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Dynamics of meiobenthic fauna in a tropical sandy coast (Chennai, Bay of Bengal) with reference to the physicochemical parameters

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Abstract: The term "meiobenthos" refers to a diverse community of organisms inhabiting the interstitial spaces between sand grains retained on sieve sizes ranging between 38 to 500 µm. This study investigates the diversity and density of meiobenthic communities across five locations along the Chennai coast. We examined the dominant meiobenthic groups, with nematodes exhibiting high dominance at Napier station (288.6 ± 91.07 ind.10cm²) and harpacticoids dominating at Marina station (449.88 ± 264.3 ind.10cm²). To establish the relationship between meiobenthic organisms and environmental parameters, we analyzed seven physicochemical factors throughout the study period. The results indicate a negative correlation between ammonia, nitrate, and phosphate levels in the water and a few meiobenthic groups, notably harpacticoids and ostracods. However, no significant relationship was observed between physicochemical parameters and dominant groups of this study, such as nematodes and polychaetes. These findings highlight substantial fluctuations in the diversity and density of meiobenthos and physicochemical parameters throughout the study period, emphasizing the dynamic nature of these coastal ecosystems. Moreover, the results of this study contribute to our understanding of meiobenthic dynamics and their interactions with the environment.

Key words: Meiobenthos, physicochemical parameters, granulometry analysis, Chennai coast

1. Introduction

Meiobenthic fauna constitutes a group of organisms inhabiting the benthic habitats, falling in size between microbenthos and macrobenthos, and encompassing various phylogenetic groups (Olafsson, E., 2003; Venekey et al., 2019; Ghellera and Corbisier, 2022; García-Gómez et al., 2022; Horacek et al., 2022; Suwartiningsih and Ardhi, 2022). The meiobenthic community encompasses thirty phyla that vary in morphology and arrangement (Zawierucha et al., 2023). These organisms are distributed both vertically and horizontally in the sediments, and their abundance is influenced by physicochemical parameters such as salinity, desiccation, and temperature (Mantha et al., 2012). In beach ecosystems, the taxonomic diversity of meiobenthic organisms is generally high around the low tide mark region, with lower diversity closer to the high tide mark region. However, this pattern may vary, and higher taxonomic diversities are sometimes found around the mid-tide mark (Urban-Malinga, 2014). Meiobenthic organisms on sandy beaches typically favor the uppermost sediment layer (Baia and Venekey, 2019). They can also be classified based on their movements in the sand grains, including endobenthic fauna (moving by displacing sand grains), mesobenthic fauna (thriving between sand grains or in interstitial space), and epibenthic fauna, (found between sediment and the water interface) (Nybakken, 1997).

Most studies have identified nematodes as the dominant group among all meiobenthic taxa, with copepods considered the second most important group (Xuan et al., 2007; Urkmez et al. 2016; Sciberras et al., 2022; Sergeeva et al., 2023). The use of free-living marine nematodes in assessing biological health and pollution extent in the oceans has been extensively studied for over four decades (Ridall & Ingels, 2021). Nematodes, due to their abundance and high taxonomic richness, have emerged as significant bioindicators for assessing the status of marine ecosystems (Urkmez et al. 2016;

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Baldrighi et al., 2020; Ridall and Ingels, 2021; Hannachi et al., 2022; Horacek et al., 2022; Michel Sciberras et al., 2022; Monserrat et al., 2003). In India, several studies have observed the dominance of nematodes in both abundance and taxonomic diversity, and the nematode-copepod ratio has been used to assess the environmental status (Ansari et al., 1984; Ingole et al., 2000; Chinnadurai and Fernando, 2007; Anila Kumary KS, 2016). Datta et al. (2022) stated that there are approximately more than 600 species of meiobenthic nematodes found in India, and they are comparably more tolerant to environmental stresses, making them valuable tools to assess the health of benthic ecosystems. Harpacticoid copepods, characterized by their high diversity and rapid turnover rates, play a crucial role in energy transfer from lower to higher trophic levels (Nicholls, 1935; Sarmento and Santos, 2012). Additionally, they are less tolerant to anthropogenic disturbances, making them extremely useful for evaluating environmental effects, particularly those associated with human-induced substrates (Barroso et al., 2018; Kim and Lee, 2020; Watanabe et al., 2021). Meiobenthic polychaetes are one of the most abundant groups within the benthic community, significantly contributing to ecosystem dynamics through their bioturbation activities, involving burrowing and feeding behaviors (Shah and Mohan, 2021). Similarly, meiobenthic oligochaetes, although posing challenges in identification, serve as valuable bioindicators for monitoring environmental changes (Vivien et al., 2016).

In general, sedimentary environments cover a vast proportion of Earth's ocean floors, constituting the largest environmental domain in terms of spatial coverage of meiobenthos (Schratzberger and Ingels, 2018). These environments fundamentally sustain human well-being through services such as food production and nutrient cycling (TEEB, 2010). Meiobenthos influence marine sediments through their stabilizing and destabilizing effects. Moreover, they facilitate energy transfer between microbenthic and macrobenthic communities, functioning as intermediaries (Arlinghaus et al., 2021). Their burrowing activities also aid in sequestering sediment-associated contaminants, thus contributing to the maintenance of water quality (Coull, 1990; De Deckere et al., 2001; Hubas et al., 2010).

Biodiversity is rapidly changing in natural environments due to anthropogenic impacts. One effective way to address this issue is to enhance or understanding of the ecosystems around us. However comparatively, less attention is given to these smaller sized meiobenthic organisms than to macrobenthic organisms (Nguyen et al., 2023). Chennai, one of India's four metropolitan cities, is home to a 30 km coastal line stretching from Neelangarai in the south to Ennore Creek in the north. The coastline of Chennai is impacted by both the northeast and southwest monsoons, resulting in variations in dissolved oxygen, salinity, and water temperature with depth. Moreover, the north margin of the Bay of Bengal is wider than the south margin, resulting in coastal seas with variable conditions (Mantha et al., 2012). Janakiraman et al. (2017) stated that the coastline of Chennai is highly polluted due to anthropogenic activities resulting from industrial effluents. In the current study, the authors examined meiobenthic diversity and density across five stations along the Chennai coastline over a period of 13 months, while simultaneously analyzing the associated physicochemical parameters. This investigation aims to elucidate the seasonal patterns in the taxonomic diversity and density of meiobenthic communities within the intertidal zones along the Chennai coast while evaluating the role of environmental factors in shaping their distribution. The expected outcome of this study is to relate the different physicochemical parameters that drive the meiobenthic taxonomic diversity and density to their local environmental conditions.

2. Materials and methods

2.1. Sampling stations

In the present study, meiobenthic fauna samples were collected for a period of 13 months, from February 2021 to February 2022 at five distinct stations located in the intertidal zones along the Chennai coast. The five stations selected for the study include Royapuram station (13°08′06”N 80°17′54”E), situated in northern Chennai, which is known for its beach and fishing harbour. The Napier station (13°03′58”N 80°17′22”E) is located below the Napier bridge, where the highly polluted Cooum River meets the coastal waters. Recently, the Tamil Nadu Pollution Control Board declared the Cooum River dead due to zero Dissolved Oxygen (DO) levels and high levels of Total Dissolved Solids (TDS) values (Gautham, 2023). The Marina station (13°03′24”N 80°17′09”E), situated between the Cooum and Adyar rivers, is a well-known tourist spot. Anthropogenic activities may affect sediment characteristics, potentially leading to alterations in the diversity patterns observed at this station (Sugumaran, et al., 2009). The Adyar station (13°00′52”N 80°16′40”E) receives polluted water through the Adyar River. The Tamil Nadu Pollution Control Board has declared the Adyar River as dead due to low levels of DO and high level of TDS (Gautham, 2023). Finally, the Besant Nagar station (12°59′33”N 80°16′16”E), located slightly away from the Adyar estuary, is the cleanest among all the other stations in the study. Figure 1 shows the locations of each of these stations.

2.2. Analysis of physicochemical parameters and sediments

Physicochemical parameters of coastal water were continuously monitored throughout the study period using

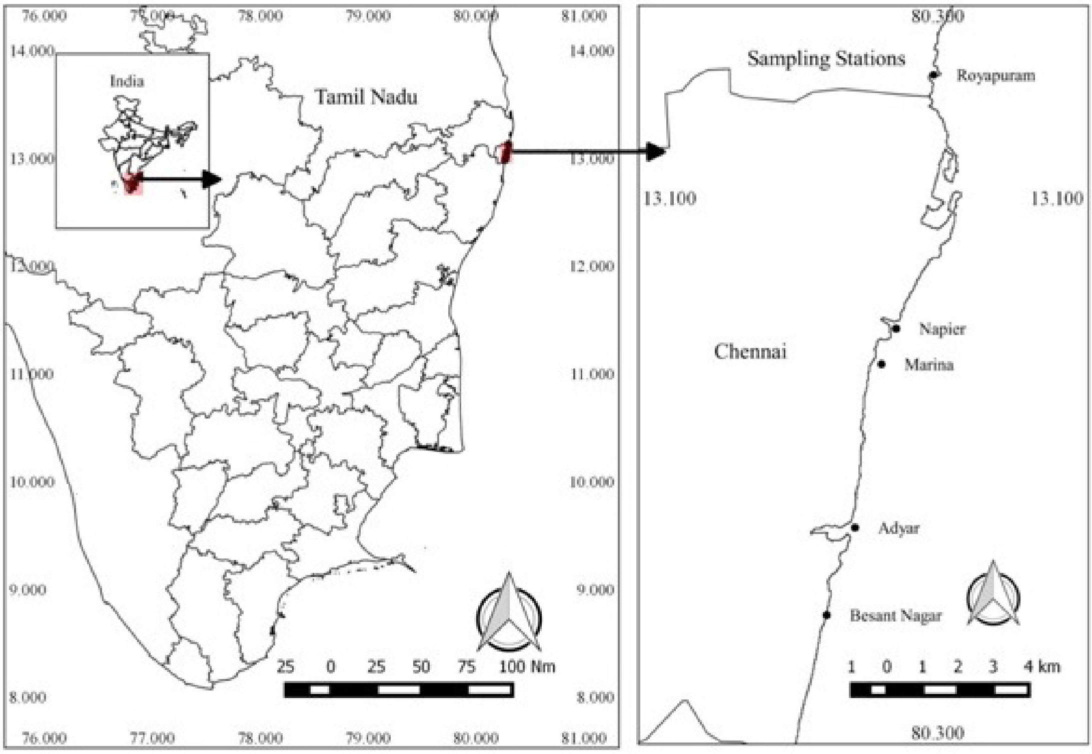

Figure 1. Sampling locations.

standard procedures. Temperature was measured using a handheld mercury thermometer (Dimple), dissolved oxygen with a DO meter (DO 5510), salinity with a salinometer (RHS 10 ATC), and pH with a pH meter (PH-210). Concentrations of nitrate, phosphate, and ammonia were determined using the protocol outlined by Strickland and Parsons (1972).

To determine different grain sizes of sediments, granulometric analysis was conducted. Wet sediment samples were air-dried at room temperature until all water had evaporated. The dried sediments were then placed in a series of sieves arranged in descending order and sieved for approximately 5 min. The weights of the dried sediments were measured using a balance with an accuracy of 0.01 units. The different sieve sizes were used to separate various grain sizes, and the percentage weight of each sieve was calculated accordingly. The sieve sizes were converted to phi (Ø) values using the formula phi (Ø) = $-\log_2$ mm (Buchanan, J.B., 1984). The percentages were converted to cumulative percentages as shown in Table 1.

2.3. Sample collection

This study follows the sampling protocol of Nybakken (1997). Sample collection was conducted during low tide, determined to be the optimal time for collection (Mantha et al., 2012). A cylindrical metal corer measuring 42.3 cm in length and with a 3.57 cm inner diameter was used to collect meiobenthic samples in triplicate from each of the five stations along the Chennai coastline. The corer was carefully inserted into the sediment up to a depth of 15 cm to collect sediment containing the meiobenthos. To preserve the integrity of the samples, sediment was immediately fixed in 5% formaldehyde and labelled appropriately (J. Sugumaran et al., 2009). Great care was taken to ensure that all the sediment in the container was fully collected. The samples were then transported to the laboratory for further analysis with utmost care to prevent any spillage.

2.4. Laboratory process

The methodology used in this study for meiobenthos analysis follows the sampling protocol of Nybakken (1997). Sediments collected were processed through the decantation method to separate the meiobenthos from the sediment. In this method, a closed container was filled with the sediment sample and water until almost full. The sample was shaken vigorously several times, and left undisturbed for a minute for the heavier sand grains to settle down. The supernatant containing the organism was then run through meshes with upper and lower limit mesh sizes of 500 µm and 63 µm, respectively. Meiobenthic organisms were retained on the lower-size mesh and then preserved in a 5% formaldehyde solution. The organisms were stained with Rose Bengal and observed under a

Table 1. Grain size composition of sand grains from the different stations of the Chennai coast.

Mesh size (micron)	Royapuram (mean ± SD) (g)	Napier (mean ± SD) (g)	Marina (mean ± SD) (g)	Adyar (mean ± SD) (g)	Besant Nagar (mean ± SD) (g)
2000	0.083 ± 0.27	0.5 ± 0.53	0.58 ± 1.25	0.4 ± 0.68	0.36 ± 0.60
1000	0.141 ± 0.12	4.25 ± 4.32	1.92 ± 1.16	3.68 ± 6.07	3.1 ± 4.74
710	1.12 ± 1.01	17.3 ± 13.92	9.51 ± 3.89	11.9 ± 12.8	13.06 ± 13.09
500	34.1 ± 39.9	81.7 ± 29.4	70.2 ± 39.6	84.59 ± 51.1	81.87 ± 57.4
355	54.7 ± 26.5	71.5 ± 30.08	83.94 ± 30.3	69.6 ± 25.3	74.7 ± 34.04
250	59.61 ± 13.18	46.1 ± 14.1	51.5 ± 21.9	42.3 ± 26.1	41.33 ± 22.1
150	70.8 ± 30.39	32.16 ± 22.71	28.48 ± 21.48	42.23 ± 34.2	21.8 ± 11.6
125	10.96 ± 8.057	2.82 ± 5.31	3.32 ± 4.48	3.60 ± 5.45	7.95 ± 14.5
90	16.08 ± 11.1	2.19 ± 2.39	1.83 ± 1.063	2.5 ± 2.105	2.31 ± 1.21
63	7.94 ± 5.68	0.66 ± 0.62	0.75 ± 0.35	0.72 ± 0.53	0.93 ± 0.61
0	0.41 ± 0.36	0.13 ± 0.24	0.05 ± 0.06	0.06 ± 0.07	0.12 ± 0.16

stereomicroscope. Organisms were separated individually into different groups based on morphological characters and observed under a compound microscope (10x, 20x, 40x &100x). For detailed identification using various keys, including Aiyar and Alikunhi (1944), Krishnaswamy (1957), Ax (1971), Rao (1972, 1989, 1993), Warwick (1973), Coull (1977), Platt and Warwick (1980), Wells and Rao (1987), and Higgins and Thiel (1988). Meiobenthic organisms were enumerated using Sedgwick-Rafter chamber and the total density was expressed as the number of individuals per 10 cm^2 (ind./10 cm^2) (Naveed, et.al., 2009; J. Sugumaran & Padmasai, 2019).

2.5. Statistical analysis

All statistical analyses were conducted using PAST 4.09 (Hammer et al., 2001) and JASP 0.16 (Love et al., 2019). ANOVA and post hoc Tukey's test were performed to determine the significance between the meiobenthic groups at different stations. Correlation analyses were conducted to evaluate the relationship between physicochemical parameters and the density of meiobenthos groups, and the correlation coefficient (R) was calculated. To visualize the relationship between meiobenthos and environmental variables, canonical correspondence analysis (CCA) was carried out with environmental parameters as explanatory variables. The index of diversity (Shannon index) and index of dominance (Simpson index) were calculated using PAST 4.09.

3. Results

3.1. Physicochemical parameters and granulometric analysis of the Chennai coast

The significant fluctuations in physicochemical parameters of the interstitial water were observed throughout the sampling period. The interstitial water temperature ranged between 24.2 °C–31.4 °C across the five sampling stations. Salinity varied from 27.4–34.9 ppt, and the dissolved oxygen levels ranged between 2.18–6.44 mgL^{-1}. pH values fluctuated between 7.09–8.07. The highest temperature was recorded at the Adyar station in August (31.4 °C), while the lowest was at the Napier station in November (24.2 °C). The highest salinity (34.9 ppt) was observed at the Marina station in December, whereas the Adyar station recorded the lowest salinity (27.4 ppt) in June. The Marina station also recorded the highest dissolved oxygen level of 6.44 mgL^{-1} in January, while the Napier station had the lowest level of 2.18 mgL–1 in March. Nitrate, phosphate, and ammonia levels were relatively low during January–June compared to September, October, and November across the stations (Figures 2a, 2b, and Figure 3a). Granulometric analysis of sand grains from different stations revealed that a high amount of sand grains was retained at mesh sizes of 355 and 500 microns in Napier, Marina, Adyar, and Besant Nagar stations indicating medium-sized sand grains. However, at Royapuram station, a high amount of sand grains was retained at the mesh size of 150 microns (Table 1). This indicates that the sands were finer at Royapuram station compared to the other stations.

3.2. Spatial and temporal variations of meiobenthic groups from the Chennai coast

In this study, we observed 61 meiobenthic species belonging to 20 groups (Supplementary table). Over the study period, the marina stations showed the highest diversity of meiobenthos followed by Adyar, Royapuram, Besant Nagar, and Napier stations. Nematodes were observed with high density at Royapuram and Napier stations, with mean values of (186.5 ± 71.6 ind.10 cm^2) and (288.6 ± 91.07 ind.10 cm^2) (Table 2). However, harpacticoids were observed in high density compared to other meiobenthic groups in Marina, Adyar and Besant Nagar stations, with

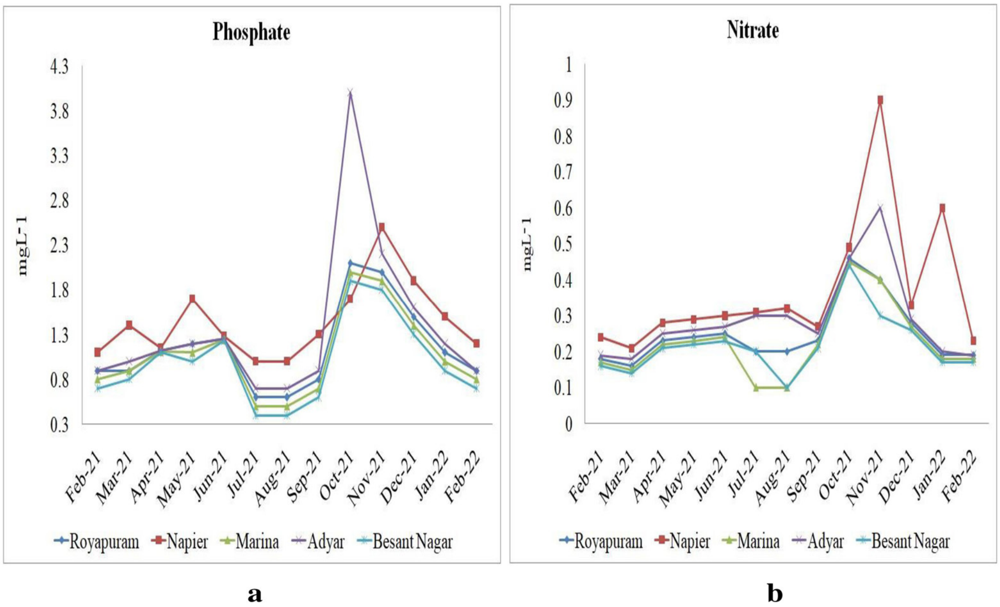

Figure 2. Physicochemical parameters of the Chennai coast (a- Phosphate; b- Nitrate).

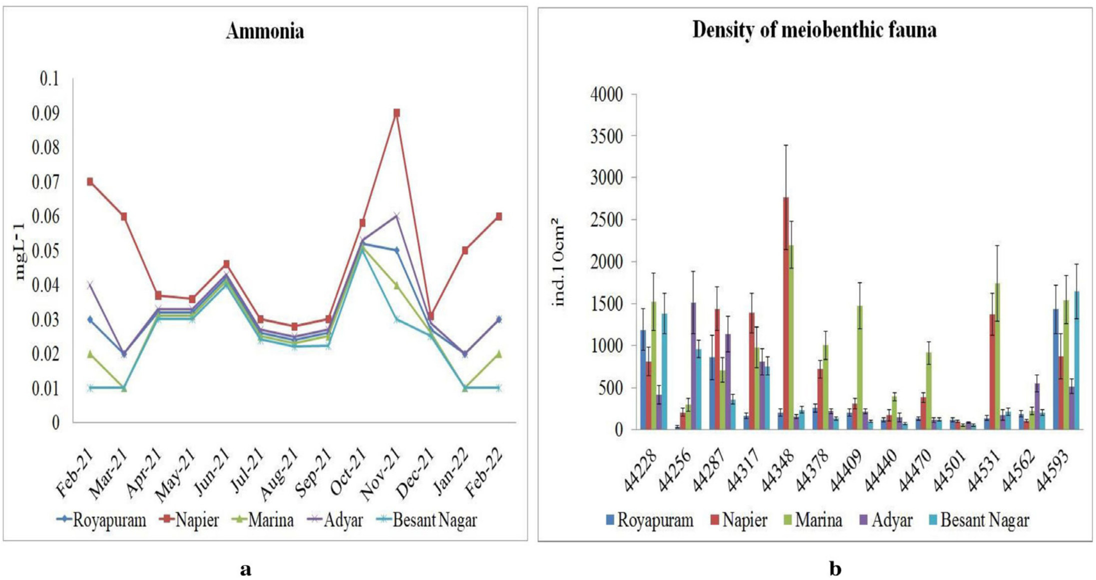

Figure 3. Physicochemical parameters of the Chennai coast (a- Ammonia; b- Density of meiobenthic fauna).

mean values of (449.88 ± 264.3 ind.10 cm²), (148.83 ± 58.54 ind.10 cm²), and (196.2 ± 71.9 ind.10 cm²) respectively. Polycheata, Oligocheaeta, Nemertinea, and Turbullaria were also commonly observed throughout the study period. However, Cumacea, Cnidaria, and Halacaridae were observed very rarely during the entire study. Temporal variation in meiobenthic groups throughout the study period revealed that high diversity of meiobenthos was observed during February across all the stations followed by Napier and Marina stations in August (Table 2). However, a high density of meiobenthos was observed in Marina and Napier stations during June. Followed by that, February and March also revealed a high density of meiobenthic groups across all the stations. However, there was a drop in diversity and density of meiobenthos between September and November (Figure 3b).

Table 2. Mean density (twelve months' average) of meiobenthic communities from different stations of the Chennai coast.

Meiobenthic groups	Royapuram (mean ± SD) (ind.10 cm²)	Napier (mean ± SD) (ind.10 cm²)	Marina (mean ± SD) (ind.10 cm²)	Adyar (mean ± SD) (ind.10 cm²)	Besant Nagar (mean ± SD) (ind.10 cm²)
Foraminiferans	3.41 ± 6.57[a]	0.85 ± 2.13[c]	1.7 ± 4.16[b]	2.48 ± 5.43[a]	1.28 ± 2.13[b]
Ciliates	–	–	1.7 ± 6.16[a]	–	1.28 ± 4.62[a]
Cnidarians	–	–	2.5 ± 6.2[a]	1.21 ± 4.62[b]	1.28 ± 4.62[b]
Turbellarians	3.41 ± 8.34[c]	1.62 ± 5.8[d]	18.5 ± 6.4[a]	6.25 ± 6.45[b]	2.22 ± 4.9[c]
Nemertines	7.089 ± 11.44[b]	3.4 ± 8.6[c]	12.8 ± 23.59[a]	3.83 ± 5.74[c]	4.1 ± 8.4[c]
Nematodes	186.5 ± 71.6[b]	288.6 ± 91.07[a]	144.8 ± 87.2[b]	69.6 ± 36.86[d]	81.5 ± 67.16[c]
Rotifers	–	0.85 ± 3.08[c]	6.8 ± 14.4[a]	4.26 ± 12.39[a]	3.33 ± 2.74[b]
Kinorhynchs	1.1 ± 4.30[c]	1.1 ± 3.22[c]	19.0 ± 16.8[a]	4.78 ± 8.14[b]	4.52 ± 8.62[b]
Polychaetes	24.18 ± 55.53[d]	196.3 ± 434.4[a]	66.29 ± 98.03[b]	49.50 ± 117.58[c]	41.00 ± 68.71[b]
Oligochaetes	38.2 ± 21.7[d]	116.36 ± 28.8[b]	157.712 ± 28.165[a]	59.76 ± 34.05[c]	29.2 ± 26.83[d]
Sipunculan	4.67 ± 6.78[d]	7.26 ± 14.23[d]	21.741 ± 25.871[b]	65.44 ± 108.27[a]	10.84 ± 12.2[c]
Cladocerans	0.83 ± 3.07[c]	–	3.417 ± 8.644[a]	1.21 ± 4.62[b]	0.85 ± 3.08[c]
Ostracods	0.51 ± 1.84[c]	0.85 ± 3.08[c]	1.281 ± 4.620[b]	14.54 ± 52.36[a]	–
Harpacticoid copepods	134.11 ± 227.39[c]	124.38 ± 193.68[c]	449.88 ± 264.3[a]	148.83 ± 58.54[b]	196.2 ± 71.9[b]
Cyclopoid copepods	0.34 ± 1.23[c]	0.68 ± 2.4[b]	2.99 ± 10.78[a]	0.51 ± 1.84[b]	–
Isopods	2.39 ± 6.4[c]	11.27 ± 14.08[b]	79.8 ± 48.41[a]	2.98 ± 5.89[c]	87.2 ± 23.85[a]
Amphipods	–	–	6.66 ± 13.04[b]	19.24 ± 37.2[a]	2.5 ± 9.24[c]
Cumacean	–	–	–	–	0.17 ± 0.61[a]
Halacarids	–	2.3 ± 5.9c	8.11 ± 15.03[a]	4.78 ± 15.07[b]	3.75 ± 9.63[b]
Insects	3.4 ± 8.34[c]	67.57 ± 22.86[a]	4.35 ± 7.59[c]	10.5 ± 10.02[b]	12.98 ± 20.64[b]

*Values with the same alphabet superscripts denote they do not show significance with each other whereas values with different alphabet superscripts in column denote they show significance with each other in ANOVA followed by Tukey's test ($p < 0.05$).

A high Shannon's index was observed at Marina Station (3.298) in April, and the minimum value was observed at Royapuram Station (1.365) in March. Throughout the study period, considerably high H indexes were observed in February across all the stations. Similarly, the highest Simpson's index was observed at Napier Station (0.229) in July, and the lowest value was observed at Marina Station (0.039) in April (Table 3).

3.3. Relationship between meiobenthic groups and physicochemical parameters

Throughout the study period, there were no strong correlation coefficients ($-0.5 < R < 0.5$) between meiobenthic groups and physicochemical parameters. However, harpacticoids showed a considerable negative coefficient with nitrate ($R = -0.27$), phosphate ($R = -0.21$) and ammonia ($R = -0.23$) compared to other meiobenthic groups (Table 4). Turbellarians and ostracods also showed a considerable negative R value with the nitrate and phosphate content of the intertidal water. Similarly, harpacticoids showed a positive coefficient with dissolved oxygen, pH, and salinity. Other dominant groups of the study like nematodes, oligochaetes, and polychaetes showed a low correlation coefficient with phosphate and nitrate. The negative relationship between harpacticoids and turbellarians with nitrate, phosphate, and ammonia was also observed in CCA, where these meiobenthic groups are placed at the opposite axis to that of nitrate, phosphate, and ammonia (Figure 4). CCA analysis also revealed the grouping of harpacticoids, ciliates, ostracods, and turbellarians on the same axis, which is negatively related to temperature, ammonia, nitrate, and phosphate and positively related to dissolved oxygen. On the other hand, nematodes, polychaetes, and isopods were grouped along with the vector line of nitrate, phosphate, and ammonia. ANOVA between the stations revealed significant variations among different stations as denoted in Table 2.

4. Discussion

The current study delves into the diversity and density of meiobenthic groups across various stations along

Table 3. Diversity indices of meiobenthic communities from the Chennai coast.

	Shannon index of Diversity					Simpson index of Dominance				
Months	**Royapuram**	**Napier**	**Marina**	**Adyar**	**Besant Nagar**	**Royapuram**	**Napier**	**Marina**	**Adyar**	**Besant Nagar**
Feb-21	3.152	2.806	3.03	2.92	2.6	0.057	0.087	0.064	0.059	0.133
Mar-21	1.365	2.327	3.08	2.57	2.77	0.294	0.105	0.048	0.114	0.09
Apr-21	2.172	2.256	3.29	2.64	2.73	0.147	0.127	0.039	0.11	0.067
May-21	2.7	1.807	3.11	2.91	2.93	0.071	0.258	0.052	0.064	0.065
Jun-21	2.784	2.014	2.71	2.6	3.1	0.075	0.199	0.098	0.081	0.054
Jul-21	2.63	1.92	3.004	2.39	2.42	0.083	0.229	0.057	0.103	0.101
Aug-21	2.16	3.08	3.09	2.75	2.31	0.137	0.058	0.061	0.077	0.107
Sep-21	2.49	2.73	2.83	2.41	2.24	0.088	0.092	0.062	0.11	0.109
Oct-21	2.63	2.76	2.56	2.3	2.75	0.077	0.067	0.14	0.092	0.064
Nov-21	2.36	2.463	2.33	2.46	2.126	0.096	0.086	0.12	0.087	0.126
Dec-21	2.74	1.912	2.58	2.33	2.934	0.066	0.204	0.093	0.102	0.056
Jan-21	2.66	2.303	2.92	2.13	2.709	0.076	0.109	0.057	0.172	0.074
Feb-22	3.18	2.51	2.96	2.96	2.306	0.064	0.121	0.068	0.056	0.187

Table 4. Correlation coefficient (R) between meiobenthic fauna with environmental parameters.

	Temperature	Salinity	DO	pH	Nitrate	Ammonia	Phosphate
Foraminiferans	0.141	0.080	0.028	–0.044	–0.167	–0.241	–0.164
Ciliates	–0.03	0.155	0.189	0.139	0.065	0.005	0.086
Cnidarians	0.117	0.025	0.038	0.062	–0.113	–0.116	–0.065
Turbellarians	–0.118	0.235	0.27	0.166	–0.189	–0.231	–0.176
Nemertines	–0.06	0.109	–0.063	0.001	–0.263	–0.139	–0.272
Nematodes	0.001	–0.141	–0.255	–0.11	–0.175	0.09	–0.127
Rotifers	0.069	0.121	0.073	0.222	–0.138	–0.184	–0.188
Kinorhynchs	0.089	–0.038	0.018	0.091	–0.113	0.023	–0.062
Polychaetes	0.169	–0.11	–0.141	–0.109	–0.051	0.052	–0.043
Oligochaetes	–0.031	0.081	0.059	0.052	–0.031	–0.063	0.084
Sipunculan	0.062	0.056	0.008	–0.008	–0.171	–0.174	–0.105
Cladocerans	0.16	0.054	–0.067	–0.032	–0.056	0.002	–0.036
Ostracods	–0.160	–0.06	0.177	–0.185	–0.21	–0.342	–0.207
Harpacticoida	0.019	0.327	0.23	0.269	–0.275	–0.21	–0.23
Cyclopoida	0.153	0.15	0.046	0.155	–0.14	–0.089	–0.173
Isopods	0.146	0.082	0.076	0.222	0.018	0.108	0.056
Amphipods	0.13	0.081	–0.027	–0.004	–0.086	–0.079	–0.049
Halacarids	0.055	0.086	0.12	0.108	0.021	0.017	0.06
Insects	0.13	–0.07	–0.13	–0.099	0.004	0.071	–0.01

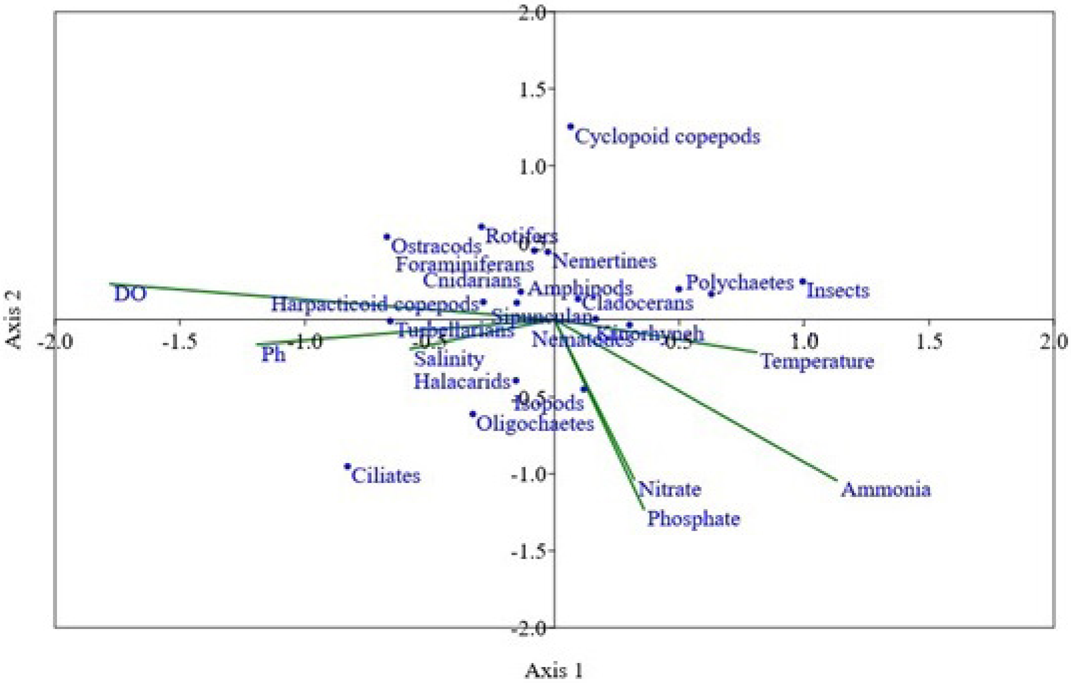

Figure 4. CCA analysis between meiobenthic groups and physicochemical parameters.

the Chennai coast. The dominant groups observed were harpacticoid copepods, nematodes, oligochaetes and polychaetes, aligning with findings by Sugumaran and Padmasai (2019). Harpacticoid copepods were notably dominant in terms of density at Marina, Adyar and Besant Nagar stations, whereas nematodes prevalant at Royapuram and Napier stations. This density pattern mirrors observations by Mantha et al. (2012) regarding the dominance of Harpacticoids over nematodes in certain parts of the Chennai coast, likely due to their dispersal behavior and preference for interstitial spaces between larger sand grains (Giere, 2009). The lower diversity observed at Royapuram station is attributed to high pollution levels and the influence of pollutants and heated coolant waters from surrounding industries (Venkataraman et al. 2007). Sugumaran et al. (2009) also noted low meiobenthic diversity at Royapuram attributing it to wave action and sand erosion. Conversely, the Marina station exhibited high meiobenthic diversity, aligning with prior studies by Sivakumar et al. 2021; Naveed et al. 2009 and Mantha et al. 2012, suggesting a general trend of higher diversification at Marina stations. Higher diversity usually corresponds to a lower dominance ratio and vice versa.

Grain size is a significant factor influencing the community richness and diversity of meiobenthic fauna (Martínez et al., 2020). The fine grain size at Royapuram stations results in fewer niches for meiobenthic organisms (Martinec et al., 2014), potentially explaining the lower diversity observed there. Nematodes generally prefer finer sediment grains, whereas harpacticoid copepods favour coarser sediments (Robert Burgess, 2001), potentially contributing to the high density of nematodes at Royapuram station. In this study, rare observations were made for groups such as cumaceans, cyclopoid copepods, ostracods, foraminiferans, and cladocerans. This rarity aligns with Gambi et al. (2010) findings regarding the low representation of these taxa in meiobenthic communities in the Mediterranean coastal zones.

Environmental factors play a crucial role in shaping the behaviour and physiology of aquatic communities (Nawaz et al., 2023). The high level of nitrate, phosphate, and ammonia in aquatic environments indicate elevated anthropogenic activities, potentially resulting in a decline in marine invertebrate density and diversity (Kennedy et al., 2019; Nawaz et al. 2023). In this study, a negative relationship was observed between ammonia, nitrate, and phosphate levels with harpacticoid copepods and most other meiobenthic groups, highlighting their sensitivity to anthropogenic impacts changes in physicochemical parameters or anthropogenic impacts significantly reduced their density (Naveed et al., 2009; Sugumaran and Padmasai, 2019), making them valuable indicators of coastal ecosystem health (Barroso et al., 2018). The nutrient content in the water typically increases from August to November, possibly due to monsoon rainfall washing nutrients from nearby rivers, and accumulating them on the ocean surface (Umer et al., 2020). The study also revealed a decrease in meiobenthos diversity and density during the rainy season in Chennai (September to December), suggesting that physicochemical parameters influence meiobenthos distribution. Conversely, dominant groups like nematodes showed no significant effects of physicochemical parameters on their distribution, potentially explaining their prevalence in most benthic habitats. Nematodes being a diverse group and environmentally resilient group (Urkmez et al., 2015; Hedfi et al., 2022), serve as ideal bioindicators for assessing coastal pollution (Semprucci and Balsamo, 2012; Zeppilli et al., 2018).

5. Conclusion

This study provides offers a thorough analysis of meiobenthic groups and their distribution across diverse stations along the Chennai coast. The investigations delve into the intricate relationship between these groups and various environmental parameters. Comparatively lower diversity noted at Royapuram station in comparison to other locations, while the Marina station exhibited superior diversity and density. Additionally, Royapuram and Napier stations displaced a notable abundance of nematodes, coinciding with a higher concentration of fine sand grains. The study underscores the sensitivity of harpacticoid diversity to fluctuations in physicochemical parameters. In contrast, nematode populations appear to be relatively unaffected by such changes. The findings strongly suggest that the distribution of meiobenthos is influenced by the presence of nitrate and ammonia, demonstrated by the decreased density of the meiobenthic community in response to elevated ammonia levels in the water. It is essential to highlight that this study represents a preliminary report, and further research is imperative to attain a comprehensive understanding of how distinct meiobenthic groups respond to variations in environmental parameters. Future investigations will significantly contribute to our comprehensive of the intricate interplay between meiobenthic communities and their surrounding environments.

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Author contributions

MK-Research work execution, sample collection, sample analysis, species identification and manuscript writing; MAN-Research plan, sample analysis, visualization and manuscript revising and editing; ZT-sample analysis, species identification and manuscript writing and editing; MAST-Sample analysis and manuscript writing and editing; KA-Research methodology, species identification, and literature review. MSN- Research plan, species identification, manuscript final revision, and supervising the entire research work.

Conflict of interest

All authors declare no conflict of interest that could affect the current study.

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Supplementary Table

Meiobenthos	Royapuram	Napier	Marina	Adyar	Besant nagar
Foraminiferans *Elphidium* sp	+	+	+	+	+
Ciliate *Litonotus lamella* (Schewiakoff, 1896)	–	–	+	–	+
Cnidarians *Halammohydra schulzei* (Remane, 1927)	–	–	+	+	+
Turbellarians *Macrostomum* sp	–	–	+	–	–
Acoela sp	–	–	+	+	–
Haplopharyngida sp	–	–	+	+	–
Otoplana sp	–	–	+	+	–
Proseriata sp	–	+	+	–	–
Nemertines *Annulonemertes* sp	+	+	+	+	+
Nematodes *Sabatieria* sp	+	+	+	+	+
Chromadora sp	+	+	+	+	+
Anticyathus sp	+	–	+	–	–
Desmodora sp	+	+	+	+	+
Halalaimus setosus (Timm, 1961)	+	+	+	+	+
Steineria sp	+	+	+	+	+
Parallelocoilas sp	+	+	+	+	+
Geomonhystera sp	–	–	+	+	–
Metepselonema sp	+	+	+	+	+
Desmoscolex sp	+	+	–	–	–
Synonema sp	+	+	+	–	–
Thalassironus sp	+	–	–	+	+
Xenolaimus sp	+	+	+	–	–
Enoploides sp	+	–	–	–	–
Gnomoxyala sp	+	–	–	–	–
Rotifers *Lecane psammophila* (Wiszniewski, 1932)	–	+	+	+	+
Brachionus sp	–	–	–	+	–
Kinorhynchs *Cateria gerlachi* (Higgins, 1968)	+	+	+	+	+
Polychaetes *Parapodrilus* sp	+	+	+	+	+
Eusyllius homocirrata (Hartmann-schroder, 1958)	+	+	+	+	+
Dorivillea sp	+	+	+	+	+
Pisione complexa (Alikuhni, 1942)	–	–	+	–	–
Hesionides arenaria (Friedrich, 1937)	+	+	+	–	+
Euthalenessa djiboutiensis (Gravier, 1902)	+	+	–	+	–
Polygordius madrasensis (Aiyar & Alikuhni, 1944)	+	+	+	+	+
Saccocirrus minor (Aiyar & Alikuhni, 1944)	+	+	+	+	+

Oligochaetes *Marionina* sp	+	+	+	+	+
Grania pusilla (Erséus, 1974)	+	+	+	+	+
Heterodrilus sp	+	+	+	+	+
Sipunculan	+	+	+	+	+
Cladoceran *Ilyocryptus spinifer* (Herrick, 1882)	+	–	+	+	+
Ostracods *Eucypris* sp	+	+	+	+	–
Harpacticoid Copepods *Arenosetella indica* (Krishnaswamy, 1957)	+	+	+	+	+
Arenopontia subterrenea (Kunz, 1937)	+	+	+	+	+
Sewellina reductus (Krishnaswamy, 1957)	+	+	+	+	+
Leptastacus euryhalinus (Krishnaswamy, 1957)	+	+	+	+	+
Emertonia pseudogracilis (Krishnaswamy, 1957)	+	+	+	+	+
Cylindropsyllus sp	–	+	+	+	+
Parapseudoleptomesochra trisetosa (Krishnaswamy, 1957)	+	+	+	+	+
Arenosetella germanica (Kunz, 1937)	+	+	+	–	+
Arenopontia (Neoleptastacus) indica (Rao, 1967)	+	+	+	+	+
Hastigerella leptoderma (Klie, 1929)	+	+	+	+	+
Psammastacus acuticaudatus (Krishnaswamy, 1957)	+	+	+	+	+
Apodopsyllus camptus (Wells, 1971)	–	–	+	–	+
Apodopsyllus madrasensis (Krishnaswamy, 1951)	+	+	+	+	+
Ameira parvula (Claus, 1866)	+	+	+	+	+
Cyclopoid copepods *Mesocyclops*	+	+	+	+	–
Isopods *Angeliera phreaticola* (Chappuis & Delamare-Deboutteville, 1952)	+	+	+	+	+
Amphipods	–	–	+	+	+
Cumacean	–	–	–	–	+
Halacarid *Acarochelopodia cuneifera* (Bartsch, 1977)	+	+	+	+	+
Insects *Entomobryidae*	+	+	+	+	+