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

Md. Jahangir Sarker*, Mehedi Hasan Tanmay, Farhana Rahman, Md. Shamsul Alam Patwary and Nazmun Nahar Rima

Department of Fisheries and Marine Science, Noakhali Science and Technology University, Noakhali-3814, Bangladesh

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./m^2 with a mean density of 609 ± 445 ind./m^2 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 microbenthic 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 microbenthic 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 sea bed 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' 26.4768" E) and S3 (Station 3) (22° 31' 34.1868" N, 91° 5' 41.5566" E). An Ekman dredge (mouth opening of 0.0225 m^2) 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 (^{0}C), salinity (ppt), pH, DO (dissolved oxygen, ppm) and transparency (cm). Temperature (^{0}C) 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.

***Corresponding author:** Md. Jahangir Sarker, Department of Fisheries and Marine Science, Noakhali Science and Technology University, Noakhali-3814, Bangladesh, Tel: +8801733910237/+880-321-71487; Fax: +880-321-62788; E-mail: swaponj@yahoo.com

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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 m^2. 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 cm^2, and

O = Actual counted number of macro-invertebrates per sampled area,

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

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

Here,

n = Total individual number.

ni = Individuals of species number i.

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

$$(1\text{-}D) = \frac{1}{\sum_{i=1}^{S} Pi\ 2}$$

Here,

P = 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,

$$H' = -\sum_{i=1}^{S} Pi\ Ln\ Pi$$

Here,

$Pi = ni/N$ = Proportion of individuals of the total sample of the i^{th} species.

N = Individual number of all the species in total,

ni = Individuals number of the i^{th} 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],

$$J = \frac{H'}{\text{Log } S}$$

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^{0}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 ± 0.71cm). 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./m^2 with a mean density of 609 ± 445.32 ind./m^2 from all stations (Table 3). The highest density of macrobenthic animal was found 919 ind./m^2 in station S1 during March while the lowest was 326 ind./m^2 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./m^2), (71 ± 42.35 ind./m^2) and (127 ± 88.37 ind./m^2) with a total of (2667 ind./m^2), (637 ind./m^2) and (1141 ind./m^2) 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 Terebridae was found in January only at station S3 (15 ind./m^2) and Oedicerotidae was only at station S1 (44 ind./m^2) 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./m^2) with a mean value of (535 ± 175.63 ind./m^2) comprising 87.85% of total abundance. Gastropoda was found only at station S3 (15 ind./m^2) and Bivalvia at station S1 (15 ind./m^2) and at S3 (30 ind./m^2) 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 benthic 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./m^2), their station wise percentage and the rank of abundance in 3 months. It shows that Polychete is ranked in number

Pearson Correlation (r)	Temperature	Salinity	DO	pH	Transparency	Abundance
Temperature	-	0.356	-0.37	0.3	-0.349	0.301
Salinity	-	-	-0.859**	0.4	0.398	-0.207
DO	-	-	-	0	-0.265	-0.141
pH	-	-	-	-	-0.472	-0.293
Transparency	-	-	-	-	-	-0.01
Abundance	-	-	-	-	-	-

**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	January			February			March						
Station	**JS1**	**JS2**	**JS3**	**FS1**	**FS2**	**FS3**	**MS1**	**MS2**	**MS3**	**Mean ± SD**	**Total**	**Percentage**	**Rank**
Lumbrineridae	148	207	222	563	504	193	370	222	237	296 ± 139.33	2667	48.65	1
Goniadidae	59	30	15	119	148	30	59	74	104	71 ± 42.35	637	11.62	3
Nephtyidae	0	0	0	0	0	0	104	30	15	16 ± 32.34	148	2.7	5
Nereididae	281	193	74	74	30	0	163	104	222	127 ± 88.37	1141	20.81	2
Polynoidae	30	15	0	0	0	0	0	0	0	5 ± 9.88	44	0.81	12
Syllidae	0	0	0	0	0	0	0	0	30	3 ± 9.31	30	0.54	13
Sabellidae	0	0	0	0	15	0	0	0	0	2 ± 4.66	15	0.27	15
Capitellidae	15	0	0	30	0	44	44	0	0	15 ± 18.48	133	2.43	7
Terebridae	0	0	15	0	0	0	0	0	0	2 ± 4.66	15	0.27	14
Isaeidae	15	44	0	0	0	0	0	0	0	7 ± 14.16	59	1.08	8
Mytilidae	15	0	30	0	0	0	0	0	0	5 ± 9.88	44	0.81	9
Oedicerotidae	0	0	0	0	0	0	44	0	0	5 ± 13.97	44	0.81	10
Mysidae	0	30	0	0	0	15	0	0	0	5 ± 9.88	44	0.81	11
Portunidae	30	0	0	0	0	0	89	30	0	16 ± 28.32	148	2.7	6
Unidentified	30	15	44	15	0	44	44	59	59	35 ± 19.75	311	5.68	4
Total	622	533	400	800	696	326	919	519	667	609 ± 445.32	5481	100	
Family Found	8	6	5	4	4	4	7	5	5		14		

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 3: Abundance of macrobenthic family (ind./m^2) at all stations during the study period.

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.

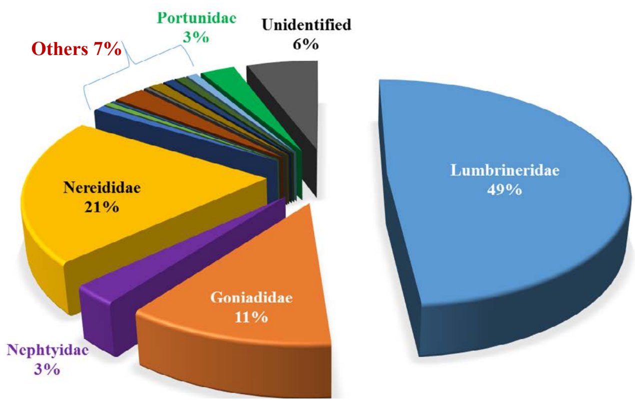

Figure 1: Composition of macrobenthic animals (family) observed in the present study.

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 is 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

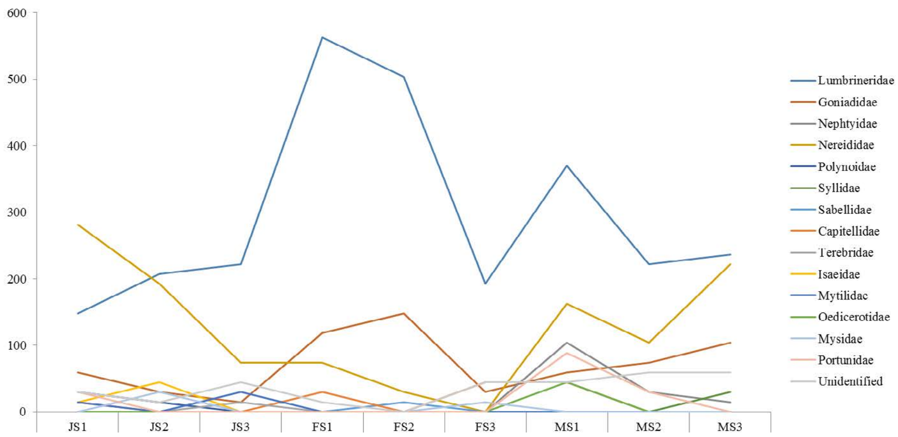

Figure 2: Monthly variation in abundance of macrobenthic animal's family (ind./m²) in three station.

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 ± 175.63	4815	1
Gastropoda	0	0	15	0	0	0	0	0	0	2 ± 4.66	15	5
Bivlvia	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	667	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.

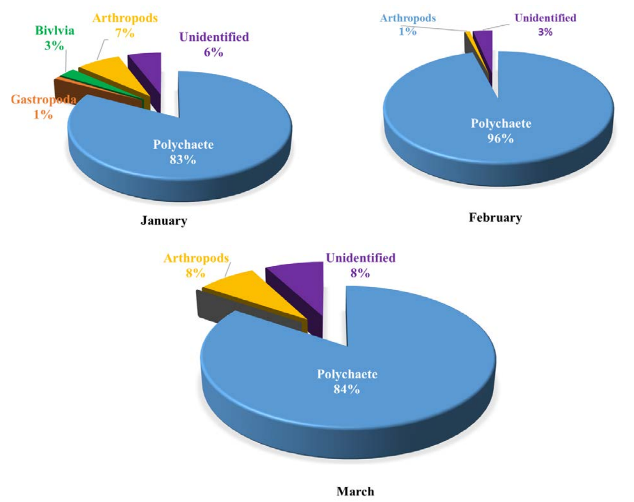

Figure 3: Composition of macrobenthic animal (group) observed during the study period (J- in January, F- in February and M- in March).

Station	Groups	Ind./m2	Percentage (%)	Station wise Rank
JS1	Polychaete	533	85.74	1
	Gastropoda	0	0	5
	Bivlvia	15	2.38	4
	Arthropods	44	7.15	2
	Unidentified	30	4.76	3
	Total	**622**	**100**	
JS2	Polychaete	444	83.39	1
	Gastropoda	0	0	4
	Bivlvia	0	0	5
	Arthropods	74	13.9	2
	Unidentified	15	2.78	3
	Total	**533**	**100**	
JS3	Polychaete	311	77.78	1
	Gastropoda	15	3.7	4
	Bivlvia	30	7.41	3
	Arthropods	0	0	5
	Unidentified	44	11.11	2
	Total	**400**	**100**	

JS1, JS2 and JS3 = S1, S2 and S3 in January respectively.

Table 5a: Density and station wise rank of macrobenthic groups based on percentage found during January of the study period.

Station	Groups	Ind./m2	Percentage (%)	Station wise Rank
FS1	Polychaete	785	98.15	1
	Gastropoda	0	0	3
	Bivlvia	0	0	4
	Arthropods	0	0	5
	Unidentified	15	1.85	2
	Total	**800**	**100**	
FS2	Polychaete	696	100	1
	Gastropoda	0	0	2
	Bivlvia	0	0	3
	Arthropods	0	0	4
	Unidentified	0	0	5
	Total	**696**	**100**	
FS3	Polychaete	267	81.8	1
	Gastropoda	0	0	4
	Bivlvia	0	0	5
	Arthropods	15	4.54	3
	Unidentified	44	13.63	2
	Total	**326**	**100**	

FS1, FS2 and FS3 = S1, S2 and S3 in February respectively.

Table 5b: Density and station wise rank of macrobenthic groups based on percentage found during February of the study period.

Station	Groups	Ind./m2	Percentage (%)	Station wise Rank
MS1	Polychaete	741	80.6	1
	Gastropoda	0	0	4
	Bivlvia	0	0	5
	Arthropods	133	14.51	2
	Unidentified	44	4.84	3
	Total	**919**	**100**	
MS2	Polychaete	430	82.78	1
	Gastropoda	0	0	4
	Bivlvia	0	0	5
	Arthropods	30	5.71	3
	Unidentified	59	11.42	2
	Total	**519**	**100**	
MS3	Polychaete	607	91.07	1
	Gastropoda	0	0	3
	Bivlvia	0	0	4
	Arthropods	0	0	5
	Unidentified	59	8.88	2
	Total	**667**	**100**	

MS1, MS2 and MS3 = S1, S2 and S3 in March respectively.

Table 5c: Density and station wise rank of macrobenthic groups based on percentage found during March of the study period.

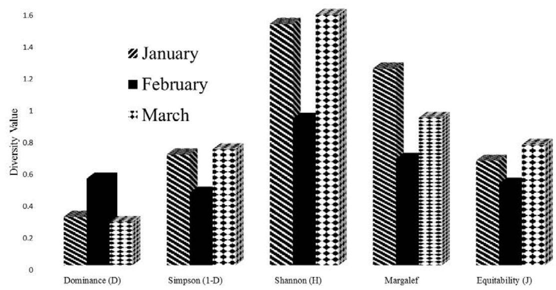

Figure 4: Monthly Values of different diversity indices of the present study.

on the other hand [41]. Depending on the number of species Margalef index (D′) shows variation having no limit on tis 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./m^2 with a mean density of 609 ± 445.32 ind./m^2 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.

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	0.8468
	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.

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

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