

## ANNUAL VARIATIONS IN ZOOPLANKTON FROM A POLLUTED COASTAL ENVIRONMENT

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### ABSTRACT

Seasonal changes in the composition and distribution of zooplankton from the coastal waters of Trivandrum were studied. The study indicated that the effluent discharged from a nearby titanium dioxide factory did not affect the zooplankton abundance. Copepods followed by cladocerans contributed to the bulk of zooplankton. Species composition of zooplankton and their ecology are discussed. Diversity of zooplankton was high in the postmonsoon months and also in April.

### INTRODUCTION

Much information has been collected on the zoogeography, distribution and ecology of various groups of zooplankton from the Indian waters during the International Indian Ocean Expedition. However, very few studies have been carried out for the entire year to illustrate the changes in the composition and distribution of zooplankton from the coastal waters. Results of the studies conducted on zooplankton in 1976-77 off Trivandrum, southwest Kerala, are presented in this paper.

### MATERIAL AND METHODS

Zooplankton samples were collected as a part of the survey conducted to study the effect of effluent discharge from a titanium factory into the coastal waters of Trivandrum (08°30'N; 76°55'E). The effluent (discharge rate-4000 m<sup>3</sup>/day) chiefly containing sulphuric acid, ferrous salts and titanium dioxide spreads along the coast imparting a reddish brown colour to the seawater extending to a width 0.3 to 0.5 km from the shore. Lowering of pH of seawater occurred at the effluent outfall area (∞3), but rapidly increased to the pH of normal (∞8) as the effluent mixed with seawater. Zooplankton were collected in oblique tows with a Heron-Tranter net (mouth area-.25 m<sup>2</sup>, mesh size-300μ) attached with a flowmeter. Samples were collected within and outside the effluent patch at monthly intervals from November 1976 to December 1977 (collections were not made in May-June and September-November in 1977) at the effluent outfall area (TTP), Thumba, 5 km north of TTP and Sankhamugam 5 km south of TTP (Fig. 1). Collections were also made at Kovalam (15 km south) which remained as a clean station. Biomass was estimated as displacement volume and organisms in each sample were counted to species level wherever possible.

Diversity indices for total zooplankton and copepods separately were found from  $\alpha$  (Fisher, Corbet and Williams, 1943) and D (Margalef, 1958) and from H

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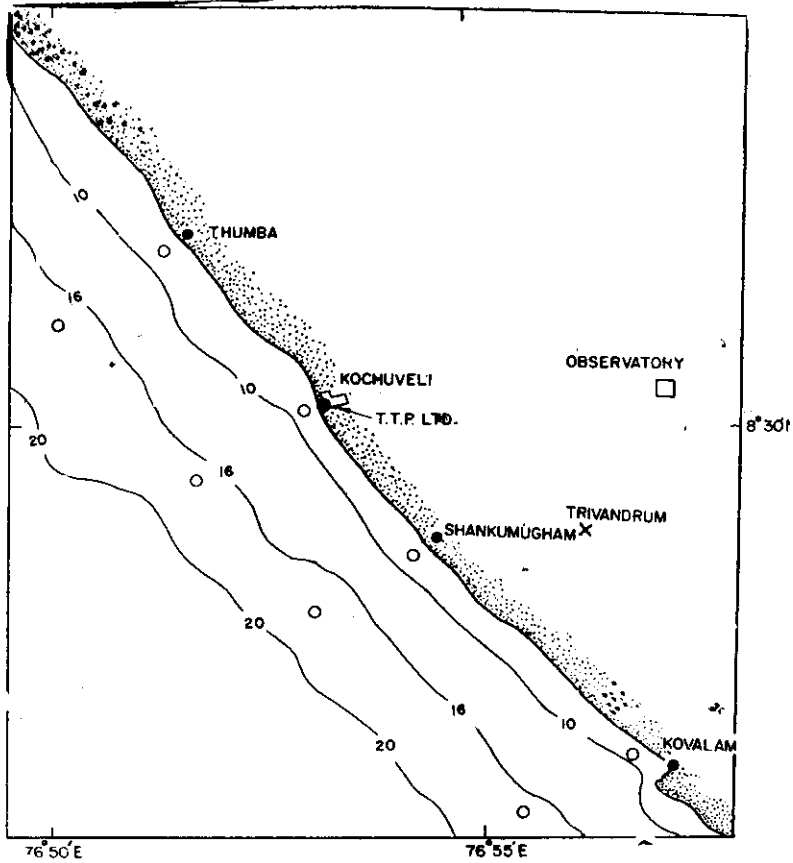


Fig. 1. Area of work (closed circles) and location of stations (open circles). (Depth in Fathoms)

(Shannon & Weiner, 1963) and E (Heip, 1974) which give the equitability component based on information theory. These were calculated after converting the numbers of zooplankton to their number per cubic metre.

#### RESULTS AND DISCUSSION

Analysis of variance performed for biomass, total numbers and common species of zooplankton (Table I) did not show any significant variation between affected and unaffected areas. This must be because the zooplankton get carried away with water movements and their sojourn in the polluted water may be too short to get affected by the sublethal effects of suspended ferric oxide flakes unlike the benthic and beach fauna which were found to be severely affected in the effluent spreading area (Menon, Madhupratap, Haridas, Vanugopal and Rao, 1979). Field and laboratory studies on acid-iron wastes from New York Bight (Grice Weibe and Hoagland, 1973; Weibe, Grice and Hoagland, 1973) had shown it to be only a minor factor affecting zooplankton abundance and distribution and mortality occurred only in pH less than 6.5. Qualitative analysis also failed to show any indicator species associated with polluted water in the present study.

Table I. Results of analysis of variance.

Source	ss.	df.	ms.	F.
<i>1. Biomass</i>				
Total	0.2677	53		
Stations	0.0240	2	0.0120	2.79 (N.S.)
Areas	0.0116	1	0.0116	2.70 (N.S.)
Months	0.0534	8	0.0067	1.56 (N.S.)
Error	0.1787	42	0.0043	
<i>2. Total Number</i>				
Total	84.4561	53		
Stations	1.9738	2	0.9869	<1 (N.S.)
Months	20.6586	8	2.5823	1.91 (N.S.)
Areas	5.1239	1	5.1239	3.80 (N.S.)
Error	56.6998	42	1.3500	
<i>3. Species</i>				
Total	48.7402	87		
Stations	1.9684	3	0.6561	<1 (N.S.)
Species	29.2646	10	2.9265	2.46 (N.S.)
Areas	0.8598	1	0.8598	<1 (N.S.)
Error	16.6474	14	1.1891	

N. S.=Not significant at 5 % level.

Analysis of variance also did not show any significant variation in zooplankton abundance (quantitative as well as qualitative) between stations probably owing to their proximity. Hence the values for all the stations in each month were pooled together and averages were taken for presenting the annual cycle.

The mean biomass ranged between 0.07 ml/m<sup>3</sup> obtained in November and July and 0.74 ml/m<sup>3</sup> in August. The latter was caused by a swarm of cladocerans and high numbers of copepods especially belonging to the genera *Temora* and *Acrocalanus* resulting in high numbers of zooplankton (7078/m<sup>3</sup>). Otherwise the total numbers of zooplankton ranged between 98 in November to 1091/m<sup>3</sup> in April with an average of 1203/m<sup>3</sup> (Table II). Annual average of biomass (0.18 ml/m<sup>3</sup>) is comparable to the average biomass value of 0.17 ml/m<sup>3</sup> obtained for the coastal station off Cochin in 1972 (Stephen, 1977) although her data showed an increase in biomass towards offshore. Nair (1978) has reported an average biomass value of 0.04 ml/m<sup>3</sup> from the Binge Bay, Karwar.

Copepods formed the major zooplankton component constituting 59.4% of the annual counts (Minimum-76/m<sup>3</sup> in December 1976, Maximum 3574/m<sup>3</sup> in August 1977, annual mean-714/m<sup>3</sup>). 42 species were identified in the present study. 34 of them belonging to 17 genera of the suborder calanoida contributed to the main bulk of copepoda. 2 genera of harpacticoids each represented by a species and 6 species of cyclopoides from 4 genera formed the rest. Copepods dominated throughout the year except in August and December 1977 when a swarm of cladocerans and siphonophores dwarfed their dominance.

8 species, viz., *Temora turbinata* (35.2%), *Acrocalanus monachus* (14.8%), *Acartia erythraea* (12.5%), *Undinula vulgaris* (6.6%), *Canthocalanus pauper* (6.5%),

*Paracalanus parvus* (4.1%), *Acrocalanus similis* (4%) and *Corycaeus speciosus* (2.5%) constituted about 86% of the total copepods.

About 50% of the copepod species occurred only sporadically. *Acrocalanus monachus*, *Paracalanus parvus*, *Eucalanus monachus*, *Pseudodiaptomus serriicaudatus* and *Corycaeus speciosus* occurred almost throughout although some of them were represented in small numbers (Fig. 2a, b, c). Some other common species like *Temora stylifera*, *Calanopia elliptica*, *Pontellina plumata*, *Undinula vulgaris* and *Acartia erythraea* were absent during the monsoon collections (July–August).

Among Acartiidae, *Acartia centrura*, *A. spinicauda*, *A. southwelli* and *A. pacifica* are known to be common high saline estuarine forms (Madhupratap and Haridas, 1975) and occurred in the coastal waters off Trivandrum during the monsoon period. This was probably because the salinity in the estuarine habitat became too low due to monsoonal inundation for survival resulting in shifting their population to the coastal waters. *A. spinicauda* was observed in the collections in April also. Salinity in the coastal waters off Trivandrum did not show extreme variations during the period of present investigation and ranged between 33.1 and 34.7‰. *Acartia erythraea* which is a neritic form was common in the samples whereas the oceanic species *A. negligens* was observed in only one collection in April.

A sudden peak in copepod numbers observed in August was

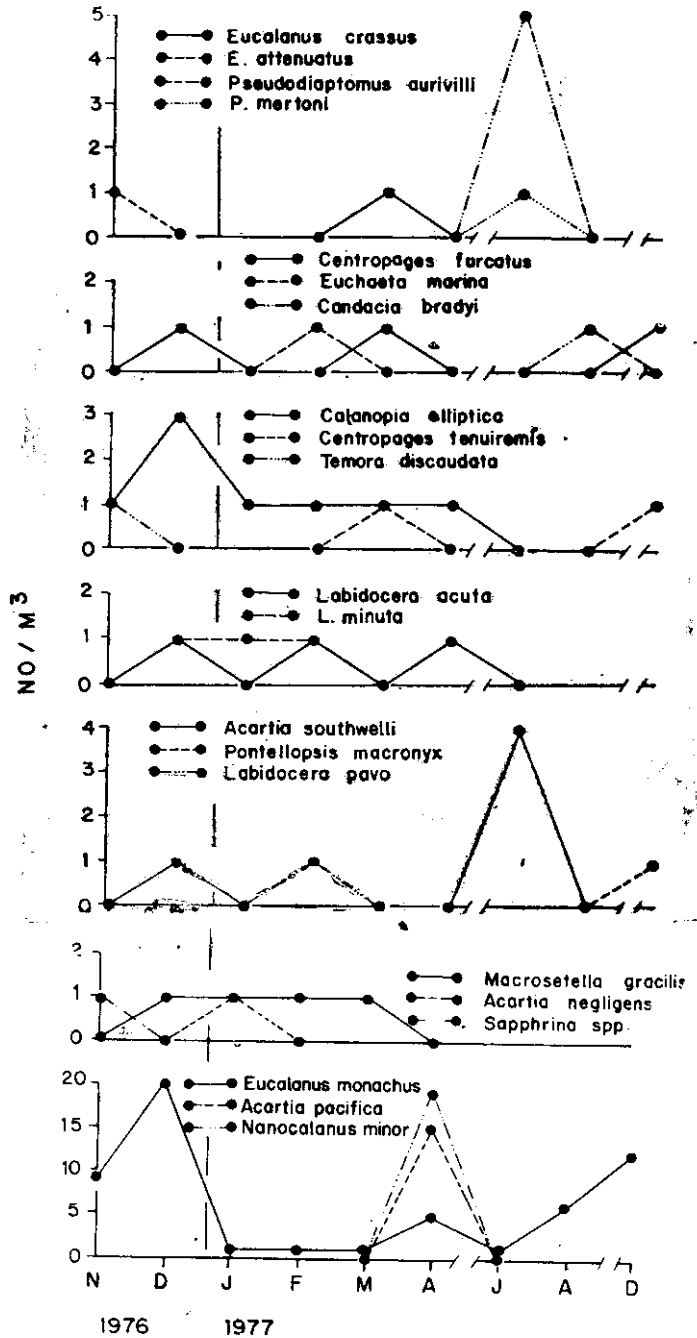


Fig. 2a.

Fig. 2 a, b, c. Monthly distribution of species of copepods off Trivandrum coast (1976–77).

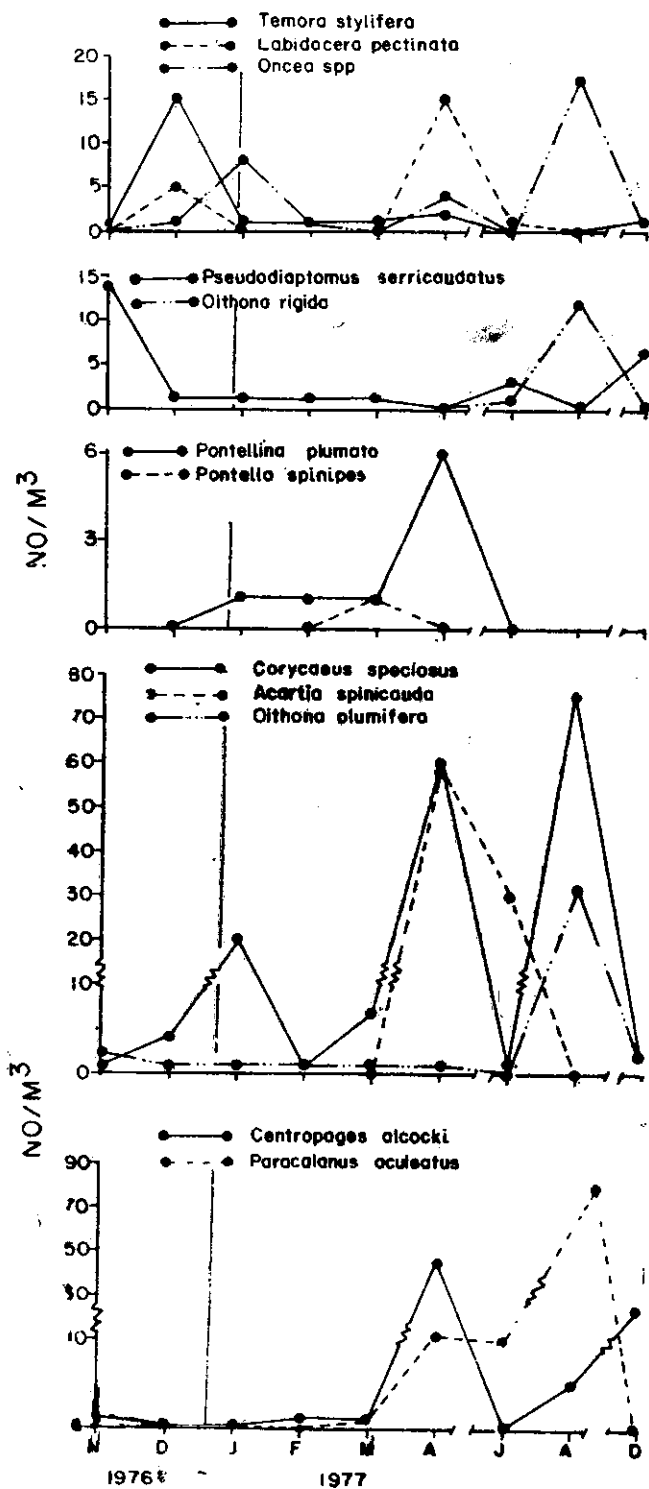


Fig. 2b.

due to the swarming of two species, viz., *Temora turbinata* and *Acrocalanus monachus*. Such sudden swarming of *T. turbinata* in the shelf waters off Trivandrum and Cochin during the upwelling period (August–September) had been reported (Menon, 1945; Stephen, 1977).

Cladocera formed the next most abundant group in the annual counts represented by two species *Penilia avirostris* and *Evadne tergestina*. They kept a low profile during most part of the year ( $<3/m^3$ ) but swarmed into abundance in August (Fig. 2). The reason for such sudden swarming of cladoceran is attributed to their capacity to proliferate by parthogenesis (Della Croce and Venugopal, 1972; Onbe, 1977). The importance of cladoceran swarms following upwelling and phytoplankton maxima in the mackerel fisheries of the coastal waters had been emphasized (Selvakumar, 1970).

*Sagitta enflata* which has a wide distribution (Indo-Pacific and Atlantic) was the abundant chaetognath (Fig. 3). The two neritic forms *S. neglecta* and *S. bedoti* were also common. The oceanic species *S. regularis* and *Pterosagitta draco* did not occur during the monsoon period.

Ctenophores (Fig. 4) were represented by *Pleurobrachia* sp. and *Beroe* sp. Siphonophores occurred in large numbers in December 1977 mainly constituted by *Lensia subteloidea*, *L. subtelis*, *Diphyes chamissonis* and *Agalma* sp. Other species observed in

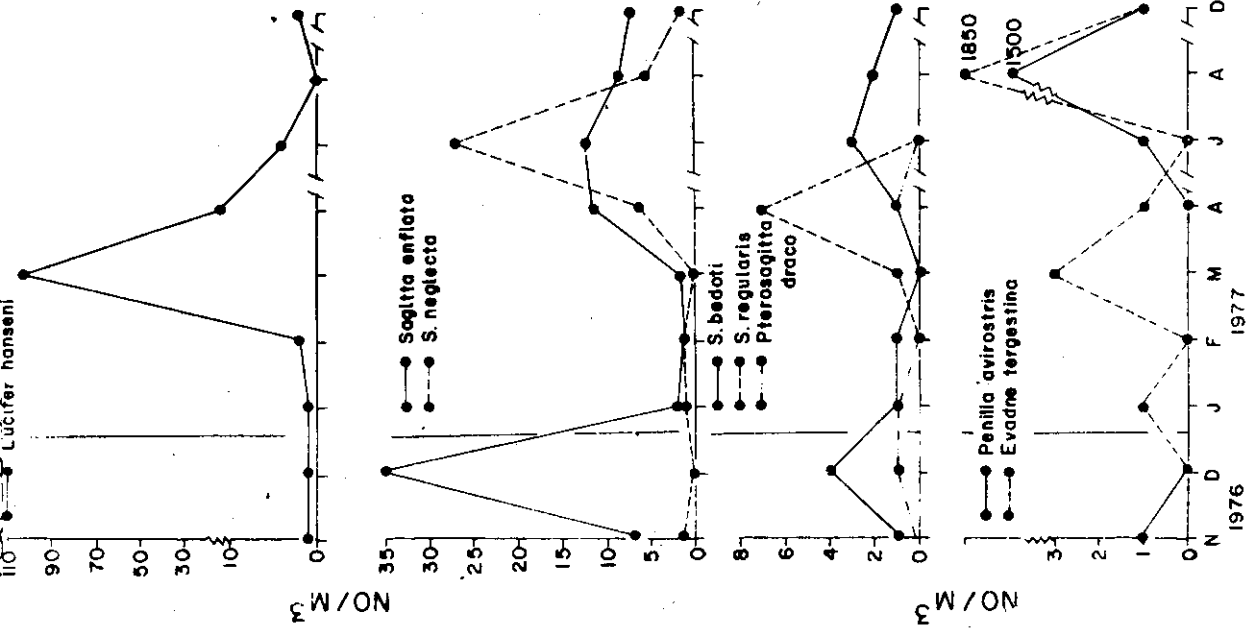


Fig. 3. Monthly distribution of species of Sergestidae, Chaetognaths and Cladocera, at Irivandrum coast (1976-77).

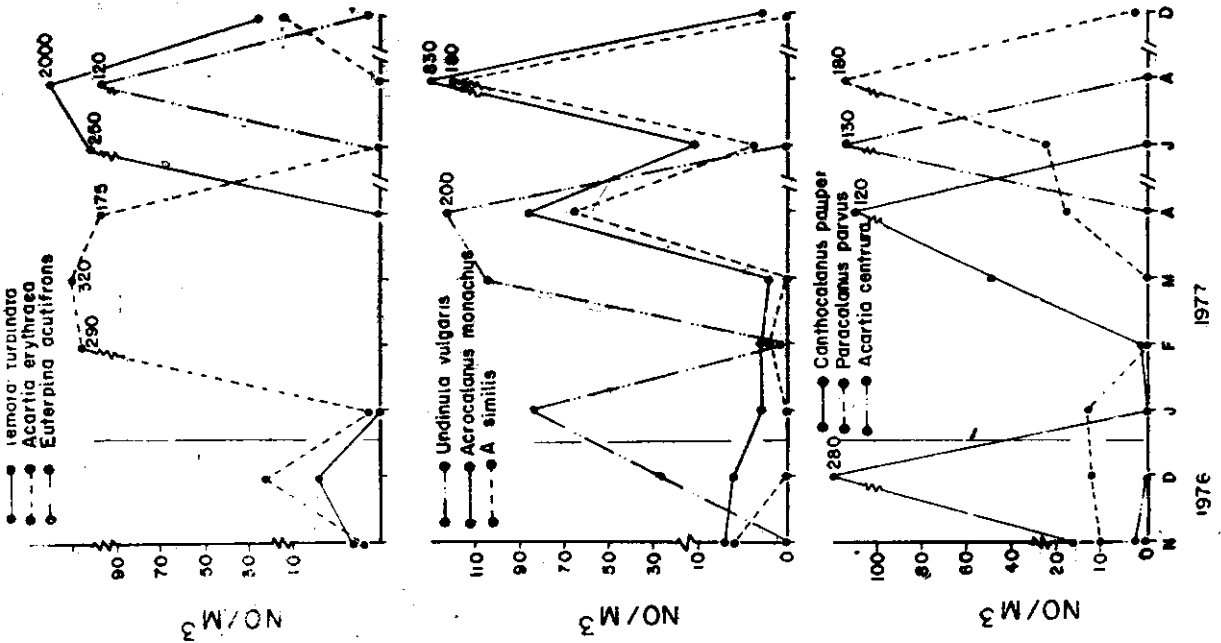


Fig. 2 c.

Table II. Biomass, total numbers and percentage composition of major groups of zooplankton (1976-77).

Month	Biomass ml/m <sup>3</sup>	Total number /m <sup>3</sup>	Hydro-medusae %	Siphonophora %	Chaetognatha %	Decapod larvae %	Sergestidae %	Copepoda %	Cladocera %	Mollusca %	Invertebrate eggs %	Fish eggs %	Appendicularia %
Nov.	.07	98	1	3	7.1	1	1	77.6	1	2	—	1	1
Dec.	.15	538	.4	.4	7.6	.5	.2	76.4	—	1.9	2.2	1.3	7.4
Jan.	.03	176	.5	1	2.8	.5	.5	79	.5	1	5.7	.5	3.4
Feb.	.03	326	.3	—	.6	.3	.6	94.8	—	.9	.3	.3	.3
Mar.	.10	689	.1	.1	.1	.7	14.8	69.7	.5	6	6.7	.3	1.3
Apr.	.28	1091	.1	.1	2.3	.2	1.3	82.2	.5	.4	1.2	.3	5.7
Jul.	.07	535	.2	.2	8.0	.6	.7	89	.2	.2	—	.2	—
Aug.	.74	7078	.2	.1	.2	—	—	50.1	47.3	—	—	.2	1.5
Dec.	.15	297	.7	56.5	3.0	2.3	.7	32.7	.3	1	—	1.7	.7
Mean	.18	1203	.4	6.8	3.5	.7	2.2	72.4	5.6	1.5	1.8	.6	2.4
% to Annual Total			.2	1.7	1.4	.2	1.1	59.4	.1	.6	.8	.3	2.1

— Absent.

Table III. Species diversity of total zooplankton and copepoda in coastal waters of Trivandrum (1976-77).

Months	No. of species (S) Total zooplankton	$\alpha^a$	D <sup>b</sup>	H <sup>c</sup>	E <sup>d</sup>	No. of species (S) Copepoda	$\alpha^a$	D <sup>b</sup>	H <sup>c</sup>	E <sup>d</sup>
November	36	20.98	7.64	3.05	.57	16	6.11	3.46	2.29	.59
December	45	11.60	6.99	2.03	.15	19	4.18	2.99	1.36	.17
January	37	14.15	6.96	2.18	.22	15	4.23	2.84	1.40	.22
February	35	7.89	5.87	0.77	.03	19	4.48	3.15	0.44	.03
March	33	7.22	4.89	1.79	.16	18	3.76	2.75	1.10	.10
April	40	8.30	5.48	2.69	.35	19	3.45	2.92	2.22	.46
July	30	6.89	4.62	1.92	.20	16	3.22	2.21	1.54	.26
August	28	3.74	3.05	1.85	.20	13	1.68	1.47	1.36	.24
December	45	14.72	7.73	2.64	.30	18	6.51	3.72	2.18	.46

$a-S = \text{Log}_e \alpha(1+N/x)$ , where S is number of species and N is the number of individuals.  $b-D = (S-1)/\log_e N$ , where S is the number of species and N is the number of individuals.

$c-H' = \sum_{i=1}^s p_i \log_e p_i$ , where  $p_i$  is the proportion of the individuals in the  $i$ th species.

$d-E = (e^{H'} - 1)/(S - 1)$ , where S is the number of species.

the study were *Diphyes bojani*, *Enneagonum hyalinum*, *Chelophys contorta*, *Eudoxid mitra* and *Bassia bassensis*. The sergestid *Lucifer hanseni*, pteropod *Creseis acicula*, salp *Thalia democratica*, doliolid *Dolioletta gegenbauri* and appendicularians belonging to the genera *Oikopleura* and *Frittilaria* also occurred in the collections.

A variety of invertebrate larvae were represented in the collections, viz., echinopluteus and ophiopluteus of Echinodermata, cyphonautes of Bryozoa, lingula of Brachiopoda, alima of Stomatopoda and polychaete larvae. Among decapod larvae penaeid, crangonid, processid, alpheid, paleomonid, hippolitid and phyllosoma larvae of *Macrura*, zoea and megalopa of *Brachyura* and albumid zoea and pagurid larvae

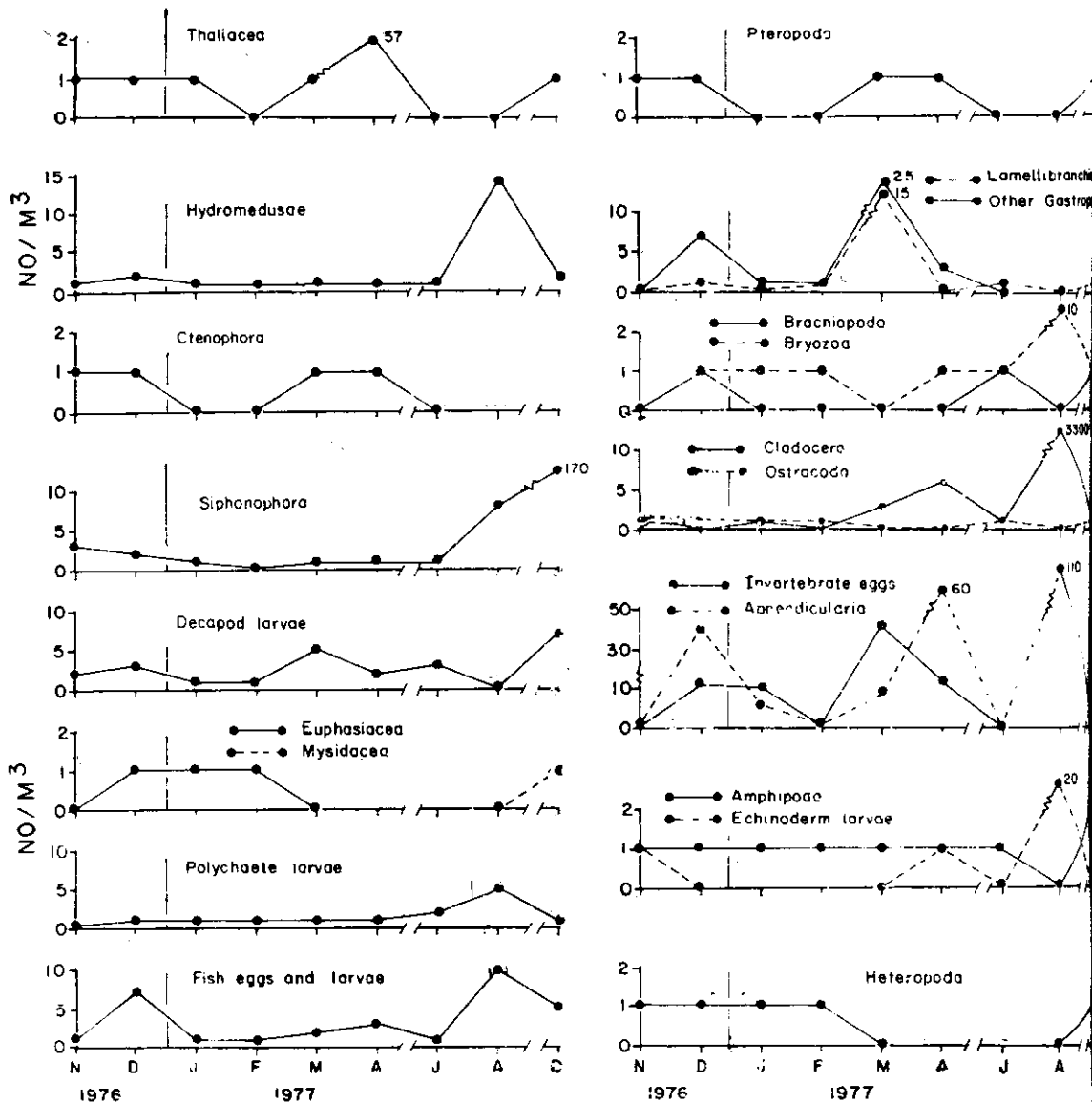


Fig. 4. Monthly distribution of groups of zooplankton off Trivandrum coast (1976-77).



of Anomura were recorded. Hydromedusae, Tanaidacea, Isopoda, Lamellibranchiata, Heteropoda, Ostracoda, Amphipoda and invertebrate eggs were other groups represented. Fish eggs and larvae occurred throughout with peaks in August and December.

Diversity indices ( $\alpha$  and D) were generally high in the postmonsoon and early premonsoon months (Table III). The lower values obtained in April albeit the number of species remaining high was due to the inherent drawback of these indices being density dependent. The month of August showed minimum value when maximum density and minimum number of species were recorded. Highest equitability in species distribution (from  $H'$  and E) were obtained in November 1976 and April and December 1977. The very low evenness obtained in February was due to the dominance of a single species, viz., *Acartia erythraea* (288 in 326/m<sup>3</sup>) in the samples. In general, the diversity indices are higher compared to the estuarine waters (Pillai, Qasim and Nair, 1973; Madhupratap, Haridas, Rao and Iyer, 1975). Nevertheless, they were found to be lower in comparison (Madhupratap, unpublished) to the zooplankton diversity in shelf slope and oceanic regions.

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#### REFERENCES

- Della Croce, N. and P. Venugopal, 1972. Distribution of marine cladocerans in the Indian Ocean. *Marine Biology*, **15**: 132-138.
- Fisher, R. A., A. S. Corbet and C. B. Williams, 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology*, **12**: 42-58.
- Grice, G. D., P. H. Weibe and E. Hoagland, 1973. Acid-iron waste as a factor affecting the distribution and abundance of zooplankton in the New York Bight: I. Laboratory studies on the effects of acid wastes on copepods. *Estuarine and Coastal Marine Science*, **1**: 45-50.
- Heip, C., 1974. A new index measuring evenness. *Journal of the Marine Biological Association of the United Kingdom*, **54**: 555-557.
- Margalef, R., 1968. *Perspectives in Ecological Theory*. The University of Chicago Press, 111 pp.
- Madhupratap, M. and P. Haridas, 1975. Composition and variations in the abundance of zooplankton of backwaters from Cochin to Alleppey. *Indian Journal of Marine Sciences*, **4**: 77-85.
- Madhupratap, M., P. Haridas, T. S. S. Rao and H. Krishna Iyer, 1976. Species associations of calanoid copepods in an estuary. *Indian Journal of Marine Sciences*, **4**: 177-180.
- Menon, M. A. S., 1945. Observations on the seasonal distribution of plankton of the Trivandrum coast. *Proceedings of the Indian Academy of Sciences*, **22**: 31-62.
- Menon, P. G., M. Madhupratap, P. Haridas, P. Venugopal and T. S. S. Rao, 1979. Faunal composition in polluted nearshore environment. *Indian Journal of Marine Sciences*, **8**: 146-149.
- Nair, V. R., 1978. Zooplankton from the nearshore waters of Karwar. *Indian Journal of Marine Sciences*, **7**: 283-287.

- Onbe, T., 1977. The biology of marine cladocerans in a warm temperate water. In: *Proceedings of the Symposium on Warm Water Zooplankton*, Special Publication, NIO/UNESCO, 383-398.
- Pillai, P. P., S. Z. Qasim and A. K. K. Nair, 1973. Copepod component of zooplankton in a tropical estuary. *Indian Journal of Marine Sciences*, 2: 38-46.
- Selvakumar, R. A., 1970. Cladoceran swarm in relation to mackerel fishery along the west coast of India. *Current Science*, 39: 481-482.
- Shannon, C. E. and W. Weiner, 1963. In: *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, 117 pp.
- Stephen, R., 1977. Calaniod copepods from the shelf and slope waters off Cochin: distribution, biomass and species diversity. In: *Proceedings of the Symposium on Warm Water Zooplankton*, Special Publication, NIO/UNESCO, 21-27.
- Weibe, P. H., G. D. Grice, and E. Hoagland, 1973. Acid-iron waste as a factor affecting the distribution and abundance of zooplankton in the New York Bight: II. Spatial variations in the field and implications for monitoring studies. *Estuarine and Coastal Marine Science*, 1: 51-64.