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Assessment of Temporal Variation of Water Quality Parameters and the Trophic State Index in a Subtropical Water Reservoir of Bangladesh

Md. Sirajul Islam*[1], Yousuf Ali[2], Md. Humayun Kabir[3], Rofi Md. Zubaer[4], Nowara Tamanna Meghla[5], Mausumi Rehnuma[6], Mir Md. Mozammal Hoque[7]

[1]Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Email: islammstazu@yahoo.com | ORCID: 0000-0002-7560-9334

[2]Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Email: er15039@mbstu.ac.bd | ORCID: 0000-0003-3429-2622

[3]Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Email: kabirmh07@gmail.com | ORCID: 0000-0002-2351-6275

[4]Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Email: zubaer016@gmail.com | ORCID: 0000-0003-2196-4901

[5]Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Email: nowaratamanna@gmail.com | ORCID: 0000-0001-7399-4446

[6]Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Email: rehnuma.mausumi@gmail.com | ORCID: 0000-0003-4257-104X

[7]Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh. Email: huqmbstu@gmail.com | ORCID: 0000-0001-9108-7735

Corresponding author

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Abstract

This study was conducted to determine the suitability of water quality for fisheries management in Kaptai Lake from February 2019 to January 2020. Results showed that the temperature, transparency, TDS, pH, DO, EC, alkalinity and hardness were 20.9 to 31.8°C, 17 to 303 cm, 40 to 105 mg/L, 6.82 to 7.96, 6.1 to 7.65 mg/L, 75.33 to 172.33 µS/cm, 37 to 83 mg/L and 35 to 190 mg/L, respectively. However, nutrients as NH_3, NO_3^-, NO_2^-, PO_4^{3-} and SO_4^{2-} were 0.01 to 0.05, 0.03 to 2.21, 36 to 96, 0.01 to 0.04 and 0.3 to 1.9 mg/L, respectively. Chlorophyll *a* and trophic state index (TSI) were 0.70 to 2.12 µg/L and 27.43 to 37.79, respectively. Study revealed that SO_4^{2-}, DO and TDS were higher than the standard of ECR. On the other hand, NH_3, NO_3^-, NO_2^-, PO_4^{3-}, temperature, transparency, pH, EC, total hardness, total alkalinity, Chlorophyll *a* and TSI were within the standard levels. Concentrations of NO_3^-, NO_2^-, PO_4^{3-}, Chlorophyll *a* and TSI (CHL) showed no significant variation with seasons. Conversely, TDS, transparency, EC, alkalinity, hardness, and SO_4^{2-} were lower in monsoon compared to pre-monsoon and post-monsoon seasons. Besides, temperature, NH_3, DO and TSI (SD) were higher in monsoon season. Results concluded that the Kaptai Lake is in mesotrophic condition with TSI (CHL) less than 40, and prominently there was a positive relationship between Chlorophyll *a* and Trophic State Index (TSI). In this regard, major nutrients and Chlorophyll *a* concentration in the Kaptai Lake may have an impact on the aquatic environment.

Keywords

Seasonal variation; Water quality; Dissolved nutrient; Chlorophyll *a*; Kaptai Lake; Bangladesh

Introduction

Bangladesh is enriched with extensive water resources distributed all over the country (Rahman *et al*., 2014). The Kaptai reservoir was created with the construction of an earthen dam across the Karnaphuli River at Kaptai, about 70 km upstream from the estuary of Chittagong, for the production of hydroelectricity, which came into operation in January 1962 (Bashar *et al*., 2015). At present, Kaptai reservoir supports small-scale fisheries, which is rich in fish species diversity and contributing approximately 63,000 ton freshwater fish annually (Ahmed *et al*., 2001). As fishery is the secondary enterprise in this lake, the Bangladesh Fisheries Development Corporation has no control over the water level fluctuations (Bashar *et al*., 2014). Over the years, 8 species of fish disappeared, 7 species dwindled (Haldar *et al*., 1992). Quality of surface water is important for long term uses, which affects community health, hampers aquaculture practices and also creates aesthetic problem in the locality. Every water use requires a certain minimum water quality ensuring no harm to the user (Kabir *et al*., 2020). At present land use changes, urban human habitation, inland navigation activity as well as major development scheme in terms of road, bridge and other construction works are greatly affecting this freshwater resource (Rubel *et al*., 2019; Kabir and Naser, 2011).

Water quality generally means the component of water that must be present for optimum growth of aquatic organisms (Ahatun *et al*., 2020). The determinant of good growth in water body includes dissolved oxygen (DO), hardness, turbidity, alkalinity, nutrients, temperature, etc. in most of the water bodies. This concentration level increases due to human activities and lack of environmental regulation (Ehiagbonare and Ogunrinde, 2010). Assessment of water resource quality of any region is an important aspect of developmental activities, because rivers, lakes and manmade reservoirs are used for water supply to domestic, industrial, agricultural and fish culture (Pal *et al*., 2015). For maintaining the productive as well as balanced aquatic environment, nutrients are the prime crucial elements (Ahatun *et al*., 2020). All aquatic organisms including fish depend directly on nutrients for their survival, growth and reproduction. Some nutrient levels are related to the chlorophyll availability on water body, which means the availability of phytoplankton in the water (Shukla *et al*., 2013). Thus, nutrient availability is directly related to the productivity of the water body (Rahaman *et al*., 2013). A shortage of nutrients causes the water body to be unproductive. An excess of nutrients causes eutrophication by algal bloom and makes the water toxic. Algae play an important role in all aquatic ecosystems by providing all living organisms of water bodies with preliminary nutrients and energy required. However, abnormal and excessive algal growth, called as algal bloom, would be detrimental as much (Ghorbani *et al*., 2014; Stauffer *et al*., 2019). So, nutrient concentration must be within an acceptable limit for a good aquatic environment and for better production of aquatic organisms including fish (Senthilkumar *et al*., 2008).

The algal flora of the Kaptai Lake is very poorly known; but the available information suggests that the Kaptai Lake has a low diverse algal flora comprised of both benthic and planktonic forms in the freshwater environments. Since algal flora play very important role in ecological context: the study of Chlorophyll *a* concentration is utmost important. Chlorophyll *a* is the pigment that allows plants and algae to photosynthesize, in which plants use the sun's energy to convert carbon-dioxide and water into oxygen and cellular material. It also absorbs energy from wavelengths of violet-blue and orange-red light, while reflecting green-yellow light (Suzuki *et al*., 1997; Islam *et al*., 2019). Chlorophyll *a* concentration may change the surrounding environment physically, chemically, and biologically in the ways that favor or not favor their continued persistence. The study of Chlorophyll *a* concentration is considered useful for interpreting hydro-chemical variations in freshwater reservoir. So, the temporal and spatial Chlorophyll *a* concentration may act as an indicator of the water quality fluctuation in response to changing environment (Rahaman *et al*., 2013; Senthilkumar *et al*., 2008). All aquatic organisms depend directly on nutrients for their survival, growth and reproduction. Some nutrient levels are related to the Chlorophyll *a* availability in the water body, which means the availability of phytoplankton in the water. Thus, nutrient availability is directly related to the productivity of the water body. A shortage of nutrients causes the water body to be unproductive, and an excess of nutrients causes eutrophication by algal bloom and makes the water toxic

(Islam *et al*., 2017; Islam *et al*., 2019). Thus, the nutrient concentration must be within suitable limit for a good aquatic environment and for better production of aquatic organisms (Rahaman *et al*., 2015). In the past decades, limnologists have developed many methods to assess the trophic status, including the character method (Rao, 1956), parameter method, the biotic indices method (Alba-Tercedor, 1996), the phosphorus budget model method (Dillon and Rigler, 1974) and the trophic state index method (Carlson, 1977). Among these developed methods, Carlson's trophic state index (TSI) is one of the most widely accepted methods in evaluating the trophic status because that Carlson's TSI is a continuous number in assessing the trophic status, which can provide a more precise assessment of the trophic status than other conventional methods (e.g., parameter method), which only provides a rough typological trophic information (Wang *et al*., 2011). In addition, Carlson's TSI is easy to be implemented with the easy analysis of the limiting factors of the trophic status (Nion *et al.*, 2020). The phytoplankton is microscopic single-celled plant that plays an important role in the ecosystem as a major primary producer through photosynthesis (Johan *et al*., 2018). The most influential factors on Chlorophyll *a* may be dependent on the different water quality patterns in lakes (Li *et al*., 2017).

Previous research on Kaptai Lake included physical and chemical limnology by Khan and Chowdhury (1994), macro-benthic invertebrate fauna by Khan *et al*. (1996), population biology and environment of two carps by Azadi *et al*. (1997), and environmental impact assessment by Alam *et al*. (2006). Although there are a few publications on the physical and chemical limnology of Kaptai Lake, a full study on the seasonal change of water quality (physical, chemical, biological, and anionic) parameters as well as the trophic status index (TSI) in Kaptai Lake is sorely lacking. Therefore, the goal of this proposed study is to collect data on changes in water quality indicators and TSI in Kaptai Lake over the course of a year in order to offer baseline data to aid in lake ecosystem management decisions. Thus, the current study attempted to evaluate seasonal variations in physicochemical parameters and nutrients in the lake water column, as well as to assess seasonal variations in Chlorophyll *a* concentration and the trophic status index (TSI) in the lake water column at Bangladesh's Kaptai Lake.

Materials and Methods

Study area: The study was conducted in Kaptai Lake water reservoir of Bangladesh. The Kaptai Lake (Latitude 22°09'N and Longitude 92°17'E) has drowned almost the whole of the middle-Karnafuli valley and the lower reaches of the Chengi, Kasalong and Rinkhyong Rivers (Figure 1). The shoreline and the Basin of Kaptai Lake are very irregular. Its important morphometric and hydrographic features are as follows: surface elevation 31.1 m, surface area 58,300 ha, volume 524,700 m^3, total annual discharge 1,707,000 m^3, storage ratio 0.31, mean depth 9 m, maximum depth 32 m, outlet depth 15.5 m, mean annual water level fluctuation 8.14 m, growing season 365 days, total dissolved solids 76 ppm and specific conductance 144 mhos at 25°C (Banglapedia, 2016).

Sample collection: For seasonal monitoring of water quality (physicochemical and anionic) such as temperature, transparency, total dissolved solids (TDS), pH, dissolved oxygen (DO), electrical conductivity (EC), total alkalinity, total hardness; major dissolved nutrients such as ammonia (NH_3), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^-), sulphate (SO_4^-) and Chlorophyll *a* concentrations, surface water samples were collected from 4 fixed sampling stations of the Kaptai Lake aquatic ecosystems during the study period from February 2019 to January 2020, whereas the period were divided as pre-monsoon (February to May), monsoon (June to September) and post-monsoon (October to January) seasons, respectively. The four sampling stations namely St-1 (Rangamati Sadar), St-2 (Kaptai), St-3 (Langadhu), and St-4 (Mohalchari) were selected taking following aspects into consideration: i) the streams and drainage arms, ii) catchment area and iii) water level of the lake. To analyze the physicochemical quality, major nutrients and Chlorophyll *a* concentration, 1,000 ml water was collected in plastic bottles with double stoppers from each sampling station. Before sampling, the bottle was cleaned and washed with detergent solution and treated with 5% nitric acid (HNO_3) over night. The bottles finally rinsed with deionized water and dried. At each sampling

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station, the sampling bottles were rinsed at least three times before sampling was done. Pre-prepared sampling bottles were immersed about 10 cm below the surface water. After sampling, the bottles were screwed carefully and marked with the respective identification number. Then the samples were kept frozen (-20°C) until analysis (within 48 hrs.) to avoid further contamination (Senthilkumar *et al*., 2008; Rahaman *et al*., 2013).

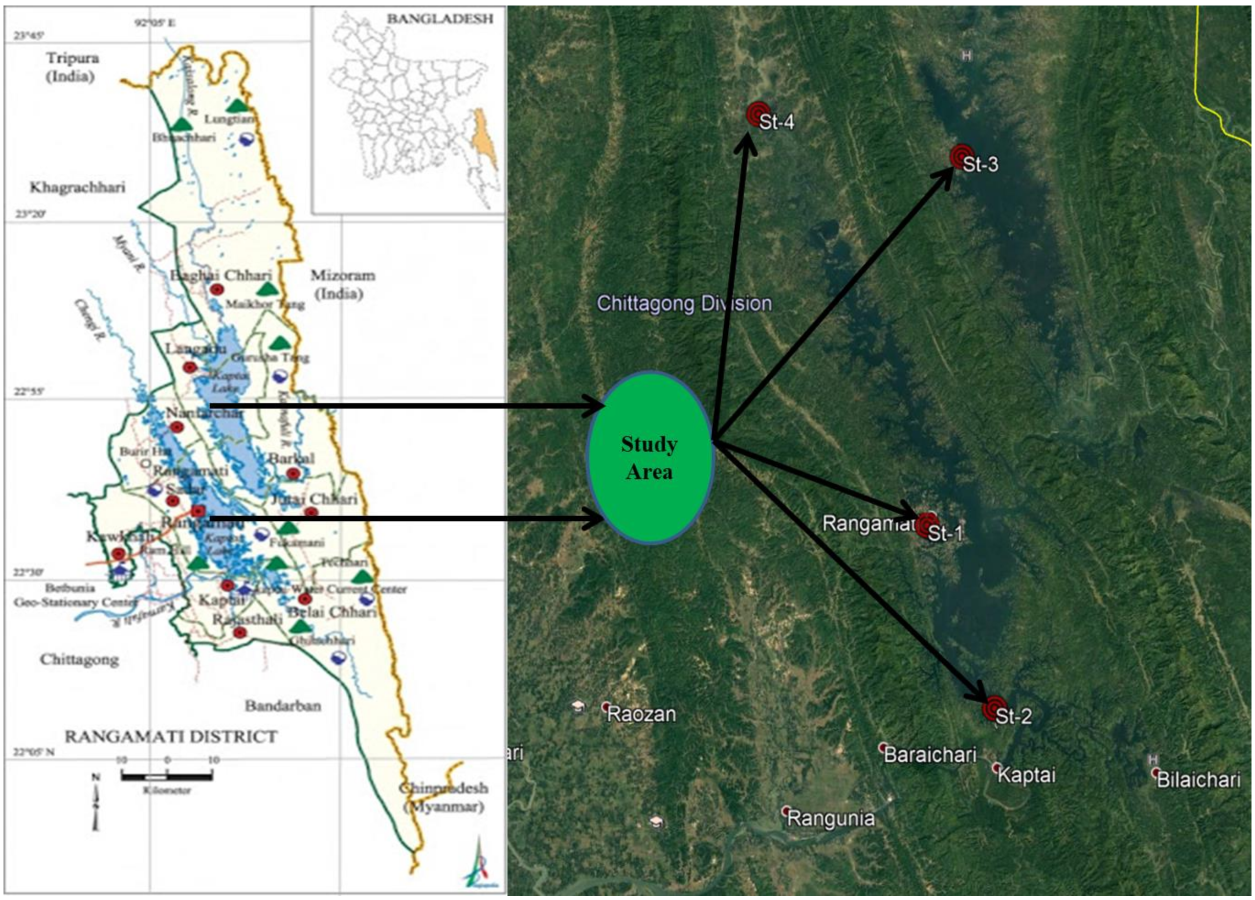

Figure 1: Map showing the study area at Kaptai Lake in Bangladesh (Banglapedia, 2016).

Sample analysis: The physicochemical parameters were analyzed in the laboratory of the Department of Environmental Science and Resource Management of the Mawlana Bhashani Science and Technology University. Temperature and pH were determined by the thermometer and digital pH meter, respectively. Buffer solution containing pH 7.0 was used to calibrate the digital pH meter. The Secchi disc was used to determine the transparency of water. The DO was determined by digital DO meter where sodium thiosulphate (0.025N) was used as a reagent. The EC and TDS were determined by EC and TDS meter, respectively. Total alkalinity (TA) and total hardness (TH) were determined by using titration technique. For the determination of dissolved nutrient concentrations, the water samples were prepared for ionic test followed by APHA (2005) using chromatographic (Shimadzu Ion Chromatograph, HIC-10-A, Japan) analysis in the Laboratory of the Bangladesh Fisheries Research Institute (BFRI), Mymensingh. After instrumental measurements, the values of ions including ammonia (NH_3-N), nitrate (NO_3-N), nitrite (NO_2-N), phosphate (PO_4-P) and sulphate (SO_4) were calculated using computer aided tools. The Chlorophyll *a* of water samples was analyzed by 90% acetone method in the Biochemistry and Molecular Biology Laboratory of the Mawlana Bhashani Science and Technology University.

Statistical analysis: The data were assembled and set out in appropriate form and were subjected to statistical analysis. The Statistical Package for Social Sciences (SPSS version 16.0) was used to present and interpret the collected data. Pearson's correlation matrix was used to examine specific relationships among the parameters studied.

Results and Discussion

Physiochemical water quality

Temperature: Water temperature is critical since it is an important environmental quality metric that must be measured. By doing so, we can see the characteristics of the water such as the chemical, biological, and physical properties of the water. Water temperature is an important factor in determining whether a body of water is acceptable for aquatic ecosystem (Kabir *et al*., 2020). During the monsoon, the highest temperature (31.8°C) was recorded at St-3, while the lowest temperature (20.9°C) was recorded at St-1 during the post-monsoon (Figure 2). The highest mean temperature 31.1°C was found in monsoon and the lowest 21.12°C was found in post-monsoon (Table 1). Bashar *et al*. (2015) discovered that the average water temperature in Kaptai Lake ranged from 21.04 to 31.52°C, with a maximum of 31.5°C in September and a minimum of 21.04°C in January. According to Meghla *et al*. (2013) the temperature of Turag River water was 30.95, 32.36 and 17.75°C during the pre-monsoon, monsoon, and post-monsoon seasons, respectively. This may be attributed to different collection timings and seasonal influences (Srivastava and Kanungo, 2013).

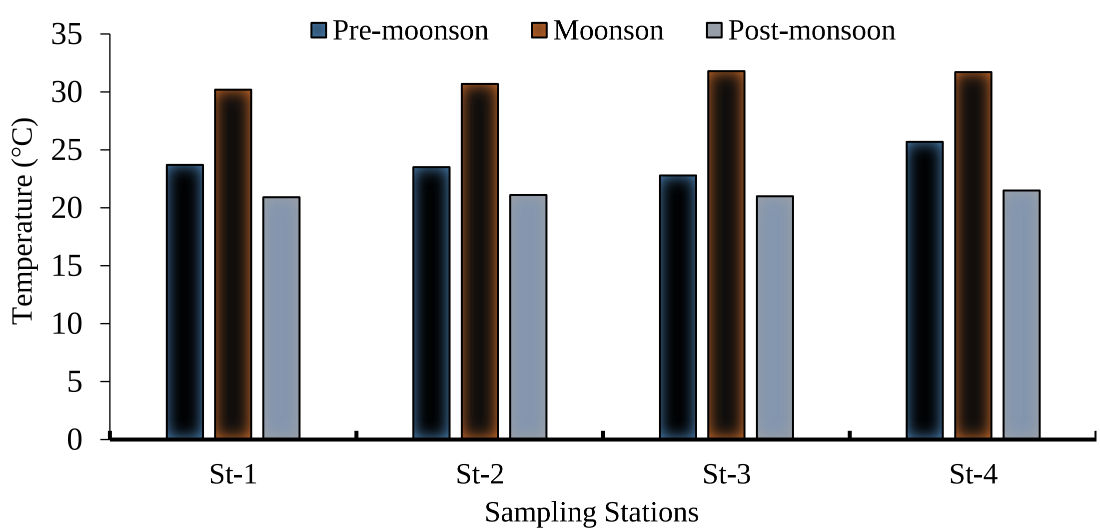

Figure 2: The temperature at various sampling stations during different seasons

Transparency: Water transparency changes can affect essential features of aquatic ecosystems, influencing the use of critical habitats or resources and resulting in phenotypic divergence. Changes in the availability of vital resources as a result of habitat productivity changes could have an impact on resource utilization and, as a consequence, population divergence (Islam *et al*., 2015a). The water transparency of the four stations was within the range of 17 to 303 cm. The highest transparency 303 cm was found at St-2 during post-monsoon and the lowest transparency 17 cm was found at St-4 during monsoon (Figure 3). On an average the highest transparency 303 cm was found in post-monsoon and the lowest transparency 17 cm was found in monsoon season (Table 1). The limit of Secchi disc visibility in Kaptai Lake was found to vary throughout the year, with high visibility in the winter and low visibility during the dry season. The inflow of suspended matter and silt from hill streams triggers a rapid increase in turbidity. During the monsoon

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season, Chowdhury and Mazumder (1981) and Haldar *et al*. (1992) recorded high turbidity in the same lake. Water bodies that are productive should have a transparency of no more than 40 cm (Rahman, 1992).

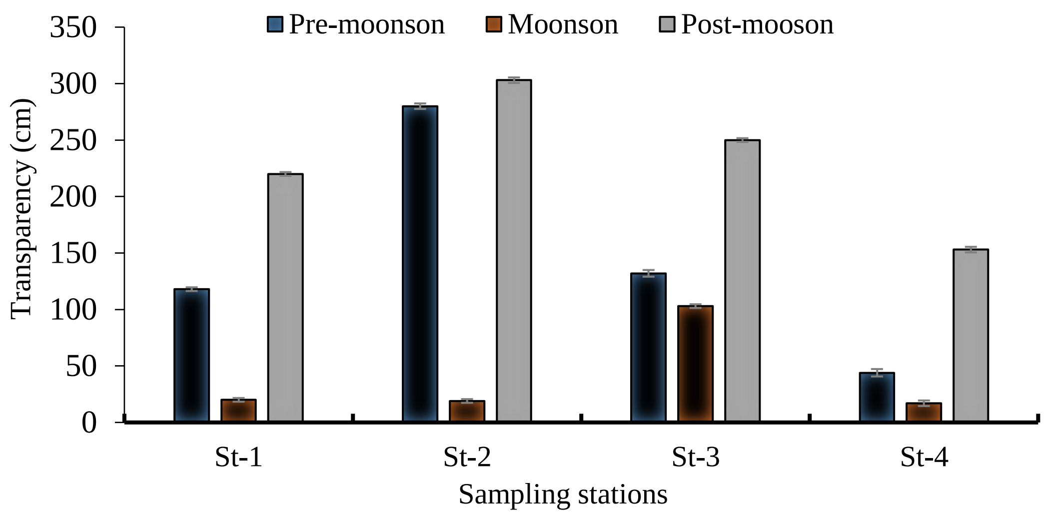

Figure 3: Water transparency at various sampling stations during several seasons

Total Dissolved Solid (TDS): In bodies of water, like rivers, higher levels of TDS often harm aquatic species. TDS changes the mineral content of the water, which is important to survival of many animals. Also, dissolved salt can dehydrate the skin of aquatic animals, which can be fatal. It can increase the temperature of the water, which many animals cannot survive in (Islam *et al*., 2012). The lowest TDS content 40 mg/L was found at St-3 during monsoon and the highest TDS 105 mg/L was found at St-2 during post-monsoon season (Figure 4). The average TDS in different season during the study period ranged from 44.5 to 80.5 mg/L. The mean highest TDS 80.5 mg/L was found in post-monsoon and the lowest TDS 44.5 mg/L was observed in monsoon season (Table 1). As a result, TDS concentrations in some stations are beyond the range, while others are within the range established by ECR (1997). TDS concentrations in Kaptai Lake were 52 to 54 mg/L, compared to 39 to 42 mg/L in Bogakain, a natural high altitude lake in Bangladesh (Barua *et al*., 2016; Khondker *et al*., 2010). The TDS levels in the Brahmaputra River ranged from 183 to 185 mg/l and 157 to 198 mg/l (Islam *et al*., 2015a,b), while TDS levels in the Buriganga River ranged from 378.75 to 616.75 mg/L and 205 to 240.5 mg/L during the dry and wet seasons, respectively, exceeding the normal level in both seasons (Islam *et al*., 2012).

pH: If the pH of water is too high or too low, the aquatic organisms living within it will die. The pH can also affect the solubility and toxicity of chemicals in the water (Islam *et al*., 2015a,b). The pH of the water at the four stations ranged from 6.82 to 7.96. During the pre-monsoon season, the highest pH 7.96 was found at St-2, while the lowest pH 6.82 was found at St-4 during the post-monsoon season (Figure 5). The highest pH 7.62 was found in pre-monsoon and the lowest pH 6.77 was found in post-monsoon season (Table 1). The pH in freshwater should be in the range of 6.5 to 9 according to EPA water quality guidelines (EPA, 2017). Kaptai Lake's water pH is between 7.46 and 7.75, which is within the appropriate range (Barua *et al*., 2016). The pH of the water in the Kaptai Lake was often found to be alkaline in nature, ranging from 6.9 in July to 7.6 in May. According to the results of the report, the pH level is within the appropriate range for fisheries production and is nearly identical to the previous record. The pH levels in Ashulia beel were 7.1 to 7.8 in the wet season and 7.1 to 8.4 in the dry season, confirming the slightly alkaline quality of the beels water (Islam *et al*., 2010). In a study conducted at Ramna, Crescent, and Hatirjheel Lakes in Dhaka City, the pH was found to be in the range of 7.67 to 7.85 (Islam *et al*., 2015c).

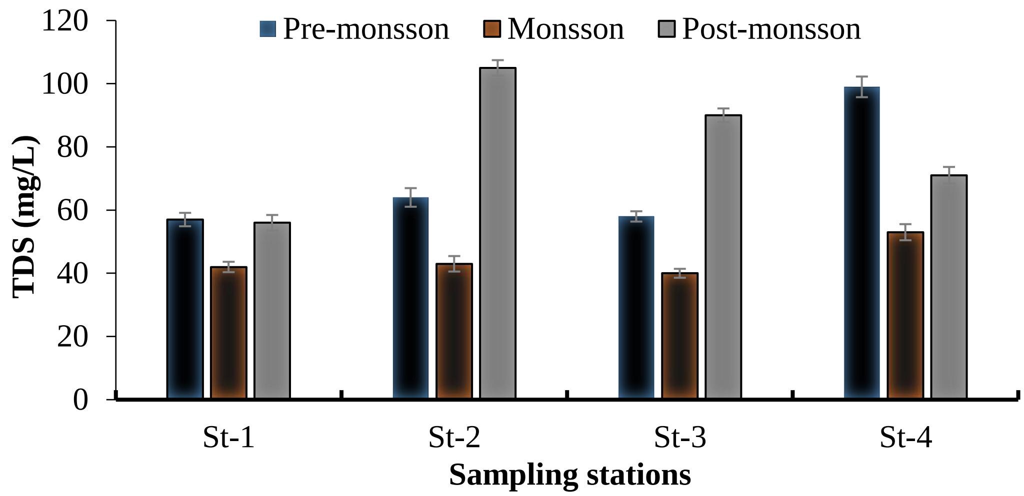

Figure 4: The TDS concentrations at various sampling stations during different seasons

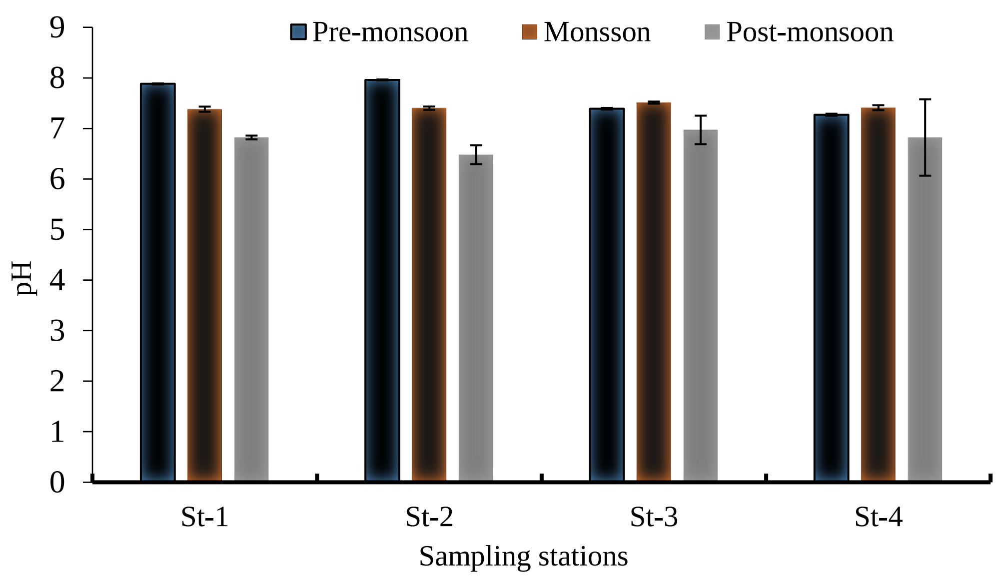

Figure 5: The pH at various sampling stations during different seasons

Dissolved Oxygen (DO): DO is one of the most important indicators of water quality. It is essential for the survival of fish and other aquatic organisms. Oxygen dissolves in surface water due to the aerating action of winds. Oxygen is also introduced into the water as a byproduct of aquatic plant photosynthesis. When dissolved oxygen becomes too low, fish and other aquatic organisms cannot survive (Islam *et al.*, 2017). The DO of the water at the four stations ranged from 6.1 to 7.65 mg/L. During the pre-monsoon season, St-1 had the lowest DO content of 6.1 mg/L, while during the monsoon season; St-3 had the highest DO content of 7.60 mg/L (Figure 6). During the study period, the average DO of the different stations ranged from 6.35 to 7.21 mg/L. Adequate DO is needed to maintain good water quality, aquatic organism endurance, and microorganism putrefaction of waste (Islam *et al.*, 2010; Rahman *et al.*, 2012). For fisheries, the optimal DO concentrations ranged from 4 to 6 mg/L (Boyd, 1998), below which most aquatic species will perish.

During the wet season, the measured DO amount of Ashulia beel was 1.1 to 2.1 mg/L, and during the dry season, it was 0.5 to 2.0 mg/L (Islam *et al*., 2010). In Dhaleswari River, the lowest value of DO was observed 4.9 mg/L in monsoon and 4.1 mg/L in post-monsoon season, suggesting that the concentration of DO was higher in monsoon than in post-monsoon and pre-monsoon seasons (Islam *et al*., 2012). However, the present investigation disclosed that the obtained results of DO were within the permissible limit (5.0 mg/L) for aquatic environment established by ECR (1997).

Table 1: Water quality parameters along with Trophic State Index (TSI) in Kaptai Lake

Parameters	*Seasons (Mean ± SD)*			*Average*
	Pre-monsoon	*Monsoon*	*Post-monsoon*	
Temp. (ºC)	23.9±1.07	31.1±0.67	21.1±0.23	25.37±5.16
Transp. (cm)	68.25±85.60	31.63±36.63	45.00±54.19	48.29±18.53
TDS (mg/L)	69.5±17.24	44.5±5.82	80.5±18.58	64.83±18.45
pH	7.63±0.30	7.43±0.05	6.77±0.18	7.28±0.45
DO (mg/L)	6.36±0.15	7.21±0.36	7.02±0.23	6.86±0.45
EC (µS/cm)	125.83±16.5	82.50±8.15	141.25±24.29	116.53±30.46
Alkalinity (mg/L)	97.5±23.04	67.00±21.9	137.5±31.12	100.67±35.36
Hardness (mg/L)	71.25±7.15	43.00±6.36	66.25±8.89	60.17±15.08
NH_3 (mg/L)	.0018±.0008	0.0325±.015	0.03±0.00707	0.02±0.02
NO_3 (mg/L)	1.25±0.34	1.33±0.61	1.605±0.204	1.40±0.19
NO_2 (mg/L)	0.02±0.007	0.025±0.015	0.02±0.00707	0.02±0.003
PO_4 (mg/L)	1.17±0.698	1.81±0.291	1.13±0.703	1.37±0.38
SO_4 (mg/L)	63.5±10.92	57±22.022	69.00±8.227	63.17±6.01
Chlorophyll *a* (µg/L)	1.51±0.076	1.60±6.476	0.978±0.160	1.36±0.34
TSI (SD)	57.73±9.49	77.49±10.35	48.33±3.59	61.18±14.88
TSI (CHL)	34.57±0.527	33.82±3.73	29.71±1.807	32.70±2.62

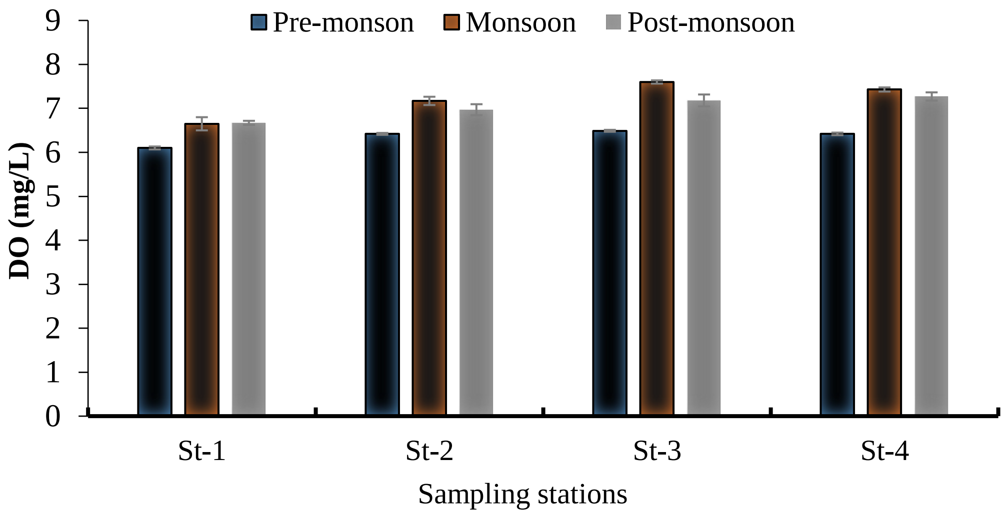

Figure 6: The DO contents in different season at different sampling station

Electrical Conductivity (EC): Significant changes (usually increases) in EC may indicate that a discharge or some other source of disturbance has decreased the relative condition or health of the water body and its associated biota (Islam *et al*., 2019). The lowest EC 75.33 µS/cm was found at St-3 during monsoon and the highest EC 172.33 µS/cm was found at St-3 during post-monsoon season (Figure 7). The average EC in different season during the study period ranged from 82.50 to 141.24 µS/cm. Usually, the highest EC 141.24 µS/cm was found in post-monsoon and the lowest EC 82.50 µS/cm was observed in monsoon season (Table 1). Ahmed *et al*. (2001) discovered that conductivity in Kaptai Lake was between 91.9 and 106.4 µS/cm, which were monitored from October to May. Patra and Azadi (1985) reported a similar phenomenon in Chittagong's Halda River. In the dry season, the EC surpassed the normal amount of 700 µS/cm (EQS, 1997), which has a negative impact on aquatic life (Yasmeen *et al*., 2012).

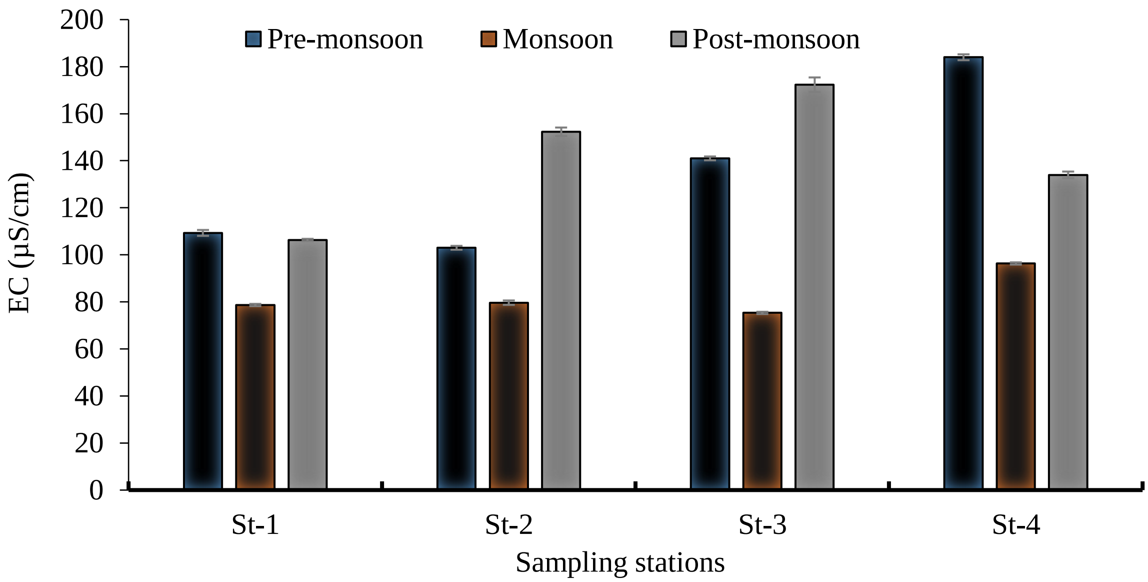

Figure 7: The EC values at various stations during various seasons

Total Alkalinity: Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life (Kabir *et al*., 2020). The alkalinities of sample water for the four stations were within the range of 35 to 190 mg/L. The lowest alkalinity 35 mg/L was found at St-3 during post-monsoon and highest alkalinity 71.90 mg/L was found at St-1 during post-monsoon season (Figure 8). On an average, the highest alkalinity 137.5 mg/L was found in post-monsoon and the lowest alkalinity 62.5 mg/L was observed in monsoon season (Table 1). According to Bashar *et al*. (2015), the highest total alkalinity (90.68 mg/L) in Kaptai Lake occurred in December of 2013 and the lowest (51.9 mg/L) occurred in December of 2012. A total alkalinity value of more than 80 mg/L suggests a nutrient-rich, hard-water lake, and such lakes are often the best fish producers (Bashar *et al*., 2015). According to the results of this study, total alkalinity indicates that Kaptai Lake could be considered medium to highly productive in terms of fish production. In monsoon, post-monsoon, and pre-monsoon seasons, the concentration of alkalinity in Dhaleshwari River was found to vary from 126 to 200, 150 to 595, and 450 to 640 mg/L, respectively (Islam *et al*. 2012). The alkalinity of the Turag River was found to be 404 mg/L in the post monsoon, 581 mg/L in the pre-monsoon and 150 mg/L in the monsoon season (Meghla *et al*., 2013).

Total Hardness: The most important impact of hardness on fish and other aquatic life appears to be the effect the presence of these ions has on the other more toxic metals such as lead, cadmium, chromium and zinc. Generally, harder the water, lower the toxicity of other metals to aquatic life (Islam *et al*., 2015a,b). The hardness of water sample for the four stations was within the range of 37 to 83 mg/L. The lowest hardness 37 mg/L was found at St-4 during monsoon and highest hardness 83 mg/L was found at St-1 during pre-monsoon (Figure 9). The average highest hardness 71.25 mg/L was found in pre-monsoon and the

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lowest hardness 43 mg/L was found in monsoon season (Table 1). Hardness of water is due to the presence of chloride, sulfate, carbonate and bicarbonate (Rahman *et al*., 2012). According to Brown *et al*. (1970) a soft water body contains 0 to 60 mg/L calcium carbonate. Accordingly, the water of the Kaptai Lake may be regarded as slightly hard (Ahmed *et al*., 2001). The concentration of total hardness of Turag River was found varying from 116 to 156 mg/L in post-monsoon, from 130 to 176 mg/L in pre-monsoon and from 42 to 70 mg/L in monsoon season (Meghla *et al*., 2013). The concentration of total hardness of Pungli River was found varying from 28 to 72 mg/L in post-monsoon, from 40 to 60 mg/L in pre-monsoon and from 20 to 56 mg/L in monsoon season (Suravi *et al*., 2013).

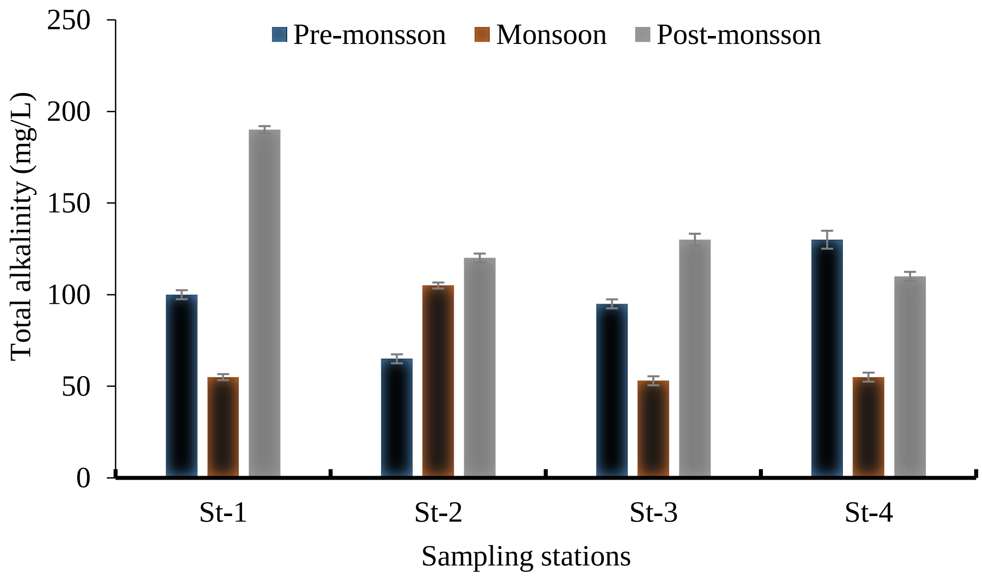

Figure 8: The total alkalinity contents in different season at different station

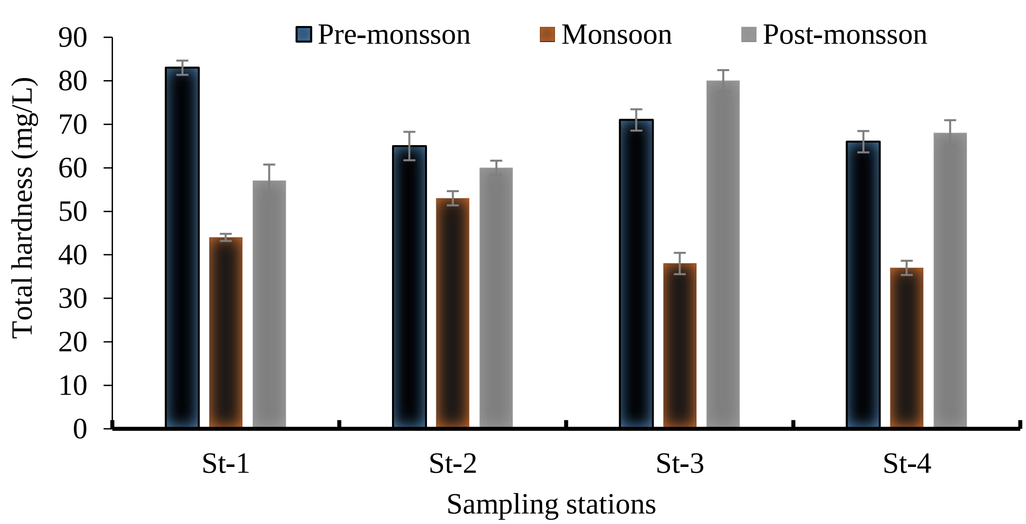

Figure 9: Total hardness contents in different season at different station

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Dissolved nutrients

Ammonia (NH_3-N): When excessive quantities of ammonia are present in water, aquatic species find it difficult to expel the toxicant, resulting in toxic accumulation in internal tissues and blood, and possibly death (Nion *et al*., 2020). The lowest concentration (0.01 mg/L) of NH_3-N was found at St-1 along with St-4 during pre-monsoon and highest concentration (0.5 mg/L) was found at St-4 during monsoon season (Table 2). On the other hand, the highest concentration of NH_3-N 0.0325 mg/L was recorded during monsoon while the lowest concentration 0.0018 mg/L was found during pre-monsoon season (Table 1). Ahmed *et al*. (2001) found NH_3-N content 0.4 mg/L in Kaptai Lake which is comparatively higher than the present findings. In Sundarbans, the NH_3-N concentrations were 0.035, 0.037 and 0.07 mg/L during high tide in pre-monsoon, monsoon and post-monsoon, respectively; and the NH_3-N concentrations were 0.078, 0.034 and 0.052 mg/L during low tide in pre-monsoon, monsoon and post-monsoon season, respectively (Nion *et al.*, 2020).

Nitrate (NO_3-N): Nitrates are necessary nutrients, but excessive levels can cause serious water quality issues. Excess nitrates, when combined with phosphorus, can hasten eutrophication, resulting in substantial increases in aquatic plant growth and changes in the types of plants and animals that dwell in streams. Thus, excess nitrates can produce hypoxia and be hazardous to warm-blooded animals (Kabir *et al*., 2020). The lowest NO_3-N concentration (0.3 mg/L) was found at St-1 and St-3 during monsoon, and highest concentration (1.9 mg/L) was found at St-4 during monsoon season (Table 2). The mean highest concentration of NO_3-N (1.625 mg/L) was recorded during post-monsoon while the lowest concentration (1.25 mg/L) was found during pre-monsoon season (Table 1). Rahman *et al*. (2017) reported that the nitrate value varied from 0.79 to 1.11 mg/L in Kaptai Lake water. The maximum concentration of NO_3-N was found in monsoon (1.11 mg/L) and the minimum was found in the early monsoon (0.79 mg/L), which is almost similar to the present investigations. The NO_3-N concentrations ranged from 3.5 to 12.3, 8.4 to 27.2 and 5 to 50 mg/L during high tide, and 6.1 to 12.2, 4.2 to 28.2 and 10 to 47 mg/L during low tide at pre-monsoon, monsoon and post-monsoon seasons, respectively, in the Sundarbans (Nion *et al*., 2020).

Nitrite (NO_2-N): Excessive nitrite may accumulate in the blood of some fish species and, among other things, cause the oxidation of iron in hemoglobin producing methemoglobin, which is not capable of transporting oxygen (Islam *et al*., 2017). The concentrations of NO_2-N at four stations were within the range of 0.01 (at St-2 along the study period) to 0.04 mg/L (at St-1 along with St-4 during monsoon) (Table 2). However, the mean highest concentration of NO_2-N (0.025 mg/L) was recorded during monsoon while the lowest concentration of NO_2-N (0.02 mg/L) was found during pre-monsoon and post-monsoon season (Table 1). Haque *et al*. (2018) found that the NO_2-N concentration varied from 0.0992 to 0.119 mg/L with a mean concentration of 0.109 mg/L in Kaptai Lake water.

Phosphate (PO_4-P): Algae, which are aquatic plants that include many single-celled, free-floating plants, grow rapidly when more phosphates are added to the water. Excessive algal cloud lowers the quantity of sunlight available to other plants, killing them in some cases. When algae die, the microorganisms that break them down deplete dissolved oxygen in the water, depriving and sometimes smothering other aquatic organisms (Nion *et al*., 2020). During pre-monsoon and post-monsoon, the lowest concentration of PO_4-P 0.09 mg/L was found at St-3 whilst the highest concentration 2.21 mg/L was found at St-3 during monsoon season (Table 2). Moreover, the highest concentration of PO_4-P (1.81 mg/L) was recorded during monsoon while the lowest concentration (1.13 mg/L) was found during post-monsoon season (Table 1). The PO_4-P in the Kaptai Lake study area varied from 0.32 to 0.41 mg/L with a mean value of 0.367 mg/L, whereas lowest value observed in pre-monsoon and highest value observed in post-monsoon season (Haque *et al*., 2018). Khan *et al*. (1996) also found a prominent increase of PO_4-P in dry season compared to rainy season in this lake water.

Table 2: Dissolved nutrient concentrations in water of Kaptai Lake

Parameter (mg/L)	*Pre-monsoon*				*Monsoon*				*Post-monsoon*			
	St-1	*St-2*	*St-3*	*St-4*	*St-1*	*St-2*	*St-3*	*St-4*	*St-1*	*St-2*	*St-3*	*St-4*
NH_3	0.002	0.001	0.003	0.001	0.01	0.03	0.05	0.01	0.002	0.001	0.003	0.001
NO_3	1.1	1.2	1.8	0.9	0.3	1.5	1.9	0.3	1.1	1.2	1.8	0.9
NO_2	0.02	0.01	0.03	0.02	0.01	0.01	0.04	0.01	0.02	0.01	0.03	0.02
PO_4	1.10	1.50	0.09	1.99	1.39	1.87	2.21	1.39	1.10	1.50	0.09	1.99
SO_4	80	50	65	59	48	50	36	48	80	50	65	59

Sulphate (SO_4): Reduced sulfur concentrations have a negative impact on algae development in aquatic species. Sulfate is the most frequent type of sulfur in well-oxygenated waters. Algal growth is impossible when sulfate levels are less than 0.5 mg/L. Sulfate salts, on the other hand, can be major pollutants in natural waters (Kabir *et al*., 2020). The lowest concentration of SO_4 (36 mg/L) was found at St-4 during monsoon and highest concentration (94 mg/L) was found at St-1 during monsoon season (Table 2). On average the highest concentration of SO_4 (69.75 mg/L) was recorded during post-monsoon while the lowest concentration of SO_4 (57 mg/L) was found during monsoon season (Table 1). The safe limits for SO_4 concentration for aquaculture ranged from 5 to 100 mg/L (Boyd, 1998) and values in both the seasons were much below this range, except at Subolong in dry season (Karmakar *et al*., 2011). The SO_4 concentrations ranged from 119 to 272, 30 to 90, 32 to 130 mg/L with mean concentrations 187.8, 53.19 and 76.87 mg/L found during high tide in pre-monsoon, monsoon and post-monsoon, respectively, in Sundarbans (Nion *et al*., 2020). However, the current analysis found lower SO_4 concentrations at all sampling sites across the three seasons of Kaptai lake water than the ECR anticipated (1997).

Biological water quality

Chlorophyll a*:* The chlorophyll molecule allows algae to absorb energy from light; a process known as photosynthesis. Thus, chlorophyll can be used as a measure of algal content in lake. Chlorophyll *a* is a type of chlorophyll molecule which is common in algae. Whilst measurement of the Chlorophyll *a* content of lake water will not measure all of the algae in a lake, it can be a good overall indicator of general patterns in phytoplankton growth and die-back and is widely used by freshwater and marine scientists. The highest Chlorophyll *a* (2.21 µg/L) was found at St-2 during monsoon and the lowest Chlorophyll *a* (0.70 µg/L) was found at St-1 during post-monsoon season (Figure 10). The mean highest Chlorophyll *a* (1.60 µg/L) was found in monsoon and the lowest Chlorophyll *a* (0.98 µg/L) was found in post-monsoon season (Table 1). Chlorophyll *a* is a good indicator of the total quantity of algae in a lake. Algae are a natural part of any lake system, but large amounts of algae decrease water clarity, make the water look green, can form surface scums, reduce dissolved oxygen levels, can alter pH levels, and can produce unpleasant tastes and smells (Pavluk and Bij De Vaate, 2017). Phytoplankton biomass as Chlorophyll *a* correlated positively with phytoplankton density and water depth. The concentrations of Chlorophyll *a* ranged from 0.611 to 0.840, 0.217 to 1.168 and 0.180 to 1.75 mg/L during high tide, and 0.638 to 0.883, 0.218 to 1.189 and 0.69 to 1.88 mg/L during low tide over pre-monsoon, monsoon and post-monsoon season, respectively (Nion *et al*., 2020).

Estimation of Trophic State Index (TSI)

Chlorophyll a *TSI:* The Chlorophyll *a* TSI status for the four sampling stations was within the range of 27.43 to 37.79. The highest Chlorophyll *a* TSI (37.79) was found at St-2 during monsoon and the lowest Chlorophyll *a* TSI **(**27.43) was found at St-1 during post-monsoon (Figure 11). However, the highest Chlorophyll *a* TSI (34.56) was found in pre-monsoon and the lowest Chlorophyll *a* TSI (29.71) was found in post-monsoon season (Table 1). Chlorophyll *a* TSI values range from 11.31 to 13.77 in the pre-monsoon, from 19.11 to 20.84 in the monsoon, and from 14.81 to 17.38 in the post-monsoon. Khondker *et al.* (2010) recorded Chlorophyll *a* TSI 41.24 in Bogakain Lake of Bandarban, Bangladesh. Results of the study revealed that Kaptai Lake tends to be more or less oligo-mesotrophic condition. According to Yang *et al.* (2012), on the basis of Chlorophyll *a* TSI the lake is oligo-mesotrophic (30<TSI≤40).

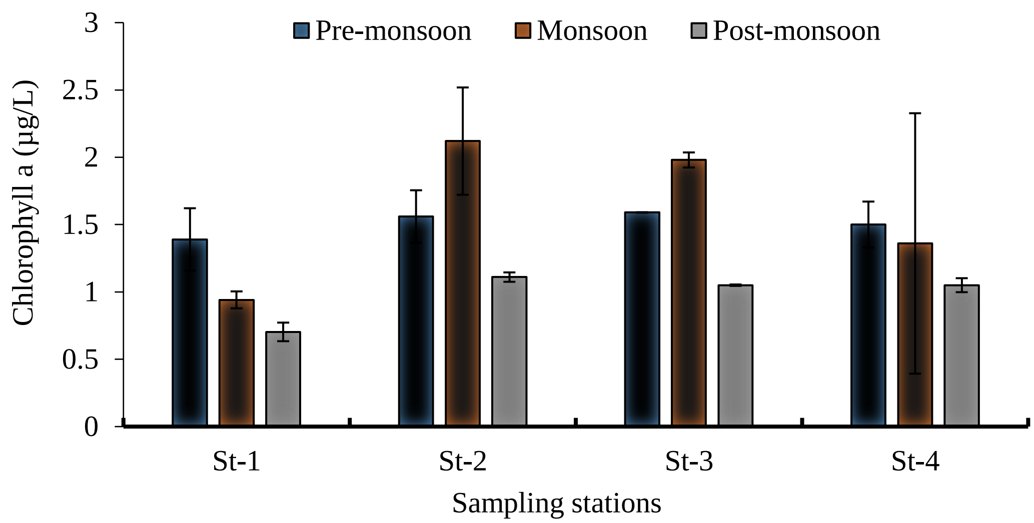

Figure 10: The context of Chlorophyll *a* (±SD) in different season at different station

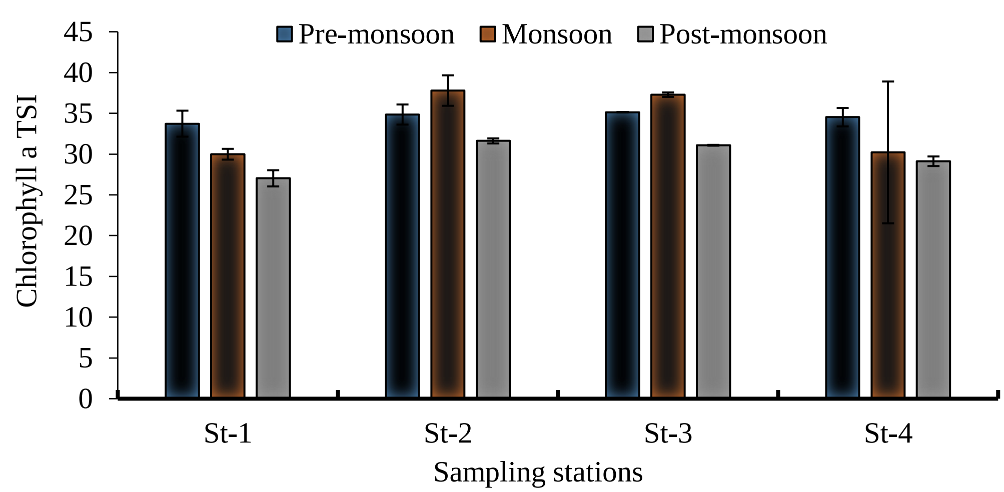

Figure 11: The status of Chlorophyll *a* TSI in different season at different sampling station

Secchi Disc TSI: The Secchi disc TSI status of water samples collected from the four sampling stations were within the range of 44.02 to 83.23. The highest Secchi disc TSI (83.23) was found at St-1 during monsoon and the lowest Secchi disc TSI **(**44**.**02) was found at St-2 during post-monsoon season (Figure 12). The highest Secchi disc TSI (77.49) was found in monsoon and the lowest Secchi disc TSI (48.33) was found in post-monsoon season (Table 1). The average TSI (SD) was found 89.80, 107.83 and 100.73 in pre-monsoon, monsoon and post-monsoon season, respectively. The Secchi disc TSI of Kaptai Lake recorded 48.19 in pre-

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monsoon and 53.00 in post-monsoon season (Rahman *et al.*, 2014). Results of the study found that according to Yang *et al*. (2012) on basis of Secchi disc TSI the lake has middle eutrophic (60<TSI ≤70) condition.

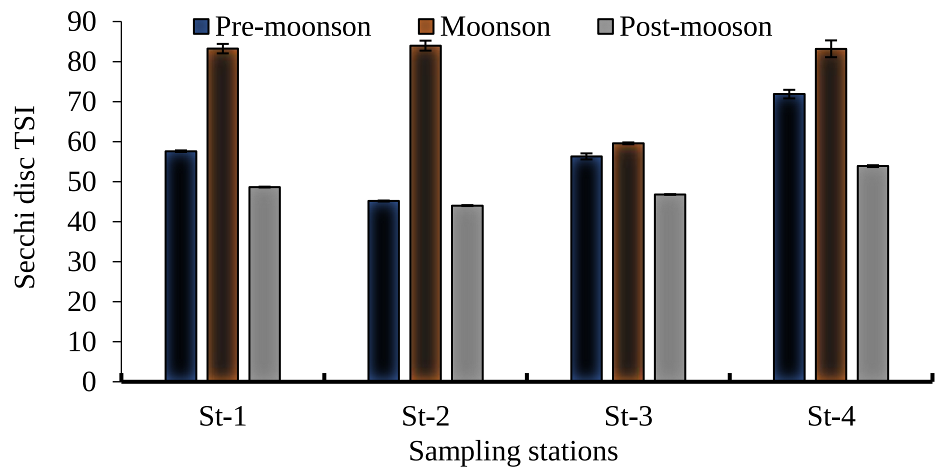

Figure 12: The status of Secchi disc TSI in different season at different sampling station

Source identification of water quality parameters and Chlorophyll *a*

Statistical analyses were performed to elucidate the associations among physicochemical parameters and nutrients quality and to identify the important factors involved in controlling the transport and distribution of physicochemical parameters. Pearson's correlation (PC) matrix for analyzed physiochemical parameters and nutrient quality parameters were calculated to see the parameters interrelations with each other and the results are presented in Table 3. pH-NO_2 and hardness-SO_4 show significant positive correlations with each other in pre-monsoon seasons, which means that one parameter can predict the significance of the other. Reversely, transparency-alkalinity and NO_3-PO_4 show significant negative correlation with each other in pre-monsoon season. Besides, transparency-pH, EC-TDS, NH_3-NO_3 show significant positive correlations with each other and temperature-TDS, temperature-EC show significant negative correlation with each other in monsoon seasons, respectively. However, pH-NO_2, DO-EC, hardness-SO_4 and transparency-alkalinity, PO_4-NH_3 show significant positive and negative correlation with each other in post-monsoon season, respectively.

Table 3: Pearson correlation coefficients (r) among physicochemical parameters and dissolved nutrients in Kaptai Lake water

Pre-monsoon	*Temp.*	*Transp.*	*TDS*	*pH*	*DO*	*EC*	*Alkalin*	*Hardn*	*NH_3*	*NO_3*	*NO_2*	*PO_4*	*SO_4*	*Chloro-phyll **a***
Temp.	1													
Transp.	-0.627	1												
TDS	0.009	0.734	1											
pH	-0.063	-0.553	-0.517	1										
DO	0.714	-0.448	0.226	0.41	1									
EC	0.592	-0.589	-0.021	0.664	**.952***	1								
Alkalin	0.607	**-.991****	-0.695	0.645	0.529	0.681	1							
Hardn	-0.679	-0.113	-0.74	0.406	-0.658	-0.398	0.095	1						
NH_3	-0.629	0.142	-0.089	0.743	0.047	0.252	-0.033	0.474	1					
NO_3	-0.54	0.492	0.441	0.413	0.188	0.243	-0.372	0.026	0.854	1				
NO_2	-0.155	-0.346	-0.285	**.964***	0.456	0.678	0.46	0.296	0.853	0.632	1			

Pre-monsoon	*Temp.*	*Transp.*	*TDS*	*pH*	*DO*	*EC*	*Alkalin*	*Hardn*	*NH_3*	*NO_3*	*NO_2*	*PO_4*	*SO_4*	*Chloro-phyll **a***
PO_4	0.707	-0.396	-0.159	-0.546	0.011	-0.131	0.286	-0.346	**-.962***	-0.946	-0.714	1		
SO_4	-0.528	-0.327	-0.835	0.614	-0.441	-0.148	0.328	**.965***	0.538	0.041	0.486	-0.358	1	
Chlorophyll ***a***	0.172	0.435	0.883	-0.091	0.609	0.433	-0.347	-0.772	0.158	0.614	0.139	-0.326	-0.745	1

Monsoon	*Temp.*	*Transp.*	*TDS*	*pH*	*DO*	*EC*	*Alkalin*	*Hardn*	*NH_3*	*NO_3*	*NO_2*	*PO_4*	*SO_4*	*Chloro-phyll **a***
Temp.	1													
Transp.	.400	1												
TDS	**-.982***	-.500	1											
pH	.217	.970*	-.303	1										
DO	-.308	.601	.288	.777	1									
EC	**-.987***	-.532	**.995****	-.350	.214	1								
Alkalin	.146	-.609	.042	-.568	-.266	.002	1							
Hardn	.521	-.438	-.357	-.493	-.463	-.382	.911	1						
NH_3	-.686	-.110	.548	-.084	-.020	.612	-.703	-.823	1					
NO_3	-.538	.155	.371	.159	.093	.430	-.868	-.921	**.963***	1				
NO_2	-.604	-.582	.532	-.597	-.480	.614	-.290	-.393	.845	.697	1			
PO_4	-.778	.098	.646	.194	.359	.677	-.734	-.933	.925	.926	.616	1		
SO_4	.523	-.158	-.578	-.389	-.876	-.497	-.136	.193	.100	.114	.363	-.253	1	
Chlorophyll ***a***	.320	.456	-.226	.549	.649	-.322	.373	.337	-.774	-.677	-.945	-.477	-.636	1

Post-monsoon	*Temp.*	*Transp.*	*TDS*	*pH*	*DO*	*EC*	*Alkalin*	*Hardn*	*NH_3*	*NO_3*	*NO_2*	*PO_4*	*SO_4*	*Chloro-phyll **a***
Temp.	1													
Transp.	-.627	1												
TDS	.009	.734	1											
pH	-.063	-.553	-.517	1										
DO	.714	-.448	.226	.410	1									
EC	.592	-.589	-.021	.664	**.952***	1								
Alkalin	.607	**-.991****	-.695	.645	.529	.681	1							
Hardn	-.679	-.113	-.740	.406	-.658	-.398	.095	1						
NH_3	-.629	.142	-.089	.743	.047	.252	-.033	.474	1					
NO_3	-.540	.492	.441	.413	.188	.243	-.372	.026	.854	1				
NO_2	-.155	-.346	-.285	**.964***	.456	.678	.460	.296	.853	.632	1			
PO_4	.707	-.396	-.159	-.546	.011	-.131	.286	-.346	**-.962***	-.946	-.714	1		
SO_4	-.528	-.327	-.835	.614	-.441	-.148	.328	**.965***	.538	.041	.486	-.358	1	
Chlorophyll ***a***	.523	.238	.834	-.295	.686	.445	-.190	-.968*	-.247	.227	-.132	.098	-.931	1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed)

Conclusion

The current study is a baseline investigation of the seasonal change of physicochemical characteristics in the Kaptai Lake, which will provide useful information for lake ecosystem management and conservation. Despite receiving wastes from many anthropogenic chemical sources, the water quality of Kaptai Lake is still good. The physiochemical parameters of Kaptai Lake such as pH, DO, EC, NH_3, NO_3^-, NO_2^- and PO_4^{2-} concentrations were in favor of aquaculture. Total alkalinity, total hardness and concentration of SO_4^{2-} were higher than the standard. The presence of a large amount of total dissolved solids in the reservoir is quite concerning. Furthermore, urban pollution has put the water supply and domestic use in Rangamati town in jeopardy. In this case, it is vital to take control measures to prevent contamination in order to preserve the lake's life.

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References

Ahatun, S., Islam, M.S., Kabir, M.H., Rehnuma, M. and Hoq, M.E. (2020). Water quality and fish diversity in Korotoa River of Bogura, Bangladesh. *Bangladesh Journal of Fisheries*, 32(1): 61-72. DOI: https://doi.org/10.52168/bjf.2020.32.08

Ahmed, K.K., Haque, M.K.I. and Haque, M.E. (2001). Studies on some physicochemical factors of Kaptai Lake. *Bangladesh Journal of Fisheries Research*, 3(1): 33-39. DOI: http://hdl.handle.net/1834/32242

Alam, M.J., Islam, M., Sharmin, R., Iqbal, M., Chowdhury, M. and Munna, G. (2006). Impact assessment due to rural electrification in hill tract of Bangladesh for sustainable development. *International Journal of Environmental Science and Technology*, 3: 391-402. DOI: https://doi.org/10.1007/BF03325948

Alba-Tercedor, J. (1996). Macroinvertebrados acuaticos y calidad de las aguas de los rios. IV Simposio del agua em Andalucia (SIAGA). *Almeira*, 2: 203-213.

APHA (American Public Health Association) (2005). Standard methods for the examination of water and wastewater. 21st ed. American Public Health Association, Washington, DC, pp. 9-45. DOI: http://www.ncbi.nlm.nih.gov/pubmed/

Azadi, M.A., Mustafa, M.G. and Rahman, A.S.M.S. (1997). Elefan based population dynamics of two clupeids *Gudusia chapra* (Ham.) and *Gonialosa manmina* (Ham) from Kaptai Reservoir, Bangladesh. *Chittagong University Studies-Part II: Science*, 21(2): 125-132.

Banglapedia (2016). National Encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka, Bangladesh. Available online: https://en.banglapedia.org/index.php/Kaptai_Lake [Accessed on 19 August 2021]

Barua, R., Barua, S., Fatema-Tuz-Zohora, R.M., Uddin, M.S., Hasegawa, H. and Rahman, I.M. (2016). Bacteriological and physicochemical characteristics of Kaptai Lake water in terms of public health significance. *International Journal of Scientific Research in Environmental Sciences*, 4(2): 31-39. DOI: https://doi.org/10.12983/ijsres-2016-p0031-0039

Bashar, M.A., Basak, S.S., Uddin, K.B., Islam, A.S. and Mahmud, Y. (2015). Seasonal variation of zooplankton population with reference to water quality of Kaptai Lake, Bangladesh. *Bangladesh Research Publications Journal*, 11: 127-133.

Bashar, M.A., Basak, S.S., Uddin, K.B., Islam, A.S. and Mahmud, Y. (2015). Changing trends of physicochemical parameters in Kaptai Lake of Bangladesh. *Research in Agriculture, Livestock and Fisheries*, 2(2): 319-327.

Bashar, M.A., Basak, S.S., Uddin, K.B., Islam, A.S., Mahmud, Y., Goutham-Bharathi, M.P. and Simon, K.D. (2014). Development of Indian major carp fry raising techniques in creeks of Kaptai Lake, Bangladesh. *World Journal of Fish and Marine Sciences*, 6(6): 532-536.

Boyd, C.E. (1998). Water quality for pond aquaculture. Alabama: International Center for Aquaculture and Aquatic Environments, Auburn University, pp. 37.

Brown, E., Skougstad, M.W. and Fishman, M.J. (1970). Methods for collection and analysis of water samples for dissolved minerals and gases. U.S. Geological Survey, U.S. Dept. of Interior, Washington, DC, pp. 166.

Carlson, R.E. (1977). A trophic state index for lakes. *Limnology and Oceanography*, 22: 361-369.

Chowdhury, S.H. and Mazumder, A. (1981). Limnology of Lake Kaptai I. Physicochemical features, Bangladesh. *Zoology*, 9(1): 59-72.

Dillon, P.J. and Rigler, F.H. (1974). The phosphorus-chlorophyll relationship in lakes. *Limnology and Oceanography*, 19:767-773.

ECR (Environment Conservation Rules) (1997). Environment conservation rules. Bangladesh: Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, pp. 22-24.

Ehiagbonare, J.E. and Ogunrinde, Y.O. (2010). Physicochemical analysis of fish pond water in Okada and its environs, Nigeria. *African Journal of Biotechnology*, 9(36): 5922-5928.

EPA (Environmental Protection Agency) (2017). Water quality standards handbook. EPA office of Water Science and Technology, Washington DC, pp. 14-27.

EQS (Environmental Quality Standards) (1997). Environmental quality standard. Bangladesh: Bangladesh Gazette, Registered. Department of Environment, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, pp. 205-208.

Ghorbani, M., Mirbagheri, S.A, Hassani, A.H., Nouri, J. and Monavari, S.M. (2014). Algal bloom in aquatic ecosystems- an overview. *Current World Environment*, 9(1): 105-108. DOI: http://dx.doi.org/10.12944/CWE.9.1.15

Haldar, G.C., Mazid, M.A. and Ahmed, K.K. (1992). Limnology and primary production of Kaptai Lake, Bangladesh. In: Reservoir Fisheries of Asia (ed. S.S. De Silva). Proceedings of the 2nd Asian reservoir fisheries workshop held in Hangzhou, People's Republic of China, pp. 2-11.

Haque, M.A., Nabi, M.R.U., Billah, M.M., Asif, A.A., Rezowan, M., Mondal, M.A.I., Siddiqui, A.A.M., Mahmud, S.S. and Khan, M.R. (2018). Effect of water parameters on temporal distribution and abundance of zooplankton at Kaptai Lake reservoir, Rangamati, Bangladesh. *Asian Journal of Medical and Biological Research*, 4(4): 389-399.

Islam, M.S., Datta, T., Ema, I.J., Kabir, M.H. and Meghla, N.T. (2015a). Investigation of water quality from the Brahmaputra River in Sherpur district. *Bangladesh Journal of Scientific Research*, 28(1): 35-41. DOI: https://doi.org/10.3329/bjsr.v28i1.26242

Islam, M.S., Imran, M.H., Rimu, S.H., Kabir, M.H. and Suravi (2019). Water quality monitoring of aquaculture hatchery in Mymensingh region of Bangladesh. *Bangladesh Journal of Environmental Science*, 36: 15-22. Available online: https://environmentalexplore.com/best-research-paper-on-bangladesh/ [Accessed on 22 July 2021]

Islam, M.S., Islam, M.A., Islam, M.J., Kabir, M.H. and Meghla, N.T. (2015b). Status of water quality in the Tista River at Kaunia point and its impact on aquatic environment. *Journal of Environmental Science and Natural Resources*, 8(1): 29-33. DOI: https:// doi.org/10.3329/jesnr.v8i1.24660

Islam, M.S., Meghla, N.T., Suravi and Sultana, N. (2012). Status of water quality in the Dhaleshwari River and its effect on aquatic organism. *Bangladesh Journal of Environmental Science*, 23: 131-138.

Islam, M.S., Rehnuma, M., Tithi, S.S., Kabir, M.H. and Sarkar, L. (2015c). Investigation of water quality parameters from Ramna, Crescent and Hatirjheel Lakes in Dhaka city. *Journal of Environmental Science and Natural Resources*, 8(1): 1-5. DOI: https://doi.org/10.3329/jesnr.v8i1.24620

Islam, M.S., Shil, S.C., Kabir, M.H. and Hoq, M.E. (2017). Investigation of heavy metal contamination in fishes from Passur River near the Sundarbans mangroves of Bangladesh. *Journal of Environmental Science and Natural Resources*, 10(1): 21-24. DOI: https://doi.org/10.3329/jesnr.v10i1.34689.

Islam, M.S., Suravi and Meghla, N.T. (2010). Investigation on water quality in the Ashulia Beel, Dhaka. *Bangladesh Journal of Fisheries Research*, 14(1-2): 55-64. Available online: http:// aquaticcommons.org/18971/1/BJFR14_055.pdf [Accessed on 11 June 2021]

Johan, F.B., Jafri, M.Z.B.M., San, L.H., Omar, W.M.W. and Ho, T.C. (2018). Chlorophyll *a* concentration of freshwater phytoplankton analysed by algorithmic based spectroscopy. *Journal of Physics* (Conf. Series), 1083: 012015. DOI: https://doi.org/10.1088/1742-6596/1083/1/012015

Kabir, A.N. and Naser, M.N. (2011). Physicochemical aspects of Chandbill Oxbow Lake of Meherpur, Bangladesh. *Dhaka University Journal of Biological Sciences*, 20(1): 31-39.

Kabir, M.H., Tusher, T.R., Hossain, M.S., Islam, M.S., Shammi, R.S., Kormoker, T., Proshad, R. and Islam, M. (2020). Evaluation of spatio-temporal variations in water quality and suitability of an ecologically critical urban river employing water quality index and multivariate statistical approaches: A study on Shitalakhya River, Bangladesh. *Human and Ecological Risk Assessment: An International Journal*, 27(5): 1388-1415. DOI: https://doi.org/10.1080/10807039.2020.1848415

Karmakar, S., Haque, S.S., Hossain, M.M. and Shafiq, M. (2011). Water quality of Kaptai Reservoir in Chittagong hill tracts of Bangladesh. *Journal of Forestry Research*, 22(1): 87-92.

Khan, M.A.G., and Chowdhury, S.H. (1994). Physical and chemical limnology of Kaptai Lake, Bangladesh. *Tropical Ecology*, 35(1): 35-51.

Khan, M.A.G., Chowdhury, S.H. and Paul, J.C. (1996). Community structure and ecology of microbenthic invertebrate fauna of Lake Kaptai, Bangladesh. *Tropical Ecology*, 37(2): 229-245.

Khondker, M., Alfasane, M.A., Islam, M.S., Bhuiyan, M.A.H. and Gani, M.A. (2010). Limnology of Lake Bogakain, Bandarban, Bangladesh. *Bangladesh Journal of Botany*, 39(2): 153-159.

Li, X., Sha, J. and Wang, Z.L. (2017). Chlorophyll a prediction of Lakes with different water quality patterns in China based on hybrid neural networks. *Water*, 9: 524. DOI: https://doi.org/10.3390/w9070524

Meghla, N.T., Islam, M.S., Ali, M.A., Suravi and Sultana, N.T. (2013). Investigation of physicochemical properties of water from the Turag River in Dhaka city, Bangladesh. *International Journal of Current Microbiology and Applied Science*, 2(5):110-167.

Nion, M.S.H., Islam, M.S., Hoq, M.E., Kabir, M.H. and Hoque, M.M.M. (2020). Seasonal and tidal dynamics of nutrients and Chlorophyll *a* concentration in water at the Sundarbans mangrove ecosystems of Bangladesh. *Grassroots Journal of Natural Resources*, 3(1): 50-67. DOI: https://doi.org/10.33002/nr2581.6853.03015

Pal, M., Samal, N.R., Roy, P.K. and Roy, M.B. (2015). Electrical conductivity of Lake water as environmental monitoring- a case study of Rudrasagar Lake. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 9: 66-71.

Patra, R.W.R. and Azadi, M.A. (1985). Limnology of the Halda River. *Journal of Noami*, 2(2): 31-38.

Pavluk, T. and Bij De Vaate, A. (2017). Trophic index and efficiency. Reference module in Earth Systems and Environmental Sciences, Elsevier. DOI: https://doi.org/10.1016/B978-0-12-409548-9.00608-4.

Rahaman, S.M.B., Rahaman, M.S., Ghosh, A.K., Gain, D., Biswas, S.K., Sarder, L., Islam, S.S. and Sayeed. A.B. (2015). A spatial and seasonal pattern of water quality in the Sundarbans River systems of Bangladesh. *Journal of Coastal Research*, 31(2): 390-397.

Rahaman, S.M.B., Sarder, L., Rahaman, M.S., Ghosh, A.K., Biswas, S.K., Siraj, S.M.S., Huq, K.A., Hasanuzzaman, A.F.M. and Islam, S.S. (2013). Nutrient dynamics in the Sundarbans mangrove estuarine system of Bangladesh under different weather and tidal cycles. *Ecological Processes*, 2(29): 1-13. DOI: https://doi.org/10.1186/2192-1709-2-29.

Rahman, A.K.M.L., Islam, M., Hossain, M.Z. and Ahsan, M.A. (2012). Study of the seasonal variations in Turag River water quality parameters. *African Journal of Pure and Applied Chemistry*, 6(10): 144-148.

Rahman, M.M., Bashar, M.A., Farhana, Z. and Hossain, M.Y. (2014). Temporal variation of physicochemical parameters in Kaptai Lake, Bangladesh. *World Journal of Fish and Marine Sciences*, 6(5): 475-478.

Rahman, M.S. (1992). *Water quality management in aquaculture*. Bangladesh: BRAC Prokashana, pp. 84.

Rao, Q.Z. (1956). *Basic knowledge for lake investigation*. Beijing: Science Press.

Rubel, M., Chowdhury, D.A., Ahmed, M.J.U. and Helal, M. (2019). Physicochemical characterization of Kaptai Lake and Foy's Lake water quality parameters in Chittagong, Bangladesh. *American Journal of Pure and Applied Biosciences*, 1(6): 49-58.

Senthilkumar, B., Purvaja, R. and Ramesh, R. (2008). Seasonal and tidal dynamics of nutrients and Chlorophyll *a* in tropical mangrove estuary, southeast coast of India. *Indian Journal of Marine Sciences*, 37(2): 132-140.

Shrivastava, S. and Kanungo, V.K. (2013). Physicochemical analysis of pond water of Surguja District, Chhattisgarh, India. *International Journal of Herbal Medicine*, 1(4): 35-43.

Shukla, P., Preeti and Singh, A. (2013). A seasonal variation of plankton population of Maheshara Lake in Gorakhpur, India. *World Journal of Zoology*, 8(1): 9-16.

Stauffer, B.A., Bowers, H.A., Buckley, E., Davis, T.W., Johengen, T.H., Kudela, R., McManus, M.A., Purcell, H., Smith, G.J., Vander, W.A. and Tamburri, M.N. (2019). Considerations in harmful algal bloom research and monitoring: Perspectives from a consensus-building workshop and technology testing. *Frontiers in Marine Science*, 6: 399. DOI: https://doi.org/10.3389/fmars.2019.00399

Suravi, Islam, M.S., Ali, M.A., Meghla, N.T. and Sultana, N. (2013). Seasonal variations of water quality parameters from the Pungli River in Tangail region. *International Journal of Current Microbiology and Applied Sciences*, 2(5): 155-167.

Suzuki, J.Y., Bollivar, D.W. and Bauer, C.E. (1997). Genetic analysis of Chlorophyll *a* biosynthesis. *Annual Review of Genetics*, 31(1): 61-89. Doi: https://doi.org/10.1146/annurev.genet.31.1.61.

Wang, L., Cai, Q.H., Xu, Y.H., Kong, L.H., Tan, L. and Zhang, M. (2011). Weekly dynamics of phytoplankton functional groups under high water level fluctuations in a subtropical reservoir-bay. *Aquatic Ecology*, 45:197-212.

Yang, J., Yu, X., Liu, L., Zhang, W. and Guo, P. (2012). Algae community and trophic state of subtropical reservoirs in southeast Fujian, China. *Environmental Science and Pollution Research*, 19(5): 1432-1442.

Yasmeen, S., Islam, M.S., Ahsan, M.A., Rahaman, M.H. and Meghla, N.T. (2012). Assessment of water qualities in the Buriganga River of Dhaka city corporation area. *Bangladesh Journal of Environmental Science*, 23: 151-158.

Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4	Author 5	Author 6	Author 7
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Collected the data	Yes	Yes	Yes	Yes	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	Yes	Yes	Yes	No	No
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	No	Yes	No	Yes	Yes	Yes
Supervision	Yes	No	Yes	No	Yes	Yes	Yes
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