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Impact of environmental stressors on the phytoplankton communities to assess the River Halda, Bangladesh

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Abstract. Halda is a 98 km-long tidal freshwater river of Bangladesh, which has a unique feature since it is the only natural breeding ground and the sole source of fertilized eggs of Indian Major Carps globally. The present study firstly summarizes the impact of environmental stressors to understand phytoplankton abundance, community, and their diversity in Halda River, Bangladesh. Environmental data as seasons (Winter, Monsoon), water depths, temperature, pH, Salinity, dissolved oxygen, and nutrients were collected and analyzed from the Halda River in January 2019 and August, 2020. Thirty-four phytoplankton genera, comprising five classes, were identified from the Halda River, Bangladesh. A two-way ANOVA was performed to analyze the effect of Monsoon and Winter on the physicochemical and biological parameters. It revealed that there was a statistically significant ((F9, 160)= 34.999, p= 0.0) interaction between Monsoon and Winter on the observed parameters. The water temperature (F 125.31, Fcrit 4.130, p= 0.0) and nutrients (F 11.118, Fcrit 2.322, p= 0.0) revealed significant change in the phytoplankton concentrations in the Halda River. As of the temperature and nutrients, water depths also significantly (F 1.790, Fcrit 1.719, p= 0.0) affect the phytoplankton communities in the Halda River showing the highest and lowest cell density in the surface and bottom water, respectively.
Keywords: Halda River, Nutrient, Phytoplankton community, Diversity

Introductions

Phytoplankton is the primary stuff of the aquatic food chain distributed throughout the world, a microscopic range between one micron and several millimeters (Marshall 2009). Phytoplankton is acknowledged worldwide as bio-indicators in the aquatic ecosystem (Yakubu *et al.* 2000) to evaluate the contamination status of aquatic bodies like algal bloom (Prabhahar *et al.* 2011). Phytoplankton is the best index of biological productivity and the quality of aquatic habitat (Wickstead 1965). The condition of the aquatic environment can be revealed through the distribution, abundance, and diversity of phytoplankton (Bahaar and Bhat 2011). Natural food intake and fish growth are positively correlated with plankton availability in aquatic bodies (Rahman et al., 2008). Knowledge of plankton is indispensable for the fruitful regulation of an aquatic ecosystem as the physical capability of an aquatic ecosystem depends upon the biomass of the plankton (Ahmed *et al.* 2003).

Aquatic surroundings are conditional to high temporal variation due to interaction between physical, chemical, and biological variables, which are interrelated with phytoplankton's relative abundance and species composition (Reynolds *et al.* 2000). The biological elements of a water ecosystem are guided by various physicochemical parameters (Saksena *et al.* 2008). The factors influencing phytoplankton community uplift, particularly in relation to physicochemical conditions, have piqued researchers' interest during the last few decades (Peerapornpisal *et al.* 1999). Therefore, the relationship between the physicochemical environment and plankton species composition has become the subject of much discussion (Margalef 1978). The natural processes and anthropogenic activities result in a gradient in abiotic and biotic factors, which has a substantial impact on phytoplankton species composition, succession, and abundance (Biswas *et al.* 2015). An increase in nutrients is readily incorporated into the plankton community, which

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finally increases the fish biomass as there is a direct relationship between nutrients (nitrates and phosphates) and phytoplankton density and species diversity (Rahman *et al.* 2008).

Halda is a resourceful River in Bangladesh. The third main River of Chattagram, after the Karnaphuli and the Sangu, is a 98 km-long tidal freshwater River that originated from the hilly Haldachora fountain at the Patachara hill ranges Ramgarh in the Khagrachari hill district (Kabir *et al.* 2013). The river is the sole source of fertilized eggs of Indian major carps such as *Catla catla*, *Labeo rohita*, *Cirrhimus cirrhosis*, and *Labeo calbasu* in the world, as it provides favorable physicochemical factors for the spawning during the monsoon between April and June (Tsai *et al.* 1981, Patra and Azadi 1987, Kabir *et al.* 2013). The Halda River is conducted for various purposes, for example, irrigation in agriculture, fish farming and livestock rearing, household drinking and bathing, transportation, waste assimilation, recreation, and tourism (Kabir *et al.* 2013). Halda is unique in that it is the only natural breeding site in Bangladesh for Indian major carps (Kibria *et al.* 2009).

Several studies on physicochemical parameters and phytoplankton community of other rivers are conducted, including the Meghna River (Ahmed 2003, Ahsan et al. 2012); Moiur river (Rahi *et al.* 2015); Dhaleshwari river (Islam *et al.* 2012); Karnafully river (Sarwar *et al.* 2010); Jamuna River (Uddin et al., 2014). Some brief studies on physicochemical parameters and phytoplankton community of the Halda River (Parta and Azadi 1987, Parvez *et al.* 2019; Nahid *et al.* 2020) were done, but no descriptive and vertical abundance of phytoplankton was performed. Therefore, the present study was conducted on the explore the impact of different environmental factors on the seasonal changes of primary producers in the Halda River.

Materials and Methods

Study period and sites: The present study was conducted during Monsoon (August 2019) and Winter (January 2020) from three sampling stations, namely Sattarghat (S1), Nazirhat (S2), and Moduanghat (S3) of Halda river nearly to Hathazary Upazila under Chattagram district in the south-east part of Bangladesh (Fig. 1).

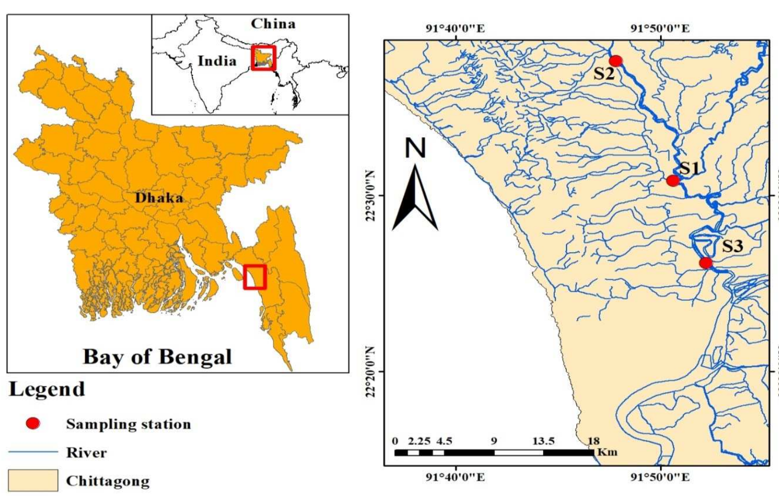

Fig. 1. Location map showing selected study area (S1 = Sattarghat, S2 = Nazirhat, S3 = Modunaghat).

Sample collection: Water samples were collected from each sampling site in the early morning from 8 am to 11 am from the surface (0.15 m), middle (3.5 m), and bottom (7.5 m) water depth with three replicates. Water samples were collected three times at each station from the middle river of 12-15m from the bank of the river. About 300 ml of the water sample were collected for phytoplankton, and another 300 ml of water were filtered through Whatman GF/F (0.45 µm) filter paper for nutrient measurement collected by using a water sampler. Water samples were stored in labeled sample bottles that were washed with 5% HNO_3 mixed with distilled water. 5% buffered formalin was added to phytoplankton samples, and nutrient samples were kept in the deep refrigerator for future analysis.

Water quality measurement: Water temperature (^{0}C), pH, salinity (ppt), and DO (mg/L) were measured directly from the collected water using a digital waterproof multi-parameter (H198194). Nutrients (mg/L) like nitrates, nitrites, phosphates, and silicates were measured directly through a spectrophotometer (HACH, DR 5500), and prior to analysis, let the sample temperature increase to room temperature.

Phytoplankton identification: Microscopic identification up to genera level and enumeration was performed following the standard manual (Belcher and Swale 1976, Bellinger and Sigiee 2015, Davis 1955) using a Luminous Stereoscopic Microscope (Model: SL 2240). Each sample was stirred well just before the microscopic examination, and 1 ml of stirred sample was transferred to Sedgewick-Rafter (S-R cell) cell with a wide mouth pipette. All the phytoplankton present in 20 randomly chosen squares of the S−R cell were counted, and the abundance was expressed as cells L^{-1}.

Statistical analysis: Two Factor and single Factor analysis of variance (ANOVA) was practiced examining significant dissimilation between physicochemical parameters, Seasons and phytoplankton abundance. All the analyses were performed through paleontological statistics (PAST) software. Shannon–Weiner index (*H′*) (Shannon and Weiner 1949) and Pielou's evenness or equitability index (*J′*) (Pielou 1966) were calculated. Microsoft Office Excel 2010 was used to represent graphs and tables and plot graphs to disseminate other results.

Results and Discussion

Physicochemical parameters: Vertical values of the physicochemical parameters of the Halda River are depicted in Table I. The mean values of temperature was 28.79 ± 0.89^{0}C and 23.42 ± 1.33^{0}C, pH was 7.33 ± 0.12 and 7.09 ± 0.23, salinity was 0.29 ± 0.04 (ppt) and 0.38 ± 0.10 (ppt), DO was 4.99 ± 1.09 (mg/L) and 5.41 ± 0.97 (mg/L), nitrates was 1.68 ± 0.64 (mg/L) and 1.17 ± 0.43 (mg/L), nitrites was 0.03 ± 0.02 (mg/L) and 0.05 ± 0.02 (mg/L), phosphates was 0.61 ± 0.10 (mg/L) and 0.62 ± 0.23 (mg/L), silicates was 0.86 ± 0.15 (mg/L) and 0.89 ± 0.12 (mg/L) during Monsoon and Winter, respectively (Table I).

The water temperature was maximum (30.33 ± 0.47^{0}C) during Monsoon in surface water at S2 and minimum (21.52 ± 0.49^{0}C) during the winter in bottom water at S3. The pH was eventually with high content (7.44 ± 0.31) during Monsoon in surface water and low in winter (6.64± 0.22) in bottom water at S2. Dissolved oxygen attained maximum in winter (6.68 ± 0.49 mg/L) in surface water at S1 while minimum (3.52 ± 0.27) mg/L) in bottom water at S3. Maximum value of salinity (0.59 ± 0.11 ppt) was recorded in middle water during winter at S1 and minimum (0.24 ± 0.06 ppt) was found in surface water during monsoon at S3. The nitrate concentration was maximum (2.96 ± 0.96 mg/L) in surface water during monsoon and minimum (0.60 ± 0.14 mg/L) was in bottom water during winter at S1. Higher nitrite value (0.28 ± 0.2 mg/L) was recorded in middle water at S1 and lower (0.01 ± 0.005 mg/L) during monsoon. The concentration of phosphate was high (1.05 ± 0.5 mg/L) in surface water and low (0.2 ± 0.14 mg/L) in bottom water during winter at S3. Maximum silicates (1.12 ± 0.11 mg/L) were found at S3 and minimum (0.64 ± 0.06 mg/L) at S1 in middle water during monsoon (Table 1). A two-way ANOVA was performed to analyze the effect of Monsoon and Winter on the physicochemical and biological parameters. It revealed that there was a statistically significant (($F_{9, 160}$) = 34.999, p = 0.000) interaction between Monsoon and Winter on the observed parameters (Table II).

Table I. Physico-chemical parameters and total phytoplankton abundance (Cell/L) in the River Halda

Season	Station	Depth (m)	Temperature (□)	pH	Salinity (ppt)	DO (mg/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	PO_4^- (mg/L)	DSi (mg/L)	Abundance (Cells × 10^4)
Monsoon	S1	0.15	29.66 ± 0.67	7.32 ± 0.03	0.28 ± 0.01	5.69 ± 0.16	2.96 ± 0.96	0.07 ± 0.01	0.63 ± 0.15	0.77 ± 0.18	14.16 ± 2.65
		3.5	28.33 ± 0.72	7.23 ± 0.03	0.29 ± 0.01	4.85 ± 0.28	1.8 ± 0.17	0.08 ± 0.02	0.68 ± 0.11	0.64 ± 0.06	12.16 ± 1.76
		7.8	27.33 ± 0.58	7.24 ± 0.06	0.32 ± 0.02	3.61 ± 0.24	1.1 ± 0.1	0.04 ± 0.01	0.63 ± 0.32	0.91 ± 0.09	10.41 ± 1.76
	S2	0.15	30.33 ± 0.47	7.44 ± 0.31	0.27 ± 0.01	6.67 ± 0.31	2.3 ± 0.2	0.02 ± 0.01	0.66 ± 0.15	0.73 ± 0.28	12.91 ± 1.76
		4.1	28.88 ± 0.64	7.21 ± 0.07	0.28 ± 0.01	5.12 ± 0.12	1.23 ± 0.25	0.02 ± 0.01	0.69 ± 0.73	0.73 ± 0.36	12.5 ± 0.88
		8.1	28.46 ± 0.55	7.26 ± 0.07	0.34 ± 0.02	4.2 ± 0.12	1.5 ± 0.43	0.01±0.005	0.69 ± 0.43	0.99 ± 0.34	10.83 ± 0.88
	S3	0.15	29.33 ± 0.57	7.56 ± 0.1	0.24 ± 0.06	6.17 ± 1.35	1.93 ± 0.2	0.01±0.005	0.65 ± 0.28	0.94 ± 0.05	10.23 ± 2.65
		3.4	28.74 ± 0.48	7.32 ± 0.09	0.25 ± 0.04	5.02 ± 0.27	1.26 ± 0.25	0.02 ± 0.01	0.42 ± 0.01	1.12 ± 0.11	10.83 ± 1.45
		6.8	28.11 ± 0.33	7.39 ± 0.22	0.34 ± 0.03	3.52 ± 0.27	1.0 ± 0.1	0.01±0.005	0.45 ± 0.2	0.94 ± 0.15	8.75 ± 0.88
Winter	S1	0.15	24.58 ± 0.79	6.97 ± 0.21	0.31 ± 0.1	6.68 ± 0.49	1.2 ± 0.14	0.08 ± 0.01	0.65 ± 0.17	0.78 ± 0.02	18.54 ± 3.66
		3.2	23.52 ± 0.71	7.2 ± 0.04	0.59 ± 0.11	5.48 ± 0.64	0.95 ± 0.21	0.03 ± 0.01	0.61 ± 0.21	0.89 ± 0.07	19.58 ± 2.46
		6.4	22.11 ± 0.95	7.37 ± 0.36	0.42 ± 0.08	4.52 ± 0.5	0.60 ± 0.14	0.05 ± 0.01	0.69 ± 0.28	0.76± 0.08	13.33 ± 3.43
	S2	0.15	25.52 ± 0.73	7.06 ± 0.14	0.31 ± 0.02	6.71 ± 0.31	1.8 ± 0.4	0.02 ± 0.01	0.7 ± 0.14	0.93 ± 0.01	15.41 ± 4.82
		3.4	23.59 ± 0.68	7.28 ± 0.14	0.46 ± 0.07	5.23 ± 0.1	0.8 ± 0.4	0.04 ± 0.01	0.45 ± 0.07	1.10 ± 0.25	13.75 ± 1.75
		6.8	22.21 ± 0.56	6.64 ± 0.22	0.36 ± 0.03	4.38 ± 0.39	1.2 ± 0.14	0.05 ± 0.02	0.75 ± 0.07	0.78 ± 0.06	11.66 ± 1.77
	S3	0.15	24.65 ± 0.81	7.32 ± 0.14	0.27 ± 0.05	6.28 ± 0.41	1.9 ± 0.56	0.02 ± 0.01	1.05 ± 0.5	0.88 ± 0.08	20.41 ± 2.91
		2.9	23.12 ± 0.68	7.04 ± 0.19	0.42 ± 0.06	5.3 ± 0.18	1.15 ± 0.07	0.07 ± 0.02	0.6 ± 0.14	0.85 ± 0.13	20.0 ± 3.68
		5.8	21.52 ± 0.49	6.94 ± 0.24	0.29 ± 0.02	4.15 ± 0.47	0.95 ± 0.2	0.08 ± 0.01	0.2 ± 0.14	1.07 ± 0.12	12.08 ± 1.75

Table II. Two factor ANOVA with replication to find the effect of seasons on different parameters

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Seasons	29.83	1	29.83	16.640	0.000	3.900
Parameters	11160.29	9	1240.03	691.654	0.000	1.939
Seasons Vs Parameter	564.73	9	62.75	34.999	0.000	1.939
Within	286.86	160	1.79			
Total	12041.7	179				

Different water depths significantly ($F_{(16, 135)}$= 1.790, p= 0.038) affect the physicochemical parameters and phytoplankton cell density (Table III). As of the water depths, different nutrient concentrations ($F_{(5, 84)}$= 11.118, p= 0.000) also significantly (Table IV) affected the cell density of phytoplankton with the highest value in the surface water.

Table III. Two factor ANOVA showing effects of water depths and different parameters

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Depths	33.22	2	16.61	7.474	0.001	3.063
Parameters	10981.16	8	1372.64	617.599	0.000	2.008
Interaction	63.65	16	3.98	1.790	0.038	1.719
Within	300.04	135	2.22			
Total	11378.07	161				

Table IV. ANOVA to find the effect of nutrient concentration on the phytoplankton abundance

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2455.59	5	491.12	181.118	0.000	2.323
Within Groups	227.77	84	2.71			
Total	2683.37	89				

The physicochemical parameters like temperature, salinity, pH, DO, and nutrients immensely influence the distribution and abundance of phytoplankton and the survival of aquatic organisms (Godhe *et al.* 2015). The physicochemical parameters found during the present study were in line with others (Patra and Azadi 1987, Parvez *et al.* 2019). The physicochemical parameters revealed relatively higher values of temperature, pH, nitrates, and nitrites during monsoon, while values of salinity, DO, phosphates, and silicates were higher during winter. The high value of temperature may be due to intense sunlight (Prabu *et al.* 2008), pH may be due to the transportation of ions (Barman *et al.* 2015), nitrates and nitrites may be due to the release of nutrients from the bottom sediments (Thillai *et al.* 2010). A higher value of salinity during winter may be due to little or no runoff of water and DO may be due to less microbial decomposition as the temperature is low (Narasimha and Benarjee 2013). The temperature, pH, and DO values were higher in surface water attributed to sunlight and phytoplankton that produce oxygen through photosynthesis, whereas lower salinity may be due to water runoff.

Phytoplankton community and abundance: A total of 34 phytoplankton genera of 5 classes were identified during the present study period (Table V).

Table V. Phytoplankton genera recorded in River Halda

Groups	Genera
Cyanophyceae	*Anabaena* spp., *Microcystis* spp., *Nodularia* spp., *Nostoc* spp., *Spirulina* spp., *Synechocystis* spp.
Bacillariophyceae	*Amphora* spp., *Aulacoseira* spp., *Cyclotella* spp., *Cymbella* spp., *Lyrella* spp., *Melosira* spp., *Meridion* spp., *Navicula* spp., *Stephanodiscus* spp.
Euglenophyceae	*Euglena* spp., *Phacus* spp.
Chlorophyceae	*Cladophora* spp., *Chorella* spp., *Closterium* spp., *Coelastrum* spp., *Crucigenia* spp., *Eudorina* spp., *Gonium* spp., *Kirchneriella* spp., *Microspora* spp., *Scenedesmus* spp., *Spirogyra* spp., *Staurastrum* spp., *Tetrastrium* spp., *Ulothrix* spp., *Volvox* spp.
Coscinidiscophyceae	*Coscinodiscus* spp., *Skeletonema* spp.

The composition of phytoplankton groups in both seasons is presented in Fig. 2. Chlorophyceae occupied highest mean composition (31%, 15 genera) among phytoplankton groups followed by Cyanophyceae (26%, 6 genera), Coscinodiscophyceae (20%, 2 genera), Euglenophyceae (12.5%, 2 genera), Bacillariophyceae (10.5%, 9 genera). The sheer abundance of phytoplankton at different stations in two seasons have presented in Table I. The highest abundance (20.41 ± 2.91 × 104 cells/L) of phytoplankton was recorded in surface water during winter and the lowest (8.75 ± 0.88 × 104 cells/L) during monsoon in bottom water at S3. The number of phytoplankton taxa was relatively lower than Patra and Azadi (1987) but higher than Nahid et al. (2020) conducted in the Halda River, attributed to the study period and seasons. Phytoplankton classes during the present study were similar to others (Patra and Azadi 1987, Nahid et al. 2020). A relatively higher abundance of phytoplankton was observed in the surface water, followed by middle and bottom water.

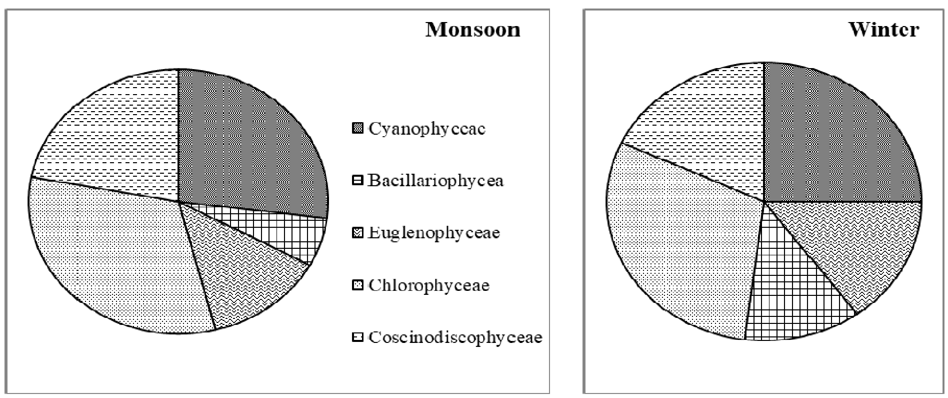

Figure 2. Composition of phytoplankton groups in the Halda River, Bangladesh.

Diversity indices

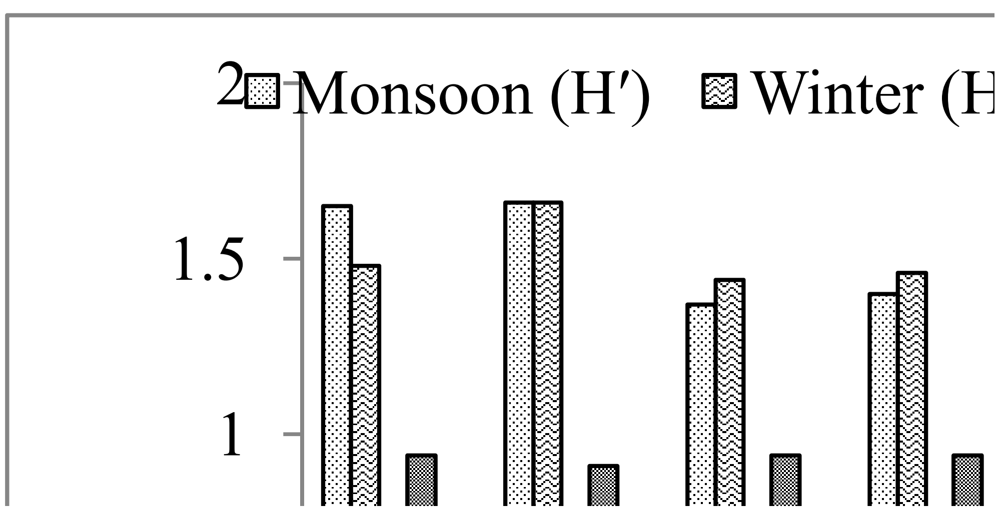

Fig. 3. Diversity indices of phytoplankton in the River Halda.

Shann-Weiner diversity index (*H*′) ranged between 1.76 in middle water during winter and 1.25 in bottom water during monsoon at S3, with a mean of 1.74 ± 0.24 in the River Halda (Fig. 3). The Shanon-Wiener diversity index (*H*′) revealed moderate diversity (Odum and Barrett 1971) in the Halda River. The highest (0.96) evenness (*J*′) was recorded in the bottom water during monsoon and the lowest (0.59) in middle water during winter at S3, with a mean of 0.58 ± 0.05 in the Halda River (Fig. 3). The Shanon-Wiener diversity index (*H*′) is widely used for measuring diversity indices and is a suitable indicator of water quality (Hardikar *et al.* 2017). The species evenness index (*J*′) demonstrates the number of individuals between community species, and the more balanced the ecosystem will be attributed to more evenly distributed individuals between species (Ulfah *et al.* 2019). The species evenness index (*J*′) indicated a stable community during monsoon and an unstable community during winter (Krebs 1989).

Conclusions

The present study firstly summarizes the different environmental drivers, phytoplankton community, abundance, and their diversity in the Halda River, Bangladesh. 34 phytoplankton genera consisting of 5 classes were identified in the Halda River. Phytoplankton cell density revealed the highest value in the surface water which was significantly higher in winter than Monsoon suggesting higher production. Environmental drivers significantly affecting phytoplankton communities in the Halda River ecosystem might indicate the higher pelagic fish production in winter of the Halda River than Monsoon owing to significantly favorable environmental factors that excel phytoplankton density.

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