Indian Journal of Marine Sciences
Vol. 28, June 1999, pp. 173-183

Trophic structure and levels of selected metals in the zooplankton community of Thane-Bassein creek, Bombay

Vijayalakshmi R Nair, Asha Jyothi Krishnamurti & S N Gajbhiye
National Institute of Oceanography, Regional Centre, Versova, Bombay 400 061, India

Received 5 December 1997, revised 9 February 1999

Community structure of zooplankton at 4 locations, 2 in the coastal waters off Bombay and 2 in interior Thane-Bassein Creek System were studied for a period of one year. Copepods as the major herbivore community contributed 76-83% to total zooplankton population. Decapods were relatively more in the outer (av. 11%) as compared to interior zone (av. 7%). Population density of carnivores were 2-4 times more in the polluted interior segment. Among the different metals studied Cu and Zn contributed 60-89% of the total elements accumulated. In general, concentration of Zn was higher than Cu in different groups. Also levels of Zn in polluted locations were 2 times higher than the outer zone. The maximum concentrations of metals was observed in gelatinous organisms which included a variety of carnivores. Metal concentration in copepods was lower than carnivores. The lowest concentrations of metals in decapods could be due to the effective elimination of a part of the concentrated metal through periodic moulting.

Contribution of herbivores, omnivores and carnivores to the zooplankton community, though follow a set pattern, can vary, depending on the nature of the ecosystem. Associated with a phytoplankton bloom initial zooplankton standing stock will be dominated by herbivores followed by the predominance of herbivore and omnivore community which later develop into a region with higher ratio of carnivores[1]. Generally herbivores form a major fraction of zooplankton community. It has been observed that in a stress induced system the normal pattern changes with relatively higher share of carnivores[2]. Though reports on the zooplankton abundance and diversity for polluted creek environments of Bombay are available[2-6] this aspect has never been studied in detail. Also the build up of low level concentrations of metals in different fractions of zooplankton from areas receiving waste helps in assessing the variability within the community and transfer of metals from herbivores to carnivores.

Materials and Methods

Four locations in the Thane-Bassein creek system (Fig. 1) were selected for regular monitoring over a period of one year from January 1986 to February 1987. Station 1 (Bombay harbour) and station 4 (off Bassein mouth) are in the open coast at a depth of 9-13 m. Station 2 (inside Thane creek) and station 3 (inside Bassein creek) are interior creek locations having a depth of 3 to 6 m. Sampling at monthly intervals was done for water quality and zooplankton. Surface water samples were collected using a clean plastic bucket while for bottom water a Niskin water

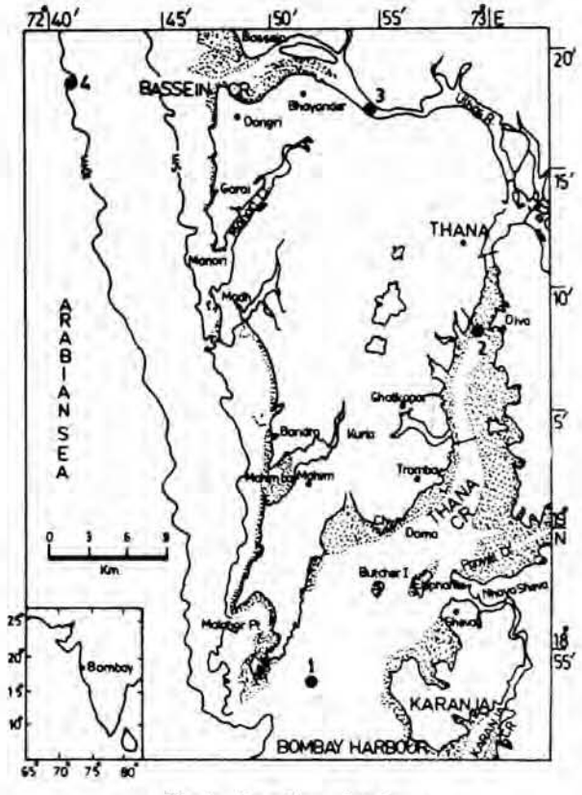

Fig. 1—Location of stations

NIO Contribution No. 2644

sampler was used. The physico-chemical parameters studied were temperature, salinity, *p*H, DO, BOD, phosphate, nitrite and nitrate. Analyses were carried out as per standard methods[7].

Zooplankton samples were collected using a Heron Tranter net (mesh size 0.3 mm, mouth area 0.25 m^2) with an attached calibrated TSK flow meter. During sampling guidelines suggested by Bernhard[8] were strictly followed to avoid contamination. Samples were kept in polyethylene bags and kept in an ice box and carried to the laboratory. In the laboratory the sample was thawed and the volume was estimated by displacement method and 50% of the sample was preserved for population count. The remaining 50% was seggregated into four groups depending mainly on the feeding habits: (i) Gelatinous organisms - included chaetognaths, medusae, and ctenophores representing the exclusive carnivores, (ii) Copepods: the dominant fraction of zooplankton constituted mostly by herbivores. Predator copepods of the families Oncaeidae, Corycaeidae and Pontellidae formed only a negligible fraction and were not included. (iii) Decapods-representing the omnivore/detritus feeders (iv) Miscellaneous group included gastropods, bivalve larvae, isopods, cladocerans, copelates, cirripede larvae, amphipods and mysids. These groups individually contributed a negligible part of total zooplankton to be considered separately.

The four groups of zooplankton were dried separately at 70°C to a constant weight, powdered and stored. The dried samples (1-2 g) were digested in conc. HNO_3 (15-25 ml) followed by concentrated perchloric acid until a clear solution was obtained. The volume of the sample solution was made up to 10 ml with milli 'Q' water. The entire method of preparation of tissue and analyses were done as per standard method[9]. Blanks were maintained along with the samples. The digested samples were examined for copper, zinc, cadmium, lead and nickel using an atomic absorption spectrophotometer model GBC 1000. Copper and zinc were determined by direct aspiration using an air-acetylene flame whereas, cadmium, lead and nickel were determined by a graphite furnace model GF 902. Along with the samples, sample of copepod tissue samples supplied by the International Laboratory of Marine Radioactivity (I.A.E.A) of Monaco was also analysed and the results were in good agreement with the results given by IAEA (error ± 5%).

Results

Temperature variations showed marginal difference between stations (Table 1). Though salinity at the interior segment (sts. 2 and 3) was very low during the peak monsoon period (July-August) on an average it showed only a difference of 6-12‰ compared to the outer locations. Relatively lower level of DO and higher level of BOD were noticed at stations 2 and 3. Concentrations of phosphates, nitrite and nitrate were unusually high inside the creek due to wastewater input[2, 10].

Along Thane sector at st. 1 zooplankton standing stock showed peak in October (Table 2) with an

Table 1—Range and average values of selected water quality parameters at different stations. (Averages given in parentheses)

Temperature (°C)	Salinity (‰)	*p*H	DO (mg/l)	BOD (mg/l)	Phosphate (µg at/l)	Nitrite (µg at/l)	Nitrate (µg at/l)
			Station 1				
21.0-30.0	26.9-37.5	7.6-8.2	4.9-8.6	0.5-4.1	0.2-4.1	0.1-2.5	1.3-23.9
(27.2)	(35.1)	(7.9)	(6.8)	(1.7)	(2.2)	(1.3)	(10.9)
			Station 2				
21.0-32.0	6.7-38.0	7.5-8.2	1.4-6.4	1.4-4.9	5.3-14.8	4.9-31.9	7.9-37.6
(28.0)	(29.5)	(7.8)	(4.1)	(2.4)	(9.1)	(11.8)	(25.1)
			Station 3				
22.0-32.0	2.0-32.9	7.5-8.2	5.2-8.9	0.6-4.7	0.6-5.4	0.1-2.7	15.6-77.0
(27.8)	(22.4)	(7.8)	(6.5)	(2.3)	(3.8)	(1.1)	(50.7)
			Station 4				
22.0-32.0	15.3-36.8	7.7-8.3	5.1-9.1	0.8-4.2	1.0-2.4	0.1-1.4	7.0-28.6
(27.4)	(34.2)	(8.0)	(7.5)	(2.1)	(0.8)	(0.3)	(13.8)

annual average biomass of 0.2 ml/m^3 and population of 1180/m^3. Copepod predominated the zooplankton community (78%) followed by decapods (14%) and gelatinous groups (2%). Compared to st. 1 zooplankton biomass (av. 1.2 ml/m^3) and population (av. 5180/m^3) were high at st. 2 with peak production in July. The average percentage contribution at this location for gelatinous groups, copepods and decapods were respectively 7, 83 and 6.

An overall decrease in zooplankton biomass and population was observed along Bassein sector. At st. 3 peak in zooplankton synchronised with that of st. 2. Average zooplankton biomass at st. 3 was 0.1 ml/m^3 while population was 1226/m^3. Percentage contribution of gelatinous group, copepods and decapods were respectively 8, 79 and 3. At st. 4 maximum standing stock was observed in October with comparable averages for biomass (0.1 ml/m^3) and population (1064/m^3). Gelatinous groups on an average contributed 4% while copepod and decapods formed respectively 76% and 9% of the total community.

Concentrations of metals indicated wide variation in all groups at different stations (Tables 3-6). The values are given as ppm dry wt. The levels of Cd, Pb and Ni were at low level in different groups at all stations while Cu and Zn were at high concentrations. At st. 1 average concentration of Cu was maximum in miscellaneous group (av. 137 ppm) followed by decapods (av. 116 ppm), gelatinous organisms (74 ppm) and copepods (65 ppm). Concentration of Zn was higher than Cu and the respective average values in gelatinous groups, copepods, decapods and miscellaneous groups were 709, 626, 486 and 501 ppm. In general, premonsoon period (February-May) indicated higher concentration of both the metals. At st. 2 concentrations of Cu was relatively more in some groups. Mean concentration of Cu, in gelatinous group, copepods, decapods and miscellaneous groups were respectively 83, 74, 89 and 72 ppm. Maximum level of Zn was in gelatinous group (av. 1810 ppm) followed by copepods (av. 1380 ppm), miscellaneous groups (1183 ppm) and decapods (868 ppm). For Cu seasonal variation did not indicate a set pattern while for Zn relatively higher concentration was observed during the premonsoon period in all the groups.

Along the Bassein segment at st. 3 Cu in gelatinous group was maximum (av. 152 ppm) among the four groups. The average concentration of Cu in the remaining groups were comparable with 94 ppm in copepods, 96 ppm in decapods and 97 ppm in miscellaneous groups. Seasonal variation in the levels of Cu did not show a consistant pattern. Average concentration of Zn in gelatinous group was 876 ppm while that in copepods, decapods and miscellaneous groups were respectively 931, 886 and 459 ppm. Seasonal variation did not indicate a regular pattern. At st. 4 average levels of Cu in gelatinous organisms, copepods, decapods and miscellaneous groups were respectively 125, 94, 96 and 104 ppm. Concentrations of Zn in the same order were 997, 615, 619 and 708 ppm. Seasonally Cu was at higher concentration in all groups during monsoon period while levels of Zn did not show any constant pattern.

Discussion

There was distinct difference in zooplankton standing stock and community structure between the nearshore and creek environment. Zooplankton peak in the nearshore waters was observed during October while that of the creek was in July. Copepods as the major herbivore community maintained almost equal contribution at all the stations. Population density of decapods showed wide variation with 2.5 to 3 times more concentrations in the nearshore than the creek stations. Gelatinous groups showed 2 to 3.5 times higher contribution within the creek. Relatively high biomass of the predator community was observed after a time lag of 2-4 months.

The interior parts of Thana and Bassein creeks were reported to be polluted[2, 10]. The observed water quality (Table 1) also indicated unfavourable conditions due to wastewater release from the Thane-Belapur-Kalyan industrial belt at the vicinity of the creek locations. The peak in zooplankton production in the creek was during the monsoon period (July) probably associated with reduced stress on account of improved water quality.

In an ecosystem which experiences stress all the groups are unable to withstand changes which affects mainly the herbivores/omnivores. The predators appear to be more tolerant and often maintain relatively high incidence for a longer period as observed in st. 3 during March to August (Table 2). These predators (gelatinous groups) though high in standing stock will not contribute significantly to the secondary production.

Wide fluctuation in the concentration of metals in different groups of zooplankton was observed. This

Table 2—Zooplankton biomass (ml/m^3), population (no/m^3 in parentheses) and percentage contribution of different groups at various stations during 1986

Months	Stations											
	St. 1			St. 2			St. 3			St. 4		
	B/P		%	B/P		%	B/P		%	B/P		%
Jan	0.06	G	0.75	1.26	G	1.37	0.05	G	1.22	0.49	G	0.98
	(832)	C	97.46	(9502)	C	97.72	(542)	C	97.60	(5161)	C	96.90
		D	1.37		D	0.56		D	0.25		D	0.32
		M	0.42		M	0.35		M	0.93		M	1.80
Feb	0.64	G	0.88	1.09	G	18.23	0.25	G	3.21	0.09	G	3.58
	(6971)	C	96.42	(1940)	C	66.75	(1113)	C	92.55	(630)	C	89.08
		D	0.56		D	5.79		D	2.14		D	3.75
		M	2.14		M	9.23		M	2.10		M	3.59
Mar	0.05	G	2.41	0.67	G	3.61	0.14	G	24.77	0.11	G	4.22
	(122)	C	84.80	(2390)	C	87.43	(383)	C	64.05	(720)	C	91.32
		D	8.77		D	8.34		D	0.34		D	2.04
		M	4.02		M	0.62		M	10.84		M	2.42
Apr	0.07	G	1.96	0.03	G	0.10	0.22	G	10.51	0.07	G	5.21
	(446)	C	43.68	(61)	C	92.27	(257)	C	70.90	(424)	C	37.94
		D	45.24		D	6.84		D	1.89		D	7.14
		M	9.12		M	0.79		M	16.70		M	49.71
May	0.04	G	2.12	0.17	G	0.56	0.19	G	7.81	0.19	G	4.37
	(482)	C	88.90	(423)	C	97.48	(399)	C	44.09	(296)	C	90.25
		D	7.99		D	1.18		D	0.42		D	0.70
		M	0.99		M	0.78		M	47.68		M	4.68
Jun	0.02	G	5.54	0.04	G	16.8	0.07	G	16.60	0.02	G	3.34
	(106)	C	47.20	(327)	C	36.53	(34)	C	53.33	(201)	C	87.94
		D	38.43		D	32.27		D	2.39		D	6.69
		M	8.83		M	14.4		M	27.68		M	2.03

B = Biomass, P = Population, G = Gelatinous group, C = Copepods, D = Decapods and M = Miscellaneous group.

Contd—

Table 2—Zooplankton biomass (ml/m^3), population (no/m^3 in parentheses) and percentage contribution of different groups at various stations during 1986—*Contd*

Months	Stations											
	St. 1			St. 2			St. 3			St. 4		
	B/P		%	B/P		%	B/P		%	B/P		%
Jul	0.78	G	1.75	4.79	G	0.62	0.49	G	0.10	-		
	(964)	C	75.20	(36693)	C	98.39	(10184)	C	99.45			
		D	10.56		D	0.86		D	0.28			
		M	12.49		M	0.13		M	0.20			
Aug	0.02	G	1.42	0.02	G	2.99	0.03	G	23.27	0.09	G	15.46
	(67)	C	50.86	(65)	C	74.96	(109)	C	64.03	(962)	C	9.40
		D	35.32		D	11.53		D	10.89		D	45.64
		M	12.40		M	10.52		M	1.81		M	29.40
Sep	0.12	G	1.13	0.43	G	2.07	0.01	G	3.31	0.05	G	2.05
	(520)	C	84.43	(1538)	C	96.46	(284)	C	89.62	(1033)	C	91.08
		D	10.59		D	1.33		D	5.84		D	1.87
		M	3.85		M	0.14		M	1.23		M	5.00
Oct	1.29	G	11.2	0.26	G	7.93	0.29	G	2.52	0.85	G	0.63
	(797)	C	66.36	(104)	C	73.06	(3061)	C	85.07	(9880)	C	97.70
		D	20.70		D	17.22		D	11.66		D	0.51
		M	1.74		M	1.79		M	0.75		M	1.16
Nov	0.23	G	4.68	1.59	G	25.39	0.04	G	1.37	0.04	G	2.61
	(586)	C	86.04	(454)	C	68.61	(210)	C	92.47	(333)	C	81.92
		D	6.00		D	4.83		D	0.96		D	5.40
		M	3.28		M	1.17		M	5.20		M	10.07
Dec	0.25	G	0.43	1.28	G	1.30	0.05	G	0.34	0.03	G	0.96
	(1938)	C	95.65	(4077)	C	96.00	(706)	C	88.83	(537)	C	89.39
		D	2.49		D	2.66		D	5.03		D	8.49
		M	1.43		M	0.04		M	5.80		M	1.16

B = Biomass, P = Population, G = Gelatinous group, C = Copepods, D = Decapods and M = Miscellaneous group.

Table 3—Variation in the concentration of selected metals (ppm dry wt) in gelatinous organisms (G), copepods (C), decapodes (D) and miscellaneous group (M) from station 1 during 1986-87

Months	Copper				Zinc				Cadmium				Lead				Nickel			
	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M
Jan '86	61.1	98.6	18.6	97.7	721.0	500.1	412.2	423.8	0.2	0.5	0.6	0.01	2.4	2.5	6.0	8.0	5.2	4.9	10.6	3.8
Feb	192.1	41.6	145.7	195.0	545.0	705.7	456.8	450.9	6.2	0.6	2.2	0.2	1.4	4.3	5.3	1.8	3.4	0.7	2.0	2.1
Mar	51.1	102.4	121.4	171.0	856.0	568.8	564.9	462.1	0.1	0.1	0.5	0.4	2.2	1.5	9.4	1.2	0.9	0.9	1.6	6.2
Apr	62.7	108.7	36.1	185.2	891.0	918.0	700.8	591.8	0.09	0.04	0.09	0.1	1.9	3.4	7.4	1.4	10.4	1.4	1.3	8.9
May	132.5	100.8	180.0	181.5	800.0	799.8	604.4	612.4	6.8	0.3	1.1	4.9	1.6	1.5	1.5	1.5	9.2	3.0	10.1	37.9
Jun	101.9	72.4	178.7	102.9	771.9	628.9	658.2	556.2	5.3	0.2	0.9	7.6	2.4	4.3	4.3	6.2	5.6	3.3	7.2	28.9
Jul	66.0	55.8	54.4	100.0	701.6	526.1	582.6	572.4	1.1	0.5	0.6	2.8	2.2	5.9	8.9	5.0	4.2	2.8	2.7	11.9
Aug	72.9	52.2	162.7	105.9	652.7	891.7	417.8	621.8	2.3	0.7	0.7	2.9	5.6	6.5	8.4	7.2	5.2	1.8	2.0	10.2
Sep	41.2	47.1	141.2	110.4	455.2	914.6	468.2	504.3	1.7	0.7	0.6	9.8	7.2	8.1	7.2	3.4	4.3	0.9	2.0	40.6
Oct	13.4	50.8	135.2	234.0	981.4	416.7	386.9	532.1	0.2	0.8	1.8	3.0	6.2	1.2	3.0	6.8	1.9	5.0	3.9	40.9
Nov	26.1	40.9	153.3	125.9	657.2	330.8	286.8	542.1	0.4	0.9	0.8	1.2	7.2	8.0	10.2	11.5	2.1	5.7	4.3	10.9
Dec	17.6	28.3	162.1	117.4	756.1	280.5	268.4	315.1	0.5	0.9	0.8	1.0	6.5	7.6	9.1	10.2	1.2	4.5	3.4	20.9
Jan '87	45.3	85.6	15.2	90.7	568.0	615.9	426.8	400.4	0.4	0.6	0.7	0.1	4.2	5.2	7.0	9.8	6.5	5.4	6.7	8.6
Feb	150.4	25.6	120.7	100.4	570.1	672.8	564.4	426.4	7.10	0.7	1.0	0.5	4.1	3.4	5.4	8.9	4.3	1.9	7.2	9.5
Mean	73.8	65.0	116.0	137.0	709.0	626.4	485.6	500.8	2.3	0.5	0.9	2.4	3.9	4.5	6.6	5.9	4.6	3.0	4.6	17.2
SEM	14.0	7.7	15.8	12.4	39.2	55.3	35.0	24.1	0.7	0.07	0.1	0.8	0.5	0.6	0.6	0.9	0.7	0.4	0.8	3.7

SEM - Standard error of mean

Table 4—Variation in the concentration of selected metals (ppm dry wt) in gelatinous organisms (G), copepods (C), decapodes (D) and miscellaneous group (M) from station 2 during 1986-87

Months	Copper				Zinc				Cadmium				Lead				Nickel			
	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M
Jan '86	54.6	61.1	55.0	ND	2645	2026	1112.5	1335	0.5	0.9	0.7	0.3	1.3	1.8	5.3	8.4	5.7	7.1	6.5	29.6
Feb	12.6	94.2	100.7	54.5	2515	1819	1012.5	1255	0.05	0.07	0.1	0.9	2.8	1.6	2.1	3.1	2.8	1.9	1.9	10.5
Mar	26.0	12.9	4.7	42.7	2413	1646	965.4	1415	0.5	0.7	0.08	0.6	2.2	1.5	1.8	9.3	3.8	2.9	1.1	15.3
Apr	30.2	46.1	156.4	61.4	2242	1242	891.3	1265	0.9	0.8	0.3	0.7	5.2	2.6	3.1	7.2	4.3	3.2	2.9	9.6
May	60.4	82.7	48.9	32.3	2016	1011	765.1	1356	0.8	0.05	0.06	1.1	4.2	0.6	0.9	4.7	3.6	1.2	0.7	6.9
Jun	72.2	68.2	84.1	101.3	2042	1216	675.2	1416	0.5	0.04	0.08	1.2	7.6	2.1	1.1	3.6	2.1	4.3	7.5	14.3
Jul	39.8	36.0	22.1	38.2	1841	1173	900.2	1106	0.2	0.08	0.05	0.2	4.9	1.2	0.8	4.2	1.3	0.9	0.5	1.2
Aug	146.6	150.4	148.0	92.6	2062	1341	871.4	1058	4.5	1.2	2.3	6.5	8.1	4.3	1.2	5.6	8.4	3.4	4.0	5.8
Sep	100.9	75.4	210.8	156.4	1455	1462	701.5	965	3.2	1.0	1.1	5.6	3.2	3.4	3.1	2.3	10.3	2.1	9.7	42.8
Oct	231.5	100.6	19.0	175.0	1642	1058	565.4	1028	2.6	0.1	0.3	9.7	6.5	1.6	4.6	8.6	6.4	4.3	1.4	62.6
Nov	206.2	59.3	10.8	105.7	1214	1181	501.8	991	0.6	0.1	0.3	6.6	8.3	1.3	5.8	10.2	1.8	5.2	2.6	50.3
Dec	95.4	62.5	156.2	45.9	1046	1417	521.4	1001	0.7	0.2	0.4	5.3	4.8	1.2	1.1	9.8	2.1	4.3	6.2	45.5
Jan '87	62.8	75.8	78.5	63.2	1162	1319	1414	1253	0.6	0.7	0.9	5.6	2.5	2.1	6.4	8.0	6.5	6.1	5.6	35.1
Feb	30.5	106.7	145.3	45.5	1042	1413	1256	1121	0.09	0.01	0.4	6.1	3.2	1.9	4.2	4.1	3.2	2.0	3.1	16.1
Mean	83.5	73.7	88.6	72.4	1809.7	1380.2	868.1	1183.2	1.1	0.5	0.5	3.6	4.6	1.9	2.9	6.3	4.4	3.4	3.8	24.6
SEM	18.0	8.9	17.5	13.0	148.4	76.4	72.7	43.5	0.3	0.1	0.1	0.8	0.6	0.2	0.5	0.7	0.7	0.4	0.7	5.1

SEM - Standard error of mean

Table 5—Variatioin in the concentration of selected metals (ppm dry wt) in gelatinous organisms (G), copepods (C), decapodes (D) and miscellaneous group (M) from station 3 during 1986-87

Months	Copper				Zinc				Cadmium				Lead				Nickel			
	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M
Jan '86	95.0	153.4	118.0	41.2	986	756	1073	562	0.1	0.1	0.8	0.4	2.8	1.3	6.6	2.7	2.8	3.0	4.0	7.3
Feb	81.9	67.5	40.9	8.0	725	819	1179	656	0.09	0.1	0.2	0.01	4.4	1.6	2.1	6.9	2.0	1.7	1.1	3.4
Mar	98.6	95.9	87.5	118.9	892	975	1146	400	0.4	0.2	0.4	0.2	3.4	0.6	1.2	0.9	3.0	1.7	2.7	2.8
Apr	156.2	159.2	211.1	109.8	1062	1089	1092	552	0.1	0.1	0.2	0.2	5.8	1.5	1.9	1.1	5.9	1.9	2.8	3.4
May	172.8	101.6	168.2	90.8	1156	1099	1157	631	0.9	0.05	0.1	0.5	7.1	0.6	2.8	3.0	6.2	1.2	1.9	3.7
Jun	201.9	108.6	128.4	56.8	1098	1125	792	431	1.1	0.8	0.9	0.9	8.9	0.9	2.5	4.1	15.8	1.6	5.6	2.9
Jul	222.1	115.1	142.8	55.3	765	1346	865	491	5.2	0.1	5.1	1.2	4.1	2.0	3.4	2.0	14.2	1.5	7.7	3.2
Aug	172.0	101.6	156.2	185.2	1221	1372	1056	358	6.4	1.2	4.3	2.6	3.9	0.8	5.6	5.1	16.8	4.1	3.4	3.9
Sep	156.8	92.8	48.9	191.8	975	1042	971	331	4.2	0.9	3.2	0.8	6.4	2.0	4.3	4.3	13.2	5.0	7.2	4.1
Oct	265.7	31.7	24.5	150.0	462	965	762	429	3.4	0.9	0.3	3.4	6.1	2.7	3.2	6.9	14.6	3.0	0.1	7.9
Nov	215.9	57.8	27.1	126.8	878	646	651	296	5.2	1.1	1.1	2.3	5.8	2.5	1.2	5.9	9.6	0.9	9.1	6.8
Dec	100.8	62.7	42.8	92.9	652	432	549	208	6.8	1.1	2.8	1.8	9.5	1.9	2.6	4.3	8.5	4.2	3.2	5.3
Jan '87	99.1	58.9	98.2	84.5	869	576	326	500	1.1	0.5	1.8	0.5	3.2	3.1	5.7	3.7	3.2	3.0	5.0	3.7
Feb	87.4	108.8	48.4	50.1	527	791	789	582	0.9	0.2	1.1	0.1	4.7	4.1	3.2	3.9	5.85	4.1	4.1	4.3
Mean	151.8	93.9	95.9	97.2	876.2	930.9	886.2	459.0	2.5	0.5	1.6	1.0	5.4	1.8	3.3	3.9	8.6	2.6	4.1	4.4
SEM	15.8	9.6	15.9	14.4	61.2	73.8	68.6	35.3	0.6	0.1	0.4	0.2	0.5	0.2	0.4	0.5	1.4	0.3	0.6	0.4

SEM - Standard error of mean

Table 6—Variation in the concentration of selected metals (ppm dry wt) in gelatinous organisms (G), copepods (C), decapodes (D) and miscellaneous group (M) from station 4 during 1986-87

Months	Copper				Zinc				Cadmium				Lead				Nickel			
	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M	G	C	D	M
Jan '86	176.6	39.5	47.6	140.7	1126	952	604	599	0.4	0.5	1.0	0.8	3.1	1.1	2.3	3.1	7.1	5.1	5.8	7.5
Feb	90.0	100.1	47.8	50.4	1080	652	550	604	2.0	0.4	0.2	2.2	2.0	2.8	2.8	4.7	8.3	14.0	1.4	12.6
Mar	114.3	61.1	45.4	—	952	791	532	—	0.3	0.3	0.3	—	2.6	1.4	4.5	—	2.2	1.2	1.7	—
Apr	181.1	149.1	52.1	118.4	996	452	467	756	1.3	0.2	0.5	2.0	2.7	2.5	3.1	2.6	6.8	2.4	3.2	9.9
May	152.8	126.7	177.8	134.1	1052	616	792	827	1.8	0.3	0.7	1.6	3.6	8.2	2.3	2.0	5.6	2.3	2.5	7.3
Jun	148.6	119.2	153.9	159.4	1163	672	819	624	1.9	0.4	1.2	1.9	1.7	7.5	4.2	3.6	4.5	7.8	3.5	8.5
Jul	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug	164.2	138.2	123.4	147.0	992	531	641	432	1.6	0.8	0.8	3.3	2.6	6.2	3.5	3.9	5.9	2.4	2.6	9.5
Sep	153.1	126.9	133.2	110.7	823	426	513	237	1.9	1.1	0.9	1.5	3.7	5.7	5.6	2.5	6.7	4.6	4.9	5.8
Oct	70.2	65.4	97.1	53.8	862	331	316	862	0.5	0.1	4.2	0.6	9.1	1.1	7.2	1.1	4.0	1.7	8.8	0.2
Nov	50.2	45.2	100.1	62.1	875	452	648	892	2.1	0.9	1.5	3.4	6.5	4.2	6.5	2.7	7.8	9.6	10.1	1.8
Dec	55.3	54.9	105.9	75.9	652	468	718	1009	0.9	1.0	1.2	1.2	4.6	3.1	3.2	1.9	3.6	7.2	6.7	1.3
Jan '87	167.1	93.5	95.6	135.4	1001	762	672	792	0.5	0.7	0.8	0.7	1.3	2.1	3.2	1.3	8.1	4.3	8.5	5.7
Feb	106.9	98.6	74.5	63.2	992	891	775	862	1.6	0.9	0.7	1.2	4.2	1.8	3.2	1.5	10.1	12.4	4.3	6.2
Mean	125.4	93.7	96.4	104.2	966.6	615.0	619.0	708	1.3	0.6	1.1	1.7	3.6	3.6	3.9	2.5	6.2	5.7	4.9	6.3
SEM	12.5	9.9	11.4	10.8	36.7	51.4	38.3	58.3	0.1	0.08	0.2	0.2	0.5	0.6	0.4	0.2	0.5	1.1	0.7	0.9

SEM - Standard error of mean

can be attributed to the capacity of each group to concentrate a particular element by different means like direct uptake from seawater or assimilation of metals through ingested food. Probably the large surface to volume ratio of zooplankton leads to differences in the amount of accumulation through adsorption[11]. The concentration in different groups indicated that Cu in the gelatinous organisms and copepods from outer zone showed low values while decapods from the creek showed relatively high concentration. In all the groups Zn was consistantly at lower levels in the samples from outer zone. Cd showed only marginal variations similar to the earlier report[12]. Pb and Ni in gelatinous organisms and the miscellaneous groups showed lower values for outer zone while concentration in copepods and decapods indicated relatively higher levels at offshore than the creek areas. The concentration of Cu in copepods in the present study was about 4 times higher than the reported value from Thana creek[12].

The concentrations of all metals on an average basis was added up and this cumulative levels of different metals considered for the study (Cu, Zn, Cd, Pb, Ni) in any group should provide the status of contaminants at a given time. The calculated average values of total metals (ppm dry wt) in different groups of zooplankton are given in Table 7.

The creek (stations 2,3) showed higher concentration than the offshore stations. The prevailing pollution load within the creek system particularly at st. 2 might have contributed to the relatively higher concentration of metals in total zooplankton. The individual groups had concentrated metals in varying quantity and this can be attributed to the feeding habit and inherent elimination process of the organisms[13]. The maximum concentrations of metals was observed in gelatinous organisms which included a variety of carnivores and hence the level is expected to be relatively high. Metal concentration in copepods was low compared to gelatinous forms. Copepods of the area were constituted mostly by herbivores[2] and hence in the marine food chain they occupy the lower point of entry for pollutants. The lowest level of accumulation was found in decapods which includes mostly larval and juvenile stages. This can be attributed partly to the periodic moulting of the exoskeleton which effectively eliminates part of the concentrated metals or preferential accumulation of metals. Among the different metals estimated with the exception of Cu trace element concentration in

Table 7—Variation in cumulative levels of selected metals in different groups of zooplankton at stations 1 to 4

Zooplankton group	Stations			
	1	2	3	4
Total zooplankton	692	1404	908	842
Gelatinous forms	794	1903	1045	1103
Copepods	699	1460	1030	719
Decapods	614	964	991	725

moults of euphausiids were significantly higher than the corresponding levels in the whole individual[14]. It has been reported that Zn concentrations in shrimp were higher in dissected exoskeleton than in internal tissue[15].

Among the five metals, on an aggregate Cu and Zn alone concentrate 60 to 89.4% of the total elements accumulated. In general copepods, decapods and gelatinous organisms concentrate higher levels of Zn than Cu. While the decapods concentrated Cu to an almost comparable level at all stations (88-116 ppm dry wt), polluted stations indicated higher concentration of Zn to the order of 1.5 to 2 times than the outer zone. The Ulhas river, a tributory to Thane-Bassein system was reported to concentrate some metals including Cu and Zn to the order of 10 to 10^3 times higher compared to harbour water[16]. The possibility of the effect of Ulhas river water in building up the levels of metals within the Thane-Bassein creek cannot be ruled out. But Zn alone got accumulated more in crustaceans from the polluted area. Probably it is due to the functioning of a special mechanism in crustaceans which effectively controls the uptake and regulation of Cu and this need to be confirmed through further studies.

References

1 Nair V R, *Indian J Mar Sci*, 9 (1980) 116.

2 Lodh N M, *Ecological studies on plankton from nearshore waters of Bombay*, Ph.D. thesis, University of Bombay, India, 1989.

3 Gajbhiye S N, *The ecology of zooplankton with special reference to polluted environments off Bombay*, Ph.D. thesis, University of Bombay, India, 1982.

4 Gajbhiye S N & Desai B N, *Mahasagar - Bull Natl Inst Oceanogr*, 14 (1981) 173.

5 Gajbhiye S N, Nair V R & Desai B N, *Mahasagar - Bull Natl Inst Oceanogr*, 17 (1984) 203.

6 Nair V R & Govindan K, *National Seminar on Mussel watch*, University of Cochin, February 13-14, 1986, 86.

7 Strickland J D H & Parson T R, *A practical handbook of seawater analysis*, Bull No 167 (Fish Res Board Can, Ottawa) 1972, pp. 310.

8 Bernhard M, *FAO Fish Tech Paper* No.158 (1976) pp. 124.
9 APHA, *Standard methods for examination of water and wastewater*, (APHA, Washington DC) 1985, 689.
10 Krishnamurti A J, *Studies on selected metals in marine organisms from the coastal waters of Bombay*, Ph.D. thesis, University of Bombay, India, 1991.
11 Martin D F, *Marine chemistry*, Vol.2, (Marcel Dekker, Inc, New York), 1970, pp. 281.
12 Gajbhiye S N, Nair V R, Narvekar P V & Desai B N, *Indian J Mar Sci*, 14 (1985) 181.
13 Davies A G, *Adv. Mar. Biol.*, 15 (1978) 381.
14 Fowler S W, *Nature*, 269 (1977) 51.
15 Bertine K K & Goldberg E D, *Limnol Oceanogr*, 17 (1972) 877.
16 Patel B, Bangera V S, Patel S & Balani M C, *Mar Poll Bull*, 16 (1985) 22.