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Intertidal Macrobenthic Fauna of the Karnafuli Estuary: Relations with Environmental Variables

[1]M. Shafiqul Islam, [1]M. Nurul Azim Sikder, [1]M. Al-Imran,
[2]M. Belal Hossain, [1]Debbrota Mallick and [3]M. Monjur Morshed

[1]Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh
[2]Biology Group, Faculty of Science, University Brunei Darussalam, Brunei BE1410
[3]Department of Statistics, University of Chittagong, Bangladesh

Abstract: This study describes the influence of 19 hydropedological factors on macrobenthic faunal assemblages of the Karnafuli estuary, Bangladesh during the period from September, 2011 to August, 2012. A total of 33 macrobenthic species/taxa belonging to annelids, molluscs, arthropods and other minor phyla were recorded. Spearman rank correlation (using BIO-ENV procedure included in PRIMER, V.6) showed significant correlation between macrobenthic faunal assemblages and hydropedological variables. Dissolved oxygen showed the highest correlation (r=0.678) with macrobenthic faunal community. Soil particle density, bulk density, porosity, soil water salinity, soil PO_4-P, soil pH and total suspended solids of water were identified as the best environmental variables that influenced the macrobenthic faunal assemblages at different range of rank correlations (r=0.442 to 0.537). The most influential factors predicting the variations of total number of individuals recorded in different sampling seasons was dissolved oxygen. Species richness of macrobenthic community was positively ($p<0.05$) influenced by dissolved oxygen and percentage of silt while it was negatively ($p<0.05$) influenced by percentage of sand and particle density. Dissolved oxygen showed higher contribution to explain the variance in species diversity in the present observations at 1% level of significance. The abundance of the most dominant molluscan fauna *Cerithidea cingulata* was significantly ($p<0.05$) influenced water salinity and bulk density of soil. The relatively of more important factor that could be able to positively influence the most abundant species *Capitella* sp. at a significant level of $p<0.01$ was soil pH while the abundance of *Capitella* sp. was negatively influenced by percentage of silt and positively influenced by bulk density at 5% level of significance.

Key words: Hydropedological Factors % Macrobenthic Fauna % Intertidal Zone % Abundance % Diversity Indices

INTRODUCTION

Benthic macrofauna are very important components of aquatic biotic communities, playing several ecological roles in wetland ecosystem functions [1-3]. They play significant roles in the energy pathway and nutrient cycling [1] and they also constitute an important link in the aquatic food chain as food resource for fishes and other animals [2]. Benthos have been employed to assess the water and soil quality in the present study as they are known as the reflector of past and present environmental conditions of an ecosystem more effectively than physical and chemical indices of water and soil and are regarded as the best indicators of pollution as they are sedentary, sessile, long lived and easily collectable [1].

The distribution of aquatic organisms is the result of interactions among their ecological role, the physical conditions that characterize the habitat and food availability [1, 4]. Thus, the community structure of benthic macro fauna depends on a number of factors, namely water quality, type of substrate, particle size of sediment, water flow, sediment organic matter availability, oxygen concentration as well as environmental conditions surrounding the watercourse [1].

Corresponding Author: M. Belal Hossain, Biology Group, Faculty of Science, University Brunei Darussalam, Brunei BE1410, E-mail: mbhnstu@gmail.com

Estuarine communities like plankton and fishes have been well studied [5-11] in this estuary. But to date, benthic estuarine fauna did not receive adequate attention. Very limited study on the macrofauna in relation to pollution in the Karnafuli estuary was undertaken [12].

The Karnafuli is the principal river of Chittagong region of Bangladesh. The biggest sea port of the country is situated in the bank of this river for its advantageous geographical position. The country earns a lot of foreign currencies through port activities. Though it has great economic value, it has been suffering from severe pollution problems like spill oil, ballast water, dredging activities. Unplanned urbanization and industrialization on the bank of the Karnafuli River has exerted unbearable pressure and stress on the river. Due to lack of proper waste collection and sanitation facilities it received millions of liters of domestic wastes, industrial wastes and sewage containing simple nutrient to highly toxic substances through five main canals. Besides sewage from numerous cargo ships, tankers, fishing trawlers and other vessels in the Chitttagong Port area and cargo sweeping dumped into the sea near the port, only add to the pollution of the city's waters. Every day, considerable amounts of blood as well as the viscera of about four hundred slaughtered animals from the Firinghee Bazar and Dewan Hat slaughter houses finds their way into the Karnafuli River. The intensity of pollution arising due to the improper disposal of sewage, industrial wastes and effluents affects the organisms living in the river by lowering the available oxygen in the water and also cause water born diseases [13]. So, this study was undertaken to assess the influence of the hydropedological factors on the intertidal macrobenthic fauna of the Karnafuli estuary.

MATERIALS AND METHODS

Water, sediment and benthic faunal samples were collected from the intertidal zone of the Karnafuli estuary (22°19.882'-22°19.537'N and 91°50.215'-91°51.516'E), Chittagong, Bangladesh during the period from September 2011 to August 2012. All the samples were collected from three sites namely Site 1, Site 2 and Site 3. Among the three sites, Site 2 was set in the mouth of the Chaktai canal through which majority of sewage materials of Chittagong city falls into the Karnafuli estuary and thus it was considered as impacted site. The other two sites like Site 1 (Gov. Fish landing station) considered as moderately impacted site and Site 3 (Eastern side of the third Karnafuli Bridge) considered as the nearly pristine site (Figure 1). Samples were collected in different seasons namely Monsoon (June-September), Post-monsoon (October-November), Winter (December-February) and Pre-monsoon (March-May) from each station placed in different sites.

Subsurface water samples were collected from three sites during high tide condition for measuring water temperature, salinity, pH, dissolved oxygen and total suspended solid. Water salinity, pH and temperature were estimated *in situ* by using Refractometer (TANAKA, New S-100, Japan), Digital pen pH meter (HANNA instruments, model HI 98107) and Centigrade thermometer respectively. DO (Dissolved Oxygen) and TSS (Total Suspended Salts) were determined followed by Standard Method [14].

Sediment and benthic faunal samples were collected from the study sites by using transect method [15]. Three transects namely T_1, T_2 and T_3 were drawn in the Site 1, Site 2 and Site 3 respectively. Each transect was drawn from the mean high tide mark to mean low tide mark. Three sampling stations namely T_1S_1, T_1S_2 and T_1S_3 were set on the transect T_1. Similarity stations T_2S_1, T_2S_2, T_2S_3 and stations T_3S_1, T_3S_2, T_3S_3 were set on the transect T_2 and T_3 respectively.

One sediment sample was taken from each station for analysis of soil temperature, pH, soil water salinity, organic carbon, organic matter, soil texture, bulk density, particle density porosity, soil NO_2-N and soil PO_4-P. Soil pH and temperature were estimated *in situ* by using Refractometer (TANAKA, New S-100, Japan) and soil pH meter (DEMETRA, Mo-36, E. M. System Soil Tester, Tokyo, Japan). Free soil water salinity in every station was estimated by using Refractometer (TANAKA, New S-100, Japan). The textural classes (percent of sand, silt and clay) of sediment, organic carbon, organic matter, bulk density, particle density and porosity were determined by the method followed by Huq and Alam [16]. Soil NO_2-N and PO_4-P were determined followed by Standard Method [14].

Macrobenthic faunal communities were sampled by taking 5 sediment cores (11.5cm diameter, 15cm depth) randomly from the quadrate of 5x5 m^2 placing at each of the station of each site. For the easy way of selection of the sampling technique had been developed. For identifying the sampling spots 16 equal cross divisions had been drawn over the square area (5 X 5 m^2). As a result a total of 25 point intercepts were formed within the square area. Each of point intercepts found in the quadrate of (5 X 5 m^2) area were numbered from 1-25. A table of random numbers has been used to determine the exact location of the core inside the square [17]. The collected samples were sieved through a 0.5mm mesh

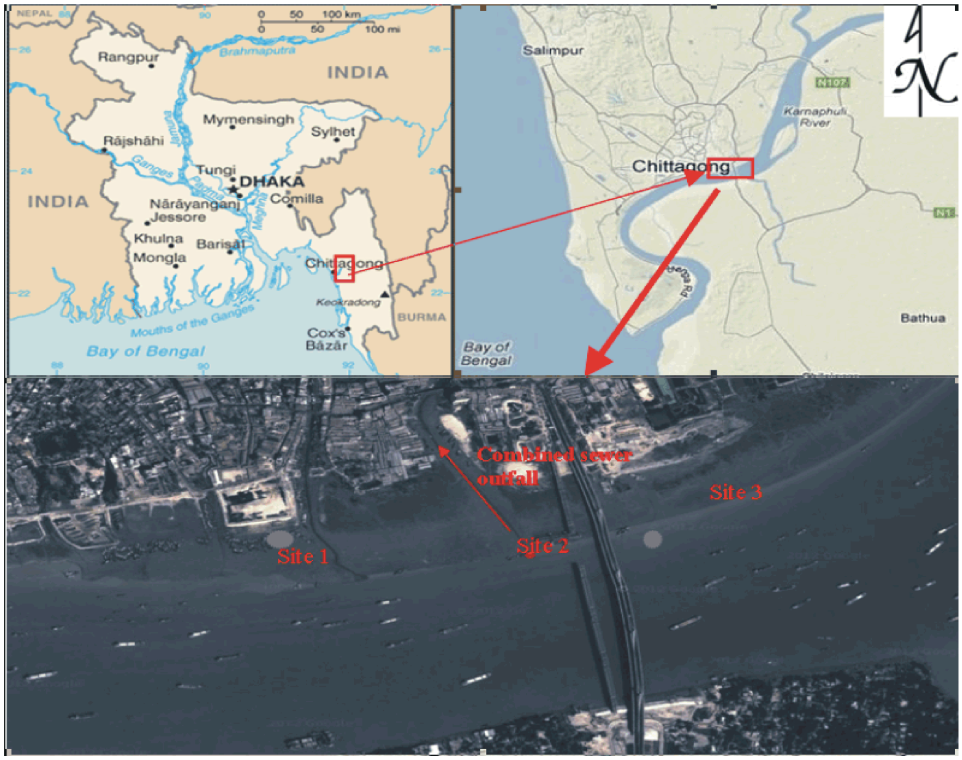

Fig. 1: Location of the study area showing three sampling sites.

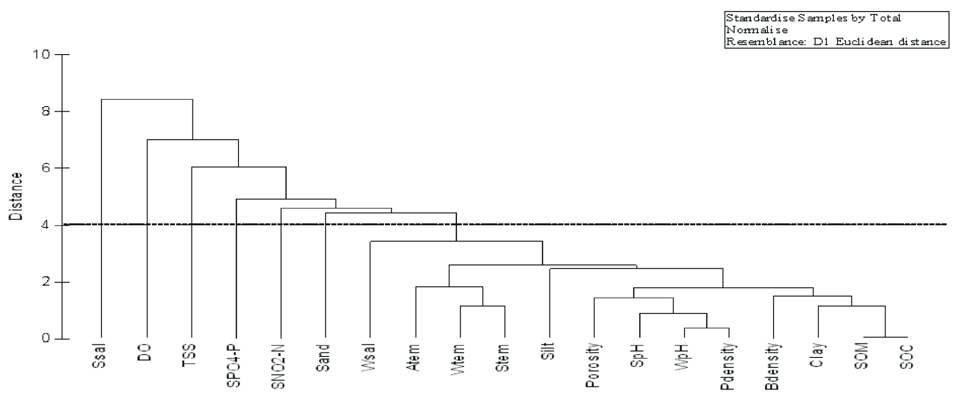

Fig. 2: Association within hydropedological factors of the Karnapfuli estuary.

Legend:

Atem=Air Temperature	Stem= Soil Temperature	Ssal= Free Soil Water Salinity	PDensity=Particle Density
Wtem= Water Temperature	DO=Dissolved Oxygen	SOC=Soil Organic Carbon	Porosity= Porosity of Soil
Wsal= Water Salinity	TSS=Total Suspended Solids	SOM=Soil Organic Matter	SPO4-P=Soil PO_4-P
WpH= Water pH	SpH= Soil pH	Bdensity=Bulk density	SNO2-N =Soil NO_2-N

and preserved with 10% formalin in water containing the vital stain Rose Bengal to aid laboratory sorting. At the subsequent stage fixed benthic macro fauna were separated systematically from debris in a sorting tray and identification was done based on taxonomic guides and manuals [18-23].

Association of different hydropedological factors and different species/taxon were shown in dendrograms that were produced by Cluster analysis of PRIMER (v.6) program. The BIO-ENV program [24] in the PRIMER (v.6) package was used to evaluate and compare the relative importance of different hydropedological factors

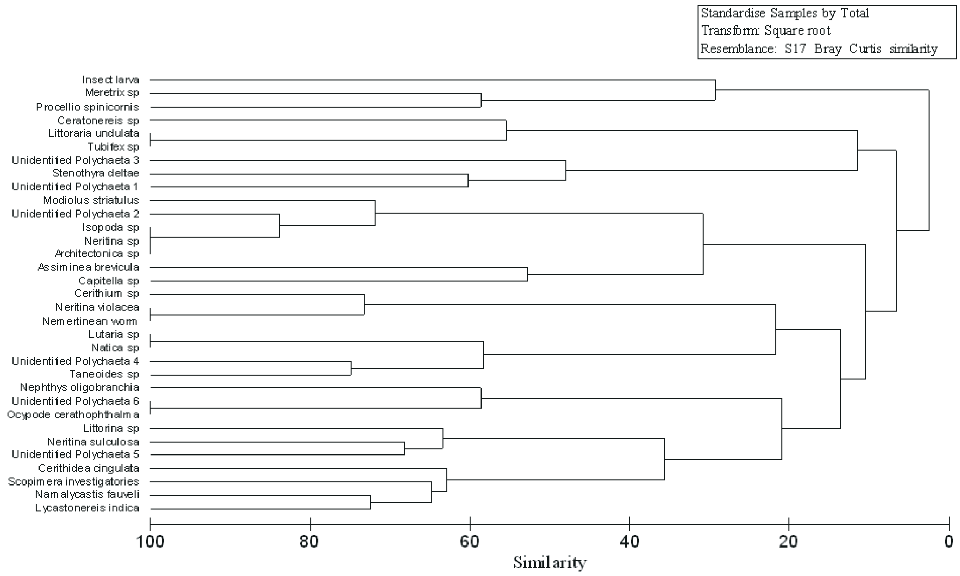

Fig. 3: Dendrogram showing the similarity among different species/taxon collected from the Karnapfuli estuary.

measured and their influence on the identified macrobenthic communities. The multivariate Spearman rank correlation between 5 hydrological, 14 pedological and the abundance data of macrobenthic community assemblages consist of 33 species/taxons of the habitat was explored by the BEST (BIO-ENV) procedure of PRIMER software (v.6). This allowed easy identification of the factors that had the greatest effect on community structure.

The data was subjected to multivariate statistical analyses to study the influence of different hydropedological factors on the abundance of the macrobenthic community using multiple linear regression analysis. Any independent variable strongly correlated with another independent variable was excluded to avoid the violation of the multicollinearity assumption, while others were retained in the analysis [25]. The contribution of hydropedological and plant factors to explaining the dependent variable (abundance of each macrobenthic species/taxon) was compared using Beta values at the 95% and 99% confidence level using the SPSS v.11.5.

RESULTS

The mean value of different hydrological factors like water temperature, water salinity, water pH, dissolve oxygen and total suspended solids were 28.3±5.16°C, 5.29±2.08 ‰, 8.33±0.20, 2.19±1.66 ml/l and 0.26±0.20 mg/l respectively.

Mean values of different pedological factors like soil temperature, soil pH, soil water salinity, soil organic carbon, soil organic matter, percentage sand, silt, clay, bulk density, particle density, porosity, NO_2-N and PO_4-P were 25.61±6.19 ºC, 5.96±0.64, 1.75±2.33 ‰, 3.13±0.38 %, 5.40±0.65 %, 29.36±13.31 %, 53.90±13 %, 16.74±3.46 %, 1.27±0.20 g/cm^3, 2.72±0.09gm/cm^3, 53.24±8.15 %, 2.21±1.02 µg - at NO_2-N/Kg and 1.59±0.92 µg - at PO_4-P/Kg respectively. And mean air temperature of the study area during the sampling period recorded as 27.72±5.95°C.

Association within different hydropedological factors of Karnapfuli estuary shown in the Figure 2. It was found that soil organic carbon and soil organic matter grouped together while air temperature, water temperature and soil temperature formed another cluster since they are highly correlated to each other.

Among 33 species/taxon, 14 species of molluscs, 12 species of annelids, 5 species of arthropods, Nemertian worm and *Taneoides* sp. was found in the present study. The abundance of the species *Cerithidea cingulata*, *Stenothyra deltae*, *Modiolus striatulus*, *Cerithium* sp, *Neritina* sp, *Assiminea brevicula*, *Architectonica* sp, *Neritina violacea*, *Neritina sulculosa*, *Littorina* sp, *Lutaria sp*, *Natica* sp, *Littoraria undulate*, *Meretrix* sp, *Namalycastis fauveli*, *Capitella* sp, *Lycastonereis indica*, *Ceratonereis* sp, *Nephthys oligobranchia*, Tubifex sp, Unidentified Polychaeta 1, Unidentified Polychaeta 2, Unidentified Polychaeta 3, Unidentified Polychaeta 4, Unidentified Polychaeta 5, Unidentified Polychaeta 6, *Scopimera investigatories*, Isopoda sp, *Ocypode* *cerathophthalma*, Insect larva, *Procellio spinicornis*, *Taneoides* sp. and Nemertinean worm were 22033-367, 15-0, 66-0, 325-0, 4-0, 12-0, 8-0, 4-0, 8-0, 8-0, 4-0, 4-0, 4-0, 8-0, 1491-12, 243687-23, 1430-0, 213-0, 8-0, 12-0, 15-0, 128-0, 8-0, 12-0, 58-0, 12-0, 201-0, 4-0, 8-0, 4-0, 4-0, 12-0 and 8-0 individuals/m^2 respectively.

Association among different species/taxon collected from the Karnapfuli estuary was shown in dendrogram by producing a cluster (Figure 3). From the cluster it was found that the species *Namalycastis fauveli* and *Lycastonereis indica* formed a cluster with the highest percentage of similarity.

The BIO-ENV analysis (PRIMER v.6) provided single and combinations of factors that were found to describe the observed influence on the abundance and distribution patterns of macrobenthic communities and from this the most important correlations were identified. Spearman rank correlations found from BIO-ENV analysis indicating significant correlations between hydropedological factors and macrobenthic faunal assemblages. Dissolved oxygen, particle density, bulk density, porosity, soil water salinity, soil PO_4-P, total suspended solids, air temperature and soil pH were identified as the best variables highly correlated with the macrobenthic faunal assemblages of the study area at different range of rank correlations ($r<0.442$-0.678). Among the identified factors dissolve oxygen provided the highest correlation ($r=0.678$) with the macrobenthic community. In the next order of highest correlation ($r=0.537$) was observed between the macrobenthic faunal assemblages and the two factors namely dissolved oxygen and particle density. And dissolved oxygen and bulk density were the primary factors related to the benthic communities and their correlation ($r=0.536$) is comparatively lower than the previous group of factors.

The abundance of different macrobenthic species/taxon identified in the present study was influenced by different hydropedological factors at different significant level that was tested by multiple regression analysis. The relationship between the univariate diversity indices (total number of species, total number of individuals, species richness, species diversity and evenness) and the hydropedological factors was also analyzed by multiple regression models.

The most important factors predicting the variations in total number of species/taxons were soil temperature, percentage of sand and particle density. Number of species/taxons negatively influenced by soil temperature, percentage of sand and particle density at 5% significance level ($p<0.05$). The most influential factors predicting the variations of total number of individuals recorded in different sampling seasons was dissolve oxygen. Total numbers of individuals negatively influenced by dissolve oxygen at 5% level of significance. Macrobenthic species richness of Karnafuli estuary was mainly influenced by dissolve oxygen, percentage of sand and silt and particle density recorded in different period of sampling of the present study. Variation of species richness of macrobenthic community was positively ($p<0.05$) influenced by dissolve oxygen and percentage of silt while it was negatively ($p<0.05$) influenced by percentage of sand and particle density. Dissolve oxygen showed higher contribution to explain the variance in species diversity in the present observations at 1% level of significance and particle density and percentage of sand showed 5% level of significance whereas dissolve oxygen showed higher contribution at 1% level of significance and particle density and percentage of sand showed 5% level of significance were the best in explaining the variance in species evenness of the whole macrobenthic assemblages.

To delineate the ecologically most influencing factors for the various species/taxons identified in the present study, it was attempted to the multiple regression model based on the maximum explained variability at different significant level. Water salinity and bulk density of soil negatively influenced the abundance of *Cerithidea cingulata* at a significant level of $p<0.05$. The relatively of more important factors that could be able to positively influence the most abundant species *Capitella* sp. at a significant level ($p<0.01$) was arranged as soil pH and negatively influenced by percentage of silt and positively influenced by bulk density at 5% level of significance. *Stenothyra deltae* was negatively influence by water salinity at 1% level and positively by percentage of silt and negatively by bulk density at 5% level of significance.

Aessiminea brevicula positively influenced by bulk density and negatively influenced by water temperature and percentage of silt at 5%level of significance. *Littorina* sp. influenced positively by soil NO_2-N and negatively DO and particle density at 5% level of significance. *Lutaria* sp. is negatively influenced by water temperature, water salinity and bulk density at 5%level of significance. *Natica* sp. is negatively influenced by water temperature, water salinity and bulk density at 5% level of significance. *Meretrix* sp. is positively influenced by the soil temperature and soil organic carbon at 5% level of significance. *Ocypode cerathophthalma* influenced by positively by DO and percentage of sand and negatively by TSS and soil PO_4-P at 5% level of significance. Insect larva influenced by soil water salinity at 1% level and air temperature, TSS and soil PO_4-P at 5% level and negatively by DO and percentage of sand ($p<0.05$). *Procellio spinicornis* is positively influenced by water pH and soil PO_4-P at 5% level. *Taneoides* sp. influenced by water temperature and water salinity negatively at 1% level of significance and also influenced positively by silt and particle density at 5% level of significance. Insect larva influenced positively by soil salinity at 1% level and total suspended solids and PO_4-P at 5% level and negatively influenced by dissolve oxygen and percentage of sand at 5% level of significance.

DISCUSSION

The hydropedological factors like dissolved oxygen, particle density, bulk density, porosity, soil water salinity, soil PO_4-P, total suspended solids and soil pH were identified as the best variables highly correlated with the macrobenthic faunal assemblages of the study area at different range of rank correlations ($r<0.442$-0.678) in the present study. Islam [26] found total suspended solids (TSS), soil water salinity, exchangeable K, exchangeable Mg, available P, field water capacity, sand content of soil were identified as the best variables highly correlated with the macrobenthic faunal assemblages of the study area at different range of rank correlations ($r<0.721$-0.733). Yuan [27] reported that salinity and sediment were the main factors affecting benthic macro fauna that coincide the findings of present research. Some other studies conducted by different authors in different locations also proved the present findings. Sarda *et al.* [28] found that the grain size and organic content of soil defined distinct species assemblages. Otani *et al.* [29] indicated that distribution of macrobenthos could be explained by the classification of physical characteristics of sediment in tidal flats. As pointed out by Santos and Simon [30] for a subtropical estuarine environment support assemblages of infaunal polychaetes distinguishable mainly by individual species densities.

Kundu *et al*. [31] postulated that the species diversity is mainly controlled by the fluctuations in the environment that lead to less diversity. Environmental variability is believed to be the key to the changes in macrobenthic structure expressed by variation in taxa richness and abundance [32] that was similar with the present findings. Dissolved oxygen variation was a significant parameter in explaining especially species diversity and population density was founded by Harkantra and Rodridgues [33] which was quite similar to the present study findings. Lamptey and Armah [34] found a number of environmental variables including sediment structure; temperature and dissolved oxygen have been correlated with the abundance, density and diversity of macrobenthic organisms. This was also similar to the present investigation.

The main environmental factors affecting the distribution and structure of macrobenthic animals reported by most authors were organic matter, salinity and sediment characteristics, especially mud or clay content [35]. The most widely accepted model was proposed by Rosenberg [36], who suggested that, as the organic matter content increases, the species diversity decreases, the number of individual increases. Organic content, mud content and water content of the sediments of the sediments were found to influence the abundance intertidal biotic communities that were reported by Growenewald [37].

Water and sediment salinity significantly influenced the species *Cerithidea cingulata*, *Stenothyra deltae*, *Littorina* sp. *Natica* sp. *Taneoides* sp. and Insect larva in the present investigation. In addition soil organic carbon and organic matter, soil texture highly influenced the species *Cerithidea cingulata*, *Aesimenea brevicula*, *Meretrix* sp. *Ocypode cerathophyalma*, *Taneoides* sp. and Insect larva at different significant levels ($p<0.05$) in this study. Major hydropedological factors of water and sediment include salinity [38] sediment structure [39], organic enrichment [36] significantly influence the macrobenthos of the shallow intertidal coastal environments that were almost similar to the findings of the present research. Hirst [41] reported that variations in salinity can promote marked shifts in species representation and community structure because marine organisms have different salinity tolerances. Organic matter in sediments is a primary source of food for infaunal organisms and is widely understood to affect benthic community structure that was reported by and David and Kirsty [42]. In this study water and sediment salinity, soil organic carbon and organic matter also influenced various species that reside in the benthic region at different significant levels either positively or negatively which confirm the findings of the previous studies.

CONCLUSION

It can be concluded that the abundance and diversity of macrobenthic faunal community of the intertidal zone of the Karnafuli estuary is significantly influenced by some hydropedological factors of the existing environment. Indiscriminate discharge of untreated municipal and industrial wastes should stop now to save the environment as well as the macrobenthic faunal community of this estuary.

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