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SEASONAL VARIATION OF PHYTOPLANKTON ABUNDANCE AND WATER QUALITY PARAMETERS IN JAMUNA RIVER

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Abstract

The study presents the abundance of phytoplankton, chlorophyll *a* content, physicochemical parameters and water nutrients of the Jamuna River. Results revealed that the mean highest and the lowest surface water temperature were measured 33.7°C and 24.0°C in the wet and the dry season. The mean highest transparency was recorded 32.42 cm and the lowest transparency (15.14 cm) was observed in the dry and the wet season. The highest TSS (0.0304 mg/L) was recorded in the wet season while the lowest (0.021 mg/L) in the dry season. The water of the river was recorded alkaline where the pH fluctuated from 7.55 to 7.30 in the wet and the dry season, respectively. The lowest average DO (2.59 mg/L) was found in the wet season, whereas the highest (3.91 mg/L) in the dry season. The maximum and the minimum nitrate concentrations were found 0.157 and 0.129 mg/L followed by ammonium 0.3134 and 0.2244 mg/L and phosphate 1.13 and 0.068 mg/L in the wet and the dry season, respectively. The minimum Chlorophyll *a* content (0.008 mg/L) was observed in the wet season while the maximum (0.138 mg/L) was observed in the dry season. Altogether 11 species of phytoplankton were recorded representing 7 species of Diatoms (Bacillariophyceae), 3 species of Dinoflagellates (Dynophyceae) and 1 species of Cyanobacteria (Cyanophyceae). The recorded phytoplankton density was found the maximum (56570.9 cells/L) and the minimum (36881.99 cells/L) in the dry and wet season, respectively. Phytoplankton density showed significant positive correlation with water transparency, DO and Chlorophyll *a* content ($r = 0.830$, $p < 0.01$; $r = 0.862$, $p < 0.01$ and $r = 0.862$, $p < 0.01$), respectively.

Keywords: Chlorophyll *a*, Nutrients, Phytoplankton abundance, Physicochemical parameters

Introduction

Phytoplanktons are the primary producer where physicochemical parameters have an immense influence on their production (Edward and Ugwumba, 2010). Nutrient concentrations and its availability are obvious factors controlling phytoplankton biomass

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where the distributional pattern of nutrient depends on the surface runoff and seasonal fluctuation (Jacquet *et al.,* 2006; Saifullah *et al.,* 2014). In freshwater bodies, nutrients play a major role as their excesses lead to eutrophication. Phosphorus and Nitrogen are nutrients that act as limiting nutrients for aquatic plant and algal growth (Kaur and Singh, 2012). Chlorophyll *a* is the major photosynthetic pigment in most of the phytoplankton. The content of chlorophyll *a* in the phytoplankton cells changes with nutrients and environmental factors. Therefore, it is essential to know about the effective factors for controlling chlorophyll content of water for ecosystem management (Balali *et al.,* 2013). Phytoplankton, the most important biological organisms in nature on which the entire array of life depends is the integral component of the riverine ecosystem. It is the bio-indicators of ecosystem health status (Komala *et al.,* 2013). Phytoplankton is vital and important communities which act as producer to the primary food supply in any aquatic ecosystem. They are the initial biological components from which the energy is transferred to higher organisms through the food chain (Tiwari and Chauhan, 2006; Saifullah *et al.*, 2014). They can convert inorganic material, such as nitrate and phosphate, into new organic compounds (e.g., lipids and proteins) through photosynthesis (Ishaq and Khan, 2013). The phytoplankton community shows high or low diversity with the seasonal fluctuation of different ecological factors which indicates the diversity in ecological niches (Joshep *et al.,* 2011). The variability of phytoplankton with the seasonal changes in the aquatic environment is very much necessary for the maintenance of water quality and sustainable aquaculture (Akter *et al.,* 2015). Any disturbance in their community structure directly decreases its productivity (Desai *et al.,* 2008). The Jamuna is a diverse river and plays an important role in fisheries of Bangladesh. Phytoplankton production is a determinant of fish production and acts as a remarkable biological factor in the fluctuation of stock. The addition of various kinds of pollutants and nutrients through some external agencies like sewage, industrial effluents, agricultural run-off etc. into the water bodies bring about a series of changes in the physicochemical characteristics of water, which have been the subject of several investigations (Maheshwari *et al.,* 2011). Therefore, observation of phytoplankton abundance in relation to water quality parameters is essential to assess the overall ecosystem health. This research was designed to measure the physicochemical parameters, nutrients, chlorophyll *a* content and the abundance of phytoplankton in the water of the Jamuna River.

Materials and Methods

Study area

The study was conducted in downstream of Jamuna River during the period from August 2016 to July 2017. The water samples were collected from five sampling stations of the Jamuna River mentioned as Hard Point (St-1), Mati Shaheber Ghat (St-2), Kata Wabda (St-3), Bilutia (St-4) and Jamuna Bridge (St-5). The geographical locations of stations were as follows, St-1 (24°28.72 N and 89°42.75 E), St-2 (24°27.53 N and 89°43.26 E), St-3 (24°26.92 N and 89°42.96 E), St-4 (24°24.89 N and 89°44.70 E) and St-5 (24°23.81 N and 89°43.89 E). The distance within two stations was maintained 2 km approximate (Fig.1).

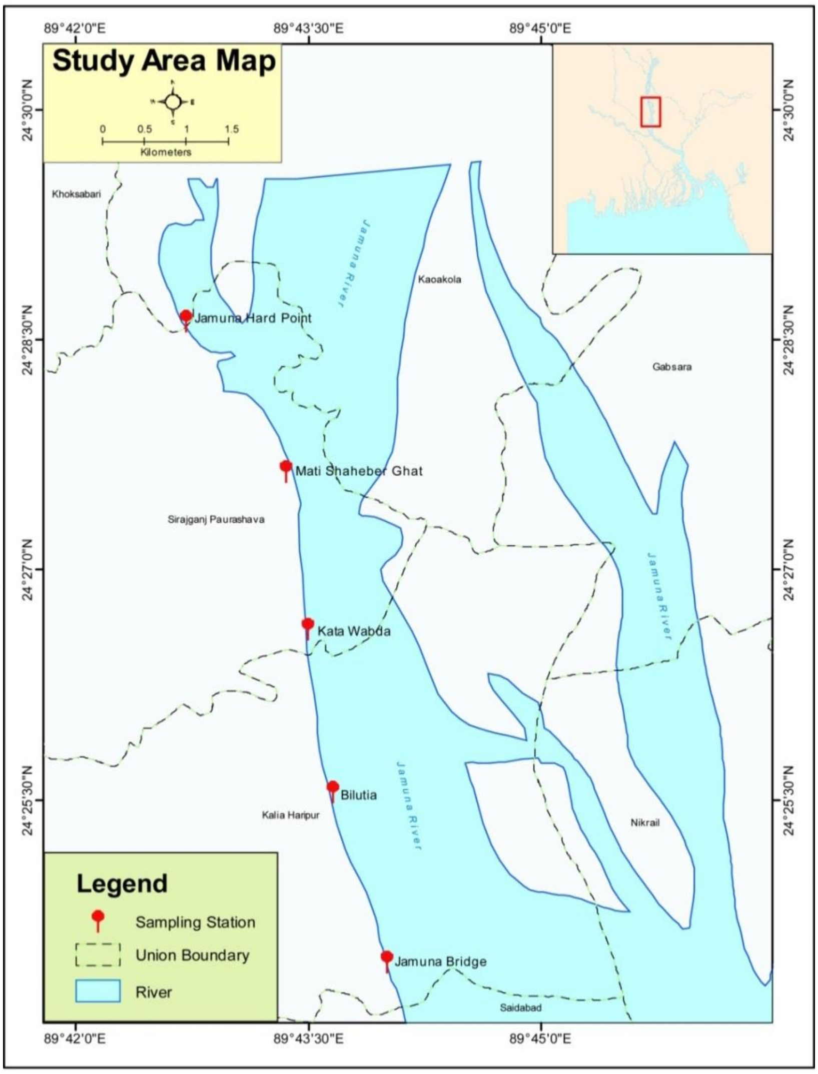

Fig.1. Map showing the study area of Jamuna River

Sample collection

Water samples were collected in acid-washed 500 mL plastic bottles with double stoppers from each sampling station. Phytoplankton samples were collected from the surface water by horizontal towing of Phytoplankton Net (mesh size 25 µm) in triplicates. The collected samples were preserved immediately in 5% neutralized formalin solution.

Sample analysis

The physicochemical parameters like water temperature were measured in-situ by using Digital Thermometer (Model: SH-113V1), whereas transparency was measured by the Secchi disc method. Total Suspended Solid was determined by using the Standard Method (Degen, 1956) in the laboratory. *In-situ* value of pH was determined by the digital pH meter (Model pH Scan WP 1, 2). Dissolved Oxygen was determined by Digital DO meter (Model: D, 46974). For analysis of water nutrients, samples were filtered using Millipore Filtering System (MFS) and analyzed for dissolved inorganic nitrate, ammonium and phosphate following the methods of Kitamura *et al.*, (1982), Weatherburn (1967) and Parsons *et al.* (1984), respectively. Chlorophyll *a* content was estimated following the method developed by Coombs and Hall (1982). Quantitative analysis and numerical estimation of phytoplankton abundance were done following the method of Sukhanova (1978) and Newell and Newell (1977), respectively. Identification of phytoplankton was made with the help of standard method described by Botes (2001), Verlencar and Desai (2004). The high-resolution microscope (Micros Austria) aided with a camera was used with 10x magnification for imaging towards identification.

Results and Discussion

Physico-chemical parameters of water

Temperature

Surface water temperature was measured from 32.0 ± 0.81°C to 35.5 ± 0.51°C in the wet season and 23.5 ± 0.2°C to 25.1 ± 0.86°C in the dry season during the study period in all the sampling stations (Fig. 2). The water temperature recorded from the study area was found to be higher in the wet season compared to the dry season.

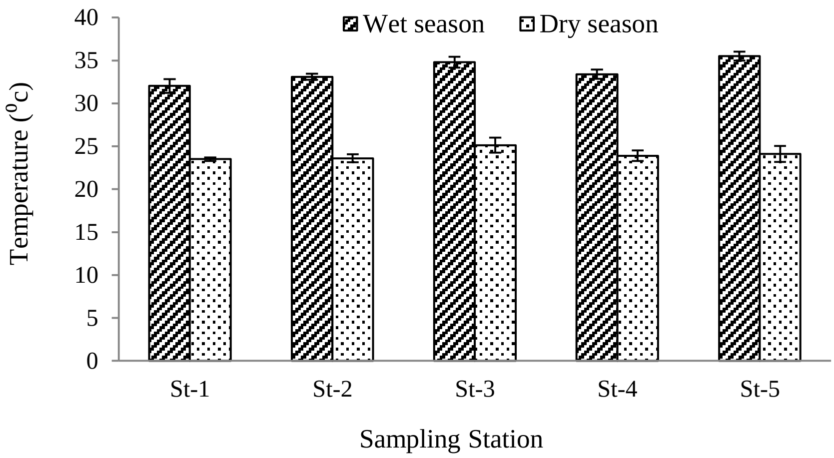

Fig. 2. Temperature variation at five sampling stations of Jamuna River.

However, the range of water temperature in the dry season is within the acceptable limit that indicates the Jamuna River is almost suitable habitat for aquatic organisms, particularly fishes. In the case of surface water temperature, the Department of Environment (DoE) standard for sustaining aquatic life is 20°C to 30°C both in the dry and the wet *season* (Bhaumik *et al.,* 2006). The variation is mainly related to the temperature of atmosphere and weather conditions. A higher temperature during summer could be due to greater heating (Adebowale *et al.*, 2008).

Transparency

During the study period, transparency varied from 13.2 ± 0.62 cm to 16.5 ± 0.25 cm and 30.6 ± 0.66 cm to 34.1 ± 0.15 cm in the wet and dry season, respectively (Fig. 3). The minimum transparency was found during the wet season, and it might be due to river bank erosion, surface runoff, and various anthropogenic activities. The maximum transparency was observed during the dry season, and it might be due to the lack of sufficient river water flow and stagnant condition of the water. Transparency showed a significant negative relationship with water temperature (r = –0.966, $p < 0.01$) in Table 3. The transparency of productive water bodies should be 40 cm or less (Rahman, 1992). According to Lazur (2007), transparency of water ranging from 20-30 cm is acceptable for a fish culture that indicates optimal plankton production. The transparency observed during the study is within the acceptable limit. Thus, it can be easily understood that the water of the Jamuna River is suitable for the sustenance of aquatic organisms, including fishes.

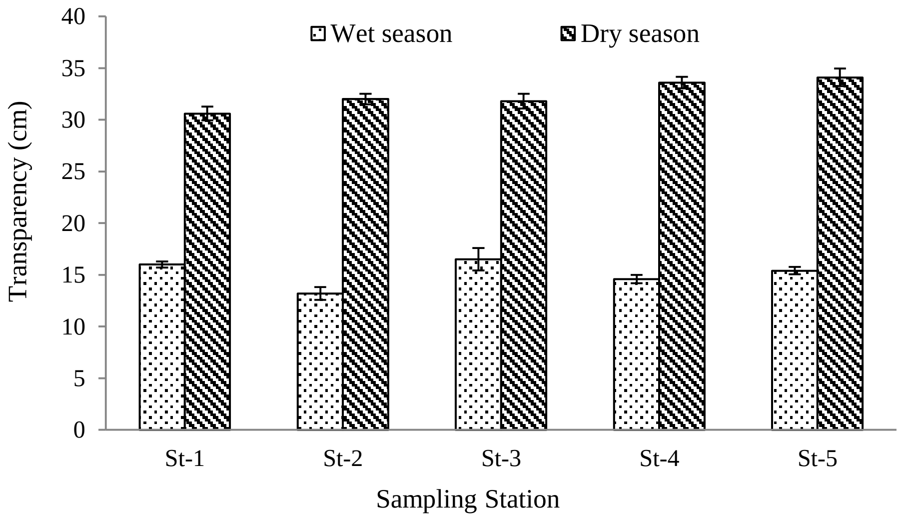

Fig. 3. Transparency variation at five sampling stations of Jamuna River.

Total suspended solids (TSS)

The range of TSS was found 0.016 ± 0.01 mg/L to 0.06 ± 0.01 mg/L and 0.013 ± 0.005 mg/L to 0.03 ± 0.02 mg/L in the wet and dry season, respectively (Fig. 4). The present study revealed that TSS remained higher in the wet season compared to the dry season. According to Gebreyohannes *et al*. (2015), the TSS content of water depends on the amount of suspended particle, soil, and silt, which is directly related to the turbidity of water. These values were attributed to the surface runoff and disposals of domestic wastes locally.

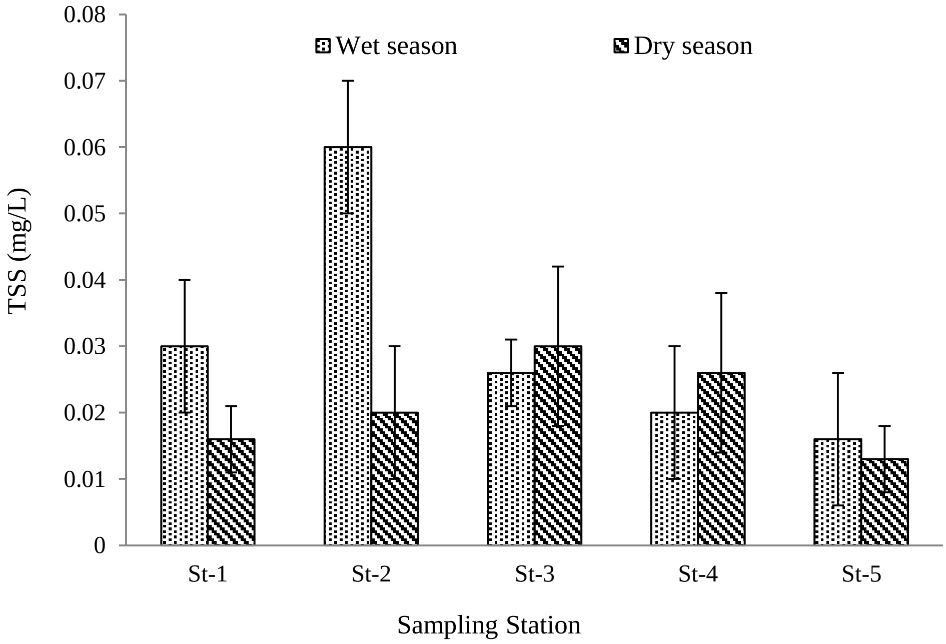

Fig. 4. The TSS variation at five sampling stations of Jamuna River.

pH

The surface water pH varied from 7.45 ± 0.034 to 7.79 ± 0.17 in the wet season, whereas 7.24 ± 0.055 to 7.46 ± 0.31 in the dry season (Fig. 5). The water was slightly alkaline both in the wet and the dry season. This might be due to heavy rainfall and upstream runoff of water or due to domestic and agricultural wastes disposed of in the bank of the river. The pH of surface water showed the significant positive relationship with water temperature (r = 0.691, p < 0.05) but showed significant negative relationship (r = –0.731, p < 0.05) with transparency (Table 3). An alkaline environment with a pH range to 7.5 to 8.4 is good for the growth of algae and range between 6.0 to 7.2 is optimum for fish eggs (EGIS, 2002). Another study by Bhaumik and Sharma (2012) stated that the permissible range of pH was between 6.4 and 8.5. Thus, the observed pH values of Jamuna River reflect its suitability for aquatic life and all types of water uses.

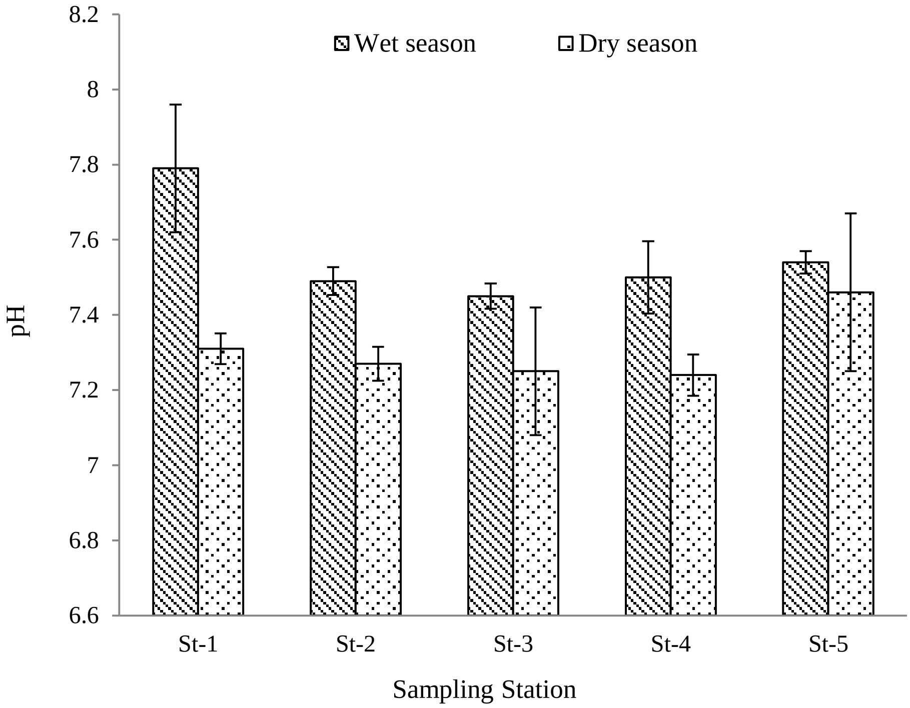

Fig. 5. The pH values at five sampling stations of Jamuna River.

Dissolved Oxygen (DO)

The DO concentration varied from 2.4 ± 0.1 mg/L to 2.7 ± 0.11 mg/L and 3.1 ± 0.25 mg/L to 4.4 ± 0.31 mg/L in the wet and dry season, respectively (Fig. 6). From the present investigation, dissolved oxygen (DO) concentrations have been found higher in the dry season compared to the wet season. The higher concentration of dissolved oxygen during the dry season was probably due to low water temperature and increased photosynthetic activity of green algae, which has been well documented by Joshi *et al.* (2009). The dissolved oxygen showed the significant positive relationship ($r = 0.929$, $p < 0.01$) with transparency but showed the significant negative relationship ($r = –0.897$, $p < 0.01$) with water temperature (Table 3). Dissolved oxygen is vital for aquatic life. The decomposition of organic matter, dissolved gases, industrial waste, mineral waste, and agricultural runoff results to get lower DO levels (Srivastava *et al.*, 2011 and Addo *et al.*, 2013). The availability of dissolved oxygen in water depends on the exchange across the air and water interface, subjected to the conditions such as temperature, the partial pressure of gases, solubility, photosynthetic activity of the aquatic plants and respiration by microorganisms, plants and animals in the water (Krishnaram *et al.*, 2007).

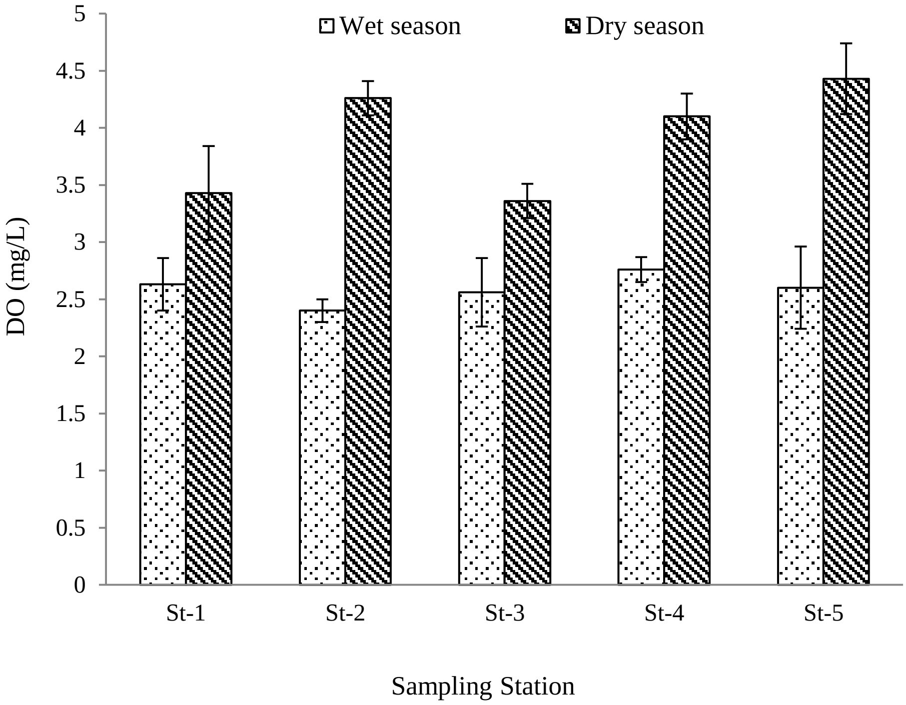

Fig. 6. The DO concentration at five sampling stations of Jamuna River.

Nutrient concentrations

Nitrate

Among the five stations, the nitrate concentration varied from 0.118 ± 0.01 mg/L to 0.186 ± 0.041 mg/L and 0.021 ± 0.011 mg/L to 0.2 ± 0.014 mg/L in the wet and dry season, respectively (Fig. 7). The average nitrate concentration of the samples in the wet season were higher than the dry season. These high values seem to be due to local run-off from the adjacent agricultural field in these areas where the farmers had used nitrogen-enriched fertilizers.

Nitrate is a form of nitrogen and a vital nutrient for growth, reproduction, and the survival of organisms. The concentration of nitrates is used as an indication of the level of micronutrients in water bodies. High nitrate levels (> 1 mg/L) are not good for aquatic life (Suma and Rajeshwari, 2013; Gebreyohannes *et al.,* 2015). The high nitrate concentration is due to the runoff of fertilizer from the nearby field areas, sewage containing nitrate and also due to the flush out of deposited nitrate from the near-surface (Suma and Rajeshwari, 2013). The measured nitrate concentration of Jamuna River were within the standard level that reflects its suitability for aquatic life both in the wet and dry season.

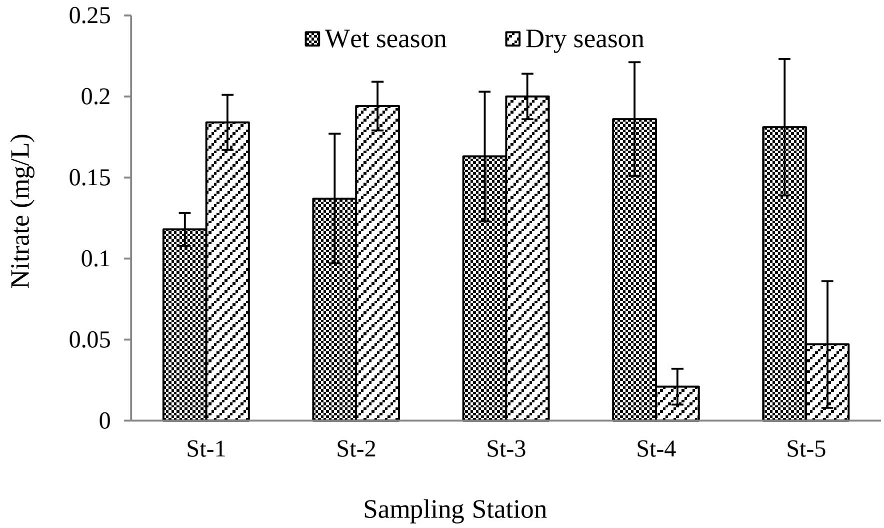

Fig. 7. The nitrate concentration at five sampling stations of Jamuna River.

Ammonium

The range of ammonium concentration was 0.159 ± 0.013 mg/L to 0.479 ± 0.376 mg/L in the wet season and 0.142 ± 0.132 mg/L to 0.335 ± 0.119 mg/L in the dry season (Fig. 8). The present study revealed that ammonium values were higher in the wet season compared to the dry season. The ammonium displayed the significant positive relationship *(r* = 0.739, *p* < 0.05) with TSS (Table 3).

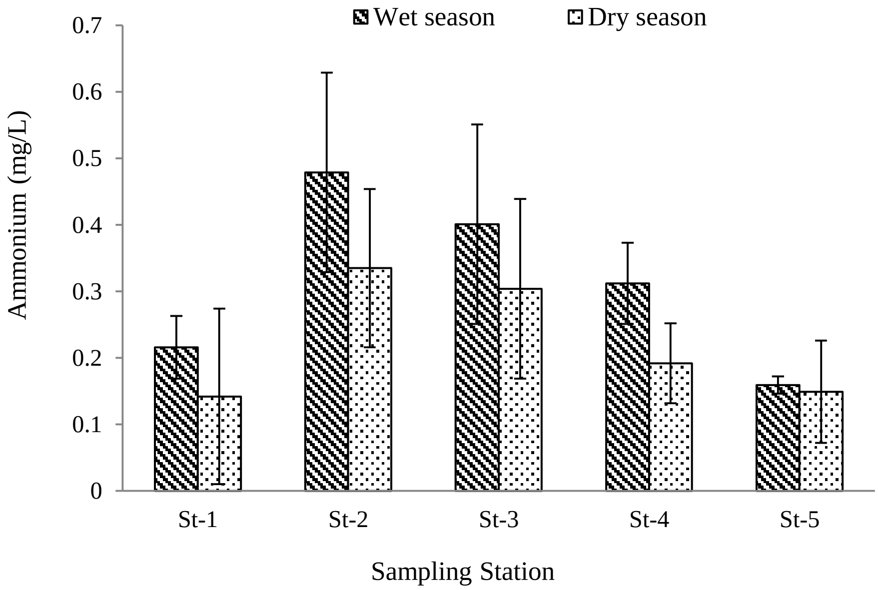

Fig. 8. The ammonium concentration at five sampling stations of Jamuna River.

The higher concentration of ammonium could be partially due to the death and subsequent decomposition of phytoplankton or other detritus matter. Uddin *et al*. (2014) observed ammonium concentration in Jamuna River ranges from 8 to 13 ppm in the dry season and 2.1 to 3.3 ppm in the wet season, which is much higher than the present findings shows the ammonium concentration is decreasing over the years.

Phosphate

During the wet and dry season, the phosphate concentration varied between 0.877 ± 0.063 mg/L to 1.68 ± 0.87 mg/L and 0.035 ± 0.029 mg/L to 0.104 ± 0.098 mg/L, respectively (Fig. 9). The present study revealed that phosphate of water samples of five stations were found higher in the wet season compared to the dry season. The phosphate displayed the significant positive relationship *(r* = 0.959, *p* < 0.01) with water temperature (Table 3). The lower value could be attributed to the utilization of phosphate by phytoplankton (Senthilkumar *et al.,* 2002 and Rajasegar, 2003). The addition of super phosphates applied in the agricultural fields as fertilizers and alkyl phosphates used in households as detergents could be sources of inorganic phosphates (Das *et al.*, 1997 and Senthilkumar *et al.*, 2002). Phosphate is known to be the main limiting nutrient for the growth of phytoplankton and chlorophyll *a* (Aziz and Radwan, 2005). Bhatnagar *et al.* (2004) suggested that 0.05 – 0.07 ppm is optimum and productive; 1.0 ppm is good for plankton production, which supports evidence that the ecosystem was productive and favorable for aquatic organisms.

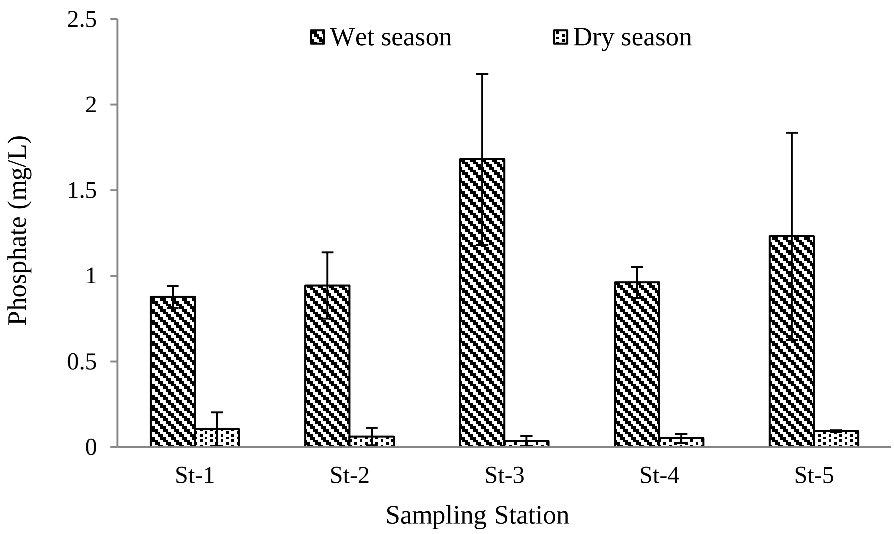

Fig. 9. The phosphate concentration at five sampling stations of Jamuna River.

Chlorophyll *a* Content

The value of Chlorophyll *a* ranged from 0.003 ± 0.002 mg/L to 0.014 ± 0.004 mg/L in the wet season and 0.07 ± 0.023 mg/L to 0.191 ± 0.076 mg/L in the dry season during the study period (Fig.10). Chlorophyll *a* content of water samples were observed higher in the dry season compared to the wet season. Chlorophyll *a* displayed the significant positive relationship with transparency (r = 0.919, $p < 0.01$) and DO (r = 0.820, $p < 0.01$) but displayed the significant negative relationships with water temperature (r = –0.859, p <0.01) and PO_4^- (r = –0.836, $p < 0.01$) respectively, (Table 3) that indicated that Chlorophyll *a* content depend on transparency and DO.

Chlorophyll *a* is the most abundant form of chlorophyll within photosynthetic organisms. Chlorophyll *a* concentration is an important parameter in reflecting phytoplankton growth, and it is often used as an estimate of algal biomass (Horne and Goldman, 1994 and Stanley *et al.,* 2003). The Chlorophyll *a* content may be influenced by the anthropogenic effects and may also be due to the freshwater discharges from the rivers, causing turbidity and less availability of light (Kawabata *et al.*, 1993 and Saifullah *et al.,* 2014). Yeragi and Shaikh (2003) showed a good prediction of the correlation pattern between DO and production efficiency in the Tansa River. However, the other physicochemical variables have a direct as well as an indirect effect on biological diversity. Pandey and Yadav (2015) measured Chlorophyll *a* biomass and productivity in Ganga River and found highest in the winter season and lowest in the monsoon season. Aziz and Radwan (2005) found the maximum (21.7 g/L) average contents of Chlorophyll *a* during the summer season, while the average minimum (1.3 g/L) values of Chlorophyll *a* were measured during the winter season in Yamuna River, which is much higher than the present study.

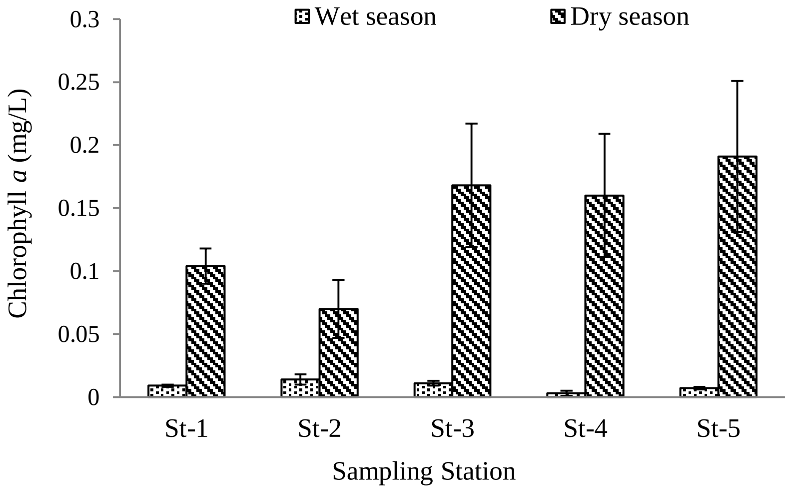

Fig. 10. The Chlorophyll *a* content at five sampling stations of Jamuna River.

Phytoplankton Abundance

A total of 11 species of phytoplankton were recorded belonging to three classes (Table 1) which comprises 7 species of Diatoms (Bacillariophyceae); 3 species of Dinoflagellates

(Dynophyceae) and 1 species of Cyanobacteria (Cyanophyceae). Diatom was the dominating group of phytoplankton in both seasons followed by Dinoflagellates (Dynophyceae) and Cyanobacteria (Cyanophyceae). Considering the cell density (cells/L) the dominant species of Diatom was *Thalassionema* sp. (12562.06 cells/L and 19688.89 cells/L) both in the wet and the dry season, respectively (Table 2). Generally, in most of the cases, diatom is dominant in the aquatic environment that was reported by Saifullah *et al.* (2014).

Table 1. List of phytoplankton species found at different sampling station in Jamuna River during the study period.

Phytoplankton species	Wet season					Dry season				
	St-1	St-2	St-3	St-4	St-5	St-1	St-2	St-3	St-4	St-5
Diatoms (Bacillariophyceae)										
Coscinodiscus sp.	+	+	+	+	+	+	+	+	+	+
*Guinardia*sp.	-	-	-	-	-	+	+	-	+	+
Leptocylindricus sp.	+	+	+	+	+	+	+	+	+	+
Licmophora sp.	-	-	+	-	+	-	-	-	+	+
Rhizosolenia sp.	+	+	+	+	+	+	+	+	+	+
Skeletonema sp.	-	-	-	-	-	-	+	+	-	+
*Thalassionema*sp.	+	+	+	+	+	+	+	+	+	+
Dinoflagellates (Dynophyceae)										
Dinophysis sp.	+	+	-	-	+	+	+	-	-	+
Gyrodinium sp.	-	-	-	-	-	+	-	-	-	+
Protoperidinum sp.	-	+	-	+	+	-	+	-	+	+
Cyanobacteria (Cyanophyceae)										
Aphanizomenon sp.	+	-	-	+	+	-	-	+	+	+

Note: + Present, - Absent

Table 2. List of phytoplankton species in Jamuna River with their seasonal mean abundance.

Phytoplankton species	Seasonal mean density (cells/L)	
	Wet season	Dry season
Diatoms (Bacillariophyceae)		
Coscinodiscus sp.	6183.97	4991.55
*Guinardia*sp.	0	4436.93
*Leptocylindricus*sp.	6558.34	9983.10
*Licmophora*sp.	457.55	1844.10
*Rhizosolenia*sp.	4894.49	7487.32
*Skeletonema*sp.	0	2121.40
*Thalassionema*sp.	12562.06	19688.89
Dinoflagellates (Dynophyceae)		
*Dinophysis*sp.	1844.1	1289.48
*Gyrodinium*sp.	0	1109.23
*Protoperidinum*sp.	1663.85	2121.40
Cyanobacteria (Cyanophyceae)		
*Aphanizomenon*sp.	1192.42	1386.54

Bacillariophyceae (Diatoms) was found as the dominant group of phytoplankton, covering a total number of 19 species in the entire phytoplankton diversity of Manakudy estuary (Jha *et al.*, 2014). Diatoms (Bacillariophyceae) were recorded as dominant phytoplankton by Ishaq and Khan (2013) in the Jamuna River. Phytoplankton community is generally dominated by members of Bacillariophyceae, perhaps because of their capability of utilizing the nutrients (Oritz and Cambra, 2007).

Table 3. Pearson Correlation Coefficient (r-values) among Physico-chemical parameters, nutrients, chlorophyll *a*and phytoplankton abundance in Jamuna River

	WT	Trans	TSS	pH	DO	NO_3	NH_4	PO_4	Chl *a*	Phyto
WT	1									
Trans	-0.966**	1								
TSS	0.309	-0.429	1							
pH	0.691*	-0.731*	0.146	1						
DO	-0.897**	0.929**	-0.476	-0.609	1					
NO_3^-	0.277	-0.312	-0.024	-0.050	-0.432	1				
NH_4^+	0.391	-0.447	0.739*	-0.020	-0.428	0.326	1			
PO_4^-	0.959**	-0.902**	0.230	0.618	-0.840**	0.255	0.408	1		
Chl*a*	-0.859**	0.919**	-0.285	-0.630	0.820**	-0.467	-0.437	-0.836**	1	
Phyto	-0.859**	0.830**	-0.118	-0.479	0.862**	-0.532	-0.277	-0.794**	0.783**	1

WT = Water temperature, Trans = Transparency, TSS = Total suspended solid, DO = Disslove oxygen, NO_3 = Nitrate, NH_4 = Ammonium, PO_4 = Phosphate, Chl *a* = Chlorophyll *a*, Phyto = Phytoplankton.
**. Correlation is significant at the 0.01 level (2-tailed)
*.Correlation is significant at the 0.05 level (2-tailed)

Phytoplankton density

The phytoplankton density recorded from the five sampling stations were ranged from 29117.37 ± 4999.24 cells/L to 47142.42 ± 4999.25 cells/L in the wet season. In the dry season, the range was recorded from 45755.88 ± 4159.62 cells/L to 67940.54 ± 6043.79 cells/L (Fig. 11). The present study revealed a higher density of plankton in the dry season compared to that of the wet season. This could be due to available nutrients and other physical and chemical factors which promote the growth of phytoplankton. The minimum values found in the dry season could be due to domestic discharge, effluents from run-off that discharge into the river (Fikrat *et al.*, 2008).

The present correlation coefficient showed that water temperature and PO_4^- had significant negative relationship (r = –0.859, p < 0.01 and r = –0.794, p < 0.01), respectively, with the phytoplankton density (Table 4.4). It is also revealed that transparency (r = 0.830, p < 0.01), DO (r = 0.862, p < 0.01) and Chlorophyll *a* (r = 0.862, p < 0.01) showed significant positive correlation with the phytoplankton density during the study periods (Table 4.4). It revealed that the water quality parameters like transparency, DO and Chlorophyll *a* content play a decisive role in the variation of the phytoplankton in the studied Jamuna River. A maximum number of total phytoplankton indicates a good physicochemical condition (Ishaq and Khan, 2013). Maximum phytoplankton density during the dry season than the wet season was also reported by Chakraborty *et al.* (1959) and Pahwa and Mehrotra (1966) in the Yamuna and Ganga River, respectively. Presence of phytoplankton diversity indicates good water quality and has been successfully reported by Ishaq and Khan (2013).

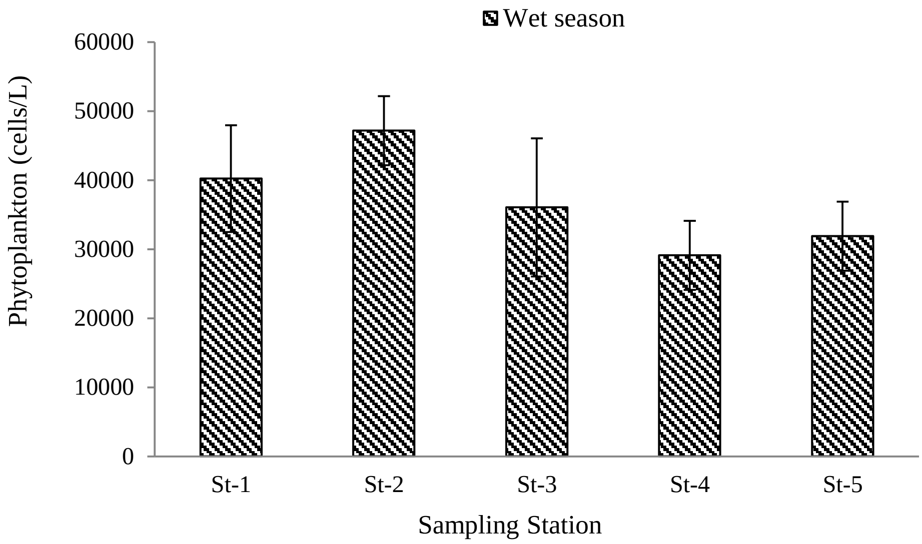

Fig. 11: Phytoplankton density at five sampling stations of Jamuna River.

Conclusion

Rivers are the most important freshwater resource for human life and the aquatic environment. The study revealed that during the dry season, the quality of water was more suitable than the wet season for all aquatic lives, domestic and agricultural uses. The variability of phytoplankton with the seasonal changes in the aquatic environment is very much necessary for the maintenance of river water quality. Diatoms were found the most dominant group of phytoplankton in both the seasons. Some common phytoplankton species were found in both seasons though there was a difference in physicochemical characteristics of water. The present study revealed that the phytoplankton density was higher in the dry season compared to that of the wet season. The abundance of phytoplankton was influenced by water quality parameters. The water quality of the river is being altered in a few areas as a result of domestic effluents direct discharge into river and human activities along the banks of the river. This indicates that though not yet polluted if the care is not taken immediately, may get polluted in the future. The present study suggested that Jamuna River in Bangladesh has to be preserved for its intended use, a sustainable management plan and water quality monitoring program should be taken throughout the year for conservation of this aquatic ecosystem.

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