

Ecology of Mandovi & Zuari Estuaries: Plankton Community in Relation to Hydrographic Conditions during Monsoon Months, 1972*

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Total zooplankton biomass and the constituent species under the major taxa in relation to hydrographical conditions in the Mandovi-Zuari estuarine complex during June to September 1972 were studied. Zuari estuary had greater marine influence and higher zooplankton biomass as compared to Mandovi estuary. The faunal composition was very diverse and also the total number of species present was more in the former. Copepoda, Decapoda, Ctenophora, Sergestidae, fish eggs and larvae constituted the bulk of the collections. Copepoda was the major component in all the samples, but during the entire monsoon period, dominance of no single group was evident.

MANDOVI-ZUARI estuarine system in Goa is being studied intensively and some of the results have been reported¹⁻⁵. The general topography of this area has been described by Dehadrai¹. The Mandovi and Zuari estuaries are connected with the Cumbarjua Canal at the upstream points at distances of 11 km and 14 km of respective rivers. The environmental features are influenced by the semidiurnal tides and the freshwater influx from land drainage, rivers and their tributaries. Studies on zooplankton biomass and faunistic composition in relation to hydrography during monsoon months, when this environment undergoes appreciable changes, are presented here.

Materials and Methods

Surface zooplankton samples were collected fortnightly at each of the 12 stations (Fig. 1) from June to September 1972. In all, 96 samples were taken during high tide using a modified version of WP-2 net⁶ (mouth area, 0.25 m² and mesh width 0.3 mm). A flowmeter was used for measuring the amount of water filtered. The duration of hauls varied 2-5 min and on an average 70 m³ of water was filtered per haul. The samples were preserved in 5% buffered formaldehyde prepared in seawater. The water samples were analysed for temperature, salinity, dissolved oxygen, inorganic phosphate and nitrate. Standard methods were adopted for the analysis of chemical parameters^{7,8}. The values for each month were averaged.

For the counts of various taxa and their species, one of the aliquots obtained by Folsom plankton splitter was made up to 150 ml, of which 10 ml was examined under a stereoscopic microscope and the number of organisms was raised to the total volume of water filtered. The planktonic copepods were classified after Kasturirangan⁹.

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Results

Hydrography

Average fortnightly values of the hydrographical parameters are presented in Table 1.

Temperature — Average value for different months varied from 26.2° to 30.9°C. Lowest temperature was recorded in the month of July at station 5. In general, the temperature was high in June but with the onset of monsoon there was a decrease and thereafter a certain amount of uniformity was maintained till September when an increase was again indicated.

Salinity — During south-west monsoon, the salinity values were low due to heavy rainfall and land drainage. In July and August, almost freshwater conditions were recorded from station 5 to station 7 (0.26-3.26‰). On the basis of salinity variation, the estuarine complex during this period could be divided into 3 zones: Zone I — from station 1

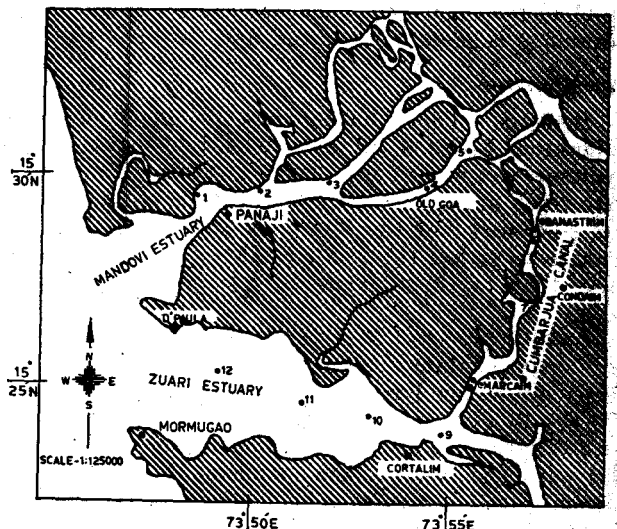


Fig. 1 — Position of the stations

TABLE 1 — AVERAGE FORTNIGHTLY VALUES OF HYDROGRAPHIC PARAMETERS DURING MONSOON MONTHS, 1972

Month	Stations											
	1	2	3	4	5	6	7	8	9	10	11	12
TEMPERATURE (°C)												
June	28.6	28.6	28.8	28.6	28.7	28.9	29.3	30.2	29.6	29.3	29.0	29.6
July	26.9	26.9	27.0	26.7	26.2	27.7	27.6	27.9	27.6	27.6	28.0	28.0
Aug.	26.4	26.5	27.2	27.6	27.6	29.0	28.5	28.6	28.6	28.9	28.7	29.8
Sept.	27.3	28.4	29.4	29.8	30.1	30.4	30.9	30.4	30.5	30.2	28.4	29.4
SALINITY (‰)												
June	18.01	17.72	16.99	15.30	15.30	18.92	18.86	19.82	21.90	22.11	22.68	24.82
July	8.37	8.32	3.76	0.62	0.26	0.72	1.12	5.44	6.65	8.31	9.76	11.85
Aug.	13.99	10.28	4.36	1.92	0.50	1.00	3.26	12.86	10.84	15.42	16.74	19.59
Sept.	23.59	16.54	11.40	5.29	3.72	6.67	11.23	16.86	19.04	21.10	26.00	30.83
DISSOLVED OXYGEN (ml/litre)												
June	4.14	4.66	4.60	4.70	4.36	4.43	4.43	4.55	4.20	3.92	3.54	4.53
July	4.60	4.23	4.76	5.09	4.98	4.56	4.81	4.73	4.67	4.78	4.87	5.01
Aug.	4.34	4.73	5.10	5.12	5.02	5.15	4.52	5.27	5.15	6.04	5.48	5.48
Sept.	3.87	4.87	5.32	5.32	5.26	4.64	4.59	4.72	4.87	5.03	4.53	4.53
PO ₄ -P (µg at/litre)												
June	1.32	1.52	1.16	1.41	1.40	1.04	1.48	1.44	1.24	1.48	1.24	1.40
July	0.84	1.68	0.58	0.58	0.58	0.50	0.91	1.45	1.26	1.56	1.37	1.45
Aug.	0.86	1.18	1.83	0.86	1.15	1.14	0.88	1.10	1.18	0.99	0.80	1.14
Sept.	0.84	1.03	0.91	0.89	0.51	0.68	0.72	0.42	0.65	0.65	0.68	0.99
NO ₃ -N (µg at/litre)												
June	2.89	1.54	1.53	2.59	1.40	3.21	1.87	2.31	1.63	2.13	2.21	1.65
July	1.45	1.64	1.77	1.24	1.65	0.69	1.92	1.08	0.93	1.44	0.60	0.80
Aug.	1.32	1.15	1.16	1.24	1.35	0.96	1.11	1.16	0.80	2.09	1.33	1.28
Sept.	1.68	0.56	0.60	0.76	0.48	0.48	0.56	0.86	0.57	0.60	0.57	0.88

to 4 (0.62-23.59‰), Zone II — from station 5 to 7 (0.26-18.92‰) and Zone III — from station 8 to 12 (5.44-30.83‰).

Dissolved oxygen — Oxygen values did not differ appreciably during the period of study, but the values were high in monsoon season than postmonsoon and premonsoon months⁵.

Nutrients — The inorganic phosphate concentration varied from 0.42 to 1.83 µg. at/litre and the nitrates varied from 0.48 to 3.21 µg at/litre during monsoon months. The nutrient values were high in the Cumbarjua canal where the effect of land drainage is more pronounced and depth is less.

Zooplankton

Biomass — Pooled mean values of the total zooplankton biomass as estimated by displacement volume, wet weight and dry weight from 12 stations, are given in Fig. 2. The highest value obtained was at station 9 and the lowest at station 5. During monsoon period the Zuari estuary is more productive than the Mandovi estuary and the Cumbarjua canal.

Faunistic composition — Percentage distribution of different planktonic groups for all the stations has been shown in Fig. 3. These include copepods, decapods, ctenophores, cladocerans, gastropods, chaetognaths, sergestids (Lucifer), fish eggs and larvae. The 'other groups' constituted less than 1% of the total composition in a sample and included Hydromedusae, Amphipoda, Mysidacea, Polychaeta, Isopoda, Oikopleura, Cumacea, Cirreped larvae and

insect larvae. Some of the important planktonic groups and their species are given below:

Ctenophora: This group was abundant during June when the temperature and salinity values were high in this estuarine system, the highest percentage recorded being 14.9% at station 2. The ctenophores were observed to be more at the stations in the Mandovi estuary.

Chaetognatha: It was poorly represented during low salinity conditions. Three species of genus *Sagitta*, viz. *S. enflata*, *S. bedoti* and *S. pulchra* were recorded. *S. bedoti* was the most common. A few specimens of *S. pulchra* were observed in the collections from stations 11 and 12 during June.

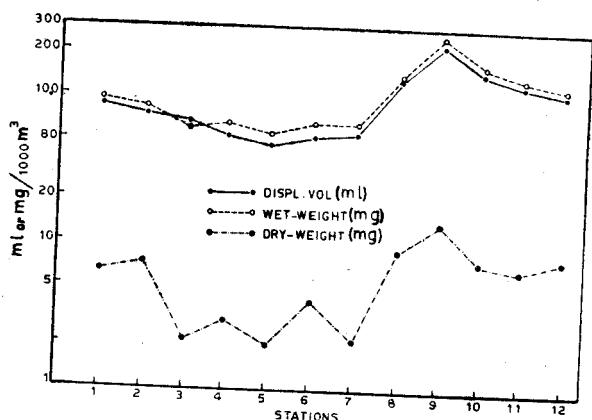


Fig. 2 — Pooled mean values of total biomass at various station are shown in semi-log scale

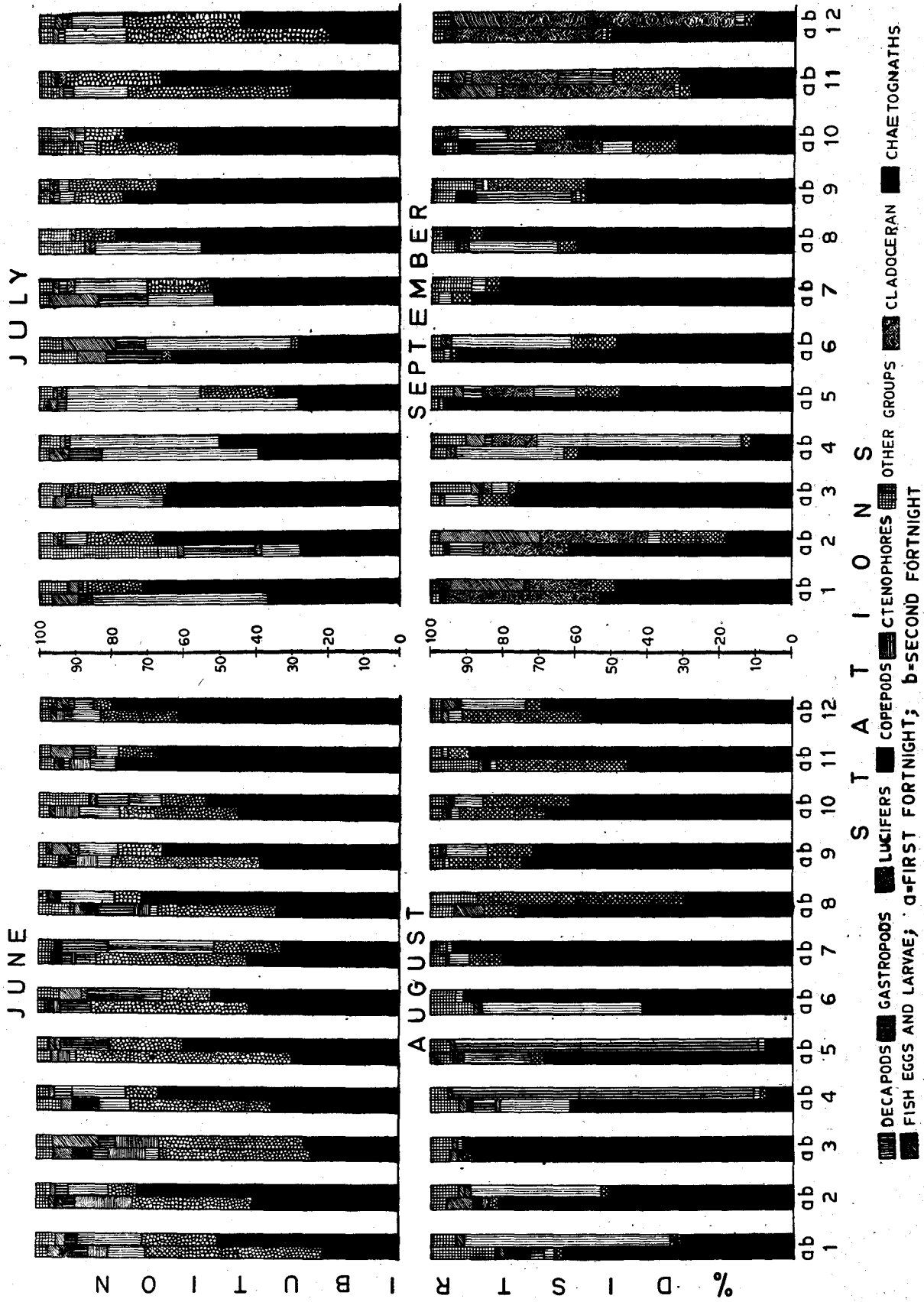


Fig. 3—Percentage composition of major planktonic groups in fortnightly collections

Cladocera: Cladocerans occurred in large numbers during second fortnight of September constituting 48.4% of the plankton at station 12. *Evadne tergestina* and *Penilia avirostris* formed the bulk of cladoceran population. The former was greater in abundance than the latter, and preferred low saline conditions. The salinity range varied from 5.29 to 23.59‰ for *Evadne* and 19.04 to 30.83‰ for *Penilia*.

Copepoda: This group was the major component of the plankton community throughout the monsoon period. In one zooplankton sample at station 5, during the first fortnight of September, it contributed as much as 97.1%. Thirty species of planktonic copepods belonging to 12 families and 15 genera were present.

The distribution of species at all stations has been shown in Table 2. It is evident that there is qualitative and quantitative variations in their distribution. The species were comparatively more in Zuari estuary than in the Mandovi estuary and Cumbarjua canal. The salinity gradient may be the limiting factor in their distribution. The salinity ranges were: 0.26-23.59‰, 0.72-19.82‰ and 6.65-30.83‰ for the stations in the Mandovi estuary, Cumbarjua canal and Zuari estuary respectively. *Undinula darwini*, *Eucalanus crassus*, *Centropages elongatus* and *Acartia erythraea* were recorded only in the Zuari. *Eucalanus subcrassus*, *Centropages trispinosus* and *Pontella danae* were observed only in the Mandovi. *Acrocalanus gibber*, *Centropages tenuiremis*, *C. orsinii* and *Pseudodiaptomus serricaudatus* were common to both the estuaries but absent in the Cumbarjua canal. The last two species were observed only at stations 1 and 12, where hydrographical conditions were almost identical. *Heliodyptomus cinctus*, *Pseudodiaptomus merotoni*, *Oithona brevicornis* and *Cyclops* sp. were common to stations in the Mandovi estuary and the Cumbarjua canal but absent in the Zuari estuary. *Pontella securifer* and *Temora turbinata* were observed at all stations in the Zuari estuary and at station 8 in the Cumbarjua canal. This indicates the flow of water from the former into the latter.

Maximum number of copepod species were recorded during June when high salinity prevailed in the Mandovi-Zuari estuarine system and the influx of neritic species was discernible. With the advent of south-west monsoon and consequent lowering of salinity, only 8 species were seen in the surface collections. The number increased again to about 19 in September, when an abundance of diatoms and dinoflagellates which constitute their food was noticed in the nutrient-enriched water. *Paracalanus parvus*, *Acrocalanus gracilis*, *Pseudodiaptomus aurivilli*, *Labidocera pectinata*, *Tortanus forcipatus*, *Oithona rigida*, *Acartia centrura*, *A. plumosa* and *A. sewelli* were the common species. The monthly variations in the distribution of 6 numerically abundant species has been shown in Fig. 4. These species in the order of dominance were *Acartia plumosa*, *Pseudodiaptomus aurivilli*, *Tortanus forcipatus*, *Acartia sewelli*, *A. spinicauda* and *A. centrura*. They were recorded at all 12 stations during June.

T. forcipatus seems to be a neritic species occurring in large numbers when the salinity is high in this environment. With the onset of monsoon,

it was not recorded in the surface collections. *A. sewelli* preferred low salinity conditions and was abundant during July and August.

Pseudodiaptomus aurivilli, *A. centrura* and *A. spinicauda* appeared to be estuarine species, the last two were distributed more in the Zuari.

Decapod larvae: Zoea of *Brachyura* and penaeid larvae were present. The highest percentage (65.4%) was recorded at station 5 during July.

Sergestidae: This group was distributed more at the stations in the Mandovi and Zuari estuaries. The highest percentage (64.3%) was recorded at station 8 in August. *Lucifer henseni* was the common species.

Gastropoda: Hydrobid gastropods of *Bithynia* sp. were the common representatives at stations 4 and 5, located near the bank in the Mandovi estuary and, in August, they formed 91.1 and 88.2% of the plankton, respectively.

Fish eggs and larvae: The eggs and larvae of the family Clupeidae were abundant during July and August.

Hydromedusae: This was represented by the species of genus *Eirene* and were recorded at stations 11 and 12.

Polychaete larvae: were present inconsistently. The highest percentage (0.94%) was recorded at station 9. Species of genus *Nereis* were present.

Amphipoda: This group was represented by a few gammarid amphipods.

Cirreped larvae: were present in small numbers in both the estuaries. Larvae of genus *Balanus* were present.

Mysids, cumaceans, isopods, oikopleura and insect larvae occurred inconsistently in the samples.

Discussion

Mandovi-Zuari estuarine system undergoes important hydrobiological changes during monsoon months, when the Zuari estuary retains its marine nature whereas the Mandovi estuary and the Cumbarjua canal become almost freshwater due to drainage from their catchment area. This results in wide salinity variations from 0.26 to 30.83‰. This fluctuation in salinity influences the distribution of plankton, different faunal taxa and their species in this area. Dehadrai¹ has recorded nil salinity during ebb in the Mandovi estuary during monsoon months and reported that the salinity variation plays an important role in the ecology of Mandovi and Zuari estuaries. No appreciable temperature difference is observed. Value of dissolved oxygen increases during August and September. This may be the effect of south-west monsoon or phytoplankton abundance in the nutrient-rich waters.

Zooplankton biomass is higher in the Zuari estuary than in the Mandovi estuary. The diversity of planktonic taxa in the former indicates that it is more productive during monsoon months. Highest biomass values are recorded at station 9; the presence of stable and true estuarine conditions there may account for it. The lowest values are obtained at station 5 where freshwater conditions prevail. Dehadrai and Bhargava² have also shown that the Zuari estuary is more productive than Mandovi estuary during south-west monsoon. Seventeen major planktonic groups are present in the zooplankton samples but no single group has

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TABLE 2— POOLED MEAN VALUES (No/100 m³) OF COPEPOD SPECIES AT DIFFERENT STATIONS IN MANDOVI-ZUARI ESTUARINE COMPLEX DURING MONSOON MONTHS

Species	Stations											
	1	2	3	4	5	6	7	8	9	10	11	12
FAMILY: CALANIDAE												
<i>Undinula darwini</i> (Lubbock) var. <i>typica</i> Sewell	—	—	—	—	—	—	—	—	—	—	3	12
FAMILY: EUCALANIDAE												
<i>Eucalanus crassus</i> Giesbrecht	1	—	—	—	—	—	—	—	—	35	—	—
<i>E. subcrassus</i> Giesbrecht	1	—	—	—	—	—	—	—	—	—	—	—
FAMILY: PARACALANIDAE												
<i>Pavacalanus parvus</i> (Claus)	46	42	34	17	3	3	33	59	209	143	192	205
<i>Acocalanus gracilis</i> Giesbrecht	378	352	367	499	364	280	282	35	185	379	895	168
<i>A. gibber</i> Giesbrecht	—	26	18	6	—	—	—	—	—	—	116	59
FAMILY: CENTROPAGIDAE												
<i>Centropages tenuiremis</i> Thompson & Scott	1	—	—	—	—	—	—	—	—	35	350	88
<i>C. orsinii</i> Giesbrecht	30	—	—	—	—	—	—	—	—	—	—	46
<i>C. trispinosus</i> Sewell	—	—	—	1	—	—	—	—	—	—	—	—
<i>C. elongatus</i> Giesbrecht	—	—	—	—	—	—	—	—	—	15	2	2
FAMILY: DIAPTOMIDAE												
<i>Heliodiaptomus cinctus</i> (Gurney)	8	136	10	30	18	807	88	187	—	—	—	—
FAMILY: PSEUDODIAPTOMIDAE												
<i>Pseudodiaptomus annandalei</i> Sewell	15	7	54	3	15	186	79	5	—	—	29	—
<i>P. aurivilli</i> Cleve	4256	1078	1007	753	308	206	42	174	591	67	1118	69
<i>P. serricaudatus</i> (T. Scott)	19	—	—	—	—	—	—	—	—	—	—	16
<i>P. mertoni</i> Fruchtl	—	3	—	149	15	690	35	4	—	—	—	—
FAMILY: TEMORIDAE												
<i>Temora turbinata</i> (Dana)	—	13	—	—	—	—	—	17	51	70	33	30
FAMILY: PONTELLIDAE												
<i>Labidocera pectinata</i> Thompson & Scott	12	3	58	61	30	50	76	13	5	35	175	—
<i>Pontella danae</i> Giesbrecht var. <i>Ceylonica</i> Thompson & Scott	29	51	—	—	—	—	—	—	—	—	—	—
<i>P. securifer</i> Brady	—	—	—	—	—	—	—	20	11	4	10	6
FAMILY: ACARTIIDAE												
<i>Acartia</i> (Odontacartia)	234	545	501	1	540	166	530	280	512	207	733	778
<i>Centruca</i> Giesbracht	—	—	—	—	—	—	—	—	—	—	—	—
<i>Acartia</i> (O) <i>spinicauda</i> Giesbrecht	939	518	163	338	—	50	156	183	1262	1219	601	2165
<i>A.</i> (O) <i>erythraea</i> Giesbrecht	—	—	—	—	—	—	—	—	—	—	197	102
<i>A.</i> (<i>Acanthacartia</i>) <i>Plumosa</i> T. Scott	5652	3431	8748	8248	3919	1776	5029	4551	5901	5858	6372	2033
<i>A.</i> (<i>Euacartia</i>) <i>southwelli</i> Sewell	2	17	—	14	4	—	—	4	21	2	56	31
<i>A. sewelli</i> Steuer	350	102	137	490	1275	1279	353	491	1069	1616	915	87
<i>Acartiella gravelyi</i> Sewell	155	2	355	1095	1204	1122	871	57	20	—	—	—
FAMILY: TORTANIDAE												
<i>Tortanus forcipatus</i> (Giesbrecht)	93	140	235	614	165	366	625	981	1926	3105	1086	51
FAMILY: OITHONIDAE												
<i>Oithona rigida</i> Giesbrecht	15	3	11	10	1	—	—	—	47	119	21	2
<i>O. brevicornis</i> Giesbrecht	—	—	11	2	2	12	13	2	—	—	—	—
FAMILY: CYCLOPODAE												
<i>Cyclops</i> sp.	—	—	—	3	—	51	16	2	—	—	—	—

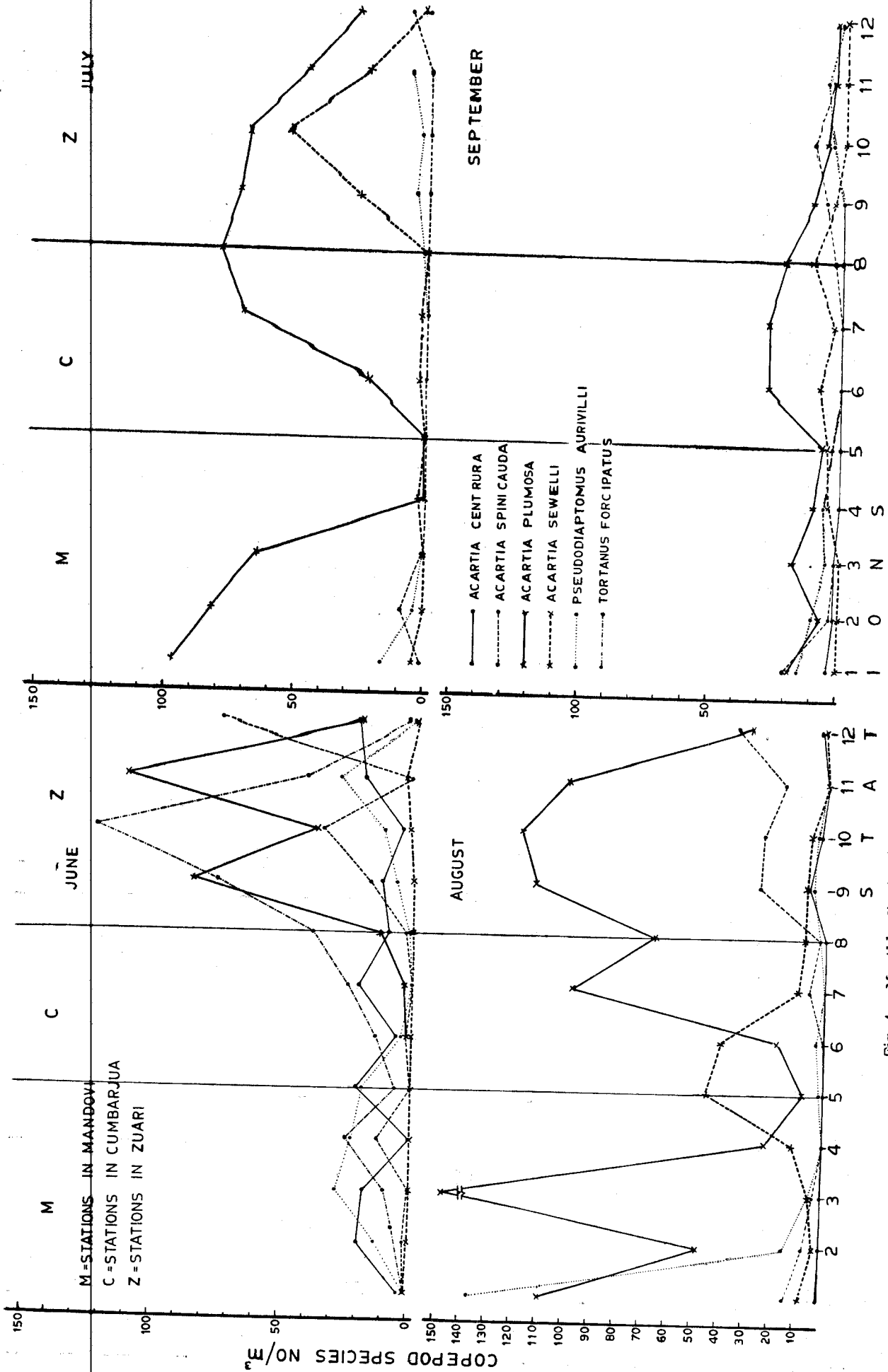


Fig. 4 — Monthly distribution of 6 dominant copepod species at different stations

dominated the community throughout the monsoon months. Lucifers, chaetognaths, ctenophores and decapod larvae are fairly well represented in the samples during June, when the salinity is high. With the onset of rains, the planktonic groups show preference to salinity zones in their distribution. Lucifers and fish eggs and larvae are more in zone I decapods and gastropods in zone II and chaetognaths in III. Cladocerans appear in large numbers in September. Selvakumar¹⁰ has also reported cladoceran abundance from September to February with peak in October in Mandovi-Zuari estuaries. Menon *et al.*¹¹ have recorded cladoceran peak during August and September in Cochin Backwater when the salinity was low. Chaetognaths occur more in the Zuari estuary *Sagitta bedoti* being dominant. *S. pulchra* is present in small numbers during June. According to Rao¹², *S. pulchra* is present in large numbers during high saline conditions in the inshore plankton.

Majority of copepods recorded occur in June. During July-August, only 8 species are seen in the surface collections. The number increases again in September, when there is abundance of diatoms and dinoflagellates in this environment. Ganapati and Sarma¹³ and Prasad and Kartha¹⁴ have also recorded close diatom-copepod relationship off Waltair coast and in the Gulf of Mannar and Palk Bay respectively. *Eucalanus subcrassus*, *Centropages tenuiremis*, *C. orsinii*, *Pontella danae*, *Pseudodiaptomus serricaudatus* are observed at the stations in the Mandovi, *Undinula darwini*, *Centropages elongatus*, *Temora turbinata*, *Acartia erythraea* and *A. spinicauda* in the Zuari. *Heliodyptomus cinctus*, *Pseudodiaptomus annandalei* and *Cyclops* sp. are recorded in the Cumbarjua canal. *Pontella securifer* and *Temora turbinata* are observed at the stations in the Zuari estuary and at station 8 in the Cumbarjua canal, indicating flow of water from the former into the latter. The movement of water from the Zuari to the Mandovi through the canal has also been reported by Das *et al.*⁴ *Paracalanus parvus*, *Acroca-*

lanus gracilis, *Pseudodiaptomus aurivilli*, *Labidocera pectinata* and *Oithona rigida* are present invariably at all stations. Pillai¹⁵ has given a list of 67 species of calanoid copepods from the estuarine waters of India. He has stated that *Acartia centrura*, *A. spinicauda*, *A. erythraea*, *Pseudodiaptomus serricaudatus* and *P. aurivilli* are marine forms which are also present in the estuarine environment. The distribution of these species in the Zuari estuary and at the mouth of the Mandovi estuary indicates the ingress of marine species into these estuaries.

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