Distribution And Diversity Of Meio-Benthos In Ennore Estuary, Southeast Coast Of India

R. Punniyamoorthy, G. Mahadevan, P. Murugesan

Abstract: In the present study, the distribution and diversity of meio-benthos in Ennore estuary was studied in relation to seasonal variation of environmental entities. A total of 41 meio-benthic species belonging to four meio-fauna taxa: foraminifera, nematodes, ostracodes and harpacticoids were recorded. Among the four meio-fauna taxa, foraminifera topped the list with 26 species followed by nematodes (8 species), ostracodes (4 species) and harpacticoids (3 species). The maximum density (448Nos/10cm²) was recorded near thermal power plant (EE-RS) and minimum (296Nos/10cm²) was recorded near estuary mouth (EM-RS). Heavy metal concentration also varied significantly in both the estuaries. Of these, the level of Cadmium (Cd), iron (Fe), chromium (Cr) and Lead (Pb) accumulation was found maximum at estuary station (EE-1) and minimum at mouth regions (EM-RS). Biota-environmental matching (BIO-ENV) showed that the environmental parameters such as Dissolved oxygen, Temperature, Salinity, Soil pH, Sand, TOC and Clay manifested as best match (ρω = 0.975) in determining meiofaunal distributions. The maximum diversity (H') of meiofauna was recorded (3.768) near estuary mouth (EM-RS), similarly the maximum species richness (d) 6.923 was recorded near thermal power plant (EE-1) and maximum species evenness (J') 0.995 was recorded at mouth region (EM-RS). The results of present study helps to develop an understanding on the meiofaunal distribution based on seasonal variation of physico-chemical parameters and heavy metal concentration, which will form a reliable tool in bio-monitoring studies.

Keywords: Meiofauna, Density, Diversity, Estuary, Ennore

1. INTRODUCTION

The estuaries are used as transport routes, which are fundamental for economic and social development and improving the quality of life. At present, about 60% of the world's populations live along the estuaries and the coast [1]. The estuary is the partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it and with a free connection to the open sea and these are among the most productive ecosystem in the world [2]. Estuaries have a unique combination of physical features associated with their shape, catchment area connection to the sea and tidal regime. Moreover, there is a great variety of human impacts like building of dams, impoundment, pollution, industrial and residential development, recreation and other activities in both the estuary and its catchment area [3]. Benthic organisms play an important role in the detrital food cycle and also act as food for other fauna e.g. worms, snails, shrimps, mussels, barnacles, clams, oysters etc., or by the biological agents like macrobenthos organism. Meiofauna includes metazoan organisms and also ecologically relevant species such as foraminifera, nematodes and ciliates inhabiting all sediment types in varied climatic zones [4], [5]. Being abundant in the benthic community both in terms of abundance and diversity, meiofauna play a key role in nutrient recycling in the estuaries and marine ecosystem [6], [7]. The diversity and distribution of meiofauna is regulated by various abiotic factors such as temperature, salinity, dissolved oxygen, organic matter, hydrodynamics and sedimentary processes. Benthic meiofauna plays significant ecological important role within any estuaries and coastal systems since they facilitate bio-mineralization, maintaining ecological balance, support various higher trophic levels and are highly sensitivity to anthropogenic actions, making them excellent organisms for pollution bio-monitoring. Hence, the present study was attempted to study the community composition, density, richness, evenness and diversity of benthic meiofauna of Ennore estuary, Southeast coast of India.

2. MATERIALS AND METHODS

2.1 Study area

Seasonal sample collection was carried out from April 2017 - March 2018 to study the benthic meiofaunal diversity in Ennore estuary (Lat. 13°13'24.28"N; Long. 80°20'34.24"E), located in the north of Chennai, which is considered as a major industrial hub of south India. Dumping of fly ash slurry from Ennore thermal plant coupled with various other anthropogenic activities like sewage pollution and industrial discharge. In Ennore estuary, five stations were fixed (Fig. 1). The details of sampling stations are given below:

- Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai – 608 502, Tamil Nadu - India
- Corresponding author E-mail: pmurugesan74@gmail.com
Fig. 1. Map showing the sampling stations: (Ennore estuary)

Table 1. Geographical locations of sampling stations in Ennore estuary

<table>
<thead>
<tr>
<th>Stations</th>
<th>Stations Code</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Location of sampling point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EE-1</td>
<td>13°13'24.28&quot;N</td>
<td>80°18'52.03&quot;E</td>
<td>Fixed near Vallur Power plant, sewage pollution</td>
</tr>
<tr>
<td>2</td>
<td>EE-2</td>
<td>13°13'57.27&quot;N</td>
<td>80°19'35.26&quot;E</td>
<td>Fixed near discharge point of Ennore Thermal Power plant</td>
</tr>
<tr>
<td>3</td>
<td>EE-M</td>
<td>13°13'52.43&quot;N</td>
<td>80°20'08.87&quot;E</td>
<td>Near Ennore river mouth</td>
</tr>
<tr>
<td>4</td>
<td>EM-LS</td>
<td>13°13'6.10&quot;N</td>
<td>80°19'54.0&quot;E</td>
<td>Fixed 500m lift side from Ennore mouth</td>
</tr>
<tr>
<td>5</td>
<td>EM-RS</td>
<td>13°14'42.47&quot;N</td>
<td>80°20'34.24&quot;E</td>
<td>Fixed 500m right side from Ennore mouth</td>
</tr>
</tbody>
</table>

(Foot note: EE- Ennore estuary, EM- Ennore Mouth, M- Mouth, RS- Right side, LS- Left side)

2.2 Collection of Water and sediment samples
Water samples were collected by using Niskin water sampler and for the sediment samples were collected by using undisturbed surface sediment samples from the grab haul were collected and shade dried for the Soil texture and Total Organic Carbon (TOC) analysis. The physico-chemical parameters such as Temperature (Hand held mercury thermometer), Salinity (Refractometer - ATAGO Japan) and pH (pH pen - model LI-120 Eutech Instrument Singapore) were recorded by using the standard instruments and was estimated using Winkler method as described by [8]. The Soil texture analysis was done using pipette method as described by [9] and Total Organic Carbon (TOC) analysis was done by following wet oxidation method of [10]. Heavy metal analysis, samples were digested with concentrated perchloric acid and nitric acid (1:3) by following [11]. The supernatant was analyzed to detect the level of heavy metals by using Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS).

2.3 Meio-benthic sample collection and identification
In each station, three replicate samples were collected using Peterson Grab (biting area 0.1 m²) by following the method of [12]. The samples collected were emptied into a plastic tray and then sieved through mesh screen (between 500 and 63μm) as described by [13]. The sieve retains were preserved in 5-7% formalin and further stained with Rose Bengal solution and the stained samples were left for two days. Subsequently, the meiofauna were sorted, counted and identified into group level and then identified using light microscope (KL-300LED Carl Zeiss microscope) up to lowest possible taxonomic level by consulting the standard works of [14], [15], [16] for foraminifers; [17], [18], [19] for nematodes; [20], [21] for ostracodes and [22] for Harpacticoids.

2.4 Data analysis
The data on environmental variables and biological variables were subjected to various multivariate statistical analyses.
such as Principal Component Analysis (PCA) by using the statistical software PAST (2.0). BIO-ENV (Biota-Environment matching), Hierarchical cluster analysis, Multi-Dimensional Scaling (MDS) and univariate analysis such as Shannon diversity (H'), Margalef richness (d), Pielou's evenness (J') and Simpson dominance (D) were analyzed using the statistical software PRIMER (Ver.7)

3. RESULTS

3.1 Physico-chemical characteristics of water samples

The mean with standard deviation (SD) values of Physico-chemical parameters recorded at each sampling station is summarized in Table 1. Water temperature varied from 24.7 - 27.3°C with minimum at estuary station (EE-1) during monsoon and maximum at near estuary mouth (EM-LS) during summer; water pH was found minimum (7.84) at estuary station (EE-1) during monsoon and maximum near estuary mouth (8.14) at (EM-RS) during summer; salinity showed a wide range of fluctuation with minimum (16.5ppt) at estuary station (EE-1) during monsoon and maximum (36.0ppt) at near estuary mouth (EM-LS) during summer. Dissolved oxygen ranged between 4.49 mg/l at near estuary mouth (EM-LS) during monsoon and 3.16 mg/l at estuary station (EE-2) during summer.

Table 2. Physico-chemical characteristics (mean and SD) recorded in various sampling stations in Ennore estuary

<table>
<thead>
<tr>
<th>Variables</th>
<th>EE-1</th>
<th>EE-2</th>
<th>EE-M</th>
<th>EM-LS</th>
<th>EM-RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>W. Temp (°C)</td>
<td>24.7 ± 0.36</td>
<td>25.1 ± 0.49</td>
<td>26.4 ± 0.51</td>
<td>27.3 ± 0.53</td>
<td>26.8 ± 0.38</td>
</tr>
<tr>
<td>Water pH</td>
<td>7.84 ± 0.36</td>
<td>7.86 ± 0.31</td>
<td>7.92 ± 0.32</td>
<td>8.12 ± 0.26</td>
<td>8.14 ± 0.36</td>
</tr>
<tr>
<td>Salinity (ppt)</td>
<td>16.5 ± 1.18</td>
<td>22.2 ± 0.41</td>
<td>33.8 ± 2.16</td>
<td>36.0 ± 1.46</td>
<td>35.3 ± 1.96</td>
</tr>
<tr>
<td>DO (mg/l)</td>
<td>3.39 ± 0.62</td>
<td>3.28 ± 0.17</td>
<td>3.95 ± 0.66</td>
<td>4.49 ± 0.38</td>
<td>4.36 ± 0.47</td>
</tr>
<tr>
<td>Soil pH</td>
<td>7.96 ± 0.25</td>
<td>7.99 ± 0.33</td>
<td>8.14 ± 0.46</td>
<td>8.29 ± 0.37</td>
<td>8.28 ± 0.31</td>
</tr>
<tr>
<td>TOC (mgC/g)</td>
<td>11.6 ± 0.62</td>
<td>8.8 ± 0.50</td>
<td>6.4 ± 0.48</td>
<td>4.15 ± 0.47</td>
<td>5.6 ± 0.63</td>
</tr>
<tr>
<td>Sand %</td>
<td>7.1 ± 0.32</td>
<td>17.9 ± 0.44</td>
<td>80.3 ± 0.36</td>
<td>80.8 ± 0.50</td>
<td>85.3 ± 0.72</td>
</tr>
<tr>
<td>Silt %</td>
<td>3.8 ± 0.41</td>
<td>10.2 ± 0.72</td>
<td>11.2 ± 0.53</td>
<td>12.7 ± 0.86</td>
<td>16.1 ± 0.58</td>
</tr>
<tr>
<td>Clay %</td>
<td>89.1 ± 0.58</td>
<td>71.9 ± 0.96</td>
<td>8.5 ± 0.76</td>
<td>6.5 ± 0.85</td>
<td>8.6 ± 0.47</td>
</tr>
<tr>
<td>PHC (µg/g)</td>
<td>1.88 ± 0.32</td>
<td>1.13 ± 0.28</td>
<td>0.60 ± 0.18</td>
<td>0.43 ± 0.20</td>
<td>0.365 ±0.17</td>
</tr>
<tr>
<td>Fe (mg/kg)</td>
<td>26.4 ± 0.36</td>
<td>22.7 ± 0.75</td>
<td>14.6 ± 0.50</td>
<td>10.2 ± 0.34</td>
<td>10.17 ± 0.88</td>
</tr>
<tr>
<td>Cd (mg/kg)</td>
<td>7.21 ± 0.45</td>
<td>8.96 ± 0.93</td>
<td>7.94 ± 0.64</td>
<td>7.08 ± 0.88</td>
<td>6.52 ± 0.79</td>
</tr>
<tr>
<td>Pb (mg/kg)</td>
<td>11.5 ± 1.67</td>
<td>8.7 ± 1.09</td>
<td>5.0 ± 0.89</td>
<td>4.7 ± 0.52</td>
<td>4.4 ± 1.04</td>
</tr>
<tr>
<td>Cr (mg/kg)</td>
<td>7.42 ± 1.84</td>
<td>9.61 ± 0.86</td>
<td>4.82 ± 1.05</td>
<td>3.3 ± 0.70</td>
<td>2.15 ± 0.95</td>
</tr>
</tbody>
</table>

(Footnotes: W. Temp - Water Temperature; W. pH - Water pH; DO - Dissolved Oxygen; TOC - Total organic carbon; PHC - Petroleum hydrocarbon; Fe - Iron; Cd - Cadmium; Pb - Lead; Cr - Chromium)

3.3 Meio-benthos

In the present study, as many as 41 species belonging to four groups of Meio-benthic organisms namely Foraminifers, Nematodes, Ostracodes and Harpacticoids were recorded. Among them, Foraminifers topped the list with 26 species. Nematodes were found to be the next dominant group in the order of abundance with 8 species. Ostracodes and Harpacticoids came next with 4 and 3 species respectively. Among the foraminifers, Ammonia beccarii, A. tepida, Bolivina limbata, Elphidium texanum and Spirillina latesperata were found commonly in various stations. With respect to nematodes, Astomonema jennleri and Halalaimus filum were found to be the common species in the samples collected in various stations. The ostracodes species such as, Basslerites lieubai and Bairdopilata scabra harpacticoids, Harpacticus chelier and Laophonte thoracica were found to be common species in the surveyed stations. The population density varied from 296 to 448nos.10cm$^{-2}$ with maximum at Ennore estuary stations (EE-1) during summer season and minimum at near estuary mouth (EM-RS) during monsoon season. Seasonally, the maximum number (37 species) of meiofaunal species was recorded during post monsoon near estuary.
mouth station and minimum (29 species) during monsoon in estuary stations.

3.4 Percentage contribution
The results of percentage composition of meio-fauna in different stations revealed that foraminiferans as dominant group maximum with 80% of the total meio-benthic organisms. Nematodes, ostracodes and harpacticoids contributed with 10%, 7% and 3% respectively to the total meio-benthic samples collected (Fig. 2).

3.5 Diversity indices
The Shannon diversity (H') index calculated for meiofaunal abundance data showed minimum (2.931) value at estuary station (EE-2) during monsoon and maximum (3.625) value at near estuary mouth (EM-LS) during summer season; Margalef species richness (d) showed minimum (5.188) value at near estuary mouth station (EE-M) during pre-monsoon and maximum (6.923) value at estuary station (EE-1) in summer; Pielou’s species evenness (J') varied between 0.741 and 0.985 with maximum value at near estuary mouth (EM-RS) during in summer and minimum value at estuary station (EE-1) during monsoon and Simpson dominance varied from 0.639 to 0.908 with maximum at estuary station (EE-1) during Summer season and minimum at near estuary mouth station (EE-M) during monsoon (Table 3).

3.6 Cluster/MDS Analysis
Further, to study the similarity/dissimilarity between stations, the data of foraminiferans abundance in five different stations were approached to cluster analysis and MDS (non-metric Multi-Dimensional Scaling) ordination (Fig. 3). The dendrogram showed that near estuary mouth stations (EM-LS, EM-RS and EE-M) formed separate cluster with similarity percentage of 70%; and similarly the stations in estuarine zone (EE-1 and EE-2) grouped together at the next level with 74%. The MDS plot also confirmed the groupings observed in the cluster analysis. The stress value, which is overlying on the top-right corner of the MDS plot is also very minimal (0.0), signaling a good ordination pattern of foraminiferal abundance (Fig. 4).

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**Table 3. Diversity indices, a-Shannon diversity (H'); b-Margalef richness (d) c- Pielou’s evenness (J') and d-Simpson dominance (D) calculated for benthic meiofauna in Ennore estuary**

<table>
<thead>
<tr>
<th>Stations</th>
<th>Shannon diversity (H')</th>
<th>Margalef richness (d)</th>
<th>Pielou’s evenness (J')</th>
<th>Simpson dominance (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE-1</td>
<td>2.946</td>
<td>6.923</td>
<td>0.741</td>
<td>0.908</td>
</tr>
<tr>
<td>EE-2</td>
<td>2.931</td>
<td>6.276</td>
<td>0.776</td>
<td>0.849</td>
</tr>
<tr>
<td>EE-M</td>
<td>3.015</td>
<td>5.188</td>
<td>0.885</td>
<td>0.639</td>
</tr>
<tr>
<td>EM-LS</td>
<td>3.625</td>
<td>5.639</td>
<td>0.982</td>
<td>0.755</td>
</tr>
<tr>
<td>EM-RS</td>
<td>3.568</td>
<td>5.923</td>
<td>0.985</td>
<td>0.731</td>
</tr>
</tbody>
</table>
3.7 BIO-ENV (Biota-Environment matching)
In the BIO-ENV procedure, which was employed to measure the agreement between the rank correlations of the biological (Bray-Curtis similarity) and environmental (Euclidean distance) matrices, ten environmental variables were allowed to match the biota. The parameters which significantly influenced the diversity and distribution of foraminiferans were temperature, salinity, W. pH, dissolved oxygen, total organic carbon, soil pH, sand, silt and clay were allowed to match the biota. Among the parameters, a combination of Seven environmental parameters ($p_\omega = 0.975$) namely Dissolved oxygen, Temperature, Salinity, Soil pH, Sand TOC and Clay got manifested as best match in determination of benthic foraminiferal distributions followed by Dissolved oxygen, Salinity, pH, Sand TOC and Clay in the next level (Table 4).
Table 4. Harmonic rank correlations ($\rho_0$) between benthic meiofauna abundance and environmental Similarity matrices in various stations of Ennore estuary

<table>
<thead>
<tr>
<th>S. No.</th>
<th>No. of variables</th>
<th>Best variable combinations</th>
<th>Correlation ($\rho_0$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>7</td>
<td>Dissolved oxygen – Temperature – Salinity – Soil pH – Sand – TOC – Clay</td>
<td>0.975</td>
</tr>
<tr>
<td>2.</td>
<td>6</td>
<td>DO – Salinity – pH – Sand – TOC – Clay</td>
<td>0.938</td>
</tr>
<tr>
<td>3.</td>
<td>5</td>
<td>Salinity – Soil pH – TOC – Sand – Temperature</td>
<td>0.902</td>
</tr>
<tr>
<td>4.</td>
<td>4</td>
<td>pH – Temperature – Clay – Salinity</td>
<td>0.886</td>
</tr>
<tr>
<td>5.</td>
<td>4</td>
<td>DO – Soil pH – Clay – Salinity</td>
<td>0.865</td>
</tr>
</tbody>
</table>

3.8 Principle component analysis
The PCA plot was drawn to set a well-defined relation between the environmental parameters (DO, temperature, pH, salinity, TSS, Sand, Silt, Clay, TOC and heavy metal concentration) against the surveyed different stations (Fig. 5). The plot revealed that, among the stations, the EM-RS, EE-M and EM_LS showed significant positive correlation with parameters such as Salinity, Water pH, TOC, Clay, Fe, Sediment pH, water temperature and Sand. While, the stations in estuarine zone EE-1 and EE-2 got highly correlated with other parameters such as silt, PHC, Cd, Pd and Cr.

Fig. 5. Principle Component Analysis for environmental parameters and meiofauna species diversity in various stations of Ennore estuary

4. DISCUSSION
Worldwide urbanization and industrialization led to widespread contamination of coastal systems and estuarine environments. As observed above, the distributions, abundance, diversity, and composition of benthic meiofauna assemblages in coastal and sub-littoral environments are controlled largely by a combination of physical and chemical parameters (temperature, salinity, currents, substrate, and sediment type), food resources and biotic interactions [23]. Among the estuary and near estuary mouth stations, the high water temperature, salinity and pH values were observed in near estuary mouth stations, which might be due to proximity to the marine zone and among the seasons, the maximum values were recorded during summer which might be due to low rain fall and the rise in atmospheric temperature [24], [25].The dissolved oxygen (DO) was found maximum in near estuary mouth station during monsoon season and minimum at estuary station during summer season. The relatively minimum DO values observed in the summer season are attributed to the entry of high saline waters in to the estuarine region, as well as fluctuations in temperature and salinity, which in turn affect the dissolution of oxygen. Similar observation was made earlier by [26] in Iranian coast and [27] from Uppanar estuary, India. TOC content varied from 4.15mgC/g to 11.60mgC/g and the maximum was recorded at estuary stations during monsoon and minimum at near estuary stations during summer. Estuaries ecosystems are able to store large amounts of organic matter (TOC) [28] it act as a food source, plays a key role in determining the foraminiferal distributions [29]. Similarly, [30] also opined that the sediment characteristics and the total organic carbon (TOC) contents influenced the distribution of benthic meiofaun in Lake Varano, Southern Italy. In the present study, heavy metal concentration also varied significantly in both the estuaries. Of these, the level of Iron (Fe), Cadmium
(Cd), Lead (Pd) and Chromium (Cr) accumulation was found maximum at near estuary stations and minimum at near estuary mouth stations. The higher concentration of metals in estuarine stations could be attributed to the heavy rainfall and subsequent river run off, bringing much industrial and land derived materials along with domestic and municipal wastes, which include residue of heavy metals [31], [32], [33].

Reported similar trend of heavy metal distribution in Ennore estuary. The values of heavy metal concentration recorded in the present study are comparable to the reports made by [34]; [35], [27] from various estuarine stations in India. A total of 41 meiofaunal species belonging to four groups of meiobenthos organisms namely Foraminifersans, Nematodes, Ostracodes and Harpacticoids were recorded during this study. Among them, Foraminifersans topped the list with 26 species. Nematodes were found to be the next dominant group in the order of abundance with 8 species. Ostracodes and Harpacticoids came next with 4 and 3 species respectively. Among the meiofaunal groups, Bolivina limbata, Spiroloculina excavate, Spirillina lateseptata, Astomonema jenneri, Bassleriates liebaui, Harpacticus chelifere and Laophonte thoracica were found commonly sensitive species in coastal stations. Benthic meiofaunal groups stress tolerant species such as, Ammonia beccarai, A. tepida, Halalaimus filum, Bairdopilata scaura were found commonly in estuaries stations. The lower diversity of meiofaunal in estuary stations might be due to the municipal domestic sewages, besides wastes, fly ash, thermal effluents, sewage pollution, leading to unfavorable environment for benthic meiofauna. Similar range of meiofaunal density was also reported earlier by [36] in East coast of the Yucatan peninsula (Mexico); [37] in Red Sea coast, Sudan. Species diversity can be an expression of the environmental stress on benthic meiofaunal assemblages, with higher diversity in more stable environments. Species diversity and evenness value was found minimum in estuarine stations during monsoon and maximum in near estuary mouth stations during summer season, which might be due to the influence of temperature salinity, sand and soil pH as reported by [38]. Similar range of meiofaunal diversity values were also reported by [39] from Conero coast, Adriatic. Species richness and dominance showed minimum value at estuary stations during premonsoon and higher value in near estuary mouth station in summer. Similar trend was also observed by [40] from Dongsha Atoll Lagoon, China. The dendrogram/cluster analysis showed that the replicate of near estuary mouth stations formed separate cluster with similarity percentage of 70% and similarly the estuary stations grouped together separately with similarity percentage of 74%. Similar grouping with coastal and estuarine stations separately was reported by [41] from Guanabara Bay, Brazil and [24] from the Kharrar Lagoon, Saudi Arabia. The PCA and Correlation coefficients results displayed a good correlation of salinity, temperature and pH to the distribution and composition of meiofauna in the surveyed stations. Similar trend was also observed by [42] from the Moorea, French Polynesia and [43] from Uppanar estuary, India.

5. CONCLUSION

The findings of the present study form the base line information pertinent to biodiversity changes of benthic meiofauna in relation to seasonal changes in physico-chemical parameters and heavy metal concentration, which will form a reliable tool in bio-monitoring studies.

6. ACKNOWLEDGEMENTS

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7. Conflict of interest statement

Authors declare that they do not have any conflict of interest.

8. REFERENCES


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