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# Spatial and temporal changes of plankton assemblages in Atrai River, Bangladesh

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**Abstract**
The present study investigates the changes in plankton assemblages and the causal factors at Atrai River in Bangladesh. Monthly sampling of plankton and water quality parameters were performed. Plankton assemblages were characterized with high dominance of phytoplankton (88%), while zooplankton represented only 12% in the plankton community. A total of 49 genera of plankton and 11 genera of zooplankton were identified. The distance-based linear model (DistLM) detected temperature, pH, water transparency and dissolved oxygen ($P$=0.001) as key environmental factors predicting the changes in plankton assemblages in the study region. The changes in abundance and distribution of plankton are primarily driven by the variability of temperature and pH following water transparency and dissolved oxygen in the Atrai River. The outcomes of this study improve our understanding of the variability in plankton community and regulating environmental drivers in the river system.

**Keywords:** Abundance, distribution, phytoplankton, zooplankton, water quality

## 1. Introduction
Bangladesh is renowned for its beautiful geomorphic features, including the massive delta rivers such as the Ganges-Brahmaputra-Meghna river system flowing throughout the country. There are hundreds of small rivers and tributaries with a total length of about 24,140 km in Bangladesh. These rivers are often inter-connected and fall to the Bay of Bengal. The total area of inland water is about 39, 07,488 hectares of which the area of river and estuaries comprises 8, 53,863 hectares [11]. These vast water resources play a significant role in the socio-economic development of the country functioning as the major habitats for the fisheries sector. The fisheries sector contributes 3.57% of the national Gross Domestic Product (GDP) and 25.30% to the agricultural GDP [6]. About 1.6 million people are directly or indirectly lived in the fisheries sector. However, the rivers have been significantly impacted by pollution and several anthropogenic activities in Bangladesh.
The major rivers in Bangladesh are typically originated from India and flow to the south towards the Bay of Bengal. In the past, India constructed a Barrage at Gazoldoba over the Teesta River which is around 100 km upstream of Teesta Barrage (Bangladesh). Moreover, Bangladesh undertook Teesta Barrage Irrigation Project for irrigation purposes which stands across the Teesta River at Dalia-Doani point in Lalmonirhat district and is bounded by the Teesta River on the North, the Atrai River on the West, Shantahar-Bogra railway line on the south and Bogra-Kaunia railway line on the East [21]. Consequently, there is an erratic flow of water with a sharp decline in the total volume of water from upstream of the Teesta River. This trend of steep reductions in flow every lean season is commonly found in this region. The decline inflow of water in the Teesta River subsequently affects the flow of Karatoya and Atrai, and even the Dhepa River. This has caused a change in water quality parameters which has a major influence on the abundance, distribution, and diversity of aquatic organisms including the plankton.
Analysis of the plankton community concerning ecological factors is an important tool to evaluate water quality conditions, as changes in nutrient concentrations determine the variation in species composition. The variability of phytoplankton and zooplankton in the aquatic environment can be potentially affected by water quality. This consequence can impact overall fisheries production in Bangladesh. Several studies on water quality i.e. Physico-chemical

parameter of the water body, ecological, limnological and biological aspects in Dhepa river [5, 20] and Punarbhaba river [12] have been performed in the last. Information on the abundance and distribution of plankton communities and the environmental impacts in the Atrai River is still very limited. Therefore, this study is focused to identify the environmental effects and the underlying causes of changes in plankton abundance in this riverine system.

## 2. Materials and Methods

### 2.1. Study region

The study was conducted at Atrai River in Dinajpur district, Bangladesh (Fig. 1). The Atrai River is originated from Siliguri near Baikanthapur forest, West Bengal of India and flows over Bangladesh directing in the north-western parts. The Atrai River supports numerous aquatic organisms including native small and large fishes to the local people of this region. The river has been critically suffering from water scarcity at the downstream as several dams were constructed at upstream.

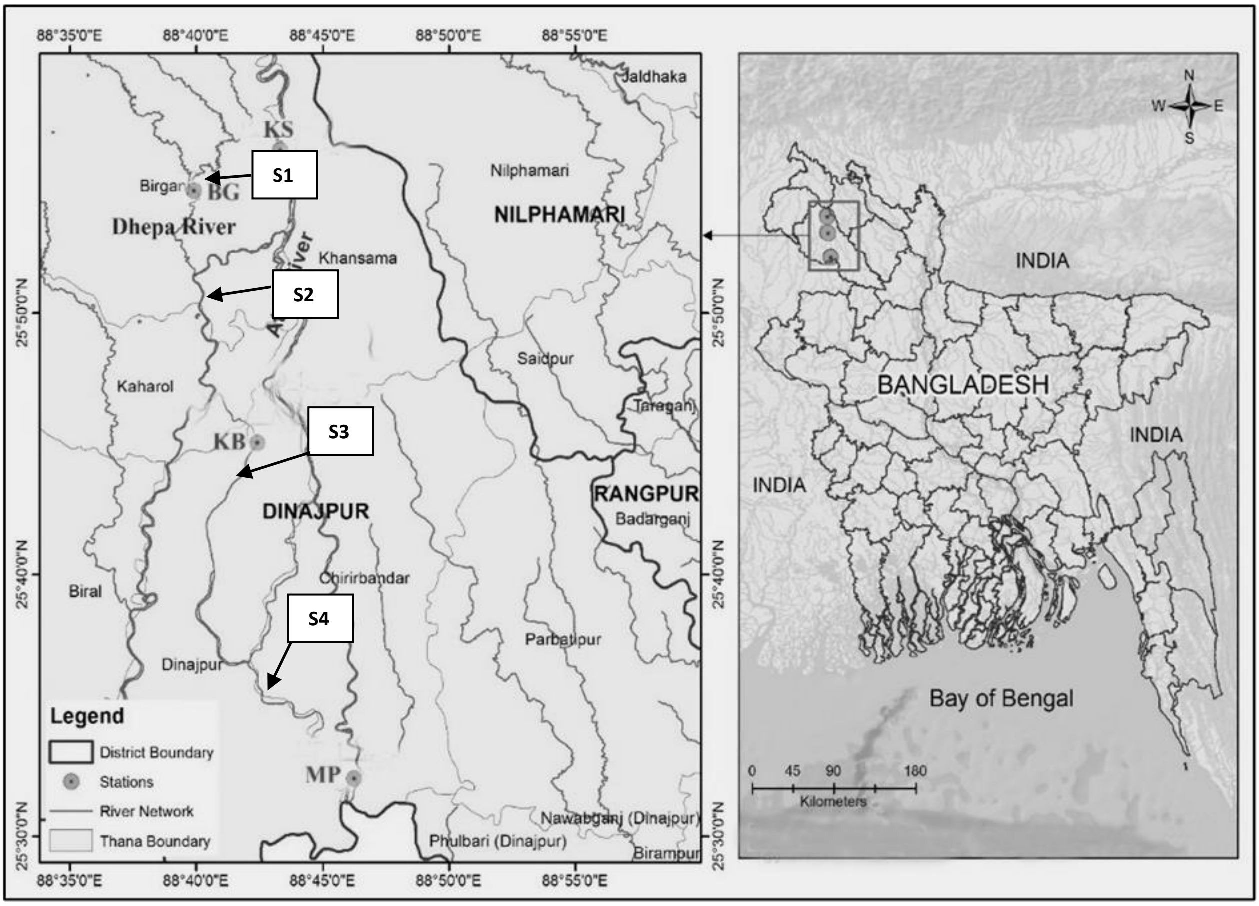



**Fig 1:** Map showing the sampling sites Khansama (S1), Mohonpur (S2), Bhusirbandar (S3), and Uttar Bholanathpur (S4) from the Atrai River in Dinajpur district, Bangladesh

### 2.2. Sample collection

Monthly sampling of plankton was performed using a plankton net (mesh size, 0.04 mm) at four sites Khanshama (S1), Mohonpur (S2) Bhusirbandar (S3) and Uttar Bholanathpur (S4) in Atrai River from Dinajpur district from October 2016 to September 2017 (Fig. 1). Collected samples were immediately preserved in black coated plastic bottles with 10% formalin solution and transported to the laboratory for analysis. Along with plankton sampling, physicochemical variables including dissolved oxygen (DO), water temperature and pH were measured at 30 cm below the water surface using a water quality meter (HANNA) around mid-day. Water transparency was also measured using a Secchi disk. Three replicates were used at each sampling site.

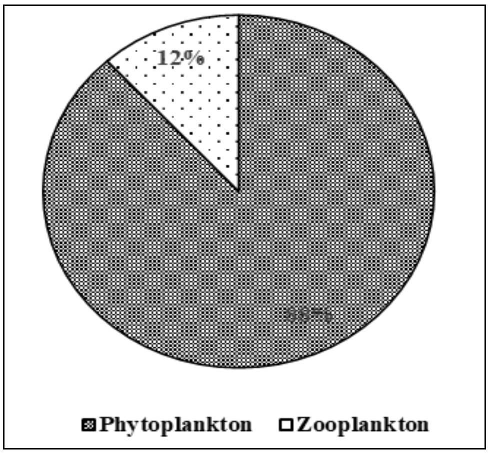
### 2.3. Statistical analysis

All environmental data were tested for normality and homogeneity using Shapiro-Wilk and Levene's test. The normally distributed data were analyzed using one-way analysis of variance (ANOVA) to compare the differences among sites or months. If significant differences were detected, then data were further analyzed using Tukey post hoc tests. These tests were performed using SPSS-IBM 22 version. On the other hand, relative-abundance data of each plankton were transformed into a log(x+1) to down-weight undue influence of highly abundant species [4] and a dummy species was added to adjust for samples [23]. The environmental variables were normalized and used to construct some Euclidean distance resemblance matrices. Permutational analysis of variance (PERMANOVA) was run using the resemblance matrices to test the difference of the relative abundance of plankton (multivariate) among months and sites. The analysis consisted of two factors, including months (fixed, 12 levels) and sites (fixed, 4 levels). When the PERMANOVA showed a significant main effect or interaction among treatments, pair wise comparisons (pseudo-t-test) were used to identify the specific level of difference. Unrestricted permutation was accomplished for each factor and interaction with 999 permutations to detect differences at 5% level of significance [3]. To identify the effect of environmental variables on plankton abundance, a distance-based linear model (DistLM) was performed where the log(x+1)-transformed plankton relative abundance and normalized environmental data were used [4]. A distance-based redundancy analysis (dbRDA) was then plotted to give a visual representation of the influence of environmental variables on the changes in plankton assemblage structure. These tests were performed using PRIMER ver. 6 [10] with the PERMANOVA add on [4].

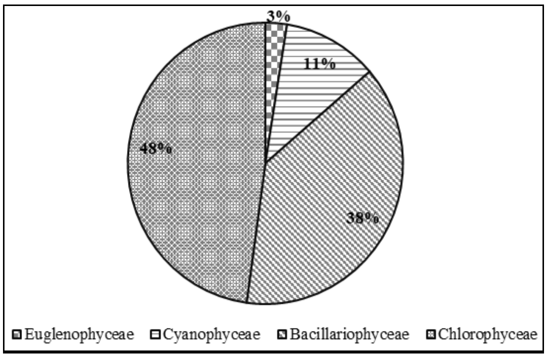
## 3. Results

### 3.1. Composition

Phytoplankton was dominant in the plankton community during the study period in the Atrai River. About 88% phytoplankton and 12% zooplankton comprises the plankton assemblages in this river over the year (Fig. 2a). Chlorophyceae, Bacillariophyceae, Cyanophyceae and the Euglenophyceae were the major phytoplankton groups. Chlorophyceae (48%) was the dominant followed by Bacillariophyceae (38%), Cyanophyceae (11%) and only Euglenophyceae (3%) in the phytoplankton community (Fig. 2b). Similarly, Rotifera (43%), crustacean (24%), Copepoda (17%) and Cladocera (16%) were dominant in the zooplankton community (Fig. 2c) during the study period. About 39 genera of phytoplankton and 11 genera of zooplankton were found from this river. Among the phytoplankton 21 genera of Chlorophyceae, 11genera of Bacillariophyceae, five genera of Cyanophyceae and two genera of Euglenophyceae were identified in the Atrai River (Table 1). Among the zooplankton, six genera of Rotifera, two genera of Cladocera and crustacean and two genera of copepod were found during the study period (Table 1).




A.

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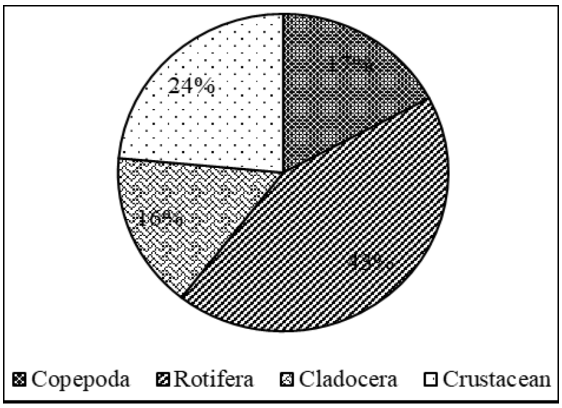


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**Fig 2:** Composition (in per cent) of (a. plankton, b. phytoplankton and c. zooplankton) in the Atrai River during the study period.

**Table 1:** List of plankton recorded from Atrai River during the study period

| Phytoplankton | | | Zooplankton |
|---|---|---|---|
| **Chlorophyceae** | **Bacillariophyceae** | **Cyanophyceae** | **Rotifera** |
| *Ankistrodesmus* | *Astorionella* | *Anabaena* | *Asplanchna* |
| *Botryococcus* | *Cyclotella* | *Aphanocapsa* | *Brachionus* |
| *Chlorella* | *Diatoma* | *Microcystis* | *Keratella* |
| *Closterium* | *Fragillaria* | *Nostoc* | *Lecane* |
| *Coelastrum* | *Melosira* | *Oscillatoria* | *Monosyla* |
| *Cosmarium* | *Navicula* | | *Notholca* |
| *Coscinodiscus* | *Nitzschia* | **Euglenophyceae** | |
| *Hydrodictyon* | *Meridion* | *Euglena* | **Cladocera** |
| *Microspora* | *Surirella* | *Phacus* | *Bosmina* |
| *Oedogonium* | *Synedra* | | *Daphnia* |
| *Plnktosphaeria* | *Tabellaria* | | |
| *Pediastrum* | | | **Crustacean** |
| *Micrasterias* | | | *Nauplius* |
| *Scenedesmus* | | | |
| *Sphaerocystis* | | | **Copepoda** |
| *Spirogyra* | | | *Cyclops* |
| *Stigeoclonium* | | | *Diaptomus* |
| *Ulothrix* | | | |
| *Tettradesmus* | | | |
| *Volvox* | | | |
| *Zygnema* | | | |

### 3.2. Variation in plankton abundance

PERMANOVA showed a significant spatial (PERMANOVA, $P$=0.02) and temporal (PERMANOVA, $P$=0.001) difference in plankton assemblage among the sites and months (Table 2). There was a significant interaction between site and months (PERMANOVA, $P$=0.04). Pair wise comparison determined significant variations among site 1, site 3 and site 4 (Site 1 vs Site 3: PERMANOVA, $P$=0.029, Site 1 vs Site 4: PERMANOVA, $P$=0.003) (Table 3).

**Table 2:** Permanova results for plankton relative abundance collected from the Atrai River from August 2016 to September 2017. This PERMANOVA table includes fixed factors contributing to the changes in prey fish assemblage during this study. The significant difference was set at $P$<0.05.

| Source | df | SS | MS | Pseudo-F | *P(perm)* | perms |
|---|---|---|---|---|---|---|
| Month | 11.00 | 102900.00 | 9354.60 | 15.35 | 0.001 | 997.00 |
| Site | 3.00 | 3027.40 | 1009.10 | 1.66 | 0.02 | 999.00 |
| Monthly site | 33.00 | 23600.00 | 715.17 | 1.17 | 0.04 | 999.00 |
| Residuals | 96.00 | 58518.00 | 609.56 | | | |
| Total | 143.00 | 188050.00 | | | | |

**Table 3:** Permanova results of pair wise comparisons of plankton abundance among the sites in the Atrai River. The significant difference was set at $P$<0.05.

| Groups | t | *P* (perm) | perms |
|---|---|---|---|
| Site 1 vs Site 2 | 1.2059 | 0.187 | 999 |
| Site 1 vs Site 3 | 1.4525 | 0.029 | 999 |
| Site 1 vs Site 4 | 1.6104 | 0.003 | 998 |
| Site2 vs Site 3 | 1.1029 | 0.303 | 998 |
| Site 2 vs Site 4 | 0.88571 | 0.647 | 999 |
| Site 3 vs Site 4 | 1.3288 | 0.074 | 998 |

### 3.3. Variation in water quality

ANOVA showed significant differences in water temperature among the months and the sites with higher water temperatures in July 2017compared to other sampling months in the AtraiRiver (ANOVA, $P$<0.05, Table 4.). Similarly, the water transparency exhibited significant temporal and spatial variations ranges between 12.00 cm to 28.30 cm (ANOVA, $P$<0.05, Table 4).The lowest range of water transparency was observed in August 2017 over the study period. For pH comparison, there was a significant spatial and temporal variation among months and sites. pH was varied from 6.34 to 8.67during the study period. Dissolved oxygen also showed spatial and temporal variation during the study period with different ranges (ANOVA, $P$<0.05, Table 4).

**Table 4:** Water quality parameters (average ± S.E.) at each site in each month from October 2016 to September 2017 in the Atrai River

| Water Quality | Site | Months | | | | | | | | | | | | Level of Significance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct. 16 | Nov. 16 | Dec. 16 | Jan. 17 | Feb. 17 | Mar. 17 | Apr. 17 | May. 17 | Jun. 17 | Jul. 17 | Aug. 17 | Sep. 17 | |
| Water temperature (ºC) | S1 | 29.60±0.06 | 24.73±0.09 | 22.27±0.27 | 19.10±0.10 | 22.33±0.18 | 25.60±0.10 | 29.63±.09 | 28.70±.12 | 31.47±0.07 | 33.10±0.06 | 31.40±0.06 | 30.33±0.18 | * |
| | S2 | 28.30±0.06 | 23.67±0.09 | 21.77±0.13 | 20.33±0.12 | 21.83±0.03 | 24.43±0.09 | 30.27±.09 | 29.70±.06 | 32.70±0.06 | 33.40±0.12 | 30.60±0.21 | 30.70±0.12 | * |
| | S3 | 29.34±0.07 | 26.22±0.09 | 23.00±0.17 | 20.04±0.06 | 22.81±0.09 | 26.23±0.17 | 30.57±.15 | 30.73±.15 | 32.87±0.06 | 33.06±0.17 | 31.49±0.12 | 30.94±0.09 | * |
| | S4 | 29.08±0.09 | 24.87±0.12 | 22.34±0.13 | 19.83±0.09 | 22.33±0.09 | 25.42±0.10 | 30.16±.12 | 29.71±.12 | 32.34±0.06 | 33.19±0.09 | 31.16±0.09 | 30.66±0.12 | * |
| Water transparency (cm) | S1 | 19.30±0.15 | 25.10±0.06 | 23.10±0.06 | 22.23±0.12 | 24.10±0.06 | 23.37±0.09 | 27.13±.13 | 27.33±0.09 | 22.97±2.19 | 18.67±1.20 | 12.33±1.45 | 13.33±0.88 | * |
| | S2 | 20.33±0.12 | 23.10±0.06 | 24.17±0.09 | 23.10±0.06 | 25.23±0.12 | 22.10±0.06 | 25.17±.09 | 26.10±.06 | 24.97±0.74 | 20.00±1.00 | 11.33±1.20 | 12.00±0.58 | * |
| | S3 | 23.43±0.23 | 24.10±0.06 | 21.17±0.09 | 21.13±0.07 | 22.23±0.12 | 24.10±0.06 | 26.23±.12 | 25.23±.12 | 24.10±0.15 | 22.00±0.58 | 12.33±0.88 | 14.67±0.33 | * |
| | S4 | 20.37±0.06 | 19.10±0.09 | 18.17±0.04 | 20.10±0.06 | 21.13±0.09 | 23.17±0.09 | 28.30±.06 | 18.27±.06 | 21.00±0.12 | 17.33±0.06 | 12.00±0.26 | 13.00±0.06 | * |
| pH | S1 | 7.27±0.09 | 6.34±0.03 | 7.31±0.06 | 7.35±0.04 | 8.53±0.09 | 7.52±0.04 | 8.67±.15 | 8.60±0.06 | 7.18±0.04 | 6.52±0.08 | 7.28±0.06 | 7.30±0.06 | * |
| | S2 | 7.30±0.06 | 7.50±0.06 | 7.45±0.09 | 7.77±0.09 | 8.40±0.03 | 8.47±0.03 | 9.30±.25 | 8.96±.07 | 7.30±0.06 | 6.72±0.04 | 7.17±0.07 | 6.60±0.06 | * |
| | S3 | 7.70±0.06 | 7.40±0.06 | 6.82±0.06 | 6.40±0.06 | 6.76±0.04 | 6.60±0.06 | 7.67±.12 | 8.20±.06 | 7.60±0.06 | 7.37±0.12 | 7.80±0.06 | 7.49±0.02 | * |
| | S4 | 7.30±0.12 | 6.25±0.01 | 7.40±0.06 | 8.47±0.09 | 7.82±0.09 | 8.40±0.06 | 8.13±.18 | 8.80±.06 | 7.77±0.09 | 7.80±0.06 | 7.40±0.06 | 7.28±0.04 | * |
| DO (ppm) | S1 | 5.80±0.06 | 6.53±0.09 | 6.60±0.09 | 7.53±0.03 | 8.07±0.09 | 8.07±0.09 | 7.77±.09 | 6.33±.12 | 5.77±0.09 | 5.13±0.13 | 5.37±0.09 | 6.37±0.09 | * |
| | S2 | 6.10±0.06 | 5.60±0.06 | 6.73±0.12 | 8.40±0.15 | 7.63±0.06 | 7.60±0.09 | 8.17±.09 | 5.80±.06 | 5.30±0.12 | 5.27±0.07 | 5.43±0.03 | 6.33±0.03 | * |
| | S3 | 5.80±0.06 | 5.40±0.06 | 8.17±0.07 | 7.73±0.12 | 7.80±0.09 | 8.10±0.06 | 7.37±.09 | 6.60±.15 | 5.20±0.25 | 5.73±0.09 | 5.07±0.12 | 6.33±0.12 | * |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S4 | 6.37±0.09 | 5.80±0.06 | 7.60±0.06 | 8.13±0.03 | 7.97±0.09 | 8.13±0.09 | 8.03±.09 | 5.27±.09 | 5.40±0.06 | 5.80±0.15 | 5.23±0.12 | 5.80±0.06 | * |

*Values indicate a significant difference at 5% significance level based on one way ANOVA followed by Tukey's test.

### 3.4. Effects of environmental factors on plankton abundance

The distance-based linear model (DistLM) analysis indicated that the environmental variables had the significant (*P*=0.001, Table 5) influence on the spatial and temporal variation of plankton assemblage in the study region. Distance-based redundancy analysis (dbRDA) showed that 83% of the variation in plankton assemblage could be explained by the first two axes where the water temperature (43%, Table 5) and pH (23%, Table 5) also contributed the changes in abundance and distribution of this plankton in the study region (Fig. 3). However, dissolved oxygen (17%) and water transparency (17%) equally contributed to the variation in abundance and distribution of plankton in the study region (Fig. 3).

**Table 5:** Distance-based linear model (distLM) sequential results of environmental variables on plankton assemblage.

| Variable | SS | Pseudo-F | DistLM *P* | Proportion | Cumulative |
|---|---|---|---|---|---|
| Water temperature | 248.01 | 108.7 | 0.001 | 0.43 | 0.43 |
| Dissolved oxygen | 98.452 | 61.548 | 0.001 | 0.17 | 0.61 |
| pH | 130.1 | 190.83 | 0.001 | 0.23 | 0.83 |
| Water transparency | 95.445 | 185.6 | 0.001 | 0.17 | 1.00 |

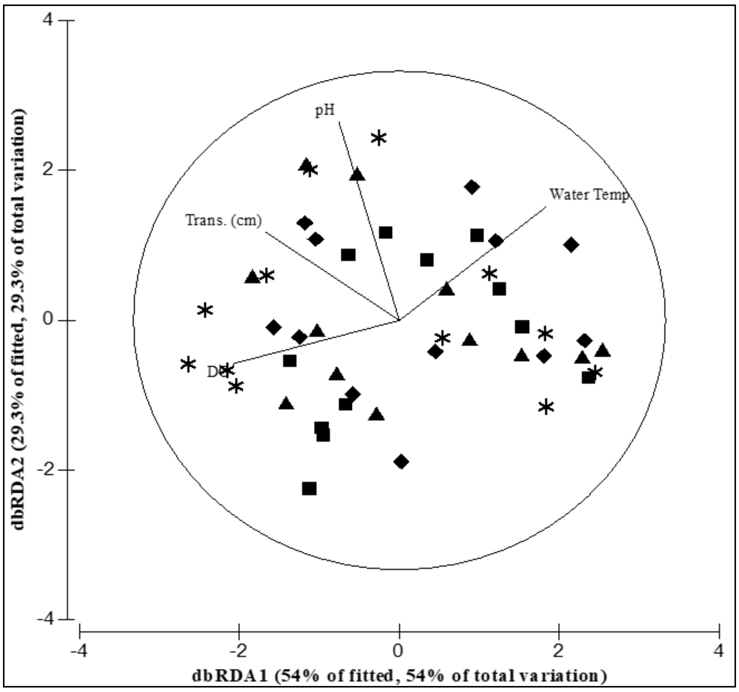


**Fig 3:** Distance-based redundancy analysis (dbRDA) ordination of species-abundance data collected from different sites and regions of the Murray Estuary and Coorong *versus* the predictor variables salinity, water transparency, temperature, pH and DO. Data points are displayed as Site 1 (triangle), Site 2 (asterisks), Site 3 (squares) and Site 4 (diamond).

## 4. Discussion

Abundance and distribution of plankton can be predominantly variable in the lotic water body. In the current study, phytoplankton was a highly dominant group (88%) among the plankton communities in the river. Chlorophyceae and Bacillariophyceae contribute the major portion of the total plankton community in the study regions during the study period. The current study showed that 48% Chlorophyceae followed by 38% Bacillariophyceae occurred in the study regions. This result can be supported by the study where Rakiba and Ferdoushi (2014) [20] found Bacillariophyceae as the second dominant group of phytoplankton in the Dhepa River. In the present study, 21 genera of Chlorophyceae and 11 genera of Bacillariophyceae were identified in the Atrai River. Current results can be correspondence to a study conducted by Mahmud *et al.* (2007) [18] who reported high dominancy of Chlorophyceae in the Mouri River. However, the high abundance and occurrence of phytoplankton in the study region are possibly due to the high nutrients accumulated by the runoff from upstream or nearby agricultural field to the dynamic riverine system.

In the present study, four groups of zooplankton were found in the study regions. Among the zooplankton, rotifera was most dominant and represents about 43% of the total zooplanktons identified. The dominance of rotifera is also reported in previous studies at Meghna [1] and Buriganga River [9] in Bangladesh. However, we found crustaceans as the second largest group in our study as opposed to the findings of Ahmed *et al.* (2003) [1] in a Meghna river Cladocera was reported as the second largest group. The difference in the plankton composition might be attributed by varied location changes, nutrients accumulation or other environmental influences.

Water quality parameters play an important role in the growth and production of fish and other aquatic organisms. The suitable water quality parameters are pre-requisite for a healthy aquatic environment. Primary productivity of a water body depends on physical, chemical and other factors of the environment [19]. However, in the current study significant differences ($P$<0.05) were observed in water parameters among months and sites during the study period. The observed temperature range (19.83-33.19 ºC) can be well suited and referred to as optimal ranges (18.3-37.8 ºC) for production of plankton [7, 15].

There is a significant correlation between the growth of plankton and transparency in different aquatic ecosystems. In the present study, transparency ranges from 12.00 cm. to 28.30 cm. Rahman (1992) [19] reported that the transparency of productive water body 40 cm or less which is similar to this report. The lowest range of water transparency was observed in September 2017 in all sites. However, it is likely occurred due to high plankton production during that time. The pH value in this study showed a significant difference among different months and found to vary from 6.34 to 8.67. Ahmed *et al.* (2010) [2] showed more or less similar result in the Buriganga river estuary in Bangladesh. Besides, the observed dissolved oxygen of the present study (5 to 8.40 ppm) could be well explained and supported a study where dissolved oxygen showed significant difference among months which is supported by the findings conducted in Karnaphuli River [17].

In a river ecosystem, biological productivity is strongly influenced by water chemistry and habitat quality [22, 13]. Seasonal variation of plankton is related to a variety of environmental factors in aquatic environments [8, 14]. The individuality of aquatic environment and plankton assemblage is influenced by the alteration in hydrological parameters such as water temperature, dissolved oxygen, pH, transparency and depth ultimately changing plankton assemblage and structure [16, 14, 13]. In the current study, there was a significant difference in plankton assemblage among the sites and months. The variation in the distribution of plankton assemblage in the Atrai River was mainly driven by the variation in water temperature and pH following DO and water transparency. In this study, it was found that the distribution of plankton in site 1 is significantly different from site 2 and site 3. It might be due to environmental variability among the sites. It is likely to be happened due to accumulation of nutrients from the adjacent of agricultural land. The results suggest that all these parameters showed to have a more or less attributable effect on the variation in plankton assemblage in the dynamic riverine system.

## 5. Conclusion

The plankton assemblages were characterized by the dominance of phytoplankton in the Atrai River. The abundance and distribution of plankton were spatially and temporally variable in the Atrai River. The changes in plankton assemblages could be influenced by environmental factors. Distance-based linear model (DistLM) analysis suggested that water temperature and pH were the most influential variables following the dissolved oxygen and water transparency for predicting the spatial and temporal variation in plankton assemblage. This study enhanced our understanding of the dynamic nature of plankton variability regulated by the water quality and environmental variability in a diverse riverine system in Bangladesh.

## 6. Acknowledgment

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