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Heterogeneity of zooplankton of the Rezukhal Estuary, Cox's Bazar, Bangladesh with seasonal environmental effects

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Abstract
This study was carried out in the Rezukhal Estuary, Ukhia, Cox's Bazar of Bangladesh from January 2013 to November 2013 at three different stations and sampling were done in the winter (January 2013), pre-monsoon (April 2013), and post-monsoon (November 2013). The abundance of zooplankton varied between 39.85 and 48.85 ind. m^{-3} during winter, 25.38 and 29.30 ind. m^{-3} during pre-monsoon and 33.31 and 38.38 ind. m^{-3} during post monsoon in the three stations. Copepods comprised the bulk of total zooplankton fauna in all three seasons; the highest 65.77% recorded at the station 3 during winter and the lowest 34.09% at the station 1 during pre-monsoon. The Shannon-Weiner Diversity Index (H') varied between 1.387 and 2.035, Evenness Index (J) between 0.5408 and 0.8981 and Species Richness (d) between 1.743 and 2.047 during the study period. Spearman rank correlation (BIO-ENV, PRIMER V.6) showed that water pH is the most important influencing factor having the highest correlation (r=0.856) with the zooplankton community. Total dissolved solid, water phosphate-phosphorus (PO_4-P) and dissolved oxygen were identified as the best environmental variables and they influenced the zooplankton assemblage at different range of rank correlations (r=0.775 to 0.823). Salinity and total dissolved solid (TDS) negatively influenced the abundance of the most dominant zooplankton group, Copepods, at a 5% and 1% level of significance respectively. Chaetognatha, fish larva and Molluscs larva was positively influenced by water pH at a 1% level of significance while crab zoea by water temperature at a 5% level of significance.

Keywords: Heterogeneity, Biodiversity, Zooplankton, Rezukhal Estuary and Environmental effects

1. Introduction
Zooplanktons play a very important role in the food chain as they are in the second tropic level as primary consumer and as contributors to the next tropic level Boyd (1982). They also play a major role in recycling nutrients as well as energy cycle within their respective environment. The zooplankton communities are composed of both primary and secondary consumers and thus provide a direct link between primary producers and higher tropic levels such as fish. Nearly all fish depend on Zooplankton for food during their larval phases, and some fish continue to eat zooplankton in their entire lives Madin *et al*. (2001). Planktonic biomass and distribution are an index to the fertility of an area; it provides information on the fishery potentiality. It is well known that the richest fisheries of the world are closely related to the plankton production Fraser (1962), because the fisheries organisms are directly or indirectly dependent upon plankton for their nourishment. Hence, for the development of potential fishery resources, the knowledge on plankton is essential. Moreover, Copepods often contributing over 80-90% of the total zooplankton counts in near shore and estuarine habitats. Thus, variations in their composition are a valid indication of ecological succession, breeding periodicity as well as environmental condition Ramaiah & Nair (1997). In Bangladesh, the peak abundance of Zooplankton is normally observed during winter and pre-monsoon season Elais (1983) when the water transparency range between 66cm to 77.5cm. On the other hand, relatively the lower zooplankton abundance is observed during the monsoon period, when the water transparency ranges between 17.5cm and 38cm Zafar (1986).
From the economical and geographical viewpoint, the Rezukhal is a very important river of Ukhia under Cox's Bazar district, located in the north eastern part of Bangladesh Iqbal (1999). Source of Rezukhal lies on the north Arakan Mountain and flow over the district Bandarban and then finally it flow over the Ukhia of Cox's Bazar district.

The two parts of Rezukhal join together near Jaliapalong and finally empty into the Bay of Bengal.

The Rezukhal estuary was found to have great contribution as nursery grounds, providing abundant food and relative safety to many commercially important species including two of the most important exporting shrimp species *Penaeus monodon* and *Macrobrachium rosenbergii* of Bangladesh. But, information on the biological properties, especially the abundance, distribution and seasonality of the zooplankton is still lacking. There is no significant report on the qualitative and quantitative abundance and distribution of Zooplankton to the Rezukhal estuary was found over the last decade. As there were a huge physical, structural and environmental change has been taken place in Rezukhal estuary due to the development of industrial infrastructure and resources over exploitation, it is necessary to conduct new assessment on physical, chemical and biological properties in this important nursery ground.

In the present study, we have tried to evaluate an important biological property, assessing the abundance, composition, and biodiversity of Zooplankton and influence of the hydrological factors on the major groups of zooplankton communities. Although, the zooplankton detection level is broad and emphasized mostly on the major groups rather species level, but, as a preliminary work these information will be very helpful for further analysis. This work will be a document to give a basic idea during the future more detailed study of zooplankton in a very economically and ecologically important estuarine system, the Rezukhal estuary of Cox's Bazar, Bangladesh.

2. Materials and Methods

2.1 Sampling Locations

Water and zooplankton samples were collected from the Rezukhal estuary (21º 22′ to 21º 15′ N and 92º 4′ to 92º 12′ E), Cox's Bazar, Bangladesh. For the investigation, the estuary was divided into three sampling stations. Approximate geographical position and the location name of those stations are Station 1-Mouth of the Rezukhal (21°18′28.34″ N and 92°2′27.15″ E), Station 2- Near Jaliapalong Bridge (21°17′21.06″ N and 92°3′36.40″ E) and Station 3- Joining of two parts of Rezukhal near Jaliapalong (21°17′35.42″ N and 92°4′30.90″ E) (Fig.1).

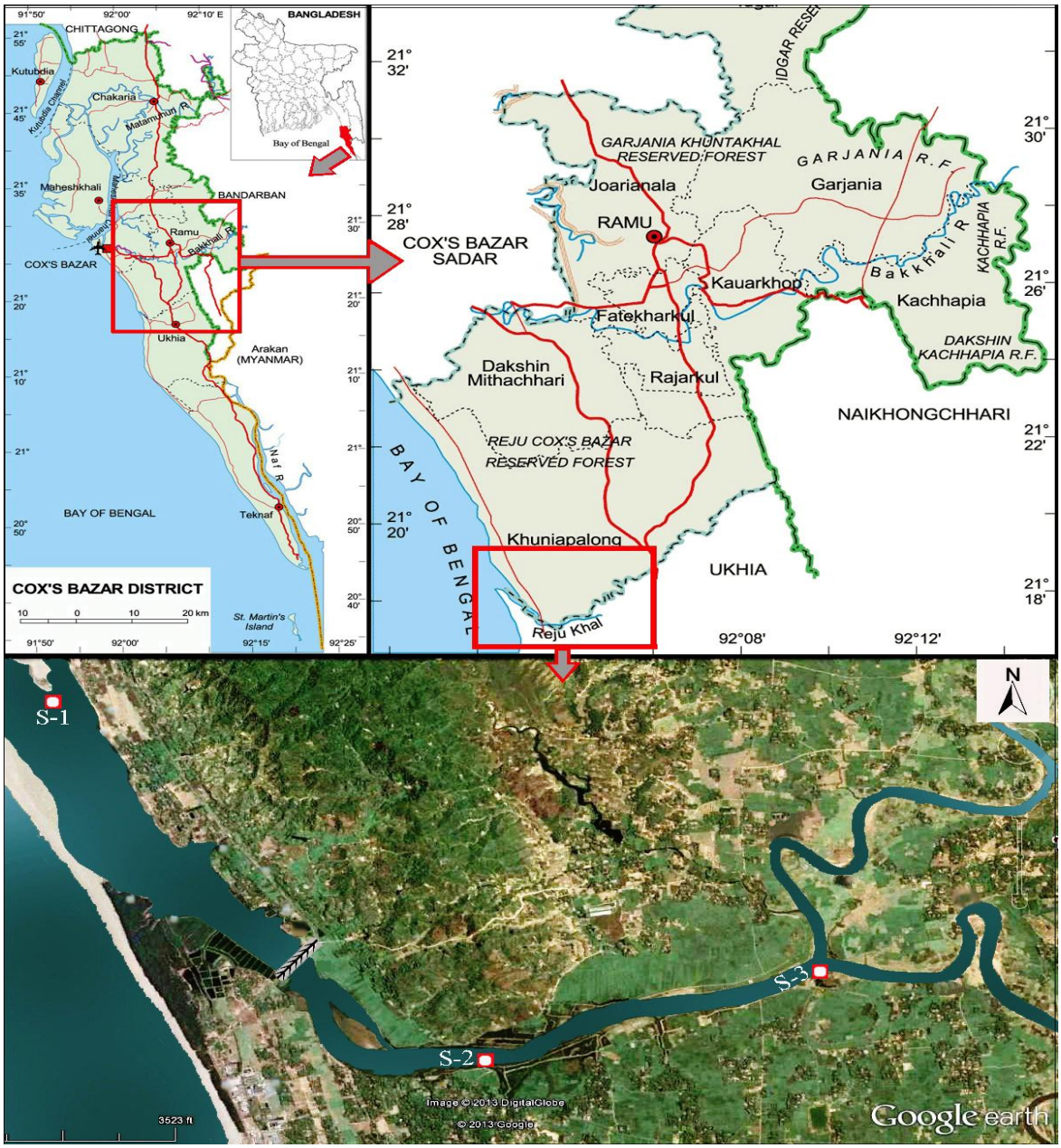

Fig 1: Location of the study area showing three sampling stations.

2.2 Sampling frequencies and studied parameters
Samples were collected in different seasons. First sampling was carried out in winter, second sampling at pre-monsoon and third sampling at post monsoon in three stations. Subsurface water samples collected from three stations during high tide condition for measuring water temperature, salinity, pH, water transparency, dissolve oxygen, total dissolved solid (TDS), Nitrate-nitrogen (NO_2-N) and Phosphate-phosphorus (PO_4-P). Water temperature, salinity, pH, and water transparency were estimated in situ by using Centigrade thermometer, Refractometer (TANAKA New S-100, Japan), Digital pen pH meter (HANNA instruments, model HI 98107) and white secchi disk respectively. DO (dissolve oxygen), TDS (total dissolved solid), Nitrate-nitrogen (NO_2-N) and Phosphate-phosphorus (PO_4-P) were determined followed by standard method APHA (2005).

2.3 Zooplankton collection, processing and counting
Zooplankton sampling have been carried out with the help of conical zooplankton net made of Nylon Silk of 335 micro meter mesh size and having 24 cm circular mouth opening fitted with a plastic bucket at the coded. A digital flow meter was set up at the mouth of the net to record the amount of water filtered through the net during sampling. Samples were collected at sampling stations from the surface water. After collecting samples were preserved in 4% formalin. For efficient sorting, the samples were stained with Rose bangle and left for overnight. All the zooplankton attained pink color rendering easy identification. The stained plankton was stored out from debris with fine brush, needle, forceps and low power microscope. The sorted organisms were preserved in 70% ethanol and brought under the microscope and identified according to Davis (1955), Newell and Newell (1973), Das (1982), Sterrer (1986), Zafar (1986), Santhanam & Srinivasan (1994). In each catch the total number of individual count either by complete counting or by sub- sampling.

The zooplankton concentration was calculated at ind. m^{-3} where, total volume of water (m^3) filtered through the net was calculated by using the following equation:

Total volume of water (m^3) = {(FR-IR) × co efficient} × $2\pi r^2$.

Where, FR=final reading; IR=Initial reading; Coefficient=0.3; r=Radius of ring of used at plankton net=12 cm; π=3.1416

Zooplankton assemblage data were analyzed with the Plymouth Routines in Multivariate Ecological Research (PRIMER) statistical package version 6. Diversity of the species assemblage was analysis by the Shannon-Wiener Index (H') (Shannon and Weaver, 1949), species richness were measured by Margalef Index (d) (Margalef, 1968) and evenness was measured by Pielou's Index (J') (Pielou, 1966). The BIO-ENV program (Clarke and Warwick, 1994) in the PRIMER (v.6) package was used to evaluate and compare the relative importance of different hydrological factor measured and their influence on the identified zooplankton communities. The multivariate Spearman rank correlation between 8 hydrological and the abundance data of Zooplankton community assemblages consist of 12 major groups of the habitat was explored by the BEST (BIO-ENV) procedure of PRIMER software (v.6). This allowed easy identification of the factors that had the greatest effect on community structure. The data was subjected to multivariate statistical analyses to study the influence of different hydrological factors on the abundance of the Zooplankton community using multiple linear regression analysis Sokal & Rholf (1981). The contribution of hydrological factors to explaining the dependent variable (abundance of each zooplankton group) was compared using Beta values at the 95% & 99% confidence level using the SPSS v.11.5.

3. Results
The Physico-chemical parameter in different seasons at the three stations of the Rezukhal estuary during the study period is presented to the Table 1.

Table 1: Physico-chemical parameters in different seasons at three stations of Rezukhal estuary

Parameters	Post monsoon			Winter			Pre monsoon		
	St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3
Water Temperature (°C)	26	26	28	16	16	17	29	29	30
Water pH	8.6	8.6	8.6	8.5	8.5	8.5	8.3	8.3	8.3
Water Salinity (‰)	32	30	31	33	31	30	32	33	31
DO (ml/L)	4.7	4.29	4.05	3.43	3.14	3.22	4.3	3.43	4.05
TDS (mg/L)	34.81	32.87	34	34.42	31.52	31.22	34.92	35.34	34.42
Secchi Depth (cm)	58	60	56	38	40	40	48	52	50
NO_2-N (µg/L)	0.2	0.15	0.25	0.4	0.69	0.79	0.79	0.5	0.4
PO_4-P (µg/L)	0.23	0.23	0.46	0.46	0.46	0.23	0.69	0.69	0.92

The investigation was conducted from January to November in three seasons- winter, pre monsoon, and post monsoon. Zooplankton samples were sorted out into 12 major groups or taxa namely Copepoda, Amphipoda, Isopoda, Chaetognatha, *Lucifer*, Mysids, *Acetes*, Shrimp larva, Crab zoea, Molluscs larva, Fish larva, Fish eggs and some are unidentified from the Rezukhal estuary. The total number of zooplanktons ranged from 48.85 ind. m^{-3} to 25.38 ind. m^{-3} to the studied stations throughout the period of investigation. During the post monsoon, the lowest value 33.31 ind. m^{-3} was recorded at station-2 and the highest value 38.38 ind. m^{-3} at station-1 which changed in the pre monsoon when the lowest value 25.38 ind. m^{-3} was recorded at station-1 and the highest value 29.30 ind. m^{-3} at station-2. In winter samples, the lowest value 39.85 ind. m^{-3} was recorded at station-1 and highest value 48.85 ind. m^{-3} at station-3 (Table 2).

Table 2: Abundance of Zooplankton (Ind. m^{-3}) in different seasons at three stations of Rezukhal estuary

SI. No.	Name of the group/Taxa	Post monsoon (Ind. m^{-3})			Winter (Ind. m^{-3})			Pre monsoon (Ind. m^{-3})		
		St-1	St-2	St-3	St-1	St-2	St-3	St-1	St-2	St-3
1	**Copepoda**	13.61	16.05	18.30	20.66	27.89	32.13	8.65	10.98	11.18
2	**Amphipoda**	1.96	1.38	0.92	2.11	1.50	0.76	0.87	0.49	0.38
3	**Shrimp larvae**	1.46	1.16	0.78	2.66	3.01	1.94	2.74	3.94	3.49
4	**Mysids**	1.04	0.83	0.52	0.37	0.98	0.42	0.22	0.36	0.19
5	**Chaetognatha**	5.24	4.69	4.25	4.40	5.79	4.51	1.37	1.88	1.21
6	**Isopoda**	0	0.61	0.39	0.55	0.90	0.56	0.58	0	0.32
7	***Lucifer***	1.74	0.44	1.18	1.29	1.58	2.43	0.58	1.21	0.76
8	**Crab Zoea**	3.70	1.93	1.96	1.66	1.50	1.60	6.48	7.10	5.40
9	**Fish larvae**	0.49	0.66	1.18	0.28	0.22	0.55	0.14	0.36	0.19
10	**Fish egg**	3.42	1.27	2.29	1.37	1.43	1.66	1.08	1.33	2.22
11	**Mollusc larvae**	4.26	3.58	3.46	3.49	0.75	1.39	1.80	0.79	1.33
12	***Acetes***	0.21	0.61	0.26	0	0.30	0.07	0.29	0.12	0
13	**Unidentified**	1.25	0.11	0.39	1.01	0.30	0.83	0.58	0.73	0.83
	Total	38.38	33.31	35.88	39.85	46.16	48.85	25.38	29.30	27.50

Copepods were the most dominant groups of zooplankton and were the main contributors to the bulk of the biomass. The contributions of the copepods at different stations ranged from 34.09% to 65.77% during the investigation period. The composition of copepods ranged from 35.46% to 51.0% during the post monsoon, from 51.84% to 65.77% during the winter and from 34.09% to 40.65% during pre-monsoon in the studied stations. The highest 65.77% was recorded during winter at station-3 and the lowest 34.09% was found during pre-monsoon at the station-1. Crab zoea showed wide seasonal variation during the study period. During post monsoon and winter the composition of crab zoea varied between 5.46% to 9.64% and 3.26% to 4.15% respectively. But, during pre-monsoon they occupied one of the major constituent of the zooplankton varied from 19.63% to 25.57%. Next to Crab zoea, Amphipoda occupied 1.39% to 5.30%, shrimp larva 2.19% to 13.46%, Mysids 0.69% to 2.73%, Chaetognatha 4.39% to 14.07%, Isopoda 0% to 2.28%, *Lucifer* 1.32% to 4.97%, Fish larvae 0.49% to 3.28%, Fish egg 3.09% to 8.91%, Molluscs larvae 1.63% to 11.09%, *Acetes* 0% to 1.82% during investigation period (Fig. 2).

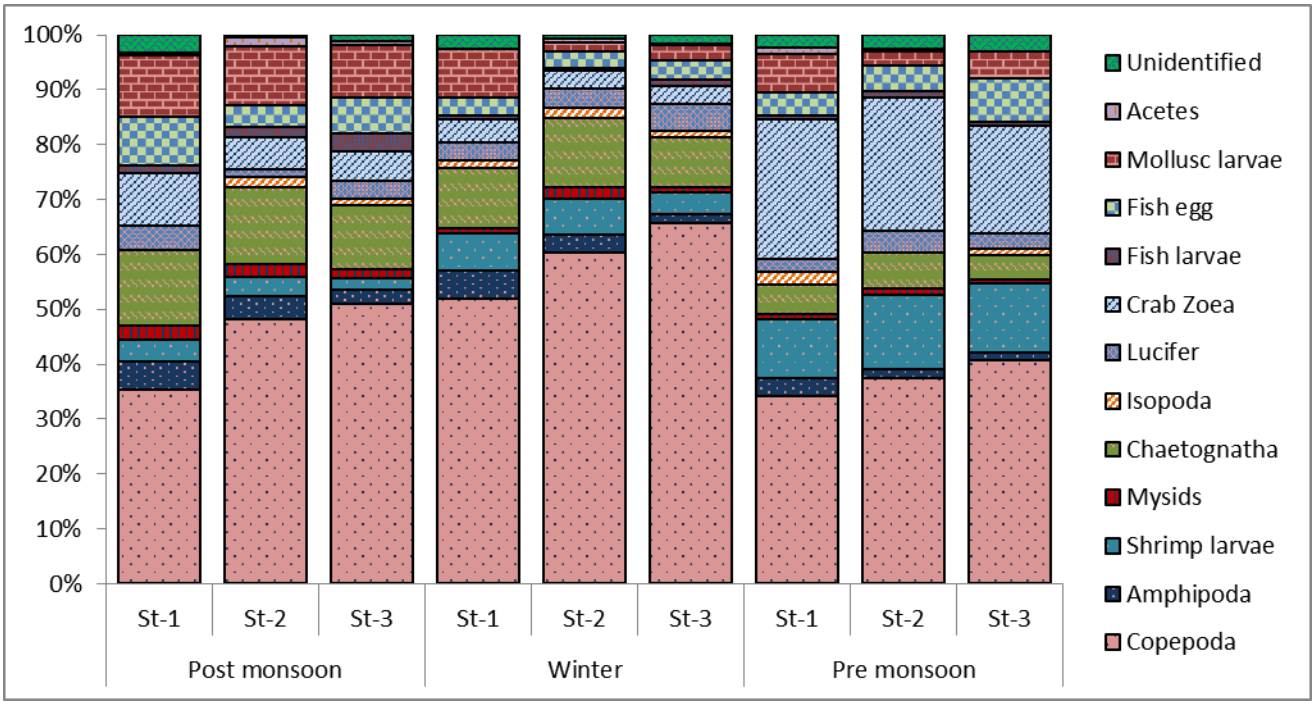

Fig 2: Composition of Zooplankton in different seasons at three stations of Rezukhal estuary.

The value of Shannon-Weiner diversity index (H') ranged from 1.753 to 2.035 during post monsoon, 1.387 to 1.723 during winter and 1.819 to 1.93 during pre-monsoon. The highest value was 2.035 recorded at station 1 in post monsoon and the lowest value 1.387 was recorded at station-3 in winter during the period of investigation (Fig. 3). The value of the Evenness index (J') ranged from 0.6836 to 0.8189 during post monsoon, 0.5408 to 0.6933 during winter and 0.7319 to 0.7524 during pre-monsoon. The highest value 0.8189 was recorded from the station 1 in post monsoon and the lowest value 0.5408 was recorded at the station 3 in winter during the period of observation (Fig. 3). The value of Species richness index (d) ranged from 1.743 to 1.902 during post monsoon, 1.811 to 1.869 during winter and 1.78 to 2.047 during pre-monsoon. The highest value 2.047 was recorded from the station 1 in pre monsoon and the lowest value 1.743 was recorded at the station 1 in post monsoon during the period of observation (Fig. 3).

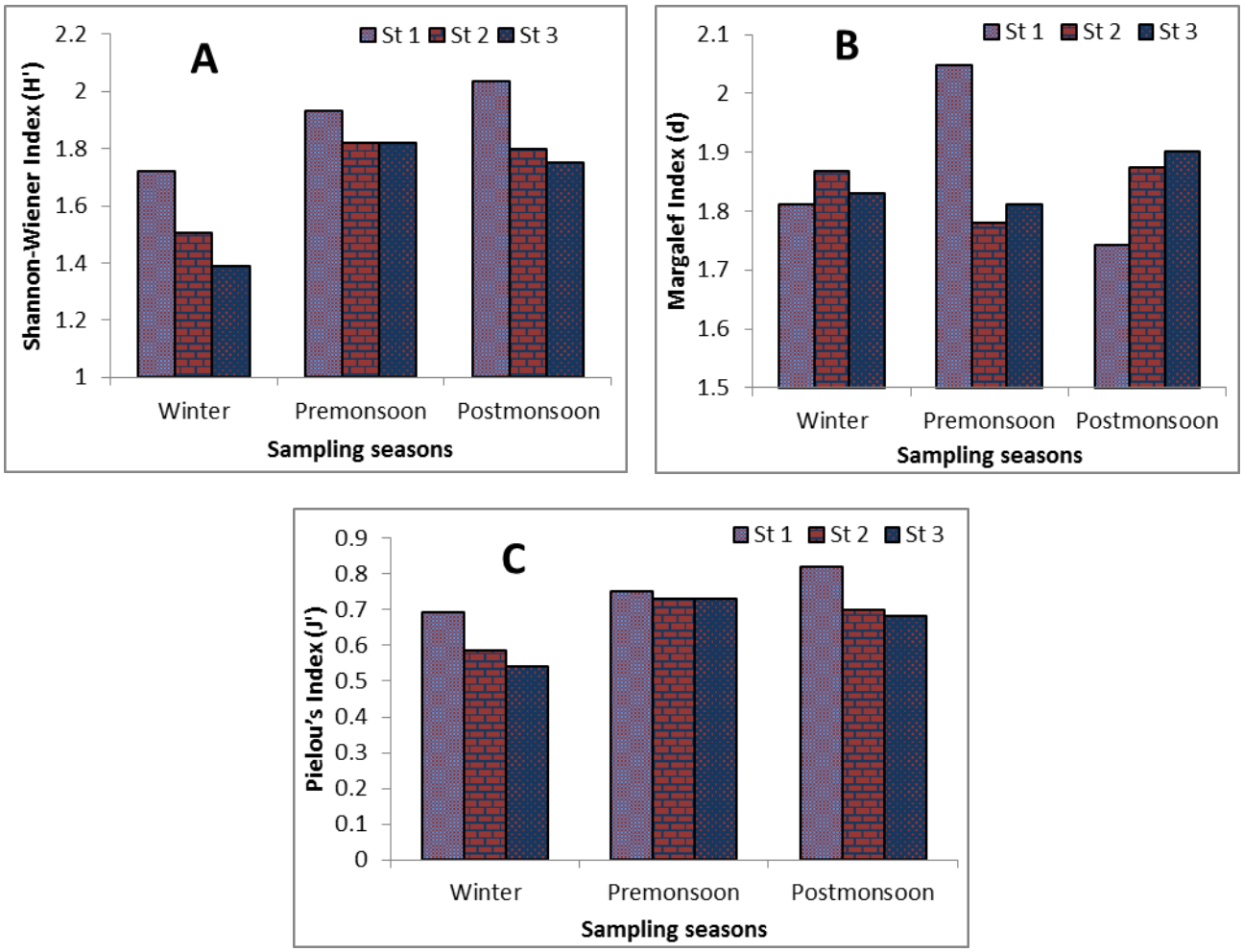

Fig 3: Biodiversity indices of zooplankton in different season at studied area: A. Shannon diversity (Shanon-Wiener Index, H'), B. Species richness (Margalef Index, d) and C. Pielou's evenness (Pielou's index, J')

The BIO-ENV analysis provided single and combinations of factors that were found to describe the observed influence on the abundance and distribution patterns of zooplankton communities and from this the most important correlation were identified. Spearman rank correlations found from BIO-ENV analysis indicating significant correlation between environmental factor and zooplankton assemblages. Water pH, total dissolved solid, water PO_4-P and dissolved oxygen were identified as the best variables highly correlated with the zooplankton assemblage of the study area at different range of rank correlation ($r<0.775$ to 0.856) (Table 3). Among the identified factors water pH provided the highest correlation ($r=0.856$) with the Zooplankton community. In the next order of highest correlation ($r=0.823$) was observed between the zooplankton community and the two factors-water pH and total dissolved solid.

Table 3: Best correlation between hydrological factors with the Zooplankton community produce by BIO-ENV analysis for combined sampling sessions

OUT PUT OF BIO-ENV OF PRIMER PROGRAMME			
Group No	**Total No. of Factor**	**Selected Best Factor**	**Co-efficient of Correlation 'r'**
1	1	Water pH	0.856
2	2	Water pH and Total dissolved solid	0.823
3	3	Water pH, Total dissolved solid and water PO_4- P	0.817
4	2	Water pH and water PO_4-P	0.781
5	3	Water pH, Dissolved Oxygen and water PO_4-P	0.775

To delineate the ecologically most influencing factors for the various zooplankton groups/taxa identified in the present study, it was attempted to the multiple regression model based on the maximum explained variability at different significant level (Table 4). Water salinity and TDS negatively influenced the abundance of copepods where, TDS at a significant level ($p<0.01$) and water salinity at significant level ($p<0.05$).

Table 4: Multiple regression analysis for showing the influence of different hydrological factors on the abundance of some groups/taxa identified from the Rezukhal estuary

Factors	Group/taxa				
	Copepods	***Chaetognatha***	**Crab Zoea**	**Fish larva**	**Molluscs larva**
Water temperature			0.821*		
Water p^H		0.838**		1.118**	0.770**
Water salinity	-0.550*				
Dissolved oxygen					
TDS	-0.706**				
Secchi depth					0.684*
NO_2-N					
PO_4-P					
Air temperature				1.059*	

****=1% level of significance, *=5% level of significance with β- coefficient value derived from the multiple regression model**

Chaetognatha, fish larva and Molluscs larva was positively influenced by water pH at 1% level of significance and also Molluscs larva was positively influenced by secchi depth at 5% level of significance. Crab zoea was positively influence by water temperature at 5% level of significance. Other groups, such as- Amphipods, Isopods, Fish eggs, Shrimp larva, *Lucifer*, Mysids, *Acetes*, and Unidentified groups did not show any significant relation with different hydrological factors.

4. Discussion

During the present study, the value of different hydrological factors like water temperature, salinity, pH, water transparency, dissolved oxygen (DO), total dissolved solid (TDS), Nitrate-nitrogen (NO_2-N) and Phosphate-phosphorus (PO_4-P) were 16 °C to 30 °C, 30% to 33%, 8.3 to 8.6, 38cm to 60cm 3.14 mlL^{-1} to 4.7 mlL^{-1}, 31.22 mgL^{-1} to 34.92 mgL^{-1}, 0.15 μgL^{-1} to 0.79 μgL^{-1} and 0.23 μgL^{-1} to 0.92 μgL^{-1} respectively. Iqbal (1999) recorded the water temperature varied from 19 °C to 31 °C, the pH from 7.8 to 8.2, PO_4-P from 0.1 mgL^{-1} to 0.8 mgL^{-1} and NO_2-N varied from 0.281 mgL^{-1} to 0.59 mgL^{-1} in the same estuary. Haque (1983) observed the water temperature in the Mathamuhuri estuary was 28 ^{0}C and pH 7.5 during October. Chowdhury (1995) and Mclusky (1974) suggested that in an estuary, the salinity ranges between 5ppt to 35ppt and Chowdhury (1995) also reported that the pH and dissolved oxygen concentration of Moheshkhali channel was 7.18 and 4.63 mlL^{-1} respectively during October. Ahmed (1983) found the salinity in the Karnafully estuary between 3.30 ppt to 22.93 ppt while Mahmood (1990) recorded the salinity in the estuarine area of Chakaria ranged from 6.14 ppt to 32.5 ppt. Rahman (1997) recorded that the D.O. level in the Naf river estuary was 4.5 ml/L. Dutta *et al*. 1954) reported that transparency was gradually increased during the winter seasons, but goes on staidly decreasing until it reaches the minimum during July and August in the Hooghly estuary. Selvam *et al*. (1992) recorded PO_4-P concentration varied from 0.345 mgL^{-1} to 1.195 mgL^{-1} in the coastal water of Kakinada coast, Andropradesh, India. All these results were more or less similar the present one.

Altogether 12 zooplankton groups were identified in the present study, namely Copepoda, Amphipoda, Isopoda, Chaetognatha, *Lucifer*, Mysids, *Acetes*, Shrimp larva, Crab zoea, Molluscs larva, Fish larva, Fish egg and some unidentified from the Rezukhal estuary. Islam and Aziz (1975) identified 18 genera and 18 species from the Bay of Bengal off the coast of Bangladesh. Das *et al*. (1982) identified 21 groups of Zooplankter's from the continental shelf of the Bay of Bengal. Zafar (1986) recorded 14 groups of zooplankton from the Coxali river estuary. Sharif (2001) identified 23 major taxa of zooplankton from the Meghna River estuary while Goswami (1985) identified 24 zooplankton taxa namely Copepoda, Cladocera, Crab larvae, *Acetes*, Isopoda, Mysids, Fish larvae, Amphipoda, Fish egg, Shrimp larvae and some other zooplankton from the coastal water of Goa.

The number of zooplankton varied between 48.85 $ind.m^{-3}$and 25.38 ind. m^{-3} and during investigation period. The highest peak 48. Ind.m-3 and was obtained in the winter and the second highest peak 38.38 ind. m^{-3} and was obtained in the post monsoon. The lowest abundance 25.38 ind. m^{-3} and occurred during pre-monsoon. Wickstead (1963) reported the peak abundance of total zooplankton during January and February in the Zanzibar area of the Indian Ocean. Khan (1995) reported two peaks during post monsoon and pre-monsoon in the Hugli-Matla Estuarine system. Wellershaus (1974) suggested that the stability of the environment is achieved only during the post monsoon and pre monsoon months and the zooplankton population is rich and diverse during this period.

Copepods comprised the bulk of total zooplankton fauna in all three seasons in the estuarine system. The composition of copepod to total zooplankton fauna in three seasons varied between 35.46% and 51% during post monsoon, 51.85 and 65.77% during winter and 34% and 40.65% during pre monsoon. Islam and Aziz (1975) reported Copepoda showed the dominant faunal element of zooplankton of the Bay of Bengal. Kumar and Sharma (1988) reported Copepoda showed highest numerical abundance and contribution to the bulk of the biomass of the Visakhapatnam harbor and near shore water. He also reported that the average percentage of the group in the near shore and Harbor water was 57.94% and 53.33% respectively. Khan (1995) reported the composition of Copepods varied between 48.5% and 91.8% in the Hugli-Matla estuarine system. The value of Shannon-Weiner diversity index (H') varied between 1.387 and 2.035, Evenness index (J) in between 0.5408 and 0.8981 and Species richness (d) varied between 1.743 and 2.047 during the study period. Ramaniah and Nair (1997) reported Shannon-Weiner index (H') and Species richness (d) of copepod 2.8 (av) and 1.6 (av) respectively in the Bombay harbor-Thana creek-bassein creek, west coast of India. The result Shannon-Weiner Diversity index for zooplankton in the Rezukhal river estuary showed similarity with the zooplankton diversity of Andaman-Nicobar Island and the Bombay Harbor-Thana creek-bassein creek, west coast of India. Prabhahar *et al*. (2011) reported evenness index (J) in between 0.57 and 3.36 and Species richness (d)

varied between 0.64 and 1.9 in kadalur to the coastal zone, Tamil Nadu, India.

Further higher population densities as well as more number of Copepoda species were observed when the salinity regime was high and relatively stable as reported by Mitra *et al*. (1990) from the Mandarmani creek of West Bengal. Prabhahar *et al*. (2011) reported temperature, pH, DO, phytoplankton population density and gross primary productivity exhibited a positive correlation with the Zooplankton population density in Kadalur coastal zone, Tamil Nadu, India reflecting similarity with present study.

5. Conclusion

The estuarine environment of Bangladesh is rich with plankton resources which play an important role in the fishery sector. These plankton communities depend on different types of hydrological factor in the estuarine environment. The distribution patterns of zooplankton have been noted to rise and fall with the water parameters. Usually, the diversity of zooplankton in the salt marsh and mangrove habitats is rich elsewhere. The present study reported around 12 groups of zooplankton in the estuarine environment of Rezukhal, Cox's Bazar, Bangladesh and Copepod was the dominant group in the abundance and composition of zooplankton, which probably play an important role in the this estuarine food chain.

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