Fisheries and Aquaculture Journal

Sarker et al., Fish Aquac J 2016, 7:1
DOI: 10.4172/2150-3508.1000157

Research Article | Open Access

Macrobenthic Community Structure - An Approach to Assess Coastal Water Pollution in Bangladesh

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Abstract

A research on the assemblages of benthic macro faunal community in the coastal areas of Bangladesh was conducted during February-March, 2015 following the standard methods to assess the status of environmental pollution. The abundance (r=0.846) and species richness (r=0.864) of the macrobenthic communities were significantly influenced by the water salinity of the sampling sites ($p \leq 0.05$). Both the study areas namely the Bakkhali River Estuary and the Meghna River Estuary showing the highest (3909 ± 540 ind./m^2) and lowest (2236 ± 689 ind./m^2) density of benthic macrofaunal abundance respectively might be considered as moderately polluted areas according to the results obtained from Shannon-Wiener index of species diversity (2.69 ± 0.13 and 2.00 ± 0.11 respectively) and Margalef's species richness (2.21 ± 0.43 and 1.36 ± 0.11 respectively). Therefore, it is plausible that the macrobenthic community explained in the present study might be a key future outline to assess the status of coastal water pollution of those concerned areas of Bangladesh.

Keywords: Macrobenthos; Bakkhali river estuary; Meghna river estuary; Shannon-wiener index; Margalef's species richness

Introduction

Benthos is the organism that inhabit in bottom of an aquatic body. Benthic communities are usually dominated by different species of polychaete, oligochaete worms, gastropods, bivalvia and various minor insect larvae. Benthic organisms such as macro, meio and micro fauna and flora play an important role in food chains in an aquatic ecosystem [1]. Macrobenthic organisms may be influenced positively or negatively by physico-chemical parameters of the environment depending on their sources [2]. According to environmental conditions benthic communities vary considerably [3]. The amount of nutrients released from the sediment by benthic communities may vary [4]. Various physical and chemical conditions of the water body such as depth, current of the water, organic contents of the sediments, contaminations of bed sediments environment, toxicity of sediments influence the abundance and distribution of macrobenthos [5]. Macrobenthos are the most commonly used organisms for bio-monitoring in lotic habitat worldwide [6]. It is evident that macrobenthos play an important role in improving and preserving water quality through mineralization and recycling of organic matters [7,8]. The physical and chemical status of the riverine ecosystem becomes recognizable through the elasticity of the community structure of the benthic organisms [9,10]. That's why benthic macro-invertebrates make ideal subject for biological assessment of water quality [11].

Bangladesh is blessed with an extensive coastline of about 710 Km [12]. The southeastern and southwestern coast of this country is mostly covered by a complex estuarine ecosystem with strong interactions of biotic and abiotic factors. The main estuarine systems of the country are Brahmaputra-Megna (Gangetic delta), Karnaphuly, Matamuhuri, Bakkhali and Naf rivers, which are comprised of mangroves, salt marshes, sea grass, seaweeds, fisheries, coastal birds, animals, coral reefs, deltas, salt beds, minerals and sand dunes. The estuarine environment, which serves as feeding, breeding and nursery grounds for a variety of animals, varies according to the volume of discharge of the river and tidal range. These diverse living resources in the estuarine environment play an important role which is economically significant in many ways. Although coastal and estuarine resources contribute a vital role in terms of both the ecosystem and the economy, study of the estuarine coastal environment in Bangladesh is still lacking [13].

Khan [14] conducted an investigation on the abundance and distribution of macrobenthic organisms in the Mouri River, Khulna to determine the level of river pollution. They identified twenty (20) different species in their study area where polychaeta dominated all over the river. Abu Hena [15] conducted a primary research work on the composition of macrobenthos in the Bakkhali Channel System, Cox's Bazar to investigate the relationship between soil parameters and the macrobenthos composition in their study area. But there is almost no information on the long term study of benthos particularly in the coastal waters of Bangladesh. Therefore the present study was designed to explore diversity of benthos in the South-Western coastal waters of Bangladesh with the following objectives.

Objectives

- To know the diversity of benthic macro fauna in the Meghna River Estuary (at Chairman Ghat, Noakhali) and the Bakkhali River Estuary (Cox's Bazar).
- To compare the benthic macro faunal abundance in between two selected estuaries.
- To assess the environmental conditions of the Meghna River Estuary and the Bakkhali River Estuary.

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Received November 25, 2015; **Accepted** February 10, 2016; **Published** February 20, 2016

Citation: Sarker J Md, Patwary SA Md, Uddin AMMB, Hasan M Md, Tanmay MH, et al. (2016) Macrobenthic Community Structure - An Approach to Assess Coastal Water Pollution in Bangladesh. Fish Aquac J 7: 157. doi:10.4172/2150-3508.1000157

Materials and Methods

Sediment samples were collected from the Meghna River Estuary (at Chairmanghat, Noakhali) and the Bakkhali River Estuary (Cox's Bazar) during February-March, 2015 (Figure 1). 6 sampling stations (3 from each estuary with triplicate fashion) were selected to carry out the present study. Among the two study sites the Bakkhali river estuary, Cox's Bazar, is situated in the southern region of Bangladesh. The approximate geographical location of this estuary is between 20085'40" to 21046'92" N latitude and 91096'60" to 92034'37"E longitude (Figure 1). The estuary is directly influenced by semi-diurnal tides and climatology impacted by monsoon winds where it's bottom consists mostly of muddy and sandy particles [16]. 3 sampling stations from the Bakhkhali River Estuary namely S-IB, S-2B, S-3B and another 3 stations from the Meghna River Estuary namely S-4M, S-5M and S-6M were selected. Besides on the coast of Bangladesh the Meghna River Estuary is a coastal plain estuary. The bathymetry, tides and outflow from the Meghna River are the important driving forces of that estuary [17]. The approximate geographical location of this estuary is between (22035'14.7"N and 91001'31.8"E to 22035'24.6"N and 91001'47.4"E) (Figure 1).

For macrobenthic fauna, samples were collected using a small boat during February to March, 2015. Sediment samples were collected using an Ekman dredge having a mouth opening of 0.02 m^2. Collected sediment samples were sieved through 500 μm mesh screen to retain macrobenthos. The sieved organisms were preserved immediately with 10% formalin solution in the plastic container with other residues. Preserved samples were then brought back to laboratory for further analysis. In the laboratory, small amount of "Rose Bengal" was added to increase visibility of organisms. Identification of macrobanthic fauna were done using simple microscope up to possible taxonomic level [18-20] and their counting were made as total individual per m^2 (ind./m^2). During sampling, in situ water quality parameters were measured at each sampling site. The water salinity (ppt), temperature (°C), pH, and DO (Dissolved Oxygen, mg/L) alkalinity (ppm) were measured using refractometer (NewS-100, TANAKA, Japan), thermometer (centigrade scale), pH meter (HANNA Instruments), DO meter (HANNA Instruments) and Hach hardness and alkalinity kit respectively.

The total number of macro invertebrates was counted in a sample and then number of macro-invertebrates per square meter occurrence was computed using the following formula Welch [21],

$$N = \frac{O}{a.s} * 10000$$

Where

N=Number of macro-invertebrates 1 sq. m. of profoundal bottom

O=No. of macro-invertebrate (actually counted) per sampled area,

a=Transverse area of Ekman dredge in sq. cm, and

s=Number of sample taken at one sampling site.

Species diversity index (H)

Species richness index (d); and evenness index were calculated according to following equations

The data harvested from monthly samples were blended to provide the value of Shannon-Wiener Index (Species diversity, H) according to [22],

$$H = -\sum_{i}^{s}=_1 PiLnPi$$

Where

S=Total number of species in a sample,

Pi=ni/N=Proportion of individuals of the total sample belonging to the ith species.

N=Total number of individual of all the species,

ni=Number of individuals belonging to the ith species.

The Margalef's index

Species Richness (D) is simple ratio between total species (S) and

Figure 1: Map showing the location of two study sites namely the Meghna River Estuary, Noakhali and Bakkhali River Estuary, Cox's Bazar of Bangladesh.

total numbers of individual (N) [23]. It can be used to compare one community with another. The index is

$$D = \frac{S-1}{\ln N}$$

Where

D=Margalef's index

S=Number of species in sample

ln=log normal

N=Total number of individuals in sample

Simpson index (D)

The Simpson Index value also ranges between 0 and 1, and the greater the value, the greater the sample diversity [24]

$$\text{Simpson Index } D = \frac{1}{\sum_{i=1}^{s} Pi2}$$

In the Simpson index, P is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and s is the number of species.

Species Evenness: According to Cox [25,26] the species evenness is

$$E = \frac{H}{H\max}$$

Where

The value of E is between 0.

Hmax=ln(S) and S=S=Total number of species in a sample

H=Shannon Diversity value

Equitability

Shannon diversity divided by the logarithm of number of taxa [27] was measured by using following formula:

$$J = \frac{Hs}{Logs}$$

Where

J=Equability index

Hs=Shannon and Weiner Index

S=Number of species in a population

The dominance index (D)

The dominance index [27] was measured to determine whether or not particular fisheries species dominate in a particular aquatic system and can be useful index of resource monopolization by a superior competitor, particularly in communities that have been invaded by exotic species. This index was determined by using following formula:

$$D = \sum_{i=1} \left(\frac{ni}{n}\right) 2$$

Where

ni=number of individuals of species i

n=total number of individuals

Menhinick's richness index

The ratio of the number of taxa to the square root of sample size [28].

$$I_{Menhinick} = S / \sqrt{N}$$

Where

S=Number of species in sample

N=Total number of individuals in sample

Brillouin index

It is measured by using following formula [29]

$$I_{Brillouin} = \frac{\ln(N!) - \sum \ln(n_i!)}{N}$$

Where

N! is N factorial, i.e., N × (N-1) × (N-2) × (N-3) × ... × 3 × 2 × 1

Fisher's alpha

A diversity index, defined implicitly by the following formula [27].

$$S = a \times \ln(!+ n / a)$$

Where

S=number of taxa,

n=number of individuals and

a=Fisher's alpha.

Berger-Parker dominance

According to Harper the Berger-Parker dominance is simply the number of individuals in the dominant taxon relative to n [27].

Paleontological Statistics (PAST) version 3.15, a software package for paleontological data analysis written by Ryan [30] was used to run the analysis. PAST has grown into a comprehensive statistical package that is used not only by paleontologists, but in many fields of life science, earth science, and even engineering and economics.

Results and Discussion

The abundance of macrobenthos was studied during February to March, 2015 in the Bakkhali river estuary situated in Cox's Bazar district and the Meghna river estuary situated at Chairman Ghat in Noakhali district. Among the observed water quality parameters (Table 1) temperature (°C) is the important one because it has a major influence on biological activity and growth and the higher the water quality the greater the biological activity (Washington State Department of Ecology, 1991). The mean temperature (°C) observed in the Bakkhali River estuary and Meghna River estuary were 28.33 ± 1.53 and 27.33 ± 1.53 respectively. Due to runoff of huge freshwater from other upper rivers of Bangladesh through the Meghna River to the Bay of Bengal, the average salinity difference of this estuary is lower than the Bakkhali River estuary (Figure 2). The average salinity of the Meghna river estuary was 5.67 ± 0.58 ppt which was lower than the average salinity of the Bakkhali River estuary (22.00 ± 2.65 ppt) during the study period (Table 1). There was no significant difference in pH values observed between two study sites. The average pH measured in the study sites were 6.98 ± 0.45 in the Bakkhali River estuary and 7.87 ± 0.81 in the Meghna River estuary (Table 1 and Figure 3). The values of dissolved oxygen observed in the present study influenced the abundance of the macrobenthic community both in the Meghna River and the Bakkhali River estuary (Figure 4). This result is supported by Islam [31], who reported that Species richness of macrobenthic

Table 1: *In situ* water quality parameters measured from the Bakkhali River Estuary and the Meghna River Estuary.

Sites	Stations	Temperature (ºC)	Salinity (ppt)	Dissolved Oxygen (ppm)	pH	Alkalinity (ppm)
Bakkhali River Estuary	*S-1B*	27	19	6.8	7.5	135
	S-2B	28	24	13.7	6.75	120
	S-3B	30	23	7.1	6.7	114
	Mean ± Sd	28.33 ± 1.53	22 ± 2.65	9.20 ± 3.9	6.98 ± 0.45	123 ± 10.82
Meghna River Estuary	*S-4M*	26	6	12.57	7.15	174
	S-5M	27	5	12.89	8.75	168
	S-6M	29	6	9.15	7.72	180
	Mean ± Sd	27.33 ± 1.53	5.67 ± 0.58	11.54 ± 2.07	7.87 ± 0.81	174 ± 6.00

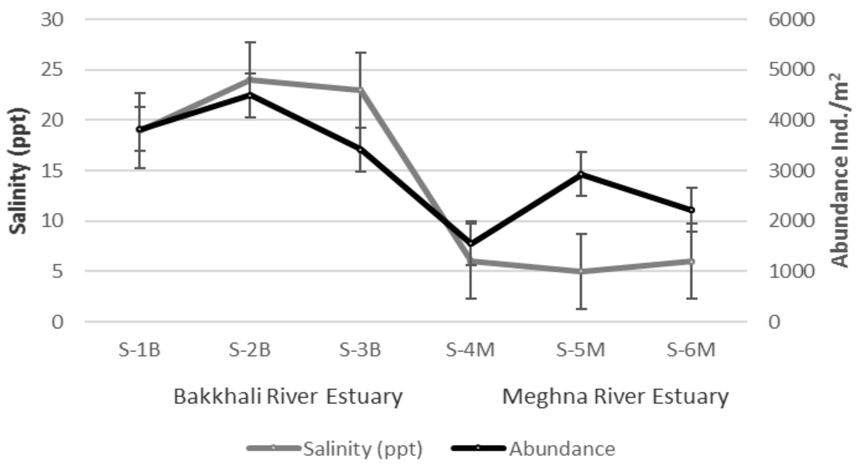

Figure 2: Relationship between the salinity (ppt) and abundance of macro benthic communities observed in the study sites. Bars indicate Standard Error.

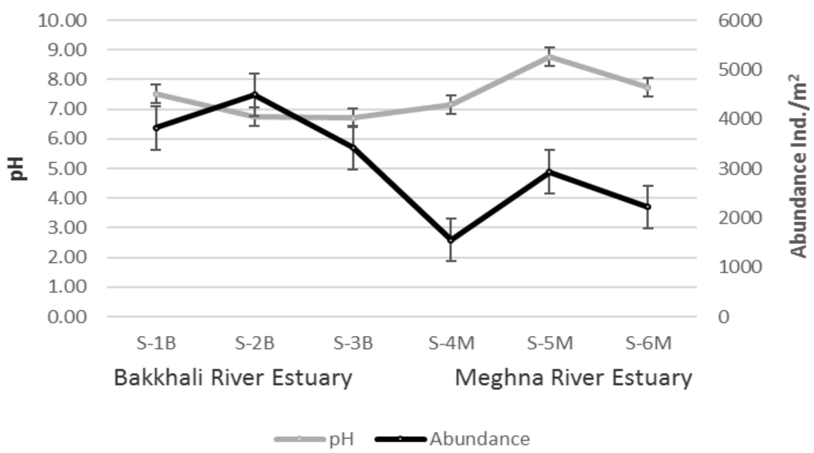

Figure 3: Relationship between the changes of pH and abundance of macro benthic communities in the study sites. Bars indicate Standard Error.

community was positively ($p < 0.005$) influenced by dissolved oxygen and percentage of silt while it was negatively ($p < 0.005$) influenced by percentage of sand and particle density. The abundance of benthic community was significantly ($p < 0.05$) influenced by water salinity (Table 1). Hossain and Marshall [32] also identified that species richness increased onwards, though abundance (density) showed no distinct directional trend. Diversity indices were generally positively correlated with salinity and pH ($p < 0.05$) and negatively with clay and organic matter. Hossain and Marshall [32] suggested that species distribution and community structuring is more strongly influenced by sediment particle characteristics than by the chemical properties of the water (pH and salinity).

5 major groups of macrobenthos (Polychaeta, Oligochaeta, Arthropods, Gastropods and Bivalvia) identified in Bakhlali river estuary (3909 ± 540) was higher than the Meghna river estuary (2236 ± 689) where the existence of bivalvia and gastropoda were found absent in the Meghna river estuary during the study period (Table 2). Polychaete and bivalvia showed the highest (49.42 %) and lowest (5.54 %) density respectively (Table 2) among 28 families (Table 3) identified from 5 major microbenthic groups. The average benthic

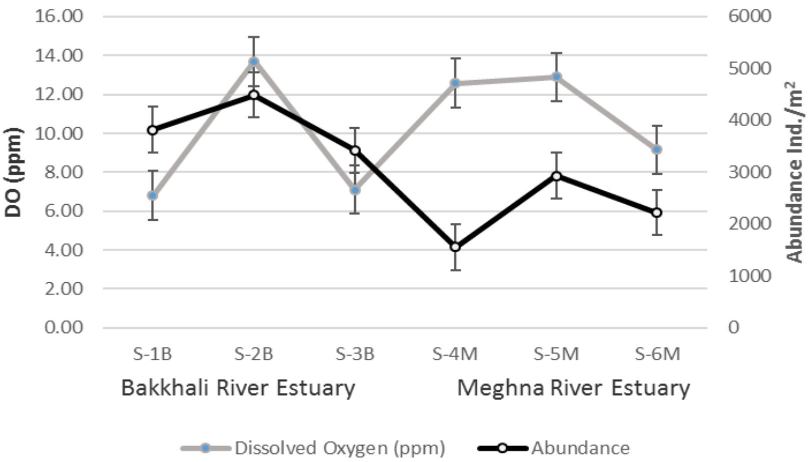

Figure 4: Relationship between the changes of DO (ppm) and abundance of macro benthic communities in the study sites. Bars indicate Standard Error.

Table 2: Abundance of Benthic groups (individuals/m^2) found in the study sites.

Benthos Groups	Bakkhali River Estuary			Meghna River Estuary			Mean ± SD	Total	Percentage (%)
	S-1B	*S-2B*	*S-3B*	*S-4M*	*S-5M*	*S-6M*			
Polychaete	1555	2089	1733	711	1733	1289	1518.33 ± 432.73	9110	49.42
Oligochaete	221	266	177	267	311	222	244 ± 42.83	1464	7.94
Arthropods	266	445	311	311	533	489	392.50 ± 100.91	2355	12.77
Bivalvia	311	400	311	0	0	0	170.33 ± 172.90	1022	5.54
Gastropoda	1066	933	711	0	0	0	451.67 ± 463.38	2710	14.70
Unidentified	400	355	177	266	355	221	295.67 ± 80.07	1774	9.62
Total	3819	4488	3420	1555	2932	2221	3072.50 ± 1070.42	18435	100
Mean ± SD	3909 ± 540			2236 ± 689					

organisms found in the sampling stations of the Bakkhali River Estuary and the Meghna River Estuary were (3909 ± 540 Ind./m^2 and 2236 ± 689 Ind./m^2 respectively) was similar to the work done by Ibrahim who identified that the benthic communities were more dominant during pre-monsoon season (25,836.8 ind./m^2) as compared to post-monsoon season (21,573.1 ind./m^2) in the coral areas of Karah Island, Terengganu, Malaysia. Besides khan identified that the population density varied from 96 to 9410 ind./m^2 in the Mouri River of Bangladesh. Amongst 28, the 10 most abundant microbenthic families recorded from the two study sites were Lumbrinereidae-12.30%, Cerithidae-10.12%, Nerediidae-8.43%, Goniadidae-7.47%, Naididae-7.47, Capitellidae-6.26%, Neptydae-5.07%, Ocypodidae- 4.83, Isaeidae-4.82% and Sternaspidae-2.89% (Table 3). Lumbrinereidae was found dominant both in the Meghna River Estuary and the Bakkhali River Estuary where Cerithidae was dominant in the Bakhkhali river estuary (Table 3). The present findings were quite similar to the findings of Hossain [33] who investigated the polychaetes faunal biodiversity of the Meghna River estuarine bed. Similar results from other study [33] on faunal composition, seasonal abundance of polychaete (ind./m^2), species richness and species biodiversity (Swandwip, Hatiya, Bhola, Barisal and Chandpur) of Bangladesh revealed that Polychaetes was the most dominant among the macrobenthic groups constituted 56.72% of the total macrobenthos. However, results from the present study on microbenthic species composition was a little bit higher than that of the results postulated from Abu Hena on Bakhlali river estuary (Polychaeta, 9.966-30.31%; Oligochaeta, 3.68-30.31%; Crustacea, 0.02-58.40%; Bivalvia, 1.40-82.09% and Gastropoda, 0.08-4.25% and similar to the results of Asadujjaman [14,15,18,34].

Among the recorded 28 macrobenthic families from the study sites, the maximum number of families was found in S-1B and S-2B of the Bakkhali River Estuary where 21 families were common in both stations (Table 3). Abundance of polychaetes were found to be the highest (9110 ind./m^2) among all macro-benthic communities (Table 2). Maximum value (2089 ind./m^2) macrobenthos was found at sampling station S-2B of the Bakkhali River Estuary and minimum (711 ind./m^2) at station S-4M of the Meghna River Estuary (Table 2). A total 15 families were identified under taxonomic group of Polychaeta (Table 3). Olygochaetes were common at all the stations and occupied fourth position as regards to the abundance of total macro-benthos (Table 2). The maximum value (311 ind./m^2) was recorded at station S-5M of the Meghna River Estuary whereas the minimum (177 ind./m^2) value was recorded at station S-2B of the Bakkhali River Estuary (Table 2). A total 2 families were identified under the group of Oligochaeta (Table 3).

Arthropods constituted 12.77% of total macro-benthos (Table 2) and ranked 3rd. The maximum value (533 ind./m^2) was found at station S-5M of the Meghna River Estuary and minimum (266 Ind./m^2) at station S-1B of the Bakkhali River Estuary (Table 2). A total of 4 families were identified under the taxonomic group of Arthropoda (Table 3).

Gastropods constituted 14.70% of total macro-benthos (Table 2) however absent in the Meghna river estuary (Table 2). Gastropods had its highest density (1066 ind./m^2) at station S-1B and lowest (711 Ind./m^2) at station S-3B of the Bakkhali River Estuary (Table 2). A total of 3 families were recorded during the study period under this group (Table 3).

Table 3: Abundance of benthos families (individuals/m²) observed in the present study.

Family	Bakkhali River Estuary			Meghna River Estuary			Total	Mean	Standard Deviation	Percentage (%)
	S-1B	*S-2B*	*S-3B*	*S-4M*	*S-5M*	*S-6M*				
Capitellidae	356	267	311	44	133	44	1155	192.50	137.09	6.26
Goniadidae	222	400	400	0	311	44	1377	229.50	174.31	7.47
Lumbrinereidae	89	0	178	*356	*756	*889	2268	378.00	366.30	12.30
Nereidae	311	400	177	222	311	133	1554	259.00	99.26	8.43
Onupidae	44	0	0	0	0	0	44	7.33	17.96	0.24
Spionidae	89	0	0	0	0	0	89	14.83	36.33	0.48
Sternaspidae	311	89	133	0	0	0	533	88.83	122.46	2.89
Syllidae	44	178	0	0	0	0	222	37.00	71.28	1.20
Magelonidae	44	89	267	0	0	89	489	81.50	99.21	2.65
Neptydae	44	313	267	44	178	89	935	155.83	115.79	5.07
Paraonidae	0	0	0	0	44	0	44	7.33	17.96	0.24
Maldanidae	0	44	0	0	0	0	44	7.33	17.96	0.24
Sabellidae	0	89	0	44	0	0	133	22.17	37.17	0.72
Glyceridae	0	44	0	0	0	0	44	7.33	17.96	0.24
Cossuridae	0	133	0	0	0	0	133	22.17	54.30	0.72
Orbiniidae	0	44	0	0	0	0	44	7.33	17.96	0.24
Naididae	178	222	177	267	311	222	1377	229.50	52.10	7.47
Tubificidae	44	44	0	0	0	0	88	14.67	22.72	0.48
Mysidae	44	44	44	0	0	44	176	29.33	22.72	0.95
Isaeidae	222	400	267	0	0	0	889	148.17	172.54	4.82
Ampeliscidae	0	0	0	133	177	89	399	66.50	77.98	2.16
Ocypodidae	0	0	0	178	356	356	890	148.33	175.01	4.83
Veneridae	133	222	89	0	0	0	444	74.00	91.69	2.41
Trapezidae	89	44	0	0	0	0	133	22.17	37.17	0.72
Tellinidae	89	133	222	0	0	0	444	74.00	91.69	2.41
Trachidae	222	222	0	0	0	0	444	74.00	114.64	2.41
Cerithidae	*533	*711	*622	0	0	0	1866	311.00	345.30	10.12
Littorinidae	311	0	89	0	0	0	400	66.67	124.88	2.17
Unidentified	400	356	177	267	356	222	1778	296.33	87.74	9.64
Total	3819	4488	3420	1555	2933	2221	18436	3072.67	1070.42	100.00

*Indicates the highest number of the stations.

Maximum value (400 ind./m²) of bivalvia was found at station S-2B and minimum (311 Ind./m²) at S-1B and S-3B (Ind./m²). Bivalvia ranked 7th and contributed 1.15% of total Macro-benthos (Table 2). Total 3 families of benthos were identified under this taxonomic group (Table 3). The percentages of Polycheate were higher than the other benthic groups at all the stations (Table 3). The stations (S-4M, S-5M, S-6M) of the Meghna river estuary showed higher percentages of Olygochaete than the stations of Bakkhali river estuary.

Some water quality parameters were strongly correlated with the abundance of the benthic macrofaunal communities. The abundance of the benthic macrofaunal communities were significantly positively correlated with salinity ($r=.846$; $p \leq 0.05$) and negatively correlated with alkalinity ($r=-.842$, $p \leq 0.05$). On the other hand, the abundance of the benthic macrofaunal communities were significantly positively correlated with hardness ($r=0.857$, $p \leq 0.05$) and TDS ($r=0.887$; $p \leq 0.05$). The abundance of benthic communities were negatively significant with DO ($r=-.106$, $p \leq 0.05$) (Table 4).

Macrobenthic species composition in Bakkhali river estuary showed the maximum numbers of Polycheate (46%) followed by gastropods-23%, atrhropods-9%, bivalvia-8% and oligochaete-6% where the Meghna river estuary (Figure 5) showed the maximum number of Polychaete (56%) followed by arthropods-20%, oligochaete-12% (Figure 5). The density of macrobenthos found in 6 stations of the two study sites were tabulated in Table 5 with percentage and ranked according to the abundance of the macrobenthos in each station. Polycheate ranked number 1 in all stations while other benthic groups were fluctuated within the stations (Table 5).

A biodiversity index seeks to characterize the diversity of a sample or community by a single number. The concept of the "species diversity" involves two components: the number of species or richness and the distribution of individuals among species. However, Shannon–Wiener diversity index considers the richness and proportion of each species while Evenness and Dominance indices represent the relative number of individuals in the sample and the fraction of common species respectively. Quality of an aquatic ecosystem is dependent on the physico-chemical qualities of waters and it is reflected on biological diversity. Different diversity indices were recorded in Table 6. About 28 families were identified from sampling stations during the study period. Among the 28 families, the highest number of families were identified from Station S-2B (22 families) followed by the S-1B (21 families), S-3B (15 families), S-6M (11 families), S-5M (10 families) and S-4M (09 families) (Table 6). The Dominance-D value of the sampling stations was found 0.06878. The highest Dominance-D value was found in station S-6M (0.2155) followed by the S-4M (0.1546), S-5M (0.1392), S-3B (0.0913), S-2B (0.07605) and S-1B (0.07552) (Table 5). The Simpson_D value of the sampling stations was identified as 0.9312. The highest and lowest values (Table 6) of Simpson_D were

Table 4: Relationship between water quality parameters and abundance of macrobenthic communities.

	Temperature	Salinity	DO	pH	Alkalinity	Abundance
Temperature		0.445	-0.491	-0.357	-0.443	0.289
Salinity			-0.318	-0.720	-0.980**	0.846**
DO				0.190	0.298	-0.106
pH					0.645*	-0.287
Alkalinity				.		-0.842**
Abundance						

=highly correlated; *=moderately correlated (*p*** ≤ 0.05)

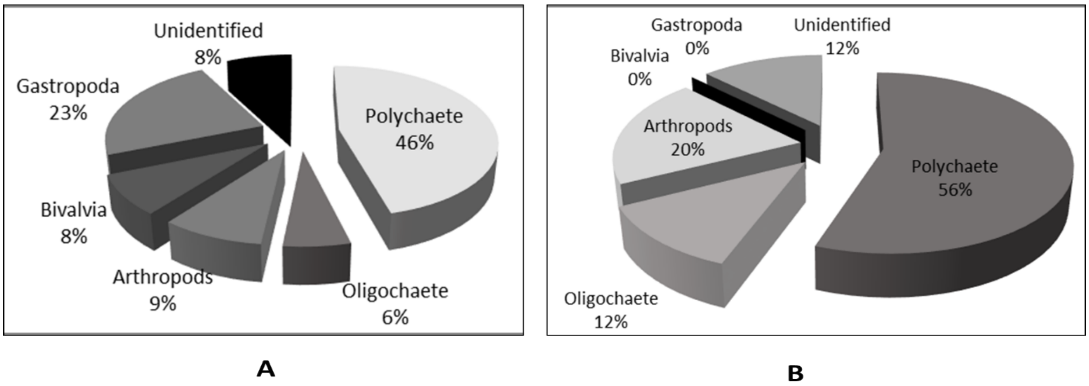

Figure 5: Percentage of macro benthic groups in the Bakkhali River Estuary (A) and the Meghna River Estuary (B).

identified in the stations S-1B (0.9245) and S-6M (0.7845) respectively. Another important diversity index is Shannon_H diversity index. The value of Shannon_H diversity index was recorded 2.89 while the value of Equitability J was found highest in the station of S-3B (0.94) and the lowest (Table 6) was in the station of S-6M (0.80). On the other hand another diversity index Fisher Alpha showed highest value in the station of S-2B (3.01) and the lowest was in the station of S-4M (1.27) (Table 6). After analyzing the diversity indices of the sampling stations of Bakkhali River Estuary and Meghna River Estuary, the significant differences were found between the two study sites which are shown in Figure 6. Different diversity indices showed significant differences between the two study sites. The diversity values of Shannon H (Bakkhali River Estuary-2.85, Meghna River Estuary-2.11), Evenness (Bakkhali River Estuary-0.67, Meghna River Estuary-0.63), Simpson Index (Bakkhali River Estuary-0.93, Meghna River Estuary-0.84), Mechinick (Bakkhali River Estuary-0.24, Meghna River Estuary-0.16), Margalef (Bakkhali River Estuary-2.67, Meghna River Estuary-1.36) and Fisher alpha (Bakkhali River Estuary-3.16, Meghna River Estuary-1.55) were found higher in the Bakkhali River Estuary and lower in the Meghna River Estuary (Figure 6). Only the Dominance-D value and Berger-Parker value of the Meghna River Estuary were found higher than the Bakkhali River Estuary (Figure 6).

Shannon Weiner diversity Index is a commonly used diversity index that takes into account both abundance and evenness of species present in the community. In the present study after analyzing the whole samples (18) from six sampling stations of two sampling sites, overall H value was found 2.89 (Table 6). The highest Shannon diversity index (2.781) was found at S-2B in the study period and lowest was found at S-6M (1.909) (Table 6). In biological communities, Shannon-Wiener diversity index varies from 0 to 5. According to this index, values less than 1 characterize heavily polluted condition, and values in the range of 1 to 2 are the characteristics of moderate polluted condition while the value above 3 signifies stable environmental conditions [35,36]. Higher value of Shannon_H indicated that the sampling stations have high number of individuals. Significant difference was found in the mean Shannon diversity index among the stations of the study sites (Table 6). This finding is similar to the findings of Bhandarkar, who investigated on the potential of benthic macro-invertebrates community assemblages in predicting the water quality status. Bhandarkar [37] identified that (Shannon-Weiner index value ranges from 1.2 to 2.9 in three ecosystems), all the selected sampling sites fall under moderate pollution. The Shannon equitability index values showed a greater equitability in the apportionment of individuals among the species in all the sites.

According to Margalef [38], the higher diversity values reflect the suitability of habitat for the organism and have been reported to be correlated with longer food chain and complex food web of the ecosystems and also more stable community. Margalef index has no limit value and it shows a variation depending upon the number of species. In the present study the values of Margalef diversity index were between 1.089 and 2.497 at station S-4M and S-2B respectively. Menhinick index, like Margalef's index, attempts to estimate species richness but at the same time it is independent on the sample size. In the present investigation, it ranged from 0.185 to 0.34 (Table 6). The low diversity associated with station S-5M, as described by the Shannon, Margalef and Menhinick indices, may be attributed to lesser number of species and environmental degradation due to anthropogenic pressures, besides other biotic factors [39]. The mean Margalef's value of the Bakkhali River Estuary (2.21) is higher than the mean value of the Meghna River Estuary (1.17). Table 5 showed how the values differ among the stations of the study sites. Again, Hossain [33] identified that the Shannon species diversity index of polychaetes varied from

Table 5: Density of macrobenthos found in the Bakkhali River Estuary and the Meghna River Estuaryo.

Study Sites	Stations	Benthos Group	Individuals/m²	Percentage (%)	Rank of Abundance
Bakkhli River Estuary	*S-1B*	Polychaete	1556	41.21	1
		Oligochaete	222	5.88	6
		Arthropods	266	7.04	6
		Bivalvia	265	7.02	6
		Gastropoda	1067	28.26	2
		Unidentified	400	10.59	5
		Total	3776	100	
	S-2B	Polychaete	2089	46.55	1
		Oligochaete	266	5.93	6
		Arthropods	445	9.92	6
		Bivalvia	400	8.91	6
		Gastropoda	933	20.79	3
		Unidentified	355	7.91	6
		Total	4488	100	
	S-3B	Polychaete	1733	50.67	1
		Oligochaete	177	5.18	6
		Arthropods	311	9.09	6
		Bivalvia	311	9.09	6
		Gastropoda	711	20.79	3
		Unidentified	177	5.18	7
		Total	3420	100	
Meghna River Estuary	*S-4M*	Polychaete	711	45.72	1
		Oligochaete	267	17.17	4
		Arthropods	311	20.00	4
		Bivalvia	0	0.00	0
		Gastropoda	0	0.00	0
		Unidentified	266	17.11	4
		Total	1555	100	
	S-5M	Polychaete	1733	59.11	1
		Oligochaete	311	10.61	5
		Arthropods	533	18.18	4
		Bivalvia	0	0.00	0
		Gastropoda	0	0.00	0
		Unidentified	355	12.11	5
		Total	2932	100	
	S-6M	Polychaete	1289	58.04	1
		Oligochaete	222	10.00	6
		Arthropods	489	22.02	3
		Bivalvia	0	0.00	0
		Gastropoda	0	0.00	0
		Unidentified	221	9.95	6
		Total	2221	100	

* 1-5% = rank 7; 06-10% = rank 6; 11-15% = rank 5; 16-20% = rank 4; 21-25% = rank 3; 26-40% = rank 2; >41%=rank 1.

0-1.36. It was the highest at Swandwip during post monsoon and lowest at Bhola during monsoon in Bangladesh. Abu Hena [15] also identified that the Shannon diversity index ranged from 0.65-1.04 among the sampling stations at the Bakkhali River Estuary, Cox's Bazar.

Species evenness refers to how close in numbers of each species in an environment are. Mathematically it is defined as a diversity index, a measure of biodiversity which quantifies how equal the community numerically. The higher value shows lower variation in number of species. Usually it has been also defined as the ratio of observed diversity to maximum diversity, the latter being said to occur when the species in a collection are equally abundant [40]. Evenness index value for collected 18 samples was 0.62, where the highest (0.85) and the lowest (0.61) values of Evenness recorded from S-3B and S-6M, respectively (Table 6). No significant difference was found in mean value of evenness value among the stations and as well as within the two study sites (Table 6).

In the present study diversity of benthic organisms were in the sequence of Polychaete (49.42%) > Gastropods (14.70%) > Arthropods (12.77%) > Oligochaete (7.94%) > Bivalvia (5.54%). On the other hand there was an inverse relationship between these two indices in the three sampling stations of the Bakkhali River Estuary. This findings is similar to the investigation of Bu-Olayan and Thomas who observed that the diversity of benthic organisms were in the sequence of Annelida > Mollusca > Crustacea > others group in Kuwait Bay of the Arabian

Table 6: Diversity Indices Observed in the Present Study.

Stations	S-1B	S-2B	S-3B	Mean ± SD	S-4M	S-5M	S-6M	Mean ± SD	All Stations
Taxa_S	21	*22	15	19.33±3.79	9	10	11	10 ± 1.0	28
Individuals	3819	*4488	3420	3909 ± 540	1555	2933	2221	2236 ± 689	18436
Dominance D	0.08	0.08	0.09	0.08 ±0.01	0.15	0.14	*0.22	0.17± 0.04	0.07
Simpson D	*0.93	0.92	0.91	0.92 ± 0.01	0.85	0.86	0.78	0.83 ± 0.04	0.93
Shannon_H	2.76	*2.78	2.54	2.69 ±0.13	1.98	2.12	1.91	2.00 ± 0.11	2.89
Evenness	0.75	0.73	*0.85	0.78 ± 0.06	0.81	0.83	0.61	0.75 ± 0.12	0.62
Brillouin	2.74	*2.77	2.53	2.68 ± 0.13	1.97	2.11	1.89	1.99 ± 0.11	2.88
Menhinick	*0.34	0.33	0.26	0.31 ± 0.04	0.23	0.18	0.23	0.22 ± 0.03	0.21
Margalef	2.43	*2.50	1.72	2.21 ± 0.43	1.09	1.13	1.30	1.17 ± 0.11	2.85
Equitability_J	0.91	0.90	*0.94	0.91 ± 0.02	0.90	0.92	0.80	0.87 ± 0.07	0.86
Fisher_alpha	2.93	*3.01	2.02	2.65 ± 0.55	1.27	1.29	1.51	1.36 ± 0.13	3.37
Berger-Parker	0.14	0.16	0.18	0.16 ± 0.02	0.23	0.26	*0.40	0.30 ± 0.09	0.12

*Indicates the highest value among the stations.

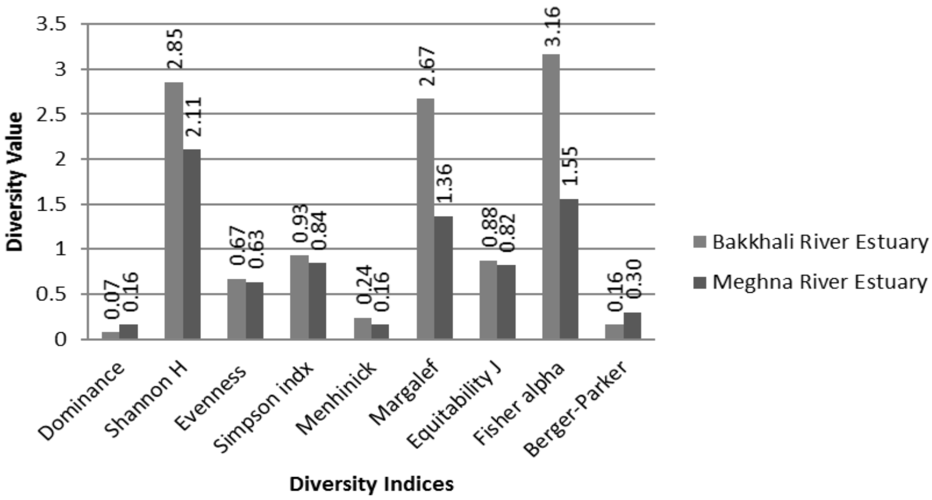

Figure 6: Diversity Indices of the two study sites.

Gulf. Evenness index (–) was found to be increased with increasing Bu-Olayan H and Thomas [41] identified that low diversity indices correspond to the increase in trace metal level in benthic species collected from four sites, wherein high abundance of certain benthic species and high trace metal levels due to manmade perturbations were observed altering the diversity indices and those indices would validate benthic organisms as an indicator to trace metal pollution in Kuwait marine ecosystem, however primary or secondary data regarding trace metal concentrations is absent in the present study area [41].

Conclusion

The coastline along the South-Eastern part of Bangladesh has high fisheries resources and the fisheries production of the estuarine areas of that coast is higher than other coastal areas of the country. Environmental pollution is believed to be the major constraints of fisheries production of an area. Although similar research is untouched to assess the environmental pollution of a water body, macrobenthic structure of those water bodies is used as indicator. Therefore, due to the lack of detailed study on the macrobenthic structure of those areas, present study was designed to assess the pollution status of the Bakkhali River estuary and the Meghna River estuary. A total 28 families under 05 major groups/taxa of macrobenthic communities were identified and the dominant group both in number of families (16 families) and individuals (49.42%) was the Polychaeta followed by Gastropoda (14.70%), Arthropods (12.77%), Oligochaete (7.94%) and the lowest was Bivalvia (5.54%). The abundance (r=.846) and species richness (r=.864) of the macrobenthic communities were significantly influenced by the water salinity of the sampling sites ($p \leq 0.05$). Both the study areas namely the Bakkhali River Estuary and the Meghna River Estuary showed the highest (3909 ± 540 ind./m^2) and lowest (2236 ± 689 ind./m^2) density of microbenthic communities respectively. These two study sites might be considered as moderately polluted areas according to the results obtained from Shannon-Wiener index of species diversity (2.69 ± 0.13 and 2.00 ± 0.11 respectively) and Margalef's species richness (2.21 ± 0.43 and 1.36 ± 0.11 respectively). Therefore, it can be concluded that the macrobenthic community explained in the present study might be a key future outline to assess the status of coastal water pollution of those concerned areas of Bangladesh.

Acknowledgment

The authors realized thanks to the laboratory staffs of the Department of Fisheries and Marine Science, Noakhali Science and Technology University (NSTU) for their help in sample collections.

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