Macrobenthic Community Structure as A Bio-Indicator for the Assessment of Coastal Water Pollution In Greater Noakhali-Bangladesh

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Abstract

Present study was aimed for the partial judgement of coastal water pollution and accordingly the abundance, diversity as well as the species composition of macrobenthic communities on the sediment of 3 selected stations were carried out following standard methods during January to March, 2015 in Noakhali, Bangladesh. 14 families under 4 major groups yielded a total of 5481 ind./m² with a mean density of 609 ± 445 ind./m² during the study. The highest and the lowest number of taxa were identified in January (10) and February (6) respectively during the study period. On the other hand, monthly diversity profile of macrobenthic communities showed clear difference in the diversity of all stations which is compatible to the other published results of macrobenthic animal as well. Based on the calculated results from Shannon-Wiener index of macrobenthic species diversity (H'), the present study might be considered as heavily polluted in February (H' = 0.9202) and moderately polluted in January (H' = 1.514) and in March (H' = 1.571). On the other hand, The Margalef’s index of benthic macro-invertebrates at station S1 (0.4501) was lowest in February and at station S1 (1.096) was highest. Therefore, the research output revealed that the abundance and diversity of macrobenthic animal community might be good indicators to assess the aquatic environmental pollution as the selected study area fall under the category of more or less polluted.

Keywords: Environmental pollution; Macrobenthic animal; Bangladesh

Introduction

Macrobenthos are commonly used as bio-monitors to detect pollution impacts in estuaries [1] for their exclusive and unique characteristics. They are abundant, easy to collect and very diverse with representatives from many different phyla [2] utilizing many different habitats and feeding strategies [3-6]. These assemblages respond predictably to pollution [7,8], integrates the stress over months to years and relatively sedentary in nature [5,9]. Besides this, macrobenthic communities are eaten by other higher tropical organisms like fin and shell fishes as food and recycle the organic matters and debris like an ecological engineer [10]. They also provide a linkage between substratum and water column predators [11]. Macrobenthos are an important role playing community in aquatic ecosystem because they mineralize, promote and mix the oxygen flux into the sediment which recycle the organic matter [12]. Benthic community determines the amount of nutrients release of the sediments [13]. Biological interactions, such as predation and competition affect the macrobenthic community structure by acting on recruitment, survival, or migration of organisms [14-18]. The characteristics of the life cycle of the species and the influence of temporal fluctuation of abiotic factors, such as environmental temperature or salinity can also change macrobenthic communities in a cyclic pattern over time [19-22]. Physical and chemical factors affect the distribution and abundance of macrobenthic community like contaminations of sediments environment, current of the water organic contents of the sediments, depth, rapid sedimentation and toxicity of sediments causes shifts of macrobenthic communities towards lower abundance [23].

Although much studies on macrobenthic community has been carried out globally however there is scanty published documents on macrobenthic community of coastal area in Bangladesh. There are few works on Hatia and Nijhum Dweep Island but the attached part of Hatia with main land of Noakhali district remain untouched. So this study was aimed for the documentation of the abundance and composition of microbenthic community of the branch of lower part of the mighty Meghna River. Therefore the objective of the present study was to know the monthly abundance of macrobenthic community, to know the species composition and diversity of macrobenthic communities in estuarine waters and to assess the status of pollution in Chairman Ghat, Noakhali.

Materials and Methods

Sediment and water samples were collected from the intertidal zone of the estuary of a branch of the Meghna River at Chairman Ghat during January, February and March, 2015 from 3 sampling stations namely S1 (Station 1) (22° 30' 48.3876" N, 91°5' 6.6078" E), S2 (Station 2) (22° 31' 5.2278" N, 91° 5' 26.4788" E) and S3 (Station 3) (22° 31' 34.1868" N, 91° 5' 41.5566" E). An Ekman dredge (mouth opening of 0.0225 m²) was used to collect sediment samples with triplicate fashion from each station. Subsurface water samples were collected from three sites during high tide condition for measuring water temperature (ºC), salinity (ppt), pH, DO (dissolved oxygen, ppm) and transparency (cm). Temperature (ºC) was measured using a centigrade thermometer in study area where water salinity, pH, transparency and DO were measured in situ by using Refractometer (INDEX, Model No. REF 201), Digital pen pH meter (HANNA Instrument, Model No. H196107), Secchi disc (20 cm diameter) and DO meter (LUTRON, Model No. DO-5509) respectively.

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Sampled sediments were sieved (through 500 µm mesh) to retain macrobenthos and then preserved immediately in the plastic container with other residues in 10% formalin solution. It was then labeled and for further analysis transferred to the laboratory. Small amount of “Rose Bengal” was added to make the macro organism visible. Benthic macrofauna was sorted manually putting on a tray under sufficient light and enumerated up to major taxa. Magnifying glass and microscope (Model No. XSZ 21-05DN, China) often were used for the identification of macrobenthos. Abundance of macrobenthic fauna was calculated in individual per m². Sample was then preserved in 70% alcohol (Ethanol).

Statistical analysis was performed using SPSS (Version 20) and PAST [24]. Occurrence of macro-invertebrates occurrence (N) was calculated using the following formula [25],

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

Here,

- s = Number of sample.
- a = Mouth opening area of Ekman dredge in cm², and
- O = Actual counted number of macro-invertebrates per sampled area.

The dominance (D) index [26] was determined by using following formula:

$$D = \frac{\sum n_{i}^{2}}{\sum n_{i}}$$

Here,

- n = Total individual number.
- ni = Individuals of species number i.

The Simpson Index (1-D) was measured by the following formula [27],

$$1-D = \sum_{i=1}^{S} P_{i}$$

Here,

- Pi = Proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N),
- S = Number of species.

Shannon-Wiener Index (Species diversity, H’) were calculated according to Wilhm and Dorris [28] formula,

$$H’ = - \sum_{i=1}^{S} P_{i} \ln P_{i}$$

Here,

- Pi = ni/N = Proportion of individuals of the total sample of the ith species.
- N = Individual number of all the species in total,
- ni = Individuals number of the ith species, and
- S = Number of species.

The Margalef’s Index (D’) was calculated by the following index [29],

$$D’ = \frac{S - 1}{\ln N}$$

Here,

- N = Individuals number in total of sample
- S = Species number in sample
- ln = Normal log

Equitability (J) was measured by using the following formula [26],

$$J = \frac{H’}{\log S}$$

Here,

- S = Species number in a population.
- H’ = Shannon and Weiner Index

### Results and Discussion

The measured water quality parameter is recorded in Table 1. The highest water temperature was recorded (32°C) in station S3 in March with mean of 30 ± 0.96 while the lower was observed in January (22.33 ± 0.47). Higher salinity was measured in February (10.33 ± 1.25) being the highest at station S3 (12 ppt) comparing to other two months while DO was lowest in this month (4.0 ± 0.29 ppm) in relation to January (6.8 ± 0.24 ppm) and March (5.3 ± 0.73 ppm). PH showed no major variation in January (7.67 ± 0.31), February (7.77 ± 0.21) or in March (7.28 ± 0.70) while transparency was recorded very low in all 3 month of the present study area in January (3.17 ± 1.03 cm), February (4.17 ± 0.85 cm), and in March (1.5 ± 0.71 cm). All the parameters varied with the seasonal variation accordingly. Salinity and transparency

| Month | Station | Temperature (°C) | Salinity (ppt) | Dissolve Oxygen (ppm) | pH | Transparency (cm) |
|-------|---------|----------------|---------------|----------------------|----|------------------|
| January | S1 | 22 | 5 | 7.1 | 7.5 | 4.5 |
|       | S2 | 22 | 4 | 6.5 | 7.4 | 3   |
|       | S3 | 23 | 6 | 6.8 | 8.1 | 2   |
|       | Mean ± SD | 22.33 ± 0.47 | 5.00 ± 0.82 | 6.8 ± 0.24 | 7.67 ± 0.31 | 3.17 ± 1.03 |
| February | S1 | 27 | 9 | 3.6 | 7.8 | 3   |
|       | S2 | 27 | 10 | 4.3 | 7.5 | 5   |
|       | S3 | 28 | 12 | 4.1 | 8   | 4.5  |
|       | Mean ± SD | 27.33 ± 0.47 | 10.33 ± 1.25 | 4.0 ± 0.29 | 7.77 ± 0.21 | 4.17 ± 0.85 |
| March  | S1 | 30 | 5 | 6.2 | 7.28 | 3   |
|       | S2 | 31 | 6 | 6.8 | 7.55 | 2   |
|       | S3 | 32 | 8 | 5.3 | 8.75 | 1.5  |
|       | Mean ± SD | 30 ± 0.96 | 5 ± 1.41 | 5.3 ± 0.73 | 7.28 ± 0.70 | 1.5 ± 0.71 |

Table 1: Water quality parameter measured from three stations during January, February and March (2015).
may fluctuated due to the water availability in different month from January to March because usually March is more close to the monsoon season where January falls under Winter season in this area. A Pearson’s correlation was run to determine the relationship between these 5 measured parameters (temperature, salinity, DO, pH and transparency) from three stations (S1, S2 and S3) along with abundance of macrofauna found during January, February and March, 2015 from the present study (Table 2). There was a very strong negative correlation between salinity and DO (r = - 0.859, p > 0.01).

A total number of 14 taxa (families) of macrofauna under 4 class identified from January to March yielded 5481 ind./m² with a mean density of 609 ± 445.32 ind./m² from all stations (Table 3). The highest density of macrobenthic animal was found 919 ind./m² in station S1 during March while the lowest was 326 ind./m² at station S3 during February (Table 3). Lumbrineridae almost dominated each months in all stations contributing 49% (Figure 1) of the total macrofauna while Goniadidae and Nereididae were also abundant in all months with a mean of (296 ± 139.33 ind./m²), (71 ± 42.35 ind./m²) and (127 ± 88.37 ind./m²) with a total of (2667 ind./m²), (637 ind./m²) and (1141 ind./m²) respectively (Figure 2). In regard of the rest 11 families, their attendance were scattered in different months at different stations. Nephtyidae was found only in March while Terebriidae was found in January only at station S3 (15 ind./m²) and Oedicerotidae was only at station S1 (44 ind./m²) in March. Variation of microbenthic density might be due to the seasonal variations of environmental parameters [30]. Observed macrobenthic diversity indices were positively correlated with salinity and pH (p <0.05) and negatively correlated with clay and organic matter [31]. Although species level identification of microbenthic animal provides better understanding of environmental impact assessment [32], present results with the family of microbenthic individual is also acceptable [33].

Quantitative distribution of intertidal macrobenthic community structure of the Chairman Ghat has been furnished in Table 4. The fauna comprised a total 4 groups including Polychaete, Gastropoda, Bivalvia and Arthropods where Polychaete was dominant in all the stations occupying the highest percentage (Figure 3) in all three months during all the study period that yield a total (4815 ind./m²) with a mean value of (535 ± 175.63 ind./m²) comprising 87.85% of total abundance. Gastropoda was found only at station S3 (15 ind./m²) and Bivalvia at station S1 (15 ind./m²) and at S3 (30 ind./m²) in January. Arthropods were common in all month after the polychaete where polychaete was 83% and Arthropods was 7% in January, polychaete was 96% and Arthropods was 1% in February and polychaete was 84% and Arthropods was 8% in March (Figure 3). In all the comparative study of bentic group it is clear that the Polychete is the most abundant and dominant group in all three month. The density of macrobenthos group found in 3 station during 3 months of study period from Chairman Ghat are tabulated in Table 5 that shows the abundance in individual per square meter (ind./m²), their station wise percentage and the rank of abundance in 3 months. It shows that Polychete is ranked in number

**Correlation is significant at the 0.01 level (1-tailed)**

### Table 2: Pearson correlation (r) among the measured parameters during the present study period.

| Month | Station | Temperature | Salinity | DO | pH | Transparency | Abundance |
|-------|---------|-------------|----------|----|----|--------------|-----------|
|       | JS1     | -0.01       | -0.356   | 0.3| -0.349| 0.301       |           |
|       | JS2     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |
|       | JS3     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |
|       | FS1     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |
|       | FS2     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |
|       | FS3     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |
|       | MS1     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |
|       | MS2     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |
|       | MS3     | -0.37       | -0.37    | 0.04| 0.398| -0.207      |           |

### Table 3: Abundance of macrobenthic family (ind./m²) at all stations during the study period.

| Station | January | February | March | Mean ± SD | Total | Percentage | Rank |
|---------|---------|----------|-------|-----------|-------|------------|------|
| JS1     | 148     | 207      | 222   | 296 ± 139.33 | 2667  | 48.65      | 1    |
| JS2     | 65      | 504      | 504   | 71 ± 42.35   | 637   | 11.62      | 3    |
| JS3     | 139.33  | 193      | 193   | 16 ± 32.34   | 148   | 2.7        | 5    |
| FS1     | 59      | 59       | 74    | 127 ± 88.37  | 1141  | 20.81      | 2    |
| FS2     | 15      | 15       | 15    | 15 ± 18.48   | 133   | 2.43       | 7    |
| FS3     | 30      | 30       | 30    | 2 ± 4.66     | 15    | 0.27       | 14   |
| MS1     | 30      | 30       | 30    | 5 ± 9.31     | 30    | 0.54       | 13   |
| MS2     | 15      | 15       | 15    | 2 ± 4.66     | 15    | 0.27       | 14   |
| MS3     | 44      | 44       | 44    | 15 ± 18.48   | 133   | 2.43       | 7    |
| Total   | 622     | 533      | 400   | 609 ± 445.32 | 5481  | 100        | 4    |

JS1, JS2 and JS3 = S1, S2 and S3 in January respectively; FS1, FS2 and FS3 = S1, S2 and S3 in February respectively; MS1, MS2 and MS3 = S1, S2 and S3 in March respectively.
1 in all stations while other groups fluctuated within different stations in different months where sometime some groups were totally absent. Similar findings was reported near the study area [34] where Polychaeta was dominant [10,35].

Diversity indices

Diversity Indices of different station characterized the present study (Table 6). Different diversity indices showed significant difference between the months (Figure 4). Higher values of the diversity indices were observed in January and March while in February the values were lower than other two months. The highest value for Dominance (D) was in February (0.5438). The Simpson (1-D) value was highest (0.728) in March and lowest (0.4562) in February. The Shannon (H') diversity index is another important one. In the present investigation it ranged from 0.7797 at station S2 in February to 1.648 at station S1 in March where 1.514, 0.9202 and 1.571 was for January, February and March respectively. The Margalef’s index of benthic macro-invertebrates at station S1 (0.4501) was lowest maintaining the value 0.6689 in February for in total and at station S1 (1.096) was highest maintaining the value 1.234 in January for in total while that value was 0.9246 in March. While the value of Equitability (J) index of benthic macro-invertebrates at station S2 (0.5452) was lowest maintaining the value 0.4183 in February for in total and at station S2 (0.7602) was highest maintaining the value 0.6016 in March for in total while that value was 0.4546 in January respectively.

Shannon-Weaver diversity index was defined [36] as H' and the highest and lowest value of H' indicated rich diversity with healthier environment and poor diversity with polluted environment respectively. Water bodies with macro-benthos Shannon-Wiener diversity index < 1 are classified as heavily polluted, 1-3 is moderately polluted and >3 clean environment [28,37-40]. So it can be said that all the selected stations in the study area was heavily polluted in February (H' = 0.9202) while pollution was moderate in January (H' = 1.514) and March (H' = 1.571). In one hand the suitability of habitat is reflected by the higher diversity values for the organism while it is reported that high species diversity is correlated with longer food chain, complex food web and more stable community

![Figure 1: Composition of macrobenthic animals (family) observed in the present study.](image)

![Figure 2: Monthly variation in abundance of macrobenthic animal’s family (ind./m²) in three station.](image)

| Month | January | February | March |
|-------|---------|----------|-------|
| Station | JS1 | JS2 | JS3 | FS1 | FS2 | FS3 | MS1 | MS2 | MS3 | Mean ± SD | Total | Rank |
| Polychaete | 533 | 444 | 311 | 785 | 696 | 267 | 741 | 430 | 607 | 535 ± 175.83 | 4815 | 1 |
| Gastropoda | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 2 ± 4.66 | 15 | 5 |
| Bivalvia | 15 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 5 ± 9.88 | 44 | 4 |
| Arthropods | 44 | 74 | 0 | 0 | 0 | 15 | 133 | 30 | 0 | 33 ± 42.92 | 296 | 3 |
| Unidentified | 30 | 15 | 44 | 15 | 0 | 44 | 44 | 59 | 59 | 35 ± 19.75 | 311 | 2 |
| Total | 622 | 533 | 400 | 800 | 696 | 326 | 919 | 519 | 609 | 609 ± 176.74 | 5481 | |

JS1, JS2 and JS3 = S1, S2 and S3 in January respectively; FS1, FS2 and FS3 = S1, S2 and S3 in February respectively; MS1, MS2 and MS3 = S1, S2 and S3 in March respectively.

Table 4: Group wise total abundance distribution of macrobenthos in all stations in Chairman Ghat observed during the present study.
on the other hand [41]. Depending on the number of species Margalef index (D') shows variation having no limit on its value. So it can be postulated that the present study area is moderately polluted according the results calculated from Margalef index which is compatible with the findings of other research [34].

**Conclusion**

14 families under 4 major groups/taxa yielded a total of 5481 ind./m² with a mean density of 609 ± 445.32 ind./m² from all stations. The Shannon-Wiener index indicate that all the stations selected was heavily polluted in February (H' = 0.9202) while pollution was moderate in January (H' = 1.514) and in March (H' = 1.571). The Margalef Species Richness Index (D') value was highest in January (1.234) and lowest in February (0.6689) where March (0.9246) maintained the medium value. Which reviles that the area falls under present study was moderately polluted.
respectively.

JS1, JS2 and JS3 = S1, S2 and S3 in January respectively; FS1, FS2 and FS3 = S1, S2 and S3 in February respectively; MS1, MS2 and MS3 = S1, S2 and S3 in March respectively.

Table 6: Different diversity indices at different stations observed during the study period.

| Month | Station | Taxa (S) | Individuals | Dominance (D) | Simpson (1-D) | Shannon (H) | Margalef (D') | Equitability (J) |
|-------|---------|----------|-------------|--------------|--------------|-------------|--------------|-----------------|
| January | JS1 | 8 | 592.58 | 0.305 | 0.695 | 1.507 | 1.096 | 0.7245 |
|       | JS2 | 6 | 518.51 | 0.3127 | 0.6873 | 1.374 | 0.7999 | 0.7666 |
|       | JS3 | 5 | 355.54 | 0.4445 | 0.5555 | 1.092 | 0.681 | 0.6787 |
|       | Total | 10 | 1466.65 | 0.3044 | 0.6956 | 1.514 | 1.234 | 0.6576 |
| February | FS1 | 4 | 785.18 | 0.5472 | 0.4528 | 0.8703 | 0.4501 | 0.6278 |
|       | FS2 | 4 | 696.29 | 0.5709 | 0.4291 | 0.7797 | 0.4583 | 0.5625 |
|       | FS3 | 4 | 281.47 | 0.5069 | 0.4931 | 0.943 | 0.5319 | 0.6802 |
|       | Total | 6 | 1762.95 | 0.5438 | 0.4562 | 0.9202 | 0.6689 | 0.5136 |
| March | MS1 | 7 | 874.06 | 0.2485 | 0.7515 | 1.648 | 0.8859 | 0.8486 |
|       | MS2 | 5 | 459.25 | 0.3195 | 0.6805 | 1.335 | 0.6526 | 0.8296 |
|       | MS3 | 5 | 607.4 | 0.3183 | 0.6817 | 1.275 | 0.6241 | 0.7921 |
|       | Total | 8 | 1940.74 | 0.272 | 0.728 | 1.571 | 0.9246 | 0.7557 |
|       | All Station | 14 | 5170.35 | 0.3327 | 0.6673 | 1.509 | 1.52 | 0.5717 |

JS1, JS2 and JS3 = S1, S2 and S3 in January respectively; FS1, FS2 and FS3 = S1, S2 and S3 in February respectively; MS1, MS2 and MS3 = S1, S2 and S3 in March respectively.

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