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Spatio-temporal variations of macrobenthic annelid community of the Karnafuli River Estuary, Chittagong, Bangladesh

Md. Habibur Rahman Molla, Md. Al-Imran, Md. Aktaruzzaman, Shamindranath Mandol, Mohammad Saydul Islam Sarkar, M. Shafiqul Islam

Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh

Corresponding author email: shafiqimscu@yahoo.com

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Abstract The spatial and temporal variation in species composition, distribution, abundance, biodiversity and succession of the macrobenthic annelid assemblages in the intertidal zone of the Karnafuli Estuary are analyzed in this paper. Samples were collected from nine stations placed in different tide marks from three sites of the study area. From the total of 180 samples collected during one year sampling period, a total of 4,46,516 individuals of macrobenthic annelids belonging to polychaete, oligochaete and clitellata classes and represented by 12 species/taxon were identified. The most abundant species recorded in this study were *Capitella* sp., *Lycastonereis indica, Namalycastis fauveli, Nephthys oligobranchia* within polychaetes; *Tubifex* sp. within oligochaete and *Tubificoides insularis* within clitellata. Capitellidae was the most abundant family represented by *Capitella* sp. which was distributed in the study area in all seasons of the year and it was ranged from a minimum value (Site1 (S_1): 23 individual/m^2) during pre monsoon to a maximum value (Site2 (S_2): 243687 individual/m^2) during post monsoon. This species supported the highest contribution (98.67%) to the average abundance recorded in post monsoon. The abundance of some species fluctuated in different seasons with a marked seasonal and spatial succession. Higher values of species diversity and evenness were recorded during monsoon and maximum numbers of individuals were counted during post monsoon. The macrobenthic annelid assemblages showed distinct seasonal differences (Analysis of similarities (ANOSIM test) by using PRIMER (v.6) software). All the seasons were distinguished at different significant level (global r = -0.083 and p = 63.8%). Average similarities within the macrobenthic annelid community compositions recorded during monsoon, post monsoon, winter and pre monsoon were 95.74%, 39.87%, 32.25% and 34.21% respectively. Similarly, average similarities recorded in site 1, site 2 and site 3 were 29.18%, 99.00% and 57.53% respectively. Average dissimilarity was highest (55.20%) between the species composition of post monsoon and winter and the lowest value (39.30%) of average dissimilarity was found between monsoon and post monsoon. Again average dissimilarity presented the highest value between site 1 & site 3 (55.93%) and the lowest value between the site 2 & site 3 (38.87%).

Keywords Karnafuli estuary; Macrobenthic annelids; Intertidal zone; ANOSIM; SIMPER

Introduction

The Karnafuli estuary is an important estuary in Bangladesh and hydro-biologically it is the place where fresh water from upstream mixes with seawater from the Bay of Bengal. It is also blessed with estuarine water, sediment, marine resources and varieties of fish species. Besides a lot of industries, fishing boats, vessels or trawlers and container ships are operating along the river hampering the status of water, sediment and biodiversity therein. Different researchers reported that the estuarine environment is polluted owing to the continuous disposal of waste materials from the industries and sewage of the town (Khan, et al., 1996). Certainly, pollution of water courses associated with industrial discharge and refuse from human settlements is a global problem (Joy et al., 1990). Estuaries are stressful environments due to the interaction of local physical, geological, chemical and biological factors (Saiz-Salinas and González-Oreja 2000; Dauvin et al., 2006) and as a consequence, the estuarine macro fauna communities exhibit high resistance to pollution (Boesch and Rosenberg 1981). Anyway, the intertidal zone accommodate most of the macro benthic species and provide valuable feeding areas for large crustaceans, birds and fish (Herman et al., 1999). On an inter-tidal flat, the benthic macro fauna community is mainly structured by environmental variables (Menge and Olson 1990). Combinations of diverse fluctuating parameters are responsible for occurrences and distributions of different macrobenthic annelids in estuarine environment (Islam, et al., 2013). Benthic animals with limited mobility have to cope with a low oxygen concentration in the predominantly fine-grained sediment, fluctuation in salinity, drying and flooding, suspended sediment etc. (McLusky et al., 1993; Ysebaert et al., 2000). The colonization by macrofauna and the subsequent development and modification of macrobenthic communities therefore depends upon several factors (Elliott et al., 1998), 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 (McLusky and Elliot, 2006). Macrofauna is also often used in many marine and estuarine monitoring programmes (Heip et al., 1992; Ysebaert and Herman 2002) and is indicator of water and sediment quality (Austen et al., 1989). Some polychaetes burrow while others live entirely on the surface, generally in moist leaf litter. The burrowers loosen the soil so that oxygen and water can penetrate it and both, surface and burrowing worms, help to produce soil by mixing organic and mineral matter, by accelerating the decomposition of organic matter and thus making it more quickly available to other organisms, and by concentrating and converting minerals simple form that plants can use more easily. (Nancarrow and Taylor, 1998). These worms are pivotal parts of food webs multiplying trophic stability (Aller, 1983). An extensive literature has described the relationships between the benthic estuarine community and the effect of contaminants (Pearson and Rosenberg, 1978; Warwick and Clarke, 1993). Organisms feed on debris that settle on the bottom of the water and in turn serve as food for a wide range of fish (Ajao, 1990.; Oke, 1990; Idowu and Ugwumba, 2005). They also accelerate the breakdown of decaying organic matter into simpler inorganic forms such as phosphates and nitrates (Gallep et al., 1978). These organisms therefore form a major link in the food chain as most estuarine and marine fish, birds and mammals depend directly or indirectly on the benthos for their food supply (Barnes and Hughes, 1988).

Although the macrobenthos in Karnafuli river carry a high importance in regard to biodiversity (Islam, et al., 2013; McLusky and Elliot, 2006; Asadujjaman, et al., 2012; Hossain, et al., 2009), unfortunately it receive less attention by the scientists of Bangladesh. The aim of our study was to characterize the benthic annelid communites of the intertidal zone in the Karnafuli estuary (Chittagong coastal area, Bangladesh) analyzing both the spatial (areas) and temporal variation (seasons) of abundance and species composition of benthic annelids.

1 Material and methods

Benthic faunal samples along with water and sediment samples were collected from the intertidal zone of the Karnafuli estuary (22º19.537′–22º19.882′N and 91º50.215′–91º51.516′E), Chittagong, Bangladesh (Figure 1) 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. 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. Site 1 (Gov. Fish landing station) was considered as moderately impacted site and Site 3 (Eastern side of the third Karnafuli Bridge) was 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.

Benthic faunal samples were collected from the study sites by quadrate method (Neckles and Dionne, 2000). 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 (Figure 2).

Macrobenthic faunal communities were sampled by taking 5 sediment cores (11.5cm diameter, 15cm depth) randomly selected from a quadrate of 5x5m^2 placing at each station of each site summarizing a total area of 3.11m^2. For identifying the sampling spots, 16 equal cross divisions were drawn over the square area

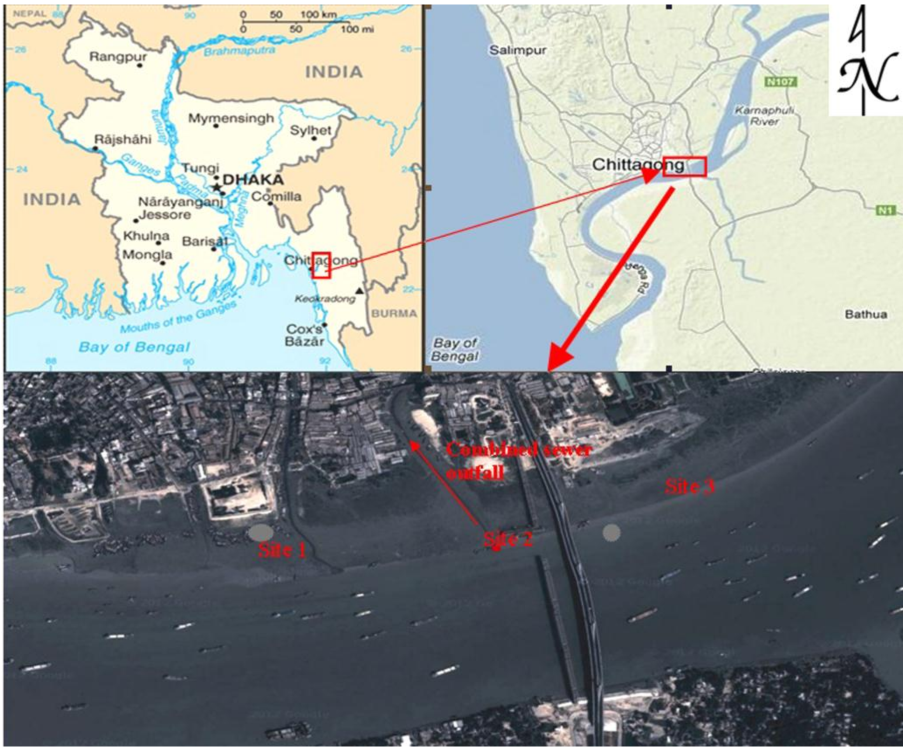

Figure 1 Location of the study area showing three sampling sites

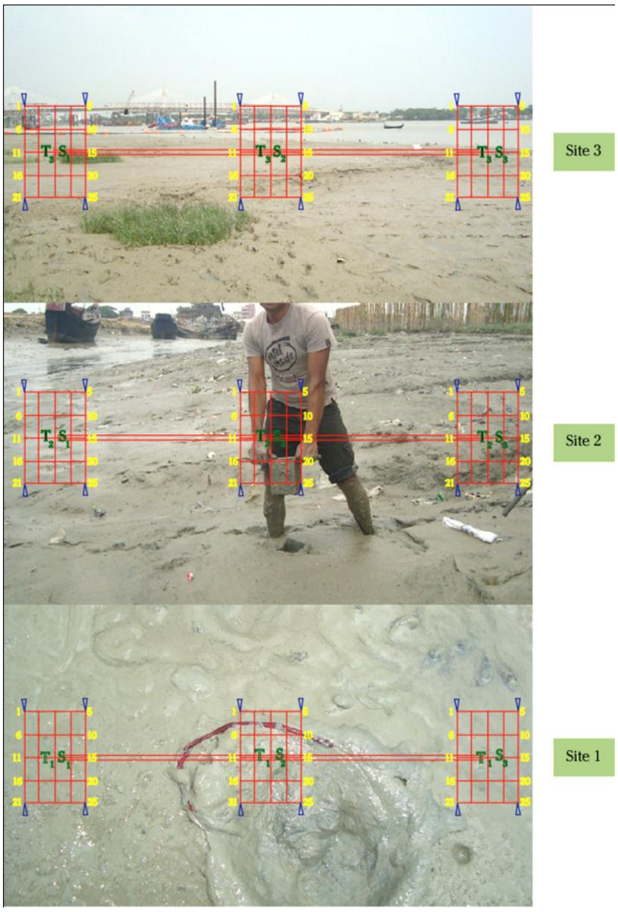

Figure 2 Sampling design showing different sampling sites, stations and spots

($5x5m^2$). A total of 25 point intercepts (namely from 1 to 25) were formed within the square area. A table of random numbers was used to determine the exact location of the core inside the square (Newmark, 1977). Samples were sieved through a 0.5mm mesh and preserved with 10% formalin in water with Rose Bengal to aid laboratory sorting. Annelids were sorted out and identified following different taxonomic guides and manuals (Heard, 1982.; Barnes et al., 1988.; Glasby, 1999.; Winstone et al., 2002; Narendan, 2006.; Kabir et al., 2009).

Subsurface water samples were collected from three sites during high tide condition for measuring water temperature, salinity, pH and dissolved oxygen. 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) was determined followed by Standard Method (APHA, 2005). One sediment sample was taken from each station for analysis of soil pH, pore water salinity, organic carbon, organic matter and soil texture. Soil pH was estimated *in situ* by using soil pH meter (DEMETRA, Mo-36, E. M. System Soil Tester, Tokyo, Japan). Free soil (pore) 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 were determined by the method followed by Huq and Alam (2005).

Statistical analyses were done using the PRIMER (v.6) software. Association of different species/taxon was shown in a dendrogram produced by Cluster analysis. Diversity of macrobenthic community was measured by different univariate descriptors for all seasons and sites such as Species number (S), Total number of individuals (N), Margalef's species richness (d), Shannon–Wiener diversity index (H'log2) and Pielou's evenness (J') (Margalef, 1968; Pielou, 1966; Shannon and Wiener, 1963) using the DIVERSE routine.

Macrobenthic faunal similarity among the species was investigated applying cluster analysis (group average) based on the Bray–Curtis similarity index of species abundance after square root transformation (Clarke and Green, 1988). The similarity matrix was used to produce a hierarchical agglomerative dendrogram for a graphical representation of community relationships (Clarke, 1993) using pooled seasonal data sets.

Significant differences between clusters of seasonal and spatial samples were tested using the Analysis of Similarities (ANOSIM), a randomization permutation test based on rank similarities of samples (Clarke and Green, 1988; Clarke, 1993). Species/taxons responsible for similarities and differences between clusters of seasonal and spatial samples were investigated using the similarity percentages procedure – SIMPER (Clarke, 1993).

2 Results

A total of 12 macrobenthic annelid species represented by three distinct classes namely polychaete, oligochaete and clitellata, were determined in the present study. Among the identified group, Capitellidae were the most important family. A total of 4,46,516 annelids were collected from 180 replicate samples. The most important species/taxons were *Capitella* sp., *Lycastonereis indica*, *Ceratonereis* sp., *Nephthys oligobranchia*, *Tubifex* sp. and *Namalycastis fauveli*.

The most abundant species, *Capitella* sp. was equally distributed in the study area in different seasons of the year that ranged from a minimum value (23indiv/m^2) to a maximum value (243687indiv/m^2) recorded during the pre-monsoon and post-monsoon season respectively. The density of *Namalycastis fauveli* measured in different seasons ranged from a minimum value (12 indiv/m^2) to a maximum value (1491 indiv/m^2) during the pre-monsoon and post-monsoon respectively (Table 1).

Table 1 Abundance (indv/m^2) of different macrobenthic Annelids of the intertidal zone of the Karnafuli estuary for different sites and seasons

Season	Monson			Post−monsoon			Winter			Pre−monsoon		
Site/Species	1	2	3	1	2	3	1	2	3	1	2	3
Namalycastis fauveli	216	479	147	1491	143	240	108	24	186	46	12	81
Capitella sp.	10087	34245	2949	359	243687	707	54	89453	77	23	58655	278
Lycastonereis indica	4	85	39	1430	8	62	70	−	441	−	−	31
Ceratonereis sp.	27	8	46	−	−	8	−	−	−	213	8	−
Nephthys oligobranchia	−	−	−	8	−		8	−	−	−	−	−
Tubifex sp.	−	−	−	−	−	−	−	−	−	12	−	−
Paraonides sp.	15	−	12	−	−	−	−	−	−	−	−	−
Tubificoides insularis	−	128	4	4	−	−	−	−	−	−	−	−
Namalycastis arista	−	−	8	−	−	−	−	−	−	−	−	−
Namalycastis nicoleae	−	−	−	−	−	12	−	−	12	−	−	−
Dendronereis sp.	−	−	−	58	−	−	−	−	−	−	−	−
Namanereis amboinensis	−	−	−	−	−	−	12	−	−	−	−	−

Species number (S), total number of individuals (N), species richness (Margalef's d), diversity (Shannon-Weiner H') and evenness (Pielou's J') recorded from the Karnafuli estuary were varied in different seasons and sites (Table 2). Species richness, diversity and evenness recorded in different seasons were fluctuated from 0.36-0.56, 0.05-0.14 and 0.03-0.07 respectively. Species richness, diversity and evenness were very low in the Site 2 (Chaktai canal) in comparison with the other two sites.

Table 2 Diversity indices of macrobenthic Annelids for different seasons and sites: species number (S), total number of individuals (N), Margalef's species richness (d), Shannon Wiener diversity index (H') and Pielou's evenness (J')

Species diversity indices in different Seasons					
	S	N	d	H'	J'
Monsoon	7	48499	0.5561	0.1432	0.0736
Post-monsoon	8	248217	0.5635	0.0849	0.0408
Winter	6	90445	0.4381	0.0618	0.0345
Pre-monsoon	5	59359	0.3639	0.0474	0.0295
Species diversity indices in different Sites					
	S	N	d	H'	J'
Site 1	10	14245	0.9410	0.8473	0.3680
Site 2	5	426935	0.3085	0.0167	0.0104
Site 3	8	5340	0.8156	0.8112	0.3901

Species composition and their inter-relationships were analyzed by using Bray-Curtis similarity index on the species abundance data (indiv./m^3) independently for the whole macrobenthic (annelida) community (12 species) were undertaken (Figure 3). From the resulting dendrogram (Figure 3), it was possible to classify the species of highly abundant, moderately abundant and less abundant species which are distributed in different months and seasons in a similar pattern in the study area. The least abundant and irregular species showed highly dissimilar pattern when they clustered in the dendrogram (Figure 3). The moderately abundant species *Namalycastis fauveli and Lycastonereis indica* grouped together with highest similarity (>60%).

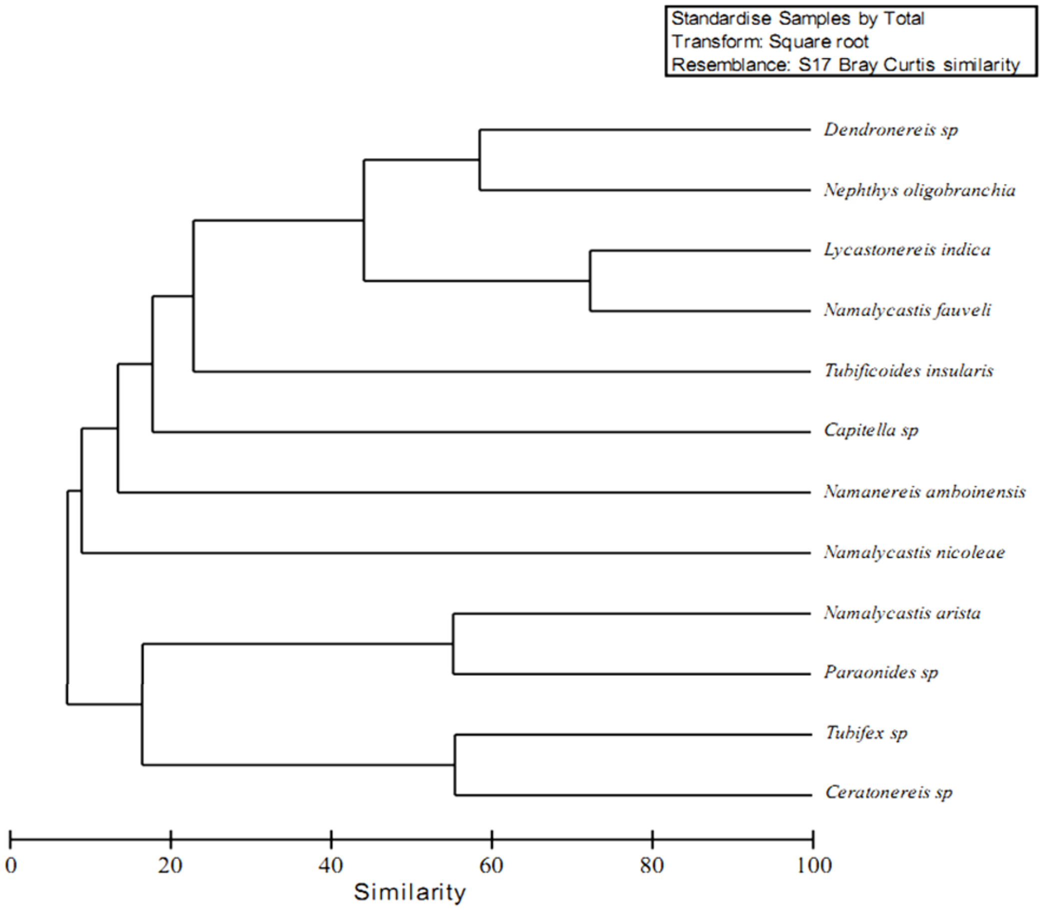

Figure 3 Dendrogram showing the percentage of similarity among different species collected in the study area during the sampling period (2011-2012)

The macrobenthic annelids assemblages showed distinct seasonal differences by the ANOSIM test (global R = −0.083; P = 63.8%). Six significantly distinct sample groups were determined corresponding to different season of the study period. The first group included the samples of monsoon & post-monsoon (R=0.074, P=40%), second group of monsoon & winter (R=0.074, P=40%), third group of monsoon & pre-monsoon (R=0.074, P=40%), fourth group of post-monsoon & winter (R=-0.37, P=100%), fifth group of post-monsoon & pre-monsoon (R=-0.222, P=90%) and sixth group of winter & pre-monsoon (R=-0.074, P=50%).

Annelid assemblages also showed distinct spatial differences while they were tested by the ANOSIM test (global R = 0.394; P = 2%). Three significantly distinct sample groups were formed. The first group included the samples of Site 1 & Site 2 (R=0.615, P=2.9%), second group of Site 1 & Site 3 (R=-0.094, P=65.7%) and third group of Site 2 & Site 3 (R=0.625, P=2.9%). From the result of SIMPER analysis, average similarity within the Annelid community composition during monsoon, postmonsoon, winter and premonsoon was 95.74%, 39.87%, 32.25% and 34.21% respectively (Table 3). Average similarity within the annelid community composition in different sites namely Site 1, Site 2 and Site 3 were 29.18%, 99.00% and 57.53% respectively (Table 4).

In the present study, average dissimilarity was highest between the groups of winter & premonsoon (61.34%) while the lowest value was for the group of monsoon & postmonsoon (39.30%). Average dissimilarity between the group of monsoon & winter, postmonsoon & winter, monsoon & premonsoon and postmonsoon & premonsoon were 55.20%, 48.36%, 39.53% and 50.96% respectively (Table 5). Within sites, average dissimilarity was highest between the groups Site 1 & Site 2 (65.23%) while the lowest average dissimilarity for the groups Site 2 & Site 3 (38.87%). Average dissimilarity between the groups of Site 1 & Site 3 was 55.93% (Table 6).

Table 3 Results of SIMPER showing the highest contributory species in terms of abundance to the similarity among seasons. Average similarity (Av. Simil.) values are also shown

(1) Group Monsoon	Av. Simil.: 95.74				
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Capitella sp.	95.83	93.83	29.79	98.01	98.01
Namalycastis fauveli	2.68	1.61	3.89	1.68	99.69
Lycastonereis indica	0.5	0.11	0.9	0.11	99.8
Ceratonereis sp.	0.57	0.1	0.74	0.11	99.91
Paraoindes sp.	0.17	0.05	0.58	0.05	99.96
Tubificoides insularis	0.16	0.04	0.58	0.04	100
(2) Group Postmonsoon	Av. Simil.: 39.87				
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Capitella sp.	59.79	30.05	0.9	75.36	75.36
Namalycastis fauveli	22.63	7.81	0.58	19.6	94.96
Lycastonereis indica	16.24	2.01	0.58	5.04	100
(3) Group Winter	Av. Simil.: 32.25				
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Capitella sp.	44.05	14.31	2.32	44.38	44.38
Lycastonereis indica	29.79	9.26	0.58	28.71	73.09
Namalycastis fauveli	22.95	8.68	0.58	26.91	100
(4) Group Premonsoon	Av. Simil.: 34.21				
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Capitella sp	59.69	28.98	0.79	84.7	84.7
Namalycastis fauveli	12.15	5.23	0.58	15.29	99.99
Ceratonereis sp.	24.15	0	0.58	0.01	100

Table 4 Results of SIMPER showing the highest contributory species in terms of abundance to the similarity among sites. Average similarity (Av. Simil.) values are also shown

(1) Group Site 1	Av. Simil.: 29.18				
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Namalycastis fauveli	26.27	13.4	0.84	45.92	45.92
Capitella sp.	34.36	11.06	2.1	37.88	83.81
Lycastonereis indica	17.63	4.64	0.41	15.91	99.71
Ceratonereis sp.	18.18	0.04	0.41	0.15	99.86
Nephtys oligobranchia	0.85	0.04	0.41	0.14	100
(2) Group Site 2	Av. Simil.: 99.00				
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Capitella sp.	99.47	98.97	92.64	99.97	99.97
Namalycastis fauveli	0.37	0.03	1.94	0.03	100
Ceratonereis sp.	0.01	0	0.41	0	100
Lycastonereis indica	0.06	0	0.41	0	100
(3)Group Site 3	Av. Simil.: 57.53				
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Capitella sp.	60.69	40.16	1.25	69.81	69.81
Namalycastis fauveli	18.66	13.1	1.4	22.78	92.59
Lycastonereis indica	19.2	3.94	1.29	6.85	99.44
Namalycastis nicoleae	0.71	0.19	0.41	0.34	99.77
Ceratonereis sp.	0.55	0.13	0.41	0.23	100

Table 5 Average dissimilarity (Av. Dissimil.) and the main responsible species for the discrimination of seasonal composition

Comparing Group (1)	Comparing Group (2)	Comparing Group (3)
Monsoon & Postmonsoon Av. Dissimil. = 39.30	Monsoon & Winter Av. Dissimil. = 55.20	Postmonsoon & Winter Av. Dissimil.= 48.36
Discriminator species	Discriminator species	Discriminator species
Nephtys oligobranchia	*Nephtys oligobranchia*	*Ceratonereis* sp.
Paraonides sp.	*Ceratonereis* sp.	*Tubificoides insularis*
Namalycastis arista	*Paraonides* sp.	*Dendronereis* sp.
Namalycastis nicoleae	*Tubificoides insularis*	*Namanereis amboinensis*
Dendronereis sp.	*Namalycastis arista*	
	Namalycastis nicoleae	
	Namanereis amboinensis	
Compering Group (4)	Compering Group (5)	Compering Group (5)
Monsoon & Premonsoon Av. Dissimil. = 39.53	Postmonsoon & Premonsoon Av. Dissimil. = 50.96	Winter & Premonsoon Av. Dissimil. = 61.34
Discriminator species	Discriminator species	Discriminator species
Tubifex sp.	*Tubifex* sp.	*Nephtys oligobranchia*
Paraonides sp.	*Tubificoides insularis*	*Tubifex* sp.
Tubificoides insularis	*Namalycastis nicoleae*	*Namalycastis nicoleae*
Namalycastis arista	*Nephtys oligobranchia*	*Dendronereis* sp
	Dendronereis sp.	*Ceratonereis* sp.

Table 6 Average dissimilarity (Av. Dissimil.) and the main responsible species to the discrimination of spatial composition among groups

Comparing Group (1)	Comparing Group (2)	Comparing Group (3)
Site 1 and Site 2 Av. Dissimil. = 65.23%	Site 1 and Site 3 Av. Dissimil. = 55.93%	Site 2 and Site 3 Av. Dissimil. = 38.87%
Discriminator species	Discriminator species	Discriminator species
Nephtys oligobranchia	*Namalycastis arista*	*Paraonides* sp.
Tubifex sp.	*Namalycastis nicoleae*	*Tubificoides insularis*
Paraonides sp.	*Tubifex* sp.	*Namalycastis arista*
Tubificoides insularis	*Nephtys oligobranchia*	
Namalycastis arista	*Namanereis amboinensis*	

Different hydropedological factors like water temperature, water pH, water salinity, dissolved oxygen (DO), soil pH, pore water salinity, soil organic matter, organic carbon and soil texture (percentage of sand, silt and clay) measured in the present in Table 7. The highest value of water temperature recorded in monsoon (36.0^{o}C) while the lowest value was measured in winter (21.67^{o}C). The highest value of DO was recorded during postmonsoon (4.52ml/L) in Site 3 and the lowest value was found in winter and premonsoon (0.00ml/L) in Site 2 (Table 7).

3 Discussion

In the present study a total of 12 species/taxon of macrobenthic annelids were recorded from the intertidal zone of the Karnafuli river estuary. Alam (1993) identified 19 species of polychaete from the intertidal zone of Halishahar coast, Chittagong, Bangladesh. Xie et al., (2007) reported 5 species of benthic polychaete in the Yangtze Estuary, China. Ysebaert et al., (2000) reported 17 species of macrobenthic polycheate from the Schelde Estuary, The Netherlands. In the present study *Capitella* sp. and *Namalycastis fauveli* were identified as the dominant species. According to Pearson and Rosenberg (1978), species or groups of species associated with organic enrichment are similar, independent of their geographical location. Associations between one or more species of capitellid polychaetes and/ or species of oligochates are common in studies of stressed environment (Rizzo and Amaral, 2001).

Percentage counts of the total number of species were annelid representing by Capitellidae (8%), Nereididae (17%), Nephtyidae (8%) and others (58%). Similar trends (number of species and individuals) were reported by Nandi and Choudhury (1983) and by Sergio and Paulo (1997). A total number of 17 species of of polychaete species in the euryhaline bed (Attolini et al., 1997). On the contrary, Braga et al., (2009) reported the high density of the polychaete *Capitella* sp. in *Spartina* marshes.

In this study, among the 12 species determined, Capitellidae represented 98.67%; Namaneridae 0.71%, Nereidae 0.56%, Nephtyidae 0.003% and others contributes 0.062% of the total abundance. So, it is clear that capitellids are the indicator family of this study area. The high numerical dominance of capitellidae species may indicate that the study area is highly polluted and it can be attributed to their high level of pollution tolerance. This assertion is in agreement with the observation of Ajao and Fagade (1990) about the association of the polychaete *Ceapitella* sp. with sites grossly polluted with organic matter, heavy metals and petroleum hydrocarbons. The species composition of benthic macrofauna in the present study shows the dominance of polychaetes that was also reported by Islam et al., 2013 while he studied in the Chittagong coastal area of Bangladesh. Similar result on the abundance of polychaetes had been previously observed by Sankar (1998) in Muthupet lagoon, Sunilkumar (1995) in Cochin backwaters, Prabha Devi (1994) in Coleroon estuary, and Ansari et al. (1986) in Mandovi estuary. The aforementioned adaptable nature of polychaetes may be a plausible reason for their dominance in the species composition and abundance in the present investigation.

In the present study *Capitella* sp., *Lycastonereis indica, Ceratonereis* sp., *Namalycastis fauveli*, *Tubifex* sp. were the indicator species in the Karnafuli estuary likely *Namalycastis terrestris*, *Mediomastus* sp., *Nephtys fluviatilis*, Tubificidae and *Capitella* sp. were reported by others (Glasby, 1999; Erseus, 2002). Polychaeta are also known for their tolerance to drastic daily and seasonal changes in environmental characteristics (salinity, temperature, dissolved oxygen), allowing them to reach high abundances in different estuaries of the world (Gambi et al., 1997; Dittman, 2000; Rosa Filho et al., 2005).

In the present study, the maximum number of species recorded during postmonsoon and the maximum number of individuals recorded in postmonsoon could be explained by the low temperature and turbidity coupled with stable environment during this season (Kundu et al., 2010). In contrast, the minimum number of species recorded during premonsoon and individual was counted during monsoon. In the present study, species richness was significantly varied among the seasons with a maximum value (0.564) during post monsoons. Similar observation was reported by Flynn et al. (1998) in the same habitat. Sanders (1968) and Redding and Cory (1975) found a high level of agreement between species diversity and the nature of environment. The pattern of lower species diversity during premonsoon and higher diversity values in postmonsoon recorded in the study area is in conformity with the earlier observation made by Xie et al. (2007). Distinct seasonal clustering of annelids assemblages were noticed in the present research. Similar seasonal changes in community structure coupled with seasonal groups have been reported in several macrobenthic faunal surveys (Grassle and Smith, 1976; Tenore, 1976) *Capitella* sp. appeared as highly dominant species during postmonsoon in comparison to the other seasons. That's why it was considered as an indicator/ discriminator species for postmonsoon and winter period in the present study. *Capitalla* sp. species are known to be opportunistic deposit-feeding polychaetes possess life history adaption that enable them to rapidly colonize disturbed or enrich site (Linton and Taghon, 2000).

4 Conclusion

From the study it was revealed that the diversity of the macrobenthic annelids of the intertidal zone of the Karnafuli estuary is impacted by the waste materials of the industries and sewage materials that discharged from the town through sewerage canal. Indiscriminate discharge of untreated municipal and industrial wastes should stop now to save the environment and the macrobenthic faunal community of the estuary.

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Table 7 Different hydropedological factors of the intertidal zone of the Karnafuli estuary for different sites and seasons

Seasons	Sites	Water temperature (°C)	Water pH	Water Salinity (ppt)	Dissolved oxygen (ml/L)	Soil pH	Pore water salinity (ppt)	Soil organic matter (%)	Soil organic carbon (%)	Sand (%)	Silt (%)	Clay (%)
Monsoon	1	33.33	8.00	2.43	3.25	5.23	0.00	4.74	2.75	44.03	43.97	11.99
	2	24.00	8.20	2.91	0.51	5.33	0.00	5.49	3.18	36.10	43.93	19.97
	3	36.00	8.70	3.39	3.56	6.80	0.00	4.54	2.63	12.13	75.89	11.98
Postmonsoon	1	28.67	8.30	6.28	4.24	5.23	2.00	6.13	3.56	15.25	63.56	21.19
	2	26.17	8.30	5.64	0.00	6.50	1.00	5.95	3.45	40.01	43.99	16.00
	3	24.67	8.20	6.12	4.52	6.02	1.33	6.21	3.60	8.13	71.90	19.97
Winter	1	21.67	8.20	8.84	2.55	5.03	4.67	5.42	3.14	36.12	43.92	19.96
	2	24.00	8.30	8.20	0.00	6.03	7.67	5.60	3.25	36.19	43.87	19.94
	3	23.00	8.30	2.91	2.78	6.50	2.67	5.00	2.90	16.12	67.90	15.98
Premonsoon	1	33.33	8.40	5.96	2.53	5.83	1.33	5.23	3.03	24.11	59.91	15.98
	2	29.67	8.30	6.12	0.00	6.83	0.33	4.33	2.51	40.05	47.96	11.99
	3	35.67	8.70	4.68	2.33	6.20	0.00	6.20	3.60	44.10	39.93	15.97