

## Zooplankton community of Bhayandar and Thane salt pans around Bombay

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The zooplankton community of the salt pans of Bhayandar and Thane was studied based on the contribution of microzooplankton and meso-macrozooplankton. Population of microzooplankton was about 4 times more in Bhayandar as compared to Thane salt pan. The protozoan ciliate *Fabrea salina* dominated the microzooplankton community. The meso-macrozooplankton standing stock was more at Thane (av 1.7g wet wt/m<sup>3</sup>) as compared to Bhayandar (av 1.4 g wet wt/m<sup>3</sup>). However, group diversity was more at Bhayandar. A reduction in group diversity to the order of 50% was observed from creek to crystallizer associated with high salinity regime. Copepods were the most abundant group at both the salt pans. Calanoids dominated the Bhayandar salt pan while cyclopoids were predominant at Thane. Decapods and mysids were common in the area. During the monsoon season mysids were dominant in the crystallizer and condenser of Thane. *Artemia* was observed only at Bhayandar. In general the salt pans sustain a fairly rich zooplankton standing stock with low diversity.

Salt pans are unique tide water impounded, enclosed ecosystems adjacent to creek environment. They are characteristically exposed to a wide range of environmental stress and perturbations manifest mainly through salinity changes. The ecosystem is simplified as the number of species in each trophic level is low. Though salt pans are used for production of salt through solar evaporation, such system can also be made useful for culturing marine organisms. Added to this some of the salt pans are good sources of *Artemia* cyst. Despite these attractive features, the ecology of salt pan ecosystem in India is yet to be studied in detail. This communication deals with the quantitative and qualitative variation of zooplankton in Bhayandar and Thane salt pans, two major salt works around Bombay.

Information on zooplankton from salt pans and lakes of India are limited. The available information on zooplankton from salt lakes of India was that of Baid<sup>1,2</sup> on *Artemia* and other arthropods from Sambar lake, Rajasthan. Sinha<sup>3</sup> and Jakher *et al.*<sup>4</sup> studied *Artemia* and other zooplankton from salt lakes of Rajasthan. The ecology of *Artemia* from salt pans around Bombay has been evaluated<sup>5,6</sup>. Study of Deshmukh<sup>7</sup> on faunal composition of salt pan ecosystem was restricted to Mulund salt-work. Rattan & Ansari<sup>8</sup> studied *Fabrea salina* from Bhayandar salt pans.

### Materials and Methods

The salt pans selected for the present study (Fig. 1)

are located at Bhayandar (19° 17' 42" N lat. and 72° 48' 42" E long) and Thane (19° 03' 36" N lat. and 72° 57' 33" E long). The enclosed space is divided in sequence into reservoirs, condensers and crystallizers. Salt-works are normally operational from postmonsoon to premonsoon period (October to May). During monsoon period (June - September) the entire area gets flooded. In the reservoir, water is taken directly from the adjacent creek during spring

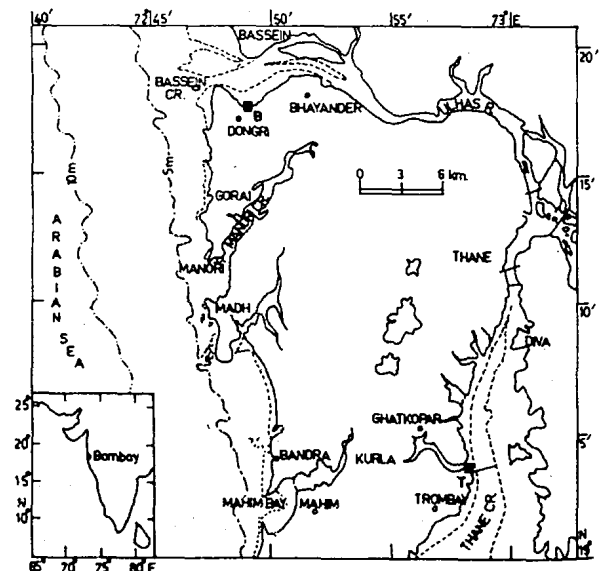


Fig. 1—Map showing location of Bhayandar (B) and Thane (T) salt pan

tide. Ten stations including the creeks spread over to Bhayandar (B1 - B5) and Thane (T1 - T5) were selected for the study. Station 1 indicates creek location, station 2 and 3 denote the locations of reservoirs and stations 4 and 5 respectively represent the condenser and crystallizer. Depth at creek stations varied from 1 - 2 m while that of reservoir was 0.9 - 1.3 m. Condenser and crystallizer are very shallow with a respective depth range of 30 - 40 and 8-12 cm.

Water samples from surface were collected using a clean polyethylene bucket for estimation of temperature, salinity, suspended solids, dissolved oxygen, phosphate, nitrite, nitrate and ammonia. For microzooplankton, water samples were collected in a 1 litre polyethylene bottle and preserved with Lugol's iodine solution and 4% formalin. Zooplankton samples were collected using a hand-net having a mouth area of 0.08<sup>2</sup> and mesh size of 0.1 mm fitted with a calibrated TSK flow meter. Hauls were made manually from one end to the other of the different sections of the salt pan.

Water samples for chemical parameters were analysed as per standard method of Strickland & Parson<sup>9</sup>. As salinity is high in salt pan, samples were diluted with distilled water as suggested by Ocean Scientific International Ltd, Surrey, U.K. who supplies the standard seawater which cannot be used for a salinity, more than 42‰. For enumeration of microzooplankton, the cells were allowed to settle by keeping the samples undisturbed for a week, concentrated the sample to 100 ml by siphoning out the supernatant solution and subsamples were taken for counting and identification using a Sedgwick Rafter chamber (capacity 1.0 ml). The copepod nauplii in the collection are not considered under microzooplankton as their counts are shown along with the copepods. Analysis of zooplankton was done as per standard procedures<sup>10</sup>. Zooplankton samples were preserved in 5% buffered formalin. Biomass of zooplankton was estimated as wet weight and expressed as g/m<sup>3</sup>. About 50% of the sample was analysed for common groups while the entire sample was considered for rare groups. Population density is given as no/m<sup>3</sup>.

## Results and Discussion

### Water quality

In the creek variation in water temperature was in accordance with the atmospheric temperature (Table 1). However, in the condensers and

crystallizers water temperature was high due to very shallow water column. Salinity steadily increased from the creek (av 26.1‰) to the crystallizer (av 149.6‰) indicating about 6 times increase in salinity. The pH is slightly lower in the crystallizer but suspended solids were high. DO level was often less than 2 mg/l in the salt pan with lowest values confined to the crystallizer. Compared to the creek the levels of nutrients were low in the salt pans. The trend in the distribution of various water quality parameters in Bhayandar and Thane salt pans indicated marginal difference between the two systems<sup>11</sup>.

### Microzooplankton

There was wide variation in microzooplankton at Bhayandar with increase in population from sts B2 to B5 (Table 2). The respective mean populations (no/l) at sts B2 to B5 were 357, 624, 5895 and 4063/l. Seasonally microzooplankton population at sts B2 and B3 were maximum during premonsoon period and for postmonsoon period at sts B4 and B5. During monsoon period microzooplankton were rare in the area.

Variation in microzooplankton at Thane salt pan showed a reverse trend compared to Bhayandar salt pan (Table 3). The mean population was maximum at st. T2 (1441 no/l) with decrease in number from st. T3 (660 no/l) to st. 4 (111 no/l). At st. T5 mean population was 375 no/l. On an average microzooplankton population was about 4 times less in Thane as compared to Bhayandar salt pan. Seasonally microzooplankton population was maximum at sts T2 and T3 during monsoon period. Stations T4 and T3 sustained maximum density of microzooplankton respectively during postmonsoon and premonsoon seasons.

The microzooplankton community was mainly comprised of protozoans, rotifers and tintinids. Protozoans dominated the total population as normally observed in hypersaline salt lake<sup>12</sup>. The total microzooplankton density at Bhayandar (av 2735 no/l) was 3.7 times more as compared to Thane (av 730 no/l). The protozoan ciliate *Fabrea salina* dominated the community and contributed on an average 99 and 82% respectively to Bhayandar and Thane salt pans. *Fabrea salina* from Bhayandar was earlier reported as a new source of live food due to its high abundance<sup>8</sup>. Other microzooplankton observed were *Brachionus* and tintinids.

### Meso and macrozooplankton

Zooplankton biomass at the Bhayandar creek

Table 1—Different water quality parameters in Bhayandar and Thane Salt pan (Range and average in parentheses).

Parameter	Bhayandar					Thane				
	St.B1	St.B2	St.B3	St.B4	St.B5	St.T1	St.T2	St.T3	St.T4	St.T5
Air temp (°C)	24.7-36.5 (28.8)	24.0-37.0 (29.2)	24.0-37.0 (29.3)	25.0-37.0 (29.5)	24.5-37.0 (29.3)	22.5-35.5 (29.6)	18.9-36.0 (29.3)	19.2-36.0 (29.3)	21.0-35.5 (29.3)	21.9-35.0 (29.5)
Water temp (°C)	23.5-37.0 (28.9)	23.2-39.0 (28.9)	24.0-39.5 (29.0)	24.9-43.0 (30.6)	25.0-44.5 (31.9)	22.0-34.0 (29.2)	20.0-38.0 (28.4)	20.1-37.0 (30.9)	21.5-42.0 (31.5)	22.0-43.0 (32.8)
pH	7.0-8.4 (7.8)	7.7-8.7 (8.2)	7.8-8.6 (8.2)	7.6-8.5 (8.1)	6.9-8.4 (7.9)	7.5-8.4 (7.8)	7.1-8.9 (8.2)	7.6-9.3 (8.3)	7.6-9.3 (8.3)	7.0-9.4 (7.4)
Salinity (‰)	0.9-36.1 (22.9)	7.2-71.5 (37.7)	7.2-63.6 (38.8)	8.8-178.5 (80.1)	8.5-360.7 (133.3)	11.2-38.2 (29.3)	7.5-99.1 (50.2)	3.3-183.4 (65.1)	4.0-220.6 (98.1)	3.3-344.6 (165.9)
Suspended solids (mg/l)	113-598 (356)	52-482 (257)	61-485 (218)	144-784 (398)	149-6220 (964)	77-1075 (337)	118-739 (339)	48-1740 (385)	112-2881 (593)	90-7101 (1084)
Diss O <sub>2</sub> (mg/l)	3.2-6.9 (5.1)	1.7-8.7 (5.6)	2.2-6.8 (5.2)	1.9-7.7 (4.2)	0.6-6.5 (3.5)	3.2-6.2 (4.8)	2.2-10.9 (6.4)	2.5-9.6 (6.2)	1.6-12.0 (5.0)	1.4-9.6 (4.6)
PO <sub>4</sub> -P (µg-at/l)	1.2-30.1 (6.4)	0.1-4.8 (1.6)	0.1-8.9 (2.4)	0.1-14.4 (2.7)	0.2-17.7 (3.8)	1.3-12.5 (6.9)	0.5-6.0 (1.8)	0.2-9.3 (1.6)	0.2-7.6 (1.9)	0.1-9.2 (1.6)
NO <sub>3</sub> -N (µg-at/l)	0.2-54.5 (25.4)	1.1-39.0 (11.5)	0.3-44.1 (12.1)	0.2-28.0 (5.6)	0.1-28.9 (6.6)	1.9-66.3 (23.2)	0.3-18.5 (6.9)	0.5-10.8 (4.1)	0.3-15.3 (4.2)	0.4-43.7 (11.0)
NO <sub>2</sub> -N (µg-at/l)	0.1-4.4 (2.0)	0.1-11.6 (1.3)	0.1-11.7 (1.4)	0.1-8.4 (0.9)	0.1-6.8 (1.2)	0.6-19.6 (7.9)	0.1-7.1 (1.4)	0.1-6.3 (1.0)	0.1-11.3 (1.8)	0.2-17.4 (2.9)
NH <sub>3</sub> -N (µg-at/l)	0.1-20.1 (4.2)	0.2-16.0 (3.7)	0.2-9.9 (2.2)	0.2-8.5 (2.6)	0.1-16.1 (2.8)	0.1-31.4 (10.2)	0.1-20.7 (6.0)	0.1-39.3 (6.3)	0.1-20.4 (4.9)	0.1-20.4 (3.9)

Table 2—Distribution of microzooplankton at different stations in the Bhayandar salt pan (Values given are no/l and percentages in parentheses)

Species/group	May'91	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'92	Feb	Mar	Apr	May	Jun	Jul
Station B2															
<i>Fabrea salina</i>	—	—	—	—	—	—	125	—	—	370	130	4720	—	—	—
							(100.0)			(100.0)	(98.48)	(100.0)			
<i>Brachionus</i> sp	—	—	—	—	—	8	—	—	—	—	2	—	—	—	3
						(44.40)					(1.51)				(100.0)
Tintinids	—	—	—	—	—	10	—	—	—	—	—	—	—	—	—
						(55.60)									
Total	—	—	—	—	—	18	125	—	—	370	130	4720	—	—	3
Station B3															
<i>Fabrea salina</i>	—	—	—	—	—	—	—	—	144	—	144	—	9000	—	—
									(100.0)		(100.0)		(100.0)		
<i>Brachionus</i> sp	—	—	—	—	—	—	68	—	—	—	—	—	—	—	—
							(100.0)								
Total	—	—	—	—	—	—	68	—	144	—	144	—	9000	—	—
Station B4															
Foraminiferans	—	—	—	—	—	—	4	16	—	—	—	—	—	—	—
							(100.0)	(0.04)							
<i>Fabrea salina</i>	8400	384	—	—	—	18000	—	25827	6240	14400	—	15300	1800	—	—
	(100.0)	(100.0)				(100.0)		(99.96)	(100.0)	(100.0)		(100.0)	(100.0)		
<i>Brachionus</i> sp	—	—	38	—	—	15	—	—	—	—	—	—	—	—	7
			(100.0)			(100.0)									(100.0)
Total	8400	384	38	—	—	16015	4	25843	6240	14400	1	15300	1800	—	7
<i>Fabrea salina</i>	—	—	—	—	—	46200	1650	—	156	740	734	4800	—	—	—
						(100.0)	(100.0)		(100.0)	(100.0)	(100.0)	(100.0)			
<i>Brachionus</i> sp	—	—	40	—	—	—	—	—	—	—	—	—	—	—	8
Total	—	—	40	—	—	46200	1650	—	156	740	7344	4800	—	—	—

Table 3—Distribution of microzooplankton at different stations in the Thane salt pan\*  
(Values given are no/l and percentages in parentheses)

Species/group	May'91	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'92	Feb	Mar	Apr	May	Jun	Jul
Station T2															
<i>Fabrea salina</i>	1740 (99.77)	18000 (100.0)	—	—	—	—	—	—	178 (34.36)	25 (18.66)	3 (23.10)	2 (100.0)	1 (100.0)	1 (100.0)	—
<i>Brachionus</i> sp	4 (0.23)	—	—	—	—	—	—	1 (2.70)	340 (85.64)	109 (81.34)	10 (76.90)	—	—	—	—
Tintinids	—	—	911 (100.0)	223 (100.0)	—	2 (100.0)	—	36 (97.30)	—	—	—	—	—	—	42 (100.0)
Total	1744	18000	911	223	—	2	—	37	518	134	13	2	1	1	42
Station T3															
<i>Fabrea salina</i>	3240 (79.41)	1440 (100.0)	2140 (100.0)	—	—	36 (22.5)	—	—	—	1 (50.0)	9 (50.0)	33 (100.0)	2 (100.0)	7 (30.43)	—
<i>Brachionus</i> sp	841 (20.60)	—	—	1365 (100.0)	—	124 (77.5)	12 (100.0)	609 (100.0)	7 (100.0)	1 (50.0)	9 (50.0)	—	—	16 (69.57)	6 (100.0)
Total	4080	1440	2140	1365	—	160	12	609	7	2	18	33	2	23	6
Station T4															
<i>Fabrea salina</i>	28 (90.42)	2550 (100.0)	—	2 (100.0)	—	2500 (100.0)	700 (100.0)	—	7 (100.0)	50 (100.0)	800 (100.0)	13 (76.47)	1 (100.0)	3 (100.0)	—
<i>Brachionus</i> sp	3 (9.68)	—	—	—	—	—	—	—	—	—	—	4 (17.64)	—	—	—
Total	31	2550	—	2	—	2500	700	—	7	50	800	17	1	3	—
Station T5															
<i>Fabrea salina</i>	3584 (100.0)	—	—	—	—	85 (100.0)	—	187 (21.77)	26 (100.0)	45 (100.0)	515 (100.0)	3 (100.0)	—	140 (100.0)	—
<i>Brachionus</i> sp	—	—	100 (100.0)	140 (100.0)	—	—	32 (100.0)	672 (78.23)	—	—	—	—	—	—	67 (100.0)
Total	3584	—	100	140	—	85	32	859	26	45	515	3	—	140	67

(st. B1) ranged between 0.2 and 1.3 (av 0.6 g/m<sup>3</sup>). Population maximum synchronized with that of biomass (Fig. 2) and the mean population was 1869 no/m<sup>3</sup>. Seasonal variation indicated peak for biomass and population during postmonsoon period (av 0.7 g/m<sup>3</sup>; 2512 no/m<sup>3</sup>). In the reservoirs (sts B2 and B3) maximum biomass (av 5.8 g/m<sup>3</sup>) and population (av 180011 no/m<sup>3</sup>) was observed during the postmonsoon period. In the condenser (B4) and crystallizer (B5) maximum biomass and population were observed respectively during the premonsoon period and August. Population maximum did not synchronize with biomass. Average biomass for sts B2, B3, B4 and B5 were respectively 0.9, 1.2, 2.5, and 1.2 g/m<sup>3</sup> while the average population in the same order were 37830, 15558, 60515 and 9524 no/m<sup>3</sup>.

At Thane creek (st. T1) biomass and population varied respectively at a rate of <0.1 to 7.7 (av 1 g/m<sup>3</sup> and 29 to 87017 - (av 15589 no/m<sup>3</sup>) with peak during monsoon period (Fig. 3). In the reservoir (sts T2 and T3) maximum biomass (av 1.9 g/m<sup>3</sup>) and population (av 192530 no/m<sup>3</sup>) were for the monsoon period. At sts T4 (av 1.7 g/m<sup>3</sup>) and T5 (1.3 g/m<sup>3</sup>) zooplankton

biomass indicated comparable values with peak respectively during postmonsoon and monsoon period. Maximum population (av 527424 no/m<sup>3</sup>) was observed at st. T5.

The creek system of Thane sustained almost 2 to 8 times more zooplankton biomass (av 1 g/m<sup>3</sup>) and population (av 15590 no/m<sup>3</sup>) as compared to the biomass (av 0.6 g/m<sup>3</sup>) and population (av 1868 no/m<sup>3</sup>) at Bhayandar creek. Like the Thane creek, the salt pan also revealed higher zooplankton standing stock to the order of 5 especially in terms of population (av 151015 no/m<sup>3</sup>) as compared to Bhayandar (av 30857 no/m<sup>3</sup>). The respective average biomass at Bhayandar and Thane salt pans were 1.4 and 1.7 g wet wt/m<sup>3</sup>. In general, higher annual averages of zooplankton standing crop were observed in crystallizer (Bhayandar) and condenser (Thane).

Copepods formed the most dominant group at the creeks as well as salt pans (Figs 4 and 5). At Bhayandar, copepods dominated the zooplankton community in 70% of the collection whereas in Thane dominance was observed in more than 90% of the samples. At Bhayandar creek copepod density was

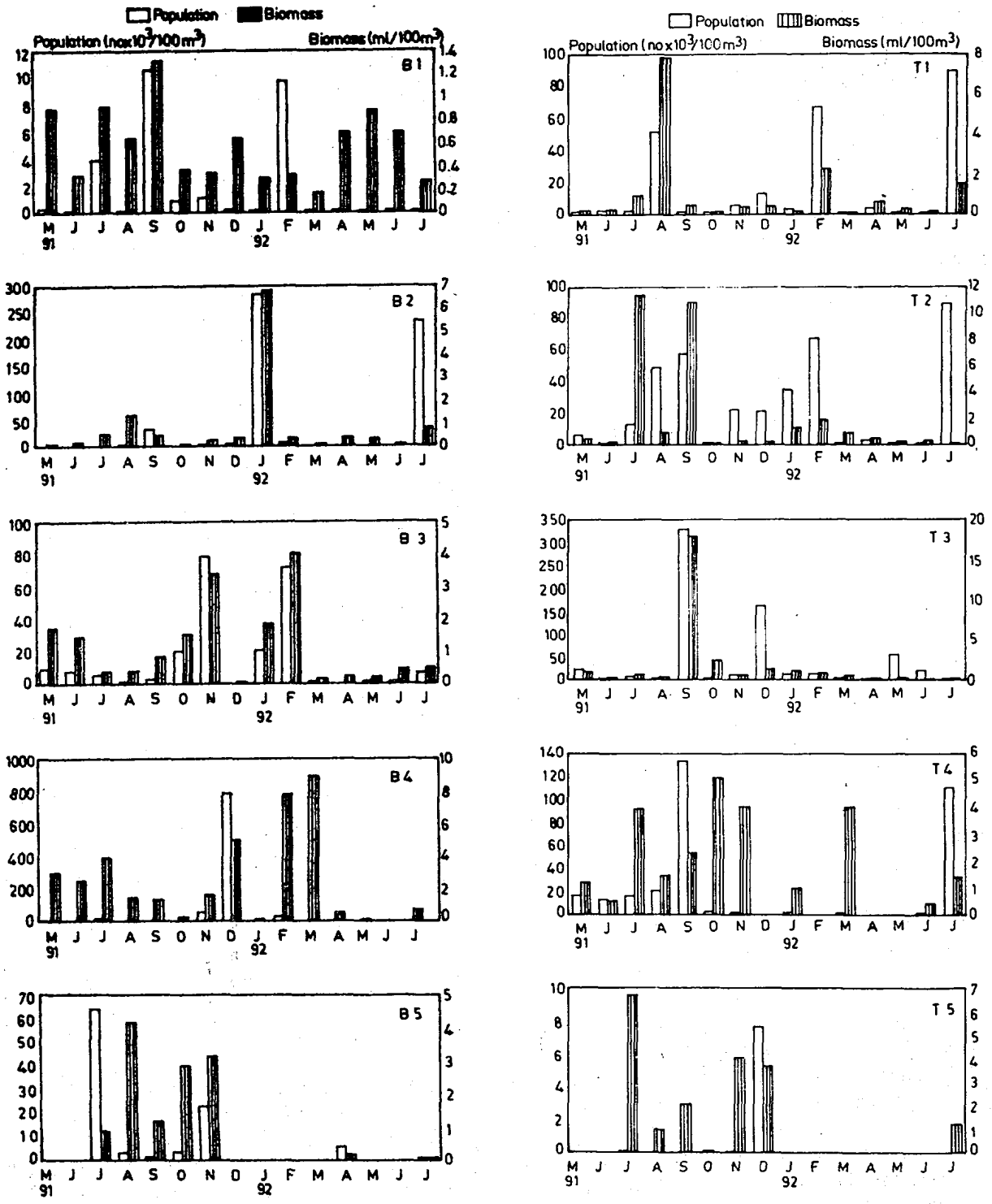


Fig.2—Total population and biomass at Bhayandar creek (B1), reservoir (B2, B3), condenser (B4) and crystallizer (B5)

Fig.3—Total population and biomass at Thane creek (T1) reservoir (T2, T3), condenser (T4) and crystallizer (T5)

much less (av 1760 no/m<sup>3</sup>) compared to the Thane creek (av 15249 no/m<sup>3</sup>). The mean population density of copepods in the reservoir, condenser and crystallizer in Bhayandar were respectively 26337, 200101 and 8847 no/m<sup>3</sup>. In Thane salt pan the average copepod population in the same order were 27887, 20992 and 526723 no/m<sup>3</sup>. In general, seasonally there was marginal difference in copepod population with respect to zooplankton population. The copepod population increased from creek to the salt pan by a factor of 1:17 and 1:10 respectively for Bhayandar and Thane. However, copepods were not found at crystallizer during premonsoon period due to prevailing high salinity regime. Copepods were mainly comprised of calanoids, cyclopoids and harpacticoids. In general, the salt pan system of Bhayandar was dominated by calanoides (39%) whereas at Thane system cyclopoids (81%) predominated.

Group diversity of zooplankton was relatively low in the reservoir, condenser and crystallizer compared to the creek area. Different groups found in the creek excluding copepods were medusae, ctenophores, polychaetes, mysids, isopods, amphipods, cypris larvae, decapod larvae, *Acetes*, gastropods, bivalves, chaetognaths, appendicularians and fish larvae. In the salt pan system medusae, ctenophores, appendicularians, isopods, cypris larvae and *Acetes* were conspicuously absent. Chaetognaths represented by the single species *Sagitta bedoti* were confined only in the reservoir. Maximum population was confined during the monsoon period with respective density of 80 and 3040 no/m<sup>3</sup> at Bhayandar and Thane salt pans. Fish eggs and larvae were rare in the area and were not observed in the condenser and crystallizer. *Artemia* was found only in the salt pans of Bhayandar (sts B4 and B5) during the premonsoon period and the population varied from 110 to 2050 no/m<sup>3</sup> contributing 49 - 91% of the total zooplankton community.

Mysids formed a very common group especially at sts 2 to 5 at Bhayandar as well as Thane systems. The group showed a discontinuous distribution. High abundance of the group was generally observed during the postmonsoon period at sts 2 and 3 while in monsoon season at sts 4 and 5. These aggregations were contributed mostly by juveniles and developing stages. The species can tolerate wide range of salinity from 3.3 to 129‰ while a narrower range of 72 to 97‰ was reported earlier<sup>7</sup>.

Molluscs represented by gastropods and bivalves

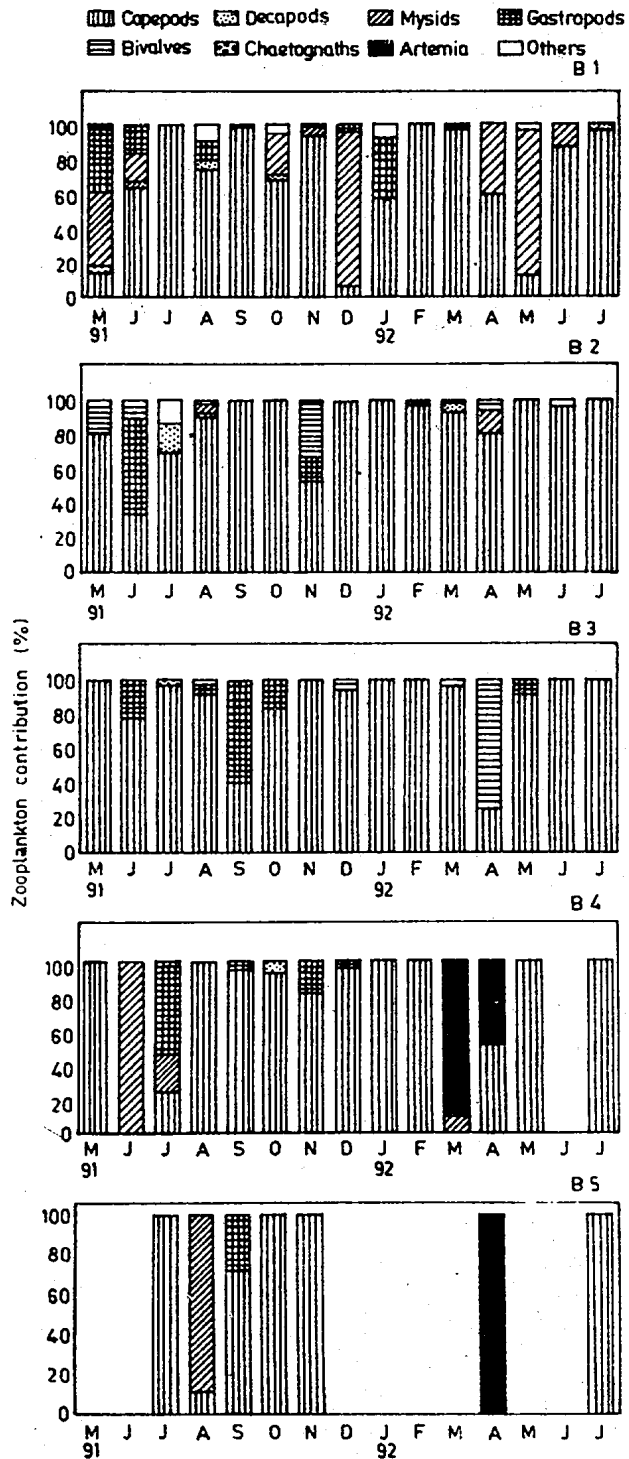


Fig.4—Percentage contribution of different groups of zooplankton at different stations in Bhayandar

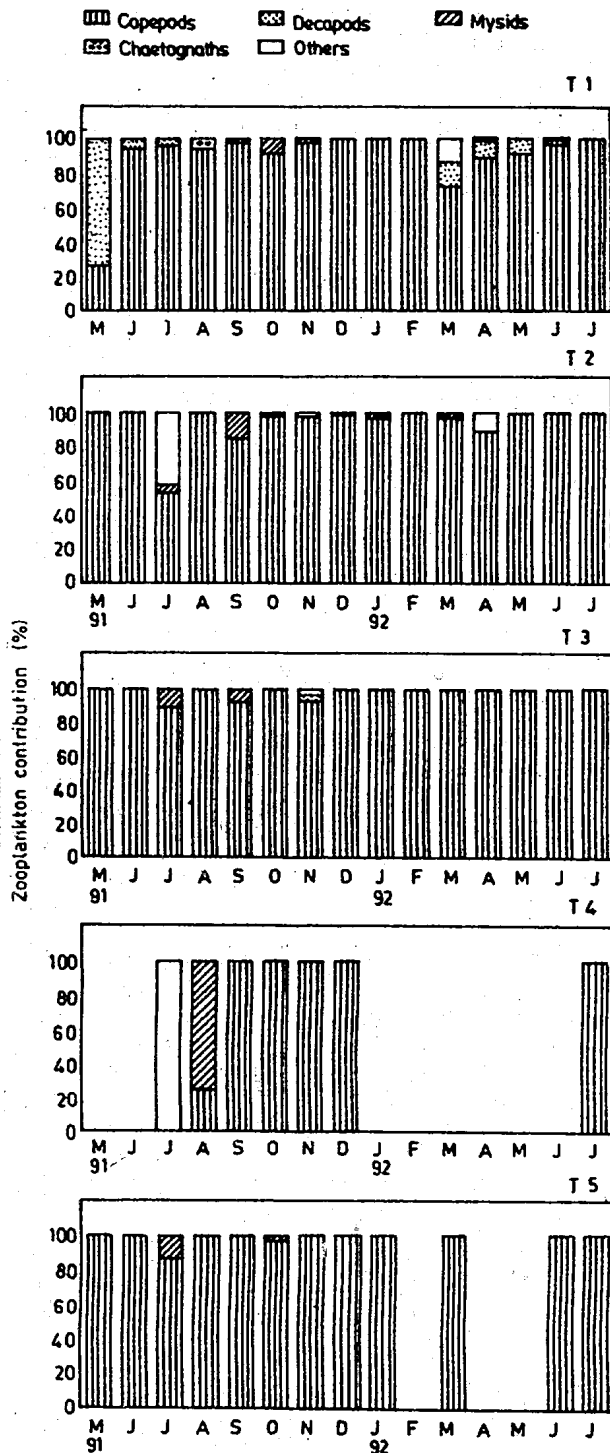


Fig.5—Percentage contribution of different groups of zooplankton at different stations in Thane

were fairly common in the salt pans. Gastropods showed relatively higher frequency of occurrence in the reservoir of Bhayandar than the other locations. Maximum density was observed at st. B4 (11192 no/m<sup>3</sup>; 58%) in November. Bivalves were less frequent compared to gastropods and were absent in the condenser and crystallizer. On a few occasions bivalves contributed 31 - 75% to the total zooplankton community (Fig. 4).

Decapod larvae, another common constituent of zooplankton were relatively more up to the reservoirs. The group was represented by larval stages of crabs (zoea and megalopa). Maximum population (97 no/m<sup>3</sup>) and contribution (16.7%) were recorded in July in the reservoir of Bhayandar. Polychaetes, cladocerans and amphipods were rare and found only during monsoon period and their distribution was limited to reservoir. Cladocerans, though rare when present formed aggregation to the extent of 5280 no/m<sup>2</sup> (42%).

Overall, zooplankton production potential of the salt pan ecosystem was fairly high. The study reveals the decrease in group diversity with enhancement in salinity from the creek to crystallizer. In general, the increase in salinity from reservoir to condenser to crystallizer was at a ratio of 1:2:3. The distribution limit of many groups were up to reservoir or to the monsoon period suggesting that the prevailing high salinity regime within the salt pan system is not congenial for all types of zooplankton. Probably the tolerant group thrives in aggregations due to limited competition resulting in relatively high population density of zooplankton in the condenser and crystallizer.

*Artemia* sp is characteristic of hypersaline water and is well adapted to salt pan ecosystem through its ability to osmoregulation, utilisation of oxygen at low level via haemoglobin and tolerance for a broad temperature range. It was observed that pH, nutrients and predominance of selective phytoplankton as food like *Dunaliella salina* were some of the important factors controlling the distribution of *Artemia* in a salt pan ecosystem<sup>11</sup>. Though these factors are comparable at Bhayandar and Thane *Artemia* was absent in Thane salt pan. It appears that the environmental stress caused by anthropogenic pollutants at Thane system<sup>13</sup> could be a major limiting factor for the presence of *Artemia*.

The overall water quality of the creeks and salt pans indicated sharp difference with enhanced levels of nutrients and dissolved oxygen in the creek

environment. The salt pan system was characterised by very high salinity, enhanced levels of temperature, pH and suspended load. Secondary productivity at Thane salt pan system was 1.2 times higher than that of Bhayandar system while group diversity was more at Bhayandar than Thane salt pan. Compared to the creek, the salt pans were 8-9 times more productive. Phytoplankton<sup>11</sup> and zooplankton characteristics of both the salt pans indicated the richness of the plankton community. The higher production of the salt pan is a positive index for utilising such unique systems for culture of fish and prawns.

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