PHYTOPLANKTON AND MACROPHYTES OF KUNIAR HAOR, KISHOREGANJ IN RELATION TO SELECTED PHYSICOCHEMICAL FACTORS

THESIS SUBMITTED IN ACCORDANCE WITH THE REQUIREMENTS OF THE UNIVERSITY OF DHAKA FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D.) IN BOTANY

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DECLARATION

I do hereby declare that this thesis entitled **"PHYTOPLANKTON AND MACROPHYTES OF KUNIAR HAOR, KISHOREGANJ IN RELATION TO SELECTED PHYSICOCHEMICAL FACTORS"** has been composed by myself and all the research works presented herein are my own. I do further declare that this work has not been submitted any where for my academic degree.

January, 2020 (**SHAFIUL AZOM SHAFI)**

Certificate

This is to certify that the research work presented in this thesis entitled **'PHYTOPLANKTON AND MACROPHYTES OF KUNIAR HAOR, KISHOREGANJ IN RELATION TO SELECTED PHYSICOCHEMICAL FACTORS'** has been carried out by **SHAFIUL AZOM SHAFI,** bearing Registration No. 169/2014-15 under our supervision. The research was carried out in the National Professor A.K.M. Nurul Islam Laboratory, Department of Botany, University of Dhaka. It is further certified that the work presented herein is original and suitable for submission and consideration of the degree of Doctor of Philosophy.

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Dedicated To

My Mother

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LIST OF ABBREVIATION

am	Ante-meridiem
AT	Air Temperature
WT	Water temperature
chl-a	Chlorophyll *a*
BGA	Blue green algae
°C	Degree centigrade
E	East
EDTA	Ethylene di amine tetra acetic acid
FAO	Food and Agricultural Organization
Fig.	Figure
Figs.	Figures
ft.	Feet
GF/C	Glass microfiber filter per circles
HBCC	Helber Bacteria Counting Cell
Ind./l	Individual per liter
km	Kilometer
kg	Kilogram
L	Liter
M	Meter
ha.	Hectare
meq./l	Milli equivalent per liter

mg	Milligram
mg/l	Milligram per liter
µg/l	Microgram per liter
min	Minutes
h	Hour
µl/l	Micro liter per liter
ml	Milliliter
mm	Millimeter
cm	Centimeter
µS	Micro Siemens
µg	Microgram
No.	Number
sp.	Species
N	North
NO_3-N	Nitrate-nitrogen
NS	Not sampled
pH	Negative logarithm of hydrogen ion concentration
pm	Post-meridiem
SD	Standard deviation
SPSS	Statistical Package for the Social Sciences
Z_S	Secchi depth
TDS	Total dissolved solids
TDI	Trophic diatom index

Cond.	Conductivity
Alk.	Alkalinity
SRP	Soluble reactive phosphorus
SRS	Soluble reactive silicate
PP	Phaeopigment
PD	Phytoplankton density
Idn.	Identification

Abstract

ABSTRACT

The area of Kuniar Haor is about 37 ha and it is interconnected with the River Dhonu. The catchment consists of 5 villages namely, Baribari, Shohila, Borohathi, Shimulbak and Mollapara under the Upazilla Itna, Kishoreganj. The Haor was investigated from February 2016 to January 2018. Samples were collected at one month intervals from 3 sampling stations. A total of 24 samplings were made where 72 samples were analysed during the two years' study period. Eleven physicochemical parameters namely air and water temperature, secchi depth (SD), pH, alkalinity, total dissolved solids (TDS), conductivity, dissolved oxygen (DO), soluble reactive silicate (SRS), soluble reactive phosphorus (SRP), NO_3-N and four biological parameters as chl-*a*, phaeopigment, phytoplankton density (PD), and macrophyte abundance were investigated. In all stations the monthly ranges of air and water temperatures were 18.5 – 38.11 ^oC and 19 – 33.41 ^oC, respectively. The ranges of other determinants were Secchi depth, 7.5 – 95 cm; pH, 6.4 – 8.1; TDS, 17 - 97 mg/l; conductivity, 31 - 208 µS/cm; DO, 4.4 – 14.8 mg/l; alkalinity, 0.5 – 5.5 meq/l; SRS, 0.77 – 23.19 mg/l; SRP, 1.05 – 55.28 µg/l; NO_3-N, 0.04 – 1.15 mg/l; chl-a, 1.18 – 32.56 µg/l; phaeopigment, 0.13 – 46.32 µg/l and phytoplankton density, 1.8 – 62.2 ($\times 10^4$ind./l).

The seasonal dynamics of the above mentioned hydrobiological components of the Haor ecosystems were also elaborated. In the studied Haor area, namely station-1, station-2 and station-3, the total species of phytoplankton recorded were 115, 120 and 90, respectively. The recorded genera were 51 in station-1, 52 in station-2 and 51 in station-3. The distribution of the recorded species showed following pattern: maximum number of species 37.4% (Station-1), 34.1% (Station-2), and 37.7% (Station-3) among the flora studied was represented by the Chrysophyta. Dominance of Chrysophyta followed by Euglenophyta (28.7% in station-1, 31.7% in station-2 and 28.8% for station-3), Chlorophyta (21.7% for station-1, 23.3% for station-2 and 21.1% for station-3), Cyanophyta (6.08% for station-1, 4.1% for station-2 and 4.4% for station-3), Cryptophyta (3.5 % for station-1, 3.3% for station-2 and 5.5% for station-3) and Pyrrophyta (2.6% for station-1, 3.3% for station-2 and 3.3% for station-3). Based on the preliminary identification, 33 species of phytoplankton may be considered as new records for the Bangladesh. The distribution of new records of phytoplankton is as follows: Euglenophyta dominate (9 taxa) followed by Chlorophyta (7 taxa), Chrysophyta (6 taxa), Cryptophyta (7 taxa), Cyanophyta (2 taxa) and Pyrrhophyta (2 taxa). A total of 48 species

of aquatic macrophytes was recorded where *Ipomoea aquatica* Forsk and *Ludwigia adscendens* (L.) Hara were found to be the most dominant species.

Pearson correlation of phytoplankton density showed significant positive correlation (at 1% and 5% level) with alkalinity, nitrarte-nitrogen and phaeopigment in all stations. DO showed only positive correlation with air and water temperature, Secchi depth at station-1, water temperature, secchi depth, pH, and phytoplankon density at station-2, secchi depth, with air, water temperature, alkalinity TDS, SRP at station-3 According to Shannon-Winner diversity index, Station-3 supports higher diversity at genus and specie level. Jaccard Index shows three stations are highest 53.84 % similar in October 2016 and their intersecting members are 7.

The value of TDI indicate the effects due to contamination of organic matter on the wetland. In the investigation TDI = 3.3% and pollution tolerant taxa is 18.5%. As the proportion of TDI count is <20%, so the wetland is free of significant organic pollution. The fish to phytoplankton ratio was calculated as 933870: 1.94×10^{12}. This indicates that the growth of plankton feeding fishes mostly depends on plankton dynamics of the water body in the studied Haor area. The macrophytes fed on by the fishes in this Haor represent several families of which major ones are Amaranthaceae, Araceae and Typhaceae. These are so potential for fish production, wildlife conservation, fertilizer and soil additive.

The present limnological and hydrobiological study on the Kuniar Haor reveals that the water body has been passing its meso-eutrophic status. After having an intensive anthropogenic disturbance from the catchment the quality of water might get changed. And it is likely that in the near future these wetlands would be turned to eutrophic followed by hypertrophic systems. This condition is undesirable not only for *ex-situ* conservation but also for implemening future conservation strategy. It also becomes detrimental to the components of the biodiversity. The study also reveals that management of Kuniar Haor should be taken into consideration not only to stop the disturbances within the study sites but also the disturbances in their surrounding land areas.

The investigation generated some important baseline data on the pollution status and phytoplankton community structure of the Haor. These data would be helpful in planning for future policy decisions on using the reservoir as an ecotourist center as well as in the better conservation and management of the precious wildlife in the world-famous sanctuary.

INTRODUCTION

1.1 Background

Wetlands are pondered as important assets for biological conservation because they support a rich biodiversity and high productivity (Mitsch and Gosselink 2000). In Bangladesh, wetland resources occupy 50% of the country's land surface and support a wide variety of floral and faunal diversity including endangered species (IUCN 2005). The Ramsar Convention (1971) has defined wetlands as *'areas of marsh, fen, peat land, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.'* Moreover, internationally important wetlands *"may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".* The Bangladesh Water Act, 2013 defines *"Wetland means any land where water remains at the levelof surface or close to it and which inundates with shallow water from time to time, and where grows such plants that may usually grow and survive in marsh land."* The greater part of the northeast region of Bangladesh consists of wetland basins and is characterised by the appearance of enormous vast, deeply flooded tectonic depressions, known as *Haors* that exist between the rivers. Fresh water comprises approximately less than 1% of the total surface of the earth. Water evaporates from the ocean and land surface and is carried out into the atmosphere and precipitates as rain or snow on the earth's surface. A portion of the rain water on the land is absorbed into soil, some part of it is evaporated and less water is either drained off into the lakes, Haor, Beel, ponds or flows back into the sea through the river system.

Different physicochemical and biological parameters are considered important regulator for water quality of wetlands. Phytoplankton communities are sensitive to changes in their environment and therefore their total biomass and species composition are used as indicators of water quality (Brettum and Andersen 2005). By monitoring water quality parameters, phytoplankton content and macrophytes, it is possible to prevent fish kill and to keep uninterrupted supply of water for domestic, agricultural and recreational purposes (Imhoff and Alberrecht, 1975).

The physical and chemical factors of the water body play a great role for aquatic

organisms where organisms are totally dependent on optimum water quality for the support of their life. Poor water quality can cause of massive death of living organisms. The term 'Water Quality' refers for the physical, chemical and biological parameters of water and all these characteristics directly or indirectly influences the survival and production of aquaculture species (Boyd 1998).

Under a definite physical set up, quality and quantity of phytoplankton are governed by concentration of nitrate, nitrite, ammonia, phosphorus (USEPA 2000) and silicate.

Macrophytes are macroscopic aquatic plants growing in or near water. They may be either emergent (i.e., with upright portions above the water surface), submerged or floating (EPA 2000). According to EPA (2000), depth, density and diversity of macrophytes serve as indicators for the so called health of wetlands. In shallow water bodies there exist a relationship between phytoplankton and submerged macrophytes. Ordination of phytoplankton species in wetlands with submerged macrophytes is best explained by environmental gradients of total nitrogen (TN), chlorophyll, pH and phosphorus (SRP) (Takamura *et al.*, 2003). Submerged macrophytes are considered to be suitable eutrophication indicators and are sensitive to local environmental conditions (Dennison *et al*. 1993).

Haors are bowl shaped depressions of considerable aerial extent lying between the natural levees of rivers or high lands of the north-east regions of Bangladesh (BHWDB, 2012). Haors have been considered as freshwater inland wetlands. There are two classes: (i) permanent i.e., *Beels* within the Haors and (ii) non-permanent or seasonal Haor (NWMP, 2004). Normally the Haors are full of water in the wet season and they dry up during winter. Howevr, their remains some deep pockets within the Haors that do not dry up even in the dry season. These deep points within the Haor are known as *Beels*, which have high aquacultural interests.At the end of monsoons, around August-September, the Haors are full with water attracting tourists from all over the country and abroad. In winter the Haor and Beels receive thousands of migratory birds. As summer sets in the Haors, most of the water has drained out but one can still see numerous *Beels* which act as sanctuary for mother fisheries.

In Bangladesh, the Haor ecosystems are situated in seven districts viz. Sunamganj, Kishoreganj, Netrokona, Sylhet, Habiganj, Maulavibazar and Brahamanbaria). Haors in Kishoregonj district is very much important in geo-physical, economic, social and cultural point of view (Kishoregonj district 1993). Among 13 Upazillas of this district, four (Itna,

Mithamoin, Austogram and Nikli) are fully and five (Tarail, Karimgonj, Bajitpur Kuliarchar and Bhairab) are partially bounded by haors. Their total number in the district is 85 with an area of 75000 ha (DAE 2003). The agricultural aspects of the district mainly rely on these unique water bodies (DAE 2010 and Khan *et al*. 2012). The geology, hydrology, soil characteristics, and socio-economic attributes of the Haor basin, also recognised as unique features from its adjacent hilly land (Uddin *et al*. 2013).

Islam and Paul (1978) reported the biodiversity from the Hakaluki Hoar of Moulvi Bazar district. Bhuiyan *et al*. (2019) conducted limnological study of Tanguar Haor of Sunamganj. But thereafter no study was carried out on the biodiversity of haors particularly in the district of Kishoreganj. Therefore, the present investigation has been aimed to study the Kuniar Haor of Itna, Kishoreganj with special reference to phytoplankton and macrophytes.

1.2 Study sites

The area of Kuniar Haor is about 37 ha and is interconnected with the River Dhonu. The catchment consists of 5 villages namely, Baribari, Shohila, Borohathi, Shimulbak and Mollapara under the Upazilla Itna, Kishoreganj. It is 20 km away from Kishoreganj district headquarter. About 500 years ago people started agriculture and other activities within the Haor (National web portal 2017, Bangladesh). Approximately 3000 people depend on this Haor for their livelihood. This is a permanent Haor and have taken oxbow shape. The wetland consist of an ancient deep large water body bearing little picks of dry lands in between it's levees. This natural excavation named as *beel* that formed by the result of leaching from the Meghaloy hilly areas and then the water falls into the Meghna, Norshunda and Dhonu river which flood the Kuniar Haor. The Haor remains waterlogged all the year round. During monsoon all of the segment of the Haor fully flooded with fresh water and the maximum depth recorded at that time is 4.2 m and average depth is 3.2 m. During winter the water column reduces and average depth comes to 1.5 m. The Haor is used as an ancient way of navigation from the prominent fish market Chamra Bondor to Itna thana headquarter, Itna government offices, Bazar and to other adjacent districts.

1.3 Wetland values of Kuniar Haor

The Kuniar Haor is a unique example of natural wetland found within the north-east biogeographic region of Bangladesh. It contains a large amount of indigenous plant and animal species creating the biological diversity of a particular region. It is a

productive wetland resource. It provides livelihood for three thousands of people through subsistence, agriculture, aquaculture, navigation, forestry, hunting grounds, natural fisheries, recreation, etc. The ideal condition for rice cultivation is a unique feature. Almost all segments of lands are used for rice cultivation. The aquatic vegetation grown here provides a rich grazing for domestic livestock. Different types of ducks, resident birds, cows, goats, horses were observed in the grazing fields. Species of herbs and macrophytes are a good sources of fuel and fertiliser by the local people. The Haor is rich in aquatic biodiversity particularly in diverse species of pelagic plankton, hydrophytes, flood tolerant plants and fishes.

The Haor areas are primarily subjected to deep monsoon flooding supporting rich fisheries while during drier winter yielding a bumper rice crop. The areas are full of aquatic flora and fauna which play important roles in the nature's economy. Besides this, people exploit the natural vegetation for domestic purposes as well as for producing commercial commodities. Conservation is one of the strategies to be undertaken for the reclamation of these natural resources of the haor areas. The results of the resent research will help to create a database regarding water quality relating aquatic macrophytes and phytoplankton diversity from the study area. Results will be useful in the contribution of documentation of different reported and unreported phytoplankton and macrophyte species and their characteristics in relation to water quality forecasting for water use by rural and urban dwellers and as well as for cultural purposes.

For ecosystem management, agricultural practices, economic activities and over all livelihood of the farmers of Haor area, the GoB has taken a number of national policies and plans for development and conservation of productive wetlands. Because Phytoplankton abundance and nutrient concentrations in shallow-water ecosystems are influenced by submerged macrophytes (Zimmer *et al*. 2003) and aquatic macrophytes are the important source of food, fodder, herbal medicine and domestic household materials for the people residing in its neighborhood (Dekha and Sarma 2014). As there is no artificial food provided, the phytoplankton and macrophytes in this Haor play an important role in the food chain. In this regard the Kuniar Haor is selected as a valued wetland.

1.4 Aims and objectives of the work

The research work has mainly focused on the hydrobiological factors of the Kuniar Haor to find out the importance and dynamism of phytoplankton and aquatic macrophytes. Additionally following aims have been targeted

- To identify the community characteristics of phytoplankton and aquatic macrophytes
- To find the composition of phytoplankton community in different pools of Kuniar Haor
- To find the seasonality of phytoplankton biomass as cell number and chlorophyll-a (chl-a)
- To study the relationship among the species composition of phytoplankton and aquatic macrophytes
- To study the relationships between the selected environmental variables such as air and water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), conductivity, alkalinity, soluble reactive phosphorus (SRP), soluble reactive silicate (SRS) and nitrate nitrogen (NO_3-N) with phytoplankton and aquatic macrophytes
- To determine the change of phytoplankton and aquatic macrophytes in the studied area during the time frame
- .To find the role of nutrients on the phytoplankton abundance
- To workout the qualitative aspects of phytoplankton and the seasonal fluctuations of its density
- To find the seasonality of phytoplankton biomass as chl-a and phaeopigment
- To analyze the interrelationships among the studied factors, by correlation studies
- Determine of phytoplankton quality, population density and grouping of different groups of phytoplankton via microscopic measurements
- To work out the diversities with qualitative aspects ofthe water communities of Kuniar Haor

1.5 Limitations

There were a little research gaps during this two years of field study as well as in laboratory works. The study area is a remote place of north-eastern region of Bangladesh. Due to the impertinent transportation system from my laboratory to the study site was a laborious journey. All sampling could not be done at the same time of the different sampling day. During wet season it was easy to carry out the sampling water and macrophytes by a motor launch but in dry season it was a laborious and difficult matter. Flooding and over flooding during full monsoon has made a formidable condition of the site which was a barrier to collect samples. The inundation time of the land varied between the two years period. For this reason all the short lived macrophytes were unable to be collected. Lack of previous limnological research on Haor ecosystem was a big limitation for the comparison with the current research work. For this reason the study has been carried out mostly by primary data. Few secondary data has been collected from the department of fisheries and land of the Government of the peoples Republic of Bangladesh and national site of information. The portable device were available for research and laboratory were well equipped. In some apparatus a few instrumental errors were observed. However this problem has been solved by measuring replicate determination of the same sample.

LITERATURE REVIEW

2.1 Hydrobiological and limnological research in Bangladesh (1966-2019)

The pioneer research done by a skilled Phycological Research Group of the Department of Botany, Dhaka University, under the guidance of Professor A.K.M. Nurul Islam. Islam and Khatun (1966) published the first limnological study in Bangladesh dealing with organically-polluted ponds in and around Dhaka University campus. In particular, they recorded the conditions under which blooms in the ponds. Other investigations carried out around the same period included the use of algal flora to characterise Lake Rainkhyongkine as a semi-hard water body in the late oligotrophic stage (Islam 1969b). Islam and Begum (1970) recorded 110 species of phytoplankton (mainly Chlorococcales) from Dhaka District and made some observations on seasonal changes in water temperature and pH.

Islam *et al*. (1974) carried out the first limnological research on the river Buriganga near Dhaka where the physicochemical factors of the river along with their seasonal dynamics were shown. Islam and Zaman (1975) described the desmids population and some green algal phytoplankton from the river Buriganga. The diatom population and zooplankton from the same river were described later on by Islam and Haroon (1975). Islam and Saha (1975) worked on Ramna Lake in Dhaka city. Islam and Paul (1978) studied the macrophytic flora and phytoplankton from the Haor Hakaluki of Moulvi Bazar district of Bangladesh. Islam *et al*. (1979) carried out a hydrobiological study on Dhanmondi lake where a handful number of desmid population and aquatic macrophytes were reported. Mahmood (1986) studied the largest man-made lake Kaptai Lake and recorded the primary productivity of phytoplankton 2.39 g O_2/m^2/day.

Since the publication of chemical data on Dhanmondi lake of Dhaka Metropolis by the Bangladesh Water Pollution Control Board (1975), very few studies of this kind was undertaken. Later on, Islam and Chowdhury (1979) have studied the phytoplankton and macrophytes qualitatively with notes on physicochemical characteristics of the lake. Khondker *et al*. (1988) reported a short term assessment of phytoplankton production and some physicochemical factors related to it. This study forecasted that the input of sewage material in Dhanmondi lake is affecting the productivity by reducing light penetration, putting stress on dissolved O_2 and might be producing a toxicity of CO_2 to photosynthetic organisms. Khondker and Parveen (1992) studied the species composition, standing crop

and seasonality of phytoplankton in the same lake and confirmed that Dhanmondi lake shows hypertrophicity. They saw that the bottom of the lake was anaerobic with high concentration of dissolved phosphorus. However, dilution caused by monsoonal rainwater improved the situation to some extent when a decrease in the mean values of some key elements was observed.

Islam *et al.* (2015) carried out to recognize the position of water quality of the Ramna, Crescent and Hatirjheel lakes in the Dhaka metropolitan area. The relative study established that the concentration of BOD, EC, TDS, alkalinity and acidity of Hatirjheel Lake was greater than Ramna and Crescent lakes which indicate pollution of the lake water. Poor water quality of these lakes disturbs the ecosystem and aesthetic beauty adversely.

Razzak *et al.* (2013) studied the evaluation of the variation in water quality parameters in two distinct seasons. To explore the sources and reasons of pollution, the whole area in and around the lake was preliminarily measured. pH of all the samples of Gulshan and Ramna lake was within the ECR Standard in both spring and winter.In Gulshan lake's samples, there were found more turbid and colored in spring than winter. Iron in water samples was within the range where 5 days BOD was found higher in both lakes. In 2012, Singh reported that the rapid urbanization together with encroachment, leading to the loss of catchments of surface water bodies and problems of siltation, pollution, which includes domestic, industrial and agricultural waste including eutrophication are the major problems of the world to protect and control water resources.

According to Mohuya (2010) Gulshan-Baridhara Lake was declared as an Ecologically Critical Area (ECA) in 2001 and to save the lake's water from becoming polluted further and to stop encroachment. Previous study revealed that among the heavy metals only Pb concentration exceeded the standard level during the monsoon, otherwise concentrations of all other four heavy metal (Cd, Cr, Cu and Ni) exceeded the standard level of drinking, fishing and surface water as set up by WHO, GoB, USEPA, DoE and FWPCA, for the summer period.

A useful research is conducted by Peeters and Shannon (2011) which analytically investigates the layered meanings of water in the city through aiming at the case study of Hatirjheel Lake, Dhaka's major inner-city water body. Another potential protection tool is the 1995 Master Plan for Dhaka, which is named the DMDP (Dhaka Metropolitan Development Plan 1995-2015). The structure plan, one of the three phases of DMDP, recognizes that river and floodplains are important for both ecology and economy of the

capital region (RAJUK, 1995a). The Master Plan also foresees holding reservoirs for storm water. According to specialists, there is evidently a deficit of such reservoirs that lag far behind the actual situation on the ground.

An algological report on Lake Rainkyhongkine was published by Islam and Uddin in 1969. In recent times, Khondker *et al.* (2010) carried out a limnology of Lake Bogakain. Alfasane *et al.* (2012) examined the water quality with the phytoplankton and macrophyte flora of Lake Ashura. In one study, Khondker *et al.* (2010) identified the ratio as a percentage of the total verified species of Cyanophyceae, Chlorophyceae and Cryptophyceae was lesser in Lake Ashura than Lake Bogakain. It was documented that species of Euglenophyceae in Bogakain were lower wherever diversity was peak in Lake Ashura. Members of Dinophyceae were absent in Lake Ashura where as two members of Dinophyceae were present in the Bogakain Lake (Khondker *et al.* 2010). From the hydrobiological viewpoint, the two studied lakes from the extreme parts of Bangladesh showed a similarity on total taxa (Lake Ashura, 35 taxa; Bogakain, 39 taxa) of phytoplankton. On the other hand, Khondker *et al.* (2010) and Alfasane *et al.* (2010) stated that Bogakain lake occupied a few members of macrophytes like *Nymphaea nouchali*, *Egeria densa*, *Potamogeton crispus* and *Polygonum* sp. Qualitatively, phytoplankton flora of Lake Ashura were found to be dominated by euglenoid algae whereas in Lake Bogakain green algae were predominant.

Ahmad *et al.* (2015) recounted that macrophytes use light energy, water and carbon dioxide to synthesise carbohydrates and discharge oxygen into the aquatic environment during photosynthesis, which is used by the biota of the similar aquatic ecosystem. Further, these plants can adjust water temperatures and existing oxygen in water, thus ultimately influencing growth and survival of fish. Besides, providing food and habitat to fish, wildlife and other aquatic organisms, macrophytes stabilize sediments, expand water transparency and enhance diversity in the shallow areas of lakes.

Macrophytes are the main exploiters of the nutrients from the sediments, which then are misplaced temporarily from the water. These nutrients are released only after death and decay of macrophytes and subsequent mineralization. Thus, the role of macrophytes in nutrient dynamics and primary efficiency of shallow aquatic ecosystems is far more important than one can imagine.

2.2 Master Plan of Haor Areas, BHWDB, 2012

"Master Plan of Haor Areas" has been prepared by the Bangladesh Haor and Wetland Development Board (BHWDB), now renamed Department of Bangladesh Haor and Wetlands Development (DBHWD), during April 2012. The BHWDB engaged the Center for Environmental and Geographic Information Services (CEGIS), a Public Trust under the Ministry of Water Resources (MoWR) for preparing the Plan.

Haors are large bowl shaped floodplain depressions located in the north-eastern region of Bangladesh, in the districts of Sunamganj, Habiganj, Netrakona, Kishoreganj, Sylhet, Maulvibazar and Brahmanbaria. There are about 373 Haors that covers an area of about 858,000 ha and covers nearly 43% of the total area of the Haor region (1.99 million ha). Haors have a unique hydrological regime which creates opportunities as well as sufferings/constraints for the inhabitants of the Haor region. Annual rainfall ranges from 2200-5800 mm and can be as high as 12000 mm. Flash flood is the main disaster in this region that is caused by excess rainfall in the upstream hilly areas and subsequent runoff and sedimentation in the rivers.

The Haor region lies in the Meghna basin which is one of the largest Ganges-Brahmaputra- Meghna (GBM) basins. The total inflow in the haor area comes from India and along with the storm water runoff drains out through Meghna River at Bhairab Bazar. The rivers of the haor region are characterized by a natural alluvial system and are unstable by nature. The area becomes inundated during monsoon and sometimes in pre-monsoon by flash flood. Inflow from India is the main cause of flash flood in the Haor region.

Floods are the characteristic of the entire river system of the North East region. Embankments are utilized for flood protection in this region. Wetland condition ranges from perennial aquatic lowlands to seasonally dry uplands. A variety of natural forest can be found in the Haor districts like hill forests, fresh water swamps, reed swap forests, cane and murta forest, bamboo and homestead vegetation etc. The biodiversity of haor wetlands is very rich. Water is central to the fragile ecosystem of the haor area.

The most significant Haors of Bangladesh are Hakaluki, Hail, Tanguar, Matian, Pasuar Beel, Dekar, Baro, Gurmar, Sonamorol, Baram, Kalni, Kawadighi and Pagner. These wetlands have a rich wildlife community including 257 species of birds, 40 species of reptiles, 29 species of mammal and 9 species of amphibians. The haor region comprises a wide variety of fin fish including 143 indigenous and 12 exotic species along with several species of freshwater prawns. The estimated fish habitat area in the haor region is about 967,000 ha. Most of the important haorareas are also enriched by wetland plants through lowland plantation.

The geological setting and formations of the northeastern part of Bangladesh favors the deposit of various types of mineral and energy resources. Mineral resources found in the Haor region are coal, crude oil, glass sand, gravel, lime stone, natural gas, peat, white clay. About 90% of the total gas production of the country is obtained from the Haor districts. A whole range of problems and issues of Haors and wetlands have been identified and solutions to these problems have been derived considering individual, cross cutting and technical issues as well as the demand of the stakeholders. The main water related problems are flash flood, drainage congestion due to sedimentation and loss of connectivity between haor and rivers, river bank and wave erosion and poor navigability. The basin is under threat of encroachment by agriculture, deforestation and capture fisheries. The main purpose of the plan is to safeguard the water resources and to preserve the natural characteristics of the whole basin with special attention to ecologically important areas. Different national policies and strategies have been thoroughly reviewed to set the main policy directives for the development of the Haor Master Plan. The National Water Policy explicitly mentions the development of the haor area considering its preservation of ecosystem.

The comprehensive Master Plan aims to preserve, protect and restore the ecosystem as well as protect the people of this area from natural disasters and improve the livelihood of poor people. The Master Plan is a framework plan that is in line with the Vision 2021, Sixth Five Year Plan and other relevant policies and plans of the Government of Bangladesh. It is a 20- year plan formulated following the principles of the Integrated Water Resource Management (IWRM). The objectives are to develop the resources of the haor Region as rapidly as possible, to improve the overall quality of life of its inhabitants, maintaining and conserving the Haor ecosystem.

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2.3 Miscellaneous studies on freshwater wetland ecosystems.

Vilbaste and Truu (2003) studied the distribution of benthic diatoms in relation to environmental variables in lowland streams in Estonia and found that the trophic level of water plays a significant role governing the structure of benthic diatom assemblages. They also reported temporal variability in the structure and function of phytoplankton community and fundamental importance to aquatic metabolism system. According to Rooney and Kalff (2003) the existence of extensive submerged macrophyte beds has a harmful effect on phytoplankton biomass, and submerged macrophytes influence bacterioplankton metabolism directly through the supply of dissolved organic carbon to

the epilimnion and indirectly by suppressing phytoplankton biomass.

Moschini-Carlos *et al.* (2001) revealed that the biomass and productivity of the plankton community are organized by the fluctuations of water level. They indicated that the epiphytic algae are essential autotrophic organisms in the aquatic ecosystem. Analysis of primary productivity that exposed an important parameter to assess the Ecology of freshwater bodies in general.

Owen *et al.* (2004) stated that pH, conductivity, temperature and nitrates act to be closely related to diatom growth. Halvorsen (2004) investigated some physical and chemical characteristics of Lake Atnsjoen, Norway. According to Ojha and Mandloi (2004) pH increases in water bodies from morning onwards and decline during the evening as temperature decreases. They also noticed that turbidity; suspended matters, clay, silt, colloidal organic particles, plankton and other microbes are an expression of light scattering and absorbing properties of water. Radhika *et al.* (2004) reported that water temperature is of enormous significance as it regulates various abiotic as well as biotic activities of an aquatic system. This perusal of literature on ecological investigations of water bodies showed that long-term monitoring and comprehensive analysis of the physicochemical parameters is crucial to a holistic approach in solving environmental problems of such systems.

Bircks *et al.* (1990) studied the diatoms and pH restoration. Vincent (1992) found that nitrogen uptake in plankton is stimulated by light. Egge and Aksnes (1992) studied silicate as a regulating nutrient in phytoplankton competition. Hornstorm *et al.* (1993) examined plankton and chemical, physical development in 6 Swedish west-coast lakes in acidic and limed conditions. Kitano *et al.* (1997) made a study of algae tolerant of pH values up to 10. Prins *et al.* (1999) reported that the level of the spring phytoplankton bloom in certain aquatic ecosystems is determined by phosphorus loading, whereas in summer the nitrogen loading determines phytoplankton biomass. According to them a variance in nutrient loading did not result in shifts in phytoplankton biomass in all nutrient treatments. Vestergaard and Sand-Jensen (2000) stated that alkalinity and trophic state regulate the aquatic plant distribution in Danish lakes. Murugavel and Pandian (2000) recorded that a reduction in temperature improves solubility of oxygen in water. Klug *et al.* (2000) investigated the compensatory dynamics in plankton community responses to pH perturbations. Carvalho *et al.* (2002) investigated the physicochemical conditions for supporting different levels of the biological quality of fresh water. Adak *et al.* (2002) reported that different physicochemical parameters of water are significant for effective

maintenance of water quality through proper control. According to Sedamkar and Angadi (2003) a low DO is an indication of organic pollution, and they saw a high percentage of Chlorococcales in waters having high dissolved oxygen. They also reported that Chlorococcales increase well in water rich in nitrates than P. According to the report by Rooney and Kalff (2003) phosphorus, phytoplankton and heterotrophic bacteria interact in the epilimnion of lakes to regulate the flow of energy and the biogeochemical pathways at the base of pelagic food webs, and macrophytes thrive well in lakes having phytoplankton concentrations even at high phosphorus concentrations. There is an interaction between phytoplankton and phosphorus that is dependent on macrophytes cover. According to Vilbaste and Truu (2003) the phytoplankton *Eunotia bilunaris* is known to be common in streams with lower pH.

From the above mentioned presentation it is clear that the physicochemical conditions of water effects the qualitative and the quantitative pattern of aquatic organisms as well as their seasonal dynamics. In some case special community may be created to support migratory species and thus provides a valuable information on the community ecology of the aquatic habitats (Khondker *et al*. 2010). Above all, the structure and function of pelagic grazing food chain and the resultant subsequent food webs in the haor ecosystem deserves much research attention because the whole secondary productivity including the fish yield is dependent upon it.

MATERIALS AND METHODS

The present research work was carried out in three stations of Kunia Haor, Upazilla Itna, District Kishoreganj, Bangladesh. A total of 76 water and biological samples were collected from the *Haor* basin in between February 2016 and January 2018. The sampling activity was done one time in each month covering the study period.

Geomorphological and meteorological condition

The area of Kuniar Haor is about 37 ha and is interconnected with the River Dhonu. The catchment consists of 5 villages namely, Baribari, Shohila, Borohathi, Shimulbak and Mollapara. It is 20 km away from the district headquarter of Kishoreganj. The study site is located in a peripheral region of Bangladesh (Fig. 1). About 500 years ago people started agriculture and other activities within the Haor. Approximately 3000 people depend on this Haor for their livelihood. The Haor is perennial and oxbow shaped.

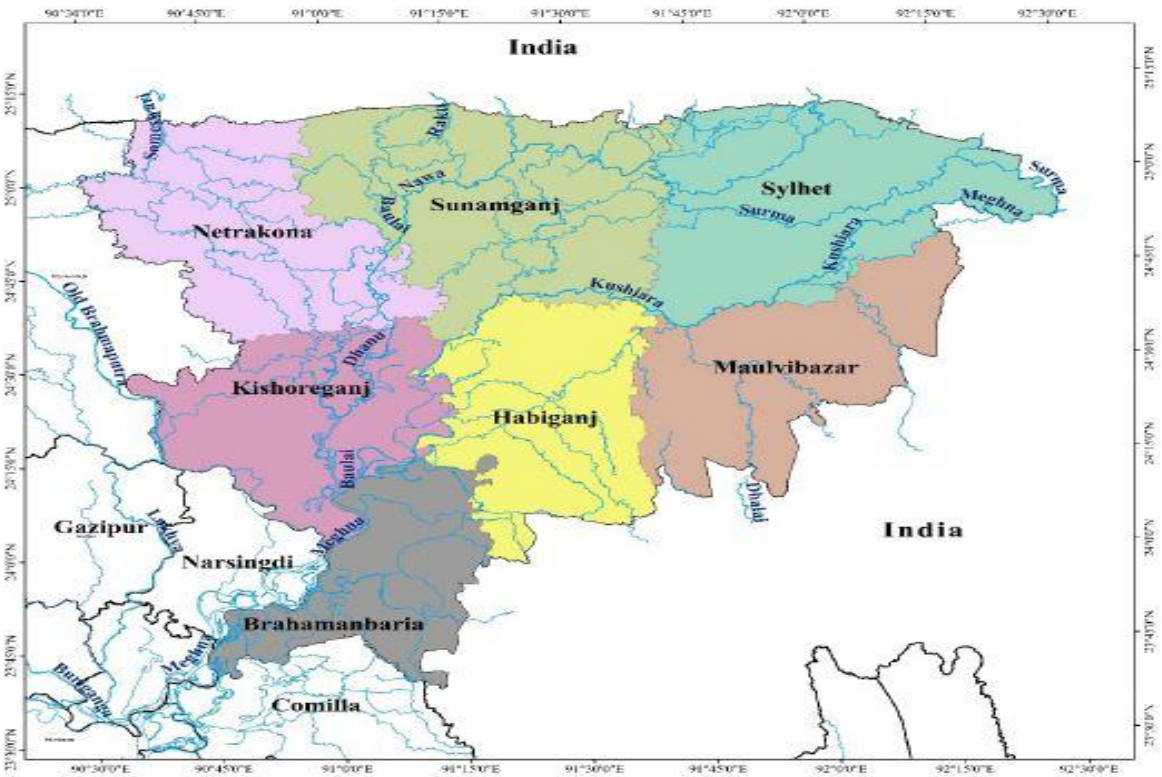


Fig. 1. The geographical locations of Haor districts of Bangladesh (Source: Directorate of National survey, Bangladesh)

Name and description of the sampling stations

Station 1

It is situated at the entrance, on the right side of the sluice gate of the interconnected river of the Haor named Dhonu. Except winter, this area experiences hydraulic pressure and the effects of tide and wave because the water of Dhonu enters when overflows at a certain level. This area is rich with phytoplankton, particularly with the population of diatom but with scanty vegetation of macrophytes. The GPS location of this sampling site is 24° 29' 58.72 " N, 91° 00' 55.28 E with an altitude of 7 m MSL.

Station 2

Its location can be viewed from the middle portion and southern side of the Haor. This site is the deepest portion of the Haor and it is nearly 1200 m away from the switch gate area. During the monsoon period a maximum depth 4.2 m is observed here.

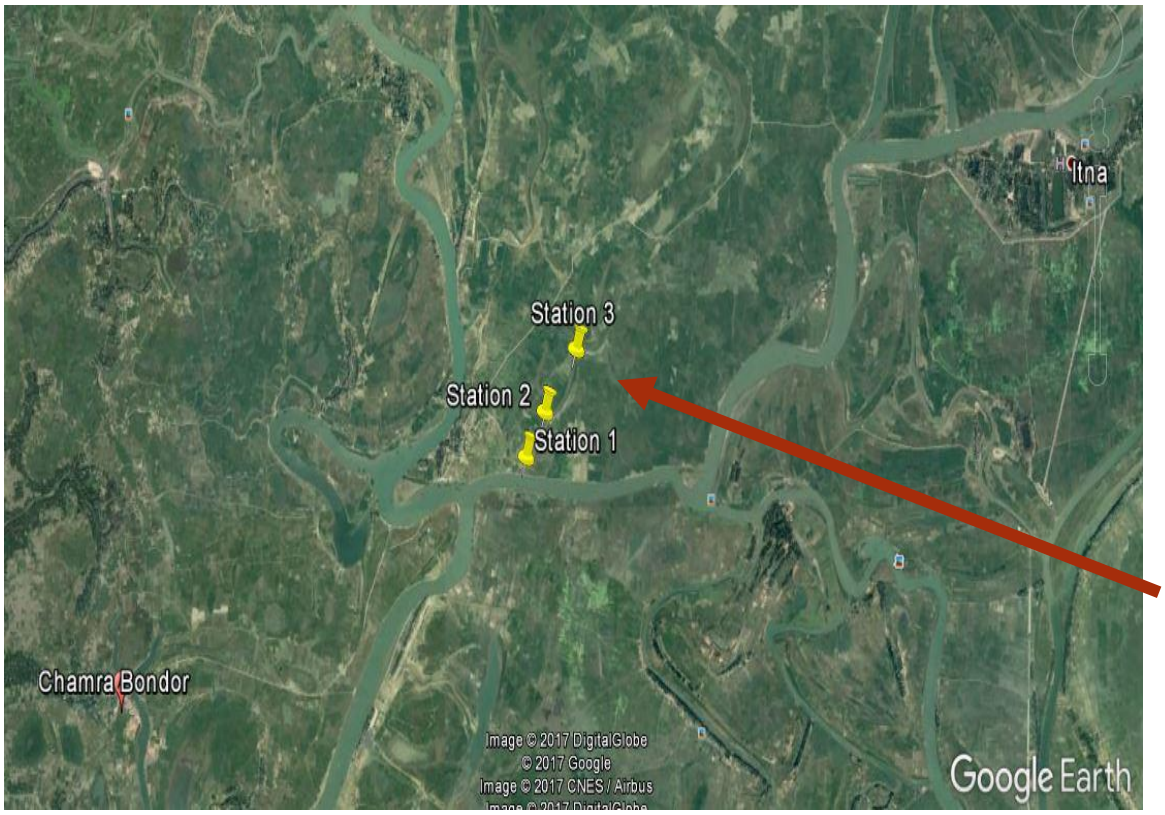
The Latitude and longitude of this sampling site is 24° 30' 13.28 N, 91° 01' 5.18 E respectively, altitude 5 m, above MSL.

Station 3

The site is near Shohilahati village which is 1300 m away from sampling station - 2. Abundance of natural well fisheries is a unique feature of this site and it is surrounded by many exotic and indigenous angiospermic plants.

The GPS location of this sampling site is 24° 30' 33.43 N, 91° 01' 21.61 E, altitude 7 m, above MSL.

(A)



(B)

Fig. 2 (A-B). Location of Study sites of Kuniar Haor. (A) Location by National survey map. (B) The sampling stations by Google Earth.

Sampling station 1

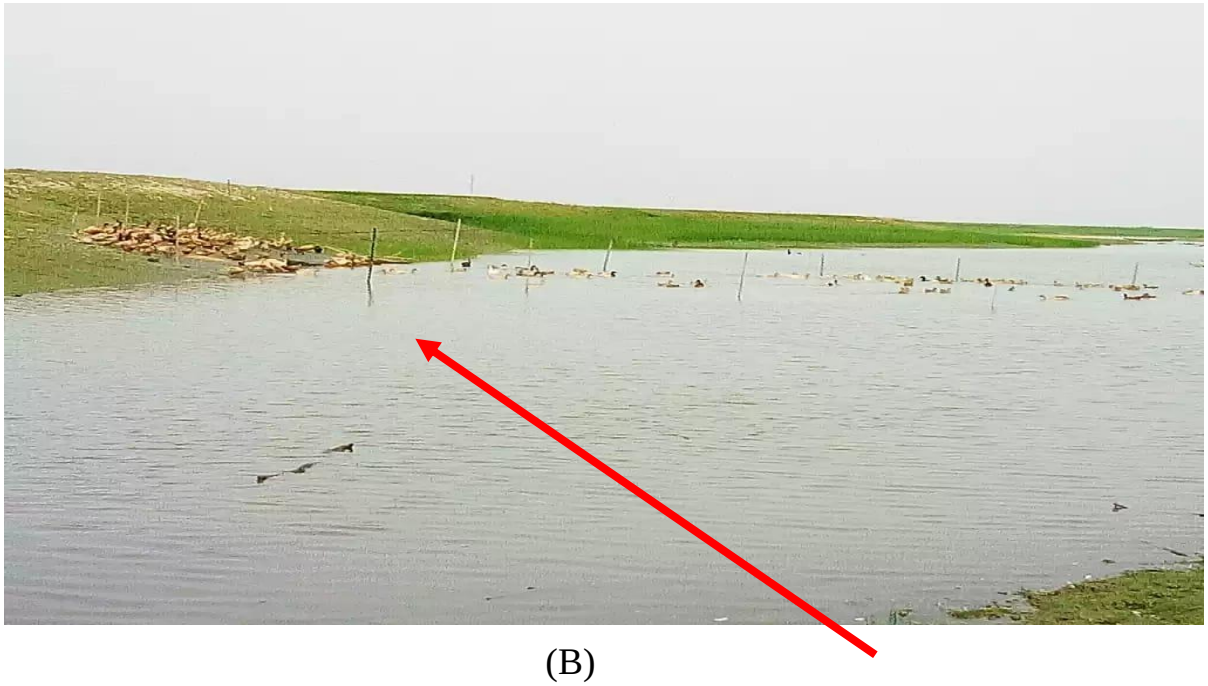
(A)

(B)

Fig. 3 (A-B). Showing the sampling station -1, (A) aerial view during flooding season, (B), the same in dry seasons.

Sampling station 2

(A)

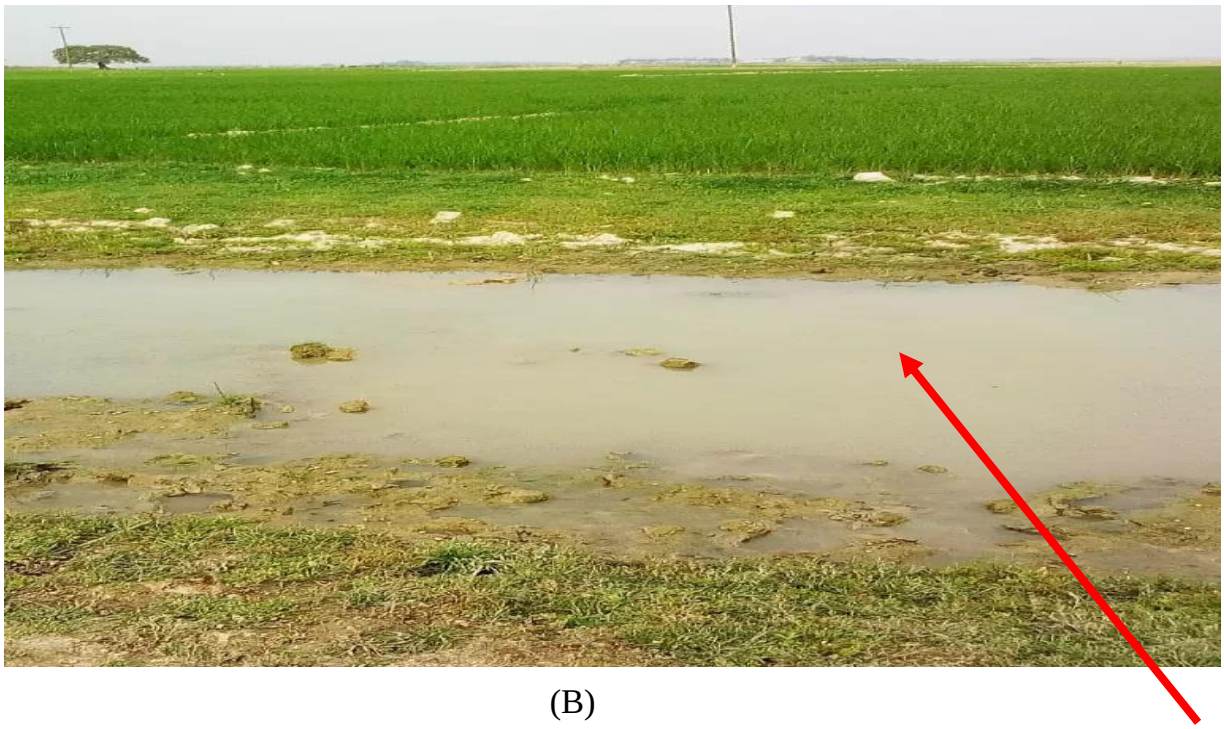


(B)

Fig. 4 (A-B). Showing the sampling station -2, (A) aerial view during flooding season, (B), the same in dry seasons.

Sampling station 3

(A)



(B)

Fig. 5 (A-B) Showing the sampling station -3, (A) aerial view during flooding season, (B) the same in dry seasons.

In situ sample collection

For collecting samples, field visits were made monthly between 2016 and 2018. Wthin a 3 km transect along the surface of the Haor 3 permanent sampling stations were fixed and on each occasion samples were collected within 10.30 a.m. - 3.00 p.m. An integrated water sample from 50 cm depth was collected each time by a Schindler-Patalas Sampler (5 l capacity) from all the 3 study stations of Kuniar Hair. At first the sampler was dipped slowly under water to 50 cm depth and then closed by applying a jerking pull from the above. After confirming the closure of the sampler, it was taken out and the water was decanted in a black plastic carboy (5 l capacity). The carboy was transported to the laboratory for further analysis of the water sample.

In situ measurements on air temperature, water temperature, conductivity, total dissolved solids (TDS), pH, and dissolved oxygen (DO) were performed using respective field meters (HANNA Instruments HI 9033, 9044). Other parameters namely, chl *a*, soluble reactive phosphorus (SRP), soluble reactive silicate (SRS) and alkalinity were determined on the same day in the laboratory (Marker *et al.* 1980, Murphy and Riley 1962, Wetzel and Likens 1979, Müller and Wiedemann 1955. However, an overnight digestion of samples for nitrate nitrogen (NO_3-N) analysis (Müller and Wiedemann 1955) was carried out.

Macrophyte collection, identification and enumeration

Concentrated samples of phytoplankton were obtained via sedimentation technique using Lugol's iodine from all the 3 studied stations of Kuniar Haor. Phytoplankton cell number was counted using a Hawksley microplankton counting chamber with the improved Neubauer Ruling (Hawksley Ltd., Lancing, England) under a Nikon compound microscope (Japan) at a magnification of 40×10. Phytoplankton were identified using standard literatures (Smith 1950, Skuja 1956, Desikachary 1959, Starmach 1966, Islam and Begum 1970, Islam and Khondker 1981, Germain 1981, Prescott 1982, Huber-Pestalozzi 1955, 1961, 1968, 1983; Dillard 1989, Yamagishi 1998, Ling and Tyler 2000, Islam and Alfasane 2002, 2004; Siddiqui *et al.* 2007, Begum, 2008, 2009; Ahmed *et al.* 2008, 2009 and Khondker *et al.* 2007, 2008, 2009).

Macrophyte samples from all the stations were collected during the field trips. After bringing those in the laboratory, the samples of macrophytes were washed with tap water cleaned and screened. From the collection of macrophytes herbarium sheets were

prepared and the taxa were identified with the help of Khondker *et al*. (2010), Alfasane *et al*. (2010), Fasset (1957), Cook (1990), Khan and Halim (1987) and Adoni (1985). After having preliminary knowledge of macrophytes present, quantified samples were collected using 1 × 1 m quadrate and average abundance was expressed as number of ind/m^2.

Sample transport from the field to the laboratory and measurements

All the collected samples were carefully transported to the laboratory within one hour of collection. All the chemical and biological analyses of water samples were carried out in the National Professor AKM Nurul Islam Laboratory, Department of Botany, University of Dhaka. Analysis of different parameters began immediately after reaching laboratory and were completed next day morning.

Sedimentation of phytoplankton sample

In a plastic bottle of 1 liter capacity, sample water from Station-1, Station-2 and Station-3 were separately poured and fixed with Lugol's iodine solution and kept undisturbed in the dark for at least 48 h in order to facilitate sedimentation. The phytoplankton cell number was counted using a Hawksley microplankton counting chamber with the improved Neubauer Ruling (Hawksley Ltd., Lancing, UK) under a Nikon student's microscope.

Laboratory processings

In the laboratory, filtration of water sample for chemical analysis was carried out. A vacuum pump fitted to a Sartorius-Membrane Filter Holder (Gmbh, Göttingen, FRG) was used for the purpose. The water sample was shaken gently and then 250 ml of water was measured with the help of a graduated measuring cylinder and poured into the cup of the Sartorius device. Whatman GF/F 4.7 cm circles were used by the device to filter the water. After filtration the filter paper was rolled up with the help of a Millipore pincet and put into a screw capped Pyrex glass tube of 10 ml capacity. This sample was used for the determination of phytoplankton biomass as chl-*a* and phaeopigment. The filtrate of each sample was transferred to an acid washed, clean screw capped polystyrene bottles (500 ml capacity) for the analysis of nitrate-nitrogen (NO_3-N), soluble reactive phosphorus (SRP) and soluble reactivate silicate (SRS). Unfiltered water samples were used for measuring pH, alkalinity, conductivity, DO (sample water was fixed in the field

by adding each of manganous suflate solutions and Winklers reagent) and TDS. All analysis was completed within the next 24 h.

Methodology applied in the measurements of physicochemical parameters

All the limnological and biological analysis made in the present investigation was followed by standard procedures. A brief description of the procedure for each determination together with the citation of the methodology followed has been presented in Table 1.

Table 1. Methodology, equipment's, unit measurement and relevant references used for vrious limnological parameters.

Parameter	Method	Unit	Equipment
AT	Gallenkamp, UK	°C	alcoholic thermometer
WT	Gallenkamp, UK	°C	alcoholic thermometer
Sec. dept.	Nil	cm	20 cm diameter crosswise-painted black and white Secchi disc
Alk.	Titration method (Mackereth *et al.* 1978)	meq/l	Jencons Digitrate, UK
pH	Griffin pH meter	Nil	PHJ-260-V-pH-meter, Model 50, UK
Cond.	Conductivity meter (Golterman *et al.* 1978)	µS/cm	Hanna instruments HI9033W, UOM EA, D/N 048053, URN 315625Y, S/N: 1414153, Singapore
TDS	TDS meter	mg/l	Hanna instrument HI9034W, UOM EA, D/N 413377, URN 330067T, S/N: 1391748, Singapore
DO	Winkler's titration method (Wetzel and Linkens, 1979)	mg/l	
SRP	Spectrophotometric method (Murphy and Riley, 1962)	µg/l	Spectrophotometer Shimadzu UV-0120-01, Japan

Table Contd.

SRS	Spectrophotometric method (Wetzel and Linkens, 1979)	mg/l	-ditto-
NO_3-N	Spectrophotometric method (Müller and Wiedemann, 1955)	mg/l	-ditto-
chl-a	Marker *et al.* 1980	µg/l	-ditto-
Pp	Marker *et al.* 1980	µg/l	-ditto-
PD	Vollenweider (1969)	Indl./l	Nikon microscope, using Hawksleys counting chamber (Lansing, UK)

A brief description of each measurements

Physical parameters

Air temperature

Measurement of the air temperature was done with the help of an alcoholic thermometer (Gallenkamp UK) graduated from 0-40°C. At first the thermometer was held by hand keeping the bulb of the thermometer in the upward direction. Then the hand was rotated in the air slowly for a minute and the reading of the temperature was recorded. The procedure was repeated thrice and a mean value was calculated in °C.

Water temperature

The water temperature was recorded with the help of the thermometer housed in the Schinder-Patalas sampler. During the *in situ* measurement of parameters in the field, the value of water temperature was read directly from the sampler as soon as it was taken out of water.

Secchi depth

A 20 cm diameter crosswise-painted black and white Secchi disc tied at the end of a graduated rope was used to measure the depth of visibility. The disc was hanged vertically by holding the rope and then slowly dipped into water. By looking at the painted surface of the disc, the depth of its disappearance and reappearance was noted. Mean value of these two depths was recorded as the Secchi depth in cm.

Chemical parameters

Alkalinity

50 ml of unfiltered water sample was measured with the help of a measuring cylinder and transferred to a conical flask (Jena Schott, Germany, 250 ml capacity).Then two drops of mixed indicator were added to the sample, the color turned light green. The flask was put on a magnetic stirrer device and was titrated by adding standardized 0.1 N HCL from a 50 ml capacity glass burette until the color first disappeared to light yellow.With the help of the volume of acid consumed in the titration the alkalinity was calculated after Mackereth *et al.* (1978).

Hydrogen ion concentration (pH)

The pH was determined with the help of a Griffin pH meter (PHJ-260-V-pH-meter, Model 50, UK). A portion of the sample water was directly poured into a 100 ml beaker. The electrode of the meter was dipped into it with gentle stirring. The pH value of the sample water was read directly from the digital display. The pH meter was checked each time with standard buffer before the measurement.

Total dissolved solids (TDS)

In a 100 ml capacity measuring cylinder 90 ml of sample water was taken. Then the electrode of the TDS meter (Hanna instrument HI9034W, UOM EA, D/N 413377, URN 330067T, S/N: 1391748, Singapore) was dipped into it up to the mark indicated on the electrode. After holding the electrode in a definite depth for about one minute the reading was taken from the digital meter display.

Conductivity

90 ml of unfiltered sample water was measured with the help of a measuring cylinder (100 ml capacity). A conductivity meter (Hanna instruments HI9033W, UOM EA, D/N 048053, URN 315625Y, S/N: 1414153, Singapore) was used to measure the conductivity of water. Electrode of the meter was cleaned with distilled water and dried with tissue paper. The scale indicator button was pushed for a probability value. Starting the meter the second knob was fixed at 20°C. The electrode was then put into the sample water slowly. A gentle stirring of electrode show movement of the meter scale. Conductivity was then measured by keeping the electrode fixed in the sample water (Golterman *et al.*1978).

Dissolved oxygen (DO)

Winkler's titration method (Wetzel and Likens 1979) has been employed for the determination of dissolved oxygen of water. For the purpose at each time of sampling duplicate 120 ml capacity Pyrex transparent glass stoppered BOD bottle was used. After collecting the surface water of the culturing habitat with the help of Schinderl's sampler the bottles were gently filled with water. Then one ml of each of manganese sulfate and the alkaline iodide solution were successively added to the bottle containing sample water with the help of a one ml syringe. The bottles were then shaken to mix the reagent properly. Brown colored precipitation appeared. The bottles were dipped under water until those were transported and analyzed for DO in the laboratory.

Soluble reactive phosphorus (SRP)

SRP determination has been followed after Murphy and Riley (1962). The dilution factor ranged from 2 to 10. Considering the dilution factor accurately measured sample was poured in acid washed 100ml capacity Pyrex conical flasks. Then required amount of distilled water was added to each sample to make the volume 50 ml. 5 ml mixed reagents (a mixture of 15 ml ammonium molybdate,37.5 ml H_2SO_4,15 ml freshly prepared ascorbic acid and 7.5 ml potassium antimonyl tartrate) was dispensed in each flask.The solution of the flask was mixed properly and after 5 to 10 minutes blue color developed, then the extinctions were measured using 885 nm wave length with the help of 4 cm path length quartz cuvettes by using a Spectrophotometer (Shimadzu UV-0120-01 Japan).

Soluble reactive silicate (SRS)

The determination of soluble reactive silicate was followed after Wetzel and Likens (1979). The dilution factor ranged from 2 to 5. Considering the dilution factor accurately measured sample was poured in acid washed Pyrex conical flask so f100mlcapacityeach used to determine SRS. Sequentially 5 ml 0.25N HCL, 5 ml of 5% ammoniummolybdate and 5 ml 1% disodium EDTA added to it. The sample was mixed properly and kept undisturbed for the next five minutes. Then 10 ml of 17% sodium sulfate was added to each flask. Blue color developed according to the concentration of SRS in the sample. A reagent blank and standard series of silica was also treated in the same manner. Sub- samples from each of these were measured in a Schimadzu spectrophotometer (UV-120-02) at a wavelength of 700 nm using a 1cm path length quartz glass cuvette. Finally the values were calculated by regression analysis with the help of standard series.

Nitrate-nitrogen (NO_3-N)

The concentration of NO_3-N in the filtered sample water was determined following the method of Müller and Wiedemann (1955). To a 25 ml sample water in a 100 ml capacity Pyrex conical flask 1 ml of 5% sodium salicylate was added and digested over night to dry in an oven (Eyela, Model-NDS-450D, Japan) set at 100°C temperature. In the next morning the residue in the flask was dissolved by adding 1ml concentrated H_2SO_4 and then added 50 ml distilled water and 7 ml sodium-potassium-tartrate solution. Light yellow color developed according to the concentration of nitrate nitrogen present in the sample. The sample volume was adjusted to 100 ml by adding distilled water and then the sub- samples were measured in a Spectrophotometer (Schimadzu UV-120-02) using 1 cm path length quartz glass cuvette at a wave length of 420 nm. A distilled water plus reagent blank and a series of NO_3-N standards were also treated in the same manner in each batch. The values of NO_3-N were calculated by regression analysis later on with the help of standard series.

Biological parameters.

Chlorophyll-a (chl-a) and phaeopigment

Pigment extraction was done from the fresh cells of phytoplankton trapped onto the filter paper during filtration of water samples. The method of extraction was as follows: Test tube containing rolled filter paper was treated with 5ml hot 90% ethanol (kept boiling at 75°C in a water bath, model Eyela, Thermopet NTT-211, Japan). Then the test tube containing filter paper dipped in ethanol was given a hot and cold treatment by putting it firstly in the hot water bath for three minutes and then cooling in tap water carefully. After cooling, the pigment was extracted (1st) and was transferred to another glass tube while the filter paper was given second extraction treatment in the same manner as mentioned above.The extracted pigment solutions (1^{st} and 2^{nd}) were poured into a measuring cylinder to make it 10 ml by adding extra 90% alcohol if necessary. Then the pigment samples were taken in1cm path length quartz glass cuvette and optical density (OD) was measured in a spectrophotometer at wave length 665 nm and 750 nm against 90% ethanol as blank. The acidification was done by adding in 3.7 µl HCL in each cuvette (for a volume c 3.7 ml). Finally the concentration of chlorophyll-*a* and phaeopigment were calculated after Marker *et al.*(1980).

Enumeration of phytoplankton

Enumeration of phytoplankton was done under a compound microscope (Nikon SE) at a magnification of 10 × 40 with the help of the Hilbert Bacteria Counting Cell (Single round, Hawksly, UK). Helber microplankton Counting Cell can be easily manipulated in counting phytoplankton and it provides reasonably reproducible data at higher magnification which is not possible by Sedgewick Rafter Counting Cell (SRCC). The Counting Cell looks just like a glass slide and is 50 mm long, 20 mm wide and 1 mm thick. A microscopic circular counting chamber with engraved grids at the center of the slide surface. The total volume of the chamber is 1.005 µl. The counting was carried out by putting one drop of well mixed phytoplankton sample on the counting chamber (HCC) and a cover slip was put on it. Before counting HCC cell was let stand for at least 1minute to settle down phytoplankton.

Phytoplankton present in the bottom of the HCC cell was the counter. All the cells present was counted and the dominant group was identified. The counting was done in triplicate for each sample. Finally, the cell density of the phytoplankton was calculated per liter water by using the following formula.

Individual/litre = TPC×SCV/TCV

Where,
TPC = Total plankton counted
SCV = Sediment of plankton concentrate volume in mL
TCV = Total Hawkleys chamber volume = (0.001005×3) µL

Qualitative analysis of phytoplankton

Before counting on the phytoplankton individual, a random checking of the sedimented phytoplanktonic material was carried out under high magnification for identification up to the species level. For identification, algal literatures as well as publications available for Bangladesh, other world monographs and books have been consulted (Smith 1950, Skuja 1956, Desikachary 1959, Starmach 1966, Islam and Begum 1970, Islam and Khondker 1981, Germain 1981, Prescott 1982, Huber-Pestalozzi 1955,1961, 1968, 1983; Dillard 1989a, Yamagishi 1998, Ling and Tyler 2000, Islam and Alfasane 2002, 2004; Siddiqui *et al.* 2007, Begum, 2008, 2009; Ahmed *et al.* 2008, 2009; Khondker *et al.* 2007, 2008, 2009).

Statistical analysis

The statistical analyses were made to study the relationship between and among the different physic-chemical and biological variables namely, Pearson correlation (SPSS v16.0) and RDA (Canoco v4.54), the Shannon diversity index and Jaccard index has been applied.

The climatic seasons followed for the analysis

1. Pre-monsoon : March- May
2. Monsoon : June- September
3. Post-monsoon : October- November
4. Dry or Winter Season : December- February (Brammer, 2002)

Pearson correlation

Pearson correlation (SPSSv16.0) have been performed to observe the relationship among physical, chemical and biological parameters of the selected stations.

Shannon diversity index

Robert MacArthur introduced the Shannon-Weiner index into ecology. The Shannon-Wiener diversity index (H) is a measure of diversity that combines species richness (the number of species in a given area) and their relative abundances. It tells the level of diversity in that particular area, i.e. it is possible to say the diversity is low or high (since H generally ranges between 0 and 5). H also helps to compare diversity between communities within an area/ecosystem and diversity between different areas species richness is the most commonly used measure of diversity, but H is a strong indicator of diversity.

Shannon-Weiner Diversity Indices calculation:

A) A diversity index is a mathematical measure of species diversity in a given community.
B) Based on the species richness (the number of species present) and species abundance (the number of individuals perspecies).
C) The more species you have, the more diverse the area.
D) However, there are two types of indices, dominance indices and information statistic indices. The Shannon index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled.

E) The equation for the Shannon-Weiner index :

$$H = -\sum_{i=1}^{s} pi \; In \; pi$$

In the Shannon index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species. The higher values of Shannon index is the representative of more diverse communities. This index represents not only the number of species but also how the abundance of the species is distributed.

Jaccard Index or Jaccard Similarity Coefficient index

The Jaccard similarity index (sometimes called the Jaccard similarity coefficient) compares members for two sets to see which members are shared and which are distinct. It is a measure of similarity for the two sets of data, with a range from 0% - 100%. The higher percentage of the Jaccard index represents the more similarity among the populations.

The formula to find the Index is:

Jaccard Index = (the number in both sets) / (the number in either set) * 100

The same formula in notation is: **J(X, Y) = |X∩Y| / |X∪Y|**

In Steps, that's:

1. Count the number of members which are shared between both sets.
2. Count the total number of members in both sets (shared and un-shared).
3. Divide the number of shared members (1) by the total number of members (2).
4. Multiply the number you found in (3) by100.

This percentage tells you how similar the two sets are:

- Two sets that share all members would be 100% similar, the closer to 100%, the more similarity (e.g. 90% are more similar than 89%).
- If they share no members, they are 0% similar.
- The midway point — 50% — means that the two sets share half of the members.

TDI (Trophic diatom index) calculation :

- For assessment of organic pollution in the U.K. Rivers (Chesters, 1980; Armitage *et al.*, 1983) the TDI value was evaluated successfully.

- The value of TDI indicate the effect of organic nutrients on the wetland that already nutrient-rich, and the measurement of large increase in the proportion of organic pollution & tolerant taxa (Whitton and Kelly, 1995).
- The value of TDI can range from 1 (very low nutrient concentrations) to 5 (very high nutrient concentrations) (Zelinka and Marvan 1961)

The Methodology to find the Index is:

Trophic diatom index (TDI) = $\sum$ asv ÷ $\sum$ av

Here, a = total counts of diatom species

S= Taxon sensitivities to pollution (1-5).

V= indicator values

Results

In the present investigation a total of three physical, eight chemical and four biological parameters were recorded for 3 selected study stations of Kuniar Haor. The time period covered were two years and as a result a total of 33 new records were yielded for each station. All the data have been plotted and tabulated wherever necessary and presented below along with the trend of their seasonal flux.

Physical parameters

Air temperature (°C)

Ranges of air temperature recorded for the period between February 2016 and January 2018 for all the stations of Kuniar Haor showed almost identical trend of variation. In Station-1, Station-2 and Station-3 the monthly ranges of air and water temperatures were 18.50 - 35.50 ºC, 19.00 - 37.20 ºC and 18.50 - 38.10 ºC, respectively. The highest monthly mean air temperature was recorded in the month of September, 2017 for Station-1, May, 2017 for Station-2 and Station-3, whereas the lowest mean air temperature were obtained for all Stations in the month of January, 2016 (Table 2).

In the present investigation, the seasonal variation of air temperature showed the highest value during pre-monsoon and lowest in winter in all stations (Fig. 6). The seasonal decreasing pattern of mean air temperature followed pre monsoon- monsoon - post monsoon and winter (Fig. 6). In both the study years the trend of annual air temperature flux showed two peaks in each study year. These were in April and August but the peak occurred in the later month showed a relatively lower range of temperature (Fig. 7A). The bimodal temperature peak is also clearly seen in Fig. 7B, where the temperature data for two consecutive years of study has been presented.

Air temperature starts increasing just after January and continues until August and therefore the fluctuation takes uniformly with slight straight tendency in few months. The temperature starts falling in September (Fig. 7B). The annual fluctuation trend of air temperature is almost same in both study years.

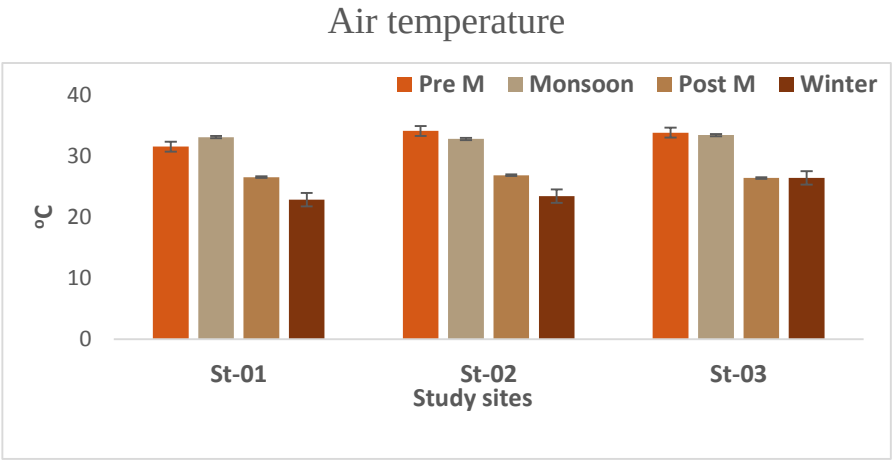


Fig. 6. Seasonal variation of air temperature in three study sites of Kuniar Haor, Kishoreganj.

Table 2. Monthly mean values (±SD) of air temperature (ºC) for all the study sites.

Months	Station-1	Station-2	Station-3
February 2016	30.5±0.24	29±0.13	30.6±0.23
March 2016	30.1±0.11	31.5±0.14	32±0.19
April 2016	31±0.14	37.1±0.16	37.5±0.18
May 2016	33±0.16	33.2±0.24	33±0.22
June 2016	31.6±0.21	30.9±0.15	31.2±0.5
July 2016	32.8±0.4	32.4±0.31	32.2±0.26
August 2016	34.1±0.24	34±0.25	34.3±0.22
September 2016	30±0.32	30.5±0.33	30±0.4
October 2016	26±0. 35	27±0.39	27±0.42
November 2016	21±0.22	20±0.3	19.5±0.34
December 2016	19±0.31	19±0.32	19.4±0.25
January 2017	18.5±0.22	19±0.21	18.5±0.3
February 2017	19.5±0.5	21.5±0.31	22±0.23
March 2017	28±0.23	29.4±0.35	29±0.42
April 2017	33.5±0.34	36±0.42	37±0.6
May 2017	32.5±0.53	37.2±0.48	38.1±0.45
June 2017	34.8±0.46	28.3±0.47	34±0.52
July 2017	32.5±0.46	33.1±0.37	33.1±0.43
August 2017	33.2±0.56	36.1±0.43	36.2±0.33
September 2017	35.5±0.34	36.1±0.43	35.4±0.48
October 2017	31.5±0.53	32±0.45	31±0.35
November 2017	28±0.54	28.8±0.4	28±0.6
December 2017	21±0.31	21.5±0.42	22±0.24
January 2018	28.5±0.21	29.4±0.32	30.1±0.45
Mean	29.004	29.7	30.04

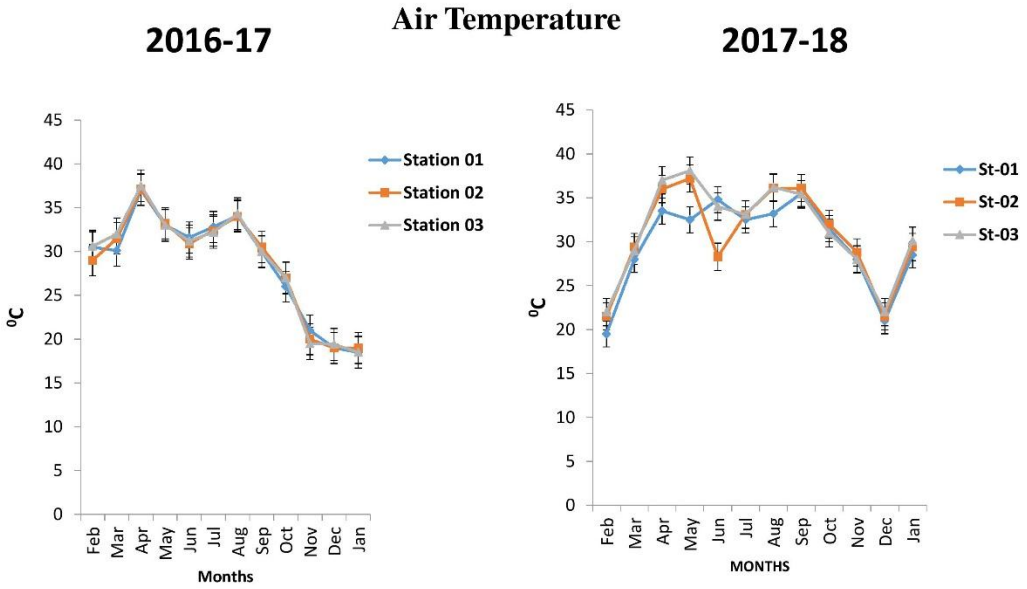


Fig. 7A. Monthly variations in air temperature (°C)

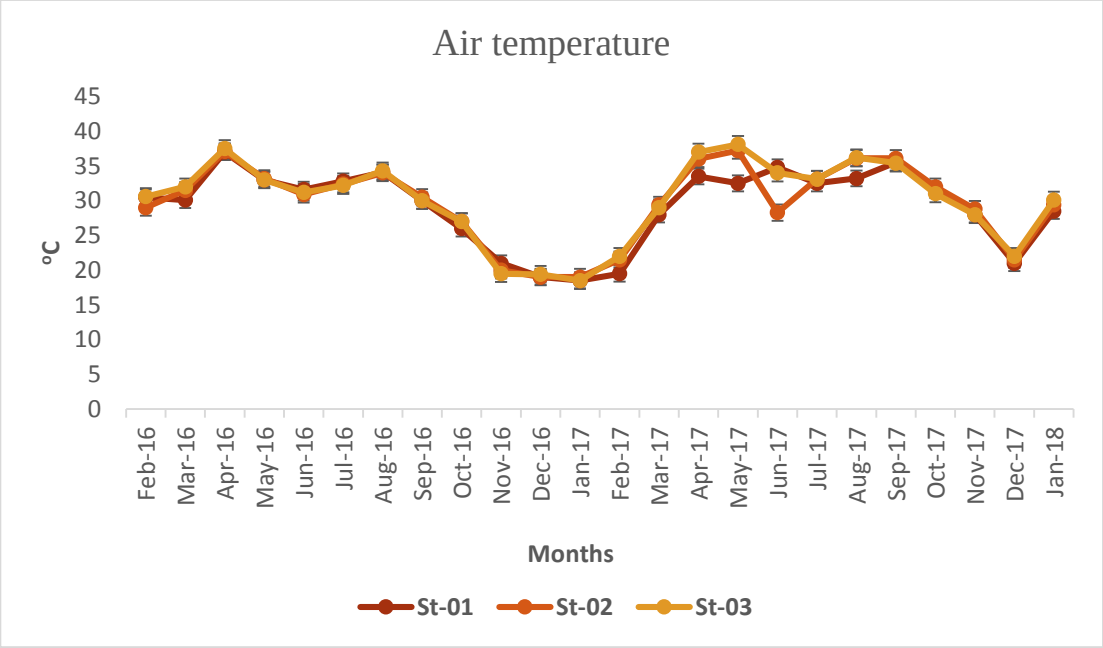


Fig.7B. Comparison of air temperature between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Water temperature

During the study period between February 2016 and January 2018, the range of water temperature for all station was 19.0– 33.4 ^{o}C. The highest monthly mean water temperature was recorded in the month of April, 2017 for Station-1 and Station-2 whereas, the lowest mean water temperature were obtained for all stations in the month of February, 2017 (Table 3). Water temperature followed a similar trend like air temperature throughout the investigation period.

In the present research the seasonal variation of water temperature showed the highest value during pre-monsoon and monsoon and lowest in winter in all stations (Fig. 8). The highest to lowest water temperature in the seasonal trend followed monsoon-post monsoon-winter (Fig. 8).

Water temperature starts increasing just after the month of December and continued until July and then a gradual fall was evident in August until December (Fig.9B). Fig. 9B shows a comparison of water temperature between the two years, i.e. 2016-2017 and 2017- 2018. The trend of annual fluctuation of water temperature is almost similar in both study years. Although, a bimodal temperature peak was evident annually in the air temperature flux of the study area, it was not so distinct in case of water temperature (Figs. 9A-B). When the trend of water temperature variation for consecutive years are plotted together, more or less an unimodal behaviour of water temperature was noticed (Fig. 9B).

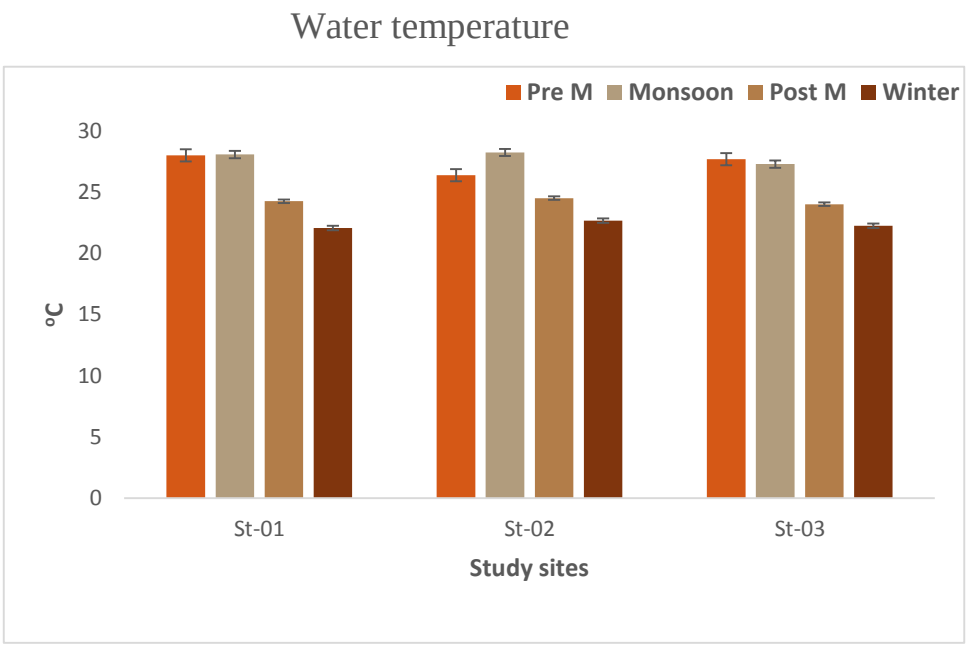


Fig. 8. Seasonal variation of water temperature in three study sites of Kuniar Haor, Kishoreganj.

Table 3. Monthly mean values (±SD) of water temperature (ºC) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	28±0.87	27.1±0.96	26.8±0.88
March 2016	27±0.67	24±0.9	28±0.76
April 2016	28±0.86	27±0.79	29±1.1
May 2016	29±0.96	26.7±0.8	26.6±0.94
June 2016	27.1±0.97	27.4±0.86	27±0.8
July 2016	27.2±0.79	26.±0.86	26.4±0.8
August 2016	30±0.86	25±0.7	25±0.85
September 2016	27.5±0.79	28.5±0.84	28±0.75
October 2016	25±0.8	25.5±0.88	25±0.86
November 2016	22±0.76	20.5±0.86	20±0.97
December 2016	20.3±0.8	20.4±0.86	21.1±0.96
January 2017	20.5±0.78	20.5±0.8	20.5±0.88
February 2017	19±0.96	19±0.97	19±0.9
March 2017	26±0.83	26±0.94	25±0.94
April 2017	30±0.84	30±0.87	29±0.9
May 2017	28±0.86	28±0.95	27.5±0.84
June 2017	29.2±0.79	29.2±0.96	28±0.95
July 2017	29.6±0.75	29.6±0.97	30±0.96
August 2017	25.7±0.78	25.7±0.87	25.3±0.95
September 2017	28.4±0.99	28.4±0.8	28.5±0.87
October 2017	27±0.93	27±0.94	26.5±0.85
November 2017	25±0.79	25±0.79	24.5±0.86
December 2017	22.5±0.79	22.5±0.75	21±0.7
January 2018	22±0.86	22±0.88	25±0.9
Mean	26	25.46	25.52

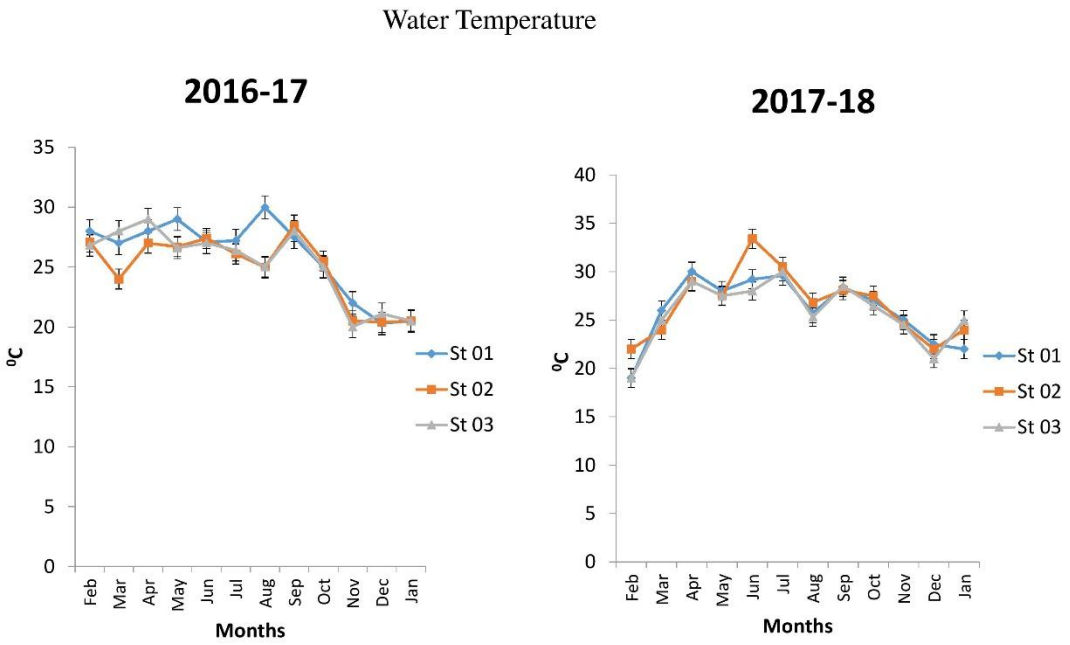


Fig. 9A. Monthly fluctuation of water temperature (°C)

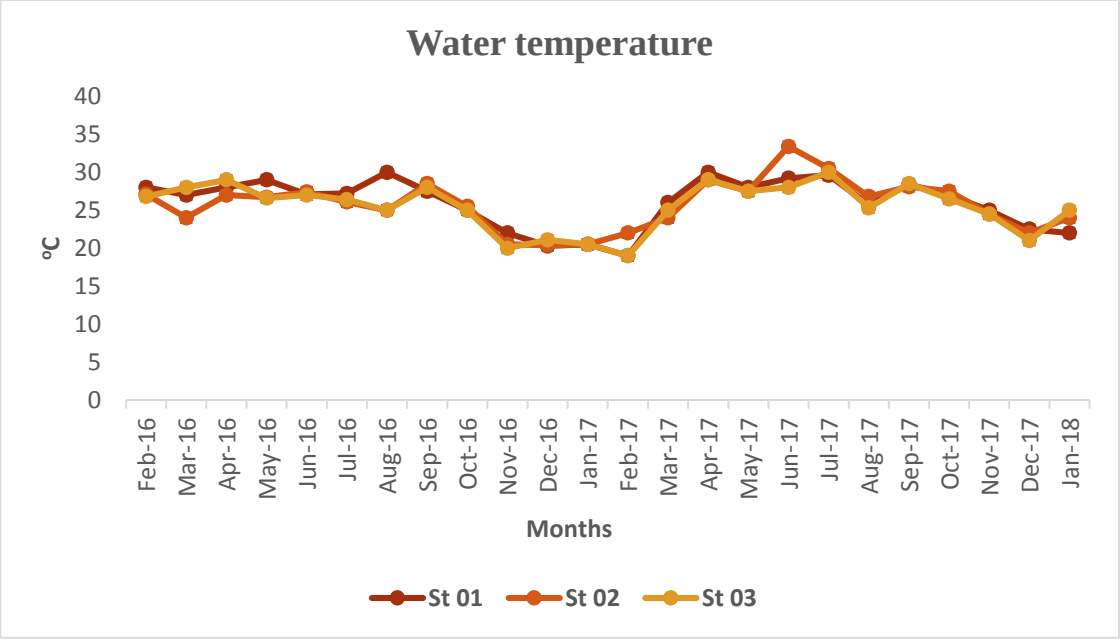


Fig. 9B. Comparison of water temperature between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Secchi depth.

The results presented in Fig. 10 showed a great fluctuation of Secchi depth among three stations in wet seasons. Secchi depth (Zs) varied from 13.00-70.50 cm for station-1, 12-75 cm for station -2 and 7.5-95 cm for station-3. The lowest value was 7.50 cm for station-3 in the month of January 2017 and the highest values of Secchi depth were recorded in the same station in August 2016 (Table 4). The annual fluctuation of this light related parameter was highly variable in nature. Strong seasonality in the mean Zs for all the study stations were observed. The flux was highly synchronising i.e., starting from pre-monsoon the Zs value increased high in the monsoon and then dropped until to the lowest in winter via post-monsoon (Fig. 10).

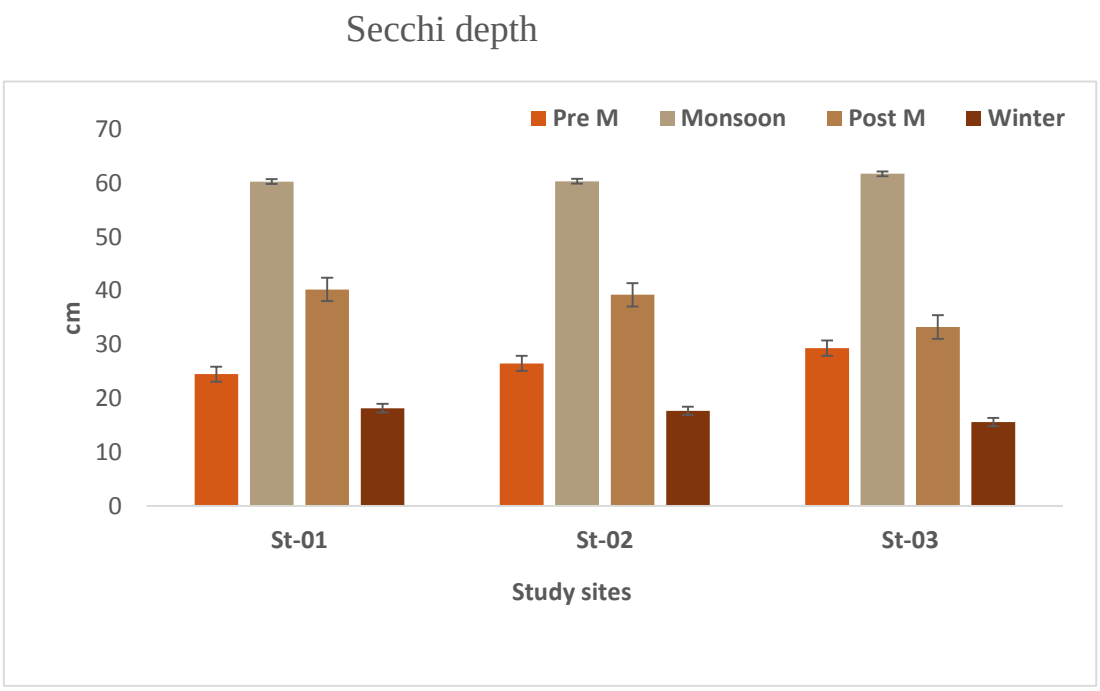


Fig. 10. Seasonal variation of Secchi depth in three study sites of Kuniar Haor, Kishoreganj.

Table 4. Monthly mean values (±SD) of Secchi depth (cm) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	14±2.3	12±1.88	7.5±1.7
March 2016	13±2.1	18±1.6	19±2.1
April 2016	24±3.2	21±2.4	21±2.8
May 2016	34±4.3	29±3.3	31±3.2
June 2016	39±4.9	45±5.1	41±3.2
July 2016	57±5.2	55±4.7	48±4.9
August 2016	70.5±7.8	75±7.9	95±9.2
September 2016	66±5.4	63±3.8	58±3.7
October 2016	61±4.1	57±3.8	44±3.6
November 2016	27±3.2	29±3.8	26±2.9
December 2016	27±2.7	23±2.5	21±2.7
January 2017	15±2.4	16±1.88	8±2.2
February 2017	18±2.2	22±3.1	26±2.3
March 2017	17±2.1	22±2.1	29±2.7
April 2017	31±3.4	33±3.2	37±3.8
May 2017	28±2.8	36±3.6	39±3.9
June 2017	54±3.4	48±3.6	47±4.8
July 2017	63±5.9	56±5.4	68±6.1
August 2017	67±7.2	71±7.4	69±6.8
September 2017	66±7.1	70±8.1	68±7.2
October 2017	51±3.9	45±5.8	42±5.5
November 2017	22±2.7	26±2.4	21±2.7
December 2017	19±3.1	19±3.2	22±2.4
January 2018	16±2.1	14±3.2	9±3.1
Mean	37.48	37.7	37.35

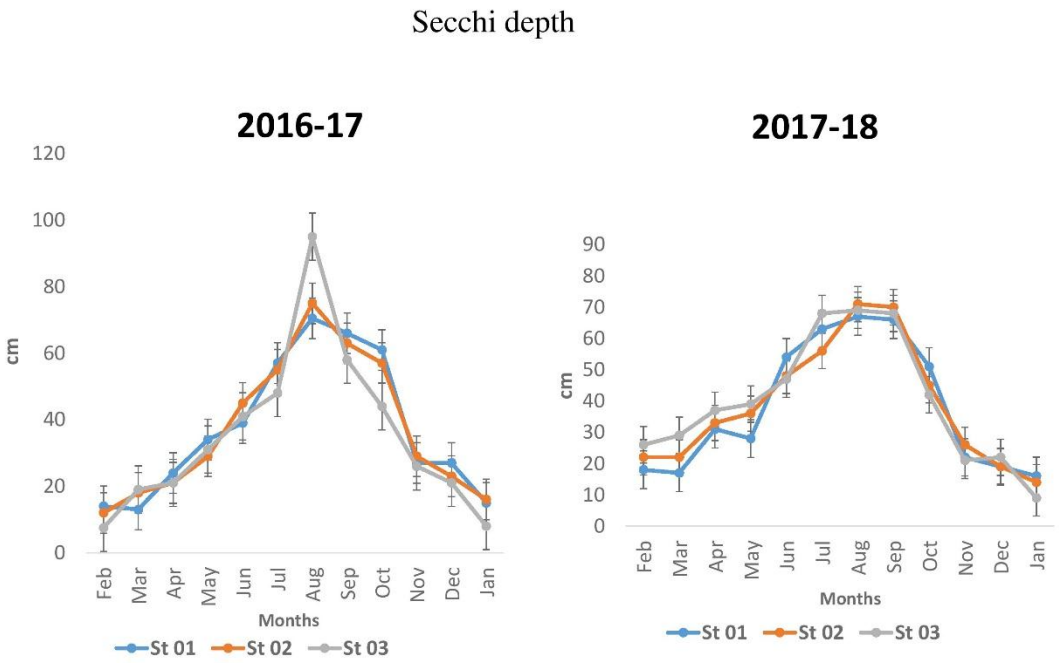


Fig. 11A. Monthly fluctuation of Secchi depth (cm)

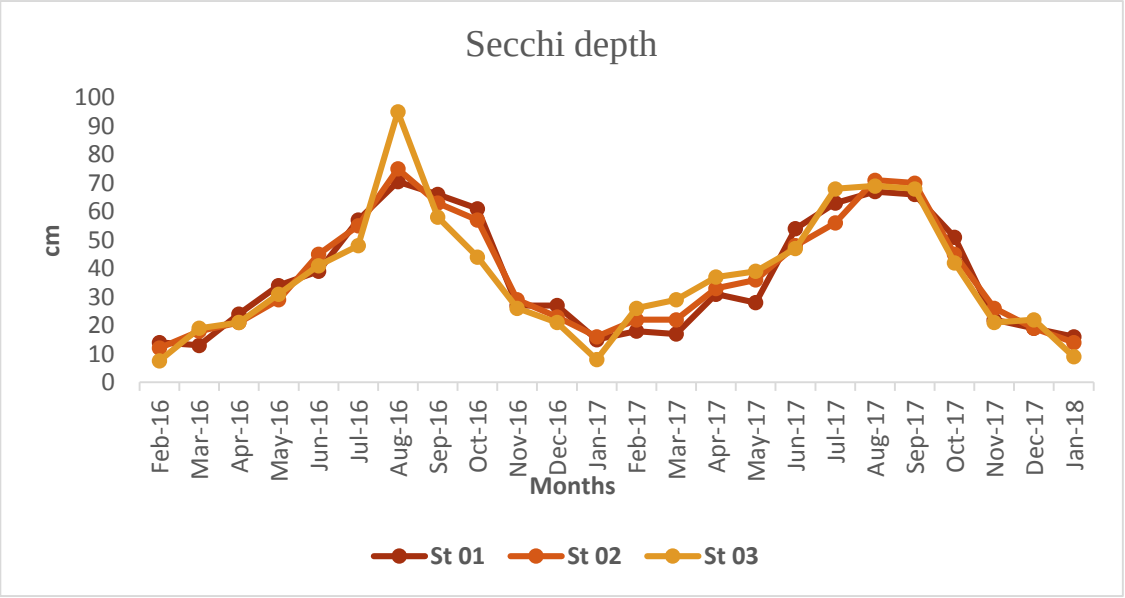


Fig.11B. Comparison of Secchi depth between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Chemical parameters

Alkalinity

Range of alkalinity for the period between February 2016 and January 2018 were recorded 0.60-5.50 meq/l for station-1, 0.60-2.70 meq/l for station-2 and 0.50-2.90 for station-3. The highest monthly average of alkalinity was recorded in the month of March-2016 at station-1 and station-2 whereas the lowest mean alkalinity was recorded in the month of February 2016 for station-3 (Table 5.)

In the present research the seasonal variation of alkalinity shows higher values during pre monsoon for station-1 but lower in winter season for station-2 (Fig. 12). The seasonal trend of alkalinity looks similar from the annual trends of fluctuation for station-3. The alkalinity starts to fall from August 2016 to January 2017 and then it again rise from December 2017 to January 2018 throughout the year for all stations. (Fig.13B).

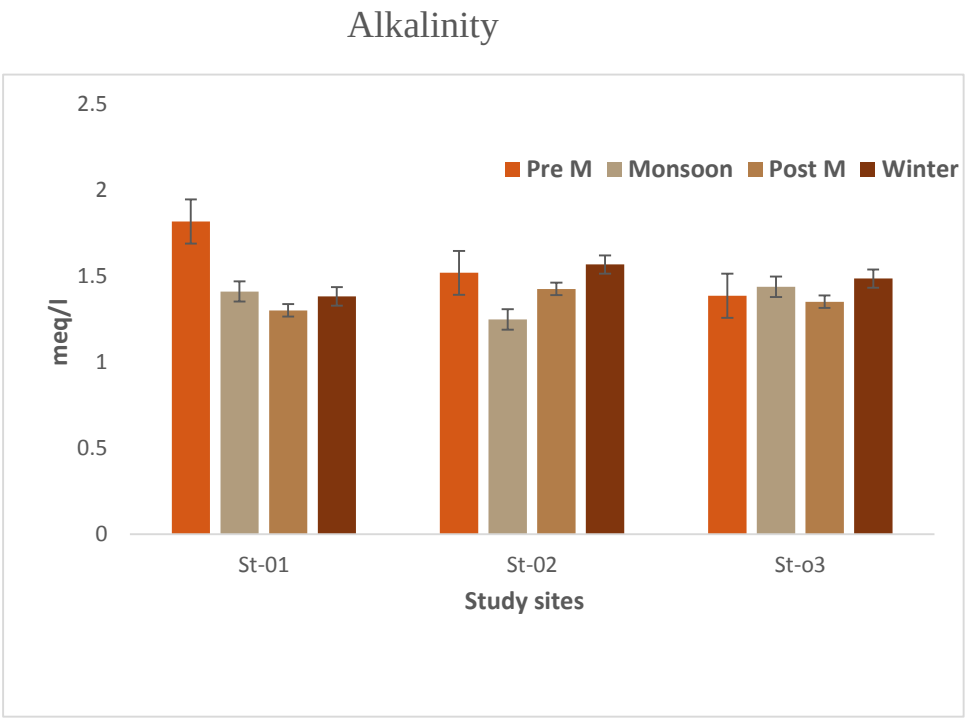


Fig. 12. Seasonal variation of Alkalinity in three study sites of Kuniar Haor, Kishoreganj.

Table 5. Monthly mean values (±SD) of alkalinity (meq/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	2.6±0.31	2.6±0.32	2.9±0.41
March 2016	5.5±0.5	2.7±0.34	2.3±0.4
April 2016	0.8±0.3	0.8±0.28	0.7±0.2
May 2016	0.9±0.32	0.6±0.2	0.8±0.2
June 2016	0.6±0.22	0.6±0.23	0.5±0.19
July 2016	1.8±0.33	1.5±0.31	1.6±0.32
August 2016	2.7±0.37	1.5±0.28	2.5±0.4
September 2016	2.2±0.3	1.7±0.29	2.6±0.4
October 2016	1.1±0.2	1.8±0.26	1.6±0.31
November 2016	1.2±0.23	1.5±0.24	1.4±0.27
December 2016	1.3±0.26	1.4±0.27	1.1±0.28
January 2017	0.7±0.2	0.8±0.2	1.3±0.24
February 2017	1.2±0.23	1.5±0.31	1.2±0.31
March 2017	1.3±0.24	1.6±0.23	1.3±0.29
April 2017	1.4±0.3	1.5±0.22	1.4±0.27
May 2017	1.8±0.2	1.9±0.2	1.8±0.21
June 2017	0.9±0.16	1.5±0.19	0.9±0.18
July 2017	1.2±0.2	1.4±0.14	1.2±0.16
August 2017	1.1±0.19	0.9±0.14	1.1±0.12
September 2017	1.1±0.18	0.9±0.16	1.1±0.1
October 2017	1.4±0.23	1.3±0.14	1.4±0.3
November 2017	1±0.17	1.1±0.19	1±0.2
December 2017	1.6±0.2	1.5±0.14	1.6±0.16
January 2018	1.5±0.17	1.6±0.15	1.5±0.18
Mean	1.53	1.42	1.45

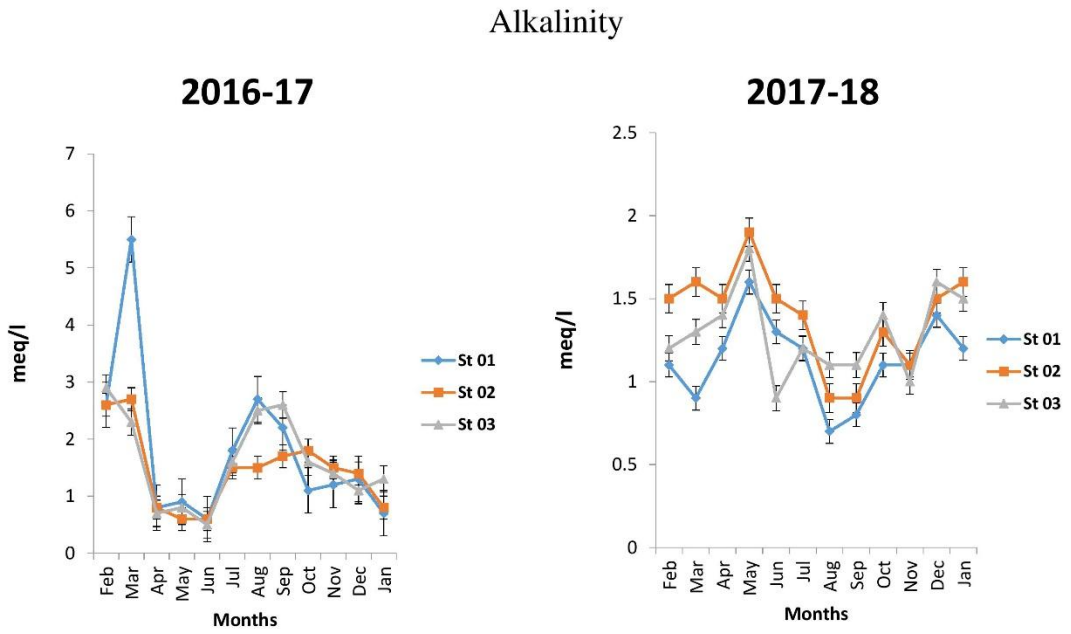


Fig. 13A. Monthly mean value of alkalinity (meq/l)

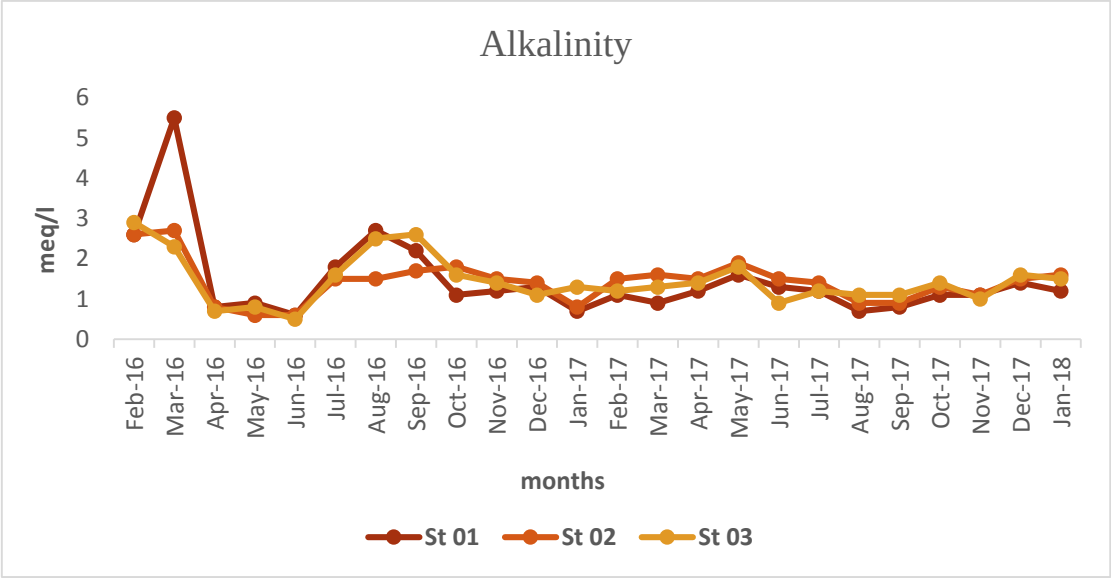


Fig. 13B. Comparison of alkalinity between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

pH

During the investigation period between February 2016 and January 2018 the range of pH was recorded 6.60-8.10 for station-1, 6.40-7.90 for station-2 and 6.80-8.10 for station-3. The highest monthly mean pH for all stations was recorded in the month of October 2017 whereas, the lowest mean pH was recorded in the month of February 2016 for Station -1 and Station-3. The lowest mean pH for Station-2 observed in July 2016 (Table 6).

In the present research, seasonal variation of pH for all the stations showed higher values during the post monsoon but lower in winter (Fig. 14). The monsoonal pH value at Station-1 was lower compared to the values of pre-monsoon and post-monsoon but at station-2, the values of pre-monsoon and monsoon were almost same (Fig. 14). At station-3 the trend of variation of seasonal mean pH followed a gradual rise from pre-monsoon to post-monsoon via monsoon and then there was an abrupt fall during winter (Fig. 14). It is also evident from the Fig. 4 that the monsoonal mean pH in the Kuniar Haor rose gradually from Station-1 to station-3 via station-2. As could be seen from the pH data of two consecutive years of study carried out in Kuniar Haor a short flux in the values are evident (Figs. 15A-B). The value fluctuated annually between 6.9 and 8.1 for all the stations (Table 6).

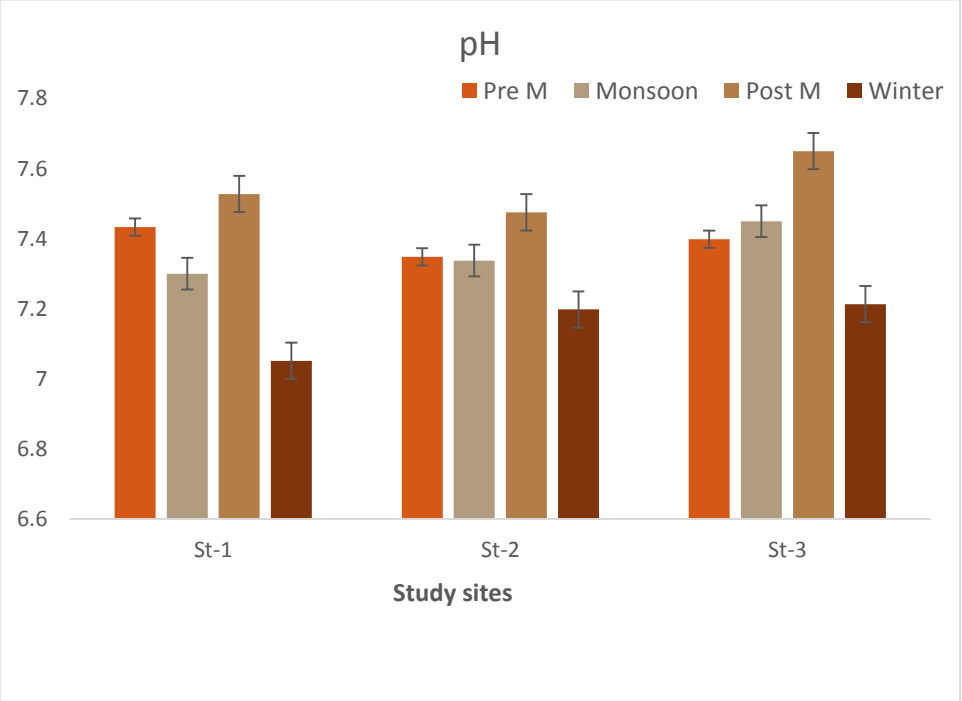


Fig. 14. Seasonal variation of pH in three study sites of Kuniar Haor, Kishoreganj.

Table 6. Monthly mean values (±SD) of pH for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	6.6±1.2	6.9±1.1	6.8±0.9
March 2016	7.6±1.7	7.5±1.6	7.5±1.8
April 2016	6.9±0.9	7.1±0.89	7.4±1.7
May 2016	7.4±1.7	7.1±1.2	6.8±1.1
June 2016	7.6±1.1	7.8±1.5	7.7±1.3
July 2016	6.8±1.2	6.4±1.1	7.2±0.8
August 2016	6.9±1.5	7.1±1.4	7.3±1.4
September 2016	7.5±1.4	7.3±1.7	7.6±1.3
October 2016	7.9±1.5	7.8±1.2	8.1±1.6
November 2016	6.9±1.1	7.1±1.6	7.1±1.2
December 2016	7.1±1.6	7.1±1.7	7.3±1.7
January 2017	6.9±1.3	7.1±1.5	7.1±1.3
February 2017	7.1±1.2	7.3±1.6	7.2±1.4
March 2017	7.7±1.4	7.5±1.4	7.6±0.9
April 2017	7.7±1.7	7.5±1.3	7.5±1.2
May 2017	7.3±1.6	7.4±1.3	7.6±1.4
June 2017	7.1±1.3	7.1±1.2	7.4±1.2
July 2017	7.7±1.7	7.5±1.6	7.8±1.3
August 2017	6.9±0.8	7.7±1.6	6.9±1.4
September 2017	7.9±1.1	7.8±1.4	7.7±1.6
October 2017	8.1±1.9	7.9±1.7	8.1±1.8
November 2017	6.81±0.8	7.1±1.3	7.3±1.4
December 2017	7.3±1.3	7.3±1.3	7.4±1.5
January 2018	7.3±1.1	7.5±1.4	7.5±1.3
Mean	7.29	7.32	7.41

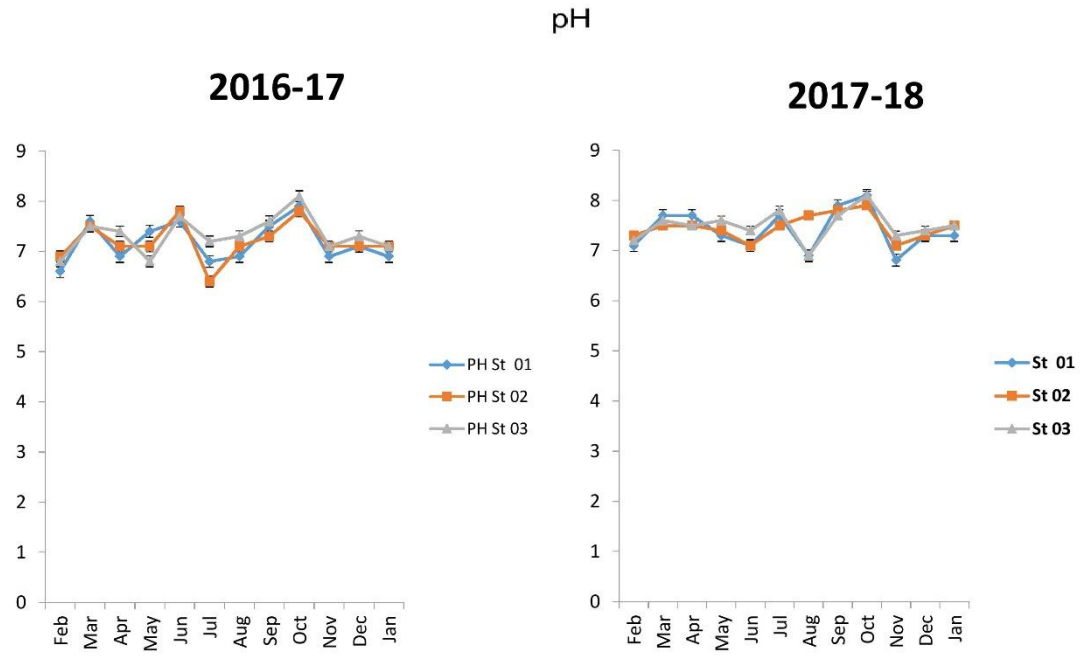


Fig. 15A. Monthly mean values of pH

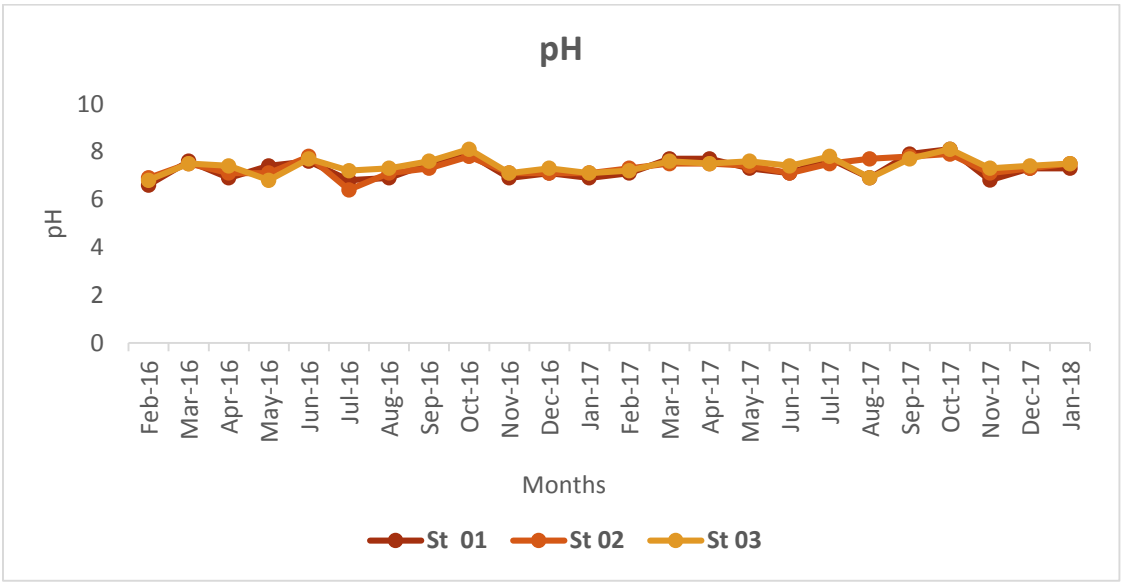


Fig. 15B. Comparison of pH between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

TDS

During the whole period of study (February 2016 to January 2018), the range of TDS showed a variation of concentration from 20.00-97.00 mg/l. Stationwise the values were 17.40-95.00 mg/l , 17.4-95.0 mg/l and 17.00-96.00 mg/l for Stations 1, 2 and 3, respectively. The highest monthly mean TDS was recorded in the month of February 2016 for all the studied stations whereas the lowest mean TDS were obtained in the month of September 2016 for Station-1, in October 2017 for Station -2 and in March 2016 for Station-3 (Table 7). Two years of consecutive study carried out in the present investigation reveals a higher range of TDS from November to October showing their highest peak in the winter months on either end of the curve as produced in Fig. 17B.

TDS content in the lean months (winter) of the year was higher for all the studied stations of Kuniar Haor. On the otherhand, the lowest concentration was observed in monsoon for all the stations (Fig. 16). TDS followed more or less similar value in the pre-monsoon and monsoon in all the studied stations. Thereafter, there was a fall in the concentration in the post monsoon leading to an elevated concentration in winter (Fig. 16). This pattern was obvious in almost all the study stations of Kuniar Haor.

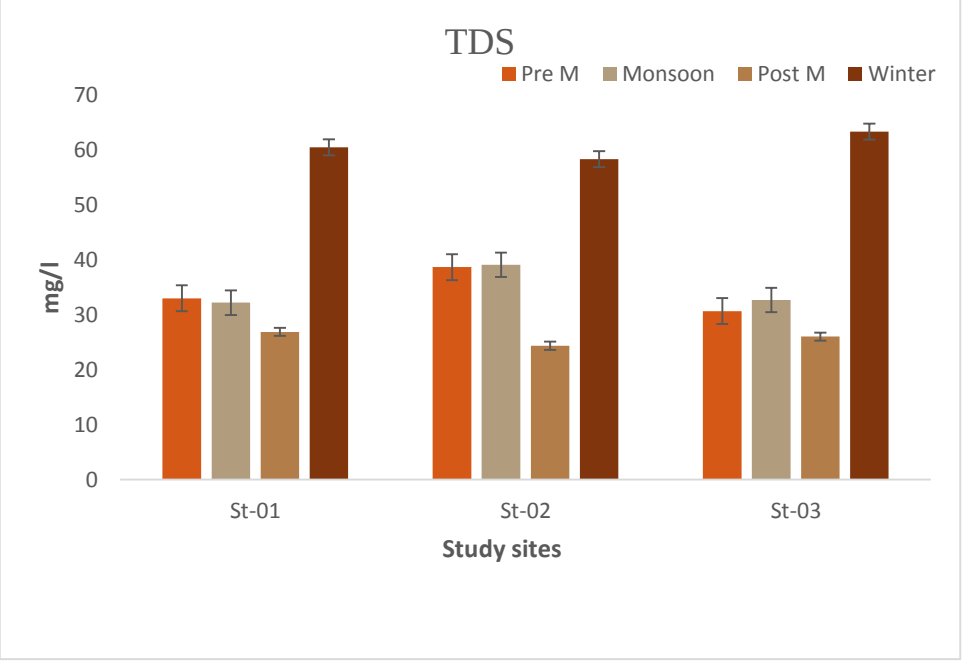


Fig. 16. Seasonal variation of TDS in three study sites of Kuniar Haor, Kishoreganj.

Table 7. Monthly mean values (±SD) of TDS (mg/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	97±14.2	95±13.6	96±12.1
March 2016	28±8.7	42±10.3	17±5.4
April 2016	27±9.3	26±9.6	25±10.1
May 2016	22±9.1	24±8.2	22±9.3
June 2016	24±8.7	25±9.2	25±8.8
July 2016	45±10.4	25±9.7	27±9.4
August 2016	24±8.9	23±8.3	23±8.6
September 2016	21±8.1	24±8.7	20±7.8
October 2016	25±8.8	29±9.8	25±9.7
November 2016	20±7.2	21±6.7	26±8.7
December 2016	45±9.2	46±9.1	58±10.2
January 2017	45±9.9	48±10.1	46±9.7
February 2017	62±12.3	43±11.2	60±12.1
March 2017	52±10.2	75±13.4	53±11.2
April 2017	31±7.4	28±6.7	34±7.2
May 2017	38±8.9	37±9.7	33±8.1
June 2017	53±8.6	75±8.8	52±7.9
July 2017	22±7.4	71±12.3	46±8.7
August 2017	41±8.6	51±9.6	51±9.7
September 2017	27.6±5.8	18.8±4.2	17.5±4.6
October 2017	24.5±6.7	17.4±5.3	22.1±5.8
November 2017	32±5.7	30±5.3	31±5.4
December 2017	41±5.6	43±7.4	46±7.6
January 2018	73±10.1	75±11.2	74±13.1
Mean	38.33	41.34	38.73

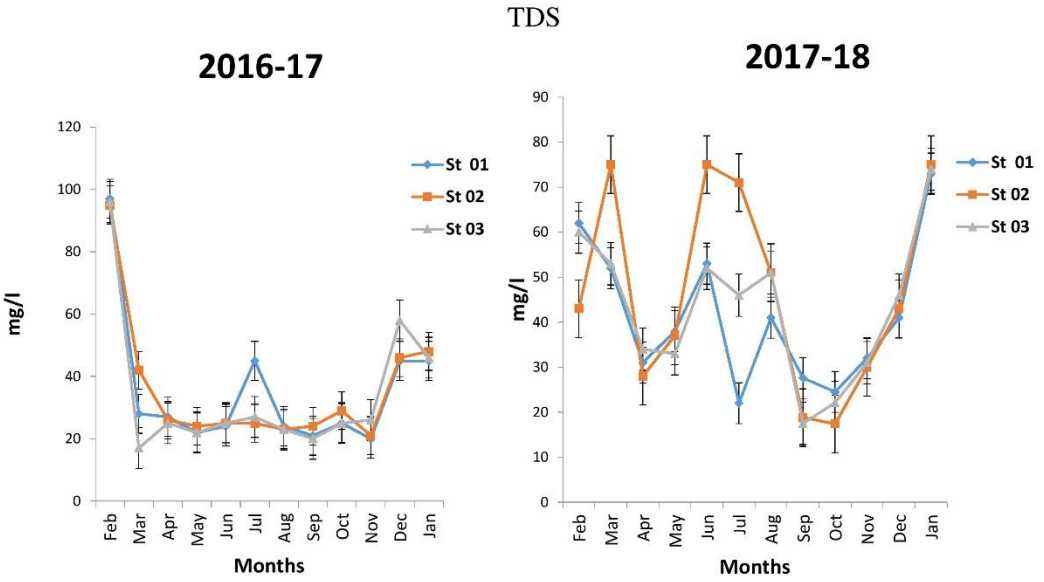


Fig. 17A. Monthly mean values of TDS (mg/l)

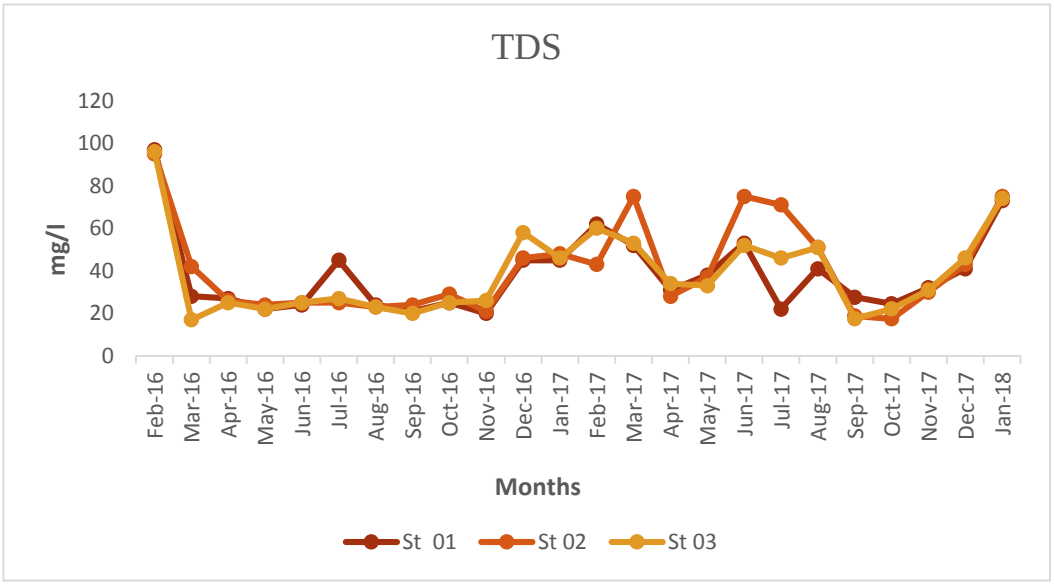


Fig. 17B. Comparison of TDS between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Conductivity

Electrical conductivity of the water of Kuniar Haor ranged from 38.00-164.00 µS/cm, 31.00-171.00 µS/cm and 36.00-161.00 µS/cm for the study Stations 1, 2 and 3, respectively. The highest monthly mean conductivity was recorded in the dry seasons for all the stations whereas the lowest mean conductivity were obtained in the month of June 2016 for station-1, in September 2016 for station-2 and in August 2016 for station-3 (Table 8).

From the seasonal graph (Fig. 18) the highest mean value were recorded during winter for all studied stations and the lowest mean value were recorded during post monsoon for both Station-1 and Station-2 and during monsoon for Station-3. The high to low values of conductivity over the seasonal trend followed a pattern winter - pre-monsoon - monsoon - post-monsoon for both the Station-1 and Station-2. But for Station-3 the trend was winter-pre-monsoon-post-monsoon- monsoon (Fig. 18).

From the graph (Fig. 19) the fluctuation shows very high for all station throughout the investigation and also similar in trends. It is obvious from the annual trend of variation from two consecutive years of study that during lean period the conductivity of the Haor water remains high (Fig.19).

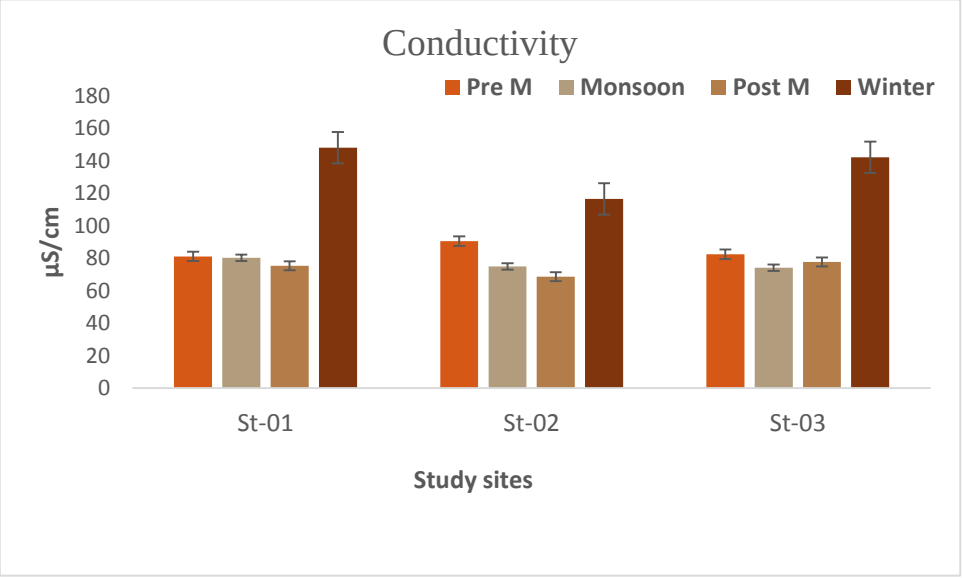


Fig. 18. Seasonal variation of conductivity in three study sites of Kuniar Haor, Kishoreganj.

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Table 8. Monthly mean values (±SD) of conductivity (µS/cm) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	108±20.6	116±17.4	103±18.6
March 2016	56±15.3	71±16.4	47±14.3
April 2016	56±14.3	64±16.6	74±15.6
May 2016	64±16.3	54±15.4	39±13.1
June 2016	38±14.1	37±13.7	48±14.4
July 2016	101±19.3	62±16.4	51±15.2
August 2016	58±17.8	40±12.4	36±11.3
September 2016	45±12.2	31±11.5	42±12.6
October 2016	48±12.4	52±15.1	57±12.3
November 2016	47±11.2	43±11.1	66±13.6
December 2016	127±18.4	66±14.3	122±17.4
January 2017	164±18.6	101±17.7	116±15.6
February 2017	136±18.9	99±16.4	158±17.5
March 2017	118±17.4	159±18.6	132±17.8
April 2017	92±15.1	89±12.3	101±17.2
May 2017	101±16.2	106±17.3	102±16.1
June 2017	112±15.1	160±19.4	161±19.6
July 2017	92±14.2	171±18.6	100±16.4
August 2017	110±16.2	101±14.3	103±15.4
September 2017	86.9±13.6	67.3±12.1	51.9±12.3
October 2017	84.8±13.2	61.4±12.3	69.3±14.5
November 2017	94±16.4	118±18.5	119±17.6
December 2017	106±17.3	99±12	104±16.7
January 2018	148±18.3	159±18.3	160±18.2
Mean	91.36	88.61	90.09

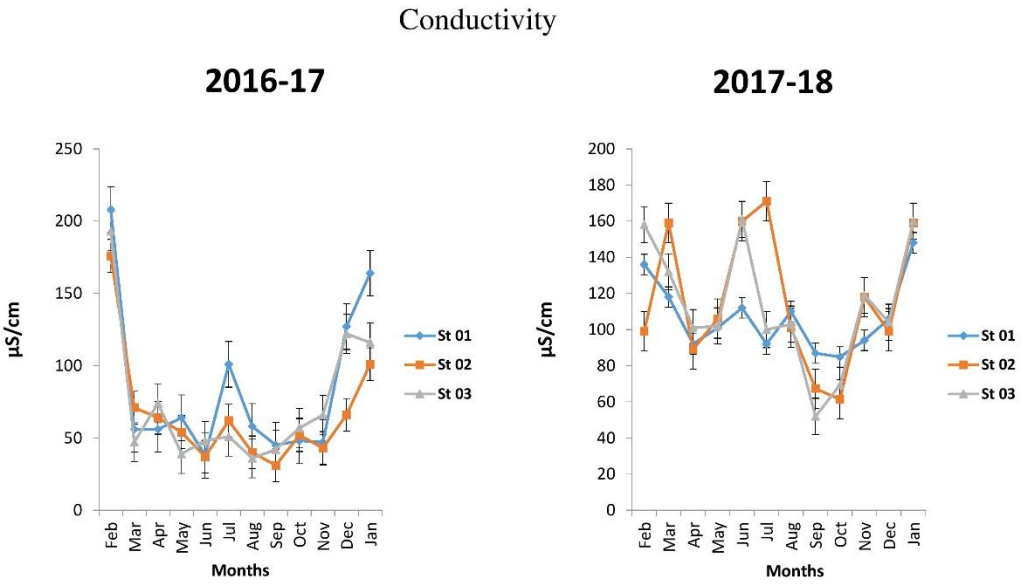


Fig. 19A. Monthly mean values of conductivity (µS/cm)

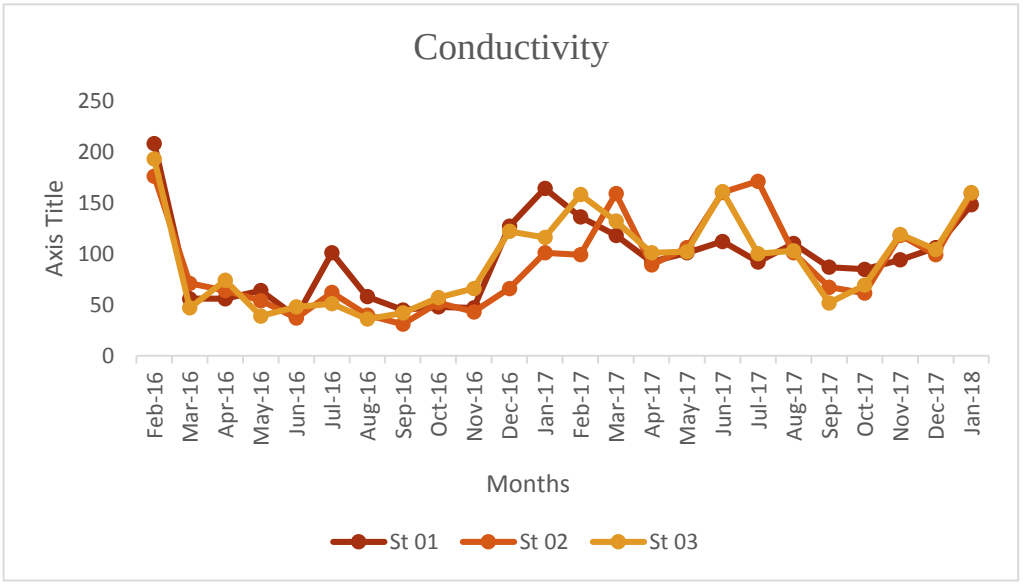


Fig.19B. Comparison of conductivity between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj

Dissolved oxygen (DO)

The range of DO recorded during the present investigation ranged, 5.20-12.80 mg/l for Station-1, 4.40-14.80 mg/l for station-2 and 4.40-13.70 mg/l for station-3. The highest monthly mean DO was recorded incase of station-1 in January 2018 and in the month of September 2017 for both the study stations 2 and 3. Whereas, the lowest mean DO was recorded in the month of January 2017 for station-1 and station-2, in the month of April 2016 for station-3 (Table 9).

In the present research seasonal variation of DO shows higher concentration during monsoon for all the stations whereas the lowest in pre-monsoon (Fig. 20). The highest to the lowest seasonal trend of DO followed monsoon - post-monsoon - winter - pre-monsoon for all the studied stations (Fig. 20).

The systemic annual trend of DO variation could be observed from the Fig. 21B. It shows quite a high fluctuating nature in the ecosystem. The pattern for the stations are almost same. A number of peak were observed in the same months.

Dissolved oxygen

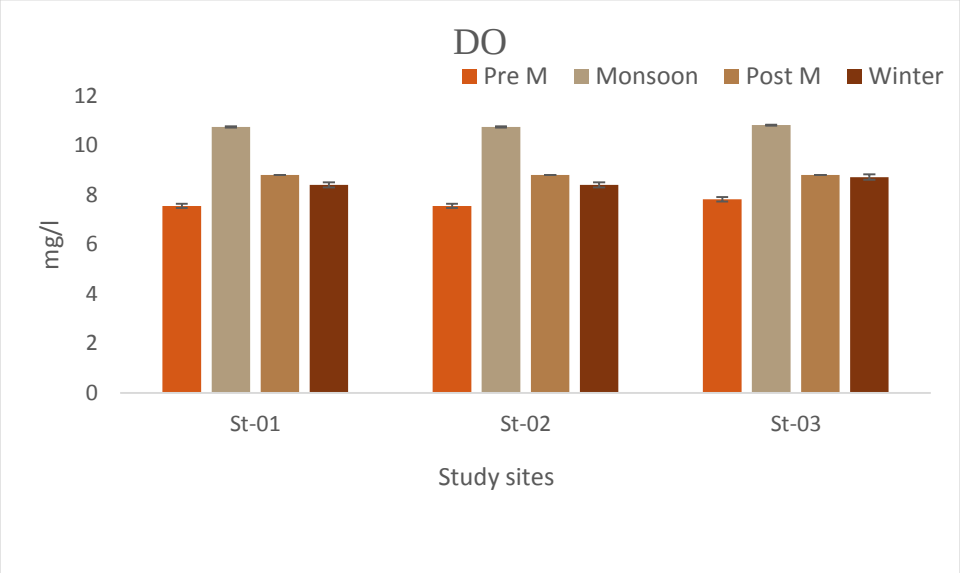


Fig. 20. Seasonal variation of DO in three study sites of Kuniar Haor, Kishoreganj.

Table 9. Monthly mean values (±SD) of DO (mg/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	12.6±2.1	12±1.9	12.9±2.1
March 2016	6.4±1.1	8.8±1.4	8.4±1.6
April 2016	5.6±1.3	4.8±1.1	4.4±0.9
May 2016	9.8±1.9	8.9±1.7	9±1.8
June 2016	12.7±2.1	12.3±2.3	12.7±2.2
July 2016	12.4±2.3	11.7±1.8	11.6±1.5
August 2016	12.6±2.1	12.6±2.1	12±1.5
September 2016	6.4±1.1	6.8±0.9	6.8±1.2
October 2016	10.8±1.7	6.8±0.9	9.6±1.9
November 2016	11.6±1.6	8.8±1.1	8.4±1.3
December 2016	8.8±1.4	4.4±1.3	8.8±2.2
January 2017	5.2±1.1	4.4±0.9	6±1.2
February 2017	8.2±1.7	9.5±2.2	8.2±1.4
March 2017	7.2±1.2	10.3±2.3	8.1±1.5
April 2017	8.4±1.6	7.7±1.2	8.9±1.8
May 2017	7.9±1.8	8.1±1.4	8.1±1.7
June 2017	11.5±1.6	14.6±2.4	10.3±1.9
July 2017	8.9±1.4	9.1±1.3	9.4±1.6
August 2017	9±1.4	11±2	10±1.3
September 2017	12.4±2.1	14.8±2.3	13.7±1.9
October 2017	8.6±1.6	8.2±1.8	8.9±1.3
November 2017	8.6±1.2	9.1±1.8	8.3±1.4
December 2017	7.8±1.3	9.5±1.7	8.1±1.1
January 2018	12.8±2.3	10.3±2.6	8.3±2.1
Mean	9.4	9.35	9.2

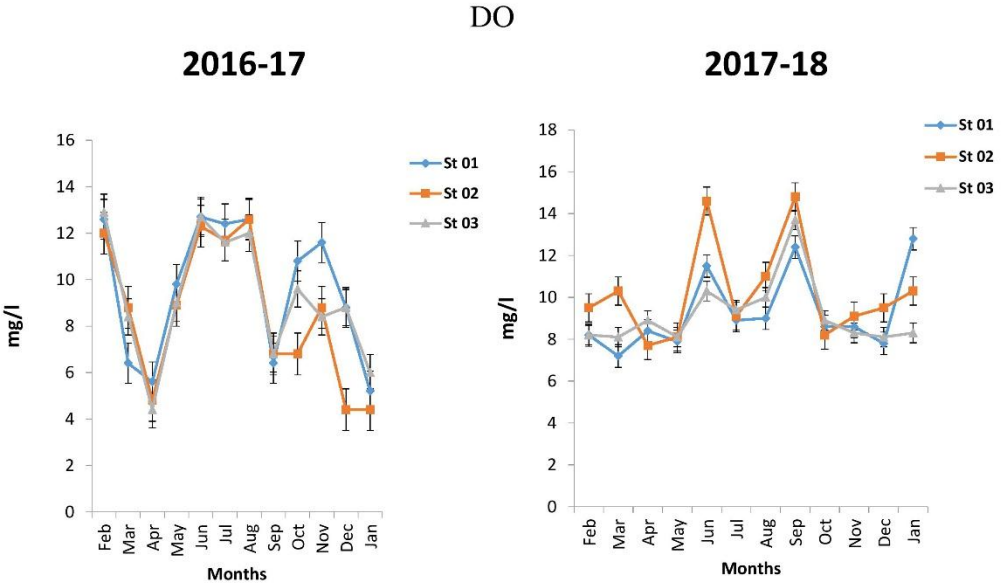


Fig. 21A. Monthly mean concentration of biogenic gas present in water (mg/l)

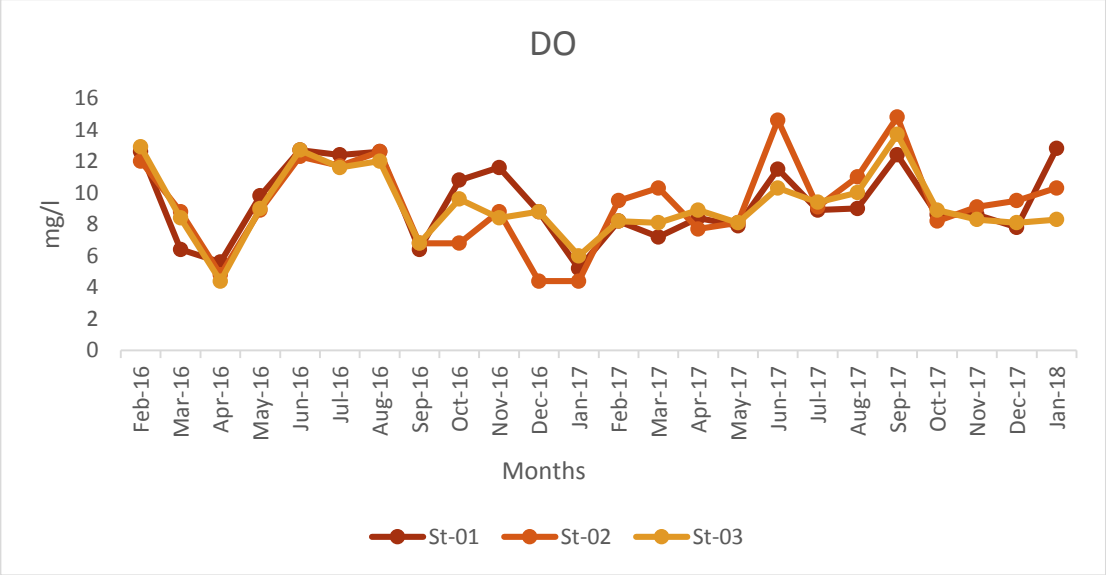


Fig. 21B. Comparison of Dissolved oxygen (DO) between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Soluble reactive phosphorus (SRP)

The overall range of SRP for the whole study period (between February 2016 and January 2018) showed 1.05-36.14 µg/l for station-1, 2.04-33.09 µg/l for station-2, and 3.65-55.28 for station-3. The highest monthly average concentration of SRP for all the stations were recorded in the month of December 2017 whereas the lowest mean SRP was recorded in the month of March 2016 for station-1, July 2016 for station-2 and September 2016 for station-3 (Table 10).

In the present research, the seasonal variation of SRP within the study period was observed higher during winter for both station-2 and station-3 and during monsoon for station-1. It was lower in post-monsoon for all stations (Fig. 22). The highest to the lowest seasonal trend of SRP followed winter-monsoon-pre monsoon-post-monsoon for station-2 and station-3, monsoon - winter - pre-monsoon - post-monsoon for station-1 (Fig. 21).

The SRP exhibited very much remarkable fluctuation over the study. It showed several peaks in different study period, i.e. June 2016 and December 2017 for all stations. (Fig. 23B).

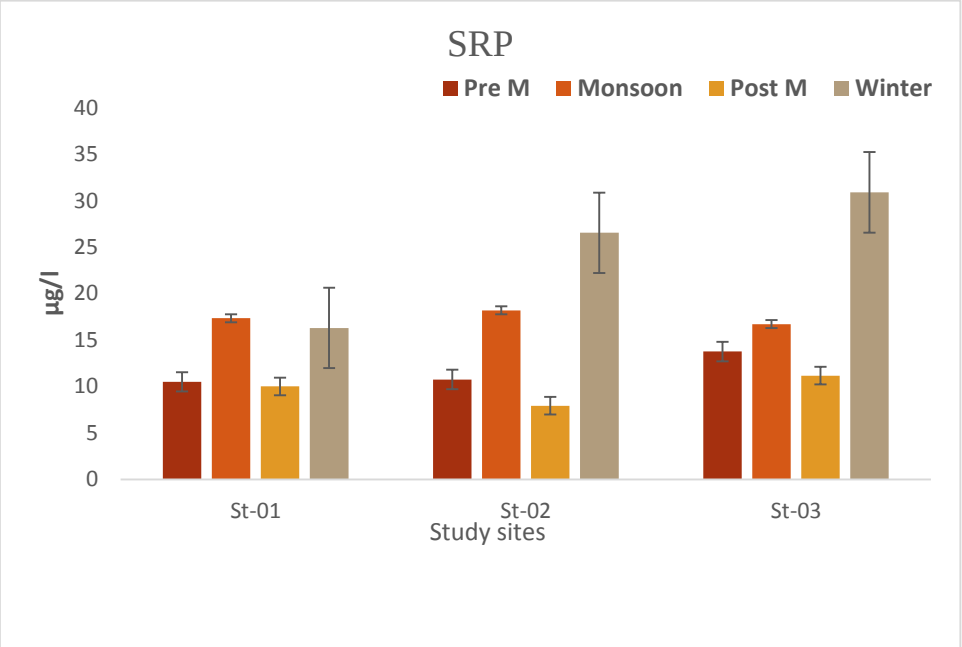


Fig. 22. Seasonal variation of SRP in three study sites of Kuniar Haor, Kishoreganj.

Table 10. Monthly mean values (±SD) of SRP (µg/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	10.05±4.5	12.83±5.2	30.3±13.2
March 2016	10.45±4.6	7.21±3.2	19.37±11.4
April 2016	8.17±2.3	2.18±1.01	11.91±3.8
May 2016	6.99±2.1	9.03±2.4	10.35±3.3
June 2016	21.21±12.1	25.31±12.3	21.21±10.1
July 2016	6.31±2.2	4.04±1.7	6.31±2.1
August 2016	14.3±7.2	13.35±6.7	16.69±7.4
September 2016	18.52±6.2	14.82±7.5	3.64±1.04
October 2016	36.02±14.8	10.63±9.7	10.06±6.4
November 2016	23.95±12.6	4.6±1.4	13.62±4.7
December 2016	4.87±1.7	15.29±3.9	24.26±11.3
January 2017	7.59±3.2	19.77±8.4	22.02±10.3
February 2017	27.43±9.7	33.09±13.6	11.77±3.8
March 2017	17.83±6.3	5.12±2.7	7.73±3.2
April 2017	15.97±5.3	31.89±12.4	20.06±9.5
May 2017	12.98±4.6	9.09±3.8	13.44±4.6
June 2017	12.12±4.3	3.76±1.2	4.42±2.1
July 2017	21.37±9.2	23.13±10.1	52.08±15.6
August 2017	17.37±	20.6±9.4	14.67±6.8
September 2017	27.52±12.3	12.47±7.8	14.62±7.3
October 2017	5.41±3.2	6.48±2.8	6.68±3.1
November 2017	10.9±4,3	10.53±7.4	14.28±7.3
December 2017	36.14±9.8	33.09±10.7	55.28±15.6
January 2018	11.7±4.7	15.12±6.3	41.65±13.4
Mean	15.65	13.79	18.59

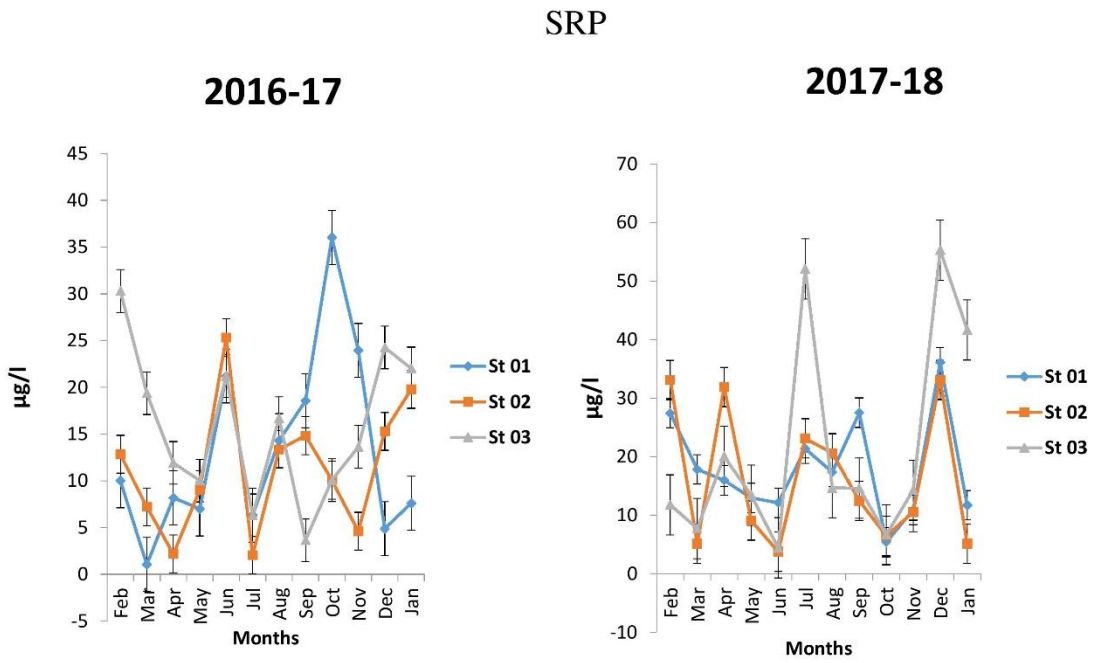


Fig. 23A. Monthly mean concentrations of SRP (µg/l)

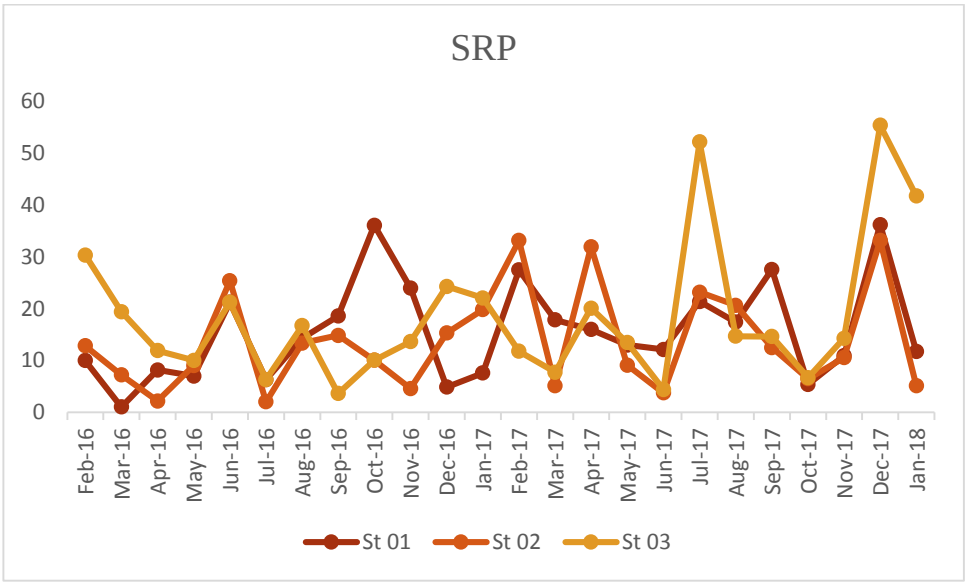


Fig. 23B. Comparison of SRP between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Soluble reactive silicate (SRS)

The concentration of SRS varied from 0.77-16.29 mg/l for station-1, 0.77-16.29 mg/l for station-2 and 2.12-23.19 mg/l for station-3. The highest monthly average of SRS was recorded in the month of September 2016 for station-1 and 2 and in the month of December 2017 for station-3. Whereas, the lowest mean SRS was recorded in the month of July 2016 for station-1 and 3 and in August 2016 for station-2 (Table 11).

Fig. 24 shows the seasonal flux of SRS, from where it is seen that the highest seasonal mean of SRS was recorded during winter for all stations. The lowest mean value was recorded during pre-monsoon for station-1 and 3. And it was recorded low for station-2 during the monsoon.

The concentrations of SRS fluctuated fairly in different months. The general pattern of variation is a gradual depleting trend in the concentration of SRS during January 2017 to June 2017 for station-1and 3. However, a regular ups and downward flux in the concentration of SRS for the station-2 was observed but no such steady trend was ever showed by any station during the study period (Fig. 25 B).

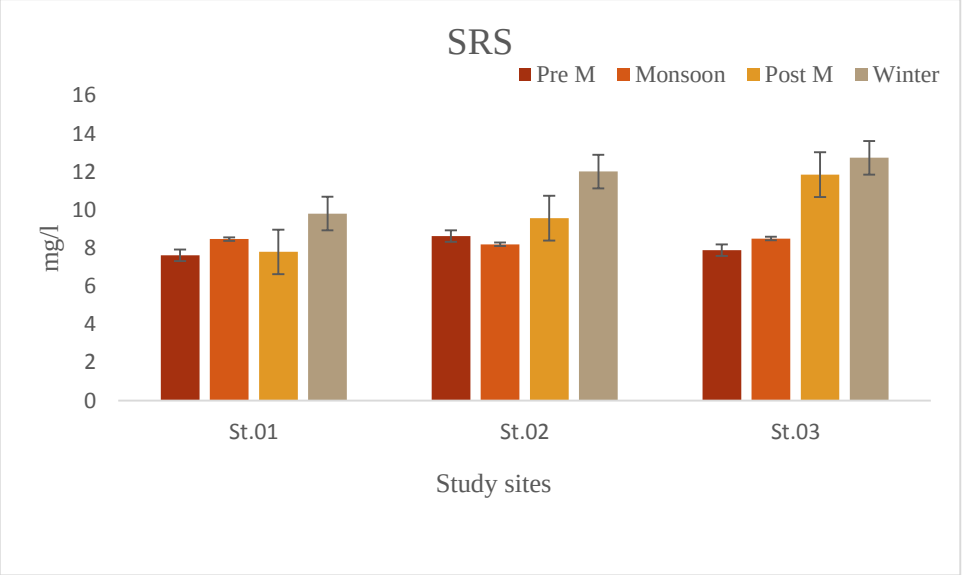


Fig. 24. Seasonal variation of SRS in three study sites of Kuniar Haor, Kishoreganj.

Table 11. Monthly mean values (±SD) of SRS (mg/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	4.13±2.2	3.12±1.6	2.92±1.2
March 2016	11.2±4.4	3.98±1.6	3.98±1.5
April 2016	5.65±1.7	9.22±3.6	15.42±5.7
May 2016	9.46±2.8	4.87±2.3	2.68±1.1
June 2016	9.46±2.4	9.07±1.5	2.9±0.7
July 2016	3.03±1.3	2.57±1.2	2.11±0.9
August 2016	0.77±0.01	2.04±1.02	16.54±3.7
September 2016	16.28±4.12	20.1±4.9	16.58±5.1
October 2016	5.05±1.6	14.04±4.7	5.93±1.7
November 2016	5.28±2.3	4.87±1.7	8.43±3.4
December 2016	15.004±3.9	16.56±4.7	13.44±4.3
January 2017	9.21±4.8	10.62±4.4	12.18±4.7
February 2017	7.92±3.4	12.99±4.6	8.51±2.7
March 2017	7.73±3.6	15.82±4.7	10.4±4.1
April 2017	7.69±2.8	5.83±2.2	9.04±3.6
May 2017	3.96±1.4	12.09±3.8	5.78±1.7
June 2017	3.24±1.3	5.003±2.4	5.18±2.1
July 2017	11.71±4.3	4.83±1.9	3.98±1.7
August 2017	14.3±4.6	11.76±3.8	10.48±3.4
September 2017	8.96±2.8	10.23±3.8	10.24±3.7
October 2017	11.79±3.2	11.35±4.1	20.37±4.3
November 2017	5.03±1.4	5.03±1.6	12.65±3.6
December 2017	11.02±4.8	12.99±5.1	23.19±5.2
January 2018	11.59±3.6	15.82±5.2	16.2±3.7
Mean	8.31	9.37	9.97

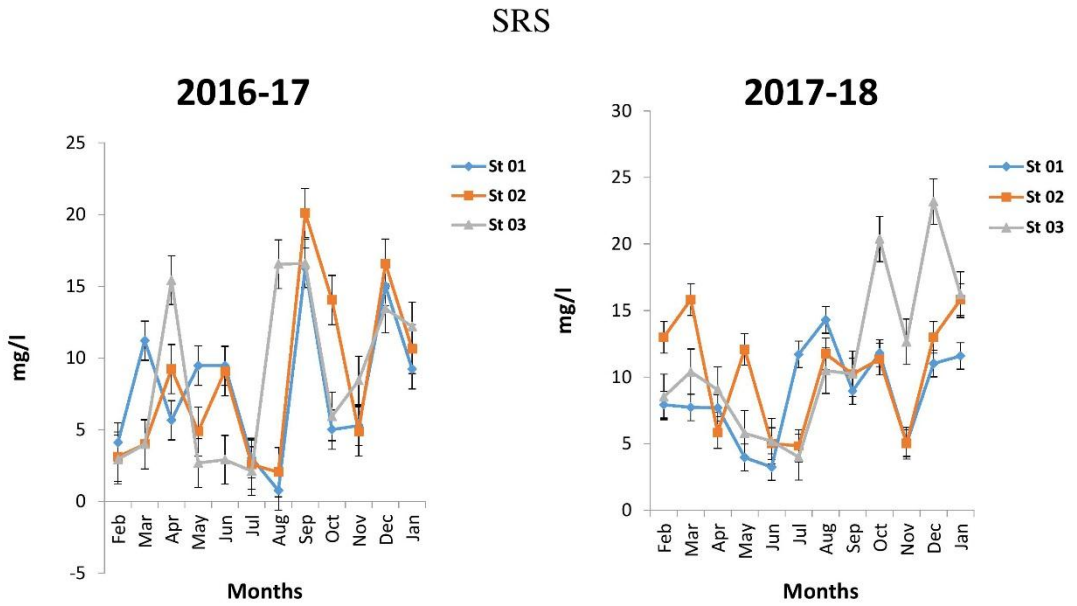


Fig. 25A. Monthly mean concentrations of SRS (µg/l)

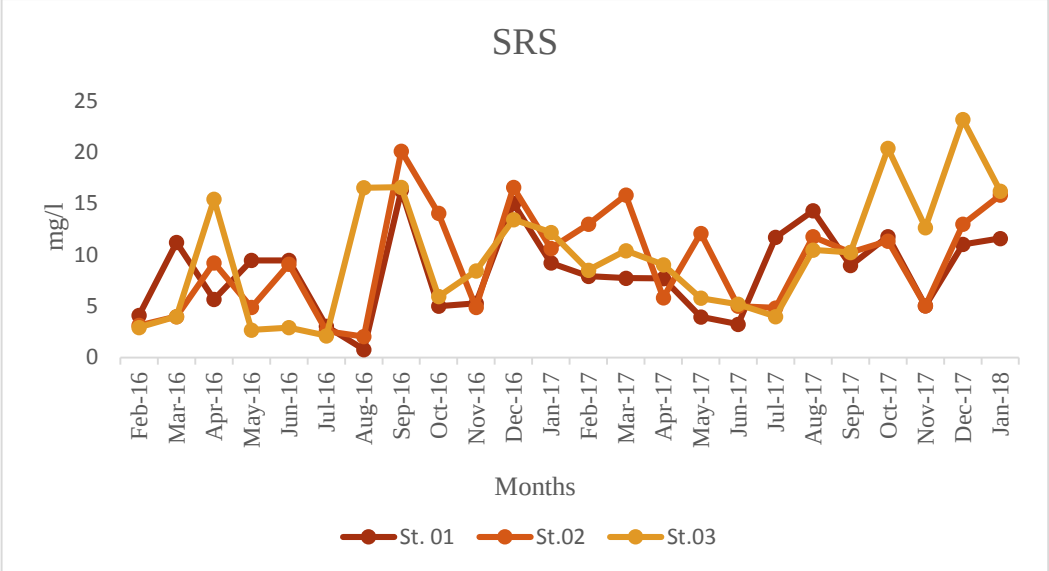


Fig. 25B. Comparison of SRS between the years of 2016-2018 of three study sites of Kuniar Haor, Kishoreganj.

Nitrate-nitrogen (NO_3-N)

During the study period between February 2016 and January 2018, the range of NO_3-N was 0.11-1.15 mg/l for station-1,0.07-0.62 mg/l for station-2 and 0.04-1.05 respectively. The highest monthly mean NO_3-N were recorded in the month of February 2016 for all stations, whereas the lowest mean NO_3-N were obtained in the month June 2017 for station-1,2 and 3. (Table 12).

In the present research the seasonal variation of NO_3-N showed the highest value during pre monsoon and lowest in post monsoon for all stations. For station-2 the highest value observed during pre monsoon and lowest in post monsoon (Fig. 26). The highest to lowest NO_3-N seasonal trend followed pre monsoon-monsoon-winter-post monsoon for station-1 and 2, pre monsoon-winter-monsoon-postmonsoon for station-3 (Fig. 26).

The concentration of NO_3-N is lower during monsoon and post monsoon in all stations. Moreover, station-1 shows higher concentration of NO_3-N comparatively. The annual fluctuation of this parameter of the studied habitat did not varied significantly during the second phase of the study period i.e. similar trends of the fluctuations noticed. (Fig. 27B).

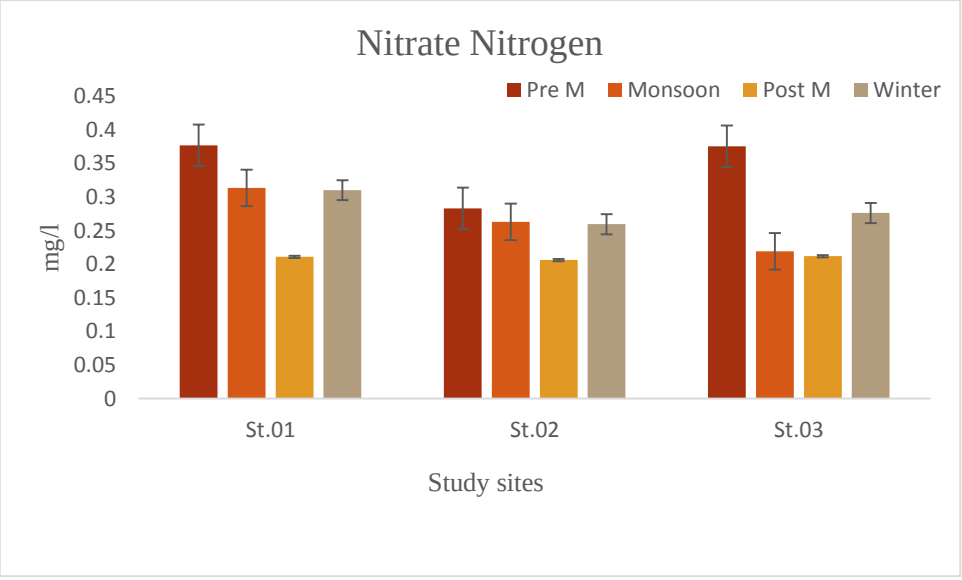


Fig. 26. Seasonal variation of NO_3-N in three study sites of Kuniar Haor, Kishoreganj.

Table 12. Monthly mean values (±SD) of NO_3-N (mg/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	0.359±0.03	0.409±0.05	0.405±0.05
March 2016	0.205±0.02	0.441±0.04	0.109±0.01
April 2016	0.248±0.02	0.324±0.03	1.05±0.02
May 2016	1.153±0.3	0.166±0.02	0.253±0.03
June 2016	0.208±0.02	0.217±0.03	0.209±0.02
July 2016	0.428±0.05	0.622±0.07	0.508±0.06
August 2016	1.148±0.2	0.412±0.06	0.277±0.03
September 2016	0.172±0.01	0.213±0.03	0.189±0.02
October 2016	0.301±0.03	0.301±0.02	0.295±0.02
November 2016	0.143±0.01	0.089±0.01	0.184±0.01
December 2016	0.231±0.02	0.208±0.02	0.157±0.01
January 2017	0.34±0.03	0.199±0.01	0.207±0.02
February 2017	0.271±0.03	0.213±0.02	0.273±0.02
March 2017	0.19±0.02	0.322±0.03	0.352±0.03
April 2017	0.351±0.03	0.138±0.01	0.285±0.02
May 2017	0.131±0.01	0.31±0.03	0.207±0.02
June 2017	0.131±0.01	0.068±0.002	0.042±0.003
July 2017	0.114±0.01	0.249±0.03	0.131±0.01
August 2017	0.169±0.02	0.167±0.02	0.219±0.02
September 2017	0.136±0.02	0.14±0.03	0.203±0.02
October 2017	0.196±0.02	0.154±0.01	0.202±0.02
November 2017	0.168±0.01	0.186±0.01	0.186±0.01
December 2017	0.306±0.03	0.213±0.02	0.241±0.03
January 2018	0.355±0.04	0.322±0.03	0.394±0.03
Mean	0.310	0.253	0.274

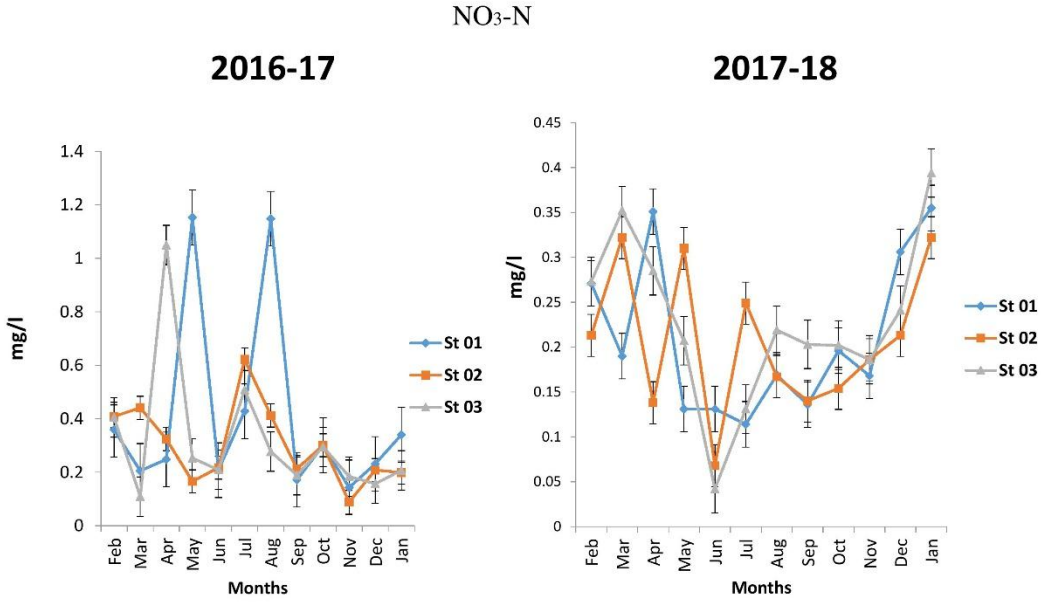


Fig. 27A. Monthly mean concentration of NO_3-N (µg/l)

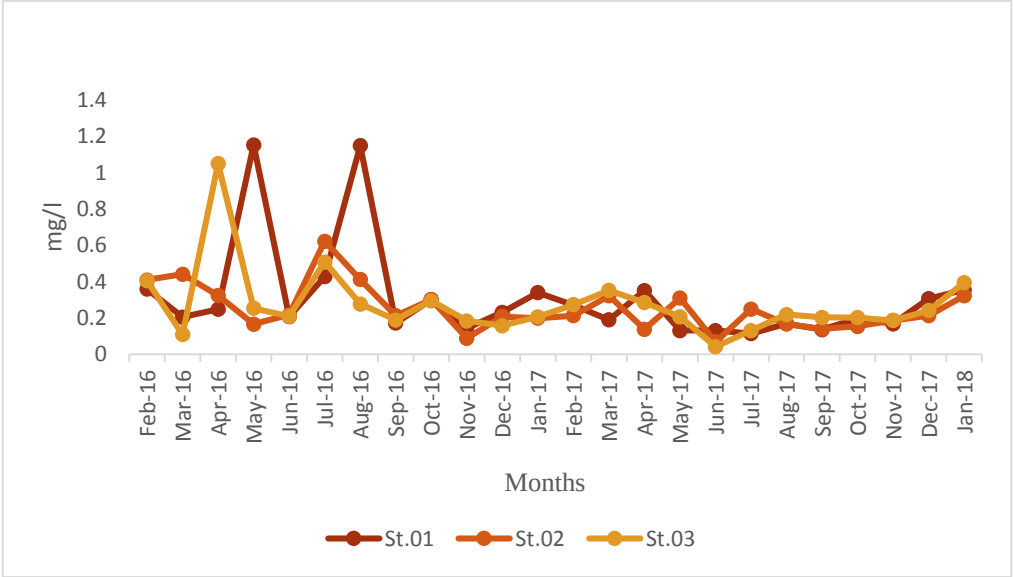


Fig. 27 B. Comparison of NO_3-N between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Biological parameters

Chlorophyll a (chl-a)

Range of chl-a for the period between February 2016 and January 2018 were recorded 1.18-24.27µg/l for station-1, 1.78-21.90 µg/l for station-2 and 2.37-32.56 µg/l for station-3. The highest monthly average value of chl-a for station-1 were recorded in June, 2016 whereas station-2 and station-3 showed higher values in the month of March, 2016. The lowest concentration of chl-*a* were recorded in the month of January, 2018 for station-1 and October, 2017 for station-2 and station-3 (Table 13).

In the present research, the seasonal variation of chl-a were observed higher during pre monsoon and lower in post monsoon for both study periods. The highest to lowest seasonal trend of chl-*a* followed pre monsoon-monsoon-winter-post monsoon for station-2 and 3 monsoon-pre monsoon-winter-post monsoonfor station-1 (Fig. 28).

The annual fluctuation of chl-a resembles with the three stations. Station-1 is rich in chl-*a* during the month of June 2016 and a continuous lower value observed during January 2017 to December 2017 for all stations (Fig. 28).

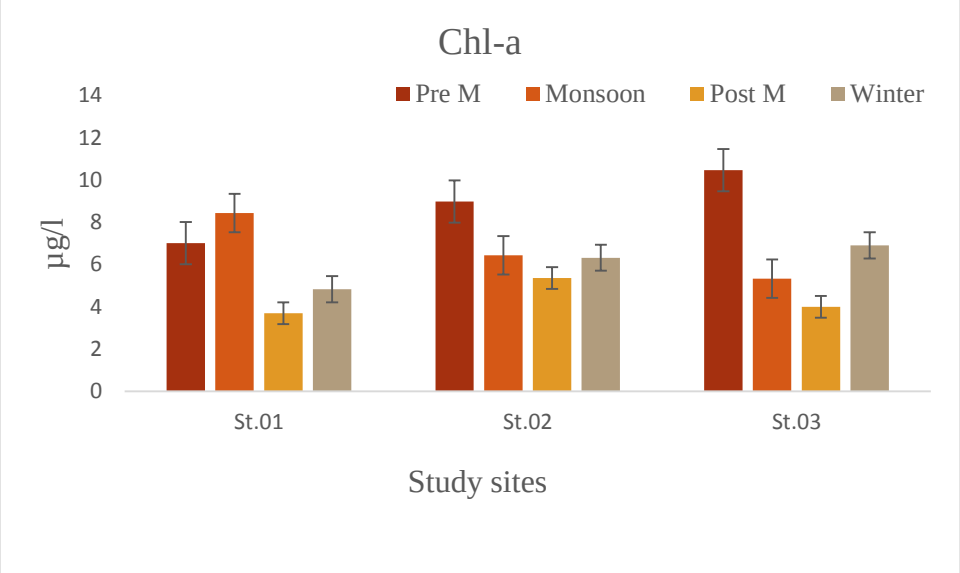


Fig. 28. Seasonal variation of chl-a in three study sites of Kuniar Haor, Kishoreganj.

Table 13. Monthly mean values (±SD) of chl-a (µg/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	4.73±1.6	7.66±2.8	6.51±2.2
March 2016	14.8±3.1	21.94±6.8	32.56±7.3
April 2016	10.65±2.7	3.55±1.6	14.28±3.2
May 2016	6.51±1.7	8.88±1.9	5.32±1.8
June 2016	24.27±6.8	4.73±1.6	4.73±1.4
July 2016	10.06±3.1	20.12±4.3	8.28±2.4
August 2016	10.06±2.7	7.14±1.9	4.73±1.3
September 2016	5.32±1.7	6.51±2.1	10.06±2.7
October 2016	8.88±2.6	11.84±3.3	8.28±2.2
November 2016	5.32±1.6	6.51±1.8	2.96±1.2
December 2016	9.47±2.8	8.28±2.7	7.14±1.6
January 2017	6.51±1.3	7.69±2.2	10.65±3.4
February 2017	5.32±1.6	2.36±1.1	5.32±1.8
March 2017	2.96±1.07	9.46±2.7	2.36±1.08
April 2017	2.36±1.04	1.77±1.02	2.36±1.61
May 2017	4.73±1.6	8.28±2.7	5.92±2.2
June 2017	6.51±2.3	2.96±1.02	4.736±1.6
July 2017	3.54±1.2	4.14±1.6	4.73±1.3
August 2017	5.91±2.4	2.36±1.3	2.36±1.1
September 2017	1.78±0.9	3.54±1.2	2.96±1.01
October 2017	1.77±0.8	1.77±0.9	2.36±1.03
November 2017	1.77±0.9	1.77±0.7	2.36±1.02
December 2017	1.18±0.8	2.36±1.04	2.36±1.06
January 2018	1.75±0.9	9.46±3.1	9.47±2.8
Mean	6.50	6.88	6.78

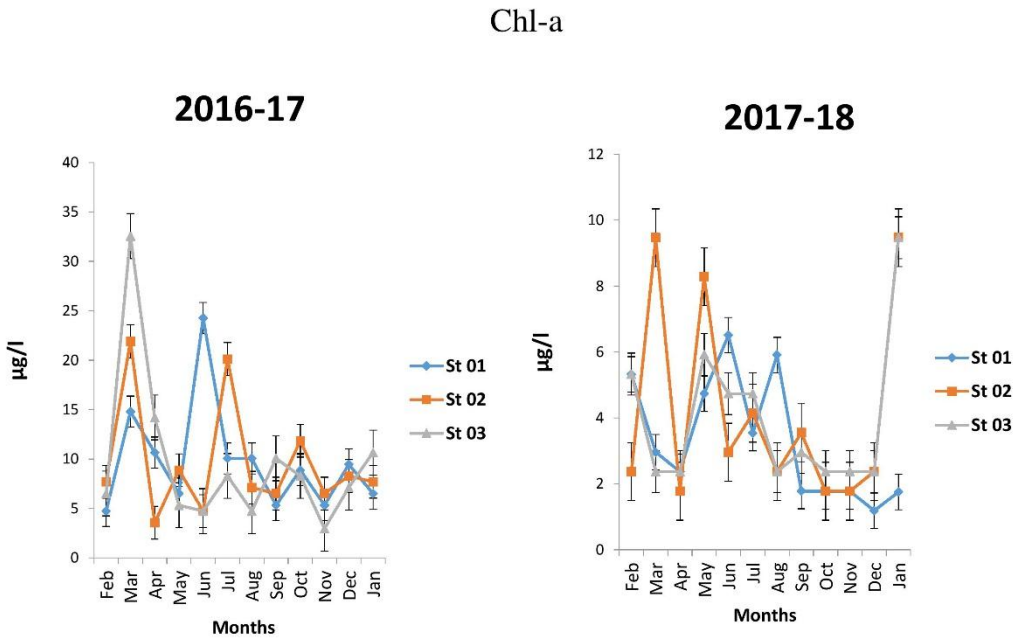


Fig. 29A. Monthly mean values of chlorophyll-*a* (µg/l)

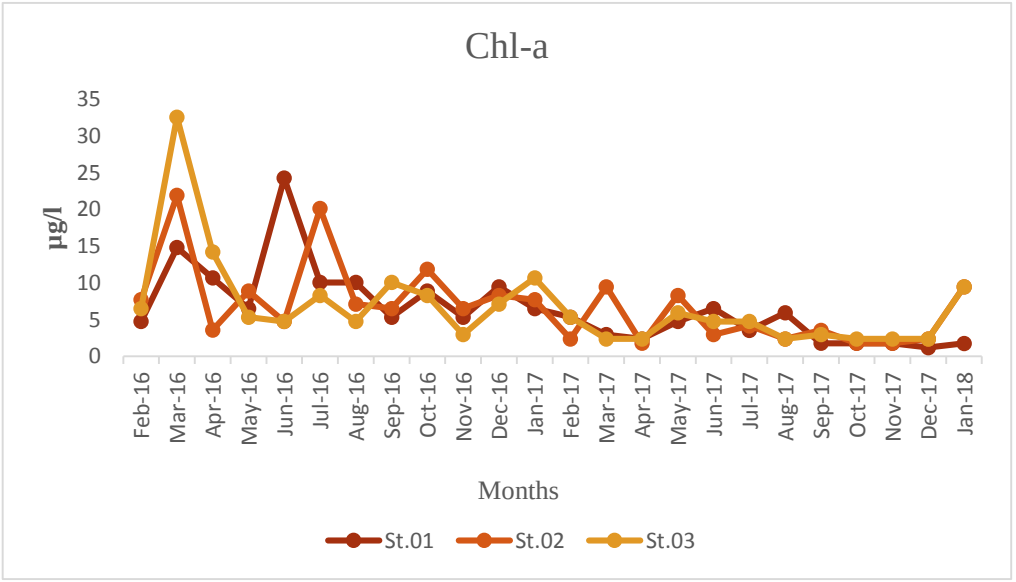


Fig.29 B. Comparison of chl-a between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Phaeopigment (PP)

Range of monthly average phaeopigment for the period between February 2016 and January 2018 were recoded 0.37-25.30 µg/l, 0.13-46.32 µg/l and 0.54-25.26 µg/l for station-1,2 and 3, respectively. The highest monthly average of phaeopigment for station-1 were recorded in June, 2016 whereas station-2 and station-3 showed higher values in the month of March, 2016. The lowest concentration of phaeopigment were recorded in the month of April, 2017 for both station -1 and station -3, August 2017 for station-2. (Table 14).

In the present investigation, during pre monsoon station-2 and station-3 showed a higher variation of phaeopigment, the higher value for station-1 were observed in monsoon. In the winter all stations attained a lower magnitude of phaeopigment. (Fig. 30).

During the study period phaeopigment concentration varied in the year of 2017-2018 than the year of 2016-2017 for all stations. It has also shown that the mean concentration of phaeopigment for station-3 is comparatively higher than other two (Fig. 31 B).

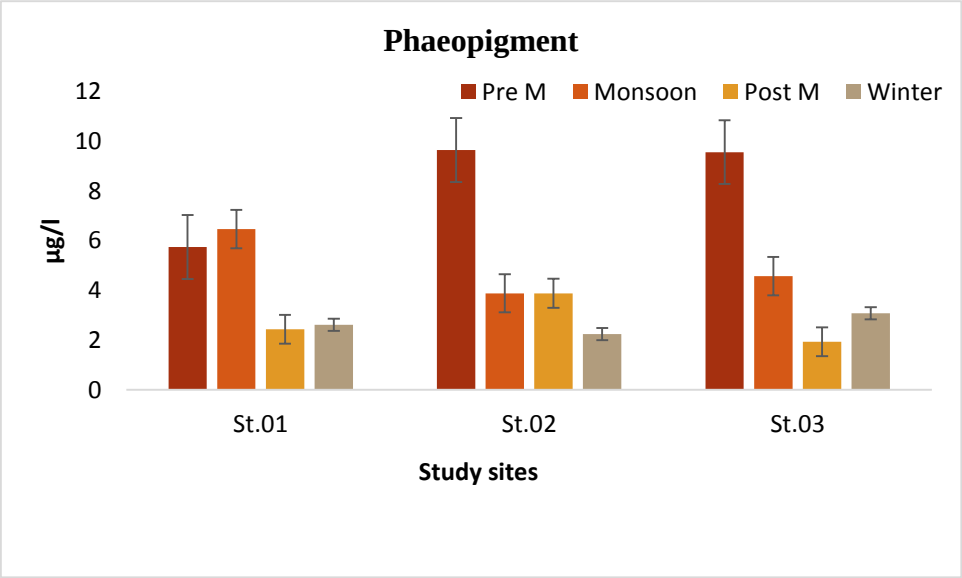


Fig. 30. Seasonal variation of phaeopigment in three study sites of Kuniar Haor, Kishoreganj.

Table 14. Monthly mean values (±SD) of phaeopigment (µg/l) for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	1.504±0.4	3.536±1.2	1.392±0.3
March 2016	23.88±5.7	46.32±8.9	25.26±6.8
April 2016	0.96±0.04	2.27±1.1	16.17±3.2
May 2016	4.304±1.6	3.476±1.2	5.412±1.9
June 2016	9.42±2.9	4.64±1.6	13.15±3.2
July 2016	25.29±5.8	7.32±2.4	3.36±1.2
August 2016	3.488±1.3	6.2±3.3	5.41±2.3
September 2016	6.736±2.4	5.136±2.1	4.496±2.7
October 2016	3.6±1.3	10.624±3.5	4.192±2.3
November 2016	2.056±1.1	1.808±0.7	2.032±1.02
December 2016	3.008±1.3	2.528±1.1	2.88±1.2
January 2017	4.304±2.2	3.952±1.03	7.64±3.7
February 2017	3.824±1.02	1.045±0.3	1.328±0.8
March 2017	0.368±0.02	1.345±0.5	2.624±1.2
April 2017	0.96±0.06	1.552±0.6	0.544±0.04
May 2017	4±1.6	2.944±1.1	7.392±2.7
June 2017	2.224±1.02	4.944±1.7	3.168±1.6
July 2017	1.024±0.4	1.267±0.3	3.168±1.2
August 2017	1.154±0.5	0.13±0.01	3.036±1.7
September 2017	2.384±0.97	1.44±0.4	0.784±0.07
October 2017	1.968±0.3	1.552±0.2	0.964±0.3
November 2017	1.552±0.2	1.55±0.7	0.544±0.03
December 2017	1.184±0.7	1.045±0.6	3.04±1.1
January 2018	1.957±0.9	1.345±0.8	2.17±1.02
Mean	4.63	4.91	5.007

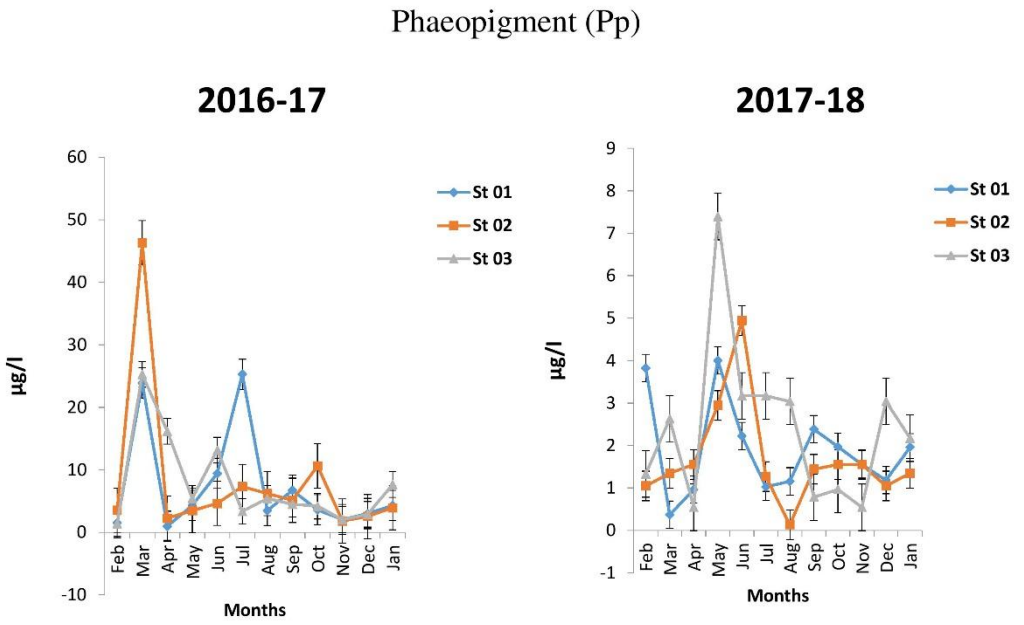


Fig. 31A. Monthly mean values of phaeophytin (µg/l)

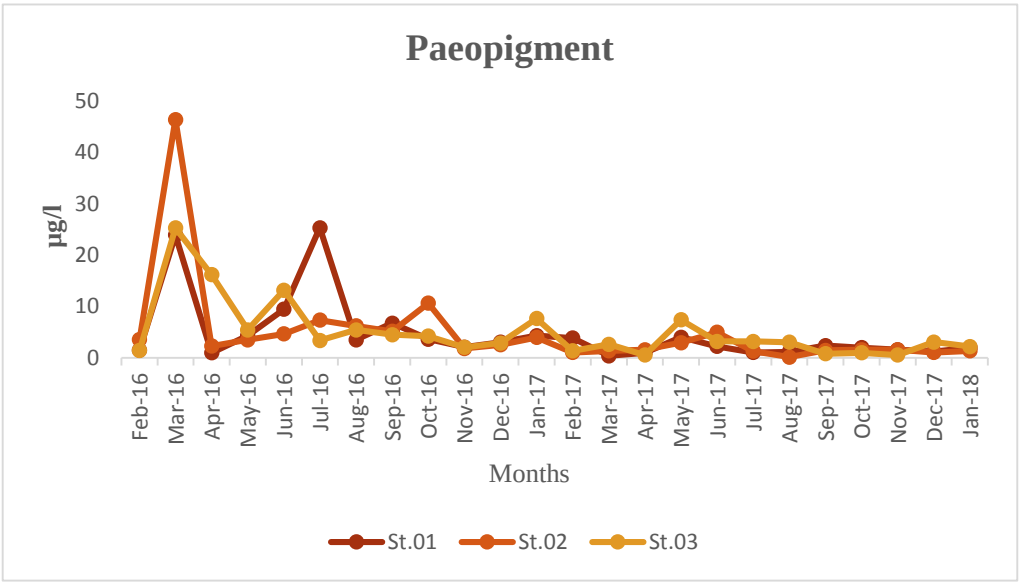


Fig. 31B. Comparison of phaeopigment between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Phytoplankton density (PD)

Range of monthly average phytoplankton density for the period between February 2016 and January 2018 were recorded 1.80-37.80× 10^4ind./l for station-1, 3.37-62.20×10^4 ind./l for station-2, and 4.08-46.90 ×10^4 ind./l for station-3. The highest monthly average of phytoplankton density was recorded during the month of April 2016 for station-1 and 3, March, 2016 showed a high range in station-2. The lowest were recorded in the month of November 2016 for station 1 and 2 July 2016 for station 3(Table 15).

In the present investigation, the seasonal variation of phytoplankton density observed higher pre monsoon and lower in post monsoon for all stations (Fig. 33).

During the study period, the amount of phytoplankton density was quite equal in both years for the stations. During the study period of phytoplankton density showed a rising tendency after the month of January and April decreasing tendency just after September (Fig. 3).

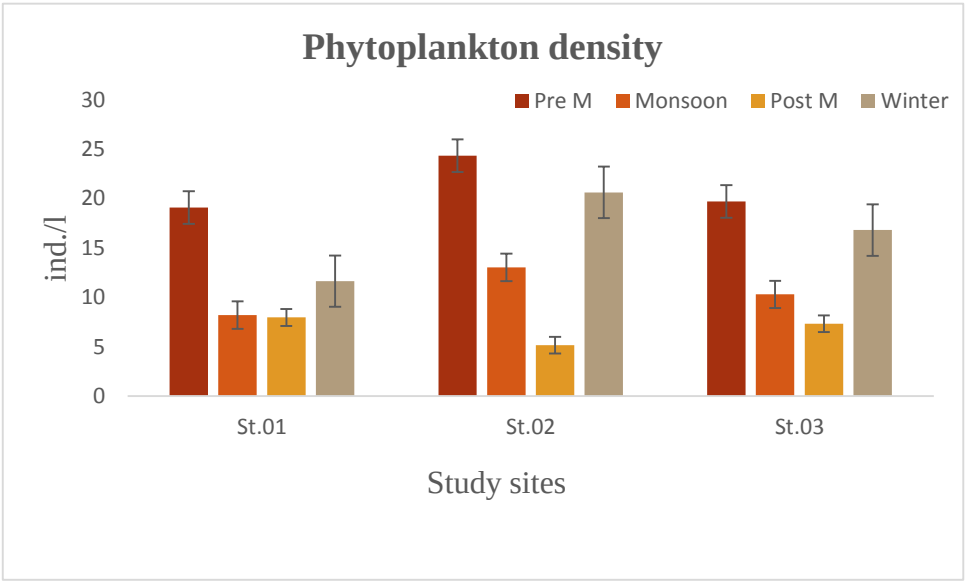


Fig. 32. Seasonal variation of phytoplankton density in three study sites of Kuniar Haor, Kishoreganj.

Table 15. Monthly mean values (±SD) of phytoplankton density for all the study sites

Months	Station-1	Station-2	Station-3
February 2016	7.4±3.4	41.2±10.1	26.6±6.8
March 2016	23.37±6.7	62.2±12.6	4.08±1.9
April 2016	23.6±5.8	23.1±5.7	46.9±11.3
May 2016	6.8±2.4	20.8±5.6	15.4±4.2
June 2016	4.3±1.3	19.3±4.2	14.2±3.6
July 2016	8±1.7	15.04±3.8	4.12±1.4
August 2016	9.5±3.2	3.37±1.1	12.6±3.4
September 2016	1.8±0.4	14±3.5	10.07±2.8
October 2016	14.04±3.6	7.1±1.3	8.4±1.8
November 2016	3.4±1.2	3.4±1.1	7.8±1.6
December 2016	14.3±3.8	8.12±2.2	6.3±1.7
January 2017	21.4±4.6	29.1±5.3	10.08±2.6
February 2017	9.36±2.4	16.43±4.2	9.3±3.1
March 2017	10.2±2.8	7.26±2,3	6.27±2.1
April 2017	37.8±9.6	17.4±3.8	35.04±7.4
May 2017	12.73±3.3	15.3±3.8	10.56±2.9
June 2017	15.18±2.6	11.22±2.8	11.34±3.1
July 2017	11.04±2.5	22.05±3.2	12.54±2.3
August 2017	12.41±3.1	13.84±2.1	12.21±2.5
September 2017	3.4±1.2	5.28±1.4	5.2±1.6
October 2017	7.37±1.8	5.1±1.2	5.85±1.1
November 2017	7±2.2	5.02±1.1	7.2±2.1
December 2017	8.82±2.4	12.8±3.1	12.6±2.8
January 2018	8.5±2.3	16.1±3.7	36±6.7
Mean	11.73833	16.43875	13.7775

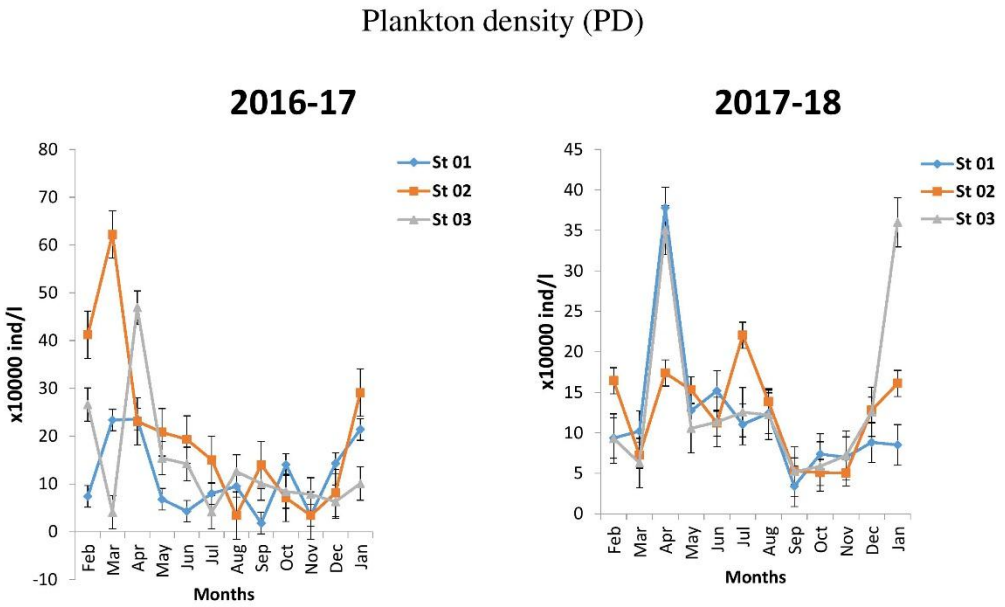


Fig. 33A. Monthly fluctuation of phytoplankton density (x10000 ind/l)

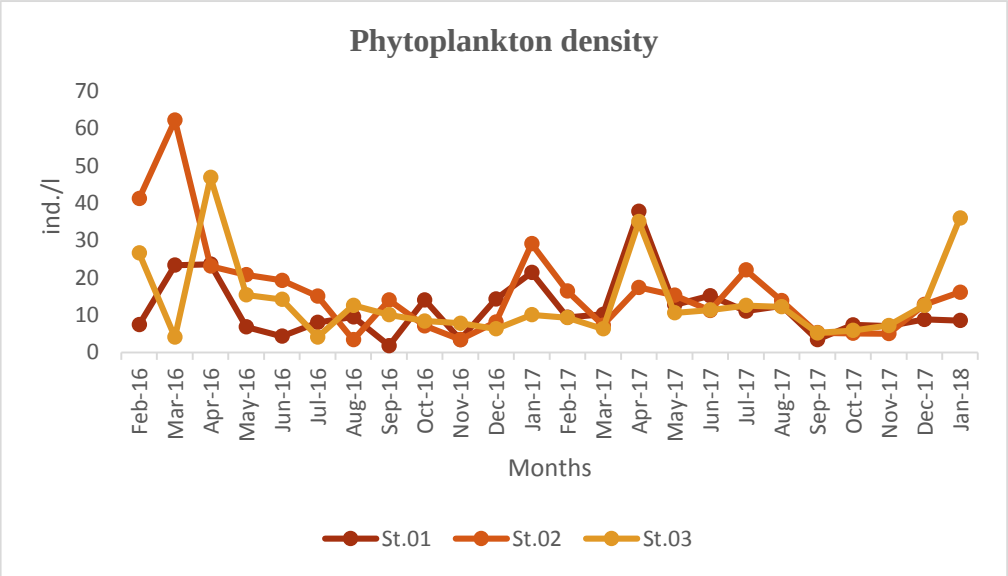


Fig. 33B. Comparison of phytoplankton density between the years of 2016 and 2018 of three study sites of Kuniar Haor, Kishoreganj.

Flora of Kuniar Haor

Macrophyte density

The community of aquatic macrophyte represented of 48 species. The distribution of macrophytes in the Haor basin varied in different seasons. The macrophyte population of the Haor was mainly represented by angiosperms. *Sesbania bispinosa*, *Ipomoea aquatica*, *Barringtonia acutangula*, *Ottelia alismoides*, *Blyxa auberti*, and *Ludwigia adscendens* were seen all over the investigation period (Table 16).

Table 16. List of macrophytes and their abundance

DICOTYLEDONS

Sl. No.	Name of Family	Name of Genus	Wetland macrophytes of Kuniar Haor	Station-1	Station-2	Station-3
1	Acanthaceae	**Hygrophila**	*Hygrophila auriculata* (K.Schum.) Heine	+	+	+
		Achyranthes	*Achyranthes aquatica* R.Br.	+	++	++
2	Amaranthaceae	**Alternanthera**	*Alternanthera phyloxeroides* (Mart.) Griseb	++	++	+++
3	Ceratophyllaceae	**Ceratophyllum**	*Ceratophyllum demersum* L.	+	+++	+++
4	Compositae	**Enhydra**	*Enhydra fluctuans* Lour.	+	+++	+++
5	Convolvulaceae	**Ipomoea**	*Ipomoea aquatica* Forsk.	++	+++	++
6	Haloragaceae	**Myriophyllum**	*Myriophyllum tuberculatam* Roxb.	-	++	++
7	Hydrophyllaceae	**Hydrolea**	*Hydrolea zeylanica* (L.) Vahl.	+	+++	+++

*** + = 0 - 2 ind/quadrat, ++ = 3 - 6 ind/quadrat and +++ = 7 - 10 ind/quadrat.

(Contd.)

DICOTYLEDONS

Sl. No.	Name of Family	Name of Genus	Wetland macrophytes of Kuniar Haor	Station-1	Station-2	Station-3
8	Menyanthaceae	**Nymphoides**	*Nymphoidea cristatum* (Roxb.) O. Kuntze	+	+	++
9	Nymphaeaceae	**Nelumbo**	*Nelumbo nucifera* Gaertn.	-	++	++
		Nymphaea	*Nymphaea nouchali* Burm. f.	-	-	+
10	Onagraceae	**Ludwigia**	*Ludwigia adscendens* (L.) Hara	+	+++	+++
			Ludwigia repens Forst. Cat.	++	++	+++
11	Papilionaceae	**Aeschynomene**	*Aeschynomene aspera* L.	-	+	+
12	Polygonaceae	**Polygonum**	*Polygonum lanatum* Roxb.	+	+	++
			Polygonum tomentosum Willd.	+	++	++
13	Scrophulariaceae	**Limnophila**	*Limnophila heterophylla* (Roxb.) Benth.	+	++	+++
			Limnophila indica (L.) Druse.	+	++	-
14	Trapaceae	**Trapa**	*Trapa maximowiczii* Korshinsky.	+	+	++

*** + = 0 - 2 ind/quadrat, ++ = 3 - 6 ind/quadrat and +++ = 7 – 10 ind/quadrat

MONOCOTYLEDONS

Sl. No.	Name of Family	Name of Genus	Aquatic Angiosperms of Kuniar Haor	Station-1	Station-2	Station-3
1	Alismataceae	**Sagittaria**	*Sagittaria guayanensis* H.B.K. Sp. Lappula.	-	+	+
			Sagittaria sagittifolia L.	-	-	+
2	Aponogetonaceae	**Aponogeton**	*Aponogeton appendiculatus* Bruggen	+	+	++
3	Araceae	**Pistia**	*Pistia stratiotes* L.	++	++	+++
4	Cyperaceae	**Cyperus**	*Cyperus articulatus* L.	+	+	++
			Cyperus cephalotes Vahl	-	+	+
			Cyperus corymbosus Rottb.	-	+	+
			Cyperus tegetiformis Roxb.	-	-	+
		Eleocharis	*Eleocharis dulcis* (Burm.f.) Trin. Ex Hensch.	+	+	++
		Schoenoplectus	*Schoenoplectus articulatus* (L.) Palla	-	+	++
5	Eriocaulaceae	**Eriocaulon**	*Eriocaulon setaceum* L.	+	++	+++
6	Gramineae	**Hygroryza**	*Hygroryza aristata* (Retz.) Nees ex Wight & Arn.	+	++	++
		Oryza	*Oryza rufipogon* Griff.	+	+	++
		Panicum	*Panicum paludosum*		+	+

*** + = 0 - 2 ind/quadrat, ++ = 3 - 6 ind/quadrat and +++ = 7 - 10 ind/quadrat.

(Contd.)

MONOCOTYLEDONS

Sl. No.	Name of Family	Name of Genus	Aquatic Angiosperms of Kuniar Haor	Station-1	Station-2	Station-3
7	Hydrocharitaceae	**Blyxa**	*Blyxa japonica* (Miq.) Maxim.	+	++	++
		Hydrilla	*Hydrilla verticillata* (L.f.) Royle	++	+++	+++
		Hydrocharis	*Hydrocharis dubia* (Bl.) Backer	-	+	+
		Nechamandra	*Nechamandra alternifolia* (Roxb.) Thw.	-	+	++
		Vallisneria	*Vallisneria spiralis* L.	+	+	+++
8	Lemnaceae	**Lemna**	*Lemna perpusilla* Torrey	+	+	++
		Spirodela	*Spirodela polyrhiza* (L.) Schleid.	-	+	+
9	Limnocharitaceae	**Limnocharis**	*Limnocharis flava* (L.) Buch. In Bremen	+	+	+
10	Najadaceae	**Najas**	*Najas indica* (Willd.) Cham.	-	+	+
11	Pontederiaceae	**Eichhornia**	*Eichhornia crassipes* (Mart.) Solms in A.DC.	++	++	+++
		Monochoria	*Monochoria hastata* (L.) Solms in A. DC.	+	+	++
			Monochoria vaginalis (Burm.f.) Presl	+	+	++
12	Potamogetonaceae	**Potamogeton**	*Potamogeton crispus* L.	+	++	++
13	**Pteridophytes** Salviniaceae	**Salvinia**	*Salivinia cucullata* Roxb.	-	+	+++
			Salvinia sp.	-	+	++

*** + = 0 - 2 ind/quadrat, ++ = 3 - 6 ind/quadrat and +++ = 7 - 10 ind/quadrat.

Qualitative and quantitative analysis of phytoplankton

Phytoplankton diversity

In the present investigation a total of 215 phytoplankton samples was collected from three study sites of Kuniar Haor. All these samples were studied for qualitative and quantitative data.

Qualitative data and Composition

In the present investigation 51, 52 and 51 genera were represented in the phytoplankton communities for station-1, station -2 and station-3 respectively. The genera were recorded from station-1, station -2 and station-3 belonged to six divisions (Cyanophyta, Chlorophyta, Euglenophyta, Chrysophyta, Pyrrophyta and Cryptophyta (Table 19-21).

Genus level percentage composition shows that Chlorophyta dominates in three stations and occupied 39.2%,40.3% and 35.2% for station-1, station -2 and station-3 respectively, followed by Chrysophyta (29.4% for station-1, 26.9% for station-2 and 31.3% for station-3), Euglenophyta (11.7% for station-1, 11.5% for station-2 and 11.7% for station-3), Cyanophyta (9.8% for station-1, 9.6% for station-2 and7.8% for station-3), Cryptophyta (7.8% for station-1, 5.8% for station-2 and 11.7% for station-3), and Pyrrhophyta can be treated as a minor group for all study sites (1.9% for station-1, 5.8% for station-2 and 3.9% for station-3). (Table 17).

At the species level, a total of 115,120 and 90 species were recorded from station-1, station -2 and station-3 respectively. Maximum number of species 37.4% (station-1), 34.1% (station-2), and 37.7% (station-3) among the flora studied was represented by the Chrysophyta. Chrysophyta followed by Euglenophyta (28.7%in station-1, 31.7% in station-2 and 28.8% for station-3), Chlorophyta (21.7% for station-1, 23.3% for station-2 and 21.1% for station-3), Cyanophyta (6.08% for station-1, 4.1% for station-2 and 4.4% for station-3), Cryptophyta (3.5 % for station-1, 3.3% for station-2 and 5.5% for station-3) and Pyrrophyta (2.6% for station-1, 3.3% for station-2 and 3.3% for station-3) (Table 18).

Table 17. The Number of genera recorded from different divisions of algae as phytoplankton from three study sites (percentage of the total has been provided within parenthesis).

Divisions	No. of genera		
	Station -1	Station -2	Station -3
Cyanophyta	5 (9.8 %)	5 (9.6%)	**4 (7.8%)**
Chrysophyta	15 (29.4%)	14 (26.9%)	**16 (31.3%)**
Chlorophyta	20 (39.2 %)	21(40.3%)	**18 (35.2%)**
Euglenophyta	6 (11.7 %)	6 (11.5%)	**6 (11.7%)**
Pyrrhophyta	1 (1.9%)	3 (5.8%)	**2 (3.9%)**
Cryptophyta	4 (7.8%)	3 (5.8%)	**5 (11.7%)**
Total	**51**	**52**	**51**

Table 18. The Number of species recorded from different divisions of algae as phytoplankton from three study sites (percentage of the total has been provided within parenthesis).

Division	No. of species		
	Station -1	Station -2	Station -3
Cyanophyta	7 (6.08%)	5 (4.1%)	**4 (4.4%)**
Chrysophyta	43 (37.4%)	41 (34.1%)	**34 (37.7%)**
Chlorophyta	25 (21.7%)	28 (23.3%)	**19 (21.1%)**
Euglenophyta	33 (28.7%)	38 (31.7%)	**26 (28.8%)**
Pyrrhophyta	3 (2.6%)	4 (3.3%)	**3 (3.3%)**
Cryptophyta	4 (3.5%)	4 (3.3%)	**5 (5.5%)**
Total	**115**	**120**	**90**

Micoscopic study of Phytoplankton

Station-1

Table 19 shows the counted phytoplankton genera and their individual proportion of counts of station-1. In this station *Oscillatoria* belonging to Cyanophyta, , *Crucigenia, Coelastrum, Scenedesmus, Carteria, Chlamydomonas, Mougeotia, Oocystis, Cosmarium* and *Staurastrum* belonging to Chlorophyta, *Trachelomonas, Lepocinclis, Euglena, Strombomonas, Rhodomonas* and *Phacus* belonging to Euglenophyta, *Melosira, Cymbella, Cyclotella, Gomphonema, Eunotia, Synedra, Fragilaria, Navicula, Pinnularia,* and *Nitzschia* belonging to Chrysophyta, *Peridinium* and *Gymnodinium* belonging to Pyrrhophyta and *Chroomonas* and *Cryptomonas* belonging to Cryptophyta were observed.

Station -2

Table 20 shows the recorded phytoplankton genera and their individual proportion of count in station-2. In this Station *Melosira, Cyclotella, Trachelomonas, Euglena, Oscillatoria, Peridinium, Cryptomonas, Synedra, Navicula, Eunotia, Gyrosigma, Rhodomonas Coelastrum, Strombomonas* and *Chlamydomonas* were dominant.

Station -3

Table 21 shows the counted phytoplankton genera and their individual density of Station-3. In this lake *Cyclotella, Trachelomonas, Dictyophaerium, Euglena, Oscillatoria, Peridinium, Cryptomonas, Crucigenia, Surirella, Pandorina, Synedra, Pelonema, Eunotia, Nitzschia Coelastrum, Strombomonas, Phacus* and *Chlamydomonas* were dominant.

Table 19. List of the phytoplankton species counted in two years of study in Station-1.

Division	Species	Total no. received
Chrysophyta	*Achnanthes* sp.	02
	Achnanthes minutissima Kütz	03
	Cymbella parva Kichner	07
	Cymbella turgidula Grun.	03
	Cyclotella meneghiniana Kütz	02
	Cyclotella comensis Grunow in Van Heurck	09
	Cyclotella comta var. *affinis* Grunow in Van Heurck	09
	Chaetoceros compressus Lauder	02
	Coscinodiscus lineatus Ehrenberg	03
	Eunotia monodon Ehr.	05
	Eunotia robusta Ralfs in Pritchard	04
	Fragilaria intermedia Grunow	03
	Fragilaria crotonensis Kitton	05
	Fragilaria capucina var.*lanceolata* Desm.	04
	Gomphonema lanceolatum var. *turris* (Ehrenberg) Hust.	08
	Gyrosigma scalproides (Rabh.) Cleve	03
	Gyrosigma distortum var parkei (Harrison.) Cleve	03
	Gyrosigma attenuatum (Kütz) Rabenhorst	06
	Melosira distans var. *alpigena* Grunow in Van Heurck	13
	Melosira granulata var. *angustissima* Mull	46
	Melosira granulata var. *curvata*	10
	Navicula Americana Ehrenberg	02
	Navicula bacillum Ehrenberg	01
	Navicula radiosa Kütz.	03
	Navicula pupula Kütz.	14
	Navicula placentula (Her.) var. *rostrata*	06
	Navicula cuspidate Kützing	03
	Navicula pseudohalophila Cholnoky	02
	Navicula grimmei krasske in Hustedt	02
	Nitzschia acicularis (Kützing) W. Smith	03
	Nitzschia longissima (Bréb.) Grunow	03
	Nitzschia linearis W. Smith	05
	Pinnularia molaris (Grun.) Cleve	07
	Pinnularia gibba var. *parva* Frenguelli	05
	Pinnularia major (Kütz.) Rabenhorst	02
	Pinnularia pulchara Østrup	02
	Surirella robusta Ehrenberg	09
	Surirella angustata Kütz in Germain	06
	Synedra acus Kütz	15
	Synedra ulna (Nizsch) Her.	13
	Synedra tabulate Kützling	02

Division	Species	Total no. received
Euglenophyta	*Astasia pygmaea* Skuja	03
	Euglena oblonga Schmitz	02
	Euglena gojdicsae Prescott	01
	Euglena rostrifera Johnson	03
	Euglena viridis (Müller) Ehrenberg	02
	Euglena acus var. *longissima* Defl.	18
	Euglena tripteris (Dujardin) Klebs.	01
	. *Euglena mainxii* Defl.	05
	Euglena spathirhyncha Skuja	02
	Euglena clavata Skuja.	03
	Euglena variabilis Klebs.	02
	Euglena caudate Lemm.	04
	Euglena agilis var. *praexicisa*	02
	Euglena hemichromata Skuja	02
	Euglena allorgei Defl.	03
	Lepocinclis salina Fitsch	02
	Lepocinclis ovum var. *major* (Huber-Pestalozzi) Conr.	08
	Phacus ephippion Pochm	03
	Phacus longicauda var. *attenuata* (Pochm.) Huber-Pestalozzi	04
	Trachelomonas volvocina Ehrenberg	08
	Trachelomonas oblonga var. *truncata* Lemm.	01
	Trachelomonas cylindrica Ehr	02
	Trachelomonas scabra var. *pygnea* Playfair	02
	Trachelomonas anguste-ovata fa. *Minor* Islam	01
	Trachelomonas hispida var. *coronata* Lemm.	01
	Trachelomonas playfairii	02
	Trachelomonas compacta	02
	Trachelomonas pulcherrima Roll	01
	Trachelomonas rugulosa Stein	02
	Trachelomonas bernardi Woloszynksa	01
	Trachelomonas intermedia Dang	02
	Trachelomonas eurystoma var. *minuta* Stein.	01
	Trachelomonas lismorensis var. *inermis* Playfair	01

Division	Species	Total no. received
	Trachelomonas planctonica Swir.	03
	Trachelomonas tshopoensis Van Oye	03
	Strombomonas verrucosa var. *borystheniensis* Stokes	02
	Strombomonas fluviatilis Defl.	04
	Strombomonas gibberosa var. *tumida*	06
Chlorophyta	*Ankistrodesmus falcatus* (Corda)Ralfs	02
	Carteria radiosa Kors.	08
	Chlamydomonas gloeopara Rodhe *et* Skuja	02
	Closterium calosporum	02
	Cosmarium pseudopyramidatum var. *lentiferum*	02
	Crucigenia mucronata (G. M. Smith) Kom.	01
	Crucigeniella crucigera (Wolle) Komérek	02
	Crucigenia tetrapedia (Kirchner) W. West G.S. West	02
	Chlorella vulgaris Beyerinck	01
	Coelastrum microporum Nägeli	02
	Dictyosphaerium granulatum Hind.	02
	Dictyosphaerium subsolitarium Van Goor	01
	Eudorina elegans Ehrenberg	01
	Kirchneriella subcapitata Korš	02
	Mougeotia sp.	07
	Monoraphidium griffithii (Berkely) Kom. Legn.	04
	Oocystis pyriformis Prescott	03
	Oocystis borgei Snow	08
	Pandorina sp.	02
	Planktosphaeria gelatinosa GM Smith	03
	Pediastrum duplex Meyen	03
	Spirogyra sp.	04
	Scenedesmus opoliensis var. *contacta*	03
	Staurastrum sp.	03
	Scenedesmus incrassatulus Bohlin	02

	Tetraedriella spinigera Skuja	01
	Tetrastrum heteracanthum fa. *elegans* Ahlstrom *et* Tiff	02
Cyanophyta	*Merismopedia punctata* Meyen in Wiegmann	02
	Gloeocapsa decorticans (A.Br.) Richter ex Wille	01
	Microcystis incerta Lemm.	01
	Pelonema aphane Skuja	05
	Microcystis holsatica Lemm	01
	Merismopedia elegans A.Braun ex Kützling	01
	Oscillatoria pseudogeminata G. Schmid	07
Cryptophyta	*Cryptomonas ovata* Ehr.	09
	Cryptomonas erosa Ehrenberg	22
	Cryptomonas reflexa Skuja	06
	Chroomonas acuta Utermöhl	03
	Rhodomonas minuta Skuja	13
Pyrrophyta	*Ceratium extensum* Cleve	06
	Peridinium cinctum (Müller) Ehrenberg	24
	Peridinium quinquecorne T.H.Abe.	04
	Peridinium aciculiferum Lemn	10
	Protoperidinium sp.	16

Table 20. List of the phytoplankton species counted in two years of study in Station-2.

Division	Species	Total no. received
Chrysophyta	*Achnanthes* sp.	02
	Achnanthes longipes	02
	Centritractus belenophorus	01
	Cymbella parva	04
	Cymbella gracilis (Rabch.) Cl.	03
	Cymbella turgidula	06
	Cyclotella meneghiniana Kütz	03
	Cyclotella comta var. *affinis* Grunow in Van Heurck	07
	Cyclotella comensis	06
	Cyclotella kuetzingiana Thwaites	02

Chrysophyta	*Eunotia monodon*	02
	Eunotia robusta	03
	Fragilaria intermedia.	05
	Fragilaria crotonensis Kitton	03
	Fragilaria capucina var. *lanceolata*	03
	Gomphonema lanceolatum var. *turris*	07
	Gyrosigma scalproides	02
	Gyrosigma distortum var. parkei	10
	Gyrosigma attenuatum	02
	Melosira distans	11
	Melosira granulata var. *angustata*	39
	Melosira granulata var. *curvata*	05
	Melosira moniliformis	04
	Navicula americana	09
	Navicula radiosa	04
	Navicula anglica	02
	Navicula pupula	12
	Navicula mutica	02
	Navicula placentula var. *rostata*	06
	Navicula cuspidata	04
	Navicula grimmei	03
	Nitzschia acicularis (Kützing) W. Smith	05
	Nitzschia alpine (Näg) Hustedt	04
	Nitzschia linearis	04
	Pinnularia molaris	02
	Pinnularia gibba var. *parva*	12
	Pinnularia major	10
	Pinnularia pulchara	02
	Surirella robusta	07

Euglenophyta	*Astasia pygmaea* Skuja	03
	Euglena oblonga Schmitz	02
	Euglena gojdicsae Prescott	02
	Euglena viridis (Müller) Ehrenberg	02
	Euglena acus var. *longissima*	10
	Euglena tripteris (Dujardin) Klebs	02
	Euglena mainxii Defl.	02
	Euglena spathirhyncha	01
	Euglena clavata Skuja	03
	Euglena variabilis Klebs	02
	Euglena caudate Lemm	02
	Euglena agilis var. praexicisa	01
	Euglena hemichromata	01
	Euglena allorgei	04
	Lepocinclis salina	02
	Lepocinclis ovum var. *major*	11
	Phacus ephippion	04
	Phacus longicauda var. *attenuata* (Pochm.) Huber-Pestalozzi	05
	Trachelomonas volvocina Ehrenberg	15
	Trachelomonas oblonga var. *truncate* Lemm.	08
	Trachelomonas cylindrica Ehr	05
	Trachelomonas scabra var. *pygnea*	04
	Trachelomonas anguste-ovata fa. *minor*	03
	Trachelomonas hispida var. *coronata*	09
	Trachelomonas playfairii	08
	Trachelomonas compacta	04
	Trachelomonas pulcherrima Roll	04
	Trachelomonas rugulosa	03
	Trachelomonas bernardi	04
	Trachelomonas intermedia	06
	Trachelomonas eurystoma var. *minuta*	02

Euglenophyta	*Trachelomonas lismorensis* var. *inermis*	03
	Trachelomonas planctonica	07
	Trachelomonas tshopoensis	04
	Strombomonas verrucosa var. *borystheniensis*	03
	Strombomonas gibberosa var. *tumida*	12
	Strombomonas fluviatilis	06

Chlorophyta	*Actinastrum hantzschii*	03
	Ankystrodesmus gracilis	03
	Carteria radiosa Kors.	O4
	Chlamydomonas gloeopara Rodhe *et* Skuja	04
	Closterium calosporum	03
	Crucigenia mucronata (G. M. Smith) Kom.	02
	Cosmarium pseudopyramidatum var. *lentiferum*	02
	Crucigeniella crucigera (Wolle) Komérek	05
	Crucigenia tetrapedia (Kirchner) W. West G.S. West	03
	Chlorella vulgaris Beyerinck	02
	Coelastrum microporum Nägeli	03
	Dictyosphaerium granulatum Hind.	02
	Dictyosphaerium pulchellum Wood.	02
	Dictyosphaerium subsolitarium Van Goor	02
	Eudorina elegans Ehrenberg	03
	Golenkinia paucispina W. West & G. S. West.	01
	Kirchneriella subcapitata Korš	03
	Mougeotia quadrangulata Hassall	05
	Mougeotia scalaris Hassall	03
	Monoraphidium griffithi	08
	Oocystis borgei	13
	Oocystis nata	03

Division	Species	Total no. received
Chlorophyta	*Planktosphaeria gelatinosa* GM Smith	03
	Pediastrum duplex	04
	Pediastrum simplex	04
	Spirogyra sp.	03
	Scenedesmus opoliensis var. *contact*a	02
	Scenedesmus incrassatulus Bohlin	03
	Staurastrum punctulatum Brébisson *ex* Ralfs	04
	Tetraedriella spinigera Skuja	02
	Tetrastrum heteracanthum fa. *elegans*	03
	Tetraedron trigonu	04
Cyanophyta	*Anabaena ballyganglii* J.C. Banerji	03
	Merismopedia minima Beck in Beck	02
	Merismopedia punctate Meyen in Wiegmann	01
	Microcystis incerta Lemm.	02
	Oscillatoria pseudogeminata G. Schmid	05
	Pelonema aphane Skuja	04
Cryptophyta	*Cryptomonas erosa* Ehrenberg	18
	Cryptomonas lucens Skuja	02
	Cryptomonas reflexa Skuja	08
	Mallomonas sp.	09
	Rhodomonas ovalis Nygaard	02
Pyrrhophyta	*Ceratium furca* (Ehrenberg) Claprède *et* Lachmann	03
	Peridinium cinctum (Müller) Ehrenberg	16
	Peridinium aciculiferum Lemn	24
	Protoperidinium conicoides	05

Table 21. List of the phytoplankton species counted in two years of study in Station-3.

Division	Species	Total no. received
Chrysophyta	*Achnanthes* sp.	03
	Achnanthes longipes	02
	Cymbella parva	07
	Cymbella turgidula	03
	Cyclotella meneghiniana Kütz	04
	Cyclotella comensis	08
	Cyclotella comta var. *affinis* Grunow in Van Heurck	07
	Amphora ovalis (Kützing) Kützing	01
	Chaetoceros compressus Lauder	02
	Eunotia monodon	03
	Eunotia veneris (Kütz) De Toni	02
	Eunotia robusta	05
	Fragilaria intermedia.	02
Chrysophyta	*Fragilaria crotonensis* Kitton	02
	Fragilaria capucina var.*lanceolata*	03
	Gomphonema lanceolatum var. *turris*	07
	Gyrosigma scalproides	04
	Gyrosigma attenuatum	04
	Melosira distans	08
	Melosira granulata var. *angustata*	32
	Melosira granulata var. *curvata*	07
	Melosira italic (Ehrenberg) Kützing	06
	Navicula americana	05
	Navicula radiosa	03
	Navicula pupula	09
	Navicula mutica	03
	Navicula placentula var. *rostata*	04
	Navicula cuspidata	07

	Navicula mutica Kütz.	04
	Nitzschia acicularis (Kützing) W. Smith	07
	Nitzschia linearis	03
	Pinnularia molaris	04
	Pinnularia gibba var. *parva*	12
	Surirella ovata var. *minuta*	03
	Synedra goulardii	02
Euglenophyta	*Trachelomonas anulifera*	02
	Euglena variabilis Klebs	02
	Euglena oblonga Schmitz	02
	Euglena gojdicsae Prescott	01
	Euglena rostrifera	03
	Euglena viridis (Müller) Ehrenberg	04
	Euglena acus var. *longissima*	12
	Euglena tripteris (Dujardin) Klebs	03
	Euglena mainxii Defl.	03
	Lepocinclis ovum var. *discifera*	13
	Trachelomonas cylindrica Ehr	02
	Trachelomonas scabra var. *pygnea*	04
	Trachelomonas anguste-ovata fa. *minor*	02
	Trachelomonas hispida var. *coronata*	02
	Trachelomonas playfairii	02
	Trachelomonas compacta	04
	Trachelomonas pulcherrima Roll	04
	Trachelomonas hexangulata	02
	Trachelomonas eurystoma var. *minuta*	02
	Trachelomonas lismorensis var. *inermis*	01
	Trachelomonas planctonica	11
	Trachelomonas dybowskii	02
	Phacus indicus	03
	Phacus schroeteri	02
	Lepocinclis ovum var. *major*	05

	Lepocinclis steinii	02
	Strombomonas gibberosa var. *tumida*	04
Chlorophyta	*Arthrodesmus curvatus*	02
	Carteria globosa	05
	Chlamydomonas sp.	07
	Closteriopsis ascicularis var. *ascicularis*	03
	Coelastrum sp.	04
	Cosmarium birame var. *barbadense*	04
	Crucigenia tetrapedia	02
	Dictyosphaerium subsolitarium Van Goor	02
	Hyaloraphidium contortum	02
	Kirchneriella subcapitata Korš	03
	Mougeotia sp.	08
	Monorahidium arcuatum (Koršikov) Hind	02
	Monoraphidium griffithi	03
	Oocystis pyriformis Prescott	06
	Oocystis borgei	11
	Phacotus angustus Pascher	04
	Planktosphaeria gelatinosa GM Smith	07
	Pediastrum duplex Meyen	05
	Schroederia setigera (Schröd.) Lemmermann	03
	Scenedesmus quadricauda	04
	Selenastrum sp.	04
	Spermatozoopsis exultans Kors.	05
	Tetraedron arthrodesmiforme var. *contorta* Wolosz.	02
	Tetraedron minimum (A. Br.) Hansg.	03

Division	Species	Total no. received
Cyanophyta	*Anabaena ballyganglii* J.C. Banerji	03
	Microcystis holsatica	03
	Merismopedia punctata Meyen in Wiegmann	02
	Oscillatoria pseudogeminata G. Schmid	12
	Oscillatoria willei Gardner em. Drouet	08
Cryptophyta	*Cryptomonas erosa* Ehrenberg	22
	Cryptomonas marssonii Skuja	07
	Cryptomonas obovata Czosnowski	03
	Cryptomonas phaseolus Skuja	04
	Chroomonas acuta Utermöhl	03
	Mallomonas sp.	03
	Rhodomonas minuta Skuja	03
	Rhodomonas lacustris	02
Pyrrhophyta	*Ceratium furca*	04
	Peridinium abei	
	Peridinium cinctum (Müller) Ehrenberg	23
	Peridinium aciculiferum Lemn.	18
	Protoperidinium pellucidum	03

Table 22. Density of dominant genus of phytoplankton (×10⁴ ind./l) at different months of collection in Station-1

Months	Dominant 1	Dominant 2	Dominant 3	Total (Dominant) x10⁴ind./l	Others x10⁴nd./l	Total PD x10⁴ind./l
Feb. '16	*Cryptomonas* 1.11	*Trachelomonas* 1.11	*Acnanthes* 0.74	2.96	4.44	7.4
Mar. '16	*Melosira* 3.69	*Cymbella 2.87*	*Nitzschia 2.46*	9.02	14.35	23.37
Apr. '16	*Peridinium 5.2*	*Melosira* 4	*Oscillatoria* 2	11.2	12.4	23.6
May '16	*Navicula* 1.21	*Trachelomonas* 0.81	*Phacus 0*.81	2.83	4.42	6.8
Jun. '16	*Cryptomonas* 0.93	*Cyclotella*0.93	*Euglena* 0.31	2.17	2.13	4.3
Jul. '16	*Trachelomonas* 3.2	*Cryptomonas* 2.88	*Melosira* 0.96	7.04	0.96	8
Aug. '16	*Cryptomonas* 1.42	*Melosira* 1.42	*Trachelomonas* 1.06	3.9	5.6	9.5
Sep. '16	*Cyclotella*1.08	*Staurastrum* 0.72	*Cymbella* 0.72	2.52	0.68	3.2
Oct. '16	*Rhodomonas* 3.6	*Peridinium* 2.16	*Melosira* 1.44	7.2	6.84	14.04
Nov. '16	*Euglena* 1.14	*Srtombomonas* 0.76	*Carteria* 0.38	2.28	1.9	4.18
Dec. '16	*Peridinium* 3.85	*Cryptomonas* 1.75	*Rhodomonas* 1.75	7.35	6.95	14.3
Jan. '17	*Melosira* 4.45	*Rhodomonas* 4.45	*Oscillatoria* 3.24	12.14	9.26	21.4
Feb. '17	*Oscillatoria* 1.56	*Peridinium* 1.56	*Trachelomonas* 1.3	4.42	4.94	9.36
Mar. '17	*Navicula* 1.86	*Oscillatoria* 1.56	*Trachelomonas* 1.24	4.66	5.54	10.2
Apr. '17	*Melosira* 7.56	*Trachelomonas* 5.4	*Cryptomonas* 4.68	17.64	20.16	37.8
May '17	*Melosira 3.01*	*Mougeotia* 2.34	*Cymbella* 0.67	6.02	6.71	12.73
Jun. '17	*Melosira* 3.3	*Peridinium* 1.65	*Coelastrum* 1.65	6.6	8.58	15.18
July. '17	*Melosira* 1.9	*Oscillatoria* 1.03	*Eunotia* 0.69	3.62	7.42	11.04
Aug. '17	*Melosira* 5.47	*Peridinium* 2.19	*Oscillatoria* 1.46	9.12	3.29	12.41
Sep. '17	*Melosira 1.02*	*Peridinium 0.68*	*Oocystis 0.68*	2.38	1.02	3.4
Oct. '17	*Melosira* 2.68	*Euglena* 0.67	*Trachelomonas* 0.67	4.02	3.35	7.37
Nov. '17	*Melosira* 2.1	*Oscillatoria* 1.75	*Peridinium* 1.4	5.25	1.75	7
Dec. '17	*Trachelomonas* 4.09	*Euglena* 1.26	*Mallomonas* 0.63	5.98	2.84	8.82
Jan. '18	*Melosira* 1.7	*Navicula* 1.27	*Fraigilaria 0*.85	3.82	4.68	8.5

Table 23. Density of dominant genus of phytoplankton (×10^4 ind./l) at different months of collection in Station-2

Months	Dominant 1	Dominant 2	Dominant 3	Total (Dominant) x10^4ind./l	Others x10^4ind./l	Total PD x10^4ind./l
Feb. '16	*Trachelomonas* 7.31	*Strombomonas* 6.54	*Euglena* 3.85	17.7	23.5	41.2
Mar. '16	*Trachelomonas* 31.32	*Euglena* 10.44	*Peridinium* 9.57	51.33	10.87	62.2
Apr. '16	*Melosira* 4.56	*Rhodomonas* 4.18	*Cryptomonas* 3.42	12.16	10.84	23.1
May '16	*Synedra* 3.24	*Fragilaria* 1.8	*Coelastrum* 1.44	6.48	14.32	20.8
Jun. '16	*Navicula* 1.52	*Melosira* 1.52	*Trachelomonas* 1.52	4.56	14.74	19.3
Jul. '16	*Melosira* 3.84	*Cryptomonas* 3.52	*Trachelomonas* 2.56	9.92	5.12	15.04
Aug. '16	*Coelastrum* 0.75	*Synedra* 0.75	*Phacus* 0.37	1.87	1.83	3.7
Sep. '16	*Rhodomonas* 3.5	*Peridinium* 3.5	*Euglena* 2.1	9.1	4.9	14
Oct. '16	*Euglena* 1.3	*Oscillatoria* 0.97	*Melosira* 0.97	3.24	3.86	7.1
Nov. '16	*Strombomonas* 1.2	*Rhodomonas* 0.8	*Surirella* 0.4	2.4	1.6	4
Dec. '16	*Cryptomonas* 2.61	*Peridinium* 1.74	*Rhodomonas* 1.74	6.09	2.03	8.12
Jan. '17	*Peridinium* 8.52	*Trachelomonas* 6.03	*Cryptomonas* 3.55	18.1	11	29.1
Feb. '17	*Oscillatoria* 3.44	*Navicula* 2.38	*Gyrosigma* 1.85	7.67	8.76	16.43
Mar. '17	*Synedra* 0.99	*Gyrosigma* 0.66	*Cryptomonas* 0.66	2.31	4.95	7.26
Apr. '17	*Melosira* 6.52	*Trachelomonas* 3.91	*Ceratium* 0.87	11.3	6.1	17.4
May '17	*Melosira* 3.28	*Synedra* 2.19	*Oscillatoria* 1.09	6.56	8.74	15.3
Jun. '17	*Peridinium* 1.36	*Cyclotella* 1.36	*Melosira* 1.36	4.08	7.14	11.22
July. '17	*Melosira* 14.8	*Nitzschia* 1.57	*Cyclotella* 0.94	17.31	4.74	22.05
Aug. '17	*Melosira* 7.81	*Peridinium* 1.42	*Synedra* 1.06	10.29	3.55	13.84
Sep. '17	*Oscillatoria* 1.65	*Melosira* 1.32	*Euglena* 0.66	3.63	1.65	5.28
Oct. '17	*Melosira* 1.09	*Nitzschia* 0.73	*Synedra* 0.73	2.55	2.55	5.1
Nov. '17	*Oscillatoria* 2.34	*Synedra* 1.05	*Fragilaria* 0.67	4.06	0.96	5.02
Dec. '17	*Rhodomonas* 4.26	*Cryptomonas* 3.55	*Trachelomonas* 2.84	10.65	2.15	12.8
Jan. '18	*Trachelomonas* 3.75	*Cryptomonas* 3.37	*Peridinium* 3	10.02	6.08	16.1

Table 24. Density of dominant genus of phytoplankton (×10^4 ind./l) at different months of collection in Station-3

Months	Dominant 1	Dominant 2	Dominant 3	Total (Dominant) x10^{4}ind./l	Others x10^{4}ind./l	Total PD x10^{4}ind./l
Feb. '16	*Peridinium* 4.55	*Closteriopsis* 3.85	*Melosira* 3.8	12.2	14.4	26.6
Mar. '16	*Rhodomonas* 0.68	*Trachelomonas* 0.68	*Surirella* 0.34	1.7	2.38	4.08
Apr. '16	*Peridinium* 9.66	*Strombomonas* 8.62	*Rhodomonas* 7.93	26.21	20.69	46.9
May '16	*Coelastrum* 2.76	*Cyclotella* 0.79	*Cryptomonas* 0.79	4.34	11.06	15.4
Jun. '16	*Euglena* 1.42	*Cyclotella* 1.42	*Trachelomonas* 1.06	3.9	10.3	14.2
Jul. '16	*Melosira* 1.8	*Nitzschia* 0.37	*Oscillatoria* 0.37	2.54	1.58	4.12
Aug. '16	*Melosira* 2.92	*Peridinium* 2.27	*Lepocinclis* 1.62	6.81	5.79	12.6
Sep. '16	*Melosira* 2.27	*Peridinium* 1.3	*Pelonema* 0.97	4.54	5.53	10.07
Oct. '16	*Rhodomonas* 2	*Peridinium* 1.6	*Cryptomonas* 1.2	4.8	3.6	8.4
Nov. '16	*Peridinium* 3.2	*Melosira* 1.84	*Nitzschia* 0.92	5.96	1.84	7.8
Dec. '16	*Trachelomonas* 2.48	*Peridinium* 1.65	*Cryptomonas* 1.1	5.23	2.17	7.4
Jan. '17	*Trachelomonas* 2.16	*Rhodomonas* 1.8	*Euglena* 1.44	5.4	4.68	10.08
Feb. '17	*Synedra* 1.33	*Peridinium* 1.3	*Oscillatoria* 1.3	3.93	5.37	9.3
Mar. '17	*Strombomonas* 0.99	*Trachelomonas* 0.99	*Oscillatoria* 0.99	2.97	3.3	6.27
Apr. '17	*Melosira* 13.92	*Trachelomonas* 7.68	*Cyclotella* 2.88	24.48	10.56	35.04
May '17	*Synedra* 1.98	*Melosira* 1.98	*Cyclotella* 1.65	5.61	4.95	10.56
Jun. '17	*Scenedesmus* 1.62	*Synedra* 1.62	*Mougeotia* 1.21	4.45	6.89	11.34
July. '17	*Melosira* 7.26	*Oscillatoria* 1.98	*Trachelomonas* 0.99	10.23	2.31	12.54
Aug. '17	*Melosira* 4.95	*Peridinium* 2.31	*Trachelomonas* 1.32	8.58	3.63	12.21
Sep. '17	*Peridinium* 1.3	*Melosira* 0.97	*Cyclotella* 0.97	3.24	1.96	5.2
Oct. '17	*Melosira* 2.6	*Peridinium* 0.97	*Trachelomonas* 0.65	4.22	1.63	5.85
Nov. '17	*Melosira* 2.31	*Cymbella* 0.99	*Oscillatoria* 0.99	4.29	2.91	7.2
Dec. '17	*Euglena* 3.96	*Rhodomonas* 2.16	*Strombomonas* 1.44	7.56	5.04	12.6
Jan. '18	*Cryptomonas* 13.8	*Trachelomonas* 5.25	*Rhodomonas* 4.5	23.55	12.45	36

Table 25. Density of dominant species of phytoplankton (×10^4 ind./l) at different months of collection in Station-1

Months	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total (Dominant) x10^4ind./l	Others x10^4ind./l	Total PD x10^4ind./1
Feb. '16	*Cryptomonas erosa* 1.77	*Trachelomonas volvocina* 0.92	*Achnanthes minutissima* 0.69	*Cymbella parva* 0.58	3.96	3.44	7.4
Mar. '16	*Melosira granulata* 4.62	*Cymbella turgidula* 2.7	*Peridinium aciculiferum* 1.84	*Nitzschia acicularis* 0.94	10.1	13.27	23.37
Apr. '16	*Peridinium aciculiferum* 5.52	*Melosira granulata* 3.89	*Oscillatoria pseudogeminata* 1.94	*Navicula cuspidata* .85	12.2	11.4	23.6
May '16	*Navicula pupula* 0.75	*Trachelomonas planktonica* 0.66	*Cryptomonas obovata* 0.58	*Phacus acuminatus* 0.34	2.33	4.47	6.8
Jun. '16	*Cryptomonas ovata* 0.92	*Cyclotella comta* 0.79	*Rhodomonas minuta* 0.64	*Peridinium aciculiferum* 0.25	2.6	1.7	4.3
Jul. '16	*Trachelomonas volvocina* 1.2	*Cryptomonas erosa* 1.05	*Melosira granulata* 0.95	*Spermatozoopsis exultans* 0.48	3.68	4.32	8
Aug. '16	*Melosira granulata* 1.37	*Trachelomonas volvocina* 1.18	*Cryptomonas lucens* 0.59	*Ankistrodesmus falcatus* 0.55	3.69	5.81	9.5
Sep. '16	*Cyclotella comta* 1.15	*Cymbella parva* 0.58	*Staurastrum orbiculare* 0.43	*Euglena acus*.22	2.38	0.82	3.2
Oct. '16	*Rhodomonas lacustris* 2.18	*Peridinium aciculiferum* 1.26	*Melosira granulata* 1.12	*Oscillatoria pseudogeminata* 0.55	5.11	8.93	14.04
Nov. '16	*Euglena allorgei* 1.16	*Strombomonas verrucosa* 0 .74	*Carteria globosa* 0.58	*Cosmarium depressum* 0.55	3.03	1.15	4.18
Dec. '16	*Peridinium cinctum* 2.38	*Cryptomonas obovata* 1.54	*Rhodomonas lacustris* 1.49	*Trachelomonas planktonica* 1.28	6.69	7.61	14.3
Jan. '17	*Trachelomonas oblonga* 4.67	*Rhodomonas minuta* 3.82	*Oscillatoria pseudogeminata* 2.59	*Euglena viridis* 1.54	12.62	8.78	21.4
Feb. '17	*Oscillatoria tenuis* 1.62	*Peridinium cinctum* 1.12	*Trachelomonas oblonga* .68	*Melosira granulate* 0.61	4.03	5.33	9.36
Mar. '17	*Navicula pupula* 1.64	*Oscillatoria pseudogeminata* 0.74	*Trachelomonas lismorensis* 0.5	*Gyrosigma acuminatum* 0.41	3.29	6.91	10.2
Apr. '17	*Melosira granulata* 7.94	*Trachelomonas volvocina* 1.85	*Cryptomonas obovata* 1.66	*Cyclotella comensis* 0.92	12.37	25.3	37.8
May '17	*Melosira granulata* 2.58	*Mougeotia quadrangulata* 1.34	*Rhodomonas lacustris* 0.72	*Scenedesmus incrassatulus* 0.25	4.89	7.84	12.73
Jun. '17	*Melosira granulata* 3.83	*Peridinium aciculiferum* 2.25	*Coelastrum pulchrum* 0.92	*Cosmarium scabrum* 0.61	7.61	7.57	15.18
July. '17	*Melosira granulata* 2.44	*Oscillatoria pseudogeminata* 1.08	*Eunotia alpine* 0.66	*Synedra acus* 0.42	4.6	6.44	11.04
Aug. '17	*Peridinium aciculiferum* 3.32	*Oscillatoria pseudogeminata* 1.88	*Nitzschia fruticosa* 0.54	*Trachelomonas oblonga* 0.32	6.06	6.35	12.41
Sep. '17	*Melosira granulata* 1.05	*Trachelomonas volvocina* 0.33	*Oocystis borgei* 0.2	*Peridinium abei* 0.08	1.66	1.74	3.4
Oct. '17	*Melosira granulata* 2.55	*Euglena mainxii* 0.51	*Trachelomonas bernardi* 0.33	*Peridinium aciculiferum* 0.26	3.65	3.72	7.37
Nov. '17	*Melosira granulata* 1.28	*Oscillatoria tenuis* 0.96	*Peridinium cinctum* 0.88	*Euglena viridis* 0.39	3.51	3.49	7
Dec. '17	*Trachelomonas compacta* 1.75	*Euglena oblonga* 0.84	*Synedra ulna* 0.68	*Strombomonas verrucosa* 0.31	3.58	5.24	8.82
Jan. '18	*Melosira granulata* 1.83	*Fragilaria capucina* 0.94	*Rhodomonas minuta* 0.65	*Fragilaria capucina* 0.23	3.65	4.85	8.5

Table 26. Density of dominant species of phytoplankton (×10^4 ind./l) at different months of collection in Station-2

Months	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total (Dominant) x10^{4}ind./l	Others x10^{4}ind./l	Total PD x10^{4}ind./l
Feb. '16	*Trachelomonas oblonga* 5.67	*Strombomonas fluviatilis* 5.12	*Astasia pygmea* 3.59	*Euglena oblonga* 2.89	17.27	23.93	41.2
Mar. '16	*Trachelomonas volvocina* 7.32	*Peridinium aciculiferum* 5.6	*Trachelomonas playfairii* 4.84	*Strombomonas gibberosa* 4.54	22.3	39.9	62.2
Apr. '16	*Melosira granulata* 5.92	*Rhodomonas minuta* 4.89	*Peridinium aciculiferum* 3.94	*Dictyosphaerium subsolitarium* 2.55	17.3	5.8	23.1
May '16	*Synedra ulna* 3.65	*Fragilaria intermedia* 3.16	*Melosira granulata* 2.58	*Coelastrum microporum* 2.34	11.73	9.07	20.8
Jun. '16	*Melosira granulata*.4.3	*Trachelomonas volvocina* 3.21	*Euglena oblonga* 1.3	*Navicula cuspidata* 1.05	9.86	9.44	19.3
Jul. '16	*Melosira granulate* 4.81	*Cryptomonas erosa* 2.59	*Trachelomonas oblonga* 1.54	*Peridinium aciculiferum* 0.98	9.92	5.12	15.04
Aug. '16	*Coelasastrum indicum* 0.77	*Synedra ulna* 0.62	*Trachelomonas armata* 0.59	*Phacus longicauda* 0.34	2.32	1.38	3.7
Sep. '16	*Peridinium cinctum* 3.25	*Rhodomonas lacustris* 2.18	*Euglena viridis* 1.13	*Melosira granulata* 0.32	6.88	7.12	14
Oct. '16	*Euglena oblonga* 2.08	*Oscillatoria pseudogeminata* 1.16	*Melosira granulata* 0.65	*Peridinium aciculiferum* 0.55	4.44	2.66	7.1
Nov. '16	*Strombomonas fluviatilis* 0.93	*Rhodomonas minuta* 0.74	*Peridinium cinctum* 0.58	*Surirella robusta* 0.45	2.7	1.3	4
Dec. '16	*Cryptomonas ovata* 2.58	*Peridinium cinctum* 1.74	*Rhodomonas minuta* 0.89	*Trachelomonas rugulosa* 0.78	5.99	2.13	8.12
Jan. '17	*Peridinium cinctum* 5.87	*Trachelomonas scabra* 4.12	*Cryptomonas erosa* 2.15	*Rhodomonas lacustris* 0.84	12.98	16.12	29.1
Feb. '17	*Oscillatoria pseudogeminata* 3.82	*Navicula bacillum* 2.82	*Gyrosigma attenuatum* 1.68	*Melosira granulate* 0.75	9.07	7.36	16.43
Mar. '17	*Synedra acus* 2.24	*Euglena limnophila* 1.54	*Trachelomonas armata* 0.55	*Cryptomonas erosa* 0.41	4.74	2.52	7.26
Apr. '17	*Melosira granulate* 4.94	*Trachelomonas volvocina* 2.85	*Rhodomonas lacustris* 1.26	*Ceratium furca* 0.51	9.56	7.84	17.4
May '17	*Melosira granulate* 3.28	*Synedra ulna* 2.14	*Oscillatoria pseudogeminata* 1.32	*Rhodomonas minuta* 0.37	7.11	8.19	15.3
Jun. '17	*Cyclotella stelligera* 2.13	*Peridinium aciculiferum* 1.25	*Melosira granulate* 0.32	*Cosmarium scabrum* 0.21	3.91	7.31	11.22
July. '17	*Melosira granulate* 5.14	*Nitzschia longissima* 3.48	*Cyclotella meneghiniana* 1.26	*Trachelomonas globosa* 0.82	10.2	11.35	22.05
Aug. '17	*Peridinium aciculiferum* 3.22	*Synedra ulna* 2.58	*Oscillatoria pseudogeminata* 1.44	*Euglena oblonga* 0.62	7.86	5.98	13.84
Sep. '17	*Oscillatoria pseudogeminata* 0.95	*Melosira granulate* 0.73	*Euglena acus* 0.51	*Peridinium cinctum* 0.28	2.47	2.81	5.28
Oct. '17	*Melosira granulate* 0.65	*Trachelomonas oblonga* 0.43	*Synedra ulna* 0.36	*Nitzschia fruticosa* 0.26	1.7	3.4	5.1
Nov. '17	*Oscillatoria pseudogeminata* 0.88	*Synedra ulna* 0.76	*Fragilaria intermedia* 0.68	*Navicula cuspidata* 0.29	2.61	2.41	5.02
Dec. '17	*Rhodomonas lacustris* 2.75	*Trachelomonas pulcherrima* 1.64	*Cryptomonas obovata* 0.98	*Euglena acus* 0.81	6.18	6.62	12.8
Jan. '18	*Trachelomonas planktonica* 2.53	*Cryptomonas lucens* 1.24	*Peridinium aciculiferum* 1.05	*Dictyosphaerium subsolitarium* 0.51	5.33	10.77	16.1

Table 27. Density of dominant species of phytoplankton (×10^4 ind./l) at different months of collection in Station-3

Months	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total (Dominant) x10^{4}ind./l	Others x10^{4}ind./l	Total PD x10^{4}ind./l
Feb. '16	*Peridinium aciculiferum* 6.27	*Oscillatoria pseudogeminata* 2.82	*Melosira granulata*1.59	*Cryptomonas ovata* 0.94	11.62	14.98	26.6
Mar. '16	*Rhodomonas minuta* 0.82	*Trachelomonas volvocina* 0.78	*Peridinium aciculiferum* 0.64	*Navicula placentula* 0.44	2.68	1.4	4.08
Apr. '16	*Peridinium aciculiferum* 5.52	*Rhodomonas minuta* 2.89	*Strombomonas verrucosa* 1.94	*Melosira granulata*.95	11.3	35.6	46.9
May '16	*Coelasastrum microporum* 2.25	*Cyclotella comensis* 1.76	*Cryptomonas erosa* 1.58	*Navicula pupula* 0.42	6.01	9.39	15.4
Jun. '16	*Euglena mainxii* 2.43	*Trachelomonas volvocina* 1.45	*Cyclotella stelligera* 1.13	*Euglena oblonga* 0.45	5.46	8.74	14.2
Jul. '16	*Melosira granulate* 0.92	*Cyclotella comensis* 0.79	*Euglena oblonga* 0.64	*Trachelomonas volvocina* 0.38	2.73	1.39	4.12
Aug. '16	*Melosira granulate* 2.87	*Peridinium aciculiferum*.72	*Rhodomonas minuta* 0.59	*Lepocinclis ovum* 0.34	4.52	8.08	12.6
Sep. '16	*Melosira granulate* 2.75	*Peridinium aciculiferum* 1.98	*Rhodomonas minuta* 0.73	*Pelonena aphane* 0.32	5.78	4.29	10.07
Oct. '16	*Rhodomonas lacustris* 1.08	*Peridinium cinctum* 0.96	*Cryptomonas phaseolus* 0.6	*Oscillatoria pseudogeminata* 0.55	3.19	5.21	8.4
Nov. '16	*Peridinium aciculiferum* 1.67	*Melosira granulate* 1.14	*Nitzschia fruticosa* 0.78	*Oscillatoria pseudogeminata* 0.55	4.14	3.66	7.8
Dec. '16	*Trachelomonas playfairii* 1.08	*Peridinium cinctum* 0.74	*Cryptomonas reflexa* 0.69	*Oscillatoria willei* 0.28	2.79	4.61	7.4
Jan. '17	*Trachelomonas oblonga* 2.57	*Rhodomonas lacustris* 1.12	*Cryptomonas reflexa* 0.69	*Euglena oblonga* 0.54	4.92	5.16	10.08
Feb. '17	*Peridinium aciculiferum* 1.62	*Synedra acus* 1.02	*Oscillatoria pseudogeminata* 0.48	*Gyrosigma distortum*.15	3.27	6.03	9.3
Mar. '17	*Strombomonas verrucosa* 0.94	*Oscillatoria pseudogeminata* 0.74	*Trachelomonas globosa* 0.55	*Synedra ulna* 0.41	2.64	3.63	6.27
Apr. '17	*Melosira granulate* 6.94	*Trachelomonas rugulosa* 3.85	*Cyclotella comensis* 1.56	*Rhodomonas minuta* 0.72	13.07	21.97	35.04
May '17	*Synedra ulna* 1.58	*Melosira granulate* 1.14	*Cyclotella comensis* 0.82	*Mougeotia scalaris* 0.27	3.81	6.75	10.56
Jun. '17	*Scenedesmus quadricauda* 2.3	*Peridinium aciculiferum* 1.15	*Melosira granulate* 0.62	*Mougeotia scalaris* 0.38	4.45	6.89	11.34
July. '17	*Oscillatoria pseudogeminata* 2.54	*Trachelomonas volvocina* 1.48	*Rhodomonas minuta* 0.96	*Trachelomonas globosa* 0.62	5.6	6.94	12.54
Aug. '17	*Melosira granulate* 3.24	*Peridinium aciculiferum* 1.88	*Synedra acus* 1.54	*Euglena oblonga* 0.42	7.08	5.13	12.21
Sep. '17	*Peridinium aciculiferum* 0.95	*Melosira granulate* 0.83	*Cyclotella comta* 0.62	*Nitzschia fruticosa* 0.38	2.78	2.42	5.2
Oct. '17	*Melosira granulate* 1.15	*Peridinium aciculiferum* 0.83	*Trachelomonas oblonga* 0.36	*Synedra ulna* 0.26	2.6	3.25	5.85
Nov. '17	*Melosira granulate* 1.18	*Oscillatoria pseudogeminata* 0.96	*Cymbella gracilis* 0.68	*Anabaena ballyganglii* 0.29	3.11	4.09	7.2
Dec. '17	*Euglena allorgei* 2.75	*Trachelomonas pulcherrima* 1.64	*Rhodomonas minuta*. 0.78	*Strombomonas verrucosa* 0.61	5.78	6.82	12.6
Jan. '18	*Cryptomonas erosa* 3.13	*Trachelomonas volvocina* 2.94	*Rhodomonas minuta* 2.55	*Peridinium aciculiferum* 1.93	10.55	25.45	36

Seasonal variation of dominant phytoplankton in genus level

Station-1

In this station, dominant phytoplankton were, *Oscillatoria* belonging to Cyanophyta, , *Crucigenia*, *Coelastrum*, *Scenedesmus*, *Carteria*, *Chlamydomonas*, *Mougeotia*, *Oocystis*, *Cosmarium* and *Staurastrum* belonging to Chlorophyta, *Trachelomonas*, *Lepocinclis*, *Euglena*, *Strombomonas*, *Rhodomonas* and *Phacus* belonging to Euglenophyta, *Melosira*, *Cymbella*, *Cyclotella*, *Gomphonema*, *Eunotia*, *Synedra*, *Fragilaria*, *Navicula*, *Pinnularia*, and *Nitzschia* belonging to Chrysophyta, *Peridinium* and *Gymnodinium* belonging to Pyrrhophyta and *Chroomonas*, *Cryptomonas* belonging to Cryptophyta were observed.

During the pre monsoon season the genus *Oscillatoria* was higher in April 2016, March 2017 and *Melosira* was higher in March 2016 and April 2017(Table 28). During both year of the study the genus *Melosira* was high in pre monsoon (Table 28).

During monsoon season the genus *Cryptomonas* was dominant in June and August 2016, *Trachelomonas* was dominant in July and August 2016, *Cryptomonas* was dominant in September 2016 in 1st year of study (Table 21). *Euglena* was dominant in June 2017, *Melosira* was dominant all over the monsoon period in the study years of 2017-2018 (Table 28).

During Post monsoon in the year of 2016-2017 the genus *Rhodomonas* and *Euglena* was highest in October to November 2016, *Melosira* was highest in the year of 2017-2018. (Table 22, 28).

During winter season the genus *Peridinium* was dominant in December 2016 and *Trachelomonas* was dominant in December 2017 and whereas in February 2017. *Oscillatoria* was observed higher in the study year 2017-2018 (Table 22).

Station-2

In this station, dominant phytoplankton were *Oscillatoria*, *Pelonema* belonging to Cyanophyta, *Coelastrum*, *Kirschneriella*, *Staurastrum*, *Carteria*, *Monoraphidium Chlamydomonas*,, *Scenedesmus* and *Pandorina* belonging to Chlorophyta, *Euglena*, *Trachelomonas*, *Lepocinclis*, *Astasia*, *Strombomonas*, and *Phacus* belonging to Euglenophyta, *Melosira*, *Cyclotella*, *Fragillaria*, *Eunotia*, *Synedra*, *Nitzschia*,*Gyrosigma* and *Navicula* belonging to Chrysophyta, *Peridinium*,*Ceratium* and *Gymnodinium*

belonging to Pyrrhophyta, *Rhodomonas* and *Cryptomonas* belonging to Cryptophyta were observed.

During pre-monsoon season the genus *Trachelomonas* was highest in March 2016, *Melosira* was highest in April of both the study periods. *Synedra* was highest in May 2016 and March 2017. In the year of 2016- 2017 a noticeable density of the genus *Euglena* was high in March 2016 (Table 23 and 29).

During monsoon season the genus *Melosira* was dominant in June - July of 2016 and all the monsoon period of 2017 but *Rhodomonas* was dominant in early September of 2016-2017whereas the genus *Oscillatoria* was high in the study year 2015-2016 (Table 29).

During post monsoon in the year of 2016-2017 the genus *Euglena* was high in Late October 2016, *Strombonas* was high in November 2016 but in the year of 2017-2018 *Oscillatoria* were highest (Table 23 and 29).

During winter season the genus *Trachelomonas, Strombomonas* and *Peridinium* were dominant in the study year of 2016-2017 where as the genus *Cryptomonas* was dominant in December 2017 and January 2018 but the genus *Rhodomonas* was highest in December 2017 in the study year of 2017-2018 (Table 23 and 29).

Station-3

In this Station, dominant phytoplankton were *Merismopedia, Microcystis,* and *Oscillatoria* belonging to Cyanophyta, *Kirschneriella, Dictyosphaerium, Crucigenia, Coelastrum, Scenedesmus, Carteria, Chlamydomonas, Chlorella, Oocystis, Cosmarium* and *Staurastrum* belonging to Chlorophyta, *Trachelomo Lepocinclis, Euglena, Strombomonas, Astasia* and *Phacus* belonging to Euglenophyta, *Cyclotella, Gomphonema, Eunotia, Synedra, Fragilaria, Navicula, Pinnularia,* and *Nitzschia* belonging to Chrysophyta, *Peridinium* and *Gymnodinium* belonging to Pyrrhophyta and *Rhodomonas, Cryptomonas* belonging to Cryptophyta were observed.

During the pre-monsoon season the genus *Rhodomonas* was higher in March 2016, *Peridinium* was higher in April 2016, *Coelastrum* was high in May 2016 in the study year of 2016-2017 but the genus *Melosira* and *Trachelomonas* was high in the year of 2017-2018 (Table 24 and 30).

During monsoon season, the genus *Euglena* was dominant in June 2016, *Melosira* was dominant in July, August, September in the study years of 2016-2017 and the genus *Melosira, Scenedesmus* and *Peridinium* were dominant in the study year of 2017-2018

(Table 24 and 30).

During post monsoon in the year of 2016-2017 the genus *Rhodomonas* was highest in Late October 2016, *Peridinium* was highest in November 2016 but in the year of 2017-2018 *Melosira* was highest. (Table24 and 30)

During winter season the genus *Trachelomonas* was dominant in December 2016 and January 2017, *Synedra* was higher in February 2017 in the study year of2016- 2017 whereas *Cryptomonas* and *Rhodomonas*was dominant in the study year 2017-2018 (Table 24 and 30).

Table 28. Density of of dominant genus of phytoplankton (×10^4 ind./l) in different seasons for Station-1

Year	Seasons	Dominant group of phytoplankton			Total (Dominant) 10^{4}ind./l	Others 10^{4}ind./l	Total 10^{4}ind./l
		Group-1	Group-2	Group-3			
2016- 17	Pre monsoon	*Melosira* sp. 7.69	*Peridinium* sp. 5.2	*Cymbella* sp. 2.87	15.76	38.01	53.77
	Monsoon	*Cryptomonas* sp..5.23	*Trachelomonas* sp 4.26	*Melosira* sp. 2.38	11.87	13.13	25
	Post monsoon	*Rhodomonas* sp. 3.6	*Peridinium* sp. 2.16	*Melosira* sp. 1.44	7.2	11.02	18.22
	Winter	*Rhodomonas* sp. 6.2	*Trachelomonas* sp.5.56	*Oscillatoria* sp. 3.25	15.01	30.05	45.06
2017-18	Pre monsoon	*Melosira* sp. 10.57	*Trachelomonas* sp. 6.64	*Navicula* sp. 1.86	19.07	41.66	60.73
	Monsoon	*Melosira* sp. 15.27	*Peridinium* sp. 3.84	*Oscillatoria* sp. 2.49	21.6	20.43	42.03
	Post monsoon	*Melosira* sp. 4.78	*Oscillatoria* sp. 1.75	*Peridinium* sp. 1.4	7.93	6.44	14.37
	Winter	*Trachelomonas* sp. 5.39	*Oscillatoria* sp. 1.54	*Melosira* sp. 1.7	8.63	16.09	24.72

Table 29. Density of dominant genus of phytoplankton (×10^4 ind./l) in different seasons for Station-2

Year	Seasons	Dominant group of phytoplankton			Total (Dominant) 10^4ind./l	Others 10^4ind./l	Total 10^4ind./l
		Group-1	Group-2	Group-3			
2016- 17	Pre monsoon	*Trachelomonas* sp.31.32	*Euglena* sp. 10.44	*Peridinium* sp. 9.57	51.33	54.77	106.1
	Monsoon	*Melosira* sp. 5.36	*Trachelomonas* sp. 4.08	*Cryptomonas* sp.3.52	12.96	39.08	52.04
	Post monsoon	*Euglena* sp 1.3	*Strombomonas* sp. 1.2	*Oscillatoria* sp. 0.97	3.47	7.63	11.1
	Winter	*Peridinium* sp. 14.11	*Trachelomonas* sp. 13.34	*Cryptomonas* sp. 6.16	33.61	20.04	53.65
2017-18	Pre monsoon	*Melosira* sp. 9.8	*Trachelomonas* sp. 3.91	*Synedra* sp. 3.18	16.89	23.07	39.96
	Monsoon	*Melosira* sp. 25.29	*Peridinium* sp. 2.78	*Cyclotella* sp. 2.3	30.37	22.02	52.39
	Post monsoon	*Oscillatoria* sp. 2.34	*Melosira* sp. 1.09	*Synedra* sp. 1.05	4.48	5.64	10.12
	Winter	*Cryptomonas* sp. 6.92	*Trachelomonas* sp. 6.6	*Peridinium* sp. 4.32	17.84	52.26	70.1

Table 30. Density of dominant genus of phytoplankton (×10^4 ind/l) in different seasons for Station-3

Year	Seasons	Dominant group of phytoplankton			Total (Dominant) 10^4ind./l	Others 10^4ind./l	Total 10^4ind./l
		Group-1	Group-2	Group-3			
2016- 17	Pre monsoon	*Peridinium* sp. 9.66	*Strombomonas* sp. 7.94	*Rhodomonas* sp. 4.65	22.25	44.13	66.38
	Monsoon	*Melosira* sp. 7.06	*Peridinium* sp. 3.57	*Lepocinclis* sp. 1.62	12.25	28.74	40.99
	Post monsoon	*Melosira* sp. 4.91	*Cymbella* sp. 1.0	*Peridinium* sp. 0.97	6.88	9.32	16.2
	Winter	*Peridinium* sp. 6.2	*Trachelomonas* sp.4.63	*Cryptomonas* sp.4.25	15.08	11.7	26.78
2017-18	Pre monsoon	*Melosira* sp. 15.88	*Trachelomonas* sp. 8.67	*Cyclotella* sp. 4.53	29.08	22.79	51.87
	Monsoon	*Melosira* sp. 12.21	*Peridinium* sp. 3.61	*Oscillatoria* sp. 1.98	17.8	23.49	41.29
	Post monsoon	*Melosira* sp. 4.9	*Oscillatoria* sp. 0.99	*Cymbella* sp. 0.99	6.88	6.17	13.05
	Winter	*Cryptomonas* sp. 13.8	*Rhodomonas.* sp 6.67	*Trachelomonas* sp. 5.25	25.72	49.48	75.2

Seasonal variation of dominant phytoplankton in species level

Station-1

In this study site, dominant phytoplankton species were *Melosira granulata, Fragilaria capucina, Navicula pupula, Navicula cuspidate, Nitzschia acicularis, Cyclotella comensis, C. comta, Cymbella turgidula, Eunotia alpine, Synedra ulna, S. acus,* belonging to Chrysophyta. *Trachelomonas volvocina, T. bernardi, T. compacta, T. lismorensis, T. oblonga, T. planktonica, Euglena acus, E allorgei, E. mainxii, E. Obolonga, E. viridis, Gyrosigma acuminatum, Strombomonas verrucosa,* and *Phacus acuminatus* belonging to Euglenophyta, *Microcystis holastica, Oscillatoria tenuis* and *O. pseudogeminata* belonging to Cyanophyta, *Mougeotia quadrangulata, Ankistrodesmus falcatus,Cosmarium scabrum, Coelastrum pulchrum, Scenedesmus incrassatulus, Carteria globosa* and *Spermatozoopsis exultans* belonging to Chlorophyta, *Peridinium aciculiferum and P. cinctum* belonging to Pyrrhophytaand *Rhodomonas minuta,Cryptomonas lucens, C. obovata* and *C. erosa* belonging to Cryptophyta were observed.

During pre-monsoon season *Melosira granulate* was high in March 2016, April 2017, May 2017, *Peridinium aciculiferum* was high in April 2016, and *Navicula pupula* was *dominant in March* 2017 in the study year of 2016-2017 and 2017-18 (Table 25).

During monsoon season *Trachelomonas volvocina* was dominant in July-August in the year of 2016-2017 and *Melosira granulata* was dominant in 2017-18 (Table 31).

During Post-monsoon in the year of 2016-2017 *Rhodomonas lacustris* was highest in October 2016 and in the year of 2017-2018 Melosira *granulata* was also highest in Late October 2017. (Table31)

During winter season *Trachelomonas oblonga* was dominant in January 2017 whereas *Trachelomonas compacta* was dominant in December 2017 (Table 25).

Station-2

In this station, dominant phytoplankton species were *Melosira granulata, Cyclotella comensis, C. comta, C. meneghiniana, Fragilaria intermedia, Gyrosigma attenuatum, Navicula exigua Navicula cuspidata, Navicula bacillum, Nitzschia fruticosa, N. acicularis, N. longissima, Synedra acus, S. ulna and Surirella robusta* belonging to Chrysophyta, *Trachelomonas armata, T. volvocina, T. pulcherrima, T. oblonga, T. planktonica, T. playfairii, T. scabra, Euglena oblonga, E. limnophila, E. acus, E. viridis Lepocinclis ovum, Strombomonas gibberosa, Strombomonas fluviatilis, Astasia pygmea* and *Phacus longicauda* belonging to Euglenophyta, *Oscillatoria pseudogeminata, Merismopedia elegans, Microcystis incerta,* and *Gloeocapsa alpine* belonging to Cyanophyta, *Kirschneriella irregularis, Dictyosphaerium subsolitarium, Crucigenia mucronata, Cosmarium scabrum, Coelastrum microporum, Carteria radiosa, Chlamydomonas cylindrus* and *Chlorella vulgaris* belonging to Chlorophyta, *Peridinium aciculiferum, Peridinium cinctum* and *Ceratium furca* belonging to Pyrrhophyta and *Chroomonas acuta, Cryptomonas lucens, Cryptomonas obovata, Cryptomonas ovate* and *Cryptomonas erosa* belonging to Cryptophyta were observed.

During pre-monsoon season *Peridinium aciculiferum* was higher in March and April of 2016 and *Melosira granulata* was higher in April and May 2017 in the study year of 2016-2017 and 2017-18 (Table 26).

During monsoon season *Melosira granulata* was dominant in Jun-July in the year of 2016-2017 and 2017-18 respectively (Table 26).

During post-monsoon in the year of 2016-2017 *Euglena oblonga* was highest in October 2016 and in the year of 2017-2018 *Synedra ulna* was highest in the whole season (Table 32).

During winter season *Peridinium cinctum* was dominant in January 2017 whereas *Rhodomonas lacustris* was dominant in December 2017 in the study year 2017-2018 (Table 32).

Station-3

The observed dominant phytoplankton species were *Cymbella gracilis, Cyclotella comensis, C. stelligera, Gyrosigma distortum, Melosira granulata, Navicula pupula, N. placentula, Nitzschia fruticosa, Synedra acus, S. ulna Surirella angustata, Fragilaria crotonensis belonging* to Chrysophyta, *Trachelomonas volvocina, T. rugulosa, T. oblonga, T. pulcherrima, T. playfairii, T. globosa, Euglena allorgei E. oblonga, E. mainxii, Lepocinclis ovum, Strombomonas verrucosa, Astasia longa* and *Phacus acuminatus* belonging to Euglenophyta, *Mougeotia scalaris, Dictyosphaerium granulatum, Crucigenia tetrapedia, Coelastrum pulchrum, Scenedesmus quadricauda* and *Carteria radiosa* belonging to Chlorophyta, *Merismopedia elegans, Pelonema aphane and Oscillatoria pseudogeminata* belonging to Cyanophyta, *Rhodomonas minuta, Cryptomonas reflexa, C. ovata* and *C. erosa* belonging to Cryptophyta, *Peridinium aciculiferum, peridinium cinctum* and *Gymnodinium* belonging to Pyrrhophyta.

During pre-monsoon season *Peridinium aciculiferum* was high in April 2016 and *Melosira granulata* was high in May 2017 in the study year of 2016-2017 and 2017-18 (Table 33).

During monsoon season *Melosira granulata* was dominant in July-September in the year of 2016-2017 and *Oscillatoria pseudogeminata* was high in August 2017-18 (Table 27).

During post-monsoon in the year of 2016-2017 *Peridinium aciculiferum* was highest in November 2016 and in the year of 2017-2018 *Melosira granulata* was also highest in the whole season. (Table 33)

During winter season *Peridinium aciculiferum* was dominant in February 2017 whereas *Rhodomonas minuta* was higher in December-January in the study year 2017-2018 (Table 33).

Table 31. Density of dominant species of phytoplankton (×10^4 ind./l) in different season for Station-1

Year	Seasons	Dominant group of phytoplankton			Total (Dominant) 10^4ind./l	Others 10^4ind./l	Total 10^4ind./l
		Group-1	Group-2	Group-3			
2016- 17	**Pre monsoon**	*Melosira granulata* 8.51	*Peridinium aciculiferum* 7.94	*Cymbella turgidula* 2.7	19.15	34.62	53.77
	Monsoon	*Trachelomonas volvocina* 2.38	*Melosira granulata* 2.32	*Cyclotella comta* 1.62	6.32	18.68	25
	Post monsoon	*Rhodomonas lacustris* 2.18	*Peridinium aciculiferum*1.26	*Euglena allorgei* 1.16	4.6	13.62	18.22
	Winter	*Trachelomonas oblonga* 4.67	*Rhodomonas minuta* 3.82	*Oscillatoria pseudogeminata* 4.25	12.74	32.32	45.06
2017-18	**Pre monsoon**	*Melosira granulata* 10.52	*Trachelomonas volvocina* 1.85	*Cryptomonasobovata* 1.66	14.03	46.7	60.73
	Monsoon	*Melosira granulata* 7.32	*Peridinium aciculiferum* 5.57	*Oscillatoria pseudogeminata*2.96	15.85	26.18	42.03
	Post monsoon	*Melosira granulata* 4.9	*Oscillatoria tenuis* 0.96	*Peridinium cinctum* 0.88	6.74	7.63	14.37
	Winter	*Cryptomonas erosa* 1.83	*Melosira granulata* 1.77	*Trachelomonas compacta*. 1.75	5.35	19.37	24.72

Table 32. Density of dominant species of phytoplankton (×10^4 ind./l) in different season for Station-2

Year	Seasons	Dominant group of phytoplankton			Total (Dominant) 10^4ind./l	Others 10^4ind./l	Total 10^4ind./l
		Group-1	Group-2	Group-3			
2016- 17	Pre monsoon	*Peridinium aciculiferum* 9.54	*Melosira granulata* 8.5	*Trachelomonas volvocina* 7.32	25.36	80.74	106.1
	Monsoon	*Melosira granulata* 9.43	*Peridinium cinctum* 3.25	*Trachelomonas volvocina* 3.21	15.89	36.15	52.04
	Post monsoon	*Euglena oblonga* 2.08	*Oscillatoria pseudogeminata* 1.16	*Strombomonas fluviatilis*. 0.93	4.17	6.93	11.1
	Winter	*Peridinium cinctum* 7.61	*Trachelomonas oblonga* 5.67	*Strombomonas fluviatilis*. 5.12	18.4	35.25	53.65
2017-18	Pre monsoon	*Melosira granulata* 8.22	*Trachelomonas volvocina* 2.85	*Synedra acus* 2.24	13.31	26.65	39.96
	Monsoon	*Melosira granulata* 6.19	*Nitzschia longissima* 3.48	*Peridinium aciculiferum* 3.22	12.89	39.5	52.39
	Post monsoon	*Synedra ulna* 1.12	*Oscillatoria pseudogeminata* 0.88	*Fragilaria intermedia* 0.68	2.68	7.44	10.12
	Winter	*Rhodomonas lacustris* 2.75	*Trachelomonas planktonica* 2.53	*Trachelomonas pulcherrima* 1.64	6.92	63.18	70.1

Table 33. Density of dominant species of phytoplankton (×10^4 ind./l) in different season for Station-3

Year	Seasons	Dominant group of phytoplankton			Total (Dominant) 10^4ind./l	Others 10^4ind./l	Total 10^4ind./l
		Group-1	Group-2	Group-3			
2016- 17	Pre monsoon	*Peridinium aciculiferum* 6.16	*Rhodomonas minuta* 2.89	*Coelastrum microporum* 2.25	11.3	55.08	66.38
	Monsoon	*Melosira granulata* 6.54	*Peridinium aciculiferum* 2.7	*Euglena mainxii* 1.62	10.86	30.13	40.99
	Post monsoon	*Peridinium aciculiferum* 1.67	*Melosira granulata* 1.14	*Oscillatoria pseudogeminata* 1.1	3.91	12.29	16.2
	Winter	*Peridinium aciculiferum* 6.27	*Trachelomonas oblonga* 2.57	*Cryptomonas reflexa* 1.38	10.22	16.56	26.78
2017-18	Pre monsoon	*Melosira granulate* 8.08	*Trachelomonas rugulosa* 3.85	*Synedra ulna* 1.99	13.92	37.95	51.87
	Monsoon	*Melosira granulata* 4.69	*Peridinium aciculiferum* 3.03	*Oscillatoria pseudogeminata* 1.1	8.82	32.47	41.29
	Post monsoon	*Melosira granulata* 2.33	*Oscillatoria pseudogeminata* 1.1	*Peridinium aciculiferum* 0.83	4.26	8.79	13.05
	Winter	*Rhodomonas minuta* 3.33	*Cryptomonas erosa* 3.13	*Trachelomonas volvocina* 2.94	9.4	65.8	75.2

Phytoplankton species recorded from Station-1, Station-2 and Station-3 already been reported in Bangladesh

During the present investigation 215 species were identified from three studied sites of Kuniar Haor, Kishoreganj. Out of 215 recorded species of phytoplankton, 182 species are reported and 33 species are new algal reports for Bangladesh (Table 34 and 35).

Table 34. List of some reported phytoplankton species together dimensions and sources of identification which were collected from Station-1, Station -2 and Station-3 in Kuniar Haor, Kishoreganj.

Division: Cyanophyta

Species	Dimension (µm)	References
Anabaena ballyganglii J.C. Banerji	Cells 4.5 µm wide; 3.5 µm long	Khondker *et al*. 2006, Desikachary 1959
Gloeocapsa decorticans (A.Br.) Richter ex Wille	Cells without sheath 8.0-9.5 µm in diameter	Aziz and Yasmin 1997, Ling and Tyler 2000, Mitra 1951
Merismopedia elegans A. Br. in Kützing	Colonies 3.0-3.5 µm broad, 4.0-5.0 µm long	Islam and Aziz 1979, Prescott 1982, Desikachary 1959
Merismopedia punctata Meyen in Wiegmann	Cells 6.5 µm long , 4.3 µm broad	Khondker *et al*. 2006, Prescott 1982
Microcystis holastica Lemm.	Cells 1.3 µm in diameter	Khondker *et al*. 2006, Desikachary 1959
Microcystis incerta Lemm.	Cells 1.1-2.5 µm in diameter	Khondker *et al*. 2006, Ling and Tyler 2000
Oscillatoria pseudogeminata G. Schmid	Cells 4.5 µm long , 2.8 µm broad	Khondker *et al*. 2006, Desikachary 1959
Oscillatoria willei Gardner em. Drouet	cell 4.3–9.1 µm long and d. 5.1 µm broad	Islam and Irfanullah 2005, Desikachary 1959
Pelonema aphane Skuja	Individual cell 7.5 µm long , 2.2 µm braod	Islam and Irfanullah 2000, Starmach 1966

Division: Chlorophyta

Species	Dimension (µm)	References
Actinastrum hantzschii Lagerheim	Cells 2.1-4.0 µm broad; 8.8-19.6 µm long	Islam and Khatun 1966, Islam and Begum 1970, Huber-Pestalozzi 1983
Ankistrodesmus barnardi Kom.	Cells 2.5 µm long, 0.7 µm broad	Khondker *et al*. 2007b, Huber-Pestalozzi 1983
Ankistrodesmus falcatus (Corda)Ralfs	Cells 1.3-1.9 µm in diameter	Islam and Paul 1978, Huber-Pestalozzi 1983
Carteria globosa Kors.	Cells 13.5-18.5µm long; 10-15.9 µm broad	Khondker *et al.* 2007a, Huber-Pestalozzi 1961, Iyenger and Desikachary 1981, Dillard 1989a
Carteria radiosa Kors.	Cells 8-17 µm long	Khondker *et al.* 2007a, Huber-Pestalozzi 1961, Iyenger and Desikachary 1981
Chlamydomonas elliptica Korškov	Cells 13 µm long, 8.5µm broad	Khondker *et al.* 2007a, Huber-Pestalozzi 1961
Chlamydomonas foveolarum Skuja	Cells 7-8 µm in diameter	Khondker et al. 2007a, Huber-Pestalozzi 1961
Chlamydomonas gloeopara Rodhe *et* Skuja.	Cells 8-9.5 µm long, 6-6.7 µm broad	Khondker *et al.* 2007a, Huber-Pestalozzi 1961
Chlamydomonas globosa Snow	Cells 5.6-8.9 µm in diameter	Khondker *et al.* 2007a, Huber-Pestalozzi 1961
Closterium intermedium var. *hibernicum* West & West	Length of cell 270 µm	Islam and Chawdhury 1979, Day *et al*. 1995
Coelastrum indicum W.B. Turner	Colony 34-42 µm in diameter, individual cells 4-5.5 µm in diameter	Khondker *et al.* 2007a, Huber-Pestalozzi 1961
Cosmarium botrydis var. *tumidum* Wolle	Cells 87 µm long, 62 µm broad, isthmus 25 µm	Islam and Chawdhury 1979, Islam and Haroon 1980
Cosmarium depressum var. intermedium (Gutw.) Messik.	Cells 30.0 µm long, 30.5 µm broad, isthmus 5.5 µm	Islam and Irfanullah 2006
Cosmarium margaritatum var. *quadrum* Krieger	Cells 30.0 µm long, 27.70 µm broad, width of isthmus 10.0 µm	Islam and Irfanullah 2006, Day *et al.* 1995
Cosmarium scabrum W.B. Turner	Cells 44 µm long, 47.2-49.6 µm broad, isthmus narrow c 10-13 µm broad	Islam and Irfanullah 2006

Species	Dimension (µm)	References
Crucigeniella crucigera (Wolle) Komérek	Vegetative cells 2.0-6.5 µm broad, 4.1-10.2 µm long	Islam and Khatun, 1966, Islam and Begum 1970, Islam and Irfanullah 2006, Huber- Pestalozzi 1983
Crucigeniella rectangularis (Näg) Kom.	Cells 2.2-3.3 µm broad; 2.4-6.3 µm long	Islam and Begum 1970, Islam and Hossain 1979, Prescott 1982, Ling and Tyler 2000
Dictyosphaerium pulchellum var. *munutum* Wood.	Individual cells 4.5 µm in diameter	Khondker *et al.* 2007b, Huber-Pestalozzi 1961
Dictyosphaerium tetrachotomum Printz	Individual cells 2.2 µm in diameter	Khondker *et al.* 2007b, Huber-Pestalozzi 1961
Eudorina elegans Ehrenberg	Cells 7.0-10.7 µm in diameter	Islam and Khatun 1966, Islam and Aziz 1977, Huber-Pestalozzi 1961
Hyaloraphidium contortum Pascher & Koršikov	Cells 19.7-27.6 µm long; 2.1-2.4 µm broad	Islam 1969b, Bhuiyan 2006, Yeasmin 2006, Huber-Pestalozzi 1983
Kirchneriella irregularis (G.M. Smith) Koršikov	Cells 4.5 µm long; 1.3-2.1 µm wide	Khondker *et al.* 2007b, Huber-Pestalozzi 1961
Kirchneriella subcapitata Korš	Cells 7.2-20.0 µm long, 1.1-4.0 µm broad	Huber-Pestalozzi 1961
Monorahidium arcuatum (Koršikov) Hind	Cells 23-29 µm long between ends; 1.1-1.5 µm broad	Khondker *et al.* 2007b, Huber-Pestalozzi 1961
Monorahidium griffithii (Berkeley) Kom.-Legn. In Fott	Cells 59.2 µm long, 2.4 µm broad	Islam and Begum 1970, Huber-Pestalozzi 1983
Mougeotia quadrangulata Hassall	Vegetative cells 80-240 µm long, 14-17 µm broad	Celekli *et al.* 2007a, Huber-Pestalozzi 1969
Mougeotia scalaris Hassall	Vegetative cells 110 µm long, 17 µm broad	Celekli *et al.* 2007a, Huber-Pestalozzi 1969
Oocystis borgei Snow, Bull	Vegetative cells 11.0-14.5 µm broad	Islam and Khatun 1966, Islam 1973a, Huber-Pestalozzi 1983
Oocystis tainoensis Kom	Individual cells 4.5 µm long, 3.3 µm broad,	Khondker *et al.* 2007b, Huber-Pestalozzi 1983
Phacotus angustus Pascher	Cells 27-35 µm long, 10-18 µm broad	Khondker *et al.* 2007b, Dillard 1989a

Pediastrum simplex Meyen	Cells 14.0-21.8 µm long, 7.2-14.5 µm broad	Islam and Khatun 1966, Islam and Zaman 1975, Islam and Hossain 1978, Dillard 1989a
Pediastrum duplex Meyen	Cells 17.8 µm long, 13.9 µm broad	Islam and Khatun 1966, Islam and Zaman 1975,
Planktosphaeria gelatinosa G. M. Smith	Cell 5.0-25.0 µm in dia meter	Islam and Alfasane 2001b, Prescott 1982, Dillard 1989a, Ling and Tyler 2000, Huber-Pestalozzi 1983
Scenedesmus opoliensis var. *contacta*	Cells 27.4 µm long, 7.9 µm broad	Khondker *et al.* 2007b, Huber-Pestalozzi 1983
Scenedesmus quadricauda (Turp.) de Brébisson in de Brébisson & Godey	Cells 9.0-17.0 µm long, 3.3-6.7.5 µm broad	Islam and Begum 1970, Islam and Saha 1975, Islam and Aziz 1979, Islam and Hossain 1978, Huber-Pestalozzi 1983
Scenedesmus similageneus Hortob.	Cells 9.0 µm long, 4.4 µm broad	Khondker *et al.* 2007b, Huber-Pestalozzi 1961
Schroederia setigera (Schröd.) Lemmermann	Cells 104.6 µm long with spine,4.2 µm broad	Islam and Begum 1970, Dillard 1989a
Staurastrum punctulatum Brébisson *ex* Ralfs	Cell length 25.0µm, median diameter 28.0 µm, isthmus 8.0µm	Islam and Akter 2004, Croasdale 1973, Skuja 1949
Staurastrum pinnatum	Cell length 39.0µm, median diameter 44.0 µm, isthmus 11.0µm	Khondker *et al.* 2007b, Prescott 1982
Spermatozoopsis exultans Kors.	Cells 10.1-17.0 µm long, 2.2-2.6 µm broad	Islam and Khondker 1993, Bhuiyan 2006, Yeasmin 2006
Tetraedron arthrodesmiforme var. *contorta* Wolosz.	Cells 13.5 µm long, 37 µm broad with spine	Khondker *et al.* 2007b, Prescott 1982
Tetraedron minimum (A. Br.) Hansg.	Cell 4.4-6.5 µm in dia meter	Islam and Khatun 1966, Islam and Begum 1970, Prescott 1982
Tetrastrum heteracanthum fa. elegans	Cells 5.6 µm long, 3.8 µm in diameter	Islam and Khondker 1993, Bhuiyan 2006, Yeasmin 2006
Thorakomonas phacotoides Iyengar	Cells 13 µm long with lorica, 7-11µm broad	Islam and Irfanullah 2005b, Iyenger and Desikachary 1973

Division: Euglenophyta

Species	Dimension (µm)	References
Astasia pygmaea Skuja	Cells 8.9 µm long, 5.5 µm broad	Khondker *et al.* 2008d, Huber-Pestalozzi 1955, Ettl and Gärtner 1995, Caraus 2002
Cryptochrysis minor	Cells 14-17 µm long, 5.8 µm broad	Khondker *et al.* 2008c, Schiller 1956
Euglena acus var. *longissima* Ehrenberg	Cells 78.0-220.0 µm long, 5.7-14.0 µm broad	Islam and Khatun 1966, Islam and khondker 1991, Huber-Pestalozzi 1955, Parra and Gonzalez 1977
Euglena allorgei Delf.	Cells 100.4 µm long, 11.7 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955, Dillard 2000, Caraus 2002
Euglena agilis var. *praeexicisa* Schiller	Cells 16-17 µm long, 6.5 µm broad	Khondker *et al.* 2008a, Schiller 1956
Euglena clavata	Cells 98.5 µm long, 15.7 µm broad	Khondker *et al.* 2008a, Gojdics 1953
Euglena ehrenbergii	Cells 74 µm long, 11.7 µm broad	Khondker *et al.* 2008a, Huber-Pestalozzi 1955, Dillard 2000
Euglena exilis Gojdics	Cells 47.3 µm long, 10.4 µm broad	Islam and khondker 1991, Gojdics 1953
Euglena gojdicsae Prescott	Cells 21-37 µm long, 10.0-12.0 µm broad	*Khondker et al.* 2008a, Gojdics 1953
Euglena hemichromata Skuja	Cells 76.0-97.1 µm long, 15.2-25.0µm broad	Khondker *et al.* 2008a, Dillard 2000
Euglena mainxii Defl.	Cells 39 µm long, 14 µm broad	Khondker *et al.* 2008a, Huber-Pestalozzi 1955, Dillard 2000

Species	Dimension (µm)	References
Euglena oblonga Schmitz	Cells 63.0-71.0 µm long, 20.0-25.0 µm broad	Khondker *et al.* 2008a, Huber-Pestalozzi 1955, Wolowski 2002
Euglena spathyryncha	Cells 101 µm long, 17 µm broad	Alfasane and Khondker 2007, Huber-Pestalozzi 1955
Euglena tripteris (Dujardin) Klebs	Cells 94.0-96.0 µm long, 14.0-17.0 µm broad	Islam *et al.* 1991, Gojdics 1953, Huber-Pestalozzi 1955, Day *et al.* 1995, Dillard 2000
Euglena viridis (Müller) Ehrenberg	Cells 30-37 µm long, 10-13 µm broad	Khondker *et al.* 2008a, Huber-Pestalozzi, 1955
Lepocinclis ovum var. *major*	Cells 35.8 µm long, 24.2 µm broad	Khondker *et al.* 2008a, Huber-Pestalozzi 1955
Lepocinclis ovum var.*conica* (Perty) Lemm.	Cells 26 µm long, 22 µm broad Ency-266	Alfasane and Khondker 2007, Huber-Pestalozzi 1955
Lepocinclis salina Fritsch	Cells 30.0-36.1 µm long, 22.0-30.0 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955, *Day et al*. 1995
Lepocinclis salina fa. *Pachyderma* Defl.	Cells 24.1 µm long, 17.7 µm broad	Islam and Alfasane 2002, Huber-Pestalozzi 1955
Phacus ephippion Skuja	Cells 45-47 µm long, 29-30 µm broad	Khondker *et al.* 2008a, Huber-Pestalozzi 1955
Phacus longicauda var. *major* Svir	Cells 99-141 µm long, 30-44 µm broad	Islam and Alfasane 2002, Huber-Pestalozzi 1955
Strombomonas fluviatilis (Lemm.) Defl.	Lorica 20-27 µm long, 10-12.1 µm broad	Khondker *et al.* 2008d, Huber-Pestalozzi 1955
Strombomonas gibberosa var. *tumida*	Lorica 43.8 µm long, 34.1 µm broad	Khondker *et al.* 2008d, Huber-Pestalozzi 1955
Strombomonas verrucosa var. *borystheniensis* (Roll) Defl.	Lorica 21 µm long, 19 µm broad	Islam and Alfasane 2003, Huber-Pestalozzi 1955

Species	Dimension (µm)	References
Trachelomonas anulifera	Lorica 23-27 µm long, 18-21 µm broad, En-317	Islam and Alfasane 2004, Huber-Pestalozzi 1955, Dillard 2000
Trachelomonas anguste-ovata Drez	Lorica 18-20 µm long, 12-15 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955
Trachelomonas armata	Lorica 22.0 µm long, 17-20.0 µm broad	Islam and Moniruzzaman 1981
Trachelomonas bernardi Wol.	Lorica 7.8 µm long, 11.2 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955
Trachelomonas compacta	Lorica 13.1 µm long, 11 µm broad	Islam and Alfasane 2003, Huber-Pestalozzi 1955
Trachelomonas crebea Ehr.	Lorica 25.7 µm long, 14.5 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955, Dillard 2000, Caraus 2002
Trachelomonas dybowskii Drez.	Lorica 16.0-17.0 µm long, 8.8 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955, Dillard 2000, Day *et al.*1995
Trachelomonas eurystoma	Lorica 15.1 µm long, 11.2 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955
Trachelomonas hispida var.*coronata* (Perty) Stein	Lorica 21-33 µm long,17-24 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955
Trachelomonas intermedia	Lorica 24.7 µm long,19.4 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955
Trachelomonas lismorensis var. *intermis* Playfair	Lorica 19 µm long,8.6 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955
Trachelomonas oblonga Lemm.	Lorica 10-15 µm long,7.0-12.0 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955
Trachelomonas oblonga fa. *ovata* Playfair	Lorica 18.2µm long, 13.1 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955
Trachelomonas oblonga var. *truncata* Lemm.	Lorica 10-11 µm long, 7.4 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955, Sherwood 2004
Trachelomonas planktonica Swir.	Lorica 26-28.7 µm long, 20.5 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955, Dillard 2000

Species	Dimension (µm)	References
Trachelomonas playfairii	Lorica 24.7 µm long, 18.1 µm broad	Khondker *et al.* 2008b, Huber-Pestalozzi 1955
Trachelomonas pulcherrima	Lorica 22.1 µm long, 11.2 µm broad	Khondker *et al.* 2008b, Huber-Pestalozzi 1955
Trachelomonas rugulosa Stein	Lorica 12-22 µm in diameter	Islam and Alfasane 2003, Huber-Pestalozzi 1955, Dillard 2000
Trachelomonas scabra var.*pygnea*	Lorica 23 µm long, 14 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955
Trachelomonas tshopoensis	Lorica 26.7 µm long, 22.6 µm broad	Khondker *et al.* 2008c, Huber-Pestalozzi 1955
Trachelomonas volvocina Ehrenberg	Lorica 7-21.0 µm in diameter	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955, Dillard 2000
Trachelomonas volvocina var. *punctata* Playfair	Lorica 10-15 µm in diameter	Khondker *et al.* 2008c, Huber-Pestalozzi 1955
Trachelomonas volvocina var. *planktonica* Playfair	Lorica 24 µm long, 19 µm broad	Islam and Moniruzzaman 1981, Huber-Pestalozzi 1955

Division: Chrysophyta

Species	Dimension (µm)	References
Achnanthes minutissima Kütz	Frustules 15.0 µm long, 2.3 µm broad	Aziz and Tanbir 2003, Hustedt, 1930, Day *et al.* 1995
Amphora ovalis (Kützing) Kützing	Frustules 45 µm long, 29 µm broad in girdle view	Islam and Aziz 1979, Germain 1981
Chaetoceros compressus Lauder	Cells 14-20.1µm long, 12 µm broad	Islam and Aziz 1975, Subrahmanyan 1946
Coscinodiscus lineatus Ehrenberg	Valves 43 µm in diameter	Islam and Aziz 1977, Day *et al.* 1995, Caraus 2002
Cyclotella comensis Grunow in Van Heurck	Valves 7.77 µm in diameter	Bhuiyan 2006, Hustedt 1930
Cyclotella comta var. *affinis* Grunow in Van Heurck	Valves 45.8 µm in diameter	Khair and Chowdhury 1983
Cyclotella meneghiniana Kütz	Cells 9.7-13.0 µm in diameter	Nahar 2001, Hustedt 1930
Cymbella affinie Kütz	Frustules 80.40 µm long, 17.15 µm broad (at the middle), 10.99 µm (at the tip)	Islam and Haroon 1975, Islam and Irfanullah 2005, Day *et al.* 1995, Caraus 2002, Sherwood 2004
Cymbella gracilis (Rabch.) Cl.	Valves 26-41 µm long, 7.5-12.5 µm broad	Aziz and Ara 2000, Germain 1981
Cymbella parva (W. Smith) Kirchner	Cells 79.5 µm long, 18.0 µm broad (at the middle), 10.5 µm (at the tip)	Islam and Haroon 1975, Caraus 2002, Soylu Gönülol 2006
Cymbella turgidula Grun.	Cells 12-13 µm broad, 38-39.2 µm long	Islam and Haroon 1975, Islam and Irfanullah 2005, Day *et al.* 1995, Caraus 2002, Sherwood 2004

Species	Dimension (µm)	References
Epithemia argus (Ehrenberg) Kützing	Cells 20-24.5 µm long, 15.0-17.1 µm broad	Aziz and Yasmin 1997b, Germain 1981, Day *et al*. 1995
Eunotia alpina (Näg.) Hustedt	Cells 38-175 µm long, 2.5-7.2 µm broad	Aziz and Ara 2000, Aziz and Tanbir 2003, Germain 1981
Eunotia monodon var. *major*	Frustules 42.5 µm long, 3.60 µm broad	Islam and Haroon 1975, Germain 1981, Antoniades *et al*. 2005
Eunotia robusta	Cells 39.3 µm long, 14.4 µm broad	Islam and Haroon 1975, Germain 1981, Antoniades *et al*. 2005
Eunotia veneris (Kütz) De Toni	Frustules 12-76.0 µm long, 3.7-9.1 µm broad	Nahar 2001, Day *et al*. 1995, Caraus 2002
Fragilaria capucina Desm.	Frustules 43.4 µm long, 4.2 µm broad	Islam and Haroon 1975, Germain 1981, Antoniades *et al*. 2005
Fragilaria capucina var. *lanceolata*	Frustules 41.1 µm long, 4.2 µm broad	Islam and Haroon 1975, Caraus 2002
Fragilaria crotonensis Kitton	Frustules 40-145 µm long, 67 µm broad	Aziz and Tanbir 2003, Germain 1981, Catling *et al*. 1981
Fragilaria intermedia (Grunow) Grunow	Frustules 15-70 µm long, 7.5-18.0 µm broad	Aziz and Ara 2000, Germain 1981
Gomphonema angustatum (Kütz) Rabh	Valve 37.0-44.0µm long, 8-9.2 µm broad	Nahar 2001, Day *et al*. 1995, Ettl and Gärtner 1995, Jamaloo *et al*. 2006
Gomphonema gracile Ehrenberg var. *naviculacea* Cl.	Frustules 14.50 broad µm , 83.40µm long	Islam and Haroon 1975, Caraus 2002
Gomphonema lanceolatum var. *turris* (Greg.) Cleve	Frustules 48.2 µm long, 9.6 µm broad	Nahar 2001, Caraus 2002
Gomphonema longiceps var. *subclavata* fa. *gracilis* Hust.	Frustules 47.0 µm long, 7.0 µm broad	Nahar 2001, Day *et al*. 1995
Gyrosigma acuminatum	Frustules 147 µm long, 23.3 µm broad	Khondker *et al*. 2007a, Day *et al*. 1995, Caraus 2002

Species	Dimension (µm)	References
Gyrosigma attenuatum	Frustules 119.5 µm long, 15.9 µm broad	Islam and Aziz 1975, Subrahmanyan 1946
Gyrosigma distortum var. parkeri	Frustules 119.5 µm long, 15.9 µm broad	Islam and Irfanullah 2005, Ettl and Gärtner 1995, Mann *et al*. 2004
Gyrosigma scalproides	Frustules 54.1 µm long, 17.9 µm broad	Khondker *et al*. 2007a, Day *et al*. 1995, Caraus 2002
Melosira granulata var. *angustissima* Müll	Cells 24-25.5µm long, 5-6.7 µm broad	Islam 1974, Hustedt 1930
Melosira granulate fa. *curvata*	Cells 14-20µm long, 4-6 µm broad	Islam 1974, Hustedt 1930
Melosira distans	Cells 12.7µm long, 6.8 µm broad	Khondker *et al*. 2007a, Day *et al*. 1995, Caraus 2002
Melosira distans var. *alpigena*	Cells 13-15.3µm long, 6-6.8 µm broad	Khondker *et al*. 2007a, Day *et al*. 1995, Caraus 2002
Melosira moniliformis	Cells 15.3µm long, 7.8 µm broad	Nahar 2001, Day *et al*. 1995
Navicula anglica	Cells 24.1 µm long, 8.5 µm broad	Nahar 2001, Hustedt 1930
Navicula Americana	Cells 71 µm long, 18.2 µm broad	Islam 1974, Hustedt 1930
Navicula bacillum	Cells 14.8-19.0 µm long, 6.0-7.5 µm broad	Islam 1974, Hustedt 1930
Navicula cuspidata (Kützing) Kützing	Cells 47.2-165.0 µm long, 16-30 µm broad	Nahar 2001, Day *et al*. 1995, Germain 1981
Navicula exigua (Dujardin) Nouv.	Frustules 25-27 µm long, 7-7.5 µm broad	Islam and Haroon 1975, Hustedt 1930, Caraus 2002
Navicula grimmei	Frustules 19.3 µm long,5.8µm broad	Islam 1974, Hustedt 1930
Navicula mutica Kütz.	Cells 14.8-19.0 µm long, 6.0-7.5 µm broad	Nahar 2001, Day *et al*. 1995

Navicula pupula Kütz	Frustules 20-41 µm long, 7-9.9 µm broad	Islam and Irfanullah 2005, Ettl and Gärtner 1995, Mann *et al*. 2004
Navicula pupula var. *capitata* Hust.	Frustules 16-40 µm long, 4-9.0 µm broad	Nahar 2001, Hustedt 1930
Navicula placentula var. *rostata*	Frustules 21.2 µm long, 7.9 µm broad	Islam and Irfanullah 2006, Ettl and Gärtner 1995, Mann *et al*. 2004
Navicula pseudohalophila	Frustules 19.6 µm long, 4.8 µm broad	Nahar 2001, Day *et al.* 1995, Ettl and Gärtner 1995, Caraus 2002
Navicula radiosa	Frustules 16-21 µm long, 3.6 µm broad	Islam and Haroon 1975, Hustedt 1930
Nitzschia acicularis (Kützing) W. Smith	Frustules 54-75 µm long, 3-4.1 µm broad	Nahar 2001, Day *et al.* 1995, Ettl and Gärtner 1995, Caraus 2002
Nitzschia alpine (Näg) Hustedt	Valve 35.5 µm long, 5.1 µm broad	Aziz and Tanbir 2003
Nitzschia linearis W. Smith	Frustules 110-115 µm long, 5.2-6.0 µm broad	Nahar 2001, Germain 1981
Nitzschia longissima (Bréb.) Grunow	Cells 32.0 µm long, 4.1 µm broad	Aziz and Tanbir 2003, Germain 1981
Pinnularia gibba var. *parva* (Grun.) Frenguelli	Frustules 32.0-41.0 µm long, 8.2-9.0 µm broad	Islam and Haroon 1975, Hustedt 1930
Pinnularia major (Kütz) Rabenhorst	Frustules 30-113 µm long, 8.0-16.0 µm broad	Nahar 2001, Day *et al*. 1995, Ettl and Gärtner 1995, Caraus 2002
Pinnularia molaris Enc-156	Frustules 28.5 µm long, 7.2 µm broad	Islam and Aziz 1975, Hustedt 1930
Pinnularia pulchra Østrup	Cells 7-7.8 µm broad, 36-56 µm long	Nahar 2001, Day *et al*. 1995, Ettl and Gärtner 1995, Caraus 2002

Species	Dimension (µm)	References
Synedra acus Kütz	Cells 7.2 µm broad, 147.8 µm long	Islam and Haroon 1975, Day *et al.* 1995
Synedra tabulata (Ag.) Kützing	Cells 4.0-5.0 µm broad, 33-92 µm long	Aziz and Ara 2000, Mizuno 1974, Germain 1981, Day *et al.* 1995
Synedra ulna (Nitzsch) Ehr.	Cells 9.0-13.5 µm broad, 166.0-3080.0 µm long	Islam and Haroon 1975, Day *et al.* 1995, Ettl and Gärtner 1995, Sherwood 2004
Synedra ulna var. *danica* (Kütz) Van Heurck	Cells 5.0-5.2 µm broad, 177-190 µm long	Nahar 2001, Day *et al.* 1995, Ettl and Gärtner 1995, Sherwood 2004
Surirella angustata	Cells 39 µm long, 18.1 µm broad	Islam and Haroon 1975, Day *et al.* 1995
Surirella ovata var. *pinnata*	Cells 38-40 µm long, 9-11 µm broad	Islam and Haroon 1975,Ettl and Gärtner 1995, Sherwood 2004
Surirella robusta	Cells 39 µm long, 18.1 µm broad	Islam and Haroon 1975, Day *et al.* 1995, Ettl and Gärtner 1995, Sherwood 2004

Division: Cryptophyta

Species	Dimension (µm)	References
Chroomonas acuta Utermöhl	Cells 7-0 µm long, 4-5.6 µm broad	Khondker *et al*. 2007a, Huber-Pestalozzi 1968
Cryptomonas erosa Ehrenberg	Cells 20-28 µm long, 10-15.2 µm broad	Khondker *et al*. 2007a, Huber-Pestalozzi 1968
Cryptomonas lucens Skuja	Cells 10.5 µm long, 6.7 µm broad	Khondker *et al*. 2007a, Huber-Pestalozzi 1968, Caraus 2002
Cryptomonas marssonii Skuja	Cells 24 µm long, 10 µm broad	Khondker *et al*. 2007a, Huber-Pestalozzi 1968
Cryptomonas obovata Czosnowski	Cells 21 µm long, 12 µm broad	Khondker *et al*. 2007a, Begum 2008, Huber-Pestalozzi 1968, Caraus 2002
Cryptomonas ovata Ehr.	Cells 28.0-32.7 µm long, 12.0-14.1 µm broad	Islam and khondker 1993, Begum 2008, Huber-Pestalozzi 1968
Cryptomonas phaseolus Skuja	Cells 12 µm long, 6.7 µm broad	Khondker *et al*. 2007a, Huber-Pestalozzi 1968
Cryptomonas reflexa Skuja	Cells 27-36.5 µm long, 12-15.8 µm broad	Khondker *et al*. 2007a, Huber-Pestalozzi 1968
Rhodomonas lacustris Pascher *et* Ruttner	Cells 14.0-15.0 µm long, 4.4-8.0 µm broad	Islam and khondker 1993, Smith 1950, Huber-Pestalozzi 1968
Rhodomonas minuta Skuja	Cells 9-14.5 µm long, 5-7.8 µm broad	Khondker *et al*. 2007a, Huber-Pestalozzi 1968

Division: Pyrrhophyta

Species	Dimension (µm)	References
Peridinium abei	Cells 62 µm long, 54 µm broad	Islam and Aziz 1977, Subrahmanyan 1968
Peridinium aciculiferum	Cells 72 µm long, 57 µm broad	Islam and Aziz 1975, Subrahmanyan 1968
Peridinium cinctum (Müller) Ehrenberg	Cells 85.5 µm long, 77.0 µm broad	Aziz and Tanbir 2003, Subrahmanyan 1968
Ceratium furca (Ehrenberg) Claprède *et* Lachmann	Cell proper 40-44 µm long, 32.5 µm broad	Islam and Aziz 1975, Subrahmanyan 1968

Phytoplankton species new records for Bangladesh

Based on the preliminary identification, 33 species of phytoplankton may be considered as new records for the Bangladesh. The distribution of new records of phytoplankton is as follows: Euglenophyta dominate (9 taxa) followed by Chlorophyta (7 taxa), Chrysophyta (6 taxa), Cryptophyta (7 taxa), Cyanophyta (2 taxa) and Pyrrhophyta (2 taxa). The recorded new reports of phytoplankton are shown in Table 35.

Table 35. List the new reports of phytoplankton for Bangladesh together with dimensions and sources of identification which were collected from Station-1, Station -2 and Station-3 in Kuniar Haor, Kishoreganj.

Division: Cyanophyta

Species	Dimension (µm)	References
Oscillatoria tanganyikae	Cell 4.2 µm wide	Desikachary 1959.
Achroonema macromeres	7.2-8.0 µm broad and upto 2.1 mm long	Starmach 1966.

Division: Chlorophyta

Species	Dimension (µm)	References
Closteriopsis acicularis var. *africana*	Cell length 61.4 µm, median diameter 16.5 µm, apex 3.2 µm broad	Huber-Pestalozzi 1983.
Oocystis lacustris var.	Cells 4-20 × 1.8-10.2 µm	Huber-Pestalozzi 1983.
Oocystis nata	Vegetative cells 13.3 µm broad	Huber-Pestalozzi 1983.
Scenedesmus hortobagyi	Cell 8-14.0 × 2-6.6 µm	Huber-Pestalozzi 1983.
Phacotus lenticularis	Cells 28.4 µm long, 11.6 µm broad	Iyengar and Desikachary 1981.
Zygnemopsis desmidioides	Vegetative cells 85 µm long, 14.5 µm broad	Prescott 1970.

Division: Euglenophyta

Species	Dimension (µm)	References
Colacium simplex	Cell 34µ long, 16µ broad	Huber-Pestalozzi 1955
Phacus aenigmaticus f. *filicauda*	Dimension: 20-22.3 × 10-15.0 µ	Huber-Pestalozzi 1955
Strombomonas amphoraeformis	Cell 30-36 µ long, 15-17.8µ width	Huber-Pestalozzi 1955
Cyclidiopsis acus	Dimension 24-33 × 16-17.1 µ, Thickness 13 µ	Huber-Pestalozzi 1955
Trachelomonas komerovii var. *punctata*	Lorica 26.0 µm long, 18-23.0 µm broad	Huber-Pestalozzi 1955
Trachelomonas hispida var. *crenulatocollis* fa. *recta*	Cell length 29-30.1×25-26 µ	Huber-Pestalozzi 1955
Trachelomonas fukiensis	Diameter 24-28 × 10-15.6 µ or 30-33.4 × 12-13µ	Huber-Pestalozzi 1955
Trachelomonas oviformis Drez.	Cell diameter 22-23.5 µ	Huber-Pestalozzi 1955
Strombomonas verrucosa var. *conspersa*	Lorica dimension 24-25.1 µ	Huber-Pestalozzi 1955

Division: Chrysophyta

Species	Dimension (µm)	References
Melosira granulata var. *mujjanensis*	Cells 13.2µm long, 6.6 µm broad	Bogopocam 1951.
Stenopterobia intermidia Syn- *Nitzschia obtusa*.	Cells 14.7µm long, 7.8 µm broad	Bourrelly1968.
Surirella robusta var. *splendida*	Cells 39.4 µm long, 18.4 µm broad	Hustedt 1930.
Surirella ovata var. *minuta*	Cells 39 µm long, 9.8 µm broad	Bourrelly1968.
Synedra goulardii	Frustules 15-30 × 5-8.8µ	Bourrelly1968
Synedra ulna var. *aequalis*.	Cells 5.3 µm broad, 182 µm long	Hustedt 1930.

Division: Pyrrhophyta

Species	Dimension (µm)	References
Peridinium conjuctum	Cells 45-56.0 µm long, 35-55.8 µm broad	Huber-Pestalozzi, 1968.
Peridinium lomnickii	Cells 20-30.7 µm long, 16-17 µm broad	Huber-Pestalozzi, 1968.
Peridinium palustre	Cells 83-84.5 µm long, 64-65 µm broad	Huber-Pestalozzi, 1968.

Division: Cryptophyta

Species	Dimension (µm)	References
Cephalomonas granulata	Lorica 14 µm long, 8.5 µm broad	Iyengar 1981.
Cryptomonas caudata	Cells 14-16.7 µm long, 7.8 µ broad	Huber-Pestalozzi 1968.
Cryptomonas erosa var.	Cells 16-19 µm long, 8-13.2 µ broad	Huber-Pestalozzi 1968.
Cryptomonas parapyrenoidifera	Cells 16-20.1 µm long, 7-8.9 µ broad	Huber-Pestalozzi 1968.
Cryptomonas platyuris	Cells 28 µm long, diameter 15.2 µm	Huber-Pestalozzi 1968.
Cryptomonas marssonii var.	Cells 16-20 µm long, 10-12 µ broad	Huber-Pestalozzi 1968.
Cryptomonas rufescens	Cells 24 µm long, 13.2 µ broad	Huber-Pestalozzi 1968.

Limnological data analysis of the studied habitats

Over the entire sampling period, the environmental characteristics of the water were found different compared to the three study sites. Observation among the studied habitats of Station-1, Station-2 and Station -3, the range of air and water temperature shows similarity for three study sites (Table 36 to Table 38). The average value of Secchi depth and Chl-a show similarity in case of three stations (Table 38). Range of DO is higher in station-2 than the other two stations. Average concentrations of air temperature, SRP, SRS, phaeopigment were found higher in Station -3 than the other two (Table 39).

Table 36. Mean values of physicochemical and biological parameters of Station- 1 during the study period.

Parameters	Unit	N	Minimum	Maximum	Mean	SD	Range
AT	°C	24	18.50	35.50	29.04	±5.34	**18.50 - 35.50**
WT	°C	24	19.00	30.00	26.00	±3.27	**19.0-30.00**
Zs	cm	24	13.00	70.50	37.48	±20.5	**13.00-70.50**
Alk.	meq/l	24	.60	5.50	1.45	±0.42	**0.60-5.50**
Cond.	µS/cm	24	38.00	208.00	95.52	±18.75	**38.00-208.00**
DO	mg/l	24	5.20	12.80	9.42	±2.43	**5.20-12.80**
pH	-	24	6.60	8.10	7.29	±0.41	**6.60-8.10**
TDS	mg/l	24	20.00	97.00	38.33	±18.82	**20.00-97.00**
SRP	µg/l	24	1.05	36.14	15.65	±9.49	**1.05-36.14**
SRS	mg/l	24	.77	16.29	8.31	±4.08	**0.77-16.29**
NO_3-N	mg/l	24	.11	1.15	.31	±0.27	**0.11-1.15**
chl-a	µg/l	24	1.18	24.27	6.50	±3.14	**1.18-24.27**
PP	µg/l	24	.37	25.30	4.63	±1.47	**0.37-25.30**
PD	**$x10^4$ ind./l**	**24**	**1.80**	**37.80**	**11.73**	**±8.07**	**1.80-37.80**

Table 37. Mean values of physicochemical and biological parameters of Station-2 during the study period.

Parameters	Unit	N	Minimum	Maximum	Mean	SD	Range
AT	°C	24	19.00	37.20	29.71	±5.75	19.00-37.20
WT	°C	24	20.40	33.40	25.75	±3.24	20.40-33.40
Zs	cm	24	12.00	75.00	37.71	±19.92	12.00-75.00
Alk.	meq/l	24	0.60	2.70	1.42	±0.52	0.60-2.70
Cond.	µS/cm	24	31.00	176.00	91.11	±15.33	31.00-176.00
DO	mg/l	24	4.40	14.80	9.35	±2.82	4.40-14.80
pH	-	24	6.40	7.90	7.33	±0.34	6.40-7.90
TDS	mg/l	24	17.40	95.00	41.34	±11.87	17.40-95.00
SRP	µg/l	24	2.04	33.09	13.78	±9.68	2.04-33.09
SRS	mg/l	24	2.04	20.11	9.37	±5.09	2.04-20.11
NO_3-N	mg/l	24	0.07	.62	0.25	±0.12	0.07-0.62
chl-a	µg/l	24	1.78	21.90	6.88	±3.26	1.78-21.90
PP	µg/l	24	0.13	46.32	4.91	±1.14	0.13-46.32
PD	$x10^4$ ind./l	24	3.37	62.20	16.43	±7.17	3.37-62.20

Table 38. Mean values of physicochemical and biological parameters of Station-3 during the study period.

Parameters	Unit	N	Minimum	Maximum	Mean	SD	Range
AT	°C	24	18.50	38.10	30.04	±5.9	**18.50 - 38.10**
WT	°C	24	19.00	30.00	25.53	±3.11	**19.00-30.00**
Zs	cm	24	7.50	95.00	37.35	±22.08	**7.50-95.00**
Alk.	meq/l	24	.50	2.90	1.45	±0.603	**0.50-2.90**
Cond.	µS/cm	24	36.00	193.00	93.84	±16.01	**36.00-193.00**
DO	mg/l	24	4.40	13.70	9.20	±2.17	**4.40-13.70**
pH	-	24	6.80	8.10	7.41	±0.34	**6.80-8.10**
TDS	mg/l	24	17.00	96.00	38.73	±12.88	**17.00-96.00**
SRP	µg/l	24	3.65	55.28	18.6	±13.77	**3.65-55.28**
SRS	mg/l	24	2.12	23.19	9.97	±5.93	**2.12-23.19**
NO_3-N	mg/l	24	0.04	1.05	0.27	±.193	**0.04-1.05**
chl-a	µg/l	24	2.37	32.56	6.78	±3.34	**2.37-32.56**
PP	µg/l	24	0.54	25.26	5.007	±2.74	**0.54-25.26**
PD	**$x10^4$ ind./l**	**24**	**4.08**	**46.90**	**13.78**	**±9.08**	**4.08-46.90**

Table 39. A comparison on monthly mean values of limnological data of Station-1, 2 and 3.

Parameters	Unit	Station-1	Station -2	Station-3
AT	°C	29.04±5.34	29.71±5.75	**30.04±5.9**
WT	°C	26±3.27	25.75±3.24	**25.53±3.11**
Zs	cm	37.48±20.5	37.71±19.92	**37.35±22.08**
Alk.	mg/l	1.45±0.42	1.42±0.52	**1.45±0.603**
Conduc.	µS/cm	95.52±18.75	91.11±15.33	**93.84±16.01**
DO	mg/l	9.42±2.43	9.35±2.82	**9.20±2.17**
pH	meq/l	7.29±0.41	7.33±0.34	**7.41±0.34**
TDS	mg/l	38.33±18.82	41.34±11.87	**38.73±12.88**
SRP	µg/l	15.65±9.49	13.78±9.68	**18.6±13.77**
SRS	mg/l	8.31±4.08	9.37±5.09	**9.97±5.93**
NO_3-N	mg/l	0.31±0.27	0.25±0.12	**0.27±.193**
Chl-a	µg/l	6.50±3.14	6.88±3.26	**6.78±3.34**
Pp	µg/l	4.63±1.47	4.91±1.14	**5.007±2.74**
PD	**x 10^4 ind./l**	**11.73±8.07**	**16.43±7.17**	**13.78±9.08**

Seasonal changes

According to Brammer (2002) four distinct seasons prevail in Bangladesh. These are: Pre-monsoon (March to May), monsoon (June to September), Post-monsoon (October to November) and winter (December to February). Depending upon the above mentioned classification, seasonal changes of different limnological parameters were calculated for the study sites and presented in Table 40 to Table 42 in the station and between years of study.

At the station and between years of study physical factors like air and water temperature along with a Secchi depth and chemical factors like pH, conductivity, alkalinity, DO, TDS, SRS, SRP, NO_3-N and biological factors like chl-*a*, PP, PD from the present investigation were consolidated seasonally to observe the variations among the mean values.

Table 40. Average value of different limnological parameters in four distinct climatic seasons of Bangladesh for Station -1

Parameters	Unit	Pre-Monsoon (Mar.-May)	Monsoon (June -Sept.)	Post-Monsoon (Oct. – Nov.)	Winter (Dec.-Feb.)
		Physical factors			
AT	°C	31.5±0.64	33.06±0.67	26.83±0.69	22.84±1.01
WT	°C	28±0.7	28.06±0.94	24.25±1.13	22.04±0.8
Zs	cm	24.5±7.43	60.32±9.02	40.25±7.17	18.17±8.23
		Chemical factors			
TDS	mg/l	33±10.37	32.2±7.42	26.88±17.67	60.5±10.68
Cond.	µS/cm	81.17±17.73	80.37±16.5	75.45±22.83	148.17±19.7
pH	-	7.43±0.42	7.3±0.31	7.52±0.377	7.05±0.37
Alk.	meq/l	1.81±0.04	1.41±0.03	1.3±0.02	1.38±0.02
DO	mg/L	7.55±2.16	10.73±1.73	8.8±2.6	8.4±1.78
NO_3-N	mg/l	0.38±0.07	0.31±0.1	0.21±0.03	0.31±0.07
SRP	µg/l	10.5±3.05	17.34±4.42	10±8.89	16.3±1.53
SRS	mg/l	7.62±1.18	8.47±2.94	7.8±1.88	9.8±1.4
		Biological factors			
chl-a	µg/l	7.07±3.77	8.43±2.75	3.69±0.82	4.82±3.62
PP	µg/l	5.74±0.53	6.47±.43	2.44±0.37	2.61±0.47
PD	$\times 10^4$ ind./l	19.08±2.81	8.2±2.18	7.95±1.9	11.63±2.43

Table 41. Average value of different limnological parameters in four distinct climatic seasons of Bangladesh for Station -2

Parameters	Unit	Pre-Monsoon (Mar.-May)	Monsoon (June -Sept.)	Post-Monsoon (Oct. – Nov.)	Winter (Dec.-Feb.)
		Physical factors			
AT	°C	34.06.±0.69	32.76±0.87	26.8±1.1	23.4±1.04
WT	°C	26.37±1.02	28.2±0.98	24.5±1.08	22.67±0.81
Zs	cm	26.5±7.36	60.37±10.67	39.25±8.25	17.67±4.34
		Chemical factors			
TDS	mg/l	38.67±9.57	39.1±11.75	24.35±6.34	58.33±13.1
Cond.	µS/cm	90.5±11.19	74.91±13.41	68.6±12.54	116.67±17.6
pH	-	74.3±0.24	7.3±0.52	7.52±0.66	7.05±0.64
Alk.	meq/l	1.51±0.02	1.25±0.04	1.42±0.04	1.57±0.02
DO	mg/L	7.55±1.58	10.73±1.03	8.8±1.73	8.4±1.45
NO_3-N	mg/l	0.28±0.06	0.26±0.27	0.2±0.05	0.26±0.02
SRP	µg/l	10.75±3.67	18.19±4.9	7.91±1.58	26.53±2.22
SRS	mg/l	8.63±2.78	8.19±3.69	9.57±3.78	12.01±4.52
		Biological factors			
chl-a	µg/l	9.65±3.83	6.4288±1.51	5.36±1.02	6.31±1.01
PP	µg/l	9.64±2.99	3.88±1.37	3.88±1.53	2.2±0.93
PD	$\times 10^4$ ind./l	24.34±4.57	13.01±2.14	5..16±1.97	20.62±6.81

Table 42. Average value of different limnological parameters in four distinct climatic seasons of Bangladesh for Station-3

Parameters	Unit	Pre-Monsoon (Mar.-May)	Monsoon (June -Sept.)	Post-Monsoon (Oct. – Nov.)	Winter (Dec.-Feb.)
		Physical factors			
AT	°C	33.78±0.71	33.4±0.57	26.37.±0.48	26.3.±0.54
WT	°C	27.67±0.62	27.27±0.98	24±1.02	22.23±0.81
Zs	cm	29.33±8.36	61.75±10.67	33.25±8.25	15.5±4.34
		Chemical factors			
TDS	mg/l	30.67±9.57	32.9±10.75	26.02±8.34	63.33±12.1
Cond.	µS/cm	82.5±14.19	74.11±13.41	77.82±12.54	142.17±17.8
pH	-	7.4±0.24	7.45±0.52	7.65±0.66	7.21±0.64
Alk.	meq/l	1.38±0.02	1.43±0.04	1.35±0.04	1.48±0.02
DO	mg/L	7.81±1.58	10.81±1.73	8.8±1.03	8.71±1.45
NO_3-N	mg/l	0.37±0.06	0.21±0.07	0.21±0.05	0.27±0.02
SRP	µg/l	13.75±3.67	16.7±2.9	11.16±2.58	30.88±4.22
SRS	mg/l	7.88±2.78	8.5±2.69	11.84±2.68	12.73±4.52
		Biological factors			
chl-a	µg/l	10.45±3.83	5.32±1.51	3.99±1.5	6.9±2.61
PP	µg/l	9.56±3.5	4.5±1.37	1.93±0.53	3.07±1.23
PD	$\times 10^4$ ind./l	19.7±4.57	10.28±2.14	7.31±1.97	16.81±3.11

Statistical Analysis

Correlation matrix

Correlation matrix was prepared with the help of SPSS (Statistical program for the Social Science) following Pearsons correlation (version 16.0) method to observe the relationship among physical, chemical and biological parameters of the selected sampling stations ofthree sampling sites of Kuniar Haor, Kishoreganj. Analysis has been performed among 14 physicals, chemical and biological parameters of three study sites. The matrix has been presented in Table. 43, 44 and 45 for station-1, station-2 and station-3 respectively.

Study sites

Station -1

Air temperature showed highly significant positive correlation with water temperature and Secchi depth. Secchi depth showed negative correlation with TDS and conductivity. Chl-a, phaeopigment and phytoplankon density showed highly significant positive correlation with alkalinity.

DO showed only positive correlation with air and water temperature, Secchi depth, but only negative correlation with, alkalinity, pH, SRS, and phaeopigment, chl-a and phytoplankon density. TDS showed significant positive correlation with Conductivity.

SRP showed highly significant negetive correlation with chl-a. Chl-a showed highly significant positive correlation with alkalinity and phaeopigment whereas only positive correlation with Secchi depth, SRS, NO_3-N and negative correlation with SRP, conductivity, TDS. Phytoplankon density showed significant positive correlation with alkalinity and phaeopigment (Table 43).

Station -2

Air temperature showed highly significant positive correlation with water temperature and Secchi depth. Alkalinity showed strong significant positive correlation with TDS and phaeopigment only positive correlation with NO_3-N, chl-a and phytoplankon density.pH showed strongly significant positive correlation with SRS and negative correlation with NO_3-N. TDS showed strongly significant positive correlation with conductivity, alkalinity and only positive correlation with NO3-N, SRS, and

phytoplankon density, whereas slight negative correlation with SRP, air temperature, Secchi depth, chl-a and phaeopigment.

DO showed highly strong significant positive correlation with water temperature and only positive correlation with Secchi depth, pH, and phytoplankon density but only negative correlation with SRP, NO_3-N, chl-a and phaeopigment.SRS showed strong significant negative correlation with pH and strong negative correlation with NO_3-N and chl-*a*.

The biological parameter chl-*a* showed highly significant positive correlation with other biological parameter, i.e. phaeopigment, phytoplankton density, NO_3-N and only negetive correlation with other physical and chemical parameters except only alkalinity. (Table43).

Station-3

Like the other sampling sites in this station air temperature showed highly significant positive correlation with water temperature and Secchi depth. Secchi depth showed strong significant positive correlation with DO and negative correlation with conductivity.

DO showed highly strong significant positive correlation with secchi depth and only positive correlation withair and water temperature, alkalinity TDS, SRP and strongly negative correlation with SRS.TDS showed strong positive correlation with SRP and conductivity.NO3-N showed strong significant positive correlation with phytoplankton density.

Chl-a showed highly significant positive correlation with phaeopigment whereas only positive correlation with air and water temperature, alkalinity, pH, NO3-N and negative correlation with Secchi depth, DO, SRP, SRS, conductivity, TDS.

Table 43. Pearson correlation (r) among different physicochemical and biological variables recorded in Station-1 from Kuniar Haor, Kishoreganj (N=24).

	AT	WT	Zs	Alk.	Cond.	DO	pH	TDS	SRP	SRS	NO_3 -N	Chl-a	PP	PD
AT	1	.919**	.545**	.123	-.274	.331	.231	-.188	-.219	-.213	.174	-.215	.103	.223
WT	.919**	1	.497*	.202	-.354	.188	.250	-.306	-.184	-.282	.234	-.165	.171	.297
Zs	.545**	.497*	1	-.122	-.433*	.335	.257	-.461*	.232	.021	.110	.007	-.059	-.339
Alk.	.123	.202	-.122	1	-.092	-.077	-.047	.045	-.338	-.043	.114	.514*	.783**	.670**
Cond.	-.274	-.354	-.433*	-.092	1	.029	-.401	.894**	-.191	-.014	-.110	-.052	-.375	.055
DO	.331	.188	.335	-.077	.029	1	-.093	.216	.170	-.385	.252	-.115	-.247	-.070
pH	.231	.250	.257	-.047	-.401	-.093	1	-.436*	.283	.370	-.184	-.161	.130	.108
TDS	-.188	-.306	-.461*	.045	.894**	.216	-.436*	1	-.133	-.133	-.087	-.015	-.271	.173
SRP	-.219	-.184	.232	-.338	-.191	.170	.283	-.133	1	-.009	-.188	-.408*	-.328	-.344
SRS	-.213	-.282	.021	-.043	-.014	-.385	.370	-.133	-.009	1	-.280	.208	.237	.076
NO_3 -N	.174	.234	.110	.114	-.110	.252	-.184	-.087	-.188	-.280	1	.038	.243	.034
Chl-a	-.215	-.165	.007	.514*	-.052	-.115	-.161	-.015	-.408*	.208	.038	1	.558**	.326
PP	.103	.171	-.059	.783**	-.375	-.247	.130	-.271	-.328	.237	.243	.558**	1	.575**
PD	.223	.297	-.339	.670**	.055	-.070	.108	.173	-.344	.076	.034	.326	.575**	1

AT=Air Temperature (°C), WT=Water Temperature (°C), Zs =Secchi depth (cm), Alk.=Alkalinity (meq/l), Cond.=Conductivity (µS/l), DO=Dissolved oxygen(mg/l), pH=Hydrogen ion concentration (Conc.), TDS=Total dissolved solids (mg/l), SRP= Soluble reactivate phosphorus (µg/l), SRS= Soluble reactivate silicate (mg/l), NO_3-N= Nitrate-nitrogen (mg/l), Chl-*a*= Chlorophyll *a* ((µg/l), PP= Phaeopigment (µg/l), PD= Phytoplankton density ($x10^3$ ind./l)

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

Table 44. Pearson correlation (r) among different physicochemical and biological variables recorded in Station -2 from Kuniar Haor, Kishoreganj (N=24).

	AT	WT	Zs	Alk.	Cond.	DO	pH	TDS	SRP	SRS	NO_3-N	Chl-a	PP	PD
AT	1	.708**	.468*	-.076	-.030	.305	.236	-.171	-.218	.005	-.216	-.078	.036	.311
WT	.708**	1	.502*	-.030	.206	.430*	.187	.101	-.113	-.169	-.241	-.055	.026	.216
Zs	.468*	.502*	1	-.224	-.350	.402	.249	-.365	-.006	-.162	-.111	-.068	.007	-.111
Alk.	-.076	-.030	-.224	1	.287	.049	-.117	.407*	-.147	-.111	.248	.326	.450*	.202
Cond.	-.030	.206	-.350	.287	1	.241	-.065	.905**	.013	.206	-.101	-.136	-.281	-.158
DO	.305	.430*	.402	.049	.241	1	.041	.204	-.064	.019	-.175	-.166	-.208	.109
pH	.236	.187	.249	-.117	-.065	.041	1	-.109	.249	.545**	-.502*	-.394	.000	.019
TDS	-.171	.101	-.365	.407*	.905**	.204	-.109	1	-.003	.148	.048	-.007	-.125	.022
SRP	-.218	-.113	-.006	-.147	.013	-.064	.249	-.003	1	.112	.013	-.110	-.024	.056
SRS	.005	-.169	-.162	-.111	.206	.019	.545**	.148	.112	1	-.468*	-.555**	-.349	-.321
NO3-N	-.216	-.241	-.111	.248	-.101	-.175	-.502*	.048	.013	-.468*	1	.746**	.418*	.176
Chl-a	-.078	-.055	-.068	.326	-.136	-.166	-.394	-.007	-.110	-.555**	.746**	1	.746**	.305
PP	.036	.026	.007	.450*	-.281	-.208	.000	-.125	-.024	-.349	.418*	.746**	1	.412*
PD	.311	.216	-.111	.202	-.158	.109	.019	.022	.056	-.321	.176	.305	.412*	1

AT=Air Temperature (°C), WT=Water Temperature (°C), Zs =Secchi depth (cm), Alk.=Alkalinity (meq/l), Cond.=Conductivity (µS/l), DO=Dissolved oxygen(mg/l), pH=Hydrogen ion concentration (Conc.), TDS=Total dissolved solids (mg/l), SRP= Soluble reactivate phosphorus (µg/l), SRS= Soluble reactivate silicate (mg/l), NO_3-N= Nitrate-nitrogen (mg/l), Chl-*a*= Chlorophyll *a* ((µg/l), PP= Phaeopigment (µg/l), PD= Phytoplankton density (x10^3 ind./l) ** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed)

Table 45. Pearson correlation (r) among different physicochemical and biological variables recorded in Station-3 from Kuniar Haor, Kishoreganj (N=24).

	AT	WT	Zs	Alk.	Cond.	DO	pH	TDS	SRP	SRS	NO_3 -N	Chl-*a*	PP	PD
AT	1	.880**	.485*	.018	-.223	.259	.160	-.248	-.203	-.237	.251	.044	.191	.352
WT	.880**	1	.379	.062	-.262	.222	.339	-.277	-.107	-.303	.161	.184	.261	.299
Zs	.485*	.379	1	.081	-.492*	.453*	.253	-.422*	-.190	-.007	-.212	-.288	-.162	-.276
Alk.	.018	.062	.081	1	.004	.136	-.066	.151	.073	.080	-.090	.313	.041	-.069
Cond..	-.223	-.262	-.492*	.004	1	-.077	-.277	.916**	.301	.004	-.019	-.210	-.382	.254
DO	.259	.222	.453*	.136	-.077	1	-.017	.071	.021	-.406*	-.294	-.284	-.243	-.263
pH	.160	.339	.253	-.066	-.277	-.017	1	-.383	-.005	.197	-.111	.024	.064	-.141
TDS	-.248	-.277	-.422*	.151	.916**	.071	-.383	1	.436*	-.032	.029	-.180	-.365	.283
SRP	-.203	-.107	-.190	.073	.301	.021	-.005	.436*	1	.190	-.077	-.024	-.047	.254
SRS	-.237	-.303	-.007	.080	.004	-.406*	.197	-.032	.190	1	.135	-.177	-.202	.138
NO_3 -N	.251	.161	-.212	-.090	-.019	-.294	-.111	.029	-.077	.135	1	.138	.211	.683**
Chl-a	.044	.184	-.288	.313	-.210	-.284	.024	-.180	-.024	-.177	.138	1	.844**	.054
PP	.191	.261	-.162	.041	-.382	-.243	.064	-.365	-.047	-.202	.211	.844**	1	.106
PD	.352	.299	-.276	-.069	.254	-.263	-.141	.283	.254	.138	.683**	.054	.106	1

AT=Air Temperature (°C), WT=Water Temperature (°C), Zs =Secchi depth (cm), Alk.=Alkalinity (meq/l), Cond.=Conductivity (µS/l), DO=Dissolved oxygen(mg/l), pH=Hydrogen ion concentration (Conc.), TDS=Total dissolved solids (mg/l), SRP= Soluble reactivate phosphorus (µg/l), SRS= Soluble reactivate silicate (mg/l), NO_3-N= Nitrate-nitrogen (mg/l), Chl-*a*= Chlorophyll *a* ((µg/l), PP= Phaeopigment (µg/l), PD= Phytoplankton density ($x10^3$ ind./l)

** Correlation is significant at the 0.01 level ($p<0.01$)(2-tailed)* Correlation is significant at the 0.05 level ($p<0.05$)(2-tailed)

Shannon diversity index

Station 1, Station 2 and Station 3

Shannon diversity index is an index that is commonly used to characterize species diversity in acommunity. Here Station-3 showed more diversity in Jun 2016 during 1st year of study. So, Station-3 is more diverse in the case of genus level. In case of 2nd year, Station-2 also showed more diversity, according to Shannon-Winner diversity index the highest diversity (2.61) occurs in the month of May 2017 (Table 46).

Table 46. Shannon-Wiener Diversity Index (Genus level) for phytoplankton

2016-2017	Station-1	Station-2	Station-3
Feb. 16	2.51	2.28	**2.18**
Mar. 16	2.43	1.53	**2.2**
Apr. 16	2.6	1.72	**2.23**
May 16	2.53	2.99	**3.12**
Jun. 16	2.29	3.1	**4.19**
Jul. 16	1.35	1.8	**0.59**
Aug. 16	2.58	2.24	**1.35**
Sep. 16	1.75	1.95	**2.31**
Oct. 16	1.99	2.32	**2.18**
Nov. 16	1.95	1.83	**1.47**
Dec. 16	2.22	1.55	**1.82**
Jan. 17	**2.1**	**2.11**	**2.18**

2017-2018	Station-1	Station-2	Station-3
Feb. 17	2.02	2.27	**2.11**
Mar. 17	2.32	2.61	**2.32**
Apr. 17	1.83	2.08	**1.83**
May 17	2.48	2.7	**2.36**
Jun. 17	2.4	2.65	**2.55**
Jul. 17	1.43	1.25	**1.43**
Aug. 17	1.62	1.54	**1.73**
Sep. 17	1.55	1.46	**1.9**
Oct. 17	2.05	1.97	**1.59**
Nov. 17	1.85	1.49	**1.56**
Dec. 17	1.68	1.45	**1.95**
Jan. 18	**2.27**	**1.83**	**1.91**

Table 47. Shannon-Wiener Diversity Index (Species level) for phytoplankton

2016-2017	Station-1	Station-2	Station-3
Feb. 16	2.21	3.18	**1.59**
Mar. 16	2.93	2.34	**1.97**
Apr. 16	3.62	2.52	**3.25**
May 16	2.7	3.85	**3.52**
Jun. 16	0.89	3.92	**4.1**
Jul. 16	1.15	1.78	**0.67**
Aug. 16	3.02	0.84	**2.35**
Sep. 16	0.82	1.45	**2.21**
Oct. 16	2.94	2.12	**1.28**
Nov. 16	0.95	0.93	**0.97**
Dec. 16	2.82	1.49	**1.02**
Jan. 17	**2.93**	**3.21**	**2.68**

2017-2018	Station-1	Station-2	Station-3
Feb. 17	2.92	3.17	**2.89**
Mar. 17	2.52	1.91	**1.82**
Apr. 17	3.23	2.28	**3.14**
May 17	1.88	2.17	**1.76**
Jun. 17	3.1	2.85	**2.18**
Jul. 17	1.53	2.15	**1.43**
Aug. 17	1.72	1.84	**1.93**
Sep. 17	0.62	0.96	**1.09**
Oct. 17	1.02	0.96	**0.98**
Nov. 17	0.65	0.89	**1.16**
Dec. 17	1.18	0.95	**1.45**
Jan. 18	**2.97**	**3.02**	**3.81**

Jaccard Index

Station 1, Station 2 and Station 3

Jaccard index is also called Jaccard Similarity Coefficient index. It's a measure of similarity for the two sets of data with a range from 0%-100%. The Jaccard Index shows that three stations are highest 53.84 % similar in October 2016 and their intersecting members are 07 i.e in this month seven individuals were available in all stations. In Jaccard index, it indicates the higher the percentage the more similar the study sites. During the 2nd year, the more similarities showed in February 2017 throughout the investigation (Table 48). It compares members for two sets to see which members are shared and which are distinct.

Table 48. Jaccard index for phytoplankton analysis

2016-2017	Number of intersecting elements	Jaccard Coefficient (%)	2017-2018	Number of intersecting elements	Jaccard Coefficient (%)
Feb. 16	05	**22.72**	**Feb. 17**	07	**58.33**
Mar. 16	04	**20**	**Mar. 17**	05	**29.41**
Apr. 16	08	**34.78**	**Apr. 17**	06	**31.58**
May 16	07	**16.27**	**May 17**	07	**28**
Jun. 16	07	**21.21**	**Jun. 17**	06	**24**
Jul. 16	03	**42.85**	**Jul. 17**	03	**17.64**
Aug. 16	04	**19.04**	**Aug. 17**	05	**45.45**
Sep. 16	03	**17.64**	**Sep. 17**	02	**18.18**
Oct. 16	07	**53.84**	**Oct. 17**	04	**33.33**
Nov. 16	01	**7.14**	**Nov. 17**	02	**18.18**
Dec. 16	04	**40**	**Dec. 17**	04	**36.36**
Jan. 17	**05**	**31.25**	**Jan. 18**	**04**	**25**

Pollution status of Kuniar Haor through TDI (Trophic diatom index)

The diatom taxa have sensitivities to increased environmental degradation, using diatom communities a measurement of environmental health can be diagnosed. (Barbour *et al*. 1999). Pollution tolerance indices are metrics that summarize the pollution sensitivity of diatom taxa in a particular community. The assemblage becomes an indicator of the relative health of the wetland. A well-established diatom taxonomic lists of ecological preference in freshwater habitats are determinator of the metric as an indicator of degradation, along with other organic components.

For assessment of organic pollution in the U.K. rivers (Chesters, 1980; Armitage *et al.*1983) the TDI value was evaluated successfully. The value of TDI indicate the effect of organic nutrients on the wetland that already nutrient-rich, and the measurement of large increase in the proportion of organic pollution & tolerant taxa. (Whitton and Kelly, 1995). The value of TDI can range from 1 (very low nutrient concentrations) to 5 (very high nutrient concentrations). (Zelinka and Marvan 1961)

Methodology

Trophic diatom index (TDI) = $\sum$ asv ÷ $\sum$ av

Here,

a = total counts of diatom species

S= Taxon sensitivities to pollution (1-5).

V= indicator values

Tble 49. Interpretation of proportion of count composed of taxa tolerant to organic pollution (Whitton and Kelly, 1995)

Proportion of count	Interpretation
<20%	free of significant organic pollution
21-40%	Some evidence of organic pollution
41-60%	organic pollution likely to contribute significantly to eutrophication site
> 61%	Site is heavily contaminated with organic pollution

Table 50. Data sheet of measuring TDI

Serial No.	Taxon	Count (a)	Sensitiv -ities (s)	Indicator values (v)	asv	av	Tolerant (*marked)
1	*Achnanthes lanceolata*	2	5	2	20	4	
2	*Achnanthes minutissima* Kütz	2	2	2	20	4	
3	*Achnanthes* spp.	3	3	1	9	3	
4	*Amphora ovalis*	1	5	1	5	1	
5	*Asterionella* sp.	2	3	1	6	2	
6	*Cymbella parva*	1	2	1	2	1	
7	*Cymbella ventricosa*	1	2	1	2	1	
8	*Cymbella turgidula*	2	3	2	12	4	
9	*Cymbella* sp.	2	4	2	16	4	
10	*Cymbella* spp.	2	2	1	4	2	
11	*Cyclotella comensis* Grunow	4	5	1	20	4	
12	*Cyclotella comta* var. *affinis*	2	5	1	10	2	
13	*Cyclotella* spp.	3	5	1	15	3	
14	*Epithemia* sp.	1	1	2	2	2	
15	*Eunotia monodon*	1	1	3	3	3	
16	*Eunotia robusta* Ralfs	2	1	3	6	6	
17	*Eunotia* other sp.	4	1	3	12	12	
18	*Fragilaria vaucheriae*	2	3	2	12	4	
19	*Fragilaria* other sp.	3	2	1	6	3	
20	*Gomphonema lanceolatum* var.	1	3	1	3	1	*
21	*Gomphonema gracile*	2	3	1	6	2	*
22	*Gomphonema longiceps*	1	3	1	3	1	*
23	*Gomphonema angustatum*	2	1	2	4	4	*
24	*Gomphonema* spp.	3	3	1	9	3	*
25	*Melosira granulata*	62	4	2	496	124	
26	*Melosira distans*	7	4	2	56	14	
27	*Melosira* fa. *curvata*	3	4	2	24	6	
28	*Melosira* spp.	11	4	2	88	22	
29	*Navicula cuspidata*	2	4	2	16	4	**
30	*Navicula pupula*	9	5	1	45	9	*
31	*Navicula radiosa*	1	5	2	10	2	*
32	*Navicula mutica*	1	5	1	5	1	*
33	*Navicula placentula*	4	5	1	20	4	*
34	*Navicula grimei*	1	5	1	5	1	*
35	*Navicula pseudohalophila*	1	5	1	5	1	*
36	*Navicula bacillum*	1	5	2	10	2	*
37	*Navicula* sp.	11	4	1	44	11	*
38	*Nitzschia linearis*	1	4	1	4	1	*
39	*Nitzschia longissima*	2	4	1	4	2	*
40	*Nitzschia acecularis*	2	3	1	6	2	*

Contd.

Serial No.	Taxon	Count(a)	Sensitivities(s)	Indicator values(v)	asv	av	Tolerant(* marked)
41	*Nitzschia* spp.	4	4	1	16	4	*
42	*Pinnularia gibba*	4	1	3	12	12	
43	*Pinnularia* spp.	7	1	3	21	21	
44	*Synedra ulna* (Nitzsch) Ehr.	5	3	1	15	5	
45	*Synedra acus*	4	4	1	16	4	
46	*Synedra tabulata*	1	4	1	4	1	
47	*Synedra* spp.	5	4	1	20	5	
48	*Coscinodiscus* sp	2	2	1	4	2	
49	Uidentified diatom sp	32	2	1	64	32	
	Total=	232			1217	368	43

Calculation of TDI

Total counts (a) = 232

Sum of asv = 1217

Sum of av = 368

Tollerant species amount = 43

So, TDI = ∑asv÷∑av = 1217÷368 =3.3 < 20%

Pollution tolerant taxa = (43÷232) × 100 =18.5%

The proportion of TDI count is <20%, so the wetland is free of significant organic pollution

Relationship statistics between Phytoplankton and fish production in Kuniar Haor on an annual scale

The phytoplanktons are the manufacturer of aquatic cellular bodies through the process of photosynthesis, taking up carbon dioxide and nutrients from the water and using light as an energy source. Phytoplankton are cultured to feed bivalve molluscs (all life stages), the early larval stages of crustaceans. Flagellates and diatoms are two important types of phytoplankton at the base of the food chain. The microalgae used as feed in hatcheries vary in size, environmental requirements, growth rate, and nutritional value

Cell Volume, Organic Weight, and Gross Lipid Content of Some Commonly Cultured Phytoplankton Species are good growth factor in Bivalve Mollusc and Fish Hatcheries (Helm et al., 2004). Microalgal culture facilities typically use seawater enriched with nutrients primarily nitrates, phosphates, essential trace elements, vitamins, and, in the case of diatoms, silicates. However, as a natural fish sanchuary the role of phytoplanktons is measured as follows-

Measurement of productive water: Total flooded area× mean Secchi depth

= 37 hectares × 37.51cm

=138750000 litre

Measurement of total phytoplankton: plankton density × total productive water

= (13.98 × $10^{4)}$ × 138750000

= 1.94 × 10^{12} individuals

Table 51. Estaimation of Fish - phytoplankton ratio

Total average fish production (UFO, Itna, Kishoreganj)	Total No. of phytoplankton individuals
933870 kg	1.94 × 10^{12}

Fish: phytoplankton = 1: 2.08 × 10^{6}

Analysis of macrophytes with fish feeding relationships and their utilization proposals

About 50 species of aquatic macrophytes are recorded as food to herbivorous fishes either directly or indirectly. These macrophytes represent several families, of which major ones are Amaranthaceae, Araceae and Typhaceae. In tropical and sub-tropical countries, there are about 40 fish species belonging to two major families viz., Cyprinidae and Chichlidae, which directly feed on macrophytes. Importantly, these macrophytes may be used as fish food components and replace costly commercial feed. Various kind of supplementary feeds have been tried to accelerate growth and production of fish per unit area, they are about 50, including Azolla. Several studies have been focused on growth and survival of herbivorous fishes including Rohu fingerlings by providing different macrophyte species. (Mandal *et al.* 2011). Petre (1993) presented a feeding relationships that resembles with Kuniar Haor is as follows-

Table 52. Feeding relationships of selected aquacultures and macrophytes

Fish	Macrophytes fed on (present in the Kuniar Haor)
	Ludwigia sp.
Astacus sp.	*Myriophyllum* sp.
Tilapia sp.	*Ceratophyllum* sp.
Ctenopharyngodon sp.	*Utracularia* sp.
Heterotis sp.	*Spirodela* sp.
	Azolla sp.
	Lemna sp.

In Bangladesh aquatic plants are basically seen as under-valued part of freshwater ecosystem. The country like Bangladesh should take some initiative to undertake a research programme by taking the following steps-

- Habitat protection, conservation of nature and livestock production.
- Fish production and wildlife conservation, fertilizer and soil additive.
- Food and medicine, industry, energy, recreation/aesthetics.

Effect of Physical variables on phytoplankton biomass as chl-a

A mentionable relation was observed between Chl-a and secchi depth. The higher length of light penetration increases the production of chl a. Air temperature and water temperature plays a vital role for phytoplankton biomas by the increase of chl-a. (Fig. 34)

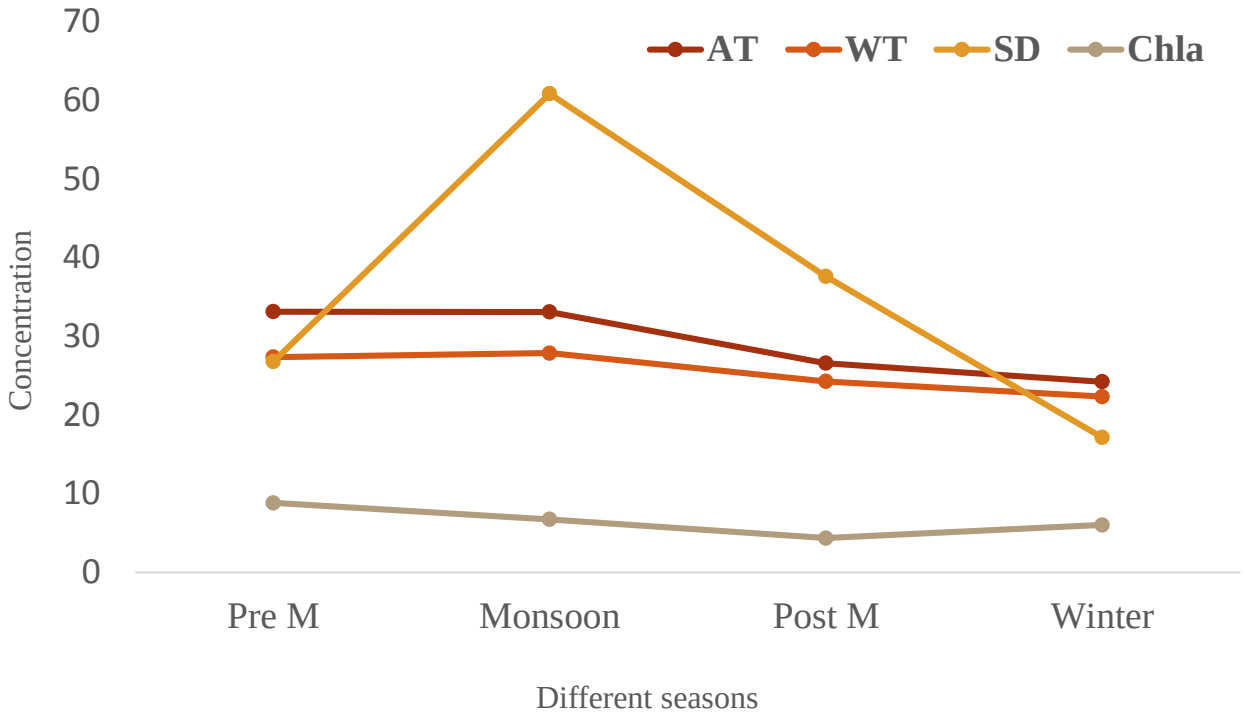


Fig. 34. Comparison among physical variables with chl-a

Nutrient concentration in relation to phytoplankton biomass as chl-a.

There is a relationship among NO_3-N, SRS, SRP and chl-a. Nitrate nitrogen did not show any fluctuation throughout the year where as the three other parameters showed some fluctuation in the different season.

In case of SRP concentration, Chl-a density showed a negative correlation with SRP in all seasons except winter. It means when SRP concentration is high the phytoplankton density is decreased and when SRP concentration is low the phytoplankton density is increased. SRS and NO_3-N does not show any effective relationship with Chl-a (Fig. 35).

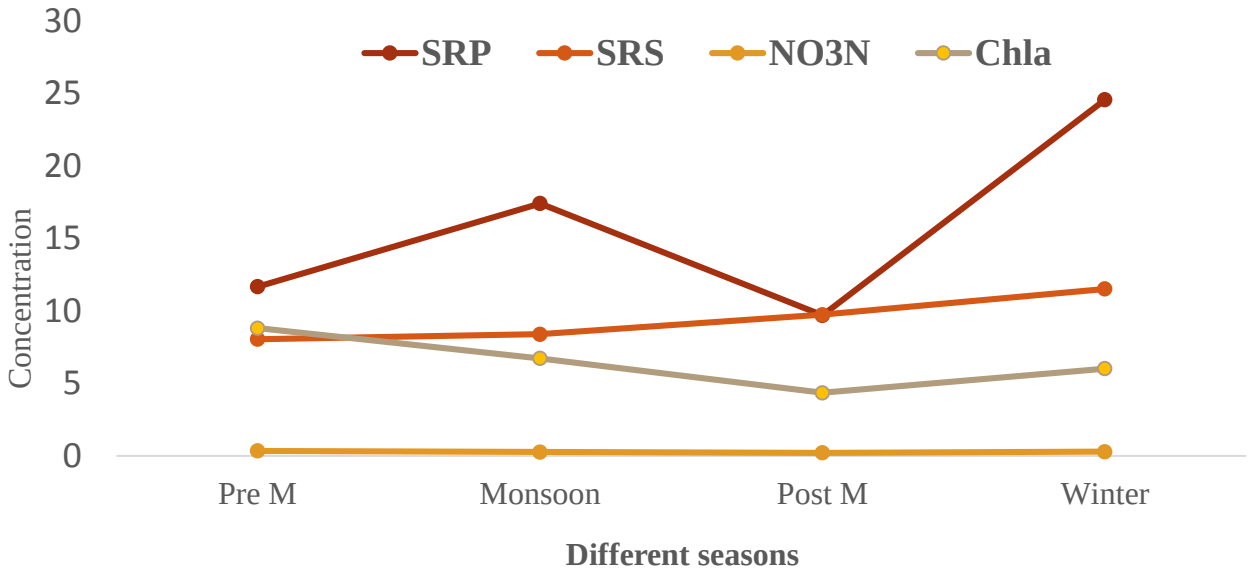


Fig- 35. Comparison among nutrients with chl-a

Effects of chemical variables on phytoplankton biomass as chl-a

Conductivity and TDS showed good similarities that an upward trend from post monsoon to winter but DO and Chl-a did not show any such type of trend. Chl a remained more or less same in respect of the other chemical parameters throughout the year (Fig. 36.)

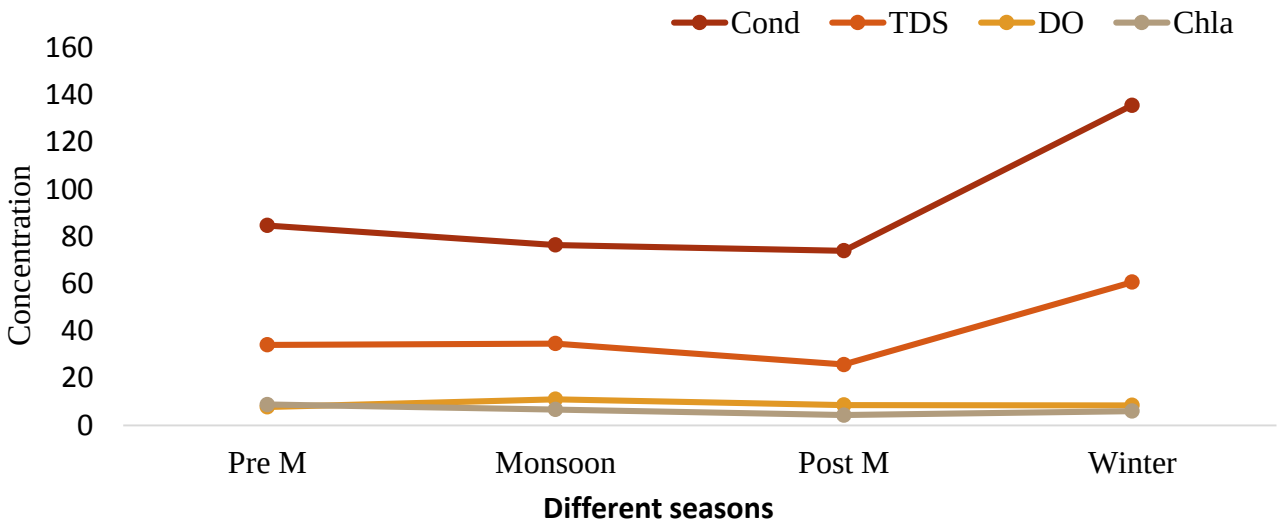


Fig.36. Comparison among chemical variables with chl-a

Effect of biological variables on phytoplankton biomass as chl-a

Phaeopigment is the function of chl-a. The graph shows that there is a positive relation among these three biological variables. Phytoplankton density showed highest peak in Pre monsoon when chl-a concentration is high, but when phytoplankton density is lower in Post monsoon, chl-a concentration is also low. (Fig. 37.)

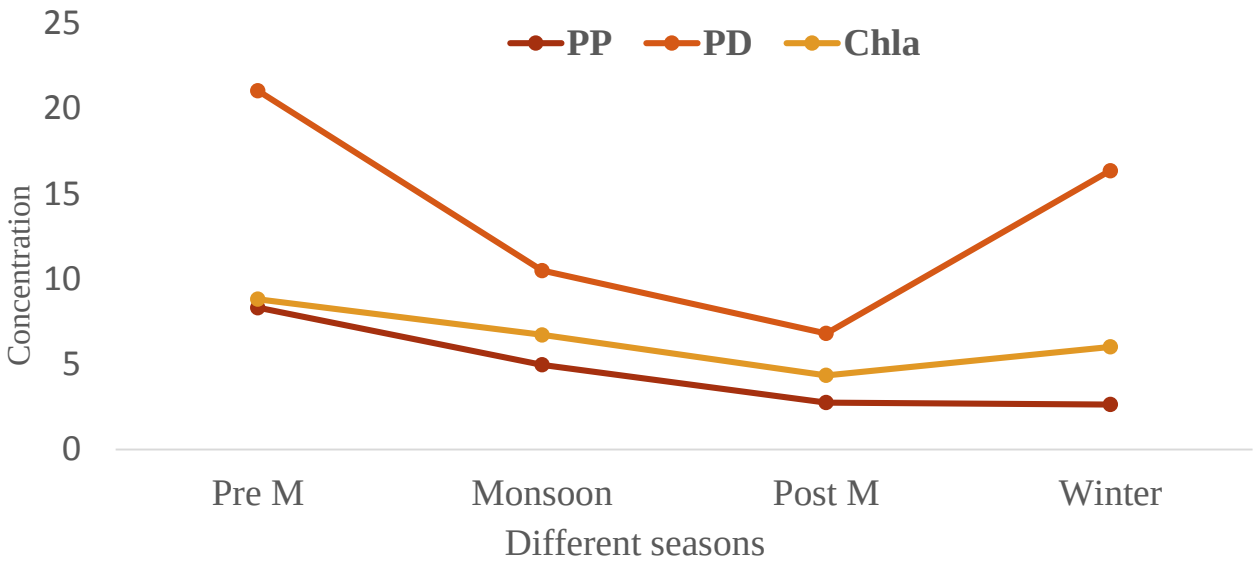


Fig. 37. Comparison among biological variables with chl-a

Comparative Analysis

It is known to all that each freshwater wetlands have unique historical variations considering water quality. To update the knowledge for their suitability for a particular use the comparison among the water quality parameters is needed. Table 53 to 54 will help to give a little idea to know the variations where a comparison of two famous Haor namely Hakaluki and Tanguar with the present study is shown.

Table 53. A comparison of some selected physicochemical parameters with other studied Haor of Bangladesh

Parameters	Hakaluki Haor (Islam *et al*, 2014)	Tanguar Haor (Bhuiyan *et al*, 2019)	Kuniar Haor (Present study)
Water temp. (^{o}C)	26.8	26.33	25.76 (±0.23)
Secchi depth.(cm)	43	248	37.51 (±0.18)
TDS (mg/l)	68.68	64.17	39.47 (±1.63)
Conductivity (µS/cm)	141.2	81.67	90.02 (±2.22)
pH	6.44	8.3	7.34 (±0.06)
Alkalinity (meq/l)	0.46	0.88	1.44 (±0.17)
DO (mg/l)	4.9	3.77	9.32 (±0.11)
SRP (µg/l)	6221	16.3	16.01 (±2.42)
NO_3-N (mg/l)	6.22	0.18	0.28 (±0.02)
SRS (mg/l)	-	9.55	10.2 (±2.01)
Chl a (µg/l)	-	5.28	6.72 (±0.19)
Phaeopigment (µg/l)	-	1.94	4.85 (±0.19)
Plankton density ($\times 10^4$ ind./l)	-	-	13.98 (±2.35)

Table 54. Standards of water quality parameters for different uses (ECR, 1997; EQS, 1997)

Parameters	For drinking purposes	For fisheries	For Irrigation
Dissolved Oxygen (DO)	6 mg/l	5 mg/l or More	4.5 - 8 mg/l
pH	6.5 – 8.5	6.5 – 8.5	6.5 - 8.5
Electrical Conductivity (EC)	700 µs/cm	800–1000 µs/cm	1200 µs/cm
Total Dissolved Solid (TDS)	1000 mg/l	0 – 1000 mg/l	450 - 2000 mg/l
Alkalinity	20 – 200 mg/l	50 – 300 mg/l	100 - 500 mg/l

Table 55. Significant correlations among the selected parameters in different study sites.

	Station-1			Station-2			Station-3		
Parameters	**Alk.**	**SRP**	**NO_3N**	**Alk.**	**SRP**	**NO_3N**	**Alk.**	**SRP**	**NO_3N**
Chl-a	0.514*	-0.408*	0.038	0.326	-0.11	0.746**	0.313	0.024	0.138
Phaeopigment	0.783**	-0.328	0.243	0.450*	-0.024	0.418*	0.041	-0.047	P0.211
Plankton density	0.670**	-0.344	0.034	0.202	0.056	0.176	-0.069	0.254	0.683**

**correlation ® is significant at the 0.01 level, * correlation ® is significant at the 0.05 level.

Discussion

The Kuniar Haor consists of a large shallow Beel with a considerable amount of floating and emergent aquatic vegetation, surrounded by rice fields and steep grassy banks. According to the wetland classification system of Bangladesh, Haors are classified as the Wetland type BP (Seasonal/intermittent freshwater lakes having area over 8 ha; includes floodplain lakes) and the Beels within Haors are classified as BO (Permanent freshwater lakes having area over 8 ha; includes large oxbow lakes) (BHWDB, 2012). Considering this aspect, the Kuniar Haor is BO type.

The hydrobiological status of Kuniar Haor in relation to the phytoplankton and macrophytes were studied in this research work. The results obtained are discussed in the light of available literatures. To assess the water quality of different study sites, a total of 14 parameters were regularly measured. These are phytoplankton quality and quantity, biomass of chlorophyll-a and phaeopigment, air and water temperature, Secchi depth, pH, conductivity, alkalinity, DO, TDS, SRS, NO_3-N and SRP. The present discussion is based on the composition, concentration and diversity of the above mentioned parameters together with their relationships among themselves and their comparison with other similar environments studied elsewhere. Water qualityis the influence of geological, hydrological, climatic and anthropogenic factors (Boon *et al*. 1992, Bartram and Balance1996).

Kuniar Haor is almost free from any direct external pollution sources, except via precipitation and seepage. The Haor area is not previously investigated limnologically. So, the present limnological investigation highlights some of the water quality parameters for the first time.

The functional aspects of aquatic ecosystem such as solubility and distribution of biogenic gases and nutrients in the water column, growth, reproduction and migration of aquatic organisms directly depend on various climatological factors. It is well known that temperature effects the density and quality of water and is very important for the maintenance of stability of any water body. In general, atmospheric and water temperature depend on geographical location and meteorological conditions such as rainfall, humidity, cloud cover, wind velocity, etc. Water temperature is of enormous significance as it regulates various abiotic characteristics and activities of an aquatic ecosystem (Hutchinson 1957, Kataria *et al.* 1995, Singh and Mathur 2005). During the course of the

present study the mean water temperature (± SD) at Station-1 was higher (26 ± 3.27°C) than that of other two stations (Table 38). Kerketta *et al*. (2013) noted the related result in a study of drinking water from different sources in and around Ranchi, Jharkhand, India. Mishra and Bhatt (2008) also found almost the similar result in V.V. Nagar and nearby places of Anand district, Gujarat, India. In Bangladesh, Rahman *et al.* (2015) found similar relationship between air and water temperature in three lakes in Jahangiragar University, Savar, Dhaka. In a recent study on the Tanguar Haor ecosystem of Sunamganj district by Bhuiyan *et al.* (2019) revealed the similar relationship.

It is recommended that the water temperature of shallow and small waterbody might follow air temperature narrowly with only small variation in amplitude and time (Vaas and Sachlan 1955, Rao 1955, Openheimer *et al.* 1978, Chowdhury and Mazumder 1981, Naser *et al.* 1990, Zaman*et al.* 1993). During the presentstudy period water temperature in three sampling sites were closely related to air temperature). Monthly mean air temperature (29.04 ± 5.34°C for station-1, 29.71 ± 5.75°C for station-2 and 30.04 ± 5.9°C for station -3) is slightly higher than the water temperature (26 ± 3.27°C for statio -1, 25.75 ± 3.24°C for station -2 and 25.53 ± 3.11°C station-3) in both the year of study. Khondker *et al.* (1988) reported similar results in Museum pond and SH pond. The fluctuating differences were within 1.0 and 0.88°C for the above mentioned two studies, respectively. However, Zaman *et al.* (1993) got a difference of 1.6 °C between air and water temperature in some pond ecosystems of Jahangirnagar University campus. In the present investigation a gradual increase in air temperature and water temperature from mid winter to post-monsoon has been observed (Fig. 7 and Fig. 9). Khondker *et al.* (1988) also observed the similar trends of water temperature in Dhanmondi lake.

Water transparency of Kuniar Haor as measured as Secchi depth over the three study sites varied from 13.00-70.50,12.00-75.00 and 7.50-95.00 cm, respectively for the study stations of 1-3 (Table 36). Transparency in water is caused by suspended and colloidal matter such as clay, silts, finely divided organic and inorganic matter, paint and other microscopic organisms. According to Boyd (1982) it was revealed that transparency ranged from 15-40 cm is considered good for fish culture.

A satisfactory transparency value for the water of Kuniar Haor happened because of the presence of less colloidal matter. The range of Secchi disc transparency for Turag river, Kaptai lake, a fishpond in Raipur ranged from 20-50, 40-340 and 58-76 cm, respectively (Chowdhury and Mazumder 1981, Ameen *et al*. 1986). Kabir and Naser (2011) reported a lower range of Secch disct transparency (8.89-53.34 cm) in an ox-bow lake named Chanda bill of Meherpur district, Bangladesh.

In aquatic ecosystems the important chemical factor pH regulates most of the biological processes and bio-chemical reactions. Scuthorpe (1967) has reported that pH, free CO_2 and ammonia are more critical factors in the survival of aquatic plants and fishes than the oxygen supply. Fluctuations in pH values mostly depend upon ingredient in put in the water bodies. It is known to us that pH of water is one of the best indicators of wetland productivity. It determines the dissolved state of the nutrient. Venkateswarlu (1969) stated that pH more or less controls the amount of iron in water.

Besides, water which is poorly buffered may exhibit a drastic fluctuation in pH, which may imbalance the physiological adjustment of many organisms living the aquatic ecosystem. There is a close link between photosynthetic activity and pH in fresh water (Sreenivasan 1970). It is evident from this study that water pH of three sampling sites was acidic to alkaline and varied from 6.60-8.10, 6.40-7.90 and 6.80-8.10 in stations 1-3, respectively. The pH difference among the study sites did not vary significantly. In addition, according to WHO (1984) water is best between pH 6.5 and 8.5. The pH value recorded for all the study stations of Kuniar Haor ranged within the limits as mentioned above. It therefore, indicates a good quality status of the water for Kuniar Haor. However, the mean values are very close to some other studied wetlands of Bangladesh. According to Khondker and Parveen (1992) the average pH of Dhanmondi lake is 7.5 which is closer to the recorded value of the present investigation. The mean recorded pH for Kaptai lake is 7.2 (Mahmood 1986).

Islam *et al*. (2012) recorded pH value ranged from 6.45-7.65 in some eutrophic water bodies of Dhaka metropolitan area. In another study, Islam *et al*. (2015) also pointed out the ranges of pH in Ramna, Crescent and Hatirjheel lakes were from 7.14-8.87, 7.30-8.83 and 7.12 -8.76 respectively. Actually a pH range of 6.0-8.5 falls mostly under drinking water qaulity (Chapman 1992). In the present investigation, it has been seen that the value of pH in all stations suddenly fell in the month of October. High values of pH were observed during summer months and low during the monsoon months of both the years. High water values of pH during summer months may be due to utilization of bicarbonates and carbonates buffer system (Bohra 1976).

Lower values obtained during rainy months may be attributed to the influence of a fresh water influx, dilution of lake water, and organic matter decomposition (Zingde *et al*.1987).

The value of alkalinity at different study stations of Kuniar Haor ranged from 0.6 - 5.5, 0.6 - 2.7 and 0.5 - 2.9 meq/l for stations 1-3, respectively (Table35-37). The alkalinity of highly productive aquatic ecosystems should go >100 meq/l (Alikunhi1957). So, the range of alkalinity in the present study indicates that the water of Kuniar Haor is not highly productive. As per Islam *et al.* (2015), it was found that the alkalinity of Ramna, Crescent and Hatirjheel lake were 30.00 - 66.67, 83.33-112.50 and 96.67-387.50 meq/l, respectively. This indicates that they are productive wetlands indeed. In the present study, the highest alkalinity was recorded in pre monsoon (1.81±0.04 meq/l) for station-1, in winter (1.57±0.02meq/l) for station-2 and (1.48±0.02meq/l) for station-3. But the lowest value was recorded in post monsoon (1.3±0.02 meq/l) for station-1 and (1.35±0.04 meq/l) for station-3 and in monsoon (1.25±0.04 meq/l) for station-2.

Electrical conductivity of water was found maximum in winter. The recorded values were 208, 176 and 193 µS/cm for stations 1-3, respectively. On the other hand, the minimum values recorded for the studied stations 1-3 were 38, 31 and 36 µS/cm, respectively (Table 35-37). During the present study the average conductivity values were 95.52±18.75, 91.11 ± 15.33 and 93.84±16.01 µS/cm for stations 1-3 (Table 38). Outside the range between 150 and 500 µS/cm for electrical conductivity, inland fresh waters could indicate the water is not suitable for certain species of fish or macro-invertebrates (APHA 1992).

The total dissolved solids (TDS) of water are represented by the sum of anions and cations dissolved in it. A high content of dissolved solids elevates the density of water, influence osmoregulation of fresh water organism, and reduces solubility of gases and utility of water for drinking purposes and results in eutrophication of the aquatic systems. TDS in the present investigation ranged from 20-97, 17.4 – 95.0 and 17 - 96 mg/l at stations 1-3, respectively. However, the annual average values were 38.33 ± 18.82, 41.34 ± 11.87 and 38.73± 12.88 mg/l, at stations 1-3, respectively. High concentrations of TDS enrich the nutrient status of the water body which resulted eutrophication status of the aquatic ecosystem (Swarnlatha and Rao 1998, Singh and Mathur 2005). The TDS levels at each sampling site differed significantly and the variation was mainly due to the changes in sampling locations. All the values of TDS recorded in the present investigation were below the minimum standard (1,000 mg/l) as set by the WHO standards. The values did not exceed the critical limit which might cause some long-term health problems

(Kempster *et al.*1997). According to Mac Cutcheon *et al.* (1983), the palatability of water with TDS level less than 600 mg/l is generally considered to be good, whereas water with TDS greater than 1,200 mg/l becomes increasingly unpalatable. Hence, the water from the streams could be considered palatable since the average TDS for all the streams were less than 600 mg/l.

The nature of an aquatic ecosystem determines to a great extent by DO. The sustenance of living organisms depends on the dissolved oxygen content of the water bodies. There are two sources of oxygen for water bodies, (i) directly from the atmosphere and (ii) by the photosynthesis activity of chlorophyll bearing aquatic plants. However, the concentration of dissolved oxygen also depends on surface agitation due to temperature, respiration rate of the aquatic living organisms, and the decomposition rate of dead organic matters. The dissolved oxygen, under present investigation, varied from 5.2 - 12.8, 4.4 - 14.8 and 4.4-13.7, respectively for stations 1-3. The annual mean value of DO recorded for all the studied stations 1-3 were 39.42 ± 2.43, 9.35 ± 2.82 and 9.2 ± 2.17 mg/l, respectively.

This study also indicates seasonal variation in DO contents of water, being maximum in monsoon and minimum in pre-monsoon for all the studied stations (1-3). The phenomenon of re-oxygenation of water during monsoon months may be due to circulation and mixing by inflow after rains (Hannan 1979). It further, progressed in winter, may be due to circulation by cooling and draw down of DO in water (Dwivedi and Pandey 2002). The low DO value has been attributed to the process of decomposition of organic matter involving the utilization of oxygen (Jameel 1998). In the present study station-1 was comparatively richer in DO than other stations. Similar results (6.25 mg/l) also detected in Kaptai Lake (Chowdhury and Mazumder 1981). Islam and Saha (1975), Islam and Mendes (1976) observed dissolved oxygen ranged from 3.51-4.59 mg/l and 4.48-9.83 mg/l in Ramnalake and Sher-e-Bangla Nagar Jheel, respectively. In Dhanmondi lake, Khondker and Parveen (1993) reported very low (0.18 mg/l) DO concentration at fewer stations. A much lower dissolved oxygen concentration ranged from 0.45-13.3 mg/l has been reported by Hasan *et al.* (2013). Paramasivam and Kannan (2005) explored that the seasonal variation of dissolved oxygen mostly occurs due to freshwater flow and terrigenous effect of sediments. DoF (1996) stated that the suitable range of dissolved oxygen for fish culture is 5-8 mg/l. The similar result (1.3-6.5 mg/l) in Madhaya Pradesh, India was also found by Sahu *et al.* (2007) from all the above discussions it can be concluded that the DO is not at all times in the optimum level in the Kuniar Haor.

Phosphorus (p) occurs almost soluble as phosphates in natural waters. It exists as soluble phosphates (SRP). P is the nutrient considered to be the critical limiting nutrient, causing eutrophications of fresh water systems (Rabalais 2002). It is a major nutrient that triggers eutrophication's and required by algae in small quantities (Bandela *et al*. 1999). Each P ion promotes the incorporation of seven molecules of N and fourty molecules of CO_2 in total algae (Wetzel 1983). The phosphate content of studying Haor water fluctuated between 1.05 and 36.14 µg/l for station-1, 2.04 and 33.09 µg/l for station -2 and 3.65 and 55.28 µg/l for station-3 with an annual average of 15.65 ± 9.49, 13.78 ± 9.68 and 18.6 ± 13.77 µg/l during the year 2016-2017 and 2017- 2018, respectively. In lake Ashura, the mean concentration of SRP was 11.60±1.60µg/l (Alfasane *et al.* 2012). The winter season exhibited higher phosphate contents among all stations.

Post-monsoon showed the lowest content of phosphate (Table 37- 39). On an average, Dhanmondi lake contains high amount of SRP (0.88 mg/l) compared to other ecosystems (Nasar and Sharma 1980, Singh and Swarup 1980 and Dokulil *et al.* 1983). The average SRP content of Kaptai Lake is about 1.66 lesser than Dhanmondi lake (Khondker and Parveen 1992). Phosphorus is the limiting nutrient for algal growth and, therefore, controls the primary productivity of a water body. In most natural surface waters, phosphorous ranges from 0.005-0.020 mg/1 PO_4-P (Chapman 1992). High concentrations of phosphate can indicate the presence of pollution and are largely responsible for eutrophic conditions. Eutrophication related problems in warm-water systems begin at P concentrations of the order 0.34–0.70 mg P/l (Rast and Thornton 1996).

Silicates are any mineral that contains silica, and include quartz (SiO_2), feldspars, clays, and others. Silicon dioxide occurs in all natural waters in various forms. Much of the silica in water comes from the dissolution of silicate minerals. Silica is significance as a major nutrient for diatoms and may become a limiting nutrient during diatom blooms. Unlike other nutrients, this is only a major requirement of diatoms so it is not regenerated in the plankton ecosystem as efficiently as, for instance, nitrogen or phosphorus nutrients. Silica additionally limits the growth of diatoms (Schindler 1978). Other researchers (Milligan and Morel 2002) have suggested that the biogenic silica in diatom cell walls acts as an effective pH buffer, facilitating the conversion of bicarbonate dissolved CO_2. In the studied area of Kuniar Haor, the amount of dissolved silica in water was low. The values ranged from 0.77 - 16.29, 2.04 -20.11 and 2.12 -23.19 mg/l in stations 1-3, respectively. The average SRS concentration were also recorded in 8.31 ± 4.08 mg/l for

station-1, 9.37 ± 5.09 mg/l for station-2 and 9.97± 5.93 for station-3 (Table 38) which is relatively lower concentration than lake Ashura (Alfasane *et al.* 2012,14.36±0.25 mg/l).

During the present investigation the range of the concentration of nitrate nitrogen was recorded 0.11-1.15, 0.07-0.62 and 0.04-1.05 mg/l for station 1-3, respectively. Whereas the average concentration was 0.31±0.07, 0.25±0.12 and 0.27 ±0.09 mg/l, respectively for stations 1-3. The values recorded here are relatively low compared to some other aquatic ecosystems of Bangladesh. For example, the concentration of nitrate nitrogen was 1.63 mg/l in Kaptai lake (Mahmood1986). In Dhanmondi lake 0.16 mg/l, was recorded (Khondker and Parveen 1992). Islam and Khondker (1991) studied some severely polluted habitats in and around Dhaka city and found a range of nitrate from 0-0.85 mg/l.

According to Islam *et al.* (2012) the amount of nitrate-nitrogen concentration is remarkably low (0.19). In Nilsagar, Nilphamari, Bangladesh. According to Reynolds (1984) lakes having anaerobic bottom contain low nitrate because under such condition most nitrates are reduced to ammonia. High phosphorus, anaerobic bottom with low nitrate is a clear indication of organic pollution in both lakes. Highest chl-a concentration showed a marked tendency to follow nutrient concentration changes, especially for nitrate-nitrogen concentration. Highest chl-a associated with less amount of nitrate nitrogen. The WHO safe limit for nitrate for lifetime use is 10 mg/l as N (WHO 1984). This limit was not exceeded in the water of Kuniar Haor. Thus, nitrate is not considered to pose a problem for the domestic use ofwater from this aquatic habitat. However, nitrate could be a problem for other uses of water because of eutrophication (Rast and Thornton 1996).

One of the major objectives in analyzing photosynthetic pigments in limnology is the estimation of phytoplanktonic biomass and its potential photosynthetic capacity. The usefulness of chlorophyll determination has proven its merit particularly for biological water quality classification as the most selective parameter and as a simple tool in laboratory practice. Spectrophotometric measurement of the concentration of chl-a in natural waters may be grossly in error when the samples contain chl-*a* degraded product. The pigment chl-a and oxidized forms of chl-a which occasionally may develop an important amount under post bloom conditions are characterized by absorption spectra identical to that of their parent chl-a. Consequently, in spectrophotometric pigment analysis such altered chlorophyll's will be included as if intact chl-a were present. On the other hand, in shallow waters with considerable re-suspension of bottom sediments, chl-a

derivative may consist pre dominantly of phaeophytin and phaeophorbide (Moed and Hallergraeff 1978). In natural waters the concentration of the pigments can be higher than the concentration of chlorophylls. If the phaeopigment is not taken into account, the error may be more than 100% (Nusch 1980). However, modern techniques are now available to determine the amount of live chl-a and phaeopigments separately from natural population (Marker *et al.* 1980, Nusch 1980, Holm-Hansen and Riemann 1978).

Therefore, by looking at the data of chl-a and phaeopigment simultaneously, it is possible to speculate whether the biomass is in a healthy state or in a moribund state. The biomass of phytoplankton as chl-a concentration showed a range of 1.18-24.27 µg/l for station-1, 1.78-21.9 µg/l for station-2 and 2.37-32.56 µg/l for station-3. Whereas, the phaeopigment concentration in the present investigation ranges from 0.37-25.3 µg/l for station-1, 0.13-46.32 µg/l for station-2 and 0.54-25.26 µg/l for station-3 (Table35- 37).

The average chl-a and phaeopigment recorded in station-1 were 6.50±3.14 µg/l and 4.63 ± 1.14 µg/l, respectively. On the other hand, in station-2, station-3 it was 6.88 ± 3.26 µg/l and 4.91±1.14 µg/l, 6.78±3.34 µg/l and 5.07±2.74 µg/l, respectively (Table 38). Sultana and Khondker (2009), and Islam *et al.* (2012) reported the lowest biomass of phytoplankton (chl-a) during September. This observation is similar to the present investigation (Fig 24). In the present experiment, the maximum algal abundance coincided with the maximum concentration of chl-a. Cyanophyta made up less of the chl-*a* than Chrysophyta, Chlorophyta and and Cryptophyta. The content of chl-a in cyanobacteria is less than in chlorophytes and euglenophytes (Reynolds 1984). Increases in chlorophyll *a* concentration in the water and pH were related to Euglenophyte density, whereas oxygen concentration changes were related to changes in density of both diatoms and Euglenophytes (Pereira *et al.* 2001).

The total phytoplankton population was highest in pre-monsoon. At this time the population dynamics of phytoplankton were 57.25 $\times 10^4$, 73.03$\times 10^4$ and 59.12 $\times 10^4$ ind./l for station 1-3, respectively. The lowest abundance was observed in post-monsoon. During which the density were 16.3$\times 10^4$, l 10.61 $\times$ 10^4 and 14.62 $\times$ 10^4 ind./l for station1-3, respectively (Tables 27-29).

Flores and Wolk (1986) showed that filamentous nitrogen-fixing cyanobacteria can directly kill related strains. *Chlorella, Cosmarium, Pediastrum, Phormidium* and *Scenedesmus* were reported to be killed in the presence of *Aphanizomenon gracile* (Legrand *et al.* 2003). Similarly, the freshwater dinoflagellate *Peridinium bipes* caused damage and subsequent cell death of the cyanobacterium *Microcustis aeruginosa* (Wu *et*

al. 1999). *Peridinium aciculiferum*, another dinoflagellate, inhibited the growth and caused blistering and lysis in the cryptophyte *Rhodomonas lacustris* (Rengefors and Legrand 2001). Their lies a big impact in the community interactions among the phytoplankton.

Correlation studies among the biological and environmental parameters reveals that a number of parameters are interrelated with each other among the studied sites of Kuniar Haor (Table 42- 44). The relationship between the physicochemical parameters of water and air temperature are examined at the 1% significance level and it is exhibited that a strongly positive significant correlation with each other. Temperature plays an important role in regulating photosynthesis and various other metabolic processes needed for life function of phytoplankton. Chakraborty *et al.* (1959), Tandon and Singh (1971) have put forwarded that temperature is the determining factor in the seasonal distribution of organisms. In the present investigation, in station-2 the temperature produced some effect on the phytoplankton fluctuations. Because phytoplankton in station-2 was found to attain peak in the month of pre-monsoon when a comparatively higher temperature was observed. So a significant positive correlation (r=0.311 and r=0.216) was observed in station-1. Station-1 and 3 showed also same significant correlation (r=0.223 and r=0.297) and (r=0.352 and r=0.299) with air temperature and water temperature, respectively. A negative correlation of phytoplankton biomass with temperature was also observed by Parveen (1987) and Zaman *et al.* (1993) in the Dhanmondi lake and three ponds of Jahangirnagar University campus, respectively.

Multiple correlation analysis was done among the recorded variables versus (vs) phytoplankton density. Results showed positive correlation of phytoplankton density vs air temperature, water temperature, pH, conductivity, alkalinity, chl-a, phaeopigment in staion-1. In station-2 the density of phytoplankton showed positive correlations with air temperature, water temperature, pH, alkalinity, DO, NO_3-N, chl-a, phaeopigment. In station-3, it correlated with air temperature, water temperature, conductivity, chl-*a*, and phaeopigment. On the other hand, it showed negative correlation with Secchi depth, DO, SRP, NO_3-N in station-1. The result of correlation of phytoplankton density with Secchi depth, conductivity, SRS in station-2 was also negative. In station-3, the standing crop of phytoplankton correlated negatively with Secchi depth, alkalinity, DO and pH (Table 42-44). The levels of significance varied from 1-5%.

Otherwise, in station-1 phytoplankton density showed significant positive correlation with alkalinity and phaeopigment at 1% level. While at station-2, phaeopigment showed significant positive correlation with phytoplankton density at 5% level of significance. The standing crop of phytoplankton however, showed significant positive correlation with NO_3-N at 1% level. The noticeable issue in correlation study is in all stations, alkalinity shows strong significant positive correlation with all biological parameters (Table 55).

Shannon diversity Index showed highest diversity in June 2016 at station-3, which maintained a sequential pick to the winter. The Jaccard Index showed that the community of phytoplankton is 58.33% similar in all the three studied stations of Kuniar Haor. This event of similarity occurred in February 2017 and the total number of species were seven.

The value of TDI indicate the effects due to contamination of organic matter on the wetland and the measurement of large increase in the proportion of organic pollution and tolerant taxa. TDI =3.3 < 20%, Pollution tolerant taxa is 18.5%. The proportion of TDI count is <20%, so the wetland is free of significant organic pollution.

In the present investigation, the fish to phytoplankton ratio was calculated as= 933870: 1.94×10^{12}. This indicates that the growth of plankton feeding fishes mostly depends on plankton dynamics of the water body in the studied Haor area. As there is no artificial food is provided, phytoplankton plays an important role as primary producer to pipe in energy in the consumer chain.

The total number of macrophytes recorded in the Kuniar Haor are 48. Their distribution was found seasonal. The macrophytic population was mainly represented by angiosperms. The dominant angiospermjc taxa recorded were *Sesbania bispinosa, Ipomoea aquatica* Forsk, *Barringtonia acutangula, Ottelia alismoides, Blyxa auberti* and *Ludwigia adscendens* (L) Hara.

From the community of phytoplankton in Kuniar Haor, the number of recorded taxa in all the three studied stations was almost same. Those were 51, 52 and 51 genera for station-1, station -2 and station-3, respectively. All the recorded genera belonged to six divisions of algal systematics. At the species level, a total of 115,120 and 90 species were recorded from station-1, station -2 and station-3, respectively. In the community, Chrysophyte represented 37.4, 34.1 and 37.7% at station 1-3, respectively. The members of Euglenophyta were next dominant and followed an occupancy of 28.7, 31.7 and 28.8% for station-1-3, respectively in the community. Chlorophyta dominated by 21.7, 23.3 and

21.1% for station 1-3, respectively. The least dominant Classes of phytoplankton were Cyanophyta 6.08, 4.1 and 4.4%; Cryptophyta 3.5, 3.3 and 5.5% and Pyrrophyta 2.6, 3.3 and 3.3% for station 1-3, respectively.

In table 53 a comparison among the physicochemical and biological parameters is presented in different Haors. The recorded water temperature of all the studied Haor is within the standard limit of 20 to 30 °C (EQS, 1997). DO of Hakaluki and Tanguar Haor indicates that these wetlands are suitable for fishing whereas DO of Kuniar Haor indicates its water is suitable for fisheries as well as irrigation also (Table 54).

The present limnological and hydrobiological study on the Kuniar Haor reveals that the water body has been passing its meso-eutrophic status. After having an intensive anthropogenic disturbance from the catchment the quality of water might get changed. And it is likely that in the near future these wetlands would be turned to eutrophic followed by hypertrophic systems which are undesirable not only for *ex-situ* conservation but also for threatening of future conservation strategy and also become detrimental to the components of the biodiversity

Lacking of management may create an adverse condition that the Haor might get turned into a burying land that would be devoid of organisms like phytoplankton, aquatic macrophytes, fishes, birds etc.Therefore,there is anurgent necessity to manage this Haor. The study also reveals that management of Kuniar Haor should be taken into consideration not only to stop the disturbances within the study sites but also the disturbances in their surrounding land areas. For carrying out the management activities of this Haor, the authority of the Haor and Wetland Development Board should be aware of the fact and accordingly, necessary management steps should be taken in hand ahead of time.

Conclusions

The present study shows detailed physico-chemical characteristics and quality of water in Station 1, Station 2 and Station 3 of Kuniar Haor, Kishoreganj, Bangladesh. The pre-monsoon, monsoon, post- monsoon and winter seasons shown different seasonal fluctuations in various physicochemical parameters.

Using two methods of measuring diversity Index, a good interrelationship of various phytoplankton species observed in the Kuniar Haor. Difference in soil components within the Haor basin is an important regulator of water chemistry as well as macrophyte diversity. However, the area is rich in diverse indigenous herbs and aquatic plants. Phytoplankton density was found to be a function of chlorophyll-a considering Pearson correlation of the parameters of the studied area. Estimation of Fish: phytoplankton = 1: 2.08×10^{6} indicate that in this Haor phytoplankton plays an important role in food chain. Feeding relationships of selected aquacultures and macrophytes in Kuniar Haor shows a uniqueness of macrophytes for maintaining the ecological balance of the wetland.

TDI (Trophic Diatom Index) indicate that Kuniar Haor is free from significant organic pollution. So it is clear that the water of the Haor is suitable for the proper growth and adaptation of aquatic biotas as well as them *in situ* conservations. There is also a need of increasing awareness among the people to maintain the water at their highest quality and purity level. The investigation generated some important baseline data on the pollution status and phytoplankton community structure of the Haor. These data would be helpful in planning for future policy decisions on using the reservoir as an ecotourist center as well as in the better conservation and management of the precious wildlife in the world-famous sanctuary.

The unplanned mining in the adjacent hilly regions of the neighbouring countries, cultivation of fish and corns and dragging of sediments within the interconnected river Dhonu are gradually creating environmental hazards in the water of the Haor. As a result, leaching is supposed to be the important operative function for facing a danger of reduction and extinction of indigenous aquatic communities of Kuniar Haor.

Photomicrographs of phytoplankton

(Magnification of the images ranges from 400-1000x)

Plate-1

1-16: Melosira granulata (different views)

Plate-1

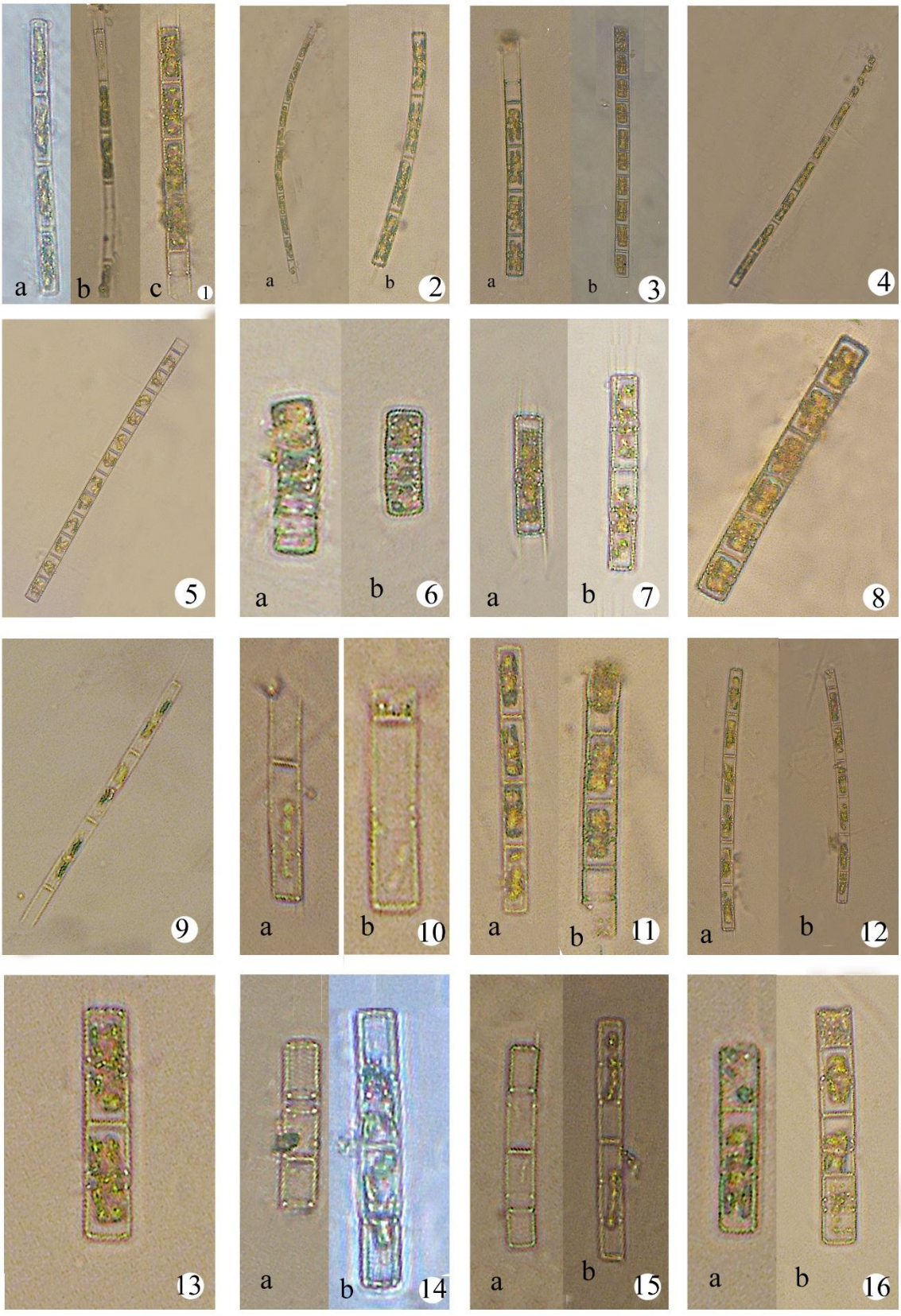


Plate-2

1. *Synedra acus*

2. *Navicula* sp.

3. *Navicula anglica*

4. *Navicula placentula*

5. *Eunotia* sp.

6. *Eunotia* sp.

7. *Eunotia* sp.

8. *Eunotia* sp.

9. *Eunotia* sp.

10. *Gomphonema longiceps*

11. *Gomphonema gracile* var. *naviculaceae*

12. *Gyrosigma acuminatum*

13. *Surirella* sp.

14. *Cymbella turgida*

15. *Navicula transitrans* var. *derasa*

16. *Synedra* sp.

Plate-2

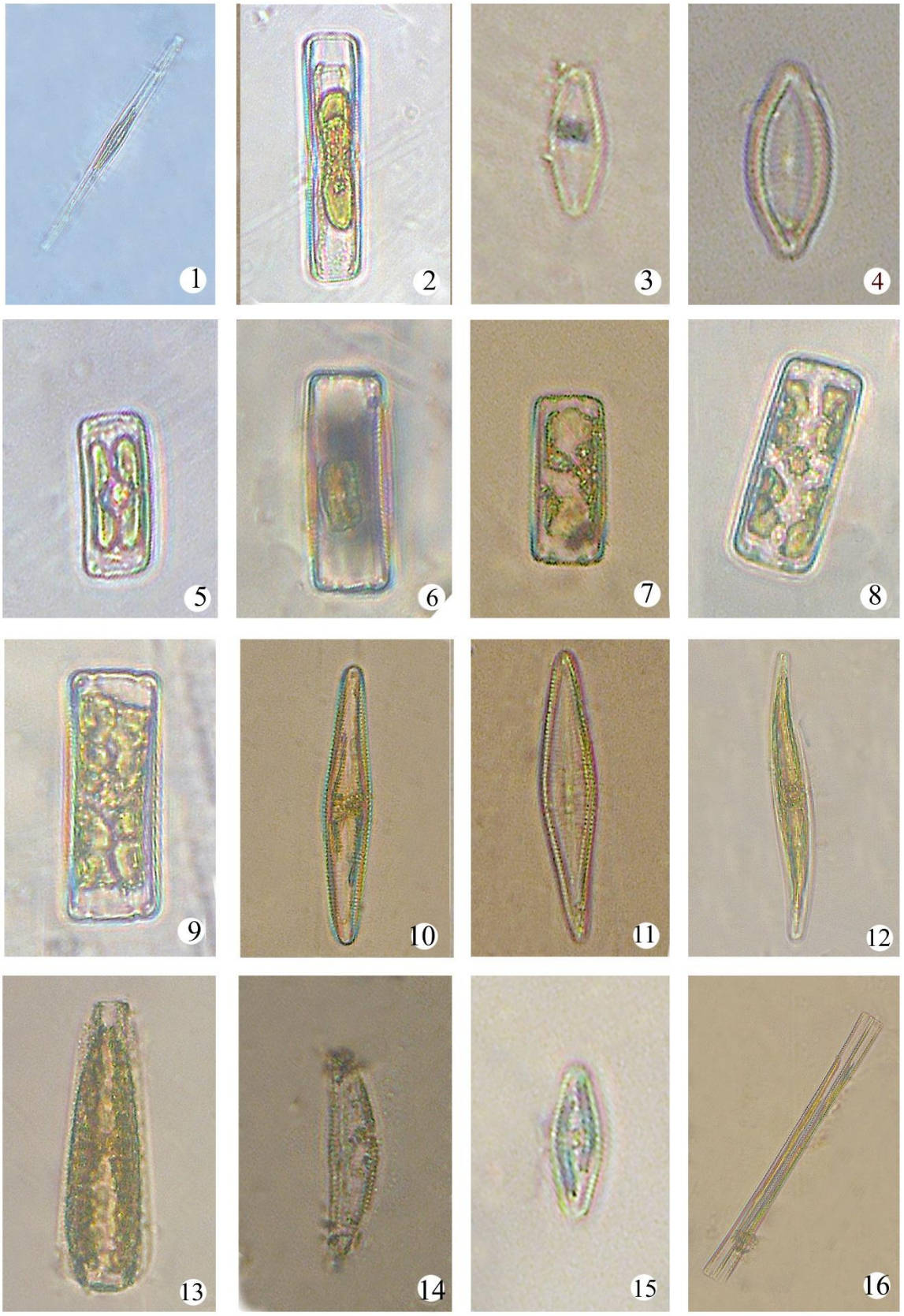


Plate-3

1. *Gyrosigma attenuatum*
2. *Pinnularia gibba*
3. *Nitzschia linearis*
4. *Cymbella parva*
5. *Navicula bacillum*
6. *Eunotia* sp.
7. *Pinnularia* sp.
8. *Nitzschia fruticosa* Hust
9. *Navicula radiosa*
10. *Navicula pupula*
11. *Navicula pseudohalophila*
12. *Surirella angustata*
13. *Pinnularia molaris*
14. *Synedra acus*
15. *Gyrosigma distiortum*

Plate-3

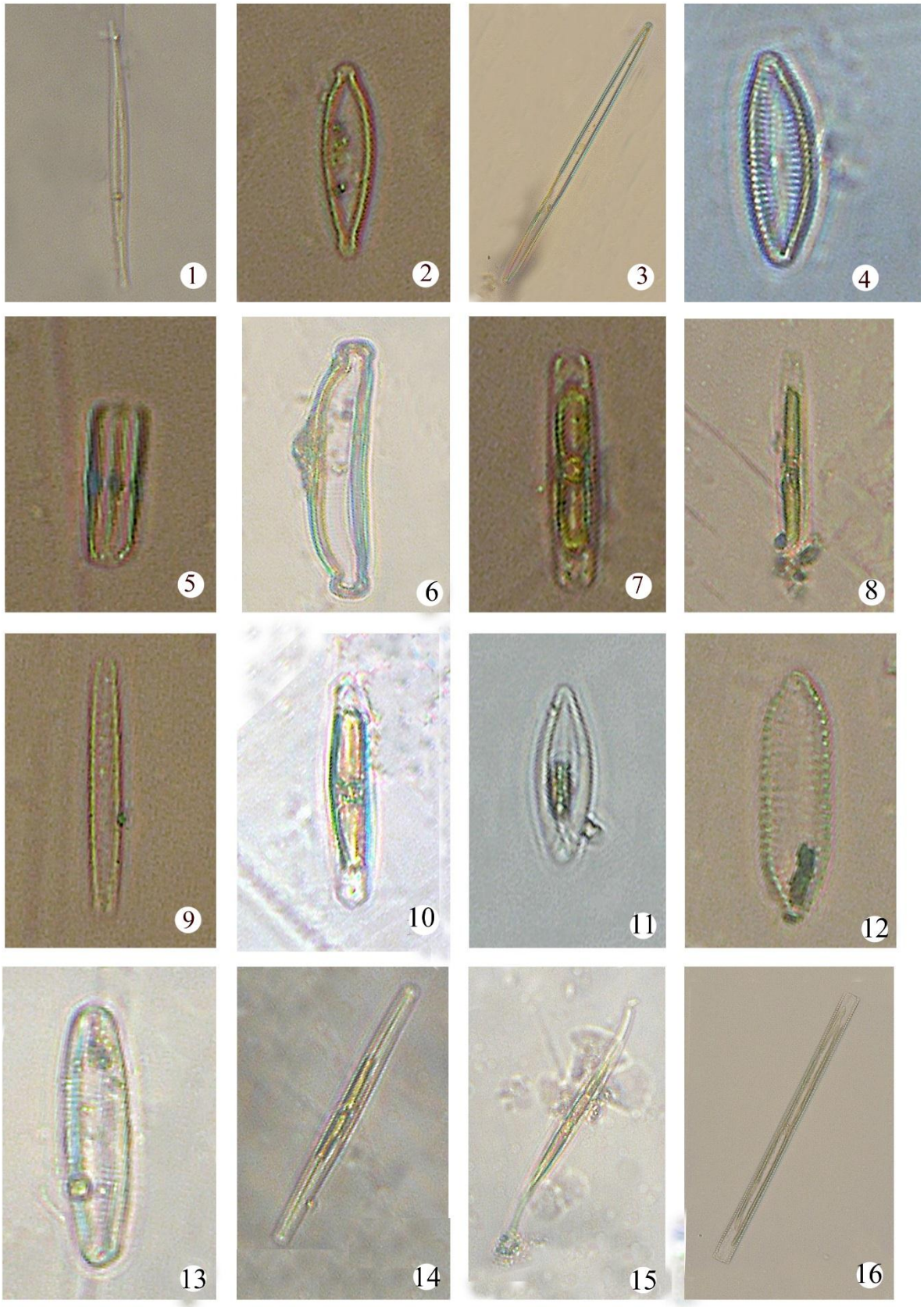


Plate-4

1. *Synedra* sp.
2. *Eunotia monodon*
3. *Fragillaria intermedia*
4. *Fragillariacapunica*
5. *Pinnularia major*
6. *Pinnularia pulchara*
7. *Gomphonema lanceolatum*
8. *Navicula delicatula.*
9. *Acnanthes* sp.
10. *Navicula pupula*
11. *Navicula pseudohalophila*
12. *Synedra ulna*
13. *Cyclotella comensis*
14. *Eunotia robusta*
15. *Synedra ulna*
16. *Melosira granulata*

Plate-4

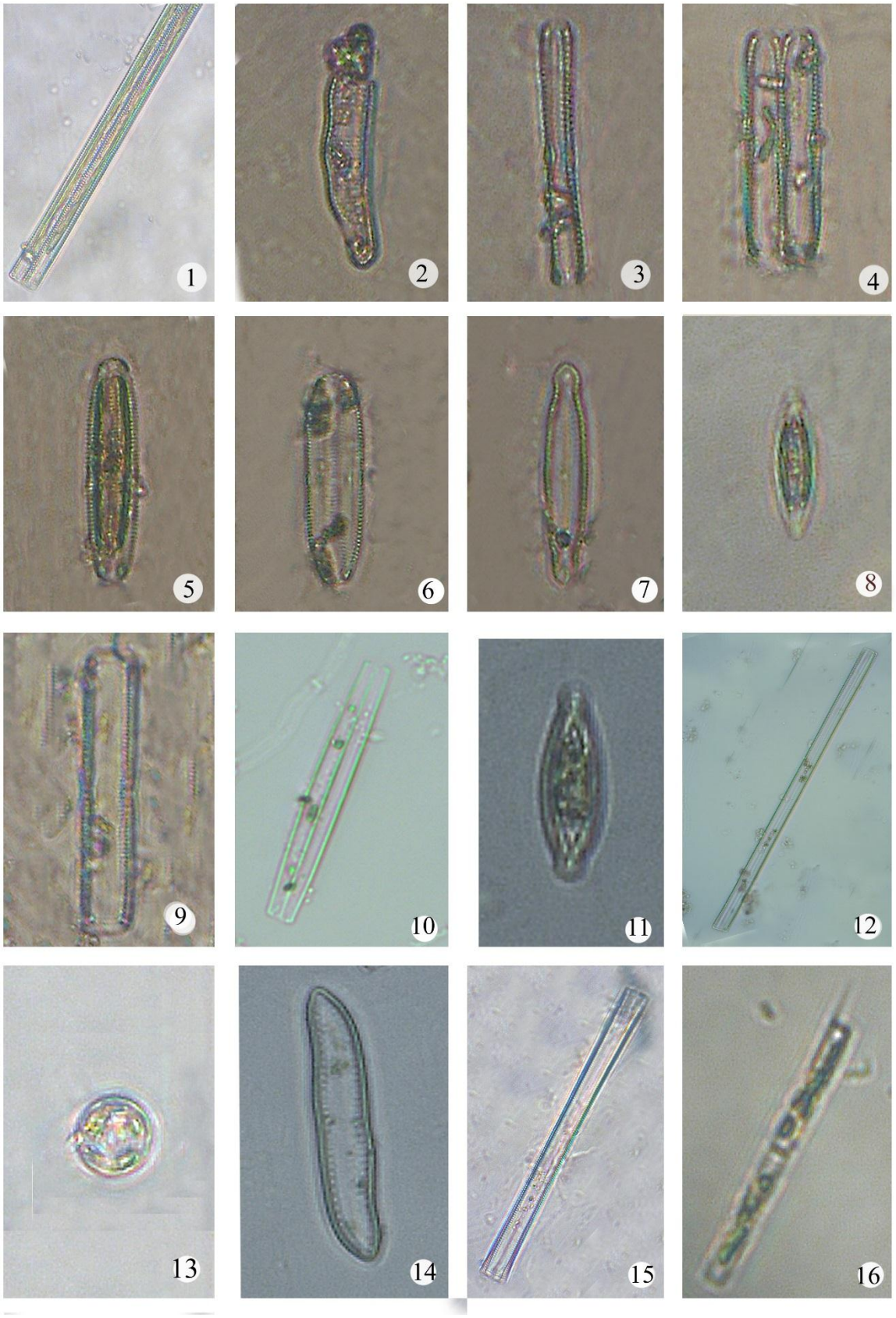


Plate-5

1. *Synedra* sp.

2. *Melosira granulata*

3. *Pinnularia* sp.

4. *Melosira granulata*

5. *Synedra acus*

6. *Synedra ulna*

7. *Surirella ovata* var. *pinnata*

8. *Navicula* sp.

9. *Syndra* sp.

10. *Navicula pupula*

11. *Melosira granulata*

12. *Gyrosigma scalpoides*

Plate-5

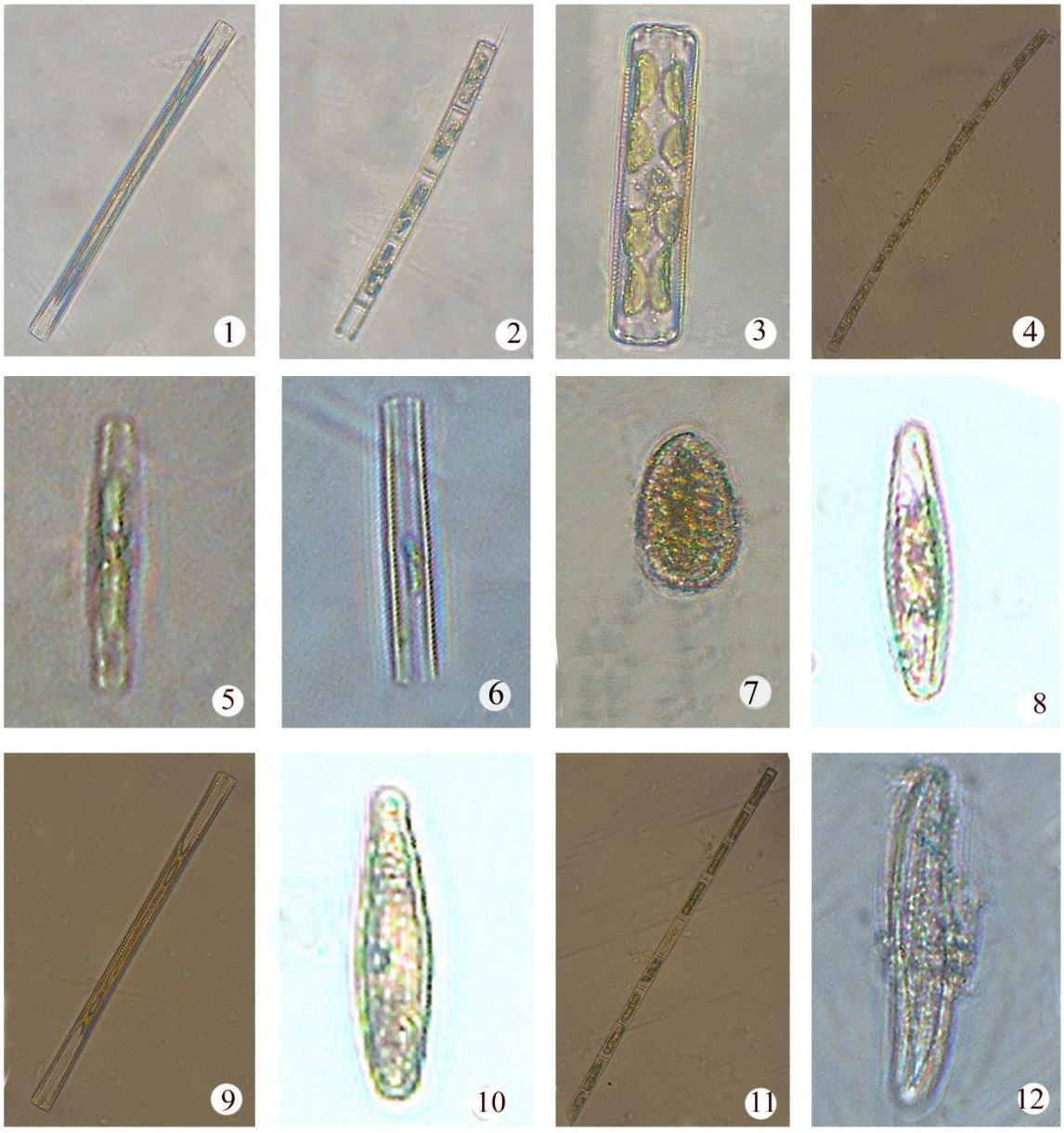


Plate-6

1. *Fragilaria* sp.
2. *Nitzschia* sp.
3. *Fragilaria*
4. *Synedra ulna*
5. *Gomphonema longiceps*
6. *Synedra* sp.
7. *Synedra* sp.
8. *Surirella robusta*
9. *Gyrosigma distiortum*
10. *Melosira granulate*
11. *Nitzschia fruticosa* Hust
12. *Pinnularia gibba*

Plate-6

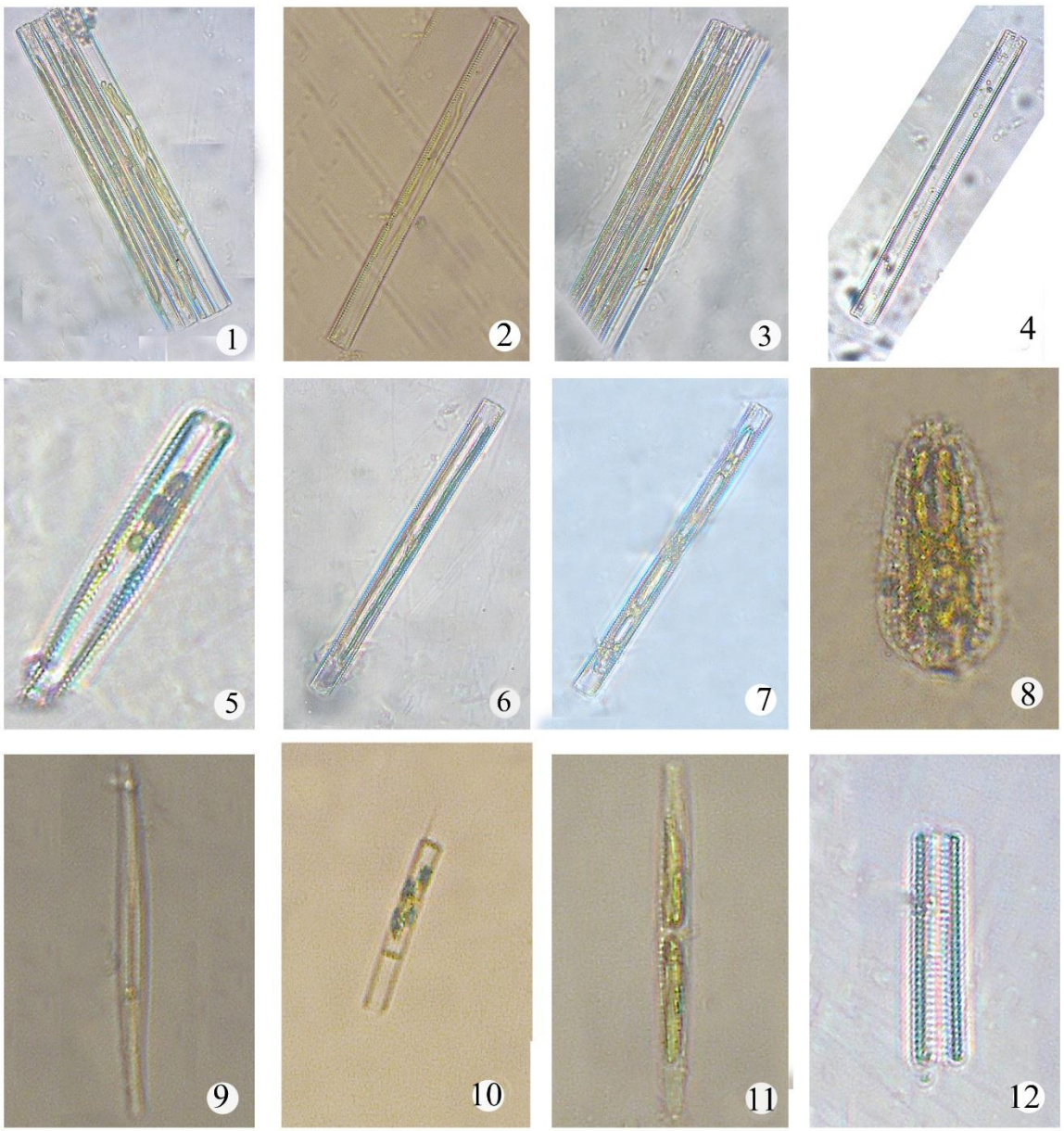


Plate-7

1. *Synedra* sp.
2. *Gyrosigma distiortum*
3. *Navicula pupula*
4. *Surirella* sp.
5. *Fragillaria* sp.
6. *Synedra tabulata*
7. *Navicula* sp.
8. *Navicula* sp.
9. *Pinnularia* sp.
10. *Cyclotella comta*
11. *Navicula pseudohalophila*
12. *Cymbella turgidula*

Plate-7

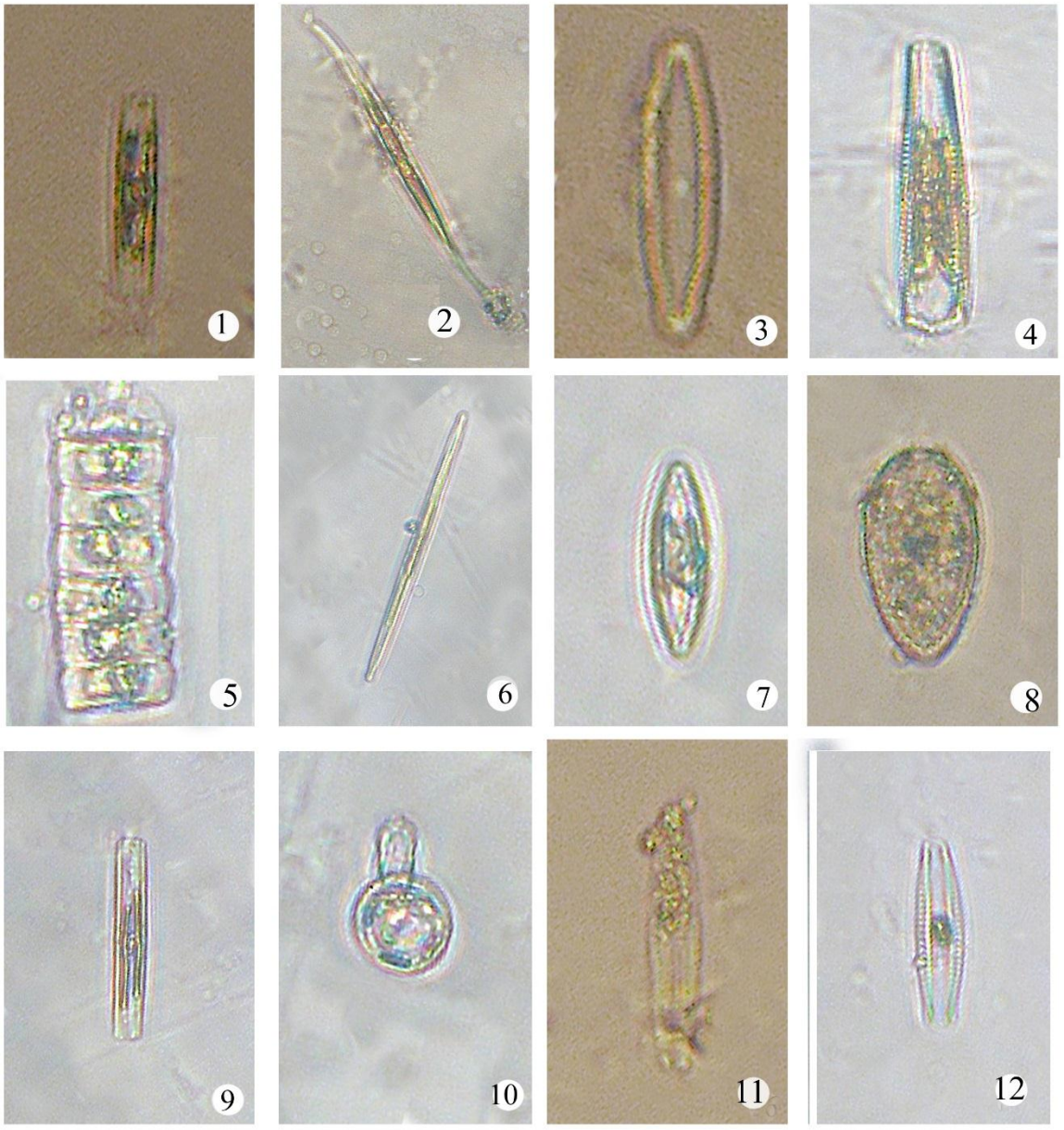


Plate- 8

1. *Lepocinclis salina*

2. *Euglena hemichromata*

3. *Lepocinclis ovum* var. *major*

4. *Euglena viridis*

5. *Euglena* sp.

6. *Trachelomonas oblonga*

7. *Lepocinclis salina*

8. *Trachelomonas eurostoma* var. *minuta*

9. *Strombomonas borystheniensis*

10. *Strombomonas borystheniensis*

11. *Euglena oblonga*

12. *Euglena allorgei*

Plate- 8

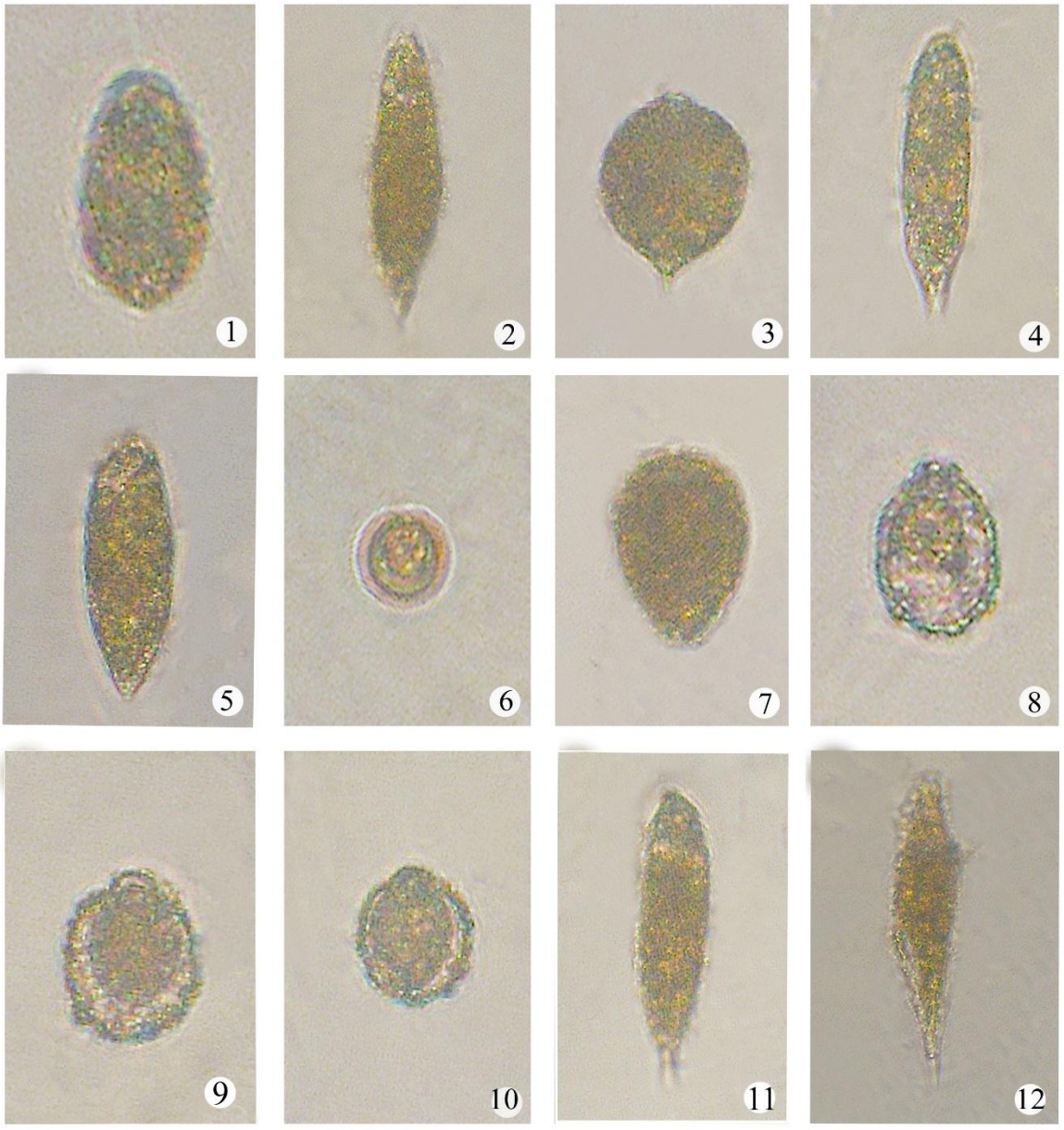


Plate- 9

1. *Trachelomonas oblonga*
2. *Trachelomonas playfairii*
3. *Trachelomonas compacta*
4. *Trachelomonas oblonga* var. *truncata*
5. *Euglena clavata*
6. *Trachelomonas parvicollis*
7. *Trachelomonas cylindrica*
8. *Trachelomonas compacta*
9. *Trachelomonas pulcherrima*
10. *Euglena spathyryncha*
11. *Trachelomonas playfairii*
12. *Trachelomonas rugulosa*
13. *Trachelomonas eurostoma*
14. *Trachelomonasplanktonica*
15. *Trachelomonas pulcherrima*
16. *Trachelomonas volvocina*

Plate- 9

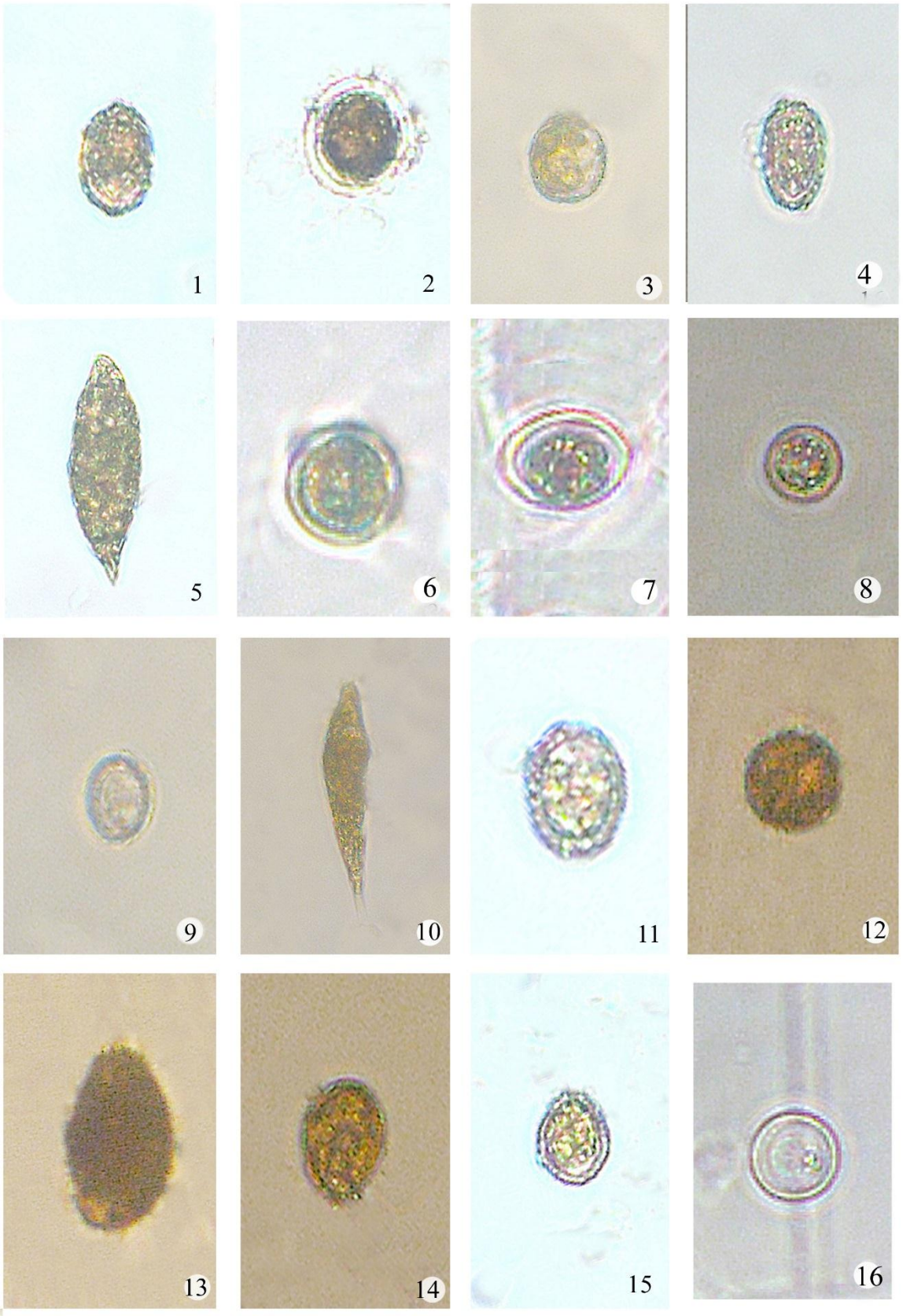


Plate-10

1. *Euglena allorgei*

2. *Trachelomonas* sp.

3. *Trachelomonas playfairii*

4. *Trachelomonastshopoensis*

5. *Trachelomonas pulcherrima*

6. *Phacus ephippion*

7. *Trachelomonas oblonga*

8. *Trachelomonas volvocina*

9. *Strombomonas fluviatilis*

10. *Euglena* sp.

11. *Euglena* sp.

12. *Rhodomonas minuta*

13. *Trachelomonas* sp.

14. *Trachelomonas dybowskii*

15. *Trachelomonas intermedia*

16. *Trachelomonas oblonga*

Plate- 10

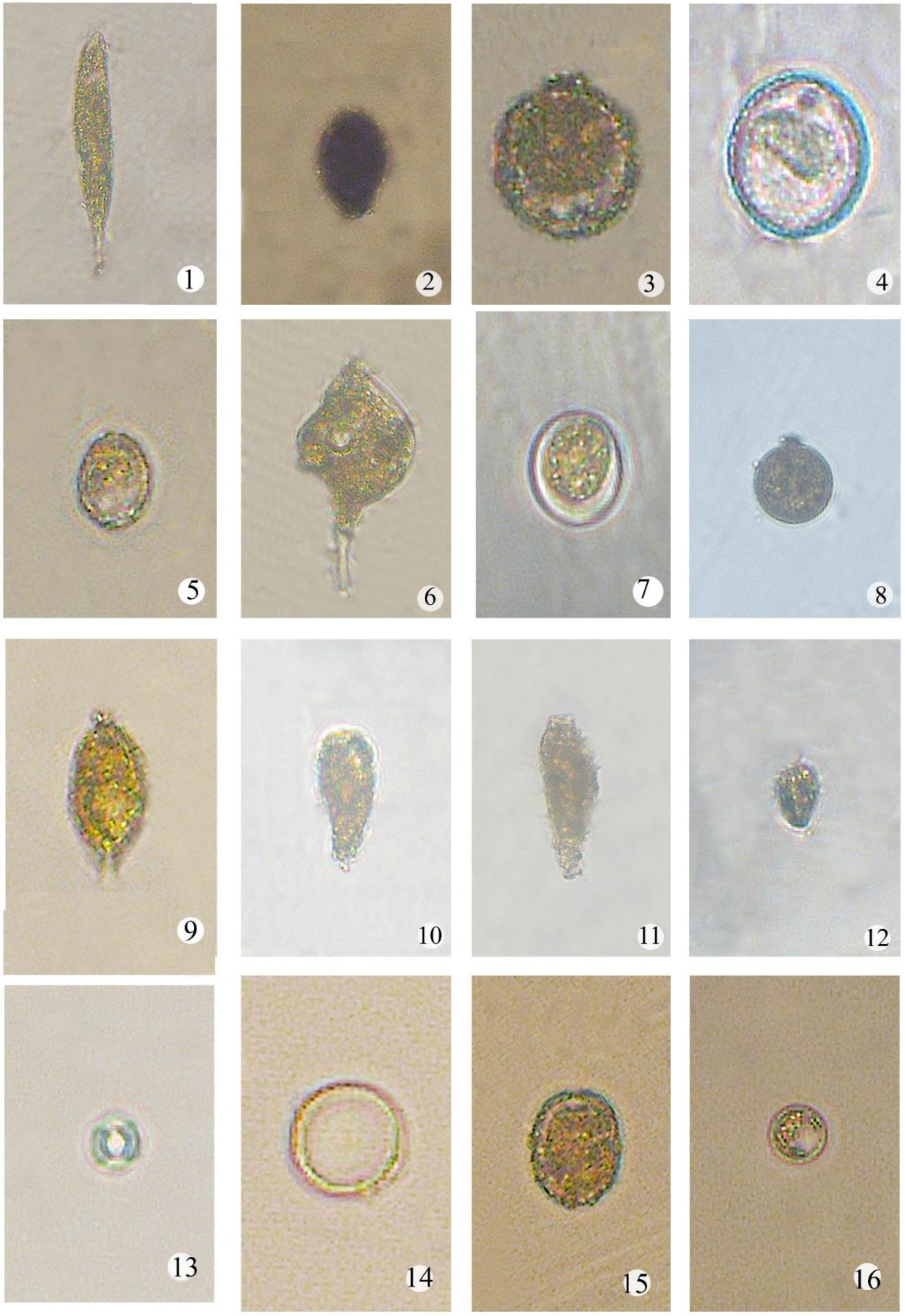


Plate-11

1. *Trachelomonas oblonga*

2. *Euglena* sp.

3. *Euglena charkowiensis*

4. *Euglena* sp.

5. *Trachelomonas hispida*

6. *Euglena chlamydophora*

7. *Trachelomonas* sp.

8. *Lepocinclis salina*

9. *Trachelomonas hispida* var. *coronata*

10. *Trachelomonas* sp.

11. *Trachelomonas hispida*

12. *Trachelomonas volvocina*

13. *Trachelomonas planktonica*

14. *Trachelomonas volvocina*

Plate-11

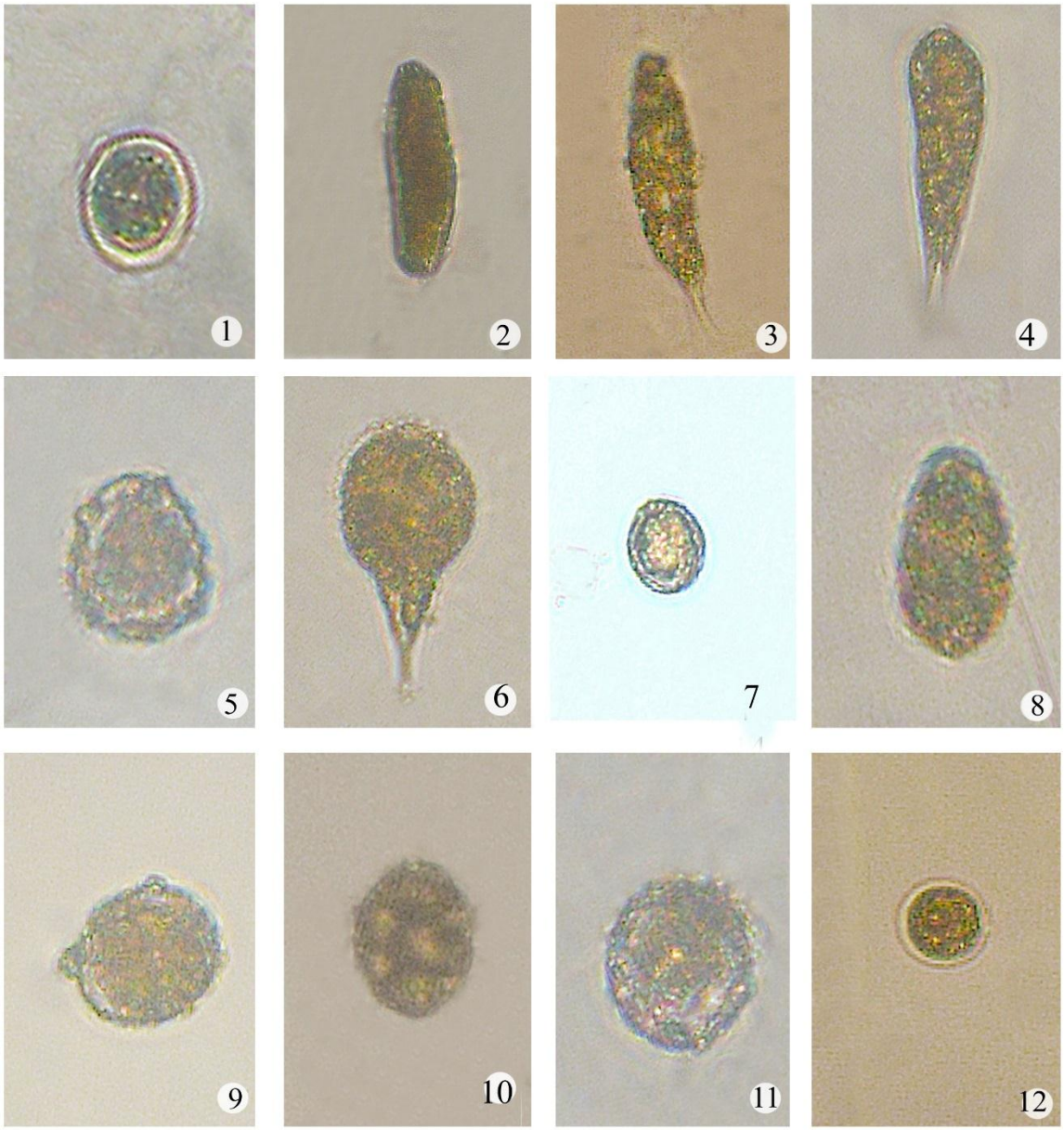


Plate- 12

1. *Euglena spathirhyncha*

2. *Trachelomonas crebea*

3. *Euglena mainxii*

4. *Trachelomonasanulifera* var. *semi-ornata*

5. *Trachelomonas* sp.

6. *Trachelomonas lismorensis* var. *inermis*

7. *Euglena allorgei*

8. *Euglena ehrenbergii*

9. *Trachelomonas bernardi*

10. *Trachelomonas rugulosa*

11. *Strombomonas fluviatilis*

12. *Trachelomonas cribea*

13. *Trachelomonas armata*

14. *Trachelomonas compacta*

15. *Euglena* sp.

16. *Euglena sanguinea*

Plate- 12

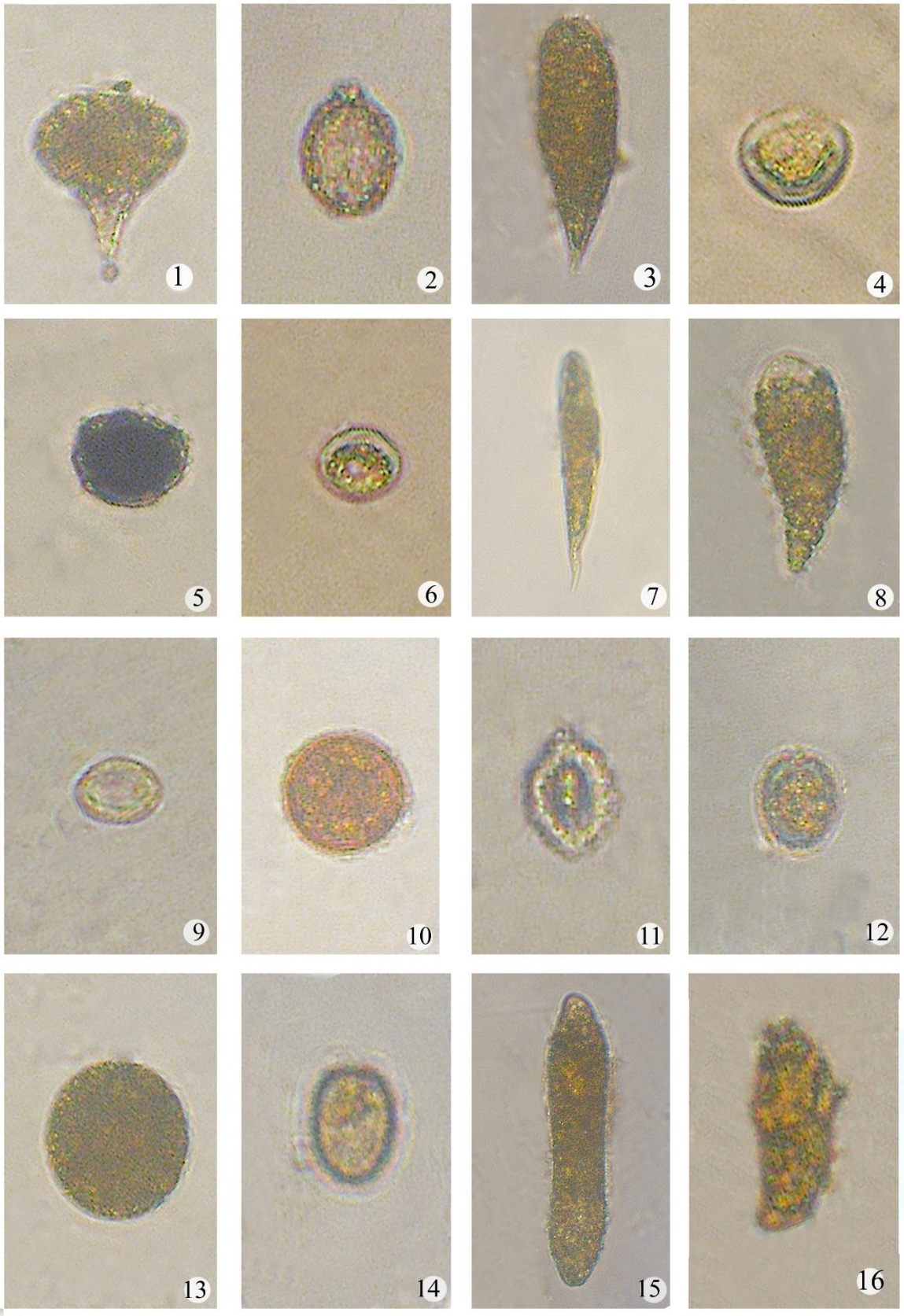


Plate- 13

1. *Trachelomonas pulcherrima* var. *minor*

2. *Trachelomonas oblonga* var. *truncate*

3. *Trachelomonas verrucosa*

4. *Trachelomonasvolvocina* var. *punctata*

5. *Lepocinclis salina*

6. *Euglena acus*

7. *Euglena longicauda*

8. *Trachelomonas planctonica*

9. *Trachelomonas rotunda*

10. *Euglena acus*

11. *Trachelomonas oblonga*

12. *T. oblonga*

Plate- 13

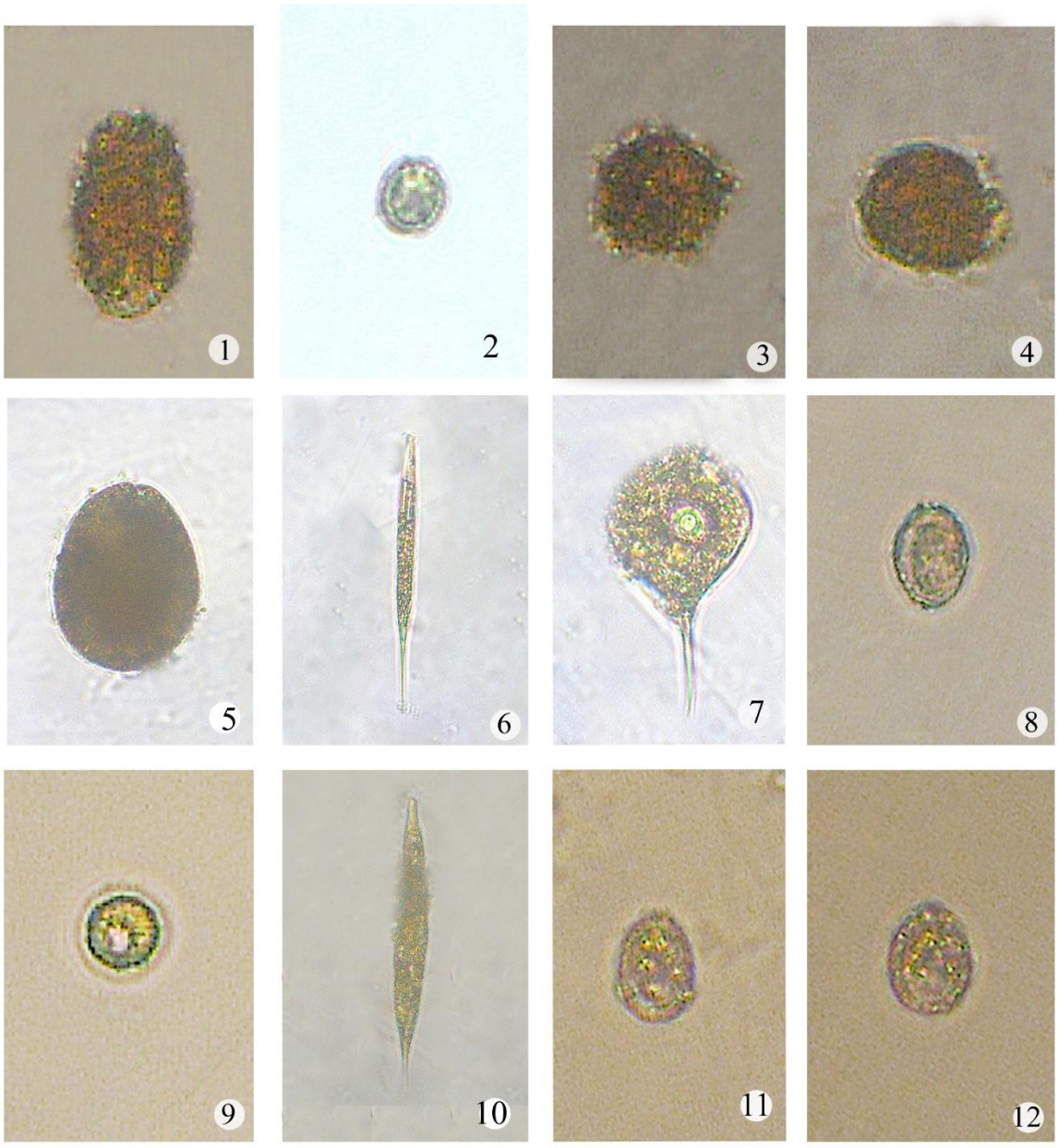


Plate- 14

1. *Trachelomonas hispida* var. *coronate*
2. *Trachelomonas volvocina*
3. *Trachelomonas lismorensis* var. *inermis*
4. *Trachelomonas lacustris* var. *ovalis*
5. *Trachelomonas silvatica*
6. *Trachelomonas sowerbii*
7. *Trachelomonas sydneyensis*
8. *Trachelomonas sydneyensis*
9. *Trachelomonas scabra* var. *pygmea*
10. *Trachelomonas scabra* var. *pygmea*
11. *Trachelomonas hystrix*
12. *Trachelomonas mucosa* var. *brevicollis*

Plate- 14

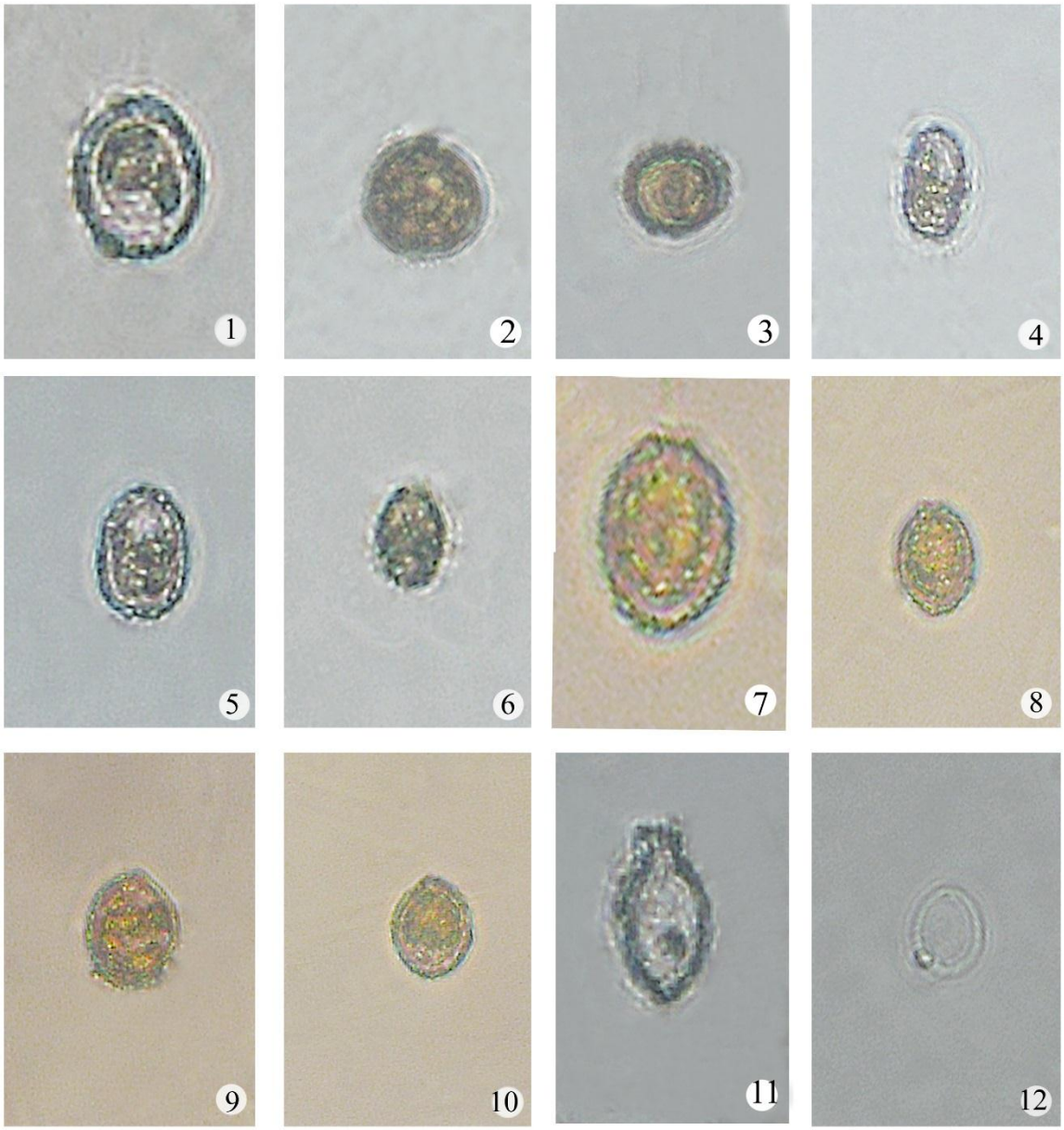


Plate- 15

1. *Trachelomonas rugulosa*
2. *Trachelomonas pulcherrima* var. *ovalis*
3. *Trachelomonas mucosa* var.*brevicollis*
4. *Trachelomonas lismorensis* var. *inermis*
5. *Trachelomonas oblonga*
6. *Trachelomonas pulcherrima* var. *latitor*
7. *Trachelomonas planctonica* var. *oblonga* Drez.
8. *Trachelomonas volvocina*
9. *Euglena tripteris*
10. *Trachelomonas oblonga*
11. *Trachelomonas hispida*
12. *Trachelomonas volvocina*

Plate- 15

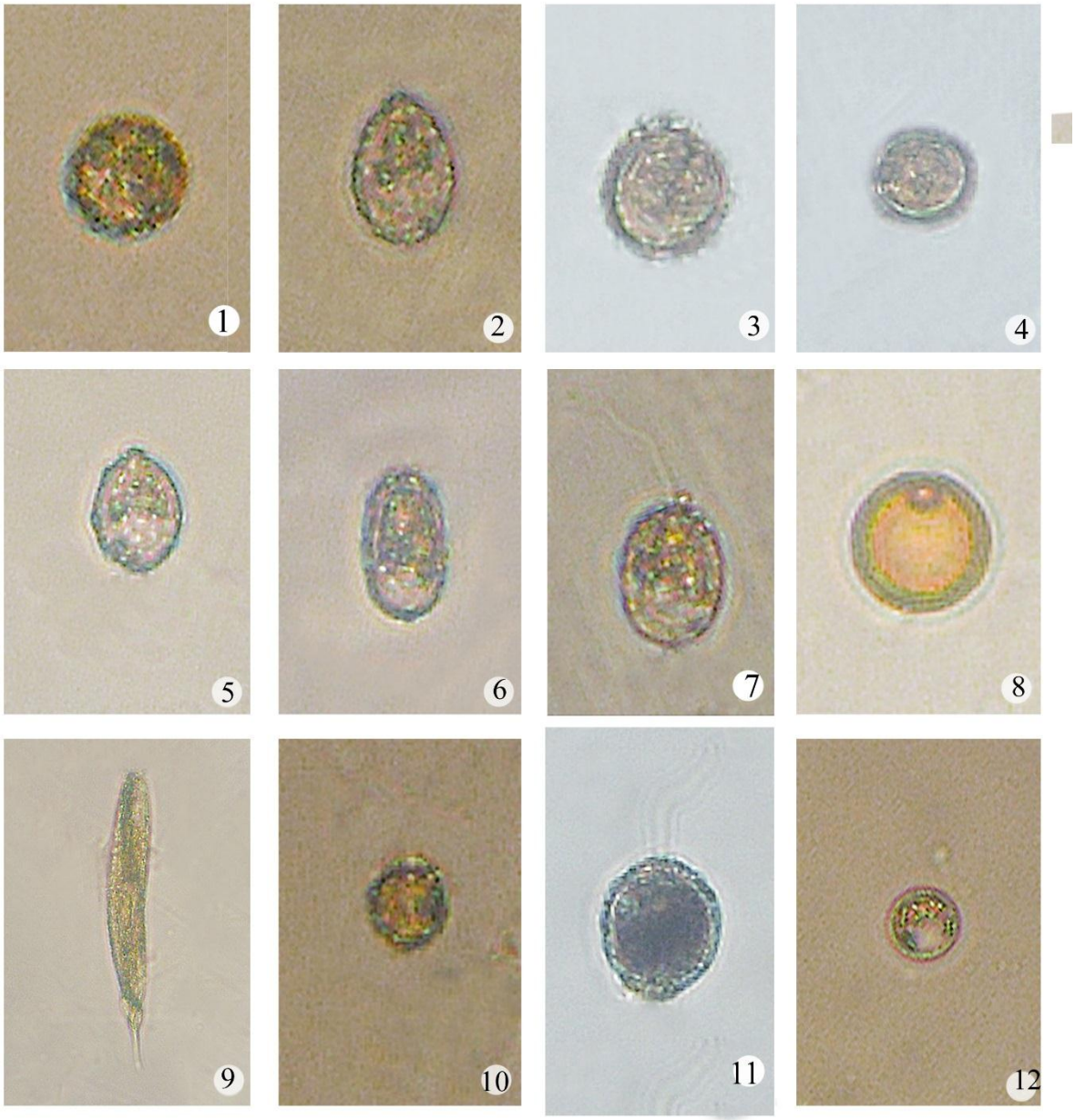


Plate- 16

1. *Pediastrum duplex*
2. *Mougeotia quadrangulata*
3. *Spirogyrra* sp.
4. Unknown sp.
5. *Planktosphaeria* sp.
6. *Staurastrum pinnatum*
7. *Cosmarium pseudopyramidatum*
8. *Monoraphidium griffithii* (Berkeley) Kom. Legn.
9. *Cosmarium* sp.
10. *Pediastrum duplex*
11. *Coelastrum sphaericum*
12. *Crucigeniella crucifera*
13. *Phacotus* sp.
14. *Phacotus* sp.
15. *Phacotus* sp.
16. *Anabaenopsis* sp.

Plate- 16

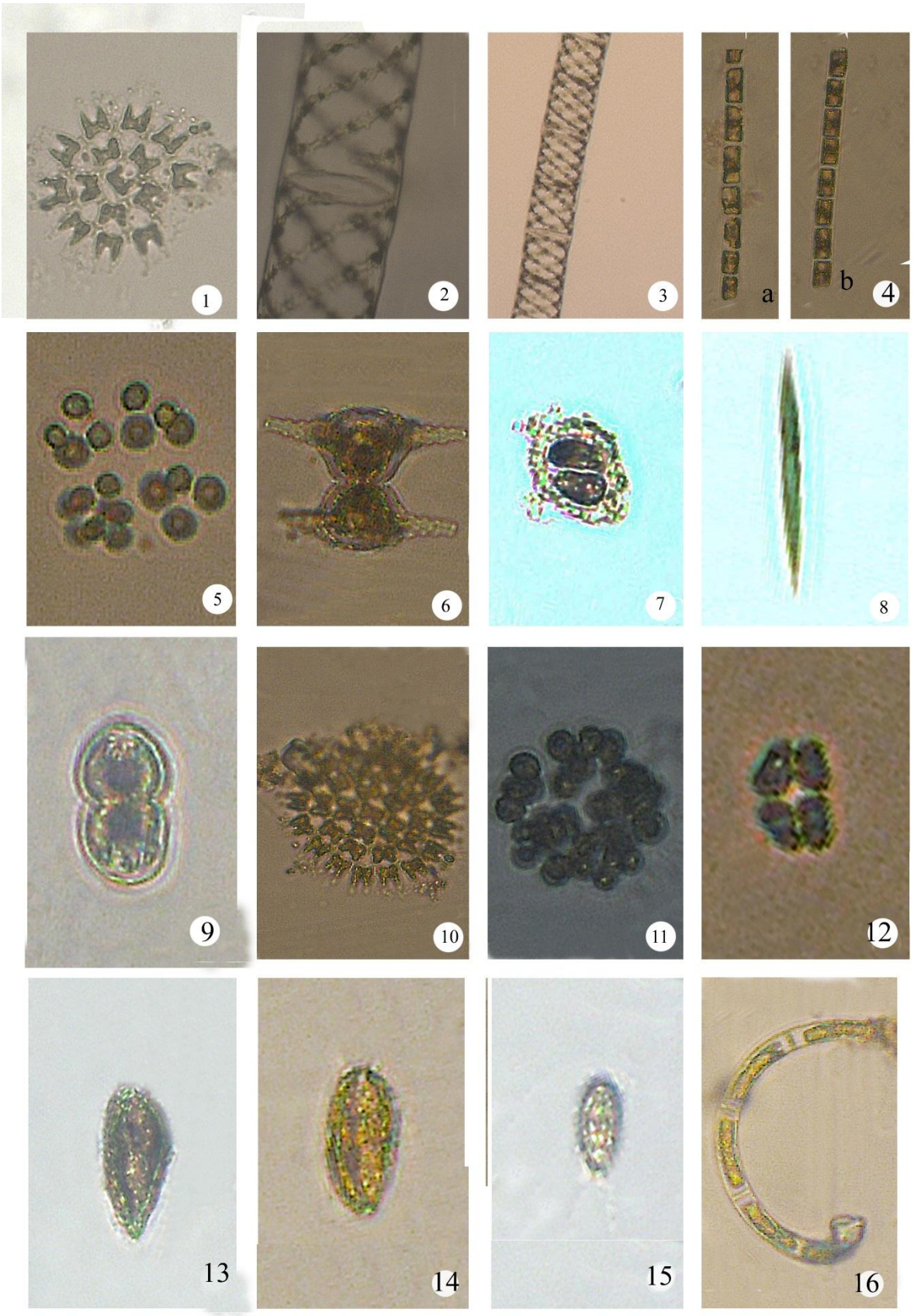


Plate- 17

1. *Spirogyrra* sp.

2. *Scenedesmus incrassatulus* Bohlin

3. *Crucigenia tetrapedia* (Kirchner) W. West & G. S. West

4. *Staurastrum* sp.

5. *Hyaloraphidium contortum* Pasch. & Korš

6. *Dictyosphaerium* sp.

7. *Scenedesmus obtusus* Meyen f. *obtusus*

8. *Chlorella vulgaris* Beyerinck

9. *Mougeotia scalaris*

10. *Spirogyrra* sp.

11. *Tetrastrum* sp.

12. *Carteria globosa*

13. *Coelastrum* sp.

14. *Closteriopsis longissima* var. *longissima* (Lemm) Lemm

15. *Phacotus lanticularis*

16. *Phacotus lanticularis*

Plate- 17

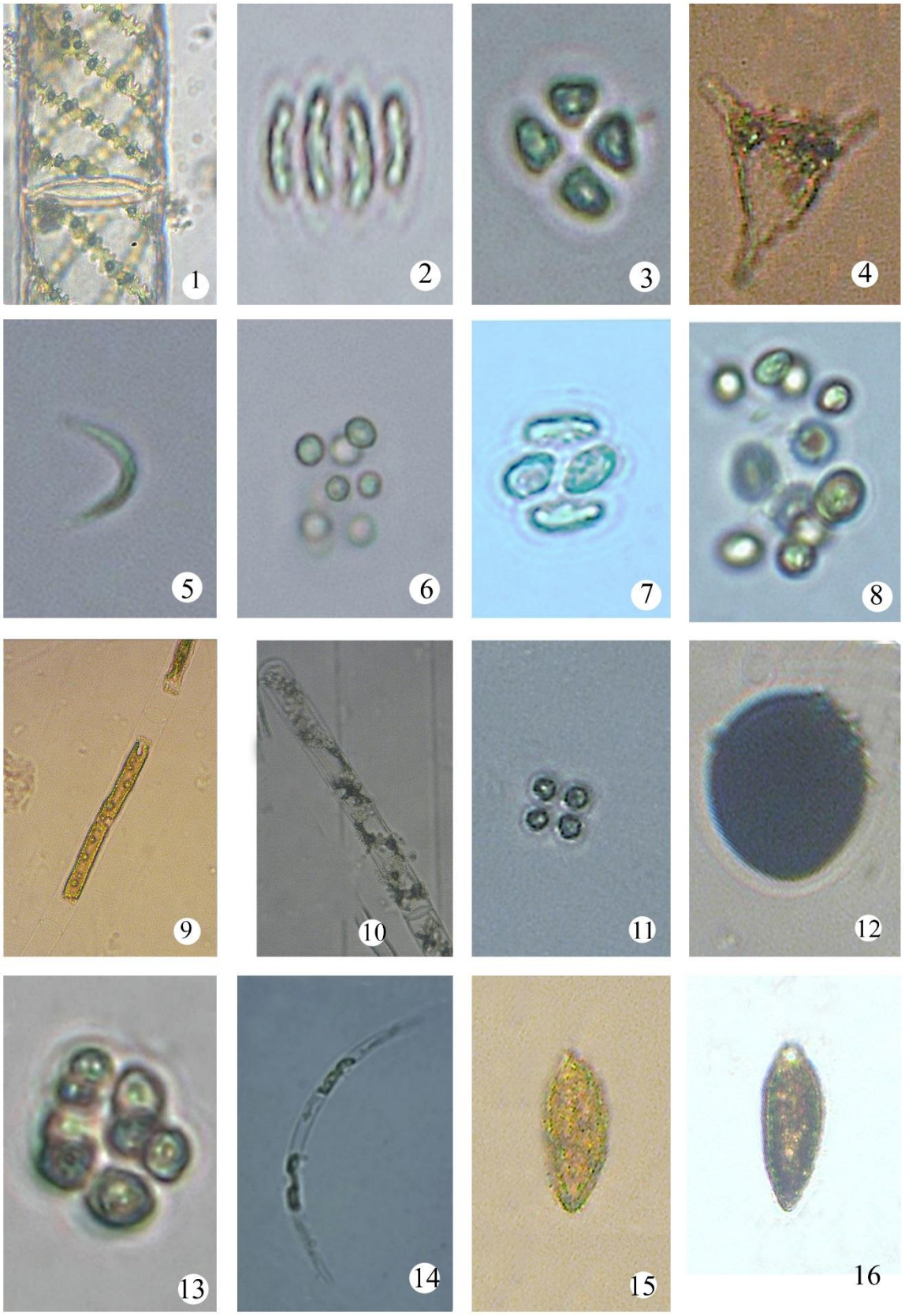


Plate- 18

1. *Pelonema aphanae*
2. *Oscillatoria pseudogeminata* G. Schmid
3. *Gomphosphaeria lacustris* Chodat
4. *Merismopedia minima*
5. *Microcystis aeruginosa* Kütz
6. *Microcystis incerta* Lemm.

Plate-18

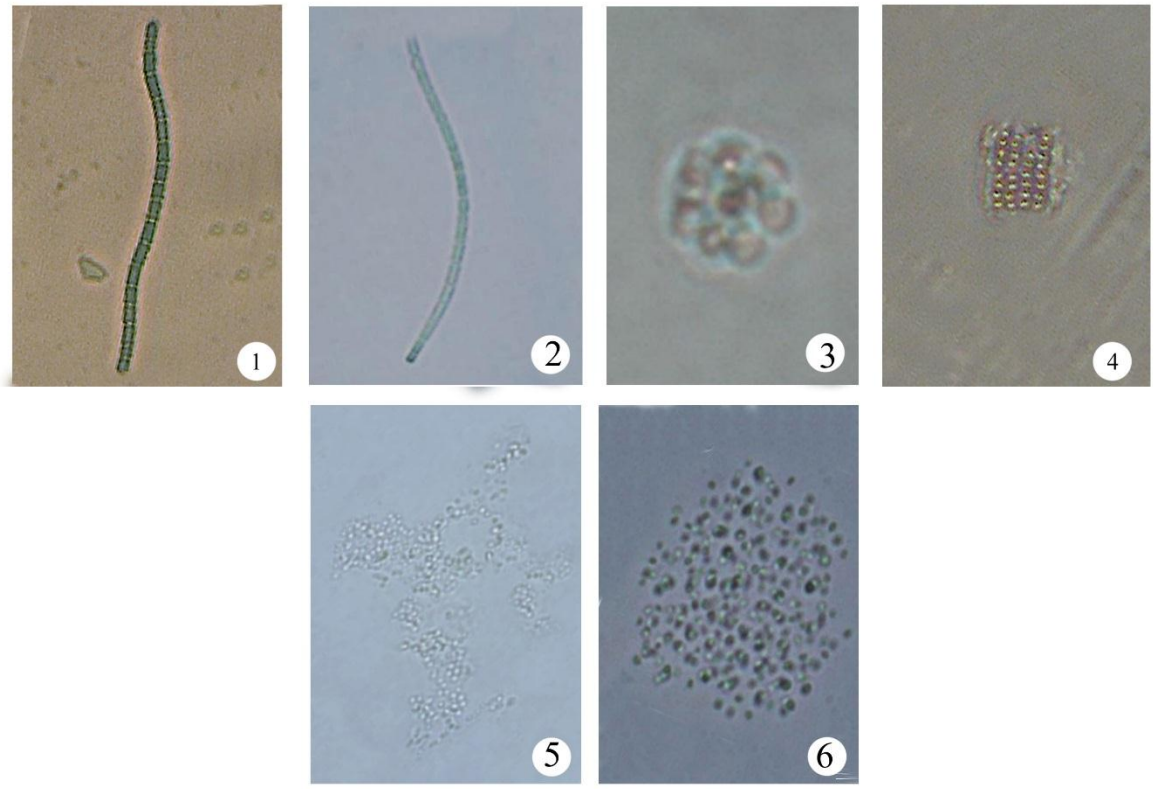


Plate- 19

1. *Cryptomonas erosa* var. *reflexa*
2. Unknown sp.
3. *Chroomonas acuta*
4. *Cryptomonas erosa*
5. *Chromonas caudata*
6. *Rhodomonas minuta*
7. *Cryptomonas* sp.
8. *Cryptomonas gracile*
9. Unknown sp.
10. *Rhodomonas lacustris*
11. *Rhodomonas* sp.
12. *Cryptomonas tenius*

Plate- 19

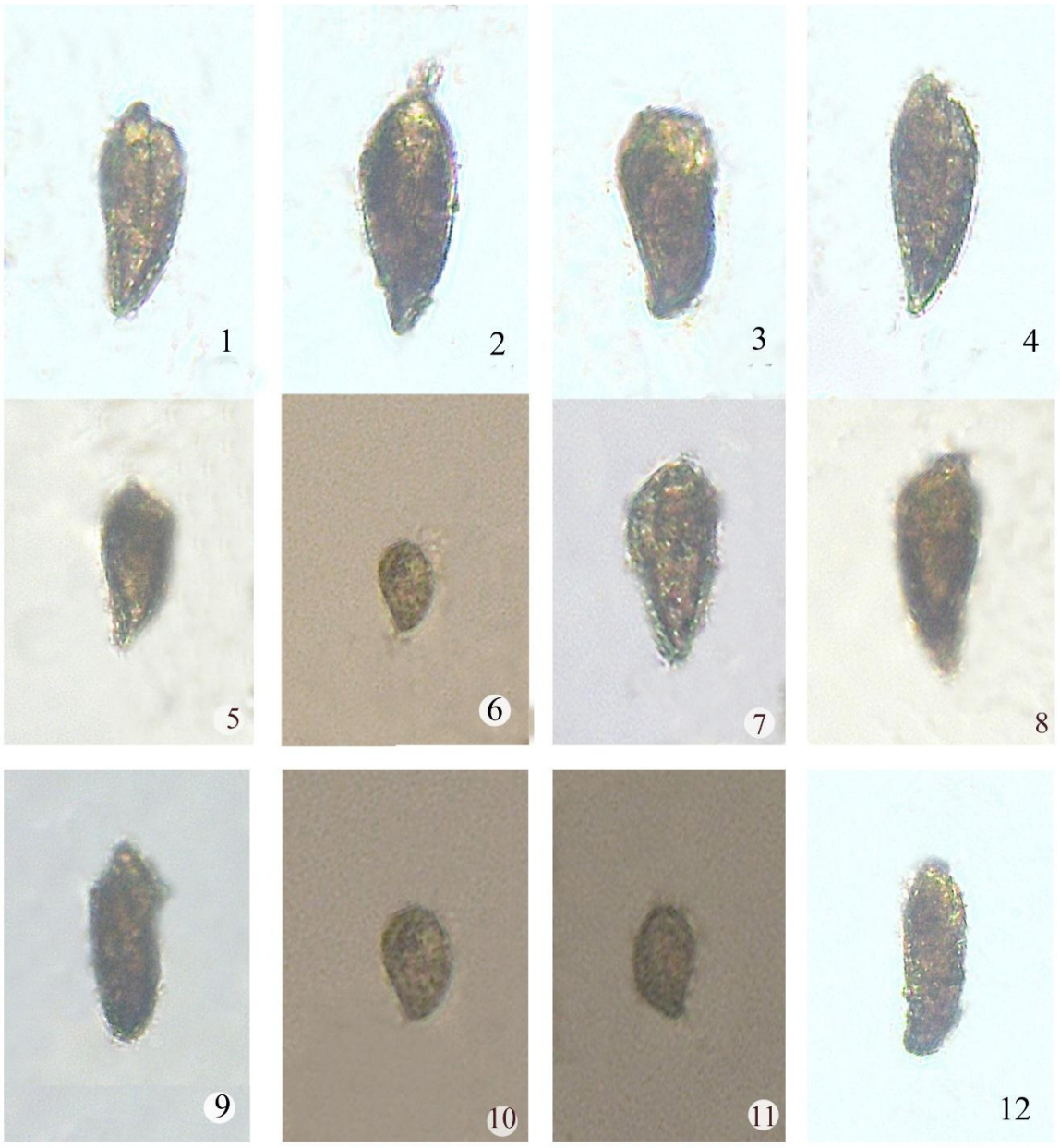


Plate- 20

1. *Cryptomonas lucens*
2. *Rhodomonas salina*
3. *Cryptomonas obovata*
4. *Chromonas caudata*
5. *Rhodomonas* sp.
6. Unknown sp.
7. *Cryptomonas reflexa*
8. *Chromonas nordstedtii*
9. *Rhodomonas lacustris*
10. *Cryptomonas marsonii*
11. *Cryptomonas obovata*
12. *Rhodomonas minuta*

Plate- 20

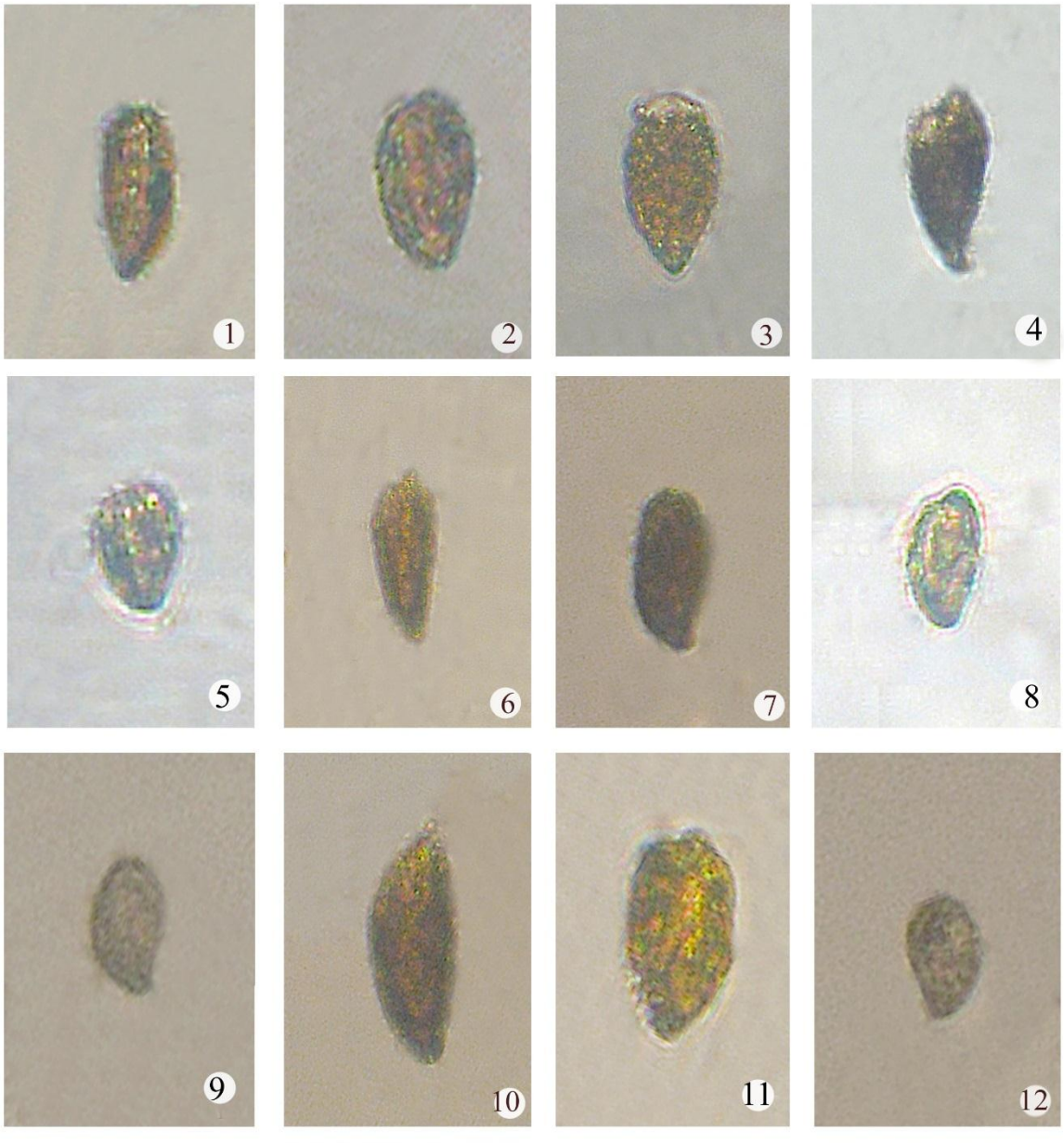


Plate- 21

1. *Peridinium aciculiferum*
2. *Protoperidinium kolezynskii*
3. *Protoperidinium pellucidum*
4. *Protoperidinium conicum*
5. *Peridinium cinctum*
6. *Peridinium* sp.
7. *Protoperidinium excentricum*
8. *Protoperidinium conicoides*
9. *Peridinium* sp.
10. *Protoperidinium pyriforme*
11. *Protoperidinium conicum*
12. *Peridinium cinctum* fa. *angulatum*

Plate-21

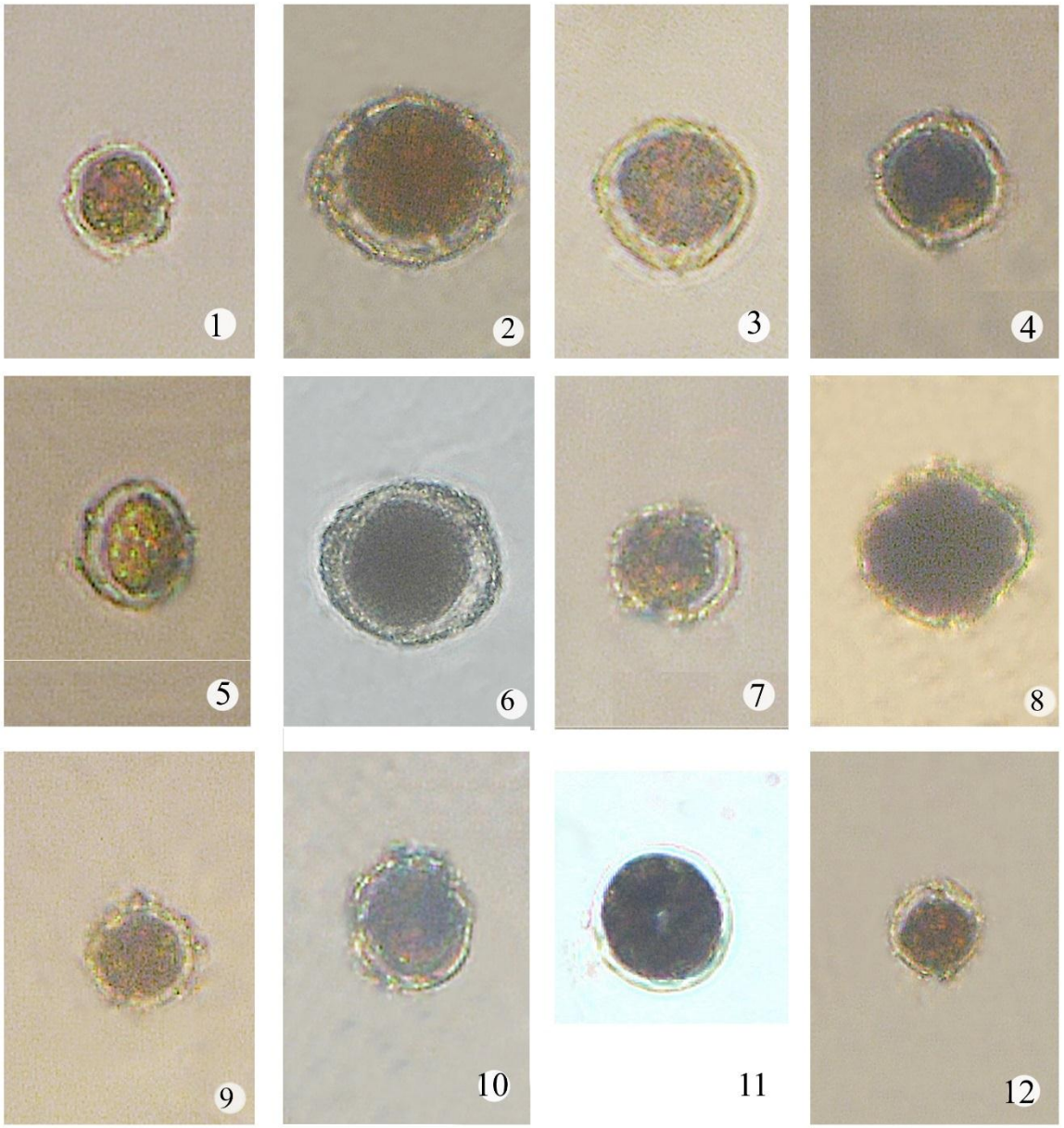
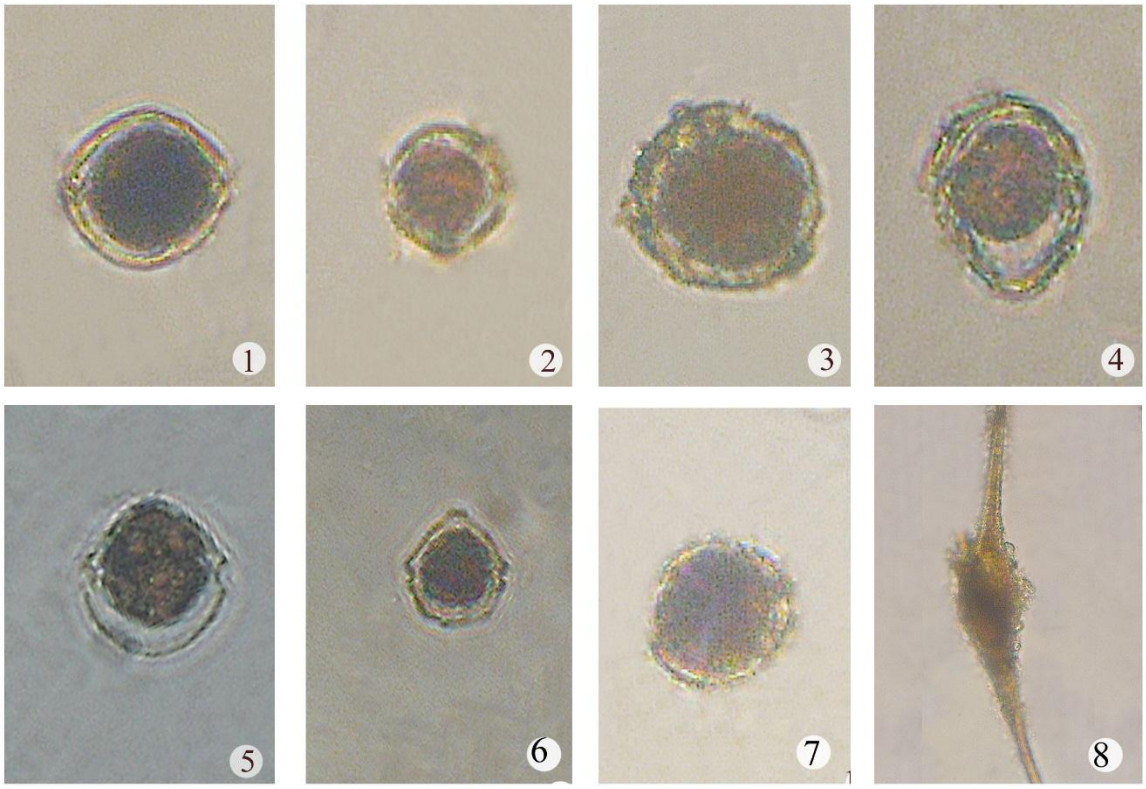


Plate-22

1. *Peridinium quinquecorne*
2. *Peridinium cinctum*
3. *Peridinium* sp.
4. *Peridinium abei*
5. *Peridinium cinctum* fa. *angulatum*
6. *Peridinium aciculiferum*
7. *Protoperidinium* sp.
8. *Ceratium furca*

Plate- 22



Photomicrographs of the new reports of phytoplankton for Bangladesh

Plate-23

Name of the organism	Name of the major Group
1. *Oscillatoria tanganyikae* G.S. West	Cyanophyta
2. *Achroonema macromeres* Skuja	Cyanophyta
3. *Zygnemopsis desmidioides* West	Chlorophyta
4. *Oocystis lacustris* f. *nivalis* Fritsch	Chlorophyta
5. *Closteriopsis acicularis* var. *africana* Hindak	Chlorophyta
6. *Scenedesmus hortobagyi* Philipose	Chlorophyta
7. *Oocystis nata*	Chlorophyta
8. *Phacotus lenticularis* Ehrenberg	Chlorophyta
9. *Phacotus* sp.	

Plate-23

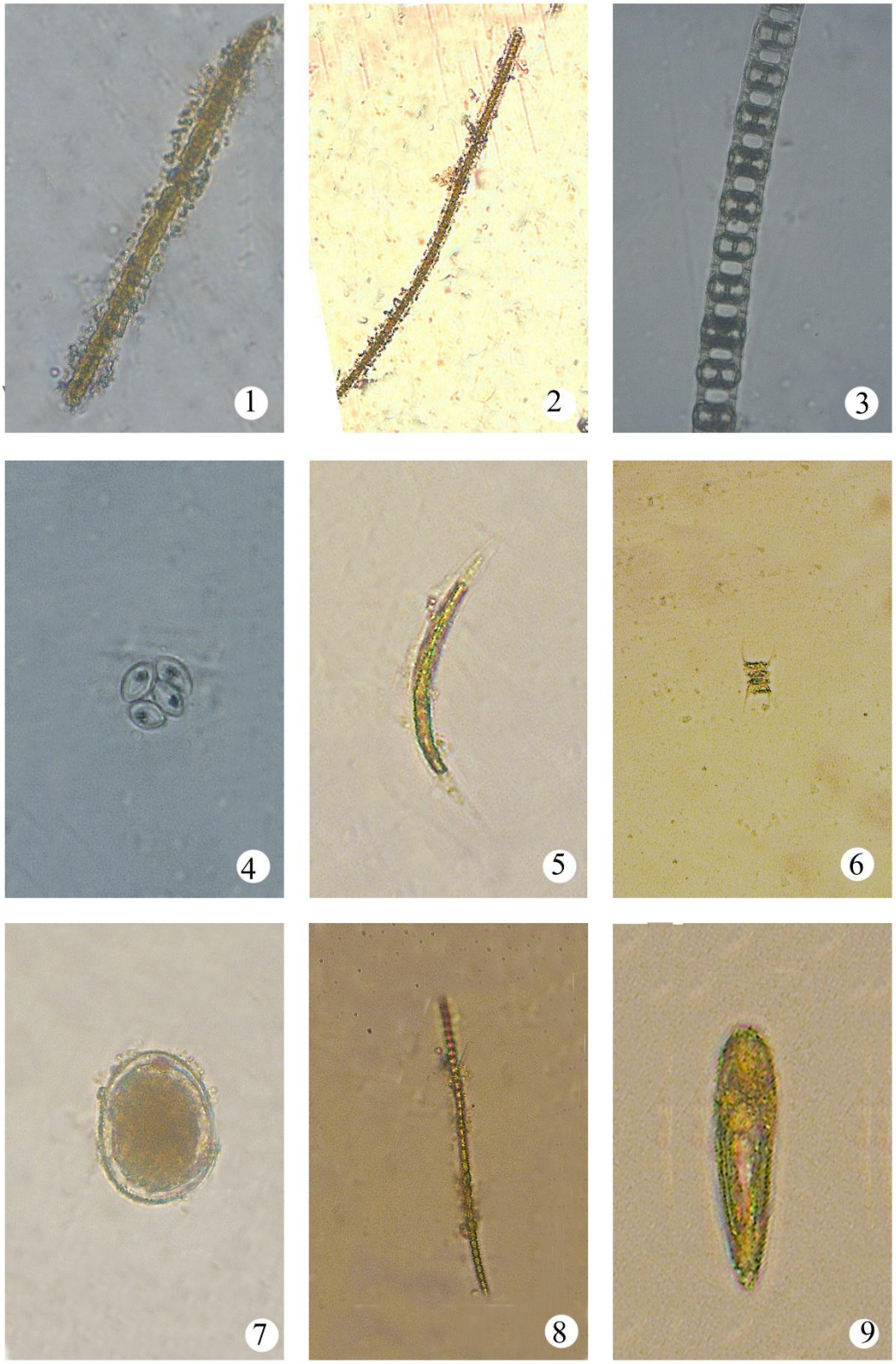


Plate-24

Name of the organism	Name of the major Group
1. *Synedra ulna* var. *aequalis* (Kützing) Brun	Chrysophyta
2. *Melosira granulata* var. *mujanensis* Muzzan	Chrysophyta
3. *Stenopterobia intermedia* F.W. Lewis	Chrysophyta
4. *Surirella robusta* var. *splendid* Ehr	Chrysophyta
5. *Surirella ovata* var. *minuta* Kirchner	Chrysophyta
6. *Synedra goulardii* (Kützing) Frenguelli	Chrysophyta

Plate-24

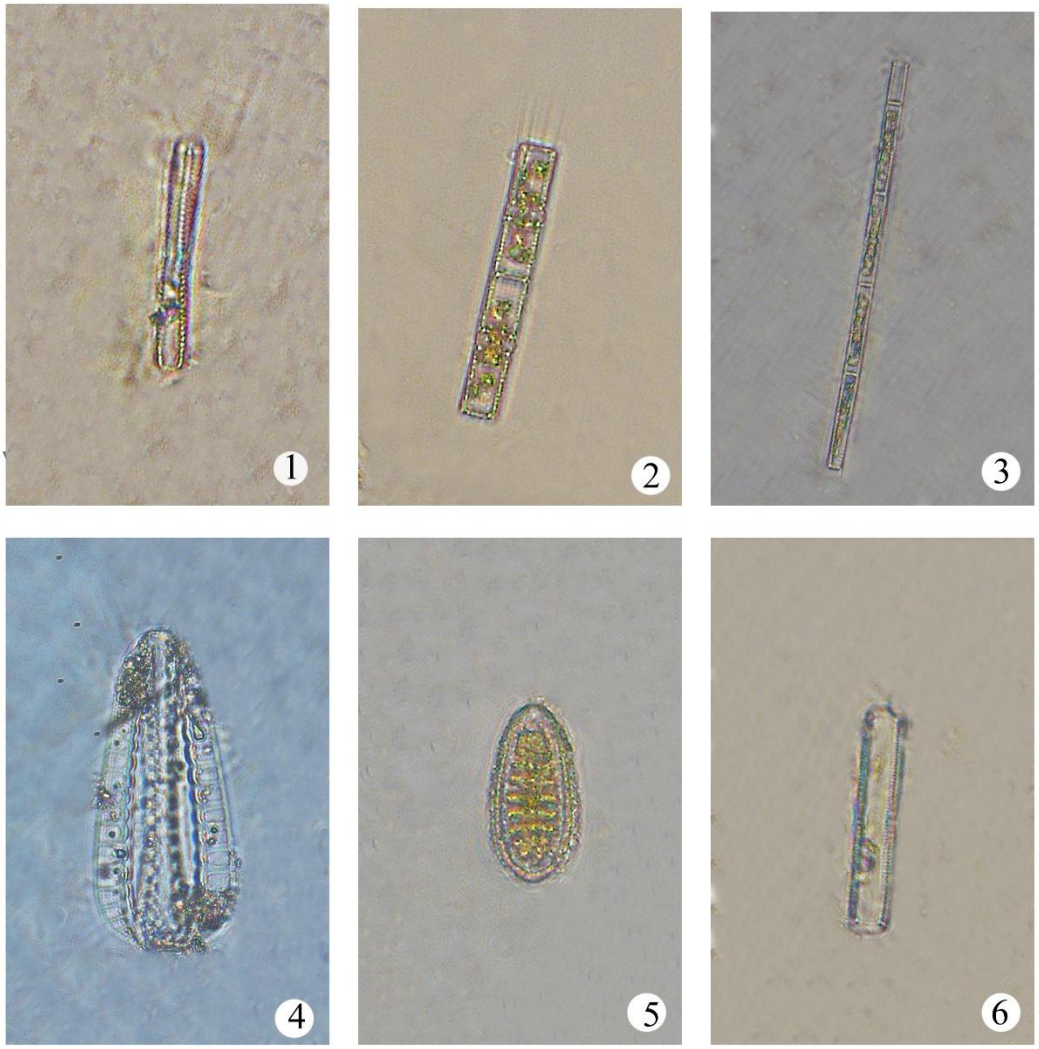


Plate-25

Name of the organism	Name of the major Group
1. *Strombomonas amphoraeformis* Hortob	Euglenophyta
2. *Colacium simplex* Huber-Pestalozzi	Euglenophyta
3. *Euglena* sp.	Euglenophyta
4. *Trachelomonas fukiensis* Skv.	Euglenophyta
5. *Cyclodiopsis acus* Flagelles	Euglenophyta
6. *Trachelomonas hispida* var. *crenulatocollis* Lemmermann	Euglenophyta
7. *Trachelomonas oviformis* Drez.	Euglenophyta
8. *Trachelomonas komarovii* var. *punctata*	Euglenophyta
9. *Strombomonas verrucosa* var. *conspersa* (Swir.)Deflandre	Euglenophyta

Plate-25

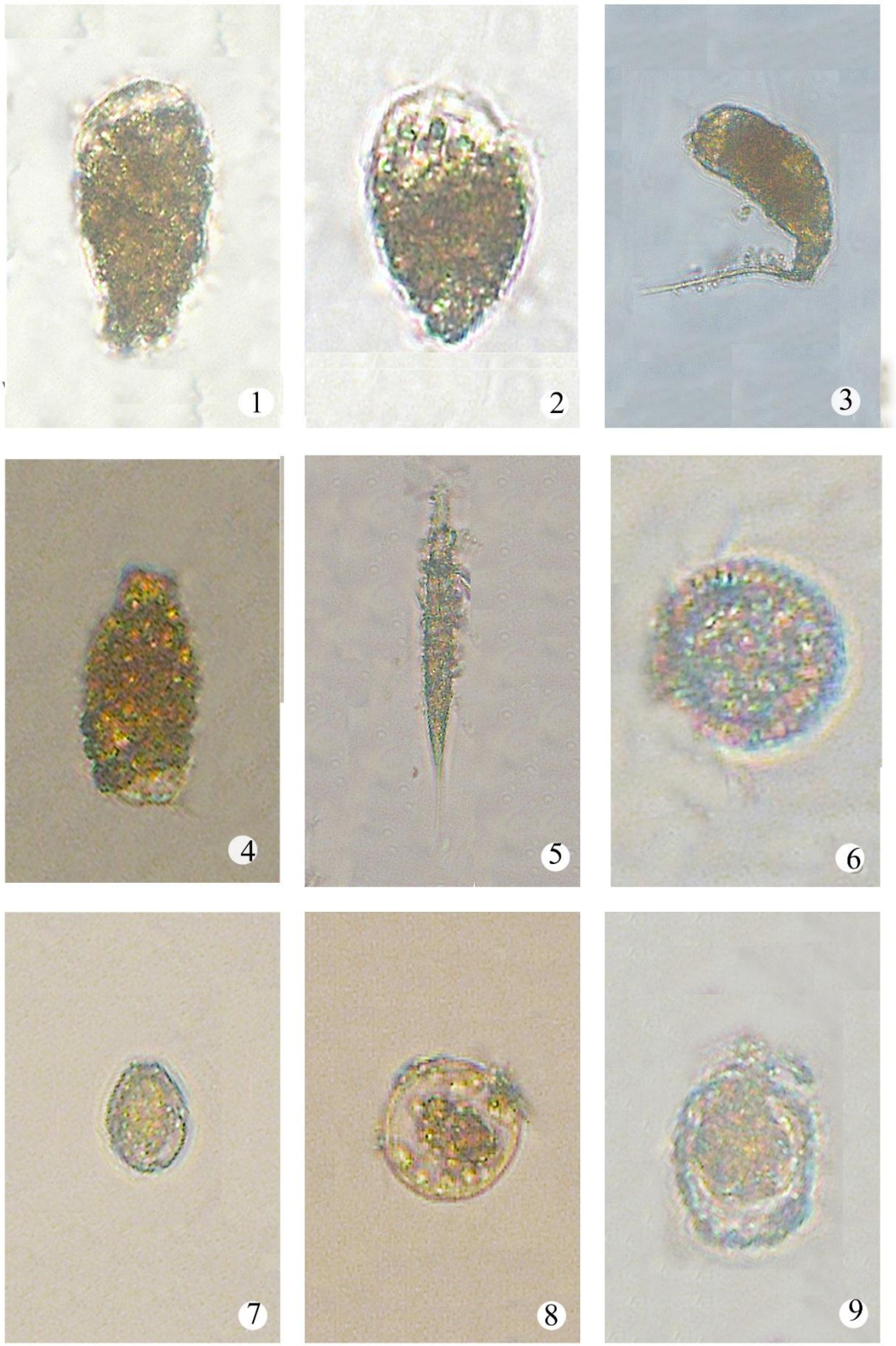


Plate-26

Name of the organism	Name of the major Group
1. *Cephalomonas granulata* Higinbotam	Cryptophyta
2. *Cephalomonas granulata* var.	Cryptophyta
3. *Cryptomonas parapyrenoitifera*	Cryptophyta
4. *Cryptomonas platyuris* Skuja	Cryptophyta
5. *Cryptomonas platyuris*	Cryptophyta
6. *Cryptomonas marssonii* var. Skuja	Cryptophyta
7. *Cryptomonas rufescens* Skuja	Cryptophyta

Plate-26

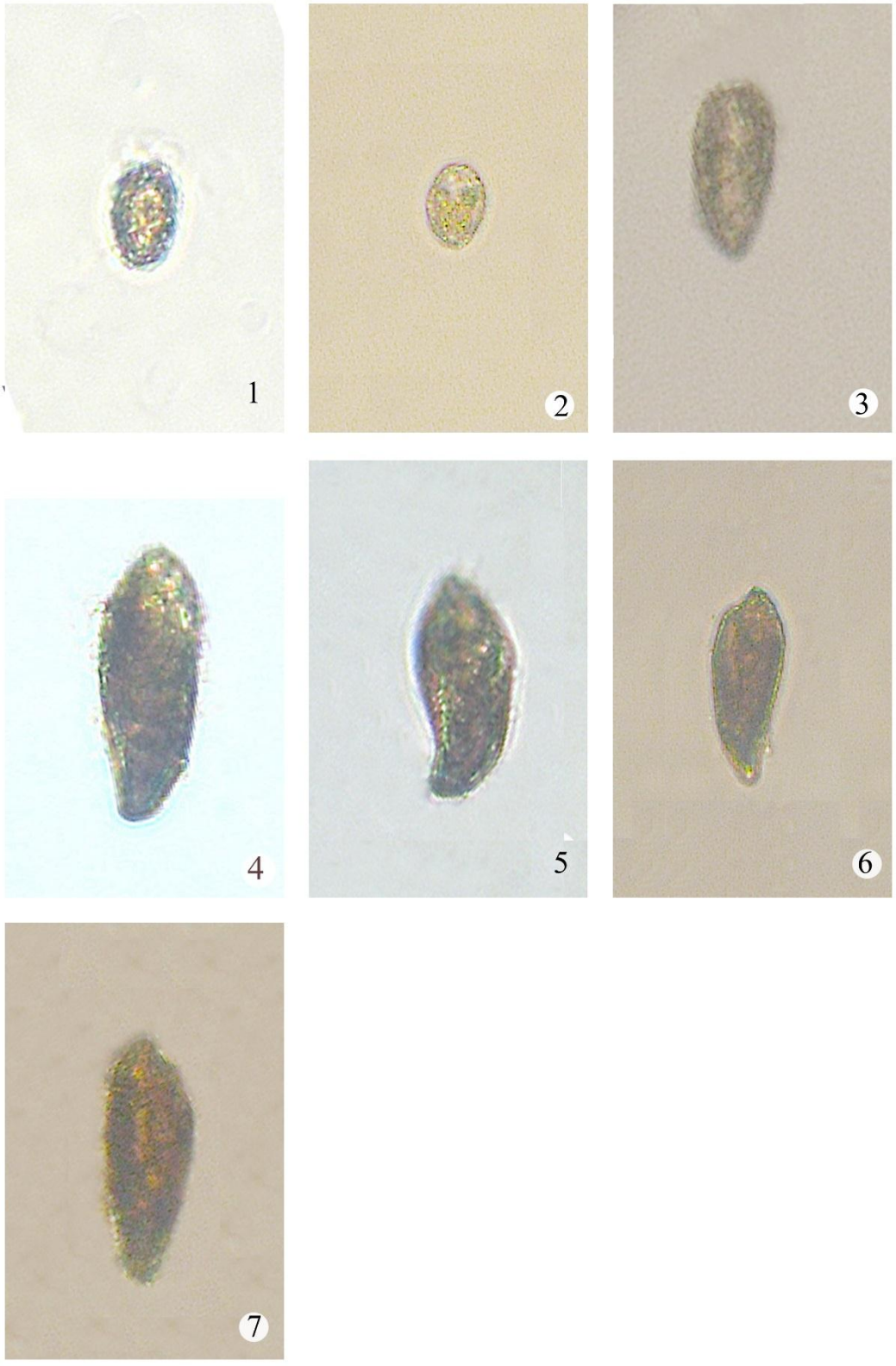


Plate-27

New reports of Division Dinophyta

1-4. *Peridinium lomnicki* Woloszynska S (Developing stage)

5-6. *Peridinium lomnicki* (Mature stage)

7. *Peridinium palustre* Er.Lindemann

Plate-27

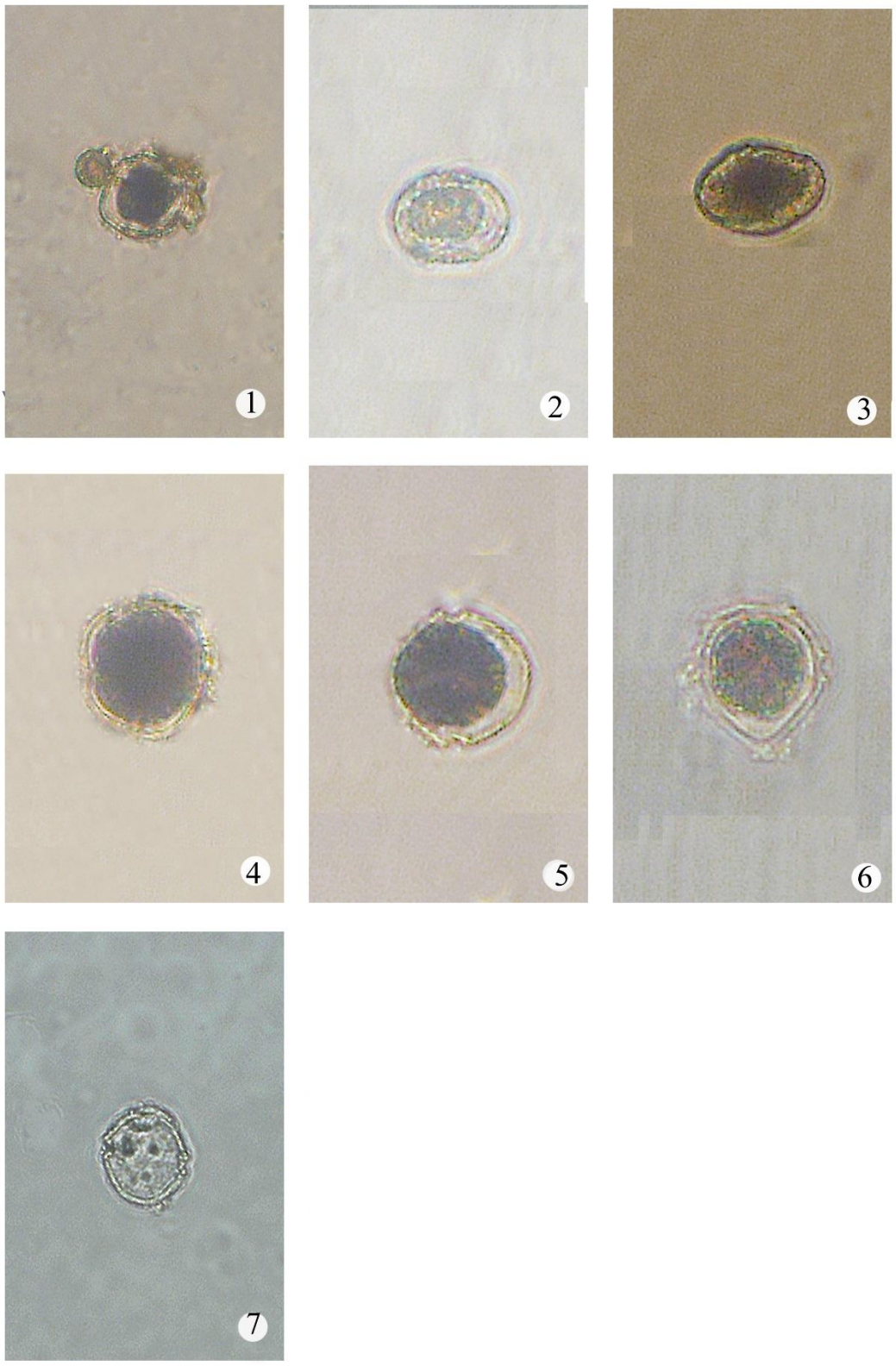


Plate-28

1. *Sesbania bispinosa*

2. *Ipomoea aquatica*

3. Barringtonia acutangula

4. Ottelia alismoides

5. Oryza sativa

6. Axonopus compressus

Plate-28

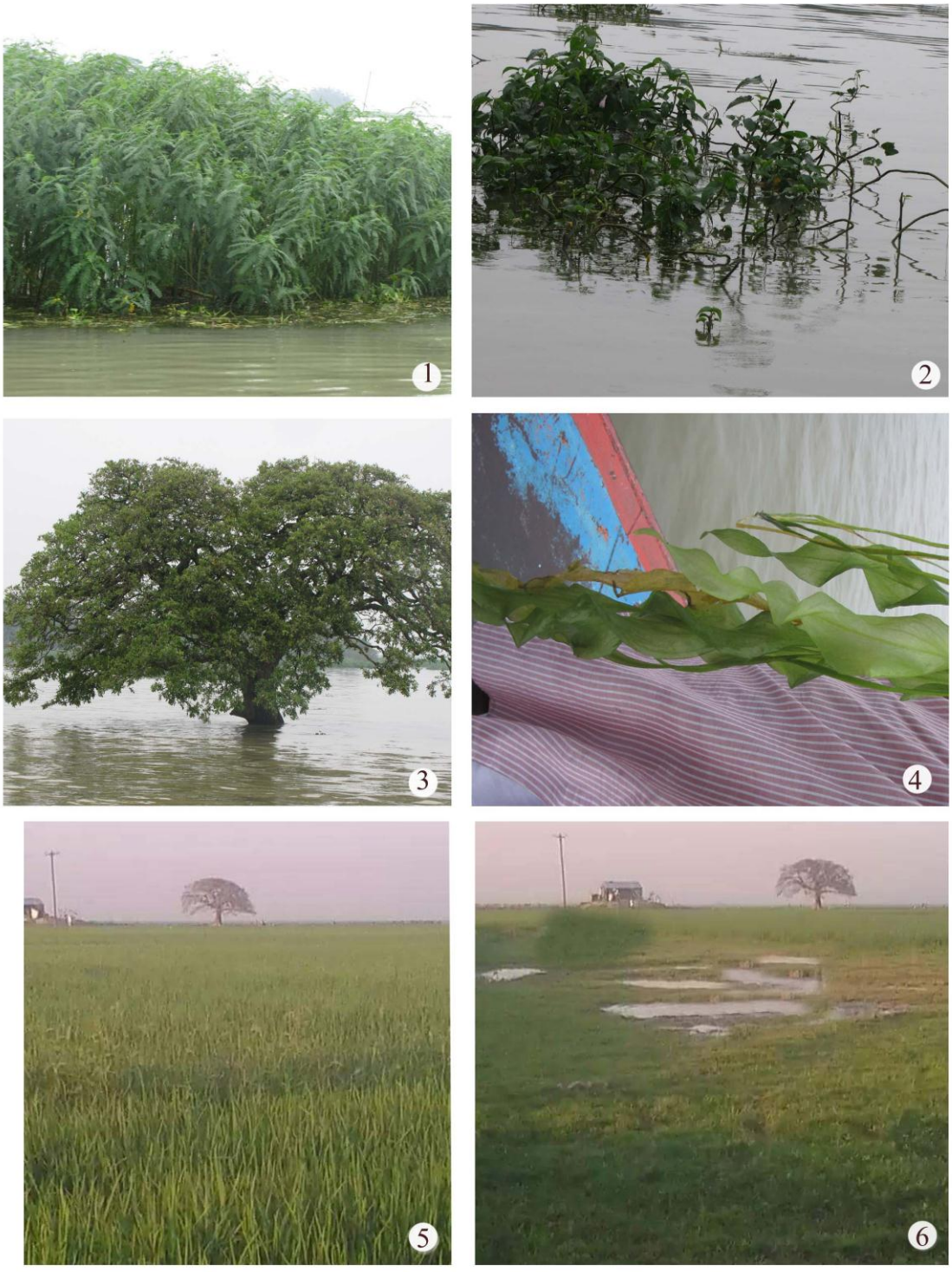


Plate-29

1. *Enhydra fluctuans*

2. *Pistia stratiotis*

3. *Eichhornia crassipes*

4. *Ludwigia adscendens*

5. *Cyperus rotundus*

6. *Alternanthera sessilis*

Plate-29

Plate-30

1. *Pseudoraphis spinescens*

2. *Cperus* sp.

3. *Cyperus tegetiformis* Roxb.

4. *Ipomoea aquatic* Foxb.

5. *Alternanthera philoxeroides* Mart.

6. *Luidwigia adscendens*

Plate-30

Plate-31

1. *Cynodon* sp.

2. *Blyxa auberti* Rich

3. Colocaisa esculenta

4. Polygonum sp.

5. Oryza sativa

6. Cynodon dactylon

Plate-31

Plate-32

1. *Polygonum tomentosum* Willd.
2. *Enhydra fluctuans* Lour.
3. Unknown sp.
4. *Spirodela polyrhiza* (L.) Schield.
5. *Azolla microphylla* Bail.

Plate-32

References

Adak MD, Adak S and Purohit KM 2002. Studies on water quality of village Timjore, Orissa: Part-I. Physico-chemical parameters, Indian J. of Envntl. Prtcn. **22**(9): 1040-1046.

Adoni AD 1985. Work Book on Limnology. Bandna Printing Service, New Delhi: 216 pp.

Ahmed ZU, Begum ZNT, Hassan MA, Khondker M, Kabir SMH, Ahmed M, Ahmed ATA, Rahman AKA and Haque EU (eds.) 2008. Encyclopedia of Flora and Fauna of Bangladesh, **vol.3.** Algae, Chlorophyta (Aphanochaetaceae- Zygnemataceae). Asiatic Society of Bangladesh, Dhaka. pp.812.

Ahmed ZU, Khondker M, Begum ZNT, Hassan MA, Kabir SMH, Ahmed M, Ahmed ATA, Rahman AKA and Haque EU (eds.) 2009. Encyclopedia of Flora and Fauna of Bangladesh, **vol.4.** Algae, Charophyta-Rhodophyta. Asiatic Society of Bangladesh, Dhaka. pp. 543.

Ahmad U, Parveen S, Hasan T and Bhat BN 2015. Diversity of Aquatic macrophytes of Aligarh, U.P. India. International Journal of Current Microbiology and Applied Sciences. **4**(4): 494-505.

Alfasane MA and Khondker M 2007. New records of phytoplankton for Bangladesh. *Phacus, Lepocinclis* and *Pteromonas.* Bangladesh J. Plant Taxon. **14**(2): 167- 169.

Alfasane MA, Khondker M, Islam MS and Bhuiyan MAH 2010. Egeria densa Planchón: a new report for Hydrocharitaceae of Bangladesh. Bangladesh J. Plant Taxon. **17**(2): 209-213.

Alfasane MA, Gani MA, Islam MS and Khondker M 2012 (June). Limnology of lake Ashura, Dinajpur, Bangladesh. Bangladesh J. Bot. **41**(1): 43-48.

Alikunhi KH 1957. Fish culture in India. Farm Bulletin Indian Council for Agricultural Research. **20**: 1-150.

Ameen M, Begum ZNT, Ali S, Rahman MK and Roy TK 1986. A comparative limnological study of two fish ponds in Raipur. Dhaka Univ. Stud. Pt E. **1**:25- 34.

APHA (American Public Health Association) 1992.Standard methods for the examination of water and waste water. 18th ed. American Public Health Association, Washington, D.C. **18**: 132.

Armitage PD,Moss D,Wright JF,Furse MT 1983. The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Wat. Res. 17:333-347.

Aziz A and Ara M 2000. Diatom taxa from deepwater rice fields at Tangail, Bangladesh. Bangladesh J. Plant Taxon. **7**(1): 7-13.

Aziz A and Tanbir M 2003. Algal flora of some northern districts of Bangladesh. Bangladesh J. Plant Taxon. **10**(1): 63-78.

Aziz A and Yasmin N 1997. Algal flora of Madhabkunda Waterfall area in Moulvibazar, Bangladesh. I. Blue-green and red algae. Bangladesh J. Bot. **26** (1): 9-18.

Aziz A and Yasmin N 1997b. Algal flora of Madhabkunda Waterfall Moulvibazar, Bangladesh. II. Green algae and diatoms. Bangladesh J. Bot. **26** (2):177-186.

Bandela NN, Vaidya DP, Lomte VS and Shivanikar SV 1999. The distribution pattern of phosphate and nitrogen forms and their interrelationships in Barul Dam water, Poll. Res. **18** (4): 411-414.

BHWDB (Bangladesh Haor and Wetland Development Board), Master Plan of Haor Area, 2012

Barbour, M. T., Gerritsen, B. D. Snyder and J.B. Stribling 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, Benthic Macroinvertebrates and Fish.Second Edition. EPA/841-B-98-010. USEPA Office of Water. Washington. D.C.

Bartram J and Balance R 1996. Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. UNEP and WHO, Geneva.

Begum ZNT 2008. A taxonomic account on the phytoplankton of a pond receivingtextile industrial effluents. Bangladesh J. Plant Taxon. **15**(2):129-139.

Begum ZNT 2009. A taxonomic account on the phytoplankton of a pond receivingtextile industrial effluents ll Euglenophyceae and Bacillariophyceae. Bangladesh J. Plant Taxon. **16** (1): 9-19.

Bhuiyan MAH, Islam SAMS, Kowsar A, Islam MR, Kakoli SA, Asaduzzaman K and Khondker M 2019. Phytoplankon in relation to water quality of Tanguar Haor ecosystem, Bangladesh:I. Rauar station. Dhaka Univ.J. Biol.Sci.**28**(2): 131-138

Bhuiyan RA 2006. Phytoplankton quality, population dynamics and ecology of *Vibrio* sp. In some ponds of Mathbaria.M.S. Thesis. Department of Botany, University of Dhaka. 68pp.

Birks HJB, Line JM, Juggins S, Stevenson AC and Terbraak CJF 1990. Diatoms and pH reconstruction. Philosophical Transactions of the Royal Society Biological Sciences. **327**(1240): 263-278.

Bogopocam D 1951. Bacillariophyta CCCP, vol., **4**, Cobetckar Hayka, Russia, pp 617

Bohra OP 1976. Some aspects of limnology of Padam Sagar and Rani Sagar. Ph.D. Thesis. University of Jodhpur, Jodhpur.

Boon J, Calow P, Petts GE., 1992. River Conservation and Management. Wiley, Chichester

Boyd CE 1982. Water Quality Management of Pond Fish Culture. Elsevier Science Publisher Company, Amsterdam, Oxford, New York, pp: 318.

Bourrelly, P. 1968. *Les Algues D'eau Douce. Initiation à la systématique.* Tome II: *Les Algues jaunes et brunes. Chrysophycées, Phéophycées, Xanthophycées et Diatomées. ed.* N. Boubée and Cie, Paris 438 pp.

Brammer H 2002. Land use and land use planning in Bangladesh. University Press Ltd, Dhaka. 482 pp.

Brettum P and Andersen T 2005. The use of phytoplankton as indicators of water quality. NIVA-reports SNO 4818-2004

Carvalho L, Bennion H, Darwell A, Gunn L, Lyle A, Monteith D and Wade M 2002. Physico-chemical conditions for supporting different levels of biological quality for the water framework directive for freshwaters, R and D Technical report: Published by Environmental agency, Rio house waterside Drive, Aztec West, Almondsbury, Bristol.

Chakraborty RD, Roy P and Singh SB 1959. A quantitative study of the plankton and the physico-chemical conditions of the river Jamuna at Allahabad in 1954-55. Indian J. Fish. **6**:186-203.

Chapman D. 1992. Water Quality Assessment; A guide to the use of biota, sediments and water in environmental monitoring. University Press, Cambridge, 585 pp. Dallas

Chesters RK 1980. Biological Monitoring Working Party. The 1978 National Testing Exercise. Department of Environment, Water Data Unit, Technical Memorandum 19: 1-37.

Chowdhury SH and Mazumder A 19981. Limnology of Kaptai lake: Physicochemical features, Bangladesh J. Zool. **9**: 59-72.

Cook CDK 1990- Aquatic Plant Book. SPB Academic Publishing: 228 pp.

DAE 2003. Annual Report: 2002–2003. Department of Agricultural Extension, Kishoregonj.

DAE 2010. Annual Report: 200 –2010. Department of Agricultural Extension, Kishoregonj.

Day SA, Wickham RP, Entwisle TJ and Tyler PA 1995. Bibliographic check-list of non- marine algae in Australia. Flora of Australia Supplementary Series. 4: vii + 276.

Dekha U and Sarma SK 2014. Present status of aquatic macrophytes of the wetlands of Nalbari district of Assam, India. Asian Journal of Plant Science and Research 4(3):67-75.

Desikachary TV 1959. Cyanophyta. Indian Council of Agric. Research, New Delhi. pp. 686.

Dennison, Willium & Orth, Robert & Moore, Kenneth & Stevenson, John & Carter, Virginia & Kollar, Stan & Bergstrom, Peter & Batiuk,Richard 1993. Assessing Water Quality with Submerged Aquatic Vegetation. BioScience. 43: 86-94.

Dillard GE 1989a Freshwater Algae of the Southeastern United States. Part 1. Chlorophyceae: Volvocales, Tetrasporales and Chlorococcales. Bibl. Phycol. Bd. **81**. J. Cramer, Berlin. 1-202 pp. +37 pls.

Dillard GE 2000. Feshwater Algae of the Southeastern United States. Part 7. Pigmented Euglenophyceae. Bibl. Phycol. Bd. 106. J. Cramer, Berlin, Stuttgart. 135 pp.+20 pls.

Dillard GE 2007. Freshwater algae of the southeastern United States Part 8. Chrysophyceae, Xanthophyceae, Cryptophyceae and Dinophyceae. *Bibliotheca Phycologica* 1**12**(i-vi): 1-127, 22 pls.

DoF 1996. Technologies and Management for Fisheries Development Fisheries Fortnight- Compendium Ramna, Dhaka. pp. 21-148.

Dokulil M, Bauer K and Silva I 1983. An assessment of the phytoplankton biomass and primary productivity of Parakrama Samudra, a shallow man-made lake in Sri Lanka. **In** : Schiemer, F. (ed.), Limnology of Parakrama Samudra-Sri Lanka. Dev. Hydrobiol. **12**:70-75.

Dwivedi, BK and Pandey GC 2002. Physicochemical factors and algal diversity of two ponds, (Girija Kund and Maqubara Pond), Faizabad. Poll. Res. **21**: 361-370.

ECR (Environment Conservation Regulaion), 1997. Government of People's Republic of Bangladesh.

Egge JK and Aksnes DL 1992. Silicate as regulating nutrient in phytoplankton competition, Mar. Ecol. Prog. Ser. **83**: 281-289.

EPA US 2012. 2012 National Lakes Assessment Field Operations Manual EPA 841B-11-003. United States Environmental Protection Agency, Washington, DC

EQS (Environmental Quality Standard), 1997. Bangladesh Gazette, registered nr. DA-1, Ministry of Environment, Government of Bangladesh

Fassett NC 1957-A Manual of Aquatic Plants. The University of Wisconsin Press (Ltd.), London.

Flores E and Wolk CP 1986. Production by filamentous, nitrogen-fixing cyanobacteria of a bacteria and of other antibiotics that kill related strains. *Archives of Microbiology* **145**: 215-219.

Germain H 1981. Flora Des Diatomees, Diatomophyceaes, Soc. Nouv. Des. Edin. Boubee. Paris. 444 pp.

Gojdics M 1953. The Genus *Euglena*. The Univ. Wisconsin Press, Madison. 268 pp. +39 pls.

Golterman HL, Clymo RS and Ohnstad MAM. 1978. Methods for physical and chemical analysis of freshwaters. IBP Handbook, No. 8. Oxford Blackwell. 213 pp.

Halvorsen G 2004. Some physical and chemical characteristics of Lake Atnsjoen, Hydrobiologia 521, pp. 129-140.

Hannan H 1979. Chemical modification in reservoir regulated streams. In the ecology of regulated streams (Edward JW and Stanford JA). Plenum corporation publication. 75-94.

Hasan MK, Hasan MK and Hossain A 2013. A comparative study of water quality in the peripheral rivers of Dhaka city. Dhaka Univ. J. Biol. Sci. **22**(2): 127-136.

Helm MM, Bourne and A. Lovatelli 2004. Hatchery Culture of Bivalves: A Practical Manual . FAO Fisheries Technical Paper Number 471. Rome, Italy. 200 pp

Holm-Hansen O and Riemann B 1978. Chlorophyll *a* determination: Improvement in methodology. Oikos **30**: 438-447.

Hornstrom E, Ekstrom C, Froberg E and Ek J 1993. Plankton and chemical physical development in 6 Swedish west–coast lakes under acidic and limed conditions, Canadian J. of Fisheries and Aquatic sciences **50**:688-702.

Huber-Pestalozzi GH 1955. Das Phytoplankton des Süßswassers. Systematik und Biologie. Euglenophyceen E. Schweizerb. Verlagsb. (Nägele u. Obermiller), Stuttgart, Germany. pp. 606+ Pls. 1-114.

Huber-Pestalozzi GH 1961. Das Phytoplankton des Süßswassers. Systematik und Biologie. 5. Teil: Chlorophyceae (Grünalgen), Ordnung: Volvocales. E. Schweizerb. Verlagsb. (Nägele u. Obermiller), Stuttgart, Germany. pp. 744 + Pls. 157.

Huber-Pestalozzi GH 1968. Das Phytoplankton des Süßswassers. Systematik und Biologie. 3. Teil: Cryptophyceae, Chloromonadophyceae Dinophyceae E. Schweizerb. Verlagsb. (Nägele u. Obermiller), Stuttgart, Germany. pp. 322.

Huber-Pestalozzi GH 1983. Das Phytoplankton des Süßswassers. Systematik und Biologie. 7. Teil: 1 Hälfte Chlorophyceae Schweizerb. Verlagsb. (Nägele u. Obermiller), Stuttgart, Germany. pp. 1044.

Hustedt F 1930. Bacillariophyta (Diatomeae) Zweite Auflage. In: *Die Süsswasser-Flora Mitteleuropas. Heft 10*. (Pascher, A. Eds), pp. [i]-vii, [1]-466. Jena: Verlag von Gustav Fischer.

Hutchinson GE 1957. A treatise on limnology Vol. II. Introduction to lake biology and limnoplankton. Weley. New York. pp. 115

Imhoff KR and Alberrecht D 1975. Oxygen dynamics in the impounded lower Ruh River programme. Water technology 7 (314). 505-518.

Islam AKMN 1969b. Some rare planktonic green algae found in East Pakistan. Pakistan J. Botany. **1**: 19-32.

Islam AKMN 1974. Preliminary studies on the food of some fish. Dacca Univ. Stud. Part B. **22**(1): 47-51.

Islam AKMN, Khondker M and Haque S 1991. Euglenoid algae of fourpolluted ponds in and around Dhaka City. Bangladesh J. Bot. **20**: 7-15.

Islam AKMN and Akter N 1999. Desmids of Chittagong, Bangladesh-Part 2: *Closterium, Docidium, Netrium, Pleurotaenium* and *Staurastrum*. Bangladesh J. Plant Taxon. **6** (1): 19-30.

Islam AKMN and Akter N 2004. Desmids of some selected areas of Bangladesh: 2. Genus *Staurastrum* Meyen. Bangladesh J. Plant Taxon. **11**(2): 15-28.

Islam AKMN and Alfasane MA 2001b. New records of some green planktonic algae for Bangladesh: *Phacotus, Planktosphaeria* and *Nephrochlamys*. Bangladesh J. Taxon. **8**(2): 51-56.

Islam AKMN and Alfasane MA 2002. Euglenophyceae from Barisal district, Bangladesh: I. Genus *Phacus.* Bangladesh J. Plant Taxon. **9** (2): 3-18.

Islam AKMN and Alfasane MA 2003. Euglenophyceae from Barisal district, Bangladesh. *Lepocinclis, Strombomonas and Trachelomonas*. Bangladesh J. Plant Taxon. **10**(1):15-26.

Islam AKMN and Alfasane MA 2004. Euglenophyceae from Barisal district, Bangladesh: Genus *Trachelomonas* Ehr. Bangladesh J. Plant Taxon. **11** (2): 33-38.

Islam AKMN and Aziz A 1975. Study of marine phytoplankton from the north eastern Bay of Bengal, Bangladesh. Bangladesh J. Bot. **4**(1-2):1-32.

Islam AKMN and Aziz A 1977. Studies on the phytoplankton of the Karnaphuli river estuary. *K Bangladesh Acad. Sci.* **1**(2): 141-154.

Islam AKMN and Aziz A 1979. Algal flora of Moheshkhali Island, Bangladesh. *The Dacca Univ. Stud.* Part B. **27** (2): 105-122.

Islam AKMN and Begum ZNT 1970. Studies on the phytoplankton of Dacca district. J. Asiatic Soc. Pakistan **15**: 227-271.

Islam AKMN and Chowdhury AR 1979. Hydrobiological studies of Dhanmondi lake, Dacca. II. Phytoplankton. J. Asiatic Soc. Bangladesh (Sc.) **5**: 47-57.

Islam AKMN and Haroon AKY 1975. Limnological studies of the river Buriganga II. Biological Aspect. Dacca Univ. Stud. Part B. **23**(1): 25-44.

Islam AKMN and Haroon AKY 1980. Desmids of Bangladesh. Int. Rev. der ges. Hydrobiol. **65**(4): 543-598.

Islam AKMN and Hossain SKT 1978. Algal flora of the ablution tanks of mosques in Dacca city. J. Asiatic Soc. Bangladesh (Sci.). **3**(2): 103-113.

Islam AKMN and Hossain M 1979. Preliminary studies on the algal flora of Bagerhat, Khulna. J. Asiatic Soc. Bangladesh (Sci.). **5**(1): 37-45.

Islam AKMN and Irfanullah HM 2000. New records of eleven algal taxa for Bangladesh. Bangladesh J. Bot. **29**(2): 115-120.

Islam AKMN and Irfanullah HM 2005. Hydrobiological studies within the tea gardens at Srimangal, Bangladesh. V. Desmids (*Euastrum, Micrasterias, Actinotaenium* and *Cosmarium*). Bangladesh J. Plant Taxon. **13**(1): 1-20.

Islam AKMN and Irfanullah HM 2006. Hydrobiological studies within the tea gardens at Srimangal, Bangladesh. II. Algal flora (excluding Chlorophyceae). Bangladesh J. Plant Taxon. **12**(1): 33-52.

Islam AKMN and Khatun M 1966. Preliminary studies on the phytoplanktons of polluted waters. Sci. Res., East Reg. lab., Pakistan. **3**(2): 94-109.

Islam AKMN and Khondker M 1981. Euglenophyta of Bangladesh l. Genus *Trachelomonas*. Her. Int. Revue. ges. Hydrobiol. **66** (1): 109-125.

Islam AKMN and Khondker M 1991. Preliminary limnology investigations of some polluted waters covered by duckweeds. Bangladesh J. Bot. **12**:70-75.

Islam AKMN and Khondker M 1993. Some unicellular flagellate algae from Bangladesh. J. Asiat. Soc. Bangladesh (Sci.). **19**(2): 75-79.

Islam AKMN and Mendes F 1976. Limnological studies of a *Jheel* in Sher-e-Bangla Nagar, Dacca, Dacca Univ. Stud. Pt. B. **24**: 63-71.

Islam AKMN and Moniruzzaman K 1981. Contribution to the study on Euglenophyta. I. Genus *Trachelomonas* Ehrenberg. Int. Rev. der Gesamt. Hydrobiol. **66**(1): 109-125.

Islam AKMN and Paul N 1978. Hydrobiological studies of the Haor Hakaluki in Sylhet. J. Asiatic Soc. Bangladesh (Sci.). **3**(2): 83-91.

Islam AKM, Rahman Mand Chowdhury AR 1979. Hydrobiological studies of Dhanmondi Lake, Dhaka. 1. Macrophytes and benthic flora. J. Asiatic Soc. Bangladesh (Sci.), **5**:59-75.

Islam AKMN and Saha JK 1975. Limnological studies of the Ramna lake at Dacca. Univ. Stud. Pt. B. **23**: 39-46.

Islam AKMN and Uddin MA 1969. A preliminary report on the phytoplankton and other algae of Chittagong Hill-Tracts. J. Asiat. Soc. Pak. **14**(3): 353-363+13 pls.

Islam AKMN and Uddin MA 1978a. Blue-green algae from Dacca, Bangladesh. II. Oscillatoriaceae. Dacca. Univ. Stid. Part B. **26**(1): 73-84.

Islam AKMN and Zaman KM 1975. Limnological studies of the river Buriganga. III. Biological Aspect. *J. Asiatic Soc. Bangladesh (Sci.)*. **1**(1): 45-65.

Islam MS, Alfasane MA and Khondker M 2012. Planktonic primary productivity of a eutrophic water body of Dhaka metropolis, Bangladesh. Bangladesh J. Bot. **41**(2): 135-142.

Islam MS, Rehnuma M, Tithi SS and Sarkar L 2015. Investigation of Water Quality Parameters from Ramna, Crescent and Htirjheel Lakes in Dhaka City. *J. Environ. Sci. & Natural Resources.* **8** (1): 1-5.

Islam MT, Rahman MM and Mahmud H 2014. Physicochemical attributes of water of Hakaluki Haor, Sylhet, Bangladesh. Jahangirnagar University J. Biol. Sci. 3(2):67-72.

IUCN Bangladesh 2005. Hydro-meteorological characteristics of *Hakaluki Haor*. IUCN Bangladesh Country Office, Dhaka, Bangladesh 10: 91.

Iyenger MOP and Desikachary TV 1981. Volvocales. Indian Council of Agricultural Research, New Delhi. 532 pp.

Jameel AA 1998. Physico-chemical studies in vyakandan channel water of river Cauvery. Poll. Res., **17**: 111-114.

Kabir AKMN and Naser MN 2011. Physico-chemical aspects of chandbill oxbow lake of Meherpur, Bangladesh. Dhaka Univ. J. Biol. Sci. **20**(1): 31- 39.

Kataria HC, Iqubal SA and Sandilya AK 1995. Limno-chemical studies of Tawa Reservoir, Indian J. of Envtl Prtcn. 16 (11), pp. 841-846.

Kempster PL, Van Vliet HR and Kuhn A 1997. The need for guide to bridge the gap between ideal drinking water quality and quality which is practicable, available and acceptable. Water South Africa, **23**(20): 163–167.

Kerketta P, Boxla SL, Gora RH, Kumari S and Roushan RK 2013. Analysis of physic-chemical properties and heavy metals in drinking water from different sources in and around Ranchi, Jharkhand, India, Vet World. **6**(7): 370-375.

Khan MS and Halim M 1987. Aquatic angiosperms of Bangladesh. Bangladesh National Herbarim, BARC, Dhaka, pp.120.

Khan MNH, Mia MY and Hossain MR 2012. Impacts of Flood on Crop Production in *Haor* Areas of Two Upazillas in Kishoregonj. *J. Environ. Sci. and Natural Resources 5*(1): 193 – 198, ISSN 1999-7361.

Khair A and Chowdhury SC 1983. The Phytoplankton members of Kaptai Lake, Chittagong Hill-Tracts, II. Bacillariophyceae. Chittagong Univ. Stud. Part II. **7**(1): 77-82.

Khondker M, Islam AKMN and Islam R 1988. Studies on the primary productivity of Dhanmondi lake. Dhaka University Studies, Part E, **3**(1): 15- 21.

Khondker M, Alfasane MA, Islam MS, Bhuiyan MAH and Gani MA 2010. Limnology of Lake Bogakain, Bandarban. Bangladesh J. Bot. **39**(2):153-159.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2006. New records of phytoplankton for Bangladesh. 1. Cyanophyceae. *Bangladesh J. Bot.* **35** (2): 173-179.

Khondker M, Bhuiyan RA,Yeasmin J,Alam M,Sack RB, Huq A and Colwell RR 2006b. New records of phytoplankton for Bangladesh. 2. Cryptophyceae and Synurophyceae. Bangladesh J. Bot. **36** (1):53-59.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2007a. New records of phytoplankton for Bangladesh. 3. Volvocales. Bangladesh J. Plant Taxon. **14** (1): 1-12.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2007b. New records of phytoplankton for Bangladesh. 4. Chlorococcales.Bangladesh J. Plant Taxon. **14** (2): 83-91.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2008a. New records of phytoplankton for Bangladesh. 5. *Euglena*, *Euglenocapsa*. Bangladesh J. Plant Taxon. **15** (1): 39-46.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2008b. New records of phytoplankton for Bangladesh. 7. *Phacus*. Bangladesh J. Plant Taxon. **37** (1):83-89.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2008c. New records of phytoplankton for Bangladesh. 4. *Trachelomonas* Ehr. Bangladesh J. Plant Bot. **37** (2):133-139.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2008d. New records of phytoplankton for Bangladesh. 6. *LEPOCINCLIS* PETRY, *STROMBOMONAS* DEFL., *ASTASIA* DUJARDIN, *MENODIUM* PETRY Bangladesh J. Plant Taxon. **15** (2):107-114.

Khondker M, Bhuiyan RA, Yeasmin J, Alam M, Sack RB, Huq A and Colwell RR 2009. New records of phytoplankton for Bangladesh. Some rare and a new species of phytoplankton for Bangladesh. Bangladesh J. Plant Taxon. **16**(1): (inpress).

Khondker M, Islam AKMN and Islam R 1988 (January). Studies on the primary productivity of Dhanmondi lake. Dhaka University Studies, Part E, **3**(1): 15- 21.

Khondker M and Parveen L 1992. Study on the physical and chemical limnology of a shallow, hypertrophic artificial lake. Bangladesh J. Sci. Res. **10**(1): 9-16.

Khondker M and Parveen L 1993. Daily rate of primary productivity in hypertrophic Dhanmondi lake. Publ. pp. 181-191.

Kishoregonj Zill 1993. History of Kishoregonj, Kishoregonj Zilla, Itihas Pronayon Committee/ Prokalpa, Kishoregonj.

Kitano M, Matsukawa R and Karube I 1997. Changes in eicosapentaenoic acid content in Navicula saprophila, Rhodomonas salina and Nitzschia sp. Undermixotrophic conditions, J. of Applied Phycol. **9:**559-563.

Klug JL, Fischer JM, Ives AR and Dennis B 2000.Compensatory dynamics in planktonic community responses to pH perturbations, Ecology **81**(2): 387-398.

Legrand C, Regefors K, Fistarol GO and Granèli E 2003. Allelopathy in phytoplankton-biochemical, ecological and evolutionary aspects. *Phycologia* **42**: 406-419.

Ling HU and Tyler PA 2000. *Australian Freshwater Algae* (exclusive of diatoms). J. Cramer, Gebrüder Borntraeger Verlagsbuchh and lung, Berlin.643pp.+159pls.

MacCutcheon SC, Martin JL and Barnwell TO Jr 1983. Water quality. In Handbook of hydrology. New York: McGraw-Hill.

Mackereth FJH, Heron J and Talling JF 1978. Water analysis: some revised methods for limnologists. Freshwater Biol. Assoc. Publ. No. 36 pp. 120.

Mahmood N 1986. Hydrobiology of Kaptai Reservoir. Final Report: FAO/UNDP Contract No. DP/BGD/79/615-4/FI, 190pp.

Mandal RN, Datta AK, Sarangi N and Mukhopadhyay PK 2011. Diversity of aquatic macrophytes as food and feed components to herbivorous fish – a review. Indian J. Fish. 57(3): 65-73

Marker AFH, Nusch EA, Rai H and Rieman B 1980. The measurement of photosynthetic pigments in freshwaters and standardization of methods: Conclusions and recommendations. Arch. Hydrobiol. Beih. Ergebn. Limnol **14**: 91-106.

Milligan AJ and Morel FMM 2002.A proton buffering role for silicain diatoms, Science 297, pp.1848-1850.

Mishra A and Bhatt V 2008. Physico-chemical and microbiological analysis of underground water in V.V. Nagar and nearby places of Anand district, Gujarat, India. E-J. Chem. **5**(3): 487-492.

Mitsch WJ and Gosselink JG. 2000. *Wetlands*. New York: John Wiley and Sons. 920 pp.

Moed JR and Hallergraeff GM 1978. Some problem in the estimation of chlorophyll *a* and phaeopigment from pre- and post- acidification spectrophotometric measurements. Int. Reveges. Hydrobiol. **63**:787-800.

Mohuya FM, Bhuiyan RA and Hoque S 2010 (January). Heavy metal contamination in Gulshan-Garidhara lake, Dhaka. Dhaka Univ. J. Biol. Sci. **19**(1): 53-61.

Moschini-Carlos V, Pompeo MLM and Henry R 2001. Periphyton on natural substratum in Jurumirim reservoir (Sao Paulo, Brazil): community biomass and primary productivity, International Journal of Ecology and Environmental Sciences **27**: 171-177.

Müller R and Wiedemann F 1955. Die Bestimmung des Nitrats in Wasser. Jahrbuch für Wasserchemie and Wasserreiningungstechnik. Verlag Chemie, Reinbek **12**: 247-271.

Murphy J and Riley JP 1962. A modified single solution method for the determination of phosphate in natural water. Analyt. Chem. Acta. **27**: 31-36.

Murugavel P and Pandian TJ 2000. Effect of altitude on hydrology, productivity and species richness in Kodayar- a tropical peninsular Indian aquatic system, Hydrobiologia 430, pp. 33-57.

Nahar K 2001. Relationships between diatom assemblage of surface sediment and some environmental factors in two wetland ecosystems of Bangladesh. Ph. D. Thesis. Department of Botany. University of Dhaka, Bangladesh. 257pp.

Nasar SAK and Sharma M 1980. Primary productivity in relation to the abiotic factors in a temporary fresh water pond. Acta. Hydrochim. Hydrobiol. **8**: 435-442.

Naser MN, Shafi M, Shah MS and Barua G 1990. Physico-chemical conditions of two catfish rearing ponds at Mymensingh, Bangladesh. J. Asiat. Soc. Bangladesh, Sci. **16**: 91-95.

National web portal of Bangladesh (2017). http://www.bangladesh.gov.bd

NWMP (National Water Management plan) 2004. Bangladesh Water Development Board.

Nusch EA 1980. Comparison of different methods for chlorophyll and phaeopigment determination. Arch. Hydrobiol. Beih. Ergebn. Limnol. **14**: 14-36.

Ojha P and Mandloi AK 2004. Diurnal variation of pH in freshwater fish culture pond, Ecol., Env. and Cons. **10** (1): 85-86.

Openheimer JR, Ahmed MG, Haque KA, Ashraful-ul-Alam AKM, Aziz KMS, Ali S and Haque ASMM 1978. Limnological studies of three ponds in Dacca, Bangladesh J. Fish. **1**: 1-28

Owen RB, Renaut RW, Hover VC, Ashley GM and Muasya AM 2004. Swamps, springs and diatoms: wetlands of the semi-arid Bogoria-Baringo Rift, Kenya, Hydrobiologia 518, pp.59-78.

Paramasivam S and Kannan L 2005. Physicochemical characteristics of Muthupettai Mangrove environment South east coast of India. International J. Ecology and Environmental Sci. **31**: 273-278.

Parveen L 1987. Daily rate of primary productivity and phytoplankton seasonality of Dhanmondi lake in Dhaka. M. Sc. thesis, Department of Botany, Universityof Dhaka, pp.92.

Peeter S and Shannon K 2011. Readdressing Dhaka's Public Water Bodies: A Design Research. See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/265941623.

Pereira AI, Fidalgo ML and Vasconcelos V 2001. Phytoplankton and nutrient dynamics in two ponds of the Esmoriz waste water treatment plant (Northern Portugal). Limnetica **20**(2):245-254.

Petre, 1993. Aquatic weeds and fisheries production in developing regions of the world.

J. Aquat. Plant Manage. 31:5-10

Prescott GW 1982. Algae of the Western Great Lakes Area. Otto Koeltz Sci. Publ., W-Germany. 977pp.

Prins TC, Escaravage V, Wetsteyn LPMJ, Peeters JCH and Smaal AC 1999. Effects of different N-and P-loading on primary and secondary production in an experimental marine ecosystem, Aquatic Ecology **33**: 65-81.

Rabalais N 2002. Nitrogen in Aquatic system, Ambio. **31**(2): 102-112.

Radhika CG, Mini I and Gangadevi T 2004. Studies on abiotic parameters of a tropical fresh waterl ake–Vellayani Lake, Trivandrum, Kerala, Poll. Res **23**(1):49-63.

Rahman MA, Sultana S and Salam MA 2015. Comparative analysis of some water quality parameters of three lakes in Jahangirnagar university campus, Savar, Bangladesh. Bangladesh J. Zool. **43** (2):239-250.

RAJUK (1995a) Dhaka Metropolitan Development Plan, Volume 1. Dhaka.

Ramsar Convention Secretariat, The Ramsar Convention Manual: A Guide to The Convention on Wetlands (Ramsar, Iran, 1971), 6th Edition, 2013

Rao B 1955. On the distribution of algae in a group of a six small ponds. II. Algal periodicity. J. Ecol. **43**: 291-308.

Rast W and Thornton J A 1996. Trends in Eutrophication Research and Control. Hydrol. Proc. **10**: 295.

Razzak NRB, Siddik AZ and Ahmeduzzaman M 2013. Evaluation of Water Quality of Ramna and Gulshan Lakes. International Journal of Environment Monitoring and Analysis. **1**(6): 273-278.

Rengefors K and Legrand C 2001. Toxicity in Peridinium aciculiferum- an adaptive strategy to out-compete other winter phytoplankton? *Limnology & Oceanography* **46**: 1990-1997.

Reynolds CS 1984. The ecology of freshwater phytoplankton. Freshwater Biol. Ass. Cambridge University Press, 384 pp.

Rooney N and Kalff J 2003. Interactions among epilimnetic phosphorus, phytoplankton biomass and bacterioplankton metabolism in lakes of varying submerged macrophyte cover, Hydrobiologia 501, pp. 75-81.

Ruzicka J 1977. Die Desmidiaceen Mitteleuropas. Bd. 1, 1. Lief. E. Schw. Verlagsb., Stuttgar. 291 pp.+ 44 pls.

Sahu K, Mehta A, Singh S and Shukla S 2007. Physico-chemical and Bacteriological Studies of discharge at Sagar, Madhaya Pradesh. Asian J. Exp. Sci. **21**(2):309-314.

Schindler DW 1978. Factors regulating phytoplankton production and standing cropi n the world's freshwaters, Limnol. Oceanogr. **23**:478-456.

Sculthorpe CD 1967. Biology of aquatic vascular plants. Edward Arnold Pub. Ltd., London: 610

SedamkarEandAngadiSB2003.PhysicoChemicalparametersoftwofreshwaterbodies of Gulbarga, India with special reference to phytoplankton, Poll. Res. **22** (3): 411-422.

Siddiqui KU, Ahmed MA, Ahmed ZU, Begum ZNT, Hassan MA, Khondker M, Kabir SMH, Ahmad M, Ahmed ATA Rahman AKA and Haque EU (eds.). 2007. Encyclopedia of Flora and Fauna of Bangladesh, vol. 2. Cyanobacteria, Bacteria and Fungi. Asiatic Society of Bangladesh, Dhaka.

Singh RP and Mathur P 2005. Investigation of variation in Physico-chemical characteristics of a fresh water reservoir of Ajmer city, Rajasthan. Ind. *J. Env. Sci*. **9**: 57-61.

Sing SR and Swarup K 1980. Studies on the primary production of phytoplankton in Suraha lake (Ballia, India). Int. Rev. Ges. Hydrobiol. **65**: 709-717.

Skuja H 1956. Taxonomische und biologische studien über das phytoplankton Schwedischer binnengeswässer. Nova. Acta. Reg. Soc. Sci. Upsaliensis, Ser. 4, **16** (3): 1-404 + pls 1-73.

Smith G 1950. The freshwater algae of the United States. 2nd Ed. McGraw-Hill Book Company, New York, pp. 1-719.

Sreenivasan, A 1970. Limnology of tropical impoundments: a comparative study of the major reservoirs in Madras state, Hydrobiologia 36, pp. 443-469.

Starmach K 1966. Cyanophyta-sinice, Glaucophyta-Glaukofity. Flora Slodkowodna PolskiTom-2. Polska Akademia Nauk, Warszawa. Pp. 806.

Sultana M and Khondker M 2009. Assesment of Phytoplankton primary productivity of two urban pond ecosytems of Bangladesh. Dhaka Univ. J. Biol. Sci. **18**(2):127-135.

Swarnlatha N and Rao NA 1998. Ecological studies of Banjara Lake with reference to water pollution. *J.Env. Biol*. **19**: 179-186.

Takamura NY, Kadono M, Fukushima M, Nakagawa and BO Kim 2003. Effects of aquatic macrophytes on water quality and phytoplankton communities in shallow lakes. *Ecological Research.* 18(4):381-95

Tandon KK and Singh H 1971. Effect of certain physico-chemical factors on the plankton of the Nangal lake. Dept. of Zool., Punjab Univ. Chandigarh, India. Environ. Health **11**:15-25.

National web portal of Bangladesh (2017). http://www.bangladesh.gov.bd

Uddin MJ, Mohiuddin ASM, Hossain STand Hakim A 2013. Eco-environmental Changes of Wetland Resources of Hakaluki haor in Bangladesh Using GIS Technology. J. Biodivers Endanger Species 1(1): 1- 4.

USEPA (United States Environmental Protection Agency) 2000. Drinking Water Quality Standards. United States Environmental Protection Agency. (http:// www. epa. gov/safewater/contaminants/index.html)

Vaas KF and Sachlan M 1955. Limnological studies on diurnal fluctuations in shallow ponds in Indonesia. Verh. Int. Ver. Limnol. **12**: 309-319.

Venkateswarlu V 1969. An ecological study of the river Moosi, Hyderabad (India) with special reference to water pollution. I. Physico-chemical complexes. Hydrobiologia **33**: 117-143.

Vestergaard O and Sand-Jensen K 2000. Alkalinity and trophic state regulate aquatic plant distribution in Danish lakes, Aquatic Botany **67**:85-107.

Vilbaste S and Truu J 2003. Distribution of benthic diatoms in relation to environmental variables in lowland streams, Hydrobiologia 493, pp. 81-93.

Vincent WF 1992. The daily pattern of nitrogen uptake by phytoplankton in dynamicmixed layer environments, Hydrobiologia 238, pp. 37-52.

Wetzel RG and Likens 1979. Limnological analysis. W.B. Saunders Co., Philadelphia, pp. 357.

Wetzel RG 1983. Limnology. 2nd edn. Saunders, Philadelphia, PA, 767 pp.

Wetzel RG 1983. Recommendations for future research on periphyton: Wetzel, R.G.(Ed), Periphyton of freshwater ecosystems, Dr. W. Junk, The Hague, pp. 339-346

Whitton BA and Kelly MG 1995. The Trophic Diatom Index: a new index for monitoring eutrophication in rivers, *J. of Applied phycology* **7**: 433-444

WHO 1984. Guidelines for Drinking Water Quality. World Health Organisation, Geneva.

Wu J 1999. A generic index of diatom assemblages as bionindicator of pollution in the Keelung river of Taiwan, Hydrobiologia 397, pp.79-87.

Yamagishi T 1998. Guide book to Photomicrographs of the freshwater algae. Uchida, Rokakuho, Japan. Pp.132.

Zaman L, Khondker M and Nabi MR 1993. A comparative limnology of three ponds in Jahangirnagar University campus: Physical and chemical aspects. Bangladesh J. Bot. **22**(1): 81-87.

Zelinka M, Marvan P 1961. Zur Prazisierung der biologichen klassifikation des Reinheit fliesssender Gewasser. Arch. Hydrobiol. 57:389-407.

Zimmer KD, MA Hanson MA, Malcolm G Butler 2003. Relationships among nutrients, phytoplankton, macrophytes, and fish in prairie wetlands. Canadian Journal of Fisheries and Aquatic Sciences, 60 (6), 721-730, 10.1139/f03-060

Zingde MD *et al.* 1987. Waste water quality of taal. In: Contribution in marine science. Dr. S. I. Qasim 60th Birthday felicitation volume. National Institute of Oceanography, Goa. pp. 307-318.