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Nutrient and Plankton Abundance in the Major Nursery Grounds of Hilsa (*Tenualosa ilisha*) in Perspective of Water Quality Factors

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ABSTRACT

This study was contemplated to depict the nutrient composition and dissertation of plankton present in the six hilsa sanctuaries. The water temperature (25.6±0.8ºC), nitrate (0.005±0.01 mg/L), phosphate (0.002±0.0004 mg/L) and DO (7.7±1.1 mg/L) followed by pH (7.6±0.6), transparency (44.4±10.6 cm), alkalinity (112.4 ±26.4 mg/L), hardness (304.5±69.5 mg/L) and CO_2 (10.3±1.2 mg/L). The chlorophyll a was estimated and represents the biomass of phytoplankton (8.21 ± 2.3 μg/L). Twelve groups (families) of phytoplankton (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. The present biological investigation disclosed the variation of physicochemical parameters and their influences on plankton community (phytoplankton and zooplankton) of hilsa sanctuary area with an exploration statistical data output to acquire the insights of the study sites and suggested the suitable hilsa fisheries management action plan for the sustainable management of hilsa fishery.

INTRODUCTION

The physicochemical parameter and biological features provide substantial information about the existing resources that is usually influenced by the water quality of the freshwater habitats (Sivakumar & Karuppasamy, 2008). The water quality is used to express the suitability of water to retain the propitious physical, chemical, and biological factors of water (Ahmed *et al*., 2000), and it may directly or indirectly affect the distribution, growth and production of fish and other aquatic animals (Varshney *et al*., 2004). These usually comprised of dissolved oxygen, salinity, water temperature, turbidity and the pH of water that stimulate the estuarine fish ecology and surrounding environment (Whitefield, 1999; Blaber, 2000). Water is also considered as a crucial source for the quality of life for the living things. The lakes, and creeks, oceans and rivers, together with the land constitute the backdrop on which life grows and developed. The ecological balance sustained by the quality and quantity of water which is essentially required for the health of living organisms, survival and for any developmental activity (Kumar *et al*., 2011; Suresh *et al*., 2013). The water is usually considered as an essential to life as an adequate, safe, and accessible supply and is undoubtedly the most precious natural resource that exists on the planet. This natural resource is not only essential for survival of human beings, but also for plants, animals and all other living things of the universe (Razo *et al*., 2004). The geomorphologic, climatic, geochemical and pollution conditions characterize the properties (physical and chemical) of freshwater body (Ishaq & Khan, 2013). On the other hand, disease and debasing the land also becomes unfit to sustain life due to the pollution which is taken into account as the greatest source of the deviation of the physicochemical parameters. The environmental quality and ecological balance are also a great concern for the water availability and existing quality as well. The sources of water are getting polluted with increasing industrialization, urbanization and technological advance in all fields,

The different kinds of nutrients and pollutants flowing through sewage, agricultural runoff, industrial effluents etc. into the water bodies bring about a series of physicochemical and biological water quality factors (Maheshwari *et al*., 2011). The water quality can be assumed and described by its chemical, biological and physical properties of the existing water quality factors (Manjare *et al*., 2010). This water drivers for multiple uses i.e., fish culture, livestock, recharge of ground water, control of floods etc. (Gurunathan & Shanmugam, 2006). Due to unrestrained industrialization, the quality of water is being degraded gradually and deteriorating the ecosystem for the aquatic species (Manjare *et al*., 2010). Basically, socio-economic activities are related with such a wayward industrialization of the territories (Thanoon *et al*., 2003, Richard 2005 and Jaillon & Poon, 2009) that are basically accountable for the alteration of the society structure (Abdullah *et al*., 2009; Thanoon *et al*., 2003 and Abdullah *et al*., 2009).

The River Meghna, Tetulia and Andharmanik were emphasized for aquatic organisms including fishes in the existing water quality parameters to perceive deviation of the physicochemical status, plankton abundance and

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alteration of nutrient fluxes in these study sites.

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.

Table 1: The six nursery grounds with eighteen treatment areas

Sl No.	Sanctuary Area	Area Length (Km)	Treatments
1.	Shatnol, Chandpur-Alexander, Laxmipur (St-1)	100	Shatnol, Confluence (Padma & Meghna) and Chor Alexandar
2.	Tarabunia, Shariotpur (St-2)	20	Tarabunia, Sureswar and Bashgari
3.	Hizla, Mehendigonj, Barisal (St-3)	82	Bhasanchor, Hizla and Mollikpur
4.	Bheduria, Bhola- Char Rustom, Patuakhali (St-4)	100	Bheduria, Kalaiya and Chor Rustam
5.	Char Ilisha-Char Pial, Bhola (St-5)	90	Elisha, Daulatkhan and Monpura
6.	Kalapara Upazila, Patuakhali (St-6)	40	Bailatoli, Khepupara and Mohipur

The hydrological, physical, chemical assessment

The water transparency was measured in situ using Secchi disc (30 cm in diameter). The portable turbidity meter (2020i) was used to measure the water turbidity. To measure the temperature the Celsius thermometer was used to follow up the deviation of the parameter. The chemical parameters (pH, DO) were measured using digital multi-parameter. HACH kit (Model-FF-2, USA) and HANNA instruments (Model HI 9829) both were used to measure DO, hardness and alkalinity. The measurement of phosphate and nitrate was carried out in the laboratory by were determined following APHA. Following UV spectrophotometric method, chlorophyll a content of water was estimated. The plankton (phytoplankton and zooplankton) was studied qualitatively and quantitatively following Bellinger and Sigiee (2015) under a compound microscope (Inverted binocular Microscope, Model: XDS-2). The genus of phytoplankton which was found in one replicate portrayed as rare (low) abundance, two replicates portrayed as common (medium) and each three replicates of the station was portrayed as very common (high). The density of phytoplankton and quantity was expressed as cells L-1. The sample (1 mm) left 5 min in the S-R cell to allow plankton to settle down and the cells in 20 randomly selected fields. Plankton density was calculated using the following 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:

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

$$D=\sum (pi)^2$$

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

$$J'=H'/\text{Log } (S)$$

where 'Pi' is denoted as 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

The 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 Figure.1, 2 and 3.

Temperature

The minimum and maximum water temperature were found mean value 24.9± 0.8ºC and 26.8±0.5ºC at (St-4) and (St-3) respectively, while the minimum and maximum air temperature were found with mean value 26± 0.7ºC and 29.4±1.3ºC at (St-4) and (St-3) respectively (Table 1 and 2). The water temperature varied between 23°C to 27°C whereas the air temperature ranged among 23°C to 30°C. The temperature of water significantly varied along with the changes in air temperature (Fig. 1). Pillay (1958) also estimated the temperatures of <20°C, >30°C were not suitable for the juvenile hilsa and 23-27°C as a suitable water temperature, whereas, Jafri (1988) reported the least suitable (<15°C, >30°C), moderately suitable

(15–20°C; 25–30°C) and most suitable (20–25°C) water temperature for hilsa spawning. On the other hand, (ECR 1997) mentioned the standard value of 20°C–30°C as water temperature in the river which shows similarity with the present findings.

With the deliberate increasing the water temperature, the solubility of oxygen is reduced because of deoxygenating (Swingle, 1967). The high positive correlation between air and water temperature in streams has been observed with the sequential increasing of the distance (Zappa *et al.*, 2000; Smith *et al.*, 2001; Uehlinger *et al.*, 2003). Similar findings were evaluated by Ahmed *et al.*, (2005) that water temperature of the Meghna River at surface level ranged between 24.1-30.5°C with a mean of 27.6±0.68°C. Bhaumik *et al.* (2011), studied for hilsa migration, breeding, rearing and estimated the water temperature ranged from 29.3-30.2°C was assumed as ideal for breeding activities and 29.8-30.8°C was observed as an appropriate temperature for the nursery activities of hilsa in the Hooghly-Bhagirathi River system.

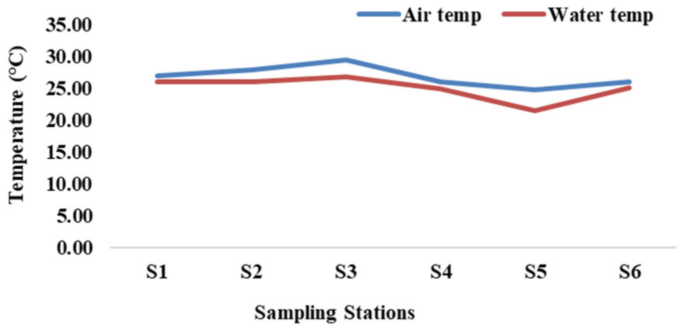


Figure 1: Variations of air and water temperature at sampling stations.

Transparency

The minimum and maximum were found 32±8.3 cm and 58.38±8.2 cm at St-6 and St-1, respectively (Table 2). The transparency of water (25 to 62 cm) was varied six different stations. The transparency of water varied along with the changes of Chlorophyll a content (Figure. 2), which was similar to the findings of Ahmed (1993) as stated water transparency is inversely related with Chlorophyll a. Transparency of water depends on the suspended solid particles, turbid water intensity from catchment area and on the plankton density (De, 2007). The water transparency (20-40 cm) is suitable for fish culture and indicates optimal for the plankton population. The transparency of 35-45 cm is propitious for aquatic environment (Saifullah *et al.*, 2016). Ahmed *et al.*, (2005) found the similar results from the Meghna River system and the transparency ranged from 12-90 cm with a mean of 34.2 ± 18.08 cm at different stations.

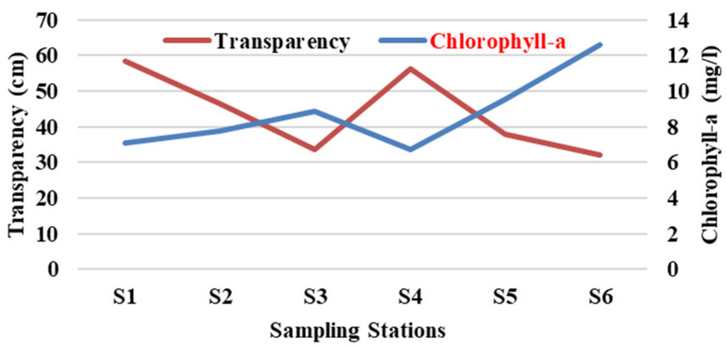


Figure 2: Variations of transparency and Chlorophyll a at sampling stations.

Dissolved oxygen (DO), pH and Carbon dioxide (CO_2)

The distribution of species and promote the survival of fish is influenced by the DO concentration especially for the juvenile and fry. The dissolved oxygen as one of the most crucial factors for the distribution and abundance of fish (Maes *et al.*, 2004). The substantial amounts of dissolved oxygen were found in the river water. The DO is influenced by partial pressure, temperature, salinity, respiration, and photosynthesis (Allan, 1995; Wetzel and Likens, 2000; Effendi, 2003; Huq and Alam, 2005). Dissolved oxygen (DO) ranged from 6.1 to 8.6 mg/L with the lowest (6.19±0.6 mg/L) at St-1 and the highest (7.64±1.1 mg/L) at St-6 (Table 2). The level of DO >5ppm is essential to promote the growth and production of fish (Bhatnagar and Singh, 2010 and Bhatnagar *et al.*, 2004). The depletion of oxygen level in water leads poor feeding, starvation, reduced growth, and mortality, either directly or indirectly (Bhatnagar and Garg, 2000). It indicates the suitable range of DO for the fish especially for the juvenile hilsa. The higher level of dissolved oxygen (DO) values might play a significant role and indicate higher productivity for the migration of hilsa. The similar result was reported by Ahmed *et al.*, (2005) and they found DO as 6.7±0.81 mg/L in the Meghna River. The dissolved oxygen (DO) (Table 2) results the growth and reproduction of fishes in these rivers for the present study. Almost the similar result was recorded by Ahammad (2004) and found the DO (4.6-5.8 mg/L) concentration in the Meghna River estuary 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. There was not found any significant difference between the sites.

The concentration of carbon dioxide is influenced by groundwater inflows that substantially enriched with carbon dioxide (Allan and Castillo, 2007; Wetzel and Likens, 2000). Free carbon dioxide is an important factor which impacts the concentration of carbonates, bicarbonates, pH, and total hardness in water. Small and Sutton (1986) and Rebsdorf *et al*. (1991) reveals that CO_2 generated by microbial respiration in an aquatic habitat. The CO_2 ranged from 7.1-15 mg/L with the lowest (8.15±1.1 mg/L) at St-1 and the highest (13.9±1.3 mg/L) at St-6 (Table 2). The similar findings were reported by Mulholland (2003) stated that groundwater influxes substantially enriched by CO_2 due to the respiration of soil. The present findings also more like the findings reported Allan and Castillo (2007).

The lowest pH (7.49±0.8) was found at St-1 and the highest pH (8.09±0.4) was found at St-4 (Table 1). The observed pH values (6.2-9.3) were within the range at six different stations in these rivers. The air temperature is considerably the prime responsible factor for changing the pH of water. The neutral to alkaline pH (7.0-8.0) were found in the Meghna River (Ahmed *et al*., 2005). The permissible range of pH was between 6.4-8.5 (Bhaumik & Sharma, 2012).

The pH of most of the water bodies ranges of 6.5-8.5 which indicates pH of the studied area was suitable and varied within the limit (Das, 1997; ECR, 1997). 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 deleterious for the reproduction and growth of fish. The increasing or decreasing pH of the adjacent water body influenced by the industrial waste materials (Campbell, 1978; APHA, 2005; Moore, 1972; Mahmood & Bhuyian, 1988; Sarma *et al*., 1982 and Roy, 1955). The pH is highly influenced by carbon-dioxide, carbonates, bicarbonates, and acid rain. An excessive pH is harmful for aquatic life like fish, plants, and microorganisms (Huq & Alam, 2005).

Table 2: The physicochemical parameters of water quality in the six stations.

Parameters	**Sampling station**	**Mean ± SD**	**Standard value**
DO (mg/L)	(St-1) (St-2) (St-3) (St-4) (St-5) (St-6)	6.19±0.6 7.07±1.1 6.59±0.9 6.88±0.8 7.48±0.6 7.64±1.1	5 (EQS, 1997)
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)
Transparency (cm)	(St-1) (St-2) (St-3) (St-4) (St-5) (St-6)	58.38±8.2 46.5±7.1 33.7±12.5 56.25±14.1 37.33±13.2 32±8.3	35-45 (Hossain *et al*., 2011)
Hardness (mg/L)	(St-1) (St-2) (St-3) (St-4) (St-5) (St-6)	64.86±17.2 88.56±15.4 76.6±15.7 296±69 314±76 987±221	200-500 (DOE, 2003)
pH	(St-1) (St-2) (St-3) (St-4) (St-5) (St-6)	7.49±0.8 7.82±0.7 7.85±0.5 8.09±0.4 7.72±0.3 7.21±0.8	6.5-8.5 (Das,1997)

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	
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)	0.0051± 0.0037	
	(St-5)	0.0043± 0.0028	
	(St-6)	0.0033± 0.001	
PO_4 (µg/L)	(St-1)	0.0020± 0.0024	0.1 (De, 2007)
	(St-2)	0.0016± 0.0002	
	(St-3)	0.0014± 0.0003	
	(St-4)	0.0018± 0.0031	
	(St-5)	0.0019± 0.0002	
	(St-6)	0.0013± 0.0006	

Alkalinity

The alkalinity (20–200 mg/L) is common in most of the freshwater ecosystems including ponds, lakes, streams and rivers (Hem, 1985; Ishaq & Khan, 2013). The observed alkalinity values (68-191) were within the range at six sampling stations. The lowest was (81.07±17mg/L) was found at St-1 and the highest alkalinity (143±38.3 mg/L) was found at St-6 (Table 2). The results were similar to the findings Moyle (1946) as ranged between 40.0-90.0 ppm and above 90.0 ppm, whereas Boyd and Lichtkoppler (1979) suggested that water with total alkalinities of 20-150 mg/L contain the accurate quantities of CO_2 to permit the plankton production, and the total alkalinity of medium productive water ranged from 25-100 mg/L (Bhuiyan, 1970). The alkaline nature of water was also reported in Greater Zab River, Iraq. This the range of alkalinity found acceptable for planktonic organisms and fish (Ali, 2010).

Hardness

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

Water nutrients

The nitrate concentrations (0.002-0.016 µg/L) were found within the suitable range. The lowest (0.0033± 0.001µg/L) was found at St-6 and the highest concentration (0.0051± 0.0037µg/L) was found at St-4 (Table 2). The nitrate concentration (0.02-1.0 ppm) is lethal to many fish species (Bhatnagar *et al.*, 2004), > 1.0 ppm is somewhat lethal for many warm water fish species and < 0.02 ppm is acceptable for aquatic environment (OATA, 2008). The nitrite concentration in water should

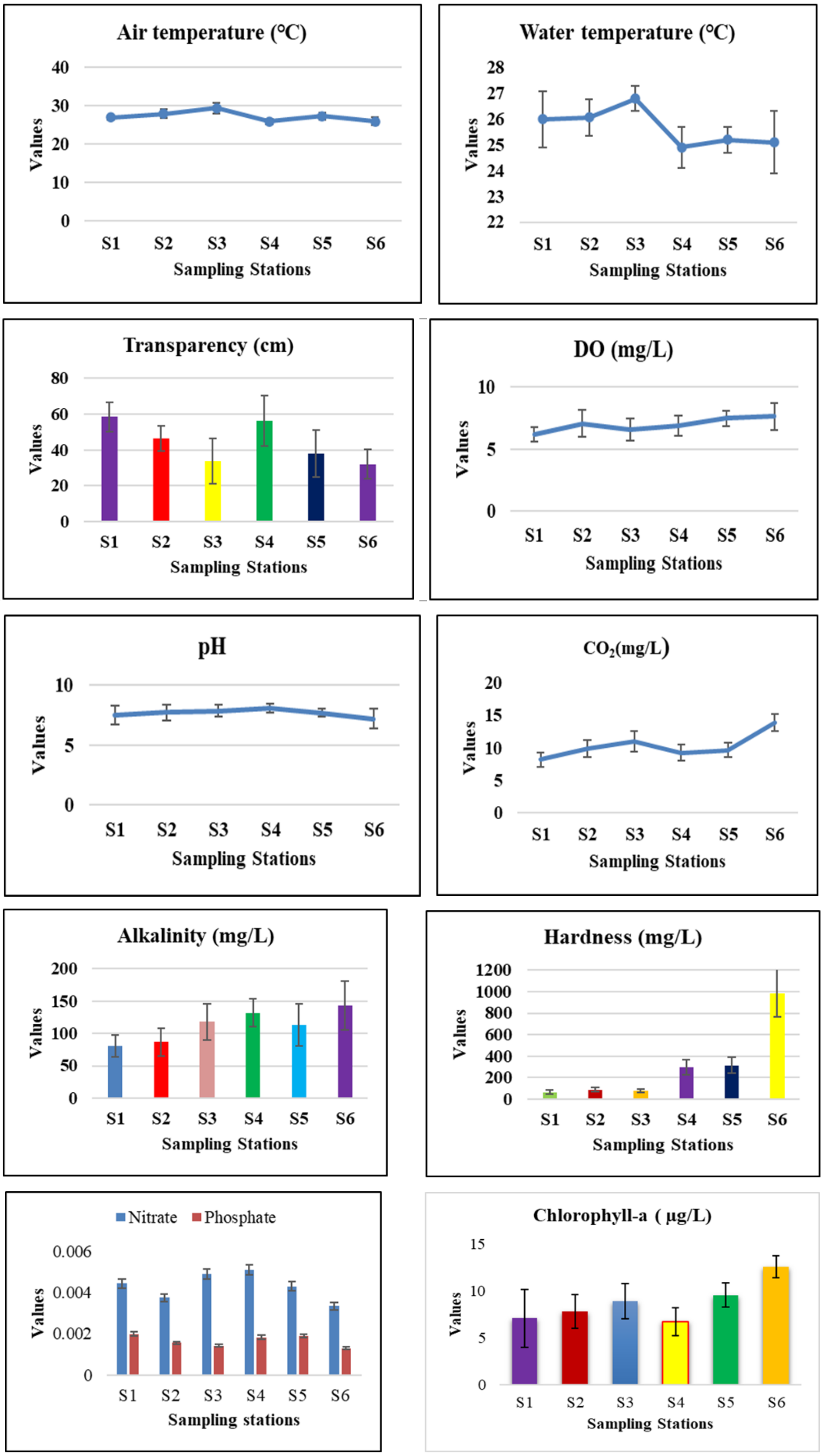


Figure 3: The variations of physicochemical parameters of water quality at six sampling stations.

not exceed 0.5 mg/L (Santhosh and Singh, 2007). Similar findings were reported that ammonia concentration was found to be elevated and ranged from 0.1-0.6 mg/L and showed a gradual decreasing trend from the upward to the downward stretches in the Meghna River systems (Ahmed *et al.*, 2005). The nitrate concentration for the present study was found within the acceptable range. Qureshimatva *et al.*, (2015) reported that, the growth of plankton could also be influenced by the amount of nitrate. Phosphate concentrations were found 0.001-0.008 μg/L where the the lowest (0.0013± 0.0005μg/L) in St-6 and the highest concentration (0.0020± 0.0026/l) was found in St-4 (Table 2). The standard value of phosphate in water is usually ranges up to 0.1 ppm (De, 2007). The phosphate level of 0.06 mg/l is desirable for fish culture (Stone and Thomforde, 2004). The phosphate value of 0.05-0.07 ppm is optimum and productive; 1.0 ppm is considered as good for plankton and shrimp production (Bhatnagar *et al.*, 2004).

Chlorophyll a concentration remains high during low-water discharges (Devercelli & Peruchet, 2008). Chlorophyll a concentration ranged from 6.2-18 μg/L where the the lowest (7.1±3.1μg/L) in St-1 and the highest concentration (12.6±1.2 μg/L) was found in St-6. Chlorophyll a value is an indicator of productivity in the water body (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 approximately 1 to 2% of dry weight in planktonic algae (APHA, 1995).

Plankton population

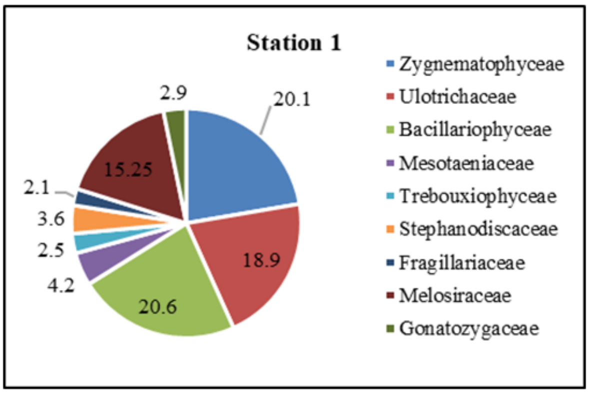
Twelve groups (families) of phytoplankton, namely Bacillariophyceae*,* Ulvophyceae*,* Zygnematophyceae*,* Bacillariophyceae*,* Dinophyceae, Fragillariophyceae, Gonatozygeceze, Cyanophyceae, Hydrodictyaceae, Stephanodiscaceae, Trebouxiophyceae, Melosiraceae and Euglenoida comprising 26 genera and zooplankton Branchiopoda*,* Hexanauplia, Heterotrichea, Diaptomidae, Eurotatoria, Cryptophyceae, Rotifera, Copepod, Crustacea, Monogononta, Bdelloida*,* having 14 genera were identified at all sampling stations (Table 3 and Fig. 4 & 5). 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 nine were phytoplankton and four 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 nine were phytoplankton and six 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 seven were phytoplankton and five were zooplankton. Phytoplankton belonged to the dominant groups Cholorophyceae but in case of zooplankton the dominant groups was Branchiopoda. In station 4, nine taxa were identified among which six were phytoplankton and three 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 nine were phytoplankton and six 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 eigth were phytoplankton and four 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 with the findings of Ahsan *et al.*, (2012) who reported 58 taxa of which 19 were of phytoplankton and 39 were of zooplankton (Table 3). Ahmed *et al.*, (2005) reported that, a relatively lower abundance of plankton including 13 genera of zooplankton and 41 genera of phytoplankton were recorded. Similar results were reported by other researchers (Ahmed *et al.*,2003; 2005 and Ahsan *et al.*, 2012). Onyema (2008), Esenowo & Ugwumba (2010) reported that, the dominance of Bacillariophyceae (Diatoms) agrees with the reports of as diatoms are the most obvious representatives of the phytoplankton in rivers, seas, and lakes. The presence of some phytoplankton species i.e., *Navicula spp., Nitzchia spp.*, *Anabaena* spp., and *Synedra spp.* as good indicators of organic pollution in any aquatic habitat (Onyema *et al.*, 2003).

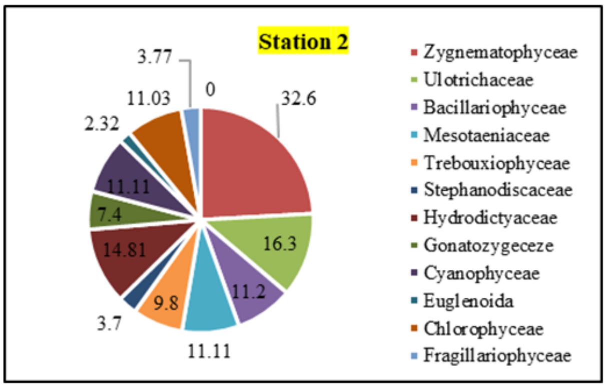
The density of plankton was found to be minimum (24×102 cells L-1) at S6, while maximum (46×102 cells L-1) at S5 during the investigation (Table 4). The phytoplankton in the Ganga Meghna River system formed about 90% of the total plankton abundance (Ahsan *et al.*, 2012). The higher percentage of phytoplankton (76.0–93.6%) from the Meghna River (Shafi *et al.*, 1978), whereas Ahmed *et al.*, (2005) reported that the plankton biomass was relatively lower in the Meghna River comprising 3.26% zooplankton and 96.74% phytoplankton of the total planktonic organisms, which is similar to the findings of the present study.

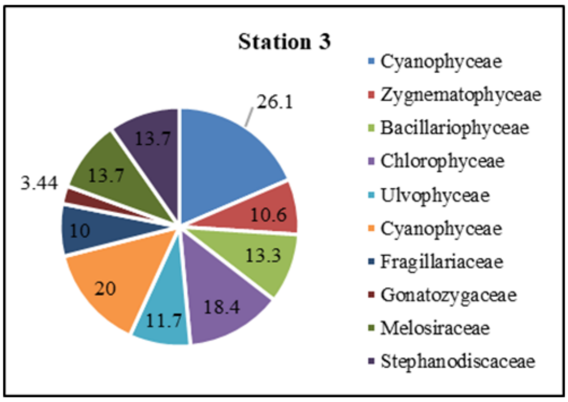
Shannon-Wiener diversity index is a commonly used diversity index that considers both evenness and abundance of species present in the community. The scale of 0–1 for high pollution, of 1-3 for moderate pollution, and 3-4 for incipient pollution (Hendley, 1977). The relatively low value (2.125) was observed at station 3 and the highest Shannon-Wiener diversity index was found to be 3.143 at station 5 (Table 5 and Figure. 6). This reveals the more abundance of plankton at station 5 than the other stations. The higher the Shannon-Wiener index (H') in Odisha Lake, the greater the planktonic diversity (Dash, 1996). The Simpson diversity index

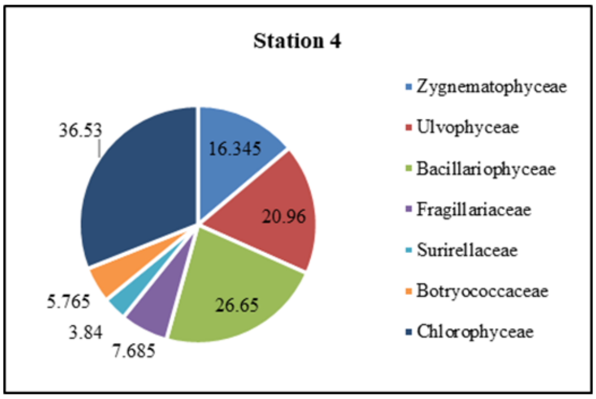
Table 3: Plankton observed in seven stations.

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*









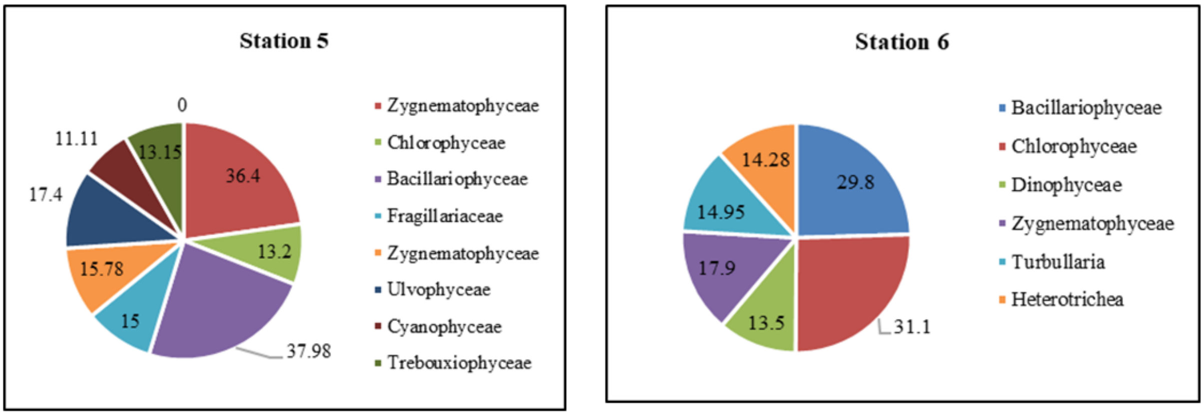


Figure **4:** Phytoplankton composition in six sampling stations

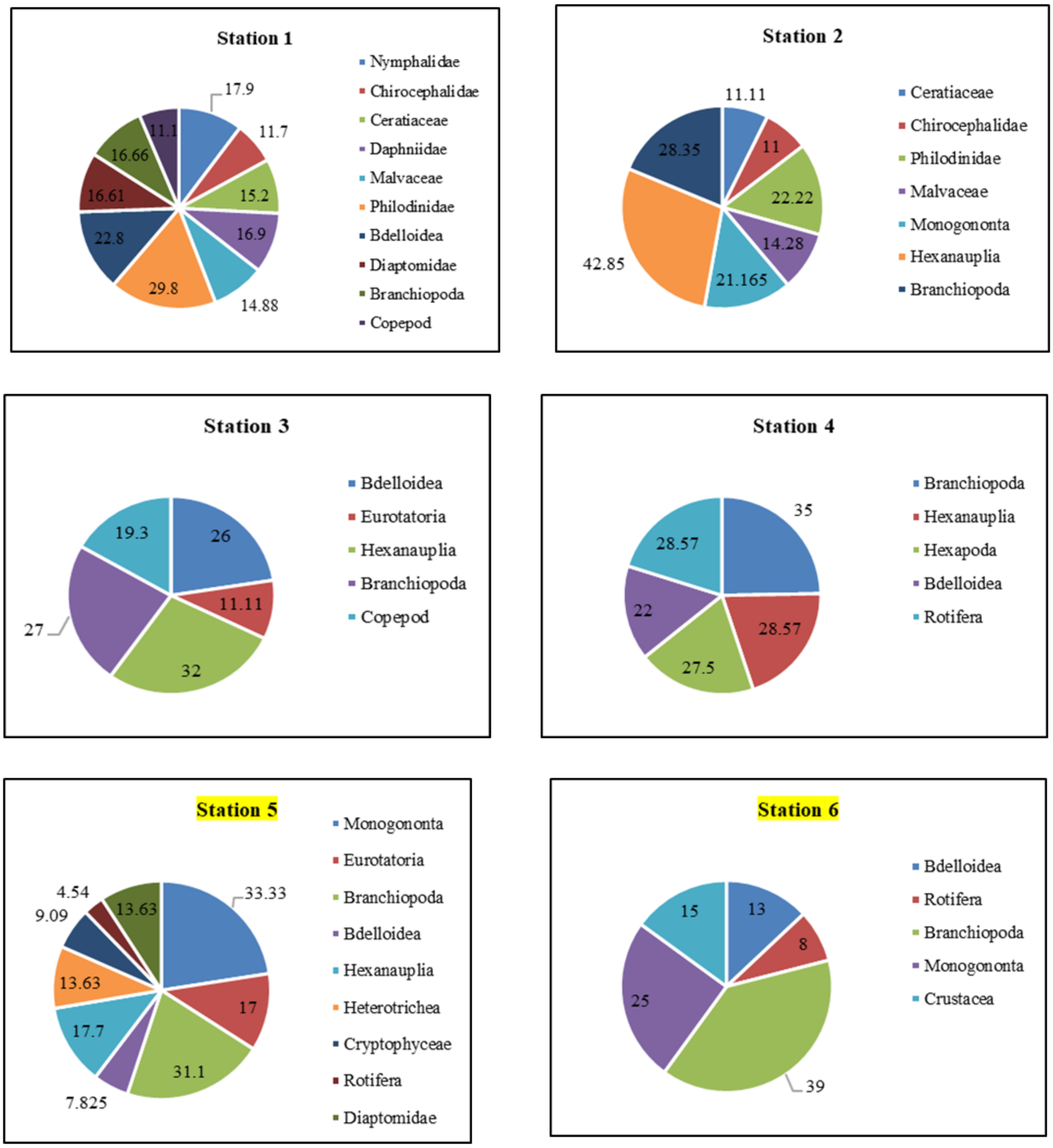


Figure **5:** Zooplankton composition in seven sampling stations

Table 4: Plankton abundance in different rivers.

Sampling sites	Plankton (No./L)	Phytoplankton (No./L)	Zooplankton (No./L)
(St-1)	42×102	37×102	5×102
(St-2)	39×102	33×102	6×102
(St-3)	41×102	32×102	9×102
(St-4)	37×102	33×102	4×102
(St-5)	46×102	37×102	9×102
(St-6)	24×102	21×102	3×102

varied from 0.872 (station 2) to 1.012 (station 5) (Table 5). This indicates that the values signifying that sites have high relative diversity due to their supporting surrounding components. The values of Margalef's index ranging between 1-3 indicate moderately polluted water with values less than 1 indicating the heavily polluted environment, while values greater than three windows clean water (Ali *et al.*, 2003). During the present study, the Margalef diversity index values varied from 1.786-2.512 (Table 5 and Figure. 6) which means the system is threatened by pollution, which may be happened due to the anthropogenic activities within the area. The Pielou's evenness index ranged between 0.4013-0.7651 (Table 5 and Fig. 6); there is no species dominance and vice versa if the evenness index is high (approaching one). The species evenness in the community was low if the evenness index approaches zero, and inversely species in the community is the same if the evenness index approaches 1 the (Pirzan *et al.*, 2008).

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

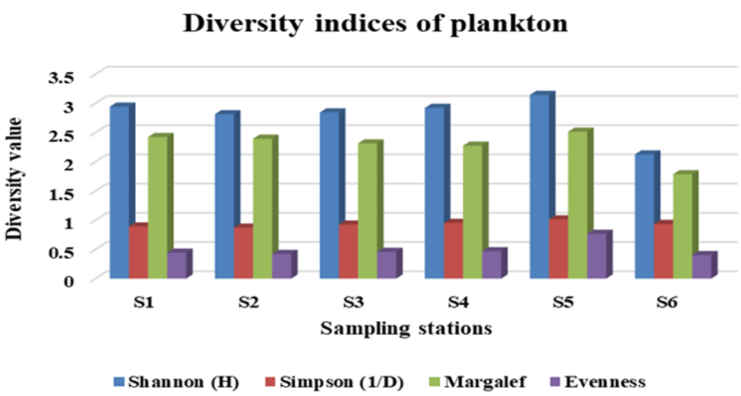


Figure 6: Diversity indices of plankton in the selected sampling stations

CONCLUSION

The diversity and density of the plankton population were higher at St-1 and St-4 with the high value of nutrients (nitrates, phosphate) than the other four stations. The density of plankton was found to be minimum (24×102 cells L-1) at St-6, while maximum (46×102 cells L-1) at St-5 during the investigation. The relatively low value (2.125) was observed at St-3 and the highest Shannon-Wiener diversity index was found to be 3.143 at St-5, which revealed the more abundance of plankton at St-5 than the other stations. From this short-term survey on physicochemical parameters and plankton abundance, it could be concluded that there is a need an imperative initiative 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. The outcomes of the study revealed the attributes of water quality parameters and uncovered 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.

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