Original Research Article

Estimation of Water Quality in the Major Nursery Grounds of Hilsa Insights from Plankton and Nutrient Regimes

Abstract

The Physicochemical and biological attributes of a river ecosystem usually reveal the status of the subsistent aquatic life and affiliated species richness index of the biodiversity. Towards appraisal of water quality, physicochemical parameters (i.e., temperature, pH, DO, transparency alkalinity and hardness), water nutrients (nitrate, phosphate) and concentration of Chlorophyll a were determined. Samples were collected from six hilsa sanctuaries. The study revealed a slight spatial variation in physicochemical parameters of river water. While the parameters were found to be at 'acceptable' levels, some measures are needed to improve the quality of water to ensure successful migration and reproduction of the hilsa fish. The water quality parameter (pH) was found slightly alkaline (7.6±0.6). The transparency was found (44.4±10.6 cm) followed by water temperature (25.6±0.8 ºC), alkalinity (112.4 ±26.4 mg/L), hardness (304.5±69.5 mg/L), CO_2 (10.3±1.2 mg/L), DO (7.7±1.1 mg/L), nitrate (0.005±0.01 mg/L), phosphate (0.002±0.0004 mg/L). Chlorophyll a, which represents the biomass of phytoplankton, was estimated (8.21 ± 2.3 µg/L).The largest quantity of plankton as a natural food (both in number and texa) was found in the Meghna river basin as station 1 and Station 4 and compared to the other stations. The present biological investigation stated the spatial variation of physicochemical parameters and their influences on plankton community of six sanctuary areas with an exploration statistical data output. This assessment of the physical, chemical and biological profile of the environment of the sanctuary areas of the country delivers obvious evidence which is important to the apprising of the hilsa fisheries management action plan and to the sustainable management of hilsa fishery to a greater extent.

Key words: Water quality, nutrients, nursery grounds, Diversity index, *Tenualosa ilisha*.

Introduction

Water is essential to life as an adequate, safe and accessible supply is certainly available to everyone. Water is undoubtedly the most precious natural resource that exists on the planet. Water is absolutely essential not only for survival of human beings, but also for animals, plants and all other living things (Razo *et al.*, 2004). Water is also crucial for the quality of life. The oceans, the rivers, lakes and creeks together with the land constitute the canvas on which life grows and interacts. The ecological balance maintained by the quantity and quality of water determines the way of life of a people. It is required essentially for the survival and health of living organisms and also for any developmental activity (Kumar *et al.*,2011; Suresh *et al.*, 2013). Water quality of the freshwater habitats provides substantial information about the

existing resources which depend on the influences of physicochemical parameter and biological features (Sivakumar and Karuppasamy, 2008). The physical and chemical properties of freshwater body are characterized by the climatic, geochemical, geomorphologic and pollution conditions (Ishaq and Khan, 2013). On the other hand, polluted water is the greatest source of disease and besides debasing the land also becomes unfit to sustain life. Today the problem is not only of water availability but of environmental quality and ecological balance. With increasing industrialization, urbanization and technological advance in all fields, sources of water are getting more and more seriously polluted.

The term "water quality" is used here to express the suitability of water to sustain various uses or processes and in its broader sense includes all the physical, chemical and biological factors of water (Ahmed *et al.*, 2000), and it may directly or indirectly affect the distribution and production of fish and other aquatic animals (Varshney *et al.*, 2004). These include water temperature, salinity, turbidity, dissolved oxygen, and the pH of water that triggers the estuarine fish ecology (Whitefield 1999; Blaber 2000). Water quality can be assessed by its physical, chemical and biological properties (Manjare *et al.*, 2010). This water delivers multiple uses for innumerable rural and urban communities and livestock, fish culture, recharge of ground water, control of floods etc. (Gurunathan and Shanmugam, 2006). The quality of water is being degraded continuously due to haphazard industrialization (Manjare *et al.*, 2010). Principally, the term industrialization is related with socio-economic activities (Thanoon *et al.*, 2003, Richard 2005 and Jaillon and Poon, 2009) that are basically responsible for the modification of the society setup (Abdullah *et al.*, 2009) through the enormous production (Thanoon *et al.*, 2003 and Abdullah *et al.*, 2009). Various kinds of pollutants and nutrients flowing through the agency sewage, industrial effluents, agricultural runoff etc. into the water bodies bring about a series of changes in the physicochemical characteristics of water, which have been the subject of several investigations (Maheshwari *et al.*, 2011).

In this study, existing water quality parameters were emphasized for aquatic organisms including fishes in the Meghna River, Tetulia River and Andharmanik River. The observed water quality parameters were compared with relevant standard to perceive the present physicochemical status and alteration of nutrient fluxes of three different rivers. The present study was intended to reveal the physicochemical and hydrobiological characteristics including nutrients influxes to determine Chlorophyll a content of the river. The fundamental purpose of this study was the assessment of subsistent water quality parameters and transformation of nutrient fluxes to report the baseline data of the proposed area that will provide an eulogistic?? opportunity to perform the future study in a broad perspectives.

Materials and Methods

Study areas and duration

The study was carried out for one year between June 2021 to 2022 at six different stations in the major nursery grounds of hilsa. Data was collected from three locations of each nursery ground

(Table 1). These nursery grounds were located Shatnol, Chandpur-Alexander, Laxmipur 100 km considered as station 1, Tarabunia, Shariotpur 20 km, Lower Padma considered as station 2, Hizla, Mehindigonj, Barishal (82 km) considered as station 3, Bheduria, Bhola, Char Rustom, Potuakhali (100 km, Tetulia River considered as station 4, Char Ilisha-Char Pial, Bhola (90 km), Shahbazpur Channel considered as station 5, and Kalapara Upazilla, Potuakhali (40km) considered as station 6 were collected and analyzed. (Fig.1).

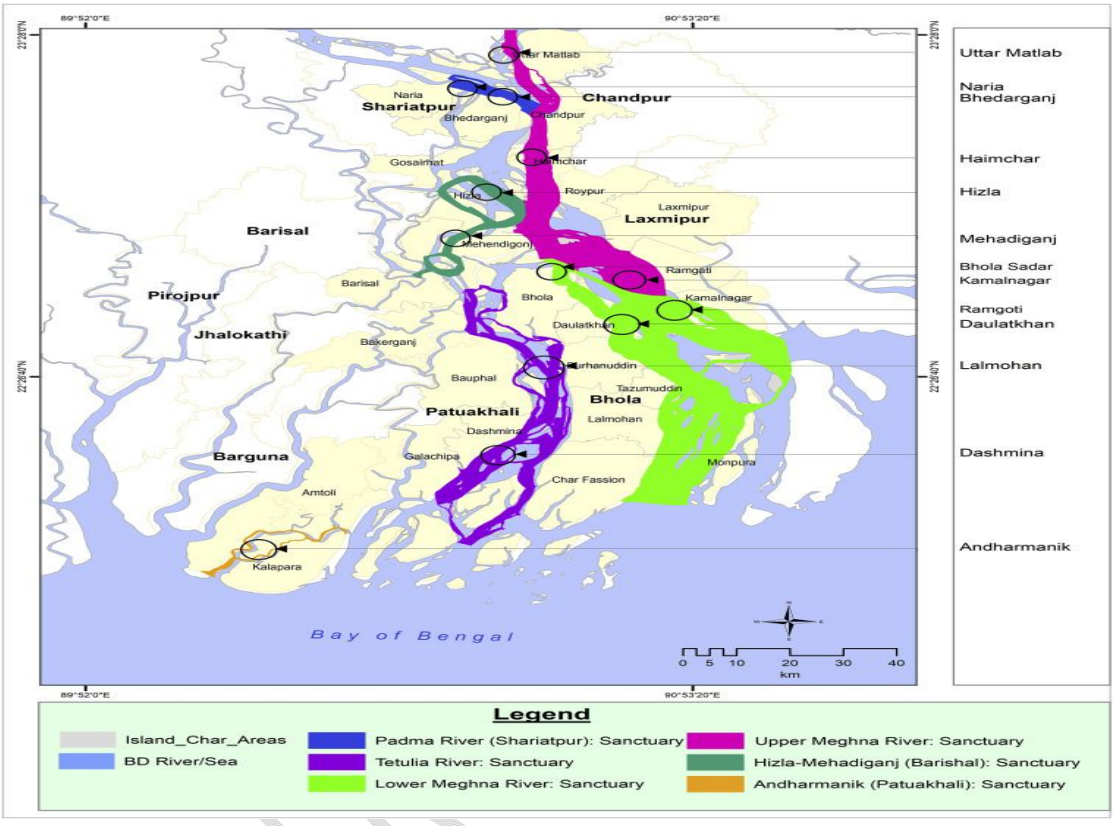


Figure. 1. Map of the study area and the location of different sampling stations

Table 1. The six nursery grounds with eighteen treatment areas

Sl No.	Sanctuary Area	Area Length (Km)	Treatments
1.	Shatnol, Chandpur-Alexander, Laxmipur (S1)	100	Shatnol, Confluence (Padma & Meghna) and Chor Alexandar
2.	Tarabunia, Shariotpur (S2)	20	Tarabunia, Sureswar and Bashgari
3.	Hizla, Mehendigonj, Barisal (S3)	82	Bhasanchor , Hizla and Mollikpur
4.	Bheduria, Bhola- Char Rustom,	100	Bheduria, Kalaiya and Chor

	Patuakhali (S4)		Rustam
5.	Char Ilisha-Char Pial, Bhola (S5)	90	Elisha, Daulatkhan and Monpura
6.	Kalapara Upazila, Patuakhali (S6)	40	Bailatoli , Khepupara and Mohipur

Physical and hydrological assessment.

Physical water quality parameters, namely: air and water temperature, water transparency, turbidity of different sampling sites, were monitored each month. Temperature was measured with Celsius thermometer. Water transparency was measured in situ using Secchi disc (30 cm in diameter). Water turbidity was measured using 2020i portable turbidity meter.

Chemical and hydrological assessment

The chemical parameters of water such as pH, DO were measured on the spot using digital multi-parameter. HACH test kit (Model-FF-2, USA) and HANNA instruments (Model HI 9829) both were used to measure alkalinity, hardness and DO. The value of Hydrogen-ion-Concentration (pH) of water was determined by using Hanna pH meter. Measurement of nitrate and phosphate was carried out in the laboratory by were determined following APHA. Chlorophyll a content of water was estimated following UV spectrophotometric method. As a part of the biological parameters, plankton (food organisms in the form of phytoplankton and zooplankton) in the river water was studied qualitatively and quantitatively. Identification of plankton up to genera level was performed following Bellinger and Sigiee (2015) under a compound microscope (Inverted binocular Microscope, Model: XDS-2). The phytoplankton genus that was found in each three replicates of the station was denoted as very common (high), two replicates denoted as common (medium) and one replicates denoted as rare (low) abundance. Enumeration of the density of phytoplankton was done using an S-R cell and the abundance was expressed as cells L-1. 1 ml sample was put in the S-R cell and left 5 min to allow plankton to settle down and the cells in 20 randomly selected fields were counted. Plankton density was calculated using the formula (Pitchaikani and Lipton 2016): $N= (P\times C\times 1000)/L$

Shannon–Weiner diversity index (H') (Shannon and Weiner, 1949), Simpson's dominance index (D) (Simpson, 1949), Margalef richness index (d) Margalef's diversity index *(Margalef 1958) and Pielou's evenness index (J') (Pielou 1977) were calculated according to following equations:*

$H' = -\sum [Pi \times \log (Pi)]$

$D=\sum (pi)^2$

$d= (S-1)/\log N$

$J'=H'/Log (S)$

where ‘Pi’ is the proportion of the individuals belonging to the ‘i’th genus, Simpson’s index of diversity=1/D, N=total number of individuals, and S=total number of the genus.

Data Analysis

After collection, all data were checked for homogeneity and equal variance. Thereafter, data were analyzed by using MS Excel (version 2016), Past software (version 4.0), to find out the seasonal variation and associated relationship among each other.

Results and Discussion

Physicochemical parameters

Analyses of various physicochemical factors and nutrients influxes from different rivers (sampling stations) are presented in Table 2 and combined graphical representations of the water quality parameter are shown in Fig.5, and Fig. 6.

Temperature

Water temperature is a vital factor of the environment which triggers physiological activities of aquatic organisms. Water temperature ranged among 23°C to 27°C whereas the air temperature ranged among 23°C to 30°C. The maximum and minimum air temperature were found with mean value 29.4±1.3ºC and 26± 0.7ºC at (St-3) and (St-4) respectively (Table 2) while the maximum and minimum water temperature were found mean value 26.8±0.5ºC and 24.9± 0.8ºC at (St-3) and (St-4) respectively (Table 1). The higher water temperature could be influenced by the high air temperature of the following day. The water temperature varied along with the changes in air temperature (Fig. 2).The high positive correlation between air and water temperature in streams increasing with distance has been observed by other workers as well (Zappa *et al.*, 2000; Smith *et al.*, 2001; Uehlinger *et al.*, 2003). Similar findings were reported by Ahmed *et al.*,(2005), who recorded that water temperature of the Meghna River at surface level ranged between 24.1 and 30.5°C with a mean of 27.6 ±0.68°C. Bhaumik *et al.*, 2011 studied values of physicochemical parameters for hilsa migration, breeding, rearing and estimated that the ideal water temperature ranged from 29.3-30.2°C for breeding activities and 29.8-30.8°C for the nursery activities of hilsa in the Hooghly-Bhagirathi river system. In the past, Pillay (1958) also estimated suitable water temperature ranged from 23-27°C and that temperatures of <20°C, >30°C were not suitable for juvenile hilsa, whereas, Jafri (1988) reported the most suitable (20–25°C), moderately suitable (15–20°C; 25–30°C) and least suitable (<15°C, >30°C) water temperature for hilsa spawning. On the other hand, (ECR 1997) stated that the standard value of water temperature in the river is 20°C–30°C which shows similarity with the present findings and water temperature was found more or less within acceptable ranges for hilsa spawning and nursing. Generally, with increasing water temperature, the solubility of oxygen is reduced causing deoxygenating (Swingle, 1967) which is also evident from negative correlation between water temperature and dissolved oxygen.

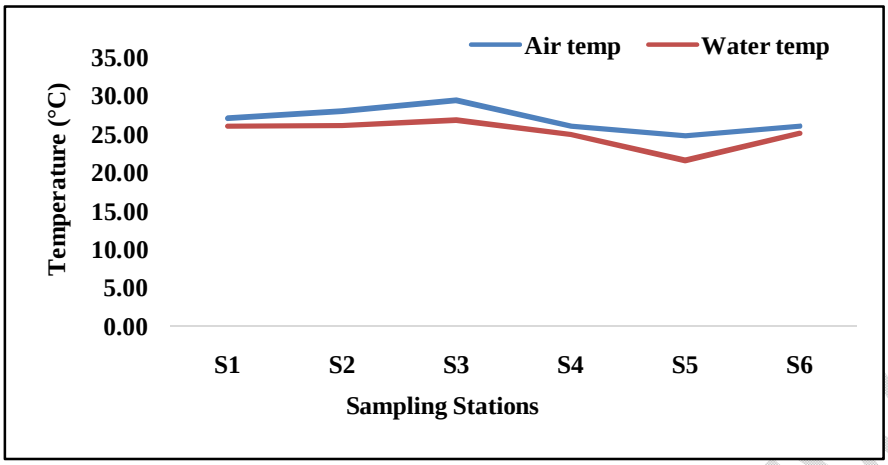


Fig.2. Variations of air and water temperature at sampling stations.

Transparency

The water transparency of six stations were found between 25 to 62 cm. Comparing all the values of transparency, the maximum and minimum were found 58.38±8.2 cm and 32±8.3 cm at St-1 and St-6 respectively (Table 2). Water transparency varied along with the changes of Chlorophyll a (Fig.3), which supports the findings of Ahmed (1993) who stated that Chlorophyll a showed an inverse relationship with water transparency. Transparency or light penetration of water depends on the intensity of sunlight, suspended solid particles, turbid water received from catchment area and density of planktons (De, 2007). Water transparency between 20 to 40 cm is acceptable for fish culture and indicates optimal plankton production. Other study depicts that the transparency of the fresh water is ranging from 35 to 45 cm is suitable for aquatic environment (Saifullah *et al.*, 2016). More or less similar results were found from the Meghna River system by Ahmed *et al.*, (2005) and they stated that the transparency (Secchi disc visibility) ranged from 12 to 90 cm with a mean of 34.2 ± 18.08 cm at different stations.

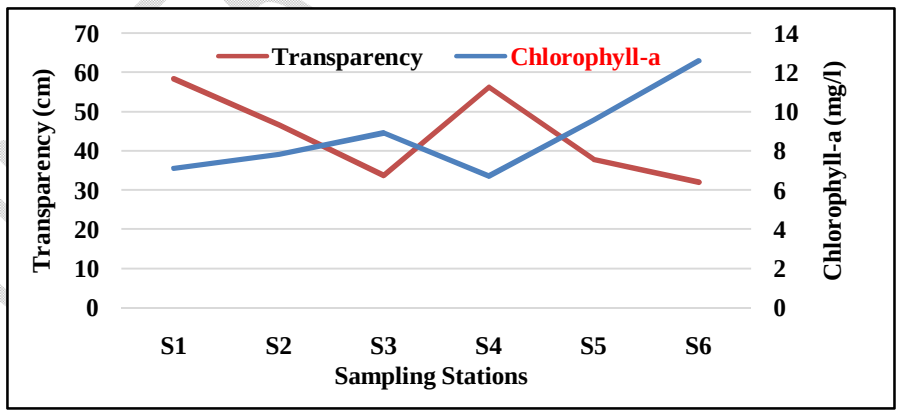


Fig.3. Variations of transparency and Chlorophyll a at sampling stations.

Turbidity

The water turbidity of Seven stations of these rivers were found between 11 to 35 fnu. Comparing all the values of turbidity, the maximum and minimum were found 34.4 ± 3.7fnu and 13 ± 2.6 fnu at St-2 and St-1 respectively (Table 2). Water turbidity varied along with the

changes of transparency and showed a positive relationship with Chlorophyll a supports the findings of Ahmed (1993) (Figures 4).

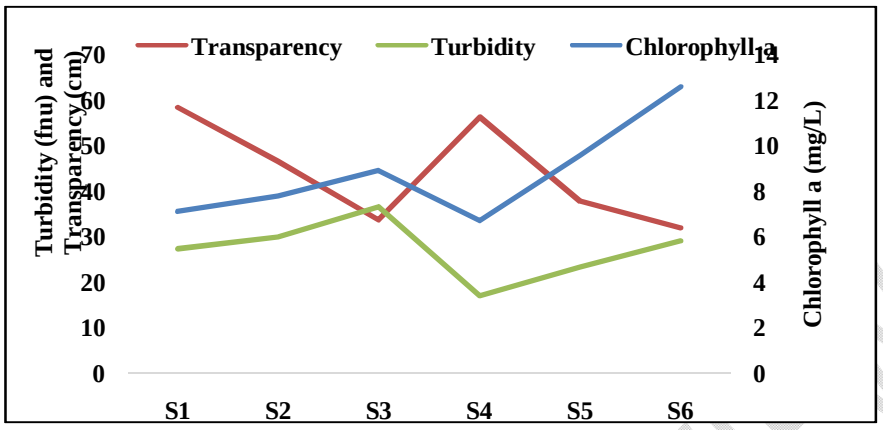


Figure 4. Variations of turbidity, transparency, and Chlorophyll a at selected sampling stations

Dissolved oxygen (DO)

Dissolved oxygen found river water in substantial amounts. The incidence of these DO is influenced by partial pressure, temperature, salinity, respiration and photosynthesis (Allan, 1995; Wetzel and Likens, 2000; Effendi, 2003; Huq and Alam, 2005). DO concentration is a major factor that triggers species distribution in bodies of natural water. DO generally promote the survival of fish, especially juvenile and fry. Maes *et al.*,(2004) mentioned dissolved oxygen as one of the most important factors for fish abundance and distribution. Dissolved oxygen (DO) in the study area ranged from 6.1 to 8.6 mg/L with the highest (7.64±1.1 mg/L) at St-6 and the lowest (6.19±0.6 mg/L) at St-1 (Table 2). According to Bhatnagar and Singh (2010) and Bhatnagar *et al.*,(2004), DO level >5ppm is essential to support good fish production. Bhatnagar and Garg, (2000) mentioned that oxygen depletion in water leads to poor feeding of fish, starvation, reduced growth and more fish mortality, either directly or indirectly. This indicates that the range of DO found in the present study is suitable for the fish especially the juvenile hilsa. Higher DO values indicate higher productivity which might play an important role for the migration of hilsa. The result was more or less similar to the findings reported by Ahmed *et al.*, (2005) and they recorded the mean value of DO as 6.7±0.81 mg/L in the Meghna River. Dissolved Oxygen in the study area not lesser than the prescribed value (Table 2) which result the growth and reproduction of fishes in these rivers. Almost the same result was reported by Ahammad (2004) and stated that DO concentration in the Meghna River estuary range from 4.6 and 5.8 mg/L)where different results from the present findings reported by (Hossain *et al.*,2012) and they stated that the values ranged from 3.63 - 6.83 mg/L. In the case of DO concentrations, no significant difference was found between the sites.

Carbon dioxide

Free carbon dioxide is an important parameter of the buffer system and impacts the concentration of carbonates, bicarbonates, pH and total hardness in water. Carbon dioxide concentration is influenced by groundwater inflows substantially enriched with carbon dioxide

(Allan and Castillo, 2007; Wetzel and Likens, 2000). Small and Sutton, 1986; Rebsdorf *et al.*, 1991 stated that CO_2 generated by microbial respiration. CO_2 in the study area ranged from 7.1 to 15 mg/L with the highest (13.9±1.3 mg/L) at St-6 and the lowest (8.15±1.1 mg/L) at St-1 (Table 2).The result was similar to the findings reported by Mulholland (2003) stated that groundwater influxes substantially enriched by CO_2 due to soil respiration. The present findings also more similar to the findings reported Allan and Castillo (2007).

pH

The observed pH values of seven six stations in these rivers were within the range of 6.2 to 9.3. The highest pH (8.09±0.4) was found at St-4 and the lowest pH (7.49±0.8) was found at St-1 (Table 1).pH of water is the most important factor for species distribution. Air temperature is the prime responsible factor for changing the pH of water. Roy (1955), Moore (1972), APHA (2005), Mahmood and Bhuyian (1988), Sarma *et al.*,(1982) and Campbell (1978) stated that the industrial or municipal waste materials had a significant role in increasing or decreasing pH of the adjacent water body where the waste materials were dumped. The value of pH is greatly influenced by the presence of carbon-dioxide, carbonates, bicarbonates and acid rain. Huq and Alam, (2005) mentioned that excessive pH is harmful for aquatic life like fish, plants and microorganisms. Das (1997) and ECR (1997) stated that most of the water bodies have pH within the range of 6.5 to 8.5 which denotes that the water pH of our studied area is within the limit. The studied results were similar to the findings of Boyd (1979) stated that water with a pH of less than 6.5 or more than 9–9.5 for a long period is harmful to the reproduction and growth of fish. Ahmed *et al.,* (2005) were found to be neutral to alkaline pH (7.0-8.0) in the Meghna River. Bhaumik and Sharma (2012) stated that the permissible range of pH was between 6.4 and 8.5. The value is similar to the present findings, which is why we can say that there were acceptable ranges of the pH of water for the fish.

Table 2. Physicochemical parameters of water quality in the six stations.

Parameters	Sampling station	Mean ± SD	Standard value
Air Temperature (ºC)	(st-1)	27±0.57	20-30 (EQS, 1997)
	(st-2)	27.9±1.1	
	(st-3)	29.4±1.3	
	(st-4)	26±0.7	
	(st-5)	27.33±0.9	
	(st-6)	26±1.1	
Water Temperature (ºC)	(st-1)	25.99±1.1	20-30 (EQS, 1997)
	(st-2)	26.06±0.7	
	(st-3)	26.8±0.5	
	(st-4)	24.9±0.8	
	(st-5)	25.55±0.5	
	(st-6)	25.1±1.2	
DO (mg/L)	(st-1)	6.19±0.6	5 (EQS, 1997)
	(st-2)	7.07±1.1	

	(st-3)	6.59±0.9	
	(st-4)	6.88±0.8	
	(st-5)	7.48±0.6	
	(st-6)	7.64±1.1	
Transparency (cm)	(st-1)	58.38±8.2	35-45 (Hossain *et al.*, 2011)
	(st-2)	46.5±7.1	
	(st-3)	33.7±12.5	
	(st-4)	56.25±14.1	
	(st-5)	37.33±13.2	
	(st-6)	32±8.3	
Turbidity(fnu)	(st-1)	27.26±11.2	
	(st-2)	29.91±13.2	
	(st-3)	24.53±7.4	
	(st-4)	17±7.3	
	(st-5)	23.33±8.2	
	(st-6)	29±9.3	
Hardness (mg/L)	(st-1)	64.86±17.2	200-500 (DOE, 2003)
	(st-2)	88.56±15.4	
	(st-3)	76.6±15.7	
	(st-4)	296±69	
	(st-5)	314±76	
	(st-6)	987±221	
pH	(st-1)	7.49±0.8	6.5-8.5 (Das,1997)
	(st-2)	7.82±0.7	
	(st-3)	7.85±0.5	
	(st-4)	8.09±0.4	
	(st-5)	7.72±0.3	
	(st-6)	7.21±0.8	
Alkalinity (mg/L)	(st-1)	81.07±17	20-200 (Ishaq and Khan, 2013)
	(st-2)	87.19±21.4	
	(st-3)	118±18.3	
	(st-4)	132.25±21.9	
	(st-5)	113.33±32.4	
	(st-6)	143±38.3	
CO_2(mg/L)	(st-1)	8.15±1.1	6 ppm (EQS,1997)
	(st-2)	9.89±1.3	
	(st-3)	11±1.6	
	(st-4)	9.25±1.2	
	(st-5)	9.67±1.1	
	(st-6)	13.9±1.3	
NO_3 (µg/L)	(st-1)	0.0044± 0.0012	0.1 (De, 2007)
	(st-2)	0.0038± 0.0056	
	(st-3)	0.0049± 0.0045	

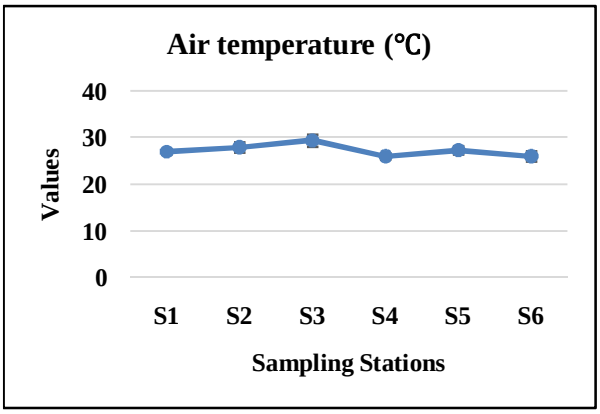
	(st-4) (st-5) (st-6)	0.0051± 0.0037 0.0043± 0.0028 0.0033± 0.001	
PO_4 (µg/L)	(st-1) (st-2) (st-3) (st-4) (st-5) (st-6)	0.0020± 0.0024 0.0016± 0.0002 0.0014± 0.0003 0.0018± 0.0031 0.0019± 0.0002 0.0013± 0.0006	0.1 (De, 2007)
Chlorophyll a (µg/L)	(st-1) (st-2) (st-3) (st-4) (st-5) (st-6)	7.1±3.1 7.8±1.8 8.9±1.9 6.7±1.5 9.56±1.3 12.6±1.2	0.24-3.00 mg/L (Rahaman *et al.*, 2013)

Alkalinity

The quantity of base present in water defines is known as total alkalinity. Measurement of alkalinity in a water body is very important. Hem, (1985); Ishaq and Khan, (2013) mentioned that alkalinity (20–200 mg/L) is common in most of the freshwater ecosystems including ponds, lakes, streams and rivers. The observed alkalinity values of six sampling stations were within the range of 68 to 191. The highest alkalinity (143±38.3 mg/L) was found at St-6 and the lowest was (81.07±17mg/L) was found at St-1 (Table 2). The studied results was similar to the findings Moyle (1946) described the total alkalinity of medium and highly productive water as ranging from 40.0 to 90.0 ppm and above 90.0 ppm, whereas Boyd and Lichtkoppler (1979) suggested that water with total alkalinities of 20 to 150 mg/L contain the right quantities of carbon dioxide to permit plankton production, and Bhuiyan (1970) stated that the total alkalinity of medium productive water ranged from 25 to 100 mg/I. Alkaline nature of water was also reported in Greater Zab River, Iraq (Ali, 2010). This indicates that the range of alkalinity found in the present study is acceptable for planktonic organisms and fish.

Hardness

Water hardness is generally the amount of dissolved calcium and magnesium in water. In the present study, hardness ranged between 61 and 1052 mg/L, with maximum concentration of hardness was found (987±221 mg/L) at St-6 and lowest was (64.86±17.2) was found at St-1(Table 2). According to the DoE (DoE, 2003) standard, the permissible limit of hardness of drinking water is 200 to 500 mg/L. According to Huq and Alam (2005), the optimum hardness for aquatic organism is 123 mg/L.Joshi et al. (2009) recorded higher hardness during monsoon season (120.62 mg/L) at Meghan River which is similar to this study.


Air temperature (℃)
Values
40
30
20
10
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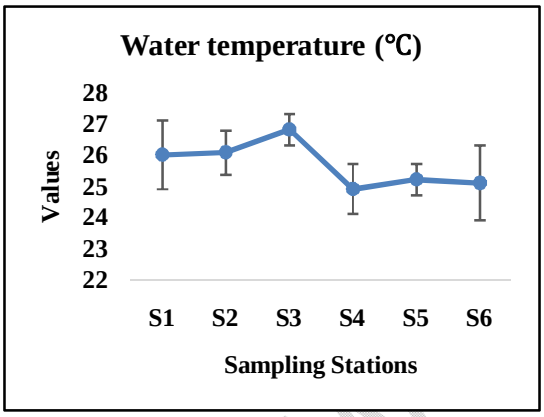
S1
S2
S3
S4
S5
S6
Sampling Stations


Water temperature (℃)
Values
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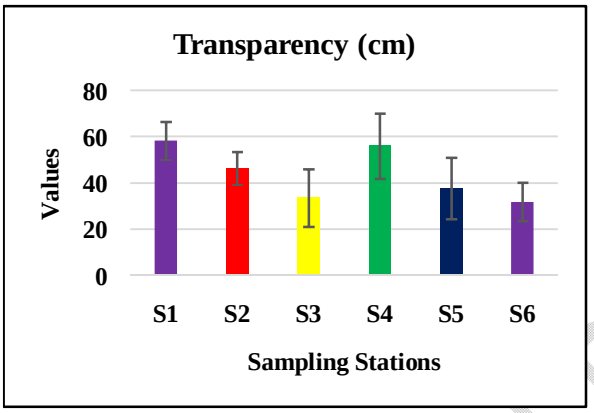
25
24
23
22
S1
S2
S3
S4
S5
S6
Sampling Stations


Transparency (cm)
Values
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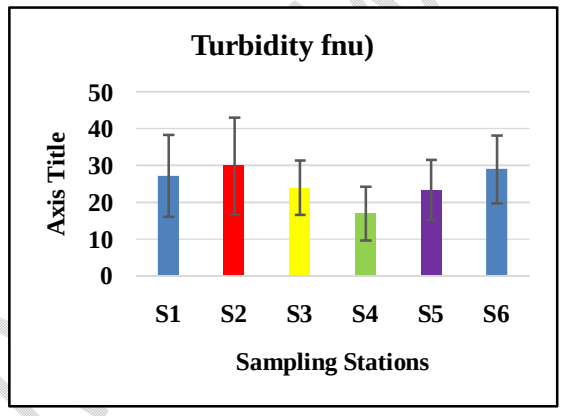
60
40
20
0
S1
S2
S3
S4
S5
S6
Sampling Stations


Turbidity fnu)
Axis Title
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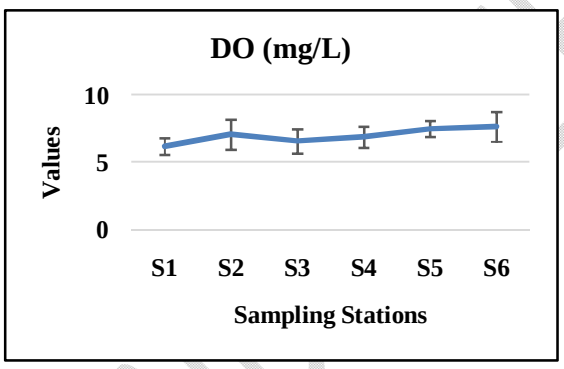
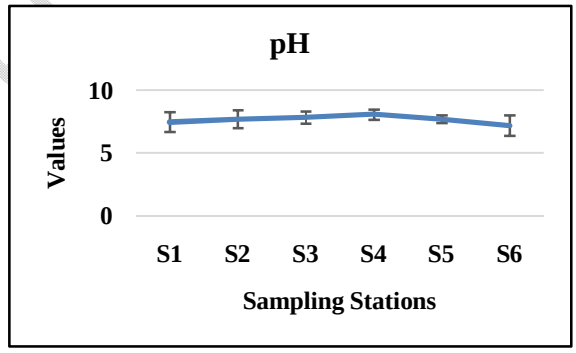
40
30
20
10
0
S1
S2
S3
S4
S5
S6
Sampling Stations


DO (mg/L)
Values
10
5
0
S1
S2
S3
S4
S5
S6
Sampling Stations


pH
Values
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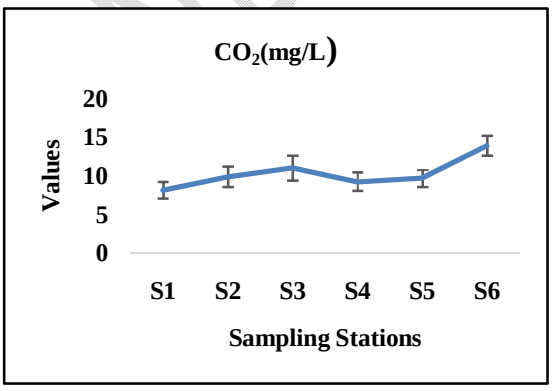
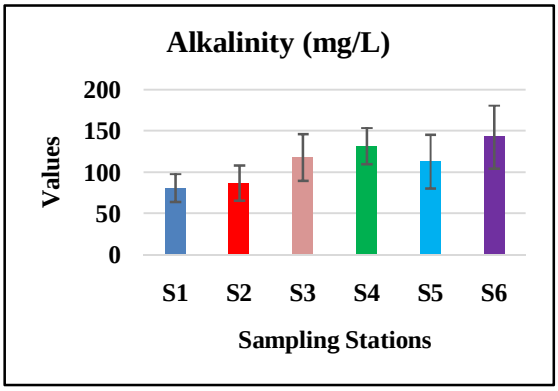
0
S1
S2
S3
S4
S5
S6
Sampling Stations


CO2(mg/L)
Values
20
15
10
5
0
S1
S2
S3
S4
S5
S6
Sampling Stations


Alkalinity (mg/L)
Values
200
150
100
50
0
S1
S2
S3
S4
S5
S6
Sampling Stations

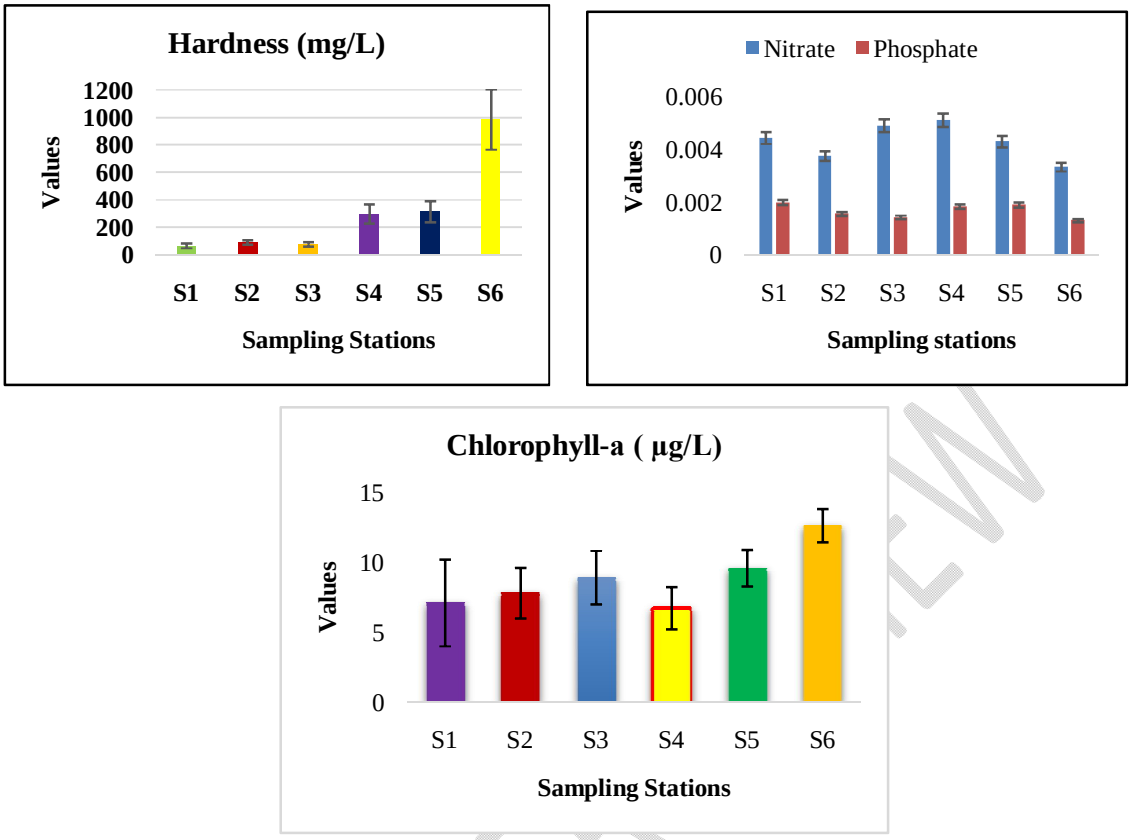


Figure 5.Variations of physicochemical parameters of water quality at six sampling stations.

Water nutrients

Nitrate is important parameters of the water quality which trigger biological production in water bodies. Nitrate concentrations were found within the range 0.002 to 0.016 µg/L. The highest concentration (0.0051± 0.0037µg/L) was found at St-4 and the lowest (0.0033± 0.001µg/L) was found at St-6 (Table 2).According to Bhatnagar *et al.*,(2004), concentration of nitrate 0.02-1.0 ppm is lethal to many fish species, > 1.0 ppm is lethal for many warm water fishes and < 0.02 ppm is acceptable (OATA, 2008) whereas Santhosh and Singh (2007) recommended that nitrite concentration in water should not exceed 0.5 mg/l. More or less similar findings were observed by Ahmed et al (2005) who reported that ammonia concentration was found to be elevated and ranged from 0.1 to 0.6 mg/L, and showed a gradual decreasing trend from the upward to the downward stretches in the Meghna River systems. Thus, the nitrate concentration in the present study was within the acceptable limit. The higher amount of contamination from fertilizers, municipal wastewaters, feedlots, septic systems in water increase the concentration of nitrate, it refers that the higher (NO_2 and NO_3) the deviation the lower the quality of water for fish and other aquatic life and for common uses. The amount of nitrate could also be influenced by the growth of plankton (Qureshimatva *et al.*, 2015).

Phosphate is a liming factor in almost all water bodies because in water, it remains in a very small amount, in most cases less than 0.1 ppm. Almost all of the phosphorus present in water is in the form of phosphate (PO_4) and in surface water mainly present as bound to living or dead

particulate matter and in the soil is found as insoluble $Ca_3(PO_4)_2$. Phosphate concentration were found 0.001 to 0.008 µg/L where the highest concentration (0.0020± 0.0026/l) was found in St-4 and the lowest (0.0013± 0.0005µg/L) in St-6 (Table 2) while the standard value of phosphate in water is 0.1 ppm (De, 2007). According to Stone and Thomforde (2004), the phosphate level of 0.06 mg/l is desirable for fish culture. Bhatnagar *et al.*,(2004), suggested 0.05-0.07 ppm is optimum and productive; 1.0 ppm is good for plankton and shrimp production.

The concentration of Chlorophyll a can act as an indicator of phytoplankton abundance in an aquatic ecosystem. One of the major objectives in analyzing photosynthetic pigments (Chlorophyll a) in limnology is the estimation of phytoplankton biomass and its photosynthetic capacity. It is also reported in other research that Chlorophyll a concentration remains high during low-water discharges (Devercelli and Peruchet, 2008). Chlorophyll a concentrations ranged from 6.2 to 18 µg/L where the highest concentration (12.6±1.2 µg/L) was found in St-6 and the lowest (7.1±3.1µg/L) in St-1. Chlorophyll a value is an indicator of productivity in the water body, which shows an inverse relationship with water transparency (Ahmed,1993) (Table 2). In exploiting the fact that algae, like all plants, contain the pigment Chlorophyll a, one can measure its concentration in a water sample then calculate algal biomass using an average factor for the Chlorophyll a concentration per cell: approximately 1 to 2% of dry weight in planktonic algae (APHA, 1995).

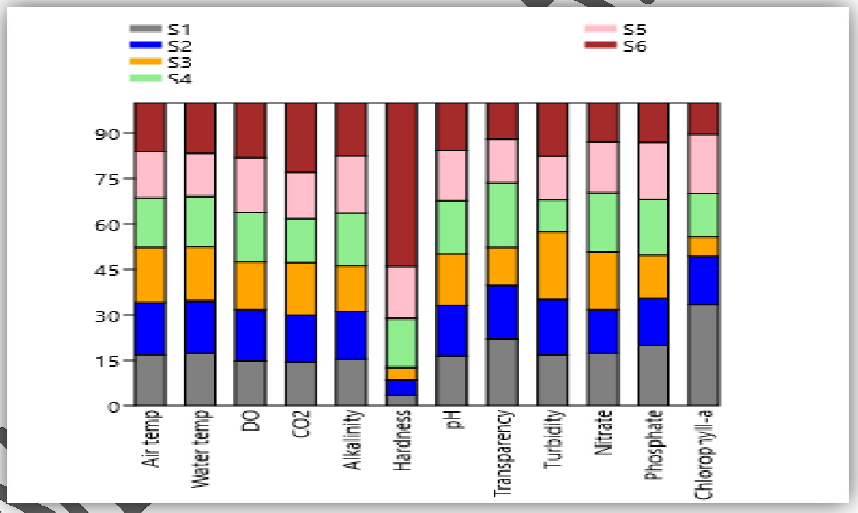


Figure 6. Stacked chart of different water quality parameters at six sampling stations.

Plankton population in six stations.

Twelve groups (families) of phytoplankton, namely *Bacillariophyceae, Ulvophyceae, Zygnematophyceae, Bacillariophyceae, Dinophyceae, Fragillariophyceae, Gonatozygeceze, Cyanophyceae, Hydrodictyaceae, Stephanodiscaceae, Trebouxiophyceae, Melosiraceae* and *Euglenoida* comprising 26 genera and zooplankton *Branchiopoda, Hexanauplia, Heterotrichea, Diaptomidae, Eurotatoria, Cryptophyceae, Rotifera, Copepod, Crustacea, Monogononta, Bdelloida,* having 14 genera were identified at all sampling stations (Table 3 and Fig. 7 & 8). *Zygnematophyceae* was the dominant group and Diatoma was the dominant genus among the

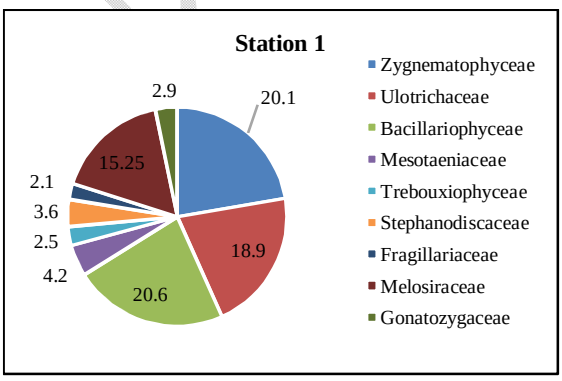
phytoplankton, however Diaptomidae was the dominant group and Diaptomus was the dominant genus in zooplankton in six sites. In station 1, 13 taxa were identified in which 9 were phytoplankton and 4 were zooplankton. Phytoplankton belonged to the dominant groups *Zygnematophyceae* in all the sites in station 1 But in case of zooplankton the dominant groups was Nymphalidae. In station 2, 15 taxa were identified among which 9 were phytoplankton and 6 were zooplankton. Phytoplankton belonged to the dominant groups *Zygnematophyceae* but in case of zooplankton the dominant groups was *Hexanauplia*. In station 3, 12 taxa were identified among which 7 were phytoplankton and 5 were zooplankton. Phytoplankton belonged to the dominant groups *Cholorophyceae* but in case of zooplankton the dominant groups was *Branchiopoda*. In station 4, 9 taxa were identified among which 6 were phytoplankton and 3 were zooplankton. Phytoplankton belonged to the dominant groups *Chlorophyceae* but in case of zooplankton the dominant groups was *Branchiopoda*. In station 5, 15 taxa were identified among which 9 were phytoplankton and 6 were zooplankton. Phytoplankton belonged to the dominant groups *Zygnematophyceae, Bacillariophyceae* and *Chlorophyceae* but in case of zooplankton the dominant groups were *Branchiopoda* and *Monogota.* In station 6, 13 taxa were identified among which 8 were phytoplankton and 4 were zooplankton. Phytoplankton belonged to the dominant groups *Zygnematophyceae, Bacillariophyceae* and *Chlorophyceae* but in case of zooplankton the dominant groups were *Monogononta* and *Branchiopoda*.The study was slightly similar to the study of Ahsan*et al.*,(2012) reported the occurrence of 58 taxa of which 19 were of phytoplankton and 39 were of zooplankton (Table 3). A relatively lower abundance of plankton including 41 genera of phytoplankton and 13 genera of zooplankton were recorded (Ahmed *et al.*,2005). Similar results were found by other researchers (Ahmed *et al.*,2003; 2005 and Ahsanet *al.*,2012). The dominance of Bacillariophyceae (Diatoms) in the present study agrees with the reports of Onyema (2008), Esenowo and Ugwumba (2010) as diatoms are the most obvious representatives of the phytoplankton in rivers, seas, and lakes. Onyema et al. (2003) reported the presence of some phytoplankton species such as Navicula spp., Nitzchiz spp., Anabana spp., and Synedra spp. as good indicators of organic pollution in any aquatic ecosystem.

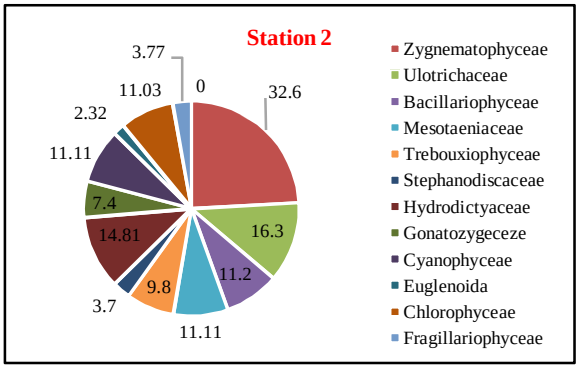
The density of plankton was found to be maximum (46×10^2cells L-1) at S5 and while minimum (24×10^2cells L-1) at S6during the investigation (Table 4). In the Ganga Meghna river system, phytoplankton formed 90 per cent of the total plankton abundance (Ahsan *et al.*, 2012). Shafi *et al.*,(1978) reported a higher percentage of phytoplankton (76.0–93.6 per cent) from the Meghna River, whereas Ahmed *et al.*,(2005) reported that the plankton biomass was relatively lower in

the Meghna River comprising 96.74 per cent phytoplankton and 3.26 per cent zooplankton of the total planktonic organisms, which is similar to the present findings.

Table 3. Plankton observed in seven stations.

Phytoplankton (Class)	**Genus**
Chlorophyceae	*Eudorina, Crucigenia, Chlamydomonas, Ceratium, Closterium, Gonatozygon, Microspora, Genecularia, Pleodarina, Spirogyra, Scenedesmus, Mougeotia, Volvox, Zygenema, Pediastrum.*
Ulvophyceae	*Ulothrix,Protoccocus*
Zygnematophyceae	*Spirogyra,Nitzschia,Netrium,Staurastrum(end),Gonatozygon*
Bacillariophyceae	*Navicula,Gomphonema,Asterionella,Diatoma,Frustulia, Stephanodiscus, Synedra, Amphora, Tabellaria, Coscinodesmus, Cyclotella, Fragilaria, Melosira, Navicula, Nitzchia, Polycistis, Stphanodesmus*
Fragillariophyceae	*Tabellaria,Synedra*
Cyanophyceae	*Spirulina,Rivularia,Oscillatoria*
Trebouxiophyceae	*Protococcus,Botryococcus*
Dinophyceae	*Ceratium*
Myxophyceae	*Tetrapedia, Oedogonium, Coelosphaerium, Aphanocapsa,Merismopedia*
Euglenoida	*Euglena*
Zootoplankton (Class)	**Genus**
Branchiopoda	*Daphnia,Ceriodaphnia,Sida,Bosmina,Diaphanosoma,Leptodora, Eubranchipus*
Hexanauplia	*Cyclops*
Heterotrichea	*Spirostomum*
Diaptomidae	*Diaptomus*
Monogononta	*Filinia,Brachionus*
Bdelloida	*Nauplius,Rotaria*
Rotifers	*Trichocera, Brachionus*





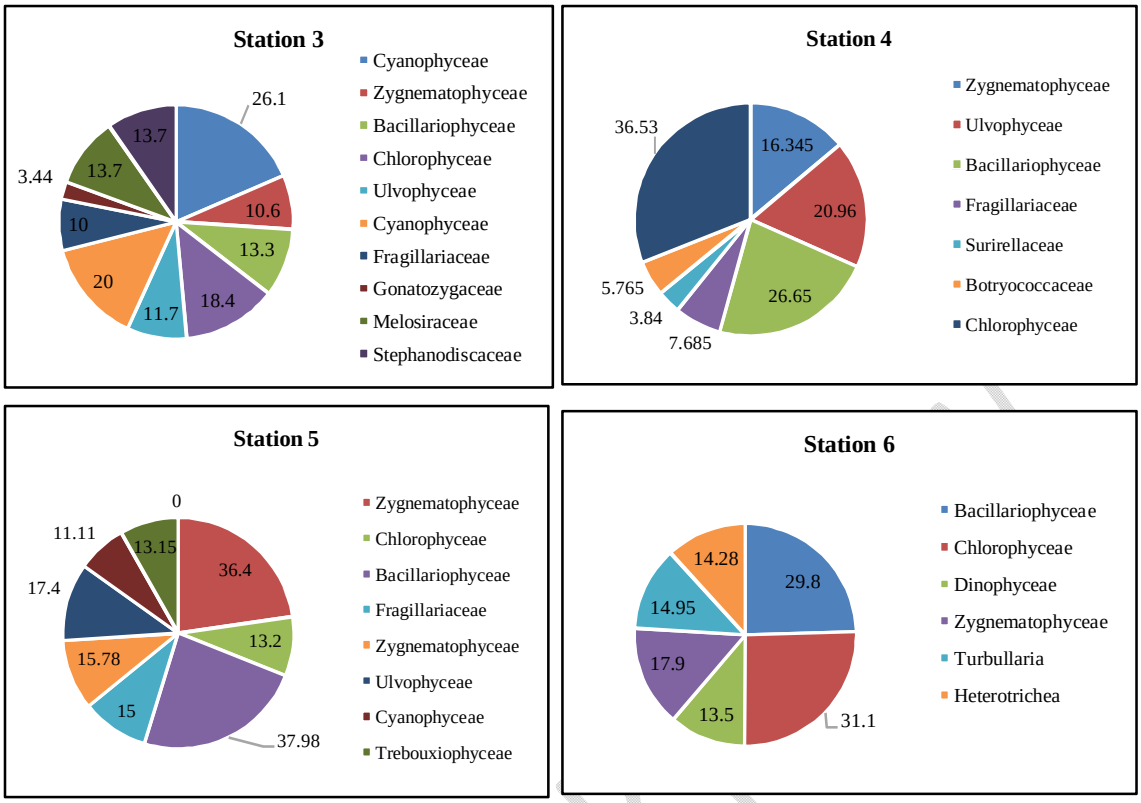
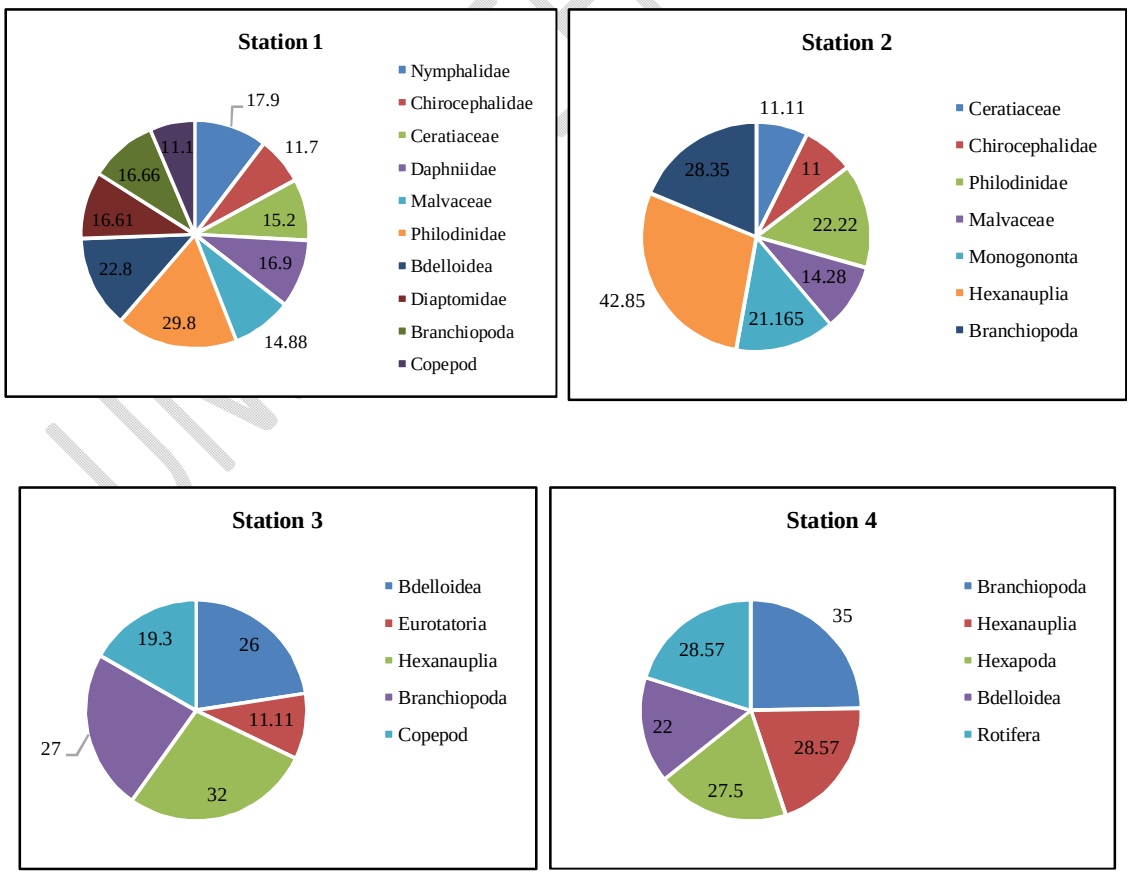


Figure 7. Phytoplankton composition in six sampling stations



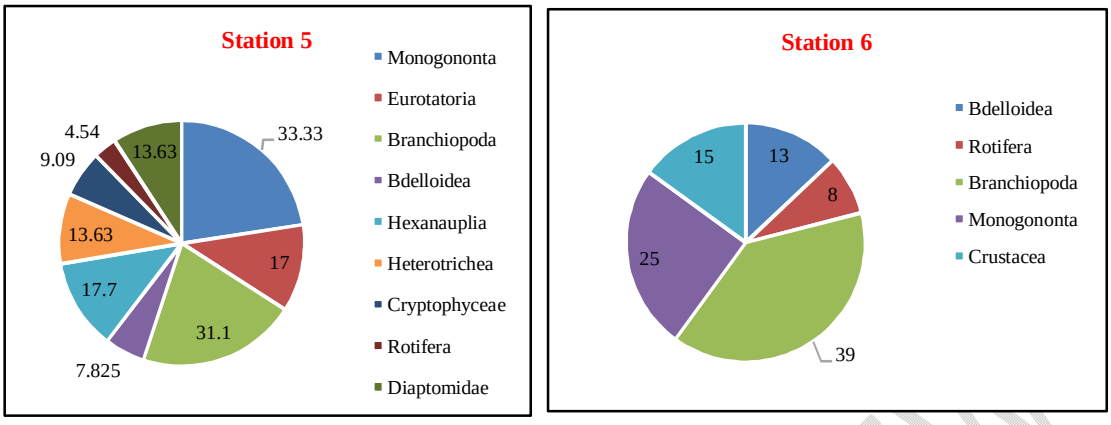


Figure 8. Zooplankton composition in seven sampling stations

Table 4. Plankton abundance in different rivers.

Sampling sites	Plankton (No./L)	Phytoplankton (No./L)	Zooplankton (No./L)
(St-1)	42×10^{2}	37×10^{2}	5×10^{2}
(St-2)	39×10^{2}	33×10^{2}	6×10^{2}
(St-3)	41×10^{2}	32×10^{2}	9×10^{2}
(St-4)	37×10^{2}	33×10^{2}	4×10^{2}
(St-5)	46×10^{2}	37×10^{2}	9×10^{2}
(St-6)	24×10^{2}	21×10^{2}	3×10^{2}

Shannon-Wiener diversity index can be used as the pollution index in diatom communities. It is a commonly used diversity index that takes into account both abundance and evenness of species present in the community. Hendley (1977) put forward the following scale: of 0–1 for high pollution, of 1-3 for moderate pollution, and 3-4 for incipient pollution. In the present study, the highest Shannon-Wiener diversity index was found to be 3.143 at station 5 and a relatively low value (2.125) was observed at station 3 (Table 5 and fig.9). This means that station 5 has more abundance of plankton than the other stations. Balloch *et al.*, found the Shannon Diversity Index to be a suitable indicator of water quality. Dash (1996) reported that the higher the Shannon-Wiener index (H′) in Odisha lake, the greater the planktonic diversity. Simpson diversity index varied from 0.872 (station 2) to 1.012 (station 5) during the present study (Table 5 and fig. 9). This indicates that the values are approaching 1, signifying that sites have high relative diversity due to their supporting surrounding components.

Table 5. Plankton diversity index of six sampling stations

Station	1	2	3	4	5	6
Shannon (H)	2.943	2.813	2.844	2.921	3.143	2.125
Simpson (1/D)	0.891	0.872	0.923	0.952	1.012	0.934
Margalef	2.422	2.393	2.313	2.274	2.512	1.786
Evenness	0.4419	0.4218	0.4572	0.4672	0.7651	0.4013

According to Ali et al. (2003), the values of Margalef's index ranging between 1 and 3 indicate moderately polluted water with values less than 1 indicating the heavily polluted environment, while values greater than 3 windows clean water. The Margalef diversity index values varied from 1.786 to 2.512, during the present study (Table 5 and fig. 9) which indicates that the system is threatened by pollution, which may be as a result of anthropogenic activities going on within the area. Pielou's evenness index refers to how close in number each species in an environment is. In the present study, the Pielou's evenness index was found to range from 0.4013 to 0.7651 (Table 5 and fig. 9); if the evenness index is high (approaching 1), there is no species dominance and vice versa. Pirzan *et al.*, (2008) opined that if the evenness index approaches zero, the species evenness in the community was low, and inversely if the evenness index approaches 1 the species in the community is the same.

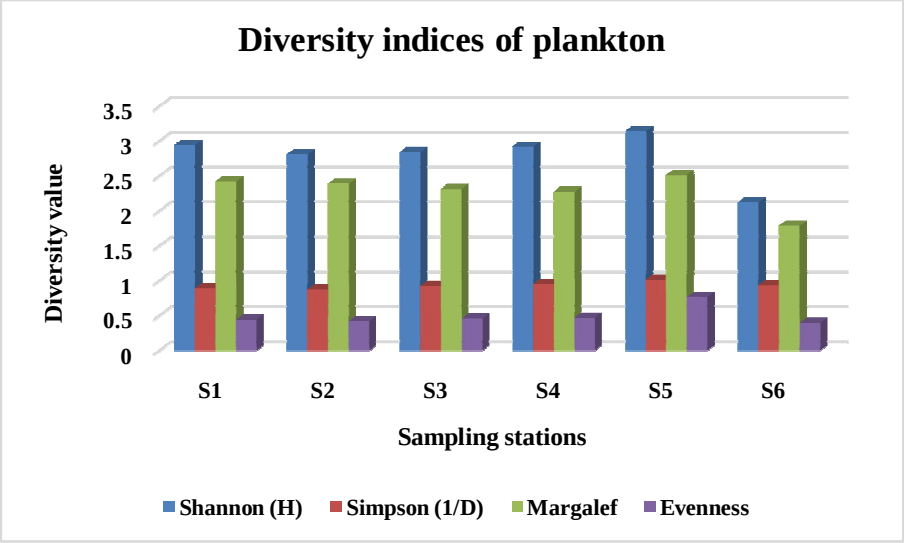


Fig 9. Diversity indices of plankton in the selected sampling stations

Cluster analysis

Cluster analyses (CA) were executed using square root and Bray Curtis Similarity to show the similarity among the parameters that contribute to water pollution. From the output of the cluster analysis, three clusters were found during different seasons: Cluster 1, includes nitrate

and phosphate; Cluster 2, includes transparency, turbidity, water temperature, air temperature and alkalinity, Cluster 3, includes Chlorophyll a, DO, pH and CO_2 (Figure 10). Nitrate and phosphate represent strong linkage with minimum cluster distance that indicates those parameters have influencing power during seasonal variations. Parameters grouped together in less distance have higher affinity with similar identical behavior during temporal variations and also exert a probable effect to each other. Chlorophyll a, DO, pH and CO_2 were under the group of cluster 3 with minimum distance than cluster 1 but have effects on environment.

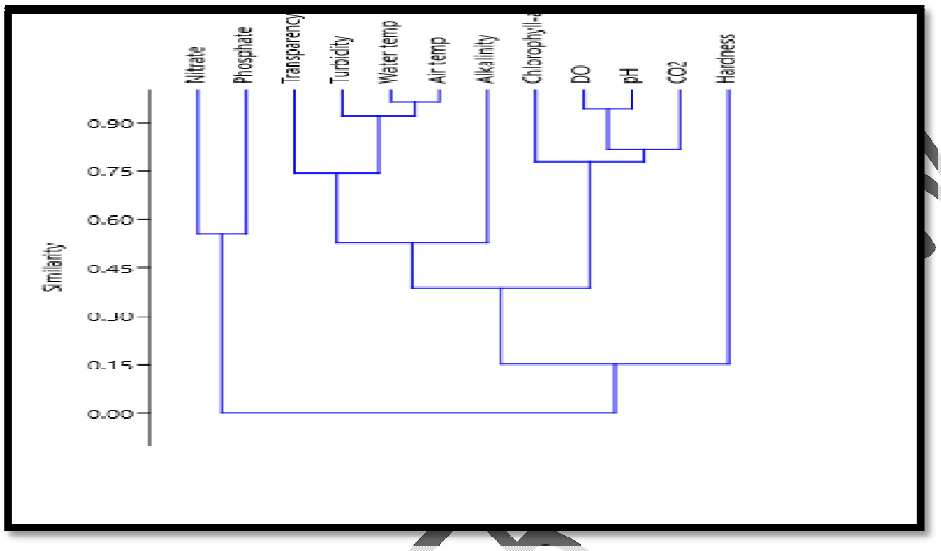


Figure 10.Dendogram showing the percentage of similarity among parameters during different samplings stations.

Correlation Matrix

In river water environment, the inter linkage among water parameters deliver noteworthy information sources and pathways of parameters. The results of correlation between water parameters fully consented with the results obtained by CA that approve some new associations between variables. Positive linear relationships were found between air temperature vs water temperature (0.86), DO vs CO_2 (0.57), DO vs alkalinity (0.78), DO vs hardness (0.74) CO_2 vs hardness (0.86), alkalinity vs hardness (0.59), turbidity vs air temperature (0.77), water temperature vs turbidity (0.56), nitrate vs pH (0.82), phosphate vs CO_2 (0.82), transparency vs phosphate (0.75), phosphate vs Chlorophyll a (0.81). The very strong, strong and moderate correlations indicate that the parameters were originated from similar sources particularly from industrial effluents, domestic wastes and agricultural inputs. Besides, strong negative correlations were found between water temperature vs DO (0.60), air temperature vs alkalinity (0.92), water temperature vs alkalinity (0.89), CO_2 vs pH (0.68), transparency vs Co_2 (0.72), turbidity vs alkalinity (-0.68), nitrate vs DO (0.61), nitrate vs CO_2 (-0.65) (Table 6). The results of the present study exhibit slightly different mode of association between water qualities which might be due to the variation of sampling procedure, sampling locations.

Table 6.Correlation matrix of physicochemical parameters and nutrients at sampling stations

	Air temp	*Water temp*	*DO*	*CO_2*	*Alkalinity*	*Hardness*	*pH*	*Transparency*	*Turbidity*	*Nitrate*	*Phosphate*	*Chlorophyll a*
Air temp	1.00											
Water temp	0.86	1.00										
DO	-0.57	-0.60	1.00									
CO_2	-0.02	0.12	0.57	1.00								
Alkalinity	-0.92	-0.89	0.78	0.17	1.00							
Hardness	-0.50	-0.26	0.74	0.86	0.59	1.00						
pH	0.17	-0.02	-0.30	-0.68	-0.04	-0.61	1.00					
Transparency	-0.09	0.16	-0.62	-0.72	-0.20	-0.50	0.34	1.00				
Turbidity	0.77	0.56	-0.18	0.38	-0.68	-0.12	-0.34	-0.56	1.00			
Nitrate	0.20	0.07	-0.61	-0.65	-0.18	-0.61	0.82	0.41	-0.26	1.00		
Phosphate	-0.44	-0.42	-0.41	0.82	0.18	-0.50	0.33	0.75	-0.64	0.48	1.00	
Chlorophyll a	-0.30	-0.15	-0.46	-0.54	-0.08	-0.35	-0.20	0.70	-0.31	0.03	0.81	1.00

Conclusion

The water quality of an aquatic body largely depends on the interactions of various physicochemical factors. The outcomes of the study show that water quality parameters, such as water pH, DO, alkalinity, hardness water nutrients are within the ranges 'suitable' for fish in all the sites where some parameters are comparatively higher levels. The study also found that water quality was not the same in all the sites, and this is likely to influence the migration of hilsa upstream, as well as their feeding and spawning. We conclude that, from the ecological view point, the hilsa sanctuaries are characterized by acceptable level of water quality. However, in some areas (particularly the Station 6 as Andermanik River) it was found to be unsuitable for hilsa fish. The present biological investigation stated the spatial variation of physicochemical parameters and their influences on plankton community of hilsa sanctuary area with an exploration statistical data output. The density and diversity of the plankton population were higher at S1 and S4 with the high value of nutrients (nitrates, phosphate) than the other four stations. From this short-term survey on physicochemical parameters and plankton abundance, it could be concluded that there is an urgent need for additional research for the betterment of water quality and maintaining sustainable production of hilsa in those sanctuaries. The outcome of this study opens window for further intensive study on seasonal variability of water quality parameters and Chlorophyll a distribution of an aquatic ecosystem.

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