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Meiofaunal response to the tidal exchange and domestic sewage in the Adyar estuary, Chennai, India

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Maximum and minimum diversity recorded was 27 species and 16 species, respectively while density was (2093.33±141.12 Ind. /10 cm^2) and (140.61±20.8 Ind. /10 cm^2), respectively. ANOVA of the density of meiofaunal taxa showed significant difference between seasons at p= 0.05 level. Higher percentage composition of rotifers (54.9%), nematodes (19.72%) and oligochaetes (12.82%) were recorded. Correlation coefficients of meiofaunal density also showed significant difference with physicochemical parameters. Tidal exchange of seawater which depended on sand bar formation in mouth of the estuary and the quantum of domestic sewage released highly influenzed the pollution status of eatuary. Depending on these factors and seasonal variations in the physicochemical parameters the meiofaunal populations showed different responses in their diversity and density. The results indicated highly polluted state of the estuary during the study period.

[Key words: Adyar estuary, Sewage, Meiofauna, Diversity]

Introduction

Estuaries are claimed to be one of the most productive non-cultivated ecosystems on earth[1]. Water pollution directly and indirectly affects the life processes of flora and fauna of the water body, surrounded by chemical toxicants[2, 3]. Adyar estuary has been identified as an "Ecological Heritage Site"[4]. Due to anthropogenic activities like the discharge of untreated sewage and effluents, encroachments and urbanization, the estuary is under great ecological stress[5]. Considering its ecological importance, eco-restoration measures have been initiated by the Government of Tamilnadu and involve various practices including scientific monitoring of the flora and fauna. Meiofauna constitute a heterogenous assemblage of organisms which inhabit the interstitial spaces between the sand grains and forms an important biotic component of the estuarine ecosystem. The ecological importance of meiofauna in marine and freshwater sediments as food sources for organisms in higher trophic levels such as macrofauna, shrimp and juvenile fish, their diverse role in mineralization of detritus and in pollution research as bio-indicator organisms is recently being highlighted[6]. Though there are studies on meiofauna from a wide range of habitats around the world[7], in the Indian context, they are meager and sporadic. Hence, the present study was undertaken to document the biodiversity and abundance of meiofauna from the Adyar estuary in relation to seasonal changes and impact of domestic sewage and as a possible "bio-monitoring tool'' for assessing the ecological status of this estuary.

Materials and Methods

The Adyar estuary is situated in the southern part of Chennai city at Lat. 13º01´N, Long 80º27´E of southeast coast of India. Monthly samplings of the sand sedments was done between 6.00-8.00 am for a period of two years (June 2010 to May 2012) to eluterate meiofauna and study their seasonal variations. The study period was categorized in to pre-monsoon (July-September), monsoon (Onset of NE monsoon in mid October-December), post-monsoon (January- March), and summer (April-June). Sampling station of the estuary is located closer to the mouth of the Adyar estuary and encloses the sand bar which may be closed or open depending on tidal action. It also represents a higher saline zone and depending on the sand bar remaining open or closed. The estuarine water might have either highly polluted or moderately polluted status due to the tidal influence. Sand sediment samples were collected using a stainless steel corer with an inner diameter of 3.57cm which comes to 10 cm^2 surface area. In the field, this corer was pushed upto 10 cm into the soil and samples were collected with minimum disturbance. These samples were fixed with 5% Rose Bengal formalin. In the laboratory, meiofauna present in the fixed samples were separated by decantation method. Procedure of decantation was repeated at least 5 times to ensure maximum extraction. The fauna that pass through 1000µm sieve and retain in 65µm sieve were considered as meiofauna and after separation animals were preserved and stored in 5% Rose Bengal formalin. Physico-chemical parameters of the interstitial water drawn from a depth of 10 cm were analysed.Temperature was recorded with the help of a mercury thermometer. pH was determined with the help of pH paper. Dissolved oxygen was analysed using Winkler's methods and the salinity was measured by Salinometer (ATAGO-Sigma Scientific Equipments, Chennai, India). Other chemical parameters such as nitrite, ammonia and phosphate were analysed using Test kits (AQUARIUM PHARMACEUTICALS CANADA, INC.) and their concentration being expressed as mg/l. Meiofaunal taxa belonging to major and minor phyla were identified following Higgins and Thiel[9]. Generic and species level identification was carried out by mounting the key characters and observing them under compound microscope at the magnifications of 40 X and 100 X. Identification of different meiofaunal species were done by following standard taxonomic descriptions of[8-15]. The samples of meiofauna were enumerated under the Sedgwick-Rafter counting chamber, the density was expressed as individuals per 10cm^2 (Ind. /10cm^2). Percentage composition of meiofaunal taxa was also calculated. Statistical analysis of the data was performed by SPSS ver. 10.0, Statistica ver. 6.0 and Microsoft Excel.

Results

Data on the range of atmospheric and interstitial water temperature, pH, salinity, DO, nitrite, ammonia and phosphate are presented in the Table 1.

Atmospheric temperature showed seasonal and annual variation.Lowest temperature was recorded during the monsoon period of the first year (27.33±0.33°C) and in thesecond year during post monsoon (24.33±1.76°C) and highest during the first year pre monsoon (30.50±0.64°C) and the second year summer (30±1°C). Interstitialwater temperature also showed seasonal and annual variation. pH ofAdyar estuary ranged from slight acidic during postmonsoon (6.93±0.13) to alkaline during summer (8±0.40). Salinity was high during first year monsoon period (27.66±4.36‰) and second year postmonsoon period (26.33±6.64‰) and low during first year premonsoon (17.50±4.36‰) and second year summer (9±1‰).Maximum dissolved oxygen was recorded during monsoon months (7.30±0.28mg/l) and in summer (1.74±0.07). Nitrite ranged from 0.06±0.02mg/l (during first year monsoon) to (0.54±0.02 mg/l during second year monsoon). Maximum ammonia was recorded in second year summer (8.50±1.50mg/l) and minimum in first year summer (2.16±0.1 mg/l). Maximum level of phosphate was recorded during pre monsoon (4.83±1.62 mg/l) and minimum during monsoon (0.23±0.09mg/l).

In the present study a total of 29 species of meiofauna belonging to foraminiferans, cnidarians, turbellarians, nemertines, nematodes, rotifers, archiannelids, polychaetes, oligochaetes, sipunculans, ostracods, harpacticoid copepods, cyclopoid copepods, halacarids, collembolans and gastropods were identified from Adyar estuary (Table 2). In the two year study period, diversity of 27 species of meiofauna during post monsoon, 26 species during pre monsoon, 23 species during summer and 16 species during monsoon were recorded.

Table 1. Physicochemical parameters of Adyar estuary during different seasons from June 2010- May 2012

	First Year (2010- 2011)				Second Year (2011-2012)			
	Pre-mon.	Monsoon	Post-mon.	Summer	Pre-mon.	Monsoon	Post-mon.	Summer
Atmospheric temp. (°C)	30.50±0.64	27.33±0.33	28.66±1.20	29.0±0.57	27.33±0.33	24.66±1.45	24.33±1.76	30±1
Water temp. (°C)	31.75±0.75	29.33±0.88	28.66±0.88	30.00±0.57	29.33±0.33	26.66±1.66	27.33±0.66	30±1
pH	7.47±0.36	7.56±0.14	7.53±0.06	7.56±0.23	7.10±0.73	7.16±0.66	6.93±0.13	8±0.40
Salinity (ppt)	17.50±4.36	27.66±1.20	26.66±2.40	19.66±5.78	24±9.64	18.33±8.51	26.33±6.64	9±1
DO (mg/L)	2.42±0.88	7.30±0.28	5.66±0.54	1.74±0.07	3.08±0.34	4.77±0.30	3.27±0.38	2.08±0.39
Nitrite (mg/L)	0.27±0.01	0.54±0.02	0.13±0.04	0.38±0.05	0.22±0.03	0.06±0.02	0.08±0.02	0.20±0.01
Ammonia (mg/L)	4.83±1.62	2.22±0.89	2.83±0.88	2.16±0.1	4.50±0.82	2.83±0.08	6.33±1.76	8.50±1.50
Phosphate (mg/L)	4.77±0.86	0.61±0.04	0.48±0.05	0.66±0.06	0.41±0.08	0.23±0.09	0.26±0.05	2±0.81

The density and dominant species of meiofauna in Adyar estuary during different seasons showed significant variation in the present study period (Fig.1).Maximum density of meiofauna during summer (2093.33±141.12 Ind. /10 cm^2) and minimum density during monsoon (140.61±20.8 Ind. /10 cm^2) was recorded.The composition of meiofauna constituted 54.9% rotifers, 19.72% nematodes,12.82% oligochaetesand other groupsless than 10% (Fig.2).

Table- 2. Diversity of Meiofauna from Adyar estuary during different seasons (July 2010- June 2012)

Meiofaunal groups	**Pre monsoon (July-Sep.)**	**Monsoon (Oct.-Dec.)**	**Post monsoon (Jan.-Mar.)**	**Summer (Apr.-June)**
Foraminiferans				
Elphidium sp.	+	+	+	+
Cnidarians				
Halammohydra schulzei	+	-	+	-
Turbellarians				
Prolecithoepitheliata sp.	+	-	+†	+†
Haplopharyngida sp.	+†	-	+	+
Nemertines				
Annulonemertes sp.	+	-	-	-
Nematodes				
Enoplolaimus sp.	+	+	+	+
Thalassironus sp.	+	+	+	+
Synoema sp.	+	+	+†	+†
Parallelocoilas sp.	+	+†	+	+
Polygastrophora sp.	+†	+	+	+
Rotifers				
Brachionus plicatilis	+†	+	+†	+†
B. routundiformis	+	+	+	+
B. urceolaris	+†	+†	+	+
Archiannelids				
Polygordius madrasensis	-	-	+†	-
Saccocirrus minor	-	-	+	-
Polychaetes				
Eusyllis homocirrata	+	-	+†	+
Dorivillea sp.	+†	-	+	+†
Oligochaetes				
Grania pusilla	+†	+†	+	+†
Heterodrilus sp.	+	+†	+	+†
Sipunculans				
Sipunculan sp.	+	-	-	-
Ostracods				
Eucypris sp.	+	+	+	+
Harpacticoid copepods				
Arenosetella indica	+†	+	+	+†
Leptastacus euryhalinus	+	+†	+†	+
Cylindropsyllus sp.	+	+	+	+†
Emertonia pseudogracilis	+	+	+	+
Cyclopoid copepods				
Neocyclopina sp.	+	-	+	+
Halacarids				
Acarochelopodia cuneifera	+	-	+	+
Insects				
Collembolans sp.	+	-	+	+
Gastropods				
Microhedyle cryptophthalma	-	-	+	-

(-) =Absent, (+) =Present, (+†) = Abundant

Fig. 1. Density of Meiofauna (Mean±SE) during different seasons of Adyar estuary from June 2010-May 2012

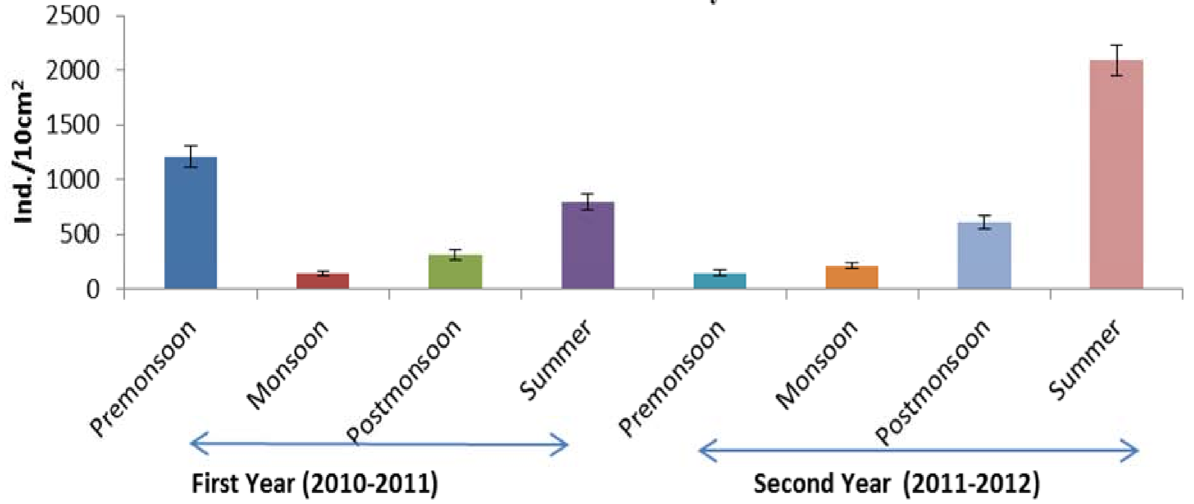
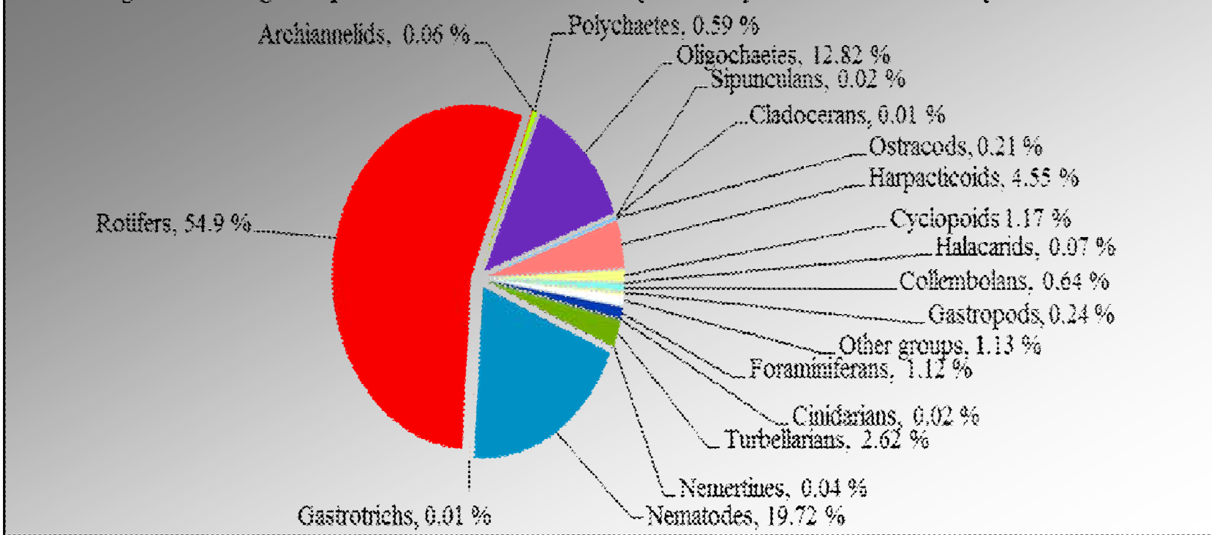


Fig. 2. Percentage composition of Meiofauna from Adyar estuary from June 2010 to May 2012



ANOVA of the density of meiofaunal taxa showed significant difference between seasons at p= 0.05 level (Foraminiferans: df=24, F=2.70, p=0.02; Turbellarians: df=24, F=69.17, p=0.00; Nematodes df=24, F=17.05, p=0.00; Rotifers df=24, F=85.69, p=0.00; Archiannelids df=24, F=2.51, p=0.02; Polychaetes df=24, F=87.08, p=0.00; Oligochaetes df=24, F=14.37, p=0.00; Harpacticoid copepods df=24, F=11.12, p=0.00; Cyclopoid copepods df=24, F=7.40, p=0.00; Collembolans df=24, F=4.31, p=0.00 and Gastropods df=24, F=7.31, p=0.00).

Correlation coefficient valuesbetween meiofauna and physicochemical factor showed positive correlation among rotifers, halacarids and collembolans with phosphate; harpacticoid and cyclopoid copepods with pH; rotifers and ostracods with ammonia showed positive correlation. While significant negative correlation was recorded in ostracods, harpacticoids and cyclopoids with salinity (Table 3).

Table 3. Correlations between environmental parameters and Meiofauna of Adyar estuary (2010 to 2012)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. Atmospheric temperature	1																						
2. Water temperature	.732*	1																					
3. pH	.476*	.380	1																				
4. Salinity	-.278	-.273	-.451*	1																			
5. Dissolved oxygen	-.338	-.334	-.404	.529*	1																		
6. Nitrite	.173	.477*	.228	.230	.133	1																	
7. Ammonia	.195	.262	.485*	-.573*	-.546*	-.156	1																
8. Phosphate	.515*	.408*	.396	-.396	-.401	-.106	.442*	1															
9. Mean grain size	.002	-.019	.004	.108	-.089	-.227	.091	.290	1														
10. Foraminiferans	.175	.152	.341	-.040	-.373	.180	.120	.048	.223	1													
12. Turbellarians	.099	-.111	.070	.150	.048	-.303	-.107	-.079	.189	.094	1												
13. Nematodes	-.229	-.316	-.181	.139	-.152	-.408*	.047	.201	.44*	.088	.184	1											
14. Rotifers	.291	.280	.339	-.414*	-.351	.022	.390	.616*	.161	-.005	-.128	.037	1										
15. Archiannelids	.305	.033	.166	-.027	-.087	-.274	.091	.120	.288	.249	.745*	.293	-.066	1									
16. Polychaetes	.265	.073	.083	.110	.149	-.117	-.190	-.085	.170	.014	.765*	-.083	-.041	.559*	1								
17. Oligochaetes	.096	-.022	.068	-.206	-.441*	-.264	.290	.238	.301	.419*	.101	.550**	-.013	.533**	.016	1							
18. Ostracods	.216	.154	.210	.038	-.048	.157	.132	.177	.127	.400	.125	-.219	.443*	.082	.107	-.231	1						
19. Harpacticoids	.354	.216	.404	-.349	-.348	-.034	.417*	.144	.040	.033	-.004	.117	.535*	.028	-.070	.046	.114	1					
20. Cyclopoids	.109	.006	.062	-.093	-.239	.012	.202	-.053	-.067	.141	-.062	.145	.387	.099	-.065	.225	-.070	.495*	1				
21. Halacarids	.207	.048	.220	-.240	-.144	-.211	-.028	.385	.063	.006	.273	-.135	.422*	.092	.420*	.017	.207	-.021	-.181	1			
22. Colombolans	.103	-.012	-.022	.066	-.163	-.146	.271	.049	.018	.019	-.041	.430*	.330	.041	-.035	.183	.110	.411*	.475*	-.024	1		
23. Minor groups	.196	.036	.171	-.279	-.518*	-.250	.403	.249	.274	.403	.083	.558*	.194	.496*	-.010	.936*	-.165	.374	.465*	-.004	.381	1	
24. Others	-.015	-.087	-.152	.119	-.314	-.109	.260	.052	.246	.235	-.028	.249	-.101	.241	-.098	.615*	-.065	-.104	.024	.050	.326	.543*	1

* Correlation is significant at the 0.05 level and (2-tailed). Minor groups include: Cnidarians, Nemertines, Gsatrotrichs, Sipunculans, Cladocerans and Gastropods

Discussion

Under the influence of a variety of inter-related biotic and abiotic structural compounds and intensive chemical, physical and biological processes, estuaries are highly variable systems[16]. Atmospheric and surface water temperature varied during different seasons and low temperature in monsoon months might be due to strong land sea breeze and precipitation.Similar findings were also recorded by earlier reports[17,20]. pH range of 6.7 to 8.4 is reported to be suitable for the growth of aquatic biota[18]. In Adyar estuary pH of water was with in this range during the study period and maximum value existed during summer and pre monsoon and minimum during monsoon and post monsoon seasons. Minimum pH value during monsoon and post monsoon could be due to removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, low primary productivity, reduction of salinity and temperature. Maximum pH value during summer might be due to influence of sewage water penetration and high biological activity[34, 20]. Salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation influence the fauna of the intertidal zone[19]. Generally, changes in the salinity in the estuaries are due to the influx of freshwater from land run off caused by monsoon or by tidal variations[20]. Higher values of salinity during post monsoon could be attributed to the heavy tidal influence and high degree of evaporation. Though perennial rivers are absent, the runoff due to domestic sewage water and formation of sand- bar during the summer season could influence the reduction in salinity[20]. Thus, the variation of salinity in the study sites could probably be due to freshwater runoff entering the creek systems[21].

Maximum dissolved oxygen was recorded during monsoon months might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the result of freshwater mixing from Adyar River and low metabolic rate of organisms. Minimum dissolved oxygen was recorded during pre monsoon and summer might be due to high temperature, availability of huge quantity of untreated domestic sewage and high metabolic rate of organisms[20, 22]. Dissolved oxygen is the regulator of metabolic activities of organisms and thus governs metabolisms of the biological community as a whole and also acts as indicator of trophic status of the water body[23]. Oxygen is generally reduced in the water due to respiration of biota, decomposition of organic matter, rise in temperature, oxygen demanding wastes and inorganic reductant such as hydrogen sulphide, ammonia, nitrites, ferrous ion, etc[24]. A minimum of 3 mg/l dissolved oxygen is necessary for healthy fish and other aquatic life[25]. In the present study, minimum values of dissolved oxygen present during pre monsoon and summeris inadequate for the most of the aquatic organisms.

Nitrite ranged from 0.06±0.02mg/l during monsoon season of first year to (0.54±0.02 mg/l during monsoon seasonof second year. Maximum ammonia was recorded during second year summer season (8.50±1.50mg/l) and minimum during first year summer and monsoon (2.16±0.1 mg/l & 2.22±0.89 mg/l) seasons. Maximum level of phosphate was recorded during first year pre monsoon (4.77±0.86 mg/l) minimum during second year monsoon (0.23±0.09mg/l).Inorganic nitrogen above 0.03mg/l stimulates algal growth to such an extent that water may not be suitable for human consumption[26]. In Adyar estuary nitrite ranged from 0.06±0.02mg/l during monsoon months to 0.54±0.02 mg/l during pre monsoon months, indicating high level eutropic nature with inorganic nitrogen present in the water. The presence of high level of ammonia is an evidence of sewage inflow to the estuary. However, free ammonia serve as an indicator of aquatic pollution[27]. In Adyar estuary maximum ammonia was recorded in second year summer (8.50±1.50mg/l) and minimum was recorded in first year summer and monsoon (2.16±0.1 mg/l & 2.22±0.89 mg/l) seasons. This result clearly indicates that high pollution of ammonia is due to the accumulation of domestic sewage on these water bodiescaused by formation of sandbar at estuary mouth. Major source of phosphate in water are domestic sewage, agriculture effluents and industrial waste waters. The high concentration of phosphate is, therefore, indicative of pollution[28] which is also evident in the Adyar estuary.Nutrients availability influences the predominance of rotifers[20, 29].

High diversity of meiofauna during post monsoon periods (27species),followed by (26 species) during pre monsoon and (23 species) during summer of both the years could be due to their ability to tolerate a wide range of salinities, high nutrients, pollution, least disturbance and high adaptability. This suggests that with favourable environmental factors meiofauna might flourish in most of the seasons. Minimum diversity was recorded during monsoon (16 species). This could be attributed to the lack of stability in estuary, tidal flushing, turbulence, scarcity of foods; salinity gradient and influx of freshwater from land run off caused by monsoon with more disturbances for diversification[30].

Meiofauna showed significant monthly and seasonal variations in their density. Among the meiofaunal groups, density of rotifers and nematodes were dominant in pre monsoon, monsoon and summer seasons. Whereas turbellarians were dominant in post monsoon season. This could be due to favourable environmental conditions such as high salinity, enough food, and least disturbances. Various studies indicated that nematodes were the predominant taxa among meiofauna[31], while occasionally other groups like harpacticoids and turbellarians might also dominate their composition[32]. In estuarine habitats, the numerically dominant metazoans were the nematodes, and copepods constituting over 90% of the animal component and are the prey for most commercially important fish species[33]. In the present study nematodes and copepods constituted only 18% and interestingly rotifers constitute 63% of meiofauna.Rotifer dominance throughout the year indicated perennial occurrence of untreated domestic sewage with high nutrients in the Adyar estuary. Further, ability to tolerate a wide range of salinity and pollution, as well as parthenogenetic mode of reproduction with high adaptability to hypoxic condition might also be reason for their abundance throughout the year in the Adyar estuary. Based on results of the present study it is evident that the rotifers showed higher tolerance to domestic sewage pollution and thrived well than nematodes in this estuary. Low diversity and density of harpacticoid copepods also indicate highpolluted state of the estuary.

Results of the ANOVA showed significant difference in the density of most of the meiofaunal taxa between the seasons. Cnidarians, nemertines, sipunculans, ostracods, halacarids and other unidentified groups showed no significant differences pertaining to their density. Results of the correlation between meiofaunal and physicochemical factor showed that rotifers, halacarids and collembolans were having significant positive correlation with phosphates; harpacticoids and cyclopoids with pH; rotifers and ostracods with ammonia. While significant negative correlation was observed in ostracods, harpacticoids and cyclopoids to salinity. Results of the present study indicated that rotiferslike *Brachionus plicatilis* and *B.urceolaris*arewell adapted to adverse physicochemical parameters such as high level of ammonia, phosphate and also to organic pollutants and showed quick response to attain numerical dominance.

Conclusion

Adyar estuary is being nursery ground for many fin and shell fishes of marine and fresh water species, which often goes to hypoxic condition due to sandbar fomation during summer and pre monsoon seasons, which prevents tidal exchange of water. It leads to over load of enriched inorganic nutrients with availability of untreated domestic sewage from Chennai city to the Adyar estuary. This alters the physical and chemical properties of water andcauses plankton bloom in the form of eutrophication. These eutrophic conditions can be favorable for meiobenthic fauna particularly those fit for hypoxic conditions, continuous breeding, fast growing, pollution tolerant and quick response to changes in biotic and abiotic factors. If such critical conditions continue it will affect the existence of sensitive meiobenthos.

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