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Assessment of Phytoplankton Diversity and Productivity with Relation to Physical and Chemical Properties of Water in Bangshi River

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Abstract

This study was conducted to determine the physical (temperature, turbidity, TDS, EC) and chemical (pH, DO, BOD_5, COD, alkalinity, free CO_2, chloride) parameters of water along with the abundance, richness, distribution, and primary productivity (gross primary productivity / GPP, net primary productivity / NPP, and respiration rate) of phytoplankton community in the Bangshi River at Nayarhat of Savar in Dhaka, Bangladesh during the monsoon (June-September 2019) and post-monsoon (October 2019-January 2020). The mean(±SD) value of temperature, TDS, turbidity, EC, pH, DO, BOD_5, COD, alkalinity, chloride and free CO_2 in water of the Bangshi River was found as 30.90(±2.35)°C, 1217(±167.78) mg/L, 36.06(±12.78) FTU, 1.47±(0.10) mS/cm, 7.27 (±0.13), 5.53(±0.22) mg/L, 0.67(±0.65) mg/L, 112(±44.78) mg/L, 134.56(±38.38) mg/L of $CaCO_3$, 30.26(±5.58) mg/L and 10.67(±3.17) mg/L, respectively. Turbidity, TDS, BOD_5, DO, COD, alkalinity, chloride and free CO_2 in water varied significantly between monsoon and post-monsoon. Primary productivity of phytoplankton community was considered as an expression of GPP, NPP, and respiration rate varied 3.41–6.56 mgC/L/day, 1.94–6.66 mgC/L/day, and 0.63–2.69 mgC/L/day, respectively. Total of 32 phytoplankton taxa belonging to three major classes Cyanophyceae (8), Bacillariophyceae (13) and Chlorophyceae (11) were found with abundance of 17%, 56.30%, and 26.71%, respectively. The mean(±SD) value of Shannon-Weaver's diversity index 2.15(±0.25) indicates moderate pollution of water. Cyanophyceae showed a very strong positive correlation with NPP and GPP. The implications of these findings can be used to monitor river ecosystem health.

Keywords: *Water quality, Bangshi River, Primary productivity, Water Pollution*

Introduction

Water is a vital resource for the survival of organisms, both on land and in aquatic environments (Hasan et al., 2014). Bangladesh, known for its extensive river network, holds significant fish production potentiality (Mustafa and Brooks, 2009). The quality of water is crucial for various purposes, including irrigation and navigation, apart from sustaining organisms (Rehnuma et al., 2016). The distribution and availability of quality water in Bangladesh are influenced by economic development, environmental quality, and overall progress (Islam et al., 2013).

Surface water worldwide is vulnerable to pollution from multiple sources, including runoff from land areas, agricultural pesticide and runoff, untreated industrial and municipal wastewater discharge, and oil spills in coastal areas resulting from river port activities (UNEP, 2001). Surface water quality is influenced by factors such as upland flow and seasonal variations of precipitation (Islam et al., 2015). Agricultural runoff, urban waste pollution, and

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untreated industrial effluents have significant impacts on aquatic organisms and water quality (Islam et al., 2014). Monitoring surface water is crucial for sustainable management and utilization of aquatic resources (Haque, 2008). Aquatic environments are influenced by physical, chemical, and biological parameters, which collectively determine water quality (Stanitski et al., 2003). Assessing the physical, chemical, and biological characteristics of surface water provide insights into its suitability for designated uses such as drinking water, fishing, and supporting aquatic life (Barthwal, 2002; Rahman et al., 2005).

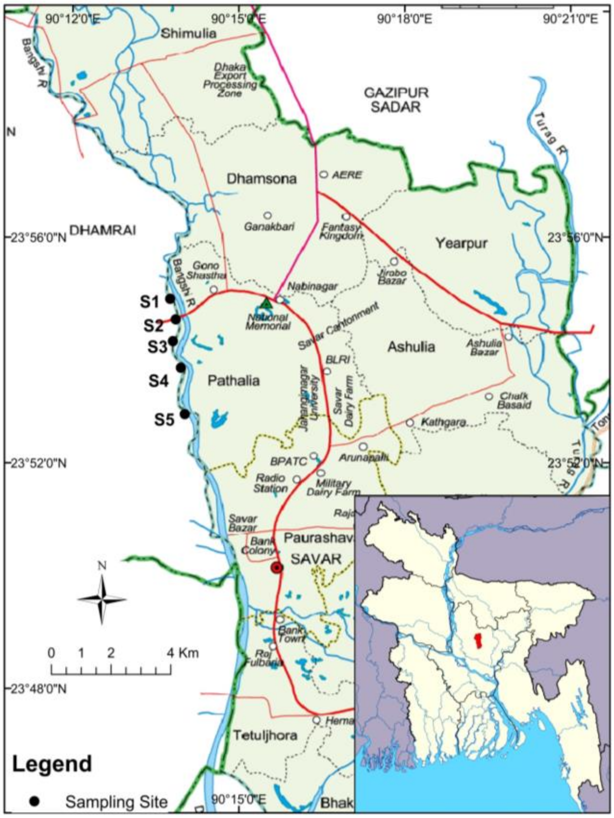
Phytoplankton, as the primary producer in natural aquatic habitats, demonstrates rapid responses to changes in physical and chemical parameters due to their crucial role in the aquatic food chain (Adeyinka and Imoobe, 2009). Phytoplankton's position in the food chain renders them highly vulnerable to even slight environmental changes (Esenowo et al., 2017). Their small size, short regeneration time, and homogeneous environment contribute to their significance in population dynamics (Rothhaupt, 2000). The presence and density of phytoplankton serve as indicators of the richness of an aquatic ecosystem (Stire et al., 2014). Plankton species diversity is influenced by environmental tolerance, while their abundance is determined by resource availability (Purushothama et al., 2011). Nutrient availability and physical and chemical factors shape the species composition and distribution of plankton (Mahar et al., 2000). Furthermore, aquatic organisms can be used as bio-indicators to assess pollution status associated with physical and chemical factors (Dirican et al., 2009). Plankton, particularly phytoplankton, serves as a valuable bio-indicator for monitoring water quality in aquatic ecosystems. Certain phytoplankton species, such as *Nitzchia* sp. and *Navicula* sp. indicate high organic pollution levels, while *Anabana* sp. and *Navicula* sp. suggest moderate organic pollution (Oneyma et al., 2003). Excessive nutrient enrichment in surface water can lead to algal blooms, resulting in reduced oxygen levels, harm to aquatic fauna, biodiversity loss, and impairment of designated water body uses (Rahman et al., 2005).

Primary production refers to the conversion of inorganic materials into organic matter through photosynthesis (Babar and Raje, 2016). Specifically, primary productivity represents the rate at which dissolved carbon dioxide is transformed into organic compounds through photosynthesis, driven by solar energy (Thurman, 2007). Organisms capable of utilizing inorganic nutrients and synthesizing organic matter via photosynthesis are known as primary producers (Rathod et al., 2016). Phytoplankton, comprising photosynthetic microorganisms in the aquatic food chain, form the foundation of the ecosystem's food web (Adeyinka and Imoobe, 2009). Primary productivity gets affected by biotic and abiotic factors and provides insights into the trophic status, fish production potential, biological activity, and overall water quality (Rathod et al., 2016).

The surface water in the Bangshi River experiences continuous change and pollution due to unplanned agricultural activities, industrial effluent discharge, pesticide and fertilizer runoff from agricultural lands, and urbanization (Rehnuma et al., 2016). While several studies have examined the phytoplankton community in Bangladesh in relation to physical and chemical characteristics of rivers and estuaries, knowledge gaps persist regarding primary productivity, abundance, and phytoplankton diversity concerning the physical and chemical properties of water in the Bangshi River. Consequently, this study aims to assess the surface water quality of the Bangshi River by evaluating its physical and chemical characteristics, and their correlation with phytoplankton abundances, and primary productivity.

Methodology

Study area



Map 1: Map shows the study sites of Bangshi River at Nayarhat in Savar; S-1, S-2, S-3, S-4, and S-5 are the demarcations of sampling sites.

This study was conducted during the monsoon (June-September 2019) and post-monsoon (October 2019-January 2020) in the Bangshi River at Nayarhat, in Savar. The study area's approximate coordinates were between latitude 23°52'51.6828" N and 23°54'54.3636" N, and longitude 90°13'45.3504" E and 90°14'01.2228" E. The Bangshi River, a distributary of the Old Brahmaputra River, flows southward through Tangail district, eventually merging with the Dhaleshwari River near Savar in Dhaka. It spans a length of approximately 280km. The study area covered a 5km stretch, which was divided into 5 sampling sites (Map-1). On the sampling sites, several bamboo stakes were set up, and the water level was marked during the monsoon. During the post monsoon, increased water level was observed in the river.

Collection of water sample

Acid-washed (5% HNO_3 solution) plastic bottles were used to collect surface seawater samples from each sampling site. The water sample bottles were filled from 10 to 20 cm below the water surface to avoid the formation of air bubbles and the entrance of surface debris inside the water sample. From each sampling site, three replications of water samples (330 ml) with appropriate demarcations were collected from three subsets of the sampling sites. Some of the physical (water temperature, TDS, EC) and chemical (pH, DO) parameters of water were measured on site. Then, the water samples were stored in an ice box with temperature-control facilities. Within half an hour of the water sample collection, all the samples, along with some extra water samples for productivity analysis, were preserved in light-controlled facilities and transported right away to a lab for further analysis.

Determination of phytoplankton composition

10 liters of surface water were sieved through plankton net of 25 µm mesh size to collect phytoplankton samples. The accumulated plankton sample was transferred to plastic bottles, promptly preserved in 5% formalin, labeled, and brought to the lab for additional analysis. Each sample was thoroughly agitated before being examined under a compound microscope (OlympusB43,Japan). A wide-mouth graduated pipette was used to transfer 1 ml of the agitated phytoplankton sample to a Sedgewick-Rafter Counting Cell (SRCC). Phytoplankton taxa were identified by reviewing relevant documents and texts (up to generic levels) (Alam et al., 2004; Alam, 2017; Khatun and Alam, 2019).

Determination of physical and chemical properties of water

At the time of sampling, the temperature, pH, and DO of water samples were measured on sites using a digital thermometer, pH meter (Hanna, HI 98127), and DO meter (Hanna, HI 9146), respectively. Electric conductivity (EC) was measured by using an EC meter (Hanna, HI 98304), TDS using a TDS meter (Hanna, HI 98301), turbidity using a turbidity meter (Hanna, HI 937053), BOD_5 using Winkler's method (Strickland et al., 1972), chloride concentration in water using Mohr’s titrimetric method (Shukla and Arya,2018). Chemical oxygen demand (COD), alkalinity, and free CO_2 of water were determined by using the American Public Health Association (APHA, 1995) guidelines.

Primary Productivity

Primary productivity was measured by using the oxygen production method, where the primary production was estimated from the changes in the dissolved oxygen (DO) content of water (Shukla and Chandel, 1972). The primary productivity was estimated by using the following equation:

$$\text{Net primary productivity (NPP)} = \text{Gross primary productivity (GPP)} - \text{Respiration}$$

Species diversity, richness and evenness index calculation

The Shannon-Weaver's Index (1949) (Shannon and Weaver, 1949) and evenness were used to quantify the species diversity and the distribution of species, respectively. The equations used to calculate the Shannon-Weaver's diversity index (H) and the evenness are as follows,

$$H = \sum -(\mathrm{P}_i \times \ln \mathrm{P}_i)$$

$$Evenness = \frac{H}{H_{\max}}$$

where, H= Shannon-Weaver's diversity index, $P_i = N_i/N$ indicates the proportion of species in a community, N_i=Number of individuals of a species, N=Total number of individuals of all species, $\sum$ = Sum of all species, $H_{max} = \ln(N)$, and the higher value of H indicates more diversity of community assemblage.

Statistical analysis

For statistical analysis, SPSS version 22.0 for windows was used. To compare the physical and chemical characteristics of water, and phytoplankton assemblage across several seasons and sites, unpaired t test was performed. The associations between physical and chemical characteristics of water and phytoplankton assemblages / productivity at various sites were evaluated by using Pearson's correlation matrix.

Results and Discussion

Physical parameters of water

The mean water temperature in the Bangshi River was found 33.11±0.26°C during the monsoon, and 28.69±0.43°C during the post-monsoon (Figure 1a). The total dissolved solids (TDS) concentration varied from 1216.67 mg/L to 1586.67 mg/L during the monsoon and from 1070 mg/L to 1103.33 mg/L during the post-monsoon. During monsoon and post-monsoon, the mean TDS values were 1344.67±149.79 mg/L and 1089.33±12.56 mg/L, respectively (Figure 1b). Turbidity ranged from 31.99 to 61.33 FTU in the monsoon and from 23.59 to 28.27 FTU in the post-monsoon (Figure 1c). The mean turbidity values were 46.12±10.62 FTU in the monsoon and 26.01±2.81 FTU in the post-monsoon, exceeding both the recommended DoE (Department of Environment) standard of Bangladesh (10FTU) (GoB, ECR, 1997) and the World Health Organization (WHO, 2004) (≤1FTU). EC values ranged from 1.31 mS/cm to 1.61 mS/cm in the monsoon and from 1.31 mS/cm to 1.56 mS/cm in the post-monsoon. The mean EC values were 1.49±0.11 mS/cm and 1.44±0.10 mS/cm during monsoon and post-monsoon, respectively, crossing the DoE (1997) standard of 1.2 mS/cm (Figure 1d).

Rikta et al. (2016) found the TDS, turbidity, and EC value of the Bangshi River water ranging from 1040 to 1580 mg/L (mean 1301 mg/L), 120 to 287 FTU (mean 189 FTU), and 1.98 to 3.98 mS/cm (mean 2.64 mS/cm), respectively. Hossain et al. (2012) found TDS, turbidity, and EC value of the Bangshi River water ranging from 410 to 1160 mg/L, 3.68 to 26.19 FTU, and 0.99 to 2.86 mS/cm, respectively.

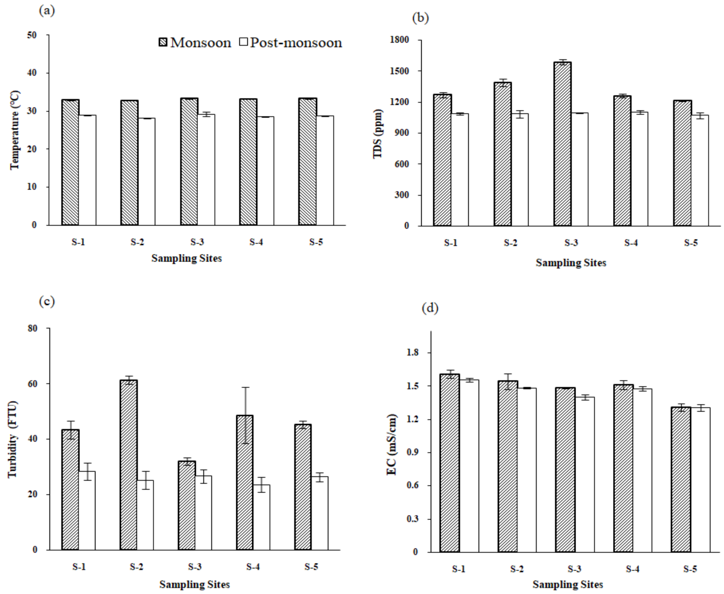


Figure 1: Observed mean a) Temperature, b) TDS, c) turbidity and d) EC in Bangshi River water during monsoon and post-monsoon (vertical bar with caps indicates standard deviation).

Chemical parameters of water

During this study, the maximum pH of the Bangshi River water was found at site S-3 (7.6) and the minimum at site S-4 (7.17) during post-monsoon (Figure 2a). The mean pH of water in the Bangshi River during monsoon and post-monsoon was 7.21±0.03 and 7.32±0.17, respectively (Table 1), and met the standards (6.5–8.5) suggested by both the Department of Environment (1991) and the World Health Organization (2004). Tahmina et al. (2018) found a pH of 7.74(±0.1) in the Turag River during the wet season, while Khondokar and Abed (2013) reported pH values of 7.13(±0.25) in the monsoon and 7.09(±0.09) in the post-monsoon. In the Bangshi River at Tangail, Rehnuma et al. (2016) recorded pH values of 7.76(±0.05) in the wet season and 8.15(±0.08) in the dry season. Rikta et al. (2016) and Hossain et al. (2012) reported a pH ranging from 5.98 to 7.95 (mean7.02), and 8.59 to 10.46 in the Bangshi River water, respectively.

Dissolved Oxygen (DO) in water of Bangshi River ranged from 5.41 to 5.84 mg/L with a mean of 5.63±0.22 mg/L in the monsoon, and 5.10 mg/L to 5.61 mg/L with a mean of 5.44±0.23 mg/L in the post-monsoon (Figure 2b) that meets the standards (>5 mg/L) for fisheries (ECR, 1997) and is higher than the DO level (3.5 mg/L–4.9 mg/L) determined during the wet season (July–September) by Rehnuma et al. (2016) in the Bangshi River at Tangail in Bangladesh. Rehnuma et al. (2016) found, the DO of dry season to be almost half that of the wet season, ranging from 1.9 mg/L to 2.8 mg/L. Additionally, Khondker and Abed (2013) observed a maximum mean dissolved oxygen (DO) of 8.97(± 4.07) mg/L in the Turag River during the monsoon, and Tahmina et al. (2018) found a mean DO value of 3.2(±0.3) mg/L in the wet season.

In monsoon, the BOD_5 of Bangshi River water ranged between 0.27 mg/L and 2.27, mg/L with a mean value of 0.98±0.90 mg/L, and in post-monsoon, the BOD_5 ranged between 0.13 mg/L and 0.79 mg/L with a mean value of 0.36±0.26 mg/L (Figure 2c) (Table 1).The mean value of BOD_5 meets the standards of EQS (1997). The mean BOD_5 values in the Bangshi River water ranged from 2.7 mg/L to 4.9 mg/L in the wet season and 4.6 mg/L to 8.2 mg/L in the dry season, as reported by Rehnuma et al. (2016). Khondokar and Abed (2013) reported the mean BOD_5 of 0.78 mg/L in the monsoon and 0.94 mg/L in the post-monsoon in the Turag River. In this study, COD ranged from 106.67 mg/L to 168.89 mg/L with a mean of 136±54.79 mg/L in monsoon and from 31.11 mg/L to 160 mg/L with a mean of 88±58.07 mg/L in post-monsoon (Figure 2d). Hossain et al. (2012) and Rikta et al. (2016) conducted studies on the water of Bangshi river and found COD ranging from 114 mg/L to 218 mg/L, and 133 mg/L to 156 mg/L (mean 145.2 mg/L), respectively.

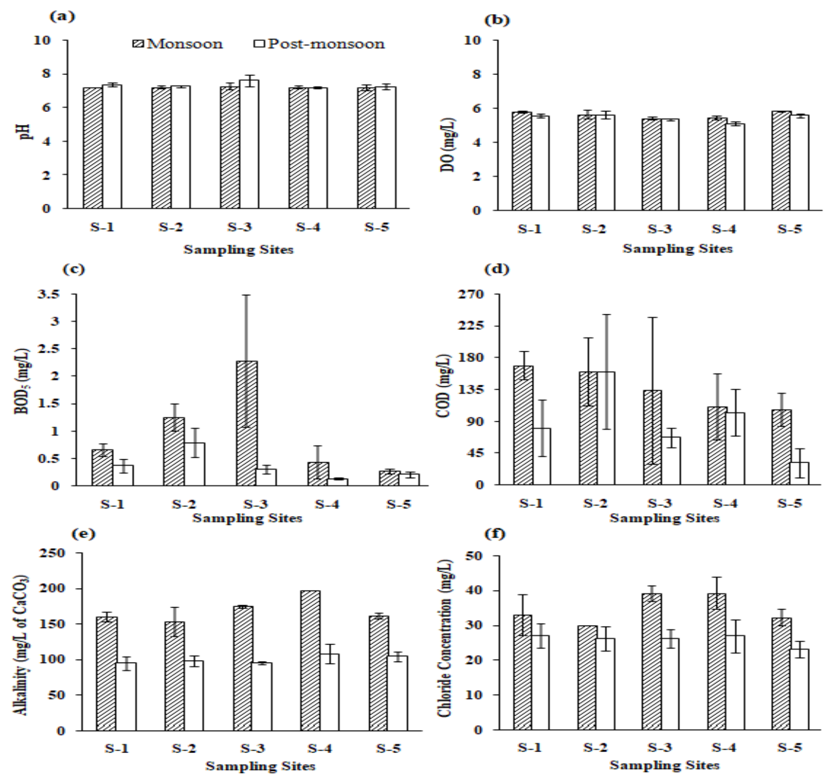


Figure 2: Observed mean a) pH, b) DO, c) BOD_5, d) COD, e)Alkalinity, and e) Chloride in water of Bangshi River during monsoon and post-monsoon (vertical bar with caps indicates standard deviation).

Alkalinity levels in water varied between 153.33 mg/L and 196.67 mg/L in monsoon and between 94.44 mg/L of $CaCO_3$ and 107.78 mg/L of $CaCO_3$ in post-monsoon. In monsoon and post-monsoon, the mean alkalinity of the water was 169.11±17.93 mg/L of $CaCO_3$ and 100±9.09 mg/L of $CaCO_3$, respectively (Figure 2e). The alkalinity values determined meets the standards for fisheries (ADB, 1994) and is higher than the mean alkalinity in the water of the Turag River determined by Khondokar and Abed (2013), which is 58.5 mg/L in the wet season and 81 mg/L in the dry season. Rehnuma et al. (2016) found mean alkalinity values of 155.3(9±39.85) in the wet season and 280.74(±64.39) in the dry season in the Bangshi River at Tangail. In monsoon, the chloride concentration in water of the Bangshi River ranged between 29.95 mg/L and 39.17 mg/L with a mean of 34.71±4.96 mg/L, and in post-monsoon, between 23.04 mg/L and 26.88 mg/L with a mean of 25.81±3.28 mg/L (Figure 2f) which meets the Bangladesh standard (150 mg/L–600 mg/L) (DoE,1991) and the standards of the World Health Organization (WHO, 2004) (≤250 mg/L).

Free CO_2 levels in water of Bangshi River found to be varied from 8.99 to 15.69 mg/L with a mean of 12.95±3.00 mg/L in monsoon, and 6.26 to 10.27 mg/L with a mean of 8.44±1.97 mg/L in post-monsoon (Figure 3).

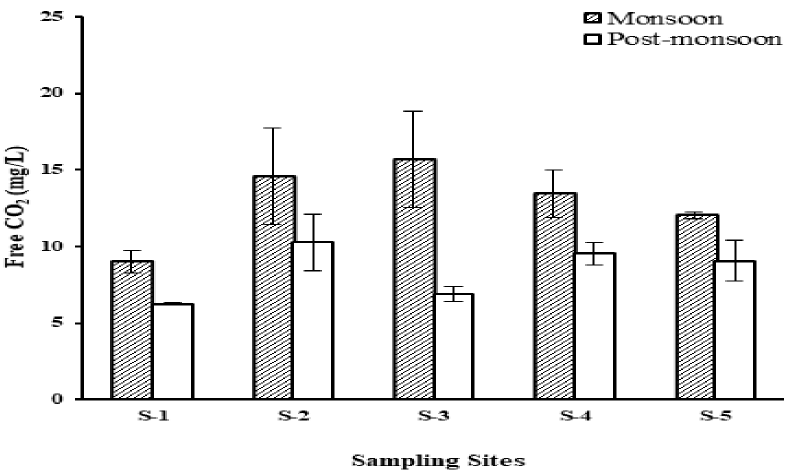


Figure 3: Observed mean free CO_2in water of Bangshi River during monsoon and post-monsoon.

Table 1: Comparison of Physical and chemical parameters of water and primary productivity of phytoplankton community in water of Bangshi River during monsoon and post-monsoon (Mean±SD, t/p, between seasons, n=3) with standards

Parameter	DoE Standard (1997)	Monsoon± SD	Post-monsoon±SD	Mean ±SD	This study	t/p
EC (mS/cm)	1.2	1.49±0.11	1.44±0.10	1.47±0.10	1.31-1.61	
TDS (mg/L)	2100	1344.67±149.79	1089.33±12.56	1217±167.78	1070–1586.67	6.967/0.000*
Turbidity (FTU)	10	46.12±10.62	26.00±2.8096	36.06±12.78	23.59–61.33	7.093/0.000*
pH	6-9	7.21±0.12	7.32±0.22	7.27±0.13	7.21–7.32	2.348/0.000*
DO (mg/L)	≥4.5-8	5.63±0.22	5.44±0.23	5.53±0.22	5.10-5.84	2.348/0.000*
BOD(mg/L)	50	0.98±0.90	0.36±0.26	0.67±0.65	0.13-2.27	2.571/0.016*
COD (mg/L)	200	136±54.79	88±58.07	112±44.78	31.11–168.89	2.328/0.027*
Free CO_2 (mg/L)	22 (WHO, 1995)	12.95±3.00	8.45±1.97	10.67±3.17	6.26–15.69	4.856/0.000*
Alkalinity (ppm of $CaCO_3$)	–	169.11±17.93	100±9.09	134.56±38.38	94.44–196.67	13.318/0.000*
Chloride Conc. (mg/L)	–	34.71±4.96	25.81±3.28	30.26±5.58	23.04-39.17	5.800/0.000*
NPP (mg C/L/day)	–	5.72±1.09	3.71±1.76	4.72±1.74	6.86-1.94	3.028/0.005*
GPP (mg C/L/day)	–	7.36±0.91	5.20±1.28	6.28±1.55	8.60-3-41	3.526/0.001*

*P≤0.05

Primary Productivity

Figure 4 displays the results of the Gross Primary Productivity (GPP) of the aquatic phytoplankton community in the Bangshi River. In the Bangshi River, the gross primary productivity (GPP), net primary productivity (NPP), and respiration rate of the phytoplankton community varied from 6.56 to 8.6 mgC/L/day with a mean of 7.36±1.76 mgC/L/day, 4.64 to 6.86 mgC/L/day with a mean of 5.72±1.77 mgC/L/day, and 1.18 to 1.92 mgC/L/day with a mean of 1.64±31 mgC/L/day in the monsoon; and 3.41 to 6.81 mgC/L/day with a mean of 5.20±1.60 mgC/L/day, 1.94 to 6.18 mgC/L/day with a mean of 3.71±1.86 mgC/L/day, and 0.63 to 2.69 mgC/L/day with a mean of 1.48±0.75 mgC/L/day in the post-monsoon, respectively.

In the Turag River, Khondker and Abed (2013) found the potential primary productivity of the phytoplankton community ranging from 0.45 mgC/L/day to 4.79 mgC/L/day. Similarly, in the Padma River at Mawa Ghat, Ahmed and Alfasane (2004) reported phytoplankton primary productivity ranging from 2.52 mgC/L/day to 14.22 mgC/L/day.

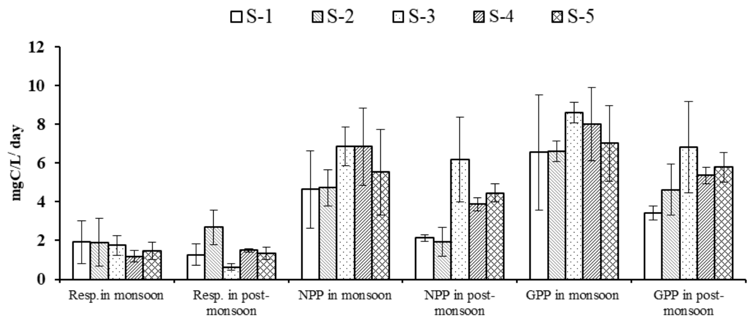


Figure 4: Observed mean primary productivity of phytoplankton community in water of Bangshi River during monsoon and post-monsoon; Resp. = Respiration, and S-1, S-2, S-3, S-4, S-5 are the demarcations of sampling sites (vertical bar with caps indicate standard deviation).

Phytoplankton richness and abundance

During the study period, a total of 32 phytoplankton taxa were identified up to the generic level, belonging to three major classes: Bacillariophyceae, Cyanophyceae, and Chlorophyceae. Among them, Bcillariophyceae was the dominant group with 13 phytoplankton taxa, followed by Chlorophyceae with 11 taxa and Cyanophyceae with 8 taxa (Table 2). In Bacillariophyceae, *Synedra*, *Cyclotella*, *Pinnularia*, and *Navicula*; in Cyanophyceae, *Spirulina*, *Oscillatoria*; and in Chlorophyceae, *Scenedesmus*, *Tetraedron*, and *Gonatozygon* were the most abundant taxa. The occurrences of different classes of phytoplankton at different sampling sites are briefly presented in Table 2. In this study period, the occurrence of major classes of phytoplankton was found as the order (Table 3), Bacillariophyceae (56.30±8.81%) >Chlorophyceae (26.71±9.00%) >Cyanophyceae (17.00±9.18%).

Table 2: Occurrence of different classes of phytoplankton in water of Bangshi River during monsoon (June-September 2019) and post-monsoon (October 2019-January 2020)

Class	Phytoplankton	S-1	S-2	S-3	S-4	S-5	Phytoplankton	S-1	S-2	S-3	S-4	S-5
Chlorophyceae	*Chlorella*	(-,-)	(-,-)	(+,+)	(+,-)	(-,-)	*Pachycladon*	(-,-)	(-,-)	(+,+)	(-,-)	(-,+)
	Dictospherium	(-,-)	(+,-)	(-,-)	(-,-)	(-,-)	*Pleodorina*	(-,-)	(-,+)	(+,-)	(-,+)	(-,-)
	Geminella	(-,-)	(+,-)	(-,-)	(-,-)	(-,-)	*Pleurotaenium*	(+,-)	(+,-)	(-,-)	(-,-)	(-,-)
	Gonatozygon	(+,+)	(+,+)	(-,+)	(+,+)	(+,+)	*Scenedesmus*	(-,-)	(+,-)	(+,-)	(-,-)	(+,-)
	Lagerheimia	(-,-)	(-,-)	(+,-)	(-,-)	(-,-)	*Tetraedron*	(+,-)	(-,-)	(+,-)	(-,-)	(+,+)
	Netrium	(-,-)	(-,+)	(-,+)	(-,+)	(+,+)						
Cyanophyceae	*Aphanocapsa*	(-,-)	(+,+)	(-,+)	(-,-)	(+,-)	*Lyngbya*	(-,-)	(+,-)	(-,-)	(-,-)	(-,-)
	Gleocapsa	(-,-)	(-,-)	(-,-)	(+,-)	(-,-)	*Nostoc*	(-,+)	(+,-)	(-,-)	(-,-)	(-,+)
	Gloeotrichia	(+,-)	(+,-)	(-,-)	(-,+)	(-,-)	*Oscillatoria*	(+,-)	(+,+)	(-,-)	(+,+)	(-,+)
	Holopedium	(-,-)	(-,-)	(+,+)	(+,-)	(-,-)	*Spirulina*	(+,+)	(+,-)	(-,-)	(+,-)	(+,+)
Bacillar ia...	*Amphora*	(-,-)	(-,-)	(-,-)	(-,-)	(+,-)	*Hemiaulus*	(-,-)	(-,+)	(-,-)	(+,-)	(-,-)

Class	Phytoplankton	S-1	S-2	S-3	S-4	S-5	Phytoplankton	S-1	S-2	S-3	S-4	S-5
	Cerataulina	(-,-)	(-,+)	(-,-)	(-,+)	(-,+)	*Navicula*	(+,+)	(+,+)	(+,+)	(-,-)	(+,+)
	Coscinodiscus	(-,-)	(-,-)	(-,-)	(+,-)	(-,-)	*Nitzchia*	(-,-)	(-,+)	(-,-)	(-,-)	(+,-)
	Cyclotella	(+,-)	(+,-)	(-,-)	(+,-)	(+,-)	*Pinnularia*	(+,+)	(+,+)	(+,+)	(+,+)	(+,+)
	Fragillaria	(+,-)	(-,-)	(-,-)	(-,-)	(-,+)	*Rhizosolenia*	(-,-)	(-,-)	(+,-)	(-,-)	(-,-)
	Gomphonema	(-,-)	(-,-)	(-,+)	(-,+)	(+,-)	*Synedra*	(+,+)	(+,+)	(+,+)	(+,+)	(+,+)
	Gyrosigma	(-,-)	(-,-)	(+,-)	(+,-)	(+,-)						

Present = + ; Absent = - ; and Inside first brackets, the first sign = presence or absence in monsoon, and the second sign = presence or absence in post-monsoon, Vertical names= Phytoplankton class

Table 3: Observed mean phytoplankton abundance (%) in Bangshi River water during monsoon and post-monsoon (Mean± SD)

Season	Cyanophyceae (%)	Bacillariophyceae (%)	Chlorophyceae (%)
Monsoon	21.61±11.50	55.24±7.41	23.15±7.77
Post-monsoon	12.38±1.99	57.36±10.81	30.26±9.49

Shannon-Weaver's diversity index and evenness

The Shannon-Weaver diversity index is used to assess water pollution by evaluating species diversity. Higher values indicate cleaner water, while lower values indicate more pollution. Values >4 indicate clean water, values between 3 and 4 indicate mild pollution, values between 2 and 3 indicate moderate pollution, and values <2 indicate heavy pollution (Shekhar et al., 2008). In the study, the highest Shannon-Weaver diversity index value (2.45) was observed at sampling site S-2 during the monsoon, while the lowest value (1.54) was found at site S-1 during the post-monsoon. The index ranged from 2.14 to 2.45 during the monsoon and from 1.54 to 2.02 during the post-monsoon (Table 4). Most sites indicated moderate pollution, except for site S-1, which showed heavy pollution during the post-monsoon. Evenness, which indicates species distribution, ranged from 0.88 to 0.92 during the monsoon and from 0.86 to 0.95 during the post-monsoon signifying more even distribution of phytoplankton taxa (Table 4).

Table 4: Shannon Weaver's diversity index and evenness for phytoplankton composition in water of Bangshi River during monsoon (June-September 2019) and post-monsoon (October 2019-January 2020)

Sampling Site	Season	No. of Species (N)	Shannon Weaver's Index (H)	H_{max}=ln(N)	Evenness =H/H_{max}
S1	Monsoon	11	2.15	2.4	0.9
	Post-monsoon	6	1.54	1.79	0.86
S2	Monsoon	16	2.45	2.77	0.88
	Post-monsoon	10	2.11	2.3	0.91
S3	Monsoon	12	2.27	2.48	0.92
	Post-monsoon	10	2.19	2.3	0.95
S4	Monsoon	12	2.26	2.48	0.91
	Post-monsoon	9	2.02	2.2	0.92

Sampling Site	Season	No. of Species (N)	Shannon Weaver's Index (H)	H_{max}=ln(N)	Evenness =H/H_{max}
S5	Monsoon	13	2.33	2.56	0.91
	Post-monsoon	12	2.14	2.48	0.86

Pearson's correlation between phytoplankton / productivity with physical / chemical parameters of water in Bangshi River

During monsoon the following associations were found: very strong positive correlation between Cyanophyceace and GPP (r=0.903*), Cyanophyceae and NPP (r=0.946*), Chloride and GPP (r=0.806**); strong positive correlation between Chloride and NPP (r=0.792**); During post-monsoon the following associations were found: very strong negative correlation between Bacillariophyceae and temperature (r=-0.898*), Chlorophyceae and free CO_2 (r=-0.883*); very strong positive correlation between Chlorophyceae and temperature (r=0.925*); strong negative correlation between respiration and temperature (r=-0.661**); strong positive correlation between NPP and temperature (r=0.758**), Respiration and BOD_5 (r=0.724**), respiration and free CO_2 (r=0.718**). During this study (monsoon and post-monsoon), the following associations were found: very strong positive correlation between Cyanophyceae and NPP (r=0.884**), Cyanophyceae and GPP (r=0.896**), strong positive correlation between chloride and Cyanophyceae (r=0.755*).

Conclusion

In terms of water quality assessment, physical and chemical parameters play an important role in evaluating the existing status of an aquatic ecosystem's health, along with the use of phytoplankton abundance and distribution as an indicator of water quality status. Through this investigation, a comprehensive understanding of the interactions among water quality, phytoplankton dynamics, and environmental factors were attained which may contribute to effective management and conservation strategies for similar freshwater environments.

In this study, observed physical parameters such as temperature, TDS, and turbidity varied from 28.07–33.3°C, 1070–1586.67 mg/L, and 23.59–61.33 FTU, and chemical parameters such as water pH, EC, DO, BOD_5, COD, alkalinity, chloride, and free CO_2 varied from 7.21–7.32, 1.31-1.61 mS/cm, 5.10–5.84 mg/L, 0.13–2.27 mg/L, 31.11–168.89 mg/L, 94.44–196.67 mg/L, 23.04–39.17 mg/L, and 6.26–15.69 mg/L, respectively. During monsoon and post-monsoon, a total of 32 taxa belonging to three major classes, Cyanophyceae (8), Bacillariophyceae (13) and Chlorophyceae (11) were identified with an abundance of 17%, 56.30%, and 26.71%, respectively. The assessment of Shannon-Weaver's diversity index and evenness during monsoon and post-monsoon provided values ranging from 1.54–2.45 indicating heavy to moderate pollution of water, and 0.86–0.95 indicating more even distribution of phytoplankton in the water of the Bangshi River, respectively. During monsoon and post-monsoon, the primary productivity of phytoplankton communities in the water of the Bangshi River was considered an expression of GPP, NPP, and respiration rate, and these varied from 3.41–6.56 mgC/L/day, 1.94–6.68 mgC/L/day, and 0.63–2.69 mgC/L/day, respectively. These findings can be used to evaluate the quality of river ecosystem health.

References

ADB (Asian Development Bank), 1994. Training manual for environmental monitoring.Engineering Science Inc., USA, 2-16.

Adeyinka, M., Imoobe, T.O.T., 2009.Zooplankton-based assessment of a tropical forest riverin Nigeria. Arch. Biol. Sci., 61(4), 733-740.

Ahmed, A., Alfasane, M.A., 2004. Ecological studies of the River Padma at Mawa Ghat, Munshiganj II. Primary productivity, phytoplankton standing crops and diversity. Pak. J. Biol. Sci., 7(11), 1870-1875.

Alam, A.K.M., Hossain, A.B.M., Aziz, A., Hoque, S., 2004. Phytoplankton seasonality of some freshwater wetlands of greater Dhaka district in relation to water chemistry. Jahangirnagar Univ. J. Biol. Sci., 27, 241-249.

Alam, A.K.M.R., 2017. Phytoplankton assemblage in relation to Water Quality of the Wetland at National Monument of Bangladesh. Jahangirnagar Univ. J. Biol. Sci., 40: 111-124.

APHA (American Public Health Association), 1995. Standard methods for the examination of water and wastewater.19th Edition, American Public Health Association, Washington DC, USA.

Babar, H.T., Raje, G.B., 2016. Primary productivity study of Morawane dam in Ratnagiri district of Maharashtra, India. J. Global Biosci., 4(2), 1430-1438.

Barthwal, R.R., 2002. Environmental Impact Assessment. New Age International Publishers, New Delhi, India, 22-24.

Dirican, S., Musul, H., Cilek, S., 2009. Some physico-chemical characteristics and rotifers of Camligoze Dam Lake, Susehri, Sivas, Turkey. J. Animal Veterinary Advan., 8(4).

DoE (Department of Environment), (1997). The Environment Conservation Rules; Ministry of Environment and Forest, Government of the People's Republic of Bangladesh: Dhaka, Bangladesh.

DoE (Department of Environment), 1991. Environmental Water Quality Standard. Department of Environment, Dhaka, Bangladesh.

ECR (Environment Conservation Rules), 1997. Ministry of Environment and Forest. Governmentof the People's Republic of Bangladesh.

EQS (Environmental Quality Standard), 1997. Bangladesh Gazette, Registered No. Da-1, Ministry of Environment and Forest, Government of Bangladesh.

Esenowo, I.K., Ugwumba, A.A.A., Akpan, A.U., 2017. Evaluating the physico-chemical characteristics and phytoplankton diversity of Nawaniba River, South-South Nigeria. Asian J. Environ. Ecol., 5(3), 1-8.

Haque, M.I., 2008. Water resources management in Bangladesh. Anushilan, Dhaka-1205 and Chuadanga-7200, 24-84.

Hasan, M.K., Khan, M.R.I., Nesha, M.K., Happy, M.A., 2014. Analysis of water quality usingchemical parameters and metal status of Balu River at Dhaka, Bangladesh. Open J. Water Poll. Treat., 1(2), 58-74.

Hossain, M.D., Rahman, M.M., Chandra, J.B., Shammi, M., Uddin M.K., 2012. Present status of water quality of the Bangshi River, Savar, Dhaka, Bangladesh. Bangladesh J. Environ. Res., 10, 17-30.

Islam, M.S., Datta, T., Ema, I.J., Kabir, M.H., Meghla, N.T., 2015. Investigation of water qualityfrom the Brahmaputra River in Sherpur district. Bangladesh J. Sci. Res., 28(1), 35-41.

Islam, M.S., Kabir, M.H., Sifat, S.A., Meghla, N.T., Tusher, T.R., 2014. Status of water qualityfrom the Padma river at Bheramara point of Kushtia in Bangladesh. Bangladesh J. Environ. Sci., 27, 110-115.

Islam, M.S., Suravi, Ali, M.A., Meghla, N.T., Sultana, S., 2013. Seasonal variations of physicochemical parameters of water in the Pungli River, Tangail, Bangladesh. Int. J. Curr. Microbiol. Appl. Sci., 2, 155-167.

Khatun, M., Alam, A.K.M.R., 2019. Phytoplankton assemblage with relation to water quality in Turag River of Bangladesh. Caspian J. Environ. Sci., 18(1), 31-45.

Khondker, M., Abed, A.S.G., 2013. Seasonality of phytoplankton productivity of the River Turag of Dhaka in relation to its water quality. Bangladesh J. Bot., 42(2), 287-284.

Mahar, M.A., Baloch, W.A., Jafri, S.I.H., 2000. Diversity and seasonal occurrence of planktonic Rotifers in Manchhar Lake, Sindh Pakistan. Pakistan J. Fish., 5-10.

Mustafa, M.G., Brooks, A.C., 2009. A comparative study of two seasonal flood plainaquaculture systems in Bangladesh. Water Policy, 11(1), 69-79.

Onyema, I.C., Otudeko, O.G., Nwankwo, D.I., 2003.The distribution and composition ofplankton around a sewage disposal site atIddo, Nigeria. J.Scient. Res.Develop. 7, 11-26.

Purushothama, R., Sayeswara, H.A., Goudar, M.A., Kumar, K.H., 2011. Physico-Chemichal Profile and Zooplankton Community Composition in Brahmana Kalasi Tank, Sagara, Karnataka, India. The Ecoscan, 43-48.

Rahman, A.K.M., Sattar, M.A., Baten, M.A., Hossain, M.A., 2005. Contamination of River waters. Bangladesh J. Environ. Sci., 11(2), 319-322.

Rathod, R.P., Chavan, B.R., Raghuvendra, K.P., 2016.Variation in primary production in relation to physico-chemical parameters of Kadwai reservoir, Ratnagiri, Maharashtra, India. Curr. World Environ., 11(1), 228-232.

Rehnuma, M., Islam, M.S., Meghla, N.T.,Kabir, M.H., 2016. Investigation of water quality from Bangshi River at Tangail in Bangladesh. J. Sci. Technol., 6(1&2), 153-160.

Rikta, S.Y., Rahaman, M.S., Mehjabin, J.J., Md. KhabirUddin, M.K., Kabir, M.M., Tareq S.M., 2016. Evaluation of water quality parameters and Humic substance status of Bangshi, Dhaleshwari and Padma Rivers in Bangladesh. Int. J. Environ. Sci., 6(6), 1129-1139.

Rothhaupt, K.O., 2000. Plankton populationdynamics: Food web interactions andabiotic constraints. Freshw. Biol., 45, 105-109.

Shannon, C.E., Weaver, W., 1949. The mathematical theory of communication Urban. Univ. Illinois Press, Illinois, 125.

Shekhar, R.T., Kiran, B., Puttaiah, E.T., Shivaraj, Y., Mahadevan, K.M., 2008. Phytoplankton as index of water quality with reference to industrial pollution. J. Environ. Biol., 29(2), 233-236.

Shukla, M., Arya, S., 2018. Determination of chloride ion (Cl^-) concentration in Ganga River water by Mohr method at Kanpur, India. Green Chemistry & Technology Letters.

Shukla, R.S., Chanddel, R.S., 1972. A Text Book of Plant Ecology including Ethnobotany and Soil Science. S. Chand and Company Limited, ISBN 81-219-0548-6.

Stanitski, C.L., Eubanks, L.P., Middlecamp, C.H., Pienta., N.J., 2003. Chemistry in Context: Applying Chemistry to Society. 4th edition, Boston: McGraw-Hill.

Stire, S.R., 2014. Zooplankton fauna of a freshwater pond in Bhadrawati town of Chandrapur district in Maharashtra state (India). Online International Interdisciplinary Research Journal, 4.

Strickland, J.D., Parsons, T.R., 1972. A practical handbook of seawater analysis. Ottawa: Fisheries Research Board of Canada, Bull. 167.

Tahmina, B., Sujan, D., Karabi, R., Hena, M.K.A., Amin, K.R., Sharmin, S., 2018.Assessment of surface water quality of the Turag River in Bangladesh. Res. J. Chem. Environ., 22(2), 49-56.

Thurman, H.V., 2007. Introductory Oceanography. Academic Internet Publishers, ISBN 978-1-4288-3314-2.

UNEP (United Nations Environment Programme), 2001. Bangladesh: State of Environment 2001, Dhaka, Bangladesh.

WHO, 2004. Guidelines for Drinking Water Quality Recommendation. World Health Organisation, Genèva.