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Distribution and abundance of copepods in the pollution gradient zones of Bombay Harbour-Thana creek-Bassein creek, west coast of India

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Forty six species of copepods were identified, of which, 40 belonged to Calanoida with an overall dominance of Acartiidae. *Acartia spinicauda, A. centrura* and *Centropages dorsispinatus* were the common species throughout the year at all locations. *Eucalanus subcrassus* and *Paracalanus aculeatus* were more abundant in the outer zone, while *A. tropica* was very common in the interior region. Hyposaline species, *Pseudodiaptomus binghami malayalus* was recorded from the interior locations particularly during the monsoon months (June-September). Diversity indices (Shannon-Weaver's H' and Margalef's D) were higher in the outer coastal waters than in creek zone indicating lethal or sublethal effects of industrial and domestic wastes on the general faunistic composition as well as water quality of the creek stations.

As copepods dominate the marine zooplankton community, often contributing over 80-90% of the total zooplankton counts in nearshore and estuarine habitats, variations in their composition is a valid indication of ecological succession, breeding periodicity as well as environmental conditions. Numerous investigations from different geographic locations have emphasized the importance of copepods in ecological studies[1-4]. Rapid industrialization and urbanization of Bombay metropolis have resulted in the disposal of enormous quantities of wastes into adjacent creeks and bays and an estimated 400 mld of domestic wastes and industrial effluents (from fertilizer, petrochemical, automobile, pharmaceutical, leather, food and chemical industries and nuclear and thermal power stations) find their way into Bombay Harbour-Thana Creek-Bassein Creek (BHTCBC) confluence[5]. Such anthropogenic inputs adversely affect water quality and are deleterious both at lethal and sublethal levels to the biotic component[1,6]. Studies on copepods from this coastal environment are few[7-11] and, incidentally, there is no previous account on the distribution of this important zooplankton community in the entire BHTCBC stretch. The present study was therefore undertaken with a view to provide the much needed information on species composition, distribution and diversity of copepods in relation to the prevailing environmental conditions. This information would be helpful in the ecological monitoring of this ecosystem in future.

Materials and Methods

Four stations along the 87 km stretch of BHTCBC were monitored monthly from August 1985 to October 1986 (Fig.1). Zooplankton samples were collected during the high tide by oblique hauls using a Heron-Tranter net (mouth area 0.25m^2; mesh size 300 µm) fitted with a calibrated TSK flow meter and preserved in 5% buffered formalin. Zooplankton volumes (or biomass) were estimated by displacement method. 25% aliquots of each original sample were taken for sorting and identification of copepods[12-14]. Most calanoid taxa were identified to species level. Owing to the difficulty in identifying the species, members of the families Longipediidae, Tachidiidae, Ectinosomidae, Oncaeidae, Oithonidae and Corycaeidae were identified only up to genus level. Diversity indices-Shannon's H'[15] and Margalef's D[16] were calculated using the individual counts (no m^{-3}) and species numbers. Analyses of parameters such as temperature, *p*H, salinity, dissolved oxygen (DO), biological oxygen demand (BOD) and nutrients like phosphate, nitrite and nitrate of the water samples collected along with zooplankton were done following Parsons *et al.*[17].

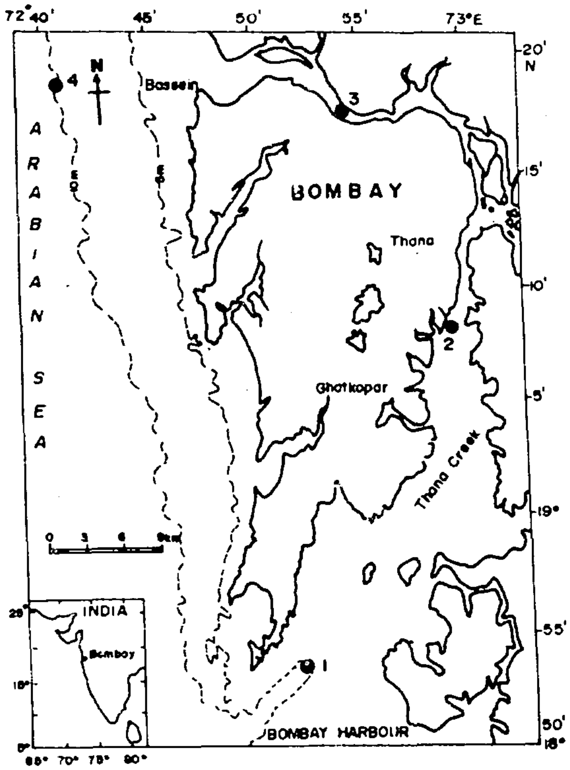

Fig. 1—Station locations

Chlorophyll *a* (chl-*a*) was extracted in 90% (v/v) acetone and extinction measured at 750 and 665 nm in a Beckman DU-6 spectrophotometer. Microscopic counts of phytoplankton cells were made following Vollenweider[18]. Correlation coefficients were worked out to study the influence of hydrobiological parameters on copepod diversity.

Results

Data on variations in hydrographic parameters (Fig.2) indicate wider fluctuations in salinity at creek stations (sts 2 and 3) generally during monsoon (June-Sept). Concentrations of nitrite and nitrate were lower in the outermost coastal stations (sts 1 and 4) and increased towards the creek area with maximum nitrite concentration (34.5 μg-at l^{-1}) at st. 2 during July and maximum nitrate (78.6 μg-at l^{-1}) at st. 3 in February. Comparatively, a low range of phosphate concentration was recorded at st. 4 (1.2-2.3 μg-at l^{-1}). Dissolved Oxygen and BOD did not indicate any discernible variations either seasonally or spatially.

Chlorophyll *a* (chl-*a*) and phytoplankton cell counts (Fig.2) showed an increasing trend from st. 1 towards the interior and were usually maximum at st. 2, indicating generally higher values during monsoon (June-September), coinciding with relatively low salinity and high nutrients due to land runoffs during this season.

Zooplankton volume (Fig.2) was invariably higher at st. 2 when gelatinous organisms like medusae, ctenophores, siphonophores, salps and doliolids dominated. Copepod counts were generally greater at st. 2 (av. 3929 m^{-3}) and st. 3 (av. 1778 m^{-3}) than at st. 1 (av. 1004 m^{-3}) and st. 4 (av. 1589 m^{-3}). Percentage contribution of copepods to zooplankton at the four stations varied respectively from 43.7-96.4 (av. 77.6%), 36.5-99.8 (av. 84%), 44.1-99.7 (av. 81.3%) and 9.4-97.7 (av.80.1%).

In all, 46 species were recorded (Table 1), 40 belonging to Calanoida with an overall dominance of species in the families Acartiidae, Paracalanidae and Pseudodiaptomidae. Five species each in Acartiidae (*Acartia centrura, A. erythreae, A. pacifica, A. spinicauda* and *A. tropica*) and Pseudodiaptomidae (*Pseudodiaptomus annandalei, P. bowmani, P. binghami malayalus, P. serricaudatus* and *P. sewelli*) were recorded. *Acartia tropica* was the major species at st. 2 (91.6%) and st. 3 (81.1%) in July. Acartiidae was the most dominant family here and showed a relatively higher abundance at st. 2 with the population dominated by *Acartia centrura* (98%) in February. Common species in the area were *Acartia centrura, A. spinicauda, A. tropica, Acrocalanus* spp, *Centropages dorsispinatus* and *Paracalanus aculeatus. Acrocalanus* spp recorded a peak at st. 3 during monsoon, while at other stations it did not show any consistent trend. *Centropages furcatus, Labidocera acuta, L. pavo, Acartiella gravelyi* and *Allodiaptomus* spp showed patchy occurrence. *Euchaeta concinna, E. indica, Pseudodiaptomus bowmani, Microsetella* spp, *Oncea* spp, *Oithona* spp, *Tortanus gracilis, T. turbinata* and *Euterpina* spp were found on rare occasions. *Pseudodiaptomus binghami malayalus* was encountered only at sts 2 and 3, with a density of 175 individuals m^{-3} at st. 2 in July, while *P. annandalei* was recorded only at sts 2 and 3 during monsoon.

Diversity indices H' (av. 2.8) and D (av. 1.6) were usually maximum at st. 4. Decrease in both H' and D was discernible towards the creek region (Fig.3) with minimum values at st. 2 (av. H'1.9; D 1.0). Although, hydrobiological parameters studied influenced the copepod diversity to a limited extent, statistically significant values were recorded only

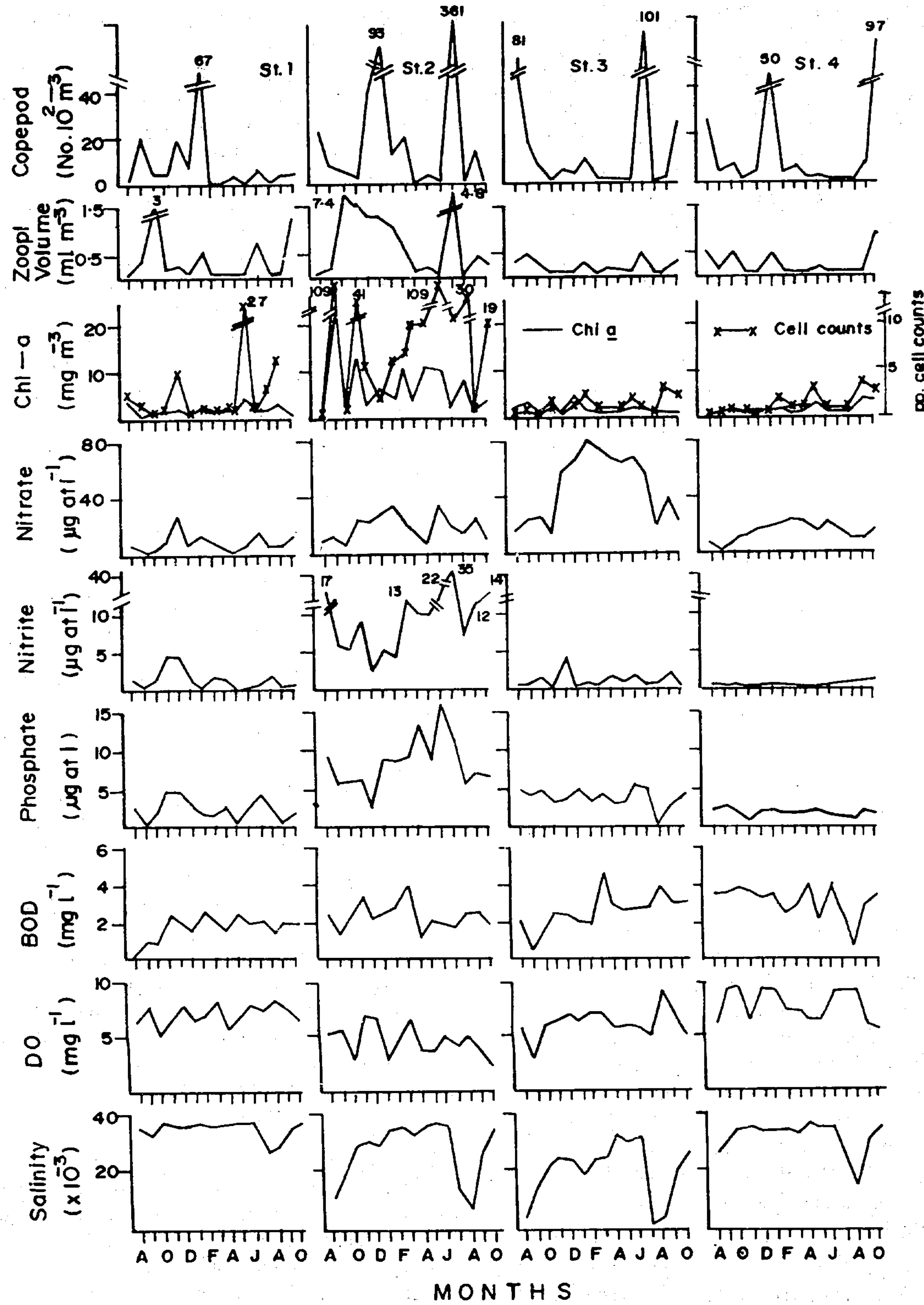

Fig. 2—Variations in physico-chemical and biological parameters at the four stations

Table 1-Average density (no m-3) of copepod species at different stations

Family	Taxa	Stations 1	2	3	4
Calanidae:	*Canthocalanus pauper* (Geisbrecht)	20	6	4	70
Eucalanidae:	*Eucalanus crassus* Geisbrecht	6	3	2	34
	E. pileatus Geisbrecht	5	22	11	58
	E. subcrassus Geisbrecht	14	15	31	194
Paracalanidae:	*Paracalanus* spp	-	-	-	1
	P. aculeatus Geisbrecht	51	3	22	105
	P. parvus (Claus)	7	-	-	6
	Acrocalanus spp	68	45	217	267
	Bestiola similis (Sewell)	5	2	474	8
Euchaetidae:	*Euchaeta* spp	-	-	2	2
	E. concinna Dana	2	-	-	1
	E. indica Wolfenden	120	-	-	1
	E. rimana Bradford	1	-	1	12
Centropagidae:	*Centropagés dorsispinatus* Thompson & Scott	81	25	52	69
	C. furcatus (Dana)	2	-	-	-
	C. orsinni Geisbrecht	-	-	-	3
	C. tenuiremis Thompson & Scott	-	1	1	1
Pseudodiaptomidae:	*Pseudodiaptomus* spp	1	-	-	-
	P. annandalei Sewell	-	13	15	-
	P. binghami malayalus Wellershaus	-	12	1	-
	P. bowmani Walter	1	22	10	4
	P. serricaudatus (T. Scott)	4	7	2	-
	P. sewelli Walter	7	15	23	2
Temoridae:	*Temora* spp	-	-	-	3
	T. turbinata (Dana)	1	1	-	1
Pontellidae:	*Labidocera* sp	-	12	-	1
	L. acuta (Dana)	-	-	-	1
	L. pavo Geisbrecht	1	-	-	-
	L. pectinata Thompson & Scott	2	14	-	-
Acartiidae:	*Acartia centrura* Geisbrecht	454	699	100	178
	A. erythreae Geisbrecht	59	19	3	9
	A. pacifica Steur	29	80	14	39
	A. spinicauda Geisbrecht	139	132	101	347
	A. tropica T. Scott	8	2714	647	111
	Acartiella gravelyi Sewell	-	11	-	-
	A. keralensis Wellershaus	2	4	20	13
Tortanidae:	*Tortanus barbatus* (Brady)	8	13	3	14
	T. forcipatus (Geisbrecht)	1	24	5	7
	T. gracilis (Brady)	2	1	2	1
Diaptomidae:	*Allodiaptomus* spp	1	-	-	-
Longipediidae:	*Longipedia* spp	-	-	1	-
Tachidiidae:	*Euterpina* spp	1	-	-	-
Ectinosomidae:	*Microsetella* spp	-	-	-	1
Oncaeidae:	*Oncea* spp	-	6	1	-
Oithonidae:	*Oithona* spp	1	7	-	4
Corycaeidae:	*Corycaeus* spp	3	2	1	8

between few. At st. 1, H' was not significantly influenced, but D correlated positively with variations in phytoplankton cell counts ($P \leq 0.1$). Positive correlation existed between H' and phytoplankton counts ($P \leq 0.05$) at st. 2 and H' and salinity at sts 2 and 3 ($P \leq 0.1$). At st. 4, positive relationships between H' and phytoplankton cell counts ($P \leq 0.1$), salinity ($P \leq 0.05$) and nitrate concentration ($P \leq 0.02$) were observed.

Discussion

Ecological observations on the zooplankton communities are important in assessing the health of coastal ecosystems[1-4,19]. Pollutants are known to reduce the species diversity and increase population sizes of tolerant species causing episodic pulses in their abundance. Higher zooplankton biomass and density, but lower H' and D observed at st. 2 (receiving sewage and other effluents) in the BHTCBC confluence may be explained by the fact that enrichment of coastal waters, may generally result in an increase in zooplankton population[1]. Copepods formed a dominant part of the zooplankton community in BHTCBC and their abundance in the interior stations (sts 2 and 3) was generally higher during monsoon either coinciding with or following the peak in phytoplankton population[11]. From the low H' and D at st. 2, it is possible to suggest that there is a pollution stress on the copepod community during most part of the year excepting the monsoon period.

Salinity is attributed as an important factor regulating distribution of copepod species in nearshore areas[1,2,4,20]. The interior stations of BHTCBC (sts 2 and 3) experience greater fluctuations in salinity particularly during monsoon due to freshwater influx from adjacent rivers. Since salinity at these two stations reduces substantially during monsoon, the conditions might have been ideally conducive for the low saline *Pseudodiaptomus binghami malayalus* to abound here during this period. BHTCBC ecosystem represents a typical tropical estuary subjected to tidal exchanges and varying salinities and only a biota adapted to such conditions can grow and survive here. Species belonging to the genera *Pseudodiaptomus, Acartia* and *Acartiella* being abundant and persistant throughout the year at st. 2 might suggest their ability to adapt to the prevailing environmental conditions. Occurrence of neritic forms in reasonably higher numbers in this confluence is suggestive of the continuous influence of coastal water from the adjoining harbour and off Bassein region. Absence of species like *Euchaeta concinna, E. indica* and *Paracalanus parvus* and low diversity in the interior stations point to the fact

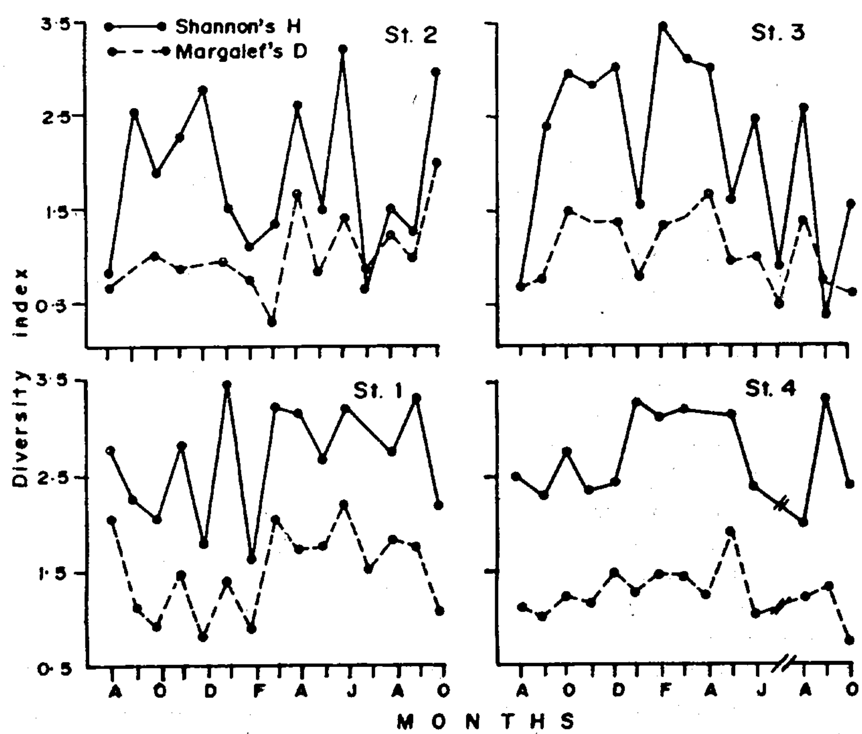

Fig. 3—Variations in diversity indices at different stations

that wastes discharged into the Thana creek may be preventing the incidence and survival of some species. Eutrophication in the Tokyo Bay in the form of introduction of excessive nutrients through domestic sewage and industrial wastes resulted in a decrease in copepod size composition[21].

Decrease in diversity of copepods in the polluted interior region is however, obvious and certainly suggestive of the habitat retardation. Similar low plankton diversity, considered as an index of poor and deteriorating water quality[22], was also reported from the east coast of India receiving sewage and industrial wastes[23]. Absence of certain chaetognath species[24] once reported to be prevalent[25,26], and the pollution stress on the ecological processes[6,27,28] in this region, are indicative of the continuous adverse effects of toxicants. Further, the density of *Acartia centrura, A. tropica* and *A. spinicauda* being high in the interior polluted regions during most part of the study period, it is discernible that such organisms have the capacity to adapt to the deteriorating environmental conditions. Although hydrobiological parameters do exert some influence, they have, as yet, not shown a statistically significant effect on the copepod diversity. However, this study provides a baseline data on the abundance and diversity of copepods in BHTCBC subjected to continuous threat by unregulated effluent discharges.

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