

Zooplankton composition and diversity in western Bay of Bengal

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Abstract. The biomass of zooplankton ranged from 1–90 ml/100 m³ in the western Bay of Bengal from off Sri Lanka to south of Calcutta in June 1978. The coastal belt between Madras and Visakhapatnam where upwelling is known to occur during the season showed higher standing stock. Copepoda formed the dominant group followed by Decapoda and Chaetognatha. Species composition of various groups and their distribution is discussed. A general inverse relationship between biomass and species diversity was the trend. Diversity was higher in the oceanic realm.

Introduction

The study of zooplankton in the Indian Ocean received considerable impetus during the International Indian Ocean Expedition (1960-65). Many aspects of its results regarding the distribution and zoogeography of most of the groups and species of zooplankton have been published (UNESCO collected reprints 1-8, 1965-72; IOBC Atlases and Handbooks 1-5, 1968-73; Zeitschell, 1973) and reviewed (Panikkar and Rao, 1973). Several follow-up studies have been conducted to augment the information as zooplankton production and distribution have an important bearing on the biological resources of the sea (NIO, 1977; Qasim, 1977; Nair *et al.*, 1977, 1978; Peter and Nair, 1978). In this communication, a comprehensive picture of the distribution of common groups and species of zooplankton along the east coast of India is attempted.

Material and methods

Zooplankton samples were collected during the 35th and 36th cruises of *R. V. Gaveshani* in the month of June 1978 along 22 stations in the western Bay of Bengal (Figure 1). Samples were collected in vertical hauls from 200 m to the surface using the Indian Ocean Standard Net (Currie, 1963, mesh size 0.3 mm). Biomass was estimated as displacement volume and dry weights were estimated using a conversion factor of .075 g dry weight/ml displacement volume (Madhupratap, unpublished data). All groups of zooplankton were sorted out and identified from aliquots up to species level as far as possible. For comparison purposes, the area investigated has been divided into three zones viz. Zone 1 - off Sri Lanka to Madras (Stations 910-918), Zone 2 - Madras to Visakhapatnam (Stations 919-929) and Zone 3 - Visakhapatnam to south of Calcutta (Stations 930-938). Stations in the first zone were located in the oceanic waters whereas collections were made in coastal area in the other two zones.

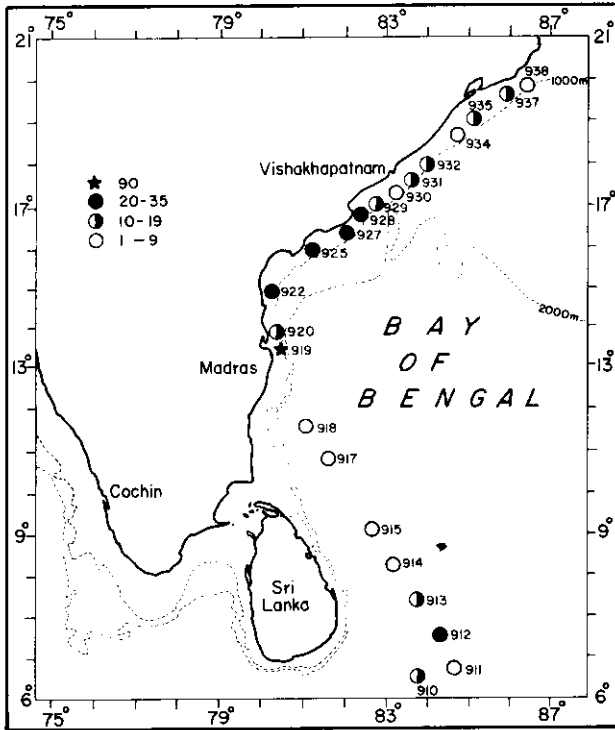


Fig. 1. Station positions and zooplankton biomass.

Hydrography

The present study was conducted during the early part of the southwest monsoon. The seasonal changes in the direction of the monsoon winds dominate the circulation pattern of the northern Indian Ocean. With the onset of southwest monsoon (May-September), an easterly drift current is developed north of the equator and the coastal circulation becomes clockwise (Wyrtki, 1973a). The salinity values showed a progressive diminution from south to north (Table I) probably due to the greater riverine discharge towards the head of the Bay. It varied from 33.39‰ to 35.33‰ in the upper 200 m of the water column in the first zone, 32.82‰ and 34.98‰ in the second zone and 31.61‰ and 35.16‰ in the third zone. A reverse trend was observed in the case of temperature (Table I). Temperature of the upper 200 m water column ranged from 11.98°C to 29.95°C in the first zone, 12.96°C to 34.24°C in the second zone and 10.73°C to 30.67°C in the third zone.

Zooplankton biomass and population

Biomass values ranged between 1–90 ml/100 m³ (Table 1, Figure 1). In general, the area between Madras and Vishakhapatnam showed higher biomass (average 33.2 ml, 2.39 g/100 m³) followed by the third zone (average 10.2 ml,

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Table I. Biomass, temperature, salinity and diversity indices in the difference stations.

Stations	Biomass (ml/100 m ³)	Temperature range (200 0m) °C	Salinity range (200-0m) ‰	D	α	H'	E
910	20	20.64 – 28.73	33.48 – 35.33	10.60	26.18	3.25	0.43
911	5	16.30 – 28.60	33.73 – 35.12	9.11	72.10	3.39	0.82
912	20.5	13.09 – 28.84	33.81 – 34.85	10.49	23.95	2.90	0.29
913	11	12.78 – 29.19	33.42 – 35.06	10.47	23.08	3.49	0.53
914	4.5	12.55 – 29.45	33.48 – 35.10	10.10	60.75	3.57	0.72
915	4.5	11.98 – 29.61	33.47 – 35.15	10.02	29.77	3.44	0.62
917	5	14.97 – 29.95	33.39 – 34.94	8.32	19.56	3.21	0.57
918	1	14.74 – 29.63	33.40 – 34.89	12.94	104.90	3.77	0.76
919	90	18.65 – 28.05	33.40 – 34.98	9.15	15.03	2.49	0.17
920	19	13.86 – 28.26	33.42 – 34.24	11.64	24.04	3.09	0.30
922	22.5	18.93 – 28.83	- - -	9.21	19.66	3.31	0.53
925	35	15.11 – 28.66	- - -	8.19	15.08	3.11	0.44
927	31	23.76 – 28.68	33.65 – 34.32	8.82	13.95	2.49	0.19
928	25	12.96 – 28.99	33.57 – 34.77	7.71	11.83	2.83	0.28
929	10	20.39 – 29.68	32.82 – 34.75	10.43	24.13	3.50	0.55
930	5	17.72 – 29.99	32.83 – 34.89	9.45	21.33	3.22	0.47
931	10	14.97 – 30.26	33.12 – 35.01	10.40	37.81	3.49	0.66
932	14	10.73 – 30.22	33.06 – 35.16	11.25	26.72	3.27	0.41
934	8.5	17.13 – 30.15	31.81 – 34.90	11.27	41.75	3.63	0.69
935	15	26.41 – 30.67	32.38 – 34.07	9.59	24.30	3.02	0.40
937	11	16.68 – 30.14	32.36 – 34.87	10.95	24.84	3.33	0.43
938	8	18.17 – 30.61	31.61 – 34.49	9.71	24.36	3.18	0.46

$S = \alpha \log_e (1 + N/\alpha)$, where S is the number of species and N is the number of individuals of all species.

$D = S-1/\log_e N$, where S is the number of species and N is the number of individuals of all species.

$H' = -\sum \pi \log \pi$, where π is the proportion of individuals in the i^{th} species.

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

0.77 g/100 m³). A maximum value of 90 ml/100 m³ was recorded at station 919 located north of Madras. The large aggregation of the sergestid shrimp *Lucifer* (27,350/100 m³) constituted the bulk of the biomass at this station. In 5 of the 7 stations covered in the second zone, biomass was more than 20 ml/100 m³. In zone 1, the average biomass was 8.9 ml (0.67 g dry weight)/100 m³.

The highest number of zooplankton counts was obtained at station 928 (142,698/100 m³) followed by station 927 (141,217/100 m³) and station 919 (135,265/100 m³). The presence of a large number of copepods, decapods and chaetognaths contributed to the high biomass at these stations. Relatively lower counts were obtained at zone 1 (Table II). Copepods were the dominant group at all the stations forming 49 to 90% of the total number of zooplankton. Chaetognaths and ostracods were the other groups present at all stations.

Distribution and species composition

Copepoda

Copepods dominated the zooplankton contributing an average of 80% of the

total counts (Table II). They contributed 83% of the total zooplankton counts in the first zone and 79.5% each in the other two zones. Of the total Copepoda, 70.2% occurred in the middle zone followed by 15.1% in the third zone and 14.7% in the first zone. Thus, this group showed the same trend of distribution as that of biomass as is evident from the distribution of the common species of copepods (Figure 2A-D). 40 species belonging to 31 genera (Calanoida -23; Harpacticoida - 3; Cyclopoida - 5) were identified in the present collections. Ten species were identified viz. *Acrocalanus similis* (18.8%), *Paracalanus parvus* (16.8%), *Eucalanus monachus* (9.7%), *Canthocalanus pauper* (5.8%), *Eucalanus crassus* (4.5%), *Euchaeta marina* (4.4%), *Temora turbinata* (3.1%), *Eucalanus subcrassus* (2.6%), *Unidnula vulgaris* (2.2%) and *Paracalanus aculeatus* (2.1%) which are common epipelagic species and formed 70% of the copepod counts.

Some of the species such as *Euchaeta tenuis*, *Aetideus giesbrechti*, *Pleuromamma indica*, *Acartia negligens*, *Scolecithrix danae*, *Scolecithricella ctenopus*, *Rhincalanus cornutus* and *Euchirella* sp. were confined to the first zone where the sampling was mostly from oceanic waters. The species that were restricted to the coastal stations were *Acartia erythraea*, *Torstranus forcipatus*, *Pontellina plumata*, *Labidocera acuta*, *Calanopia minor*, *Centropages furcatus* and *Macrosetella gracilis*. Species like *Calanus tenuicornis*, *Eucalanus attenuatus*, *Undinula darwini*, *Centropages calaninus*, *Labidocera minuta*, *L. pectinata*, *Pontella* sp., *Acartia danae*, *Miracia efferata*, *Microsetella norvegica*, *Copilia* sp. and *Sapphirina* sp. occurred sporadically in small numbers.

Table II. Zonal averages of groups of zooplankton (no./100 m³)

Groups	Zone I (St. 910-918)	Zone II (St. 919-929)	Zone III (St. 930-938)
Hydromedusae	22	164	19
Siphonophora	63	63	50
Ctenophora	--	8	8
Polychaeta	126	689	108
Chaetognatha	983	3212	790
Copepoda	11115	53206	11429
Ostracoda	270	1482	744
Euphausiacea	134	400	19
Cladocera	83	217	169
Mysidacea	25	55	22
Amphipoda	49	127	50
Decapoda	126	5386	499
Pteropoda	3	183	80
Heteropoda	3	5	21
Lamellibranchiata	6	3	46
Thaliacea	135	310	134
Appendicularia	249	1125	119
Fish eggs	9	36	2
Fish larvae	35	200	64

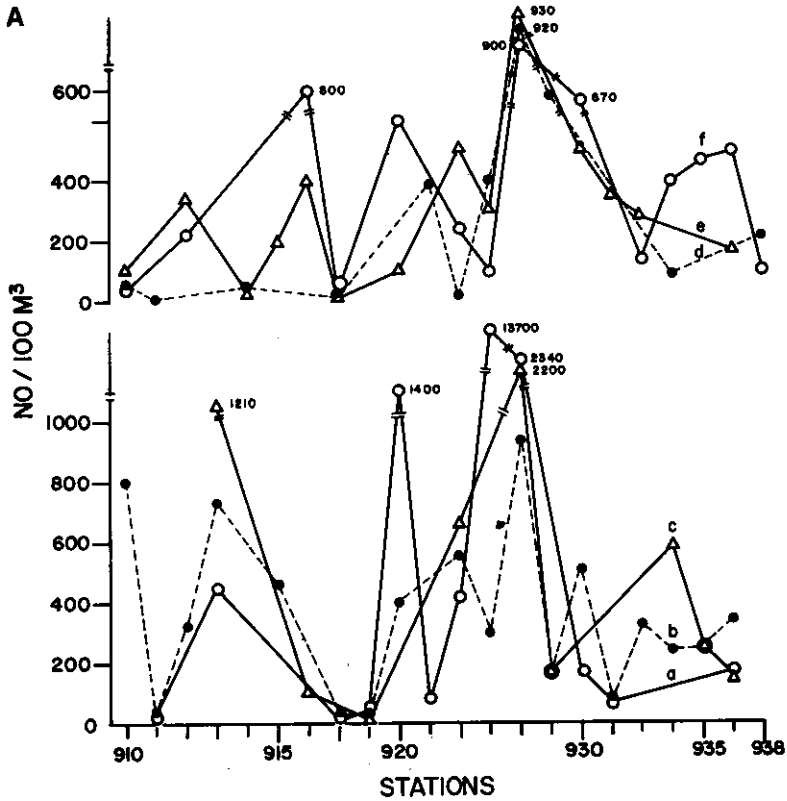


Fig. 2. Numerical abundance of common species of copepods A. (a) *Temora turbinata* (b) *T. discaudata* (c) *T. stylifera* (d) *Candacia discaudata* (e) *Lucicutia* sp. (f) *Candacia* spp.

Chaetognatha

Chaetognaths were fairly abundant at all the stations and formed an average of 5.3% of the total number of zooplankton. In general, the area between Madras and Visakhapatnam sustained a higher density of this group. 12 species of chaetognaths belonging to three genera - *Krohnitta*, *Pterosagitta* and *Sagitta* - were present in the samples (Figure 3A and B). *Sagitta enflata* was the most abundant species occurring at all the stations. Other common species were *S. neglecta*, *S. bipunctata*, *S. pacifica*, *S. bedoti* and *Pterosagitta draco*. *Krohnitta pacifica*, *S. ferox*, *S. regularis* and *S. robusta* were moderately present in the collections. *K. subtilis* and *S. hexaptera*, though considered to be epipelagic (Alvarino, 1965) are rarely found in the epipelagic realm of the Indian Ocean (Nair, 1977). In the present collection, their incidence was limited to stations 912 to 915.

Ostracoda

Ostracods were present at all the stations and like other dominant groups, were more abundant in the area between Madras and Visakhapatnam. Nine species of

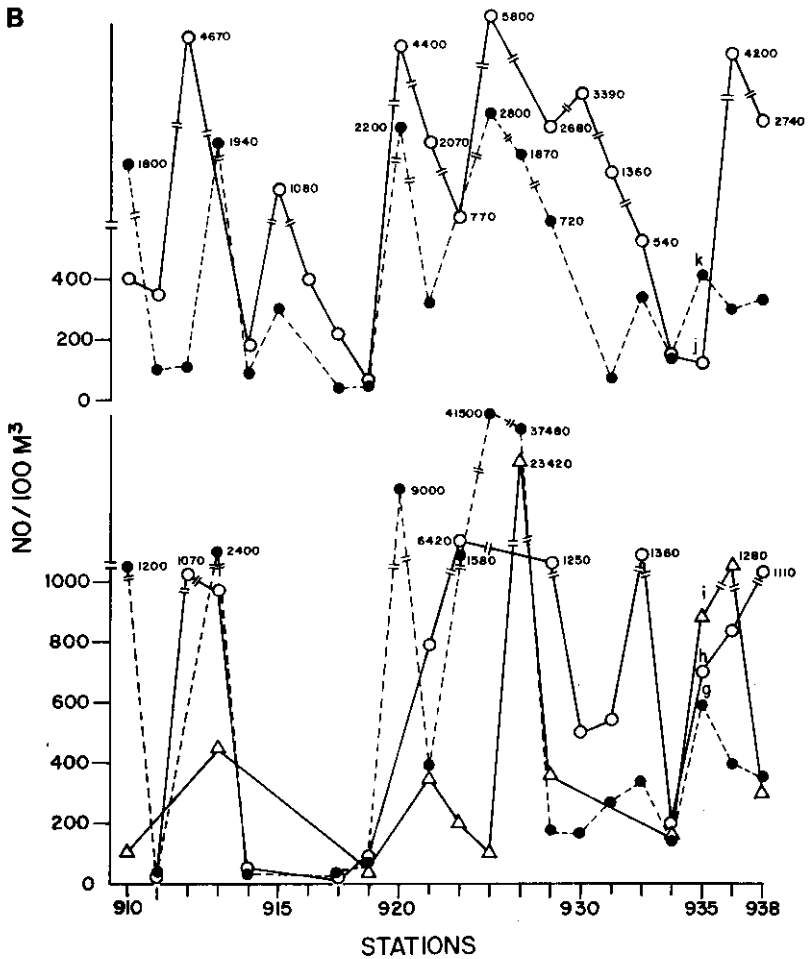


Fig. 2(cont.) B. (g) *Eucalanus monachus* (h) *E. subcrassus* (i) *E. crassus*. (j) *Canthocalanus pauper* (k) *Undinula vulgaris*

ostracods belonging to eight genera were recorded. *Euconchoecia aculeata* was the dominant species at most of the stations. Other common species observed were *Cypridina dentata*, *Metaconchoecia rotundata*, *Conchoecetta giesbrechti* and *Spinoecia porrecta*. (Figure 4). *C. dentata* has been reported to be abundant in the Arabian Sea but rare in the Bay of Bengal (George and Nair, 1980). However, in the present collections, *C. dentata* was well represented between stations 920 and 938 and at stations 929-931 they formed the dominant ostracod species. Other species of ostracods collected in small numbers from a few stations were *Orthoconchoecia atlantica*, *Paraconchoecia procera*, *P. decipiens* and *Halocypris brevisrostris*. While *C. dentata* and *E. aculeata* are reported to be found in the neritic as well as oceanic waters, all other species are strictly oceanic (George and Nair, 1980).

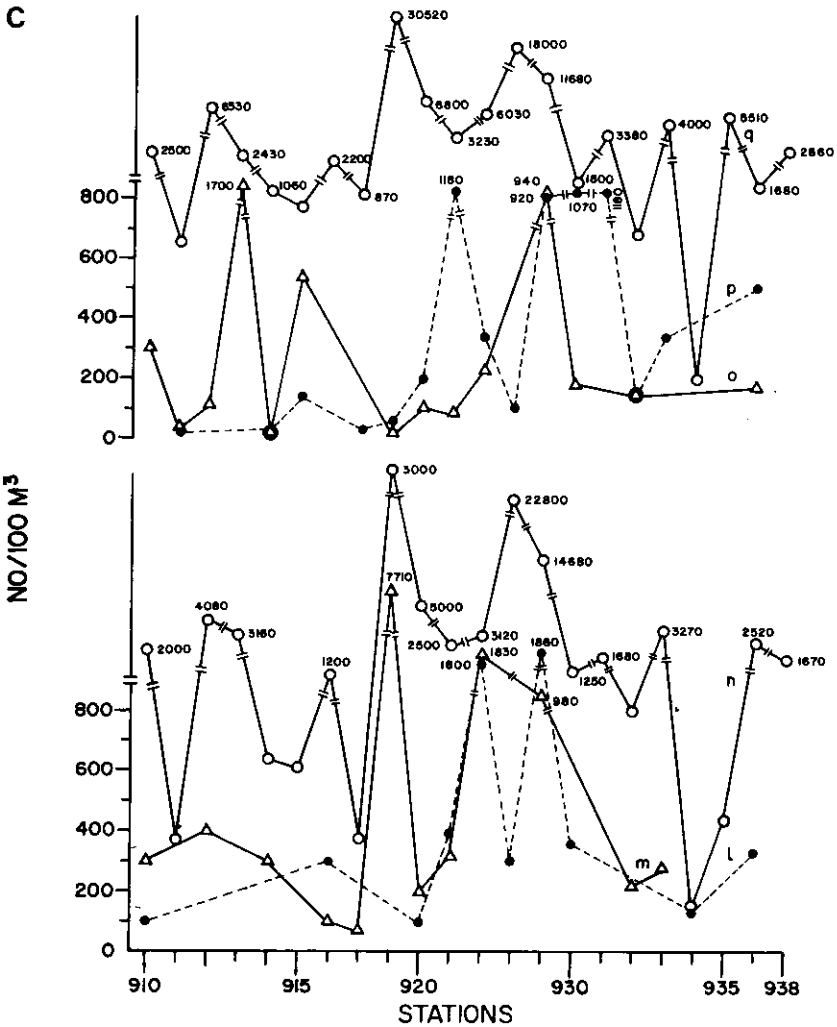


Fig. 2(cont.) C. (l) *Euchaeta wolfendeni* (m) *Paracalanus aculeatus* (n) *P. parvus* (o) *Rhincalanus nasutus* (p) *Euchaeta concinna* (q) *Acrocalanus similis*

Decapoda

Decapods and decapod larvae constituted 6.3% of the total number of zooplankton.

The distribution of the major species of decapods is given in Figure 5. Adult *Lucifer* indicated three distinct zones in their distribution. From off Sri Lanka to south of Madras, *Lucifer typus* was the only species found except at station 912 where *L. hanseni* and *L. penicillifer* were also recorded. However, larvae of *L. hanseni* were collected from many stations in this zone indicating their distribution in this region also. The area between Madras and Visakhapatnam was a zone

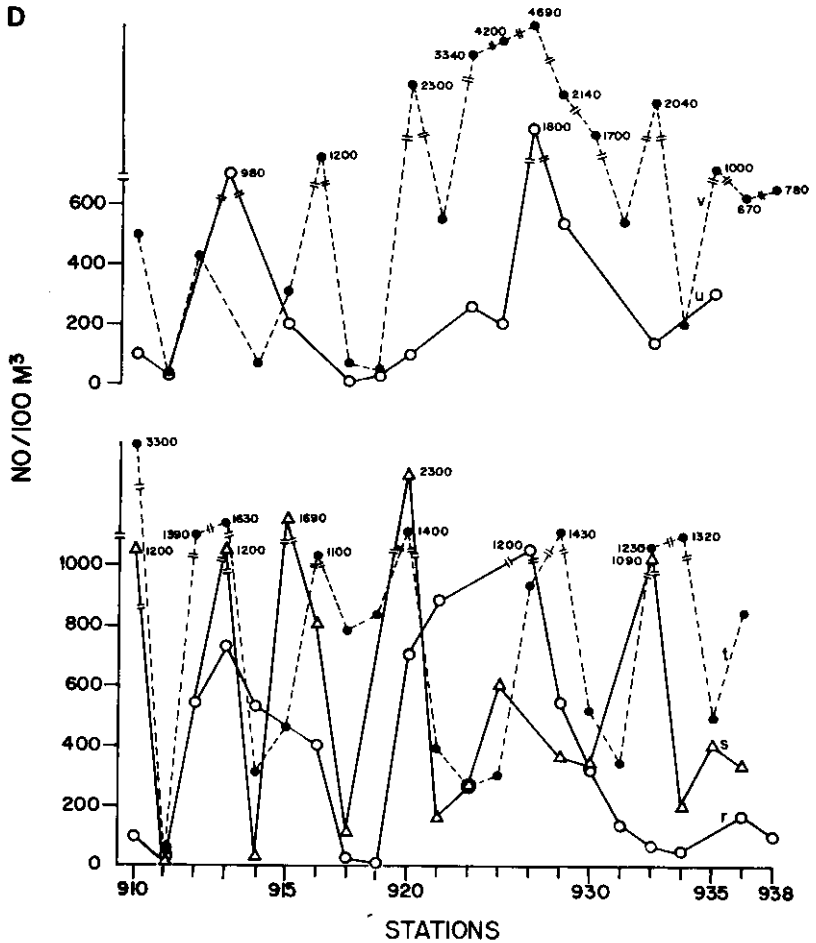


Fig. 2(cont.) D. (r) *Oithona* spp. (s) *Oncaea* spp. (t) *Corycaeus* spp. (u) *Calanopia elliptica* (v) *Euchaeta marina*.

of the *faxonii* group (Omori, 1977), where three species belonging to this group viz. *L. hanseni*, *L. faxonii* and *L. penicillifer* were abundant whereas *L. typus* was completely absent. The third zone was dominated by *L. hanseni* although *L. penicillifer* occurred at a few stations.

Penaeid larvae were not abundant. *Parapenaeus* sp. and *Penaeopsis rectacuta* were observed (Figure 5) in small numbers in the third zone whereas *Metapenaeus* sp. was distributed in the second and third zones. Brachyuran larvae were present in almost all the stations in the second and third zones sampled but were absent in the first zone. *Trachypenaeus* sp., *Leptochela* sp., *Hippolyte* spp., *Nephrops* sp., *Stenopus* sp., *Callianassa* sp., *Upogebia* sp. and *Pagurus* sp. were occasionally collected.

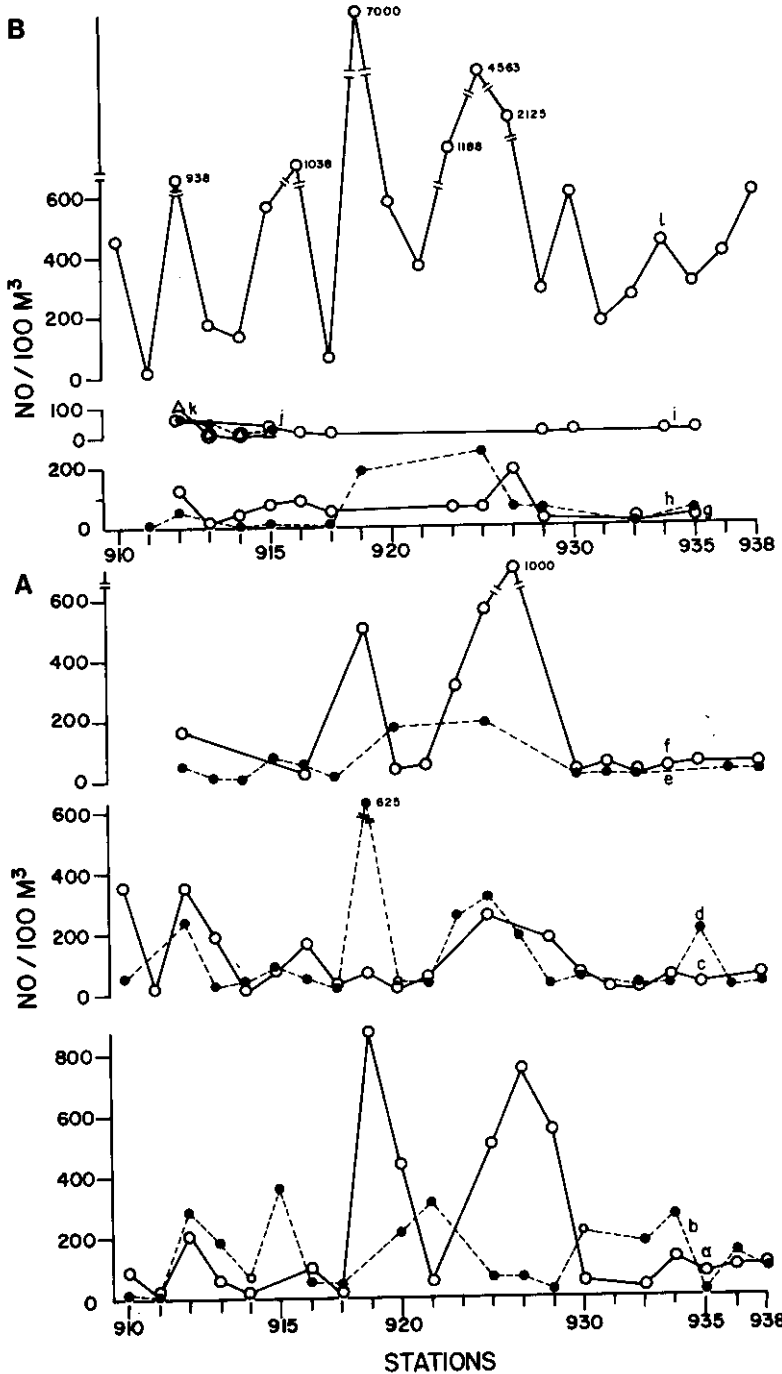


Fig. 3 Numerical abundance of species of chaetognaths A. (a) *Sagitta neglecta* (b) *S. bipunctata* (c) *S. pacifica* (d) *Pterosagitta draco* (e) *Krohnitta pacifica* (f) *S. bedoti* B. (g) *S. regularis* (h) *S. ferox* (i) *S. robusta* (j) *S. hexaptera* (k) *Krohnitta subtilis* (l) *S. enflata*.

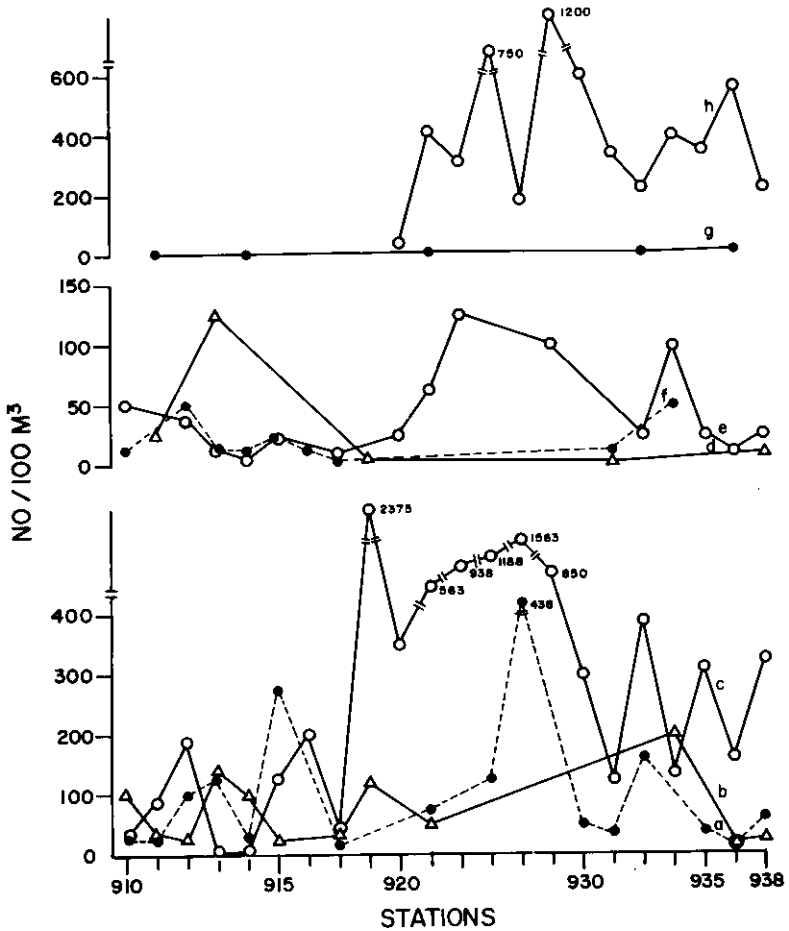


Fig. 4. Numerical abundance of common species of ostracods (a) *Metaconchoecia rotundata* (b) *Conchoecetta giesbrechti* (c) *Euconchoecia aculeata* (d) *Paraconchoecia decipiens* (e) *Spinoecia porrecta* (f) *Orthoconchoecia atlantica* (g) *P. procerca* (h) *Cypridina dentata*.

Euphausiacea

Euphausiids occurred in small numbers in most of the samples and constituted 0.5% of the total zooplankton counts. North of Visakhapatnam, they were sparsely represented. Species belonging to 4 genera were identified in the collections. Of these, *Euphausia diomediae*, *Stylocheiron carinatum*, *S. longicorne*, *S. affine* and *Stylocheiron* sp. were more abundant in the first zone (Figure 6). *Thysanopoda* sp., *Thysanopoda monacantha* and *Euphausia* spp. were relatively well represented in the second zone. Other stray euphausiids that occurred were *Stylocheiron suhmi*, *S. elongatum*, *Nematoscelis microps* and *Nematoscelis* sp.

Other groups

Hydromedusae were relatively more common in the zones 1 and 2 and there was only a single record of them from the third zone. Siphonophores were

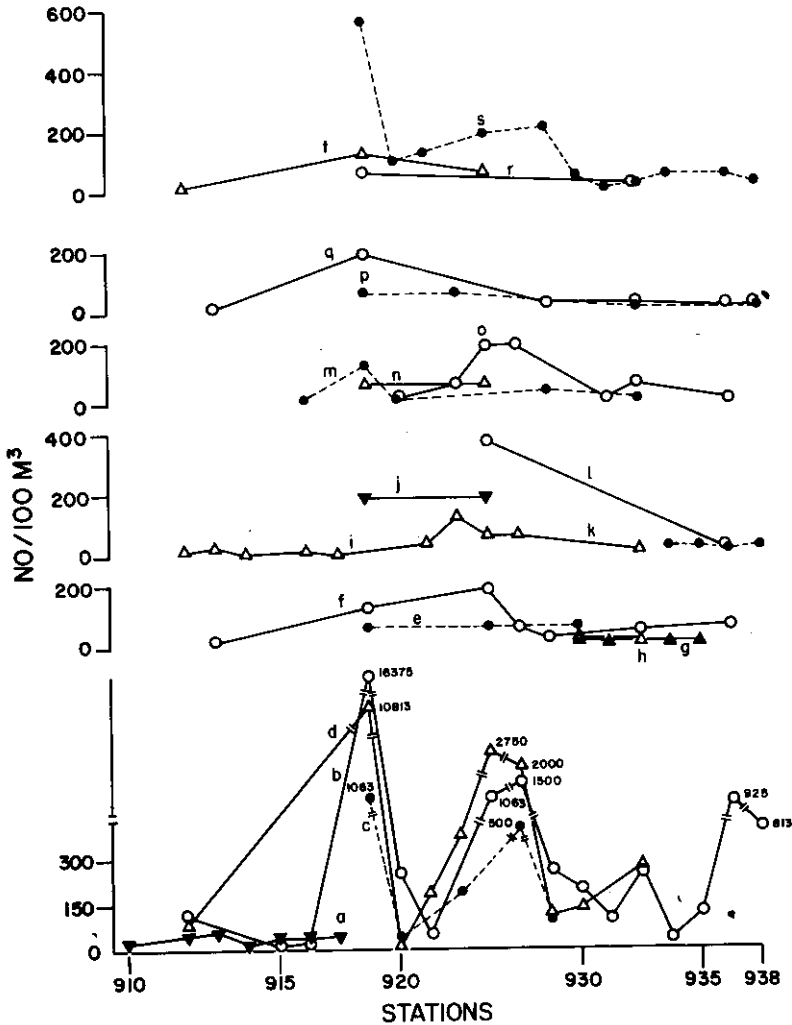


Fig. 5. Numerical abundance of common species of decapods (a) *Lucifer typus* (b) *L. hanseni* (c) *L. faxoni* (d) *L. penicillifer* (e) *Solenocera* spp. (f) *Metapenaeus* spp. (g) *Penaeopsis rectacuta* (h) *Parapenaeopsis* sp. (i) *Sergestes* sp. (j) *Acetes* sp. (k) *Acetes erythraeus* (l) *A. indicus* (m) *Athanax* sp. (n) *Leptochela aculeocaudata* (o) *Alpheus* sp. (p) *Periclimenes* sp. (q) *Leander* spp. (r) *Galathea* sp. (s) *Brachyura* larvae (t) *Eupagurus* sp.

uniformly represented in most of the stations. *Lensia subteloides*, *Diphyes chamissonis* and *Bassia bassensis* were the common species of siphonophores observed. Ctenophores *Pleurobrachia* sp. and *Beroe* sp. were recorded at a few stations.

Polychaetes were present in most of the samples and were more abundant in zone 2. *Pelagobia longicirrata* and *Lopadorhynchus* sp. were the common species present.

Cladocerans, *Evadne tergestina* and *Penilia avirostris* were present at most of

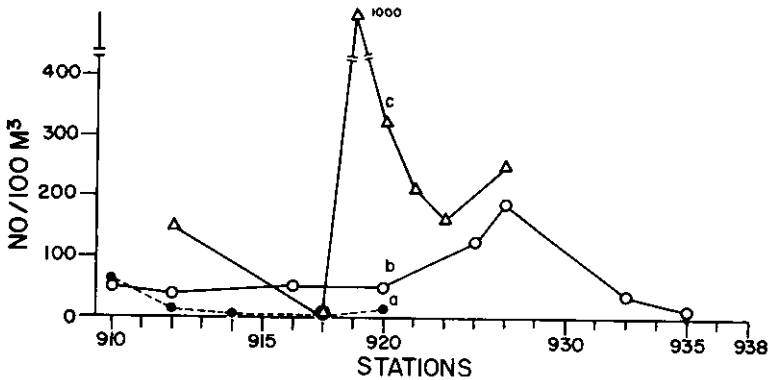


Fig. 6. Numerical abundance of common species of euphausiids (a) *Stylocheiron longicorne* (b) *Euphausia* spp. (c) *Thysanopoda* spp.

the stations and were relatively more abundant in the second and third zones. Hyperiid amphipods were recorded at most of the stations. Mysids were more abundant in the northwestern part of the Bay of Bengal.

Lamellibranchs were better represented in the collections from the third zone. The pteropods *Creseis acicula* and *Cavolinia* sp. were collected more from the second and third zones. Heteropods were rare and occurred only at 6 stations.

Tunicates constituted 2.2% of the total zooplankton counts. Salps occurred at about 82% of the stations and *Thalia democratica* and *Salpa cylindrica* were the most common species. Among doliolids, *Doliolitta gegenbauri* was common while *Pegea confederata* also occurred at a few stations. Appendicularians were more common in zone 1 and 2. *Oikopleura longicauda*, *O. rufescens* and *Megalocercus huxleyi* were the dominant copelates observed.

Species diversity

The diversity of zooplankton was evaluated from methods developed by Fischer *et al.* (α , 1943) and Margalef (D, 1960) which are to a great extent density dependent and Shannon-Weiner (H' , 1963) and Heip (E, 1974) which derive the equitability component based on information theory. Indices were calculated after transforming the zooplankton counts to their numbers per cubic meter.

Zone 1 showed a higher species richness (α and D, Table I). On average, a relatively higher equitability (H' and E) in the population was also found in the first zone followed by the third zone. In general, the richness and evenness were inversely related to the biomass and lowest values were obtained in the coastal belt between Madras and Visakhapatnam where higher biomass and total counts were obtained. Of the two species richness indices, D showed more stability compared to α and the evenness index E gave better comparison between the stations.

Discussion

The hydrography and biology of Indian Ocean north of the frontal zone (10-12°S) undergo considerable variations due to the seasonal monsoonal gyre (Wyrski, 1973b; Panikkar and Rao, 1973). One major factor affecting the pro-

ductivity of the northern Indian Ocean is the upwelling associated with this. The upwelling systems of the Arabian Sea are fairly well studied (Currie *et al.*, 1973) and high zooplankton standing crops have been reported from these areas (Prasad, 1969). On the other hand no large scale upwelling similar to the Somali current or the upwelling systems of the Arabian Sea have been reported from the Bay of Bengal. However, studies based on the International Indian Ocean Expedition (IOBC, 1968) have shown that some portions of the Bay of Bengal are equally rich in zooplankton biomass especially between the Madras and Orissa coasts. Upwelling, although not on a massive scale, has been reported in this area during February-April (Lafond, 1954; Varadachari, 1961) resulting in high plankton production in April-July (Panikkar and Rao, 1973). Subsequent studies (Anand *et al.*, 1968; Murthy and Varadachari, 1968) have confirmed upwelling off Madras and Visakhapatnam during the premonsoon and monsoon periods. The average biomass (33.2 ml/100 m³) obtained from this area (Zone 2) in the present study is quite high and comparable to the rich standing stock of zooplankton (average 27.4 ml/100 m³) obtained off the Saudi Arabian coast during the IIOE. The average zooplankton biomass obtained from the entire area of study (17.6 ml/100 m³) was also high.

The distribution of the standing stock and various groups of zooplankton in the northern Indian Ocean is highly variable depending on the season and associated environmental changes (Rao, 1973, 1979). A study conducted during the later part of the southwest monsoon in August 1978 (Achuthankutty *et al.*, 1980) showed a southward shift in abundance of zooplankton (average biomass 15.4 ml/100 m³) south of Madras associated with a mild upwelling in the area. Areas north of Madras were comparatively poor; the biomass ranged between 2.5 and 3.1 ml/100 m³.

The lower biomass encountered in Zone 1 could be because the sampling was confined to the oceanic region. Zooplankton densities along the upper 200 m along a New York-Bermuda transect have been reported to average 1.07 cm³/m³ in the neritic region, 0.2 cm³/m³ in the slope water and 0.02 cm³/m³ in the oceanic Sargasso Sea (Grice and Hart, 1962).

Species belonging to the families Calanidae (*Canthocalanus* sp., *Undinula* spp.), Eucalanidae (*Eucalanus* spp.), Paracalanidae (*Paracalanus* spp., *Acrocalanus* spp.) and Euchaetidae (*Euchaeta* spp.) usually constitute the majority of zooplankton counts in the coastal waters of India. However, in the inshore and estuarine waters species of the families Acartiidae, Paracalanidae and Pseudodiaptomidae dominate. Most species of these families except the Euchaetidae are herbivores or omnivores (as in the Acartiidae) and are important in the trophic structure of shelf waters. Species of the families Euchaetidae, Candaciidae (*Candacia* spp.) and Pontellidae (*Labidocera* spp., *Pontella* spp., *Pontellina* spp.) constitute the common carnivorous forms.

Although some of the species like *Centropages furcatus*, *Pontellina plumata* and *Labidocera acuta* were confined to the coastal waters in the present collections, they are known to be much more widely distributed. Whereas *Pontellina plumata* has a circumglobal distribution, *Centropages furcatus* is limited to the Indo-Pacific region (Fleminger and Hulsemann, 1973). Although they consider

Temora stylifera endemic to the Atlantic, this species has also been recorded from the Indian Ocean earlier (Kasturirangan, 1963, Stephen, 1976).

Among the different species of chaetognaths encountered in the present study, *Krohnitta pacifica*, *K. subtilis*, *Pterosagitta draco*, *Sagitta enflata* and *S. hexaptera* are cosmopolitan species of the Atlantic, Indian and Pacific Oceans. While the remaining species are characteristic of the Indo-Pacific region, *S. bedoti* and *S. neglecta* are typically neritic and the latter is quite abundant in the Bay of Bengal (Nair, 1977).

The euphausiid species *Pseudeuphausia latifrons* reported to be common in Indian waters (Brinton and Gopalakrishnan, 1973) was not recorded in the present study. *Euphausia diomediae*, another common species of the northern Indian Ocean (Brinton and Gopalakrishnan, 1973), *Stylocheiron longicorne*, *Euphausia* spp. and *Thysanopoda* spp. were the common forms.

Plant and animal diversity in the tropics is considerably higher compared to higher latitudes. In the marine environment higher diversity is sustained in the oceanic realm where more stable conditions occur allowing ideal conditions to attain a high degree of equilibrium and niche separation. Collections from the first zone were taken from the oceanic region and understandably this area showed higher species richness and equitability. In general, the diversity in the coastal stations was also high compared to a study conducted along the inshore waters off Trivandrum, southwest coast of India (Haridas *et al.*, 1980) where D values ranged from 1.5 to 3.7 and E from 0.03 to 0.6. The results obtained in the present study were comparable to zooplankton diversity observed from oceanic stations around the Andaman Islands (Madhupratap, unpublished data) where D ranged between 3.2 and 8 and E from 0.4 to 0.7. An inverse relationship between equitability and biomass as observed in the present study has been reported from station 'S' in the Sargasso Sea (Deevey, 1971).

Abundance and diversity of zooplankton in the present collections indicated two distinct areas. (1) Stations 919 to 930 located in the coastal waters sustained relatively higher biomass but were poorer in diversity. Larval forms of decapods, molluscs and fishes were better represented in this area. Most species of copepods and chaetognaths were more abundant here. Some species like *Cypridina dentata*, *Solenocera* spp., *Acetes indicus* and brachyuran larvae were confined to this area. (2) Stations 910 to 918 located in the oceanic waters showed less biomass and higher diversity. Oceanic species of copepods and some of the euphausiids like *Euphausia* spp.* and *Stylocheiron* spp., were obtained mostly from this zone. Chaetognaths like *Krohnitta subtilis* and *Sagitta hexaptera* were typical of this zone. Importance of upwelling in the zooplankton biomass and abundance of various groups is another important aspect emerging from the study. Better understanding of this physical aspect and seasonal coverage of zooplankton in the Bay would be rewarding.

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References

Achuthankutty, C.T., Madhupratap, M., Nair, V.R., Nair, S.R.S. and Rao, T.S.: 1980, 'Zooplankton biomass and composition in the western Bay of Bengal'. *Indian J. Mar. Sci.* **9**; 210-206

Alvarino, A.: 1965, 'Chaetognaths'. *Oceanogr. Mar. Biol. Ann. Rev.* **3**; 115-194.

Anand, S.P., Murthy, C.B., Jayaraman, R. and Aggarwal, D.M.: 1968, 'Distribution of temperature and oxygen in the Arabian Sea and Bay of Bengal during the monsoon season'. *Proc. Symp. Indian Ocean, Bull. Natn. Sci. India*, **38**; 1-24.

Brinton, E. and Gopalakrishnan, K.: 1973, 'The distribution of Indian Ocean Euphausiids', In B. Zeitschel (ed.) *The Biology of the Indian Ocean*, Springer-Verlag, Berlin; 357-382.

Currie, R.I.: 1963, 'The Indian Ocean Standard Net' *Deep-Sea Res.* **10**; 27-32.

Currie, R.I., Fisher, A.E. and Hargreaves, P.M.: 1973, 'Arabian Sea upwelling', In B. Zeitschel (ed.) *The Biology of the Indian Ocean*, Springer-Verlag, Berlin; 37-52.

Deevey, G.B.: 1971, 'The annual cycle in quantity and composition of the zooplankton of the Sargasso Sea off Bermuda. I. The upper 500 m'. *Limnol. Oceanogr.*, **16**; 219-240.

Fischer, R.A., Corbet, A.S. and Williams, C.B.: 1943, 'The relation between the number of species and the number of individuals in a random sample of an animal population'. *J. Anim. Ecol.* **12**; 42-58.

Fleminger, A. and Hulsemann, K.: 1973, 'Relationship of Indian Ocean epiplanktonic calanoids to the world oceans', In B. Zeitschel (ed.) *The Biology of the Indian Ocean*, Springer-Verlag, Berlin; 339-348.

George, J. and Nair, V.R.: 1980, 'Planktonic ostracods of the northern Indian Ocean'. *Mahasagar - Bull. natn. Inst. Oceanogr.* **13**; 29-44.

Grice, G.D., and Hart, A.D.: 1962, 'The abundance, seasonal occurrence and distribution of the epizooplankton between New York and Bermuda'. *Ecol. Monogr.* **32**; 287-309.

Haridas, P., Menon, P.G. and Madhupratap, M.: 1980, 'Annual variations in zooplankton from a polluted coastal environment'. *Mahasagar - Bull. natn. Inst. Oceanogr.* **13**; 239-248.

Heip, C.: 1974, 'A new index measuring evenness'. *J. Mar. Biol. Ass. U.K.* **54**, 555-557.

IOBC: 1968-73, 'IIOE Zooplankton Atlases' 1-5; NIO, CSIR, India.

IOBC: 1969-73, 'Handbook to the international zooplankton collections' 1-5; NIO, CSIR, India.

Kasturirangan, L.R.: 1963, 'A key for the identification of the more common planktonic Copepoda of Indian coastal waters'. Publication No. 2 of the INCOR (CSIR), New Delhi, 87 pp.

La Fond, E.C.: 1954, 'On upwelling and sinking off the east coast of India', *Andhra Univ. Mem. Oceanogr.* **1**; 94-101.

Margalef, R.: 1968, '*Perspectives in ecological theory*', The University of Chicago Press, 111 pp.

Murthy, C.S. and Varadachari, V.V.R.: 1968, 'Upwelling along the east coast of India'. *Proc. Symp. Indian Ocean, Bull. Natn. Sci. India*, **38**; 80-86.

Nair, V.R.: 1977, 'Chaetognaths of the Indian Ocean'. *Proc. Symp. Warm Water Zoopl. Spl. Publ. NIO.* 168-195.

Nair, V.R., Peter, G. and Paulinose, V.T.: 1977, 'Zooplankton studies in the Indian Ocean. I. From Bay of Bengal during southwest monsoon period'. *Mahasagar - Bull. natn. Inst. Oceanogr.* **10**; 45-54.

Nair, V.R., Peter, G. and Paulinose, V.T.: 1978, 'Zooplankton studies in the Indian Ocean. II. From the Arabian Sea during the postmonsoon period'. *Mahasagar - Bull. natn. Inst. Oceanogr.*, **11**; 35-43.

NIO, 1977, '*Proceedings of the Symposium on Warm Water Zooplankton. Special Publication*, 722 pp.

Omori, M.: 1977, 'Distribution of warm water epiplanktonic shrimps of the genera *Lucifer* and *Acetes* (Macrura, Penaeidae, Sergestidae)'. *Proc. Symp. Warm Water Zoopl. Spl. Publ. NIO.* 1-12.

Panikkar, N.K. and Rao, T.S.S.: 1973, 'Zooplankton investigation in Indian water and the role of the Indian Ocean Biological Centre'. *Handbook to the IIOE Collections*, 5, NIO, CSIR, India.

Peter, G. and Nair, V.R.: 1978, 'Vertical distribution of zooplankton in relation to thermocline', *Mahasagar - Bull. natn. Inst. Oceanogr.*, **11**; 169-175.

Prasad, R.R.: 1969, 'Zooplankton biomass in the Arabian Sea and the Bay of Bengal with a discussion on the fisheries of the region', *Proc. Nat. Inst. Sci. India*. **35**; 399-437.

Qasim, S.Z.: 1977, 'Contributions of zooplankton in the food chains of some warm water environments'. *Proc. Symp. Warm Water Zoopl. Spl. Publ. NIO.* 700-708.

Rao, T.S.S.: 1973, 'Zooplankton studies in the Indian Ocean. In B. Zeitschel (ed.) *The Biology of the Indian Ocean*, Springer-Verlag, Berlin; 243-256.

Rao, T.S.S.: 1979, 'Zoogeography of the Indian Ocean'. In S. van Der Spoel and A.C. Pierrot-Bults (eds.) *Zoogeography and diversity of plankton*, Bunge Scientific Publishers, Utrecht; 254-292.

- Shannon,C.E. and Weiner,W.: 1963, '*The Mathematical theory of Communications*'. University of Illinois Press, Urbana, 117 pp.
- Stephen,R.: 1977, 'Calanoid copepods from the shelf and slope waters off Cochin: distribution, biomass and species diversity, *Proc. Symp. Warm Water Zoopl. Spl. Publ. NIO*. 21-27.
- UNESCO.: 1965-72, '*International Indian Ocean Expedition*' *Collected Reprints*. 1-8, Paris.
- Varadachari,V.V.R.: 1961, 'On the process of upwelling and sinking on the east coast of India', *Prof. Mahadevan Shastyabdapurti Commemoration Volume*, 159-162.
- Wyrтки,K.: 1973a, '*Oceanographic Atlases of the International Indian Ocean Expedition*'. National Science Foundation, US Government Printing Office, Washington, D.C. 531 pp.
- Wyrтки,K.: 1973b, 'Physical Oceanography of the Indian Ocean'. In B.Zeitschel (ed.) *The Biology of the Indian Ocean*, Springer Verlag, Berlin; 18-36.
- Zeitschel,B. (ed.): 1973, '*The biology of the Indian Ocean*' '*Ecological studies*', 3, Springer-Verlag, Berlin, Heidelberg, New York, 549 pp.