

Zooplankton distribution in neuston and water column along west coast of India from Goa to Gujarat

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Zooplankton distribution and abundance in neuston layer and water column at 4 transects between Goa to Gujarat during January-February, 1988 were studied. The ambient water temperature, salinity and dissolved oxygen at surface layer ranged between 26.3° and 27.3°C, 35.7 and 36.2×10^{-3} and 4.3 and 4.5 ml.l^{-1} respectively. The temperature and dissolved oxygen values decreased with depth. Their values at 200 m depth were 18.2°C and 0.27 ml.l^{-1} . Zooplankton biomass (ml.m^{-3}) and population density (no. m^{-3}) were higher in the water column ($av = 0.5, 592$) than in the upper neustonic layer ($av = 0.3, 245$). Copepods were dominant (51.8 to 71.6%). The other important groups were ostracods, invertebrate larvae, chaetognaths, amphipods, pteropods, fish eggs and fish larvae. Sixtyone species of pelagic copepods were identified. Copepod species of genera *Nannocalanus*, *Eucalanus*, *Clausocalanus* and *Canthocalanus* were abundant both in the upper and lower neuston layers and water column. Significant correlation ($P > 0.05$) was obtained among species of first 2 genera. The species richness and evenness were inversely related to the zooplankton biomass.

The coastal zone is a highly dynamic and productive area. The west coast of India accounts for about 70 to 75% of the India's total marine fish catch. The Indian mackerel, *Rastrelliger kanagurta* and oil sardine, *Sardinella longiceps*, are the two major pelagic fisheries. The success or failure of pelagic fishery is dependent upon the availability of plankton. A general account of distribution of zooplankton in the near-shore waters of Goa was given¹⁻³. Neuston composition in central Arabian Sea was described⁴. Not much information is available on zooplankton in neuston and water column. The present communication deals with zooplankton distribution, abundance, species association and diversity in the neustonic layers and water column in the coastal waters of west coast of India between Goa to Gujarat.

Materials and Methods

Neuston and vertical zooplankton hauls were taken at 7 stations (Fig. 1) located between Goa to Gujarat during Cruise no. 38 of *ORV Sagar Kanya* (January-February 1988). The sampling depth at the stations varied from 35 to 200 m. Neuston samples were collected using a David/Hempel neuston net (model 200, 30 × 15 cm bag and mesh size 200 μm). The net was towed for 5 min at 2 knot speed. The net sampled at 2 depths, the upper net filtered the upper 15 cm layer of the water column and the lower net filtered 30 to 45

cm layer below. Vertical hauls were taken with a modified HT net (mouth area 0.25 m^2 , mesh size 300 μm) fitted with a calibrated flowmeter. An aliquot (5 to 10% of total sample) was examined for enumeration

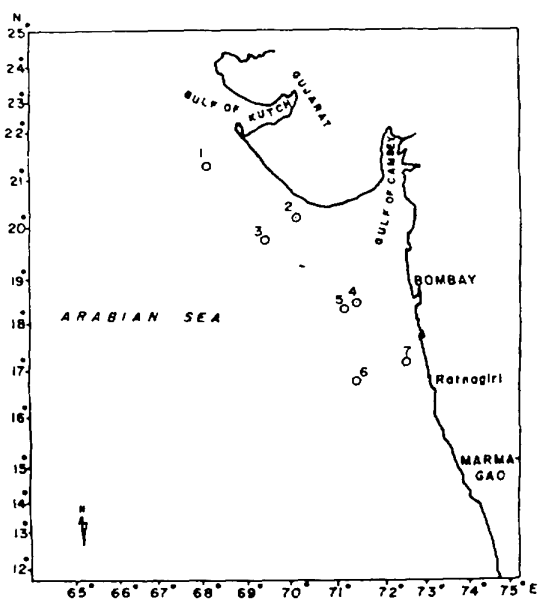


Fig. 1—Station locations

of major taxa and species. Number of organisms was then calculated for the whole sample and given as no. m^{-3} . Zooplankton diversity was evaluated by methods of Margalef⁵ and species richness and equitability by Shannon-Weaver⁶. The water samples were taken simultaneously along with the zooplankton collections for environmental parameters. The salinity was determined by argentometric titration and dissolved oxygen by Winkler's method as described by Grasshoff⁷.

Results and Discussion

Water temperature, salinity and dissolved oxygen values at the neustonic layers and at depths from which hauls were made (35 to 200 m) at 7 stations were tabulated (Table 1). Surface temperature ranged between 26.3° and 27.3°C. The temperature did not vary much within the upper 50 m layer. It decreased gradually below

this layer and was 18.2°C at 200 m depth. Surface salinity fluctuated between 35.7 and 36.1 $\times 10^{-3}$ but salinity profile up to 200 m depth showed not much different at various stations. The dissolved oxygen value indicated that the surface layer was well oxygenated. The values ranged between 4.3 and 4.5 ml.l^{-1} . The upwelling was not observed during the period of present study. Coastal upwelling along the central west coast of India during May-June was reported⁸.

Zooplankton biomass and total zooplankton counts at 7 stations were tabulated (Table 2). Biomass and population density was higher in the water column in general than in the neuston. The upper neustonic layer (up to 15 cm) gave poor biomass ($\text{av} = 0.3 \text{ ml.m}^{-3}$) in comparison to layer below (35 to 45 cm) and the water column ($\text{av} = 0.5 \text{ ml.m}^{-3}$). High surface temperature, intense solar radiation and avoidance of predators were the reasons attributed for poor occurrence of zooplankton in the upper neustonic layer⁹. Low production of phytoplankton in the upper microlayer was given as possible cause for poor zooplankton abundance in the surface layer¹⁰. Nineteen taxa were identified from the samples collected from neuston and water column. Numerical counts and percentage composition of 16 common groups were tabulated (Table 3). The individuals of remaining 3 groups viz. water insects (*Halobates*), cephalochordates (*Amphioxus*) and cephalopod juveniles occurred sporadically and in small numbers (<1%). These were combined together and given as miscellaneous. Faunal composition of zooplankton occurring in neuston was not much different from that of the water column. However, percentage occurrence of taxa varied in these biotopes. Among the 16 groups, 11 had higher abundance in the water column while 4

Table 1—Variations in the physico-chemical parameters at different stations located between Goa to Gujarat during January-February 1988

St. no.	Depth of the water column (m)	Temperature (°C)		Salinity ($\times 10^{-3}$)		Diss. O ₂ (ml.l^{-1})	
		S	B	S	B	S	B
1	110	27.2	23.5	36.2	35.6	4.3	1.0
2	50	26.3	26.2	36.1	36.2	4.5	4.5
3	90	27.3	26.7	36.0	36.1	4.4	4.3
4	60	27.2	27.1	35.9	36.0	4.4	4.4
5	—	27.2	—	36.0	—	4.4	—
6	200	27.3	18.2	35.9	35.6	4.5	0.27
7	35	27.2	27.0	35.7	35.7	4.3	4.2

S—Surface; B—Bottom

Table 2—Zooplankton biomass and population density at different stations between Goa to Gujarat during January-February, 1988

St. no.	Type of Hauls					
	Neuston				Vertical water column	
	Upper layer		Lower layer		Biomass (ml.m^{-3})	Density (no.m^{-3})
Biomass (ml.m^{-3})	Density (no.m^{-3})	Biomass (ml.m^{-3})	Density (no.m^{-3})			
1	0.2	189.3	0.2	322.8	0.3	373.2
2	0.4	297.1	0.3	366.3	0.7	723.4
3	0.1	98.9	0.3	430.1	0.4	580.9
4	0.3	359.7	0.3	452.6	0.8	1207.1
5	0.5	151.6	0.8	483.8	—	—
6	0.7	572.3	0.6	790.8	0.2	286.2
7	0.05	43.5	0.05	23.7	0.5	386.4

(Amphipoda, Mysidacea, Euphausiacea and Brachyura zoeae) were more in the neuston realm. Crustaceans were abundant and Copepoda was the dominant group (51.8 and 71.6%) in the upper and lower neustonic layers followed by Ostracoda (24.5 and 8.5%) and invertebrate larvae (9.4 and 7.5%). The other important groups were Amphipoda (5.5%), Siphonophora (1.6%) and Chaetognatha (1.2%) in the upper layer and Copelata and Chaetognata (2.4% each) in the lower neustonic layer. Higher abundance of ostracods in the neustonic layer in the eastern Arabian Sea during southwest monsoon was reported⁹. Dominance of taxa viz. coelenterates, tunicates and molluscs in the neuston was described in the lower latitudes¹⁰. However, these constituted only minor components during present study. In the water column, copepods formed 64.7% of the total count followed by ostracods (9.7%), copelates (7.7%), invertebrate eggs (3.7%) and chaetognaths (3.5%). The other groups individually constituted < 2% of the population density (Table 3). Zooplankton distribution was more variable in the vertical realm than in the neustonic layers. The presence of oxygen deficient layer below from 100 to 1500 m and thermocline (50 to 70 m) inhibit the downward extension of surface fauna¹¹. Higher aggregations of zooplankton in the shallow upper mixed layer (above the thermocline) compared to stratum below was observed⁸.

Copepods predominated constituting 80.4% of population densities in neuston and water column.

Table 3—Averages of numerical counts (no. m⁻³) and percentage composition (in parentheses) of major groups of zooplankton

Group	Upper layer (0-15 cm)	Lower layer (30-45 cm)	Water column
Hydromedusae	0.5 (0.2)	0.3 (0.1)	0.8 (0.1)
Siphonophora	3.9 (1.6)	5.5 (1.3)	8.6 (1.4)
Chaetognatha	2.9 (1.2)	9.9 (2.4)	20.8 (3.5)
Ostracoda	59.7 (24.5)	34.8 (8.5)	88.9 (9.7)
Euphausiacea	0.3 (0.1)	4.2 (1.0)	1.2 (0.2)
Copepoda	126.4 (51.8)	293.5 (71.6)	383.2 (54.7)
Amphipoda	13.4 (5.5)	5.0 (1.2)	1.3 (0.2)
Sergestidae	1.4 (0.6)	3.0 (0.7)	5.2 (0.9)
Mysidacea	2.6 (1.1)	1.0 (0.2)	0.3 (0.1)
Invertebrate eggs	0.3 (0.1)	0.3 (0.1)	0.1 (0.03)
Invertebrate larvae	23.0 (9.4)	30.6 (7.5)	22.7 (3.7)
Pteropoda	2.9 (1.2)	5.1 (1.2)	10.3 (1.7)
Copelata	1.9 (0.8)	9.6 (2.4)	45.4 (7.7)
Thaliacea	1.7 (0.7)	3.1 (0.7)	2.6 (0.4)
Fish eggs	2.1 (0.9)	2.8 (0.8)	0.1 (0.02)
Fish larvae	0.6 (0.2)	0.9 (0.2)	1.3 (0.2)
Miscellaneous	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)

They were represented by 26 families, 39 genera and 61 species of which calanoids were the most common. Members of families Calanidae, Paracalanidae, Clausocalanidae, Acartiidae and Pontellidae were common both in neuston and water column. Distribution of some of the common pelagic copepod species is shown (Fig. 2). In the upper layer *Acrocalanus* spp accounted for 17% followed by *Paracalanus* spp (12.6%), *Corycaeus* spp (11.4%), *Clausocalanus* sp. (7.9%), *Oithona* spp (6.7%), *Canthocalanus pauper* (5.9%), *Undinula vulgaris* and *Temora turbinata* (5.1% each). Pontellids constituted 5.7% in upper and 3.9% in lower neuston layers. Besides Pontellids, *Acrocalanus* spp accounted for 17.8%, *Paracalanus* spp 11.0%, *Acartia erythroa* 10.1%, *Clausocalanus* sp. 9.6%, *Canthocalanus pauper* 8.7% of total copepod population in the lower neustonic layer. Species of families Paracalanidae, Pontellidae, Clausocalanidae, Calanidae, Acartiidae and Corycaeidae were reported to be common in both the layers⁹. In the water column *Acrocalanus* spp constituted 19.4% of total copepod counts followed by *Clausocalanus* sp. (14%), *Oithona* spp (12.8%), *Paracalanus* spp (11.8%), *Oncaea* spp (6.7%) and *Canthocalanus pauper* (6.2%). Pontellids were scanty (0.4%). Occurrence

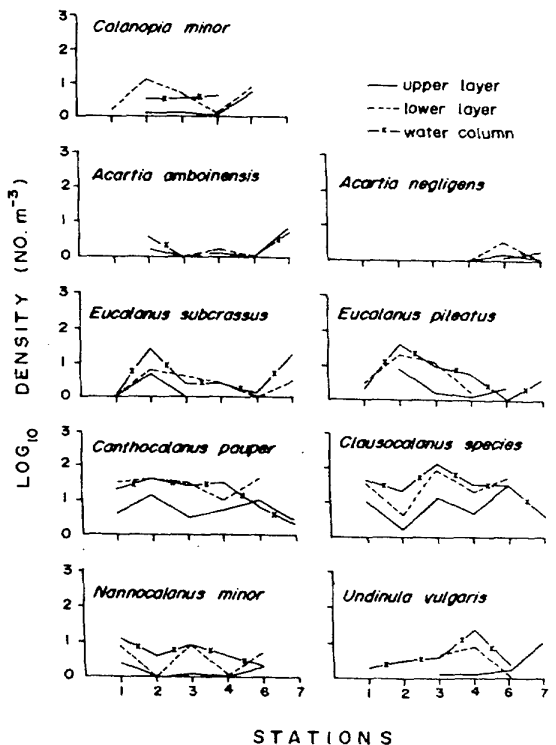


Fig. 2—Distribution of selected copepod species in the upper and lower neuston layer and water column

Table 4—Occurrence of common copepod species at different strata in the coastal waters between Goa to Gujarat during January-February 1988

Warm surface layer (0 to 50 m)	Discontinuity layer between (50 to 150 m)	Between 150 to 200 m
<i>Acartia negligens</i>	<i>Nannocalanus minor</i>	<i>Pleuromamma indica</i>
<i>A. amboinensis</i>	<i>Cosmocalanus darwini</i>	<i>P. gracilis</i>
<i>Canthocalanus pauper</i>	<i>Calocalanus pavo</i>	<i>Euchirella bella</i>
<i>Eucalanus subcrassus</i>	<i>Temoropia mayumbaensis</i>	<i>E. pulchra</i>
<i>E. mucronatus</i>	<i>Haloptilus longicornis</i>	
<i>E. attenuatus</i>	<i>Lucicutia flavicornis</i>	
<i>Candacia catula</i>	<i>Calanopia minor</i>	
<i>C. plumulosus</i>	<i>Temora turbinata</i>	
<i>Temora discaudata</i>	<i>Clausocalanus</i> sp.	
<i>Paracalanus</i> spp		
<i>Acrocalanus</i> spp		

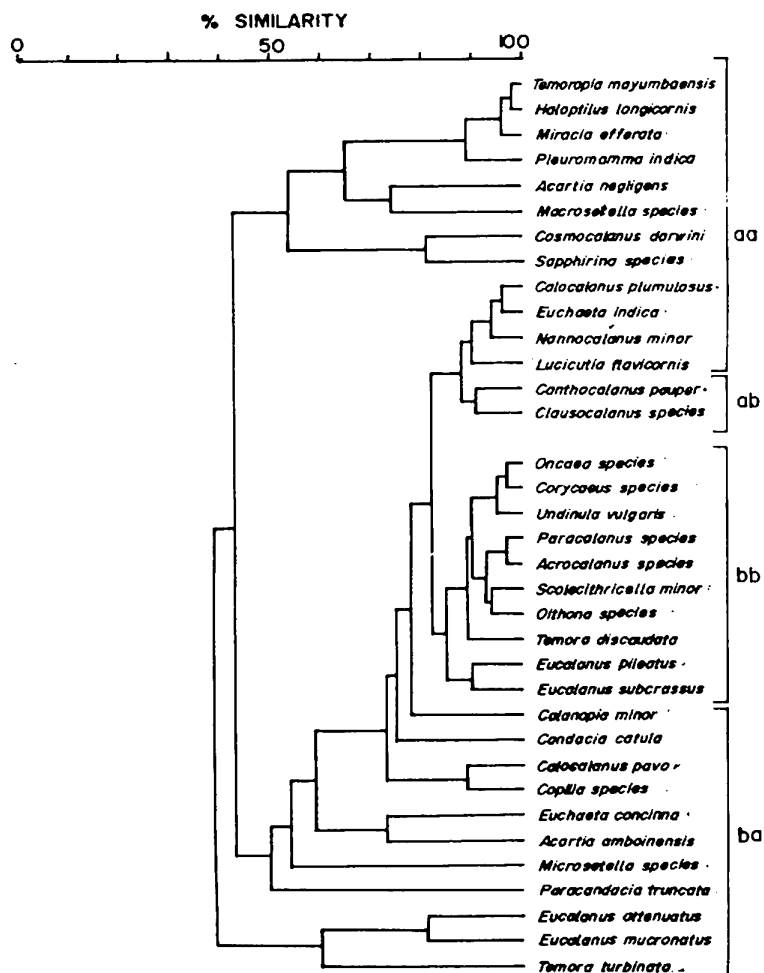


Fig. 3— Hierarchical cluster analysis showing affinities of copepod species and formation of groups in the coastal waters

nce and abundance of copepod species in the water column was influenced by ambient temperature and dissolved oxygen content. Distribution of species at different depths was tabulated (Table 4). The warm surface layer (0 to 50 m) was dominated by species of genera *Acartia*, *Eucalanus*, *Candacia* and *Canthocalanus*. In the discontinuity layer, species of genera *Nannocalanus*, *Haloptilus*, *Lucicutia* and *Calanopia* were abundant. The distribution of bathypelagic copepods viz. *Pleuromamma* spp along the north-south transect in the Indian Ocean was described¹². Copepod species such as *Euchirella curticauda*, *Pleuromamma indica*, *Heterostylis longicornis*, *Scaphocalanus magnus* and *Scottocalanus securifrons* were stated to be common¹¹ in layer between 150 and 500 m. Madhupratap & Haridas¹³ divided the calanoid copepod species into 3 groups based on their vertical range. These groups were (i) species occurring predominantly in the epipelagic zone, (ii) relatively sparser deep water forms confined to depths of over 200 m and (iii) species present throughout the water column. Based on the vertical ranges of copepod species four types of associations were deduced during the present study. These were (i) a shelf association of species like *Temoropia mayumbaensis*, *Haloptilus longicornis*, *Miracia efferata* and *Pleuromamma indica*. The species were more abundant in the discontinuity layer between 50-150 m and represented by cluster 'aa', (ii) a coastal association of species which were generally restricted to the coastal waters and shown by cluster 'bb' with maximum abundance in the warm surface layer (0-50 m), (iii) a subsurface association between *Canthocalanus pauper* and *Clausocalanus* sp. represented by cluster 'ab' of strong association (79%) similarity. The species showed similar pattern of distribution. The last association was a weakly linked cluster 'ba'. This included overlapping species between the first 2 groups (Fig. 3). The mechanisms responsible for co-existence among the zooplankton species is not properly understood. The feeding habits of the organisms could be one of the important factors responsible for their association.

Eutima commensalis and *Eirene menoni* were the common hydromedusae in the samples. Siphonophores were represented by *Diphyes* sp. *Sagitta bedoti*, *S. enflata* and *Sagitta* spp were the chaetognaths, *S. enflata* being the dominant form, occurring more in the water column. *Cypridina* sp. and *Siriella* sp. were the common ostracods and mysids respectively. *Lucifer hanseni* and *Acetes* spp were the sergestids, the former being abundant in the samples. *Oikopleura* spp were the copepates and *Thalia democratica* the thaliaceans in the zooplankton samples from neuston and water column.

Table 5—Range of number of species per samples (S), species diversity (H'), Species richness (D) and evenness (E) in the coastal waters from Goa to Gujarat during January-February 1988 (averages in parentheses)

Type of hauls	S	H'	D	E
Water column	16-36 (27.0)	1.9-2.8 (2.4)	2.8-6.6 (4.6)	0.3-0.5 (0.4)
Upper layer	13-30 (25.3)	1.9-2.3 (2.5)	3.4-6.3 (5.3)	0.3-0.1 (0.5)
Lower layer	17-34 (26.6)	1.3-2.5 (2.2)	3.0-5.7 (4.6)	0.2-0.5 (0.3)

Mean number of species in the water column was higher (27.0) as compared to the lower (26.6) and upper (25.3) neuston layers. However, average species density (2.5), species richness (D = 5.3) and equitability (E = 0.5) values were more for upper neuston layer than the lower layer and water column. Species diversity values varied from 1.9 to 2.8, 1.9 to 2.3 and 1.3 to 2.5 in the water column, upper and lower neuston layers respectively (Table 5). The species diversity values were reported to range between 1.5 and 3.7 in the inshore waters off Trivandrum¹⁴, 8.2 and 12.9 in the coastal and oceanic waters of the western Bay of Bengal¹⁵ and 3.2 and 8.1 in the Andaman Sea¹⁶. In general, species richness and evenness were inversely related to the zooplankton biomass. Their highest values were obtained in the upper neuston where the lowest average biomass and numerical counts were obtained (Table 2). Higher species richness in the upper neuston could be due to occurrence of numerous Pontellid species. Several species of Pontellids were reported to be permanent inhabitants of the surface layers¹⁷⁻¹⁸.

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