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Spatio-temporal variation of some physico-chemical parameters and abundance of planktonic community in the Atrai River, Dinajpur, Bangladesh

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Key words: Temporal variation, Seasonal variation, Physico-chemical parameters, Abundance, Plankton

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Abstract

An experiment was conducted to assess seasonal variations of some physico-chemical parameters and plankton community of the Atrai River in Dinajpur district from August 2017 to July 2018. Summer (May to July), autumn (August to October) winter (November to January) and spring (February to April) were the four seasons of the study. Samples were collected monthly from three sampling sites namely, Vushi, Birga and Jhanjira assigned as site-1, site-2 and site-3, respectively. Physico-chemical parameters and plankton abundance did not vary significantly ($P>0.05$) among the sites but varied significantly ($P<0.05$) among the seasons. However, all physico-chemical parameters were within acceptable limits, except transparency. A total 28 genera of phytoplankton comprising Chlorophyceae (11), Bacillariophyceae (11), Cyanophyceae (4) and Euglenophyceae 2) and 9 genera of zooplankton comprising Rotifera (3), Cladocera (3), Copepoda (2) and Nauplius (1) were identified. The highest mean value of total phytoplankton was observed in winter season with a peak in November and January at Site 1 whereas, the lowest mean value was observed in July of summer season at Site 3. The highest mean value of total zooplankton was observed in autumn season with a peak in September in Site 1 while, the lowest mean value was in March of spring season in Site 2. However, total plankton density was the maximum in winter and the minimum in summer where, phytoplankton (79%) dominated over zooplankton (21%). Therefore, the existing water quality and plankton density of the Atrai River would be contributed significantly to enhance the ecosystem productivity.

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Introduction

Bangladesh is a small country in the world but it is rich in fisheries resources. Rivers are the most important freshwater resources, used as many purposes such as, supply of water that provides fertile lands (Mouri *et al*., 2011)., make up the main inland water body for domestic, industrial, and agricultural activities (Singh *et al*., 2004 and Pradhan *et al*., 2009), clean huge loads of waste from industries, domestic sewage and agricultural practices (Datar and Vashistha, 1992 and Das and Sinha, 1993) and so on. The Atrai River is one of the most important rivers flowing in the northern region of Bangladesh, especially in Dinajpur. It has been flowing through the eastern part of Dinajpur town. In the past, it was one of the greatest rivers of north Bengal because it was the main channel by which the waters of the Teesta used to discharge into the Ganga or the Jamuna, but in 1787-88 and later it changed its course and made its way to the Brahmanputra, thereby greatly diminishing the volume of water passing through the Atrai (Saleheen, 2012). Since those days the importance of the Atrai has suffered still further diminution from a tendency to slit up noticeable in many Bengal Rivers. Besides, various anthropogenic processes are degrading the river ecosystem physically, chemically and biologically. However, it is still the most important river in the district as it serves as a perennial source of fishing, even though it is often the cause of flooding in many areas during monsoon.

Plankton are microscopic plants and animals,and used as food for fish and other aquatic organisms. They comprised of primary producers, phytoplankton and secondary producers, zooplankton (Battish, 1992). The phytoplankton population represents the biological wealth of a waterbody, constituting a vital link in the food chain (Boyd, 1982; Hossain *et al*., 2007). They are the best index of the biological productivity and the nature of aquatic habitat (Wickstead, 1965). Their abundance also reflects the average ecological condition and therefore, they may be used as an indicator of water quality (Bhat *et al*., 1999; Saha *et al*., 2000). They are base of the aquatic food web, the primary producers (Battish, 1992) support fishery as nutrition in food web (Rahman and Jewel, 2008). Almost all the aquatic fauna directly or indirectly feed on phytoplankton (for their food) at the early stage of their life cycle. The productivity of the water body largely depends on the amount of phytoplankton in particular (Davies *et al*., 2009). Distribution, abundance and diversity of phytoplankton indicate the nutrient status, more specifically the heath condition of the aquatic system (Farahani *et al*., 2006; Rahman and Hossain, 2009; Bahaar and Bhat, 2011). Species composition and the seasonal variations of planktonic and benthic forms in freshwaters are dependent on interactions between physical and chemical factors (Cetin and Sen, 2004). Higher amount of nutrients can yield eutrophication with its associated problems, such as harmful algal blooms worsening of water quality (Domingues *et al*., 2011). Zooplankton communities are greatly sensitive to environmental variation. Therefore, changes in their abundance, species diversity or community composition can give important indications of environmental change or disturbance. These are susceptible to variations in a wide number of environmental factors including water temperature, light, chemistry (particularly pH, oxygen, salinity, toxic contaminants), food availability (algae, bacteria), and predation by fish and invertebrates.

As the Atrai River is an important river of Dinajpur, and serves a major source of perennial fishing, the fish production can be increased in many folds by conserving the biodiversity of this river, especially the planktonic community that play important roles in fish production. Therefore, the present study was designed to assess the physico-chemical parameters and abundance of plankton community with their variation of the both among space and time (season) of the Atrai River. These research findings will be also helpful to other scientist for further research on water quality and plankton to explore in depth in different ecosystems of Bangladesh.

Materials and methods

Site selection and experimental design

Three sites were selected randomly for sampling along the Atrai River (Longitude 24°29'00" N and

Latitude 89°03'00" E) namely, Vushi, Birga and Jhanjira assigned as site-1, site-2 and site-3, respectively (Fig. 1.). Samples were taken monthly between 8 to 11am with three horizontal replicates throughout one-year study period. The sampling sites were one kilometer away from each other.

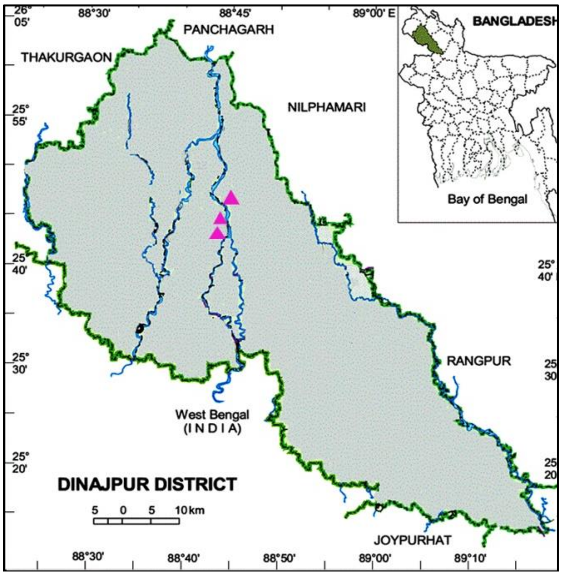

Fig. 1. Geographical position of 3 (three) sampling sites of the Atrai River.

Study Period

The study was conducted for one year, started from August 2017 and ended in July 2018. May to July, August to October, November to January, and February to April were grouped together according to seasons as summer, autumn, winter and spring, respectively.

Water sample collection

Water samples were collected from the selected sites and kept into separate bottles of 250ml to determine different physico-chemical parameters. Bottles were then labeled with site name and date of sampling.

Physico-Chemical Parameters

Temperature

For measuring air temperature, the thermometer was kept in the air for one minute and noted the reading from the thermometer with three replications. Similarly, for measuring water temperature, the thermometer was immersed directly into the water and kept it there for about one minute. Then, the reading of temperature was noted from the thermometer with three replications immediately.

Transparency

Transparency of water was measured with the help of a Secchi disk. This was determined by using the following formula (Lind, 1979):

Secchi disc reading (cm) =A+B/2Where,

A= Dept at which secchi disk disappears

B= Dept at which secchi disk reappears

2= Standard value of equation

Dissolved Oxygen (DO)

The dissolve oxygen concentration of water (mgL^{-1}) was determined using a digital DO meter (YK-22DO).

pH

A manually adjusted pH meter (HANNA instruments, model: HI-8140) was used to determine the pH of water. It was calibrated according to instructional manual provided by the company.

Total Alkalinity

A 50ml water sample was taken in a 250ml conical flask and 2-3 drops of methyl orange indicator was added. The sample was then titrated with 0.02N H_2SO_4 until the color disappears. The titration was continued until the end point with change of color from orange to pink. This was determined by using the following formula:

Total Alkalinity (mg/L) =A*N*50,000/ml of sample used

Where,

A=TotalmL of titrate used

N= Normality of acid (H_2SO_4, 0.02 N)

Collection of plankton sample and preservation

Plankton samples were collected monthly by pooling 10L of water from five locations in each site and passing it through plankton net (mesh size 25µm). Each filtered sample was transferred to a measuring cylinder and made up to a standard volume of 50mL with distilled water and buffered formalin (5%), and preserved in a small, sealed plastic bottle until analysis.

Qualitative and quantitative analysis of plankton

From each 50mL preserved sample, 1mL sub-sample was examined using a Sedgewick-Rafter (S-R) cell and a binocular microscope with phase contrast facilities.Taxonomic classification was identified to genus level using keys from APHA (1992) and Bellinger (1992). Plankton abundance permL of preserved 50mL sample was calculated using the following formula (Azim *et al.*, 2001):

N = (P × C × 100) / L Here, N=number of plankton cells/L of original water,P= number of plankton counted in 10 fields, C= the volume of final concentrate of sample, L=volume of site water sample.

Statistical analysis

One-way ANOVA (Analysis of Variance) was performed for assessing any significant difference of physico-chemical parameters and plankton abundance among the sampling sites as well as months or seasons at a 5% level of significance using SPSS (Statistical Package for Social Science) version 22.0. Graphs and tables were represented in Microsoft excel and Microsoft word, respectively. The assumptions of normal distribution and homogeneity of variances were checked before analysis.

Results and discussion

Water Quality Parameters

The growth and production of fish and other aquatic organisms mainly depends on environmental parameters such as temperature, transparency, depth, DO, pH, alkalinity etc. Temperature is a significant water quality parameter that directly or indirectly influences the availability of dissolved oxygen (Ahmed *et al.*, 2003). Adequate dissolve oxygen is necessary for good water quality, survival of aquatic organism and decomposition of waste by microorganism (Chowdhury and Raknuzzaman 2005). The observed water temperature and dissolved oxygen were varied from 21.02°C to 30.24°C and 8.69mg/L to 9.62mg/L, respectively (Table 1). Begum *et al.* (2007) reported that 18.3 to 37.8°C water temperature is suitable for plankton production. In another study, Khandaker (1986) reported that dissolved oxygen concentration at least 5mg/L for maintaining aquatic life in sound condition and less than 5mg/L are indicator of pollution. Therefore, considering the above statement it may be said that a healthy environment was prevailed in the study area in relation to water temperature and dissolved oxygen content.

Table 1. Mean values (±SD) and ranges of physico-chemical parameters at three sampling sites during study period (N = 108) in the Atrai River.

Parameters	Sampling Sites			Level of Significance at 5%
	Site - 1	Site - 2	Site - 3	
Air Temperature (°C)	26.19±4.56 (18-32)	26.65±4.57 (20-33)	27.57±4.07 (20-34)	NS
Water Temperature (°C)	25.71±5.12 (17-33)	25.94±4.98 (19-34)	26.85±4.38 (19-34)	NS
Transparency (cm)	60.78±10.79 (38-85)	62.61±13.44 (42-102)	56.36±10.36 (35-80)	NS
Depth (m)	3.75^a±2.13 (1.50-8.20)	3.50^a±2.02 (1.50-7.90)	3.58±1.00 (1.60-7.90)	NS
pH	8.14±0.96 (6.4-9.5)	8.17±1.00 (6.6-9.6)	8.38±1.14 (5.9-10.0)	NS
Dissolved Oxygen (mg/L)	9.29±0.75 (7.90-11.00)	9.05±1.04 (7.10-11.50)	9.11±0.89 (8.00-11.40)	NS
Alkalinity (mg/L)	41.22±8.13 (24-50)	39.78±6.80 (22-48)	39.17±8.34 (20-50)	NS

NS= Not significant

Transparency, another physical parameter has a significant relation with the growth of plankton in different aquatic ecosystems (Cetin and Sen, 2004; Begum *et al.*, 2007). The transparency was varied between 54.37cm and 67.74cm; and the highest mean depth (6.66m) was recorded in August of autumn season in Site 1 and the lowest mean depth (1.95m) was recorded in May of summer season in the same site (Table 2). Ferdoushi and Rakiba (2014) found the highest depth in September following rainfall which was more or less similar to the present findings. However, in another study, Stepenuck *et al.* (2002) stated that transparency should be 40cm or less in a productive water body which was dissimilarin to the finding of the present study. It might be due to difference in geographical location, season, sampling time, higher consumption of phytoplankton by phytophagus fishes and so on. The pH of a water body is very important in determination of water quality since it affects other chemical reactions such as solubility and metal toxicity (Dara 2002). According to Swingle (1967) suitable pH range for fish culture is 6.5-9. The mean values of pH varied from 7.67 to 9.42 throughout the study period which was more or less identical to the finding of the above author. Total Alkalinity of water is a measure of weak acid present in it and of the cation balanced against them (Sileika *et al.*, 2006). The mean values of total alkalinity varied from 29.18-45.19mg/L during the study period (Table 1). Mairs (1966) stated that total alkalinity of a waterbody is 40 ppm or more considered more productive than waterbody having less alkalinity. Therefore, total alkalinity of the study area indicated that the waterbody was a productive one.

Table 2. Mean values (±SD) and ranges of physico-chemical parameters in four seasons during study period (N=108).

Parameters	Sampling Seasons				Level of Significance at 5%
	Autumn (Aug.-Oct.)	Winter (Nov.-Jan.)	Spring (Feb.-Apr.)	Summer (May-Jul.)	
Air Temperature (°C)	$31.04^{d}\pm 1.83$ (28-34)	$22.04^{a}\pm 2.25$ (18-27)	$25.04^{b}\pm 3.52$ (20-31)	$29.11^{c}\pm 2.81$ (24-33)	*
Water Temperature (°C)	$30.24^{a}\pm 1.1$ (27-33)	$21.02^{c}\pm 2.29$ (17-26)	$24.02^{b}\pm 3.45$ (19-30)	$29.39^{a}\pm 3.73$ (23-34)	*
Transparency (cm)	$55.48^{bc}\pm 8.85$ (35-70)	$67.74^{a}\pm 13.58$ (38-102)	$62.07^{ab}\pm 9.47$ (45-85)	$54.37^{c}\pm 9.98$ (38-72)	*
Depth (m)	$6.66^{a}\pm 1.34$ (3.7-8.2)	$3.64^{b}\pm 0.65$ (2.8-5.5)	$2.2^{c}\pm 0.44$ (1.5-3.0)	$1.95^{c}\pm 0.17$ (1.5-2.3)	*
pH	$7.67^{b}\pm 0.53$ (5.9-8.8)	$9.42^{a}\pm 0.34$ (8.7-10)	$7.73^{ab}\pm 1.14$ (6.4-9.8)	$8.10^{b}\pm 0.79$ (6.7-9.1)	*
Dissolved Oxygen(mgL^{-1})	$8.69^{c}\pm 0.96$ (7.1-11.0)	$9.62^{a}\pm 1.00$ (8.1-11.5)	$9.44^{d}\pm 0.67$ (8.2-10.4)	$8.86^{bc}\pm 0.57$ (8.0-10.2)	*
Alkalinity (mgL^{-1})	$29.18^{c}\pm 6.75$ (20-50)	$41.85^{b}\pm 3.28$ (36-48)	$45.19^{a}\pm 2.90$ (40-50)	$44.0^{ab}\pm 3.72$ (36-50)	*

*Values with different superscript letters in the same row indicate a significant difference at 5% level of significance based on one-way ANOVA followed by Tukey's test.

Abundance and variation of plankton community

It is almost well established that the planktons can be an index to compare the relative productivity and fishery potential of different water bodies. They play an important role in the food chain of fishes. The abundance of plankton population (phytoplankton and zooplankton) and their different groups did not vary significantly ($P>0.05$) among the sampling sites (Table 3). However, significant ($P<0.05$) variations among different seasons were observed on the abundance of plankton as well as their groups during the study period (Table 4). Phytoplankton (Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae) and zooplankton (Rotifera, CladoceraCopepoda and crustacea) were the main planktonic community of the Atrai River. A total of 28 genera of phytoplankton belongingto Chlorophyceae (11), Bacillariophyceae (11), Cyanophyceae (4) and Euglenophyceae (2)and 9 genera of zooplankton belonging to Rotifera (3), Cladocera (3), Copepoda (2) and Nauplius (1) was identified during the study period (Table 5) which was almost similar to the findings of Kamal *et al.* (2010). The highest mean value of total phytoplankton ($42.54\pm 7.15\times 10^{3}$ cells/L) was observed in winter season with a peak value in November and January at Site 1 and the lowest mean value ($17.51\pm 3.7\times 10^{3}$ cells/L) was observed in summer season with the lowermost value in July at Site 3 (Fig. 2.). These findings were more or less identical to the findings of Jain *et al.* (2018) who recorded the maximum phytoplankton diversity and density in winter, moderate in summer and minimum in monsoon. In addition, Malik and Panwar (2014) recorded the maximum values of phytoplankton in winter and the minimum during rainy season. The highest mean value of total zooplankton ($8.07\pm2.36\times10^3$ cells/L)was observed in autumn season with peak value in September in Site 1 followed by total zooplankton ($7.96\pm2.85\times10^3$ cells/L) with a peak value in July of summer season in Site 3, and the lowest average value ($5.09\pm1.68\times10^3$ cells/L) was in March of spring season with the lowermost value in March of Spring season in Site 2 (Fig. 3.). These findings were more or less comparable to the findings of Chowdhury *et al.* (2007) who found two peak seasons of zooplankton, one in the month of August to October and another in the month of May in Borobila *beel* of Rangpur district.The highest mean value of total plankton ($48.83\pm7.80\times10^3$ cells/L) was noticed in winter season with a peak in January at Site 1 and the lowest mean value (22.96±3.32×103 cells/L) was observed in summer season with the lowermost in May at Site 2 (Fig. 4.). The highest and the lowest values of total plankton might be reflected by the highest and lowest values of phytoplankton, respectively during the study.

Table 3. Mean values (±SD) and ranges of plankton groups ($\times10^3$ cells/L) at 3 sampling sites during study period.

Plankton groups($\times10^3$ cells/L)	Sampling Sites			Level of Significance at 5%
	Site 1	Site 2	Site 3	
Bacillariophyceae	9.85±4.85 (4-21.5)	10.00±4.38 (5-23)	8.76±4.06 (3-19.5)	NS
Chlorophyceae	11.33±5.98 (4-25)	8.98±6.13 (2.52-29)	9.70±5.46 (3.52-24.5)	NS
Cyanophyceae	3.86±2.34 (1-10)	3.30±1.96 (0.5-7.5)	3.55±2.49 (5-11)	NS
Euglenophyceae	1.94±1.60 (0-5.5)	2.07±2.07 (0-8.5)	1.93±1.48 (0-7.5)	NS
Rotifera	2.88±1.67 (1-7)	2.40±1.53 (0-5.5)	2.70±1.77 (0.5-8)	NS
Cladocera	2.11±1.32 (0.0-5.5)	1.72±1.17 (0-5)	2.34±2.11 (0.5-10)	NS
Copepoda	1.38±0.97 (0-3.5)	1.27±0.82 (0-3)	1.25±0.86 (0-3)	NS
Crustacea	4.43±1.81 (1-8)	3.77±1.61 (1-7)	4.36±2.01 (1-10.5)	NS
Total phytoplankton	26.98±11.95 (12.5-54.5)	24.36±11.50 (12.5-60.5)	23.95±10.65 (12-55.5)	NS
Total zooplankton	7.32±2.21 (3-12.5)	6.18±2.35 (1.5-12)	7.06±2.95 (1.5-12)	NS
Total plankton	34.30±12.53 (18-65)	30.54±11.07 (18.5-64.5)	31.02±10.61 (17-60)	NS

NS= Not Significant

Table 4. Mean vales (±SD) and ranges of plankton groups ($\times10^3$ cells/L) in four seasons during study period.

Plankton groups ($\times10^3$ cells/L)	Sampling Season				Level of Significance at 5%
	Autumn	Winter	Spring	Summer	
Bacillariophyceae	$7.61^b\pm1.91$ (4.5-13)	$15.90^d\pm3.50$ (8.5-23)	$7.64^c\pm2.07$ (4-13.59)	$6.98^a\pm2.08$ (3-11.5)	*
Chlorophyceae	$8.07^c\pm2.49$ (3.5-12.5)	$18.83^d\pm4.32$ (12-29)	$6.76^b\pm2.12$ (3.5-11.5)	$6.37^a\pm2.03$ (2.5-10.5)	*
Cyanophyceae	$2.61^b\pm1.43$ (.5-6)	$6.52^d\pm2.08$ (2-11)	$2.29^a\pm.95$ (.5-4)	$2.87^c\pm1.31$ (1-5.5)	*
Euglenophyceae	$4.18^d\pm2.14$ (0-8.5)	$1.28^b\pm.85$ (0-3)	$1.16^a\pm.89$ (0-3)	$1.29^c\pm1.04$ (0-4)	*
Rotifera	$4.31^d\pm1.72$ (1.5-8)	$1.68^a\pm.76$ (0-4)	$1.85^b\pm1.32$ (0-5)	$2.81^c\pm1.22$ (1-5.5)	*
Cladocera	$1.61^b\pm.95$ (0-3.5)	$1.67^c\pm1.16$ (0-5)	$1.50^a\pm.72$ (0-2.5)	$3.46^d\pm2.7$ (.5-10)	*
Copepoda	$1.06^b\pm.68$ (0-2)	$2.17^d\pm.87$ (0-3.5)	$0.95^a\pm.57$ (0-2)	$1.06^c\pm.78$ (0-3)	*
Crustacea	$3.76^b\pm1.63$	$4.61^c\pm1.59$	$3.24^a\pm1.31$	$5.15^d\pm2.4$	*

Plankton groups (×10³ cells/L)	Sampling Season				Level of Significance at 5%
	Autumn	Winter	Spring	Summer	
	(1-6.5)	(2-8)	(1-5.5)	(2-10.5)	
Total phytoplankton	22.48^{c}±4.29 (15-29.5)	42.54^{d}±7.15 (31.5-60.5)	17.87^{b}±2.92 (12-23)	17.51^{a}±3.7 (12-27.5)	*
Total zooplankton	8.07^{d}±2.36 (3.5-12.5)	6.30^{b}±1.98 (2.5-11.5)	5.09^{a}±1.68 (1.5-9)	7.96^{c}±2.85 (4-15.5)	*
Total plankton	30.55^{c}±4.96 (20-39.5)	48.83^{d}±7.80 (37.5-65)	22.96^{a}±3.32 (17-28)	25.48^{b}±42 (18-38.5)	*

*Values with different superscript letters in the same row indicate a significant difference at 5% significance based on one-way ANOVA followed by Tukey's test.

Table 5. List of plankton recorded from the Atrai River during the study period.

Phytoplankton			Zooplankton
Bacillariophyceae	Chlorophyceae	Cyanophyceae	Rotifera
Cyclotella	*Chlorella*	*Microcystis*	*Keratella*
Actinella	*Actinastrum*	*Anabaena*	*Asplanchna*
Asterionella	*Ankistrodesmus*	*Nostoc*	*Brachionus*
Diotoma	*Ceratium*	*Oscillatoria*	Cladocera
Fragillaria	*Closterium*	Euglenophyceae	*Daphnia*
Navicula	*Pediastrum*	*Euglena*	*Sida*
Nitzschia	*Microspora*	*Phacus*	*Moina*
Surirella	*Spirogyra*		Copepoda
Synedra	*Ulothrix*		*Cyclops*
Tabellaria	*Volvox*		*Diaptomus*
Coscinodescus	*Zygnema*		Crustacean Larvae
			Nauplius

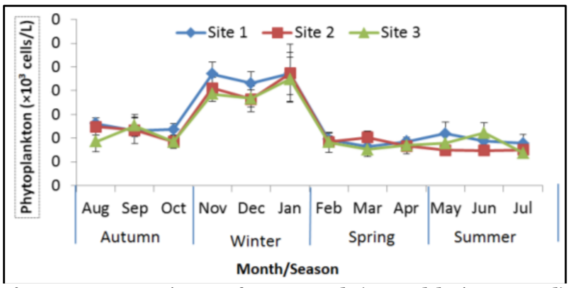

Fig. 2. Comparison of temporal (Monthly/Seasonal) variations of total phytoplankton abundance (×10³ cells/L) in the sampling sites.

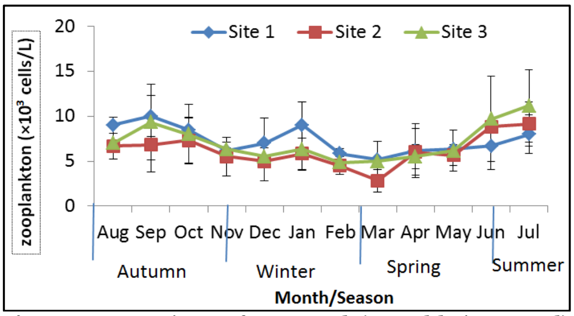

Fig. 3. Comparison of temporal (Monthly/Seasonal) variations of total zooplankton abundance (×10³ cells/L) in the sampling sites.

The mean contribution of phytoplankton was about 79% in all sampling spots and zooplankton contributed the rest (Fig. 5.). Rahman *et al.* (2012) reported that percent composition of phytoplankton ranged from 76.0% to 93.6% while, they conducted research in the Meghna river.

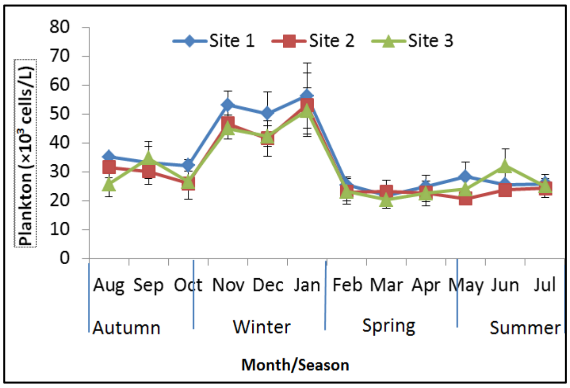

Fig. 4. Comparison of temporal (Monthly/Seasonal) variations of total plankton abundance (×10³ cells/L) in the sampling sites.

In another study, Rahman (1992) found that the major contribution of phytoplankton was over 97.0% and the lowest concentration of zooplankton ranged from 0.13% to 2.4% at three stations in the Guala river of Uttar Pradesh, India. During the study period, phytoplankton was dominant over zooplankton which was more or less agreed to the above findings. It is reported that Chlorophyceae was the most dominating group and Bacillariophyceae was formed 2nd place among total phytoplankton abundance from the Mouri river of Khulna (Mahmud *et al.*2007). Similar result was found by Kamal *et al.* (2010) who reported that Chlorophyceae was the most abundant group, Bacillariophyceae was placed in 2nd position, and Euglenophyceae was the least abundant group among the phytoplankton group in freshwater prawn post larvae rearing ponds. These findings were more or less identical to the present study. Crustaceae (6) was the most dominating group than Rotifera (5) during the study period. Kamal *et al.* (2010) found similar results during their study. In this investigation, it was noticed that the dominant Chlorophyceae was high in winter season and low in both autumn and summer season and a lesser dominant Bacillariophyceae was high in spring season and low in autumn season. Euglenophyceae was high in autumn and low in winter and Cyanophyceae was high in summer and low in autumn season (Fig. 6.). Jain *et al.* (2018) reported that Chlorophyceae was the maximum in the month of November to January and the minimum in June to October while, Bacillariophyceae was the maximum in winter season and the minimum in summer season in the Alaknanda River in Garhwal region of Uttarakhand. Therefore, the maximum abundance of Cholorophyceae in the present investigation was comparable to the above findings but unalike in case of Bacillariophyceae. It might be due to the difference in combination of physical, chemical and biological factors that determine the distribution of the Bacillariophyceae in Rivers (Jain *et al.*, 2018).

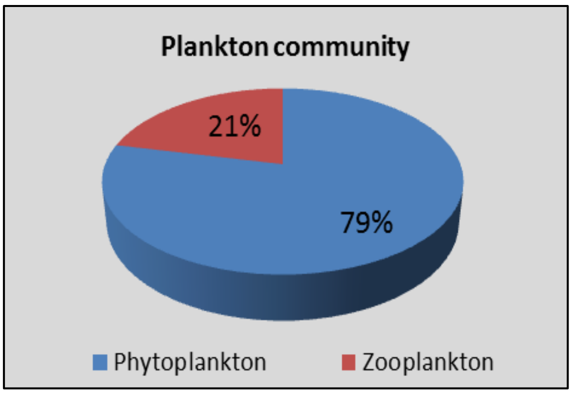

Fig. 5. Percentage composition of plankton community of the Atrai River during the study period.

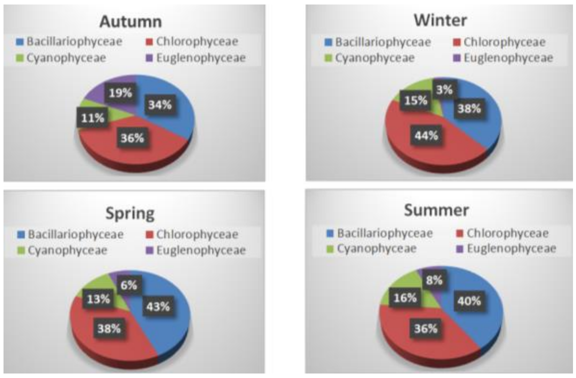

Fig. 6. Phytoplankton composition of each group in four seasons of the Atrai River.

Among different groups of zooplankton, the most dominant crustacean larvae was higher in winter and lower in spring season whereas, the lesser dominant, Rotifera was higher in autumn season and lower in spring season; Cladocera was higher in summer and lower in spring; Copepoda was higher in winter and lower in spring and Crustacean larvae were higher in winter and lower in autumn season (Fig. 7.). However, the density of total zooplankton was higher in autumn season and lower in spring season in the present study.

These findings are more or less comparable to the findings of Chowdhury *et al.* (2007) who observed two peaks of zooplankton abundance, one in the months of August to October and another in the month of May. From the present study, it was found that all physico-chemical parameters were varied according to season but not to the sites.

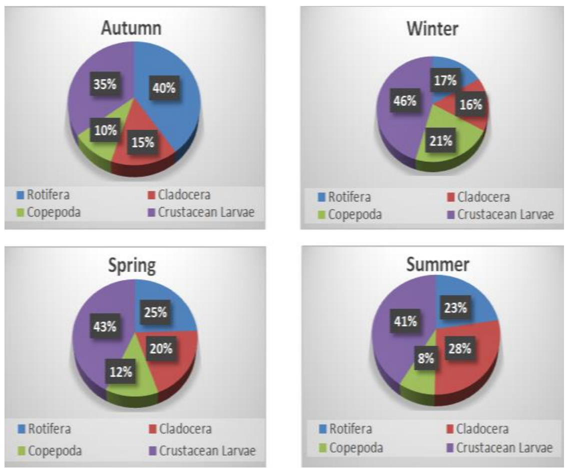

Fig. 7. Zooplankton composition of each group in four seasons of the Atrai River.

Conclusion

To assess any appreciable change of water quality parameters and plankton abundance in response to different sites and seasons, a large number of samples were analyzed in this experiment which may become very important for understanding the variability of benthic organisms of the Atrai River. In addition, the study will provide base line information regarding variation of some physico-chemical parameters and planktonic community among space and season in the river that may also be helpful to assess the level of pollution of the water body or other further research works.

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Conflict of interest

The authors declare that there is no conflict of interest.

Contribution of the authors

MA Salam- Sample collection and manuscript (MS) preparation; MR Haque-Research supervision and MS preparation; KC Roy- MS preparation and data analysis; MAS Jewel- Data analysis and MS evaluation; and MA Samad- MS preparation and evaluation.

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