

## Assessment of Coastal Water Habitat with Reference to the Variability of Plankton during Spawning Season of Indian River Shad in Greater Noakhali-Bangladesh

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### Abstract

The present study was conducted to quantify the water quality parameters and plankton concentrations of the Meghna river estuary during the spawning season of Hilsa (*Tenualosa ilisha*) and also to establish knowledge about the habitat. Hilsa (*Tenualosa ilisha*) is one of the flagship anadromous fish species of Bangladesh that migrate downstream for spawning purposes only through the Ganges-Meghna river system route. The study period constitutes two spawning seasons of Hilsa (*Tenualosa ilisha*) (June 2014 and February, March 2015). The water quality parameters and plankton concentrations were measured and analyzed by standard methods. A total of 50 genera of plankton identified from the water body belonging to the group *Bacillariophyceae*, *Cyanophyceae*, *Chlorophyceae*, *Dinophyceae*, *Coscinodiscophyceae*, *Copepoda*, *Rotifera*, *Cladoceran*, *Protozoa*, *Crustacean larvae* and *Meroplankton*. The phytoplankton density was varied from  $2.93 \times 10^3$  to  $7.94 \times 10^3$  cells/L and zooplankton density of  $1.15 \times 10^3$  cells/L to  $1.8 \times 10^3$  cells/L. The plankton concentrations were strongly correlated with the fluctuations of water quality. The water temperature and phytoplankton density was positively correlated ( $r = 0.75$ ), on the other hand, negative correlation was found between phytoplankton and transparency ( $r = -0.84$ ). *Bacillariophyceae* was the most dominant group contributing 78% of phytoplankton and among zooplankton, Copepoda contributes 36%. Shannon-Weiner species diversity index (H') used as an indicator of water quality. It ranged from 2.07 to 2.74 (phytoplankton) and 1.82 to 2.38 (zooplankton). The mean value of phytoplankton was  $2.42 \pm 0.19$  and zooplankton was  $2.14 \pm 0.16$  and it was within the range of 1 to 3, so the water body is moderately polluted. The phytoplankton cell density is a good indicator to determine the trophic status of a particular water body. The mean cell density of phytoplankton was 5372 cells/L and could be classified as oligotrophic. Oligotrophic water body characters lack nutrients which resulted in the lowest density of plankton. Based on plankton density it can be concluded that during spawning season, plankton profile is low which might be hindered Hilsa to migrate this spawning ground.

**Keywords:** Indian river shad; Plankton; Coastal water habitat; Noakhali; Bangladesh

### Introduction

Estuaries considered as the most productive aquatic ecosystem which plays an important role in breeding and nursery ground for wide variety fish species. In Bangladesh, the Meghna river estuary is the largest estuarine ecosystem and support diverse fisheries communities in comparison to others. It is one of the prominent habitats of Hilsa (*Tenualosa ilisha*) fishery which is used for their spawning purpose. Hilsa is a migratory fish species and in the spawning season it migrates to the lower reaches of the Meghna River in the estuarine zone. According to Ward and Whipple [1], Hilsa is primarily planktivore species and its food items are diatoms, blue-green algae, copepods, desmids, cladocerans, rotifers etc. It is very important to understand the feeding habit of Hilsa like the presence of their preferable food items with abundance. The qualitative and quantitative abundance of plankton and its relation to environmental condition consider as a prerequisite to manage an aquatic ecosystem successfully. In most cases, the abundance of planktonic organisms proved as beneficial for fish production. However, if the plankton abundance causes bloom then it exerts negative effect likely severe economic loss to aquaculture, fisheries operation and causing major environmental and human health related problem. Due to rapid industrialization and urbanization in the country, at the same time, river erosion which is thoroughly associated with heavy surface runoff causing siltation and have an effect on growth and production rate of Hilsa and exerts influence on primary production in the eastern region. So, the monitoring program of plankton during the spawning season of Hilsa will provide up-to-date information on that habitat. The pollution status of aquatic habitat

can detect through the species diversity index, which is one of the best ways to evaluate the impact of pollution on aquatic communities [2]. In spite of having overwhelming importance, no research has not yet been conducted to date on the assessment of ecological conditions of the Meghna estuary for Hilsa fishery. The present study was undertaken to study monthly variations of plankton with some water quality parameters and assessing the status of this habitat.

### Materials and Methods

#### The study area:

The research work was conducted in the Meghna estuary, Char Alexander, Ramgati Upazilla of Lakshmipur district, Bangladesh (Figure 1). The Hatiya Island situated in the east, Bhola to the west, greater Noakhali to the north and the Bay of Bengal to the south around the study area. The study was carried out over three season winter (February 2015), pre-summer (March 2015) and summer (June 2014)

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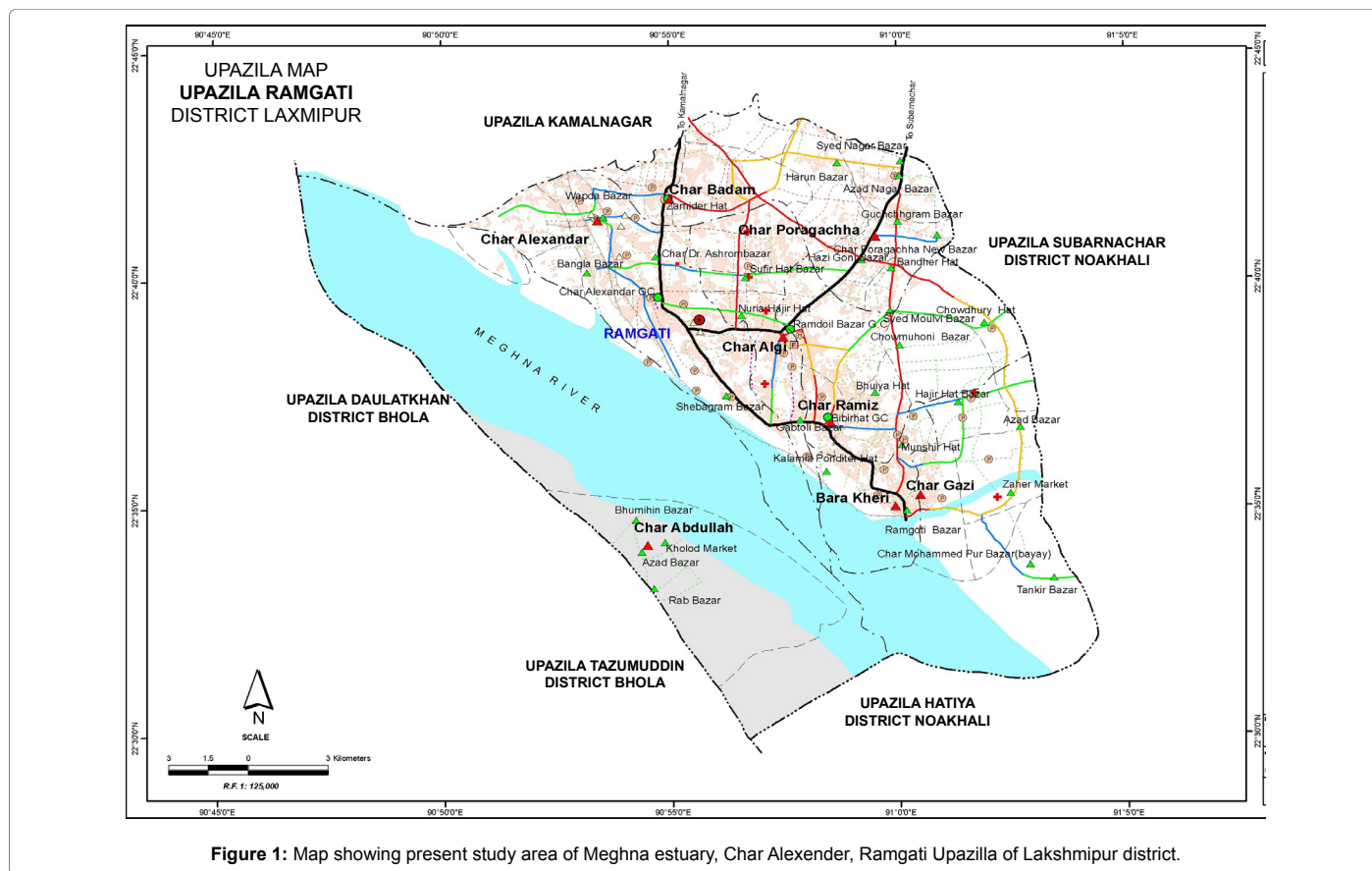


Figure 1: Map showing present study area of Meghna estuary, Char Alexander, Rangati Upazilla of Lakshmipur district.

covered two spawning seasons of Hilsa from June-July and January-March. Water sampling was done from six stations of the Meghna river estuary, which is the most important estuarine ecosystem in the southeast coastal portion of Bangladesh.

### Water quality parameters

Surface water samples were collected and analyzed in situ to determine salinity (ppt), temperature (°C), transparency (cm) and pH using a Multiparameter analyzer. Water temperatures were recorded directly on the spot by a Celsius thermometer and pH by a digital pH meter. Water transparency values were measured by a simple Secchi disc. Salinity was measured by using Refractometer (NewS-100, TANAKA, Japan) and expressed as the parts per thousand (ppt).

### Phytoplankton study

The phytoplankton quantitative and qualitative estimations were taken for each month of the study period. Plankton samples (20 L) were collected from the surface water of estuary by passing water samples through fine-meshed plankton net (25 µm meshes sized). The samples were preserved immediately with 10% buffered formalin in plastic bottles. A Sedgwick-Rafter (S-R) cell was used under a luminous microscope (XSZ21-05DN, made in China) for phytoplankton counting. Phytoplankton was identified to genus level and counted using the formula proposed by Stirling [3] and was expressed as the number of cells per liter of water.

### Zooplankton study

Zooplankton quantitative and qualitative estimations were taken during sampling month of the study period. Plankton samples (20

L) were collected from the surface water of estuary by passing water samples through fine-meshed plankton net (40 µm meshes sized). The samples were preserved immediately with 10% buffered formalin in plastic bottles. A Sedgwick-Rafter (S-R) cell was used under a luminous microscope (XSZ21-05DN, made in China) for zooplankton counting. Zooplankton was identified to genus level and counted using the formula proposed by Stirling [3] and was expressed as the number of cells per liter of water.

### Species richness, diversity and evenness index calculation

Species richness index (d):

Margalef index (d) [2] was used to measure species richness by using the following formula:

$$d = (S-1) / \ln N$$

Where,

d = Species richness index,

S = Number of species in a population,

N = Total number of individuals in S species

**Species diversity index (H):** Shannon-Weiner diversity index [4-6] considers the number of species and the distribution of individuals among species. The Shannon-Weiner diversity was calculated by the following formula.

$$H = -\sum P_i \ln P_i$$

Where,

H = Diversity index,

i = Counts denoting the  $i^{\text{th}}$  species ranging from 1-n,

Pi = Proportion that the  $i^{\text{th}}$  species represents in terms of numbers of individuals with respect to the total number of individuals in the sampling space as the whole.

**Evenness index (j):** Buzas and Gibson's [7] was measured by using the following formula:

$$j = H / \ln S$$

Where,

j = Equitability index,

H = Shannon and weaver index,

S = Number of species in a population.

### Statistical analysis

For all sampling techniques, three replicates were analyzed and means and standard deviations were calculated and expressed as mean ( $\pm$  SD). Paleontological Statistics (PAST) version 3.15, a software package for paleontological data analysis written by Ryan et al. [8] was used to run the analysis.

## Results and Discussion

### Water quality parameters

In the present study, water salinity of February and March were varied in the ranges of (2-4) ppt where in June salinity varies between (1-2) ppt (Table 1). The dropping of salinity in June was might be due to freshwater inflow from the surrounding land area. According to McErlean et al. [9] salinity of an estuary ranged between 0.50 and 35 ppt. Surface water pH value varies between 7.0 (February, 2015) – 7.5 (March, 2015). The mean water pH found maximum in March (7.3) and minimum one was in June (7.08). More or less similar results found by Hossain et al. [10] where water pH values vary between 7.7 to 6.9 in the Meghna estuary. As salinity was considerably higher in winter and freshwater influx was low as compared to summer period, hence it might be due to greater concentration of available alkali metals in their ionic forms pH in winter was higher than in summer months. Surface water temperature ( $^{\circ}\text{C}$ ) showed maximum in June ( $27^{\circ}\text{C}$ ) in the summer period and a minimum in February ( $20^{\circ}\text{C}$ ) during winter. Maximum average water temperature occurred  $24.92 \pm 1.93$  in June and minimum average one was resulted  $22.42 \pm 1.74$  in February

(Table 1). It can be said that the higher surface water temperature was observed in sampling month June due to strong solar irradiance as the sample collection day was sunny. Patra and Azadi [11] studied on the planktonic organisms of Halda river recorded highest water temperature during summer and lowest in winter months. The highest water transparency was recorded in the sampling month February and March (32 cm) where the minimum value observed (19 cm) during June. The water transparency ranged between (28-32 cm) in February and March, (19-25) cm (Table 1) in June during the study period. Water transparency was lower in June might be due to raining when river erosion occurs and makes the water body turbid by carrying large amount of sand and silt. Reid and Wood reported that water transparency depends on several factors likely silting, plankton density, suspended organic matter, latitude, season and the angle and intensity of incident light.

### Qualitative and quantitative plankton count

**Phytoplankton:** In the current study period, 31 genera of phytoplankton were identified which belonged to five major groups likely *Bacillariophyceae*, *Chlorophyceae*, *Coscinodiscophyceae*, *Cyanophyceae* and *Dinophyceae* (Table 2). Therefore, 31 phytoplankton genera were divided as 22 belonged to *Bacillariophyceae*, 5 to *Chlorophyceae*, 1 to *Coscinodiscophyceae*, 3 to *Cyanophyceae* and 1 to *Dinophyceae* (Table 2). A study of Halda River recorded the phytoplankton population as algal flora under the classes *Chlorophyceae*, *Cyanophyceae*, *Bacillariophyceae* and *Myxophyceae* [11]. The findings of the present study can be compared with Shah et al. [12] studied on the seasonal variations of phytoplankton communities in the southwest coastal waters of Bangladesh recorded a total of 31 phytoplankton species; where 17 to *Bacillariophyceae*, 7 to *Cyanophyceae*, 5 to *Chlorophyceae*, and 2 to *Dinophyceae*. During the present study period for total abundance of plankton population phytoplankton was contributed about 79%. Shafi et al. [13] reported higher percentage composition of phytoplankton (76.0 - 93.6) % from the Meghna river. Similar findings were found in the recent investigation by Ahsan et al. [14] studied on the plankton abundance of the Meghna river, observed that phytoplankton formed 90% of the total plankton abundance.

Phytoplankton counts (number of cells per liter of water) were  $2.93-4.62 \times 10^3$  cells/L,  $4.50-5.9^3 \times 10^3$  cells/L, and  $5.50-7.93 \times 10^3$  cells/L in February, March, and June respectively. Maximum phytoplankton density was also observed in June ( $175.8 \times 10^3$  cells/L) by Shah et al. [12] where the minimum number in September ( $12.0 \times 10^3$  cells/L) in Shibsra river, southwest coast of Bangladesh. These higher densities of Shibsra river were attributed due to continuous discharge of sewage

Station		St-1	St-2	St-3	St-4	St-5	St-6	Mean $\pm$ SD
February	Temperature ( $^{\circ}\text{C}$ )	21	22.5	23	20	23	25	$22.42 \pm 1.74$
	Transparency (cm)	31	30	32	32	28	32	$30.83 \pm 1.60$
	pH	7.2	7.2	7.1	7	7.3	7.1	$7.15 \pm 0.10$
	Salinity (ppt)	2	3	2	2	4	2	$2.5 \pm 0.84$
March	Temperature ( $^{\circ}\text{C}$ )	23	24	22.5	24.5	22	25	$23.5 \pm 1.18$
	Transparency (cm)	31	31	32	28	32	30	$30.67 \pm 1.51$
	pH	7.3	7.5	7.4	7.1	7.3	7.2	$7.3 \pm 0.14$
	Salinity (ppt)	2	4	4	2	3	2	$2.83 \pm 0.98$
June	Temperature ( $^{\circ}\text{C}$ )	24	27	25	24.5	26	23	$24.92 \pm 1.93$
	Transparency (cm)	21	19	20	22	20	25	$21.17 \pm 2.14$
	pH	7	7.1	7.1	7.2	7	7.1	$7.08 \pm 0.07$
	Salinity (ppt)	1	1	2	2	2	1	$1.67 \pm 0.82$

St-1 = Station-1 and respectively

**Table 1:** Water quality parameters observed in three different months in the Meghna river estuary during the present study.

Bacillariophyceae	Chlorophyceae	Coscinodiscophyceae	Cyanophyceae	Dinophyceae
<i>Amphora</i> <i>Bacillaria</i> <i>Biddulphia</i> <i>Chaetoceros</i> <i>Coscinodiscus</i> <i>Cyclotella</i> <i>Diploneis</i> <i>Fragilaria</i> <i>Melosira</i> <i>Nitzschia</i> <i>Pleurosigma</i> <i>Rhizosolenia</i> <i>Stephanophysis</i> <i>Suirella</i> <i>Thalassionema</i> <i>Cymbella</i> <i>Synedra</i> <i>Gyrosigma</i> <i>Licmophora</i> <i>Cocconeis</i> <i>Pseudo-nitzschia</i> <i>Tabellaria</i> sp.	<i>Ulothrix</i> <i>Spirogyra</i> <i>Closterium</i> <i>Characium</i> <i>Monoraphidium</i>	<i>Hemisdiscus</i>	<i>Oscillatoria</i> <i>Anabaena</i> <i>Microcystis</i>	<i>Procentrum</i>

**Table 2:** List of phytoplankton genera recorded from the surface water of the Meghna river estuary throughout the experimental period.

water during the rainy periods. The phytoplankton densities can be compared with Boonyapiwat [15] who worked in the coasts of the Gulf of Thailand and east coast of Peninsular Malaysia recorded 214-33520 cells/L and 178-14223 cells/L of phytoplankton. However, another study of Boonyapiwat et al. [16] was also recorded lower (2800-4380 cells/L) density of phytoplankton using 80 µm mesh size of the net.

The seasonal phytoplankton community indicated that diatoms especially the *Rhizosolenia* sp. as most dominant species during summer (June) while some other diatoms including *Coscinodiscus* sp., *Thalassionema* sp., *Melosira* sp., *Amphora* sp., *Characium* sp. also found more or less throughout the study period. Blue-green algae, especially *Oscillatoria* sp. were most abundant in February.

In the present study, *Bacillariophyceae* was the largest group by quality and quantity which comprised 78% (approx.) of total phytoplankton abundance. Similar findings by Shah et al. [12] where *Bacillariophyceae* comprising 75% of total cell counts. The dominance of diatoms in estuarine and marine aquatic environment was also agreed Boonyapiwat [15], Sevindik [17] and Al-Hashmi et al. [18]. It showed availability throughout the present study period, the dominant species in this included *Melosira* sp., *Coscinodiscus* sp., *Nitzschia* sp., *Fragilaria* sp., *Rhizosolenia* sp. and *Thalassionema* sp. *Coscinodiscus* sp. comprised about 23% and *Melosira* sp. 17% approximately of *Bacillariophyceae*. Among diatoms, *Pseudo-nitzschia* sp. was showed maximum density in February, and *Tabellaria* sp. was only present in June where cell density 63 cells/L. The highest density of *Bacillariophyceae* was observed during summer (June at station-2) about  $6.375 \times 10^3$  cells/L and lowest density in winter (February at station-6)  $2.625 \times 10^3$  cells/L. In the present study, mean cell density becomes higher from February (3073.166 cells/L) to March (3864.833 cells/L) to June (5656.666 cells/L) (Figure 2).

Among all phytoplankton groups, *Cyanophyceae* is the second most dominant group in term of abundance. The group was dominated by *Oscillatoria* sp. and other species like *Anabaena* sp. and *Microcystis* sp. *Cyanophyceae* contributed approximately 9% of total phytoplankton abundance which was recorded larger amount in pre-summer (March) about 875 cells/L at sampling station-1. The mean abundance of *Cyanophyceae* 552.5, 604.333 and 271.166 cells/L in February, March and June respectively (Figure 2).

On the other hand, *Chlorophyceae* was ranked as third among

phytoplankton group in accordance of abundance. Among *Chlorophytes*, the different species in order of abundance *Characium* sp., *Ulothrix* sp., *Closterium* sp., *Spirogyrasp.*, and *Monoraphidium* sp. The highest number of species was presented in March. Like *Cyanophyceae* highest cell density was also observed in March about 938 cells/L at station-4. The average cell density was 260.5, 667.166 and 375.333 cells/L in February, March and June respectively (Figure 2).

In the present study, *Dinophyceae* was only found in the month of June and it constituted approximately 1% of total phytoplankton abundance. The highest cell density 563 cells/L in station-2 of June. The genera in this group were *Procentrum*. The mean abundance of *dinophyceae* was 198 cells/L in June (Figure 2).

Another class was found in the present study which is *Coscinodiscophyceae*, only species belonged to this group was *Hemisdiscus* sp. This was only present in February and highest density was 125 cells/L at station-3. It constituted <1% of total phytoplankton abundance. The average density of this group was 41.833 cells/L in February (Figure 2).

The dominance of *Bacillariophyceae* suppresses the abundance of other phytoplankton groups. According to abundance phytoplankton group was found in the following order:

*Bacillariophyceae* > *Cyanophyceae* > *Chlorophyceae* > *Dinophyceae* > *Coscinodiscophyceae*

**Zooplankton:** The recorded zooplanktonic organisms were belonging to the group of *rotifers*, *copepods*, *cladocerans*, *crustacean larvae* and *meroplankton*. A total of 18 genera were identified from the zooplankton community where 8 belong to *Copepoda*, 2 to *Rotifera*, 2 to *Cladocera*, 3 to *Protozoa* and 3 to *Meroplankton* (Table 3). No genera were identified under the group of crustacean larvae. In the current investigation, zooplankton contributed about 21% of total plankton abundance which differs from Ahsan et al. [14] where they observed zooplankton population about 10% of total plankton. It can be said that in a lotic waterbody low population of zooplankton is not uncommon. Sundar et al. [19] reported the major contribution of phytoplankton (>97.0%) and lower concentration of zooplankton (0.13 - 2.4) % at three stations in the Guala river of Uttar Pradesh, India. In the present study, zooplankton counts (number of cells per liter of water) were ranging from  $1.20-1.50 \times 10^3$  cells/L,  $1.25-1.80 \times 10^3$  cells/L,

and  $1.15-1.60 \times 10^3$  cells/L in February, March, and June respectively. The highest zooplankton production was recorded in March  $1.80 \times 10^3$  cells/L and minimum one was  $1.15 \times 10^3$  cells/L in June. The average zooplankton density of February, March and June was  $1391.66 \pm 142.88$  cells/L,  $1575.67 \pm 201.86$  cells/L and  $1275.33 \pm 117.26$  cells/L respectively (Figure 3). Islam et al. [20] recorded the highest density of zooplankton in January (1350 cells/L). The peak of zooplankton in winter may be due to the favourable conditions of the physicochemical parameters and the availability of nutrients. Also, zooplankton showed their abundance in winter might be due to the lesser abundance of phytoplankton in winter.

Copepods were dominated throughout the study period, constituted approximately 36% of total zooplankton abundance. The present study can be compared with Gutkowska et al. [21] stated that in the saline region, copepods (45%) were the predominant species. Higher percentage found by Omondi et al. [22] studied on Lake Baringo, Kenya also observed Copepoda as a dominant group formed (60-72) % of the total zooplankton. The percentage variation might be due to a presence of nutrients in an aquatic habitat. The representative species of copepod was recorded from all sampling stations of the entire study period. The mean abundance of copepods was  $513.55 \pm$

109.55 cells/L. The highest cell density was 700 cells/L which recorded in March at sampling station-4 and lowest density was observed in June station-2 and February station-6 (350 cells/L). Cyclops sp. was the most dominant species of copepods and occupied approximately 36%. Other dominant species of copepods were *Cyclops nauplius* and *Diaptomus* sp.

Crustacean larvae were the second dominant group and contributed 14% (approx.) of the total zooplankton population. It varied from 100 cells/L to 350 cells/L. The highest cell density was observed in June (station-2) and lowest in March (station-1 and 3). The mean abundance of crustacean larvae was  $200 \pm 70.71$  cells/L.

Protozoa group constituted the third dominant and comprised about 16% (approx.) of the total zooplankton population. Volvox, Arcella, and Actinophrys genera have identified in this study (Table 2). *Actinophrys* sp. was the most dominant protozoan. The cell density of protozoa ranged from 100 cells/L to 400 cells/L. Density was higher in February (station-2) and lower in March (station-2) and June (station-6). The mean protozoa cell density was  $222.22 \pm 82.64$  cells/L.

Meroplankton was the fourth dominant group constituting 12% (approx.) of total zooplankton abundance and ranged from 100 to

Copepods	Cladocerans	Rotifer	Crustacean larvae	Protozoan	Meroplankton
<i>Candacia Cyclops</i> <i>Diaptomus Calanus</i> <i>Onacaea Oithona</i> <i>Eucalanus Cyclops nauplius</i>	<i>Moina Diaphanosoma</i>	<i>Brachionus Rotaria</i>	Nil	<i>Volvox</i> <i>Arcella Actinophrys</i>	Nauplius Copepodite Zoea

Table 3: List of zooplankton genera recorded from the surface water of the Meghna river estuary throughout the experimental period.

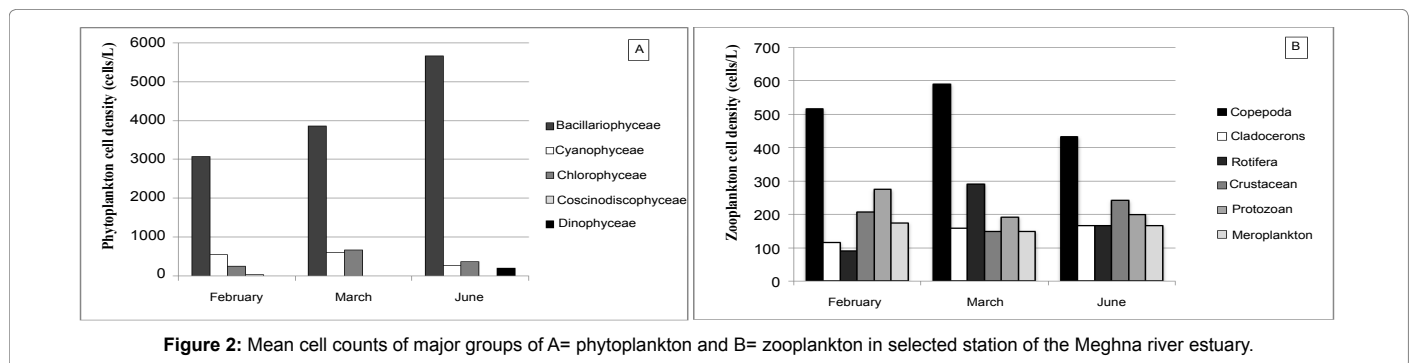


Figure 2: Mean cell counts of major groups of A= phytoplankton and B= zooplankton in selected station of the Meghna river estuary.

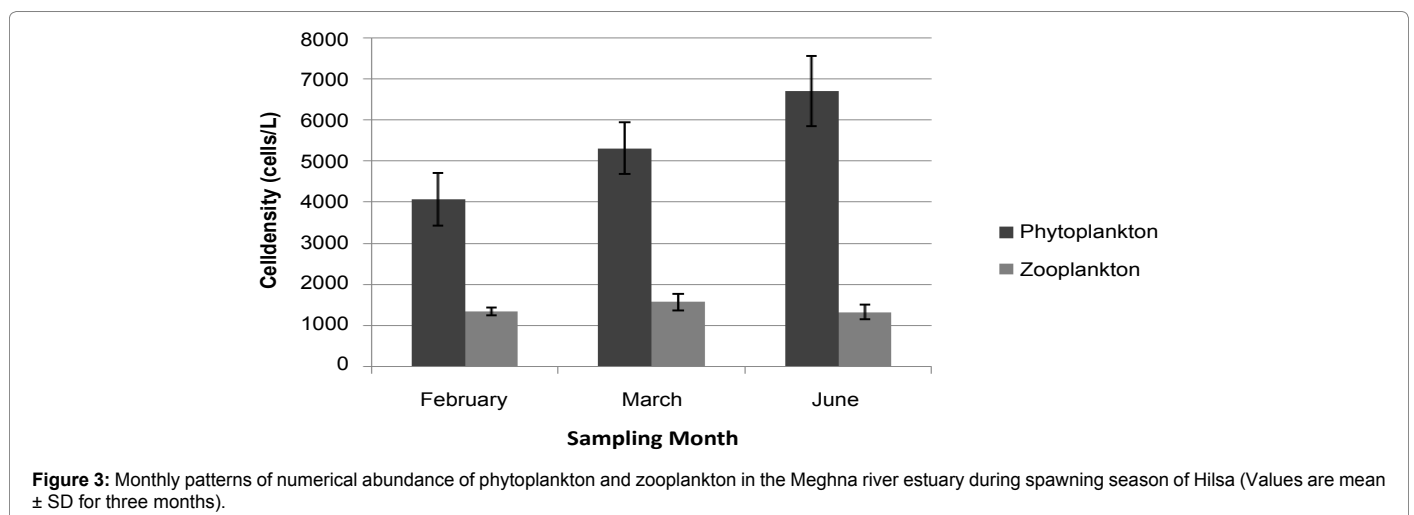


Figure 3: Monthly patterns of numerical abundance of phytoplankton and zooplankton in the Meghna river estuary during spawning season of Hilsa (Values are mean  $\pm$  SD for three months).

200 cells/L. The mean abundance of meroplankton was  $163.88 \pm 65.98$  cells/L.

Cladocerans were the fifth, dominant group of total zooplankton. It was formed 10% of total zooplankton abundance. The highest density of Cladocerans was found at station-4 of March (250 cells/L) and lowest in February at station-1 and station-2 (50 cells/L). The average density of Cladocerans was  $147.22 \pm 49.40$  cells/L.

Rotifers were the least dominant among total zooplankton groups. They contributed to 10% of zooplankton population. *Brachionus* and *Rotaria* were the identified genera in this study period. Lowest total cell density (50 cells/L) was observed in June and highest total cell density (400 cells/L) was recorded in March (station-1).

Seasonal zooplankton population indicated that copepods especially the *Cyclops* sp. Were dominant in three months and also found in abundance. The mean ( $\pm$  SD) zooplankton variations showed that highest density was in March, then it became lowest gradually to February and then June (Figure 3).

### Relationship of plankton density with water quality parameters

**Variation of plankton density with Temperature:** During the study period, three months (February, March, and June) cover six sampling stations with three replicates in total of eighteen had an individual temperature with the individual cell density of phytoplankton and zooplankton showed in Figure 4.

In the month of June, station-1 upholds the water temperature  $24^{\circ}\text{C}$  and respective phytoplankton cell density was 6063 cells/L, wherein station-2 with increasing temperature,  $27^{\circ}\text{C}$  phytoplankton cell density also caught the increasing trend, 7939 cells/L. In the present study period, water temperature was positively correlated ( $r = 0.75$ ) with phytoplankton cell density (Table 4). On the other hand, zooplankton

cell density picked the decreasing trend with increasing temperature. Radhakrishnan et al. [23] studied in the phytoplankton population in relation to the fluctuation of a physicochemical characteristic of Muthannankulam pond, the phytoplankton population was positively correlated with temperature ( $^{\circ}\text{C}$ ).

In the sampling station-3, water temperature was recorded  $25^{\circ}\text{C}$  and zooplankton cell density was 1150 cells/L, wherein station-4 water temperature was decreased to  $24.5^{\circ}\text{C}$  but zooplankton cell density was increased, 1300 cells/L. This inverse relationship of zooplankton and water temperature was found by Patra and Azadi [11].

**Variation of plankton density with Transparency:** Phytoplankton and zooplankton cell density had shown the different value with the variation of water transparency (Figure 5). There is a significant correlation between the growth of plankton and transparency in different aquatic ecosystems recorded by several authors Çetin et al. [24]; Hossain et al. [25]; and Begum et al. [26].

In the month of June, lowest water transparency (19 cm) was recorded during the entire study period. This lowest water transparency was recorded at sampling station-2 where phytoplankton cell density showed the maximum value about 7939 cells/L. On the other hand, when water transparency was increased (20 cm at the station-3) phytoplankton cell density decreased (7000 cells/L). In the present study, water transparency had an inverse relationship with phytoplankton abundance and negatively correlated ( $r = -0.84$ ) (Table 4).

In the case of zooplankton, transparency also showed a negative relationship with cell density. The mean water transparencies of March was 31 cm (approx.) and mean zooplankton density was observed about 1575 cells/L. In June mean water transparency was recorded lower (21 cm) where the lowest zooplankton cell density was observed (1275 cells/L). On the other hand, transparency showed the positive relationship ( $r = 0.31$ ) with zooplankton abundance (Table 4). Zooplankton cell density showed a negative relationship with the

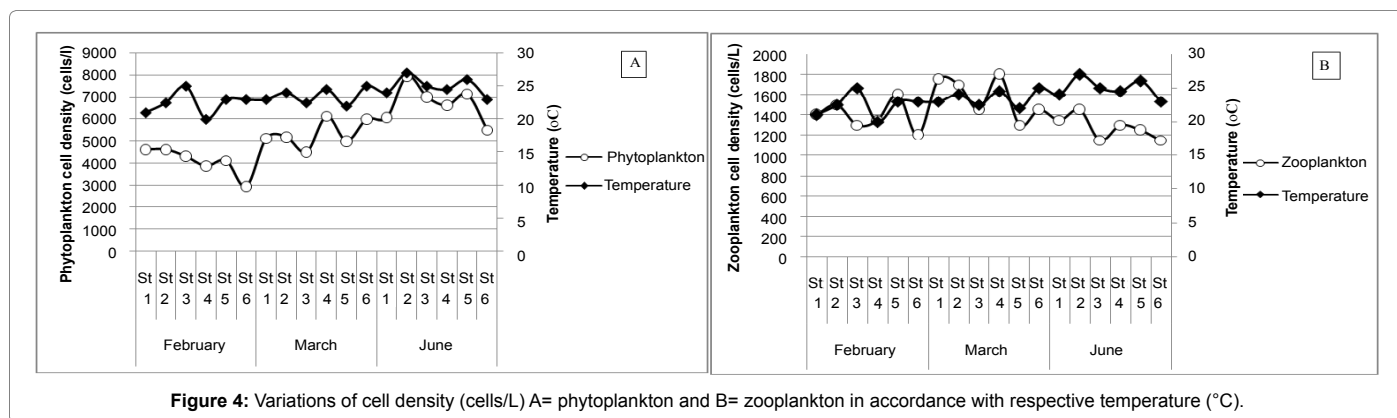


Figure 4: Variations of cell density (cells/L) A= phytoplankton and B= zooplankton in accordance with respective temperature ( $^{\circ}\text{C}$ ).

	pH	Salinity	Temperature	Transparency	Phytoplankton	Zooplankton
pH	1					
Salinity	0.717	1				
Temperature	-0.019	-0.250	1			
Transparency	0.343	0.413	-0.666	1		
Phytoplankton	-0.097	-0.351	0.751	-0.845	1	
Zooplankton	0.495	0.315	-0.022	0.317	-0.047	1

Table 4: Interactions (in terms of the values of the correlation coefficient  $r$ ) between different physico-chemical properties of water and phytoplankton and zooplankton density.

individual month, but with overall consideration, it exerts positivity might be due to the presence of phytoplankton in larger densities in the sampling period.

### Diversity indices

Diversity (or biodiversity) is typically measured by a species count (richness) and sometimes with an evenness index; it may also be measured by a proportional statistic that combines both measures (e.g. Shannon–Wiener index  $H'$ ) [27]. In the present study, Species richness index ( $d$ ), Shannon–Wiener diversity ( $H'$ ), and Evenness ( $J'$ ) were used to describe the diversity in a community and also used to assess water quality of the habitat. The mean ( $\pm$  SD) plankton diversity indices (Species richness, Shannon–Wiener, and Evenness)

are presented in Table 5. Among phytoplankton, *Bacillariophyceae* showed highest species diversity about  $1.95 \pm 0.13$ ,  $2.16 \pm 0.11$  and  $2.22 \pm 0.19$  in February, March and June respectively (Table 5). Others group of phytoplankton recorded much lower diversity ( $<1$ ) than *Bacillariophyceae*. It might be due to the higher abundance of one group which resulted in higher diversity can lower the diversity of others. Shannon–Wiener species wise diversity index ( $H'$ ) ranged from 0.37 to 2.46. *Coscinodiscophyceae* and *Dinophyceae* resulted in no diversity in the study period because during observation only one species was recorded for both groups for that it nullify species diversity index. Ahsan et al. [14] studied on plankton composition, abundance and diversity in Hilsha (*Tenualosa ilisha*) migratory rivers of Bangladesh during spawning season found the diversity

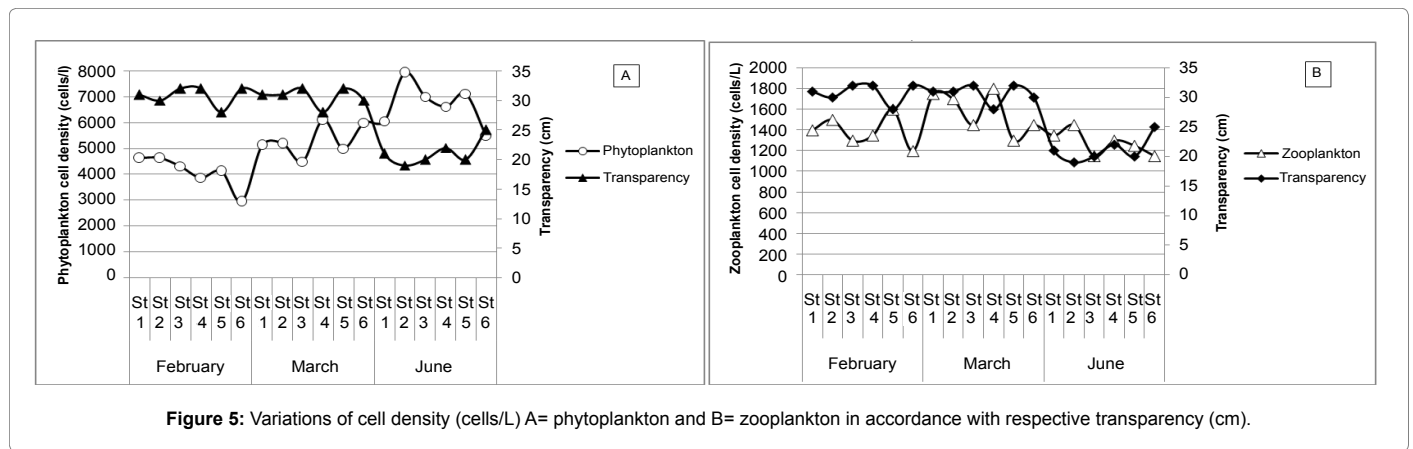


Figure 5: Variations of cell density (cells/L) A= phytoplankton and B= zooplankton in accordance with respective transparency (cm).

Plankton	Group	Months	Evenness	Margalef	Shannon
Phytoplankton	Bacillariophyceae	February	0.90 ± 0.03	2.19 ± 0.22	1.95 ± 0.13
		March	0.92 ± 0.02	2.65 ± 0.21	2.16 ± 0.11
		June	0.87 ± 0.06	3.10 ± 0.45	2.22 ± 0.19
	Cyanophyceae	February	0.55 ± 0.45	0.24 ± 0.19	0.38 ± 0.31
		March	0.47 ± 0.40	0.30 ± 0.14	0.32 ± 0.27
		June	0.57 ± 0.46	0.38 ± 0.32	0.49 ± 0.40
	Chlorophyceae	February	0.65 ± 0.50	0.32 ± 0.18	0.45 ± 0.34
		March	0.82 ± 0.23	0.65 ± 0.24	0.85 ± 0.36
		June	0.65 ± 0.41	0.68 ± 0.50	0.76 ± 0.59
	Coscinodiscophyceae	February	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
March		0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	
June		0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	
Dinophyceae	February	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	
	March	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	
	June	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	
Zooplankton	Copepoda	February	0.95 ± 0.04	1.11 ± 0.22	1.30 ± 0.14
		March	0.96 ± 0.03	1.26 ± 0.29	1.42 ± 0.18
		June	0.94 ± 0.04	1.13 ± 0.51	1.25 ± 0.38
	Cladoceron	February	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
		March	0.63 ± 0.49	0.29 ± 0.22	0.44 ± 0.34
		June	0.49 ± 0.53	0.22 ± 0.24	0.34 ± 0.36
	Rotier	February	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
		March	0.53 ± 0.42	0.27 ± 0.20	0.27 ± 0.20
		June	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	Protozoan	February	0.89 ± 0.09	0.62 ± 0.06	0.62 ± 0.06
		March	0.56 ± 0.44	0.39 ± 0.30	0.28 ± 0.22
		June	0.77 ± 0.38	0.53 ± 0.26	0.53 ± 0.26
Meroplankton	February	0.63 ± 0.49	0.41 ± 0.02	0.44 ± 0.34	
	March	0.65 ± 0.50	0.45 ± 0.35	0.29 ± 0.22	
	June	0.65 ± 0.50	0.36 ± 0.18	0.54 ± 0.27	
Crustacean larvae	February	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	
	March	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	
	June	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	

Table 5: Monthly variations of plankton diversity indices in February, March and June.

index ( $H'$ ) ranged from 1.500 to 3.334 with the mean value of  $2.717 \pm 0.147$ .

Species richness index ( $d$ ) was also higher in Bacillariophyceae because there were about 22 species recorded belonged to this group and deliberately increased richness index. The species richness index ( $d$ ) of Bacillariophyceae ranged from 2.00 (February, station-3) to 3.71 (June, station-4) with the highest mean value which was observed in June ( $3.10 \pm 0.45$ ) (Table 5). The richness index ( $d$ ) becomes lower where a recorded number of species were lower.

Evenness index ( $J'$ ) was used to determine how evenly species are distributed in the community. The highest mean value of evenness was observed in Bacillariophyceae,  $0.92 \pm 0.02$  (March) and lowest in Cyanophyceae,  $0.47 \pm 0.40$  (March) (Table 5).

In zooplankton, highest species diversity ( $H'$ ) was recorded in Copepoda and it ranged from 0.64 to 1.76. The mean value of Copepoda species diversity was  $1.30 \pm 0.14$ ,  $1.42 \pm 0.18$  and  $1.25 \pm 0.38$  in February, March, and June respectively (Table 5). It has resulted from the highest species richness and evenness index. No species were identified from the group Crustacean larvae so it was given no species richness index, no evenness and ultimately, no species diversity index.

The ecosystem of water bodies is continuously changing with an environment which was affecting the composition of the biota. Rivers, reservoirs, and estuaries are constantly going into detour condition due to lack of awareness during discharge of pollutants, river erosion, heavy fishing pressures, navigation, etc. Diversity index is a good indicator to determine the pollution status of these aquatic ecosystems. Species diversity within aquatic communities is closely related to the trophic state of the water body [28]. Being properly identified, measured on the unified basis and monitored variability (or stability) of structural and functional parameters (such as Shannon–Wiener index  $H'$ ) of plankton communities in the estuaries, can serve as an indicator for the modification of ecosystems under the eutrophication/pollution stress [28].

Balloch et al. [29] found the Shannon–Wiener diversity index to be a suitable indicator of water quality. Hendley [30] used the Shannon–Wiener diversity index as pollution index in diatom communities and put forward the following scale: of 0–1 for high pollution, of 1–2 for moderate pollution, of 2–3 for small pollution and of 3–4 for incipient pollution. In the present study, diversity index of diatom ranged from 1.82 to 2.46 and the mean value was 2.10 which indicate small pollution in the water body. But the total phytoplankton diversity ranged from 2.07 to 2.74 during the entire study period with a mean value of  $2.42 \pm 0.19$ . Species diversity index of zooplankton ranged from 1.82 to 2.38 with a mean value of  $2.14 \pm 0.16$ . The diversity index value of plankton greater than 3.00 indicates clean water. Values in the range of 1.00 to 3.00 are characteristics of moderately healthy conditions and values less than 1.00 characterize heavily deterioration condition. It can be said that diversity index values of plankton are within the range of 1-3 indicates the moderately polluted environment of the Meghna River from the present study. There is a similarity found by Ahsan et al. [14] where the pollution status of Hilsa migratory river resulted moderate pollution.

The phytoplankton cell density is a good indicator to determine the trophic status of a particular water body. The mean cell density of phytoplankton was 5372 cells/L and could be classified as oligotrophic. According to the classification scheme proposed by Siokou-Frangou et al. [31]; Pagou [32], oligotrophic systems are defined by this scheme to be systems with phytoplankton cell densities less than 6000 cells/L. Kiteresi et al. [33] studied on the Ramisi-Vanga system with

phytoplankton cell densities ranging only from 194.96 cells/L to 3919.6 cells/L and classified as oligotrophic. In an oligotrophic system, water is in the clear state, but in the Meghna River turbidity was present. The water turbidity can occur due to the sandy bottom, river erosion, navigation. In the study area extreme river erosion occurs and it might be the reason of the turbid water body.

## Conclusion

It may be concluded that cell density of phytoplankton was very low in the present study comparing to the productive ecosystem (104-105 cells/ml). Growth of plankton depends on the availability of nutrients (N, P, and Si) but in the present study phytoplankton cell density was less than 6000 cells/L and by considering that the Meghna estuary considered as Oligotrophic. Bacillariophyceae and Copepoda in phytoplankton and zooplankton respectively, were found in dominant number and showed highest density. According to value of Shannon–Weiner diversity index ( $H'$ ) the Meghna estuary considered as moderately polluted environment.

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