SPATIO-TEMPORAL VARIATION OF WATER QUALITY PARAMETERS AND SEDIMENTS ORGANIC MATTER IN RELATION TO DEPTH OF THE KAPTAI LAKE, RANGAMATI

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Roll No: 0120/18

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Department of Fisheries Resource Management
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JUNE 2022

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Abstract

The present study was carried out to reveal the physical and chemical status of the Kaptai Lake, Bangladesh. From four sampling points (Jolojan Ghaat, Kandemu, Shubholong Jhorna and Shubholong Bazar), water samples were taken over a period of 6 months from September, 2021 to February, 2022. Temporal variations in physical and chemical parameters were discovered in all cases. Highest air temperature (32.8°C) was recorded in October 2021 and the lowest (24.1°C) in January 2022. On the other hand, the water temperature varied from 21.9°C in January 2022 to 31.6°C in October. The value of dissolved oxygen (DO) was found to fluctuate from the minimum value of 5.5 mg/l in September to the maximum value of 8.30 mg/l in November. The maximum free CO_2 value was 6.5 mg/l in February and the minimum value was 2.3 mg/l in November whereas the pH of the water was always found to be alkaline in nature and varied between 7.30 and 9.02. The total alkalinity value fluctuated from 62.8 mg/l in October to 89.10 mg/l in January whereas the hardness of lake water varied from 55.7 mg/l in September to 85.68 mg/l in February. The lowest concentration of NH_3-N was found at Shubholong Jhorna (0.018 mg/l) in October and the highest concentration was found at Kandemu (0.49 mg/l) in February. The highest and lowest organic matter was 6.32 % and 4.09 %, with a mean value of 5.50 ± 0.55%. Water temperature and dissolved oxygen concentration were higher in the surface water whereas the TDS was higher in the bottom water. The physical and chemical characteristics of lake water were found to be within the ranges that were suitable for the survival of aquatic life, including the production of fish by supporting a good ecosystem. The current study offers baseline data on Kaptai Lake's physical and chemical parameters' monthly changes, which will be useful for the lake's significant ecosystem's sustainable management and preservation.

Keywords: **Kaptai Lake, Physicochemical Parameters, Organic matter**

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ABBREVIATION

mg	Milligram
g	Gram
ft.	Feet
m	meter
μm	Micro Meter
°C	Degree Celsius
DO	Dissolve oxygen
OM	Organic matter
EDTA	Ethylenediaminettraacetic acid

Chapter:01

Introduction

Bangladesh is regarded as the world's largest inundated wetland and Asia's third-largest aquatic biodiversity. Thus, this country is assumed as one of the world's best-suited fisheries regions (Shamsuzzaman et al., 2017). Bangladesh is among Asia's significant fish-producing countries (FAO, 2020). The total fisheries production was 4. 27 million MT with a 3.52 % contribution to national GDP, 26.307 % to agricultural GDP, and 12% of the population fully or partly engaged in the fisheries sector. Inland culture fisheries contribute 57.38 % of total fish production and the rest comes from inland and marine capture (DoF, 2021). Bangladesh has achieved the third position in inland water capture fisheries and the fifth position in freshwater culture fisheries, third in the tilapia culture development in Asia (FAO, 2018). Bangladesh's second-most valuable crop is fish and its production contributes to the millions of people's livelihood and employment. People of Bangladesh are referred to as "Macche-Bhate Bangali" or "a Bengali made of rice and fish" because of fish's popularity as a food product. The culture and consumption of fish contribute to Bangladesh's national income and food security (Ghose, 2014). There are 289 freshwater fish species, 475 marine fish species, 24 prawn species, 36 shrimp species, and 12 exotic fish species available in the diversified aquatic ecosystem of Bangladesh (Khan et al., 2013).

Generally, freshwater aquaculture is practiced in ponds, lakes and other water bodies. In Bangladesh, most of the lakes are not under aquaculture practice. The greatest manmade South-East Asian freshwater resource including Bangladesh, is regarded to be Kaptai Lake, one of the most important freshwater bodies (Halder et al., 1991). In 1961, the river Karnaphuli was dammed near Kaptai in the Rangamati district in order to create the Kaptai Lake for the purpose of generating hydroelectric power. This lake has a surface size of 68,800 hectares and a maximum depth of 32 meters, with an average depth of roughly 9 meters (Halder et al., 1991; Alamgir et.al.,2008). This body of water's shoreline and basin are highly erratic (Halder et al., 1991). Although this lake was built to generate electricity, it also aids in navigation, flood control, and the production of a sizable number of freshwater fish. Additionally, the water from these lakes is used for a variety of purposes, including domestic chores, agriculture, boat maintenance, and fishing, which could lead to lake ecosystem contamination. In 1965–1966, there were 1200 metric tons of commercial fishing in this lake. Today, there are up to 12696 MT (DoF, 2021). The Bangladesh Fisheries Development Corporation has little control over the water level changes in this lake because fishing is a secondary industry (Bashar et al., 2014). The Kaptai Lake fisheries have recently contributed, albeit mostly with undesirable species. The principal carp species that is most valued (*Labeo rohita, Catla catla, Cirrhinus cirrhosus, Labeo calbasu,* and *Tor tor*) from the initial 81 percent recorded in 1965/66 to roughly 5 percent at this time, have dramatically decreased (Alamgir and Ahmed, 2008). The little forager fish, which has minimal value (e.g., *Corica soborna*, *Gonialosa* sp, *Ompok pabda*) have increased dramatically from the initial 3 percent in 1965/66 to roughly 92 percent at this time (Alamgir and Ahmed, 2008).

Halder et al. (1991) reported in Kaptai Lake have found 71 fish species in total including two varieties of prawn and five foreign fish species. In 1986 the Aquatic Research Group (ARG) counted 49 native fish species and 5 invasive fish species. Surface water quality is critical for long-term use since it impacts community health inhibits aquaculture techniques and causes aesthetic issues in the area. Each usage of water needs a unique level of quality of the water to ensure that the user is not harmed (Kabir et al., 2020). This freshwater resource is currently being negatively impacted by land use changes, urban human settlement, navigation on inland waterways, large development schemes in contex of roads, bridges, and other construction works (Rubel et al., 2019; Kabir and Naser, 2011). Generally speaking, water quality refers to the element of water that essential for aquatic creatures for satisfactory growth (Ahatun et al., 2020). The primary productivity of a waterbody is the expression of its biological production. Directly or indirectly, phytoplankton is the basis of the primary output in all aquatic ecosystems. Primary production largely depends on the Physico-chemical properties of water like temperature, dissolved oxygen, alkalinity, hardness, pH, free CO_2, nitrate, phosphate, soil organic matter, etc. Fishes are primarily dependent on water temperature, pH, dissolved oxygen, free CO_2, alkalinity, and some other salts for growth and development (Ahmed et al., 1999). The Physico-chemical factors of water and soil affect plankton periodicity (Haque, et al., 1978). In most water bodies, the factors that determine healthy growth include dissolved oxygen (DO), hardness, turbidity, alkalinity, nutrients, temperature and these factors become more concentrated as a result of human activity and an Environmentally unregulated (Ehiagbonare and Ogunrinde, 2010). Since rivers, lakes, and artificial reservoirs are utilized to provide domestic, industrial, agricultural, and fish cultures, evaluating the quality of each region's water resources is a crucial component of developmental operations (Pal et al., 2015). Nutrients are the most important components for maintaining a productive and healthy aquatic ecosystem (Ahatun et al., 2020). Nutrients are essential for the survival, growth, and reproduction of all aquatic species including fish. Some nutrients are correlated with the quantity of chlorophyll in the water, which is a measure of the amount of phytoplankton present (Shukla et al., 2013). As a result, nutrient availability is proportional to the water body's productivity (Rahaman et al., 2013). The water body is unproductive due to a lack of nutrients. Eutrophication is brought on by an excess of nutrients which speeds up the growth of algae and makes the water harmful. All aquatic ecosystems depend on algae because they give all living things in water bodies the initial nutrients and energy they need to survive. Algal blooms, an unnatural and excessive growth of algae, would be harmful (Ghorbani et al., 2014; Stauffer et al., 2019). As a result, nutrient concentrations should be kept below allowable limits in order to maintain a healthy aquatic environment and increase the production of marine species such as fish and marine aquatic organisms (Senthikumar et. al.,2008). The availability of nutrients depends on the water quality and organic matter of sediment. So regular study is needed on the lake's limnological parameters and sediment profile for sustainable management. To observe this, numerous scholars also investigated the limnological characteristics of this lake. For example, Sandercock (1966) documented this lake's Physical and chemical parameters and phytoplankton. Chowdhury (1980), Chowdhury and Mazumder (1981), ARG (1986), described the hydrobiology of Kaptai Lake.

Nonetheless, Jenkins (1985) proposed a prolonged study effort to ensure the lake ecosystem's maintenance. The reservoir's morphometric details were then documented by Rahman et al. (2014), and Characterization of the Kaptai Lake's limnology and primary production by Halder et al. (1991) and Bashar et al. (2015).

Any aquatic habitat must include soil because it provides water for aquatic life and enriches the water body with a variety of nutrients needed for biological production (Saha, 2003). Minerals, water, air, organic matter (OM), and living substances make up sediments, which are variables in space and time (Adesuyi et al., 2015). Clay, silt, sand, and gravel are examples of minerals found in sediment, whereas organic matter (OM) might include shells and decomposing organic waste (Gupte and Shaikh, 2014). The wastes play role for nutrients turnover (Kiani et al., 2021; Cardoso et al., 2019) by organic matter degradation (Hopkinson et al., 1999) which eventually improve biological process (Kumar, 1996; Gupta et al., 2001) and support plant growths in the natural medium. Due to its active function as a raw buffer through carbon cycling, sediment may potentially have an impact on environmental quality (Cardoso et al., 2019) and filtering method for water's physical cycle (Singare et al., 2011) and exchange of micronutrients between a deposit and nearby aquatic bodies (Abowei, 2010). If the water quality parameter and the nutrients are in nice condition then the lake's primary production and ultimate production will be good. So, without regular observation, it’s impossible to manage and increase the primary productivity of the Kaptai Lake. A good environment is a must for great primary production. Therefore, this research aims to provide data on variations of physicochemical parameters and organic matter of the Kaptai Lake over six months to provide baseline information to assist management decisions of the Lake Ecosystem.

Significance of the research:

This research will describe the physical, chemical, and biological characteristics of Kaptai Lake, which will inform overall limnological features of the Kaptai Lake. Limnological parameters are the most important of the lake for a healthy ecosystem and productivity. Phytoplankton and zooplankton play a vital role in sustaining a balanced aquatic ecosystem by supplying food and dissolving oxygen to fish and other aquatic fauna. The Kaptai Lake is South-East Asia's most enormous artificial lake ecosystem. It plays a significant part in the production of fish and the livelihood of thousands of Rangamati District people. Maintaining primary productivity and a healthy ecosystem plays a vital role in lake fish production. This research will determine the variation of physicochemical parameters monthly in the different stations. The result of the proposed study will notify the overall state of the lake ecosystem and help the policymaker take the necessary initiative to boost fish production in the Kaptai Lake.

Objectives of the Study:

The study aims to provide information to policymakers to take the necessary initiative to exacerbate fish production in the Kaptai Lake with the specific objectives such as:

I. To determine the physicochemical parameters and to observe the spatiotemporal variations of lake water quality parameters.

II. To observe the variation of organic matter in different stations.

Chapter: 02

Review of Literature

2. Review of Literature

Before conducting any research, it is a prime concern of gathering information from previously conducted related research. For this purpose, some previously conducted research is reviewed here. A lot of research regarding the variation of Physiochemical parameters of a freshwater sub-tropical lake according to physical and chemical variables in pre-monsoon, monsoon, and post-monsoon seasons has been carried out. The following information has been reviewed in favor of the present study.

2.1 History of the Kaptai Lake:

Fernando, (1980) described the Kaptai reservoir in Bangladesh, as one of the largest man-made freshwater reservoirs in Southeast Asia. It's in the Kaptai Upazila of Chattogram Division's Rangamati District. The lake was created in 1961 by damming the Karnaphuli River in Kaptai as part of the Karnaphuli Hydro-electric Project, which was designed to provide hydropower for electrical generation. The dam stretches for 670.8 meters and rises 54.7 meters. A 745-foot (227-meter) long spillway with 16 gates is part of the dam's design. 5,250,000 cu ft/s (149,000 m3/s) of water can flow via the spillway. The reservoir which covers an area of about 58,300 ha (68,800 ha at full supply) and accounts for 46.8% of Bangladesh's total pond area, is an important component of inland water resources. As a result of the dam's construction, 40% of the area's entire arable land was submerged. In addition, the Government-owned Forest and 234 square miles (610 km_2) of additional forest area were flooded. Around 18,000 families were also relocated, totaling nearly 100 thousand individuals. The Chakmas king's palace was also inundated, and it is now submerged.

2.2 Fisheries of the Kaptai Lake:

Ahmed et al. (2006) worked on "Managing fisheries resources in the Kaptai reservoir, Bangladesh, where he outlined the different problems impeding the development of fishing resources in Bangladesh's Kaptai reservoir since its impoundment, the reservoir's catch has changed dramatically. He concluded that the productivity of high-value fish has been dropping in recent years, according to production records. The reservoir's potential to offer high-value freshwater fish has been underutilized due to a variety of administrative, social, and environmental issues, and he found that degradation of the natural breeding ground, environmental harm, poor regulation implementation, ineffective fish farming technology, and poor management practices are only a few of them.

A survey on the Kaptai Lake revealed that, at a time from the Kaptai Lake a mean harvest was 242 kg/brush, with major carps comprising 17%, catfish 24%, clupeid 13%, feather back 9%, tilapia 6% of the catch (Ahmed et al., 1999). They also reported that the harvested of major carps from brush shelter, almost 23% were less than 23 cm in length. According to Uddin et al. (2014), Siluriformes (catfish) were the most prominent order, accounting for 36.76 percent of total fish output, followed by Cypriniformes (22.79%), Perciformes (21.32%), Osteoglossiformes (7.21%), Synbranchiformes (5.15%), tiny prawn and others (6.79%).

Suman et al. (2021) reported that fish output in Kaptai Lake grew from 1,200 metric tons (MT) in (1965–1966) to 10,577 MT in (2018–2019). According to their research small fish, notably *Gudusia chapra*, *Gonialosa manmina*, and *Corica soborna*, dominated the lake's productivity in 2018–2019, accounting for 64 percent of overall production, where seven foreign fish species were among the seventy-six fish species observed under 10 orders. They also stated that the largest fish yield in the recent 11 years was 10,577 MT in (2018-19) and the lowest 5,578 MT in (2008–2009).

According to Ahmed et al. (2001) the present contribution from this fishery is around 6,000 MT per annum, with high annual fluctuation. The Kaptai reservoir's performance is hampered by a slew of environmental, social, and management issues that limit its potential. This reservoir is vital to the lives of a vast number of people who live in the surrounding areas. Despite its significant socioeconomic worth, previous research on the Kaptai reservoir concentrated on biological and limnological elements of fishing. DoF, (2021) documented that, the current fish production of the lake is 12696 metric tons (MT) (0.26 % of total fish production) while the country’s total fish production was 4.5 million MT.

Suman et al. (2021) reported that, over five decades, the total fish production from this lake increased remarkably; the production capacity reached 123 kg/ ha in 2011– 2012, 148 kg/ha in 2017–2018, and 181.42 kg. ha-1 in (2018–2019). They also reported that the alarming issue is the drastic reduction of the Indian major carps (IMC), (*Labeo calbasu*, *Gibelion catla, Labeo rohita*, *Cirrhinus cirrhosis*), and other native carps (*Labeo gonius*, and *Labeo bata*). In 2018–2019, *Corica soborna*, *Gonialosa manmina* and *Gudusia chapra* together contributed 63.76 %, whereas different carp species (*Labeo calbasu, Gibelion catla*, *Labeo rohita, Cirhinus cirrhosis, Labeo gonius,* and *Labeo bata*) contributed only 1.56 % of the total fish yield from the lake. However, in 1965– 1966 the above-mentioned carp species accounted for 81 % of the total fish production, and only 3 % were from *G. manmina*, *G. chapra, Ompok pabda,* and *Ompok bimaculatus* together.

2.3 Hydrology & primary productivity:

Bashar et al. (2015) documented that the mean water temperature in the Kaptai Lake varied from 21.04 to 31.52°C, with a highest of 31.5°C in September and a lowest of 21.04°C in January. Haque et al. (2018) described the highest air temperature (27.50±0.70°C) before monsoon and water temperature (31.5±0.80°C) was in monsoon was noted while lowest air temperature (21.00±1.30°C) in after-monsoon and lowest water temperature (23.5 ± 1.50°C) in post-monsoon were noted in Kaptai Lake and water temperature in the Lake ranged from 23.5°C to 31.5°C with a average value of 28.17±1.13°C. Haldar et al. (1992) reported a correlation between air and water temperature in the Kaptai Lake.

Chowdhury and Muzumder, (1981) described the highest level of oxygen was in the winter seasons, and dissolved oxygen at different water column showed no remarkable charges (1.0-2.4 mg/1) from surface to bottom. Rani et al. (2004) noted dissolved oxygen lower in Kaptai Lake during the summer due to the greater rate of organic matter decomposition and reduced water flow in low holding environment as a result of high temperatures. Ahmed et al. (1999) revealed that 6.4-9.1 mg/L dissolved oxygen (DO) and 4.7-6.0 mg/l free carbon dioxide contents are suitable conditions for aquatic lives. Haque et al. (2018) described that dissolve oxygen level in the study area ranged from 5.72 mg/l to 8.58 mg/l with a mean value of 7.15±0.39 mg/l in Kaptai Lake. The most significant greenhouse gas on earth is CO_2. Its ability to snivel across the air-water or sediment-water interface is one of the most crucial issues in studies of worldwide change and is frequently employed as a gauge of the overall ecosystem productivity or metabolism of the aquatic system. Ahmed et al. (1999) noted that free carbon dioxide ranged between 4.7 ± 0.3 and 6.0 ± 0.3 mg/1 in the Kaptai lake. Carbon dioxide concentration never surpass 6.2 mg/1 and were noted almost uniform in annual cycle in the Kaptai Lake water.

Carbon dioxide is the final output of organic carbon decomposition in practically all waterbody and its change is commonly a metric of ecosystem net metabolic rate (Hopkinson et al., 1985).

According to Wurts and Durborow, (1992) the majority of aquatic creatures can stay in a wide variation of alkalinity levels, and the optimal alkalinity level for majority of aquatic species is ranged 50 and 150 mg/l $CaCO_3$ but not fewer than 20 mg/l. Jhingran, (1989) discovered that alkalinity concentrations of greater than 50 mg/l are most productive and those of fewer than 10 mg/l do not produce adequate crops. He also noted that total alkalinity concentration of up to 20 mg/l remarks inadequate output of any kind of waterbody such as river lake pond etc, 40-90 mg/l demonstrate medium production, and values above 90 mg/l show high output. Barrett, (1953) noted that having alkalinity value of more than 80 mg/l means a lake to be nutrient-rich and of hard water type and such type of waters are often the greatest producers of fish. Bashar et al. (2015) noted a positive correlation between alkalinity and hardness (r=0.52). Mookerjee and Bhattracharya, (1949) reported that a sudden fall of alkalinity of a freshwater body may occur as a result of water dilution due to heavy rainfall. They also stated that the optimum level of pH was 6.5 to 8.5 for any aquatic life.

According to Wurts and Durborow, (1992) the most prevalent sources of water hardness are calcium and magnesium. Calcium and magnesium are important in the biological processes of aquatic animals, particularly in the production of bones and scales in fish. From the same reservoir, a narrow range of hardness (50.00-66.67 mg/l) was discovered Chowdhury and Mazumder, (1981). According to Rahman et al. (2012) Chloride, sulfate, carbonate, and bicarbonate are responsible for the water's hardness. Brown et al, (1970) stated that a soft water body comprises 0 to 60 mg/L of calcium carbonate.

Villadolid et al. (1954) stated that the range of water pH from 7.8 to 8.4 is optimum for plankton growth and the low level of pH adversely affected the growth of plankton and fish. EPA water quality recommended (EPA, 2017) that fresh water's pH should be between 6.5 and 9. According to Barua et al. (2016) pH of Kaptai Lake’s water was between 7.46 and 7.75 which is within the optimum range. According to Islam et al. (2021) the pH of the water in the Kaptai Lake ranged from 6.82 to 7.96 and during the pre-monsoon season the highest pH was 7.96 while the lowest pH was 6.82 during the post-monsoon season where 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.

Islam et al. (2021), Kaptai Lake's average TDS varied by season during the research phase and ranged from 44.5 to 80.5 mg/l. The maximum TDS of 80.5 mg/l was recorded in post-monsoon and the minimum TDS 44.5 mg/l was noted in monsoon season in Kaptai Lake. Bogakain, a naturally occurring high-altitude lake in Bangladesh, had TDS concentrations of 39 to 42 mg/l compared to 52 to 54 mg/l in Kaptai Lake (Barua et al., 2016; Khondker et al., 2010). Kambole, (2003) revealed that high TDS was due to the various dying stuff which is used in the textile mills and they might be major sources of the heavy metals. It is also noted that the increase of heavy metal concentrations in the river sediment could increase the suspended solids concentrations.

According to Boyd and Tucker, (1992) ammonia level between 0.4 to 2mg/L is toxic for fish. Jhingran, (1989) reported that a dissolved ammonia concentration of 0.2-0.5 mg/1 is favorable for fish life. Ahmed et al. (2001) stated NH_3-N concentration 0.4 mg/l in the Kaptai Lake.

2.4 Organic Matter of Sediment:

According to Forsberg, (1989) nutrients both organic and inorganic are transported continually to lake bottoms through sedimentation. Different biological, physical, chemical and mechanical processes can return specified nutrient levels to the free water. Depending on the lake's type and bottom conditions, several cycles between the sediments and water may take place. The size of nutrient pools and rates of turnover can be significantly influenced by lake topography, temperature regimes, trophic level, and sediment type.

Avramidis et al. (2013) said that the sediment of lake that come from the nearby areas of catchment and the headwaters after processes that cause weathering and erosion hold traces of a variety of weather conditions and processes involved in transportation brought about by the wind action, water, or ice by the impact of gravity or Stream processes on the particles can bring about a lot of proof that its surroundings environment has changed (Velez et al., 2011). Adesuyi et al. (2015) documented minerals, water, organic matter (OM) and living components are the constituting element of sediment that vary spatiotemporally. Gupte and Shaikh, (2014) stated that clay, silt, sand, and gravel are example of minerals found sediment while decaying organic matter and shells are example materials found in OM. Kiani et al. (2021) noted that the sediment acts in nutrient cycling by OM degradation eventually enhancing biological activity within a natural environment, and facilitating plant growth. Cardoso et al. (2019) noted that due to the carbon cycle's active function as a natural buffer, filtering water, and exchange of micronutrients between he deposits and above-ground water bodies, sediment may have an impact on environmental quality Abowei, (2010). Hence, Kumary, (2007) suggests that any environment, such as streams and reservoirs, or vice versa, can have its environmental health status and the characteristics of its overall ecosystem determined by the sediment and the water that lies on top of it (Singare et al., 2011). Adesuyi et al. (2016) recorded that the nature of the sediment and the organic matter composition determines the structure benthic community in water.

Hoque et al. (2021) conducted a study on physical -chemical properties organic matter percentage of Kaptai lake where they found organic matter ranged from 4.25 -8.18% which indicate the healthy ecosystem of a water body for aquatic organism. But the effect of land use and other watershed factors on sediment would change over time and space depending on regional dynamics. So, in order to ensure a healthy ecosystem, productivity boost up the fish production water quality parameter should be managed properly.

Chapter: 03

Materials and Methods

3.1 Study area

The research was done in the Kaptai Lake (Figure-01). It was built in 1961 by damming the Karnaphuli river at Kaptai lake Point in order to generate hydroelectric power. The lake has two major tributaries and is divided into two diverse arms by hilly regions in between this lake. This euphotic lake's total surface area is made up of approximately 68,800 hectares of water bodies with an average depth of 9.0 meters and an average fluctuation of annual water level is 8.1 meters (Mahmood, 1986). The most populated and densely populated region in the catchment is the major reservoir area, which comprises the surroundings of Rangamati Pourashava and Rangamati area. On the other hand, the lowest population density was in the Karnaphuli River region (55.13 person/km^2) and even though there are scattered concentrated communities, this is the catchment's highest vegetated area.

Fig-01: The Kaptai Lake

3.2 Sampling station:

Four stations of the Kaptai Lake were selected for sampling purposes (Fig 2). The local name and geographical location of those four sites are:

- ✓ Jolojan Ghaat (22°39′30″ and 92°10′43″);
- ✓ Kandemu (22°39′15″ and 92°11′52″);
- ✓ Shubholong Waterfall (22°42′29″ and 92°14′33″);
- ✓ Shubholong Bazar (22°42′40″ and 92°15′75″ (Fig. 2).

Shuvolong is the starting part of the reservoir as well as the confluence of Kasalong tributary with Karnaphuli river. The study was carried out from September, 2021 to February, 2022.

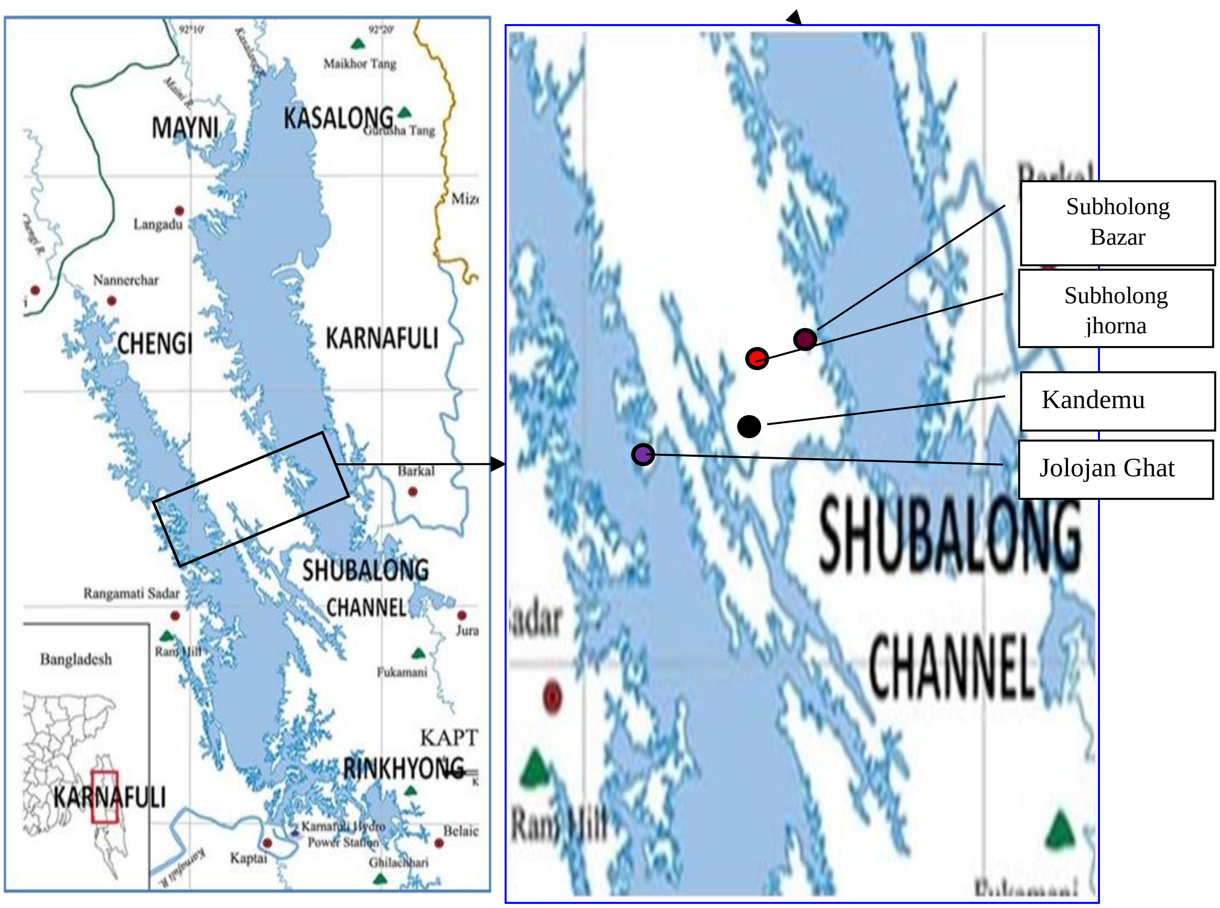


Fig -02: Map of the sampling stations

3.3 Sampling procedure:

3.3.1 Preparation for sampling

Necessary types of equipment such as pH meter (HI211), TDS meter (Sens IONEC71) DO meter (Edg DO), measuring tape, Secchi disc, rope, sampling bottle, and formalin were carried to the sampling sites by Chattogram Veterinary & Animal Sciences University (CVASU) Research Vessel (Figure-03) to collect the sample and for further activities.

Fig-03: CVASU Research Vessel

3.3.2 Sample collection:

Samples of surface water were taken for three times from four fixed sampling stations of the aquatic ecosystems of Kaptai Lake during the research period from September 2021 to February 2022 in order to measure various water quality parameters (physical and chemical) including total alkalinity, and total hardness, dissolved oxygen (DO), temperature, transparency, total dissolved solids (TDS), pH. A bucket was used to take samples of the surface water, while the Kemerrer Water Sampler (1200-B15) was used to take samples of the middle and bottom layers of the water column. The samples were then stored separately for future analysis. Samples of sediment were taken by Ekman Grab

Sampler (196-B15) and stored in black polythene. All the water and sediment samples were brought to the Aquatic Ecology Laboratory, Faculty of Fisheries, CVASU for further analysis.

3.3.3 Determination of water quality parameters:

i) Water temperature and air temperature:

Water temperature is a significant environmental quality which play a vital role in any aquatic ecosystem and this is must be measured to observe the productivity of tha waterbody. If a body of water is suitable for an aquatic environment, the temperature of the water is a key deciding factor (Kabir et al., 2020). Water temperature was determined by using a thermometer.

ii) Water depth:

Water depth is an important issue for aquatic organism. Water depth data of the sampling site was collected from the control room of the research vessel.

iii) Transparency:

Alternation of water transparency can alter crucial characteristics of ecosystems in water, impacting the use of important habitats or resources which causes phenotypic diversity. Using a 20 cm diameter Secchi disk with graduated ropes, transparency was measured (Figure 04).

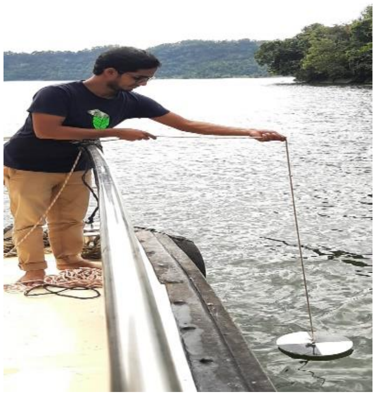


Figure 04: Determination of transparency

iv) TDS (Total dissolved solid):

Higher TDS concentrations frequently affect aquatic animals in water systems like rivers. TDS alters the water's mineral composition which is crucial for many creatures' survival. Additionally, aquatic animals' skin can become fatally dehydrated due to dissolved salt. TDS was measured using a TDS meter (Figure 05).

Figure 05: Determination of TDS

v) pH:

pH is an important water parameter of waterbody which indicate the alkalinity or acidity. A Hannah pen pH meter was used to measure it.

vi) Dissolved oxygen (DO):

The most crucial element in the aquatic environment is dissolved oxygen. Aquatic life directly depends on dissolved oxygen. DO meter was used to test DO (Figure-06).

Figure 06: Determination of pH & DO

vii) Alkalinity:

To measure the alkalinity (Tritimetric method), at first, the sample was collected from the surface of water body. Then 50ml of water sample was taken in a beaker. After that 2-4 drops of Phenolphthalein indicator were added to the sample. Due to the absence of Phenolphthalein Alkalinity color didn’t change. Again, 50ml of water sample was taken in a beaker, and 2-4 drops of Methyl Orange indicator were added to the sample and the color turned yellow. Then burette was filled with Sulphuric acid, and after that the content was titrated against sulphuric acid (0.02N), and it was continued until the color changed pink. After that, the content was titrated again with Sulphuric acid until the color changed to red. Finally, the following formula was used to calculate Alkalinity-

$$\text{Alkalinity (mg/L) as } CaCO_3 = \frac{\text{mL of titrant} \times \text{N of acid used} \times 50 \times 1000}{\text{mL of sample}}$$

Figure 07: Determination of Alkalinity

viii) **Carbon-di-Oxide (CO_2):**

To measure the carbon-di-oxide (Tritimetric method) at first, the sample was collected from the surface of water body. Then 50ml water was taken in a conical flask where 2-4 drops of phenolphthalein indicator were added. When color became pink then NaOH was added to determine the amount of free CO_2. Specific table and calculating equation were used to determine the amount of free CO_2. Finally, the following formula was used to calculate Carbon-di-Oxide

$$CO_2 = \frac{\text{ml of NaOH used} \times \text{(N) of NaOH} \times \text{Molecular wt.of NaOH} \times 1000}{\text{Volume of sample}}$$

Figure 08: Determination of CO_2

ix) Hardness:

To measure hardness ((Tritimetric method) sample was collected from the surface of the water body. Then 50 ml of the sample water was taken in a conical flask along with 5ml of the buffer. A pinch of eriochrome Black indicator was added and then titrated against standard EDTA until the wine turned from red to indicates the endpoint. The amount of standard EDTA required was recorded. Finally, the following formula was used to calculate total hardness:

$$\text{Toral Hardness} = \frac{T \times 100}{V}$$

Where,

T= Volume of EDTA

V = Volume of sample

x) Determination of Ammonia:

To measure ammonia at first, the sample was collected from the surface of the water body. Amount of Ammonia was determined by the direct nesslerization method. At first a little NaOH was added to a filtered 100 ml of sample, to neutralize the acid for storage. Then 10 % $ZnSO_4$ was added followed by 1ml of 10% NaOH. The sample was Stired and filtered (Ca, Mg, S are precipitated). Then the filtrate was collected and 1 drop of 50% EDTA was added and mixed well**.** Then 2ml of Nessler reagent was added and mixed well. A series was prepared of dilution using 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1 ml of standard NH_4Cl Solution in Nessler's tube and diluted with distilled water to make up to 50 ml. Then 2 ml of Nessler's reagent was added to each individual tube. After 10 minutes, the intensity of the resulting yellow color was measured with the help of a spectrophotometer (EMPHO I) at 420 nm.

3.4 Determination of organic carbon and organic matter:

The Kaptai Lake sediment's organic Matter was estimated using Walkley and Black's rapid mathod. The samples were dried air and room temperature for few days after being sun dried for two days. After that, samples were individually ground with a hand grinder and run through a 2 mm mesh sieve. The produced samples were filtered and then stored in a plastic container for laboratory testing.

After drying 2g soil sample was taken in a 500 ml conical flask. Then 10 ml of (N) $K_2Cr_2O_7$, 20ml of concentrated H_2SO_4, and a pitch of silver nitrate or silver sulfate were added. To digest the mixture was slightly heated, and shaked and then allowed for 30 minutes. When the mixture becomes green then known amount of $K_2Cr_2O_7$ solution was added in excess to make it yellow color. Then the sample was diluted with water to 200 ml. Then 5ml of ortho phosphoric acid or phosphoric acid was added. Then the sample were titrated with standard $FeSO_4$ solution by using 1ml diphenylamine indicator (end point – blue to brilliant green). Also, run a blank (without soil) in the same way.

Finally, the following formula was used to **Calculation of Organic Carbon:**

% Organic Carbon (OC) = (B-U) *D*N*A*100/(B*W)

Where,

B = Volume of $FeSo_4$ required for blank

U = Volume of $FeSo_4$ required for Sample

D = ml of $K_2Cr_2O_7$ used

N = Normality of of $K_2Cr_2O_7$(1N)

A = meq of carbon (0.003)

W = Weight of sample used

Calculation of Organic Matter

% Organic matter (OM) = OC* 1.724

Figure-09: Determination of Organic matter

3.5 Statistical analysis:

The data were collected, formatted properly, and statistical analysis was performed on them. The data was presented and analyzed using the Statistical Package for Social Sciences (SPSS) version 26) and R programing (3.6.3). To investigate precise connections between the factors under investigation, Pearson's correlation matrix was used.

Chapter :04

Result

4. Temporal Variation of Water Quality Parameters of the Kaptai Lake:

i) Water & Air Temperature

The highest water temperature (31.60°C) was noted in October Shubholong Jhorna and the lowest (21.9°C) in January Jolojan Ghat (Figure -10, Table-01) with a mean of 27.95 ± 0.544°C. The maximum air temperature (32.8°C) was noted in October at Shubholong Jhorna and the minimum (24.10°C) in January at Jolojan Ghat, (Figure -10, Table-01) with a mean of (29.21 ± 0.564°C).

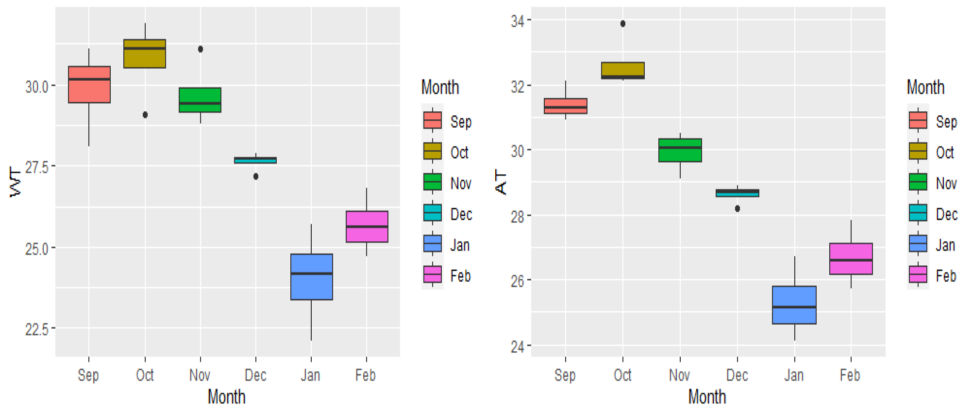


Figure-10: Monthly fluctuations of air and water temperature

Station		DO (mg/l)	pH	Alkalinity (mg/l)	Hardness (mg/l)	CO_2 (mg/l)	Ammonia (mg/l)	WT (ºC)	AT (ºC)	TDS (mg/l)	OM (%)
Jolojan Ghaat	Mean	5.6	7.40	79.47	66.25	3.90	0.34	25.14	27.15	49.78	6.08
	Std.	1.42	0.49	8.37	7.99	1.310	0.096	2.07	3.32	16.8	.12
	Min	5.5	7.30	69.4	55.7	3.1	0.36	21.9	24.1	45	5.9
	Max	7.2	8.6	87.3.	78	6.5	0.49	28.3	29.8	54	6.32
Kandemu	Mean	5.8	7.6	77.92	67.20	3.58	0.14	27.32	29.20	44.4	5.5
	Std.	1.48	0.82	7.709	9.90	0.82	0.19	2.62	3.16	16.34	0.27
	Min	5.6	7.4	62.80	55.7	2.3	0.018	26.9	28.5	38	5.6
	Max	8.3	9.02	88.1	81.4	5.3	0.21	30.3	31.1	49	5.9
Shubholong Jhorna	Mean	5.9	7.60	79.18	70.23	4.22	0.21	28.24	29.08	50.6	5.07
	Std.	1.95	0.50	8.22	10.06	1.26	0.12	2.91	2.99	15.94	.673
	Min	5.7	7.4	70.2	60	3.1	0.018	25.6	26.2	40	4.09
	Max	7.6	8	90.1	86	6.2	0.12	31.60	32.8	53	6.12
Shubholong Bazar	Mean	5.8	7.80	83.47	70.78	4.97	0.17	28.65	29.57	48.03	5.28
	Std.	1.55	.62	9.19	9.57	1.35	0.078	2.423	2.18	14.65	0.36
	Min	5.6	7.4	63	60	4.1	0.19	5.7	7.1	44	5.4
	Max	7.6	8.6	88.1	85.70	4.9	0.23	30.4	31.1	55	5.9

Table-01: Water quality parameters, OM (%) of the Kaptai Lake in term of Stations

ii) Dissolved Oxygen (DO):

The four sites water's DO ranged from 5.5 to 8.3 mg/l. The lowest DO content was 5.5 mg/l in Jolojan Ghaat in January and the highest DO content was 8.3 mg/l in Kandemu in October (Figure-11, Table-01) with a mean of 7.60±0.76 mg/l.

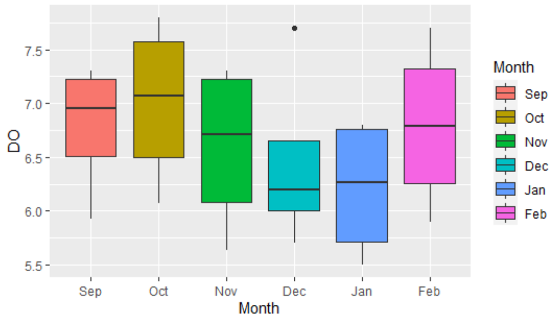


Figure-11: Monthly variation of Dissolved oxygen (mg/l)

iii) Carbon dioxide (CO_2):

Free CO_2 varied between 2.3 to 6.5 mg/l with an average value of 4.16 ±1.24 mg/l. The maximum value of CO_2 (6.5mg/l) was noted in December and the minimum value (2.3 mg/l) in November (Figure-12).

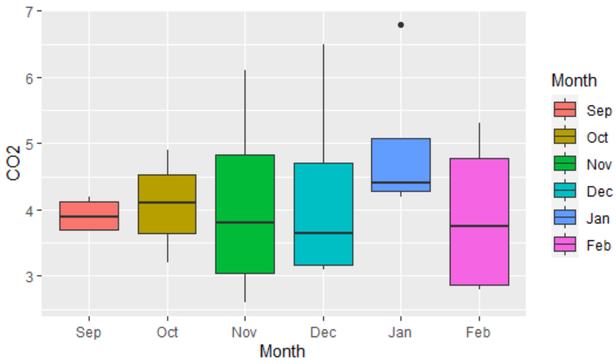


Figure-12: Monthly fluctuation of carbon dioxide (mg/l) in Kaptai Lake water

iv) **Alkalinity:**

Total alkalinity ranges from 62.80 mg/l to 90 mg/l with an average value of 78.50 ±7.87 mg/l. Maximum alkalinity was estimated as 89.10 mg/l from Shubholong Jhorna in

January and minimum alkalinity was estimated as 62.80 mg/l in October (Figure-13, Table 1).

v) Hardness:

The range of the water's hardness for the four sites ranged between 55.7 to 85.68 mg/l with a mean value of 68.62 ±9.05. The lowest hardness 55.7 mg/l was found in the Jolojan Ghaat and Kandemu in September and the highest hardness 85.80 mg/l was found at Shubholong Bazar in February (Figure-13, Table -01).

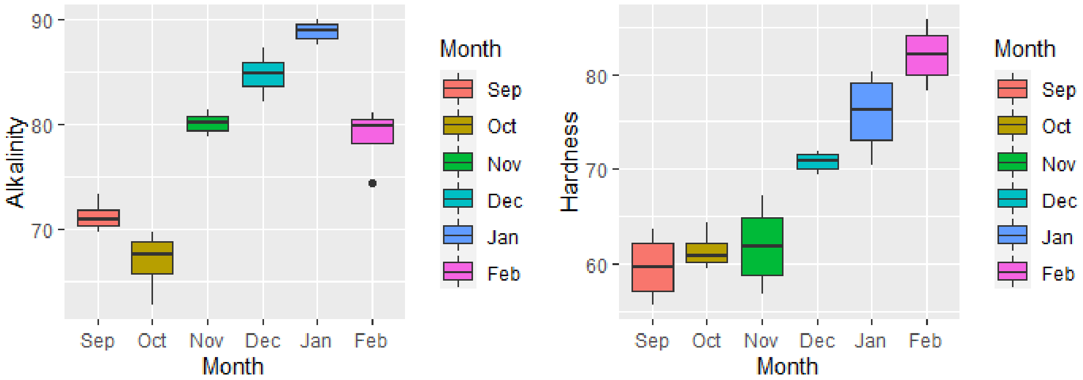


Figure-13: Monthly fluctuation of Alkalinity and Hardness (mg/l) of Kaptai Lake

vi) pH:

The four sites water's pH values ranged from 7.30 to 9.02 with a mean value of 7.67±0.603. The highest pH was recorded 9.02 in October while the lowest pH 7.30 was found in September (Figure-14).

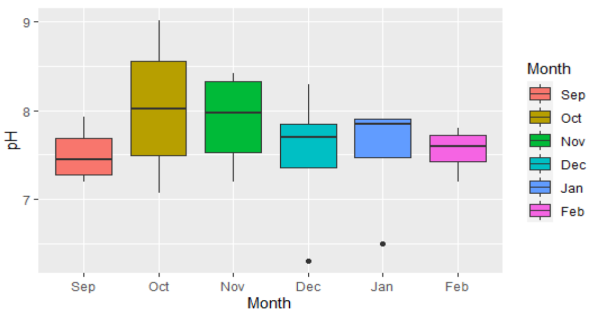


Figure-14: Monthly variation of pH of Kaptai Lake water

vii) Total Dissolved Solid (TDS):

The lowest TDS content was found (40 mg/l) at Shubholong Jhorna (Table-01, Figure 15) in November and the maximum TDS 55 mg/l was discovered at Shubholong Bazar in September (Table-01, Figure-15) with a mean value of 47.75 ± 3.92 mg/l.

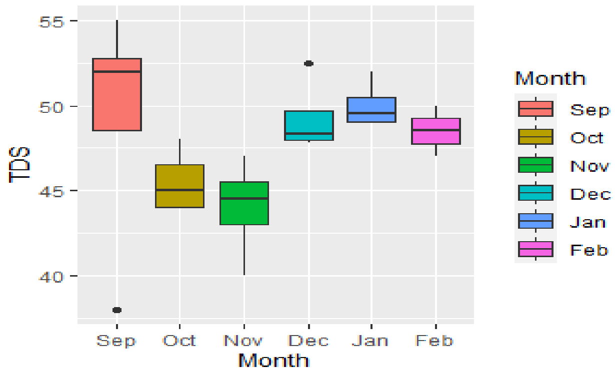


Figure-15: Monthly variation of TDS (mg/l) of Kaptai Lake water

viii) Ammonia (NH_3-N):

The ammonia of the four-station varied from 0.018 to 0.49 mg/l. The lowest content of ammonia (0.018 mg/l) recorded in September, November and December and the highest concentration (0.49 mg/l) was found in February (Figure-16).

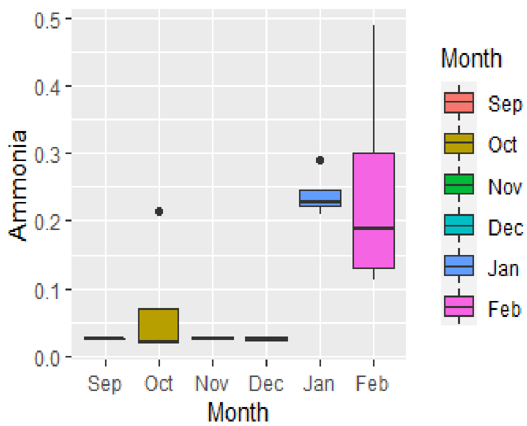


Figure-16: Monthly variation of ammonia (mg/l) of Kaptai Lake water

4.1 Correlation among different water quality parameters of the Kaptai Lake:

Air and water temperature showed a strong correlation (r = 0.943). CO_2 showed a strong negative correlation with dissolved Oxygen (r = -0.736), and a weak positive correlation with alkalinity (r = 0.183), hardness (r =-0.185) and pH (r= 0.084). Dissolved Oxygen has a strong negative correlation with CO_2 (r = -0.736). A significant positive correlation between total hardness and total alkalinity was observed (r=0.559). pH has a weak positive correlation with Carbon dioxide (r =0.084). TDS has a very weak correlation with Organic matter (r = 0.023). Ammonia has a positive correlation with organic carbon (r=0.343), organic matter (r=0.365) and a strong correlation with hardness (r =0.645).A strong positive correlation is observed between organic carbon and organic matter (r = 0.996). Every correlation is showed in figure -17

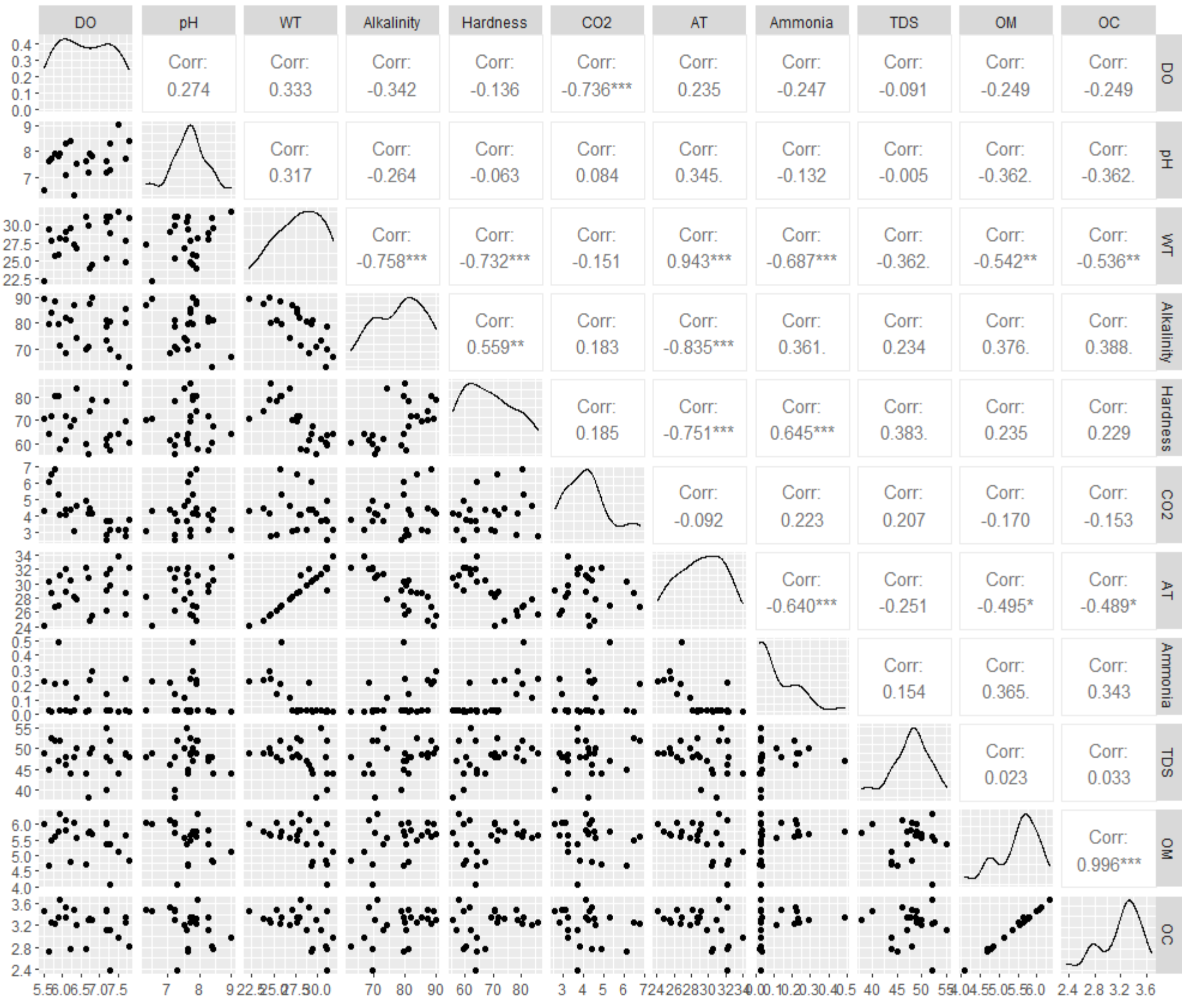
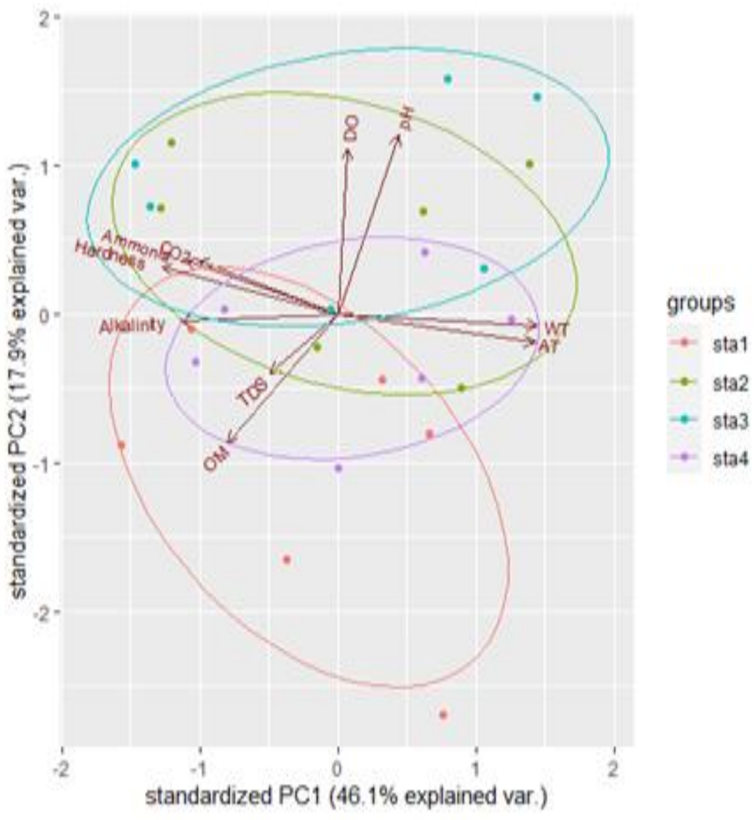


Figure-17: Correlation Matrix of water quality parameters

4.2 PCA for Spatial variation:

PCA was applied to the datasets of four different stations to compare the spatial composition of the lake water and to find the dominant water quality in the lake. Spatial composition of water quality parameters were explained by using PC1 and PC2 which cover about 64 % of the total variance. During the sampling period, TDS, air temperature, and water temperature were found dominant in Shubholong Bazer and Kandemu whereas dissolved oxygen, carbon-d-oxide, pH, ammonia, alkalinity and hardness composition were higher in Kandemu. This figure (Figure17) notifies that Kandemu, Shuvolong Jhorna and Shuvolong Bazar were closely related for dissolved oxygen, carbon-di-oxide, pH, ammonia, alkalinity and hardness, air temperature and water temperature.



Figurer-18: Variation of water quality parameters at Jolojan Ghat (Sta 1), Kandemu (Sta 2), Shubolong Jhorna (Sta 3) and Shubholong Bazar (Sta 4) of Kaptai Lake

4.3 PCA for water Column:

PCA was applied to the datasets of the surface, middle, and bottom water column to compare dissolved oxygen, pH, temperature, and TDS of the Kaptai Lake. Variation of water quality parameters in case of water column were observed by using PC1 and PC2 which cover about 85.6% of the total variance. PCA analysis shows that, water temperature and dissolved oxygen concentration were higher in the surface water, whereas the TDS was higher in the bottom water.

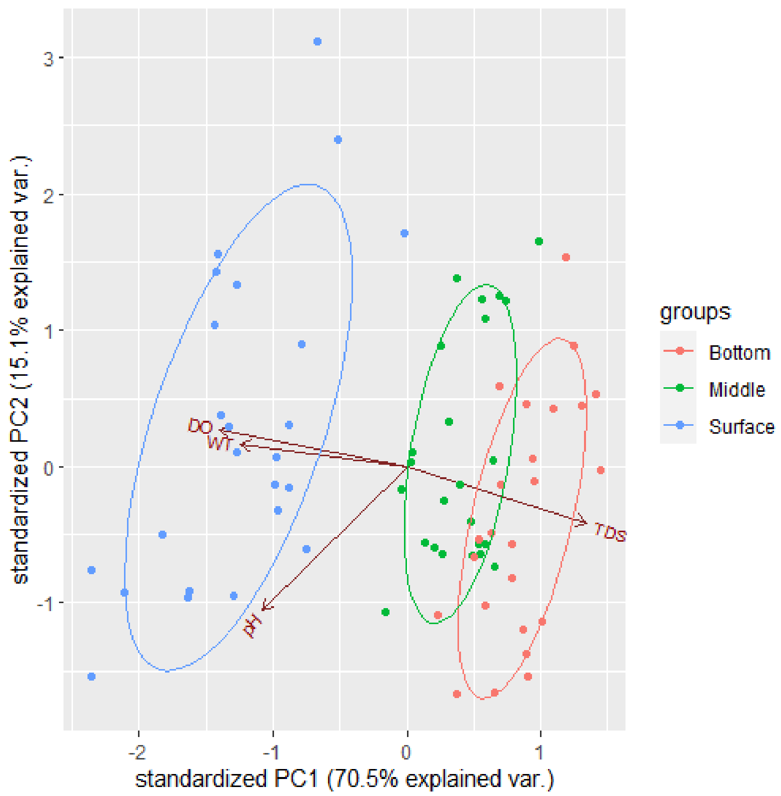


Figure-19: Variation of water quality parameters among water column

4.4. Organic carbon and Organic matter percentage with depth:

Mean organic matter of the lake in the sampling period was observed 5.50 ± 0.55%. There was no significant relationship observed between depth and mean percentage of organic matter (Pearson Correlation, r =0.060, Table-03). That's why the occurrence of organic matter was more or less similar in all depths (Figure-19). Organic carbon and organic matter was found strongly positively correlated (r=0.996, Table 3).

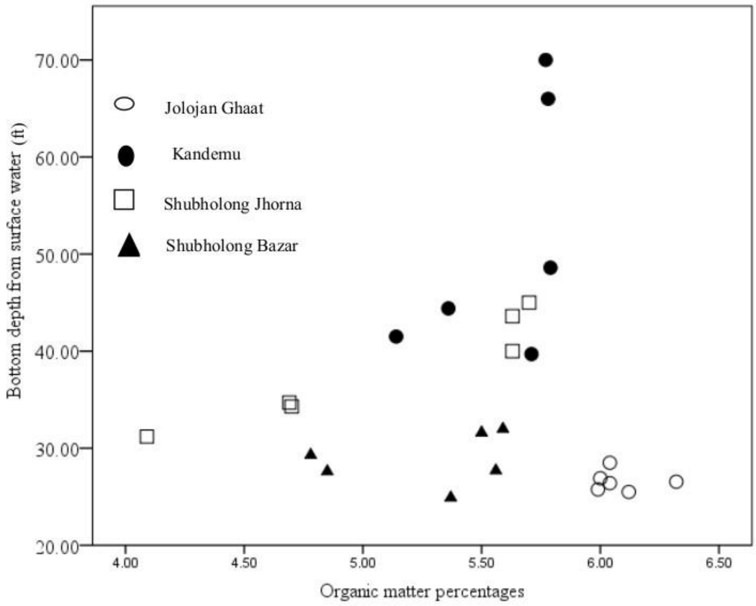


Figure-20: Variation of organic matter with depth

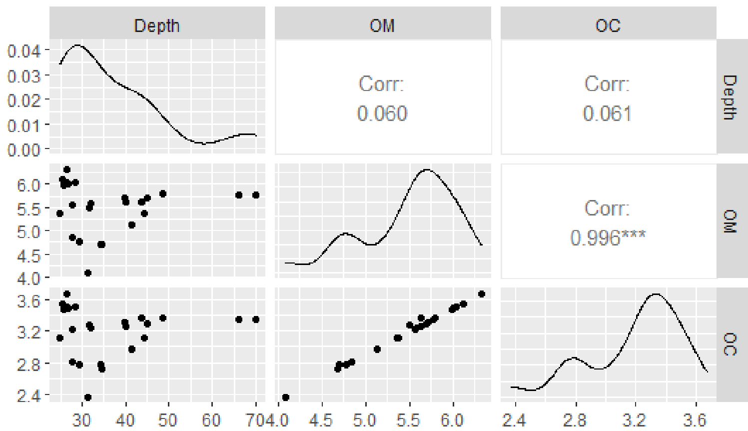


Figure-21: Correlation between organic matter and organic carbon with depth

4.5 Variation in sediment organic matter over space in Kaptai Lake:

The highest and lowest organic matter was 6.32 % and 4.09% in Jolojan Ghaat and Shubholong Jhorna, respectively. Krushkal Wallis Test was performed to evaluate whether the percentage of OM is significantly dependent stations or not. There was a significant difference observed among stations and mean percentage of matter (p =0.002). The mean of organic matter of Jolojan Ghaat signicantly vary with Kandemu, Shubholong Jhorna and Shubholong Bazar (Figure-20, Table -04).

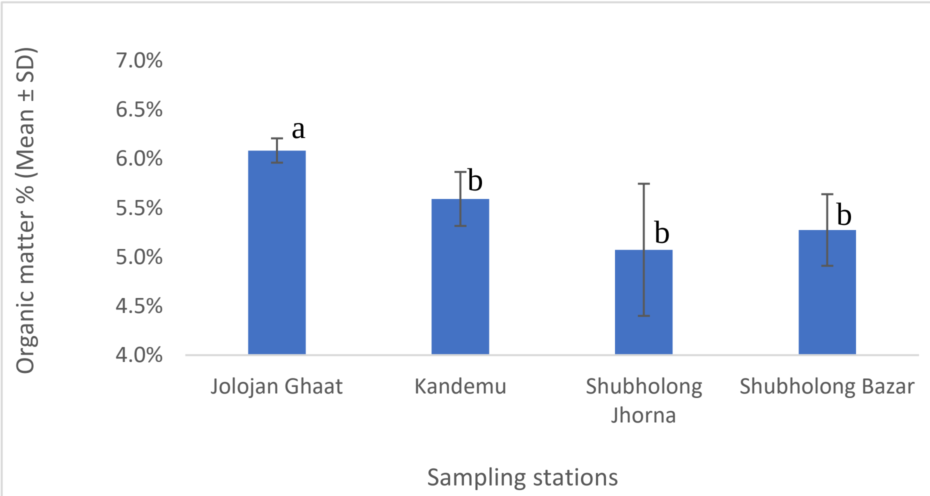


Figure 22: Spatial variations of Organic matter in different stations

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Sampling stations	Organic matter percentages (Mean ± SD)
1. Jolojan Ghaat	6.09 ± 0.124[a]
2. Kandemu	5.59 ± 0.275[b]
3. Shubholong Jhorna	5.07 ± 0.673[b]
4. Shubholong Bazar	5.28 ± 0.365[b]

Table 02: Significant difference of Organic matter in different stations

Chapter: 05

Discussion

Physical, chemical, and biological parameters are the most important issue of a water body. Fish and other aquatic organisms are also influenced by these parameters. Suitable water quality variables are prerequisites for a productive ecosystem and healthy aquatic environment for fish production. According to Rahman et al. (1999) physical, chemical, and biological parameters regulate the productivity of a waterbody.

5.1 Temporal variation of water quality parameters of the Kaptai Lake.

a) Temperature

Water temperature play vital role in aquatic ecosystem which determine the productivity of any reservoir. As temperature is a significant environmental parameter it must be determined to observe productivity of waterbody. The temperature of a body of water is a significant component in deciding whether it is suitable for an aquatic environment (Kabir et al., 2020). The temperature has an influence on all other parameters of water and has great importance in chemical and biological activities. Generally, chemical and biological activity may be double with the increase of 10°C temperature. Organisms use dissolve oxygen twice and the chemical reaction will also progress with the increase of each 10°C temperature. So, dissolve oxygen requirement for fish and other aquatic organisms is more critical in warmer water than in cold water. The maximum water temperature is found 31.60°C in October and minimum of 21.9°C in January with an average value of 27.95 °C. According to Boyd, (1990) aquatic organisms of the tropical and sub-tropical region do not grow well below 26-28°C. So, the temperature of the Kaptai Lake is suitable for fish growth. A strong and positive correlation (r =0.943)) was observed between air temperature and water temperature which is represented in Table -02. Rahman et al. (2014) and Chowdhury and Mazumder, (1981) both noted a correlation between air and water temperature.

b) Dissolved oxygen:

Dissolved oxygen (DO) may be the most critical water quality parameter in fish culture. Photosynthesis is the primary source of DO in the water body and the second source is the atmosphere. To ensure acceptable water quality, aquatic creature endurance, and waste bacterial putrefaction, an adequate DO level is required (Islam et al, 2010 and Rahman et al., 2012). The DO of the water at the 4 stations varied from 5.5 to 8.3 mg/l. According to Ellis et al. (1946) the value of DO below 3 mg/l is lethal for fish and other aquatic organisms and more than 5 mg/l is suitable for fish production. In the Kaptai Lake, the DO level was more than 5 mg/l which is suitable for fish production.

When dissolved oxygen concentrations are low in the water then the presence of carbon dioxide obstructs the uptake of oxygen by fish. When concentrations of dissolved oxygen are very low, the carbon dioxide concentration becomes quite high. At a low concentration of oxygen, photosynthesis is not proceeding properly. This is because carbon dioxide is released and oxygen is used during respiration. According to Boyd, (1998) the ideal DO concentrations for fisheries were between 4 and 6 mg/l, below which most aquatic organisms would perish. The Dissolved Oxygen of the Kaptai Lake is suitable for a healthy ecosystem and fish growth. The current investigation found a strong association between DO and water temperature (r=0.333), air temperature (r= 0.235) and strong negative correlation with CO_2 (r = -0.736), hardness (r= -0.136), and total alkalinity (r=-0.342) which is represented in table -02. Ahmed et al. (1993) also noted a similar statement.

c) Carbon-di-oxide:

Carbon dioxide is the basis of all life on earth although sometime it may be considered a troublesome substance. Without free carbon dioxide, basic food production by plants through photosynthesis is not possible. The major source of carbon dioxide is respiration by organisms' bacterial decomposition. Boyd, (1982) suggested that a carbon dioxide level of 1 to 10 mg/l is suitable for fish culture. In this present investigation, carbon dioxide concentration of four stations ranged between 2.3 to 6.5 mg/l with a mean of 4.28 ±1.51 mg/l which is in the ideal range for fish growth. The rise in free CO_2 is a result of the rising trend in water level brought on by the inflow of precipitation from hilly streams (Ahmed et al., 1993). According to the current research, the low free CO_2 concentration in November was likely caused by minimal rainfall, which resulted in little organic matter being broken down, and enhanced photosynthesis, which ate up CO_2 (Kabir and Naser, 2011; Rahman et al., 2014).

d) pH:

pH is the concentration of hydrogen ion (H^+) in water which is a significant parameters of water quality. It describes the waterbody's acidity-alkalinity balance. The Kaptai Lake's water's pH level at the four stations ranged from 7.30 to 9.02 with a mean value of 7.67±0.60. The higher organic matter present in Jolojan Ghat. So, it produces different types of gases such as Carbon-di-oxide, ammonia etc at Jolojan Ghat. But this is not under standard level.

According to Sreenivasanr, 1970 a pH of 6.5 to 9 is suitable for fish culture and a pH of more than 9.5 is unsuitable because free carbon dioxide is not available in this situation and at a pH of 11 fish dies. He also noted that the metabolic rate, growth rate, and other physiological activity of fish are reduced by acidic pH. Boyd, (1982) said that the pH range for fish culture should be 7 to 9 and the result of the present study match with the findings of Boyd. It can be said that the pH of Kaptai Lake is suitable for fish culture.

e) Total Dissolved Solid (TDS):

Higher amounts of TDS in bodies of water, such as rivers, can be harmful to aquatic organisms. TDS alters the mineral content of water which is critical for many creatures' survival. TDS concentration of the Kaptai Lake was 38 mg/l to 55 mg/l with a mean value of 47.75 ± 3.92. Bogakain, a naturally occurring high-altitude lake in Bangladesh, had TDS concentrations of 39 to 42 mg/l compared to 52 to 54 mg/l in the Kaptai Lake (Barua et al., 2016; Khondker et al., 2010). The Buriganga River's TDS varied from 378.75 to 616.75 mg/L and 205 to 240.5 mg/l during the summer and rainy seasons accordingly, above the usual threshold in both seasons. In contrast, The Brahmaputra River's TDS level varied from 183 to 185 mg/l and 157 to 198 mg/l (Islam et al., 2015; Islam et al., 2012). Present study expresses that TDS concentration of Kaptai Lake is in congenital condition and favorable for fish growth.

f) Alkalinity:

Aquatic creatures and fish benefit from alkalinity as it prevents or buffers them from fast pH shifts. A pH range of 6.0 to 9.0 is ideal for living organisms especially aquatic life. Acid rain and other acid pollutants will be buffered by higher alkalinity levels in surface waters which will prevent pH shifts that are hazardous to aquatic life (Kabir et al., 2020). Alkalinity means the buffering capacity of the water body which neutralizes acids and bases and maintain a stable pH level. A pH range of 6.0 to 9.0 is ideal for all living organisms, especially aquatic life. Acid rain and other acid wastes will be buffered by higher alkalinity levels in surface waters, preventing hazardous pH changes to aquatic life (Kabir et al., 2020). Total alkalinity of Kaptai Lake ranges from 62.80mg/l to 90.10 mg/l with a mean value of 78.50 ±7.87 mg/L. Bashar et al. (2015) discovered The Kaptai Lake's total alkalinity ranged from 51.9 mg/L in December 2012 to 90.68 mg/L in December 2013. Bashar et al. (2015) documented that a lake with a value of total alkalinity more than 80 mg/L is likely to have hard water and be nutrient-rich, and lakes like these are frequently the finest fish producers. The findings of this study suggest that Kaptai Lake might be regarded as moderate to high productivity in terms of fish production because of its total alkalinity. Carbon dioxide availability for plankton growth is related to total alkalinity. According to Boyd, (1982) CO_2 is little available for plankton growth when alkalinity ranges from 15 to 20 mg/l. In alkalinity ranges between 20 to 150 mg/l suitable amount of carbon dioxide is available for plankton growth in fish culture. The value of alkalinity in the present study lies in this ideal value which means the availability of carbon dioxide is suitable for primary production.

g) Hardness:

Hardness has a significant impact on fish and other aquatic organisms and it appears that these ions have an impact on other, more dangerous metals including lead, cadmium, chromium, and zinc. In general, the toxicity of various metals to aquatic life decreases with increasing water hardness (Islam et al., 2015). Chloride, sulfate, carbonate, and bicarbonate are what cause the water to be hard water (Rahman et al., 2012). The most prevalent causes of water hardness are calcium and magnesium. Calcium and magnesium are necessary for aquatic animal biological processes such as bone and scale formation in fish and other aquatic organisms. The critical component of total hardness is calcium concentration or calcium hardness. Environmental calcium is crucial for osmoregulation which is maintaining the precise levels of internal salt for normal heart, muscle, and nerve function. The mean value of the hardness of the water sample for the four locations was (68.62 to 90.0) and it ranged from 55.7 to 85.68 mg/L. According to Brown et al. (1970) a soft water body, comprises with content of calcium carbonate 0 to 60 mg/l. As a result, the Kaptai Lake water can be characterized as being slightly hard (Ahmed et al., 2001). In present study a range of 14-73 mg/l of the Kaptai lake water of the hardness was noted by ARG, (1986). A small variation of hardness (50.00 - 66.67 mg/l) from the same waterbody was also recorded by Chowdhury and Mazumder (1981).

h) Ammonia:

Ammonia is another important factor for fish culture, ammonia is incorporated in water with feces of fish and bacterial decomposition of organic matter. If the concentration of ammonia increases in water, ammonia excreted by fishes diminishes, and ammonia level in fish blood and other tissue increase. This elevated result increases blood pH level which has an adverse effect on enzyme catalyzed reactions. Ammonia increases the oxygen consumption rate by tissue, damages gills, and reduces the oxygen transport ability of blood. A poisonous buildup in internal tissues and blood, as well as possible mortality occurs when surpass amounts of ammonia are found in water and aquatic creatures are unable to evacuate the poison (Nion et al., 2020). According to Boyd and Tucker, (1992) an ammonia level between 0.5 to 2 mg/l is toxic for fish. The ammonia of the four-station of the Kaptai Lake varied from 0.018 to 0.49 mg/L. The minimal content (0.018 mg/l) of NH_3-N was discovered at Shubholong Jhorna in October and the maximum concentration (0.49 mg/l) was noted at Kandemu. Islam et al. (2021) found ammonia (0.5 mg/l) during pre-monsoon and Ahmed et al. (2001) found NH_3-N content of 0.4 mg/l in the Kaptai Lake which is similar to recent finding. There is a higher amount of organic waste matter that is coming from household activities of dwellers on the adjacent hill. The main source of ammonia may be gaseous exchange with the atmosphere and nitrogen fixation.

5.2 Spatial variation of water quality parameters:

Samplings were conducted in four stations of the Kaptai Lake such as Jolojan Ghaat, Kandemu, Shubholong Jhorna, and Shubholong Bazar. The study sites are closely related except for Jolojan Ghaat. Each station has a long distance from the other station.

So, the water quality parameters especially air temperature, water temperature, dissolve oxygen, pH, Alkalinity, and Hardness of Jolojan Ghaat vary with other stations. In the morning the air temperature is lower than in noon and afternoon that's why the water temperature was also lower in the morning. As water temperature influences the oxygen holding capacity, the concentration of dissolved oxygen was lower during the morning. In September the dissolved oxygen was 5.5 mg/l in Jolojan Ghaat in the morning and 8.3 mg/l in October at Shubholong Bazar in late noon. So, it is said that the variation of water quality parameters in the same reservoir may occur due to the sampling time. But the organic matter percentage is higher in Jolojan Ghaat because of having higher mud content and is adjacent to the urban area.

5.3 Changing trend of water quality parameters in water column:

Sampling was carried out from three water columns (surface, middle, and bottom) of each station of Kaptai Lake. In these three water columns four specific parameters such as water temperature, dissolved oxygen, pH and TDS were determined to investigate the variation of this parameter. Surface water temperature, dissolved oxygen, and pH are higher than the middle and bottom water column. The reservoir's surface water dissolved oxygen concentrations ranges between 4 mg/l and 8.3 mg/l. Maximum concentration of oxygen may be credited because of wind action and other surface agitation enabling highest oxygen from the air to mix into the solution at the surface water. Wide variations in dissolved oxygen (2.43 - 4.80 mg/l) from the surface to the bottom were observed at various depths. Dissolved oxygen levels at the reservoir's bottom varied from 2.43 to 3.80 mg/l. A dissolved oxygen shortage at the lake's bottom was identified by Sreenivasan et al. (1970) as a distinguishing feature of productive lakes. The pH scale had a very narrow range (0.4 -1.22) of fluctuation from surface to bottom. In all months, there was a vertical variation in temperature. Thermal stratification was observed to occur when the temperature differential between the top and bottom was between 0.8 and 4.7 degrees Celsius. Thermal stratification is observed clearly when sampling is done with an interval of 1 meter of waterbody (Vashist, 1968). This cannot be said with certainty because the temperature was noted only at 3 different depths (Surface, middle and bottom). However, during two years study period (covering all depth at 1 and 2 m intervals) at Kaptai lake, ten temporaries epilimnion and one typical thermocline were observed by Azadi, (1996). Thermal stratification in lakes is related to the difference between the surface and bottom temperature and the presence or absence of strong winds (Vashist, 1968). The TDS concentration is higher in the bottom water column than in the surface and middle water column. TDS has a positive correlation (r =0.183, Table -02) with organic matter. As organic matter exists in the sediment that's why the TDS concentration is higher in the bottom water column

5.4 Variation of organic matter with stations

Organic matter sediment from the lake may be regarded the most significant environmental indicator of land use patterns in any lake's higher catchment areas. The highest and lowest organic matter was 6.32 % and 4.09% in Jolojan Ghaat and Shubholong Jhorna, respectively. The presence of organic matter and the amount of mud are closely connected. Sediment with a lower mud content has less organic matter, whereas sediment with a higher mud content has more organic matter (Burone et al., 2003). Due to the higher land use, Jolojan Ghaat and Kandemu have higher mud content than the two other stations. The sediment of Shubholong Jhorna and shubholong Bazar was sandy. According to Waltham et al. (2014) urban runoff is typically a substantial organic material source in lake surface sediment which could lead to increased organic matter and clay levels than in other places. Jolojan Ghaat is adjacent to the urban area and the mud content is higher resulting in the higher organic matter rather than three other stations. Low total nitrogen levels in the soil are indicated by low levels of organic matter, which ultimately translates to unhealthy ecosystems (Mondol et al., 2014). By consuming oxygen and releasing the poisonous gases CO_2, H_2S, and NH_3, OM enhances capacity for cation exchange, which aids in the breakdown of dead algae in the bottoms of pond (Boyd, 1995; Camargo et al., 2005). Hoque et al. (2021) found that in the Kaptai Lake organic matter range from 4.25 - 8.18% which indicates a reservoir with a good soil system for producing fish (Golterman, 2004). The present investigation of soil organic matter indicates a good soil system in all stations.

5.5 Variation of organic matter with depth:

Depleted dissolved oxygen (DO) conditions in deep lakes accelerate the decomposition of organic matter and the cycling of nutrients in the sediment. The depth of the studied area ranges from 26.6 ft to 70.1 ft. According to Hyne, (1978) the deposition of organic carbon and organic matter is positively correlated with water depth in Gibson reservoir where there is minimal river sediment input from the river. The findings of organic carbon and organic matter in the Kaptai Lake disagreed with this statement. The percentage of organic matter is more or less similar in all depths probably irregular shape of the bottom topography of the Kaptai Lake (Halder et al., 1991).

Chapter:06

Conclusion

The current study is preliminary research of monthly fluctuations of physical and chemical features and organic matter of sediment in the Kaptai Lake which will offer valuable knowledge for managing and protecting the lake ecology. The results of this study will help future researchers focus on this issue, change the discrete data for the Kaptai Lake water quality parameter and create a document that is incredibly clear and precise about how the various physicochemical parameters of Kaptai Lake vary and relate to one another. The Kaptai Lake's water quality is still excellent despite absorbing effluent from numerous anthropogenic chemical sources. The physical and chemical parameters of Kaptai Lake such as pH, DO, total alkalinity, total hardness was in favor of aquaculture. Ammonia concentration of one station is concerning. Additionally, the water supply and residential use in Rangamati are under danger due to urban pollution. In this situation, it is crucial to take precautions against contamination in order to protect the lake's existence.

Recommendations

According to this research work, the following recommendations should be done:

1. Sampling should be done more station of Kaptai Lake
2. Sampling frequency should be increased
3. Duration of sampling should be conducted for long period of time
4. Plantation should be done to minimize erosion
5. Urban and domestic waste disposal should be minimized

Chapter: 07

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Appendix

Appendix-01: Water quality parameters in term of water column:

		Depth(ft)	DO (mg/l)	Ph	Alkalinity (mg/l)	Hadness (mg/l)	CO_2 (mg/l)	Ammonia (mg/l)	WT (℃)	AT (℃)	TDS (mg/l)	OM(%)
Surface	Mean	36.32	6.60	7.67	78.50	68.61	4.16	.104	27.95	29.25	47.75	5.50
	Std. Deviation	12.13	0.76	060	7.87	9.05	1.24	.123	0.544	0.564	3.92	.54
	Minimum	24.90	5.5	7.30	62.80	55.70	2.3	.018	21.9	24.10	38.0	4.09
	Maximum	70.00	8.3	9.02	90.10	85.68	6.5	.490	31.6	32.8	55.0	6.32
Middle	Mean		3.95	6.90					24.35		67.87	
	Std. Deviation		.44	.47					.848		6.50	
	Minimum		3.10	5.90					22.40		55.00	
	Maximum		4.80	7.80					25.80		82.00	
	Variance		.196	.232					.720		42.28	
Bottom	Mean		3.26	6.92					24.21		82.750	
	Std. Deviation		.35	.522					1.28		7.58	
	Minimum		2.50	5.90					21.40		70.00	
	Maximum		3.80	7.80					26.60		96.00	
	Variance		.129	.273					1.65		57.50	
Total	Mean	36.32	4.63	7.18	78.50	68.61	4.16	.104	29.12	29.25	66.12	5.50
	Std. Deviation	12.13	1.57	.630	7.87	9.05	1.24	.123	31.62	2.75	15.68	.54
	Minimum	24.90	2.50	5.90	62.80	55.70	2.30	.018	21.40	24.10	38.00	4.09
	Maximum	70.0	7.80	9.02	90.10	85.80	6.80	.490	293.00	33.90	96.00	6.32

Appendix-02: **Kruskal-Wallis Test**

Ranks

	Sampling stations	N	Mean Rank
Organic matter percentages	Jolojan Ghaat	6	21.50
	Kandemu	6	13.17
	Shubholong Jhorna	6	7.50
	Shubholong Bazar	6	7.83
	Total	24	

Test Statistics[a,b]

	Organic matter percentages
Chi-Square	15.400
df	3
Asymp. Sig.	.002

a. Kruskal Wallis Test

b. Grouping Variable: Sampling stations

	Mean	Std. Deviation	N
Organic matter percentages	5.5063	.54714	24
Bottom depth from surface water	36.3213	12.13637	24

Appendix-03: Correlation of organic matter with depth

Correlations

		Organic matter percentages	Bottom depth from surface water
Organic matter percentages	Pearson Correlation	1	.060
	Sig. (2-tailed)		.782
	N	24	24
Bottom depth from surface water	Pearson Correlation	.060	1
	Sig. (2-tailed)	.782	
	N	24	24

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