	28.0	3.39	2200	27.0	31.65	2130	27.0	30.68	1730	31.1	36.12	1800	31.0	36.17
5	2130	28.2	12.95	2030	28.0	4.31	0100	27.0	32.09	0030	26.5	31.87	2030	31.0	36.04	2100	31.0	35.59
6	00.0	28.0	13.51	2330	27.7	8.01	0400	24.5	32.45	0330	26.7	32.27	2330	30.5	36.26	0000	30.6	36.22
7	0330	28.3	5.71	0730	28.2	5.61	0700	27.0	31.20	0630	26.9	31.88	0230	30.5	36.18	0300	31.0	36.22
8	0630	29.0	4.31	05.0	28.2	1.70	1000	27.0	31.56	0930	26.7	31.02	0530	30.7	36.05	0600	30.8	36.00
9	0930	28.3	13.69	0830	28.0	5.61	1300	27.9	31.91	1230	27.8	31.20	0830	31.0	35.98	0900	31.0	36.10
Ave. range	—	28.5	9.37	—	28.1	5.56	—	27.2	31.90	—	26.9	31.47	—	30.9	36.20	—	30.9	36.15

Table III Occurrence of ten common copepod species at two stations in the Zuari estuary during different seasons.

	Monsoon	
	Postmonsoon	Premonsoon
<i>Paracalanus parvus</i>		<i>Acrocalanus gracilis</i>
<i>Heliodiaptomus cinctus</i>		<i>Centropages tenuiremis</i>
<i>Pseudodiaptomus binghami</i>		<i>C. dorsispinatus</i>
<i>P. aurivilli</i>		<i>Pseudodiaptomus aurivilli</i>
<i>Acartia plumosa</i>		<i>P. ardjuna</i>
<i>A. southwelli</i>		<i>Labidocera pectinata</i>
<i>Acartiella gravelyi</i>		<i>Acartia centrura</i>
<i>Ac. sewelli</i>		<i>A. southwelli</i>
<i>Oithona hebes</i>		<i>A. spinicauda</i>
<i>Cyclops</i> sp.		<i>Oithona rigida</i>
		<i>Eucalanus suberassus</i>
		<i>Paracalanus aculeatus</i>
		<i>Centropages orsinii</i>
		<i>Pseudodiaptomus aurivilli</i>
		<i>Labidocera pectinata</i>
		<i>Acartia spinicauda</i>
		<i>A. erythraea</i>
		<i>Tortanus forcipatus</i>
		<i>Euterpina acutifrons</i>
		<i>Oithona rigida</i>

during the postmonsoon and premonsoon respectively. Of the remaining 5 species, *Pseudodiaptomus aurivilli* occurred during all the seasons. *Acartia southwelli* was recorded in the monsoon and postmonsoon seasons while *Labidocera pectinata*, *Acartia spinicauda* and *Oithona rigida* were recorded during the postmonsoon and premonsoon seasons (Table III). Most of the common species were observed to be more in the day samples. Species of the family Acartiidae formed the dominant component of copepods at both the stations. Six members of this family, viz. *Acartia plumosa*, *A. southwelli*, *A. centrura*, *A. erythraea*, *A. spinicauda* and *Acartiella graveyi* were selected for statistical analysis for their distribution and abundance in relation to the time of collection of zooplankton samples. The results of the analysis indicate that out of these species, 5 occurred in greater numbers during day time contributing sometimes as much as 60% of total copepod counts (Fig. 5).

#### *Chaetognatha*

The chaetognaths were represented in the samples by four species of genus *Sagitta*. These, in order of dominance, are *S. bedoti*, *S. enflata*, *S. pulchra* and *S. robusta*. Only 3 specimens of *S. robusta* were recorded in the plankton samples from station 1. *S. pulchra* occurred at both the stations but in very small numbers. The distribution of the remaining two species over entire tidal cycle during the period of observation is given in Table IV. *S. bedoti* occurred in all the seasons, tolerating wide fluctuations in salinity (1.7 to 36.1‰). *S. enflata* was not observed in the samples taken during the monsoon. The tides also influenced the distribution of chaetognaths. The highest number (129/10 m<sup>3</sup>) was observed at 1230 hrs at station 1 during the postmonsoon season when the tidal range was about 2 m.

#### *Cladocera*

Three species, namely *Evadne tergestina*, *Penilia avirostris* and *Podon* sp. were observed in the plankton samples. A few specimens of the last mentioned limnetic species were recorded only during the monsoon at station 2. The cladoceran population was recorded more at station 1 than at station 2 and occurred in greater numbers during the high tide. Maximum and minimum number of cladocerans was encountered during the monsoon and the premonsoon seasons respectively. The diel rhythm also influenced the distribution of the common species. *Evadne* was observed to be in greater numbers in the day samples while *Penilia* occurred more in the night samples (Table V).

#### *Decapod larvae*

This group comprised mostly of zoea and megalopa stages of Brachyurans, adults of *Acetes* sp., members of the families Palaemonidae, Hippolytidae and Alpheidae, mysis and postlarval stages of commercially important prawns such as *Metapenaeus dobsoni*, *Penaeus merguensis*, *Parapenaeopsis stylifera* and *Metapenaeus* sp. Crab zoea occurred more at station 2 and were recorded in greater numbers during low tide. Species of families Hippolytidae and Alpheidae were abundant at station 1. Nocturnal abundance of developmental stages of all the 4 species of penaeid prawns was noticed in the zooplankton from both the stations in the month of February.

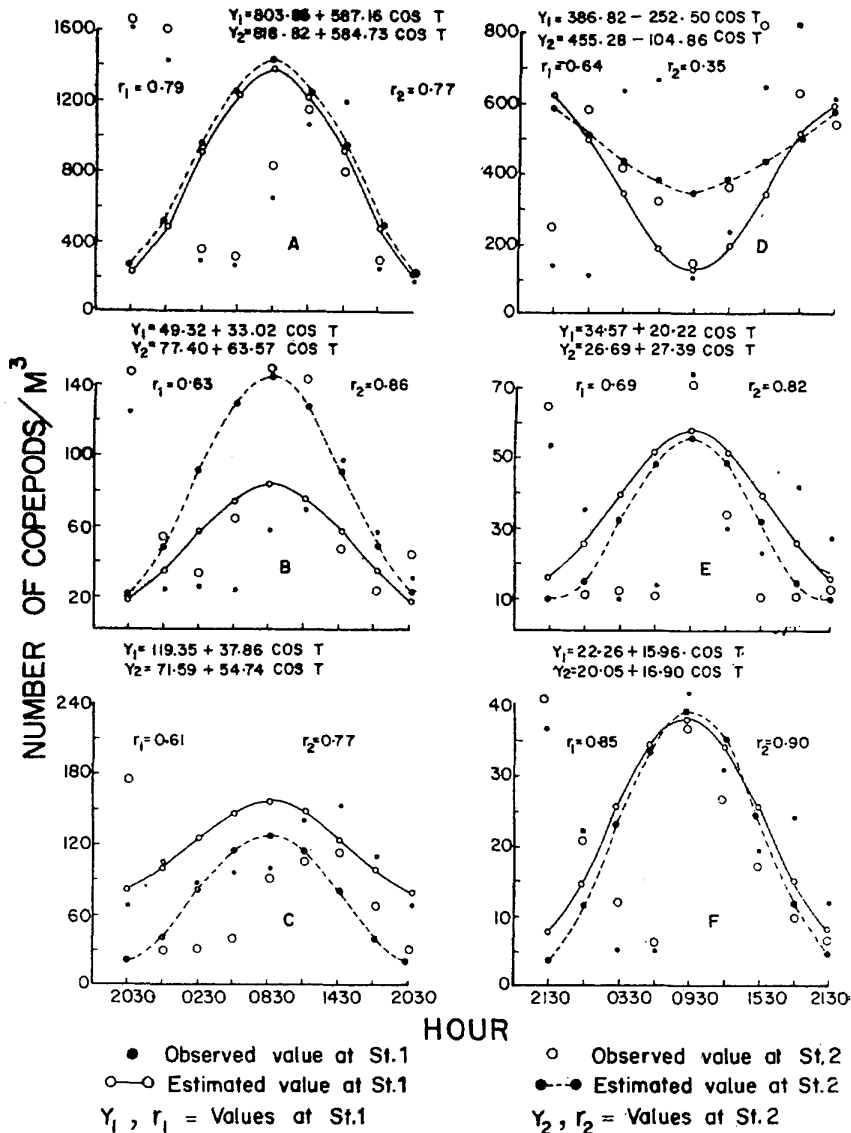


Fig. 5. Abundance of six species of family Acartiidae during different times of the day.

A = *Acartia plumosa* B = *A. southwelli* C = *A. centrura* D = *Acartiella gravelyi*  
 E = *Acartia spinicauda* F = *A. erythraea*

#### Sergestidae

*Lucifer hanseni* was the only species recorded with the maximum abundance (852/1000 m<sup>3</sup>) during the premonsoon at station 1. This group was poorly represented.



Table IV Diurnal variations of two species of Chaetognatha (No./10 m<sup>3</sup>) at two stations in Zuari estuary during different seasons.

Season	Species	Station 1 / Samples									Station 2 / Samples									
		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	
Monsoon	<i>Sagitta bedoti</i>	19	18	5	0	11	7	16	23	41	12	4	0	0	0	0	9	4	10	6
	<i>S. enflata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Post - monsoon	<i>S. bedoti</i>	45	28	17	31	44	23	57	68	73	66	31	14	18	22	41	53	77	110	
	<i>S. enflata</i>	12	8	0	0	10	0	8	16	20	7	0	0	0	0	0	4	12	19	
Pre - monsoon	<i>S. bedoti</i>	31	34	31	20	22	17	9	14	26	18	7	19	5	7	11	8	13	21	
	<i>S. enflata</i>	52	40	8	17	10	9	13	51	88	31	14	10	6	18	24	30	13	40	

Table V. Diurnal variations of two Cladoceran species (No./10 m<sup>3</sup>) at two stations in Zuari estuary during different seasons.

Season	Species	Station 1 / Samples									Station 2 / Samples									
		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	
Monsoon	<i>Evadne tergestina</i>	109	112	96	45	21	17	54	81	115	65	79	90	52	14	16	34	48	51	
	<i>Penilia avirostris</i>	70	52	55	50	45	26	39	72	91	40	46	57	31	36	42	29	35	44	
Post - monsoon	<i>E. tergestina</i>	49	57	31	36	12	4	7	18	35	33	48	19	22	10	18	35	26	30	
	<i>P. avirostris</i>	30	7	20	14	23	9	11	22	10	18	27	12	29	31	12	17	14	11	
Pre - monsoon	<i>E. tergestina</i>	12	9	13	6	3	—	4	—	5	14	10	7	1	0	0	0	14	18	
	<i>P. avirostris</i>	3	—	5	4	10	24	13	7	9	6	2	0	0	4	0	6	10	5	

in the samples collected during the low tide and the monsoon season. The occurrence of lucifers was observed to be independent of diel rhythm.

### *Mysidacea*

*Mesopodopsis orientalis* was the commonest species in this estuarine system. The distribution of mysids was not related to tides but occurred more in the night samples. They were also in greater numbers during the monsoon and the postmonsoon seasons.

### *Fish eggs and larvae*

Fish eggs and larvae were obtained in large numbers during the monsoon. The number of fish eggs was more in the collection made between 2200 to 0330 hrs. Fish larvae were abundant in the samples taken during the day. The fish larvae of the family Clupeidae were common in the plankton samples.

### *Other groups*

A clear relationship was observed between the abundance of hydromedusae and tides. Their highest number (89/100 m<sup>3</sup>) was obtained at station I during the high tide of the premonsoon. Species of the genus *Eirene* were most dominant. The distribution of polychaete larvae was independent of tides but was associated with the phenomenon of vertical migration of zooplankters. The polychaetes and also the cumaceans, amphipods and isopods occurred more in the night samples. The neritic forms such as stomatopod larvae and pelagic tunicates were recorded only at station I in the samples taken during the flood tide of the day and during the high saline period (35.9 to 36.10‰).

## DISCUSSION

The tides in the Zuari estuary are of the semi-diurnal type with a maximum range of about 2 m. Constant flushing and flooding by the semi-diurnal tides make this estuary a dynamic environment. Zooplankton production was found to be quite high during the monsoon. The highest (490 ml/1000 m<sup>3</sup>) and the lowest (134 ml/1000 m<sup>3</sup>) average biomass values at both the stations were obtained during the monsoon and the premonsoon seasons respectively. Goswami and Selvakumar (1977) reported the highest mean zooplankton biomass value of 220 g/1000 m<sup>3</sup> at station in the Zuari estuary during September. The high biomass values recorded in the Zuari estuary during monsoon is interesting. In all other Indian estuaries and backwaters on the west coast (Nair and Tranter, 1971; Menon, Venugopal and Goswami, 1971 and Madhupratap and Haridas, 1975 from Cochin backwaters; Goswami and Singbal, 1974 from Mandovi estuary, Goa) and east coast of India (Chandramohan, 1963 and Ganapati, 1964 from Godavari estuary; Krishnamurthy, 1961 and Subbaraju and Krishnamurthy, 1972 from Vellar estuary) very poor zooplankton production has been reported during the monsoon months. Recently, Rao (1977) traced direct relationship between zooplankton production and salinity in the Indian estuarine and backwater systems. The high biomass values obtained at stations in the Zuari estuary may be due to a comparatively high salinity (1.7 to 13.69‰) during monsoon (Table II) whereas in other areas, almost freshwater conditions prevail during the rainy season which may

account for poor zooplankton production. Whatever freshwater discharge is received from the catchment area of Zuari estuary during monsoon, it enriches this system with nutrients. It has been shown earlier (Subrahmanyam, 1959 and Qasim, Bhattathiri and Devassy, 1972) that the enrichment of nutrients associated with sudden fall in temperature and salinity results in high phytoplankton production. But during the present study, an inverse relationship was seen between phyto and zooplankton production during the monsoon. The poor phytoplankton population may be due to the prevailing turbidity or owing to grazing by copepods as the zooplankton community was dominated mostly by herbivorous copepods. Bhargava and Dwivedi (1974), in their studies of diurnal variation of phytoplankton pigments in this area, have also recorded poor chlorophyll concentration of 0.13 to 3.09 mg/m<sup>3</sup> for station 1 and 0.06 to 1.94 mg/m<sup>3</sup> for station 2 during the monsoon.

Different zooplankton taxa and their species showed a complex pattern of distribution in the estuarine system. The occurrence of neritic organisms such as hydromedusae, siphonophores, pteropods, pelagic tunicates etc. is dependent upon the state of tide as reported from other areas (Chandramohan and Rao, 1972; Pillai and Pillai, 1973 and Mathew, Gopinathan, Rao, Regunathan and Murthy, 1977). The distribution and abundance of copepods which were the important constituents of zooplankton population were influenced by the location of sampling station, time of collection and seasons. Most of the common copepod species did not show appreciable variance in abundance in the zooplankton samples collected during tidal exchanges. Species of genus *Acartia* were recorded in greater numbers in the day samples at both the stations. However, Madhupratap and Rao (1979) reported abundance of members of this genus to be significantly higher in the night zooplankton collections taken at Narakkal in Cochin backwaters. This variation in the occurrence of species of genus *Acartia* in relation to diel rhythm in Zuari estuary and in Cochin backwater may be due to two different ecosystems. The estuarine copepod *Pseudodiaptomus annandalei* occurred only in the night samples at both the stations. Pillai and Pillai (1973) and Madhupratap and Rao (1979) also reported the occurrence of *P. annandalei* and *P. jonesi* in the night samples from Cochin backwaters. The distribution of most of the species of genus *Pseudodiaptomus* seems to be associated with the phenomenon of vertical migration of plankters, irrespective of the prevailing environmental conditions and the state of the tides.

#### ACKNOWLEDGEMENTS

The authors are grateful to Dr. S.Z. Qasim, Director, National Institute of Oceanography, Goa, for help and facilities. Sincere thanks are due to Dr. T.S.S. Rao and Dr. V.K. Venugopalan for their useful suggestions on the manuscript and to Shri S.G. Dalal for statistical help.

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