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ZOOPLANKTON DIVERSITY AND ECOLOGICAL VARIATIONS OF COASTAL WETLANDS OF BAKERGANJ, BANGLADESH

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Abstract: Ecology and diversity of zooplankton species in relation to some physico-chemical parameters at three sites namely Thana Health Complex Pond, Tulatoli River and Harun Dakua's Pond of the coastal ecosystems of Bakerganj were studied from January 2008 to December 2009. A total of 56 zooplankton species were recorded out of which 35 were rotifers, 6 protozoan, 8 copepods, 5 cladocerans and 2 ostracods species. During study, rotifera was the most abundant group (61.44 % in Thana Health Complex pond, 38.36 % in Tulatoli River, and 86.03 % in Harun Dakua's pond), while the ostracoda were the least abundant group (0.2 % in Harun Dakua's pond). The highest monthly average value of zooplankton was 707.75 ± 189.56 indv /L at Thana Health Complex pond and the lowest was 127.42 ± 19.95 indv /L at Tulatoli River of Bakerganj. Zooplankton species richness (R1 and R2) was comparatively higher (R1: 1.63 ± 0.10; R2: 0.64 ± 0.06) in Harun Dakua's pond while both the species diversity (Shanon Weiner Index) ($H' = 0.87 \pm 0.08$; $e^{H'} = 2.52 \pm 0.17$) and species evenness (E1 and E2) (E1 = 0.44 ± 0.04; E2 = 0.43 ± 0.05) were higher in the Tulatoli River. The zooplankton population showed positive correlation with physico-chemical parameters like water temperature, air temperature and water depth, whereas negatively correlated with pH, DO, TDS, conductivity and salinity with a few exception.

***Key words*:** Ecology, Bakerganj, Diversity, and Zooplankton

INTRODUCTION

Zooplankton are basic character in the significance of an aquatic ecosystem and play a key role in the energy transfer by linking the primary producers (by consuming phytoplankton, mainly various bacterioplankton and sometimes zooplankton) and higher trophic levels. The freshwater zooplankton comprise of protozoa, rotifers, cladocerans, copepods and ostracods. Zooplankton species have different types of life histories influenced by seasonal variations of abiotic factors, biotic factors, feeding ecology and predation pressure. Zooplankton diversity has assumed added importance during recent years due to the ability of certain species to indicate the deterioration in the quality of water caused by pollution or eutrophication. Zooplanktons are considered as good ecological indicators of water bodies (Gajbhiye and Desai 1981).

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Monitoring the zooplankton as biological indicators could act as forewarning, when pollution affects food chain (Mahajan 1981). According to Huq *et al.* (1996) zooplankton plays a major role in the multiplication, survival and potential transmission of cholera in coastal Bangladesh. Present study was undertaken to observe zooplankton diversity and ecological variations of coastal wetlands of Bakerganj.

MATERIAL AND METHODS

Physico-chemical parameters: Air and water temperature, conductivity, CO_2 and salinity were measured using a portable meter (HACH model CO150, U.SA.). DO, pH was also measured, using a portable (HACH model DO 175, U.S.A.) dissolved oxygen meter and Orion field pH meter (model 210A, Orion Laboratories, U.S.A), respectively. A graduated rope with a heavy iron ring attached was used to measure water depth. All physico-chemical parameters were measured instantly.

Collection, preservation and analysis of zooplankton samples: Water samples were collected monthly between January 2008 and December 2009 from three water bodies namely Thana Health Complex pond, Tulatoli River and Harun Dakua's pond of Bakerganj Upazila of Barisal division in Bangladesh. For zooplankton sample collection, 100 liters of water were filtered successively through 64µm mesh nylon nets (Millipore corp., Bedford, MA), and 50 ml of the concentrates were collected initially as a crude measure of zooplankton. From 50 ml concentrates, 10 ml was used for analysis and the samples were immediately preserved in 5% buffered formaldehyde solution. For qualitative and quantitative study, 1 ml samples were observed under a compound microscope (Axioskop 40, Japan) in a S-R (Sedgeweak-Rafter cell) cell. The specimens were identified up to genera or species level. Identification was made following Ward and Whipple (1959), Tonapai (1980), Mellanby (1975), Bhouyain and Asmat (1992), and Ali and Chakrabarty (1992). Quantitative analysis of zooplankton was followed by the total count method. The number of zooplankton estimated per ml was calculated by adopting the following formula (Santhanam *et al.*, 1989):

$N = A \times C / L$

Here,

N is number of zooplankton/L

A is total concentrate amount of zooplankton (50 ml).

C is number of zooplankton counted in 1 ml sample

L is amount of water (In litre) passed through plankton net (100 litre).

Zooplankton community structure analysis

Statistical analysis and diversity indices: The statistical analysis were done using software programmed for total zooplankton numbers of individual species, diversity indices namely; Shannon's diversity index (H'), species evenness and species richness were calculated using Excel software package

(version = 10). Three indices were used to obtain the estimation of species diversity, species richness and species evenness.

i. Shanon and Weiner (1948) diversity index value was obtained using the following equation:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where,

Pi = is the proportion of the first species. The proportions are given Pi = ni/N

ii. Species richness (R1 and R2) was obtained using the following equation:

R1 = (S – 1) /log N (Margalef, 1958)

R2 = S √n (Menhinic, 1964)

Where,

R = is the index of species richness

S = total number of species

N = total number of individuals

iii. Species equitability or evenness was determined by using the expression of Pielou (1966) and Sheldon (1969).

E1 = N_1/ N_0 (Pielou evenness)

E1 = N_1/ N_0 (Sheldon evenness)

Where,

N_0 = number of species on the sample

N_1 = number of abundant species in the sample

RESULTS AND DISCUSSION

Physico-chemical parameters of water: During study, high value of air temperature (36.4°C) was recorded during October, 2008 at Thana Health Complex pond and whereas low (22.1°C) during December, 2008 at Tulatoli River and High value of water temperature (33°C) was recorded during September, 2008 at Thana Health Complex pond and whereas low (18.6°C) during January, 2009 at Tulatoli River (Table 1). Among the three aquatic environments of Bakerganj, the populations of zooplankton were positively correlated with both water surface temperature and air temperature except Tulatoli River (Table 1). These values are definitely suitable for life in aquatic life. So, in Bakerganj, temperature was responsible for increasing of plankton population. During study, air and water temperature were found to be responsible for total zooplankton increase at Thana Health Complex pond and Harun Dakua's pond. Mozumder *et al.,* (2011) observed inverse relationship between protozoan and water temperature. High value of pH (9.39) was recorded during December, 2008 at Thana Health Complex pond and whereas low (7.06) during September, 2009 at Harun Dakua's pond

Table 1. Physico-chemical parameters of water in study areas of Bakerganj

Parameters	Thana health complex pond				Tulatoli river				Harun Dakua's pond			
	Year 2008		Year 2009		Year 2008		Year 2009		Year 2008		Year 2009	
	Range	Avr.	Range	Avr.	Range	Avr.	Range	Avr.	Range	Avr.	Range	Avr.
Air Temp. (° C)	24.7-36.4	32.1	23.9-35.1	30.4	22.1-36	31.23	24.1-35	29.68	26.2-34.6	31.26	24.3-34.6	30
Water Temp. (° C)	24.2-33.4	29.18	22.9-32.3	29.58	20.1-32.4	27.17	18.6-30.2	26.92	23.1-32.3	29.35	21.4-32.4	28.91
pH	7.25-9.39	8.21	7.23-8.88	7.76	7.35-8.48	7.84	6.71-8.52	7.77	7.28-8.53	7.81	7.06-9.12	8.06
D.O.(mg/L)	5.87-8.73	7.39	4.79-10.57	7.33	2.22-9.97	6.54	4.85-12.85	7.28	6.11-11.29	8.40	4.54-15.25	8.03
TDS (mg/L)	25.3-161.6	92.53	25.1-91.4	61.51	67.4-315	153.78	59.7-161.5	102.91	76.9-180.7	113.43	55.2-155.7	95.59
Conductivity (µS/cm)	53.9-336	198.8	60.8-218	136.1	134.9-602	321.09	129.4-362	216.72	161.1-393	243.67	116-366	212.88
Salinity (ppt)	0-0.1	0.025	0	0	0-0.3	0.09	0-0.1	0.025	0-0.1	0.03	0-0.1	0.03
Water Depth (m)	0.93-2.31	2.01	1.86-2.59	2.21	0.43-2.87	1.57	0.5-2.86	1.86	1.7-2.64	2.20	1.56-2.68	2.13

(Table 1). pH plays important role on the suitability of water media for growth. Among the three aquatic environments of Bakerganj, the populations of zooplankton were negatively correlated with pH except Tulatoli River where the relationship was positive (Table 1). Mozumder *et al.* (2011) observed inverse relationship between protozoan and pH. Chowdhury *et al.* (1989) found that pH showed significant positive correlation with the occurrence of zooplankton (the coefficient being 0.38). High value of DO (15.25 mg/L) was recorded during June, 2009 at Harun Dakua's pond and whereas the value was lowest (2.22 mg/L) during January, 2008 at Tulatoli River (Table 1).

Among the three aquatic environments, the populations of zooplankton were negatively correlated with DO (Table 2). Sahib (2004) observed the direct correlation between highly saturated dissolved oxygen level and zooplankton populations of Shendurni River, Kerela, India. But Chowdhury *et al.* (1989) observed negative correlation between dissolve oxygen (DO) and zooplankton (coefficients being -0.26). Mozumder *et al.* (2011) observed positive relationship between protozoan and dissolved oxygen.

Table 2. Showing correlation co-efficient computed between physicochemical parameters of water and density of total zooplankton of three sampling stations of Bakerganj

Relationship	Correlation co-efficient 'r'		
	Thana Health Complex Pond	Tulatoli River	Harun Dakua's Pond
Air temperature vs total zooplankton	0.008	-0.369	0.248
Surface water temperature vs total zooplankton	0.116	-0.447	0.273
pH vs total zooplankton	-0.132	0.165	-0.078
DO vs total zooplankton	-0.437	-0.023	-0.256
TDS vs total zooplankton	-0.061	0.202	-0.073
Conductivity vs total zooplankton	-0.031	0.172	-0.044
Salinity vs total zooplankton	-0.119	0.233	-0.169
Water depth vs total zooplankton	-0.104	-0.502	-0.195

Dissolved solids indicate the total amount of inorganic chemicals in solution. A maximum value of 400 mg/L of total dissolved solids (TDS) is permissible for various fish population and auatic population (Nadeem

1994). During study, high value of TDS (315 mg/L) was recorded during December, 2008 at Tulatoli River and whereas low (25.1 mg/L) during September, 2009 at Thana Health Complex pond (Table 2). Among the three aquatic environments, the populations of zooplankton were negatively correlated with TDS except Tulatoli River, where the relationships was positive (Table 2). Ahmad *et al.* (2011) observed the range of TDS between 298 mg/L to 662 mg/L. They also observed positive but insignificant correlation (r = 0.125) between TDS and zooplankton.

High value of conductivity (602 µS/cm) was recorded during November and December, 2008 at Tulatoli River and whereas low (53.9 µS/cm) during May, 2008 at Thana Health Complex pond (Table 2). Among the three aquatic environments, the populations of zooplankton were negatively correlated with conductivity except Tulatoli River where the relationships was positive (Table 2). During the study, there was a fluctuating trend in electronic conductivity. The fluctuations in electronic conductivity were due to fluctuation in total dissolved solids and salinity (Boyd 1981). According to Gaikwad *et al.* (2008) the dilution of solid substance in turn reduces the electronic conductivity value , alkalinity and zooplankton production.

The fluctuation in salinity is probably due to fluctuation in total solids (Boyd and Tucker 1998). High value of salinity (0.3ppt) was recorded during November and December, 2008 at Tulatoli River and whereas low (0.1 ppt) during April, November, December, 2008 at Thana Health Complex pond; February, March, April, September, October, 2008 and January, February, April, 2009 at Tulatoli River and September, October November, December, 2008 and January, April, June, 2009 at Harun Dakua's pond (Table 2). Among the three aquatic environments, the populations of zooplankton were negatively correlated with salinity except Tulatoli River where the relationships was positive (Table 2). Rajagopal *et al.* (2010) observed negative correlation between zooplankton population and salinity. Kumar *et al.* (2011) observed positive and high correlation between zooplankton population and salinity in three ponds of Karwar district, Karnataka, India.

High value of water depth (2.87 m) was recorded during July, 2008 at Tulatoli River and whereas low (0.43 m) during March, 2008 at Tulatoli River (Table 2). Among the three aquatic environments, the populations of zooplankton were negatively correlated with water depth (Table 2). Mozumder *et al.,* (2014) observed positive coefficient of correlation (0.55) between water depth and total zooplankton in a fish culture pond of Manikganj, Bangladesh.

Abundance and seasonal diversity of zooplankton of Bakerganj: A total of 56 zooplankton species were identified from three sites of Bakerganj (Table 3). Among them, 35 species belonged to rotifer, 6 species were of protozoan, 8 species were copepods, 5 were from cladoceran and 2 species were from ostracods. Mozumder *et al.* (2010) found 47 taxa from five groups: protozoa (4 taxa), rotifera (31 taxa), copepoda (5 taxa), cladocera (5 taxa) and ostracoda (2 taxa) from eight different aquatic environments of Bakerganj.

Table 3. Abundance of zooplankton species of Bakerganj (Ranking 6 = Dominant: up to 500 individuals, 5 = Abundant; up to 100 individuals, 4 = Common: up to 50 individuals 3 = Frequent: up to 10 individuals, 2 = Occasional: up to 3 individuals, 1 = Rare: 1 individuals, NF = Not Found)

Group	Species Name	Year 2008			Year 2009		
		Thana Health Complex Pond	Tulatoli River	Harun Dakua's Pond	Thana Health Complex Pond	Tulatoli River	Harun Dakua's Pond
Protozoa	*Arcella* sp.	NF	1	NF	NF	NF	NF
	Difflugia sp.	4	2	NF	3	1	1
	Endosphaera sp.	NF	NF	NF	3	NF	NF
	Acanthocystis spinibera	NF	NF	4	NF	NF	3
	Centropyxis sp.	NF	NF	1	NF	NF	1
	Paramecium sp.	NF	NF	NF	1	NF	NF
Rotifera							
	Asplanchna priodonta	4	1	5	4	1	5
	Brachionus angularis	1	2	4	3	1	4
	B. caudatus	6	3	3	6	3	4
	B. calyciflorus	2	NF	3	2	NF	3
	B. diversicornis	6	3	3	4	3	3
	B. donneri	1	NF	NF	NF	NF	NF
	B. forficula	6	4	2	6	4	4
	B. havanensis	NF	NF	NF	NF	NF	1
	B. falcatus	4	3	4	4	3	4
	B. nilsoni	NF	NF	1	NF	NF	1
	B. plicatilis	NF	NF	NF	NF	NF	1
	B. quadridentatus	NF	NF	2	1	NF	2
	B. urceolaris	1	NF	3	1	NF	3
	Brachionus sp.	NF	1	2	NF	NF	NF
	Filinia sp.	NF	NF	NF	NF	2	4
	Filinia longiseta	4	1	1	4	NF	3
	F. camascela	NF	1	NF	NF	NF	NF
	F. opoliensis	6	2	1	6	2	NF
	F. terminalis	3	2	NF	2	2	NF
	Harringia sp.	NF	NF	1	NF	NF	1
	Hexarthra intermedia	4	NF	3	4	NF	3
	Horaella brehmi	3	1	3	3	1	3
	Keratella cochlearis	1	3	NF	NF	3	NF
	K. tropica	6	3	2	4	3	2
	Keratella sp.	NF	1	NF	NF	NF	NF
	Lecane luna	1	NF	NF	1	NF	1
	Monostyla lunaris	1	1	1	1	1	
	Monommata sp.	NF	NF	2	NF	NF	NF
	Platyias patulus	NF	1	NF	NF	NF	NF
	Polyarthra vulgaris	6	3	5	5	3	6
	Rotaria neptunia	NF	NF	NF	1	NF	NF

Group	Species Name	Year 2008			Year 2009		
		Thana Health Complex Pond	Tulatoli River	Harun Dakua's Pond	Thana Health Complex Pond	Tulatoli River	Harun Dakua's Pond
	Testudinella patina	3	NF	3	3	NF	3
	Trichocerca sp.	NF	NF	NF	3	1	3
	Trichocerca similis	2	1	4	NF	NF	NF
	T. multicrinis	NF	NF	NF	NF	NF	3
	Unidentified rotifera	3	3	5	4	1	4
Nauplii	Nauplius	5	4	4	4	4	4
	Metanauplius	5	4	4	5	4	4
Copepoda							
	Cyclops sp	4	3	2	4	4	3
	Cyclops nanus	3	1	1	3	1	1
	C. varicans	1	NF	NF	NF	NF	NF
	C. vernalis	NF	1	1	NF	NF	NF
	Diaptomus gracilis	NF	1	NF	NF	1	NF
	Diaptomus sp.	4	3	2	4	3	2
	Mesocyclops sp.	3	1	NF	3	1	NF
	Mesocyclops leuckarti	NF	NF	NF	1	NF	NF
Cladocera							
	Bosmina coregoni	NF	1	NF	NF	1	NF
	Simocephalus serrulatus	1	NF	NF	NF	NF	NF
	Diaphanosoma brachyurum	2	2	3	2	1	4
	Daphnia lumholtzi	3	NF	NF	3	NF	NF
	Moina brachiata	NF	NF	NF	1	1	1
Ostracoda							
	Stenocypris malcolmsoni	NF	NF	1	NF	NF	1
	Eucypris fuscatus	NF	NF	NF	NF	NF	1
	TOTAL	31	30	31	33	25	34

Monthly assemblies of zooplankton in Bakerganj: In Thana Health Complex pond, the monthly assemblies of zooplankton species were maximum in December 2009 for protozoa (66 indv/L), May 2009 for rotifera (4014 indv/L), June 2008 for nauplii (939 indv/L), June 2008 for copepoda (954 indv/L) and June 2008 for cladocera (111 indv/L) L (Fig. 1). In contrast, the monthly assemblies of zooplankton species were minimum in June 2009 for Protozoa (3 indv/L), March; April and June 2008 for rotifera (6 indv/L), November 2008 for nauplii (12 indv/L), November 2008 for copepoda (3 indv/L), and January 2008 and July; November 2009 for cladocera (6 indv/L) L (Fig. 1). Furthermore, the total assemblies of the zooplankton species were maximum (4407 indv/L) in May 2009 and minimum (48 indv/L) in November 2008 with monthly average value of 707.75 ± 189.56 indv /L (Fig. 1).

In Tulatoli River, the monthly assemblies of zooplankton species were maximum in September 2008 for protozoa (15 indv/L), February 2009 for rotifera (228 indv/L), December 2009 for nauplii (142 indv/L) June 2008 and March;April 2009 for copepoda (54 indv/L) and June 2008 for cladocera (24 indv/L). In contrast, the monthly assemblies of zooplankton species were minimum in May 2009 for protozoa (3 indv/L), September 2009 for rotifera (3 indv/L), October 2008 for nauplii (9 indv/L), July; August 2008 and June; October 2009 for copepoda (03 indv/L), and March; September 2008 and December 2009 for cladocera (3 indv/L). Furthermore, the total assemblies of the zooplankton species were maximum (354 indv/L) in April 2009 and minimum (3 indv/L) in September and October 2009 with monthly average value of 127.42 ± 19.95 indv / L (Fi. 2).

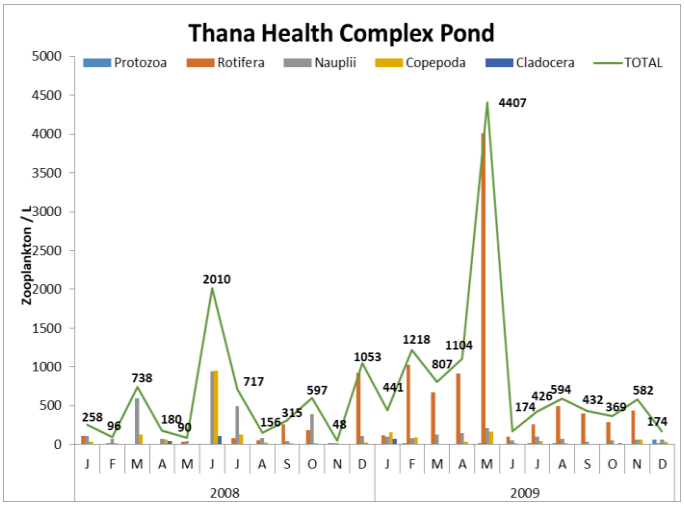

Fig. 1. Density variation of zooplankton groups and total zooplankton of Thana Health Complex Pond of Bakerganj

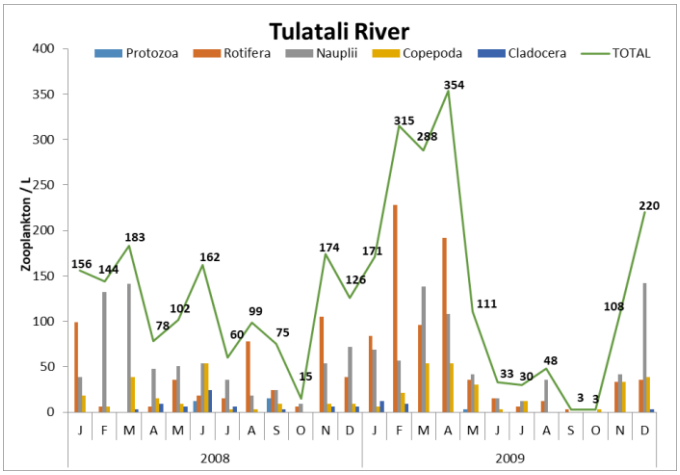

Fig. 2. Density variation of zooplankton groups and total zooplankton of Tulatoli River of Bakerganj

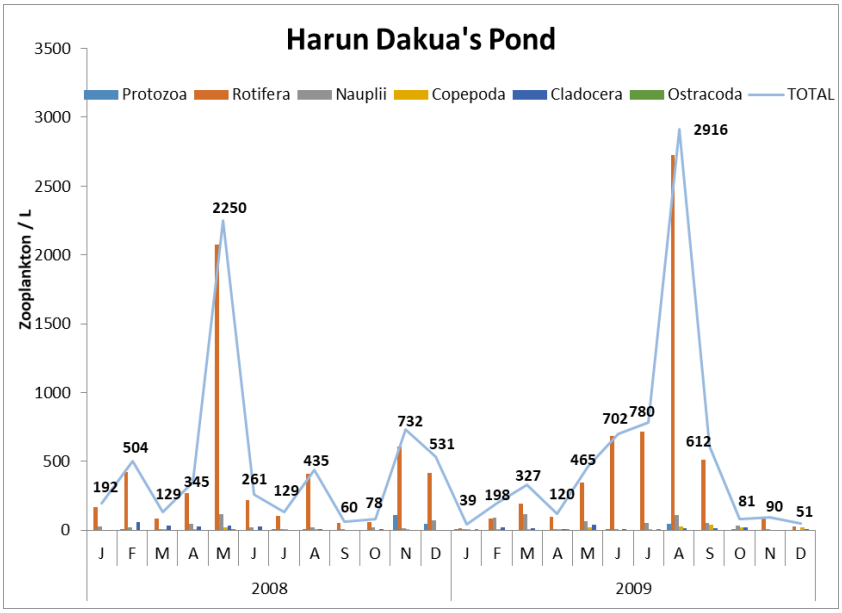

Fig. 3. Density variation of zooplankton groups and total zooplankton of Harun Dakua's Pond of Bakerganj

In Harun Dakua's pond, the monthly assemblies of zooplankton species were maximum in November 2008 for protozoa (111 indv/L), August 2009 for rotifera (2724 indv/L), May 2008 for nauplii (117 indv/L), September 2009 for copepoda (36 indv/L), February 2008 for cladocera (60 indv/L), and January 2009 for ostracoda (9 indv/L). On the other hand, the monthly assemblies of zooplankton species were minimum in August 2008 for protozoa (3 indv/L), October 2009 for rotifera (06 indv/L), July 2008 and January; June; November 2009 for nauplii (6 indv/L), April;August;November 2008 and January 2009 for copepoda (3 indv/L), August;October 2008 and April 2009 for cladocera (3 indv/L) and April 2009 for ostracoda. Furthermore, the total assemblies of the zooplankton species were maximum (2916 indv/L) in August 2009 and minimum (39 indv/L) in January 2009 with monthly average value of 501.13 ± 143.79 indv/L (Fig. 3).

Total zooplankton population in the present study, showed a distinct peak in the month of May 2009 (4407 indv /L) in Thana Health Complex pond. Majority of the aquatic environments expressed the highest number of zooplankton in March, April, May in summer and lowest in September, October, November and December. This study shows that, seasonal diversity and abundance of zooplankton species varied with seasons. Oppenheimer *et al.,* (1978) observed that the zooplankton population decreases during the monsoon season (May to July) in response to a reduction in nutrient concentrations in the water as a result of the heavy influx of rain water. Subsequently, the zooplankton blooms generally occur during March and April as well as August and September, being preceded by a phytoplankton bloom.

Percentage of zooplankton groups in study sites: In Thana Health Complex pond, protozoa comprised 0.94%, rotifera comprised 61.44%, nauplii comprised 23.99%, copepoda comprised 11.99%, and cladocera comprised 1.64% of the total zooplankton (Figure 4). In Tulatoli River, protozoa comprised 0.98%, rotifera comprised 38.36%, nauplii comprised 43.79 %, copepoda comprised 14.03%, and cladocera comprised 2.84% of the total zooplankton (Figure 5). In Harun Dakua's pond, protozoa comprised 1.97%, rotifera comprised 86.03%, nauplii comprised 7.58%, copepoda comprised 1.57%, cladocera comprised 2.64% and ostracoda comprised 0.20% of the total zooplankton (Fig. 6).

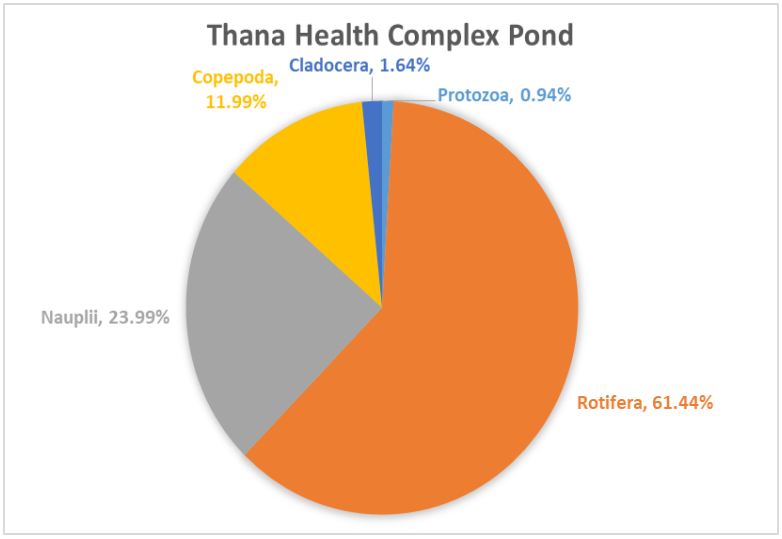

Fig. 4. Pie-chart showing the average percentage of different groups of zooplankton in Thana Health Complex pond.

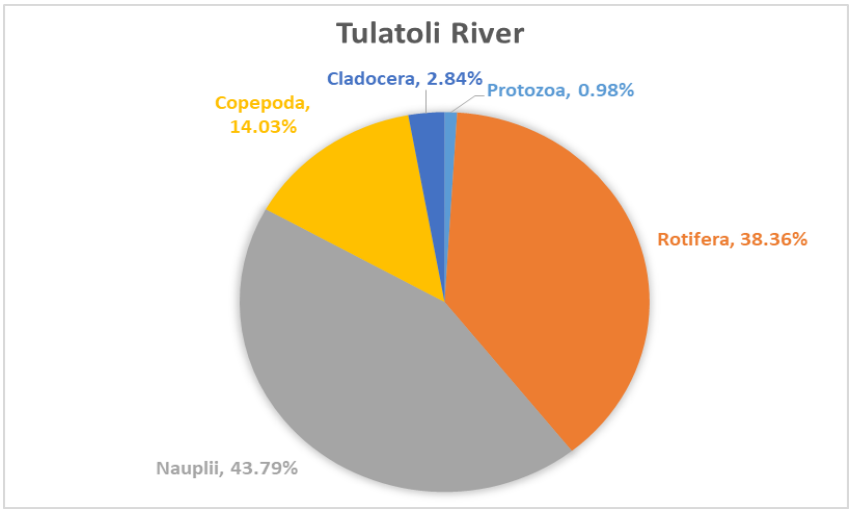

Fig. 5. Pie-chart showing the average percentage of different groups of zooplankton in Tulatoli River.

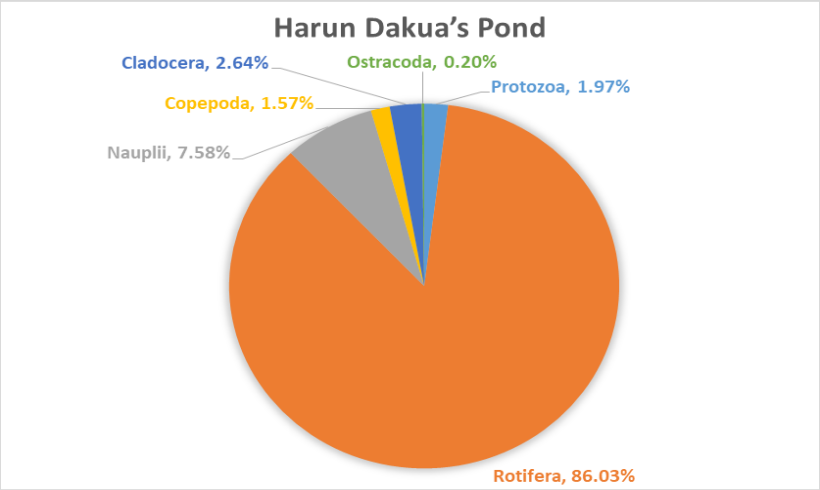

Fig. 6. Pie-chart showing the average percentage of different groups of zooplankton in Harun Dakua's pond.

The order of dominance by percentage occurrence from maximum to minimum were as rotifera > nauplii (copepod larva) > copepoda > cladocera > protozoa > ostracoda for Bakerganj. The dominance of rotifer (at Thana Health Complex pond and Harun Dakua's pond sites) indicates the eutrophic nature of the water body. According to Brooks and Dodson (1965) selective predation by planktivorous fish results in shifting of zooplankton communities with the dominance of rotifers. Thana Health Complex pond and Harun Dakua's pond recorded some culture fish population and hence the dominance of rotifers. Singh *et al.* (2002) reported that higher rotifer populations occurs during summer and winter might be dominant due to hypertrophical conditions of the pond at high temperature and low level of water.

Zooplankton community structure of Bakerganj: During study, three indices were used to obtain the estimation of species diversity, species richness and species evenness, such as.

Species richness: The zooplankton species richness (R1 and R2) was found to be high in Harun Dakua's pond (R1: 1.63 ± 0.10; R2: 0.64 ± 0.06) followed by Thana Health Complex pond (R1: 1.53 ± 0.11; R2: 0.51 ± 0.04) and Tulatoli River (R1: 1.36 ± 0.14; R2: 0.74 ± 0.05) (Table 4).

The mean value of species richness ranges between R1 = 0.45 to 2.33and R2 = 0.15 to 0.99 at Thana Health Complex pond, R1 = 0.52 to 2.71and R2 = 0.30 to 1.16 at Tulatoli River and R1 = 0.57 to 2.68 and R2 = 0.29 to 1.44 at Harun Dakua's pond (Table 4).

Among the three sites of Bakerganj, Harun Dakua's pond site was the 'richer' than any other sites. Zooplankton species richness (R1 and R2) was found to be highest in Harun Dakua's pond > Thana Health Complex pond >

Tulatoli River. Mukherjee (1997) observed that the higher species richness (R1 and R2) is characterized by larger food chain.

Shannon –Weiner diversity index:

High mean value of Shannon –Weiner diversity index (H' and $e^{H'}$) was recorded in Tulatoli River (H' = 0.87 ± 0.08; $e^{H'}$ = 2.52 ± 0.17) as compared to Thana Health Complex pond (H' = 0.78 ± 0.06; $e^{H'}$ = 2.27 ± 0.15) and Harun Dakua's pond (H' = 0.66 ± 0.07; $e^{H'}$ = 2.04 ± 0.16) (Table 4).

The mean value of the Shannon – Weiner diversity index ranges between H' = 0.25 to 1.35 and $e^{H'}$ = 1.29 - 3.86 at Thana Health Complex pond, H' = 0.34 to 1.43 and $e^{H'}$ = 1.00 - 4.27 at Tulatoli River and H' = 0.15 to 1.48 $e^{H'}$ = 1.28 - 3.52 at Harun Dakua's pond (Table 4).

Table 4. Zooplankton species richness, diversity and evenness of three aquatic environments of Bakerganj

Diversity Indices	Thana Health Complex pond		Tulatoli River		Harun Dakua's Pond	
	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE	Range
Species richness						
R1 (Margalef's index)	1.53 ± 0.11	0.45 - 2.33	1.36 ± 0.14	0.52 - 2.71	1.63 ± 0.10	0.57 - 2.68
R2 (Menhinick's index)	0.51 ± 0.04	0.15 - 0.99	0.74 ± 0.05	0.30 - 1.16	0.64 ± 0.06	0.29 - 1.44
Shannon -Weiner diversity index						
H'	0.78 ± 0.06	0.25 - 1.35	0.87 ± 0.08	0.34 - 1.43	0.66 ± 0.07	0.15 - 1.48
$e^{H'}$	2.27 ± 0.15	1.29 - 3.86	2.52 ± 0.17	1.00 - 4.27	2.04 ± 0.16	1.28 - 3.52
Species evenness						
E1 (Pielou evenness)	0.36 ± 0.03	0.10 - 0.70	0.44 ± 0.04	0.25 - 0.76	0.31 ± 0.04	0.06 - 0.78
E2 (Sheldon evenness)	0.26 ± 0.03	0.09 - 0.58	0.43 ± 0.05	0.17 –1.00	0.24 ± 0.03	0.07 - 0.70

The Shannon-Weiner index indicates species diversity of a community or area. In this study, Tulatoli River site showed higher zooplankton species diversity and less competition between zooplankton species than other sites in Bakerganj. Highest mean value of Shannon - Weiner diversity index (H' and eH') was recorded in Tulatoli River as compared to Thana Health Complex pond and Harun Dakua's pond. During study, Tulatoli River showed higher zooplankton species diversity and less competition between zooplankton species than other sites. Dash (1996) reported that high value of Shannon's index (H') the greater is the planktonic diversity. Although Balloch *et al.* (1976) and Ismael and Dorgham (2003) found that the diversity index (Shannon's) to be a suitable indicator for water quality assessment.

Species evenness: The zooplankton species evenness (E1 and E2) was found to be high in Tulatoli River (E1 = 0.44 ± 0.04; E2 = 0.43 ± 0.05) followed by Thana Health Complex pond (E1 = 0.36 ± 0.03; E2 = 0.26 ± 0.03) and Harun Dakua's pond (E1 = 0.31 ± 0.04; E2 = 0.24 ± 0.03) (Table 4). The mean value of species evenness ranges between E1 = 0.10 to 0.70 and E2 = 0.09 - 0.58 at Thana Health Complex pond, E1 = 0.25 to 0.76 and E2 = 0.17 to 1.00 at Tulatoli River and E1 = 0.06 to 0.78 and E2 = 0.07 to 0.70 at Harun Dakua's pond of Bakerganj (Table 4). Tulatoli River has more evenness in species composition than the other two sites. That means, the

total number of zooplankton species in the sample was quite evenly distributed between the species at Tulatoli River of Bakerganj. Zooplankton species evenness (E1 and E2) was found to be highest in Tulatoli River followed by Thana Health Complex pond and Harun Dakua's pond. Peet (1974) has reported that species diversity implies both richness and evenness in the number of species and equitability for the distribution of individual among the species.

CONCLUSION

During study, zooplankton collected from Bakerganj across seasons was identified and a total of 52 zooplankton species were recorded of which 34 were rotifers, 6 protozoan, 5 copepods, 5 cladocerans and 2 ostracods species. Physico-chemical parameters of aquatic environment of Bakerganj were found to be suitable for the persistence of a diverse zooplankton species. However, the spatio-temporal fluctuations of zooplankton species in the study areas were related to the changes in physico-chemical parameters. Species belonging to the protozoa, rotifera, copepoda, cladocera, and ostracoda mainly constituted the zooplankton groups of the studied coastal aquatic environments of Bakerganj. Rotifers were the most dominant and diverse group of zooplankton in the studied aquatic environments of Bakerganj.

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