

ZOOPLANKTON DISTRIBUTION IN THE POLLUTED ENVIRONMENT AROUND BOMBAY

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Zooplankton distribution, abundance and composition with reference to polluted environments off Bombay was estimated. This study was taken up along three transects viz. Versova, Mahim and Thana covering eleven stations around Bombay during 1980. These stations are representative of polluted and relatively unpolluted environment. The creek stations of Versova and Mahim are affected by sewage pollution especially during ebb tide, whereas upper stations of Thana Creek are influenced by industrial effluents.

(The prevailing physico-chemical conditions in certain areas clearly indicated the adverse effect of pollution, resulting in the quantitative and qualitative changes in the ecosystem. Zooplankton in the near shore waters of Bombay is quite rich with two peaks in year, the zooplankton standing stock was more at Thana (av. 22.5 ml/100 m³), Versova (av. 10.4 ml/100 m³) and Mahim av. 76.0 ml/100 m³). The annual variation in zooplankton biomass varied widely 0.1-114.3 ml/100 m³. Zooplankton was dominated by copepods, chaetognaths, medusae, ctenophores, siphonophores and decapod larvae. The diversity for copepods, medusae and chaetognaths showed an increasing trend towards the offshore area and the lowest diversity was in the polluted regions.

INTRODUCTION

Bombay waters offer a good example of various aquatic biotopes with having a number of polluted areas as well as relatively clean areas

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(Fig. 1). Most of the creek inlets around the city of Bombay are highly polluted due to indiscriminate disposal of wastes (NIO Report, 1978). Some of the important polluted water bodies around Bombay are the Thana creek, Mahim creek, Worli and Versova creek, whereas places like off Versova, off Mahim etc. are relatively unpolluted (Zingde *et al.*, 1979). Gupta and Shankaranarayanan (1974) and NIO/DOD (1989) reports indicated that the offshore waters at a depth of 15 to 20 metres off Bombay are unpolluted.

Due to the various types of waste disposal, the biota of the inshore water of Bombay are subjected to environmental stresses which may eventually cause alternation in the structure of natural ecosystem. As a result, the possible biological effect may be deleterious, beneficial or neutral to a specific organisms, to a population or to a community.

Zooplankton are drifting organisms in the aquatic environment and include numerous larval and juvenile stages of crustaceans, other invertebrates and fishes. Compared to the adults, the developmental stages of the organisms are more sensitive to the unfavourable conditions. The decrease or elimination of one variety of life of a particular ecological level has a serious impact on the other stages of the concerned organisms. The present study evaluates and discusses the effects of effluent, both domestic and industrial on the abundance and distribution of zooplankton. Some of the variations exhibited by zooplankton are due to the increase in stress and hence these organisms can be used as biological indicators of pollution.

ENVIRONMENTAL CONDITION

The aquatic environment around Bombay is greatly influenced by Southwest monsoon which brings in large amount of freshwater. In the marine environment, especially in the Thana Creek region, where several freshwater creeks and 2 rivers open and as a result of dominating freshwater supply, changes in environment occurred in this area. Consequently salinity varied widely from 1.79 to 37.07‰ during the study period (1980). Salinity variation was more pronounced at Thana and creek regions of Versova and Mahim. The minima in salinity curves attained in July/August at all the stations can be attributed to the surface runoff and the freshwater

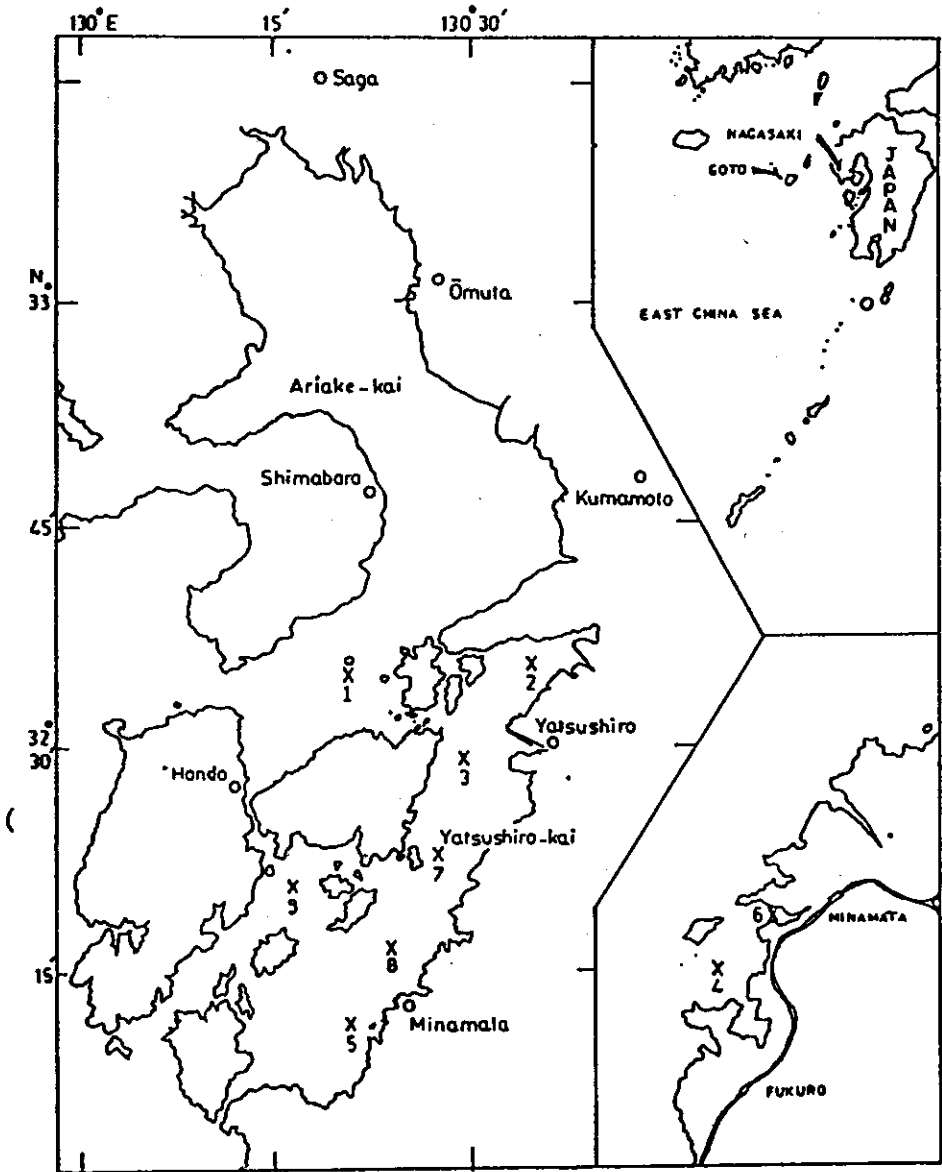


Fig. 1. Map showing location of stations around Bombay.

discharges through the creeks and Ulhas river. However, because of the large discharge of domestic waste, the low salinity at creek region of Mahim and Versova was noticed as a regular feature (Tab. 1 and 2). The values observed at Thana creek during the dry period were higher than those recorded at the other regions. The high salinity in the creek region as compared to the coastal stations could result from some local factors. Thana creek has on its either side large areas of salt pans. It is possible that high saline water from the salt pans and mangrove regions exposed during ebb tide gets mixed with the creek water resulting in high salinity. Overall, the surface and bottom water is well mixed with the absence of any appreciable diffusion boundary except in polluted area of Mahim and Versova where vertical gradient in salinity was observed.

Higher dissolved oxygen values at offshore stations and lower value at creek and st. 1 in Mahim and Versova are indication of pronounced effect of organic load released in Mahim creek, Versova creek and uppermost stations of Thana regions through sewage and industrial outfalls. The average values were higher during monsoon months. The high DO during this period is mainly due to the influx of freshwater with higher oxygen content. Wind velocity during monsoons also induces a greater aeration of surface water due to turbulence and contribute to higher DO. The decrease in DO levels during September appears to be due to biochemical oxidation of waste transported into the water system by the runoff. Biochemical consumption continues even after the runoff is considerably reduced resulting in the supply of oxygen rich water. The temperature, however gradually increased from 24.0°C during February to 31.0°C during April/May decreasing the rate of dissolution of the atmosphere oxygen. The biochemical oxidation of the inorganic matter also increased with temperature imposing additional oxygen demand and hence DO decreased till the commencement of monsoons (Gajbhiye, 1992).

The higher BOD at creek stations and Thana is due to the influence of sewage and industrial effluents in the nearby area. The values decreased from shore station to offshore stations indicating minimum organic load in this area. Although BOD is very high (20-80 mg/l) in the creek region (NIO Report, 1978) with oxygen levels often falling to zero (during low tide at Mahim and Versova), at the bay and creek mouth the conditions are

Table 1: Range and mean value of different parameters at four stations of Versova

Parameters	STATIONS			
	VC	V1	V2	V3
Temp. (°C)	23.0-32.8 (27.7)	23.0-32.5 (27.7)	23.5-31.8 (27.6)	23.5-31.5 (27.5)
Salinity (X 10 ⁻³)	21.6-36.3 (31.2)	21.5-37.0 (32.5)	21.8-37.1 (33.2)	22.3-36.7 (33.5)
D.O. (mg l ⁻¹)	0.0-7.3 (3.3)	0.8-7.9 (4.8)	2.3-8.9 (6.0)	2.3-7.7 (6.1)
Nitrate (ug.at l ⁻¹)	0.3-31.0 (11.2)	0.9-28.5 (7.6)	0.6-11.6 (5.0)	0.1-25.5 (5.1)
Phosphate (ug. at l ⁻¹)	0.3-30.4 (4.7)	0.3-6.5 (2.2)	0.1-4.8 (1.6)	0.1-5.0 (1.5)
Biomass (ml/100 m ³)	0.2-114.3 (12.5)	0.1-32.3 (9.0)	0.8-42.7 (11.5)	0.8-26.3 (8.8)
Population (no/100 m ³)	652-126378 (20929)	1723-295418 (33666)	2769-107336 (30088)	1883-131534 (32212)
Group diversity	2-15 (10)	3-14 (11)	7-17 (11)	7-15 (10)
Copepods (no/100 m ³)	0-101333 (13478)	10-284284 (27585)	1540-52232 (20866)	1333-99257 (23104)
Chaetognaths (no/100 m ³)	0-20267 (1063)	0-17920 (1393)	30-16723 (2117)	11-11171 (2082)
Medusae (no/100 m ³)	0-2240 (143)	0-501 (48)	0-141 (36)	0-162 (21)
Decapods (no/100 m ³)	17-8710 (842)	0-24320 (1612)	9-18710 (3136)	27-20267 (1475)
Siphonophores (no/100 m ³)	0-225 (20)	0-30 (4)	0-1200 (85)	0-571 (53)
Ctenophores (no/100 m ³)	0-133 (11)	0-69 (8)	0-36 (3)	0-19 (2)
Mysids (no/100 m ³)	0-102514 (4805)	0-57227 (2273)	0-14700 (626)	0-621 (39)
Gastropods (n/100 m ³)	0-1400 (197)	0-1275 (130)	0-6982 (473)	0-3400 (271)
Lamellibranchs (no/100 m ³)	0-1067 (49)	0-4955 (222)	0-2048 (316)	0-10635 (628)
Fish eggs (no/100 m ³)	0-427 (67)	0-371 (65)	0-300 (33)	0-310 (23)
Fish larvae (no/100 m ³)	0-81 (7)	0-200 (27)	0-400 (62)	0-412 (61)

Table 2: Range and mean value of different parameters at four stations of Mahim

Parameters	STATIONS			
	VC	V1	V2	V3
Temp.(°C)	24.3-32.5 (27.2)	24.0-34.5 (27.6)	23.5-33.0 (27.4)	24.2-32.5 (27.4)
Salinity (X 10 ⁻³)	1.8-35.1 (12.2)	22.3-35.8 (32.4)	22.7-35.7 (32.6)	23.4-36.4 (33.3)
D.O. (mg l ⁻¹)	0.0-3.6 (0.4)	2.1-8.3 (5.0)	2.1-7.6 (5.6)	2.3-7.6 (5.8)
Nitrate (ug.at l ⁻¹)	0.6-45.7 (18.1)	0.2-34.5 (11.4)	0.1-20.7 (7.8)	0.1-15.1 (5.6)
Phosphate (ug.at l ⁻¹)	4.0-60.9 (21.5)	0.9-23.9 (3.7)	0.4-8.5 (2.3)	0.1-5.3 (1.4)
Biomass (ml/100 m ³)	0.0-6.1 (1.1)	0.1-35.7 (9.2)	0.8-48.0 (10.1)	0.7-50.0 (9.6)
Population (no/100 m ³)	0-35886 (4786)	192-167798 (33266)	4287-282434 (55149)	1956-420189 (47552)
Group diversity	0-10 (4)	5-15 (10)	6-15 (10)	7-15 (11)
Copepods (no/100 m ³)	0-32000 (4430)	135-162400 (30227)	1312-133647 (44709)	1225-407000 (44561)
Chaetognaths (no/100 m ³)	0-408 (33)	0-5091 (968)	10-11768 (1679)	8-19006 (2396)
Medusae (no/100 m ³)	0-20 (2)	0-1152 (65)	0-519 (55)	0-141 (15)
Decapods (no/100 m ³)	0-900 (71)	38-9973 (777)	0-24824 (1707)	133-6969 (1325)
Siphonophores (no/100 m ³)	0-10 (1)	0-135 (14)	0-1241 (85)	0-135 (85)
Ctenophores (no/100 m ³)	0-67 (6)	0-556 (40)	0-85 (7)	0-180 (8)
Mysids (no/100 m ³)	0-128 (5)	0-3900 (159)	0-1067 (44)	0-376 (16)
Gastropods (no/100 m ³)	0-3040 (191)	0-5527 (526)	0-2731 (251)	0-2172 (226)
Lamellibranchs (no/100 m ³)	0-53 (4)	0-576 (37)	0-683 (65)	0-931 (125)
Fish eggs (no/100 m ³)	0-80 (5)	0-1173 (96)	0-1845 (246)	0-3953 (299)
Fish larvae (no/100 m ³)	0-5 (1)	0-125 (23)	0-490 (53)	0-363 (45)

better due to the tidal exchange and good mixing. The BOD values were lower in flood tide than ebb tide.

Although salinity and DO profile indicate homogenous nature of the water for most part of the year, BOD shows some gradient with surface water with higher BOD than the bottom layer. The movement of the water is predominantly in the south west direction in low tide and north easternly during flood. This might facilitate the transfer of less polluted water from north off Bombay to Versova during ebb tide while during flood the water mass from north of Bombay would move southward.

Nitrite and nitrate concentration is too high at creek station and upper stations of Thana indicating the influence of waste water discharges in and around these regions (Tab.3). The concentration reduced toward the offshore stations. The distribution of phosphate also reveal similar trends. The concentration of both nutrients decreased during flood tide. The levels of phosphate and nitrate at creek stations of Versova and Mahim are somewhat higher than the observed at Thana. Comparison of values reported earlier by Bal and Pradhan (1946), Gogate (1960), Pillai (1968) with those obtained during the present study reveals that values increased drastically over the 30 years, particularly in creek stations during ebb tide. Similar increases in nutrients values has been reported by the NIO (1978) and Zingde *et al.* (1979).

ZOOPLANKTON DISTRIBUTION

Zooplankton abundances in nearshore waters off Bombay are quite rich. Most of the stations showed two peaks in a year, a major one in October/November and another in April/May. However, at some stations intermediate peaks were observed during monsoon period. A similar trend of a biomodal peak in Bombay waters was reported in an earlier study (Gajbhiye and Desai, 1981). Nair *et al.* (1978). While studying the zooplankton from the Arbaian sea for the postmonsoon period, noticed that the biomass increased towards the northern region with maximum abundance off Bombay.

In terms of biomass, the zooplankton abundance was more at Thana (22.5 ml/100 m³) as compared to the Versova (10.4 ml/100 m³) and Mahim

Table 3: Range and mean value of different parameters at three stations of Thana

Parameters	STATIONS		
	T1	T2	T3
Temp. (°C)	23.0-33.8 (27.9)	23.0-33.0 (27.9)	22.5-34.0 (27.7)
Salinity (X 10 ⁻³)	5.2-36.8 (28.7)	5.3-36.9 (29.4)	10.9-36.8 (31.2)
D.O.(mg l ⁻¹)	2.0-8.1 (5.3)	1.3-7.6 (5.4)	2.1-7.5 (5.8)
Nitrate (µg.at l ⁻¹)	3.1-45.5 (20.7)	4.7-46.0 (19.5)	4.3-35.5 (15.2)
Phosphate (µg.at l ⁻¹)	1.1-15.5 (4.5)	0.5-11.6 (4.1)	0.6-7.2 (3.7)
Biomass (ml/100 m ³)	0.9-101.0 (25.3)	0.8-107.1 (28.8)	0.9-50.0 (13.5)
Population (no/100 m ³)	1839-252672 (34730)	1509-144603 (27110)	1023-57272 (18484)
Group diversity	6-16 (10)	6-15 (10)	6-14 (11)
Copepods (no/100 m ³)	413-126133 (25112)	160-137600 (20071)	200-40339 (11326)
Chaetognaths (no/100 m ³)	0-9007 (1639)	11-13653 (1597)	50-4706 (1404)
Medusae (no/100 m ³)	0-2662 (294)	0-3657 (528)	0-2014 (162)
Decapods (no/100 m ³)	41-10286 (1749)	0-53096 (3750)	66-53500 (3431)
Siphonophores (no/100 m ³)	0-8 (1)	0-50 (4)	0-1164 (47)
Ctenophores (no/100 m ³)	0-1335 (96)	0-489 (84)	0-3840 (187)
Mysids (no/100 m ³)	0-41 (3)	0-1450 (54)	0-91 (6)
Gastropods (no/100 m ³)	0-130607 (4798)	0-13714 (619)	0-3474 (812)
Lamellibranchs (no/100 m ³)	0-126 (11)	0-617 (55)	0-3474 (589)
Fish eggs (no/100 m ³)	0-20 (3)	0-330 (31)	0-4680 (218)
Fish larvae (no/100 m ³)	0-1050 (57)	0-160 (18)	0-512 (50)

(7.6 ml/100 m³). This was due to the predominance of gelatinous group like medusae and ctenophores at the Thana creek. The annual variation in biomass varied widely from negligible volume to 114.3 ml/100 m³. The higher zooplankton biomass and wide variation in creek regions could be the result of increase in the general level of nutrients (NIO 1978, Naidu and Shringarpure, 1975) leading to higher primary productivity (Jiyalal Ram, 1985) which subsequently lead to high standing stock of zooplankton. It is a known fact that the higher level of nutrients increases biological production, but excess of nutrients also cause an adverse effect on the general pattern of zooplankton distribution (Wiktor and Plinski 1975). Eventhough, zooplankton biomass in the polluted region of Thana is high, the higher abundance of gelatinous organisms in the area decrease their importance as secondary producers.

Another important observation during this study was the influence of tide on the distribution of zooplankton. During flood tide, zooplankton biomass showed an increasing trend from offshore to shore side. A reverse pattern was established during ebb tide. During flood tide the mean biomass values at four stations of Versova transect were 6.0, 9.5, 9.3 and 23.4 ml/100 m³ respectively for sts. 3, 2, 1 and creek. The corresponding ebb tide values for those stations were 11.5, 13.5, 8.1 and 1.7 ml/100 m³. The mean values of biomass at Mahim during flood tide were 2.1, 9.2, 9.0 and 5.2 ml/100 m³ respectively at creek, sts. 1, 2, and 3. The corresponding value for ebb tide were 0.1, 9.2, 12.4 and 14.0 ml/100 m³. The Thana region, where the higher biomass were recorded showed significant differences in zooplankton distribution. Biomass values increased from st. 3 to st. 1. The mean values during flood tides were 11.4, 16.5 and 24.4/100 m³ respectively.

Reports on the effect of tide on zooplankton from Indian coastal water are limited to a few investigation. At Thal (Maharashtra) Gajbhiye *et al.* (1983) found a similar variability in the disposition of zooplankton under different tidal conditions with higher biomass during ebb tide cycle. In general, there was shoreward increase in zooplankton biomass during the flood period and a reverse trend during the ebb period. Studies on the current from Bombay area (NIO Report 1978) reveals that the shoreward component was stronger during the flood tide and the offshore component was stronger during the ebb tide.

In the monsoon months the biomass of creek and nearshore stations decreased drastically and increased significantly towards offshore. This could be very well associated with the decrease in salinity brought by the monsoon which carried large amount of freshwater from land.

In terms of faunal groups the higher group diversity was noticed along the Versova transect. The average values for Versova was (11) followed by Thana (10) and Mahim (9). Considering the seasonal pattern, the diversity was more in postmonsoon showing the direct correlation with the higher zooplankton production. The diversity at nearshore stations reduced very much during ebb tide and subsequently increased at offshore stations.

POPULATION AND FAUNAL COMPOSITION

Eventhough, Thana transect recorded higher production in terms of biomass, numerical counts were lowest among all the transect (Tab. 3). In term of total population Mahim sustained a higher mean values (35188/100 m³) than Versova (29224/100 m³) and Thana (26775/100 m³). Copepoda was the predominant group at all stations, except during the swarming period of medusae and ctenophores at Thana, mysids at Versova and polychaetes at Versova and Mahim. The other important groups were chaetognaths, medusae, ctenophores and decapods. The mean values of total copepods were higher at Mahim (30982/100 m³) than Versova (21258/100 m³) and Thana (18836/100 m³). The contribution of copepods to the total zooplankton was 72.67, 79.56 and 62.84% respectively for Versova, Mahim and Thana. The distribution of copepods followed the tidal pattern similar to that biomass and total population. During flood tide their number increased towards inshore area and during ebb tide the pattern was reversed. However, overall mean number of copepods were higher at offshore stations. The seasonal distribution of copepod also showed variation. They were more in number during the postmonsoon periods. Seventy four species of copepods were identified and the detail distribution of copepod is reported separately (Gajbhiye *et al.*, 1991). The maximum number of 60 species observed at Versova. At the Mahim total number of recorded species were 58, whereas only 43 species were obtained from Thana creek. The species diversity of copepods increased towards off-

shore stations. The present report of 74 copepods species is much higher than that of Pillai (1968a). *Eucalanus crassus*, *E. subcrassus*, *Canthocalanus papur*, *Acrocalanus similis*, *Paracalanus crassirostris* and *Acartia spinicauda* were noticed as the common copepods along the Versova transect, whereas *A. spinicauda*, *A. similis*, *P. crassirostris*, *C. pauper*, *Acrocalanus gibber*, *Labidocera* sp., *Eucalanus* and *Acartia* sp. were found as the common copepods of Mahim. The common copepods of Thana were *A. spinicauda*, *Pseudodiaptomus*, *A. similis*, *P. crassirostris*, *Acartia* sp., *Labidocera pectinata*, *E. subcrassus* and *Paracalanus aculeatus*, *P. aurivillii* and *Acartiella sewelli* were restricted to the estuarine region of Thana and other creek stations. The dominance of estuarine species like *A. spinicauda*, *Acartia southwelli*, *A. sewelli*, *L. pectinata* and *P. aurivillii* clearly indicate the influence of fresh water at all the stations of Thana and creek station of Versova and Mahim particularly during ebb tide.

Chaetognaths were represented throughout the study period and detail account of chaetognaths has been published earlier (Nair *et al.*, 1991). The observed density of chaetognath was more along the Versova transect (av. 1664/100 m³) as compared to Thana (1545/100m³) and Mahim (1269/100 m³). The offshore stations of Versova and Mahim sustained higher population density of chaetognaths. Six species of chaetognaths were recorded from the collection. *Sagitta bedoti* was the dominant species at all the stations. *S. oceania* was confined to Thana creek and this has already been reported earlier by Nair *et al.* (1991). *S. enflata* a common species at offshore stations of Versova and Mahim was found rarely at Thana transect and at other creek stations. The species number of chaetognaths was higher at Versova (6) as compared to Mahim (4) and Thana (4).

Hydromedusae were more abundant at Thana creek (av. 328/100 m³) than along the Versova (62/100 m³) and Mahim (34/100 m³) transects. *Blackfordia virginica*, *Eirene ceylonensis*, *Gossea* sp. and *Phialidium* sp. were the most dominant species at Thana creek, whereas *Aequorea conica*, *Streenstrupia bigelowi*, *Liriope tetraphylla* and *Solmundella bitentaculata* were the predominant species of Versova and Mahim. The occurrence of estuarine species like *B. virginica*, *Phialidium* sp., *E. cey-*

Ionensis and *Gossea* sp. were restricted to creek and nearshore waters and their abundance at the Thana creek station shows their preference to the estuarine and brackish water environments. On the other hand the occurrence of *S. bitentaculata*, *L. tetraphylla*, *Aequorea* sp., *A. conica*, *Pelagia noctiluca* were confined to the offshore stations of Versova and Mahim show their association with the oceanic conditions.

Abundance of *Pleurobrachia globosa* was noticed during post-monsoon months at Versova and Mahim. At Thana their occurrence was common throughout the year excepting the monsoon months.

Decapods were found more abundant at Thana (2977/100 m³) than Versova (1766/100 m³) and Mahim (970/100 m³). *Alpheids* have dominated the other decapod larvae in most of the stations. *Stenopides* and *Palaemonidae* showed their preference to creek waters. A very low population density of *Lucifer* sp. at Versova (av. 17/100 m³) and Mahim (av. 60/100 m³) as compared to the Thana (av. 342/100 m³) clearly indicated preference of *Lucifers* (*L. hansenii*) to the estuarine and neritic water, similarly the abundance of *Acetes* sp. was also more at Thana (av. 87/100 m³) than Versova (14/100 m³) and Mahim (14/100 m³). The *Acetes* sp. were represented by *A. indicus*, *A. sibogae* and *A. erythraeus*. Of these *A. indicus* was the most dominant species. Density of mysids was higher at Versova (av. 1936/100 m³) than to Mahim (56/100 m³) and Thana (21/100 m³). A swarm of mysids (*Mesopodopsis zeylonica*) was observed from Versova (Gajbhiye *et al.*, 1984).

Similarly a swarm of polychaetes *Poecilochaetus serpens* was recorded at Mahim (st. 2 and st. 3) and Versova st. 2 and st. 3. During rest of the period they were represented by *Tomopteris* sp. and *Nereis* sp. and their peak abundance was obtained during postmonsoon months.

Molluscs were represented by Gastropods and Lamellibranchiates. Two major peaks in the abundance of molluscs were observed, a major one in December/January and a lesser peak during April/May. Abundance of appendicularians were noticed more at the coastal water of Mahim (101/100 m³) and Versova (95/100 m³) than Thana creek (14/100 m³) and was represented by *Oikopleura* sp.

Fish eggs and larvae were commonly recorded in the area with maximum abundance in December, April and August. Eventhough the abundance of fish eggs was quantitatively more at Mahim (160/100 m³), the recorded number of fish larvae was more at Versova (av. 33/100 m³) showing the favourably breeding ground of the fishes. A less diversity in the number of families of fish has been noticed at Thana and Mahim than Versova.

Groups like siphonophores, amphipods, cirripede nauplii, ostracods, stomatopod larvae, isopods were occassional inhabitants of the area and their incidence and contribution to total number was very low.

SUMMARY AND CONCLUSIONS

The overall pattern of zooplankton distribution indicates the effect of the prevailing tide and the environmental factors which brings changes in the distribution of zooplankton. There was significant variation in the biomass and total population of different groups of zooplankton associated with the flood and ebb tide. Polluted areas are characterised by wide fluctuation in zooplankton biomass follows by lower diversity. Often the tolerant species contribute to unusual swarming leading to bloom situation. All the 11 stations of Versova, Mahim and Thana were represented by the some species or groups, which are common to all the area. However, the occurrence of some species to particular stations reflects the ecological differences between station to station. The presence of some individuals in abundance shows their preference to the particular water body and their absence shows their avoidance to the unfavourably environment.

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