PHYTODIVERSITY AND THEIR SEASONAL VARIATIONS IN WETLANDS OF LALMAI HILL AREAS OF COMILLA

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

BY

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DECLARATION

I, do hereby declare that this thesis entitled **“Phytodiversity and their seasonal variations in wetlands of Lalmai Hill areas of Comilla”** 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 anywhere for my academic degree.

December 2021 (**Rauf Ahmed Bhuiyan**)

Certificate

This is to certify that the research work presented in this thesis entitled **'Phytodiversity and their seasonal variations in wetlands of Lalmai Hill areas of Comilla'** has been carried out by **Rauf Ahmed Bhuiyan,** bearing Registration No. 25/2016-2017 under our supervision 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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Author

Dedicated to

The Members of My Family

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LIST OF ABBREVIATION

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

mg	Milligram
mg/l	Milligram per liter
µg/l	Microgram per liter
min	Minutes
h	Hour
µl/l	Microliter
Ml	Milleliter
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
Std	Standard deviation
SPSS	Statistical Package for the Social Sciences
SD	Secchi depth
TDS	Total dissolved solids
Cond	Conductivity

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

ABSTRACT

ABSTRACT

A hydrobiological study on three different water bodies of Lalmai Hill areas of Cumilla was carried out from October 2017-September 2019. In the study, relationships among several water quality parameters, the diversity of phytoplankton and composition of aquatic macrophytes were seen. The seasonal variations of the above mentioned hydrobiological components of the wetland ecosystems were also elaborated. In the seven studied stations, namely, station 1 to station 7, the total species of phytoplankton recorded were 352. The recorded genera of this investigation which were reported previously were 65. The division wise distribution of the recorded species showed following distributional pattern: Cyanophyta 39, Chlorophyta 123, Euglenophyta 81, Chrysophyta 54, Cryptophyta 13 and Pyrrhophyta 2. Algal division wise percentage distribution of phytoplankton in the wetlands of Lalmai Hill areas of Cumilla was: Cyanophyta, 12.50%; Chlorophyta, 39.42%; Euglenophyta, 25.96%; Chrysophyta 17.31%; Pyrrhophyta, 0.64% and Cryptophyta, 4.17%. Members of Chlorophyta were found to dominate in all the studied stations which contributed more than 39% of the total phytoplankton community. Out of 352 recorded species of phytoplankton, 312 species were previously recorded in different studies in Bangladesh. Preliminary data on the rest 40 species of phytoplankton cast hope that this will be new algal reports for Bangladesh. The unreported 40 species, dominated division was Euglenophyta (15 taxa) followed by Chlorophyta (14 taxa) and Cyanophyta (11 taxa). A total of 42 species of aquatic macrophytes was recorded where *Ludwigia adscendens* (L.) Hara and *Lemna minor* Roxb. were found to be the most dominant species.

The monthly ranges of recorded physical parameters were air temperature 16.4-35.5ºC for all the stations, water temperature 16.2-35.4ºC and Secchi depth 52-112 cm. During the period of investigation, the ranges of chemical parameters were alkalinity 0.03-4.4 meq/l, conductivity 31.0- 640 µS/cm, DO 6.4-14.9 mg/l, pH 5.8-8.5, TDS 12.0-753.0 mg/l, SRP 2.31-613.52 µg/l l, SRS 0.17-265.82 mg/l and NO_3-N 0.01-1.58 mg/l for all seven stations. The range of recorded biological parameters where total phytoplankton density was 0.06×10^6 ind/l - 30.40×10^6 ind/l, chl-*a* was 4.00-249.82 µg/l and phaeopigment was 0.19-92.06 µg/l for all seven studied stations.

Pearson correlation of phytoplankton density showed positive correlation with alkalinity, soluble reactive silicate, chlorophyll *a* and phaeopigment in station 1. All these, alkalinity showed 1% level significant. In station 2, phytoplankton density showed positive correlation with only nitrate nitrogen. It showed 1% level significant with nitrate nitrogen. In station 3, phytoplankton density showed positive correlation pH and chlorophyll-*a*. Among these phytoplankton density showed 5% level significant with pH and 1% level significant with chlorophyll-a. In station 4, phytoplankton density showed positive chlorophyll-*a*. Here phytoplankton density showed 5% level significant with chlorophyll-*a*. In station 5, phytoplankton density showed positive correlation with dissolved oxygen. In this station phytoplankton density showed 1% level significant with dissolve oxygen. In station 6, phytoplankton density showed positive correlation with alkalinity, conductivity, soluble reactive phosphate, chlorophyll-*a* and phaeopigment. Among these phytoplankton density showed 5% level significant with conductivity and soluble reactive phosphate and 1% level significant with alkalinity, chlorophyll-*a* and phaeopigment. In station 7, phytoplankton density showed positive correlation with pH, alkalinity, conductivity, soluble reactive silicate, chlorophyll-*a* and phaeopigment. Among these phytoplankton density showed 1% level significant with conductivity, chlorophyll-*a* and phaeopigment and 5% level significant with pH, alkalinity and soluble reactive silicate.

According to Shannon-Winner diversity index, station 7 is more diverse than all other stations and in Jaccard Index shows all the stations are highest 9.45% similar in September 2018 and their intersecting members were 19.

In this research work, diversity of phytoplankton and macrophytes were studied according to four different seasons. Winter and pre-monsoon was dominated by a diverse group of phytoplankton in both study year whereas monsoon was dominated by the abundance of different species of macrophytes.

The present investigation has revealed that the studied stations have a diverse variety of phytoplankton and macrophytes according to the four distinct seasons. Total diatom index showed that the studied wetlands are free from significant organic pollution. The investigation generated some important baseline data on the pollution status and phytoplankton community structure of wetlands of Hill areas. These data would be helpful in planning for future policy decisions on using these wetlands as an ecotourist center as well as in the better conservation and management of the precious wildlife in the world-famous sanctuary. Analysis and interpretation of the data on phytoplankton and water quality parameters provided the necessary information to assess the impact of tourism related activities on the hydrobiology of the wetlands.

Chapter-1

INTRODUCTION

INTRODUCTION

The term Biodiversity is a recent concept and is one of the most popular keywords discussed in the history of modern civilization. It is used to denote the variety of life existing on earth, and its rapid application in science and popular culture, indicate the importance (Jeffries 1997). Photoautotrophism is a mechanism which is in operation in chlorophyll bearing organisms, the plants, and thought to be the prime cause of expansion of biodiversity since the ancient. This section of biodiversity can be designated as phytodiversity. It means variations among plants. The diversity of animal is mainly dependent on the diversity of plants. Principally there are three different stages of biodiversity, namely: genetic diversity, species diversity, and ecosystem diversity (Hasan 2000). These are also divided into three steps, namely, compositional, structural and functional. Plants are of various size, shape, and types depend upon the presence of photosynthetic pigments, way of photosynthesis, habitats, reserve food, etc. Plants is a very diverse group of organisms. It started from prokaryotic to eukaryotic i.e. Cyanophyceae to Angiospermic plant. The principal concerns of the phytodiversity of wetlands are the study of aquatic macrophytes and phytoplankton.

The diversity of plants i.e., phytodiversity in the aquatic ecosystem changes with the change of season. The growth and development of plant and their diversity depend on the total rainfall of the country. the average annual rainfall of Bangladesh was recorded as 265.5 and 179.3 cm in 2017 and 2018, respectively. It rained throughout the year in Bangladesh but more than 64 - 66% of total rainfall occurs during monsoon followed by pre-monsoon (22-29%), post-monsoon (5-11%) and winter (1-2%) (BWDB report 2019). Aquatic macrophytes grow luxuriantly during monsoon whereas strong growth of phytoplankton is observed during winter and pre-monsoon. So, it is clear that there must be a variation of phytodiversity with the regular change of seasons. Brammer (2000) divided the climatic seasons of Bangladesh into four. These are, pre-monsoon, monsoon, post-monsoon and winter. The diversity of plants is mainly dependent on the change of these seasons. Phytoplankton is abundant during the pre-monsoon and winter but aquatic macrophytes are abundant during monsoon with the excess of water and at the end of post-monsoon they just disappear with the decrease of water from the wetlands. So, there is a regular seasonal variation of the diversity of plants throughout Bangladesh.

Wetlands are considered as important resources for biological conservation because they support a rich biodiversity with high productivity (Mitsch and Gosselink 2000). In Bangladesh, wetland resources occupy 50% of the country's land surface and support a wide variety of plant and animal 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 integrate riparian and coastal zones next 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 level of 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 characterized 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 land surface and the ocean and is carried out into the atmosphere and is precipitated as rain or snow on surface of the earth. 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, Baors, Beel, ponds or flows back into the sea through the river system.

Different physicochemical and biological parameters are considered to be important regulator for phytodiversity and water quality of wetlands. Phytodiversity of wetland means the diversity of phytoplankton and aquatic macrophytes. Phytoplankton communities are sensitive to vicissitudes 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 an uninterrupted supply of water for domestic, agricultural and recreational purposes (Imhoff and Albrecht 1982).

Lakes are stagnant water bodies lacking a direct connection to the sea and whose basins are usually formed by different natural and artificial forces (Wetzel 2001). Man-made or artificial lakes are very common in existence and whose basins are dug out by mechanical means or by excavation using human forces. In the National parks, Botanical gardens, Zoos, Countryside and eco-parks of many countries, these kinds of wetlands are predominantly present. They usually serve to increase the aesthetic beauty of the visiting spot as well as provide environmental and ecosystem services in the area. These wetlands can hold important aquatic flora and fauna characteristics to the area as well as can be utilized as a shelter and breeding ground for local freshwater fishes and migratory birds. On an emergency basis, its freshwater reserve can be a good source for nurturing plants and animals.

Inland aquatic ecosystems are the important section of the hydrological cycle, which provide great opportunities to human being. A huge majority of its biological production is applied by man and other animals for their nutrition and development (Bharucha 1996). The science of hydrobiology is based on the concept of aquatic ecosystem, the study of life and diversity of organisms in water bodies. It is a special branch of biology that resembles much with Limnology (the science of inland waters). Hydrobiology deals with the animals, plants and microorganisms that live in water. This discipline has been contributing a lot towards our understanding of the proper value of freshwater resources and other problem related to environmental pollutions nowadays. The applied aspect of limnology through hydrobiological studies thus comprises in evaluating the plant and animal life that a body of water is capable of supporting.

From the global perspective, a wetland is an area (prototypically filled with water, also of variable size), localized in a basin, that is enclosed by land apart from any river or other channel that serves to feed or trench the lake (Esko and Hyvärinen 2000). Ponds and wetlands lie on land and are not a portion of the ocean, and thus are distinct from lagoons and lakes, though there are no certified or methodical definitions lakes can be contrasted with streams or rivers, and are usually flowing. However, most ponds and wetlands are nourished and drained by rivers and streams (Aloi 1990).

Limnologists have defined wetlands as water bodies which are simply a bigger version of a pond, which can have wave action on the coastline or where wind-induced turbulent plays a major role in mixing the water column. Another definition of lake, is a body of water of 2 ha or more in the zone. However, others have defined lakes as aquatic bodies of 5 or 8 ha and above (Elton and Miller 1954).

Phytoplankton, such as diatoms and dinoflagellates, perform in the presence of daylight and nutrients such as nitrogen and phosphorous. These unique organisms are the 'grasses of water' and make the vital base of the major productivity. Most phytoplankton contain photosynthetically effective pigments, such as chlorophyll, which qualify them to convert energy of sunlight from carbon dioxide to complex organic molecules, such as sugar or protein (For this reason they are called autotrophs).

In aquatic bodies, the emphasis of investigation and environmental observation has customarily been on the phytoplankton (Vadeboncoeur *et al.* 2002), whilst benthic primary producers are often not considered in lake monitoring programs. Some countries, however, use macrophytes (aquatic vascular plants) or phytobenthos (Birks *et al.* 1990, U.S. EPA 2012, Brucet *et al.* 2013, Kelly 2013). One of the essential parts of lake food webs, in specific in shallow wetlands are phytobenthos (Vadeboncoeur *et al.* 2002): the phytobenthos can significantly donate to the aquatic primary production (0.5-92 %) and serve as a significant food source for many consumers (Vadeboncoeur *et al.* 2002, Vander Zanden *et al.* 2011).

Plankton is those organisms which are floated rather passively in the water and are incapable of maintaining a definite location within their habitat against water movement, such as current and eddies (Reynolds 1984). Of all the communities of organisms on earth, the plankton community shelters the maximum part of the water body and is changeable with season and space. The plankton community consists of the primary producers, i.e. phytoplankton and secondary producers, i.e. zooplankton (Battish 1992). The phytoplankton population characterizes the biological affluence of a water body, establishing a vital link in the food chain (Boyd 1982, Hossain *et al.* 2007). The communities of phytoplankton (composed of both eukaryotic and prokaryotic species) in wetlands, rivers and ponds are symbolized by the species of diverse micro-algal groups.

Latest trends in universal climate support the requirement for research aimed at understanding natural climate changeability. Since historical climate records are geographically scant and temporally restricted, alternative means for accepting past climatic conditions are mandatory. The nonstop accumulation of deposit and entrained biological and chemical constituents in wet lands over time can deal a detailed record of past environmental inconsistency if the relationship between sedimentary components and environmental situations are well understood. For example, fossil diatoms are often used in paleolimnological restorations because the seasonal sensitivities and ecological targets and tolerances of many taxa are well recognized (Smol and Cumming 2000). Moreover, the response of diatoms is quick to the changing environmental conditions and are generally well-preserved in the sediments of wetlands due to the silica satisfied of their cell walls (Smol and Cumming 2000). The ecological sensitivities and rapid reaction rates of diatoms may be mainly relevant for high latitude rolling waters characterized by extreme rate of modifications in environmental conditions over relatively little periods of phase (Irons and Oswood 1992).

Variation in phytoplankton community configuration depends on the availability of nutrients, temperature, intensity of light and on other limnological elements. Generally, phytoplankton follows an honestly identifiable annual cycle of growth, but sometimes the synchrony in their normal annual cycle is dislocated by the explosive growth of some species (Vaulted 2001). Some of the unique features of phytoplankton are their population turnover on a much shorter time rate and eruptions of growth (bloom) being of only a limited time. Phytoplankton produces blooms generally in the epilimnion region of water bodies. The entire plankton community can be considered as complex machinery which originates its energy mainly from radiant flux of the sun and its raw material from mineral salts and dissolved nutrients in the water, the producers (phytoplankton) produce their plant biomass by the process of photosynthesis and designated as producers from the first trophic level (Rao 1993).

Plants that grow in the littoral zone, as well as open water of wetland ecosystems are known as Macrophytes. The classification of macrophytes fall into a group of plants which can be seen or at least recognized up to genus level by naked eye and which complete they're at least a part or full of their life cycle in water. More than 100 Angiosperms, 3 species of Bryophytes and 8 species of Pteridophytes have commonly taken place in different wetland habitats of Bangladesh (Khan and Halim 1987, Karim 1993). These significant plant species serve as a source of food, fodder, medicine, fuel and thatching materials for the people of Bangladesh. These are also very valuable genetic resources which have been exploited by human beings since the millennium for the progress of many actual day crop plants. In Bangladesh, so far four species, *Aldrovanda vesiculosa* L., *Lagenandra gomez*ii (Schott) Bogner and Jacobson, *Limnophila cana* Griff. And *Rotala simpliciuscula* (S. Kürz) Koehne have been recorded in the Red Data Book (Khan *et al.* 2001) and for many more no living sample has been collected from the wild since long. So, there is a full expectation that the species of wetland macrophytes have been reduced in number beyond all of our thoughts. Severe human interference has been considered as one of the most important reasons of depletion for the aquatic plant diversity in the wetlands, which shields nearly 50% of the total area of Bangladesh (Nishat 1993).

Macrophyte community arrangement and distribution differ with climate, hydrology, substrate type, and nutrient obtainability (Cronk and Fennessy 2001) and can be influenced by geology, use of land and chemistry of water and sediment (Moyle 1945, Stewart and Kantrud 1972, Barko and Smart 1986, Barko *et al.* 1991, Koch 2001, Lougheed *et al.* 2001, Hansel-Welch *et al.* 2003, del Pozo *et al.* 2011).

The existing study focused mainly on shallow lakes and wetlands which are well-defined these do not stratify for long times, mix repeatedly, have strong interaction of sediment-water and are mostly occupied by macrophytes (Scheffer 2004, Heiskary and Wilson 2005). Different patterns of variation in nutrients, chlorophyll-a and transparency are known for shallow lakes compared to deeper, stratified lakes (Heiskary and Wilson 2005) and plant groups in shallow lakes often utilized in ways that affect whole lake ecosystems (Scheffer 2004). For example, it is believed that aquatic macrophytes are to exert a large adjacent effect over the changes between clear macrophyte and turbid, phytoplankton-dominated regimes in shallow lakes (Scheffer and Jeppesen 1998, Bayley and Prather 2003). These shifts often happen over a short time period (within 1 year) or sometimes over more than a few years (Bayley *et al.* 2007) and factors inducing these system shifts are often unidentified. Questions about the role of macrophytes in such regime shifts led to the current study, which aims to explain influences on plant communities in these active systems.

Eutrophication mainly reflects increases in the biomass of primary producers and changes in the competition among them (Philips *et al.* 1978). The nutrient levels in earlier oligotrophic-mesotrophic (clear water) systems increased, thereby encouraging the growth of autotrophic organisms (Schindler 1977, Hecky and Kilham 1988). Shallow wetland ecosystems can support numerous types of autotrophic organisms: epiphyton, vascular plants, macroalgae and phytoplankton. The amplified turbidity of wetland water, due to increases in phytoplankton densities, declined the underwater light climate, and caused fluctuations in ecological interactions between the different autotrophs (Sand-Jensen and Borum 1991). Subsequently, shading by primary producers, like phytoplankton and epiphytes, was exposed to be the basic reason for the shift from a dominance of vascular plants to that of phytoplankton (Philips *et al.* 1978, Sand-Jensen and Borum 1991).

Lalmai Hill is composed of Pleistocene sediments having a maximum altitude of 15 m MSL and area 33 km^2. It is 16 km long from north to south and 2-3 km broad from east to west (Rashid *et al.* 2006). The hill area is mainly dry with red soil type except a few manmade and natural wetlands. Bangladesh Academy for Rural Development (BARD) is one of the prestigious and old institutes of Bangladesh and is located inside Lalmai Hill area. BARD has a premise of 64 ha and situated about 10 km away from Cumilla city. In it several perennial ponds are present. From BARD, one large pond was selected for carrying out the present study.

Dutia Dighi is another oldest waterbody of Cumilla District (previously called Comilla district) and is located at the southern part of Lalmai Hill. It was dug by Raja Gobindo Maniyakya of British Tripura for the purpose of drinking water for the pilgrims of the temple of Hindu Goddess Chandi and is about 16 km away from the district headquarter. Horeshpur Jola is one of the biggest natural fish reservoirs of Cumilla. It is located in between Lalmai Hill and Cumilla-Chandpur Highway. It is about 9 km to the south of Cumilla city. All the above-mentioned wetlands are located about 100 km away from the Dhaka Metropolis and is accessible via road connection. These three wetlands occupy an area of about 1.5 ha, 7 ha, and 49 ha respectively.

Considering the ecological importance of Lalmai Hills, one research works on angiosperms and wild animals were carried out before (Hossain *et al.* 2005). Study on wetlands in Bangladesh started before the independence (Islam and Khatun, 1966). A number of research works on wetlands has already been done and most of those were Beel, Haor, Baor, natural- and manmade lakes, and rivers (Khondker *et al.* 1994, Begum *et al.* 2012, Yeasmin 2019, Shafi 2000). Water quality of famous wetland Dharma Sagar of Comilla city was studied by Bhuiyan and Khondker (2017). Limnology of some waterbodies of Gomti floodplain was assessed by Khandker and Talukder (1995). Talukder and Khondker (1995) also studied some waterbodies in the Noakhali north flood prone areas of Bangladesh. They carried out their research on 4 rivers, 7 Canals, 5 beels and four ponds. Other than this, there is almost no research work on the aquatic flora of different wetlands Cumilla Sadar South Upazilla. So, there exists a knowledge gap on the qualitative and quantitative study of phytodiversity and their relationship with the environmental factors.

The district of Cumilla including its Metropolis head quarter is enriched with a number of historically famous and some recently excavated manmade waterbodies. In almost all the premises of the parks and gardens, occurrences of ponds and man-made lakes of variable depth and size are seen. The famous Dharma Sagor, Nanua Dighi, Ranir Dighi, and Dutia Dighi of Sadar South Upazilla, all support small lakes of tremendous limnological interest. Similar to those places, the Hill areas of Cumilla has a number of manmade and natural wetlands and reservoirs. In Bangladesh, a significant number of limnological research were carried out in the past covering the district of Dhaka, Dinajpur, Chittagong, Chittagong Hill Tracts, Sylhet, Moulvibazar, Barishal, Dhaka and Kishoreganj (Islam and Saha 1975, Islam and Mendes 1976, Islam *et al.* 1979, Khondker *et al.* 1994, Begum *et al.* 2012, Yeasmin 2019, Shafi 2000). But there is almost no study devoted to the phytodiversity and their relationship with the environmental factors. Therefore, the present study was undertaken to fill up the existing knowledge gaps.

In the present investigation three wetlands namely, the big pond of BARD, Dutia dighi and Horeshpur Jola were selected. The waterbodies are the characteristics to soil types of the Lalmai Hill areas in Bangladesh. These three wetlands are very important water bodies of the Sadar South upazilla of Cumilla district, because those are routinely visited by the tourists, particularly by those intend to visit Lalmai Hills. Several species of local and migratory bird population visit the waterbodies and carry out their breeding and serve as an agent to the dispersal of aquatic plants from distant habitats. There is great possibility to find out a number of new phytoplankton and macrophytes species which were not recorded from Bangladesh previously. This establishes the necessity of carrying out hydrobiological investigation in this kind of habitats. This will help to assess the growing anthropogenic disturbances created to the wetlands as well as to undertake the policies for conserving the ecosystems. Moreover, no work has been done on the wetlands having red soil basin. This investigation will also focus on the aquatic phytoplankton and macrophytes of these wetlands.

The study had been conducted to fill this knowledge gap. The findings of the current research will lay foundations for the authority of the Environmentalists, the garden planners and designers to get important information on surface water quality in the wetlands. The study can also facilitate water modelers in formulating the strategy for water abstraction and the water supply in wetlands.

AIMS AND OBJECTIVES

The present present research is based on the following objectives:

- To know the monthly and seasonal fluctuations of the physicochemical and biological water quality parameters e.g., air-, and water temperature, Secchi depth, alkalinity, pH, electrolytic conductivity, total dissolved solids (TDS), dissolved oxygen (DO), soluble reactive phosphorus (SRP), soluble reactive silicate (SRS), nitrate nitrogen (NO_3-N), chl-*a* (chlorophyll-*a*), phaeopigment, and phytoplankton- and macrophyte density.
- To identify the niche characteristics of the phytoplankton and macrophyte population.
- To find the role of nutrients on the abundance of phytoplankton and aquatic macrophytes.
- To work out the qualitative and systematic evaluation of phytoplankton and macrophytes
- To find the seasonality of phytoplankton biomass as chlorophyll-*a* and its degraded product phaeopigment.
- To analyze the interrelationships among the studied factors, by correlation studies.
- To determine the morphological features of phytoplankton population by collecting data on their length, breadth, flagellar structure and other external cellular characteristics via microscopic measurements.
- To work out the taxonomy of macrophytes.
- To study the relationship between and among the different physicochemical and biological variables where SPSS, Shannon-Wienner diversity index, Jaccard index and Trophic Diatom Index (TDI) will be applied.
- To propose a model for better ecosystem service from this study.
- To analyze the risks imposed upon the studied wetland ecosystems and to propose recommendation for conservation.

Chapter-2

LITERATURE REVIEW

LITERATURE REVIEW

Hydrobiological and limnological research in Bangladesh was pioneered by the research group of Phycology of the Department of Botany, University of Dhaka, 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 physicochemical conditions of water under which blooms usually occur in ponds. Other investigations carried out around the same period included the use of algal flora to characterize Lake Rainkhyongkine as a semi-hard water body in the late oligotrophic stage (Islam 1969). Islam and Begum (1970) recorded 110 species of phytoplankton, mainly from the algal Order Chlorococcales from Dhaka district. They have also made some observations on seasonal changes in water temperature and pH.

A well-planned research work on Ramna Lake in Dhaka city was carried out by Islam and Saha (1975). A comparative research work on the macrophytic flora and phytoplankton from Hakaluki Haor of Moulvi Bazar district of Bangladesh was carried out by Islam and Paul (1978). Manmade Dhanmondi Lake of Dhaka Metropolis was studied by Islam *et al.* (1979) where a handful number of desmid population and aquatic macrophytes were reported. Mahmood (1986) studied the primary productivity (2.39 g O_2/m^2/day) of the largest manmade lake Kaptai.

A very few studies of this kind have been undertaken since the publication of chemical data on Dhanmondi lake of Dhaka Metropolis by the Bangladesh Water Pollution Control Board (1975). Later on, Islam and Chowdhury (1979) and Islam *et al.* (1992) 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 physico-chemical factors related to it. This study revealed that the input of sewage material in Dhanmondi lake is affecting the productivity by reducing light penetration, putting stress on dissolved oxygen 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 showed that the bottom sediment of the lake was anaerobic with high concentration of dissolved phosphorus. However, dilution caused by rainwater during monsoon improved the water quality 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 lake, Crescent Lake, and Hatirjheel lake in the Dhaka metropolitan area. The relative study established that the concentration of BOD, electrical conductivity, TDS, alkalinity, and acidity of Hatirjheel lake was greater than that of 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. Samples studied from Gulshan and Ramna lake had the pH range within the Ecologically Critical Area (ECR) standard in both spring and winter. In Gulshan lake, there were more turbidity and colored substances in spring than in winter. In water samples Iron was within the range, where BOD_5 was found higher in both lakes. Singh (2012) reported that the fast urbanization together with infringement, leading to the loss of catchments of surface water bodies and problems of siltation, pollution, which includes domestic, agricultural and industrial waste including eutrophication are the major complications of the world to protect and control water resources.

Khondker *et al.* (1990) carried out a limnological studies on four polluted ponds in and around Dhaka city with reference to the indicator species and found 50 species of Euglenophyceae and as dominant flora in three ponds and diatom was dominant in one pond. They found euglenoid algae were the indicator of organic pollution in ponds contaminated organically.

Islam *et al.* (1992) studied hydrobiology of two habitats (pond opposite Uttara shopping centre and Khilkhet *beel*) of Dhaka city and recorded the values of 12 limnological parameters. They had found that the pond was more productive than the *beel*. They also recorded 22 species of macrophytes from the pond and 19 species of macrophytes from the Khikhet *beel*, respectively. There were 10 species of macrophytes common in both the waterbodies.

Jewson *et al.* (1993) studied on auxosporulation of freshwater diatom in Banani Lake and found that with the excessive production of water hyacinth the cell connection of *Aulacoseira herzogii* declined.

Limnological assessment of some water bodies of Gomti floodplain, Cumilla was carried out by Khondker and Talukder (1995), where they recorded 13 limnological parameters and compared among the studied habitats. They found 79 genera of algae from different classes and 40 genera of macrophytes in these waterbodies of Gomti floodplain which was very rich in case of the number of genera present in Bangladesh at that time. Talukder and Khondker (1995) also studied limnology of some waterbodies in the Noakhali north flood prone areas of Bangladesh. They carried out their research on 4 rivers, 7 canals, 5 *beels* and four ponds. In these waterbodies they studied 13 limnological parameters and fecal, and total coliform bacteria. In these waterbodies they found 88 genera of algae and 38 genera of aquatic macrophytes.

Khondker *et al.* (2006) studied the limnological parameters of seven ponds and a river from Bakerganj, Barisal and six ponds of Mathbaria, Pirojpur, two southern districts of Bangladesh. They had recorded 16 species of blue-green-algae as new report for Bangladesh. Nahar and Khondker (2009) added some freshwater diatoms from Joyasagor and Sitlai *beel* of Northern Bangladesh. They added some species of Coscinodiscaceae, Fragillariaceae and Eunotiaceae. They found 11 species of diatoms from these two wetlands. Alfasane *et al.* (2010) reported an angiospermic plant from Lake Bogakain of Bandarban district of Bangladesh. They recorded *Ergeria densa* Planch. from this lake. Islam *et al.* (2012) presented a note on the limnology of Nilshagar, Nilphamari, Bangladesh. They studied 13 limnological parameters and recorded 15 species of algae from that wetland. They also presented a comparative study on three distinct wetlands of Northern Bangladesh.

Phytoplankton in relation to water quality of Tanguar Haor ecosystem, Bangladesh was studied by Bhuiyan *et al.* (2019). They studied 15 limnological parameters including phytoplankton density. In it, they presented a comparative study of five prominent wetlands of Bangladesh. There was a significant correlation among the studied parameters of the studied habitats. An important research work was also carried out by Bhuiyan *et al.* (2021) where the floristic composition of phytoplankton from Hakaluki *Haor*, Moulvibazar was done. They studied 12 limnological parameters of the *Haor* and phytoplankton species along with zooplankton. From zooplankton, they recorded at least 12 species.

After the limnological research results published by Mohuya *et al.* (2010), Gulshan-Baridhara lake was declared as an Ecologically Critical Area (ECA) in 2001 and suggestions were made to save the lake from further deterioration of its water quality. Previous study in the same lake revealed lead (Pb) concentration exceeded the standard level during the monsoon, otherwise concentrations of all other four heavy metals (Cd, Cr, Cu and Ni) exceeded the standard level set up by WHO, GoB, USEPA, DoE and FWPCA.

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 that Euglenoid algae were dominant whereas in Lake Bogakain green algae were predominant.

Ahmad *et al.* (2015) recounted that macrophytes use light energy, water and carbon dioxide to synthesize 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 be used for the adjustment of water temperatures and existing oxygen in water, thus ultimately influencing the 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.

Rørslett *et al.* (1986) examined the total phosphorus, phytoplankton biomass and productivity in the profound (Z= 10.2 m) oligotrophic and transparent (S= 5.5 m) in a wetland over 7 years where *Elodea canadensis* Michx. occupied in the wetlands and recognized the extensive areal cover (79%). The combined production of phytoplankton and macrophytes increased significantly without nutrient enrichment of the water of wetlands. Usually, sediment nutrients exploited by the macrophytes were used within the macrophytes viewpoints.

Wetzel (1983) mentioned that the phytoplankton is responsible for almost the whole primary production in oceanic waters, large deep lakes and downstream regions of rivers because the water column is deep and the illuminated bottom regions are small.

Lewis (1987) mentioned that in the absence of protective organization, tropical lakes would drop greatly in their efficacy for water supply, production of commercially useful species, and recreation, because tropical lakes are more sensitive than temperate lakes to pollution. So, management programs for tropical lakes will emphasis on seizure of nutrients, protection of aquatic habitats from invasive species, and minimization of hydrological fluctuations in rivers to which lakes are linked. The consciousness of the scientific community and the civic of the manner in which the fresh water system functions as an entire and their combined opinions are significant in the resolution of public policy and the subsequent management of these arrangements. All these authors have thus highlighted the consequence of ecological investigations of freshwater, especially that in the tropics.

Finlayson *et al.* (1980) studied the significance of aquatic vegetation in governing the nutrient enrichment in a synthetic high-altitude wetland, Moondarra in the North Western Queensland, and establish that cessation of the sewage input along with a regular harvest of macrophytes could support in reducing the internal nutrient and metal load in the lake. In South America, Heide (1982) carried out a complete study of Limnology of a man-made wetland Brokopondo, the first tropical lakes of over 1000 km^2 surface areas, built on the Suriname River. General environmental uniqueness of tropical lakes are described in that work. According to the author periods of rainfall seem to exert little influence upon mixing of water in the wetland. He worried that the same situation occurs in some wetlands of Africa also. In almost all wetlands revealed by the author wind is a chief mixing agent and the rainwater has a great influence in determining the quality of water in tropical freshwater bodies. Hart *et al.* (1987) made a thorough study of the Magela Creek wetland system in Australia. According to the author rain water has an extreme impact in the quality of water in freshwater bodies. Hilton and Phillips (1982) found algae and boat activity as the two major providers of turbidity in a water body which affect the growth of macrophytes vegetation.

Odum (1971) has given a good description of the producer components of aquatic systems and found that Diatoms are good indicators of water quality. Hunding (1971) observed the benthic algae as a significant producer element of the littoral zone of a eutrophic lake. Palmer (1980) noticed that plankton, algae is much more important than the attached algae in deep water bodies such as reservoirs. The author has also emphasized that both the dissolved and suspended nutrients support the growth of algae and other aquatic life, and considered algae as good indicators of water quality. Moore (1980) analyzed all the epipelic, epilithic, and planktonic forms of algae in three widely detached inshore areas of the Great Bear Lake and found resemblances in species composition and standing crop between diverse groups, over seasons and across different sites due to similarity of water chemistry and temperature all over the Lake. Osborne *et al.* (1987) reported that dissimilar temperate lakes, tropical lakes, particularly those that arise in areas where the climate is divided into distinct wet and dry periods do not show stable water quality characteristics throughout the year.

In most of the water bodies, An and Jones (2000) noticed that the flagellate algae are dominant in summer. According to them Asian wetlands are regulated by the intensity of monsoon due to variation in the physical and chemical features of water. The authors reported that Diatoms have an expert benefit during deep mixing of water. Anand (2000) ponders the ecology of a Diatom species in relation to the changes in water quality parameters at different regions of a stream in Jammu and described its limnological importance. Coesel (2001) noted that, Desmids are ecologically highly sensitive microorganisms and are valuable tools in aquatic conservation management particularly in those cases where macro-organisms fail.

Mahadev and Hosmani (2002) correlated phytoplankton in two lakes of Mysore city in India. They informed that the absence of Desmids indicates strong water pollution.

Steinhart et al. (2002) studied phytoplankton, they mentioned them as an indicator of nutrient deficiency in the lakes of southern Chile and found that phosphorus should not be discounted as a limiting nutrient in aquatic systems. They recognized that Desmids are the indicators of water's good quality.

According to Brunberg and Blomqvist (2002), a broadly dispersed organism is *Microcystis*, which dominates the phytoplankton community in nutrient rich wetlands. Lange and Tiffany (2002) found that when turbulence is high in a wetland during strong winds, diatoms that are generally associated with benthic and epiphytic habitats becomes mixed into plankton in such systems. Trick *et al.* (2002) explored spatial variation in diatom communities within the Turkey lakes and found that the diatom community is influenced by a nutrient gradient.

Johnston and Jacoby (2003) examined the Cyanobacterial toxicity and migration in a mesotrophic lake in western Washington and found that dense surface accumulation or blooms of Cyanobacteria in freshwater ecosystems are primarily recognized to nutrient, mainly phosphorus enrichment. Krupa and Czernas (2003) noticed the mass appearance of Cyanobacterium, *Planktothrix rubescence* in Lake Piaseczno, Poland. Vilbaste and Truu (2003) studied benthic Diatom's distribution 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 function and structure 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) found out 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.

Diatoms and pH restoration were studied by Vincent (1992) and found that light stimulated the nitrogen uptake in planktons. Egge and Aksnes (1992) studied silicate as a regulating nutrient in phytoplankton competition. 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) specified that alkalinity and trophic state regulate the distribution of aquatic plant in Danish lakes. A reduction in temperature improves solubility of oxygen in water which was recorded by Murugavel and Pandian (2000). Carvalho *et al.* (2002) investigated the physico-chemical conditions for supporting different levels of the biological quality of fresh water. Adak *et al.* (2002) reported that different physico-chemical 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 of 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 low 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 wetlands with lower pH.

Owen *et al.* (2004) stated that pH, electrical conductivity, temperature and nitrates act to be closely related to Diatom growth. Literature studied support long-term monitoring of ecological investigations of water bodies and comprehensive analysis of the physico-chemical parameters is crucial to a holistic approach in solving environmental problems of such systems.

From the above discussion, it is clear that the physicochemical conditions of water in wetlands actually determine the qualitative and the quantitative pattern of aquatic organisms as well as their seasonal variations. In some cases, special community may be created to support migratory species and thus provides 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 wetland ecosystem deserves much research attention because the whole secondary production including the phytodiversity and their seasonal variation may mainly be dependent upon it.

Chapter-3

MATERIALS AND METHODS

MATERIALS AND METHODS

I carried out the present research work in 3 different water bodies of Sadar South Upazilla, of the district of Cumilla, Bangladesh (Figs. 1-2). The names of the studied waterbodies are: Big pond of BARD, Dutia Dighi, and Horeshpur Jola (white circles, Figs. 3-9). A total 168 water and biological samples were collected from seven stations of the three wetlands between October 2017 to September 2019. The samplings were carried out at monthly intervals.

Study area

Name and description of the sampling stations

Big Pond of BARD

There are several water bodies inside BARD premises. I carried out my research work on the Big pond of BARD, which is located at the Northeastern part of the BARD. The area of this pond is >1.5 ha, and the water depth ranges from 2.20-3.46 m. In this pond two stations were fixed (Station 1 and 2) to collect samples. In the monsoon, the pond overflows, and the water rushes out to the nearby fountain (locally known as Cherra). This pond is usually used for aquaculture and recreational purposes for the visitors of BARD.

Dutia Dighi

It is one of the biggest artificial water bodies of Sadar South Upazilla of Cumilla district. Its location can be viewed from the temple of Hindu Goddess Chandi and Cumilla-Chandpur highway. The area of this water body is ~6.0 ha or above and the depth of this lake is 3.25-3.85 m. Two stations were selected from this water body (3 and 4). There is no external connection of the Dighi except the rainwater rushes through the hill area. This waterbody is used for fish cultivation, recreational purposes and household water supply for the people of the adjacent area.

Horeshpur Jola

It is one of the most giant natural fish reservoirs of Cumilla district having an area of 49 ha. This wetland is visible from the Cumilla-Noakhali highway and is about 9 km away from the district headquarter. Water depth range of the wetland over the annual cycle is about 2.36-3.20 m. This wetland is one of the starting points of the River Dakatia. This wetland is about 3 km long waterbody and selected three different stations from this site (5, 6 and 7). Several aquatic macrophytes and natural fish are available during the monsoon and post-monsoon periods. In the winter a greater part of this wetland is used for rice cultivation as like as the other Haor areas of greater Sylhet district of Bangladesh. Local peoples of the catchment of this wetland are dependent on the aquatic resource extraction for their consumption. The soil of the basin is used in pottery making cottage-industry of the adjacent areas.

Geomorphological and meteorological condition

Lalmai Hill is situated at three different Upazillas of Cumilla, namely Cumilla Sadar, Burichang, and Sadar South, about 8 km west of Cumilla city and is accessible by road. The Hill occupies an area of 33 km^2 and it was originated during the Pleistocene epoch of Cenozoic era. The latitude and longitude of this area are 23°35´´-23°49´´ N and 91°11´´-91°13´´ E.

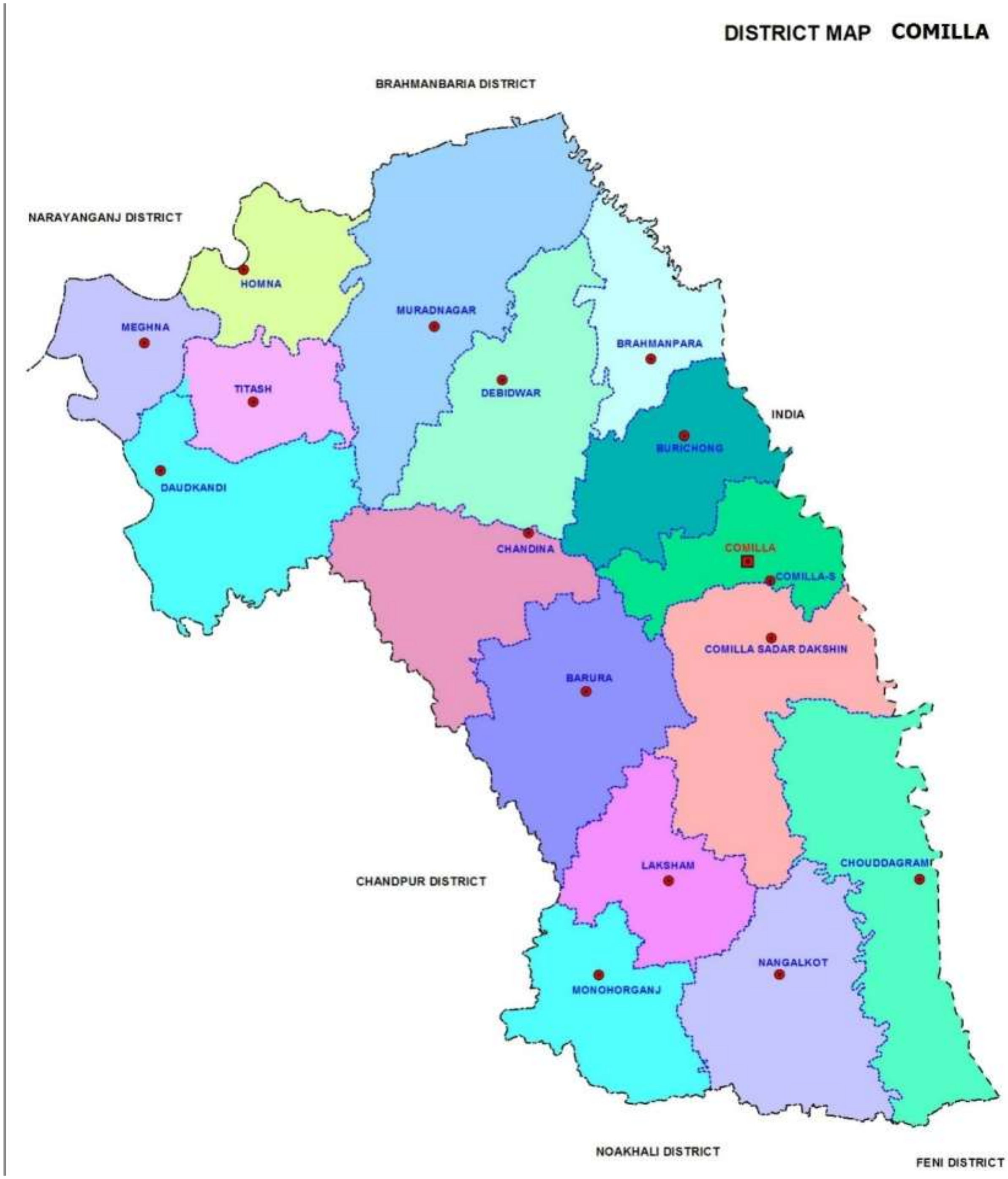


Fig. 1. District map of study area showing different upazillas along with the studied areas of Lalmai Hill areas of Cumilla.

Fig. 2. Location of sampling stations at Lalmai Hill areas of Cumilla. (Source: Google map)

Fig. 3. Sampling Station 1 of BARD pond.

Fig. 4. Sampling Station 2 of BARD pond.

Fig. 5. Sampling Station 3 of Dutia Dighi.

Fig. 6. Sampling Station 4 of Dutia Dighi.

Fig. 7. Sampling Station 5 of Horeshpur Jola.

Fig. 8. Sampling Station 6 of Horeshpur Jola.

Fig. 9. Sampling Station 7 of Horeshpur Jola.

***In situ* sample collection**

Collection of water and phytoplankton samples

The sampling was carried out from 09.00 AM - 1.00 PM. A Schindler-Patalas water sampler (5 L capacity) was used to collect integrated water sample from 50 cm depth of each study station (1-7). At first the sampler was dipped slowly underwater and then closed by applying a jerking pull from the above. After confirming the closure of the sampler, it was taken out and decanted the water in a black plastic carboy (5 L capacity). The carboy was transported to the laboratory for further analysis.

During the time of sample collection, *in situ* measurement of air temperature, water temperature, Secchi depth, conductivity, pH, DO, and TDS were carried out by using portable respective field meters (HANNA Instruments HI 9033, 9044). Chlorophyll a (chl-a), soluble reactive phosphorus (SRP), soluble reactive silicate (SRS) and alkalinity were determined on the same day (Marker *et al*. 1980, Murphy and Riley 1962, Wetzel and Likens 1979). However, an overnight digestion of the samples for nitrate nitrogen (NO_3-N) analysis (Müller and Wiedemann 1955) was also carried out.

Collection of macrophyte vegetation, identification and enumeration

The samples of littoral macrophytes were collected from the studied wetlands. After bringing those in the laboratory, the macrophyte samples were washed with tap water to be cleaned and screened. The taxa found, were identified with the help of Khan and Halim (1987), Khondker *et al*. (2010), Alfasane *et al*. (2010), Fasset (1957), Cook (1990) and Adoni (1985). After completing the preliminary identification of the macrophytes, their abundance was recorded *in situ*, by applying two randomly selected quadrats, 1×1 m^2, and then the average abundance was expressed as number of ind/m^2.

In situ measurements

Air temperature

The air temperature was measured with the help of an alcoholic thermometer (Gallenkamp UK) graduated from 0-60°C. The thermometer was held by hand and keeping the bulb in upward direction then rotated in the air slowly for a minute. Finally, the reading of temperature was recorded quickly. The procedure was repeated thrice and a mean value was calculated in °C.

Water temperature

After taking the record of air temperature, the same thermometer was dipped in the water of the wetlands up to a depth of 10 cm below the surface. The thermometer was kept quiet in this position for one minute and then the reading from the scale was read and recorded. The process was repeated at least for three times and the mean was taken in °C.

Secchi depth

A 20 cm diameter crosswise-painted black and white Secchi disc tied at the end of a graduated rope was used for the determining 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. The mean value of these two depths was recorded as the Secchi depth in cm.

Similarly, electrolytic conductivity, total dissolved solids (TDS), pH, and dissolved oxygen (DO) were performed using respective field meters (HANNA Instruments HI 9033, 9044).

Transportation of sample from the field to the laboratory and measurements

All the collected samples were kept inside a polystyrene icebox and carefully transported to the laboratory within two and a half an hour of collection giving ice pack. All the chemical and biological analyses of water samples were conducted in the National Professor AKM Nurul Islam Laboratory, Phycology, Limnology and Hydrobiology, Department of Botany, University of Dhaka. Analyses of different parameters began immediately after reaching to the laboratory and were completed within next morning.

Sedimentation of phytoplankton sample

In a plastic bottle of 1-litre capacity, sample water collected with the help of the sampler from each station was separately poured and fixed with Lugol's iodine solution. The bottle was kept undisturbed in the dark for 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, England) under a Nikon compound microscope (Japan) at a magnification of 400-1000×.

Laboratory processing

Filtration and preservation

Filtration of sample water for chemical analysis was carried out in the laboratory with the help of a vacuum pump fitted to a Sartorius-Membrane Filter Holder (Gmbh, Göttingen, FRG). The water sample was shaken gently for at least three times 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 47 mm circles were used in 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. The samples were 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, soluble reactive phosphorus (SRP) and soluble reactivate silicate (SRS). Unfiltered water samples were used for measuring pH, alkalinity, conductivity, DO (sample water fixed in Pyrex BOD bottle in the field) and TDS. All analysis was completed within the next 24 h.

A brief description of each measurement

All the biological and limnological analysis made in the present investigation followed standard procedures. Brief descriptions of the procedure for each determination together with the citation of the methodology followed have been presented in Table 1.

Table 1. Methodology, equipments, units of measurement and relevant references used for various 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 Likens, 1979)	mg/l	Hanna instrument HI9034W, UOM EA, D/N 413377, URN 330067T, S/N: 1391748, Singapore
SRP	Spectrophotometric method (Murphy and Riley, 1962)	μg/l	Spectrophotometer Shimadzu UV-0120-01, Japan

Parameter	Method	Unit	Equipment
SRS	Spectrophotometric method (Wetzel and Likens, 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)	Ind./l	Nikon microscope, using Hawksley's counting chamber (Lansing, UK)
Imaging and dimensions	Photomicrographs	µm	Axiocam ERc 5s, Axio Lab. A1, Carl Zeiss Promende 10, Germany
Phytoplankton quality	Consulting Australian, European and American monographs and literatures on the phytoplankton of Bangladesh		
Macrophyte quality	Consulting local, European and American monographs and literatures on macrophytes of Bangladesh		

Chemical parameters

Alkalinity

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

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 was dipped into it up to the mark which is 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 and recorded.

Electrical conductivity (EC)

From unfiltered sample water, 90 ml was measured with the help of a measuring cylinder. The electrode of the meter was cleaned with distilled water and dried with tissue paper. To set the meter following operations were carried out: the scale indicator button was rotated to place for a selected range, the meter was then switched on, and the second knob was fixed at 20°C. The electrode was then put into the sample water gently. A slight stirring of the electrode showed movement of the meter scale. Then conductivity was measured by keeping the electrode fixed in the sample water (Golterman *et al*. 1978).

Dissolved oxygen (DO)

In a 100 ml capacity measuring cylinder 90 ml of sample water was taken. Then the electrode of the DO 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 and write down into the notebook.

Soluble reactive phosphorus (SRP)

SRP determination has been followed after Murphy and Riley (1962). The dilution factor ranged from 2-10. Considering the dilution factor, accurately measured sample was poured in acid washed Pyrex conical flasks having 100 ml capacity. Then, I added required amount of distilled water to each sample to make the volume 50 ml. Five 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 antimony tartrate) was dispensed in each flask. The solution of the flask was mixed properly and after 5 to 10 minutes, a light blue to blue color developed, then the extinctions were measured using 885 nm wavelength with the help of 4 cm path length quartz cuvettes by using a Spectrophotometer.

Soluble reactive silicate (SRS)

The determination of soluble reactive silicate was followed after Wetzel and Likens (1979). The dilution factor ranged from 2 - 5. Considering the dilution factor accurately measured sample was poured in acid washed Pyrex conical flasks of 100 ml capacity to determine SRS. Sequentially 5 ml 0.25N HCL, 5 ml of 5% ammonium molybdate 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 sulfite was added to each flask and according to the concentration of SRS in the sample, blue color developed. A reagent blank and standard series of silica was also treated in the same manner. Sub-samples from each of these were measured 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 of the water sample 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 overnight to dryness 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 1 ml 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 extra distilled water. Then the sub-samples were measured in spectrophotometer using 1 cm path length quartz glass cuvette at 420 nm wavelengths. 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 immersed 5 ml hot 90% ethyl alcohol (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 for three minutes also. After cooling, the pigment was extracted (1st) and was transferred to another cleaned glass tube while the filter paper was given second extraction treatment in the same manner as mentioned above. The extracted pigment solutions (1st and 2nd) were poured into a measuring cylinder to make it 10 ml by adding extra 90% alcohol if necessary. Then the pigment samples were taken in 1 cm path length quartz glass cuvette and I measured the optical density (OD) 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) with the help of a micro pipette. 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 Helber Counting Chamber (HCC). A circular microscopic counting chamber is engraved with grids at the center of the HCC. 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 and a cover slip was put on it. Before counting, HCC was let to stand in rest for at least 2-5 minutes to settle down phytoplankton. Then counting of phytoplankton cells present in the microchamber of the HCC was done. All the cells present were counted, and the dominant group was identified. The counting was done for three times for each sample. Finally, the phytoplankton cell density was calculated per litre of 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 Hawksley's chamber volume (0.001005×3) in µL

Qualitative analysis of phytoplankton

Before counting on the phytoplankton individual, a random checking of the sedimented phytoplankton 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 were 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, Yamagishi and Akiama 1995, 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 Physico-chemical and biological variables, namely, Pearson correlation (SPSS v16.0), the Shannon-Weiner diversity index, Trophic Diatom Index (TDI) and Jaccard index have been applied.

Pearson correlation analysis

Pearson correlation (SPSS v16.0) has been performed to observe the relationship among physical, chemical and biological parameters of the sampling stations. Prior to applying SPSS individual phytoplankton diversity and environmental data were transformed log except for standardized temperature and pH.

Shannon diversity index

The Shannon-Weiner index into ecology was introduced by Robert MacArthur. The Shannon-Wiener diversity index (H) is a measurement 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 (e.g. station 1 to station 7). Species richness is the most commonly used measure of diversity, but H is a strong indicator of diversity.

<u>Shannon-Weiner Diversity Indices Calculation:</u>

a) A diversity index is a mathematical measure of species diversity in a given community.

b) Based on species abundance (the number of individuals per species) and the species richness (the number of species present).

c) The greater number of species you have, the more diverse the area.

d) However, there are two types of indices, information statistic indices and dominance indices. The Shannon-Weiner index is mainly an information statistic index, that means it assumes all species are embodied in a sample and that they are randomly sampled.

e) The equation for the Shannon-Weiner index we studied is:

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

In the Shannon-Weiner 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.

Jaccard Similarity Coefficient index

The Jaccard similarity index (sometimes called the Jaccard similarity coefficient) compares members of two sets to see which members are distinct and which are shared. It's a measurement of similarity for the two sets of data, with a range from 0% to 100%. The higher the percentage shows the more similarity between the two 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:

$J(X,Y) = |X \cap Y| / |X \cup Y|$

In Steps, that's:

a) The number of common members which are available in both sets are counted.

b) The total number of members in both sets are also counted (shared and un-shared).

c) The total number of members (2) are divided by the number of shared members in both sets (1).

d) Now, multiply the number you found (3) by 100.

This percentage tells you the similarity of the two sets, which are:

a) 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%).

b) If they share no members, they are 0% similar.

c) The midway point — 50% — means that the two sets share half of the members.

Trophic Diatom Index (TDI)

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

b) 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 & Kelly, 1995).

c) 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) = $\sum asv \div \sum av$

Here, a = total counts of diatom species

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

V= indicator values

Chapter-4

RESULTS

RESULTS

In the present investigation, a total of three physical, eight chemical, and four biological parameters were recorded for 7 selected study stations of the wetlands. In addition, qualitative and quantitative analyses of phytoplankton were made. The interrelationships among the physical, chemical, and biological parameters were also carried out via SPSS.

Physical parameters

Air temperature (°C)

During the study period (2017 – 2019), the ranges of air temperature were 19.2-35.4, 17.2-35.2, 16.6-34.1, 16.8-33.5, 17.2-34.4, 17.5-34.5, and 17.3-35.4 ºC for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean air temperature was recorded in July, 2018 for all the stations, whereas the lowest mean air temperature was obtained for all the stations in the month of January 2018 and January, 2019 (Table 2). Air temperature followed a distinct trend throughout the investigation period.

In the present research, the seasonal variation of air temperature showed the highest value during monsoon and the lowest in winter in all the stations. Over the seasons, the mean values of water temperature followed a pattern of monsoon>pre-monsoon>post-monsoon> winter (Fig. 10).

Air temperature starts increasing just after January and continues until July and thereafter a gradual fall was evident from August to December (Fig. 11). Fig. 11 also compares air temperature of 2017-2018 and 2018-2019. There was a sudden fall of air temperature in July 2019 in all the stations. With this the trend of annual fluctuation of air temperature is almost same in both study years.

Mean air temperature (30.12 ºC) was the highest in Station 7 and the lowest mean air temperature (26.79 ºC) was recorded in Station 3 (Table 2).

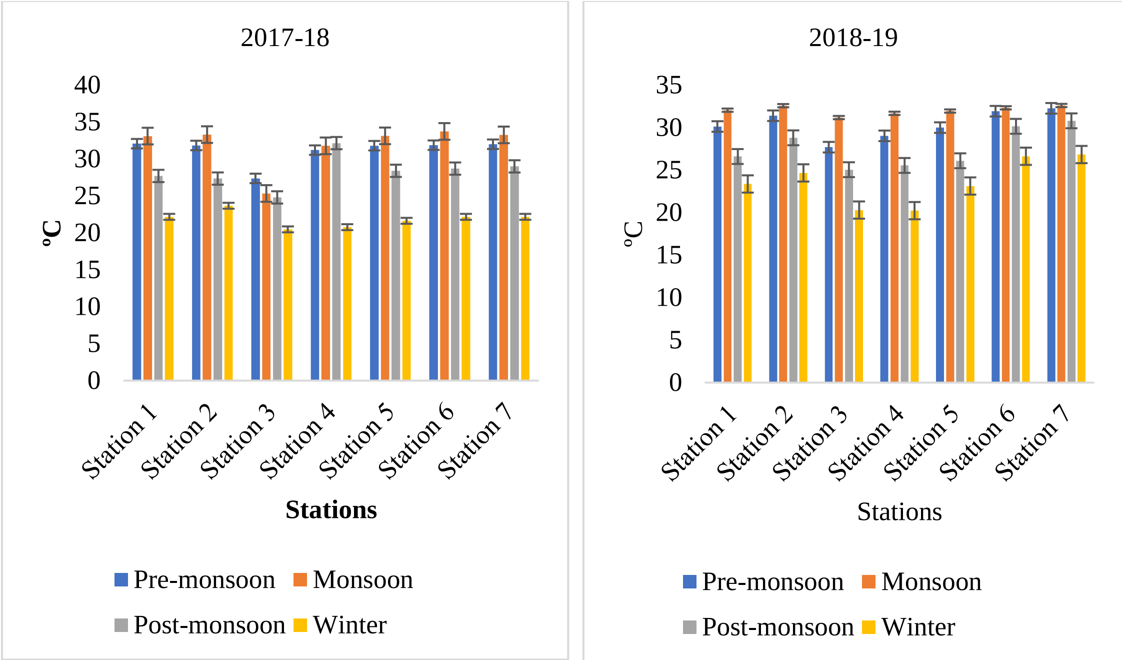


Fig. 10. Seasonal dynamics of air temperature (ºC).

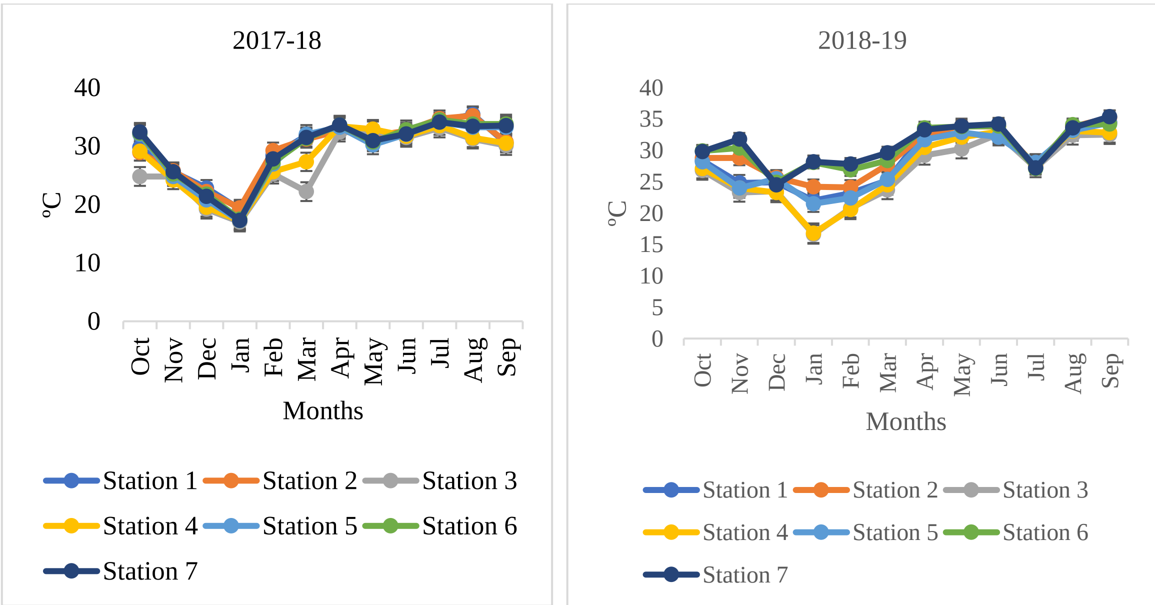


Fig. 11. Comparison of monthly values of air temperature from two study years.

Table 2. Monthly mean values (±SD) of air temperature (ºC).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	29.9±2.70	28.9±2.70	24.8±2.70	29.1±2.70	32.0±2.70	32.2±2.70	32.4±2.70
Nov-17	25.6±0.56	25.8±0.56	24.8±0.56	24.2±0.56	24.8±0.56	25.2±0.56	25.6±0.56
Dec-17	22.8±1.35	22.2±1.35	19.2±1.35	19.5±1.35	20.8±1.35	21.8±1.35	21.4±1.35
Jan-18	19.2±1.02	19.4±1.02	17.0±1.02	17.2±1.02	17.2±1.02	17.5±1.02	17.3±1.02
Feb-18	28.4±1.44	29.2±1.44	25.2±1.44	25.6±1.44	26.9±1.44	27.2±1.44	27.8±1.44
Mar-18	31.8±3.65	31.2±3.65	22.2±3.65	27.3±3.65	32.0±3.65	31.3±3.65	31.5±3.65
Apr-18	32.8±0.49	32.6±0.49	32.4±0.49	33.4±0.49	33.2±0.49	33.6±0.49	33.6±0.49
May-18	32.2±0.99	31.7±0.99	32.6±0.99	32.9±0.99	30.2±0.99	30.7±0.99	30.9±0.99
Jun-18	34.3±0.46	32.6±0.46	31.5±0.46	31.7±0.46	32.0±0.46	32.8±0.46	32.1±0.46
Jul-18	35.4±0.56	34.7±0.56	33.1±0.56	33.5±0.56	34.1±0.56	34.5±0.56	34.1±0.56
Aug-18	30.5±1.64	35.2±1.64	31.2±1.64	31.4±1.64	33.2±1.64	33.8±1.64	33.4±1.64
Sep-18	28.4±1.65	30.7±1.65	30.1±1.65	30.5±1.65	33.2±1.65	33.8±1.65	33.5±1.65
Oct-18	24.8±1.20	28.8±1.20	26.8±1.20	27.1±1.20	28.2±1.20	29.9±1.20	29.8±1.20
Nov-18	24.9±3.51	28.8±3.51	23.3±3.51	24.0±3.51	24.0±3.51	30.2±3.51	31.8±3.51
Dec-18	22.0±0.92	25.7±0.92	23.5±0.92	23.3±0.92	25.5±0.92	24.9±0.92	24.5±0.92
Jan-19	23.2±4.75	24.2±4.75	16.6±4.75	16.8±4.75	21.5±4.75	28.1±4.75	28.2±4.75
Feb-19	25.2±2.80	24.1±2.80	20.8±2.80	20.6±2.80	22.4±2.80	26.9±2.80	27.8±2.80
Mar-19	32.7±2.21	27.7±2.21	23.7±2.21	24.5±2.21	25.4±2.21	28.4±2.21	29.6±2.21
Apr-19	32.5±1.60	32.6±1.60	29.2±1.60	30.5±1.60	31.7±1.60	33.6±1.60	33.3±1.60
May-19	32.4±1.34	33.9±1.34	30.2±1.34	32.1±1.34	32.9±1.34	33.8±1.34	33.9±1.34
Jun-19	32.4±0.82	33.8±0.82	32.6±0.82	33.0±0.82	32.1±0.82	33.9±0.82	34.2±0.82
Jul-19	27.8±0.38	27.5±0.38	27.2±0.38	27.8±0.38	28.1±0.38	27.1±0.38	27.2±0.38
Aug-19	33.5±0.55	33.8±0.55	32.4±0.55	33.1±0.55	33.2±0.55	34.1±0.55	33.6±0.55
Sep-19	34.5±1.11	35.2±1.11	32.5±1.11	32.8±1.11	34.4±1.11	34.2±1.11	35.4±1.11
Mean	29.01	29.60	26.79	27.58	28.71	29.99	30.12

Water temperature (°C)

The ranges of water temperature were 18.9-34.2, 18.9-35.4, 16.2-34.0, 18.9-35.4, 16.2-33.9, 16.9-34.1, and 16.8-34.2 ºC for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean water temperature was recorded in July, 2018 for all the sites, whereas the lowest mean water temperature was obtained for all the sites in the month of January 2018 and January, 2019 (Table 3). Water temperature followed a similar trend to air temperature throughout the investigation period.

In the present research, the seasonal variation of water temperature showed the highest value during monsoon and the lowest in winter in all the stations. Over the seasons, the mean values of water temperature followed a pattern of monsoon>post-monsoon>pre-monsoon > winter (Fig. 12).

Water temperature starts increasing just after January and continues until July and thereafter a gradual fall was evident from August to December (Fig. 13). Fig. 13 compares water temperature of 2017-2018 and 2018-2019. There was a sudden fall of water temperature in July 2019 for all the stations. The trend of annual fluctuation of water temperature is almost same in both study years except the sudden fall in July 2019.

Mean water temperature (28.32 ºC) was the highest in Station 4 and the lowest mean water temperature was (27.28 ºC) recorded in Station 5 (Table 3).

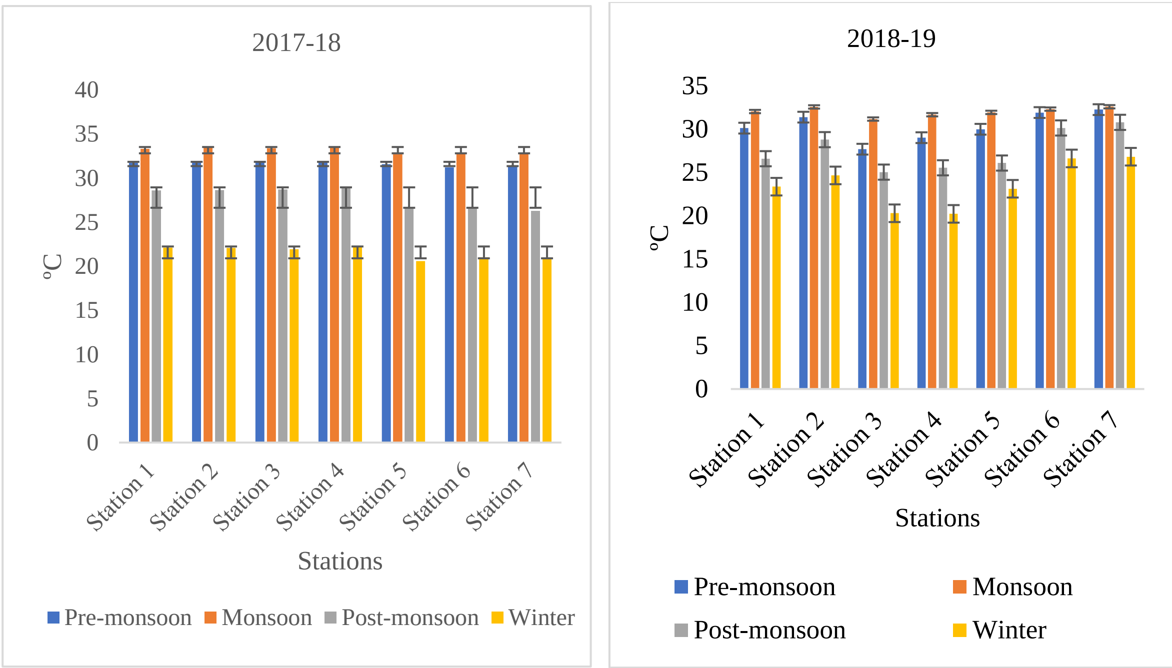


Fig. 12. Seasonal dynamics of water temperature (ºC).

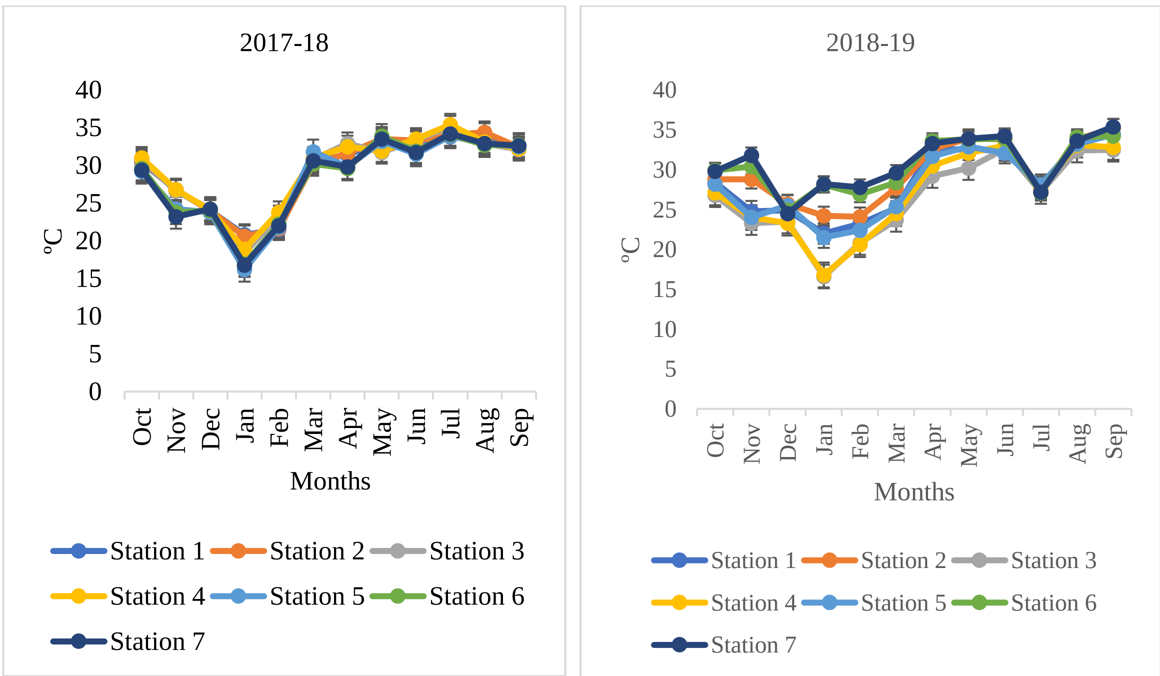


Fig. 13. Comparison of monthly values of water temperature from two study years.

Table 3. Monthly mean values (±SD) of water temperature (ºC).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	30.4±0.73	30.6±0.73	30.8±0.73	31±0.73	29.2±0.73	29.6±0.73	29.4±0.73
Nov-17	26.8±1.63	26.7±1.63	26.6±1.63	26.8±1.63	24.2±1.63	23.8±1.63	23.2±1.63
Dec-17	24.0±0.14	24.0±0.14	24.2±0.14	24.1±0.14	23.8±0.14	24.0±0.14	24.2±0.14
Jan-18	20.8±1.85	20.6±1.85	18.4±1.85	18.9±1.85	16.2±1.85	16.9±1.85	16.8±1.85
Feb-18	21.5±0.87	21.6±0.87	23.2±0.87	23.8±0.87	21.8±0.87	22.2±0.87	22.0±0.87
Mar-18	30.6±0.55	30.2±0.55	30.8±0.55	31.0±0.55	31.8±0.55	30.2±0.55	30.6±0.55
Apr-18	31.4±1.36	31.6±1.36	32.9±1.36	32.5±1.36	29.8±1.36	29.6±1.36	29.8±1.36
May-18	33.2±0.85	33.5±0.85	31.7±0.85	31.9±0.85	33.2±0.85	33.9±0.85	33.5±0.85
Jun-18	33.1±0.88	33.3±0.88	33.4±0.88	33.5±0.88	31.5±0.88	31.9±0.88	31.7±0.88
Jul-18	33.8±0.63	34.0±0.63	35.1±0.63	35.4±0.63	33.9±0.63	34.1±0.63	34.2±0.63
Aug-18	34.2±0.70	34.4±0.70	32.9±0.70	33.1±0.70	32.9±0.70	32.7±0.70	32.9±0.70
Sep-18	32.2±0.23	32.4±0.23	32.1±0.23	32.2±0.23	32.5±0.23	32.7±0.23	32.6±0.23
Oct-18	26.2±1.64	26.7±1.64	27.9±1.64	28.9±1.64	25.8±1.64	29.1±1.64	29.3±1.64
Nov-18	23.2±1.15	25.4±1.15	25.8±1.15	26.0±1.15	23.6±1.15	25.6±1.15	25.8±1.15
Dec-18	19.8±0.79	22.1±0.79	20.9±0.79	20.6±0.79	21.9±0.79	21.3±0.79	20.9±0.79
Jan-19	18.9±0.58	19.5±0.58	17.8±0.58	19.4±0.58	25.8±0.58	19.3±0.58	19.0±0.58
Feb-19	20.2±1.97	21.8±1.97	21.2±1.97	21.4±1.97	23.6±1.97	24.3±1.97	25.0±1.97
Mar-19	23.8±2.67	25.1±2.67	20.1±2.67	20.3±2.67	21.9±2.67	26.1±2.67	26.9±2.67
Apr-19	29.9±0.62	30.2±0.62	29.8±0.62	30.8±0.62	30.0±0.62	31.4±0.62	31.0±0.62
May-19	32.0±0.68	32.4±0.68	31.5±0.68	32.9±0.68	31.6±0.68	32.9±0.68	31.2±0.68
Jun-19	27.9±2.42	29.8±2.42	31.8±2.42	32.3±2.42	26.8±2.42	32.2±2.42	33.0±2.42
Jul-19	28.1±1.12	27.9±1.12	25.6±1.12	26.2±1.12	28.3±1.12	28.3±1.12	28.1±1.12
Aug-19	31.4±0.72	31.6±0.72	31.9±0.72	32.6±0.72	31.3±0.72	33.3±0.72	32.1±0.72
Sep-19	32.7±0.69	33.5±0.69	34.0±0.69	34.1±0.69	32.9±0.69	32.2±0.69	33.1±0.69
Mean	27.75	28.29	27.93	28.32	27.28	28.23	28.18

Secchi depth

The ranges of Secchi depth were 52-101, 55-105, 54-102, 55-84, 54-102, 55-110, and 52-112 cm for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean Secchi depth was recorded in August, 2019 for all the stations, whereas the lowest mean Secchi depth was obtained for Station 1 and 2 in the month of February, 2018 (Table 4). Secchi depth followed a unique trend throughout the investigation period.

In the present research, the seasonal variation of Secchi depth showed the highest value during monsoon and the lowest in winter in all the stations. Over the seasons, the mean values of Secchi depth followed a pattern of monsoon>post-monsoon> winter> pre-monsoon for Station 1 and 2 whereas the pattern was post-monsoon>monsoon>winter > pre-monsoon for Station 3, 4, 5, 6, and 7. (Fig. 14).

Most of the time Secchi depth was inconsistent so there was no definite trend. It was higher in the monsoon or post-monsoon but comparatively lower during pre-monsoon or winter. Thus, there were several ups and downs in the values of Secchi depth throughout the investigation period (Fig. 15).

Mean Secchi depth (76.75 cm) was the highest in Station 7 and the lowest mean Secchi depth (67.42 cm) was recorded in Station 3 (Table 4).

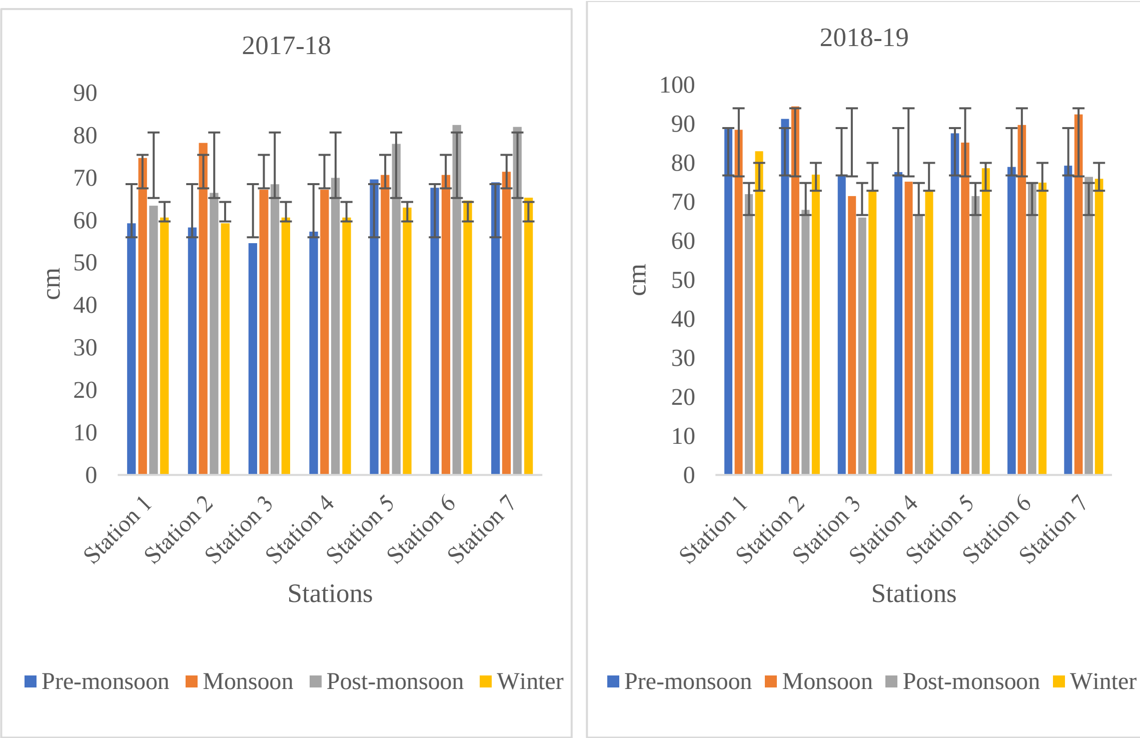


Fig. 14. Seasonal dynamics of Secchi depth (cm).

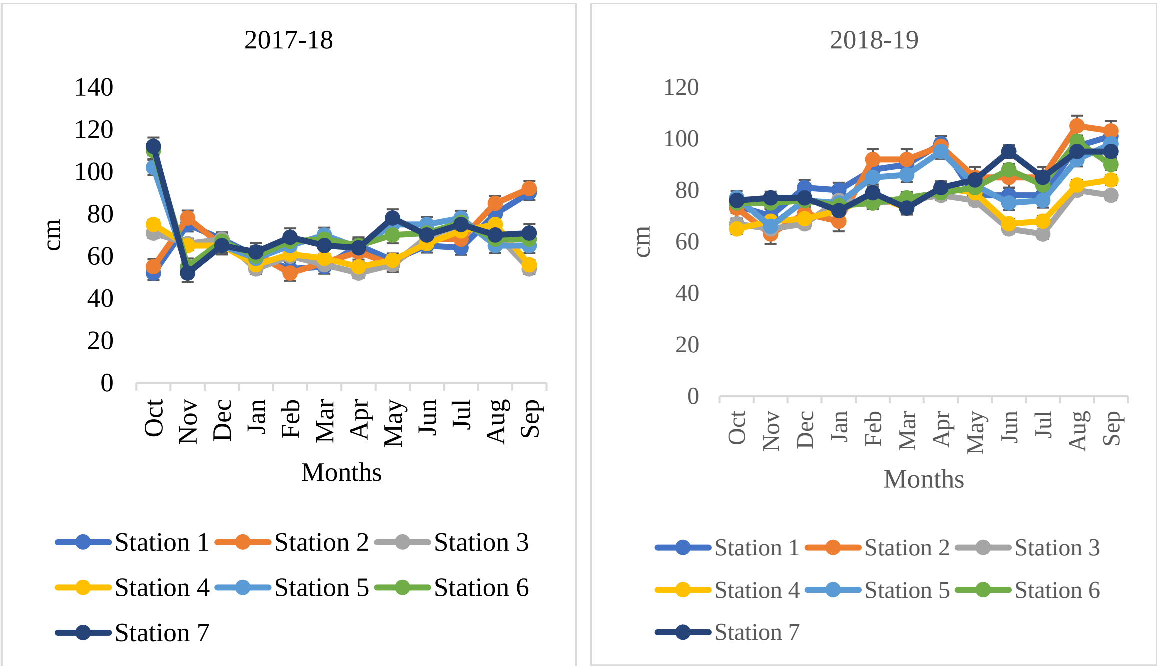


Fig. 15. Comparison of monthly values of Secchi depth from two study years.

Table 4. Monthly mean values (±SD) of Secchi depth (cm).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	52±25.44	55±25.44	71±25.44	75±25.44	102±25.44	110±25.44	112±25.44
Nov-17	75±10.37	78±10.37	66±10.37	65±10.37	54±10.37	55±10.37	52±10.37
Dec-17	68±1.46	65±1.46	68±1.46	65±1.46	65±1.46	67±1.46	65±1.46
Jan-18	60±2.85	61±2.85	54±2.85	56±2.85	69±2.85	60±2.85	62±2.85
Feb-18	54±6.41	52±6.41	60±6.41	61±6.41	65±6.41	67±6.41	69±6.41
Mar-18	55±6.13	57±6.13	56±6.13	59±6.13	70±6.13	68±6.13	65±6.13
Apr-18	65±5.29	62±5.29	62±5.29	55±5.29	64±5.29	65±5.29	64±5.29
May-18	58±9.59	56±9.59	56±9.59	58±9.59	75±9.59	70±9.59	78±9.59
Jun-18	65±3.34	68±3.34	69±3.34	66±3.34	75±3.34	71±3.34	70±3.34
Jul-18	64±4.96	68±4.96	75±4.96	72±4.96	78±4.96	76±4.96	75±4.96
Aug-18	80±7.04	85±7.04	71±7.04	75±7.04	65±7.04	68±7.04	70±7.04
Sep-18	90±15.06	92±15.06	54±15.06	56±15.06	65±15.06	68±15.06	71±15.06
Oct-18	74±4.61	73±4.61	67±4.61	65±4.61	77±4.61	75±4.61	76±4.61
Nov-18	70±5.21	63±5.21	65±5.21	68±5.21	66±5.21	75±5.21	77±5.21
Dec-18	81±4.98	71±4.98	67±4.98	69±4.98	76±4.98	76±4.98	77±4.98
Jan-19	80±3.76	68±3.76	76±3.76	72±3.76	75±3.76	74±3.76	72±3.76
Feb-19	88±6.68	92±6.68	75±6.68	78±6.68	85±6.68	75±6.68	79±6.68
Mar-19	90±8.12	92±8.12	76±8.12	73±8.12	86±8.12	77±8.12	73±8.12
Apr-19	98±9.15	97±9.15	78±9.15	81±9.15	95±9.15	79±9.15	81±9.15
May-19	78±3.25	85±3.25	76±3.25	79±3.25	82±3.25	81±3.25	84±3.25
Jun-19	78±11.03	85±11.03	65±11.03	67±11.03	75±11.03	88±11.03	95±11.03
Jul-19	78±8.48	85±8.48	63±8.48	68±8.48	76±8.48	82±8.48	85±8.48
Aug-19	97±9.05	105±9.05	80±9.05	82±9.05	92±9.05	99±9.05	95±9.05
Sep-19	101±9.20	103±9.20	78±9.20	84±9.20	98±9.20	90±9.20	95±9.20
Mean	74.95	75.75	67.42	68.71	75.83	75.67	76.75

Chemical parameters

Alkalinity

The ranges of alkalinity were 1.00-3.00, 0.40-2.80, 0.40-2.90, 0.30-1.30, 1.00-2.90, 1.20-4.40, and 1.00-2.80 meq./l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean alkalinity was recorded in July, 2018 for Station 6, whereas the lowest mean alkalinity was obtained for Station 4 in the month of April 2018 (Table 5). Alkalinity followed a distinct trend throughout the investigation period.

The seasonal variation of alkalinity showed the highest value during winter in Station 2, 4, 5 and 6 and the lowest in monsoon for the first year and in post-monsoon in the second year of investigations. Over the seasons, the mean values of alkalinity followed a pattern of pre-monsoon> winter> monsoon>post-monsoon. Station 3 and 4 showed lower values of alkalinity in both years (Fig. 16).

Annual trends of alkalinity fluctuation for most of the stations showed a fall from April to August and then a rise from September to March, falls again in of April. At the same time, one or two stations showed a number of fluctuations during both years (Fig. 17).

Mean of alkalinity (2.15 meq./l) was the highest in Station 6 whereas the lowest mean alkalinity (0.66 meq./l) was recorded in Station 3 and 4 (Table 5).

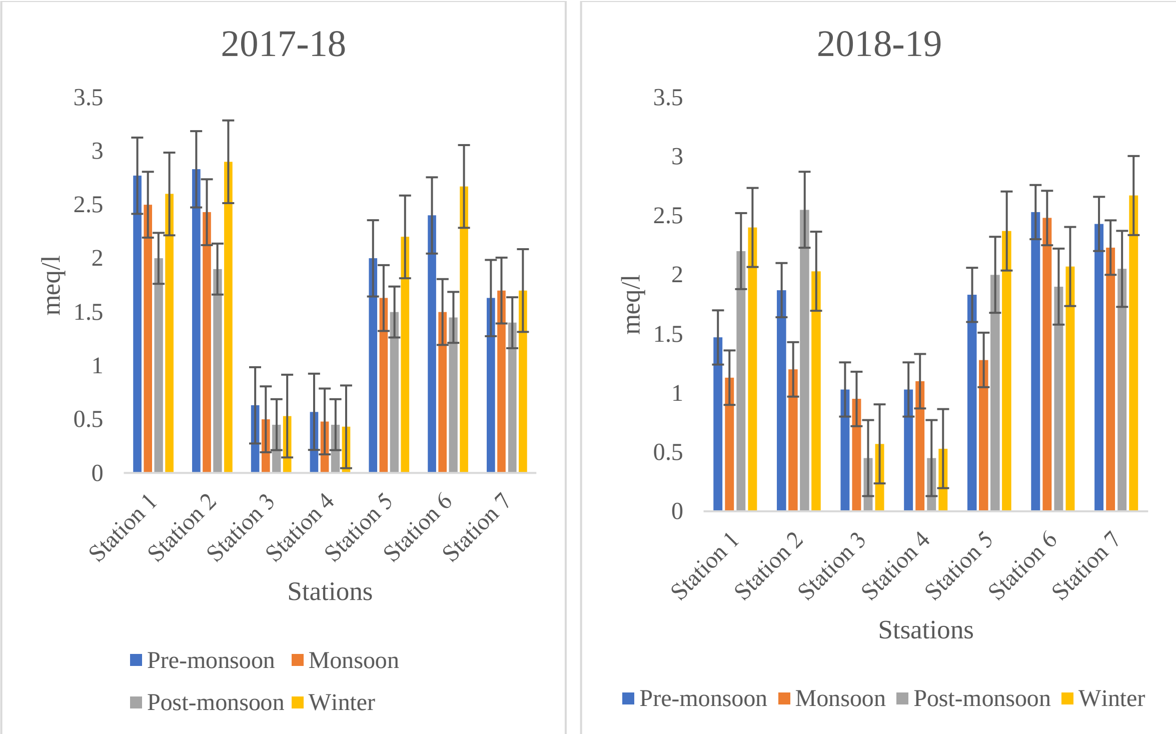


Fig. 16. Seasonal dynamics of alkalinity (meq/l).

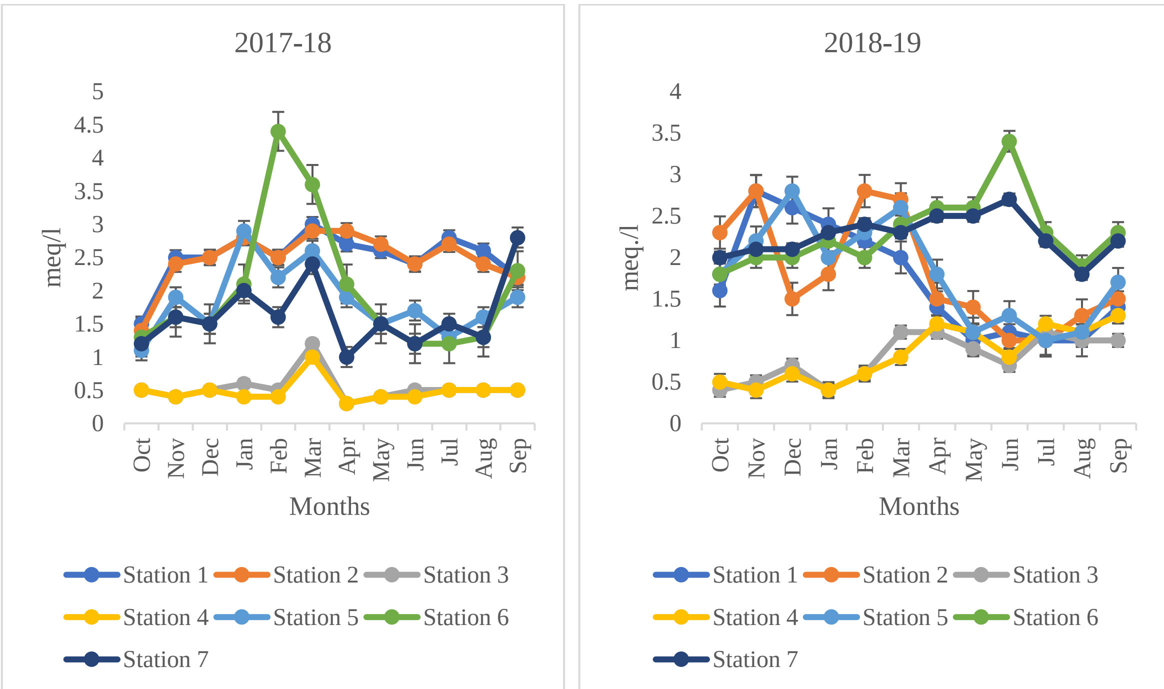


Fig. 17. Comparison of monthly values of alkalinity from two study years.

Table 5. Monthly mean values (±SD) of alkalinity (meq/l).

Months	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Oct-17	1.5±0.41	1.4±0.41	0.5±0.41	0.5±0.41	1.1±0.41	1.3±0.41	1.2±0.41
Nov-17	2.5±0.86	2.4±0.86	0.4±0.86	0.4±0.86	1.9±0.86	1.6±0.86	1.6±0.86
Dec-17	2.5±0.82	2.5±0.82	0.5±0.82	0.5±0.82	1.5±0.82	1.5±0.82	1.5±0.82
Jan-18	2.8±1.05	2.8±1.05	0.6±1.05	0.4±1.05	2.9±1.05	2.1±1.05	2.0±1.05
Feb-18	2.5±1.37	2.5±1.37	0.5±1.37	0.4±1.37	2.2±1.37	4.4±1.37	1.6±1.37
Mar-18	3.0±0.96	2.9±0.96	1.2±0.96	1.0±0.96	2.6±0.96	3.6±0.96	2.4±0.96
Apr-18	2.7±1.08	2.9±1.08	0.3±1.08	0.3±1.08	1.9±1.08	2.1±1.08	1.0±1.08
May-18	2.6±0.92	2.7±0.92	0.4±0.92	0.4±0.92	1.5±0.92	1.5±0.92	1.5±0.92
Jun-18	2.4±0.81	2.4±0.81	0.5±0.81	0.4±0.81	1.7±0.81	1.2±0.81	1.2±0.81
Jul-18	2.8±0.94	2.7±0.94	0.5±0.94	0.5±0.94	1.3±0.94	1.2±0.94	1.5±0.94
Aug-18	2.6±0.83	2.4±0.83	0.5±0.83	0.5±0.83	1.6±0.83	1.3±0.83	1.3±0.83
Sep-18	2.2±0.91	2.2±0.91	0.5±0.91	0.5±0.91	1.9±0.91	2.3±0.91	2.8±0.91
Oct-18	1.6±0.74	2.3±0.74	0.4±0.74	0.5±0.74	1.8±0.74	1.8±0.74	2.0±0.74
Nov-18	2.8±0.99	2.8±0.99	0.5±0.99	0.4±0.99	2.2±0.99	2.0±0.99	2.1±0.99
Dec-18	2.6±0.87	1.5±0.87	0.7±0.87	0.6±0.87	2.8±0.87	2.0±0.87	2.1±0.87
Jan-19	2.4±0.87	1.8±0.87	0.4±0.87	0.4±0.87	2.0±0.87	2.2±0.87	2.3±0.87
Feb-19	2.2±0.88	2.8±0.88	0.6±0.88	0.6±0.88	2.3±0.88	2.0±0.88	2.4±0.88
Mar-19	2±0.75	2.7±0.75	1.1±0.75	0.8±0.75	2.6±0.75	2.4±0.75	2.3±0.75
Apr-19	1.4±0.61	1.5±0.61	1.1±0.61	1.2±0.61	1.8±0.61	2.4±0.61	2.5±0.61
May-19	1.0±0.72	1.4±0.72	0.9±0.72	1.1±0.72	1.1±0.72	2.6±0.72	2.5±0.72
Jun-19	1.1±1.05	1.0±1.05	0.7±1.05	0.8±1.05	1.3±1.05	3.4±1.05	2.7±1.05
Jul-19	1.0±0.59	1.0±0.59	1.1±0.59	1.2±0.59	1.0±0.59	2.3±0.59	2.2±0.59
Aug-19	1.0±0.38	1.3±0.38	1.0±0.38	1.1±0.38	1.1±0.38	1.9±0.38	1.8±0.38
Sep-19	1.4±0.48	1.5±0.48	1.0±0.48	1.3±0.48	1.7±0.48	2.3±0.48	2.2±0.48
Mean	2.11	2.14	0.66	0.66	1.83	2.15	1.95

Hydrogen ion concentration (pH)

The ranges of pH were 6.30-8.40, 5.80-8.40, 5.80-8.70, 5.80-8.50, 5.80-8.30, 5.80-8.10, and 6.20-8.10 meq/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean pH was recorded in December, 2018 for Station 3, whereas the lowest mean pH was obtained for Station 3 and Station 4 in November 2017. The trend of alkalinity distinct throughout the investigation period.

The seasonal variation of pH showed the highest value during monsoon in Station 2, 3, 4, 5, 6 and 7 and the lowest in winter for all the stations first year and in pre-monsoon in the second year of investigations. Over the seasons, the mean values of alkalinity followed a pattern of pre-monsoon> monsoon> post-monsoon>winter for the first year and it was just opposite in the second year of investigation (Fig. 18).

Fig. 19 shows the annual range of pH and for the two consecutive years of study, the pH of all the stations showed more or less a similar pattern of fluctuation in both years of investigation. In the first year, there was a sharp fall of pH in November 2017 and July 2018 for all stations but no pattern like this was observed in the second year (Fig. 19).

Mean value of pH (7.85 meq./l) was the highest in Station 3 whereas the lowest mean value of pH (7.24 meq./l) was recorded in Station 5 (Table 6).

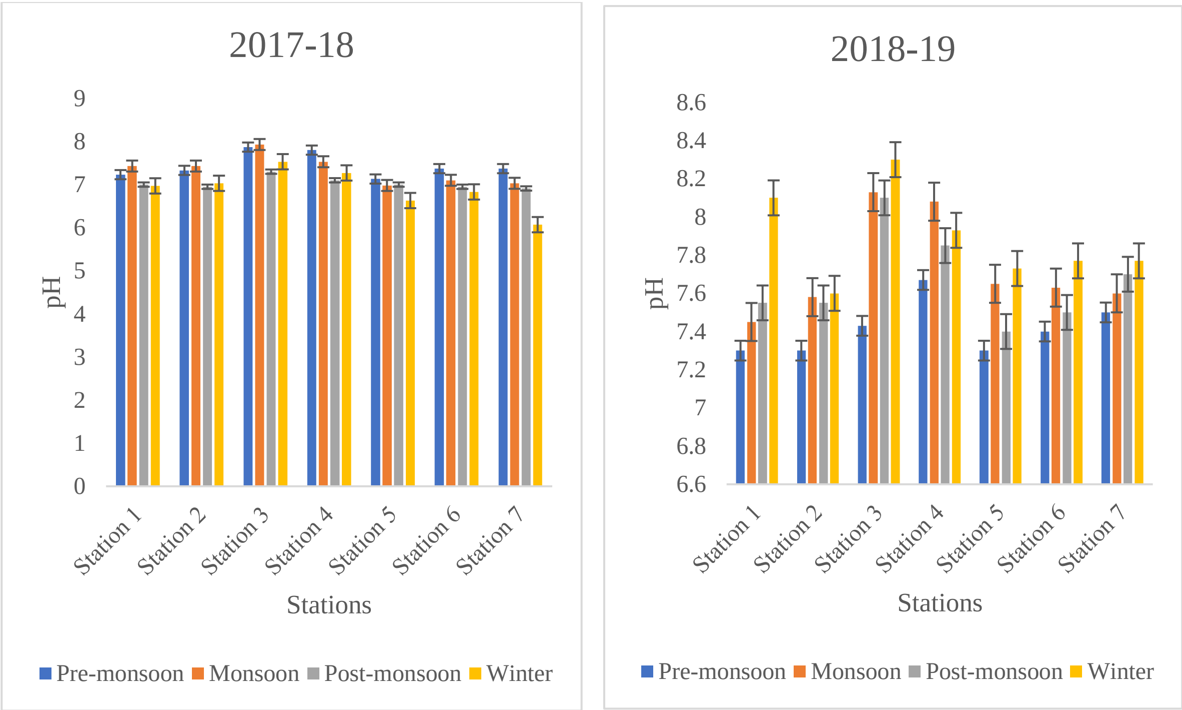


Fig. 18. Seasonal dynamics of pH.

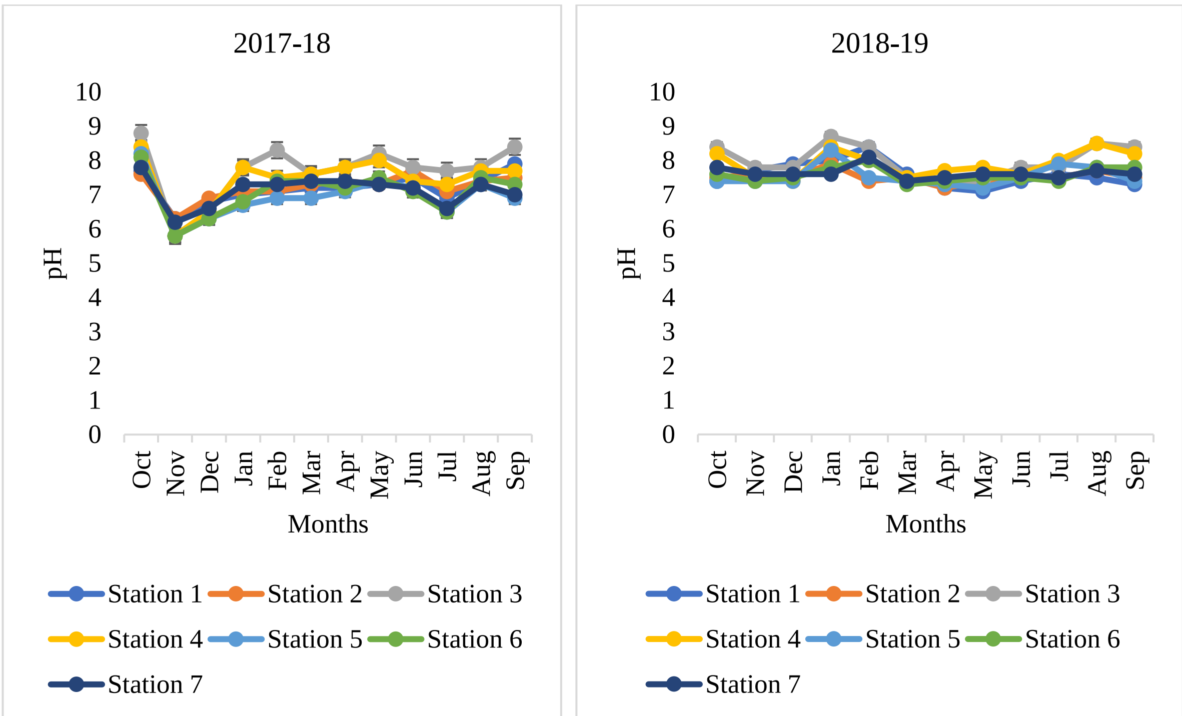


Fig. 19. Comparison of monthly values of pH from two study years.

Table 6. Monthly mean values (±SD) of pH.

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	7.7±0.43	7.6±0.43	8.8±0.43	8.4±0.43	8.2±0.43	8.1±0.43	7.8±0.43
Nov-17	6.3±0.24	6.3±0.24	5.8±0.24	5.8±0.24	5.8±0.24	5.8±0.24	6.2±0.24
Dec-17	6.8±0.23	6.9±0.23	6.5±0.23	6.5±0.23	6.3±0.23	6.3±0.23	6.6±0.23
Jan-18	7.0±0.45	7.1±0.45	7.8±0.45	7.8±0.45	6.7±0.45	6.8±0.45	7.3±0.45
Feb-18	7.1±0.46	7.1±0.46	8.3±0.46	7.5±0.46	6.9±0.46	7.4±0.46	7.3±0.46
Mar-18	7.2±0.24	7.3±0.24	7.6±0.24	7.6±0.24	6.9±0.24	7.4±0.24	7.4±0.24
Apr-18	7.2±0.29	7.4±0.29	7.8±0.29	7.8±0.29	7.1±0.29	7.2±0.29	7.4±0.29
May-18	7.3±0.37	7.3±0.37	8.2±0.37	8.0±0.37	7.4±0.37	7.5±0.37	7.3±0.37
Jun-18	7.5±0.27	7.7±0.27	7.8±0.27	7.4±0.27	7.2±0.27	7.1±0.27	7.2±0.27
Jul-18	6.9±0.45	7.1±0.45	7.7±0.45	7.3±0.45	6.5±0.45	6.5±0.45	6.6±0.45
Aug-18	7.4±0.20	7.4±0.20	7.8±0.20	7.7±0.20	7.3±0.20	7.5±0.20	7.3±0.20
Sep-18	7.9±0.53	7.5±0.53	8.4±0.53	7.7±0.53	6.9±0.53	7.3±0.53	7.0±0.53
Oct-18	7.4±0.40	7.5±0.40	8.4±0.40	8.2±0.40	7.4±0.40	7.6±0.40	7.8±0.40
Nov-18	7.7±0.15	7.6±0.15	7.8±0.15	7.5±0.15	7.4±0.15	7.4±0.15	7.6±0.15
Dec-18	7.9±0.20	7.5±0.20	7.8±0.20	7.4±0.20	7.4±0.20	7.5±0.20	7.6±0.20
Jan-19	8.0±0.38	7.9±0.38	8.7±0.38	8.4±0.38	8.3±0.38	7.8±0.38	7.6±0.38
Feb-19	8.4±0.40	7.4±0.40	8.4±0.40	8.0±0.40	7.5±0.40	8.0±0.40	8.1±0.40
Mar-19	7.6±0.10	7.5±0.10	7.5±0.10	7.5±0.10	7.4±0.10	7.3±0.10	7.4±0.10
Apr-19	7.2±0.18	7.2±0.18	7.4±0.18	7.7±0.18	7.3±0.18	7.4±0.18	7.5±0.18
May-19	7.1±0.24	7.4±0.24	7.4±0.24	7.8±0.24	7.2±0.24	7.5±0.24	7.6±0.24
Jun-19	7.4±0.13	7.6±0.13	7.8±0.13	7.6±0.13	7.5±0.13	7.5±0.13	7.6±0.13
Jul-19	7.6±0.23	7.5±0.23	7.8±0.23	8.0±0.23	7.9±0.23	7.4±0.23	7.5±0.23
Aug-19	7.5±0.40	7.7±0.40	8.5±0.40	8.5±0.40	7.8±0.40	7.7±0.40	7.7±0.40
Sep-19	7.3±0.42	7.5±0.42	8.4±0.42	8.2±0.42	7.4±0.42	7.6±0.42	7.6±0.42
Mean	7.39	7.38	7.85	7.68	7.24	7.33	7.38

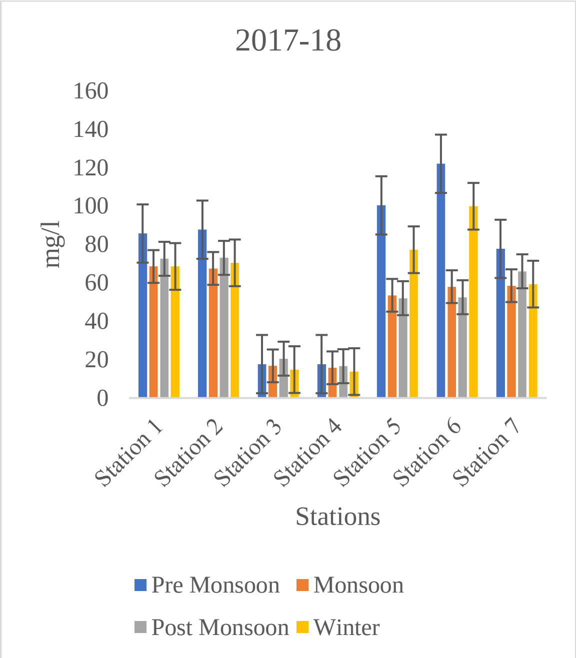
Total dissolved solids (TDS)

TDS ranged from 32-157, 34-344, 17-153, 12-74, 23-753, 24-184, and 31-115 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean TDS (753 mg/l) was recorded in February, 2019 for Station 5 whereas the lowest mean TDS (12 mg/l) was obtained in December, 2017 for Station 3. The trend of alkalinity distinct but different in two years of investigation period.

The seasonal variation of TDS showed the highest value during pre-monsoon in all the stations and the lowest in winter for all the stations in the first year and in monsoon for Station 1, 2, and 5 and during post-monsoon for Station 3, 4, 6, and 7 in the second year of investigations. Over the seasons, the mean values of alkalinity followed a pattern of pre-monsoon> winter > post-monsoon> monsoon for the first year and it was more or less opposite in the second year of investigation. In both years of investigation TDS concentrations remained low in Station 3 and 4 (Fig. 20).

Fig. 21 shows the annual range of TDS and for the two consecutive years of study, the TDS of all the stations showed more or less a similar pattern of fluctuation in both years of investigation. In the first year, there was a sharp raise of TDS in March 2018 for Station 5, 6, and 7 and February 2019 for Station 2 but no pattern like this was observed in the second year (Fig. 21).

Mean value of TDS (105.51 mg/l) was the highest in Station 2 whereas the lowest mean value of TDS (25.43 mg/l) was recorded in Station 4 (Table 7).



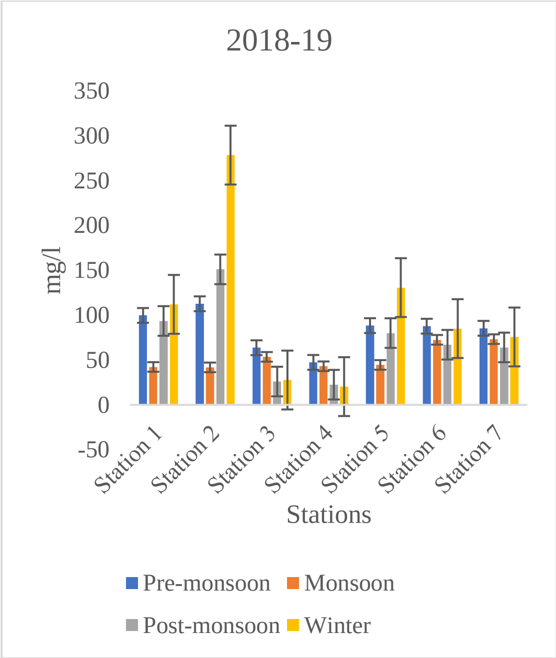
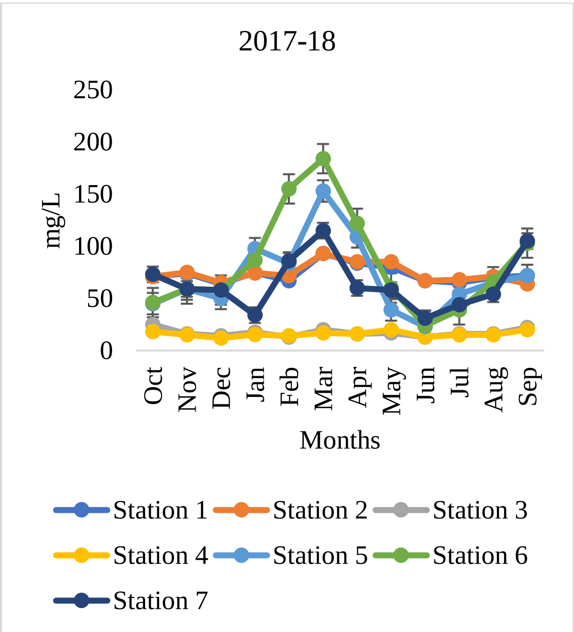


Fig. 20. Seasonal dynamics of TDS (mg/l).



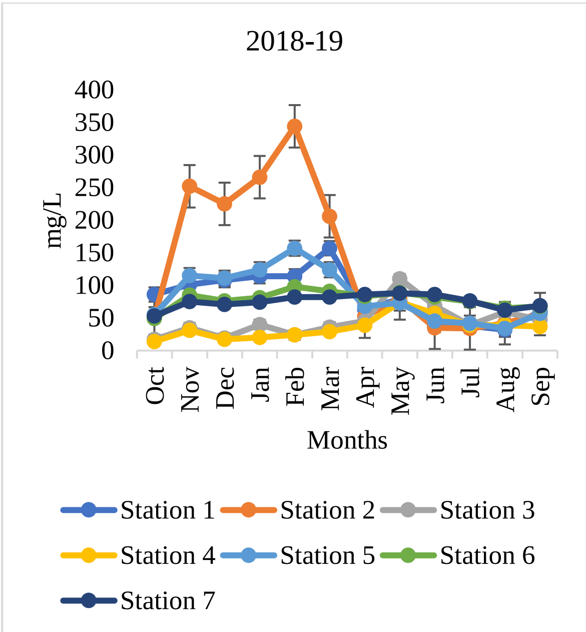


Fig. 21. Comparison of monthly values of TDS from two study years.

Table 7. Monthly mean values (±SD) of TDS (mg/l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	71±22.73	71±22.73	25±22.73	18±22.73	45±22.73	46±22.73	73±22.73
Nov-17	74±25.23	75±25.23	16±25.23	15±25.23	59±25.23	59±25.23	59±25.23
Dec-17	64±22.98	65±22.98	14±22.98	12±22.98	50±22.98	58±22.98	58±22.98
Jan-18	75±34.09	74±34.09	17±34.09	15±34.09	98±34.09	87±34.09	34±34.09
Feb-18	67±48.43	72±48.43	13±48.43	14±48.43	84±48.43	155±48.43	86±48.43
Mar-18	93±62.43	93±62.43	20±62.43	17±62.43	153±62.43	184±62.43	115±62.43
Apr-18	84±41.98	85±41.98	16±41.98	16±41.98	109±41.98	122±41.98	60±41.98
May-18	80±27.04	85±27.04	17±27.04	20±27.04	39±27.04	60±27.04	58±27.04
Jun-18	67±23.42	67±23.42	13±23.42	13±23.42	23±23.42	24±23.42	31±23.42
Jul-18	65±21.45	68±21.45	16±21.45	15±21.45	54±21.45	39±21.45	44±21.45
Aug-18	70±24.87	71±24.87	16±24.87	15±24.87	65±24.87	66±24.87	54±24.87
Sep-18	72±34.19	64±34.19	22±34.19	20±34.19	72±34.19	103±34.19	105±34.19
Oct-18	86±24.56	50±24.56	17±24.56	14±24.56	55±24.56	49±24.56	53±24.56
Nov-18	101±74.34	252±74.34	35±74.34	31±74.34	115±74.34	85±74.34	75±74.34
Dec-18	108±70.61	225±70.61	19±70.61	17±70.61	111±70.61	76±70.61	71±70.61
Jan-19	114±80.95	266±80.95	40±80.95	20±80.95	124±80.95	81±80.95	74±80.95
Feb-19	114±109.5	344±109.5	24±109.5	24±109.5	753±109.5	98±109.5	82±109.5
Mar-19	157±63.92	206±63.92	36±63.92	29±63.92	124±63.92	91±63.92	82±63.92
Apr-19	63±18.12	52±18.12	45±18.12	39±18.12	68±18.12	83±18.12	86±18.12
May-19	79±12.75	80±12.75	110±12.75	74±12.75	73±12.75	89±12.75	88±12.75
Jun-19	39±29.55	35±29.55	69±29.55	57±29.55	45±29.55	82±29.55	86±29.55
Jul-19	38±18.26	34±18.26	39±18.26	39±18.26	42±18.26	75±18.26	76±18.26
Aug-19	32±13,99	42±13,99	59±13,99	39±13,99	34±13,99	65±13,99	62±13,99
Sep-19	60±11.34	56±11.34	47±11.34	37±11.34	57±11.34	68±11.34	69±11.34
Mean	78.03	105.51	31.06	25.43	77.32	81.03	70.14

Electrical conductivity (EC)

The ranges of electrical conductivity were 135-640, 31-1109, 30-413, 30-328, 55-558, 54-436, and 66-440 µS/cm for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean electrical conductivity (1322 µS/cm) was recorded in November, 2018 for Station 2 whereas the lowest mean EC (22 µS/cm) was obtained in February, 2018 for Station 4. The trend of EC was distinct but different in two years of investigation.

The seasonal variation of EC showed the highest value during winter for Station 1, 2, 6, and 7 but during post-monsoon for Station 3, 4, and 5 in the first year and the lowest was recorded in monsoon for Station 1, 2, 3, 4 and 7 but during winter for Station 5 and post-monsoon for Station 6 in the first year and in second year it was highest during winter for all the stations and the lowest during pre-monsoon for all the stations. Over the seasons, the mean values of EC followed a pattern of winter> post-monsoon> pre-monsoon> monsoon the period of investigation. In both years of investigation EC concentrations remained low in Station 3 and 4 (Fig. 22).

Fig. 23 shows the annual range of EC and for the two consecutive years of study, the EC of all the stations showed more or less a similar pattern of fluctuation in both years of investigation. In the first year, graph showed a zig zag pattern for Station 1, 2, 5, 6, and 7 but Station 3 and 4 remained the same and in the second year there was at least three sharp raise of EC for Station 2 and in other stations there was no distinct pattern (Fig. 23).

Mean value of EC (370.75 µS/cm) was the highest in Station 2 whereas the lowest mean value (100.25 µS/cm) was recorded in Station 4 (Table 8).

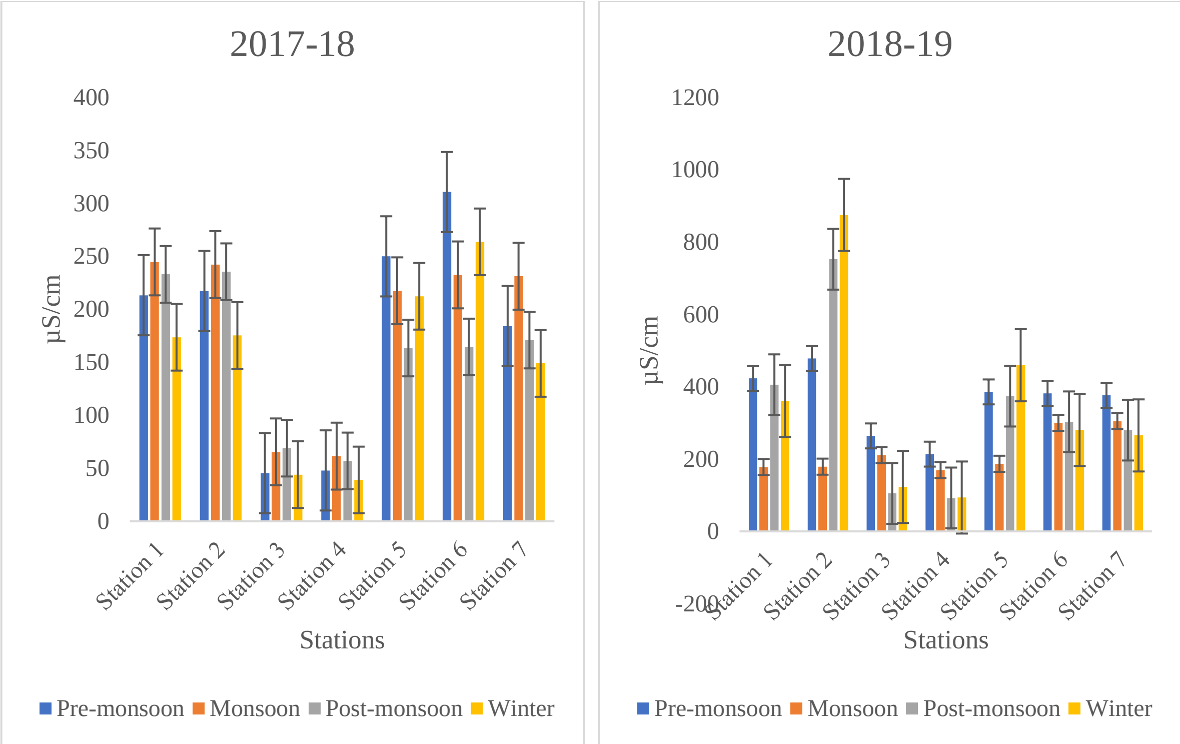


Fig. 22. Seasonal dynamics of electrical conductivity (µS/cm).

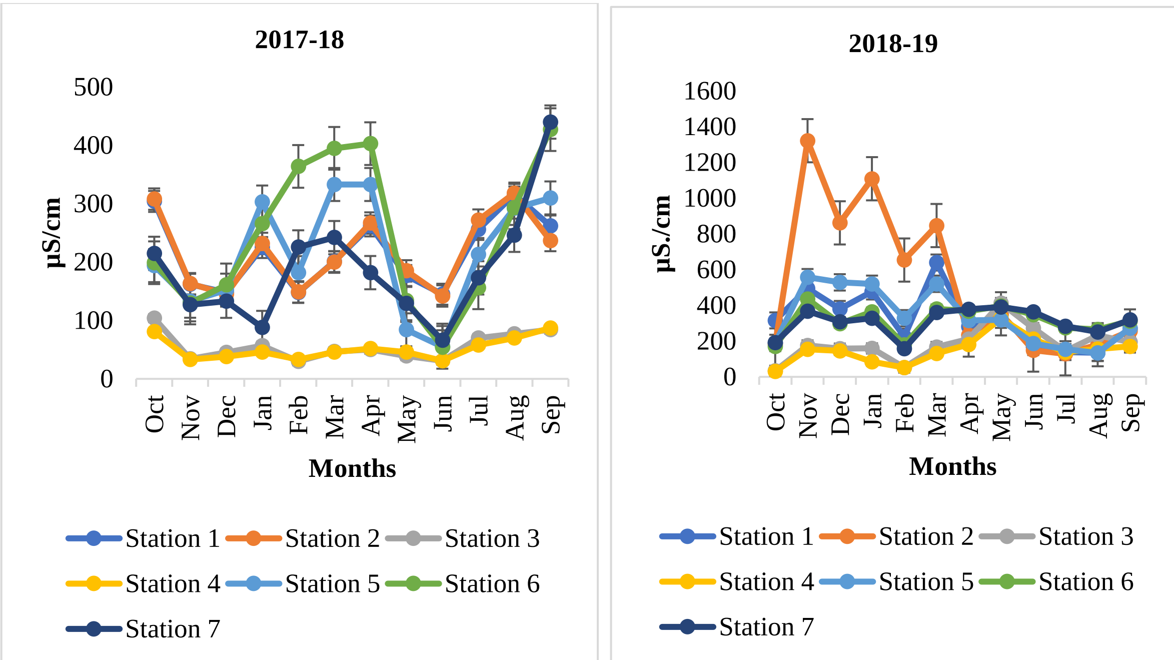


Fig. 23. Comparison of monthly values of electrical conductivity from two study years.

Table 8. Monthly mean values (±SD) of electrical conductivity (µS/cm) .

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	304±87.66	308±87.66	104±87.66	81±87.66	194±87.66	199±87.66	215±87.66
Nov-17	162±55.40	163±55.40	34±55.40	33±55.40	133±55.40	130±55.40	127±55.40
Dec-17	148±52.58	145±52.58	45±52.58	38±52.58	152±52.58	161±52.58	133±52.58
Jan-18	225±106.88	232±106.88	57±106.88	46±106.88	303±106.88	266±106.88	88±106.88
Feb-18	148±115.28	149±115.28	30±115.28	22±115.28	182±115.28	364±115.28	226±115.28
Mar-18	201±131.67	200±131.67	47±131.67	46±131.67	333±131.67	395±131.67	242±131.67
Apr-18	262±134.65	267±134.65	50±134.65	52±134.65	333±134.65	403±134.65	182±134.65
May-18	177±58.85	185±58.85	39±58.85	46±58.85	84±58.85	134±58.85	129±58.85
Jun-18	145±48.62	142±48.62	31±48.62	31±48.62	55±48.62	54±48.62	66±48.62
Jul-18	256±84.05	272±84.05	70±84.05	58±84.05	213±84.05	156±84.05	173±84.05
Aug-18	316±109.71	318±109.71	77±109.71	70±109.71	292±109.71	293±109.71	246±109.71
Sep-18	262±134.83	237±134.83	84±134.83	87±134.83	310±134.83	427±134.83	440±134.83
Oct-18	316±99.77	183±99.77	34±99.77	30±99.77	190±99.77	170±99.77	193±99.77
Nov-18	495±392.61	1322±392.61	176±392.61	155±392.61	558±392.61	436±392.61	367±392.61
Dec-18	380±248.58	862±248.58	158±248.58	145±248.58	529±248.58	298±248.58	309±248.58
Jan-19	478±336.45	1109±336.45	159±336.45	84±336.45	521±336.45	364±336.45	329±336.45
Feb-19	224±208.32	654±208.32	52±208.32	52±208.32	328±208.32	179±208.32	158±208.32
Mar-19	640±255.39	847±255.39	167±255.39	132±255.39	521±255.39	381±255.39	360±255.39
Apr-19	281±76.38	234±76.38	212±76.38	181±76.38	316±76.38	367±76.38	378±76.38
May-19	348±35.97	353±35.97	413±35.97	328±35.97	320±35.97	396±35.97	391±35.97
Jun-19	167±86.89	150±86.89	273±86.89	212±86.89	187±86.89	349±86.89	364±86.89
Jul-19	139±67.64	129±67.64	143±67.64	139±67.64	154±67.64	274±67.64	283±67.64
Aug-19	135±55.73	180±55.73	232±55.73	157±55.73	134±55.73	266±55.73	252±55.73
Sep-19	271±55.88	257±55.88	196±55.88	170±55.88	273±55.88	312±55.88	320±55.88
Mean	270	370.75	120.13	100.25	275.63	282.25	248.79

Dissolved oxygen (DO)

During the study period (2017 – 2019), the ranges of dissolved oxygen (DO) were 5.1-14.9, 6.5-10.6, 5.9-10, 5.2-10.6, 3.2-10, 4.5-10.2, and 5.2-10.5 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean DO (14.9 mg/l) was recorded in January, 2018 for Station 1 whereas the lowest mean DO (3.2 mg/l) was obtained in December, 2017 for Station 5. The trend of DO distinct but different in two years of investigation.

The seasonal variation of DO show the highest value during winter for Station 1, 2, 6, and 7 but during post-monsoon for Station 3, 4, and 5 in the first year and the lowest was recorded in monsoon for Station 1, 2, 3, 4 and 7 but during winter for Station 5 and post-monsoon for Station 6 in the first year and in second year it was highest during winter for all the stations and the lowest during pre-monsoon for all the stations. Over the seasons, the mean values of DO follow a pattern of winter> post-monsoon> pre-monsoon> monsoon in the both year of investigation (Fig. 24).

Fig. 25 shows the annual range of DO for the two consecutive years of study, the DO of all the stations showed more or less a similar pattern of fluctuation in both years of investigation. In the first year, graph showed a zig zag pattern for all the stations but there was a sudden fall of DO during December, 2017 in Station 5 and there was a sharp raise of DO in January 2018 in Station 2, 5, 6, and 7 and in the second year the graph showed a zig zag pattern (Fig. 25).

Mean value (7.53 mg/l) of DO was the highest in Station 1 whereas the lowest mean value of DO (7.11 mg/l) was recorded in Station 6 (Table 9).

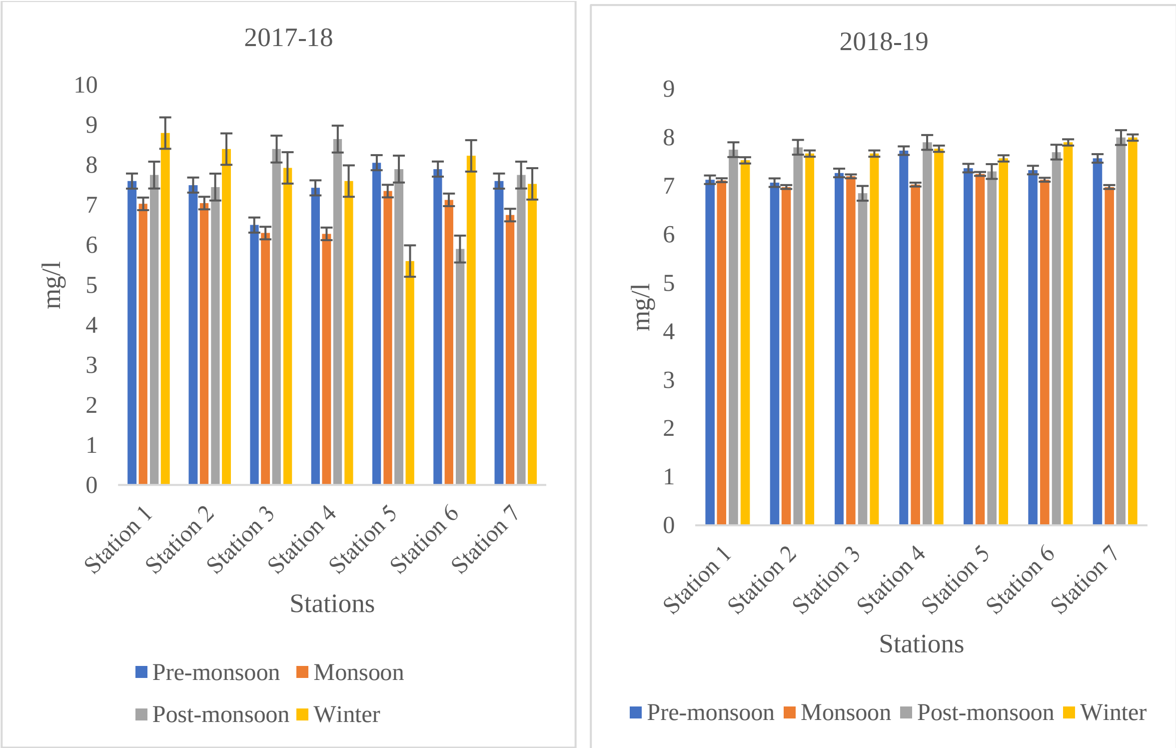


Fig. 24. Seasonal dynamics of DO (mg/l).

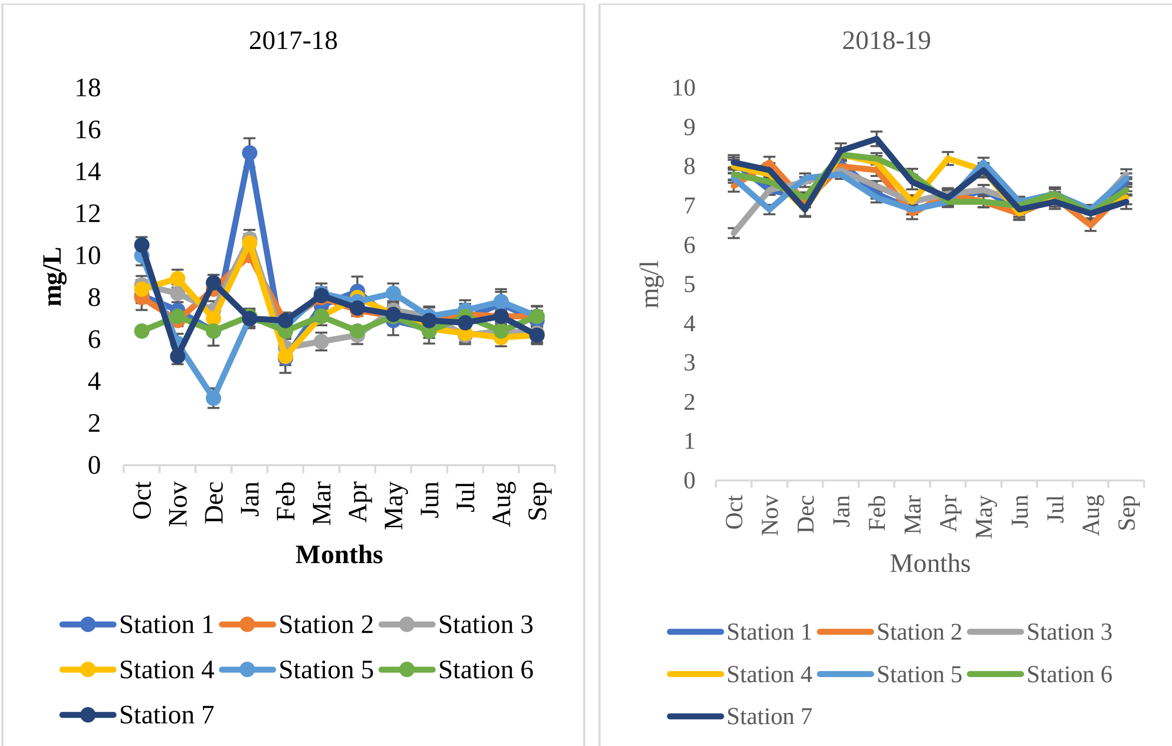


Fig. 25. Comparison of monthly values of DO from two study years.

Table 9. Monthly mean values (±SD) of DO (mg/l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	8.1±1.36	8.0±1.36	8.6±1.36	8.4±1.36	10.0±1.36	7.3±1.36	10.5±1.36
Nov-17	7.4±1.28	6.9±1.28	8.2±1.28	8.9±1.28	5.8±1.28	4.5±1.28	5.2±1.28
Dec-17	6.4±1.82	8.4±1.82	7.4±1.82	7.0±1.82	3.2±1.82	4.5±1.82	8.7±1.82
Jan-18	14.9±2.90	10.0±2.90	10.8±2.90	10.6±2.90	7.0±2.90	10.0±2.90	7.0±2.90
Feb-18	5.1±0.77	6.8±0.77	5.6±0.77	5.2±0.77	6.6±0.77	10.2±0.77	6.9±0.77
Mar-18	7.6±0.81	8.0±0.81	5.9±0.81	7.1±0.81	8.2±0.81	8.1±0.81	8.1±0.81
Apr-18	8.3±0.79	7.4±0.79	6.2±0.79	8.0±0.79	7.8±0.79	8.2±0.79	7.5±0.79
May-18	6.9±0.42	7.1±0.42	7.4±0.42	7.2±0.42	8.2±0.42	7.4±0.42	7.2±0.42
Jun-18	6.5±0.29	6.8±0.29	7.1±0.29	6.5±0.29	7.1±0.29	6.4±0.29	6.9±0.29
Jul-18	7.0±0.45	7.2±0.45	6.2±0.45	6.3±0.45	7.4±0.45	7.1±0.45	6.8±0.45
Aug-18	7.7±0.67	7.1±0.67	6.4±0.67	6.1±0.67	7.8±0.67	7.4±0.67	7.1±0.67
Sep-18	6.9±0.44	7.1±0.44	6.3±0.44	6.2±0.44	7.1±0.44	7.6±0.44	6.2±0.44
Oct-18	8.1±0.63	7.5±0.63	6.3±0.63	8.0±0.63	7.7±0.63	7.8±0.63	8.1±0.63
Nov-18	7.4±0.40	8.1±0.40	7.4±0.40	7.8±0.40	6.9±0.40	7.6±0.40	7.9±0.40
Dec-18	7.2±0.32	7.1±0.32	7.6±0.32	6.9±0.32	7.7±0.32	7.2±0.32	6.9±0.32
Jan-19	8.1±0.23	8.0±0.23	7.9±0.23	8.3±0.23	7.8±0.23	8.3±0.23	8.4±0.23
Feb-19	7.3±0.54	7.9±0.54	7.5±0.54	8.1±0.54	7.2±0.54	8.2±0.54	8.7±0.54
Mar-19	6.9±0.38	6.8±0.38	7.5±0.38	7.1±0.38	6.9±0.38	7.8±0.38	7.6±0.38
Apr-19	7.1±0.40	7.3±0.40	7.3±0.40	8.2±0.40	7.1±0.40	7.1±0.40	7.2±0.40
May-19	7.4±0.41	7.1±0.41	7.4±0.41	7.9±0.41	8.1±0.41	7.1±0.41	7.9±0.41
Jun-19	6.9±0.13	6.8±0.13	7.1±0.13	6.8±0.13	7.1±0.13	7.0±0.13	6.9±0.13
Jul-19	7.2±0.10	7.2±0.10	7.1±0.10	7.3±0.10	7.3±0.10	7.3±0.10	7.1±0.10
Aug-19	6.8±0.12	6.5±0.12	6.8±0.12	6.8±0.12	6.9±0.12	6.8±0.12	6.8±0.12
Sep-19	7.6±0.26	7.4±0.26	7.8±0.26	7.2±0.26	7.7±0.26	7.4±0.26	7.1±0.26
Mean	7.53	7.44	7.23	7.41	7.28	7.11	7.45

Soluble reactive phosphorus (SRP)

During the study period (2017 – 2019), the ranges of Soluble reactive phosphorus (SRP) were 4.80-310.53, 4.80-182.15, 8.28-613.52, 2.31-448.52, 8.28-244.38, 9.81-112.89, and 11.98-120.32 µg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean SRP (613.52 µg/l) was recorded in June, 2019 for Station 3 whereas the lowest mean SRP (3.2 µg/l) was in October, 2017 for Station 4. The trend of SRP distinct but different in two years of investigation.

The seasonal variation of SRP show the highest value during monsoon for Station 1, 2, 3, and 4 but during pre-monsoon for Station 5 and 6 and in winter for Station 7 in the first year and the lowest was recorded in post-monsoon for Station 1, 3, 4, 5, 6, and 7 but during pre-monsoon for Station 2 in the first year and in second year it was highest during monsoon for Station 1, 2, 5, 6, and 7 but during pre-monsoon in Station 3 and the lowest during winter for Station 1 and 2. Over the seasons, the mean values of SRP did not follow any distinct trend or pattern (Fig. 26).

Fig. 27 shows the annual range of SRP for the two consecutive years of study, the SRP of all the stations showed two different types of patterns of fluctuation in two years of investigation. In the first year, graph showed a zig zag pattern for all the stations but there were a number of sharp raises of SRP in Station 2, 5, 6, and 7 and there were also a number of sharp raises of SRP in Station 3, 4, 5, and 7 in the second year (Fig. 27).

Mean value of SRP (64.54 µg/l) was the highest in Station 1 whereas the lowest mean value of SRP (40.51 µg/l) was recorded in Station 2 (Table 10).

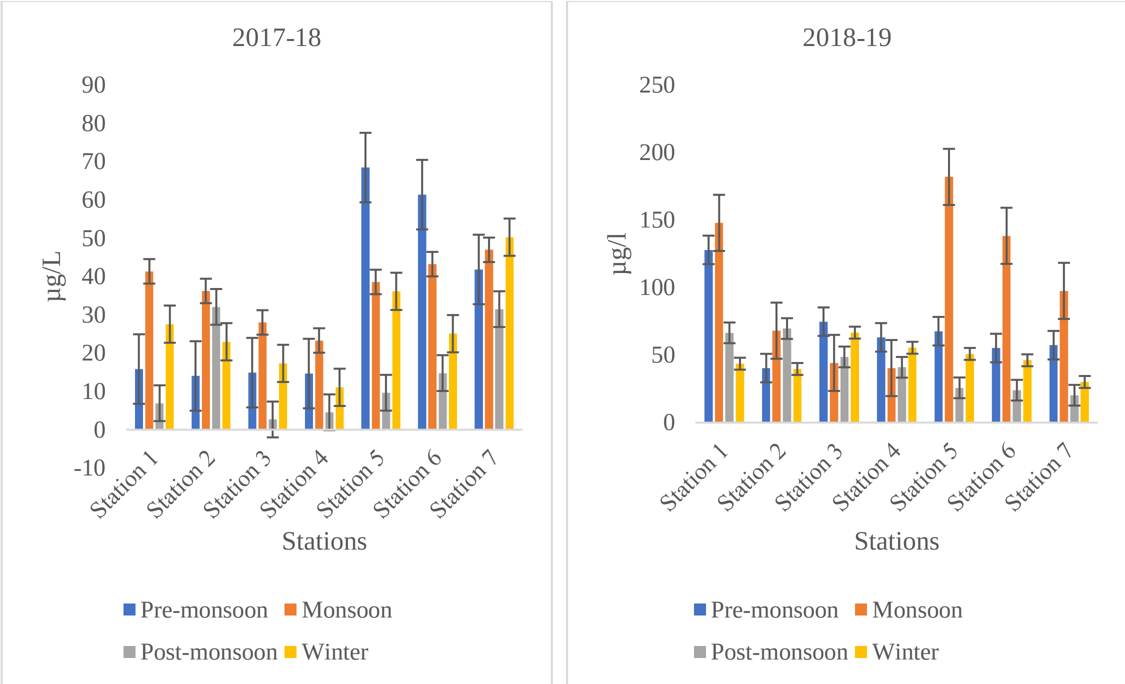


Fig. 26. Seasonal dynamics of SRP (µg/l).

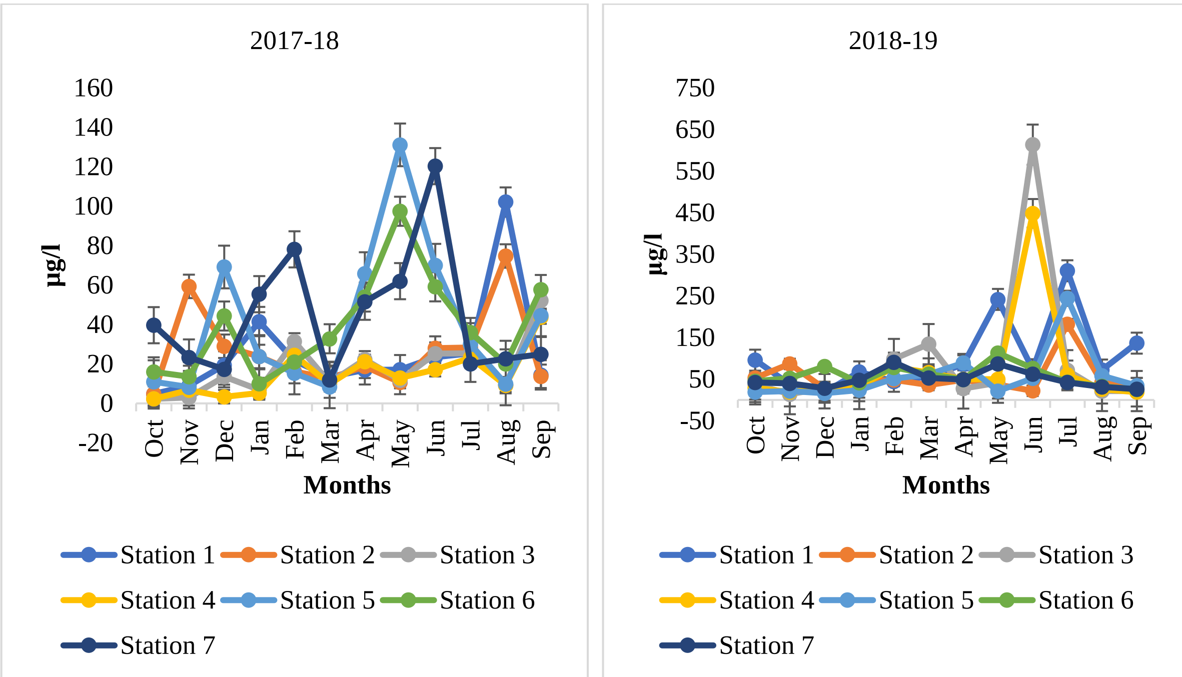


Fig. 27. Comparison of monthly values of SRP from two study years.

Table 10. Monthly mean values (±SD) of SRP (µg/l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	4.80±13.37	4.80±13.37	2.31±13.37	2.31±13.37	11.02±13.37	16.01±13.37	29.66±13.37
Nov-17	9.03±19.50	59.34±19.50	3.02±19.50	6.78±19.50	8.28±19.50	13.54±19.50	23.29±19.50
Dec-17	19.48±22.22	28.98±22.22	13.63±22.22	3.4±22.22	69.17±22.22	44.32±22.22	17.29±22.22
Jan-18	41.51±18.86	23.79±18.86	6.83±18.86	5.29±18.86	23.79±18.86	9.91±18.86	55.39±18.86
Feb-18	21.69±22.00	16.11±22.00	31.47±22.00	24.48±22.00	15.42±22.00	20.99±22.00	78.13±22.00
Mar-18	13.42±8.36	12.70±8.36	10.55±8.36	9.83±8.36	8.39±8.36	32.78±8.36	11.98±8.36
Apr-18	17.01±20.48	18.79±20.48	22.37±20.48	21.18±20.48	65.84±20.48	53.93±20.48	51.55±20.48
May-18	17.10±49.05	10.60±49.05	11.78±49.05	12.96±49.05	131.12±49.05	97.44±49.05	61.99±49.05
Jun-18	23.49±37.20	28.06±37.20	25.32±37.20	17.09±37.20	70.08±37.20	59.12±37.20	120.32±37.20
Jul-18	25.34±5.17	28.37±5.17	25.34±5.17	23.07±5.17	29.88±5.17	35.99±5.17	20.05±5.17
Aug-18	102.11±37.47	74.75±37.47	9.22±37.47	9.22±37.47	9.86±37.47	20.04±37.47	22.58±37.47
Sep-18	14.44±18.13	13.74±18.13	52.17±18.13	43.78±18.13	44.48±18.13	57.76±18.13	24.92±18.13
Oct-18	95.63±26.50	52.82±26.50	37.54±26.50	29.13±26.50	19.19±26.50	45.18±26.50	42.12±26.50
Nov-18	37.35±25.05	86.52±25.05	13.99±25.05	18.91±25.05	21.37±25.05	52.10±25.05	39.81±25.05
Dec-18	18.63±21.85	26.82±21.85	27.99±21.85	27.99±21.85	16.29±21.85	80.63±21.85	27.99±21.85
Jan-19	67.50±15.04	43.75±15.04	26.25±15.04	31.25±15.04	23.75±15.04	41.25±15.04	47.50±15.04
Feb-19	44.82±21.74	48.65±21.74	98.46±21.74	79.30±21.74	51.21±21.74	78.02±21.74	90.79±21.74
Mar-19	56.64±31.19	35.91±31.19	134.14±31.19	65.65±31.19	61.14±31.19	62.04±31.19	53.03±31.19
Apr-19	85.50±22.21	48.15±22.21	27.60±22.21	50.01±22.21	79.24±22.21	49.39±22.21	49.39±22.21
May-19	241.66±76.10	37.11±76.10	41.42±76.10	50.05±76.10	21.71±76.10	112.89±76.10	87.01±76.10
Jun-19	72.68±236.79	21.96±236.79	613.52±236.79	448.52±236.79	52.52±236.79	75.74±236.79	62.29±236.79
Jul-19	310.53±109.38	182.15±109.38	71.46±109.38	60.32±109.38	244.38±109.38	42.63±109.38	41.98±109.38
Aug-19	71.96±18.42	42.19±18.42	21.54±18.42	25,80±18.42	58.59±18.42	33.08±18.42	31.26±18.42
Sep-19	136.52±42.29	26.09±42.29	21.4±42.29	18.72±42.29	34.80±42.29	25.42±42.29	26.09±42.29
Mean	64.54	40.51	56.22	45.21	49.23	48.34	46.93

Soluble reactive silicate (SRS)

During the study period (2017 – 2019), the ranges of Soluble reactive silicate (SRS) were 1.18-34.62, 1.58-21.20, 0.76-22.66, 0.17-21.20, 0.64-22.66, 2.28-26.92, and 0.57-25.82 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean SRS (344.62 mg/l) was recorded in November, 2017 for Station 1 whereas the lowest mean SRS (0.17 mg/l) was in October, 2017 for Station 4. The trend of SRS was distinct but different in two years of investigation.

The seasonal variation of SRS show the highest value during post-monsoon for Station 1, 2, 6, and 7 but during winter for Station 3 and 4 and during monsoon for Station 5 and the lowest was recorded during winter for Station 1 and 2 but during pre-monsoon for rest of the stations in the first year and in second year it was highest during post-monsoon for Station 1, 2, and 5 but during monsoon for Station 3 and 4 and during winter for Station 6 and 7 but the lowest during post-monsoon for Station 3, 4, 6 and 7 and during pre-monsoon for the rest of the stations. Over the seasons, the mean values of SRP did not follow any distinct pattern (Fig. 28).

Fig. 29 shows the annual range of SRS for the two consecutive years of study, the SRS of all the stations showed two different types of patterns of fluctuation in two years of investigation. Graphs show a zig zag pattern for all the stations but there were a number of ups and downs of SRS concentrations in all the stations for the two years (Fig. 29).

Mean value of SRS (15.80 mg/l) was the highest in Station 1 whereas the lowest mean value of SRS (3.58mg/l) was recorded in Station 4 (Table 11).

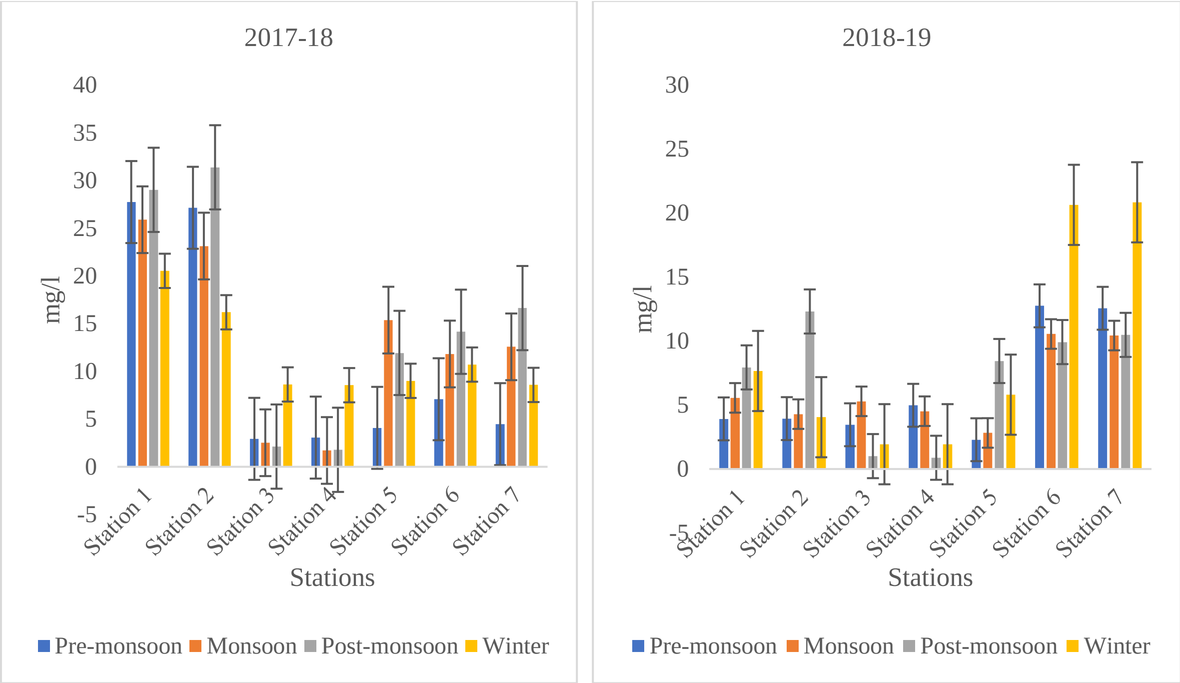


Fig. 28. Seasonal dynamics of SRS (mg/l).

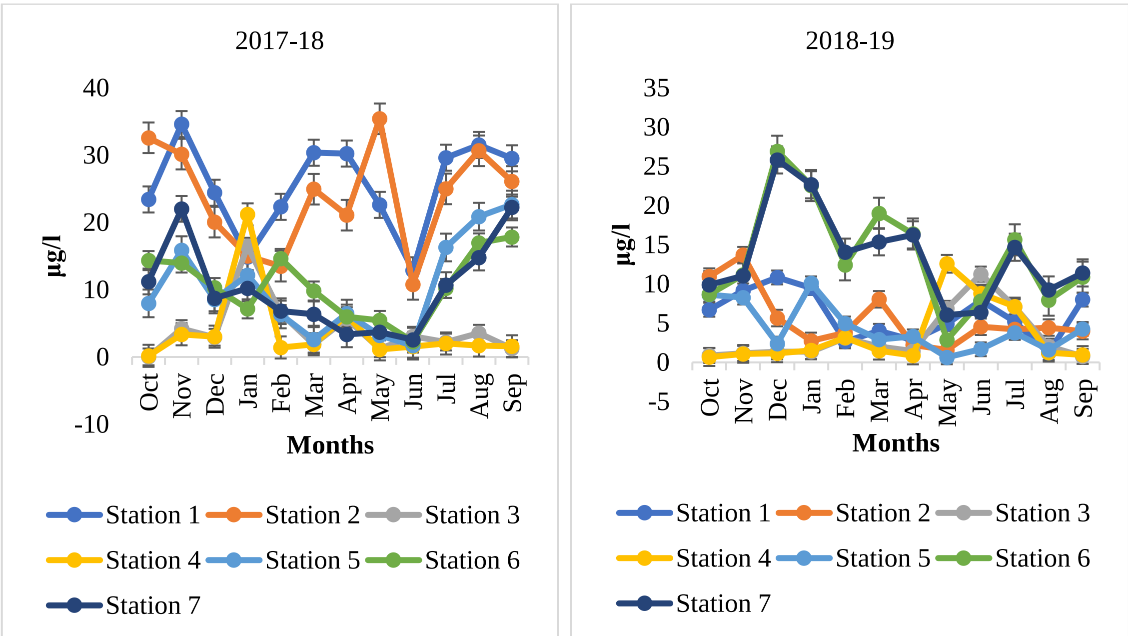


Fig. 29. Comparison of monthly values of SRS from two study years.

Table 11. Monthly mean values (±SD) of SRS (mg/l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	23.42±11.94	32.59±11.94	0.02±11.94	0.17±11.94	7.97±11.94	14.33±11.94	11.23±11.94
Nov-17	34.62±11.99	30.16±11.99	4.23±11.99	3.38±11.99	15.89±11.99	13.97±11.99	22. 02±11.99
Dec-17	24.41±8.19	20.05±8.19	2.93±8.19	3.02±8.19	8.55±8.19	10.32±8.19	8.72±8.19
Jan-18	14.86±4.55	15.03±4.55	16.47±4.55	21.2±4.55	12.14±4.55	7.16±4.55	10.21±4.55
Feb-18	22.32±7.01	13.50±7.01	6.48±7.01	1.42±7.01	6.32±7.01	14.65±7.01	6.81±7.01
Mar-18	30.36±11.75	24.94±11.75	1.90±11.75	1.90±11.75	2.58±11.75	9.81±11.75	6.35±11.75
Apr-18	30.24±10.22	21.08±10.22	5.68±10.22	6.14±10.22	6.45±10.22	5.99±10.22	3.37±10.22
May-18	22.61±13.33	35.41±13.33	1.22±13.33	1.14±13.33	3.2±13.33	5.43±13.33	3.69±13.33
Jun-18	12.89±4.76	10.79±4.76	3.09±4.76	1.53±4.76	1.68±4.76	2.28±4.76	2.57±4.76
Jul-18	29.62±10.63	24.99±10.63	2.22±10.63	2.01±10.63	16.28±10.63	10.19±10.63	10.69±10.63
Aug-18	31.52±11.78	30.65±11.78	3.53±11.78	1.71±11.78	20.86±11.78	16.96±11.78	14.79±11.78
Sep-18	29.54±11.44	26.10±11.44	1.25±11.44	1.59±11.44	22.66±11.44	17.84±11.44	22.24±11.44
Oct-18	6.71±4.20	10.94±4.20	0.88±4.20	0.67±4.20	8.62±4.20	8.67±4.20	9.91±4.20
Nov-18	9.17±4.96	13.67±4.96	1.14±4.96	1.08±4.96	8.26±4.96	11.16±4.96	11.05±4.96
Dec-18	10.83±11.29	5.65±11.29	1.34±11.29	1.15±11.29	2.39±11.29	26.92±11.29	25.82±11.29
Jan-19	9.48±9.28	2.74±9.28	1.37±9.28	1.53±9.28	10.08±9.28	22.55±9.28	22.65±9.28
Feb-19	2.68±4.82	3.75±4.82	3.12±4.82	3.15±4.82	4.96±4.82	12.44±4.82	14.05±4.82
Mar-19	4.02±6.99	8.04±6.99	2.03±6.99	1.59±6.99	2.93±6.99	19.01±6.99	15.38±6.99
Apr-19	2.84±6.96	2.21±6.96	1.46±6.96	0.88±6.96	3.32±6.96	16.37±6.96	16.26±6.96
May-19	4.90±4.02	1.58±4.02	6.88±4.02	12.57±4.02	0.642±4.02	2.87±4.02	6.04±4.02
Jun-19	7.89±3.09	4.54±3.09	11.25±3.09	8.77±3.09	1.67±3.09	7.79±3.09	6.39±3.09
Jul-19	5.18±4.91	4.22±4.91	7.08±4.91	7.12±4.91	3.75±4.91	15.63±4.91	14.68±4.91
Aug-19	1.18±3.37	4.44±3.37	2.06±3.37	1.23±3.37	1.59±3.37	7.93±3.37	9.23±3.37
Sep-19	8.0±4.41	3.99±4.41	0.76±4.41	0.94±4.41	4.26±4.41	10.86±4.41	11.41±4.41
Mean	15.80	14.63	3.68	3.58	7.38	12.13	11.90

Nitrate-nitrogen (NO_3-N)

The ranges of Nitrate-nitrogen (NO_3-N) were 0.01-1.24, 0.01-0.74, 0.01-1.58, 0.01-0.74, 0.01-0.72, 0.01-1.22, and 0.01-0.73 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean NO_3-N (1.58 mg/l) was recorded in May, 2019 for Station 3 whereas the lowest mean NO_3-N (0.001 mg/l) was recorded for several times for all the stations. The trend of NO_3-N was unique but different in two years of investigation.

The seasonal variation of NO_3-N shows the highest value during post-monsoon for Station 1, 2, 3, 4, 5, and 6 but during winter for Station 7 and the lowest was recorded during pre-monsoon for all the stations in the first year and in second year it was highest during monsoon for Station 1, 2, 4, 5, 6, and 7 and during pre-monsoon for Station 3 and 7 but the lowest during post-monsoon for Station 3, 4, 6 and 7 and during pre-monsoon for the rest of the stations. Over the seasons, the mean values of NO_3-N did not follow any distinct pattern (Fig. 30).

Fig. 31 shows the annual range of NO_3-N for the two consecutive years of study, the NO_3-N of all the stations showed two different types of patterns of fluctuation in two years of investigation. Graphs show a zig zag pattern for all the stations but there were a number of ups and downs of NO_3-N concentrations in all the stations for both years (Fig. 31).

Mean value of NO_3-N (0.21 mg/l) was the highest in Station 3 whereas the lowest mean value of NO_3-N (0.12 mg/l) was recorded in Station 7 (Table 12).

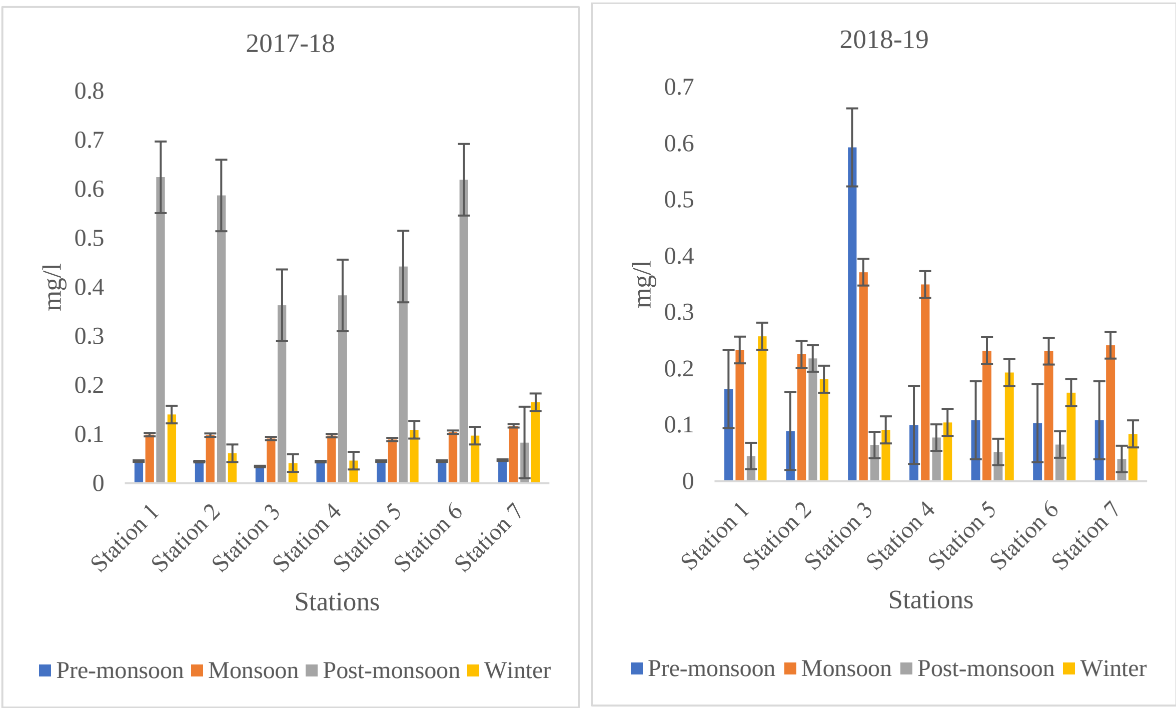


Fig 30. Seasonal dynamics of NO_3-N (mg/l).

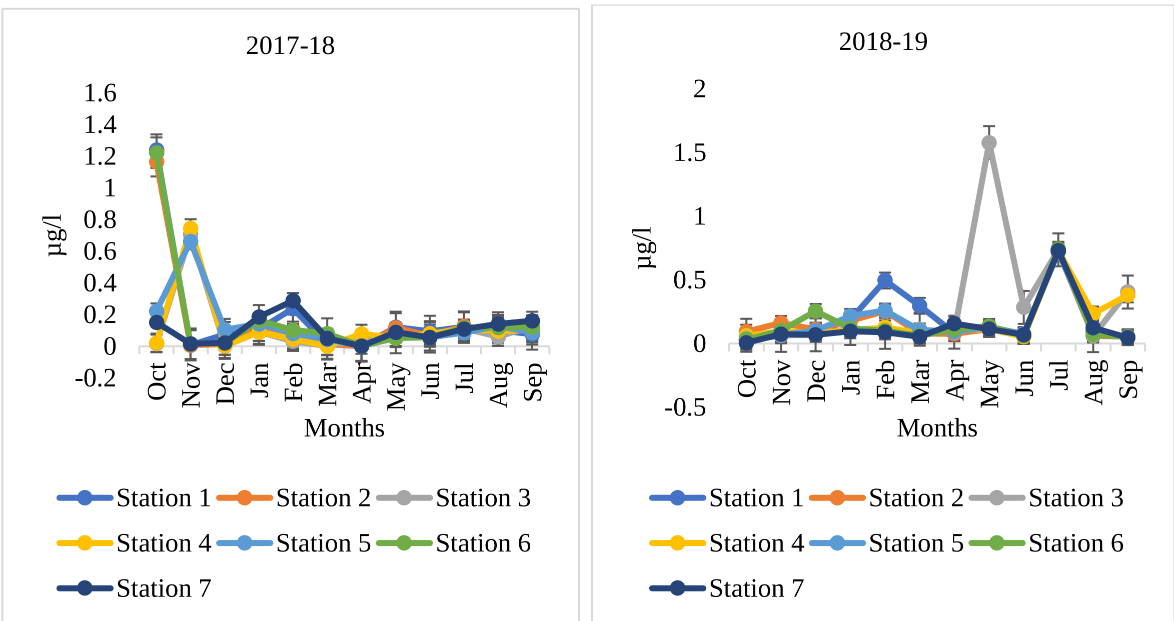


Fig. 31. Comparison of monthly values of NO_3-N from two study years.

Table 12. Monthly mean values (±SD) of NO_3-N (mg/l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	1.24±0.60	1.17±0.60	0.02±0.60	0.02±0.60	0.22±0.60	1.22±0.60	0.15±0.60
Nov-17	0.01±0.37	0.01±0.37	0.71±0.37	0.74±0.37	0.66±0.37	0.02±0.37	0.02±0.37
Dec-17	0.075±0.04	0.013±0.04	0.003±0.04	0.01±0.04	0.11±0.04	0.023±0.04	0.023±0.04
Jan-18	0.11±0.04	0.11±0.04	0.09±0.04	0.09±0.04	0.14±0.04	0.16±0.04	0.19±0.04
Feb-18	0.24±0.10	0.06±0.10	0.03±0.10	0.05±0.10	0.08±0.10	0.10±0.10	0.29±0.10
Mar-18	0.02±0.03	0.02±0.03	0.002±0.03	0.002±0.03	0.04±0.03	0.08±0.03	0.05±0.03
Apr-18	0.001±0.03	0.001±0.03	0.04±0.03	0.08±0.03	0.003±0.03	0.002±0.03	0.001±0.03
May-18	0.12±0.03	0.12±0.03	0.04±0.03	0.05±0.03	0.09±0.03	0.05±0.03	0.09±0.03
Jun-18	0.10±0.01	0.07±0.01	0.07±0.01	0.08±0.01	0.06±0.01	0.06±0.01	0.06±0.01
Jul-18	0.12±0.01	0.13±0.01	0.11±0.01	0.11±0.01	0.09±0.01	0.12±0.01	0.11±0.01
Aug-18	0.10±0.03	0.10±0.03	0.06±0.03	0.10±0.03	0.13±0.03	0.12±0.03	0.14±0.03
Sep-18	0.08±0.03	0.10±0.03	0.13±0.03	0.10±0.03	0.09±0.03	0.12±0.03	0.16±0.03
Oct-18	0.03±0.03	0.09±0.03	0.06±0.03	0.06±0.03	0.04±0.03	0.03±0.03	0.01±0.03
Nov-18	0.06±0.04	0.16±0.04	0.06±0.04	0.10±0.04	0.07±0.04	0.10±0.04	0.07±0.04
Dec-18	0.09±0.07	0.11±0.07	0.07±0.07	0.09±0.07	0.10±0.07	0.25±0.07	0.07±0.07
Jan-19	0.19±0.05	0.18±0.05	0.12±0.05	0.10±0.05	0.22±0.05	0.12±0.05	0.10±0.05
Feb-19	0.50±0.15	0.26±0.15	0.09±0.15	0.13±0.15	0.26±0.15	0.10±0.15	0.09±0.15
Mar-19	0.30±0.08	0.08±0.08	0.11±0.08	0.08±0.08	0.10±0.08	0.06±0.08	0.05±0.08
Apr-19	0.03±0.03	0.08±0.03	0.09±0.03	0.11±0.03	0.09±0.03	0.11±0.03	0.16±0.03
May-19	0.08±0.55	0.11±0.55	1.58±0.55	0.11±0.55	0.13±0.55	0.14±0.55	0.11±0.55
Jun-19	0.11±0.08	0.06±0.08	0.28±0.08	0.05±0.08	0.08±0.08	0.06±0.08	0.67±0.08
Jul-19	0.06±0.01	0.73±0.01	0.74±0.01	0.73±0.01	0.72±0.01	0.74±0.01	0.73±0.01
Aug-19	0.73±0.06	0.06±0.06	0.06±0.06	0.23±0.06	0.08±0.06	0.07±0.06	0.13±0.06
Sep-19	0.10±0.17	0.05±0.17	0.40±0.17	0.38±0.17	0.05±0.17	0.05±0.17	0.05±0.17
Mean	0.19	0.16	0.21	0.15	0.15	0.16	0.12

Biological parameters

Chlorophyll a (chl-a)

The ranges of chlorophyll a (chl-a) were 8.29-249.82, 5.92-107.74, 5.92-104.19, 5.92-112.48, 5.92-43.81, 8.29-223.78, and 5.92-171.68 µg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean chl-a (249.82 µg/l) was recorded in May, 2019 for Station 1 whereas the lowest mean chl-a (5.92 µg/l) was recorded for several times for Station 2, 3, 4, 5, and 7. The trend of chl-a was unique but different in two years of investigation.

The seasonal variation of chl-a shows the highest value during pre-monsoon for Station 1, 2, 4, and 6 but during post-monsoon for Station3 and 7 and during winter for Station 6 and the lowest was recorded during monsoon for Station 1, 2, and 3 but during post-monsoon for Station 4, 5, and 6 in the first year and in second year it was highest during winter for Station 1 and 2 and during post-monsoon for the rest of the stations but the lowest during monsoon for all the stations. Over the seasons, the mean values of chl-a did not follow any distinct pattern (Fig. 32).

Fig. 33 shows the annual range of chl-a for the two consecutive years of study, the chl-a of all the stations showed two different types of patterns of fluctuation in two years of investigation. Graphs show a zig zag pattern for all the stations but there were a number of ups and downs of chl-a concentrations in all the stations for both years (Fig. 33).

Mean value of chl-a (122.51 µg/l) was the highest in Station 1 whereas the lowest mean value of chl-a (23.09 µg/l) was recorded in Station 7 (Table 13).

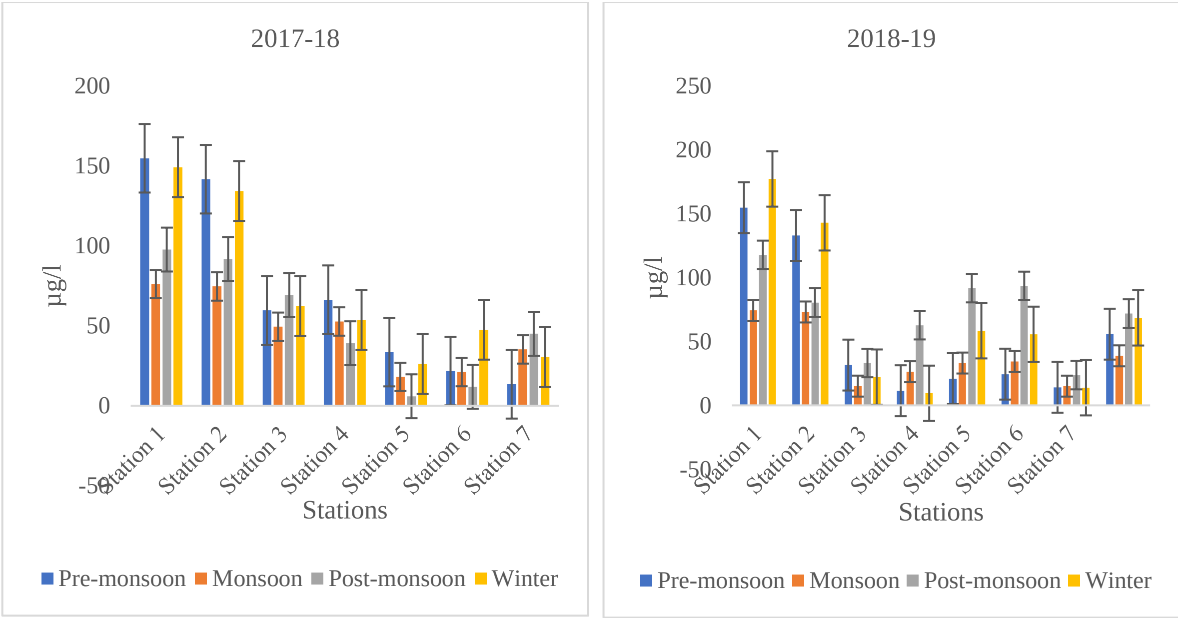


Fig. 32. Seasonal dynamics of chl-a (µg/l).

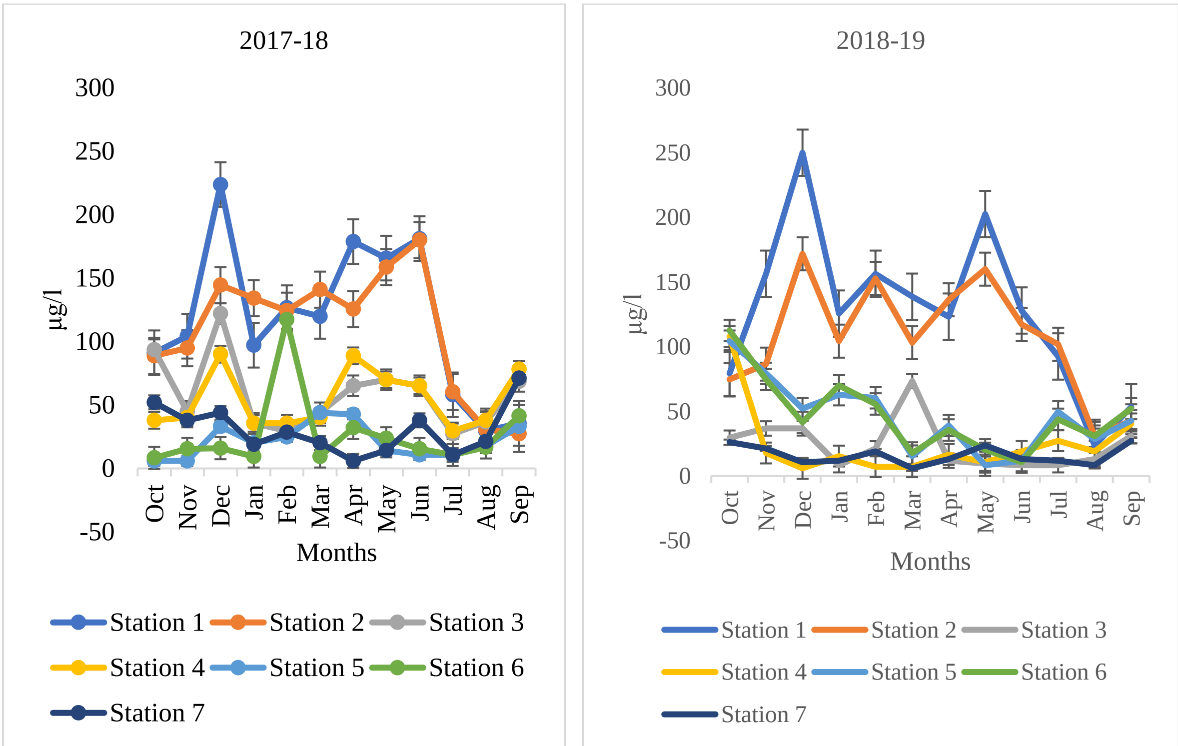


Fig. 33. Comparison of monthly values of chl-a from two study years.

Table 13. Showing monthly mean values (±SD) of chl-a (μg/l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	91.17±38.34	88.80±38.34	91.17±38.34	88.8±38.34	5.92±38.34	8.29±38.34	52.09±38.34
Nov-17	104.19±37.27	94.72±37.27	104.19±37.27	94.72±37.27	5.92±37.27	15.39±37.27	37.89±37.27
Dec-17	223.78±73.55	144.45±73.55	223.78±73.55	144.45±73.55	33.15±73.55	15.98±73.55	43.81±73.55
Jan-18	97.09±46.95	134.18±46.95	97.09±46.95	134.18±46.95	20.18±46.95	9.47±46.95	18.94±46.95
Feb-18	126.69±49.97	124.32±49.97	126.69±49.97	124.32±49.97	24.86±49.97	117.22±49.97	28.42±49.97
Mar-18	119.84±50.30	140.89±50.30	119.84±50.30	140.89±50.30	43.81±50.30	9.47±50.30	20.13±50.30
Apr-18	178.78±59.52	125.50±59.52	178.78±59.52	125.50±59.52	42.62±59.52	31.97±59.52	5.92±59.52
May-18	165.76±64.94	158.66±64.94	165.76±64.94	158.66±64.94	14.21±64.94	23.68±64.94	14.21±64.94
Jun-18	181.15±72.37	179.97±72.37	181.15±72.37	179.97±72.37	10.66±72.37	15.39±72.37	37.89±72.37
Jul-18	58.02±21.74	60.38±21.74	58.02±21.74	60.38±21.74	10.66±21.74	10.66±21.74	10.66±21.74
Aug-18	29.60±8.76	30.78±8.76	29.60±8.76	30.78±8.76	17.76±8.76	16.58±8.76	21.31±8.76
Sep-18	35.52±21.07	27.23±21.07	35.52±21.07	27.23±21.07	33.15±21.07	41.44±21.07	71.04±21.07
Oct-18	79.33±36.04	74.59±36.04	29.60±36.04	107.74±36.04	104.19±36.04	112.48±36.04	26.05±36.04
Nov-18	156.29±48.28	86.43±48.28	36.71±48.28	17.76±48.28	79.33±48.28	74.59±48.28	21.31±48.28
Dec-18	249.82±92.79	171.68±92.79	36.77±92.79	5.92±92.79	52.09±92.79	41.44±92.79	10.66±92.79
Jan-19	125.5±47.01	104.19±47.01	8.29±47.01	15.39±47.01	62.75±47.01	69.86±47.01	11.84±47.01
Feb-19	156.29±62.55	152.74±62.55	21.31±62.55	7.12±62.55	60.38±62.55	55.65±62.55	18.54±62.55
Mar-19	138.53±53.54	103.01±53.54	73.41±53.54	7.11±53.54	15.39±53.54	17.76±53.54	5.92±53.54
Apr-19	123.14±53.15	136.16±53.15	11.84±53.15	16.58±53.15	39.07±53.15	35.52±53.15	13.03±53.15
May-19	202.46±82.47	159.84±82.47	9.47±82.47	10.66±82.47	8.29±82.47	20.13±82.47	23.68±82.47
Jun-19	127.87±53.86	117.22±53.86	8.29±53.86	18.94±53.86	11.84±53.86	10.66±53.86	13.02±53.86
Jul-19	92.35±36.97	101.82±36.97	8.29±36.97	27.23±36.97	49.73±36.97	43.81±36.97	11.84±36.97
Aug-19	23.68±8.91	30.78±8.91	13.02±8.91	18.94±8.91	28.42±8.91	30.78±8.91	8.29±8.91
Sep-19	53.28±9.77	42.62±9.77	30.78±9.77	40.26±9.77	42.62±9.77	52.09±9.77	27.23±9.77
Mean	122.51	107.96	70.81	66.81	34.04	36.68	23.09

Phaeopigment (PP)

During the study period (2017 – 2019), the ranges of phaeopigment (PP) were 0.86-52.62, 0.38-107.07, 4.19-38.78, 1.50-50.21, 1.21-16.93, 0.19-73.76, and 0.19-38.88 µg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean phaeopigment (107.07 µg/l) was recorded in June, 2018 for Station 2 whereas the lowest mean PP (0.19 µg/l) was recorded for Station 6 and 7 in December 2017 and January 2018 respectively. The trend of PP was as like as chl-a in two years of investigation.

The seasonal variation of PP shows the highest value during post-monsoon for Station 1 and 2 but during monsoon for Station 3, 4. 5, 6, and 7 and the lowest was recorded during monsoon for Station 1 but during winter for Station 2 and 3 in the first year and in second year it was highest during winter for Station 1 and during post-monsoon for the rest of the stations but the lowest during monsoon for all the stations. Over the seasons, the mean values of PP did not follow any distinct pattern. Amount of PP was comparatively lower during the second year of investigation (Fig. 34).

Fig. 35 shows the annual range of PP for the two consecutive years of study, the PP of all the stations showed two different types of patterns of fluctuation in two years of investigation. Graphs show a zig zag pattern for all the stations but there were a number of ups and downs of PP concentrations in all the stations for both years (Fig. 35).

Mean value of PP (39.62 µg/l) was the highest in Station 2 whereas the lowest mean value of PP (8.52 µg/l) was recorded in Station 7 (Table 14).

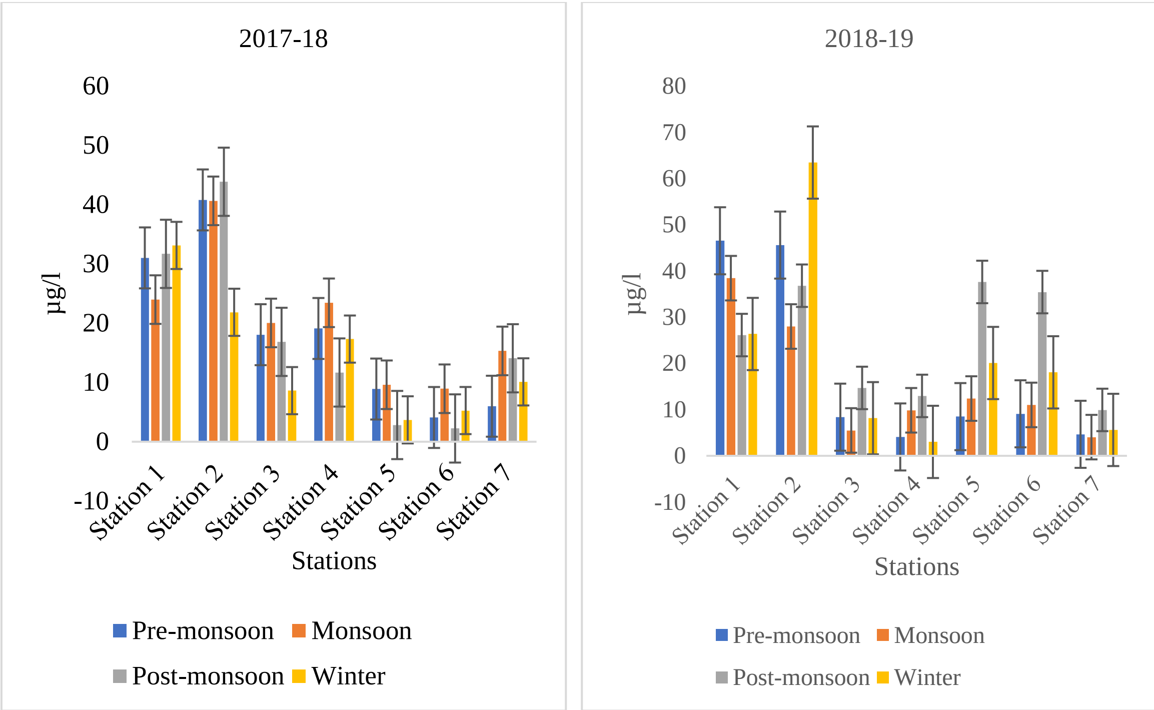


Fig. 34. Seasonal dynamics of phaeopigment (µg/l).

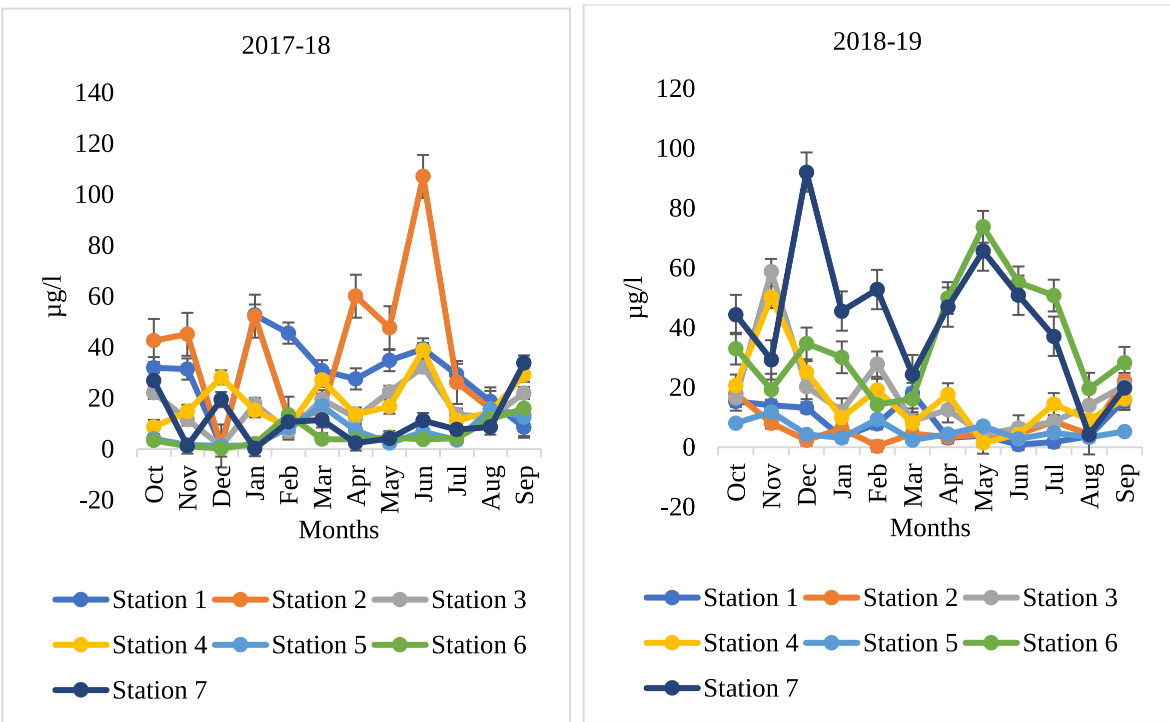


Fig. 35. Comparison of monthly values of phaeopigment from two study years.

Table 14. Monthly mean values (±SD) of phaeopigment (µg/l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	31.97±15.10	42.66±15.10	22.11±15.10	8.7±15.10	4.06±15.10	3.36±15.10	26.95±15.10
Nov-17	31.43±17.07	45.06±17.07	11.59±17.07	14.65±17.07	1.57±17.07	1.11±17.07	1.21±17.07
Dec-17	1.21±11.41	1.21±11.41	1.12±11.41	28.16±11.41	1.21±11.41	0.192±11.41	19.42±11.41
Jan-18	52.62±23.03	52.19±23.03	17.73±23.03	15.23±23.03	1.45±23.03	2.18±23.03	0.192±23.03
Feb-18	45.54±13.60	12.13±13.60	7.01±13.60	8.58±13.60	8.42±13.60	13.41±13.60	10.69±13.60
Mar-18	30.75±9.15	14.69±9.15	19.42±9.15	27.13±9.15	16.93±9.15	3.84±9.15	11.49±9.15
Apr-18	27.56±20.29	60.04±20.29	12.26±20.29	13.54±20.29	7.3±20.29	3.81±20.29	2.40±20.29
May-18	34.75±17.28	47.68±17.28	22.49±17.28	16.67±17.28	2.43±17.28	4.61±17.28	4.10±17.28
Jun-18	39.33±35.52	107.07±35.52	32.22±35.52	38.88±35.52	6.81±35.52	3.75±35.52	11.19±35.52
Jul-18	29.34±10.29	26.15±10.29	13.54±10.29	11.17±10.29	3.48±10.29	4.32±10.29	7.64±10.29
Aug-18	18.66±3.27	15.81±3.27	12.38±3.27	14.53±3.27	15.52±3.27	11.71±3.27	8.64±3.27
Sep-18	8.58±9.30	13.54±9.30	22.02±9.30	29.19±9.30	12.61±9.30	15.97±9.30	33.79±9.30
Oct-18	32.99±12.32	44.39±12.32	15.33±12.32	17.89±12.32	16.45±12.32	20.64±12.32	8.06±12.32
Nov-18	19.26±19.88	29.22±19.88	14.04±19.88	8.03±19.88	58.78±19.88	50.21±19.88	11.79±19.88
Dec-18	34.72±30.68	92.06±30.68	13.21±30.68	2.40±30.68	20.29±30.68	25.12±30.68	4.32±30.68
Jan-19	30.08±16.05	45.57±16.05	3.36±16.05	6.24±16.05	12.13±16.05	9.84±16.05	3.14±16.05
Feb-19	14.27±17.34	52.76±17.34	7.81±17.34	0.38±17.34	27.81±17.34	19.23±17.34	9.35±17.34
Mar-19	16.22±7.96	24.29±7.96	18.11±7.96	4.54±7.96	8.74±7.96	8.03±7.96	2.40±7.96
Apr-19	49.92±20/33	46.88±20/33	3.14±20/33	3.39±20/33	12.51±20/33	17.73±20/33	4.44±20/33
May-19	73.76±32.09	65.63±32.09	3.84±32.09	4.32±32.09	4.19±32.09	1.50±32.09	7.11±32.09
Jun-19	55.17±24.12	50.84±24.12	0.86±24.12	4.36±24.12	6.46±24.12	4.32±24.12	2.79±24.12
Jul-19	50.75±18.58	37.12±18.58	1.69±18.58	8.55±18.58	8.51±18.58	14.43±18.58	4.80±18.58
Aug-19	19.58±6.32	4.16±6.32	3.62±6.32	4.36±6.32	14.01±6.32	9.16±6.32	3.36±6.32
Sep-19	28.26±7.11	19.78±7.11	15.81±7.11	22.14±7.11	20.61±7.11	16.13±7.11	5.22±7.11
Mean	32.36	39.62	12.28	13.04	12.18	11.03	8.52

Qualitative and quantitative analysis of phytoplankton

Phytoplankton diversity

In the present investigation a total of 168 phytoplankton samples were collected from two artificial or man-made wetlands and a natural wetland. All these samples were studied for qualitative and quantitative aspects.

Qualitative data

Composition

In the present investigation 63 genera were represented in the phytoplankton from all the seven stations was identified which belonged to six divisions (Cyanophyta, Chlorophyta, Euglenophyta, Chrysophyta, Pyrrophyta and Cryptophyta) (Table 15).

Genus level percentage composition shows that Chlorophyta dominates in all seven stations and occupied 40.23, 42.86, 39.54, 40.00, 41.82, 41.30, and 44.83% for Station 1, 2, 3, 4, 5, 6, and 7, respectively, followed by Chrysophyta (17.02, 22.45, 23.26, 20.00, 23.64, 21.74, and 18.97% for Station 1, 2, 3, 4, 5, 6, and 7, respectively), Euglenopyta (10.63, 10.20, 11.64, 11.11, 9.09, 10.87, and 8.62% for Station 1, 2, 3, 4, 5, 6, and 7, respectively), Cyanophyta (17.02, 14.29, 13.95, 15.56, 16.36, 17.39, and 17.24% for Station 1, 2, 3, 4, 5, 6, and 7, respectively), Cryptophyta (8.51, 5.70, 6.98, 8.88, 5.46, 6.52, and 6.90% for Station 1, 2, 3, 4, 5, 6, and 7, respectively) and Pyrrophyta (4.25, 3.80, 4.65, 4.44, 3.64, 2.17, and 3.45% for Station 1, 2, 3, 4, 5, 6, and 7, respectively). Pyrrhophyta can be treated as a minor group for all the stations (Table 15).

At the species level, 351 species from different classes were recorded from all the stations. Maximum number of species (33.60% in Station 7) found in the division Euglenophyta and the minimum number of species (0.91% in Station 6) was recorded from the division Pyrrophyta. Euglenophyta was dominant followed by Chlorophyta, Chrysophyta, Cyanophyta, Cryptophyta and Pyrrophyta (Table 16).

Table 15. The number of genera recorded from different divisions of phytoplankton (percentage values are given in the parenthesis).

Division	No. of genera						
	Station 1	Station 2	Station 3	Station 4	Station5	Station6	Station7
Cyanophyta	8 (17.02)	7(14.29	6 (13.95)	7 (15.56)	9 (16.36)	8(17.39)	10(17.24)
Chrysophyta	8 (17.02)	11(22.45)	10(23.26)	9 (20.00)	13(23.64)	10(21.74)	11(18.97)
Chlorophyta	19(40.23)	21 (42.86)	17 (39.54)	18 (40.00)	23(41.82)	19(41.30)	26(44.83)
Euglenophyta	5 (30.67)	5 (10.2)	5 (11.64)	5 (11.11)	5 (9.09)	5(10.87)	5(8.62)
Pyrrophyta	2 (2.67)	2 (3.8)	2(4.65)	2 (4.44)	2 (3.64)	1(2.17)	2(3.45)
Cryptophyta	4 (6.67)	3 (5.7)	3(6.98)	4 (8.88)	3 (5.46)	3(6.52)	4(6.90)
Total	47	49	43	45	55	46	58

Table 16. The Number of species recorded from different divisions of phytoplankton (percentage of the total has been provided within parenthesis).

Division	No. of species						
	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Cyanophyta	7 (7.46)	11 (8.37)	13 (9.47)	11 (12.36)	17 (14.91)	23 (20.91)	20 (16.00)
Chlorophyta	14 (12.08)	13 (14.35)	11 (10.47)	27 (30.34)	31 (27.18)	27 (24.55)	41 (32.80)
Euglenophyta	26 (25.96)	29 (27.06)	23 (21.47)	20 (22.47)	38 (33.33)	33 (30.00)	42 (33.60)
Chrysophyta	43 (30.57)	47 (32.47)	41 (29.47)	21 (23.60)	19 (16.67)	14 (12.73)	11 (8.80)
Pyrrophyta	2 (1.24)	2 (1.66)	2 (1.47)	1 (1.12)	2 (1.75)	1 (0.91)	2 (1.60)
Cryptophyta	9 (5.87)	13 (5.88)	7 (16.47)	9 (10.11)	7 (6.14)	11 (10.00)	9 (7.20)
Total	102	116	98	89	114	110	125

Dominant phytoplankton flora

Table 20 to Table 26 show the dominant phytoplankton genera and their individual density of Station 1 to Station 7. In these stations, dominant genera of phytoplankton are described along with their density.

Station-1

Table 20 shows the most dominant phytoplankton genera and their individual density of Station 1. In this station, *Trachelomonas, Cyclotella, Dictyosphaerium, Microcystis, Euglena, Chorella, Carteria, Kirchneriella, Chlamydomonas, Crucigenia, Lepocinclis, Strombomonas, Cryptomonas, Coelastrum, Synedra, Scenedesmus, Chroomonas* and *Merismopedia* were dominant. In this station, *Trachelomonas* was dominant genus for most of the months throughout the period of investigation.

Station 2

Table 21 shows the dominant phytoplankton genera and their individual density of Station 2. In this station *Cyclotella, Trachelomonas, Dictyosphaerium, Euglena, Oscillatoria, Microcystis, Peridinium, Cryptomonas, Crucigenia, Kirchneriella, Pandorina, Synedra, Pelonema, Eunotia, Chlorella, Merismopedia, Coelastrum, Strombomonas,* and *Chlamydomonas* were dominant in this station. In this station, *Dictyosphaerium, Trachelomonas, Cyclotellla,* and *Microcystis* were dominant genera for most of the months throughout the period of investigation.

Station 3

Table 22 shows the dominant phytoplankton genera and their individual density of Station 3. In this station *Hyaloraphidium, Monoraphidium, Scenedesmus, Ankistrodesmus, Microcystis, Oscillatoria, Spirulina, Chlamydomonas, Trachelomonas, Synedra* and *Melosira* were dominant in this station. In this station, *Hyaloraphidium, Monoraphidium, Scenedesmus, Synedra, Trachelomonas, Microcystis,* and *Chlamydomonas* were the dominant genera for most of the months throughout the period of investigation.

Station-4

Table 23 shows the dominant phytoplankton genera and their individual density of Station 4. In this station, *Hyaloraphidium, Monoraphidium, Scenedesmus, Ankistrodesmus, Microcystis, Oscillatoria, Spirulina, Chlamydomonas, Synedra. Trachelomonas,* and *Melosira* were dominant in this station. In this station, *Hyaloraphidium, Monoraphidium, Scenedesmus, Synedra, Trachelomonas, Microcystis,* and *Chlamydomonas* were dominant genera for most of the months throughout the period of investigation.

Station 5

Table 24 shows the dominant phytoplankton genera and their individual density of Station 5. In this station, *Trachelomonas, Rhodomonas, Euglena, Phacus, Cryptomonas, Synedra, Oscillatoria, Anabaena, Perdinium, Strombomonas, Scenedesmus,* and *Carteria* were dominant in this station throughout the investigation period. In this station, *Rhodomonas, Trachelomonas, Scenedesmus, Phacus* and *Euglena* were the most dominant genera for most of the months throughout the period of investigation.

Station 6

Table 25 shows the dominant phytoplankton genera and their individual density of Station 6. In this station *Trachelomonas, Rhodomonas, Euglena, Oscillatoria, Ceratium, Cryptomonas, Chroomonas, Schroederia, Peridinium, Pandorina,* and *Chlamydomonas* were dominant in this station. In this station, *Trachelomonas Oscillatoria, Schroederia, Chroomonas, Pandorina, Peridinium, Ceratium,* and *Chlamydomonas* were the most dominant genera for most of the months throughout the period of investigation.

Station 7

Table 26 shows the dominant phytoplankton genera and their individual density of Station 7. In this station, *Monoraphidium, Trachelomonas, Scenedesmus, Euglena, Oscillatoria, Crucigenia, Peridinium, Rhodomonas, Cryptomonas, Phacotus, Navicula, Synedra, Anabaena, Strombomonas, Lepocinclis, Phacus,* and *Chlamydomonas* were dominant in this station. In this station, *Monoraphidium fontinale, Trachelomonas intermedia, Tr. oblonga, Tr. volvocina, Synedra ulna, Phacus curvicauda, Euglena oxyuris, Lepocinclis clavata, Rhodomonas minuta, Cryptomonas erosa,* and *Navicula pupula* were the most dominant species throughout the period of investigation.

Density of phytoplankton (PD)

During the study period (2017 – 2019), the ranges of density of phytoplankton (PD) were 0.44-15.28×10^6, 0.22-28.05×10^6, 0.33-8.09×10^6, 0.33-9.34×10^6, 0.30-3.96×10^6, 0.06-19.62×10^6, and 0.03-22.47×10^6 ind./l for Station 1, 2, 3, 4, 5, 6, and 7, respectively. The highest monthly mean PD (28.05×10^6 ind./l) was recorded in March, 2018 for Station 2 whereas the lowest mean PD (0.03×10^6 ind./l) was recorded in January, 2018 for Station 7. The trend of PP was unique and distinct in two years of investigation.

In the present research, the seasonal variation of PD shows the highest value during pre-monsoon for Station 1 and 2 but during monsoon for Station 3, 4. 5, and 7 while during winter for Station 6 and the lowest was recorded during monsoon for Station 1 and 2 but during pre-monsoon for Station 3, 4, and 7 in the first year and in second year it was highest during pre-monsoon for Station 1, 2, and 3 and during post-monsoon for the rest of the stations but the lowest during monsoon for all the stations. Over the seasons, the mean values of PP did not follow any distinct pattern. PD was comparatively lower during the second year of investigation (Fig. 36).

Fig. 37 shows the annual range of PD for the two consecutive years of study, the PD of all the stations showed two different types of patterns of fluctuation in two years of investigation. Graphs show a zig zag pattern for all the stations but there were a number of ups and downs of PD in all the stations for both years (Fig. 37).

Mean value of PD (10.11×10^6 ind./l) was the highest in Station 2 whereas the lowest mean value of PD (1.92×10^6 ind./l) was recorded in Station 7 (Table 17).

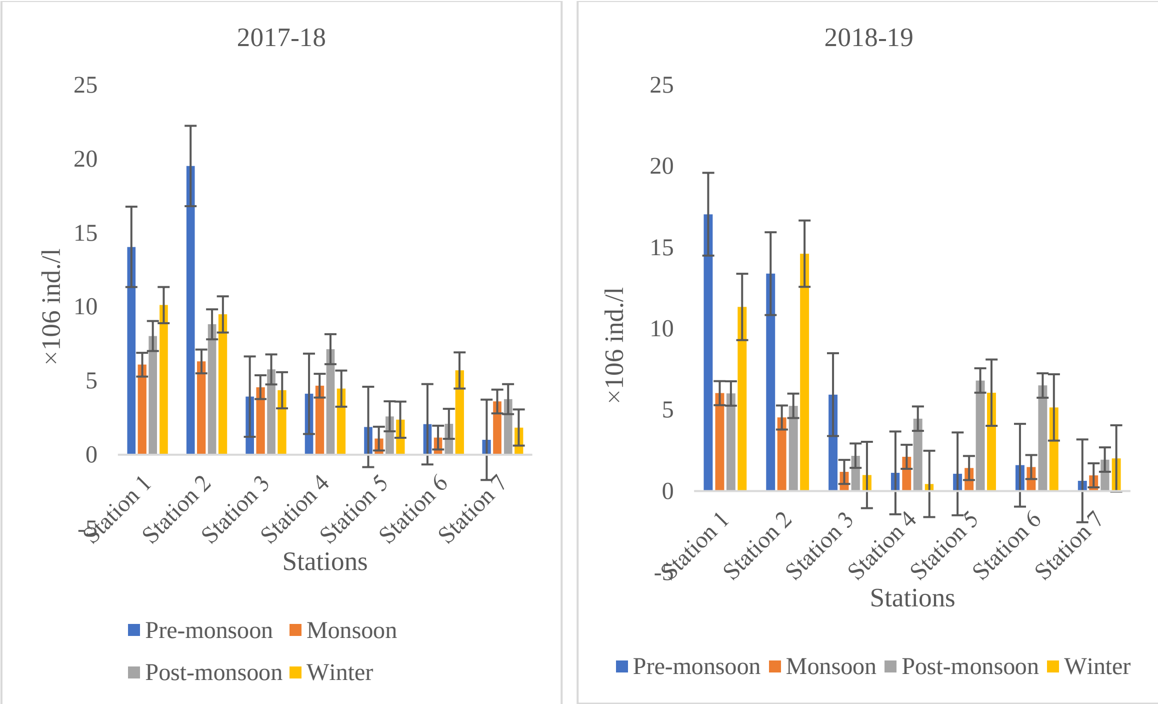


Fig. 36. Seasonal dynamics of phytoplankton density (×10^6 ind./l).

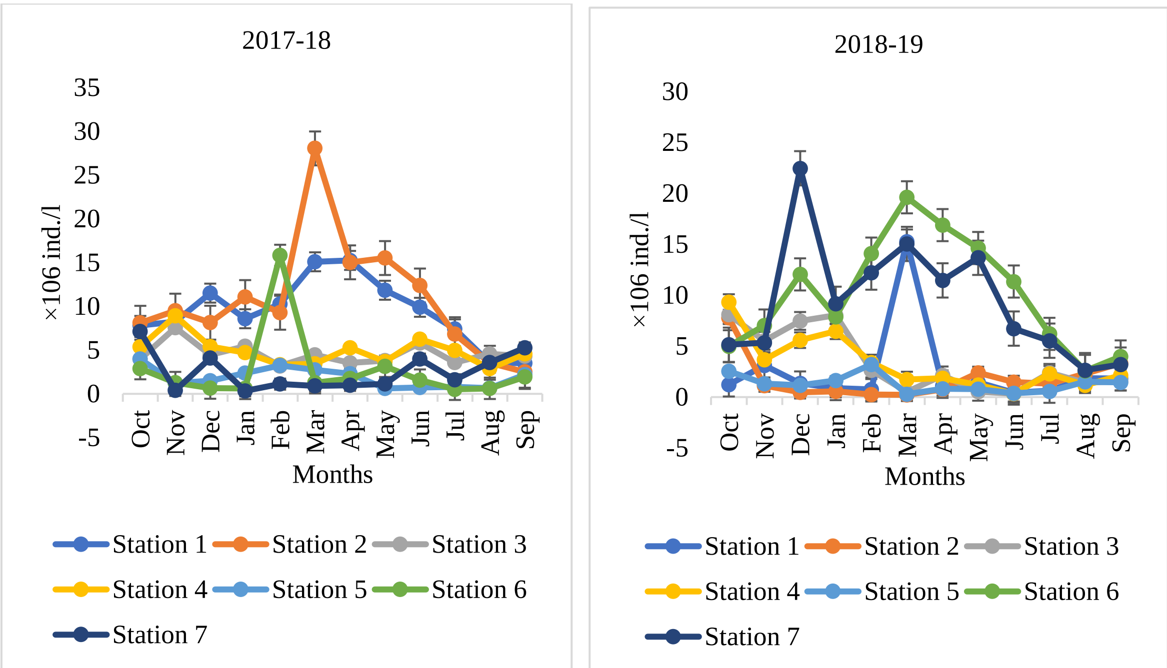


Fig. 37. Comparison of monthly values of phytoplankton density from two study years.

Table 17. Monthly mean values (±SD) of phytoplankton density (×10^6 ind./l).

Months	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-17	7.82±2.10	8.12±2.10	3.97±2.10	5.37±2.10	3.96±2.10	2.88±2.10	7.12±2.10
Nov-17	8.24±4.11	9.51±4.11	7.56±4.11	8.9±4.11	1.24±4.11	1.29±4.11	0.39±4.11
Dec-17	11.51±3.75	8.13±3.75	4.44±3.75	5.41±3.75	1.51±3.75	0.66±3.75	4.07±3.75
Jan-18	8.58±4.02	11.06±4.02	5.45±4.02	4.7±4.02	2.36±4.02	0.62±4.02	0.34±4.02
Feb-18	10.26±5.31	9.27±5.31	3.19±5.31	3.31±5.31	3.24±5.31	15.82±5.31	1.11±5.31
Mar-18	15.09±10.08	28.05±10.08	4.46±10.08	3.42±10.08	2.74±10.08	1.27±10.08	0.91±10.08
Apr-18	15.25±6.20	15.03±6.20	3.53±6.20	5.25±6.20	2.28±6.20	1.76±6.20	0.97±6.20
May-18	11.84±5.70	15.52±5.70	3.81±5.70	3.69±5.70	0.62±5.70	3.15±5.70	1.14±5.70
Jun-18	9.89±4.23	12.38±4.23	5.82±4.23	6.23±4.23	0.72±4.23	1.57±4.23	3.97±4.23
Jul-18	7.43±2.83	6.82±2.83	3.58±2.83	4.97±2.83	0.81±2.83	0.52±2.83	1.61±2.83
Aug-18	3.55±1.54	3.55±1.54	4.58±1.54	2.89±1.54	0.66±1.54	0.63±1.54	3.59±1.54
Sep-18	3.51±1.29	2.5±1.29	4.29±1.29	4.58±1.29	2.18±1.29	1.92±1.29	5.24±1.29
Oct-18	4.99±2.99	5.14±2.99	1.24±2.99	7.78±2.99	8.09±2.99	9.34±2.99	2.56±2.99
Nov-18	7.03±2.22	5.35±2.22	3.11±2.22	1.13±2.22	5.53±2.22	3.66±2.22	1.31±2.22
Dec-18	12.05±7.91	22.47±7.91	1.34±7.91	0.47±7.91	7.48±7.91	5.59±7.91	1.16±7.91
Jan-19	7.89±3.76	9.16±3.76	0.88±3.76	0.57±3.76	8.04±3.76	6.46±3.76	1.64±3.76
Feb-19	14.09±5.57	12.23±5.57	0.75±5.57	0.26±5.57	2.65±5.57	3.4±5.57	3.22±5.57
Mar-19	19.62±8.67	15.04±8.67	15.28±8.67	0.22±8.67	0.51±8.67	1.73±8.67	0.30±8.67
Apr-19	16.89±6.48	11.46±6.48	1.10±6.48	0.74±6.48	2.13±6.48	1.86±6.48	0.81±6.48
May-19	14.64±6.33	13.68±6.33	1.43±6.33	2.38±6.33	0.53±6.33	1.19±6.33	0.78±6.33
Jun-19	11.35±4.35	6.73±4.35	0.44±4.35	1.49±4.35	0.33±4.35	0.33±4.35	0.36±4.35
Jul-19	6.21±2.29	5.54±2.29	0.62±2.29	1.31±2.29	2.38±2.29	2.30±2.29	0.56±2.29
Aug-19	2.57±0.59	2.65±0.59	1.84±0.59	2.29±0.59	1.42±0.59	1.16±0.59	1.52±0.59
Sep-19	3.99±1.00	3.19±1.00	1.83±1.00	3.32±1.00	1.53±1.00	2.13±1.00	1.45±1.00
Mean	9.76	10.11	3.53	3.36	2.62	2.97	1.92

Density of macrophytes

Without two species of aquatic ferns, angiosperms represented the macrophyte population of these three wetlands. Total 40 species of macrophytes were recorded with vast floating masses of *Eichhornia crassipes* intersected by *Ludwigia adscendens, Salvinia cucullata* and *Lemna minor. Utricularia geminiscapa, Hydrilla verticillata, Ceratophyllum demersum,* and *Ipomoea aquatica* are also the most dominant groups. Second dominant group was composed of *Monochoria hastata, Hygroryza aristata, Ludwigia repens, Potamogeton crispus, Myriophyllum tuberculatam, Alternanthera phyloxeroides, Limnophila heterophylla, Sagittaria sagittifolia, Aponogeton appendiculatus, Pistia stratiotes, Spirodela polyrhiza, Limnocharis flava,* and *Salvinia natans*. The third dominant group of macrophytes were *Hygrophila auriculata, Achyranthes aquatica, Enhydra fluctuans, Hydrolea zeylanica, Nymphoides cristatum, Nymphaea nouchali, Aeschynomene aspera, Polygonum lanatum, Limnophila indica, Trapa maximowiczii, Sagittaria guayanensis, Eleocharis dulcis, Oryza rufipogon, Blyxa japonica, Lemna perpusilla, Vallisneria spiralis, Najas indica, Utricularia geminiscapa,* and *Monochoria vaginalis* (Table 18-19).

Seasonal variations of macrophytes

Macrophytes were found throughout the year in the three wetlands and documented accordingly. Total recorded number of species from these three wetlands were 42 among which 2 were floating higher cryptograms and rest of them were Angiosperms. No. of dicotyledons were 17 and 23 rest were monocotyledons. Some of the macrophytes were available throughout the year, but most were seasonal i.e. available either during pre-monsoon or monsoon or post-monsoon or winter. The seasonal variation according to site were as follows:

Big pond of BARD (Station 1 and 2)

This stie was rich in the seasonal variation of phytoplankton but poor in the case of macrophyte's seasonal variation. Both of the stations (1 and 2) were poor in the diversity of macrophyte. In this site, pre-monsoon was dominated by *Lemna minor* and *Salvinia cucullata* but monsoon was dominated by *Ottelia alismoides, Ipomoea aquatica, Monochoria hastata, Hydrilla verticillata, Nechamandra alternifolia* and *Eichhornia cressipes*; post-monsoon was dominated by *Ceratophyllum demersum, Ludwigia adsendens* and *Spirodela polyrrhiza* and the winter was dominated by *Eichhornia cressipes*.

Dutia Dighi (Station 3 and 4)

This site was richer than the first one in case of variation of macrophytes throughout the year. Both the stations (3 and 4) were rich in macrophyte diversity compared to Station 1 and 2. In this site, pre-monsoon was dominated by *Eichhornia cressipes, Lemna minor, Potamogeton crispus, Aponogeton appendiculatus, Limnophila heterophylla,* and *Utricularia geminiscapa*; monsoon was dominated by *Enhydra fluctuans, Ipomoea aquatica, Aponogeton appendiculatus, Pistia stratiotes, Ereocaulon setacium, Ottelia alismoides, Monochoria hastata,* and *Salvinia cucullata*; post-monsoon was dominated by *Eichhornia cressipes, Ceratophyllum demersum, Hydrilla verticillata, Vallisnaria spiralis,* and *Limnocharis flava* and winter was dominated by *Eichhornia cressipes, Enhydra fluctuans, Nymphoides cristata,* and *Ipomoea camara* subsp. *fistulosa.*

Horeshpur Jola (Station 5, 6, and 7)

This was the richest site in terms of variation of macrophytes throughout the period of investigation. Three stations of this site were rich in diversity and abundance of macrophyte species. In this site, pre-monsoon was dominated by *Alternanthera phyloxeroides, Blyxa auberti*, *Oryza sativa*, *Ipomoea camara* sub sp. *fistolosa, Polygonum lanatum* and *Eichhornia crassipes;* monsoon was characterized by *Nymphaea noucheli, Ottelia alismoides, Eichhornia crassipes, Utricularia geminiscapa, Ipomoea aquatica, Pistia stratiotes, Nymphoides indica, Salvinia natans, Ludwigia adscendens, Trapa maximowiczii, Schoenoplectus articulates, Hygroryza aristata, Limnocharis flava*, *Hygrophila auriculata, Hydrilla verticillata, Hydrocharis dubia, Vallisneria spiralis, Lemna minor, Spirodela polyrhiza*, *Monochoria hastata* and *Potamogeton crispus*; post monsoon was dominated by *Eichhornia crassipes, Ceratophyllum demersum, Hydrilla verticillata, Nymphaea nouchali, Nymphoides cristata*, *Vallisneria spiralis* and *Limnocharis flava,* Winter was dominated by *Oryza sativa, Panicum padulosum, Eichhornia crassipes, Enhydra fluctuans and E. camara* subsp. *fistulosa.*

Table 18. Abundance of macrophytes (Dicotyledons) with families.

Sl. No.	Name of Family	Name of Genus	Name of Species	BARD pond	Dutia Dighi	Horeshpur Jola
1	Acanthaceae	***Hygrophila***	*Hygrophila auriculata* (K.Schum.) Heine,	-	+	+++
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.,	+	+++	+++
			Ipomoea camara sub sp. fistolosa	-	++	+++
6	Haloragaceae	***Myriophyllum***	*Myriophyllum tuberculatam* Roxb.,	-	-	++
7	Hydrophyllaceae	***Ottelia***	*Ottelia alismoides* (L)	-	+	+++
8	Salviniaceae	***Salvinia***	*Salvinia natans*	-	++	++
9	Menyanthaceae	***Nymphoides***	*Nymphoides cristatum* (Roxb.) O. Kuntze,	+	+	+++
10	Nymphaeaceae	***Nymphaer***	*Nymphaea noucheli L*	-	+	+++
11	Onagraceae	***Ludwigia***	*Ludwigia adscendens* (L.) Hara,	+	++	+++
12	Papilionaceae	***Aeschynomene***	*Aeschynomene aspera* L.,	+	+	+++
13	Polygonaceae	***Polygonum***	*Polygonum lanatum* Roxb.,	-	+	
14	Scrophulariaceae	***Limnophila***	*Limnophila heterophylla* (Roxb.) Benth.,	-	++	+++
15	Trapaceae	***Trapa***	*Trapa maximowiczii* Korshinsky.,	-	-	+++
16	Lentibulariaceae	***Utricularia***	*Utricularia geminiscapa* *B*enj.	+	++	+++

+ = 0 - 2 ind/m^2, ++ = 3 - 6 ind/ m^2, and +++ = 7 - 10 ind/ m^2.

Table 19. Abundance of macrophytes (Monocotyledons) with families.

Sl. No.	Name of Family	Name of Genus	Name of species	BARD pond	Dutia Dighi	Horeshpur Jola
1	Aponogetonaceae	***Aponogeton***	*Aponogeton appendiculatus* Bruggen,	-	++	+++
2	Araceae	***Pistia***	*Pistia stratiotes* L	+	++	+++
3	Cyperaceae	***Cyperus***	*Cyperus articulatus* L.	+	+	++
			Cyperus cephalotes Vahl,	+	+	+
		Eleocharis	*Eleocharis dulcis* (Burm.f.) Trin. Ex Hensch.,	+	+	++
		Schoenoplectus	*Schoenoplectus articulatus* (L.) Palla,	-	+	+++
4	Eriocaulaceae	***Eriocaulon***	*Eriocaulon setaceum* L.,	+	++	+++
5	Gramineae	***Hygroryza***	*Hygroryza aristata* (Retz.) Nees ex Wight & Arn.,	+	++	+++
		Oryza	*Oryza sativa* Griff.,	-	+	+++
		Panicum	*Panicum paludosum* Roxb.,	-	+	+++
6	Hydrocharitaceae	***Blyxa***	*Blyxa auberti* Rich.,	+	++	++
		Hydrilla	*Hydrilla verticillata* (L.f.) Royle,	++	+++	++
		Hydrocharis	*Hydrocharis dubia* (Bl.) Backer,	-	+	+++
		Nechamandra	*Nechamandra alternifolia* (Roxb.) Thw.,	+	+	++
		Vallisneria	*Vallisneria spiralis* L.,	+	+++	+
7	Lemnaceae	***Lemna***	*Lemna minor* Torrey,	+	+	++
		Spirodela	*Spirodela polyrhiza* (L.) Schleid.,	++	++	+
8	Limnocharitaceae	***Limnocharis***	*Limnocharis flava* (L.) Buch. In Bremen,	+	+++	++
9	Najadaceae	***Najas***	*Najas indica* (Willd.) Cham.,	-	+	+
10	Pontederiaceae	***Eichhornia***	*Eichhornia crassipes* (Mart.) Solms in A.DC.,	++	++	++
		Monochoria	*Monochoria hastata* (L.) Solms in A. DC.,	-	++	+
			Monochoria vaginalis (Burm.f.) Presl,	+	+	+
11	Potamogetonaceae	***Potamogeton***	*Potamogeton crispus* L.,	-	+	++

+ = 0 - 2 ind/ m^2, ++ = 3 - 6 ind/ $m^2$and +++ = 7 - 10 ind/ m^2.

Density of dominant genera of phytoplankton

Table 20. Monthly density of dominant genus of phytoplankton ($\times10^6$ ind./l) in Station 1.

Month	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total dominant × 10^6 ind./l	Other $\times10^6$ ind./l	Total PD $\times10^6$ ind./l
17-Oct	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Peridinium*	4.36	3.46	7.82
17-Nov	*Peridinium*	*Scenedesmus*	*Crucigenia*	*Euglena*	4.69	3.55	8.24
17-Dec	*Peridinium*	*Cryptomonas*	*Trachelomonas*	*Scenedesmus*	7.80	3.71	11.51
18-Jan	*Scenedesmus*	*Trachelomonas*	*Cryptomonas*	*Peridinium*	3.81	4.77	8.38
18-Feb	*Hyaloraphidium*	*Crucigenia*	*Monoraphidium*	*Cryptomonas*	4.90	5.36	11.26
18-Mar	*Chlamydomonas*	*Monoraphidium*	*Hyaloraphidium*	*Euglena*	11.41	3.68	15.09
18-Apr	*Hyaloraphidium*	*Merismopedia*	*Crucigenia*	*Peridinium*	5.40	9.85	15.25
18-May	*Chlamydomonas*	*Hyaloraphidium*	*Trachelomonas*	*Oscillatoria*	5.46	5.69	11.14
18-Jun	*Trachelomonas*	*Peridinium*	*Scenedesmus*	*Merismopedia*	4.86	5.03	9.89
18-Jul	*Trachelomonas*	*Peridinium*	*Microcystis*	*Scenedesmus*	3.54	3.89	7.43
18-Aug	*Trachelomonas*	*Peridinium*	*Rhodomonas*	*Scenedesmus*	2.70	0.85	3.55
18-Sep	*Crucigenia*	*Rhodomonas*	*Trachelomonas*	*Scenedesmus*	1.99	1.52	3.51
18-Oct	*Rhodomonas*	*Scenedesmus*	*Trachelomonas*	*Cryptomonas*	2.20	2.79	4.99
18-Nov	*Peridinium*	*Rhodomonas*	*Cryptomonas*	*Trachelomonas*	5.54	1.49	7.03
18-Dec	*Chlamydomonas*	*Peridinium*	*Trachelomonas*	*Scenedesmus*	8.28	3.77	12.05
19-Jan	*Chlamydomonas*	*Trachelomonas*	*Peridinium*	*Euglena*	5.33	2.56	7.89
19-Feb	*Chlamydomonas*	*Cryptomonas*	*Scenedesmus*	*Tetrastrum*	7.91	6.18	14.09
19-Mar	*Chlamydomonas*	*Monoraphidium*	*Hyaloraphidium*	*Scenedesmus*	15.12	4.50	19.62
19-Apr	*Chlamydomonas*	*Oscillatoria*	*Trachelomonas*	*Monoraphidium*	8.37	8.52	16.89
19-May	*Chlamydomonas*	*Peridinium*	*Trachelomonas*	*Synedra*	9.08	5.38	14.64
19-Jun	*Melosira*	*Cryptomonas*	*Scenedesmus*	*Monoraphidium*	5.58	5.77	11.35
19-Jul	*Trachelomonas*	*Scenedesmus*	*Tetrastrum*	*Merismopedia*	3.57	2.64	6.21
19-Aug	*Trachelomonas*	*Scenedesmus*	*Euglena*	*Melosira*	2.17	0.40	2.57
19-Sep	*Rhodomonas*	*Peridinium*	*Scenedesmus*	*Cryptomonas*	2.62	1.37	3.99

Table 21. Monthly density of dominant genus of phytoplankton ($\times 10^6$ ind./l) in Station 2.

Month	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total dominant $\times 10^6$ ind./l	Other $\times 10^6$ ind./l	Total PD $\times 10^6$ ind./l
17-Oct	*Trachelomonas*	*Cryptomonas*	*Scenedesmus*	*Microcystis*	4.39	3.73	8.12
17-Nov	*Chlamydomonas*	*Peridinium*	*Scenedesmus*	*Crucigenia*	4.55	4.96	9.51
17-Dec	*Peridinium*	*Euglena*	*Trachelomonas*	*Merismopedia*	4.55	3.58	8.13
18-Jan	*Hyaloraphidium*	*Monoraphidium*	*Scenedesmus*	*Trachelomonas*	5.27	5.79	11.06
18-Feb	*Crucigenia*	*Monoraphidium*	*Oscillatoria*	*Trachelomonas*	3.91	5.3	9.27
18-Mar	*Chlamydomonas*	*Merismopedia*	*Monoraphidium*	*Oscillatoria*	20.1	7.95	28.05
18-Apr	*Hyaloraphidium*	*Peridinium*	*Trachelomonas*	*Euglena*	6.37	8.66	15.03
18-May	*Chlamydomonas*	*Trachelomonas*	*Synedra*	*Scenedesmus*	7.29	8.23	15.52
18-Jun	*Trachelomonas*	*Peridinium*	*Scenedesmus*	*Staurestrum*	4.88	7.5	12.38
18-Jul	*Trachelomonas*	*Peridinium*	*Rhodomonas*	*Crucigenia*	2.55	4.27	6.82
18-Aug	*Trachelomonas*	*Peridinium*	*Scenedesmus*	*Cryptomonas*	2.55	1.00	3.55
18-Sep	*Crucigenia*	*Scenedesmus*	*Rhodomonas*	*Hyaloraphidium*	1.40	1.10	2.50
18-Oct	*Rhodomonas*	*Trachelomonas*	*Cryptomonas*	*Scenedesmus*	2.48	2.66	5.14
18-Nov	*Peridinium*	*Cryptomonas*	*Trachelomonas*	*Euglena*	3.32	2.03	5.35
18-Dec	*Chlamydomonas*	*Peridinium*	*Trachelomonas*	*Melosira*	19.24	3.23	22.47
19-Jan	*Trachelomonas*	*Chlamydomonas*	*Cryptomonas*	*Cosmerium*	6.58	2.58	9.16
19-Feb	*Chlamydomonas*	*Cryptomonas*	*Scenedesmus*	*Trachelomonas*	7.45	4.78	12.23
19-Mar	*Chlamydomonas*	*Trachelomonas*	*Hyaloraphidium*	*Monoraphidium*	10.64	4.40	15.04
19-Apr	*Chlamydomonas*	*Scenedesmus*	*Oscillatoria*	*Trachelomonas*	5.99	5.47	11.46
19-May	*Chlamydomonas*	*Peridinium*	*Trachelomonas*	*Scenedesmus*	7.93	5.75	13.68
19-Jun	*Trachelomonas*	*Scenedesmus*	*Merismopedia*	*Synedra*	2.96	3.77	6.73
19-Jul	*Trachelomonas*	*Coelastrum*	*Tetrastrum*	*Rhodomonas*	2.70	2.84	5.54
19-Aug	*Trachelomonas*	*Scenedesmus*	*Peridinium*	*Melosira*	2.11	0.54	2.65
19-Sep	*Rhodomonas*	*Peridinium*	*Scenedesmus*	*Cryptomonas*	1.90	1.29	3.19

Table 22. Monthly density of dominant genera of phytoplankton (×10^6 ind./l) in Station 3.

Month	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
17-Oct	*Hyaloraphidium*	*Scenedesmus*	*Microcystis*	*Merismopedia*	2.26	1.51	3.77
17-Nov	*Monoraphidium*	*Scenedesmus*	*Spirulina*	*Chlamydomonas*	5.87	1.69	7.56
17-Dec	*Scenedesmus*	*Microcystis*	*Synedra*	*Ankistrodesmus*	3.98	0.46	4.44
18-Jan	*Ankistrodesmus*	*Monoraphidium*	*Oscillatoria*	*Hyaloraphidium*	2.96	2.49	5.45
18-Feb	*Hyaloraphidium*	*Spirulina*	*Oscillatoria*	*Scenedesmus*	1.98	1.21	3.19
18-Mar	*Hyaloraphidium*	*Oscillatoria*	*Scenedesmus*	*Pediastrum*	2.92	1.54	4.46
18-Apr	*Microcystis*	*Ankistrodesmus*	*Pediastrum*	*Spirulina*	2.49	1.04	3.53
18-May	*Oscillatoria*	*Spirulina*	*Scenedesmus*	*Crucigenia*	2.74	1.07	3.81
18-Jun	*Spirulina*	*Trachelomonas*	*Scenedesmus*	*Hyaloraphidium*	2.87	2.95	5.82
18-Jul	*Hyaloraphidium*	*Oscillatoria*	*Anabaenopsis*	*Peridinium*	1.63	1.95	3.58
18-Aug	*Microcystis*	*Hyaloraphidium*	*Oscillatoria*	*Peridinium*	3.69	0.89	4.58
18-Sep	*Oscillatoria*	*Scenedesmus*	*Pediastrum*	*Spirulina*	3.38	0.91	4.29
18-Oct	*Scenedesmus*	*Hyaloraphidium*	*Phacus*	*Peridinium*	5.11	2.98	8.09
18-Nov	*Hyaloraphidium*	*Oscillatoria*	*Spirulina*	*Peridinium*	3.92	1.61	5.53
18-Dec	*Hyaloraphidium*	*Monoraphidium*	*Trachelomonas*	*Euglena*	4.68	2.8	7.48
19-Jan	*Chlamydomonas*	*Hyaloraphidium*	*Peridinium*	*Pediastrum*	5.63	2.41	8.04
19-Feb	*Scenedesmus*	*Peridinium*	*Botryococcus*	*Oocystis*	1.79	0.86	2.65
19-Mar	*Trachelomonas*	*Scenedesmus*	*Crucigenia*	*Melosira*	0.35	0.16	0.51
19-Apr	*Trachelomonas*	*Rhodomonas*	*Peridinium*	*Cryptomonas*	1.62	0.51	2.13
19-May	*Synedra*	*Euglena*	*Oscillatoria*	*Chlamydomonas*	0.32	0.21	0.53
19-Jun	*Trachelomonas*	*Monoraphidium*	*Chlamydomonas*	*Oscillatoria*	0.2	0.13	0.33
19-Jul	*Trachelomonas*	*Crucigenia*	*Coelastrum*	*Scenedesmus*	1.72	0.66	2.38
19-Aug	*Trachelomonas*	*Scenedesmus*	*Anabaena*	*Rhodomonas*	0.82	0.6	1.42
19-Sep	*Melosira*	*Rhodomonas*	*Peridinium*	*Scenedesmus*	0.92	0.61	1.53

Table 23. Monthly density of dominant genera of phytoplankton (×10^6 ind./l) in Station 4.

Month	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
17-Oct	*Hyaloraphidium*	*Scenedesmus*	*Microcystis*	*Pelonema*	4.36	1.01	5.37
17-Nov	*Monoraphidium*	*Scenedesmus*	*Spirulina*	*Chlamydomonas*	7.63	1.27	8.90
17-Dec	*Hyaloraphidium*	*Monoraphidium*	*Rhodomonas*	*Synedra*	3.54	1.87	5.41
18-Jan	*Ankistrodesmus*	*Hyaloraphidium*	*Pediastrum*	*Monoraphidium*	2.70	2.00	4.70
18-Feb	*Hyaloraphidium*	*Spirogyra*	*Oscillatoria*	*Scenedesmus*	1.89	1.42	3.31
18-Mar	*Oscillatoria*	*Hyaloraphidium*	*Scenedesmus*	*Monoraphidium*	2.26	1.16	3.42
18-Apr	*Microcystis*	*Monoraphidium*	*Ankistrodesmus*	*Pediastrum*	2.59	2.66	5.25
18-May	*Scenedesmus*	*Microcystis*	*Oscillatoria*	*Spirulina*	2.57	1.12	3.69
18-Jun	*Spirulina*	*Trachelomonas*	*Crucigenia*	*Peridinium*	2.63	3.60	6.23
18-Jul	*Hyaloraphidium*	*Ankistrodesmus*	*Scenedesmus*	*Oscillatoria*	2.77	2.20	4.97
18-Aug	*Hyaloraphidium*	*Oscillatoria*	*Microcystis*	*Scenedesmus*	2.27	0.62	2.89
18-Sep	*Oscillatoria*	*Scenedesmus*	*Crucigenia*	*Pediastrum*	3.67	0.91	4.58
18-Oct	*Scenedesmus*	*Hyaloraphidium*	*Merismopedia*	*Crucigenia*	5.32	4.02	9.34
18-Nov	*Oscillatoria*	*Hyaloraphidium*	*Peridinium*	*Trachelomonas*	2.79	0.87	3.66
18-Dec	*Hyaloraphidium*	*Ankistrodesmus*	*Monoraphidium*	*Oscillatoria*	3.36	2.23	5.59
19-Jan	*Chlamydomonas*	*Ankistrodesmus*	*Scenedesmus*	*Pediastrum*	4.85	1.61	6.46
19-Feb	*Scenedesmus*	*Botryococcus*	*Pediastrum*	*Crucigenia*	2.19	1.21	3.40
19-Mar	*Scenedesmus*	*Trachelomonas*	*Crucigenia*	*Euglena*	1.25	0.48	1.73
19-Apr	*Trachelomonas*	*Euglena*	*Peridinium*	*Rhodomonas*	1.5	0.36	1.86
19-May	*Chlamydomonas*	*Syedra*	*Oscillatoria*	*Trachelomonas*	1.18	0.10	1.28
19-Jun	*Trachelomonas*	*Monoraphidium*	*Chlamydomonas*	*Cryptomonas*	0.20	0.13	0.33
19-Jul	*Trachelomonas*	*Coelastrum*	*Scenedesmus*	*Crucigenia*	1.76	0.54	2.30
19-Aug	*Trachelomonas*	*Scenedesmus*	*Microcystis*	*Anabaena*	0.72	0.44	1.16
19-Sep	*Melosira*	*Scenedesmus*	*Rhodomonas*	*Trachelomonas*	1.25	0.88	2.13

Table 24. Monthly density of dominant genera of phytoplankton ($\times 10^6$ ind./l) in Station 5.

Month	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total dominant $\times 10^6$ ind./l	Other $\times 10^6$ ind./l	Total PD $\times 10^6$ ind./l
17-Oct	*Rhodomonas*	*Cryptomonas*	*Trachelomonas*	*Carteria*	2.62	1.34	3.96
17-Nov	*Trachelomonas*	*Rhodomonas*	*Oscillatoria*	*Euglena*	0.725	0.515	1.24
17-Dec	*Trachelomonas*	*Euglena*	*Cryptomonas*	*Oscillatoria*	1.25	0.26	1.51
18-Jan	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Cryptomonas*	1.65	0.71	2.36
18-Feb	*Trachelomonas*	*Rhodomonas*	*Cryptomonas*	*Euglena*	2.89	0.35	3.24
18-Mar	*Trachelomonas*	*Euglena*	*Phacus*	*Rhodomonas*	2.24	0.5	2.74
18-Apr	*Trachelomonas*	*Euglena*	*Phacus*	*Cryptomonas*	1.85	0.43	2.28
18-May	*Rhodomonas*	*Euglena*	*Trachelomonas*	*Cryptomonas*	0.37	0.25	0.62
18-Jun	*Trachelomonas*	*Rhodomonas*	*Euglena*	*Peridinium*	0.53	0.19	0.72
18-Jul	*Trachelomonas*	*Euglena*	*Oscillatoria*	*Rhodomonas*	0.48	0.33	0.81
18-Aug	*Trachelomonas*	*Euglena*	*Peridinium*	*Cryptomonas*	0.41	0.25	0.66
18-Sep	*Trachelomonas*	*Rhodomonas*	*Euglena*	*Strombomonas*	1.69	0.49	2.18
18-Oct	*Trachelomonas*	*Strombomonas*	*Cryptomonas*	*Euglena*	1.82	0.74	2.56
18-Nov	*Euglena*	*Cryptomonas*	*Trachelomonas*	*Rhodomonas*	1.02	0.29	1.31
18-Dec	*Rhodomonas*	*Cryptomonas*	*Trachelomonas*	*Euglena*	0.79	0.37	1.16
19-Jan	*Rhodomonas*	*Cryptomonas*	*Synedra*	*Peridinium*	1.32	0.32	1.64
19-Feb	*Trachelomonas*	*Rhodomonas*	*Peridinium*	*Cryptomonas*	2.57	0.65	3.22
19-Mar	*Phacus*	*Rhodomonas*	*Euglena*	*Scenedesmus*	0.20	0.10	0.30
19-Apr	*Trachelomonas*	*Phacotus*	*Rhodomonas*	*Cryptomonas*	0.71	0.10	0.82
19-May	*Trachelomonas*	*Cryptomonas*	*Phacus*	*Strombomonas*	0.57	0.21	0.78
19-Jun	*Trachelomonas*	*Euglena*	*Oscillatoria*	*Peridinium*	0.25	0.11	0.36
19-Jul	*Rhodomonas*	*Trachelomonas*	*Euglena*	*Anabaena*	0.34	0.22	0.56
19-Aug	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Oscillatoria*	1.35	0.18	1.53
19-Sep	*Trachelomonas*	*Rhodomonas*	*Euglena*	*Cryptomonas*	1.11	0.34	1.45

Table 25. Monthly density of dominant genera of phytoplankton ($\times 10^6$ ind./l) in Station 6.

Month	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total dominant $\times 10^6$ ind./l	Other $\times 10^6$ ind./l	Total PD $\times 10^6$ ind./l
17-Oct	*Rhodomonas*	*Cryptomonas*	*Phacotus*	*Trachelomonas*	2.21	0.67	2.88
17-Nov	*Trachelomonas*	*Cryptomonas*	*Rhodomonas*	*Oscillatoria*	0.93	0.36	1.29
17-Dec	*Oscillatoria*	*Euglena*	*Cryptomonas*	*Rhodomonas*	0.40	0.26	0.66
18-Jan	*Rhodomonas*	*Trachelomonas*	*Euglena*	*Cryptomonas*	0.39	0.23	0.62
18-Feb	*Chlamydomonas*	*Euglena*	*Trachelomonas*	*Rhodomonas*	11.92	3.90	15.82
18-Mar	*Monoraphidium*	*Trachelomonas*	*Chlamydomonas*	*Rhodomonas*	1.01	0.26	1.27
18-Apr	*Trachelomonas*	*Euglena*	*Cryptomonas*	*Peridinium*	1.33	0.43	1.76
18-May	*Trachelomonas*	*Rhodomonas*	*Euglena*	*Dictyosphaerium*	1.49	1.66	3.15
18-Jun	*Trachelomonas*	*Rhodomonas*	*Synedra*	*Pandorina*	1.07	0.50	1.57
18-Jul	*Trachelomonas*	*Euglena*	*Oscillatoria*	*Rhodomonas*	0.35	0.17	0.52
18-Aug	*Rhodomonas*	*Trachelomonas*	*Cryptomonas*	*Euglena*	0.38	0.25	0.63
18-Sep	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Pandorina*	1.32	0.60	1.92
18-Oct	*Euglena*	*Trachelomonas*	*Phacus*	*Pinnularia*	0.74	0.50	1.24
18-Nov	*Trachelomonas*	*Euglena*	*Melosira*	*Hyaloraphidium*	2.16	0.95	3.11
18-Dec	*Monoraphidium*	*Cryptomonas*	*Peridinium*	*Synedra*	0.74	0.60	1.34
19-Jan	*Chroomonas*	*Schroederia*	*Cryptomonas*	*Chlamydomonas*	0.64	0.24	0.88
19-Feb	*Cryptomonas*	*Rhodomonas*	*Chroomonas*	*Trachelomonas*	0.53	0.22	0.75
19-Mar	*Chlamydomonas*	*Trachelomonas*	*Ceratium*	*Rhodomonas*	15.1	0.18	15.28
19-Apr	*Ceratium*	*Trachelomonas*	*Cryptomonas*	*Rhodomonas*	0.85	0.25	1.10
19-May	*Euglena*	*Trachelomonas*	*Rhodomonas*	*Colacim*	1.08	0.35	1.43
19-Jun	*Trachelomonas*	*Euglena*	*Oscillatoria*	*Cryptomonas*	0.29	0.15	0.44
19-Jul	*Trachelomonas*	*Oscillatoria*	*Euglena*	*Rhodomonas*	0.44	0.18	0.62
19-Aug	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Phacus*	1.54	0.30	1.84
19-Sep	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Cryptomonas*	1.35	0.48	1.83

Table 26. Monthly density of dominant genus of phytoplankton ($\times 10^6$ ind./l) in Station 7.

Month	Dominant 1	Dominant 2	Dominant 3	Dominant 4	Total dominant $\times 10^6$ ind./l	Other $\times 10^6$ ind./l	Total PD $\times 10^6$ ind./l
17-Oct	*Euglena*	*Trachelomonas*	*Cryptomonas*	*Lepocinclis*	5.17	1.95	7.12
17-Nov	*Peridinium*	*Euglena*	*Oscillatoria*	*Phacus*	0.27	0.12	0.39
17-Dec	*Rhodomonas*	*Euglena*	*Trachelomonas*	*Dictyosphaerium*	2.94	1.13	4.07
18-Jan	*Euglena*	*Peridinium*	*Lepocinclis*	*Phacus*	0.22	0.12	0.34
18-Feb	*Trachelomonas*	*Euglena*	*Strombomonas*	*Phacus*	0.94	0.17	1.11
18-Mar	*Trachelomonas*	*Euglena*	*Monoraphidium*	*Oscillatoria*	0.62	0.29	0.91
18-Apr	*Trachelomonas*	*Euglena*	*Peridinium*	*Oscillatoria*	0.80	0.17	0.97
18-May	*Trachelomonas*	*Rhodomonas*	*Cryptomonas*	*Cyclotella*	0.59	0.55	1.14
18-Jun	*Trachelomonas*	*Euglena*	*Strombomonas*	*Phacus*	3.20	0.77	3.97
18-Jul	*Trachelomonas*	*Rhodomonas*	*Euglena*	*Hyaloraphidium*	1.10	0.51	1.61
18-Aug	*Trachelomonas*	*Euglena*	*Synedra*	*Lepocinclis*	3.23	0.36	3.59
18-Sep	*Oscillatoria*	*Euglena*	*Trachelomonas*	*Merismopedia*	2.57	2.67	5.24
18-Oct	*Trachelomonas*	*Crucigenia*	*Coelastrum*	*Scenedesmus*	3.86	3.92	7.78
18-Nov	*Euglena*	*Trachelomonas*	*Phacus*	*Synedra*	0.89	0.24	1.13
18-Dec	*Synedra*	*Oscillatoria*	*Astasia*	*Navicula*	0.28	0.19	0.47
19-Jan	*Synedra*	*Oscillatoria*	*Chlamydomonas*	*Monoraphidium*	0.24	0.34	0.58
19-Feb	*Rhodomonas*	*Navicula*	*Oscillatoria*	*Trachelomonas*	0.14	0.12	0.26
19-Mar	*Anabaena*	*Gomphonema*	*Peridinium*	*Synedra*	0.14	0.08	0.22
19-Apr	*Trachelomonas*	*Euglena*	*Phacotus*	*Cryptomonas*	0.59	0.15	0.74
19-May	*Trachelomonas*	*Euglena*	*Crucigenia*	*Monoraphidium*	1.76	0.62	2.38
19-Jun	*Trachelomonas*	*Euglena*	*Peridinium*	*Cryptomonas*	1.13	0.36	1.49
19-Jul	*Peridinium*	*Trachelomonas*	*Euglena*	*Cryptomonas*	0.86	0.45	1.31
19-Aug	*Trachelomonas*	*Euglena*	*Cryptomonas*	*Peridinium*	1.86	0.43	2.29
19-Sep	*Euglena*	*Trachelomonas*	*Strombomonas*	*Phacus*	2.51	0.81	3.32

Seasonal variation of dominant phytoplankton at genus level

Station 1

In this station, dominant phytoplankton were *Merismopedia, Microcystis, Hyaloraphidium,* and *Oscillatoria* belonging to Cyanophyta, *Kirschneriella, Dictyosphaerium, Crucigenia, Coelastrum, Scenedesmus, Carteria, Chlamydomonas, Oocystis, Cosmarium,* and *Staurastrum* belonging to Chlorophyta, *Trachelomonas, Lepocinclis, Euglena, Strombomonas,* and *Phacus* belonging to Euglenophyta, *Cyclotella, Gomphonema, Eunotia, Synedra, Fragillaria, Navicula, Pinnularia,* and *Nitzschia* belonging to Chrysophyta, *Peridinium* and *Ceratium* belonging to Pyrrhophyta and *Chroomonas, Cryptomonas* and *Rhodomonas* belonging to Cryptophyta were observed.

During pre-monsoon, the genus *Chlamydomonas* was dominant followed by *Merismopedia, Crucigenia,* and *Peridinium* in the first year but in second year *Chlamydomonas* was dominant followed by *Oscillatoria, Trachelomonas,* and *Monoraphidium*.

During monsoon, the genus *Trachelomonas* was dominant followed by *Peridinium, Rhodomonas,* and *Scenedesmus* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Scenedesmus, Euglena,* and *Cryptomonas*.

During post-monsoon the genus *Peridinium* was dominant followed by *Scenedesmus, Crucigenia,* and *Euglena* in first year but in second year, the genus *Rhodomonas* was most dominant followed by *Scenedesmus, Trachelomonas,* and *Cryptomonas*.

Winter was dominated by the genus *Scenedesmus* followed by *Trachelomonas, Cryptomonas,* and *Peridinium* in the first year where as in second year, *Chlamydomonas* was dominant followed by *Trachelomonas, Peridinium,* and *Scenedesmus* (Table 27).

Station 2

In this Station, dominant phytoplankton were *Microcystis, Oscillatoria, Pelonema,* and *Merismopedia* belonging to Cyanophyta, *Dictyosphaerium, Coelastrum, Chlorella, Kirschneriella, Staurastrum, Carteria, Chlamydomonas, Crucigenia, Ankistrodesmus, Scenedesmus,* and *Pandorina* belonging to Chlorophyta; *Euglena, Trachelomonas, Lepocinclis, Strombomonas,* and *Phacus* belonging to Euglenophyta; *Cyclotella, Eunotia, Synedra, Nitzschia,* and *Navicula* belonging to Chrysophyta, *Peridinium* and *Ceratium* belonging to Pyrrhophyta and *Rhodomonas, Chroomonas*, and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Chlamydomonas* was dominant followed by *Merismopedia, Trachelomonas,* and *Scenedesmus* in first year but in the second year, the genus *Chlamydomonas* was also dominant followed by *Trachelomonas*, *Scenedesmus*, and *Hyaloraphidium*.

During Monsoon the genus *Trachelomonas* was dominant followed by *Peridinium, Rhodomonas and Crucigenia* in the first year and in second year, the genus *Trachelomonas* was also dominant followed by *Scenedesmus, Rhodomonas*, and *Cryptomonas*.

In post-monsoon, the genus *Trachelomonas* was dominant followed by *Peridinium, Scenedesmus, and Microcystis* in the first year but in second year, *Rhodomonas* was dominant followed by *Cryptomonas*, *Tracchelomonas,* and *Scenedesmus*.

During winter the genus *Hyaloraphidium* was dominant followed by *Monoraphidum, Crucigenia*, and *Trachelomonas* in the first year but in second year, the genus *Chlamydomonas* was dominant followed by *Trachelomonas, Cryptomonas, and Cosmarium* (Table 28).

Station-3

In this Station, dominant phytoplankton were *Microcystis, Oscillatoria, Pelonema, Spirulina*, and *Merismopedia* belonging to Cyanophyta; *Dictyosphaerium*, *Coelastrum, Monoraphidium, Staurastrum, Chlamydomonas, Crucigenia, Monoraphidium, Ankistrodesmus, Scenedesmus,* and *Pandorina* belonging to Chlorophyta; *Euglena, Trachelomonas, Lepocinclis, Strombomonas,* and *Phacus* belonging to Euglenophyta; *Cyclotella, Eunotia, Synedra, Nitzschia,* and *Navicula* belonging to Chrysophyta; *Peridinium* and *Ceratium* belonging to Pyrrhophyta and *Rhodomonas, Chroomonas*, and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Oscillatoria* was dominant followed by *Hyaloraphidium*, *Scenedesmus,* and *Spirulina* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Rhodomonas*, *Cryptomonas,* and *Melosira*.

During monsoon the genus *Hyaloraphidium* was dominant followed by *Oscillaria*, *Scenedesmus*, and *Peridinium* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Rhodomonas, Anabaena,* and *Scenedesmus*.

In Post-monsoon, the genus *Hyaloraphidium* was dominant followed by *Scenedesmus, Microcystis,* and *Chlamydomonas* in the first year but in second year, the genus *Hyaloraphidium* was dominant followed by *Oscillatoria, Scenedesmus*, and *Peridinium*.

During winter the genus *Hyaloraphidium* was dominant followed by *Microcystis*, *Oscillatoria,* and *Ankistrodesmus* in the first year but in second year, the genus *Hyaloraphidium* was dominant followed by *Monoraphidium, Trachelomonas,* and *Pediastrum* (Table 29).

Station-4

In this Station, dominant phytoplankton were *Microcystis, Oscillatoria,* and *Pelonema* belonging to Cyanophyta; *Dictyosphaerium, Coelastrum, Hyaloraphidium, Staurastrum, Chlamydomonas, Crucigenia, Ankistrodesmus,* and *Scenedesmus* belonging to Chlorophyta; *Euglena, Trachelomonas, Strombomonas,* and *Phacus* belonging to Euglenophyta; *Pinnularia, Synedra, Nitzschia,* and *Navicula* belonging to Chrysophyta; *Peridinium* and *Ceratium* belonging to Pyrrhophyta and *Rhodomonas, Chilomonas,* and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Microcysis* was dominant followed by *Scenedesmus, Monoraphidium,* and *Peridinium* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Scenedesmus, Peridinium,* and *Rhodomonas*.

During monsoon the genus *Hyaloraphidium* was dominant followed by *Oscillatoria, Crucigenia,* and *Scenedesmus* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Scenedesmus, Rhodomonas,* and *Cryptomonas*.

In post-monsoon, the genus *Hyaloraphidium* was dominant followed by *Scenedesmus, Microcystis, and Pelonema* in the first year but in second year, *Scenedesmus* was dominant followed by *Hyaloraphidium, Oscillatoria, and Trachelomonas*.

During winter, the genus *Hyaloraphidium* was dominant followed by *Monoraphidium, Scenedesmus* and *Oscillatoria* in the first year but in second year, the genus *Scenedesmus* was dominant followed by *Ankistrodesmus, Pediastrum,* and *Crucigenia* (Table 30).

Station-5

In this Station, dominant phytoplankton were *Microcystis, Oscillatoria,* and *Merismopedia* belonging to Cyanophyta; *Coelastrum, Staurastrum, Cosmarium, Crucigenia, Ankistrodesmus,* and *Scenedesmus* belonging to Chlorophyta; *Euglena, Trachelomonas, Strombomonas,* and *Phacus* belonging to Euglenophyta; *Pinnularia, Synedra, Gomphonema, Nitzschia,* and *Navicula* belonging to Chrysophyta; *Peridinium* and *Ceratium* belonging to Pyrrhophyta and *Rhodomonas, Chroomonas,* and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Trachelomonas* was dominant followed by *Euglena, Rhodomonas,* and *Cryoptomonas* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Euglena, Cryptomonas,* and *Rhodomonas*.

During monsoon the genus *Trachelomonas* was dominant followed by *Euglena, Rhodomonas,* and *Peridinium* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Rhodomonas, Euglena,* and *Oscillotoria*.

In post-monsoon, the genus *Rhodomonas* was dominant followed by *Trachelomonas, Cryptomonas, and Euglena* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Euglena, Cryptomonas,* and *Strombomonas*.

During winter *Trachelomonas* was dominant followed by *Euglena, Cryptomonas,* and *Rhodomonas* in the first year but in second year, the genus *Rhodomonas* was dominant followed by *Cryptomonas, Trachelomonas,* and *Peridinium* (Table 31).

Station-6

In this Station, dominant phytoplankton were *Microcystis, Oscillatoria,* and *Merismopedia* belonging to Cyanophyta; *Hyaloraphidium, Monoraphidium, Chlamydomonas, Crucigenia, Ankistrodesmus, Pandorina,* and *Scenedesmus* belonging to Chlorophyta; *Euglena, Trachelomonas, Strombomonas,* and *Phacus* belonging to Euglenophyta; *Pinnularia, Synedra, Melosira,* and *Navicula* belonging to Chrysophyta; *Peridinium* and *Ceratium* belonging to Pyrrhophyta and *Rhodomonas, Chilomonas, Chroomonas,* and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Trachelomonas* was dominant followed by *Rhodomonas, Monoraphidium,* and *Cryptomonas* in the first year but in second year, the genus *Chlamydomonas* was dominant followed by *Scenedesmus, Peridinium,* and *Rhodomonas*.

During monsoon the genus *Trachelomonas* was dominant followed by *Rhodomonas, Euglena,* and *Pandorina* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Euglena, Rhodomonas,* and *Cryptomonas*.

In post-monsoon, *Trachelomonas* was dominant followed by *Cryptomonas, Rhodomonas,* and *Oscillatoria* in the first year but in second year, the genus *Euglena* was dominant followed by *Trachelomonas, Pinnularia,* and *Hyaloraphidium*.

During winter *Rhodomonas* was dominant followed by *Trachelomonas, Euglena,* and *Oscillatoria* in first year but in second year, the genus *Chroomonas* was dominant followed by *Cryptomonas, Monoraphidium,* and *Chlamydomonas* (Table 32).

Station-7

In this Station, dominant phytoplankton were *Anabaena, Oscillatoria,* and *Merismopedia* belonging to Cyanophyta; *Hyaloraphidium, Staurastrum, Scenedesmus, Chlamydomonas, Crucigenia, Ankistrodesmus,* and *Monoraphidium* belonging to Chlorophyta; *Euglena, Trachelomonas, Strombomonas,* and *Phacus* belonging to Euglenophyta; *Pinnularia, Synedra, Gomphonema,* and *Melosira* belonging to Chrysophyta; *Peridinium* and *Ceratium* belonging to Pyrrhophyta and *Rhodomonas, Chroomonas,* and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Trachelomonas* was dominant followed by *Euglena, Monoraphidium,* and *Oscillatoria* in the first year but in second year, the genus *Trachelomonas* was also dominant followed by *Euglena, Anabaena,* and *Gomphonema*.

During monsoon the genus *Trachelomonas* was dominant followed by *Euglena, Oscillatoria,* and *Hyaloraphidium* in the first year but in second year, the genus *Trachelomonas* was also dominant followed by *Euglena, Cryptomonas,* and *Peridinium*.

In post-monsoon, the genus *Euglena* was dominant followed by *Trachelomonas, Peridinium, and Oscillatoria* in the first year but in second year, *Trachelomonas* was dominant followed by *Euglena, Crucigenia,* and *Scenedesmus*.

During winter *Euglena* was dominant followed by *Trachelomonas, Peridinium,* and *Phacus* in the first year but in second year, the genus *Synedra* was dominant followed by *Oscillatoria, Rhodomonas,* and *Monoraphidium* (Table 33).

Table 27. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station 1.

Year	Seasons	Genus 1	Genus 2	Genus 3	Genus 4	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
		Dominant genus of phytoplankton						
2017-2018	Pre-monsoon	*Chlamydomonas*	*Merismopedia*	*Crucigeniella*	*Peridinium*	7.42	6.41	13.83
	Monsoon	*Trachelomonas*	*Peridinium*	*Rhodomonas*	*Scenedesmus*	3.27	2.82	6.09
	Post-monsoon	*Peridinium*	*Scenedesmus*	*Crucigenia*	*Euglena*	4.53	3.49	8.02
	Winter	*Scenedesmus*	*Trachelomonas*	*Cryptomonas*	*Peridinium*	5.50	4.61	10.39
2018-2019	Pre-monsoon	*Chlamydomonas*	*Oscillatoria*	*Trachelomonas*	*Monoraphidium*	10.85	6.13	17.05
	Monsoon	*Trachelomonas*	*Scenedesmus*	*Euglena*	*Cryptomonas*	3.49	2.55	6.03
	Post-monsoon	*Rhodomonas*	*Scenedesmus*	*Trachelomonas*	*Cryptomonas*	3.87	2.14	6.01
	Winter	*Chlamydomonas*	*Trachelomonas*	*Peridinium*	*Scenedesmus*	7.17	4.17	11.34

Table 28. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station 2.

Year	Seasons	Dominant genus of plankton				Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
		Genus 1	Genus 2	Genus 3	Genus 4			
2017-2018	Pre-monsoon	*Chlamydomonas*	*Merismopedia*	*Trachelomonas*	*Scenedesmus*	11.25	8.28	19.53
	Monsoon	*Trachelomonas*	*Peridinium*	*Rhodomonas*	*Crucigenia*	2.85	3.47	6.31
	Post-monsoon	*Trachelomonas*	*Peridinium*	*Scenedesmus*	*Microcystis*	4.47	4.35	8.82
	Winter	*Hyaloraphidium*	*Monoraphidium*	*Crucigenia*	*Trachelomonas*	4.58	4.89	9.49
2018-2019	Pre-monsoon	*Chlamydomonas*	*Trachelomonas*	*Scenedesmus*	*Hyaloraphidium*	8.19	5.21	13.4
	Monsoon	*Trachelomonas*	*Scenedesmus*	*Rhodomonas*	*Cryptomonas*	2.42	2.11	4.53
	Post-monsoon	*Rhodomonas*	*Cryptomonas*	*Trachelomonas*	*Scenedesmus*	2.90	2.35	5.25
	Winter	*Chlamydomonas*	*Trachelomonas*	*Cryptomonas*	*Cosmarium*	11.09	3.53	14.62

Table 29. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station 3.

Year	Seasons	Dominant genus of plankton Genus 1	Genus 2	Genus 3	Genus 4	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
2017-2018	Pre-monsoon	*Oscillatoria*	*Hyaloraphidium*	*Scenedesmus*	*Spirulina*	2.72	1.22	3.94
	Monsoon	*Hyaloraphidium*	*Oscillatoria*	*Scenedesmus*	*Peridinium*	2.89	1.68	4.57
	Post-monsoon	*Hyaloraphidium*	*Scenedesmus*	*Microcystis*	*Chlamydomonas*	4.06	1.6	5.67
	Winter	*Hyaloraphidium*	*Microcystis*	*Oscillatoria*	*Ankistrodesmus*	2.97	1.39	4.36
2018-2019	Pre-monsoon	*Trachelomonas*	*Rhodomonas*	*Cryptomonas*	*Melosira*	0.76	0.29	1.06
	Monsoon	*Trachelomonas*	*Rhodomonas*	*Anabaena*	*Scenedesmus*	0.92	0.50	1.42
	Post-monsoon	*Hyaloraphidium*	*Oscillatoria*	*Scenedesmus*	*Peridinium*	4.52	2.30	6.82
	Winter	*Hyaloraphidium*	*Monoraphidium*	*Trachelomonas*	*Pediastrum*	4.03	2.02	6.05

Table 30. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station 4.

Year	Seasons	Dominant genus of plankton				Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
		Genus 1	Genus 2	Genus 3	Genus 4			
2017-2018	Pre-monsoon	*Microcystis*	*Scenedesmus*	*Monoraphidium*	*Scenedesmus*	2.47	1.65	4.12
	Monsoon	*Hyaloraphidium*	*Oscillatoria*	*Crucigenia*	*Scenedesmus*	2.84	1.83	4.67
	Post-monsoon	*Hyaloraphidium*	*Scenedesmus*	*Microcystis*	*Pelonema*	5.99	1.14	7.14
	Winter	*Hyaloraphidium*	*Monoraphidium*	*Scenedesmus*	*Oscillatoria*	2.71	1.76	4.47
2018-2019	Pre-monsoon	*Trachelomonas*	*Scenedesmus*	*Peridinium*	*Rhodomonas*	1.31	0.31	1.62
	Monsoon	*Trachelomonas*	*Scenedesmus*	*Rhodomonas*	*Cryptomonas*	0.98	0.50	1.48
	Post-monsoon	*Scenedesmus*	*Hyaloraphidium*	*Oscillatoria*	*Trachelomonas*	4.06	2.45	6.51
	Winter	*Scenedesmus*	*Ankistrodesmus*	*Pediastrum*	*Crucigenia*	3.47	1.68	5.15

Table 31. Seasonal density of dominant genera of phytoplankton ($\times10^6$ ind./l) in Station 5.

Year	Seasons	Dominant genus of phytoplankton				Total Dominant $\times10^6$ ind./l	Others $\times10^6$ind./l	Total $\times10^6$ind./l
		Genus 1	Genus 2	Genus 3	Genus 4			
2017-2018	Pre-monsoon	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Cryptomonas*	1.49	0.39	1.88
	Monsoon	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Peridinium*	0.78	0.32	1.10
	Post-monsoon	*Rhodomonas*	*Trachelomonas*	*Cryptomonas*	*Euglena*	1.67	0.93	2.6
	Winter	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Cryptomonas*	1.93	0.44	2.37
2018-2019	Pre-monsoon	*Trachelomonas*	*Euglena*	*Cryptomonas*	*Rhodomonas*	0.49	0.14	0.63
	Monsoon	*Trachelomonas*	*Rhodomonas*	*Euglena*	*Oscillatoria*	0.76	0.21	0.97
	Post-monsoon	*Trachelomonas*	*Euglena*	*Cryptomonas*	*Strombomonas*	1.42	0.52	1.94
	Winter	*Rhodomonas*	*Cryptomonas*	*Trachelomonas*	*Peridinium*	1.56	0.45	2.01

Table 32. Seasonal density of dominant genera of phytoplankton ($\times10^6$ ind./l) in Station 6.

Year	Seasons	Dominant genus of phytoplankton				Total Dominant	Others	Total
		Genus 1	Genus 2	Genus 3	Genus 4	$\times10^6$ ind./l	$\times10^6$ ind./l	$\times10^6$ ind./l
2017-2018	Pre-monsoon	*Trachelomonas*	*Rhodomonas*	*Monoraphidium*	*Cryptomonas*	1.28	0.78	2.06
	Monsoon	*Trachelomonas*	*Rhodomonas*	*Euglena*	*Pandorina*	0.78	0.38	1.16
	Post-monsoon	*Trachelomonas*	*Cryptomonas*	*Rhodomonas*	*Oscillatoria*	1.57	0.52	2.09
	Winter	*Rhodomonas*	*Trachelomonas*	*Euglena*	*Oscillatoria*	4.24	1.46	5.7
2018-2019	Pre-monsoon	*Chlamydomonas*	*Trachelomonas*	*Euglena*	*Rhodomonas*	5.68	0.26	5.94
	Monsoon	*Trachelomonas*	*Euglena*	*Rhodomonas*	*Cryptomonas*	0.91	0.28	1.19
	Post-monsoon	*Euglena*	*Trachelomonas*	*Pinnularia*	*Hyaloraphidium*	1.45	0.73	2.18
	Winter	*Chroomonas*	*Cryptomonas*	*Monoraphidium*	*Chlymodomonas*	0.64	0.35	0.99

Table 33. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station 7.

Year	Seasons	Dominant genus of phytoplankton Genus 1	Genus 2	Genus 3	Genus 4	Total Dominant ×106 ind./l	Others ×10^6ind./l	Total ×10^6ind./l
2017-2018	Pre-M	*Trachelomonas*	*Euglena*	*Monoraphidium*	*Oscillatoria*	0.67	0.34	1.01
	Monsoon	*Trachelomonas*	*Euglena*	*Oscillatoria*	*Hyaloraphidium*	2.53	1.08	3.61
	Post-M	*Euglena*	*Trachelomonas*	*Peridinium*	*Oscillatoria*	2.72	1.04	3.76
	Winter	*Euglena*	*Trachelomonas*	*Peridinium*	*Phacus*	1.37	0.47	1.84
2018-2019	Pre-M	*Trachelomonas*	*Euglena*	*Anabaena*	*Gomphonema*	0.83	0.28	1.11
	Monsoon	*Trachelomonas*	*Euglena*	*Cryptomonas*	*Peridinium*	1.59	0.51	2.1
	Post-M	*Trachelomonas*	*Euglena*	*Crucigenia*	*Scenedesmus*	2.38	2.08	4.46
	Winter	*Synedra*	*Oscillatoria*	*Rhodomonas*	*Monoraphidium*	0.22	0.22	0.44

Table 34. Density of dominant species of phytoplankton (×10^3 ind./l) in Station 1.

Division	Species	Density (×10^3 ind./l)
Cyanophyta	*Anabaena affinis* Lemm.	1.78
	A. ballyganglii J. C. Banerji	0.82
	Anabaenopsis tanganikae (West) Wol.	0.54
	Cylindrospermopsis raciborskii	1.61
	Merismopedia punctata	0.81
	Microcystis aeruginosa	1.88
	Oscillatoria pseudogeminata	1.86
	Pelonema aphane	0.96
Chlorophyta	*Actinastrum hantzschii* var. *subtile* Wolosz.	1.15
	Ankistrodesmus barnardii Kom.	0.69
	Ankis. blibraianus (Rein.) Kors.	1.57
	Arthrodesmus curvatus Turner	0.92
	Chlamydomonas globosa Snow	1.06
	Closterium venus var. *venus* Kuetzing	2.25
	Coelastrum indicum Turner	1.22
	Coel. microphorum Nägeli	0.09
	Cosmarium subcostatum Nordst.	1.2
	Cos. trachypleurum var. *minus* Racib.	1.02
	Crucigenia quadrata Morren	0.17
	Cru. lauterbournii (Schim.) Schim.	1.54
	Eudorina elegans Ehrenberg	1.20
	Gonium pectorale Müller	0.18
	Hyaloraphidium contortum Pascher and Kors.	0.12
	Pediastrum tetras (Ehrenberg) Ralfs	0.36
	Scenedesmus arcuatus Lemm.	1.36
Euglenophyta	*Euglena acus var. longissima* Defl.	2.34
	E. chlamydophora Mainx	0.24
	E. clavata Skuja	0.59
	E. pseudospiroides	1.93
	E. rubra Hardy	0.67
	Lepocinclis salina fa. *obtusa* (H.-P) Conr.	1.47
	L. texta fa. *minor* Conr.	0.23
	Phacus acuminatus var. acuminatus Stokes	0.77
	P. ranula Pochm.	0.53
	P. suecious var. oidion Pochm.	1.52
	Strombomonas gibberosa (Playf.) Defl.	0.34

Division	Species	Density (×10^3 ind./l)
	Str. gibberosa var. longicollis (Playf.) Defl.	1.12
	Trachelomonas hispida var. punctata Lemm.	0.41
	Tr. intermedia Dang.	0.86
	Tr. lacustris var. ovalis Drez.	0.20
	Tr. rogulosa Stein	0.71
	Tr. sydneyensis Playfair	0.19
	Tr. volvocina Ehrenberg	0.82
Chrysophyta	*Cymbella cistula* (Hemp. and Ehr,) Kirch.	0.38
	Eunotia veneris (Kuetz.) De Tony	0.49
	Gomphonema sphaerophorum Ehren.	0.71
	Gyrosigma attenuatum (Kütz,) Rab.	0.19
	Navicula spicula Hickey	0.82
	Nitz. acicularis (Kuetz.) G.M. Smith	0.10
	Nitz. acicularis var. *closteroides* Grun.	0.12
	Pinnularia krookii. (Grun.) Cleve	0.18
	Synedra ulna var. *oxyrhynchus* (Kütz.) O'Meara	0.27
Cryptophyta	*Chroomonas acuta* Utermöhi	1.13
	Cryptomonas erosa Ehreberg	0.90
	Rhodomonas lacustris Pascher *et* Ruttner	0.58
Pyrrophyta	*Ceratium hirundinella* (O.F. Müller) Dujardin	0.12
	Peridinium abei	0.18

Table 35. Density of dominant species of phytoplankton ($\times10^3$ ind./l) in Station 2.

Division	Species	Density ($\times10^3$ ind./l)
Cyanophyta	*Anabaena variabilis* Kuetz ex Born	1.98
	Anabaenopsis arnoldii Aptkerj	0.45
	Merismopedia elegans	0.21
	Microcystis roseana	0.95
	Oscillatoria geitleriana	0.26
	O. geminata	2.20
	O. proteus	1.09
	Spirulina laxa	1.37
Chlorophyta	*Actinastrum gracillimum* var. *gracillimum* Smith	0.37
	Ankistrodesmus densus Kors.	1.19
	Chlamydomonas pulchra Skvortz.	0.77
	Chlorogonium elongatum (Dang.) France	0.72
	Chlorotetraedron polymorphum Mc Entee	0.54
	Closterium praelongum var. *praelongum* Brėb.	0.94
	Cl. toxon var. *toxon* W. West	1.03
	Cosmarium clepsydra Nordst.	0.96
	Cos. contractum var. *cracoviense* fa. *angulatus* Islam and Irfanullah	0.53
	Crucigeniella rectangularis (Näg.) Kom.	0.81
	Oocystis solitaria Wittr.	0.62
	Ooc. submarina Lagerheim	0.65
	Scenedesmus dimorphus (Trup.) Kütz.	0.89
	S. ecornis var. *ecornis* (Ehr.) Chodat	0.94
Euglenophyta	*Euglena güntheri* Gojdics	1.29
	E. hemichromata Skuja	1.98
	E. limnophila Lemm.	2.39
	E. tripteris (Dujardin) Klebs	2.47
	Lepocinclis acuta Prescott	0.58
	Phacus hamelii Allorge and Lafevre	1.58
	P. helicoides Pochm.	2.33
	P. horridus Pochm.	1.74
	Strombomonas napiformis var. *brevicollis* (Playf.) Defl.	0.65

Division	Species	Density (×10^3 ind./l)
	Trachelomonas abrupta var. arcuata (Playf.) comb. Defl.	0.43
	Tr. nadsoni Skv.	0.46
	Tr. nadsoni var. acuta Islam	0.55
	Tr. volvocina var. punctata Playf.	0.96
	Tr. volvocinopsis Swirenko	3.17
Chrysophyta	*Eunotia lunaris* (Ehren.) Grun.	1.37
	Fragillaria crotonensis Kitton	0.17
	Gomphonema lanceolatum var. *insignis* (Greg,) Cleve	1.31
	Gyrosigma scalproides (Rab.) Cleve	0.37
	Melosira distans var. *alpigena* Grunow	1.22
	Navicula grimmei Krasske	0.31
	N. integra (W. Sm.) Ralfs	1.88
	N. menisculus Schum.	1.33
	Nitzschia subtubicola H. Germain	0.52
	Pinnularia microstauron (Ehr.) Cleve	1.54
	Stauroneis anceps fa. *gracilis* (Ehr.) Hust.	0.39
	Synedra acus Kütz.	0.38
Pyrrhophyta	*Ceratium hirundinella* (O.F. Müller) Dujardin	1.73
	Peridinium abei	1.10
Cryptophyta	*Chilomonas acuta var. insignis* Skuja	1.27
	Cryptomonas erosa Ehreberg	1.43
	Rhodomonas minuta var. nanoplanktica Skuja	1.21

Table 36. Density of dominant species of phytoplankton ($\times 10^3$ ind./l) in Station 3.

Division	Species	Density ($\times 10^3$ ind./l)
Cyanophyta	*Anabaena oryzae* Fritsch	1.32
	A. oscillarioides Bory ex Born	0.82
	Anabaenopsis raciborskii Wolosz.	0.54
	Merismopedia minima	1.61
	Microcystis marginata	2.81
	Oscillatoria limosa	1.88
	O. margaritifera	1.86
	Spirulina gigentea	1.96
Chlorophyta	*Actinastrum hantzschii* Lager.	2.15
	Ankistrodesmus spiralis (Turner) Lemm.	0.69
	Chlamydomonas pulchra Skvortz.	1.57
	Chlorogonium elongatum (Dang.) France	3.92
	Closterium angustum var. *angustum* Kutz. ex Ralfs	1.06
	Cl. diane var. *pseudodiane* (Roy) Krieg.	1.25
	Coelastrum sphaericum Nägeli	1.22
	Cosmarium moniliforme var. *moniliforme* (Turp.) Ralfs	0.09
	Cos. pachydermum var. *pachydermum* Lundell	1.20
	Crucigenia truncata G.M. Smith	1.02
	Crucigeniella apiculata (Lemm.) Kom.	1.17
	Dictyosphaerium tetrachotomum Printz	1.54
	Euastrum denticulatum (KIrch.) Gay	1.2
	Eudorina unicocca G.M. Smith	0.18
	Golenkinia pausispina West & West	0.12
	Monoraphidium griffithi (Berkeley) Kom.	0.36
	Pediastrum duplex Meyen	1.36
	Scenedesmus acuminatus (Lag.) Chodat	0.67
	S. acuminatus var. *minor* G.M. Smith	1.47
	Staurastrum polymorphum var. *polymorphum breb.*	0.23
	Tetraedron constrictum G. M. Smith	0.77
Euglenophyta	*Euglena acus* (Müller) Ehrenberg	2.24
	E. australica Playfair	1.93
	E. australica var. claviformis Palyfair	0.67
	E. oblonga Schmitz	1.47
	E. oxyuris var. charkowiensis (Swir.) Chu	0.23
	Lepocinclis playfairiana Defl.	0.77
	Phacus longicauda var. *attenuata* (Pochm.) Huber-Pest.	0.53

Division	Species	Density ($\times10^3$ ind./l)
	P. longicauda var. *major* Svir.	1.52
	Trachelomonas anguste-ovata var. *ellipsoidea* Islam	0.34
	Tr. anguste-ovata fa. minor Islam	1.12
	Tr. anulifera var. semi-ornata (Conrad) Huber-Pest.	1.86
	Tr. armata (Ehren.) Stein	1.20
	Tr. oblonga var. truncata Lemm.	0.71
	Tr. planctonica Swir.	0.19
	Tr. planctonica var. oblonga Drez.	0.82
Chrysophyta	*Eunotia pectinalis* var. *valvariae* (Kuetz.) Rabh.	1.38
	Fragillaria crotonensis Kitton	0.49
	Gomphonema longiceps var. *subclavata* Grun.	0.71
	Melosira granulata var. *angustissima* Müller	0.19
	Navicula americana Ehrenberg	1.82
	Nitzschia gracilis Hantz. in Raben.	2.10
	Synedra rumpens var. *familiaris* (Kütz.) Poretzky	0.12
	Syn. tabulata (Ag.) Kütz.	0.27
Cryptophyta	*Chilomonas paramaecium* Ehreberg	1.13
	Chroomonas acuta Utermöhi	0.90
	Cryptomonas reflexa var. recurva Islam *et* Khondker	0.58
Pyrrophyta	*Ceratium hirundinella* (O.F. Müller) Dujardin	0.12
	Peridinium abei	0.18

Table 37. Density of dominant species of phytoplankton ($\times 10^3$ ind./l) in Station 4.

Division	Species	Density ($\times 10^3$ ind./l)
Cyanophyta	*Anabaena californica* O. Borge	1.45
	A. circinalis Rab.ex Bornet and Flahault	0.82
	Cylindrospermum doryphorum Brühl & Biswas	0.54
	Gomphosphaeria lacustris Chodat	2.61
	Microcystis flos-aquae (Wittrock) Kirchner	1.81
	Oscillatoria minnesotensis Tilden	1.88
	O. perornata Skuja	1.86
	Spirulina laxa	0.96
Chlorophyta	*Actinastrum hantzschii* Lager.	1.15
	Ankistrodesmus spiralis (Turner) Lemm.	0.69
	Chlamydomonas gracilis Snow	1.57
	Chl. pertyi Gor.	3.92
	Closterium limneticum Lemm.	1.06
	Cl. pitchardianum var. *angustum* Bor.	2.25
	Coelastrum sphaericum Nägeli	1.22
	Cosmarium birame var. *berbadense* G.S. West	0.09
	Crucigenia rectangularis (Näg.) Gay	1.20
	Crucigeniella crucifera (Wolle) Kom.	1.02
	Dictyosphaerium granulatum Hind.	1.17
	Monoraphidium fontinale Hind.	1.54
	Pediastrum duplex var. *gracillimum* W & W	1.20
	Scenedesmus magnus Meyen	0.18
	S. opoliensis Richter	0.12
	S. opoliensis var. *contacta* Prescott	0.36
	S. perforatus Lemm.	1.36
Euglenophyta	*Euglena ehrenbergii* Klebs	0.34
	E. exilis Gojdics	1.24
	E. granulata (Klebs) Fr. Schmitz	2.59
	Lepocinclis ovum var. bütschlii (Lemm.) Con.	1.93
	Phacus acuminatus var. granulata (Roll) Huber-Pest.	0.67
	P. bicarinatus Weik	1.47
	Strombomonas napiformis var. *brevicollis* (Playf.) Defl.	0.23
	Trachelomonas abrupta var. arcuata (Playf.) comb. Defl.	0.77
	Tr. raciborskii Wolosz.	0.53
	Tr. volvocinopsis var. khanne (Skv.) Bour.	1.52

Division	Species	Density ($\times10^3$ ind./l)
	Tr. volzii Lemmermann	0.34
Chrysophyta	*Amphora veneta* Kütz.	2.38
	Cymbella affinis Kütz.	0.49
	Gomphonema lanceolatum var. *turnis* (Ehr.) Hust.	0.71
	Gyrosigma scalproides (Rab.) Cleve	0.19
	Melosira granulata (Ehrenberg) Ralfs	2.82
	Navicula pupula var. *capitata* Hust.	1.10
	Nitzschia pungens Grunow	0.12
	Stauroneis anceps fa. *gracilis* (Ehr.) Hust.	0.18
	Synedra ulna var. *danica* (Kütz.) Heurck	0.27
Cryptophyta	*Cryptomonas erosa* Ehreberg	1.13
	Cryptomonas lucens Skuja	0.90
	Rhodomonas minuta var. nanoplanktica Skuja	0.58
Pyrrophyta	*Ceratium hirundinella* (O.F. Müller) Dujardin	0.12
	Peridinium abei	0.18

Table 38. Density of dominant species of phytoplankton ($\times 10^3$ ind./l) in Station 5.

Division	Species	Density ($\times 10^3$ ind./l)
Cyanophyta	*Anabaena torulosa* (Cram.) Larger	1.29
	A. utermöhlii Geitler	0.82
	Anabaenopsis elenkinii Miller	0.54
	Microcystis marginata	3.61
	Oscillatoria irrigua Kützing ex Gomont	0.81
	O. limosa	1.88
	Spirulina gigentea	1.86
	Sp. laxa	1.96
Chlorophyta	*Actinastrum hantzschii* Lager.	1.15
	Ankistrodesmus densus Kors.	0.69
	Chlorotetraedron polymorphum Mc Entee	1.57
	Closterium subulatum var. *striolatum* Islam	1.92
	Cosmarium pseudopyramidatum var. *extensum* (Nordst.) Krieg.	2.06
	Crucigenia rectangularis (Näg.) Gay	2.25
	Crucigeniella crucifera (Wolle) Kom.	1.22
	Lagerheimia wratislaviensis Schroeder	0.09
	Monoraphidium arcuatum (Kors.) Hind.	1.2
	Oocystis elliptica W. West	1.02
	Pediastrum tetras var. *tetraedron* (Corda) Hansg.	1.17
	Phacotus angustus Pascher	1.54
	Scenedesmus longus var. *apiculatus* Meyen	1.20
	S. quadricauda (Turp.) de Breb.	0.18
	S. quadricauda var. *longispina* (Chod.) G.M. Smith	0.12
	S. quadricauda var. *quadrispina* (Chod.) G.M. Smith	0.36
	S. quadricauda var. *rectangularis* West	1.36
	S. regularis Svir.	1.34
	Schroederia setigera (Schroeder) Lemm.	0.24
	Tetraedron regulare Kuetz.	0.59
	Tetraedron trigonum (Naeg.) Hansgirg	1.93
Euglenophyta	*Euglena allorgei* Defl.	1.93
	Lepocinclis salina Fritsch	0.67
	Phacus circumflexus Pochm.	1.47
	P. curvicauda Swirenko	0.23
	Strombomonas napiformis var. *brevicollis* (Playf.) Defl.	0.77
	Trachelomonas dybowskii Drez.	0.53
	Tr. lismorensis var. inermis Playfair	1.52

Division	Species	Density (×10^3 ind./l)
	Tr. mirabilis var. minor Woron.	0.34
	Tr. mucosa var. brevicollis Skv.	1.12
	Tr. oblonga Lemm.	0.41
Chrysophyta	*Amphora veneta* Kütz.	1.38
	Cymbella affinis Kütz.	0.49
	Diatoma vulgare var. *linearis* (W. Smith) Heurck	0.71
	Eunotia alpina (Näg.) Hust.	0.19
	Melosira granulata (Ehrenberg) Ralfs	1.82
	Navicula bacillum Ehrenberg	2.10
	N. exigua (Dujardin) Nouv.	0.12
	Nitzschia longissima (Brėb.) Grunow	0.18
	Pinnularia acrosphaeria (Brėb.) Rab.	0.27
	Synedra ulna var. *danica* (Kütz.) Heurck	0.58
Cryptophyta	*Cryptomonas obovate* Czosnowski	1.13
	Cryptomonas ovata Ehreberg	0.90
	Rhodomonas minuta var. nanoplanktica Skuja	0.58
Pyrrophyta	*Ceratium hirundinella* (O.F. Müller) Dujardin	0.12
	Peridinium abei	0.18

Table 39. Density of dominant species of phytoplankton ($\times 10^3$ ind./l) in Station 6.

Division	Species	Density ($\times 10^6$ ind./l)
Cyanophyta	*Anabaena torulosa* (Cram.) Larger	1.78
	A. utermöhlii Geitler	0.82
	Anabaenopsis elenkinii Miller	0.54
	Merismopedia minima	0.61
	Microcystis marginata	0.81
	Oscillatoria planktonica	1.88
	O. proteus	1.86
	Spirulina gigentea	0.96
Chlorophyta	*Actinastrum gracillimum* var. *gracillimum* Smith	0.15
	Ankistrodesmus falcatus var. *radiatus* (Chod.) Lemm.	0.69
	Ankis. spiralis (Turner) Lemm.	0.18
	Chlamydomonas pertyi Gor.	1.57
	Chlorotetraedron polymorphum Mc Entee	3.92
	Closterium subulatum var. *striolatum* Islam	1.06
	Cosmarium phaseolus var. *minutum* (Bis.) Kr.	1.25
	Crucigenia rectangularis (Näg.) Gay	1.22
	Dictyosphaerium granulatum Hind.	0.09
	Golenkinia pausispina West & West	1.20
	Monoraphidium griffithi (Berkeley) Kom	1.02
	Oocystis borgei Snow	0.17
	Oo. nägelli A. Br.	1.54
	Pediastrum duplex var. *clathratum* (A. Br.) Lag.	1.2
	P. duplex var. *rogulosum* Racib.	0.18
	Phacotus lenticularis (Ehren.) Diesing	0.12
	Scenedesmus arcuatus var. *platydiscus* G.M. Smith	0.36
	S. bijuga var. *irregularis* (Wolle) G.M. Smith	1.36
	S. brevispina (G.M. Smith) Chodat	1.34
	S. denticulatus Lag.	0.24
	S. denticulatus fa. *maximus* Uhrek	0.59
	Schroederia spiralis (Printz.) Kors.	1.93
	Staurastrum acanthocephalum Skuja	0.67
	St. chaetoceros (Schroeder) Smith	1.47
	St. gladiosum Turner	1.52
	Tetraedron muticum (A. Br.) Hansgirg	0.34
	Tet. verrucosum G. M. Smith	1.12
	Tetrastrum elegans Playfair	0.41
	Euglena oxyuris var. *minor* Prescott	0.23

Division	Species	Density (×10^6 ind./l)
Euglenophyta	*E. platydesma* Skuja	0.77
	E. sociabilis Dangeard	0.53
	Lepocinclis playfairiana Defl.	1.52
	Phacus lismorensis Playf.	0.34
	P. longicauda var. *rotunda* (Pochm.) Huber-Pest.	1.12
	Strombomonas napiformis var. *brevicollis* (Playf.) Defl.	0.41
	Trachelomonas abrupta var. arcuata (Playf.) comb. Defl.	1.86
	Tr. armata var. longispina (Playf.) Defl.	1.20
	Tr. armata var. rangpurense Islam	0.71
	Tr. volvocinopsis var. khanne (Skv.) Bour.	0.19
	Tr. volzii Lemmermann	0.82
Chrysophyta	*Amphora veneta* Kütz.	0.38
	Eunotia pectinalis fa. *minor* (Kuetz.) Muel.	0.49
	Gomphonema lanceolatum var. *insignis* (Greg,) Cleve	0.71
	Navicula placentula var. *rostrata* Backman and Cleve-Euler	1.19
	N. pupula Kütz	1.82
	Pinnularia gibba var. *mesogonglya* (Ehr.) Hust.	0.10
	Pin. stauroptera (Grun.) Rab.	0.12
	Synedra acus Kütz.	0.27
Cryptophyta	*Chilomonas acuta var. insignis* Skuja	1.13
	Cryptomonas erosa Ehreberg	0.90
	Rhodomonas minuta Skuja	0.58
Pyrrophyta	*Ceratium hirundinella* (O.F. Müller) Dujardin	0.12
	Peridinium abei	0.18

Table 40. Density of dominant species of phytoplankton ($\times10^3$ ind./l) in Station 7.

Division	Species	Density ($\times10^6$ ind./l)
Cyanophyta	*Anabaena fertilissima* Rao	1.78
	A. orientalis Dixit	0.82
	Cylindrospermum doryphorum	0.54
	Gomphosphaeria lacustris	0.61
	Microcystis robusta	081
	Oscillatoria margaritifera	1.88
	Spirulina laxa	0.96
Chlorophyta	*Ankistrodesmus stipitatus* (Chod.) Kom.	1.15
	Chlamydomonas gracilis Snow	0.69
	Closterium toxon var. *toxon* W. West	1.57
	Coelastrum pulchellum var. *pulchellum* Schmid.	0.92
	Cosmarium contractum var. reductum Islam	0.06
	Cos. laeve var. *octangulare* (Wille) West	0.25
	Crucigeniella crucifera (Wolle) Kom.	1.22
	Dictyosphaerium pulchellum Wood	0.09
	Euastrum spinolosum var. *burmense* (W.&W.) Krieg.	1.24
	Eudorina unicocca G.M. Smith	1.02
	Monoraphidium tortile (W. & W.) Kom.	0.17
	Oocystis granulata Hortob.	1.22
	Oo. pusilla Hansg.	1.54
	Pandorina morum (Müller) Bory	1.21
	Pediastrum biradiatum Meyen	0.18
	Ped. boryanum var. *brevicorne* A. Br.	0.18
	Pyrobotrys gracilis (Kors.) Kors.	1.12
	Scenedesmus acutiformis Schroeder	0.36
	S. acutus var. *acutus* Meyen	1.54
	S. incrassatulus Bohlin	2.11
	S. longispina var. *asymmetricus* Hort.	1.22
	Staurastrum johnsonii West and West	0.18
	St. paradoxum Meyen	0.77
	St. parundulatum Groen.	0.23
	St. pinnatum Turner	1.22
	Tetraedron limneticum var. *gracile* Prescott	1.93
	T. minimum (A. Br.) Hansgirg	1.36
	Treubaria setigera (Archer) G. M. Smith	1.36
	Euglena agilis var. praecxicisa Schiller	2.34
	E. spathirhyncha Skuja	0.24

Division	Species	Density ($\times10^6$ ind./l)
Euglenophyta	*Lepocinclis cymbiformis* Play.	0.59
	Phacus orbicularis var. *caudatus* Skvr.	1.4
	P. pleuronectes (O.F.M) Dujardin	0.67
	Strombomonas napiformis var. *brevicollis* (Playf.) Defl.	1.47
	Trachelomonas playfairii Defl.	0.23
	Tr. volvocina var. derephora Conrad	0.77
	Tr. volvocinopsis var. khanne (Skv.) Bour.	0.53
	Tr. volzii Lemmermann	1.52
Chrysophyta	*Cymbella affinis* Kütz.	1.38
	Diatoma vulgare var. *linearis* (W. Smith) Heurck	0.49
	Eunotia monodon Ehrenberg	0.71
	Gomphonema pervulum (Kütz.) Van Heurck	0.19
	Gyrosigma scalproides (Rab.) Cleve	1.82
	Melosira distans var. *alpigena* Grunow	1.10
	Navicula pseudohalophila Cholnoky	0.49
	N. radiosa Kütz.	0.71
	Nitzschia alpina (Naeg.) Hustedt	0.19
	Pinnularia gibba var. *parva* (Grun.) Fre.	0.12
	Pin. karelica var. *tibetana* (Hust.) Cleve	0.18
	Synedra vaucheriae Kütz.	0.27
Cryptophyta	*Cryptomonas lucens* Skuja	1.13
	Cr. Phaseolus Skuja	0.90
	Cr. reflexa Skuja	0.29
	Rhodomonas lacustris Pascher *et* Ruttner	0.58
Pyrrophyta	*Ceratium hirundinella* (O.F. Müller) Dujardin	0.12
	Peridinium abei	0.18

Seasonal variation of dominant phytoplankton in species level

Station 1

In this station, dominant phytoplankton species were *Anabaena ballygangly, A. orientatlis, Anabaenopsis elenkinii, Merismopedia minima, M. elegans, Microcystis flos-aquae, Oscillatoria agardhii,* and *Pelonema aphane* belonging to Cyanophyta; *Actinastrum hantzschii, Ankistrodesmus falcatus, Chlamydomonas gracilis, Closterium limneticum, Coelastrum microphorum, Cosmarium subcostatum, Crucigenia tetrapedia, Crucigeniella crucifera, Dictyosphaerium granulatum, Eudorina elegens, Scenedesmus quadricauda, Monoraphidium arcuatum, Oocystis granulata, Pandorina morum, Pedeastrum duplex, Staurastrum radiosum,* and *Tetraedron muticum* belonging to Chlorophyta; *Euglena caudata, E. oblonga, Lepocinclis ovum, Phacus curvicauda, Strombomonas verrucosa, Trachelomonas cylindrica, Trachelomonas oblonga,* and *Trachelomonas volvocina* belonging to Euglenophyta; *Amphora veneta, Cymbella affinis, Eunotia lunaris, Fragillaria crotonensis, Gomphonema pervulum, Navicula exigua, N. spicula, Nitzschia acicularis, Pinnularia stauroptera, Synedra acus,* and *Syn. tabulata* belonging to Chrysophyta, *Peridinium abei* belonging to Pyrrhophyta and *Chroomonas acuta, Cryptomonas erosa, Cryp. ovata,* and *Rhodomonas lacustris* belonging to Cryptophyta were observed.

During pre-monsoon *Chlamydomonas gracilis* was dominant in April 2018 in the first year and in the second year, it was also dominant in May 2019.

In the monsoon *Trachelomonas oblonga* was dominant in July 2018 in the first year and in second year, it was also dominant in August 2019.

During post-monsoon *Scenedesmus denticulatus* was dominant in December 2017 in the first year but in second year, *Rhodomonas lacustris* was dominant in October 2018.

In the winter, *Scenedesmus dimorphus* was dominant in November 2017 in the first year but in second year, *Chlamydomonas gracilis* was dominant in January 2019 (Table 41).

Station 2

In this station, dominant phytoplankton species were *Anabaena ballygangly, A. orientatlis, Anabaenopsis elenkinii, Merismopedia minima, M. elegans, Microcystis flos-aquae, Oscillatoria agardhii,* and *Pelonema aphane* belonging to Cyanophyta; *Actinastrum hantzschii, Ankistrodesmus bibraianus, Chlamydomonas globosa, Closterium toxon, Coelastrum indicum, Cosmarium clepsydra, Crucigenia lauterbornii, Crucigeniella crucifera, Dictyosphaerium granulatum, Eudorina elegens, Monoraphidium arcuatum, Oocystis granulata, Pandorina morum, Pedeastrum biradiatum, Scenedesmus incrassatulus, S. quadricauda,* and *Tetraedron trigonum* belonging to Chlorophyta; *Euglena oblonga, E. caudata, Lepocinclis ovum, Phacus curvicauda, Strombomonas verrucosa, Trachelomonas volvocina, Tr. cylindrica, Tr. oblonga* and *Tr. volzii* belonging to Euglenophyta; *Cymbella cistula, Eunotia lunaris, Fragillaria crotonensis, Gomphonema sphaerophorum, Melosira granula, Navicula exigua, N. spicula, Nitzschia acicularis, Pinnularia gibba, Synedra acus,* and *Syn. tabulata* belonging to Chrysophyta, *Peridinium abei* belonging to Pyrrhophyta and *Chroomonas acuta, Cryptomonas erosa, Cryp. obovata* and *Rhodomonas minuta* belonging to Cryptophyta were observed.

In pre-monsoon *Cymbella cistula* was dominat in February 2018 in the first year but in second year, *Trachelomonas volzii* was dominant in December 2018.

During monsoon *Scenedesmus incrassatulus* was dominant in July 2018 in the first year but in second year, *Euglena clavata* was dominant in August 2019.

In post-monsoon *Pelonema aphane* was dominant in September 2018 in the first year but in second year, *Trachelomonas cylindrica* was dominant in September 2019.

During winter *Pediastrum biradiatum* was dominant in December 2017 in the first year but in second year, *Lepocinclis ovum* was dominant in February 2019 (Table 42).

Station-3

In this station, dominant phytoplankton species were *Anabaena ballygangly, A. fertilissima, Anabaenopsis arnoldii, Cylindrospermum doryphorum, Merismopedia minima, M. punctata, Oscillatoria agardhii, O. limosa,* and *Spirulina laxa* belonging to Cyanophyta; *Actinastrum gracillimum, Ankistrodesmus densus, Chlamydomonas gracilis, Closterium venus, Coelastrum sphaericum, Cosmarium contractum, Crucigenia quadrata, Crucigeniella rectangularis, Eudorina unicocca, Golenkinia pausispina, Hyaloraphidium contortum, Monoraphidium griffithi, Oocystis borgei, Pandorina morum, Pedeastrum duplex, Scenedesmus acuminatus, S. acutiformis, S. magnus, Staurastrum gladiosum, St. pinnatum,* and *Tetraedron verrucosum* belonging to Chlorophyta; *Euglena cylindrica, E. ehrenbergii, Lepocinclis salina, Phacus longicauda, P. ranula, Trachelomonas armata, Tr. dybowskii, Tr. Volvocina,* and *Tr. volzii* belonging to Euglenophyta; *Eunotia lunaris, Fragillaria crotonensis, Gomphonema sphaerophorum, Gyrosigma attenuatum, Melosira granulata, Navicula exigua, N. spicula, Nitzschia acicularis, Nitz. gracilis, Pinnularia krooki, Synedra tabulate,* and *Syn. ulna* belonging to Chrysophyta, *Peridinium abei* and *Ceratium hirundinella* belonging to Pyrrhophyta and *Chroomonas acuta, Cryptomonas erosa, Cryp. lucens* and *Rhodomonas lacustris* belonging to Cryptophyta were observed.

In pre-monsoon *Trachelomonas anulifera* var. *semi-ornata* was dominant in March 2018 in the first year but in second year, *Closterium angustatum* was higher in May 2019.

During monsoon *Merismopedia minima* was dominant in July 2018 in the first year but in second year, *Eunotia pectinalis* var. *valvariae* was found in August 2019.

In post-monsoon *Trachelomonas planctonica* var. *oblonga* was dominant in October 2017 in the first year but in second year *Euglena acus* was dominant in September 2019.

During winter *Hyaloraphidium contortum* was dominant in December 2017 in the first year but in second year, it was also dominant in February 2019 (Table 43).

Station-4

In this station, dominant phytoplankton species were *Anabaena californica, A. circinalis, Gomphosphaeria lacustris, Microcystis flos-aquae,* and *Spirulina laxa* belonging to Cyanophyta, *Actinastrum hantzschii, Ankistrodesmus spiralis, Chlamydomonas gracilis, Closterium limneticum, Cosmarium birame, Crucigeniella crucifera, Monoraphidium fontinale, Scenedesmus magnus,* and *S. perforatus* belonging to Chlorophyta, *Euglena granulata, Lepocinclis ovum, Phacus bicarinatus, Strombomonas napiformis, Trachelomonas volvocinopsis* and *Tr. volzii* belonging to Euglenophyta; *Amphora veneta, Cymbella affinis, Gyrosigma scalproides, melosira granulate, Navicula pupula, Nitzschia pungens,* and *Synedra ulna* belonging to Chrysophyta; *Peridinium abei* and *Ceratium hirundinella* belonging to Pyrrhophyta and *Cryptomonas lucens*, *Cryp. erosa* and *Rhodomonas minuta* belonging to Cryptophyta were observed.

In pre-monsoon *Trachelomonas volvocinopsis* var. *khanne* was higher in June 2018 in the first year but in second year, *Navicula pupula* var. *capitata* was higher in May 2019.

During monsoon *Monoraphidium fontinale* was dominant in August 2018 in the first year but in second year, *Scenedesmus magnus* was dominant in September 2019.

In post-monsoon *Euglena granulata* was the dominant November 2017 in the first year but in second year, *Anabaena circinalis* was dominant in October 2018.

During winter *Dictyosphaerium granulatum* was dominant in December 2017 in the first year but in second year, *Microcystis flos-aquae* was dominant in February 2019 (Table 44).

Station-5

In this station, dominant phytoplankton species were *Anabaena torulosa*, *Anabenopsis elenkinii*, *Microcystis marginate*, *Oscillatoria irrigua*, *O. limosa* and *Spirulina gigentia* belonging to Cyanophyta; *Ankistrodesmus densus, Chlorotetraedron polymorphum, Closterium sobulatum, Cosmarium pseudopyramidatum, Crucigenia rectangularis, Monoraphidium arcuatum, Oocystis eliptica, Pediastrum tetras, Phacotus angustatus, Scenedesmus quadricauda, S. regularis, Schroederia setigera, and Tetraedron regulare* belonging to Chlorophyta; *Euglena allorgei*, *Lepocinclis salina*, *Phacus circumflexus, Strombomonas napiformis, Trachelomonas lismorensis and Tr. oblonga* belonging to Euglenophyta; *Amphora veneta, Diatoma vulgare, Eunotia alpina*, *Melosira granulata, Nitzschia longissima and Synedra ulna* belonging to Chrysophyta; *Peridinium abei* and *Ceratium hirundinella* belonging to Pyrrhophyta and *Cryptomonas obovara*, *Cryp. ovata* and *Rhodomonas minuta* belonging to Cryptophyta were observed.

In pre-monsoon, *Anabaena utermöhlii* was dominant in April 2018 in the first year but in second year, *Trachelomonas lismorensis* was dominant in June 2019.

During monsoon *Trachelomonas oblonga* was dominant in August 2018 in the first year but in second year, *Monoraphidium arcuatum* was dominant in September 2019.

In post-monsoon *Melosira granulata* was dominant in November 2017 in the first year but in second year, *Euglena allorgei* was dominant in October 2018.

In winter *Dictyosphaerium granulatum* was dominant in December 2017 in the first year but in second year, *Crucigenia rectangularis* was dominant in February 2019 (Table 45).

Station-6

In this station, dominant phytoplankton species *Anabaena torulosa, Anabaenopsis elenkinii, Merismopedia minima, Oscillatoria planktoniaca, O. proteus* and *Spirulina gigentia* belonging to Cyanophyta, *Ankistrodesmus spiralis, Chlamydomonas pertyi, Chlorotetraedron polymorphum, Closterium subulatum, Cosmarium phaseolus, Crucigenia rectangularis, Monoraphidium griffithi, Oocystis borgei, Pediastrum duplex, Scenedesmus denticulatus, Schroederia spiralis, Staaurastrum gladiosum, Tetraedronm verrucosum,* and *Tet. elegans* belonging to Chlorophyta, *Euglena platydesma, Lepocinclis playfairaiana, Phacus longicauda, Strombomonas napiformis, Trachelomonas abrupta, Tr. volvocinopsis,* and *Tr. volzii* belonging to Euglenophyta, *Eunotia pectinalis, Gomphonema lanceolatum, Navicula placentula, Pinnularia gibba,* and *Synedra acus* belonging to Chrysophyta, *Ceratium hirundinella* and *Peridinium abei* belonging to Pyrrhophyta and *Chilomonas acuta, Cryptomonas erosa* and *Rhodomonas minuta* belonging to Cryptophyta were observed.

In pre-monsoon *Synedra acus* was dominant in April 2018 in the first year but in second year, *Crucigenia rectangularis* was dominant in March 2019.

During monsoon *Trachelomonas volvocinopsis* was dominant in July 2018 in the first year but in second year *Cryptomonas erosa* was dominant in September 2019.

In post-monsoon *Euglena platydesma* was dominant in October 2017 in the first year but in second year, *Peridinium abei* was dominant in November 2018.

During winter *Dictyosphaerium granulatum* was dominant in January 2018 in the first year but in second year, *Merismopedia minima* was dominant in February 2019 (Table 46).

Station-7

In this station, dominant phytoplankton species were *Anabaena fertilissima, A. orientalis, Cylindrospermum doryphorum, Gomphosphaeria lacustris, Microcystis robusta, Oscillatoria margaritifera,* and *Spirulina laxa* belonging to Cyanophyta; *Anksitrodesmus stipitatus, Chlamydomonas gracilis, Closterium pulchellumm Cosmarium leave, Crucigeniella crucigera, Eudorina unicocca, Monoraphidium tortile, Oocystis pusilla, Pediastrum biradiatum, Scenedesmus incrassatulus, Staurastrum paradoxum, Tetraedron minimum,* and *Treubaria setigera* belonging to Chlorophyta; *Euglena spathirhyncha, Lepocinclis cymbiformis, Phacus Pleuronectes, Strombomonas napiformis, Trachelomonas volvocina,* and *Tr. volvocinopsis* belonging to Euglenophyta; *Cymbella affinis, Diatoma vulgare, Eunotia monodon, Gyrosigma scalproides, Melosira distans, Navicula radiosa, Nitzschia alpina, Pinnularia gibba,* and *Synedra vaucheriae* belonging to Chrysophyta; *Peridinium abei* and *Ceratium hirundinella* belonging to Pyrrhophyta and *Cryptomonas lucens, Cryp, phaseolus, Cryp. reflexa* and *Rhodomonas lacustris* belonging to Cryptophyta were observed.

In pre-monsoon *Nitzschia alpina* was dominant in March 2018 in the first year but in second year, *Trachelomonas volvocinopsis* was dominant in May 2019.

During monsoon *Scenedesmus incrassatulus* was dominant in July 2018 in the first year but in the second year, *Peridinium abei* was dominant in August 2019.

In post-monsoon *Pinnularia gibba* was dominant in October 2017 in the first year but in second year, *Trachelomonas volvocina* was dominant in November 2018.

During winter *Chlamydomonas gracilis* was dominant in December 2017 in the first year but in second year, *Cryptomonas reflexa* was dominant in February 2019 (Table 47).

Table 41. Seasonal density of dominant species of phytoplankton (×10^6 ind./l) in Station 1.

Year	Seasons	Dominant species of phytoplankton: Species 1	Species 2	Species 3	Species 4	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
2017-2018	Pre-monsoon	*Chlamydomonas gracilis*	*Merismopedia punctata*	*Crucigeniella crucifera*	*Peridinium abei*	7.42	6.41	13.83
	Monsoon	*Trachelomonas oblonga*	*Peridinium abei*	*Rhodomonas lacustris*	*Scenedesmus denticulatus*	3.27	2.82	6.09
	Post-monsoon	*Peridinium abei*	*Scenedesmus dimorphus*	*Crucigenia mucronata*	*Euglena platydesma*	4.53	3.49	8.02
	Winter	*Scenedesmus ecornis*	*Trachelomonas abrupta*	*Cryptomonas reflexa*	*Peridinium abei*	5.50	4.61	10.39
2018-2019	Pre-monsoon	*Chlamydomonas gracilis*	*Oscillatoria agardhi*	*Trachelomonas volvocina*	*Monoraphidium griffithi*	10.85	6.13	17.05
	Monsoon	*Trachelomonas volvocina*	*Scenedesmus perforatus*	*Euglena oblonga*	*Cryptomonas erosa*	3.49	2.55	6.03
	Post-monsoon	*Rhodomonas lacustris*	*Scenedesmus denticulatus*	*Trachelomonas oblonga*	*Cryptomonas ovata*	3.87	2.14	6.01
	Winter	*Chlamydomonas gracilis*	*Trachelomonas volvocina*	*Peridinium abei*	*Scenedesmus ecornis*	7.17	4.17	11.34

Table 42. Seasonal density of dominant species of phytoplankton (×10^6 ind./l) in Station 2.

Year	Seasons	Dominant species of phytoplankton				Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
		Species 1	Species 2	Species 3	Species 4			
2017-2018	Pre-monsoon	*Chlamydomonas globosa*	*Merismopedia elegens*	*Trachelomonas oblonga*	*Scenedesmus incrassatulus*	11.25	8.28	19.53
	Monsoon	*Trachelomonas cylindrica*	*Peridinium abei*	*Rhodomonas lacustris*	*Crucigenia lauterbornii*	2.85	3.47	6.31
	Post-monsoon	*Trachelomonas volzii*	*Peridinium abei*	*Scenedesmus quadricauda*	*Microcystis flos-aquae*	4.47	4.35	8.82
	Winter	*Hyaloraphidium contortum*	*Monoraphidium griffithi*	*Crucigenia lauterbornii*	*Trachelomonas oblonga*	4.58	4.89	9.49
2018-2019	Pre-monsoon	*Chlamydomonas globose*	*Trachelomonas volzii*	*Scenedesmus quadricauda*	*Hyaloraphidium contortum*	8.19	5.21	13.4
	Monsoon	*Trachelomonas cylindrica*	*Scenedesmus incrassatulus*	*Rhodomonas minuta*	*Cryptomonas erosa*	2.42	2.11	4.53
	Post-monsoon	*Rhodomonas minuta*	*Cryptomonas erosa*	*Trachelomonas volzii*	*Scenedesmus incrassatulus*	2.90	2.35	5.25
	Winter	*Chlamydomonas globose*	*Trachelomonas oblonga*	*Cryptomonas erosa*	*Cosmarium clepsydra*	11.09	3.53	14.62

Table 43. Seasonal density of dominant species of phytoplankton (×10^{6}ind./l) in Station 3.

Year	Seasons	Dominant species of phytoplankton				Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
		Species 1	Species 2	Species 3	Species 4			
2017-2018	Pre-monsoon	*Oscillatoria limosa*	*Hyaloraphidium contortum*	*Scenedesmus magnus*	*Spirulina laxa*	2.72	1.22	3.94
	Monsoon	*Hyaloraphidium contortum*	*Oscillatoria agardhii*	*Scenedesmus acuminatus*	*Peridinium abei*	2.89	1.68	4.57
	Post-monsoon	*Hyaloraphidium contortum*	*Scenedesmus acutiformis*	*Microcystis flos-aquae*	*Chlamydomonas gracilis*	4.06	1.60	5.67
	Winter	*Hyaloraphidium contortum*	*Microcystis flos-aquae*	*Oscillatoria agardhii*	*Ankistrodesmus densus*	2.97	1.39	4.36
2018-2019	Pre-monsoon	*Trachelomonas armata*	*Rhodomonas lacustris*	*Cryptomonas lucens*	*Melosira granulata*	0.76	0.29	1.06
	Monsoon	*Trachelomonas volvocina*	*Rhodomonas lacustris*	*Anabaena fertilissima*	*Scenedesmus magnus*	0.92	0.50	1.42
	Post-monsoon	*Hyaloraphidium contortum*	*Oscillatoria limosa*	*Scenedesmus magnus*	*Peridinium abei*	4.52	2.30	6.82
	Winter	*Hyaloraphidium contortum*	*Monoraphidium tortile*	*Trachelomonas volzii*	*Pediastrum duplex*	4.03	2.02	6.05

Table 44. Seasonal density of dominant species of phytoplankton ($\times10^6$ind./l) in Station 4.

Year	Seasons	Dominant species of phytoplankton				Total dominant $\times 10^6$ ind./l	Other $\times10^6$ ind./l	Total PD $\times10^6$ ind./l
		Species 1	Species 2	Species 3	Species 4			
2017-2018	Pre-monsoon	*Microcystis flos-aquae*	*Scenedesmus perforatus*	*Monoraphidium fontinale*	*Scenedesmus magnus*	2.47	1.65	4.12
	Monsoon	*Hyaloraphidium contortum*	*Oscillatoria agardhii*	*Crucigeniella crucifera*	*Scenedesmus perforatus*	2.84	1.83	4.67
	Post-monsoon	*Hyaloraphidium contortum*	*Scenedesmus magnus*	*Microcystis flos-aquae*	*Pelonema aphane*	5.99	1.14	7.14
	Winter	*Hyaloraphidium contortum*	*Monoraphidium fontinale*	*Scenedesmus magnus*	*Oscillatoria agardhii*	2.71	1.76	4.47
2018-2019	Pre-monsoon	*Trachelomonas volvocinopsis*	*Scenedesmus perforatus*	*Peridinium abei*	*Rhodomonas minuta*	1.31	0.31	1.62
	Monsoon	*Trachelomonas volzii*	*Scenedesmus magnus*	*Rhodomonas minuta*	*Cryptomonas erosa*	0.98	0.50	1.48
	Post-monsoon	*Scenedesmus perforatus*	*Hyaloraphidium contortum*	*Oscillatoria agardhii*	*Trachelomonas volzii*	4.06	2.45	6.51
	Winter	*Scenedesmus magnus*	*Ankistrodesmus spiralis*	*Pediastrum duplex*	*Crucigeniella crucifera*	3.47	1.68	5.15

Table 45. Seasonal density of dominant species of phytoplankton (×10^{6}ind./l) in Station 5.

Year	Seasons	Dominant species of phytoplankton Species	Species 2	Species 3	Species 4	Total Dominant ×10^6 ind./l	Others ×10^{6}ind./l	Total ×10^{6}ind./l
2017-2018	Pre-monsoon	*Trachelomonas lismorensis*	*Euglena allorgei*	*Rhodomonas minuta*	*Cryptomonas ovata*	1.49	0.39	1.88
	Monsoon	*Trachelomonas oblonga*	*Euglena allorgei*	*Rhodomonas minuta*	*Peridinium abei*	0.78	0.32	1.10
	Post-monsoon	*Rhodomonas minuta*	*Trachelomonas oblonga*	*Cryptomonas ovata*	*Euglena allorgei*	1.67	0.93	2.6
	Winter	*Trachelomonas lismorensis*	*Euglena allorgei*	*Rhodomonas minuta*	*Cryptomonas obovata*	1.93	0.44	2.37
2018-2019	Pre-monsoon	*Trachelomonas oblonga*	*Euglena allorgei*	*Cryptomonas ovata*	*Rhodomonas minuta*	0.49	0.14	0.63
	Monsoon	*Trachelomonas lismorensis*	*Rhodomonas minuta*	*Euglena allorgei*	*Oscillatoria limosa*	0.76	0.21	0.97
	Post-monsoon	*Trachelomonas oblonga*	*Euglena allorgei*	*Cryptomonas obovata*	*Strombomonas napiformis*	1.42	0.52	1.94
	Winter	*Rhodomonas minuta*	*Cryptomonas ovata*	*Trachelomonas oblonga*	*Peridinium abei*	1.56	0.45	2.01

Table 46. Seasonal density of dominant species of phytoplankton (×10^6 ind./l) in Station 6.

Year	Seasons	Species 1	Species 2	Species 3	Species 4	Total Dominant ×10^6 ind./l	Others ×10^6 ind./l	Total ×10^6 ind./l
		Dominant species of phytoplankton						
2017-2018	Pre-monsoon	*Trachelomonas volsii*	*Rhodomonas minuta*	*Monoraphidium griffithi*	*Cryptomonas erosa*	1.28	0.78	2.06
	Monsoon	*Trachelomonas abrupta*	*Rhodomonas minuta*	*Euglena platydesma*	*Pandorina morum*	0.78	0.38	1.16
	Post-monsoon	*Trachelomonas volvocinopsis*	*Cryptomonas erosa*	*Rhodomonas minuta*	*Oscillatoria proteus*	1.57	0.52	2.09
	Winter	*Rhodomonas minuta*	*Trachelomonas volzii*	*Euglena platydesma*	*Oscillatoria planktonica*	4.24	1.46	5.70
2018-2019	Pre-monsoon	*Chlamydomonas partei*	*Trachelomonas abrupta*	*Euglena platydesma*	*Rhodomonas minuta*	5.68	0.26	5.94
	Monsoon	*Trachelomonas volzii*	*Euglena platydesma*	*Rhodomonas minuta*	*Cryptomonas erosa*	0.91	0.28	1.19
	Post-monsoon	*Euglena platydesma*	*Trachelomonas volzii*	*Pinnularia gibba*	*Hyaloraphidium contortum*	1.45	0.73	2.18
	Winter	*Chroomonas acuta*	*Cryptomonas erosa*	*Monoraphidium griffithi*	*Chlymodomonas partei*	0.64	0.35	0.99

Table 47. Seasonal density of dominant species of phytoplankton (×10^6 ind./l) in Station 7.

Year	Seasons	Species 1	Species 2	Species 3	Species 4	Total Dominant ×10^6 ind./l	Others ×10^6ind./l	Total ×10^6ind./l
2017-2018	Pre-monsoon	*Trachelomonas volvocina*	*Euglena spathirhynca*	*Monoraphidium tortile*	*Oscillatoria margaritifera*	0.67	0.34	1.01
	Monsoon	*Trachelomonas volvocina*	*Euglena spathirhynca*	*Oscillatoria margaritifera*	*Hyaloraphidium contortum*	2.53	1.08	3.61
	Post-monsoon	*Euglena spathirhynca*	*Trachelomonas volvocina*	*Peridinium abei*	*Oscillatoria margaritifera*	2.72	1.04	3.76
	Winter	*Euglena spathirhynca*	*Trachelomonas volvocina*	*Peridinium abei*	*Phacus pleuronectes*	1.37	0.47	1.84
2018-2019	Pre-monsoon	*Trachelomonas volvocina*	*Euglena spathirhynca*	*Anabaena orientalis*	*Gomphonema sp.*	0.83	0.28	1.11
	Monsoon	*Trachelomonas volvocina*	*Euglena spathirhynca*	*Cryptomonas lucens*	*Peridinium abei*	1.59	0.51	2.10
	Post-monsoon	*Trachelomonas volvocina*	*Euglena spathirhynca*	*Crucigenellia crucifera*	*Scenedesmus incrassatulus*	2.38	2.08	4.46
	Winter	*Synedra vaucheriae*	*Oscillatoria margaritifera*	*Rhodomonas lacustris*	*Monoraphidium tortile*	0.22	0.22	0.44

Cummulative phytoplankton species list from the present investigation (Station 1-7)

During the present investigation, a total of 352 species of phytoplankton were identified from 1-7 study Stations. Out of this, 312 species were previously reported for Bangladesh which are appended in Appendix I and 40 species have been preliminarily identified as new algal reports for Bangladesh and these are also appended in Appendix II.

Phytoplankton species as new records for Bangladesh

On the basis of preliminary identification, 40 species of phytoplankton may be considered as new records. The distribution is as follows: dominated by Euglenophyta (15 taxa) followed by Chlorophyta (14 taxa) and Cyanophyta (11 taxa) (Appendix II).

Limnological data analyses of the studied habitats

Over the entire sampling period, the environmental characteristics of the water were found different compared to all the studied stations. Observation among the studied habitats of Station 1 to Station 7, the range of air temperature is more or less equal for most of the stations (Table 48 to 54) but the average air temperature is higher in Station 1 than the other whereas range value and average mean value of water temperature is higher in Station 2 than other stations. The average mean value of Secchi depth is higher in station 7 than other stations. Range of alkalinity is recorded the higher in the Station 6 than the other stations. Conductivity was higher in station 2 than the other. TDS was higher in station 5 than the other. pH values were higher in station 3 than other stations whereas DO was found higher in Stations 1 than the other. Mean concentration of SRP was recorded higher in Station 3 than the other stations. SRS value was recorded higher in Station 7, whereas the higher value of NO_3-N was recorded in Station 3. Phytoplankton biomass as chlorophyll-a was recorded higher in Station 7 and phaeopigment was also found higher in Station 7 than the other stations. Phytoplankton density was recorded higher in Station 7 than the other stations (Table 55).

Table 48. Annual mean values of physicochemical and biological parameters in Station 1.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	19.2	35.4	29.0125	4.5633	19.2-35.4
WT	°C	24	18.9	34.2	28.0042	4.86545	18.9-34.2
SD	cm	24	52	101	74.9583	14.29649	52-101
pH	-	24	6.3	8.4	7.3917	0.43928	6.3-8.4
TDS	µS/cm	24	32	157	78.0417	27.31376	32-157
EC	mg/l	24	135	640	272.71	127.7583	135-640
Alk.	meq/l	24	1.00	3.00	2.11	0.67	1--3
DO	mg/l	24	7.4	14.9	7.40	3.10441	7.4-14.9
NO_3-N	µg/l	24	0.01	1.24	0.1879	0.27788	0.01-1.24
SRP	mg/l	24	4.8	310.53	64.535	74.37019	4.8-310.53
SRS	mg/l	24	1.18	34.62	15.8038	11.17231	1.18-34.62
Chl a	µg/l	24	8.29	223.78	70.8071	65.10396	8.29-223.78
PP	µg/l	24	0.86	52.62	18.8567	15.26676	0.86-52.62
PD	x 10^6 ind./l	24	0.44	15.28	5.9512	5.22195	0.44-15.28

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, EC=Electrical conductivity, Alk.- Alkalinity, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble dissolve solids. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 49. Annual mean values of physicochemical and biological parameters of station 2.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	17.2	35.2	28.85	4.75495	17.2-35.2
WT	°C	24	18.9	35.4	28.3417	4.79782	18.9-35.4
SD	cm	24	55	105	74.25	15.32049	55-105
pH		24	5.8	8.4	7.4917	0.49336	5.8-8.4
TDS	µS/cm	24	12	344	76.3333	99.51564	12-344
EC	mg/l	24	31	1322	2.88E+02	376.9374	31-132.2
Alk.	meq/l	24	0.4	2.8	1.1542	0.81666	0.4-2.8
DO	mg/l	24	7.2	10.6	7.58	2.64093	7.2-10.6
NO3-N	mg/l	24	0.01	0.74	0.1421	0.19054	0.01-0.74
SRP	µg/l	24	2.31	182.15	34.6462	37.18526	2.31-182.15
SRS	µg/l	24	0.17	21.2	4.6242	4.75213	0.17-21.2
Chl a	µg/l	24	5.92	107.74	39.2704	29.0981	5.92-107.74
PP	µg/l	24	0.38	38.88	13.0429	9.96591	0.38-38.88
PD	$\times 10^6$ ind./l	24	0.22	8.9	3.3617	2.41139	0.22-8.9

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, EC=Electrical conductivity, Alk.- Alkalinity, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble dissolve solids. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 50. Annual mean values of physicochemical and biological parameters in Station 3.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	16.6	34.1	27.85	5.36624	16.6-34.1
WT	°C	24	16.2	34	27.4625	5.49765	16.2-34
SD	cm	24	54	102	70.9583	9.57115	54-102
pH		24	5.8	8.7	7.4625	0.75343	5.8-8.7
TDS	µS/cm	24	17	153	57.9458	33.0553	17-153
EC	mg/l	24	34	413	202	97.36863	34-413
Alk.	meq/l	24	0.4	2.9	1.3167	0.67352	0.4-2.9
DO	mg/l	24	6.4	10.0	7.15	2.13745	6.4-10
NO3-N	mg/l	24	0.01	1.58	0.2238	0.34299	0.01-1.58
SRP	µg/l	24	8.28	613.52	67.61	121.80294	8.28-613.52
SRS	µg/l	24	0.76	22.66	6.8313	6.53421	0.76-22.66
Chl a	µg/l	24	5.92	104.19	34.0417	25.08809	5.92-104.19
PP	µg/l	24	4.19	58.78	18.205	12.11387	4.19-58.78
PD	$\times 10^6$ ind./l	24	0.33	8.09	2.6221	2.36692	0.33-8.09

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, EC=Electrical conductivity, Alk.- Alkalinity, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble dissolve solids. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 51. Annual mean values of physicochemical and biological parameters in Station 4.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	16.8	33.5	27.5792	5.31593	16.8-33.5
WT	°C	24	18.9	35.4	28.3208	5.29594	18.9-35.4
SD	cm	24	55	84	68.7083	8.6098	55-84
pH		24	5.8	8.5	7.6792	0.58754	5.8-8.5
TDS	µS/cm	24	12	74	25.4292	15.4465	12-74
EC	mg/l	24	30	328	1.00E+02	74.05066	30-328
Alk.	meq/l	24	0.3	1.3	0.6583	0.31611	0.3-1.3
DO	mg/l	24	7.0	10.6	7.49	2.64731	7.0-10.6
NO3-N	mg/l	24	0.01	0.74	0.1504	0.19506	0.01-0.74
SRP	µg/l	24	2.31	448.52	45.21	88.35944	2.31-448.52
SRS	µg/l	24	0.17	21.2	3.5747	4.78224	0.17-21.2
Chl a	µg/l	24	4	112.48	49.0562	27.14382	4-112.48
PP	µg/l	24	1.5	50.21	17.6154	11.10267	1.5-50.21
PD	$\times 10^6$ ind./l	24	0.33	9.34	4.0779	2.29644	0.33-9.34

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, EC=Electrical conductivity, Alk.- Alkalinity, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble dissolve solids. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 52. Annual mean values of physicochemical and biological parameters in Station 5.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	17.2	34.4	28.7083	4.95299	17.2-34.4
WT	°C	24	16.2	33.9	27.2792	5.21844	16.2-33.9
SD	cm	24	54	102	75.7083	12.18509	54-102
pH	-	24	5.8	8.3	7.2375	0.56168	5.8-8.3
TDS	µS/cm	24	23	753	104	142.75686	23-753
EC	mg/l	24	55	558	278	142.9338	55-558
Alk.	meq/l	24	1	2.9	1.825	0.5503	1-2.9
DO	mg/l	24	6.4	10	7.2	2.13765	6.4-10
NO3-N	mg/l	24	0.01	0.72	0.1521	0.17602	0.01-0.72
SRP	µg/l	24	8.28	244.38	49.23	51.35691	8.28-244.38
SRS	µg/l	24	0.64	22.66	7.3771	6.17603	0.64-22.66
Chl a	µg/l	24	5.92	43.81	18.9462	11.01238	5.92-43.81
PP	µg/l	24	1.21	16.93	6.1904	4.38966	1.21-16.93
PD	$\times 10^6$ ind./l	24	0.3	3.96	1.5829	1.01656	0.3-3.96

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, EC=Electrical conductivity, Alk.- Alkalinity, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble dissolve solids. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 53. Annual mean values of physicochemical and biological parameters in Station 6.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	17.5	34.5	29.9875	4.46604	17.5-34.5
WT	°C	24	16.9	34.1	28.2333	4.99754	16.9-34.1
SD	cm	24	55	110	75.6667	12.03859	55-110
pH		24	5.8	8.1	7.3292	0.52707	5.8-8.1
TDS	µS/cm	24	24	184	81	35.00062	24-184
EC	mg/l	24	54	436	282.02	110.23936	54-436
Alk.	meq/l	24	1.2	4.4	2.15	0.77796	1.2-4.4
DO	mg/l	24	7.0	10.2	7.35	2.48158	7.0-10.2
NO3-N	mg/l	24	0.01	1.22	0.1629	0.26665	0.01-1.22
SRP	µg/l	24	9.91	112.89	48.3417	26.56807	9.91-112.89
SRS	µg/l	24	2.28	26.92	12.1304	6.00352	2.28-26.92
Chl a	µg/l	24	8.29	249.82	76.8367	70.2922	8.29-249.82
PP	µg/l	24	0.19	73.76	20.5517	20.11464	0.19-73.76
PD	$\times 10^6$ ind./l	24	0.06	19.62	6.3441	6.15211	0.06-19.62

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, EC=Electrical conductivity, Alk.- Alkalinity, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble dissolve solids. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 54. Annual mean values of physicochemical and biological parameters in Station 7.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	17.3	35.4	30.1208	4.47884	17.3-35.4
WT	°C	24	16.8	34.2	28.1875	4.98226	16.8-34.2
SD	cm	24	52	112	76.75	12.98913	52-112
pH	-	24	6.2	8.1	7.375	0.42247	6.2-8.1
TDS	µS/cm	24	31	115	70.0417	20.13968	31-115
EC	mg/l	24	66	440	249.02	105.19877	66-440
Alk.	meq/l	24	1	2.8	1.9708	0.53931	1.0-2.8
DO	mg/l	24	7.3	10.5	7.7	2.48088	7.3-10.5
NO3-N	mg/l	24	0.01	0.73	0.1221	0.14488	0.01-0.73
SRP	µg/l	24	11.98	120.32	46.9338	26.48824	11.98-120.32
SRS	µg/l	24	2.57	25.82	11.8983	6.41343	2.57-265.82
Chl a	µg/l	24	5.92	171.68	68.3912	51.38516	5.92-171.68
PP	µg/l	24	0.19	92.06	27.1004	23.56598	0.19-92.06
PD	$\times 10^6$ ind./l	24	0.03	22.47	5.9498	5.56426	0.03-22.47

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, EC=Electrical conductivity, Alk.- Alkalinity, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble dissolve solids. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 55. A comparison on mean values of limnological data of Station 1 to Station 7.

Parameters	Unit	N	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
AT	°C	24	19.2-35.4	17.2-35.2	16.6-34.1	16.8-33.5	17.2-34.4	17.5-34.5	17.3-35.4
WT	°C	24	18.9-34.2	18.9-35.4	16.2-34	18.9-35.4	16.2-33.9	16.9-34.1	16.8-34.2
SD	cm	24	52-101	55-105	54-102	55-84	54-102	55-110	52-112
Alk.	meq/l	24	1-3	0.4-2.8	0.4-2.9	0.3-1.3	1-2.9	1.2-4.4	1.0-2.8
EC	µS/cm	24	135-640	31-132.2	34-413	30-328	55-558	54-436	66-440
DO	mg/l	24	7.4-14.9	7.2-10.6	6.4-10	7.0-10.6	6.4-10	7.0-10.2	7.3-10.5
pH	-	24	6.3-8.4	5.8-8.4	5.8-8.7	5.8-8.5	5.8-8.3	5.8-8.1	6.2-8.1
TDS	mg/l	24	32-157	12-344	17-153	12-74	23-753	24-184	31-115
SRP	µg/l	24	4.8-310.53	2.31-182.15	8.28-613.52	2.31-448.52	8.28-244.38	9.91-112.89	11.98-120.32
SRS	mg/l	24	1.18-34.62	0.17-21.2	0.76-22.66	0.17-21.2	0.64-22.66	2.28-26.92	2.57-265.82
NO3-N	mg/l	24	0.01-1.24	0.01-0.74	0.01-1.58	0.01-0.74	0.01-0.72	0.01-1.22	0.01-0.73
Chl-a	µg/l	24	8.29-223.78	5.92-107.74	5.92-104.19	4-112.48	5.92-43.81	8.29-249.82	5.92-171.68
PP	µg/l	24	0.86-52.62	0.38-38.88	4.19-58.78	1.5-50.21	1.21-16.93	0.19-73.76	0.19-92.06
PD	x 10^6 ind./l	24	0.44-15.28	0.22-8.9	0.33-8.09	0.33-9.34	0.3-3.96	0.06-19.62	0.03-22.47

Seasonal changes (mean values) of different limnological parameters

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 all stations and presented in Table 56 and Table 62 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, NO3-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 56. Seasonal mean values of different limnological parameters for Station 1.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
			Physical factors		
AT	°C	30.13	32.05	26.60	23.37
WT	°C	27.57	30.03	24.7	19.63
SD	cm	88.67	88.5	72	83
			Chemical factors		
TDS	mg/l	99.67	42.25	93.5	112
EC	µS/cm	423	178	405.5	360.67
pH	-	7.3	7.45	7.55	8.1
Alk.	meq/l	1.47	1.13	2.2	2.4
DO	mg/l	7.13	7.12	7.75	7.53
SRP	mg/l	127.93	147.92	66.49	43.65
SRS	µg/l	3.92	5.56	7.94	7.66
NO_3-N	mg/l	0.1634	0.233	0.0447	0.2575
			Biological factors		
chl-a	µg/l	154.71	74.29	117.81	177.2
PP	µg/l	46.53	38.44	26.13	26.36
PD	$\times 10^3$ ind./l	17.05	6.03	6.01	11.34

Table 57. Seasonal mean values of different limnological parameters for Station 2.

Parameters	Unit	Pre monsoon (Mar-May)	Monsoon (Jun-Sept)	Post monsoon (Oct -Nov)	Winter (Dec-Feb)
			Physical factors		
AT	°C	31.4	32.58	28.8	24.67
WT	°C	29.23	30.7	26.05	21.13
SD	cm	91.33	94.5	68	77
			Chemical factors		
TDS	mg/l	112.67	41.75	151	278.33
EC	µS/cm	478	179	752.5	875
pH	-	7.3	7.58	7.55	7.6
Alk	meq/l	1.87	1.2	2.55	2.03
DO	mg/l	7.07	6.98	7.8	7.67
SRP	mg/l	40.39	68.09	69.67	39.74
SRS	µg/l	3.94	4.29	12.31	4.05
NO_3-N	mg/l	0.0892	0.2252	0.2179	0.1811
			Biological factors		
chl-a	µg/l	133.03	73.11	80.51	142.87
PP	µg/l	45.6	27.98	36.81	63.46
PD	$\times 10^3$ ind./l	13.39	4.53	5.25	14.62

Table 58. Seasonal mean values of different limnological parameters for Station 3.

Parameters	Unit	Pre monsoon (Mar-May)	Monsoon (Jun-Sept)	Post monsoon (Oct -Nov)	Winter (Dec-Feb)
		Physical factors			
AT	°C	27.7	31.18	25.05	20.30
WT	°C	27.13	30.83	26.85	19.97
SD	cm	76.67	71.5	66	72.67
		Chemical factors			
TDS	mg/l	63.67	53.5	26	27.67
EC	µS/cm	264	211	105	123
pH	-	7.43	8.13	8.1	8.3
Alk.	meq/l	1.03	0.95	0.45	0.57
DO	mg/l	7.27	7.2	6.85	7.67
SRP	mg/l	74.77	44.22	48.64	66.63
SRS	µg/l	3.46	5.29	1.01	1.94
NO_3-N	mg/l	0.5928	0.3712	0.0642	0.0911
		Biological factors			
chl-*a*	µg/l	31.57	15.1	33.16	22.12
PP	µg/l	8.36	5.49	14.69	8.13
PD	$\times10^3$ ind./l	5.94	1.18	2.18	0.99

Table 59. Seasonal mean values of different limnological parameters for Station 4

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
		Physical factors			
AT	°C	29.03	31.68	25.55	20.23
WT	°C	28	31.3	27.45	20.47
SD	cm	77.67	75.25	66.5	73
		Chemical factors			
TDS	mg/l	47.33	43	22.5	20.33
EC	µS/cm	213.67	169.5	92.5	93.67
pH	-	7.67	8.08	7.85	7.93
Alk.	meq/l	1.03	1.1	0.45	0.53
DO	mg/l	7.73	7.03	7.9	7.77
SRP	mg/l	63.14	40.41	40.97	55.43
SRS	µg/l	4.98	4.52	0.88	1.94
NO_3-N	mg/l	0.0999	0.3493	0.0774	0.1045
		Biological factors			
chl-a	µg/l	11.45	26.34	62.75	9.48
PP	µg/l	4.08	9.85	12.96	3.01
PD	$\times 10^3$ ind./l	1.12	2.11	4.46	0.44

Table 60. Seasonal mean values of different limnological parameters for Station 5.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
		Physical factors			
AT	°C	30	31.95	26.1	23.13
WT	°C	28.27	29.83	24.7	20.13
SD	cm	87.67	85.25	71.5	78.67
		Chemical factors			
TDS	mg/l	88.33	44.5	80	130.67
EC	µS/cm	385.67	187	374	459.33
pH	-	7.3	7.65	7.4	7.73
Alk.	meq/l	1.83	1.28	2	2.37
DO	mg/l	7.37	7.25	7.3	7.57
SRP	mg/l	67.72	181.98	25.77	50.9
SRS	µg/l	2.29	2.82	8.44	5.81
NO_3-N	mg/l	0.1081	0.2319	0.0519	0.1928
		Biological factors			
chl-a	µg/l	20.92	33.15	91.76	58.41
PP	µg/l	8.48	12.39	37.62	20.08
PD	$\times10^3$ ind./l	1.06	1.42	6.81	6.06

Table 61. Seasonal mean values of different limnological parameters for Station 6.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sep.)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
			Physical factors		
AT	°C	31.93	32.33	30.15	26.63
WT	°C	30.13	31.5	27.35	21.63
SD	cm	79	89.75	75	75
			Chemical factors		
TDS	mg/l	87.67	72.5	67	85
EC	µS/cm	381.33	300.25	303	280.33
pH	-	7.4	7.63	7.5	7.77
Alk.	meq/l	2.53	2.48	1.9	2.07
DO	mg/l	7.33	7.13	7.7	7.9
SRP	mg/l	55.24	138.34	24.02	46.18
SRS	µg/l	12.75	10.55	9.92	20.64
NO_3-N	mg/l	0.1029	0.2309	0.0651	0.1573
			Biological factors		
chl-a	µg/l	24.47	34.34	93.54	55.65
PP	µg/l	9.09	11.01	35.43	18.06
PD	$\times 10^6$ ind./l	1.59	1.48	6.5	5.15

Table 62. Seasonal mean values of different limnological parameters for Station 7.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
Physical factors					
AT	°C	32.27	32.6	30.8	26.83
WT	°C	29.7	31.58	27.55	21.63
SD	cm	79.33	92.5	76.5	76
Chemical factors					
TDS	mg/l	85.33	73.25	64	75.67
EC	μS/cm	376.33	304.75	280	265.33
pH	-	7.5	7.6	7.7	7.77
Alk.	meq/l	2.43	2.23	2.05	2.67
DO	mgl	7.57	6.98	8	8
SRP	mg/l	57.36	97.57	20.28	30.12
SRS	μg/l	12.56	10.43	10.48	20.84
NO_3-N	mg/l	0.1081	0.2415	0.0395	0.084
Biological factors					
chl-a	μg/l	14.21	15.09	23.68	13.81
PP	μg/l	4.65	4.04	9.93	5.6
PD	$\times 10^3$ ind./l	0.63	0.97	1.94	2.01

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 all the selected sampling stations. Analysis has been performed among 14 physical, chemical and biological parameters of seven stations of three study sites. The extract of the matrix has been presented in Table 62 to Table 68 for Station 1, 2, 3, 4, 5, 6, and 7, respectively and the detailed tables of the matrix have been appended in Appendix III-IX.

Study Stations

Station-1

Air temperature showed a highly significant positive correlation with water temperature, but water temperature showed a negative correlation with TDS. Secchi depth showed significant negative correlation with Alkalinity, SRS, chl-a, phaeopigment and phytoplankton density. TDS showed significant positive correlation with conductivity. Alkalinity showed significant positive correlation with SRS, chl-a, phaeopigment and phytoplankton density but negative correlation with SRP.

DO showed significant positive correlation with Phaeopigments and SRP showed significant positive correlation with chl-a. SRS showed significant positive correlation with chl-a and PD. chl-a showed significant positive correlation with PP and PD and filally PD showed significant positive correlation with alkalinity, SRS, chl-a and PP but significant negative correlation with SD (Table 63).

Station-2

Air temperature showed highly significant positive correlation with water temperature and DO. Water temperature also showed significant positive correlation with DO. pH showed significant negative correlation with NO3-N.

Phytoplankton density showed significant positive correlation with NO3-N. But there is no noticeable significant correlation among physical, chemical or biological parameters (Table 64).

Station-3

Air temperature showed highly significant positive correlation with water temperature. Alkalinity showed significant negative correlation with pH but significant positive correlation with TDS. Alkalinity also showed positive correlation with DO and SRS but negative correlation with chl-a and PD.

SRS showed negative correlation with chl-a. pH also showed significant negative correlation with SRS. pH also showed positive correlation with SD. TDS showed negative correlation with pH. Conductivity showed positive correlation with SRS.

Chlorophyl-a showed significant positive correlation with phytoplankton density (Table 65).

Station-4

Air temperature showed highly significant positive correlation with water temperature and DO. Secchi depth showed strong positive correlation with Conductivity and Alkalinity and negative correlation with Phytoplankton density.

TDS showed highly significant positive correlation with Conductivity, Alkalinity and SRP and highly significant negative correlation with PD. In addition, conductivity showed a strong negative correlation with PD.

Chlorophyll-a showed highly significant positive correlation with phaeopigments and only positive correlation with phytoplankton density.

Phytoplankton density showed only positive correlation with Chlorophyll-a and significant negative correlation with TDS, Conductivity and Alkalinity but only negative correlation with Secchi depth and SRP (Table 66).

Station-5

Air temperature showed highly significant positive correlation with water temperature and highly significant negative correlation with Alkalinity. Water temperature also showed highly significant negative correlation with Alkalinity and only negative correlation with conductivity. SD showed only negative correlation with SRS. pH showed highly significant positive correlation with Secchi depth.

TDS showed highly significant correlation with PP and only significant correlation with Alkalinity. Conductivity showed highly significant positive correlation with Alkalinity and only negative correlation with water temperature.

DO showed strongly significant positive correlation with phytoplankton density. SRS showed only negative correlation with Secchi depth.

The biological parameter chl-a showed highly significant positive correlation with other biological parameters, i.e. phaeopigment and only positive correlation with other physical parameters i.e TDS.

Phaeopigment showed highly significant positive correlation with total dissolve solids (TDS). In addition, phytoplankton density showed highly significant positive correlation with dissolve oxygen (Table 67).

Station-6

Air temperature showed highly significant positive correlation with water temperature and only positive correlation with Secchi depth but a negative correlation with TDS and NO3-N. On the other hand, SD showed strong significant positive correlation with pH and NO3-N and only positive correlation with air temperature, whereas slight negative correlation with TDS, Alkalinity and DO.

TDS showed highly strong significant positive correlation with conductivity and Alkalinity whereas slight negative correlation with air and water temperature, Secchi depth, NO3-N and SRP.

Alkalinity showed strong significant positive correlation with TDS, Conductivity and phytoplankton density whereas slight negative correlation with water temperature, Secchi depth and NO3-N.

DO showed highly strong significant negative correlation with air and water temperature and only negative correlation with SRP but slight negative correlation with SD, pH, SRS, SRS, chl-a, phaeopigment and phytoplankton density.

SRP showed strong significant positive correlation with chl-a and only positive correlation with phaeopigment and phytoplankton density but only negative correlation with DO and slightly negative correlation with TDS, NO3-N and SRS.

The biological parameter chl-a showed a highly significant positive correlation with other biological parameters, i.e. phaeopigment and phytoplankton density and also with SRS and only positive correlation with conductivity and slight negative correlation with air and water temperature and dissolve oxygen (Table 68).

Station-7

Air temperature showed highly significant positive correlation with water temperature and only positive correlation with Secchi depth and conductivity but a strong negative correlation with DO and showed slightly negative correlation with SRS, chl-a, phaeopigment and phytoplankton density. Water temperature showed strong significant negative correlation with DO.

SD showed highly strong significant positive correlation with pH and only positive correlation with air and water temperature. SD also showed slightly negative correlation with DO and SRS.

pH showed highly strong positive correlation with SD and only positive correlation with all the biological parameters i.e. chl-a, phaeopigment and phytoplankton density.

TDS showed highly strong positive correlation with conductivity and alkalinity and only positive correlation with chl-a. It also showed slight negative correlation with SRP.

Conductivity showed highly strong positive correlation with TDS. Alkalinity and all biological parameters i.e. chl-a, phaeopigment and phytoplankton density, showed only positive correlation with air temperature. This parameter also showed slightly negative correlation with DO and SRS.

Alkalinity showed a highly strong significant correlation with TDS, conductivity, chl-a and phaeopigment and only positive correlation with phytoplankton density and slight negative correlation with watr temperature, DO and SRS.

DO showed highly strong significant negative correlation with air and water temperature and slight negative correlation with all other parameters except SRS.

The biological parameter chl-a showed highly significant positive correlation with conductivity, alkalinity and other biological parameter, i.e. phaeopigment and phytoplankton density and only positive correlation with pH, TDS and SRS. chl-a also showed slight negative correlation with DO, air and water temperature.

Phaeopigment showed highly strong significant positive correlation with conductivity, alkalinity, chl-a and phytoplankton density and only positive correlation with pH and SRS. It also showed slight negative correlation with DO, air and water temperature.

Phytoplankton density showed highly strong positive correlation with conductivity, chlorophyll-a and phaeopigment and only positive correlation with pH, alkalinity and SRS. PD also showed slight negative correlation with air and water temperature, dissolve oxygen and nitrate nitrogen (NO3-N) (Table 69).

Table 63. Results of significant correlation between pairs of studied variables (n=24) in Station 1.

Parameters	Correlation value (r)
AT vs WT	0.920
WT vs TDS	-0.537
SD vs Alk.	-0.518
SD vs SRS	-0.551
SD vs chl-a	-0.636
SD vs PP	-0.693
SD vs PD	-0.588
TDS vs EC	0.780
Alk. vs SRP	-0.670
Alk. vs SRS	0.635
Alk. vs chl-a	0.546
Alk. vs PP	0.570
Alk. vs PD	0.564
SRP vs chl-a	-0.523
SRS vs chl-a	0.554
SRS vs PP	0.499
SRS vs PD	0.563
Chl-a vs PP	0.567
Chl-a vs PD	0.841
PP vs PD	0.632

Table 64. Results of significant correlation between pairs of studied variables (n=24) in Station 2

Parameters	Correlation value (r)
AT vs WT	0.938
AT vs DO	-0.812
WT vs DO	-0.799
pH vs NO_3-N	-0.731
NO_3-N vs PD	0.771

Table 65. Results of significant correlation between pairs of studied variables (n=24) in Station 3

Parameters	Correlation value (r)
AT vs WT	0.928
pH vs Alk.	-0.726
pH vs SRS	-0.571
TDS vs EC	0.827
TDS vs Alk.	0.665
Chl-a vs PD	0.770

Table 66. Results of significant correlation between pairs of studied variables (n=24) in Station 4

Parameters	Correlation value (r)
AT vs WT	0.924
AT vs DO	-0.539
SD vs EC	o.557
SD vs Alk.	0.601
TDS vs EC	0.938
TDS vs Alk.	0.692
TDS vs SRP	0.527
TDS vs PD	-0.706
EC vs Alk.	0.674
EC vs PD	-0.665
Alk. vs PD	-0.658
Chl-a vs PP	0.727

Table 67. Results of significant correlation between pairs of studied variables (n=24) in Station 5

Parameters	Correlation value (r)
AT vs WT	0.923
AT vs Alk.	-0.554
WT vs Alk.	-0.602
SD vs pH	0.630
TDS vs PP	0.547
EC vs Alk.	0.599
DO vs PD	0.705
Chl-a vs PP	0.551

Table 68. Results of significant correlation between pairs of studied variables (n=24) in Station 6

Parameters	Correlation value (r)
AT vs WT	0.873
AT vs DO	-0.556
WT vs DO	-0.565
SD vs pH	0.646
TDS vs EC	0.681
TDS vs Alk.	0.818
EC vs Alk.	0.638
Alk. vs PD	0.524
SRP vs chl-a	0.590
Chl-a vs PP	0.686
Chl-a vs PD	0.827
PP vs PD	0.586

Table 69. Results of significant correlation between pairs of studied variables (n=24) in Station 7

Parameters	**Correlation value (r)**
AT vs WT	0.849
AT vs DO	-0.556
WT vs DO	-0.602
SD vs pH	0.610
TDS vs EC	0.707
TDS vs Alk.	0.655
EC vs Alk.	0.691
EC vs chl-a	0.573
EC vs PP	0.553
EC vs PD	0.526
Alk. vs chl-a	0.665
Alk. vs PP	0.582
Chl-a vs PP	0.973
Chl-a vs PD	0.891
PP vs PD	0.873

Comparison of limnological variables among the studied wetlands and other studied wetlands carried out elsewhere in Bangladesh

Table 70 showed a comparison of limnological variables between studied wetlands and other studied wetlands of Bangladesh. Here it is clear that the wetlands of Lalmai Hill areas of Cumilla are highly productive than the other studied wetlands of Bangladesh. The range of the values of physical variables are more or less similar but there are a lot of dissimilarities among the values of chemical and biological variables.

Table 70. Comparison of limnological variables between the studied wetlands of the present investigation and other studies carried out elsewhere in Bangladesh.

Parameters	BARD-pond (n=24)	Dutia Dighi (n=24)	Horeshpur Jola (n=24)	Mean and ranges	Chanda Beel	Ashura Beel	Marjad Baor	Kuniar Haor	Botanical Garden Pond
AT (^{0}C)	28.93	27.72	29.61	28.75 (16.6-35.4)	31.63	31.5	29.5	27.58	26.52
WT (^{o}C)	28.17	27.76	28.23	28.05 (16.2-35.4)	28.65	30.0	25.82	25.76	25.89
Alk. (meq/l)	1.63	0.99	1.98	1.53 (0.3-4.4)	-	2.96	6.15	1.44	0.16
TDS (mg/l)	77.19	41.69	85.01	67.96 (12-344)	-	104.67	151.04	39.47	94.59
EC (µS/cm)	280.36	151	269.68	233.68 (30-1322)	192.31	760.67	230	90.02	256.23
pH	7.44	7.57	7.32	7.44 (5.8-8.5)	7.46	7.11	7.45	7.34	7.25
SD (cm)	74.61	69.84	76.04	73.50 (52-112)	-	-	-	37.51	58.68
DO (mg/l)	7.49	7.32	7.42	7.41 (6.4-14.9)	6.21	7.72	80	9.32	6.74
SRP (µg/l)	49.50	67.61	48.17	55.08 (2.31-448.52)	-	11.60	93.0	16.01	13.77
NO_3-N (mg/l)	0.17	0.21	0.15	0.18 (0.01-1.58)	-	63.33	1.23	0.28	0.28
SRS (mg/l)	10.21	5.21	10.47	8.6 (0.17-265.82)	-	14.36	-	10.2	6.02
Chl-a (µg/l)	55.04	41.55	54.73	50.44 (4.0-249.82)	-	5.33	-	6.72	7.98
PP (µg/l)	15.95	17.91	17.95	17.27 (0.19-92.06)	-	3.41	-	4.85	7.11
PD ($\times 10^6$)	4.66	3.35	4.62	4.21 (0.03-22.47)	-	-	-	0.14	0.16

Shannon-Wiener diversity index

Shannon-Wiener diversity index is an index that is generally used to describe species diversity in a community. Here, Station 7 showed 19 months more diverse out of 24 months. So, Station 7 is more diverse in Shannon-Wiener diversity index. The highest diversity (5.43) occurs in Station 7 on November 2017 and the lowest diversity was obtained in Station 5 in January, 2018 (Table 69). In the second year of investigation, Station 7 also showed more diversity, according to Shannon-Winner diversity index (11 months out of 12 months) and the highest diversity (5.32) occurs in the month of March 2019 but the lowest diversity was observed in Station 5 in the same month i.e in March 2019 (Table 71-72).

Table 71. Shannon-Wiener Diversity Index (2017-18) for phytoplankton

2017-2018	Station -1	Station -2	Station -3	Station -4	Station -5	Station -6	Station -7
Oct-17	2.91	1.98	2.88	3.32	2.56	3.54	4.29
Nov-17	1.33	1.53	1.48	1.71	2.33	4.02	**5.43**
Dec-17	1.71	1.79	1.19	2.03	3.24	3.89	3.56
Jan-18	2.11	2.29	2.23	1.97	**0.88**	4.11	3.49
Feb-18	2.03	3.1	1.29	1.88	1.78	2.88	4.3
Mar-18	1.91	1.82	1.45	1.57	2.11	2.98	3.92
Apr-18	2.23	2.04	2.98	2.89	3.91	4.31	4.1
May-18	1.13	1.65	1.93	1.98	2.31	3.55	3.92
Jun-18	2.88	3.98	1.74	3.21	3.33	2.98	2.87
Jul-18	1.81	1.83	1.83	2.79	5.21	3.23	1.99
Aug-18	1.34	1.55	2.02	2.54	2.37	3.44	3.01
Sep-18	1.22	2.31	2.1	1.99	2.32	3.27	3.89

Table 72. Shannon-Wiener Diversity Index (2018-19) for phytoplankton

2018-2019	Station-1	Station-2	Station-3	Station-4	Station-5	Station-6	Station-7
Oct-18	1.92	2.03	2.11	2.17	2.27	2.94	4.33
Nov-18	3.02	3.65	2.32	1.97	2.61	2.73	4.23
Dec-18	1.93	2.03	1.83	1.99	2.08	1.99	3.96
Jan-19	1.78	1.97	2.36	2.23	2.67	2.34	3.73
Feb-19	3.32	2.23	2.55	3.43	2.65	1.99	4.21
Mar-19	2.31	1.79	1.43	1.67	**1.25**	2.93	**5.32**
Apr-19	2.62	3.32	1.73	1.84	1.54	2.67	3.76
May-19	3.35	1.88	1.79	2.23	1.46	4.13	4.55
Jun-19	2.75	2.79	1.59	1.43	1.97	3.27	3.67
Jul-19	1.95	2.07	2.56	2.37	1.49	1.98	1.99
Aug-19	1.93	2.32	1.95	2.17	1.45	3.31	2.38
Sep-19	2.27	1.79	1.91	1.94	1.83	2.97	3.87

Jaccard Index

Station 1 - 7

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 all the stations are highest 9.45% similar in September 2018 and their intersecting members are 19. In Jaccard index, it indicates the higher the percentage the more similar in all the stations. It equivalences members for two sets to see which members are shared and which are distinct. So, the wetlands showed more similarities in September 2018 throughout the period of investigation (Table 73).

Table 73. Jaccard index for phytoplankton analysis

2017-18	Number of intersecting species	Jaccard coefficient (%)	2018-19	Number of intersecting species	Jaccard coefficient (%)
Oct-17	8	7.17	**Oct-18**	12	6.09
Nov-17	8	6.25	**Nov-18**	11	6.51
Dec-17	10	7.29	**Dec-18**	**12**	**6.70**
Jan-18	9	6.08	**Jan-19**	9	4.81
Feb-18	8	4.81	**Feb-19**	8	4.26
Mar-18	9	4.94	**Mar-19**	**6**	**4.03**
Apr-18	**8**	**4.52**	**Apr-19**	7	4.49
May-18	13	6.57	**May-19**	8	5.06
Jun-18	11	5.88	**Jun-19**	7	4.76
Jul-18	10	5.59	**Jul-19**	9	5.26
Aug-18	13	6.77	**Aug-19**	8	5.19
Sep-18	**19**	**9.45**	**Sep-19**	11	6.31

Pollution status of the wetlands through Trophic Diatom Index (TDI)

It is evident that diatom taxa have sensitivities to increased environmental degradation. So, a measurement of the health of the environment can be diagnosed by using diatom communities (Barbour et al., 1999). Pollution tolerance indices are metrics that recapitulate the pollution sensitivity of diatom taxa in a specific community. Thus, the accumulation becomes an indicator of the comparative health of the wetland. A well-established taxonomic list of diatoms of ecological preference in freshwater habitats is a determinator of the metric as an indicator of degradation, along with other organic components.

For assessing organic pollution in the U.K. rivers (Chesters, 1980; Armitage et al.,1983) the TDI value was evaluated successfully. The value of TDI indicates 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 & Kelly, 1995). The value of TDI can range from 1 (very low nutrient concentrations) to 5 (very high nutrient concentrations). (Zelinka and Marvan, 1961) (Table 74-75).

Table 74. Interpretation of proportion of count composed of taxa tolerant to organic pollution (Whitton & Kelly, 1995).

Proportion of count	Interpretation
<20% total valves belonging to tolerant taxa	Free of significant organic pollution
21-40% total valves belonging to tolerant taxa	Some evidence of organic pollution
41-60% total valves belonging to tolerant taxa	Organic pollution likely to contribute significantly to eutrophication of site
>61% total valves belonging to tolerant taxa of flora tolerant of flora tolerant	Site is heavily contaminated with organic of flora tolerant pollution

Table 75. TDI and its components.

No	Taxon	Count(a)	Sensitivities(s)	Indicator values(v)	asv	av	Tolerant (*)
1	*Amphora veneta*	2	5	2	20	4	
2	*Cymbella affinis*	12	2	2	48	24	
3	*Cym. cistula*	3	3	1	9	3	
4	*Diatoma vulgare* var. *linearis*	5	5	1	25	5	
5	*Eunotia alpina*	2	3	1	6	2	
6	*Eu. lunaris*	1	2	1	2	1	
7	*Eu. monodon*	1	2	1	2	1	
8	*Eu. pectinalis* fa. *minor*	2	3	2	12	4	
9	*Eu. pectinalis* var. *valvariae*	2	4	2	16	4	
10	*Eu. veneris*	2	2	1	4	2	
11	*Fragillaria crotonensis*	4	5	1	20	4	
12	*Gomphonema lanceolatum* var. *insignis*	2	5	1	10	2	
13	*G. lanceolatum* var. *turnis*	3	5	1	15	3	
14	*G. longiceps* var. *subclavata*	1	1	2	2	2	
15	*G. pervulum*	1	1	3	3	3	
16	*G. sphaerophorum*.	2	1	3	6	6	
17	*Gyrosigma attenuatum*	4	1	4	16	16	
18	*Gy. scalproides*	6	3	2	36	12	
19	*Melosira distans* var. *alpigena*	3	2	1	6	3	
20	*Mel. granulata*	18	3	1	54	18	*
21	*Mel. granulata* var. *angustissima*	12	3	2	72	24	*
22	*Navicula americana*	7	3	7	147	49	*
23	*N. bacillum*	2	1	2	4	4	*
24	*N. exigua*	3	3	1	9	3	*
25	*N. grimmei*	61	4	2	488	122	
26	*N. integra*	7	4	2	56	14	
27	*N. menisculus*	3	4	2	24	6	
28	*N. placentula* var. *rostrata*	11	4	2	88	22	
29	*N. pseudohalophila*	2	4	2	16	4	*
30	*N. pupula*	9	5	1	45	9	*
31	*N. pupula* var. *capitata*	9	5	2	90	18	*
32	*N. radiosa*	1	5	1	5	1	*
33	*N. spicula*	4	5	1	20	4	*

34	*Nitzschia acicularis*	17	5	1	85	17	*
35	*Nitz. acicularis* var. *closteroides*	1	5	1	5	1	*
36	*Nitz. alpina*	6	5	2	60	12	*
37	*Nitz. gracilis*	11	4	1	44	11	*
38	*Nitz. longissima*	1	4	1	4	1	*
39	*Nitzs. pungens*	2	4	1	4	2	*
40	*Nitzschia subtubicola*	2	3	1	6	2	*
41	*Pinnularia acrosphaeria*.	4	4	1	16	4	*
42	*Pin. gibba* var. *mesogonglya*	4	1	3	12	12	
43	*Pin. gibba* var. *parva*	7	1	3	21	21	
44	*Pin. karelica* var. *tibetana*	5	3	1	15	5	
45	*Pin. krookii*	4	4	1	16	4	
46	*Pin. microstauron*	1	4	1	4	1	
47	*Pin. stauroptera*	5	4	1	20	5	
48	*Stauroneis anceps* fa. *gracilis*	2	2	1	4	2	
49	*Synedra acus*	32	2	1	64	32	
50	*Syn. rumpens* var. *familiaris*	22	4	2	176	44	
51	*Syn. tabulate*	17	4	2	136	34	
52	*Syn. ulna* var. *danica*	18	4	2	144	36	
53	*Syn. ulna* var. *oxyrhynchus*	21	4	2	168	42	
54	*Syn. vaucheriae*	13	4	2	104	26	*
	Total	400			2476	713	124

TDI

The result of trophic diatom index (TDI) for the present study was calculated as:

Total counts (a) = 400, Sum of asv = 2476, Sum of av = 713, Tolerant species amount = 124

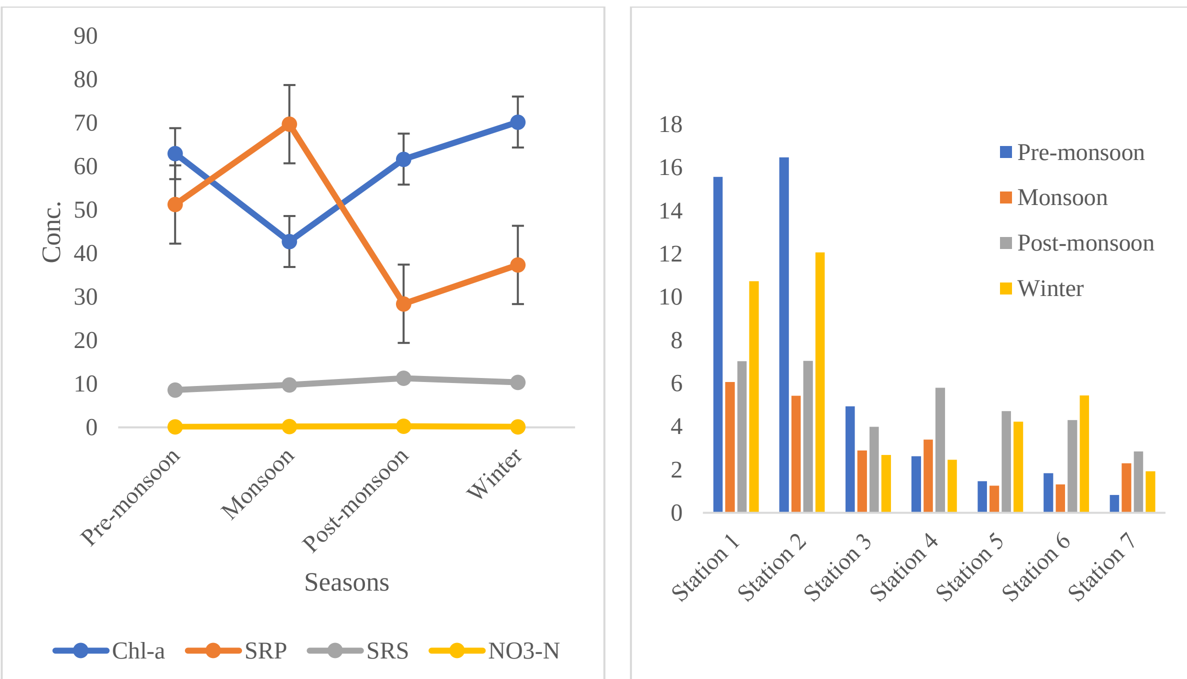
So, TDI = $\sum asv \div \sum av$ = 2476÷713 =3.47 < 20%, Pollution tolerant taxa = (124÷400) ×100 =31.00%

The proportion of TDI is < 20%.

Relationship among phytoplankton density and nutrient concentration and phytoplankton biomass (chl-a)

Nutrient concentration

Phytoplankton density showed highest peak in autumn when chl-a concentration is higher, but when phytoplankton density is lower in summer, chl-a concentration is also lower. In case of SRP concentration, chl-a concentration showed a negative correlation with it i.e., the concentration of chl-a is reverse proportional to the concentration of SRP. It also means when SRP concentration is higher the chl-a concentration is lower and vice versa. SRS and NO_3-N did not show any substantial effect or relationship with phytoplankton biomass as chl-a (Fig. 38).



Nutrient concentration in relation to phytoplankton biomass as chl-a.	Seasonal variation of phytoplankton density.

Fig. 38. Relationships among phytoplankton density, biomass (chl-a), and nutrient concentrations.

Effects of physical, chemical, and biological parameters on phytoplankton biomass (chl-a) in different seasons.

Physical parameters

With the raise of air and water temperature show slight positive effect on phytoplankton biomass as chl-a but the relationship between SD and chl-a are reverse proportional i.e. increase in Secchi depth decrease the concentration of phytoplankton biomass as chl-a in all seasons throughout the period of investigation (Fig. 39).

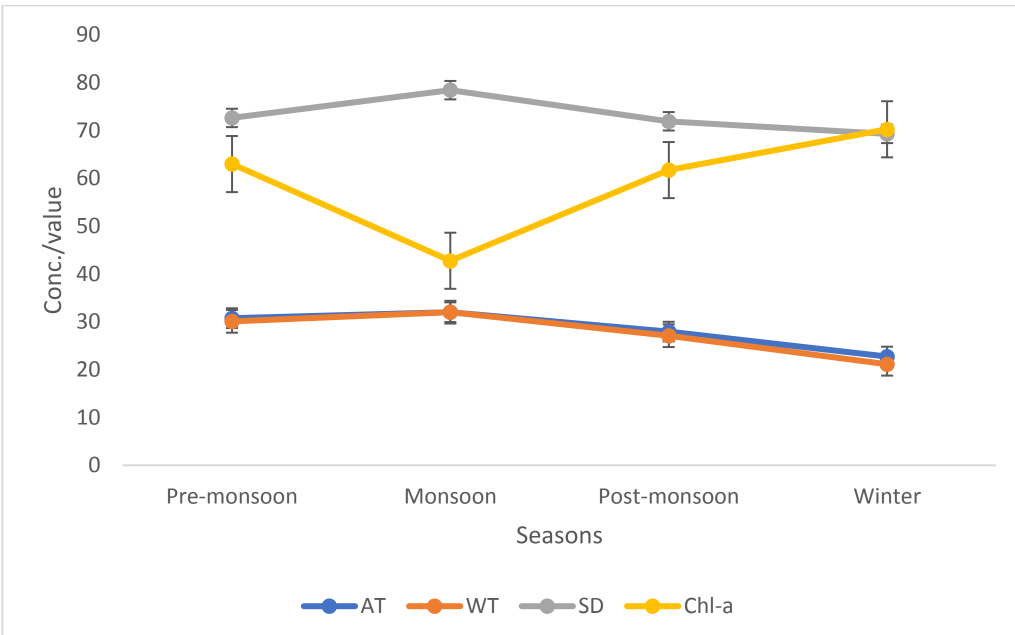


Fig. 39. Interrelationships between physical factors and phytoplankton biomass (chl-a). (AT and WT in ºC; SD in cm; chl-a in µg/l).

Chemical parameters

TDS and electrical conductivity showed positive correlation with phytoplankton biomass as chl-a whereas DO did not show any types of correlation with phytoplankton biomass as chl-a in all the studied stations in different seasons throughout the period of investigation (Fig. 40).

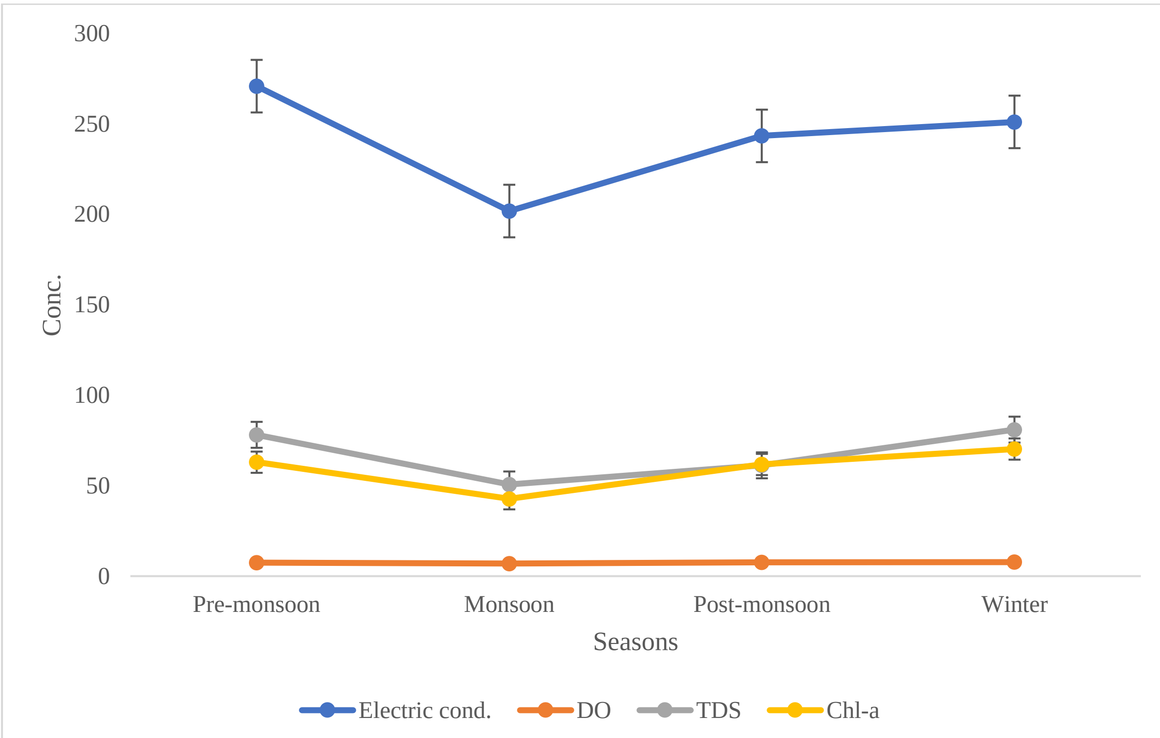


Fig. 40. Interrelationships between chemiacl factors and phytoplankton biomass (chl-a). (EC in µS/cm; DO and TDS in mg/l; chl-a in µg/l).

Biological parameters

Biological parameters like phytoplankton density and phaeopigment concentration showed strong positive effect on phytoplankton biomass as chl-a in all seven studied stations. Phaeopigments showed a strong positive correlation with chl-a i.e. the relationship between phaeopigments and chl-a is directly proportional to each other and PD and chl-a showed a same strong positive correlation (Fig. 41).

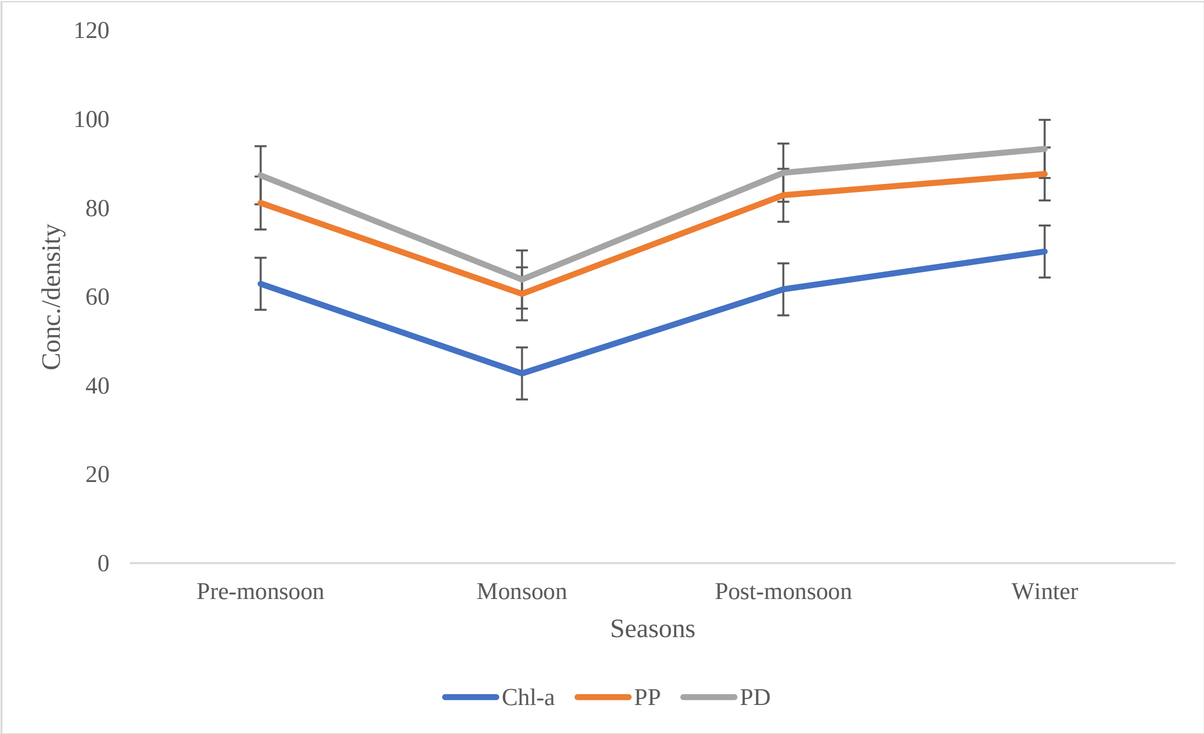


Fig. 41. Interrelationships between biological factors and phytoplankton biomass (chl-a). (PD in No. of ind./l; PP and chl-a in µg/l).

Chapter-5

DISCUSSION

DISCUSSION

The research carried out in three wetlands (Station 1-7) of Lalmai Hill areas of Cumilla from 2017 to 2019 to see the phytodiversity and their seasonal variations. The qualitative and quantitative aspects of phytodiversity were addressed for phytoplankton and aquatic macrophytes. Besides, a total of 14 water quality parameters of the wetlands were measured. These are phytoplankton quality and quantity, biomass as chl-a and phaeopigment, air and water temperature, Secchi depth, pH, conductivity and 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.

Of the three studied wetlands, BARD pond and Dutia Dighi are almost free from any external sources of pollution, apart from via precipitation and seepage. But the third one is a natural wetland which is directly connected with the nearby stream (locally known as cherra) of the hill and the Dakatia river. Phytodiversity and their seasonal variations of these three wetlands were not investigated previously. So, the present limnological investigation highlights some of the water quality parameters in these wetlands for the first time.

Many 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 (Boon *et al*. 1992, Bartram and Balance 1996).

Both air and water temperature has got significant effect on the density and quality of water (Hutchinson 1957, Kataria *et al.* 1995, Singh and Mathur 2005). Geographical location and meteorological conditions such as rainfall, humidity, cloud cover, wind velocity, etc. are also responsible for air and water temperature. In the course of my research period, the mean water temperature at Station 2 was recorded as the highest value (30.12±4.48°C) but the lowest mean water temperature was recorded in Station 5 (27.57±5.32°C) (Table 54). The range of mean maximum and minimum water temperature recorded in the present investigation is almost similar to those reported by Kerketta *et al*. (2013) and Mishra and Bhatt (2008). In Bangladesh, Rahman *et al.* (2015) also found the same result in a relative examination of some water quality parameters of three lakes in Jahangiragar University, Savar, Dhaka. A close relationship between air and water temperature was observed during the study present study. Such relationships have also been reported in some other studies (Vaas and Sachlan 1955, Rao 1955, Openheimer *et al.* 1978, Chowdhury and Mazumder 1981, Naser *et al.* 1990, Zaman *et al.* 1993, Yeasmin, 2019, Shafi, 2020). They recommended that the water temperature of shallow and small water-body might follow air temperature narrowly with only small variation in amplitude and time. In the present investigation, the monthly mean air temperature (29.01±4.56, 28.85±4.76, 27.85±5.37, 27.58±5.32, 28.71±4.95, 28.71±4.95, and 30.12±4.48 °C for Station 1, 2, 3, 4, 5, 6, and 7, respectively) were slightly higher than the water temperatures (28.00±4.86, 28.34±4.80, 27.46±5.50, 28.32±5.29, 27.28±5.22, 28.23±4.99, and 28.19±4.98 °C for Station 1, 2, 3, 4, 5, 6, and 7, respectively) in all the stations except the 4th one. Alam *et al.* (1985) and Begum *et al.* (1989) reported similar results in Museum Pond and Shahidullah Hall pond. The values were 1.0°C and 0.88°C higher for the above mentioned two studies, respectively. However, Zaman *et al.* (1993) got a difference of 1.6°C. Annual water temperature of lentic habitats within Dhaka city ranges between 18 and 34°C (Islam and Saha 1975, Islam and Mendes 1976 and Openheimer *et al.* 1978). In the present investigation a gradual increase in air temperature and water temperature from winter to monsoon has been observed (Figs. 11 and 13). Khondker *et al.* (1988) also observed the similar trends of water temperature in Dhanmondi lake, Dhaka. Yeasmin (2019) and Shafi (2020) also observed the similar trends of air and water temperature in two lakes of National Botanical Garden, Dhaka and Kuniar *Haor*, Kishoreganj, respectively.

In the present study, Secchi depth of all the seven stations varied from 52-101, 55-105, 54-102, 55-84, 54-102, 55-110, and 52-112 cm for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55). Water transparency is mainly governed by the concentration of suspended and colloidal matter such as clay, silts, finely divided organic and inorganic matter, paint, and microscopic organisms. According to Boyd (1982) it was revealed that transparency ranged from 15 - 40 cm is considered good for fish culture. The wide range of transparency in the present study was due to land runoff and anthropogenic contamination. The range of Secchi depth is almost similar to other aquatic habitats of Bangladesh (Khondker and Abed 2013, Turag river: 20 - 50 cm; Chowdhury and Mazumder 1981, Kaptai lake: 40-340 cm; Ameen *et al*. 1986, Fish Pond, Raipur: 58-76 cm) but the range of Secchi disc transparency (52-110 cm) is higher compared to the Chanda bill oxbow lake of Meherpur, Bangladesh (Kabir and Naser 2011).

Most of the bio-chemical reactions and biological processes are regulated by pH. Sculthorpe (1967) has described that pH, free CO_2 and NH_3 are more crucial factors in the survival of aquatic plants and fishes than the O_2 supply. Fluctuations in pH values mostly depend upon ingredient input in the wetlands. We know, pH of water is one of the best indicators of lake 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 clear from this study that pH of the water of all seven stations were slightly alkaline and varied from 6.30-8.40, 5.80-8.40, 5.80-8.70, 5.80-8.50, 5.80-8.30, 5.80-8.10, and 6.20-8.10 for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55). The pH differences among Station 1 to Station 7 were not significant. In addition, WHO (1984) explored that the inland water is best ranging between 6.5 and 8.5 pH. The recorded values of pH at Station 1 and Station 4 in October (pH 5.80) and Station 5 to Station 7 in March (pH 5.80) were slightly acidic in nature. However, the pH values for all other stations were within the recommended pH range by WHO. The mean values are very close to some of the other water bodies of Bangladesh. According to Khondker and Parveen (1992) the average pH of Dhanmondi lake was 7.5 which is closer to that recorded in the present investigation and Kaptai lake (7.2, Mahmood 1986). The annual pH value ranged from 6.45-7.65 was recorded in a eutrophic water body of the Dhaka metropolis in Bangladesh (Islam *et al.* 2012). In another study, Islam *et al.* (2015) pointed out the ranges of pH were from 7.14-8.87, 7.30-8.83 and 7.12 - 8.76 in Ramna, Crescent and Hatirjheel lakes, respectively. The pH range associated with most natural waters which is between 6.0 and 8.5 and is recommended for water use for drinking and domestic purposes (Chapman 1992). In the present investigation, it has been found that the value of pH in wetlands of Lalmai Hill areas of Cumilla suddenly fell in the month of October, 2017. High values of pH were observed during pre-monsoon and winter and low during the monsoon and post monsoon of both the investigating years. High pH values of water during pre-monsoon and winter may be due to utilization of bicarbonates and carbonates buffer system (Bohra 1976). Lower values obtained during monsoon and post-monsoon may be due to the influence of a fresh water influx, dilution of the water, and organic matter decomposition (Zingde *et al*. 1987). Shafi (2020) recorded the same pH (4.5-5.5) as present investigation and Yeasmin (2019) also recorded more or less same pH.

During the study period, the ranges of alkalinity were from 1.00 -3.00, 0.40-2.80, 0.40-2.90, 0.30-1.30, 1.00-2.90, 1.20-4.40, and 1.10-2.80 meq/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55), with the highest mean value (2.15 ± 0.77 meq/l) at Station 6 and the lowest mean value (0.66±0.32 meq/l) at station 4 (Table 50). According to Alikunhi (1957), alkalinity >100 meq/l was the indicator of highly productive waters. So, the range of alkalinity in the present study area indicates within the unproductive level. Islam *et al.* (2015) found that the alkalinity of Ramna, Crescent, and Hatirjheel lake water alkalinity were ranged from 30.00 - 66.67, 83.33 - 112.50, and 96.67 - 387.50 meq/l which indicate that these wetlands are productive. In the present study the highest alkalinity was recorded in Station 6 in the monsoon (4.40 meq/l) but the lowest value was recorded in Station 4 in the winter (0.3 meq/l).

In my study area, the highest electrical conductivity was found in pre-monsoon in Station 2 during monsoon (1322 µS/cm) and the lowest was found in Station 4 in winter (30 µS/cm) (Table 54). The mean conductivity was 272.71 ± 127.76, 288.02± 376.94, 202.00 ± 97.27, 100.02 ± 74.05, 278.00 ± 142.93, 282.02 ± 110.24, and 249.02 ± 105.20 µS/cm for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55). According to WHO the range of conductivity in between 300 and 600 (max.1000) µS/cm indicates that the water is suitable for fresh water biota but APHA (1992) explained that the outside range of conductivity between 150 and 500 µS/cm of inland fresh water might indicate that the water is not suitable for a number species of fishes or macro-invertebrates.

The sum of cations and anions concentration of water is measured by total dissolved solids (TDS). A high content of dissolved solids influences osmoregulation of fresh water organism, elevates the density of water, and decreases solubility of gases and utility of water for the purpose of drinking and results in the aquatic system's eutrophication. TDS in the present investigation ranged from 32-157, 12-344, 17-153, 12-74, 23-753, 24-184, and 31-115 mg/l with an average of 78.04 ± 27.31, 76.33± 99.52, 57.94±33.06, 25.43±15.45, 104.00±142.76, 81.00±35.01, and 70.04 ±20.14 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55). Higher amounts of TDS enrich the nutrient status of the water body which resulted in the eutrophication of the aquatic ecosystem (Swarnlatha and Rao 1998, Singh and Mathur 2005). The levels of TDS at each sampling site varied significantly and the dissimilarity due to changes in sampling location was also significant ($p < 0.05$). All the values of TDS were below the lowest standard (1,000 mg/L) set by the WHO. The values did not surpass the critical value above which some long-term health problems might be estimated (Kempster *et al.* 1997). According to MacCutcheon *et al.* (1983), the delectableness of water with TDS level less than 600 mg/l is generally considered to be good, on the other hand water with TDS > 1,200 mg/l becomes gradually nonedible. Hence, the water from the studied stations could consider edible, since the average value of TDS for all the stations were less than 600 mg/l. The values of TDS of present investigation were also similar to that of Yeasmin (2019) and Shafi (2020)

The nature of an aquatic ecosystem is determined by Dissolve Oxygen (DO) to a great extent. The nourishment of living organisms depends on the content of DO of the water bodies. Two sources of oxygen for water bodies had been described; (i) directly from the atmosphere and (ii) by the photosynthetic activity of chlorophyll bearing aquatic plants. However, the amount of DO also depends on surface tension due to temperature, respiration rate of the aquatic organisms and the rate of decomposition of dead organic matters. In the present investigation, DO varied from 7.40-14.09, 7.20-10.6, 6.40-10.00, 7.00-10.60, 6.40-10.00, 7.00-10.20, and 7.30-10.50 mg/l with an average of 8.40±3.10, 7.58±2.64, 7.15±2.14, 7.59±2.64, 7.20±2.14, 7.35±2.48, and 7.70±2.48 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55). This study also indicated seasonal variation in DO contents of water, being maximum in post-monsoon for Station 7 and minimum in monsoon for Station 1 and winter in Station 2. The phenomenon of re-oxygenation of water during the months of monsoon may be due to rotation and mixing by inflow after rains (Hannan 1979). It further, development in winter, may be due to rotation by cooling and draw down of DO in water (Dwivedi and Pandey 2002). The lower values of DO have been accredited to the process of breakdown of organic matter involving the consumption of oxygen (Jameel 1998). In the present study Station 1 is comparative lyrical in DO than the other stations. Similar results (6.25 mg/l) also detected in Kaptai Lake (Chowdhury and Mazumder1981). 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 Ramna lake 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). According to WHO optimum level of pH is 5.5-8.5 for proper growth and development of freshwater biota. From all the above discussion it can be concluded that the DO concentrations of all stations of present investigation are suitable for aquaculture and freshwater macrophytes.

In natural waters phosphorus (P) occurs almost solely as phosphates. Phosphorus exists as soluble reactive phosphates (SRP) in natural waters. P is the nutrient considered to be the critical limiting nutrient, causing eutrophication 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 Phosphorus ion promotes the incorporation of seven molecules of N and 40 molecules of CO_2 into algae (Wetzel 1983). The phosphate content of studying stations water fluctuated between 4.80-310.53, 2.31-182.15, 8.26-613.52, 2.31-448.52, 8.28-244.38, 9.91-112.89, and 11.98-120.32 µg/l with an average of 64.54±74.34, 34.64±37.19, 67.61±121.80, 45.21±88.36, 49.23±51.36, 48.34±26.57, and 46.93±26.49 µg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55). In Lake Ashura, the mean concentration of SRP was 11.60 ± 1.60 µg/l (Alfasane *et al.* 2012). Pre-monsoon exhibited higher phosphate contents (231.52±26.57 µg/l) in Station 3 whereas winter showed the lowest (29.43±31.53 µg/l) in Station 4 (Table 55). 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-fold lesser than Dhanmondi lake (Khondker and Parveen 1992). Phosphorus is the preventive nutrient for algal growth and therefore, controls the primary productivity of a water body. In maximum natural surface waterbodies, phosphorous varies from 0.005-0.020 mg/1 PO_4-P (Chapman 1992). Higher amount of phosphate can indicate the presence of pollution and are largely responsible for eutrophication of wetlands. Eutrophication related problems in warm-water systems begin at the concentrations of phosphorus of the order 0.34–0.70 mg/l (Rast and Thornton 1996).

Silicates are the mineral that contains silica, and include quartz (SiO_2), feldspars, clays, and others. Silicon dioxide occurs in almost every natural waterbody in various forms. Much of the silica in water comes from the dissolution of silicate minerals. Silica is of significance as a major nutrient for diatoms and may become a limiting nutrient during diatom blooms. Contrasting other nutrients, this is only a major requirement of diatoms so it is not redeveloped 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 recommended that the biogenic silica in diatom cell walls acts as an actual pH buffer, enabling the alteration of bicarbonate to dissolved CO_2. The amount of dissolved silica in water was comparatively low (1.18-34.62, 0.17-21.2, 0.76-22.66, 0.17-21.2, 0.64-22.66, 2.28-26.92, and 2.57-256.82 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55), with a mean SRS concentration 15.80±11.17, 4.62±4.75, 6.83±6.35, 3.57±4.78, 7.37±6.18, 12.13±6.01, and 11.89±6.41 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55) which are relatively lower than lake Ashura (Alfasane *et al.* 2012, 14.36 ± 0.25 mg/l).

During the present investigation, ranges of nitrate nitrogen concentration (NO_3-N) were ranged from 0.01- 1.24, 0.01-0.74, 0.01-1.58, 0.01-0.74, 0.01-1.22, and 0.01-0.73 mg/l with mean concentration 0.19±0.07, 0.16±0.25, 0.11±0.19, 0.15±0.20, 0.15±0.18, 0.16±0.27, and 0.12±0.15 mg/l for Station 1, 2, 3, 4, 5, 6, and 7, respectively (Table 55). On the contrary, concentration of nitrate nitrogen was higher in Kaptai lake (1.63 mg/l, Mahmood 1986) than Dhanmondi lake (0.16 mg/l, Khondker and Parveen 1992) and in the present study stations. 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 (except one habitat). According to Islam *et al.* (2012) the amount of nitrate-nitrogen concentration is remarkably low (0.19) on 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. WHO (1984) suggested the safe limit of NO_3-N for lifetime use is 10 mg/l as N. This limit was not beaten in the river water; thus, nitrate is not considered to pose a problem for the household use of water from the rivers. However, nitrate could be a problem for other uses because of eutrophication (Rast and Thornton 1996). Yeasmin (2019) studied two lakes of National Botanical Garden, Dhaka and found the concentration more or less same as the findings of this investigation. Shafi (2020) investigated Kuniar *Haor*, Kishoregonj and his findings was also as same as the current one.

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 8.29-223.78, 5.92-107.74, 5,92-104.19, 4.00-112.48, 5.92-43.81, 8.29-249.82, and 5.92-171.68 µg/l for Station1, 2, 3, 4, 5, 6, and 7, respectively and the concentration of phaeopigment in the present investigation ranges from 0.86-52.62, 0.38-38.88, 4.19-58.78, 1.5-50.21, 1.21-16.93, 0.19-73.76, and 0.19-92.06 µg/l Station1, 2, 3, 4, 5, 6, and 7, respectively (Table 54).

The mean chl-a recorded in were 122.51±60.29. 107.96±45.79, 70.81±65.10, 66.81±58.35, 34.04±25.09, 36.68±30.72, 23.09±15.83 µg/l for Station1, 2, 3, 4, 5, 6, and 7, respectively and the mean phaeopigment concentration recorded were 32.36±16.46, 39.62±25.83, 12.28±8.24, 13.04±9.97, 12.18±12.13, 11.03±10.94, and 8.52±8.07 µg/l Station1, 2, 3, 4, 5, 6, and 7, respectively (Table 54). Sultana and Khondker (2009), and Islam *et al.* (2012) reported the lowest biomass of phytoplankton (chl-a) during September. This observation is different to the present investigation and the concentration was the lowest during July and August (Fig. 33). In the present investigation, the highest algal abundance coincided with the highest concentration of chl-a. Cyanophyta made up less of the chl-a than Chrysophyta, Chlorophyta and and Cryptophyta. Chl-a content in cyanobacteria is less than in Chlorophyta and Euglenophyta (Reynolds 1984). Increased chl-a concentration in water and pH were related to density of Euglenophyta, whereas the concentration changes of oxygen were related to changes in density of both Euglenophyta and Bacillariophyta (Pereira *et al.* 2001).

The total phytoplankton population was 0.44-15.28 $\times10^6$, 0.22-8.9$\times10^6$, 0.33-8.09$\times10^6$, 0.33-9.34$\times10^6$, 0.30-3.96 $\times10^6$, 0.06-19.62$\times10^6$, and 0.03-22.47$\times10^6$ ind./l with mean phytoplankton density were 9.76±4.59$\times10^6$, 10.11±6.19 $\times10^6$, 3.52±3.14 $\times10^6$, 3.36±2.41$\times10^6$, 2.62±2.41 $\times10^6$, 2.97±3.46$\times10^6$, and 1.92±1.75$\times10^6$ ind./l for Station1, 2, 3, 4, 5, 6, and 7, respectively (Table 55).

Filamentous nitrogen-fixing cyanobacteria (BGA) can directly kill related strains and that was shown by Flores and Wolk (1986). The presence of Aphanizomenon gracile can kill *Chlorella*, *Cosmarium, Pediastrum, Phormidium* and *Scenedesmus* were recorded by Legrand *et al.* 2003. Similarly, the damage and subsequent death of cell of the cyanobacterium *Microcustis aeruginosa* can be caused by the freshwater dinoflagellate *Peridinium bipes* (Wu 1999). *Peridinium aciculiferum*, another dinoflagellate, inhibited the growth and caused roasting and lysis in the cryptophyte *Rhodomonas lacustris* (Rengefors and Legrand 2001).

Correlation studies among the biological and environmental parameters reveals that a number of parameters are interrelated with each other in the investigated stations (Table 63 - 69). The relationship between the physicochemical parameters of air and water temperature were examined at the 1% significance level and it's 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 forward that temperature is the determining factor in the seasonal distribution of organisms. In the present investigation, the temperature produced some effect on the phytoplankton fluctuations. Because phytoplankton was found to attain peak in the month of May when a comparatively higher temperature was observed. So, a significant correlation (r=-0.027 and r=0.162) was observed in Station 1; Station 2 showed same pattern of correlation as (r=-0.19 and r=-0 .092); Station 3 showed significant negative correlation (r=-0.471, r=-0.456); Station 4 showed same pattern as the previous one (r=-0.362, r=-.198); Station 5 showed same pattern as previous two (r=-0.171, r=-0.279); Station 6 showed same pattern as Station 1 (r=0.006, r=-0.176) and station 7 showed same pattern as Station 4 (r=-0.012, r=-0.179) with air temperature and water temperature. A negative correlation of phytoplankton biomass with air and water temperature was also observed by Parveen (1987) in the Dhanmondi Lake and Zaman *et al.* (1993) in three ponds of Jahangirnagar University campus.

Multiple correlation analysis was done among the recorded variables versus (vs) phytoplankton density showed significant positive correlation with alkalinity, SRS, chl-*a* and phaeopigment in Station-1; NO_3-N in Station-2; chl-a in Station 3; DO in Station 5; alkalinity, chl-a, and phaeopigment in Station 6 and conductivity, chl-a, and phaeopigment in Station 7, respectively. On the other hand, it showed a significant negative correlation with Secchi depth, in station 1; TDS, conductivity and alkalinity in station 4, respectively. In showed no significant negative correlation with any parameters in other stations (Table 61-67). The levels of significance varied from 1-5%.

In Station 1, phytoplankton density showed positive correlation with Alk, SRS, chl-a, and phaeopigment but Secchi depth showed significant negative correlation. All these parameters showed 1% level significant with phytoplankton density. In Station 2, phytoplankton density showed 1% level significant positive correlation with NO_3-N. Among these phytoplankton density showed 5% level negative significant with pH. In Station 3, phytoplankton density showed 1% level significant with chl-a and among these phytoplankton density showed 5% level significant with air and water temperature, pH and alkalinity. In Station 4, phytoplankton density showed 1% level significant TDS, Conductivity and Alkalinity and 5% level significant with Secchi depth and chl-a. In Station 5, phytoplankton density showed 1% level significant with DO and there is no 5% level significant with any parameters. In Station 6, phytoplankton density showed 1% level significant with alkalinity, chl-a and phaeopigment but 5% level significant with conductivity and SRP. In Station 6, phytoplankton density showed 1% level significant with Conductivity, chl a and phaeopigment and 5% level significant with pH, alkalinity and SRS. In Station 7, phytoplankton density showed 1% level significant with electrical conductivity, chl-a, and phaeopigment and 5% level significant with pH, alkalinity, and SRS.

According to Shannon-Winner diversity index, Station 7 is more diverse than the other stations in case of genus and species level and in Jaccard Index, there shows two lakes are highest 9.45% similar in September 2018 and the number of their intersecting members were 19.

The present hydrobiological study of Station 1 to Station 7 in Lalmai Hill areas of Cumilla, the recorded species of hydrophytes are 42 which is similar to the polluted Dhanmondi lake at Dhaka (Islam *et al.* 1979) and two lakes of National Botanical Garden, Mirpur, Dhaka (Yeasmin, 2019). Only the exception of two species of aquatic ferns, macrophyte population of the stations are characterized by angiosperms. Total 42 species of macrophytes are documented with vast floating masses of *Eichhornia crassipes* intersected by *Pistia stratiotes* and *Salvinia cucullata*.

In the present investigation 63 genera and 351 species were represented in the phytoplankton communities for Station 1 to Station 7. Division wise distribution of species level was the highest 33.60% found in Euglenophyta (Station 7) and the lowest was 0.91% found in pyrrophyta (Station 6) among the phytoplankton studied. Euglenophyta dominated followed by Chlorophyta, Chrysophyta, Cyanophyta, Cryptophyta and Pyrrophyta (Appendix I). On the preliminary identification, 40 species of phytoplankton may be considered as new records, Euglenophyta dominated (15 taxa) followed by Chlorophyta (14 taxa) and Cyanophyta (11 taxa) (Appendix II).

From the overall study it can be clinched that all the seven stations are presently passing their mesotrophic status and it may be proceeding towards eutrophic status. If the anthropogenic disturbances in the catchment area continued in these stations, it is likely that in the near future these stations 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. Since, hypertrophism will bring anoxia and excessive concentration of essential nutrients which sometimes becomes toxic to the booming community. The final result will be that these stations might get turned into a breeding ground of snails, mosquitoes and other pathogenic organisms. Therefore, there is an urgent necessity to manage these stations. The study also reveals that management of the wetlands of Lalmai Hill areas of Cumilla should be taken into consideration not only to stop the disturbances within the waterbodies but also the disturbances in their surrounding land areas. For carrying out the management activities of these wetlands, the authority should be aware of the fact and accordingly, necessary management steps should be taken in hand in no time.

Ecosystem service model

Ecosystem service model

It is a concept of getting maximum benefits from an ecosystem by implementing some ideas and rules. These ideas and rules are implemented to an ecosystem to develop an ecosystem which will provide maximum service for the welfare of the people neighbouring a natural ecosystem. The model which I proposed here may be useful or beneficial for the people neighbouring the wetlands of Lalmai Hill areas of Cumilla.

The proposed ecosystem service model is given below:

World standard of different parameters of wetland ecosystem (According to WHO and US-EPA)

- TDS-300-600 (up to 1000) mg/lit; Conductivity-300 µS/cm; Alkalinity-29-200 mg/l ; pH-6.5-8.5 and NO_3-N- 50 mg/l

Wetlands of Lalmai Hill areas of Cumilla

Big pond of BARD

- pH according to the level of WHO standard (Max. 8.5)
- TDS is also up to the level of standards
- Conductivity is higher than the level of standards (1322mg/l)
- Alkalinity and NO_3-N is much lower than the level of standards

1. Manmade ecosystem
2. Protected from any type of lose
3. Used for fish cultivation and recreation purposes
4. No destructive work had been noticed during the period of investigation
5. The environment is properly taken care of

Interaction between nature and human being is quite friendly and satisfactory

Dutia Dighi

- pH is a little bit higher than the level of WHO standard (Max. 8.7)
- TDS is up to the level of standards
- Conductivity is up to the level of standards (Max. 423mg/l)
- Alkalinity and NO_3-N is much lower than the level of standards

1. Manmade ecosystem
2. Protected but open for any type of use
3. Used for fish cultivation, recreation purposes
4. No destructive work had been noticed during the period of investigation
5. The environment is properly taken care of

Interaction between nature and human being is good and quite satisfactory

Horeshpur Jola

- pH according to the level of WHO standard (Max. 8.3)
- TDS is also up to the level of standards
- Conductivity is up to the level of WHO standards (max. 558mg/l)
- Alkalinity and NO_3-N is much lower than the level of standards

1. Natural ecosystem
2. Unprotected and easy for the land grabbers to destroy
3. Used for fish and rice cultivation
4. A lot of destructive works had been noticed during the time of investigation
5. The environment is not properly taken care of

Interaction between nature and human being is hostile and humans destroying natural environment of this site

Recommendations

The condition of the Ecosystem of the wetland of Hill areas of Cumilla is quite satisfactory except the third one (Horeshpur Jola). Proper initiative should be taken to protect the wetland ecosystem from the land grabbers from abuse of land and environment of the area. Then we can think of getting maximum ecosystem service from the wetlands of Lalmai Hill areas of Cumilla.

CONCLUSIONS

The present study shows detailed phytodiversity, their seasonal variations, physicochemical characteristics and water quality of the wetlands of Lalmai Hill areas. The pre-monsoon, monsoon, post-monsoon and winter seasons have shown different seasonal fluctuations in various physicochemical parameters, growth and abundance of phytoplankton and macrophytes. All the way of the investigation AT showed strong significant positive correlation with WT. Most of the time chl-a, phaeopigment and phytoplankton density showed strong significant positive correlation to one another. WT showed strong significant negative correlation with TDS and DO. Total 20, 5, 6, 12, 8, 12, and 15 pairs of parameters showed strong significant correlation to one another for Station 1, 2, 3, 4, 5, 6, and 7, respectively.

In comparison to other wetlands of Bangladesh, wetlands of the current investigation area are more productive in comparison to phytoplankton biomass as chl-a. The studied wetlands are twenty-five to thirty times more productive than the other studied wetlands of Bangladesh.

Pearson correlation analysis reveals a significant positive correlation with the concentration of chl-a, phaeopigment, and phytoplankton density. It also shows significant positive correlation between air and water temperature in the studied wetlands.

Most of the macrophytes were available during monsoon and post-monsoon. In the winter abundance of macrophytes was less, it may be due to rice cultivation and decreasing water level. The area of current investigation is rich in macrophyte community in comparison to other wetlands of Bangladesh.

According to Shannon-Wiener Diversity Index, Station 7 showed higher phytodiversity and Station 6 was the least. Jaccard Index calculation for phytoplankton and macrophytes showed that the wetlands were 9.45% similar in September 2018 and their intersecting members were 19.

The present investigation has thus revealed the mesotrophic status of the wetlands. The investigation generated some important baseline data on the pollution status of the water quality and phytoplankton and macrophyte community structure of the wetlands. These data would be helpful for planning 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. Analysis and interpretation of the data on phytoplankton and water quality parameters had supplied the necessary information to evaluate the impact of tourism related activities on the hydrobiology of the wetlands of the area.

It is also necessary to increase awareness among the people neighboring the wetlands to maintain the water at their highest level of quality and purity. To improve water quality there should be a continuous monitoring of the pollution level and methods should be applied for removing water pollution in the tourist place and natural fish breeding ground. Monitoring of the water quality of sampling stations of the wetlands should be done at regular basis.

However, conservation efforts in wildlife reserves around reservoirs should include not only the wild flora and fauna of the land but also of the aquatic systems because both the watersheds and reservoir in such places represent one integrated system. Careless management of aquatic resources and tourism activities of water bodies in such places may ultimately downfall the stability of the precious wildlife in the terrestrial ecosystem as well.

PHOTOMICROGRAPHS

OF

PHYTOPLANKTON AND MACROPHYTES

Phytoplankton

Photomicrographs of reported phytoplankton

(Magnification of the images range 400-1000×)

Division: Cyanophyta

Plate 1

No.	Name of the species
1.	*Anabaena ballyganglii*
2.	*A. oscillarioides*
3.	*A. oryzae*
4.	*A. torulosa*
5.	*A. circinalis*
6.	*A. california*
7.	*A. affinis*
8.	*A. fertilissima*
9.	*A. orientalis*
10.	*A. utermöhlii*
11.	*Anabaenopsis tanganikae*
12.	*A. arnoldii*
13.	*Anabaena ballyganglii*
14.	*A. fertilissima*
15.	*A. variabilis*
16.	*A. torulosa*

Plate 1

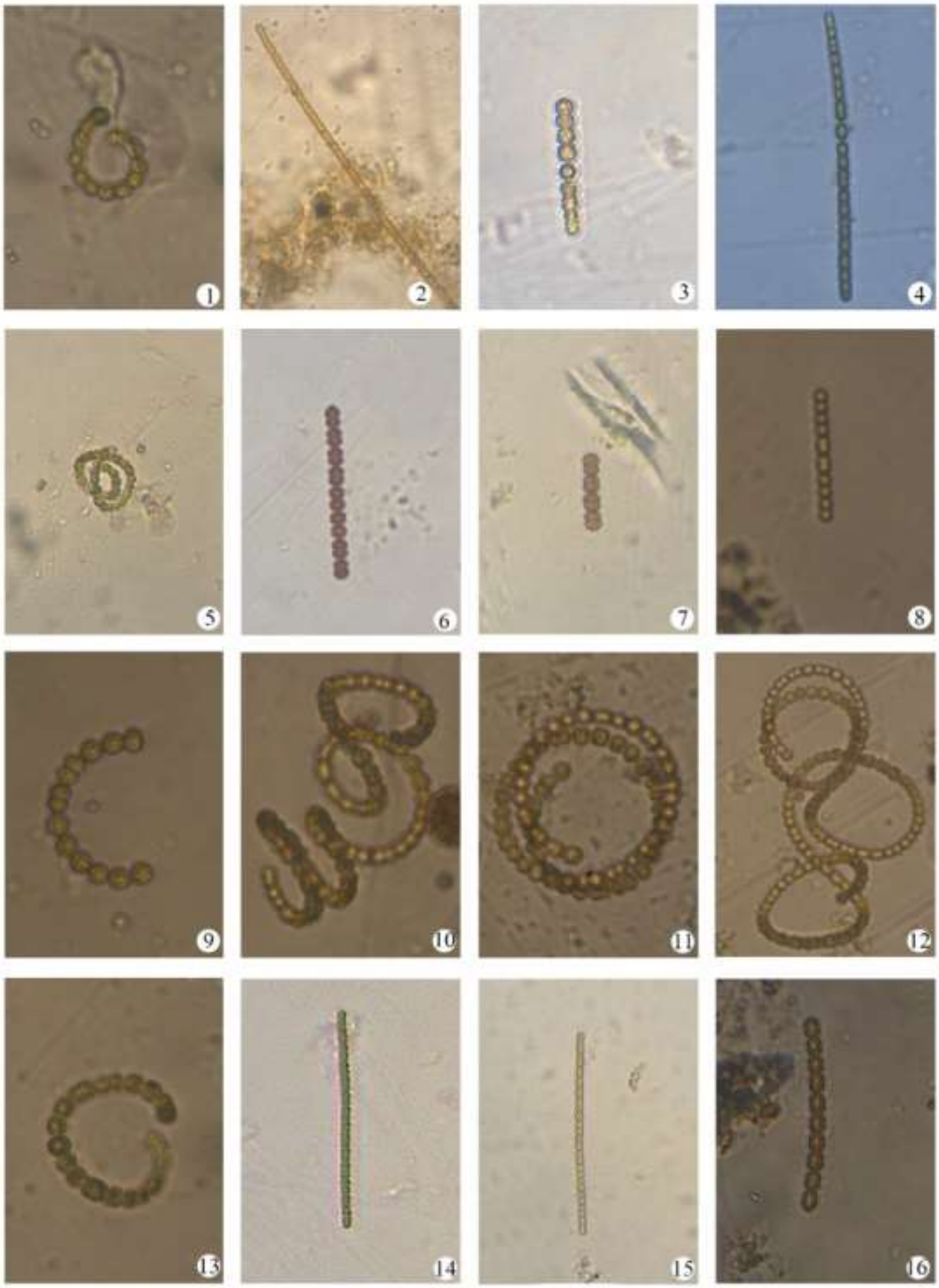


Plate 2

No.	Name of the species
17.	*Cylindrospermopsis raciborskii*
18.	*Anabaenopsis tanganikae*
19.	*Cylindrospermum doryphorum*
20.	*Anabaenopsis elenkinii*
21.	*A. raciborskii*
22.	*Merismopedia punctata*
23.	*M. minima*
24.	*M. elegans*
25.	*Microcystis aeruginosa*
26.	*Gomphosphaeria lacustris*
27.	*Microcystis flos-aquae*
28.	*M. robusta*
29.	*M. flos-aquae*
30.	*M. roseana*
31.	*M. marginata*
32.	*M. aeruginosa*

Plate 2

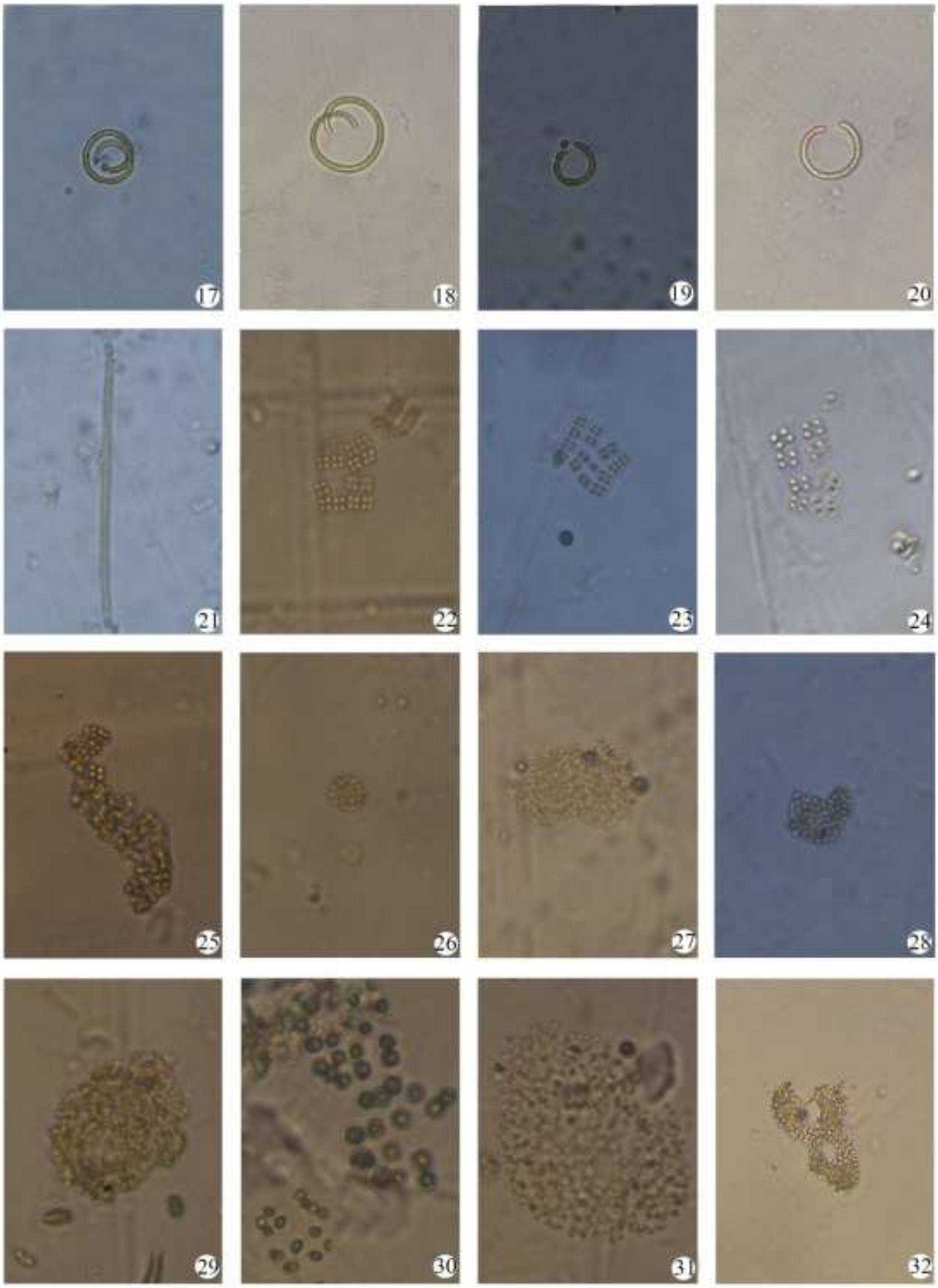
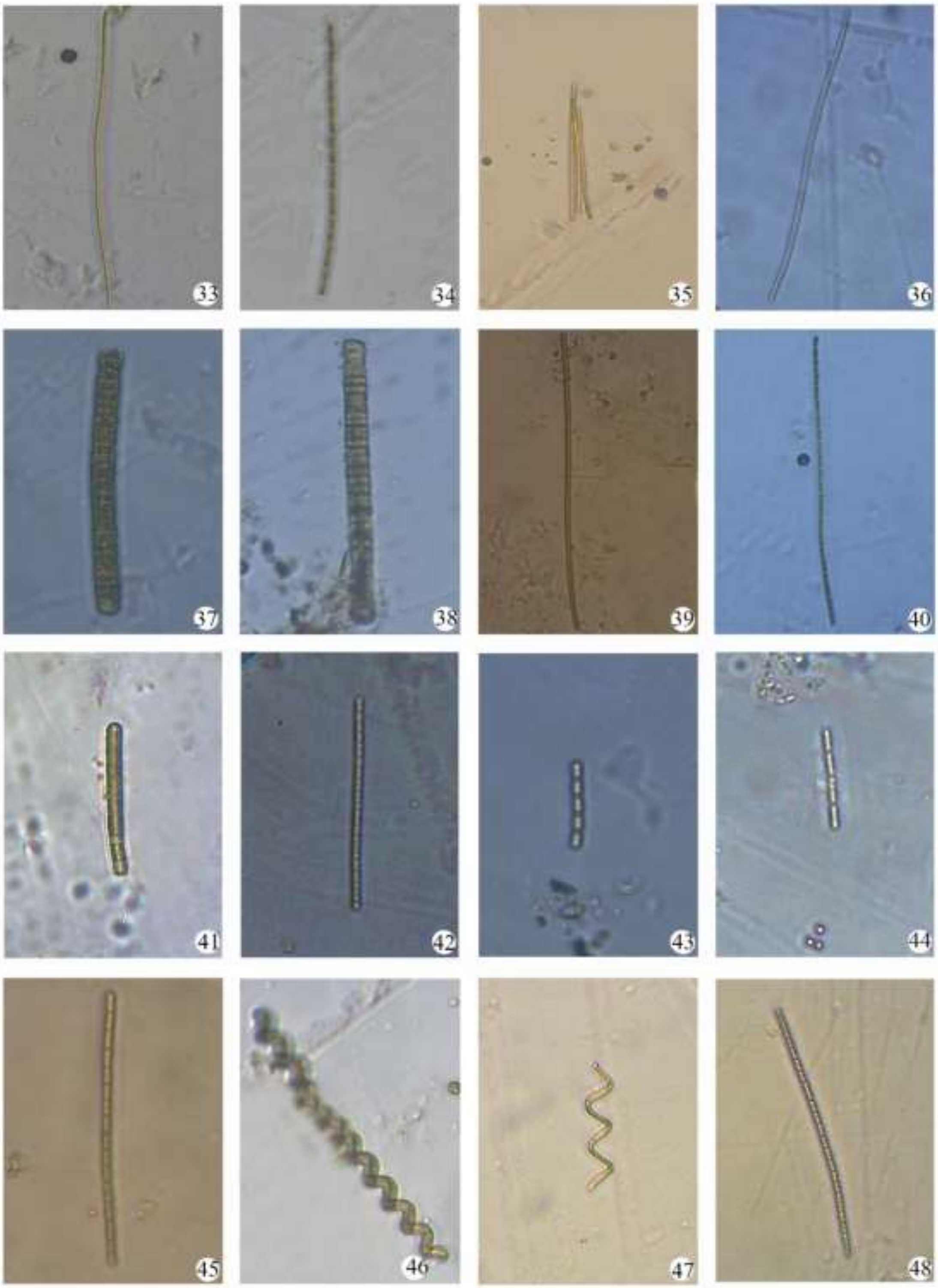


Plate 3

No.	Name of Species
33.	*Oscillatoria margaritifera*
34.	*O. planktonica*
35.	*O. geminata*
36.	*O. pseudogeminata*
37.	*O. perornata*
38.	*O. limosa*
39.	*O. proteus*
40.	*Pelonema aphane*
41.	*Oscillatoria irrigua*
42.	*O. minnesotensis*
43.	*O. geitleriana*
44.	*O. geitleriana*
45.	*O. minnesotensis*
46.	*Spirulina gigentia*
47.	*S. laxa*
48.	*Oscillatoria proteus*

Plate 3



Division: Chlorophyta
Order: Chlorococcales

Plate 4

No.	Name of the species
1.	*Actinastrum hantzschii*
2.	*A. hantzschii* var. *subtile*
3.	*A. hantzschii* var. *subtile*
4.	*A. gracillimum* var. *gracillimum*
5.	*Coelastrum sphaericum*
6.	*C. sphaericum*
7.	*C. indicum*
8.	*C. indicum*
9.	*C. pulchellum* var. *pulchellum*
10.	*C. pulchellum*
11.	*C. indicum*
12.	*C. microphorum*
13.	1*C. sphaericum*
14.	*C. microphorum*
15.	*C. sphaericum*
16.	*C. microphorum*

Plate 4

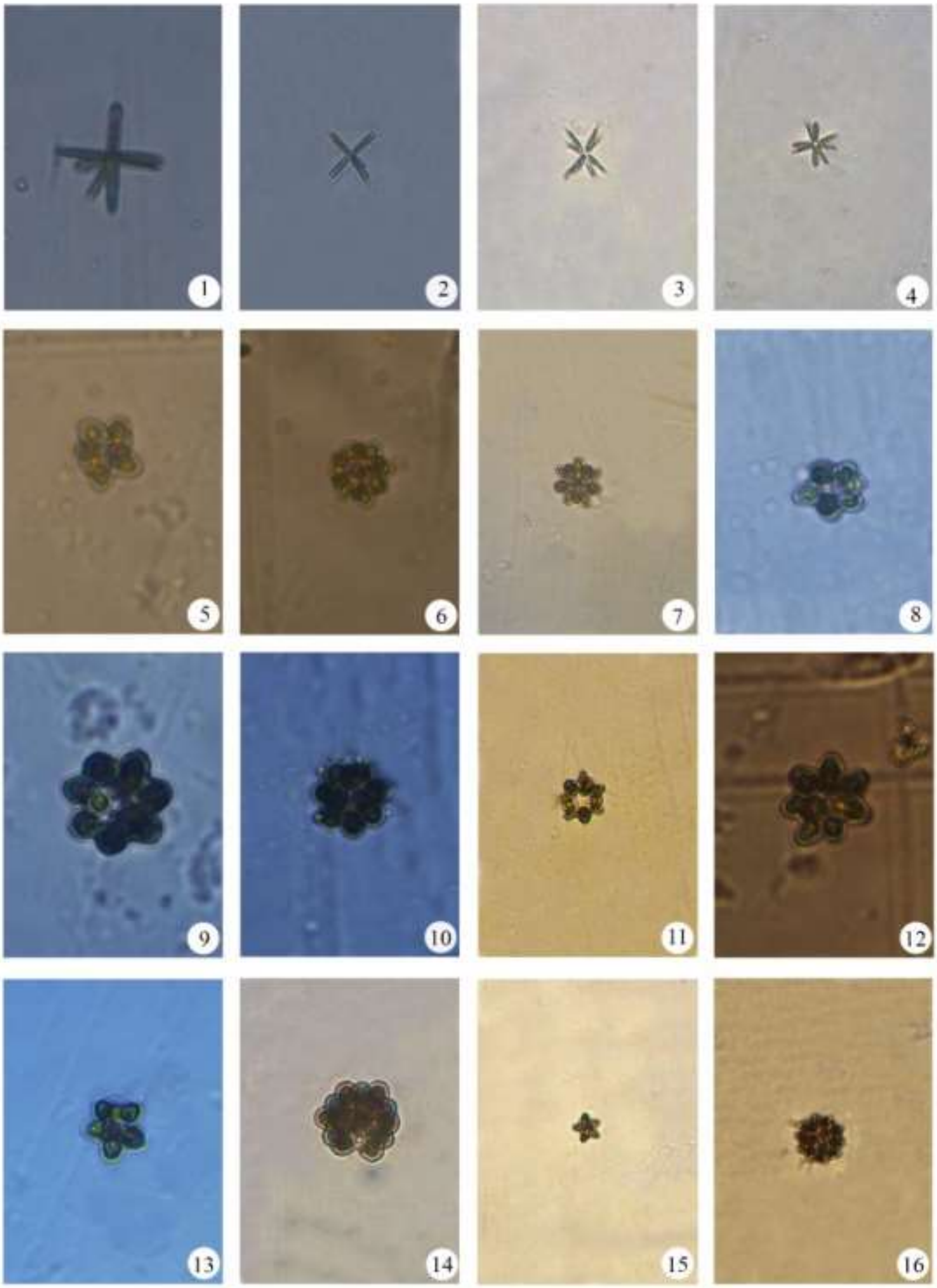


Plate 5

No.	Name of the species
17.	*Crucigenia rectangularis*
18.	*C. quadrata*
19.	*Crucigeniella apiculata*
20.	*C. crucifera*
21.	*C. crucifera*
22.	*C. crucifera*
23.	*C. lauterbournii*
24.	*C. lauterbournii*
25.	*C. rectangularis*
26.	*C. apiculata*
27.	*C. lauterbournii*
28.	*C. truncata*
29.	*C. apiculata*
30.	*C. lauterbournii*
31.	*C. apiculata*
32.	*C. crucifera*

Plate 5

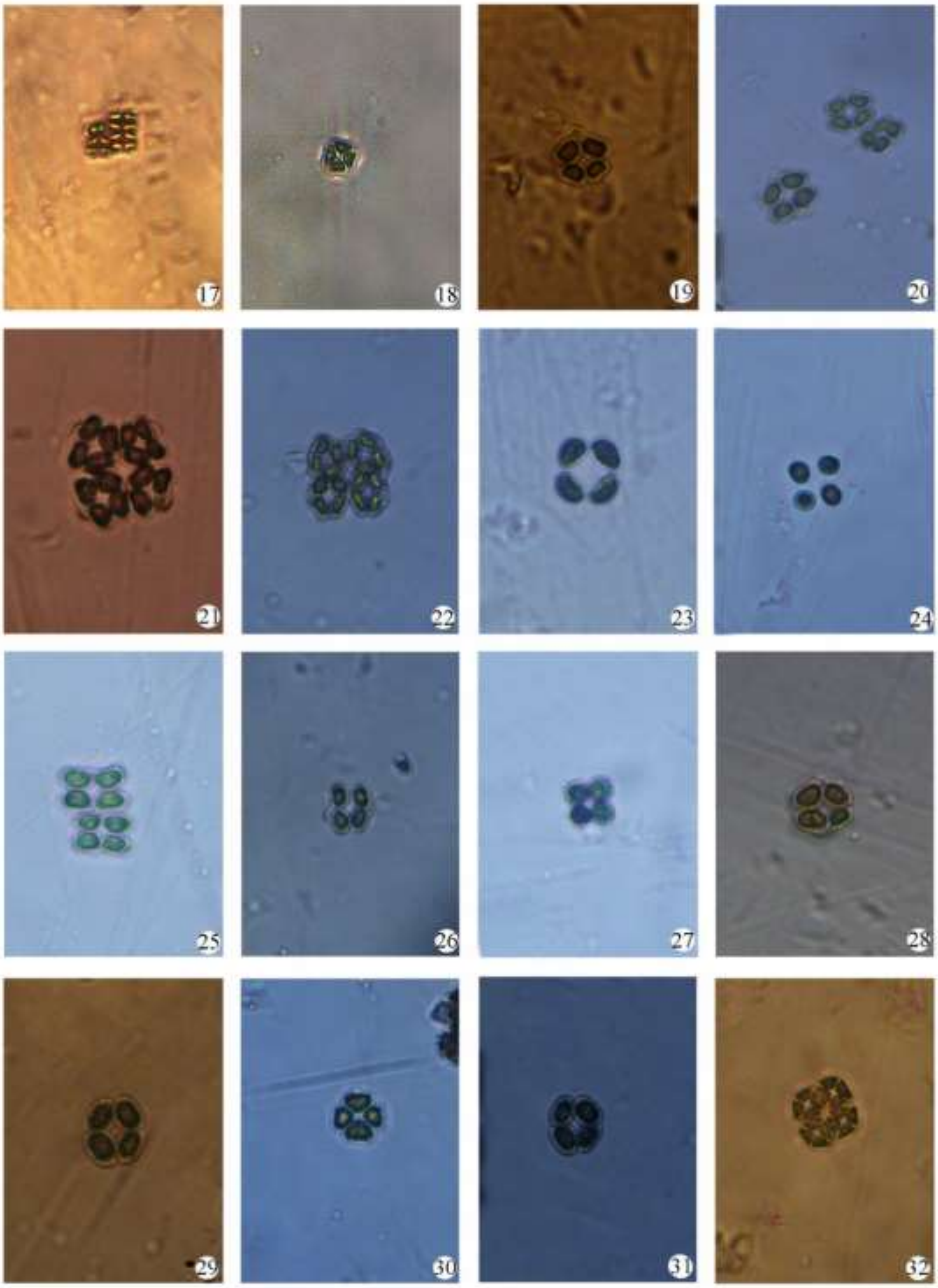


Plate 6

No.	Name of the species
33.	*Dictyosphaerium granulatum*
34.	*D. pulchellum*
35.	*D. tetrachotomum*
36.	*D. granulatum*
37.	*D. pulchellum*
38.	*Monoraphidium griffithi*
39.	*M. arcuatum*
40.	*. M. tortile*
41.	*Ankistrodesmus barnardii*
42.	*A. falcatus* var. *radiatus*
43.	*A. densus*
44.	*Monoraphidium griffithi*
45.	*Ankistrodesmus barnardii*
46.	*A. stipitatus*
47.	*A. falcatus* var. *radiatus*
48.	*A. spiralis*

Plate 6

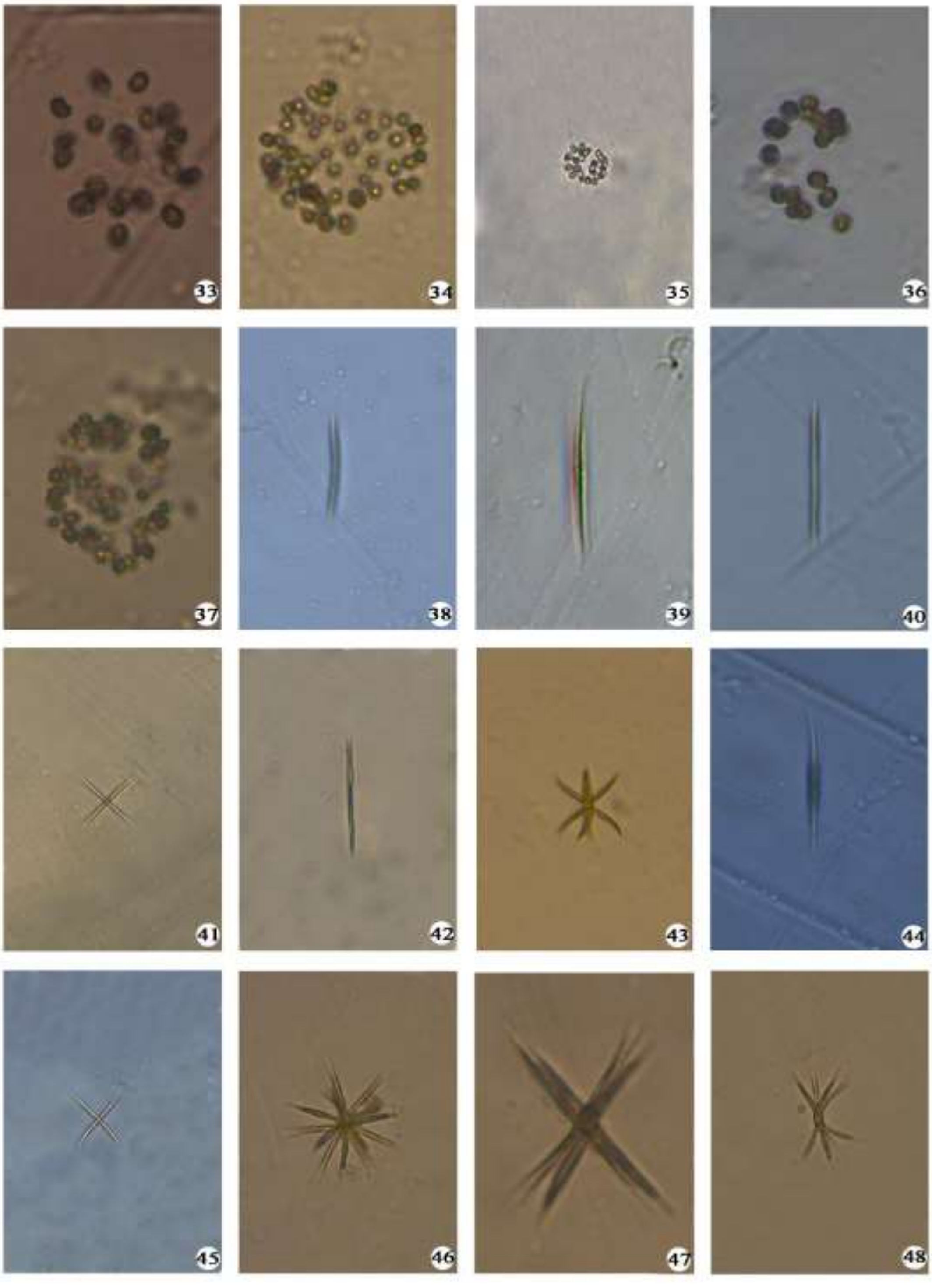


Plate 7

No.	Name of the species
49.	*Ankistrodesmus spiralis*
50.	*A*. blibraianus
51.	*A*. *bibraianus*
52.	*A. densus*
53.	*A. bibraianus*
54.	*A. bibraianus*
55.	*Monoraphidium griffithi*
56.	*Ankistrodesmus bibraianus*
57.	*A. bibraianus*
58.	*A. falcatus* var. *radiatus*
59.	*Monoraphidium fontinale*
60.	*Oocystis granulata*
61.	*O. elliptica*
62.	*O. solitaria*
63.	*O. pusilla*
64.	*O. nägelli*

Plate 7

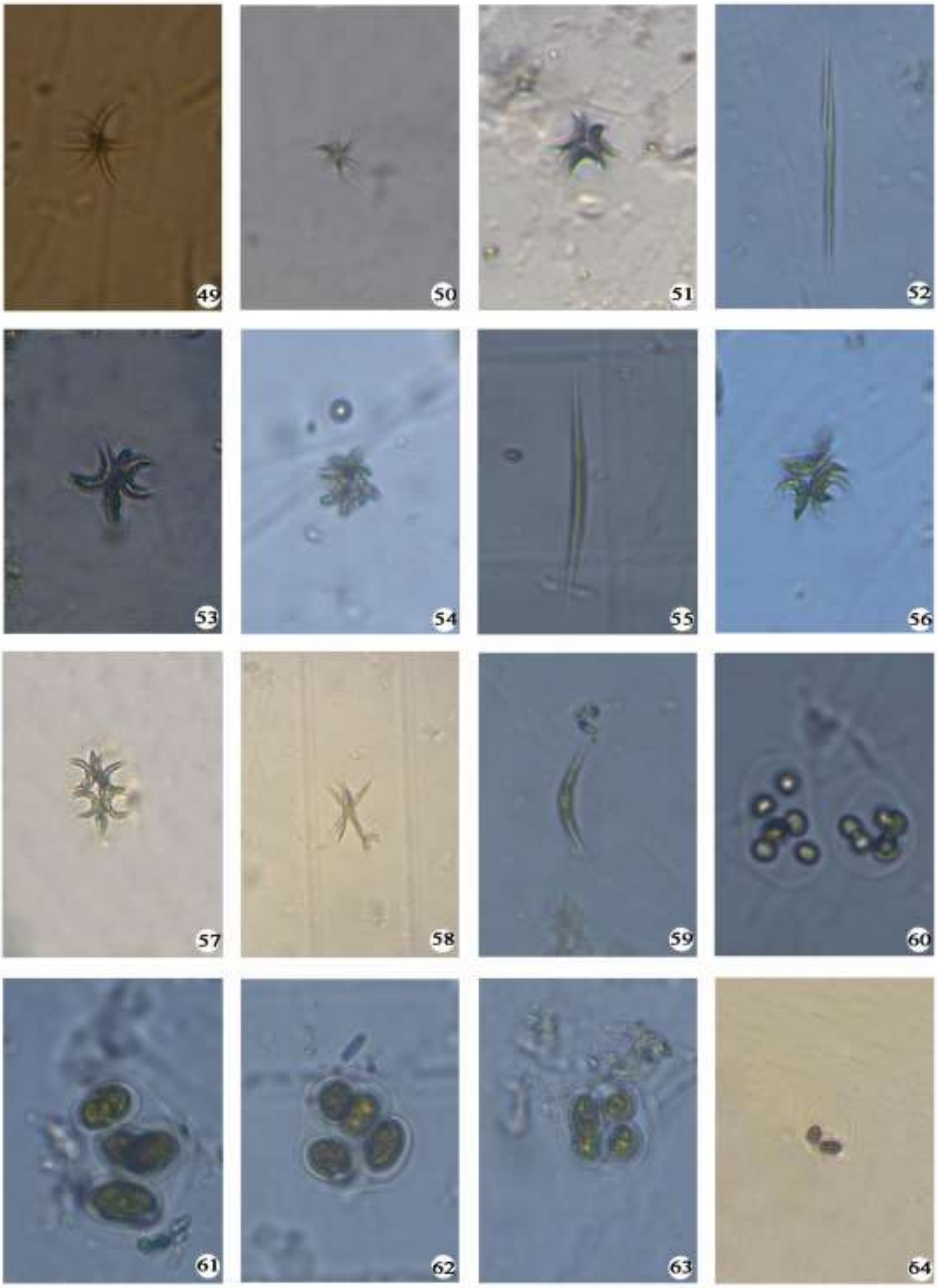


Plate 8

No.	Name of the species
65.	*Oocystis borgei*
66.	*O. submarina*
67.	*Pandorina morum*
68.	*Eudorina elegans*
69.	*E. elegans*
70.	*E. unicocca*
71.	*Gonium pectorale*
72.	*Pandorina morum*
73.	*Pediastrum duplex* var. *clathratum*
74.	*P. tetras*
75.	*P. duplex*
76.	*P. tetras* var. *tetraedron*
77.	*P. biradiatum*
78.	*P. duplex* var. *rogulosum*
79.	*P. tetras*
80.	*P. biradiatum*

Plate 8

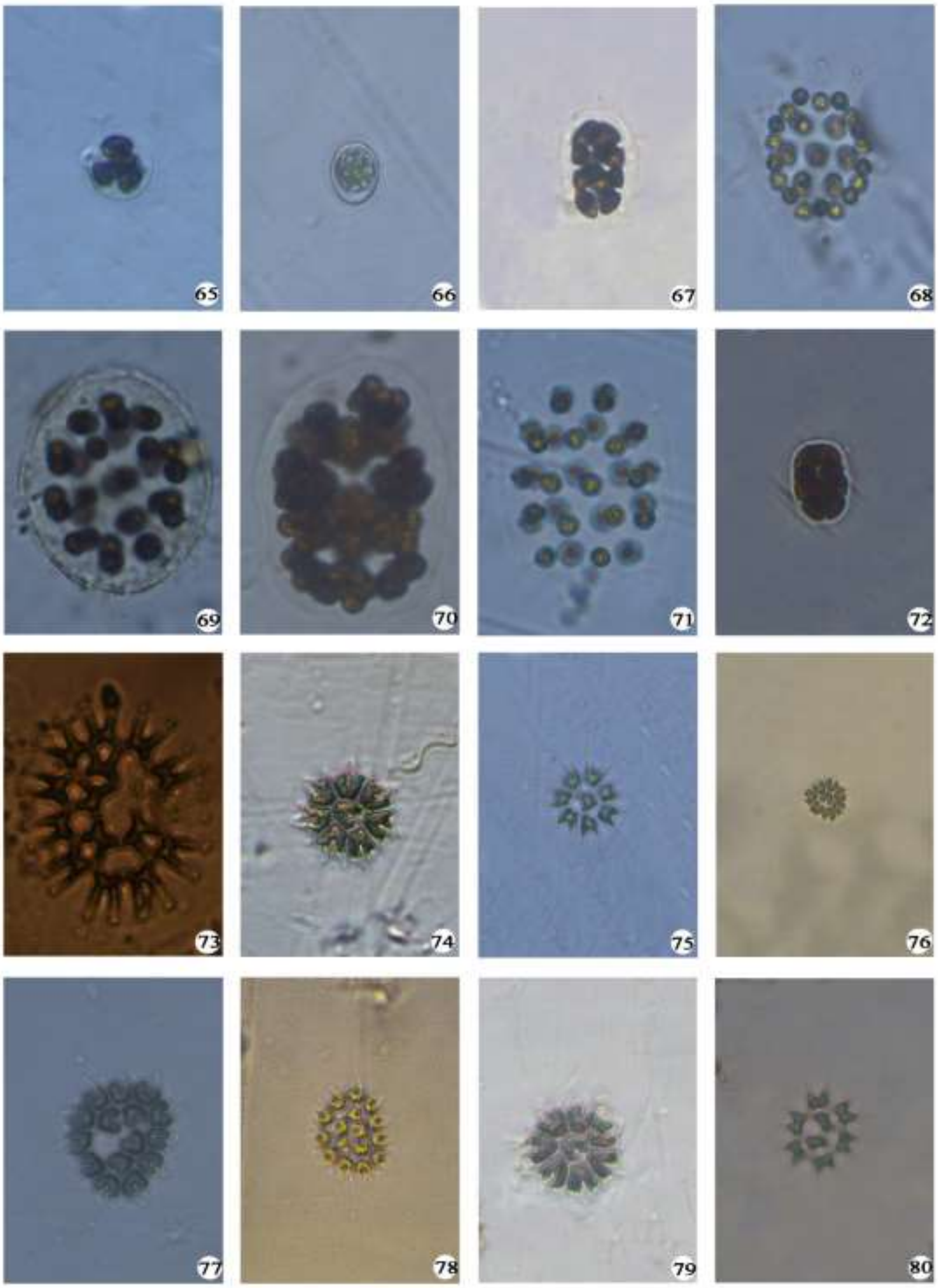


Plate 9

No.	Name of the species
81.	*Pediastrum duplex*
82.	*P. tetras*
83.	*P. duplex*
84.	*P. tetras*
85.	*P. duplex* var. *rogulosum*
86.	*P. boryanum* var. *brevicorne*
87.	*P. tetras* var. *tetraedron*
88.	*P. duplex* var. *gracillimum*
89.	*Scenedesmus acutiformis*
90.	*S. longispina var. asymmetricus*
91.	*S. perforatus*
92.	*S. regularis*
93.	*S. opoliensis* var. *contacta*
94.	*S. incrassatulus*
95.	*S. opoliensis* var. *contacta*
96.	*S. denticulatus*

Plate 9

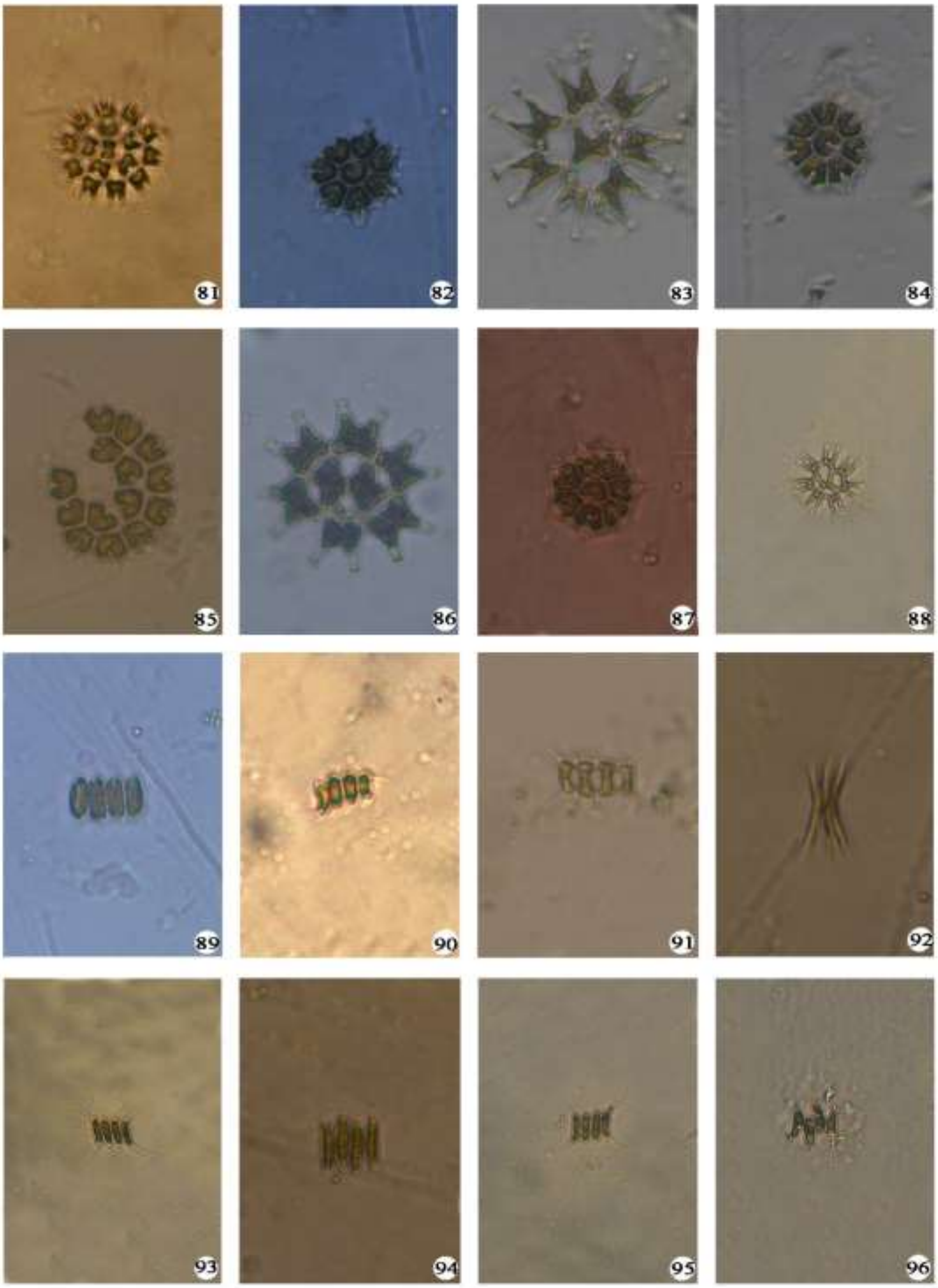


Plate 10

No.	Name of the species
97.	*Scenedesmus magnus*
98.	*S. incrassatulus*
99.	*S. quadricauda*
100.	*S. denticulatus*
101.	*S. denticulatus* fa. *maximus*
102.	*S. opoliensis* var. *contacta*
103.	*S. quadricauda*
104.	*S. quadricauda*
105.	*S. quadricauda* var. *quadrispina*
106.	*S. arcuatus*
107.	*S. regularis*
108.	*S. longispina* var. *asymmetricus*
109.	*S. acutus*
110.	*S. opoliensis*
111.	*S. ecornis* var. *ecornis*
112.	*S. arcuatus*

Plate 10

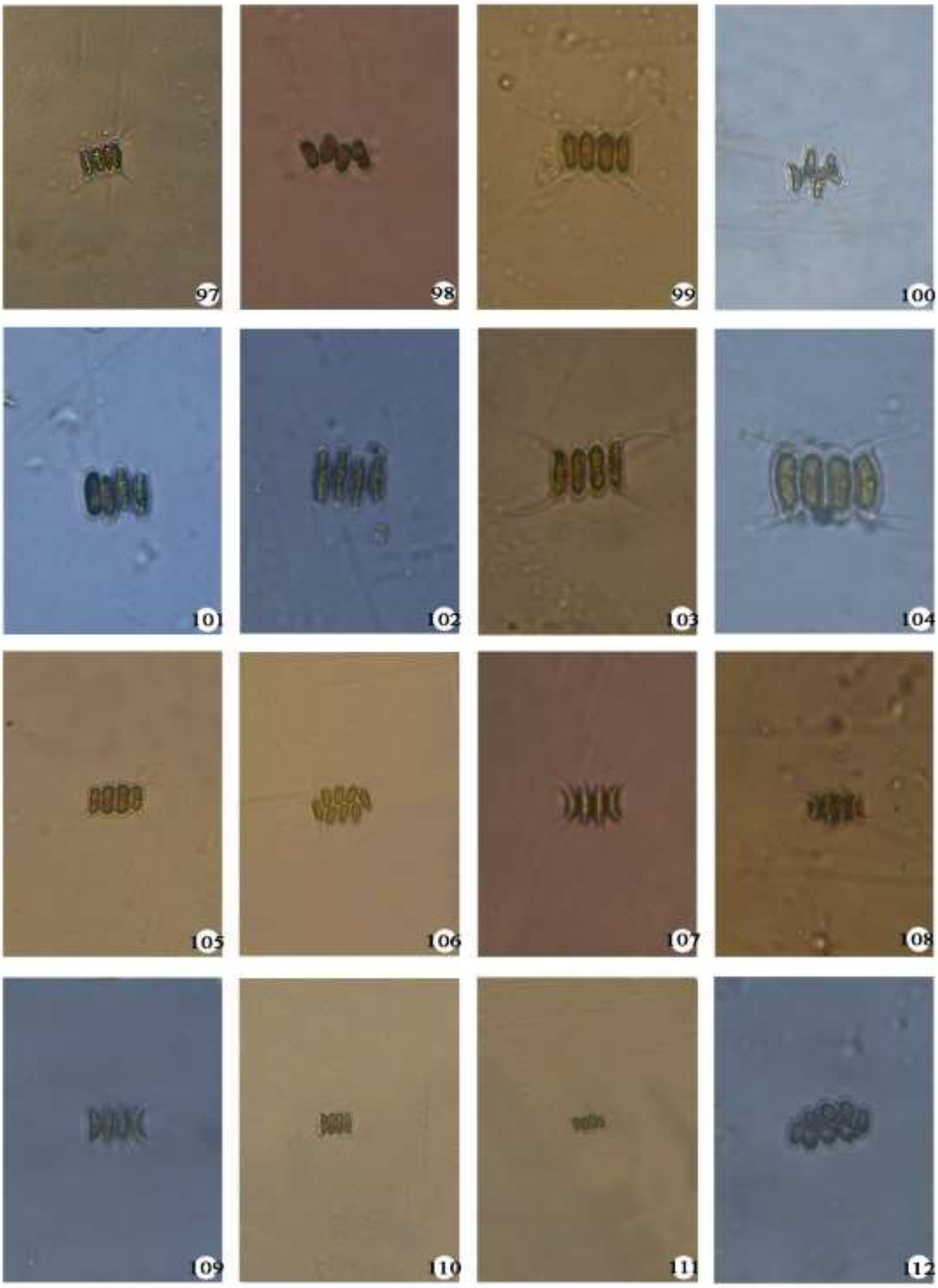


Plate 11

No.	Name of the species
113.	*Scenedesmus opliensis var. contacta*
114.	*S. incrassatulus*
115.	*S. perforatus*
116.	*S. bijuga* var. *irregularis*
117.	*S. bijuga* var. *irregularis*
118.	*S. bijuga* var. *irregularis*
119.	*S. brevispina*
120.	*S. arcuatus*
121.	*S. acuminatus*
122.	*S. acutus* var. *acutus*
123.	*S. longus* var. *apiculatus*
124.	*S. arcuatus* var. *platydiscus*
125.	*S. regularis*
126.	*S. quadricauda* var. *longispina*
127.	*S. acutus* var. *acutus*
128.	*S. quadricauda* var. *rectangularis*

Plate 11

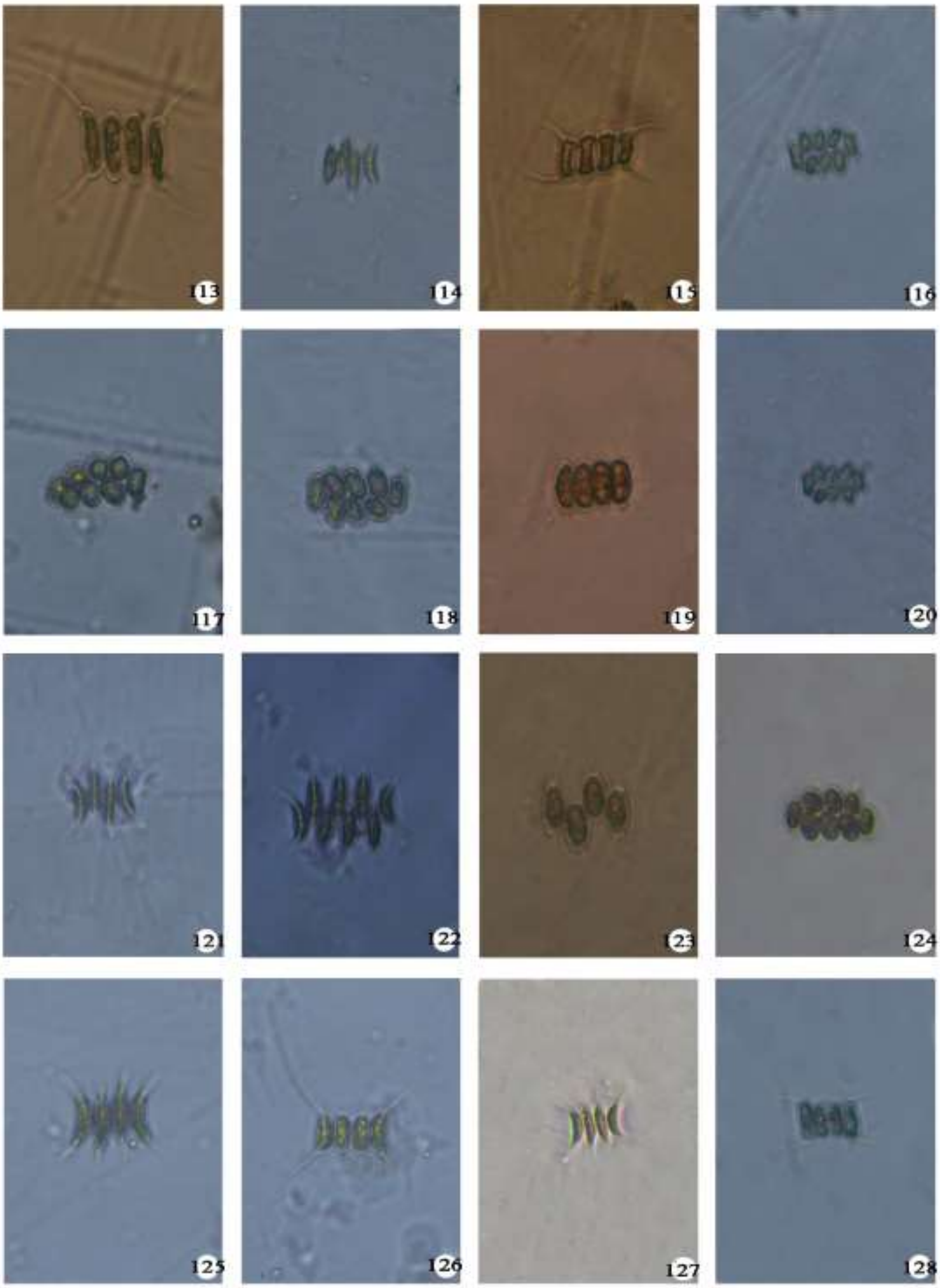


Plate 12

No.	Name of the species
129.	*Scenedesmus opoliensis* var. *contacta*
130.	*S. quadricauda* var. *longispina*
131.	*S. Arcuatus* var. *platydiscus*
132.	*S. denticulatus* fa. maximus
133.	*S. dimorphus*
134.	*S. ecornis* var. *ecornis*
135.	*S. regularis*
136.	*S. arcuatus*
137.	*S. denticulatus*
138.	*S. opliensis* var. *contacta*
139.	*S. acuminatus* var. *minor*
140.	*S. arcuatus*
141.	*S. dimorphus*
142.	*S. acuminatus*
143.	*S. quadricauda* var. *quadricauda*
144.	*S. quadricauda* var. *longispina*

Plate 12

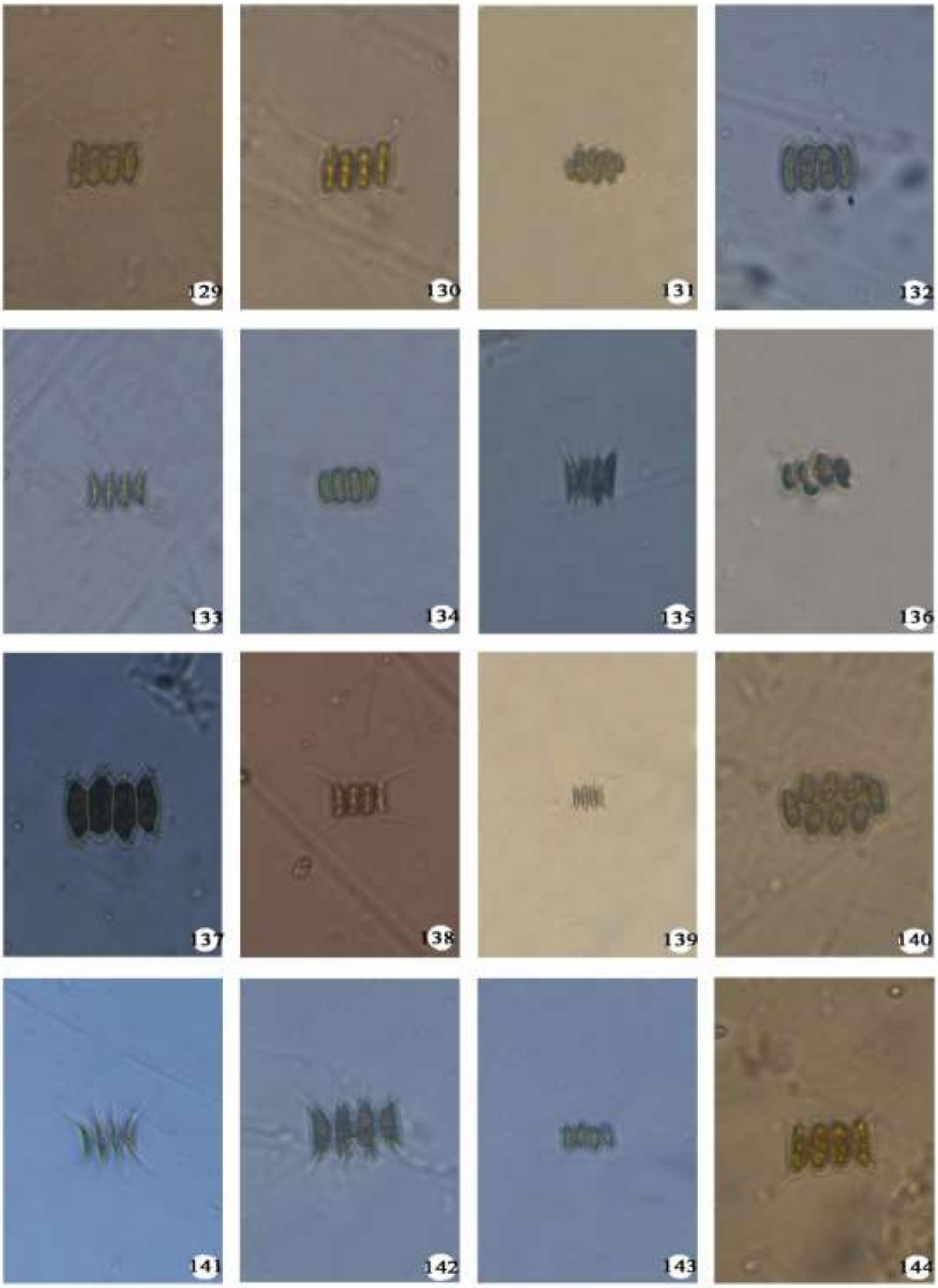


Plate 13

No.	Name of the species
145.	*Scenedesmus longus* var. *apiculata*
146.	*S. denticulatus*
147.	*Schroederia setigera*
148.	*S. spiralis*
149.	*Tetraedron trigonum*
150.	*Treubaria setigera*
151.	*T. setigera*
152.	*Tetraedron minima*
153.	*T. constrictum*
154.	*T. trigonum*
155.	*T. muticum*
156.	*T. muticum*
157.	*T. verrucosum*
158.	*T. limneticum* var. *gracile*
159.	*T. regulare*
160.	*Chlorotetraedron polymorphum*

Plate 13

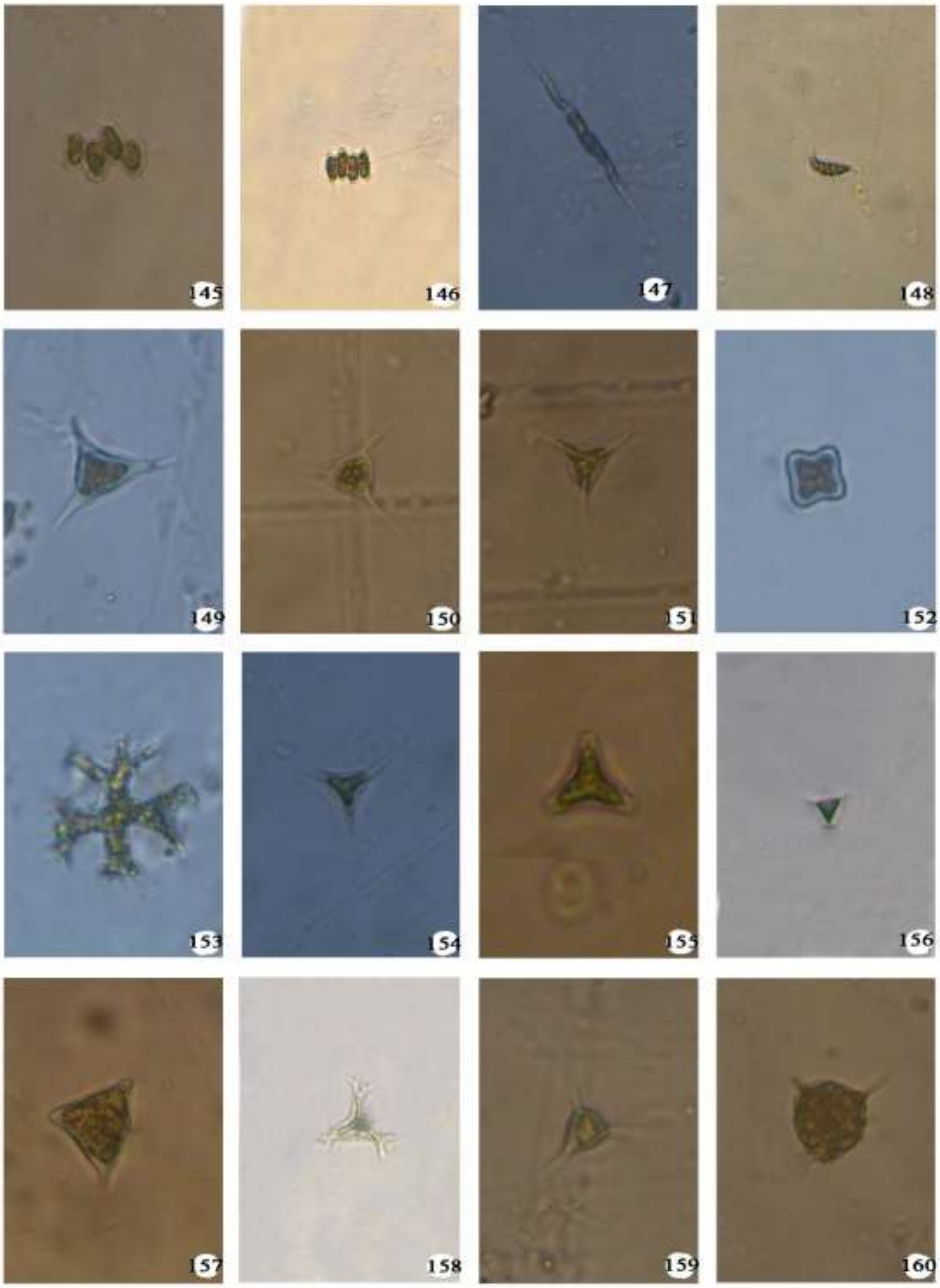
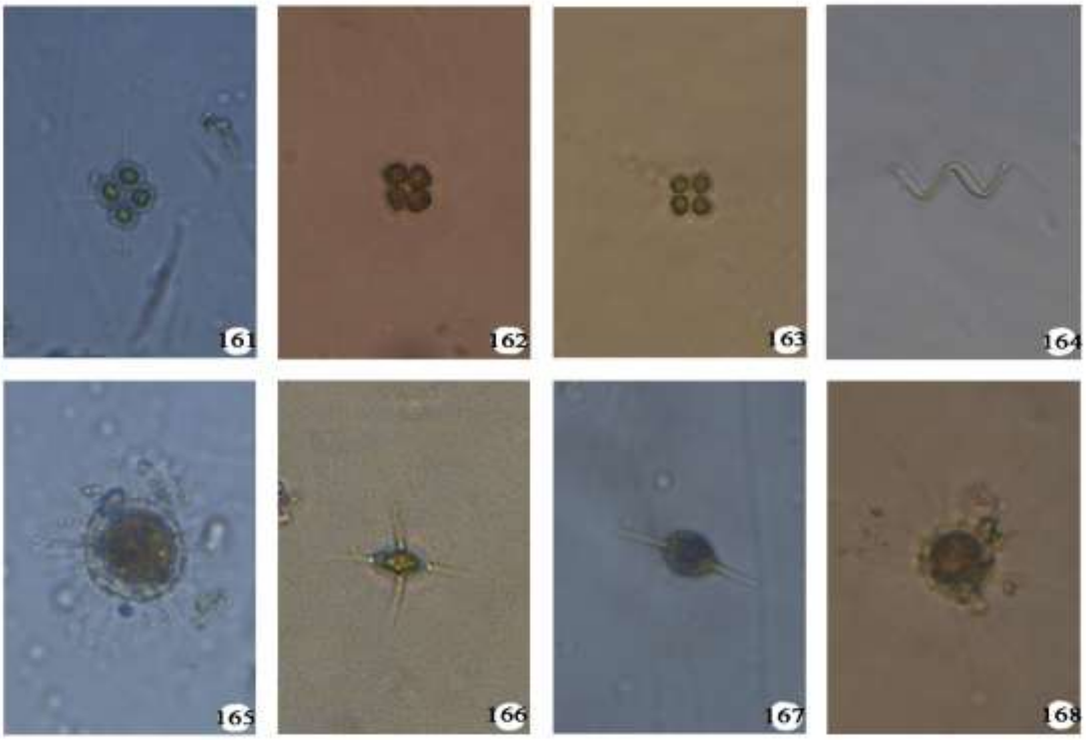


Plate 14

No.	Name of the species
161.	*Tetrastrum elegans*
162.	*T. elegans*
163.	*T. elegans*
164.	*Hyaloraphidium contortum*
165.	*Golenkinia pausispina*
166.	*Lagerheimia wratislaviensis*
167.	*Chlorotetraedron polymorphum*
168.	*Golenkinia pausispina*

Plate 14



Order: Desmidiales

Plate 15

No.	Name of the species
1.	*Arthrodesmus curvatus*
2.	*A. curvatus*
3.	*Closterium toxon* var. *toxon*
4.	*Cl. diane* var. *pseudodiane*
5.	*Cl. angustum* var. *angustum*
6.	*Cl. praelongum* var. *praelongum*
7.	*Cl. limneticum*
8.	*Cl. venus* var. *venus*
9.	*Cl. pitchardianum* var. *angustum*
10.	*Cl. sobulatum* var. *striolatum*
11.	*Cosmarium birame* var. *berbadense*
12.	*C. clepsydra*
13.	*C. contractum* var. *cracoviense* fa. *angulatus*
14.	*C. phaseolus* var. *minutum*
15.	*C. pseudopyramidatum* var. *extensum*
16.	*C. subcostatum*

Plate 15

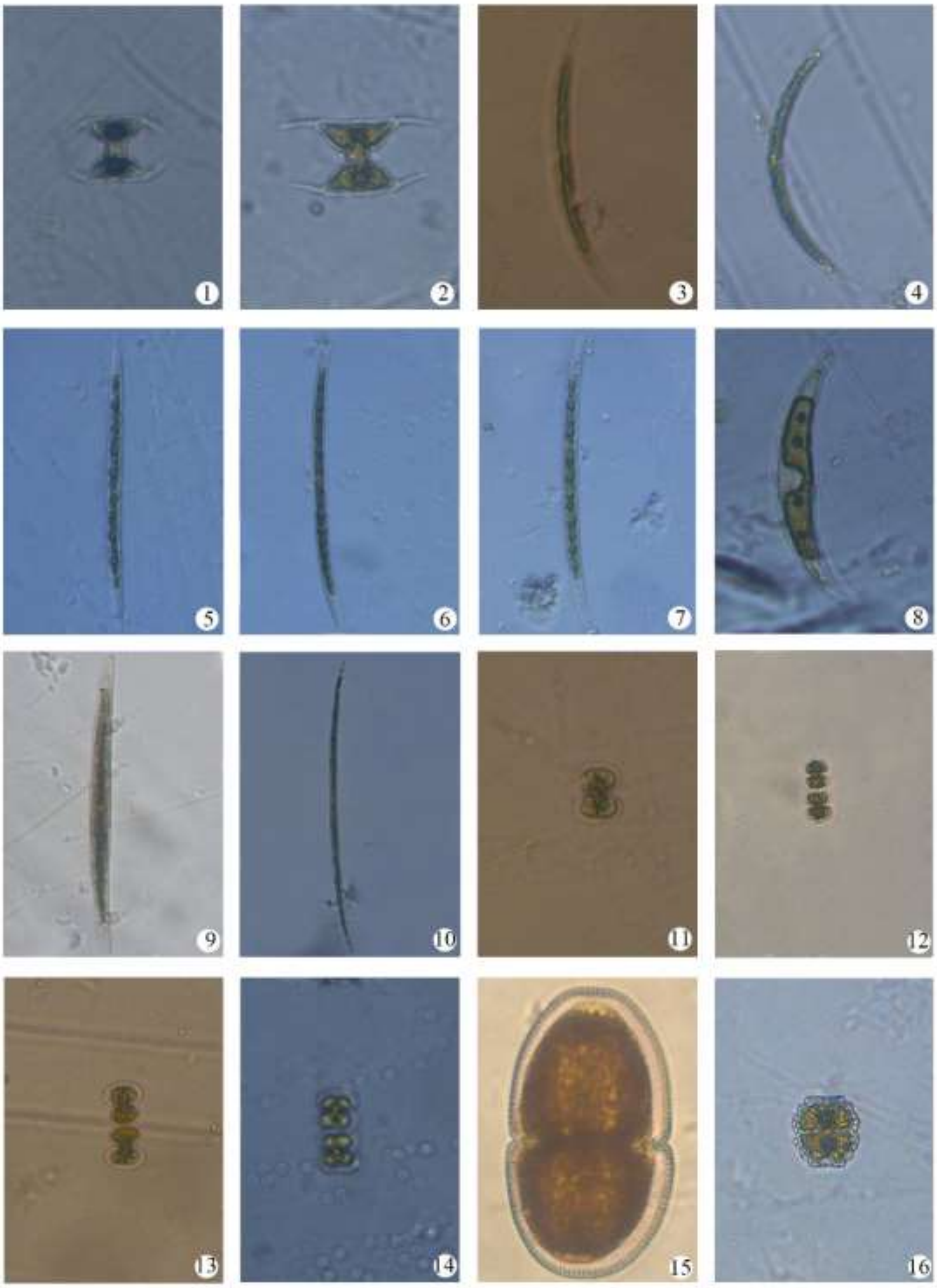


Plate 16

No.	Name of the species
17.	*Cosmarium laeve* var. *octangulare*
18.	*C. moniliforme* var. *moniliforme*
19.	*C. contractum* var. *reductum*
20.	*C. trachypleurum* var. *minus*
21.	*C. pachydermum* var. *pachydermum*
22.	*C. moniliforme* var. *moniliforme*
23.	*C. contractum* var. *reductum*
24.	*C. moniliforme* var. *moniliforme*
25.	*Euastrum denticulatum*
26.	*E. spinolosum* var. *burmense*
27.	*Staurastrum parundulatum*
28.	*S. paradoxum*
29.	*S. paradoxum*
30.	*S. johnsonii*
31.	*S. paradoxum*
32.	*S. pinnatum*

Plate 16

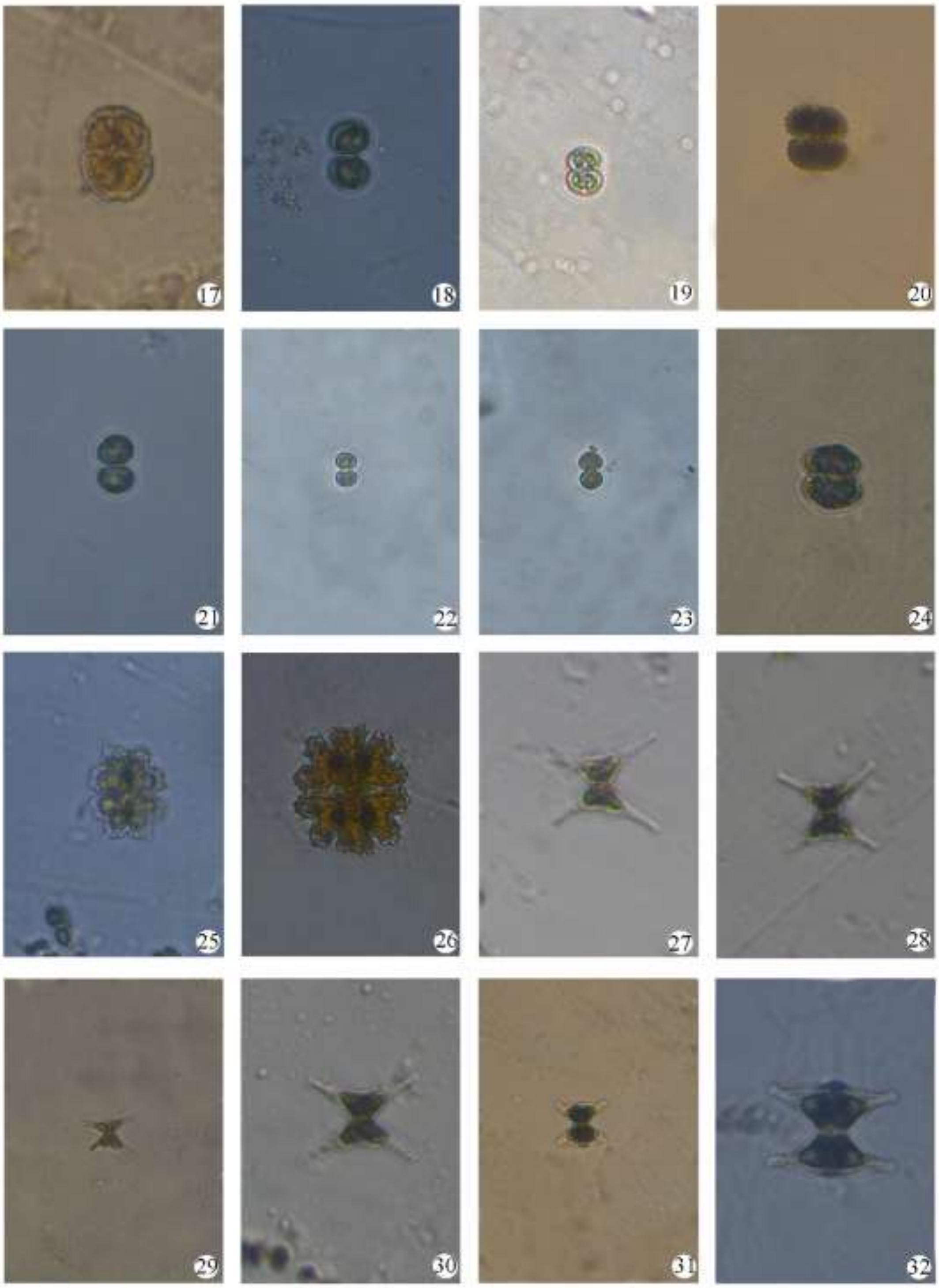
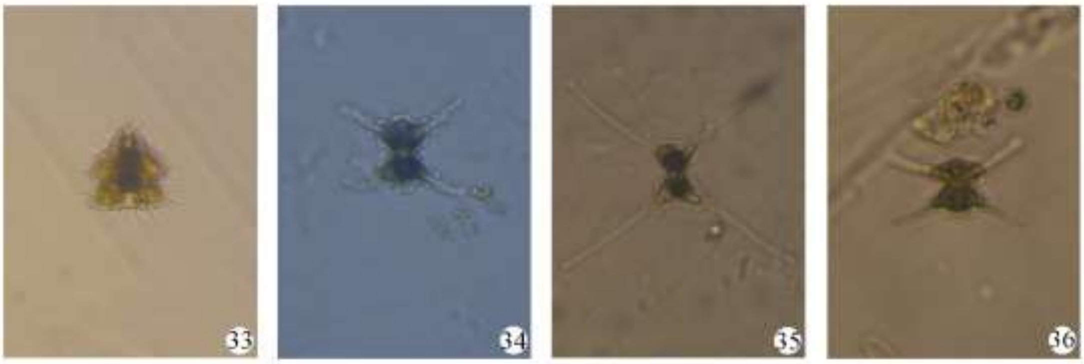


Plate 17

No.	Name of the species
33.	*Staurastrum polymorphum*
34.	*S. gladiosum*
35.	*S. chaetoceros*
36.	*S. acanthocephalum*

Plate 17

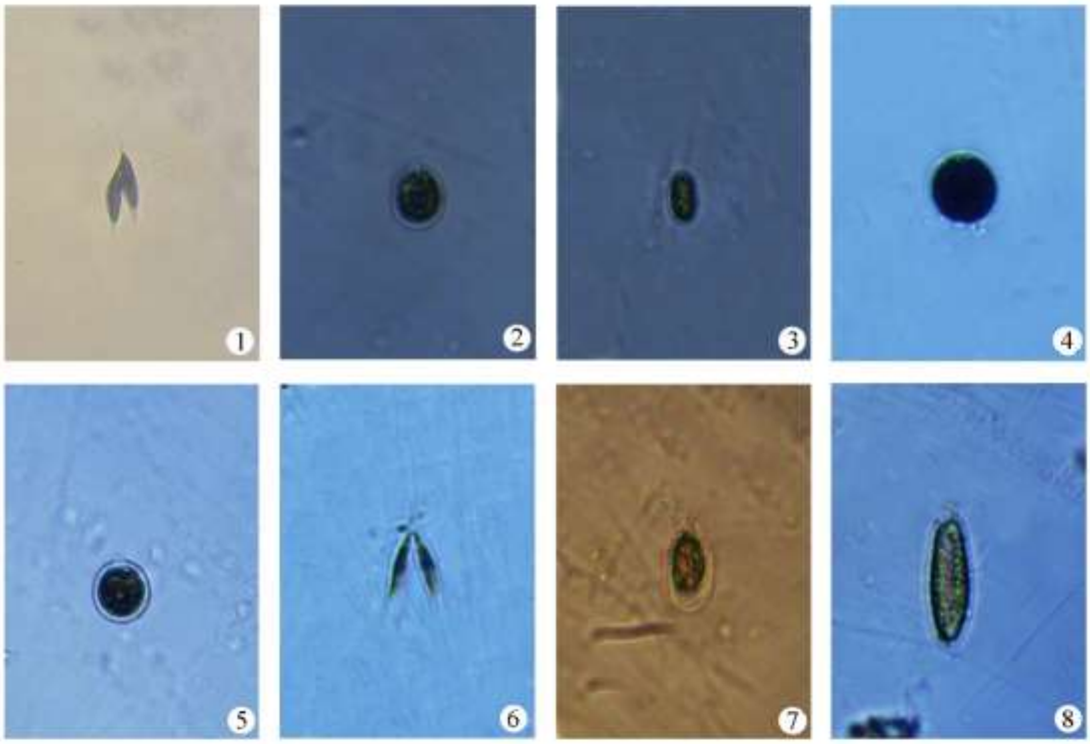


Order: Volvocales

Plate 18

No.	Name of the species
1.	*Chlorogonium elongatum*
2.	*Chlamydomonas pulchra*
3.	*C. gracilis*
4.	*C. pertyi*
5.	*C. globosa*
6.	*Chlorogonium elongatum*
7.	*Phacotus angustus*
8.	*P. lenticularis*

Plate 18



Division: Chrysophyta

Plate 19

No.	Name of the species
1.	*Centritractus belenophorus*
2.	*C. belenophorus*
3.	*Cyclotella comensis*
4.	*C.* meneghiniana
5.	*C. kuetzingiana*
6.	*Cymbella cistula*
7.	*C. affinis*
8.	*Eunotia monodon*
9.	*E. pectinalis* fa. *minor*
10.	*E. pectinalis* var. *valvariae*
11.	*E. veneris*
12.	*E. lunaris*
13.	*Cymbella ventricosa*
14.	*C. stuxbergii*
15.	*Eunotia alpina*
16.	*Amphora veneta*

Plate 19

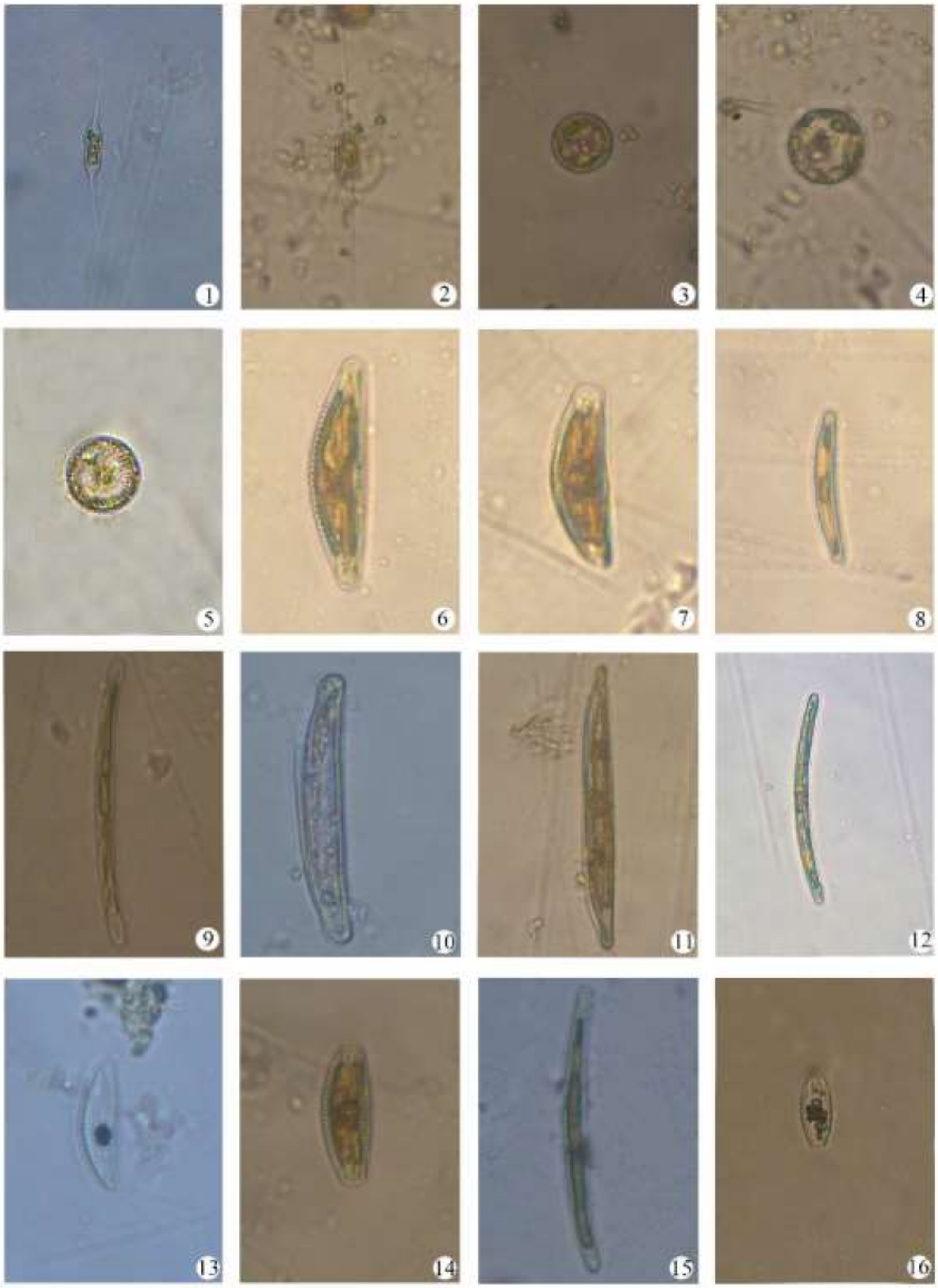


Plate 20

No.	Name of the species
17.	*Fragillaria crotonensis*
18.	*Diatoma vulgare* var. *linearis*
19.	*Gomphonema longiceps* var. *subclavata*
20.	*G. pervulum*
21.	*G. lanceolatum* var. *turnis*
22.	*G. sphaerophorum*
23.	*G. longiceps* var. *subclavata*
24.	*G. lanceolatum* var. *turnis*
25.	*G. lanceolatum* var. *insignis*
26.	*G. pervulum*
27.	*Gyrosigma attenuatum*
28.	*G. scalproides*
29.	*Melosira distans* var. *alpigena*
30.	*M. granulata*
31.	*M. granulata* var. *angustissima*
32.	*M. granulata* var. *angustissima*

Plate 20

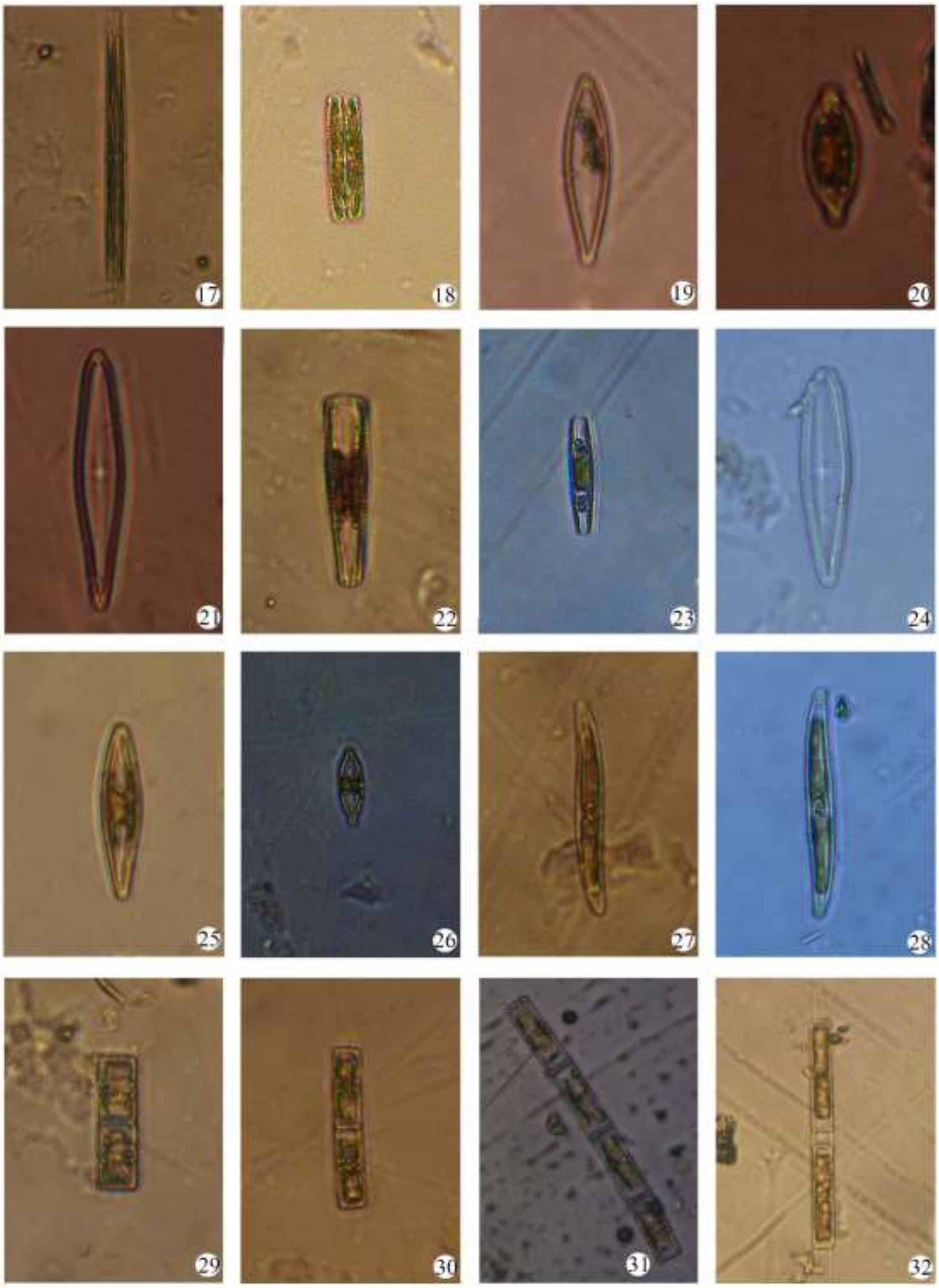


Plate 21

No.	Name of the species
33.	*Navicula grimmei*
34.	*N. exigua*
35.	*N. radiosa*
36.	*N. pseudohalophila*
37.	*N. pseudohalophila*
38.	*N. pupula*
39.	*N. pupula* var. *capitata*
40.	*N. placentula* var. *rostrata*
41.	*N. placentula* var. *rostrata*
42.	*N. spicula*
43.	*Stauroneis anceps* fa. *gracilis*
44.	*Navicula bacillum*
45.	*N. integra*
46.	*N. radiosa*
47.	*N. placentula* var. *rostrata*
48.	*N. pseudohalophila*

Plate 21

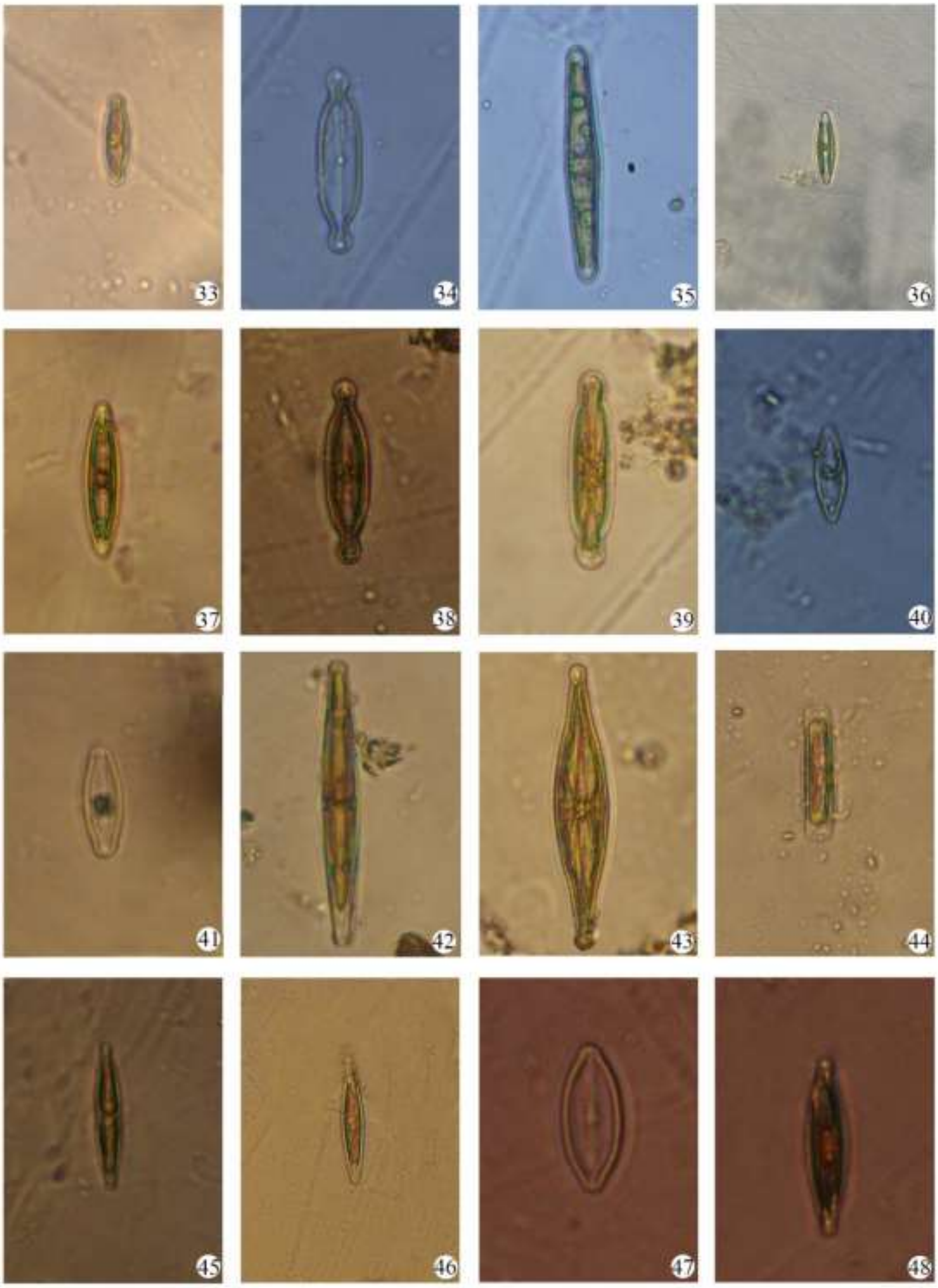


Plate 22

No.	Name of the species
49.	*Synedra acus*
50.	*Nitzschia acicularis*
51.	*N. gracilis*
52.	*N. acicularis var. closteroides*
53.	*N. longissima*
54.	*N. menisculus*
55.	*Pinnularia microstauron*
56.	*P. gibba* var. *parva*
57.	*P. gibba* var. *parva*
58.	*P. gibba* var. mesogonglya
59.	*P. stauroptera*
60.	*P. acrosphaeria*
61.	*P. stauroptera*
62.	*P. microstauron*
63.	*P. karelica* var. *tibetana*
64.	*P. stauroptera*

Plate 22

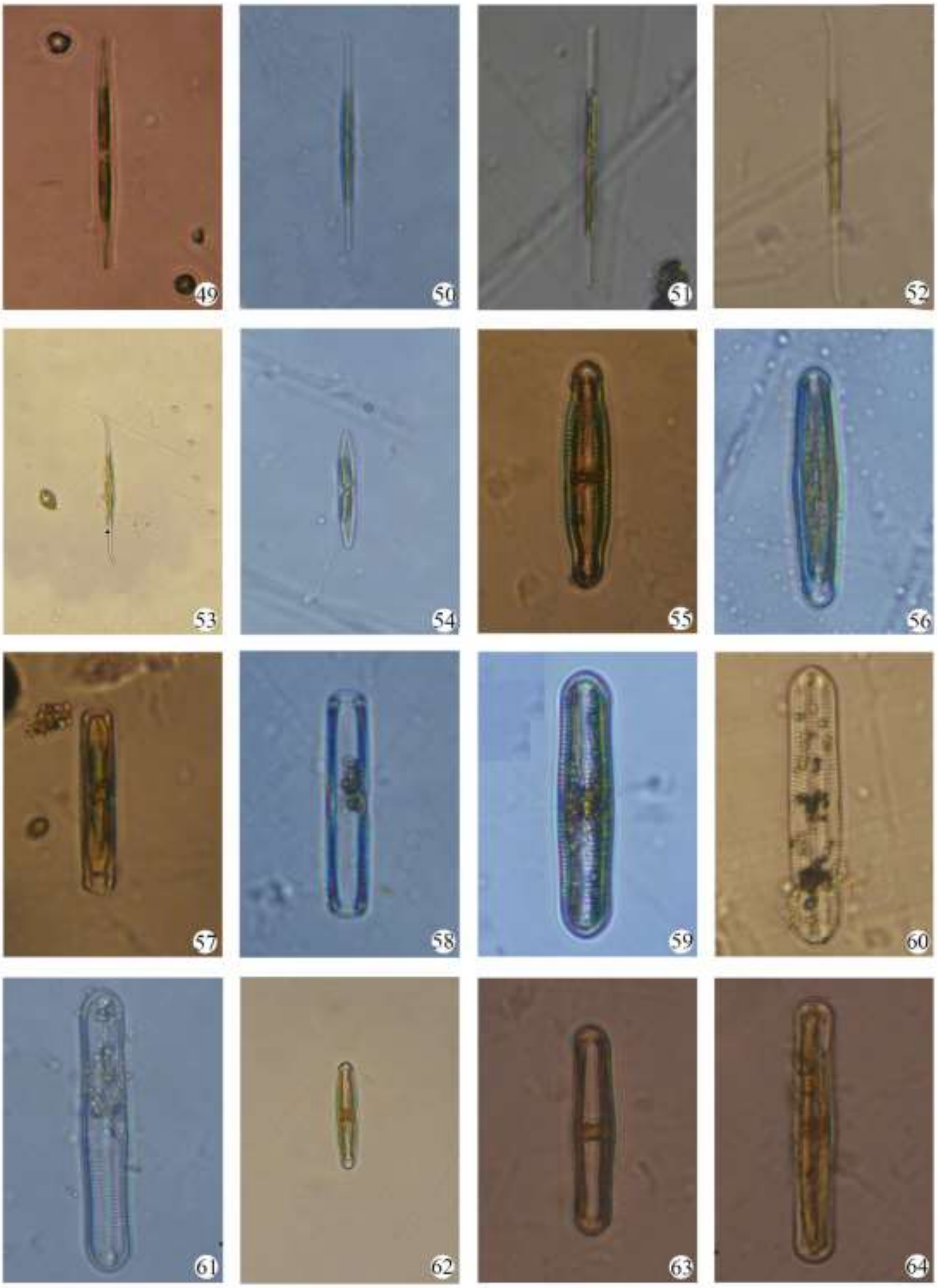
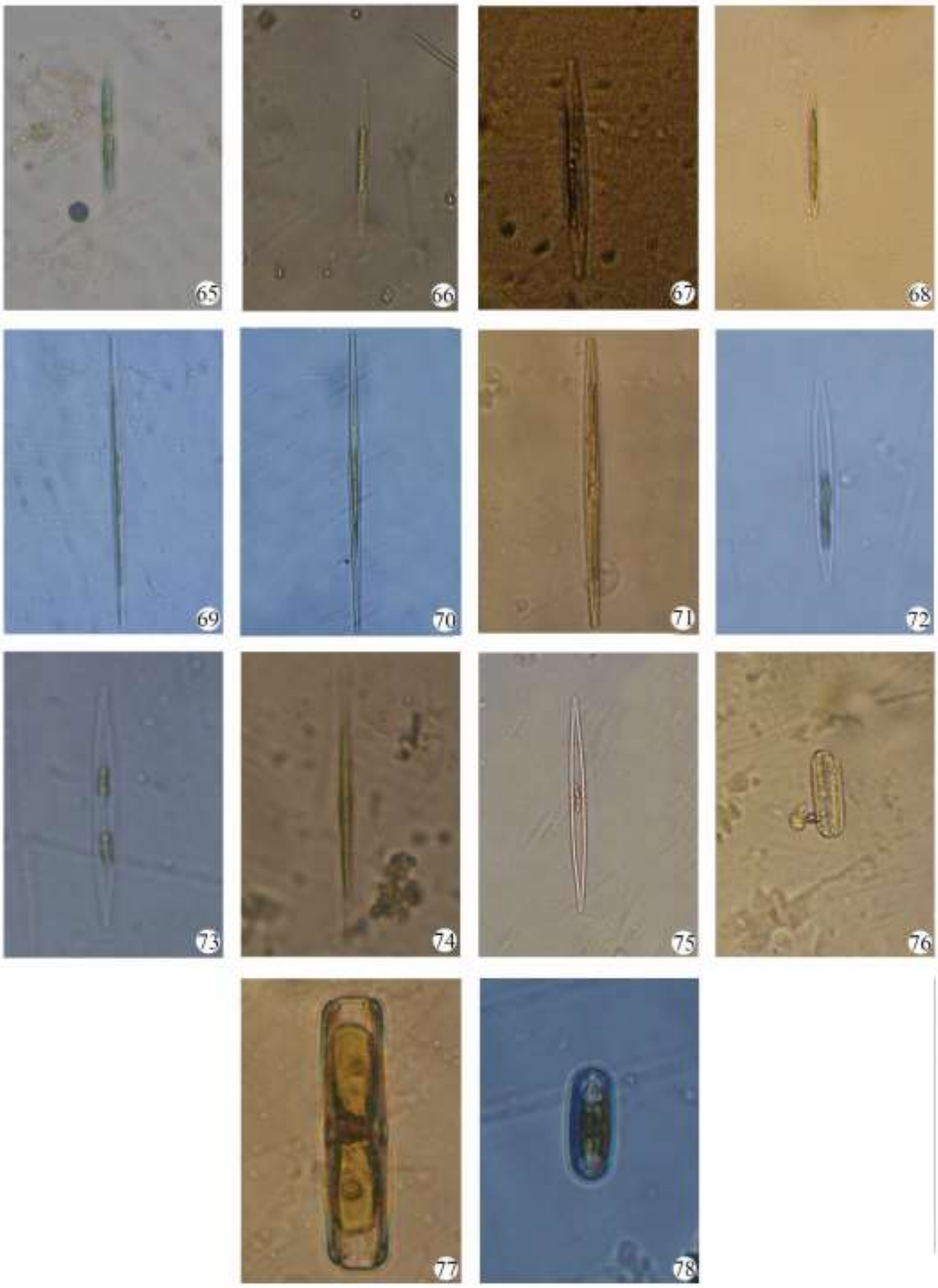


Plate 23

No.	Name of the species
65.	*Synedra vaucheri*
66.	*Nitzschia alpina*
67.	*Synedra ulna* var. *oxyrhynchus*
68.	*S. tabulata*
69.	*S. ulna* var. *danica*
70.	*S. rumpens* var. *familiaris*
71.	*S. ulna* var. *danica*
72.	*Nitzschia subtubicola*
73.	*N. subtubicola*
74.	*Synedra ulna* var. *oxyrhynchus*
75.	*N. pungens*
76.	*Navicula americana*
77.	*Pinnularia krookii.*
78.	*Navicula americana*

Plate 23



Division: Euglenophyta

Plate 24

No.	Name of the species
1.	*Euglena acus* var. *longissima*
2.	*E. ehrenbergii*
3.	*E. limnophila*
4.	*E. allorgei*
5.	*E. hemichromata*
6.	*E. güntheri*
7.	*E. granulata*
8.	*E. sociabilis*
9.	*E. mutabilis* var. *lafevri*
10.	*E. pseudospiroides*
11.	*E. allorgei*
12.	*E. spathirhyncha*
13.	*E. tripteris*
14.	*E. acus*
15.	*E. oxyuris* var. *minor*
16.	*E. exilis*

Plate 24

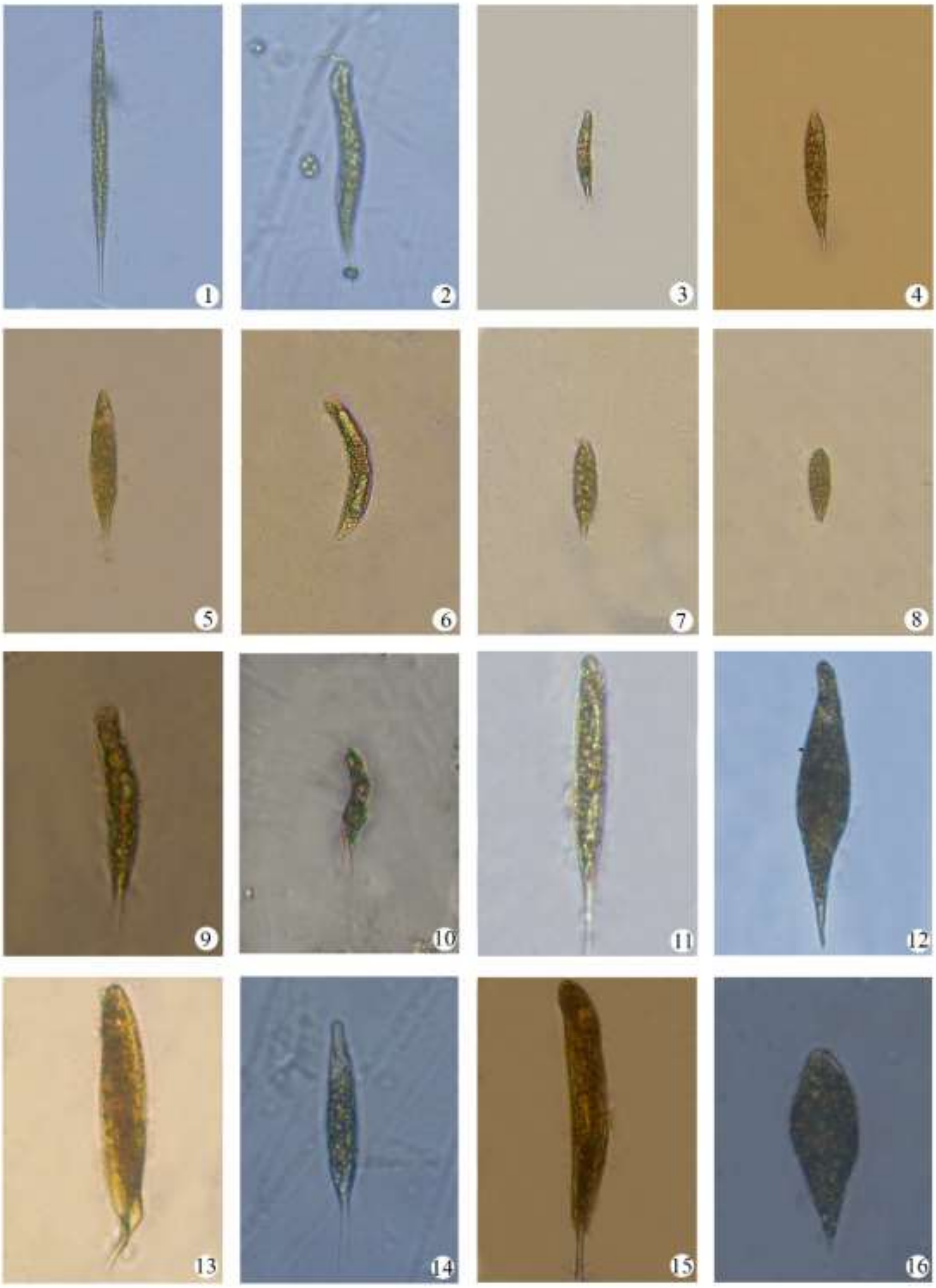


Plate 25

No.	Name of the species
17.	*Euglena clavata*
18.	*E. oblonga*
19.	*E. granulata*
20.	*E. hemichromata*
21.	*E. rubra*
22.	*E. australica* var. *claviformis*
23.	*E. chlamydophora*
24.	*E. oxyuris* var. *charkowiensis*
25.	*E. platydesma*
26.	*E. australica*
27.	*E. agilis var. praecxicisa*
28.	*E. güntheri*
29.	*Lepocinclis salina*
30.	*L. texta* fa. *minor*
31.	*L. acuta*
32.	*L. cymbiformis*

Plate 25

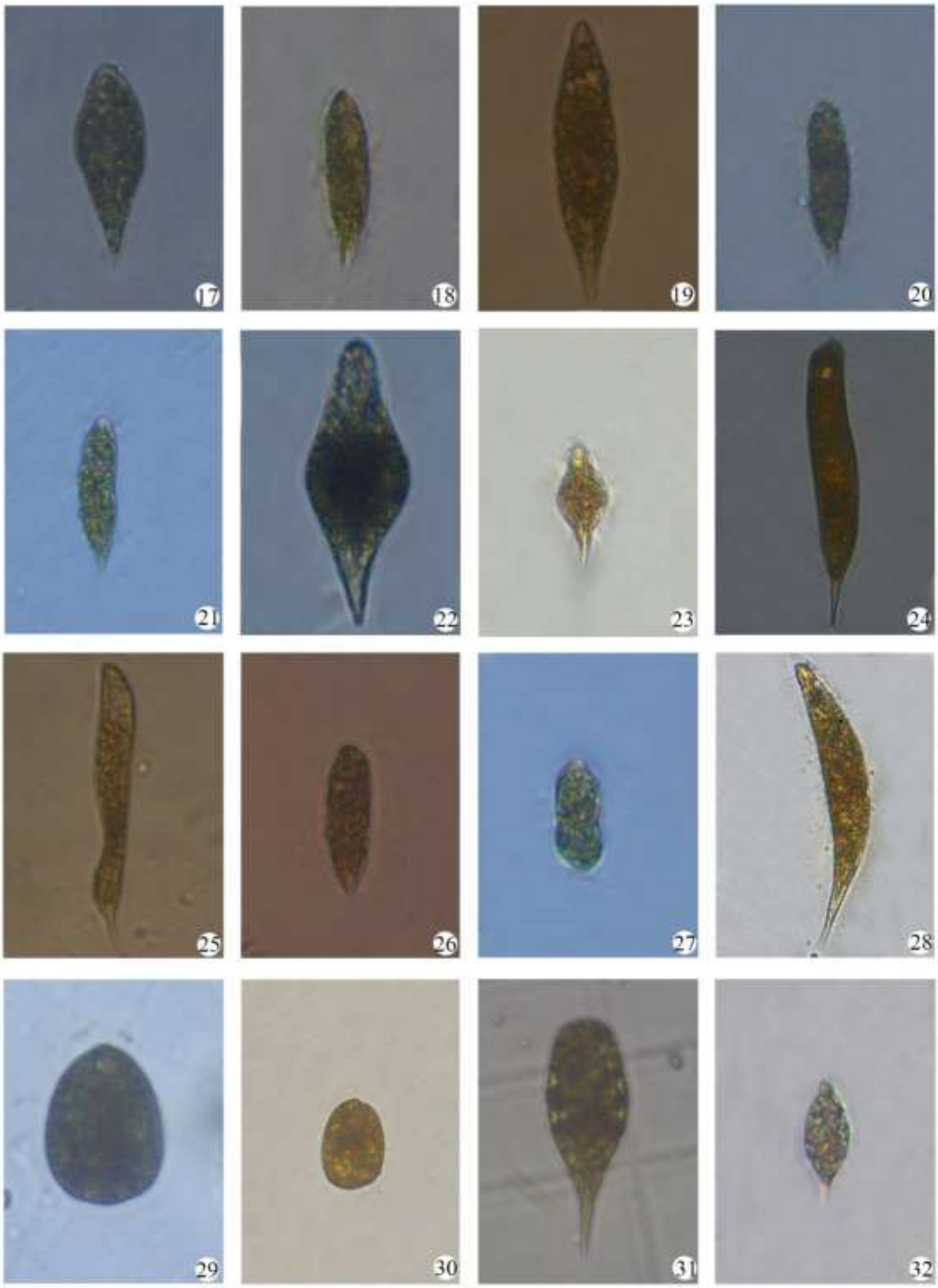


Plate 26

No.	Name of the species
33.	*Lepocinclis playfairiana*
34.	*L. salina* fa. *obtusa*
35.	*L. ovum* var. *bütschlii*
36.	*L. cymbiformis*
37.	*L. playfairiana*
38.	*Phacus longicauda* var. *attenuata*
39.	*P. longicauda* var. *major*
40.	*P. lismorensis*
41.	*P. circumflexus*
42.	*P. helikoides*
43.	*P. acuminatus* var. *acuminatus*
44.	*P. curvicauda*
45.	*P. acuminatus* var. *granulata*
46.	*P. bicarinatus*
47.	*P. longicauda* var. *rotunda*
48.	*P. pleuronectes*

Plate 26

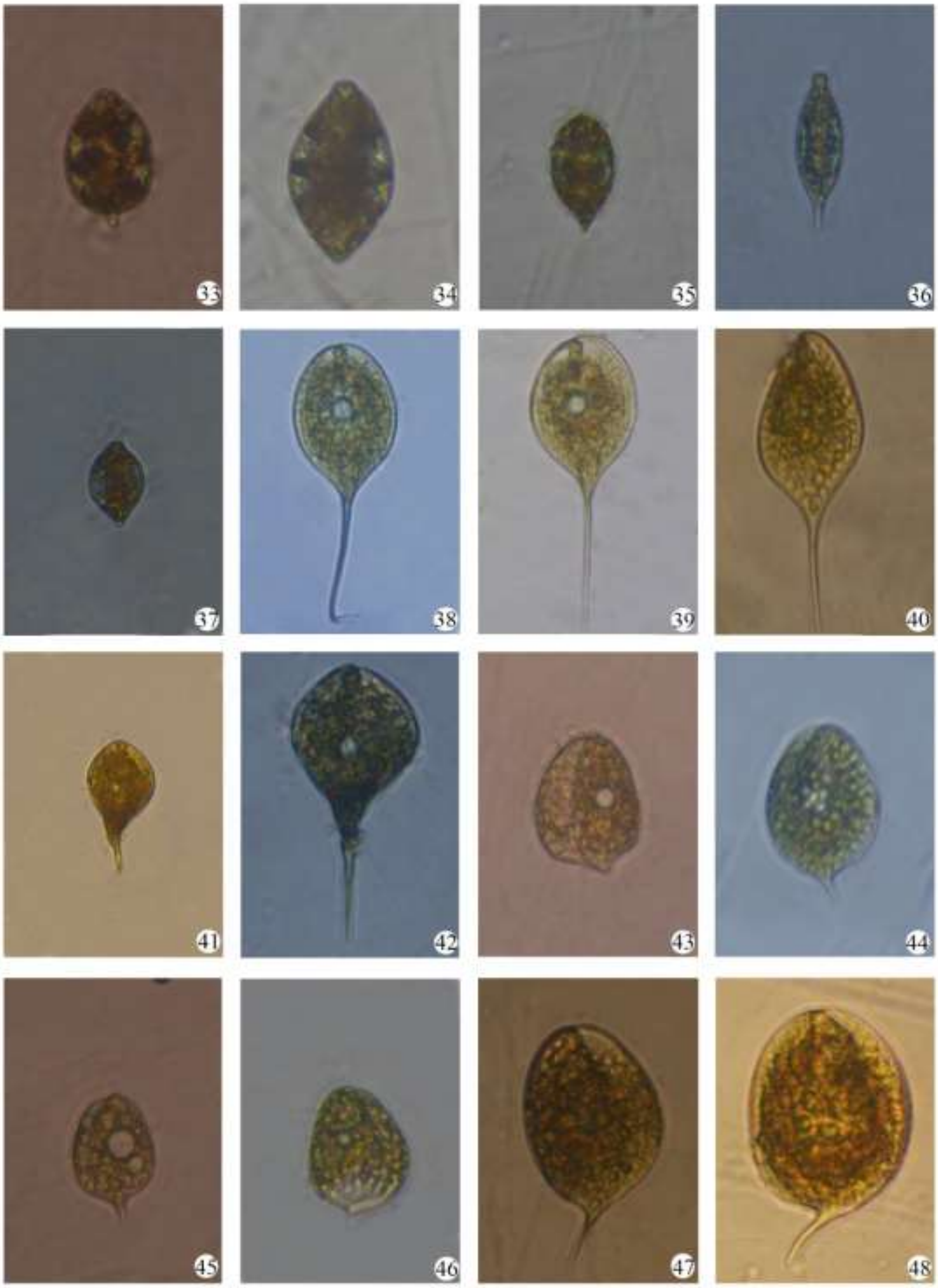


Plate 27

No.	Name of the species
49.	*Phacus orbicularis* var. *caudatus*
50.	*P. horridus*
51.	*P. inflatus*
52.	*P. suecious* var. *oidion*
53.	*P. rotunda*
54.	*P. helicoides*
55.	*P. hamelii*
56.	*P. orbicularis* var. *caudatus*
57.	*Trachelomonas oblonga*
58.	*T. volvocina*
59.	*T. volvocina* var. *punctata*
60.	*T. volvocinopsis*
61.	*T. oblonga* var. *truncata*
62.	*T. intermedia*
63.	*T. raciborskii*
64.	*T. anulifera* var. *semi-ornata*

Plate 27

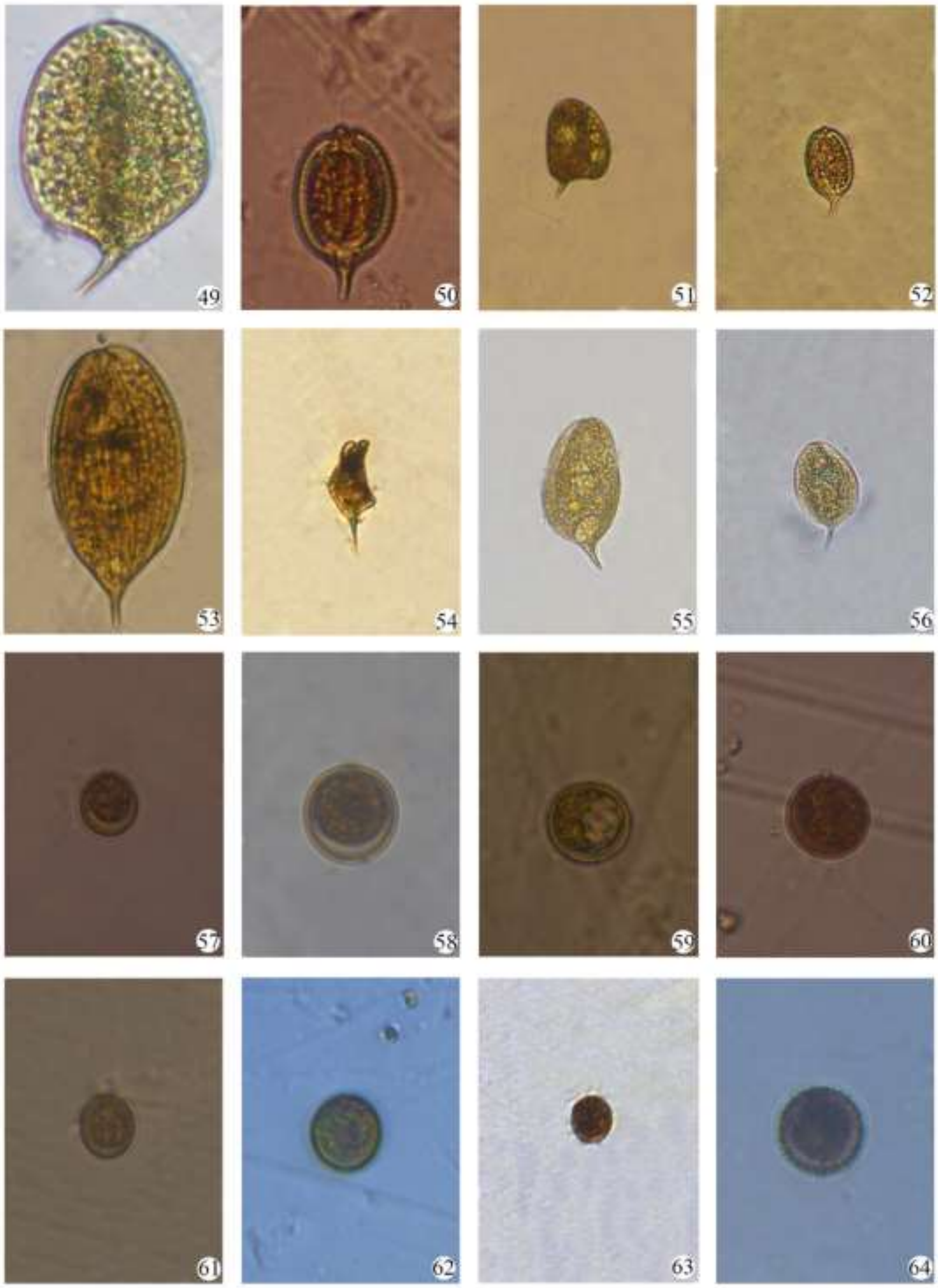


Plate 28

No.	Name of the species
65.	*Trachelomonas volvocinopsis* var. *khanne*
66.	*T. mucosa* var. *brevicollis*
67.	*T. Lismorensis* var. *inermis*
68.	*T. anulifera* var. *semi-ornata*
69.	*T. volvocinopsis*
70.	*T. mucosa* var. *brevicollis*
71.	*T. volvocina* var. *derephora*
72.	*T. volvocina* var. *punctata*
73.	*T. lismorensis* var. *inermis*
74.	*T. rogulosa*
75.	*T. oblonga*
76.	*T. oblonga* var. *truncata*
77.	*T. playfairii*
78.	*T. planctonica*
79.	*T. sydneyensis*
80.	*T. hispida* var. *punctata*

Plate 28

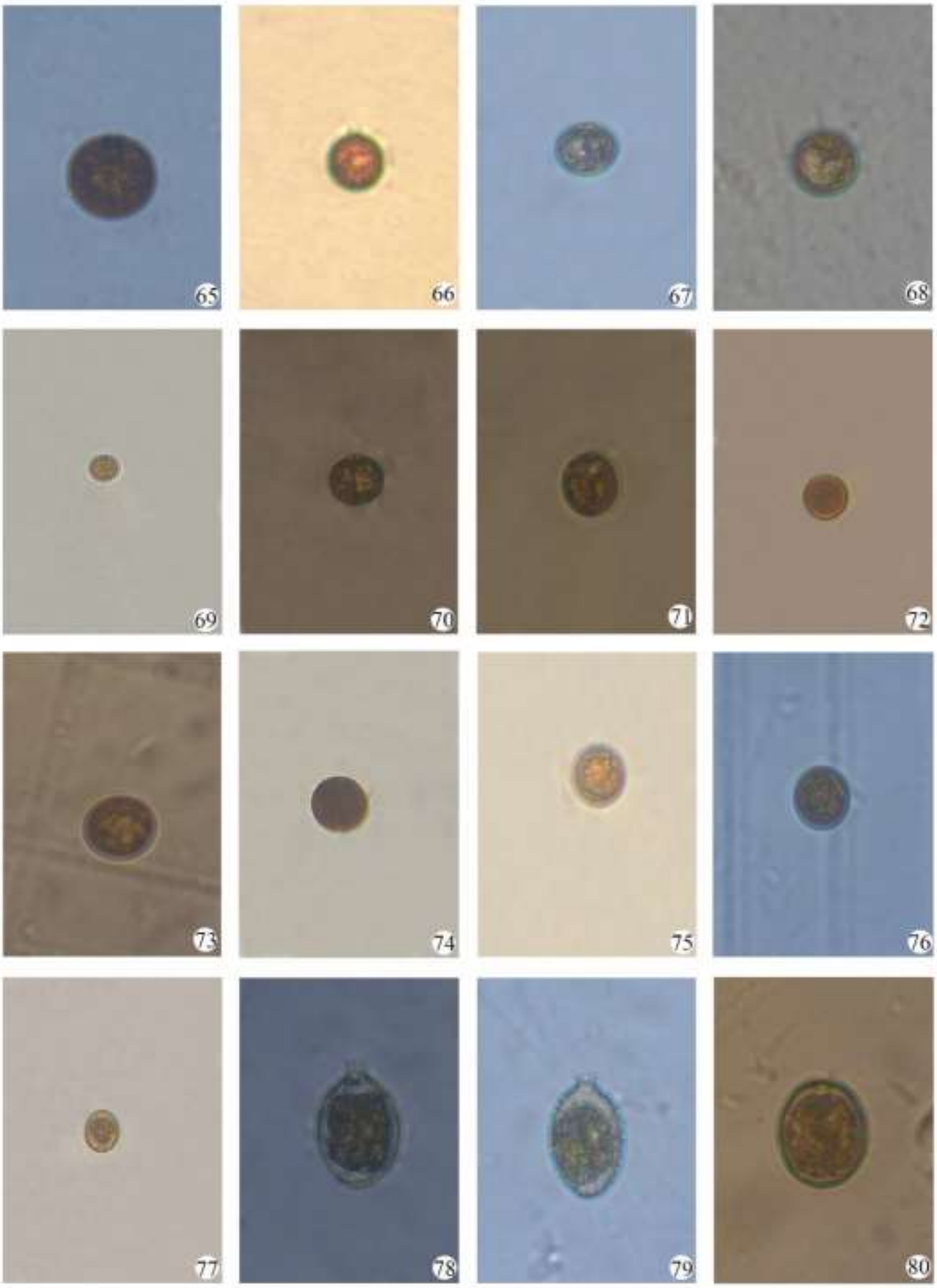


Plate 29

No.	Name of the species
81.	*Trachelomonas playfairii*
82.	*T. raciborskii*
83.	*T. mirabilis* var. *minor*
84.	*T. planctonica* var. *oblonga*
85.	*T. armata* var. *longispina*
86.	*T. lacustris* var. *ovalis*
87.	*T. nadsoni*
88.	*T. anguste-ovata* fa. *minor*
89.	*T. armata* var. *rangpurense*
90.	*T. dybowskii*
91.	*T. hispida* var. *punctata*
92.	*T. anulifera* var. *semiornata*
93.	*Strombomonas napiformis*
94.	*T. armata*
95.	*T. abrupta* var. *arcuata*
96.	*T. nadsoni* var. *acuta*

Plate 29

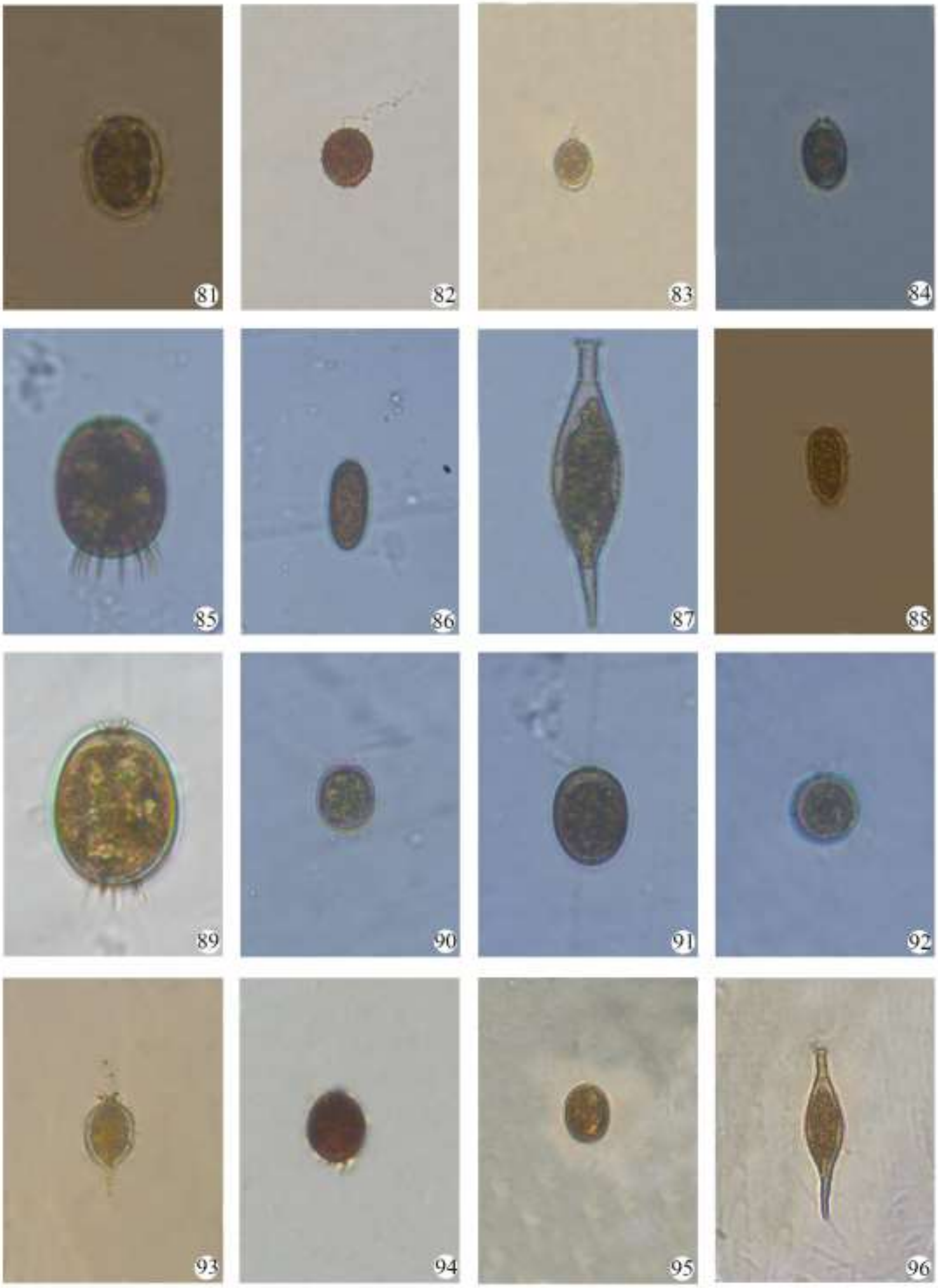
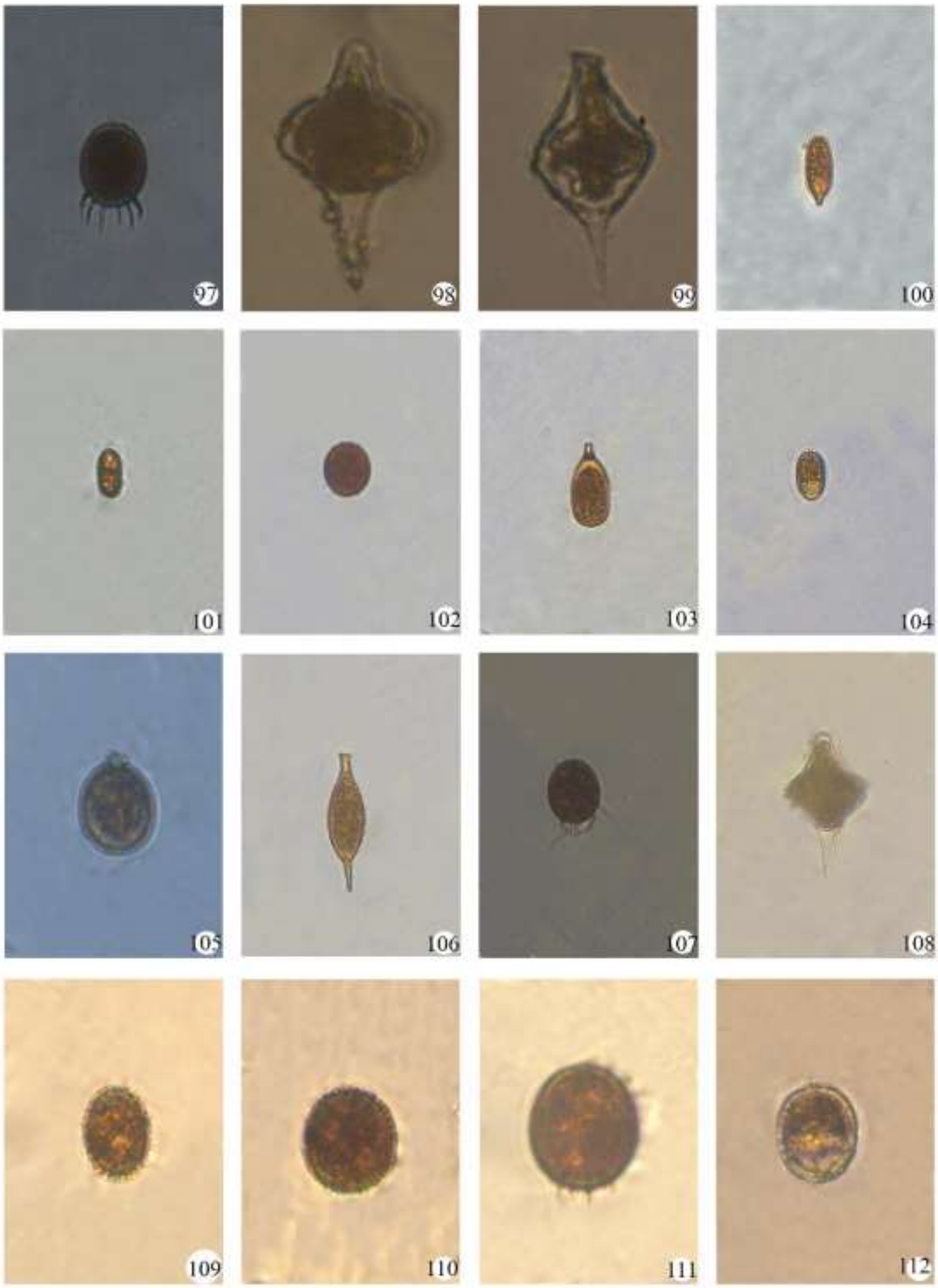


Plate 30

No.	Name of the species
97.	*Trachelomonas armata* var. *longispina*
98.	*Strombomonas gibberosa* var. *longicollis*
99.	*S. gibberosa*
100.	*Trachelomonas anguste-ovata*
101.	*T. lacustris* var. *ovalis*
102.	*T. raciborskii*
103.	*T. volzii*
104.	*T. lacustris* var. *ovalis*
105.	*T. palyfairii*
106.	*T. nadsoni*
107.	*T. armata* var. *longispina*
108.	*Strombomonas gibberosa*
109.	*Trachelomonas raciborskii*
110.	*T. raciborskii*
111.	*T. armata* var. *rangpurense*
112.	*T. raciborskii*

Plate 30



Division-Cryptophyta

Plate 31

No.	Name of the species
1.	*Cryptomonas reflexa var. recurva*
2.	*C. reflexa*
3.	*C. ovata*
4.	*C. lucens*
5.	*Chilomonas acuta* var. *insignis*
6.	*C. paramaecium*
7.	*Cryptomonas erosa*
8.	*C. obovata*
9.	*C. refexa* var. *recurva*
10.	*C. lucens*
11.	*C. refexa* var. *recurva*
12.	*C. reflexa*
13.	*Rhodomonas minuta*
14.	*Chilomonas paramaecium*
15.	*C. acuta* var. *insignis*
16.	*C. obovata*

Plate 31

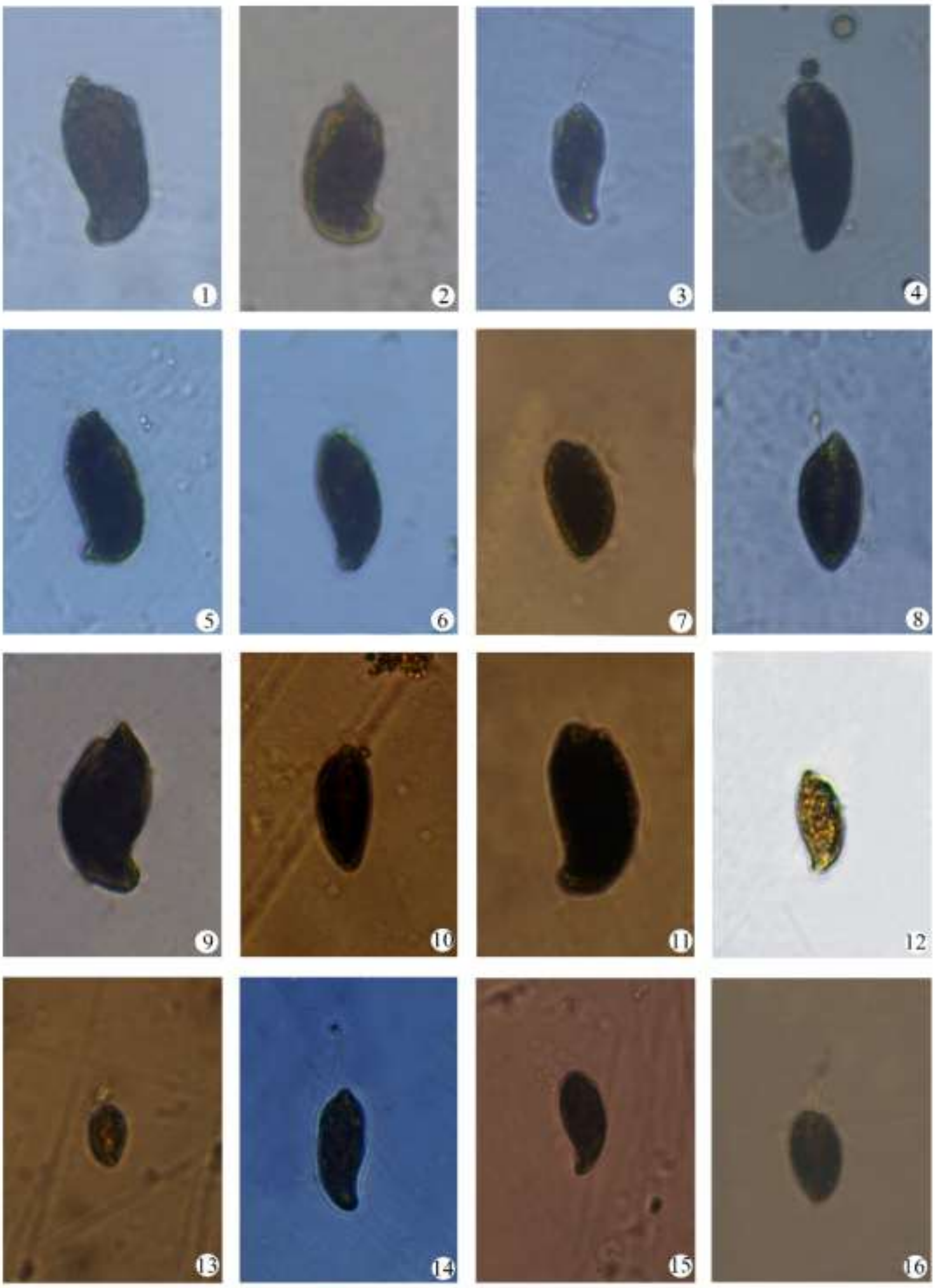
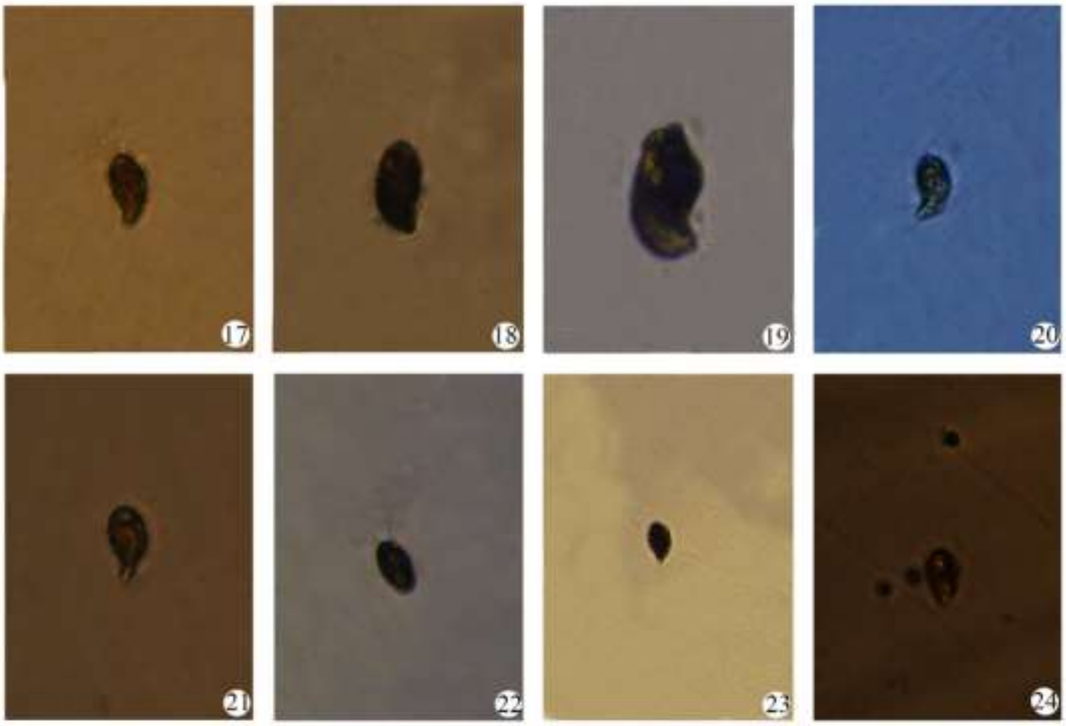


Plate 32

No.	Name of the species
17.	*Rhodomonas lacustris*
18.	*R. minuta*
19.	*Cryptomonas reflexa* var. *recurva*
20.	*Rhodomonas minuta* var. *nanoplanktica*
21.	*Chroomonas acuta*
22.	*Cryptomonas phaseolus*
23.	*Chroomonas acuta*
24.	*Rhodomonas lacustris*

Plate 32

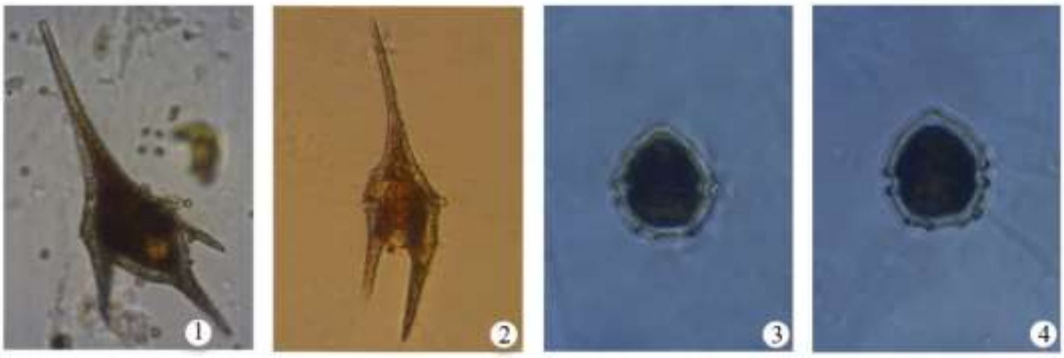


Division: Dinophyta

Plate 33

No.	Name of the species
1.	*Ceratium hirundinella*
2.	*C. hirundinella*
3.	*Peridinium abei*
4.	*P. abei*

Plate 33



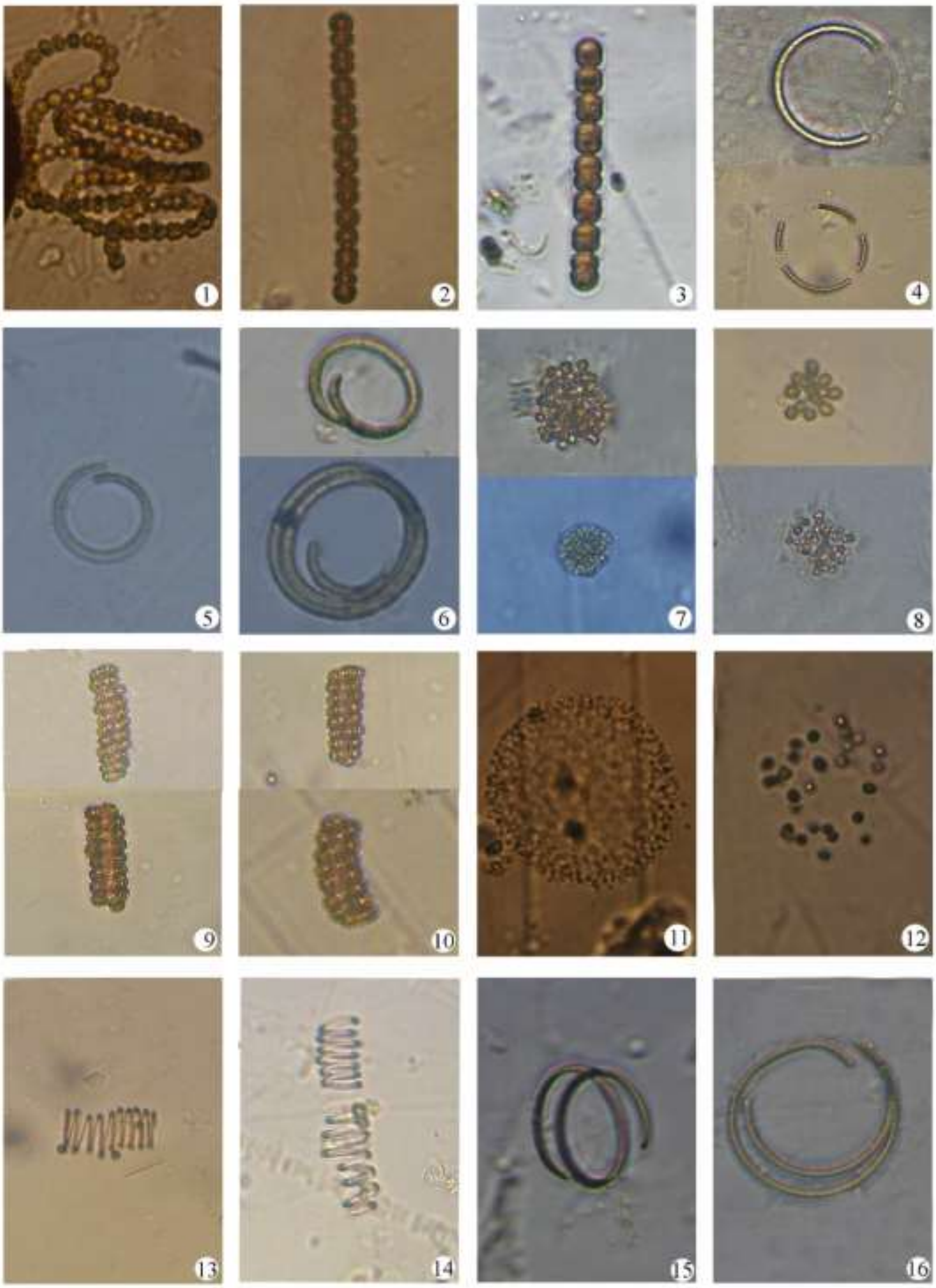
Photomicrographs of the probitionary new list of phytoplankton for Bangladesh

Division Cyanophyta

Plate 1

No.	Name of the species
1.	*Anabaena spiroides* (Woronichin) Elenkin
2-3.	*Pseudoanabaena constricta* (Szafar) Lauterborn
4-5.	*Cylindrospermopsis curvispora* M. Watanabe
6.	*Lyngbya contorta* fa.
7.	*Gomphosphaeria fusca* Skuja
8.	*Xenococcus minumus* fa. *starmarchii* Geitler
9-10.	*Spirulina subsalsa* Oersted ex Gomont
11.	*Gomphosphaeria nageliana* (Unger) Lemm.
12.	*Gomphosphaeria rosea* (Snow) Lemm.
13-14.	*Arthrospira platensis* fa. *granulata* Gomont
15-16.	*L. contorta* var. *contorta* Lemm.

Plate 1

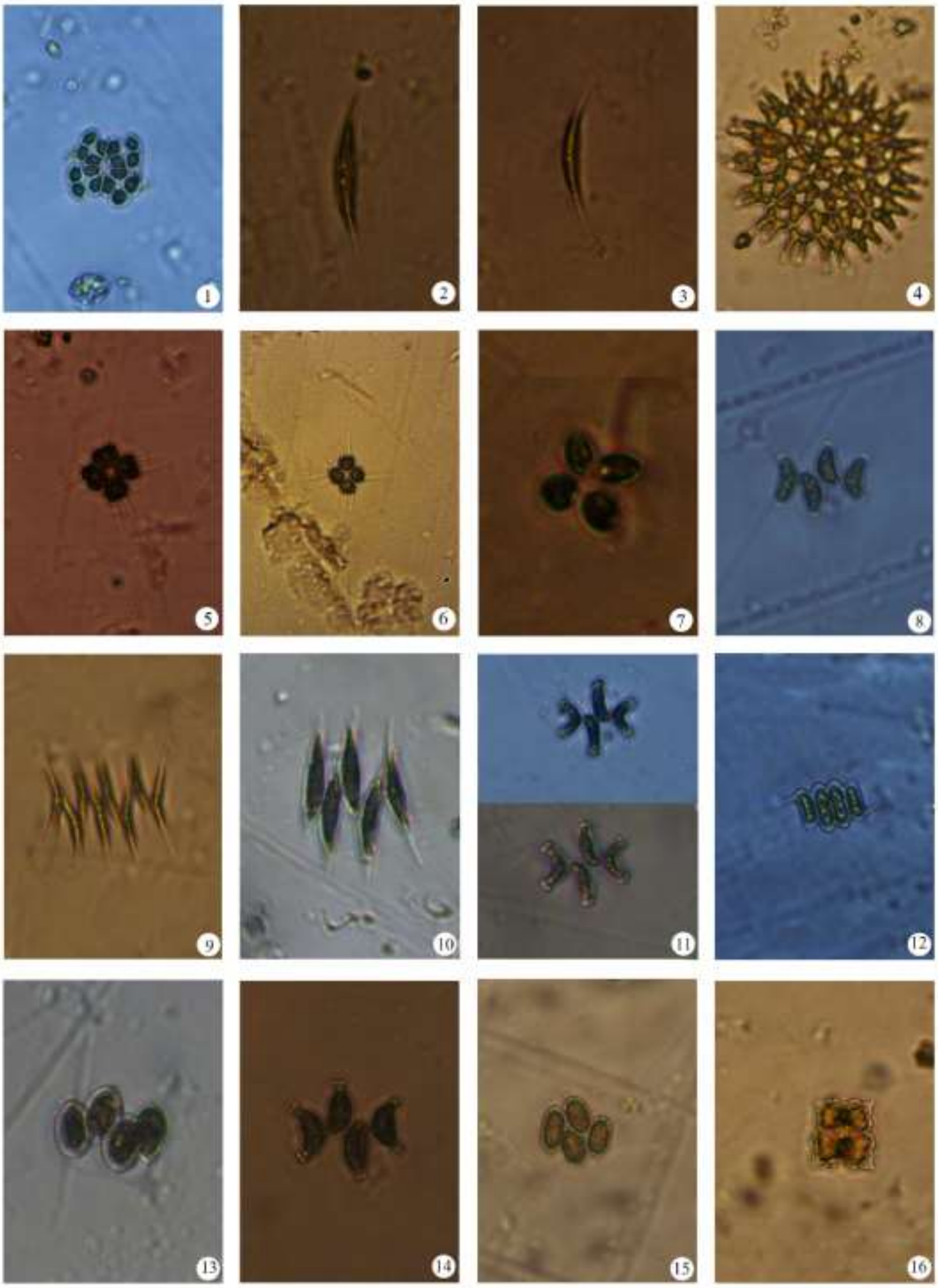


Division: Chlorophyta

Plate 2

No.	Name of the species
1.	*Crucigenia mucronata* (Smith) Kom.
2-3.	*Keratococcus bicaudatus* (Br. ex Rab.) Petersen
4.	*Pediastrum duplex* var. *asperum* Meyen
5-6.	*Tetrastrum heteracanthum* (Nordst.) Chodat
7.	*T. triangulare* (Chodat) Kom.
8.	*Scenedesmus aquatus* var. *globosus*
9.	*S. javanensis* Chodat
10.	*S. bernardii* G. M. Smith
11.	*S. indicus* Philipis ex Hegewald
12.	*Scenedesmus bicaudatus* var. *brevicaudatus* Hortob.
13.	*S. apiculatus* var. *apiculatus* Corda
14.	*S. productocapitatus* Schmula
15.	*S. verrucosus* Y.V. Roll
16.	*Euastrum denticulatum* var. *quqdriferium* F. Gay

Plate 2

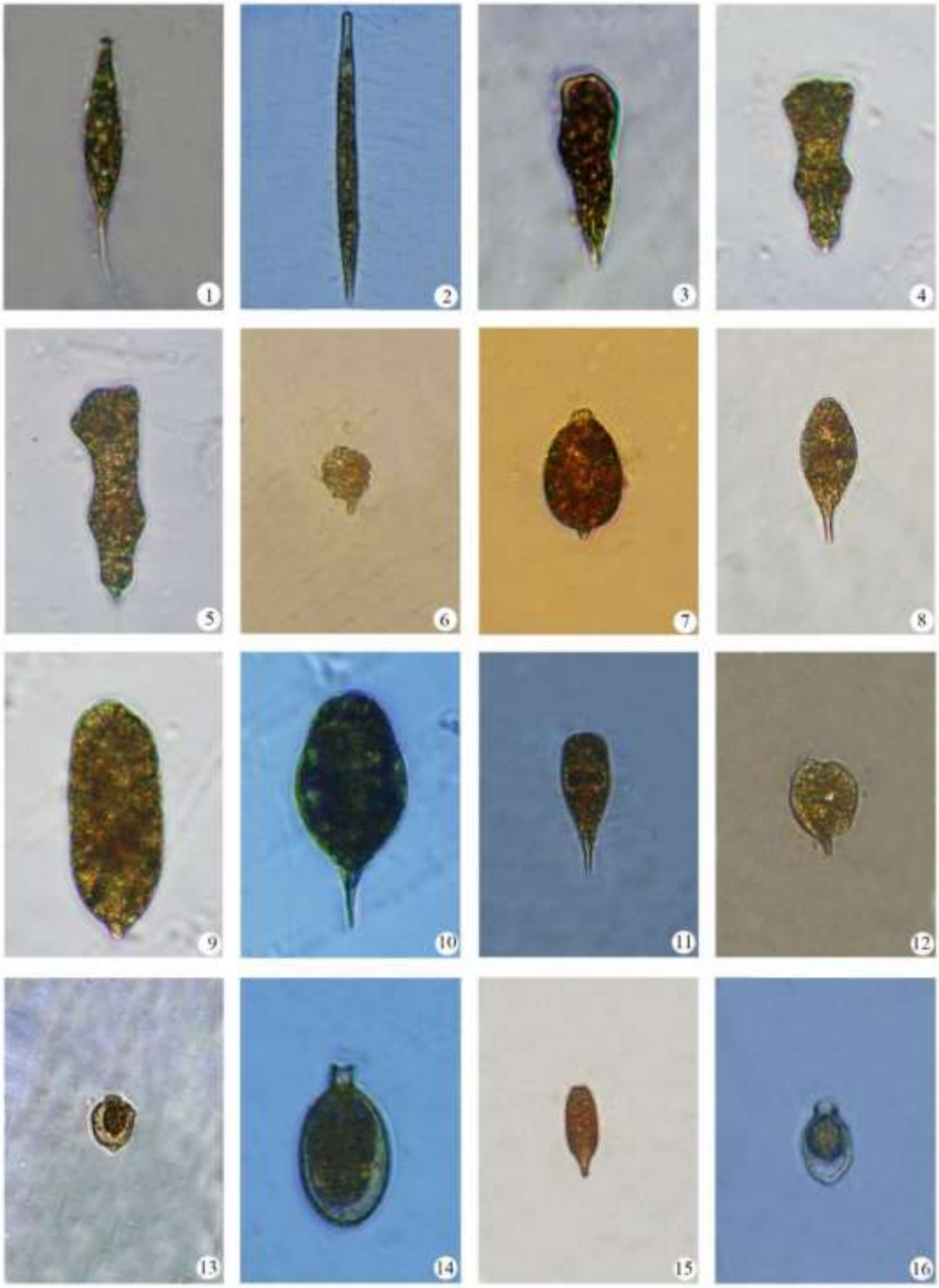


Division Euglenophyta

Plate 3

No.	Name of the species
1.	*Euglena limnophila* var. *lammermanii* Lemm.
2.	*E. klebsii* (Lemm.) Mainx
3.	*E. lucens* E. K.F. Günther
4-5.	*Phacus aenigmaticus* Drez.
6.	*P. monilatus* (Stokes) Lemm.
7.	*Euglena mespiliformis* Skv.
8.	*Lepocinclis caudata* var. *nasuta* (Chunha) Pascher
9.	*Euglena neustonica* F. Gessner
10.	*Lepocinclis caudata* (Chunha) Pascher
11.	*L. paxilliformis* Playfair
12.	*Phacus inflatus* Playfair
13.	*Strombomonas vermonti* (Defl.) Defl.
14.	*T. bulla* F. Stein
15.	*T. crispa* Balech
16.	*T. hexangulare* fa. *lata* Svir.

Plate 3



Macrophytes

List of Macrophytes

Plate-1

No.	Name of the species
1.	*Alternanthera philoxeroides* (Mart.) Griseb.
2.	*Oryza sativa* L.
3.	*Monochoria hastata* L.
4.	*Lwiduigia adscendens* L.
5.	*Enhydra fluctuans* Lour.
6.	*Barringtonia aqutangula (*L.) Geartn.
7.	*Limnocharis* sp.
8.	*Nymphaea noucheli* N. L. Burman

Plate-1

Plate-2

No.	Name of the species
9.	*Trapa* sp
10.	*Polygonum* sp.
11.	*Ipomoea aquatica* Forssk.
12.	*Panicum paludosum* Roxb.
13.	*Pistia stratiotes* L.
14.	*Lemna minor* L.
15.	*Hydrolea sp.*
16.	*Ipomoea camara* sub sp. *fistolosa*

Plate-2

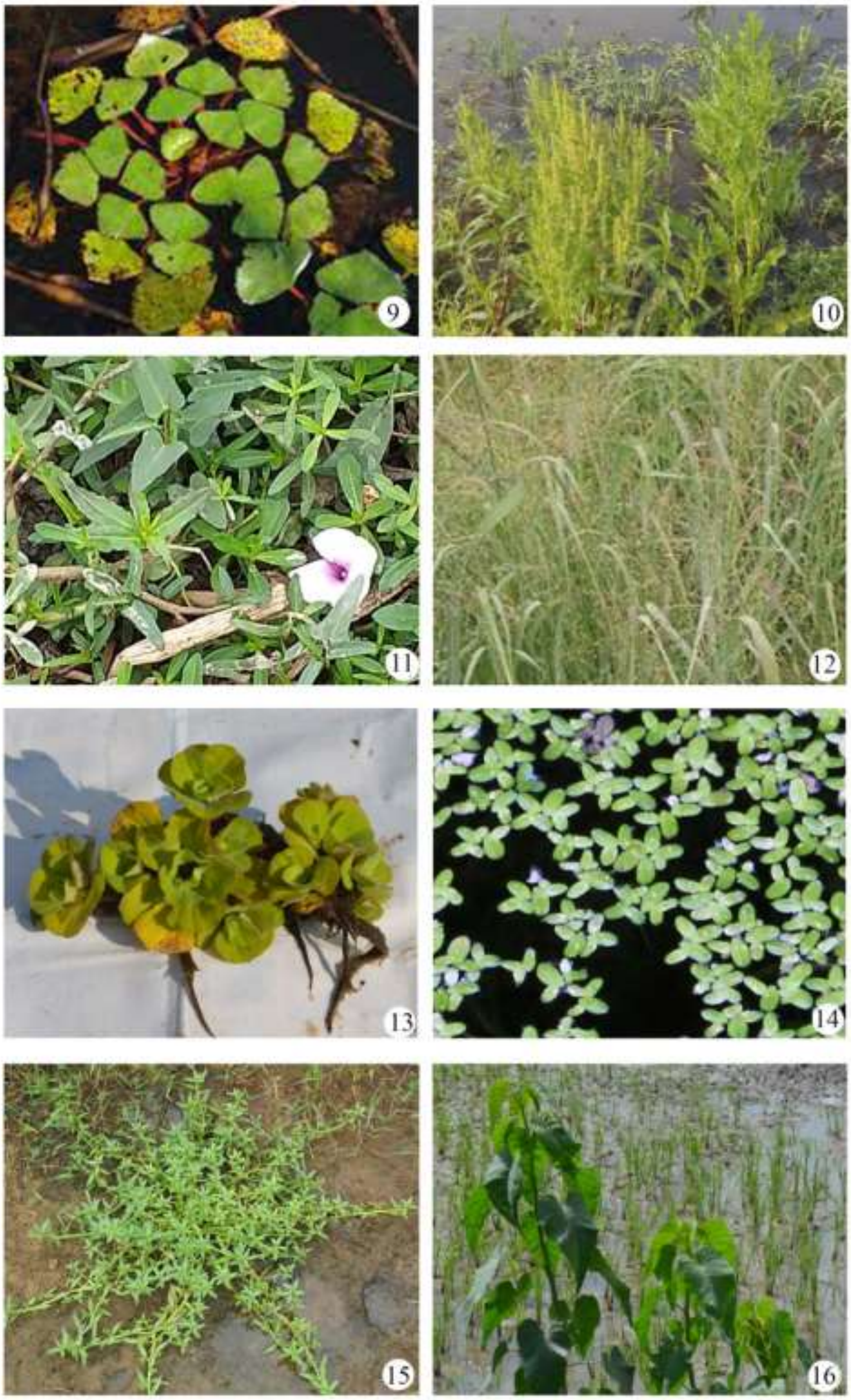


Plate-3

No.	Name of the species
17.	*Utricularia* sp.
18.	*Eichhornia crassipes* L.
19.	*Aponogeton* sp.
20.	*Hygrophila auriculata* L.
21.	*Aeschynomene* sp.
22.	*Cyperus* sp.
23.	*Alternanthera* sp.
24.	*Heliotropium indicum* L.

Plate 3

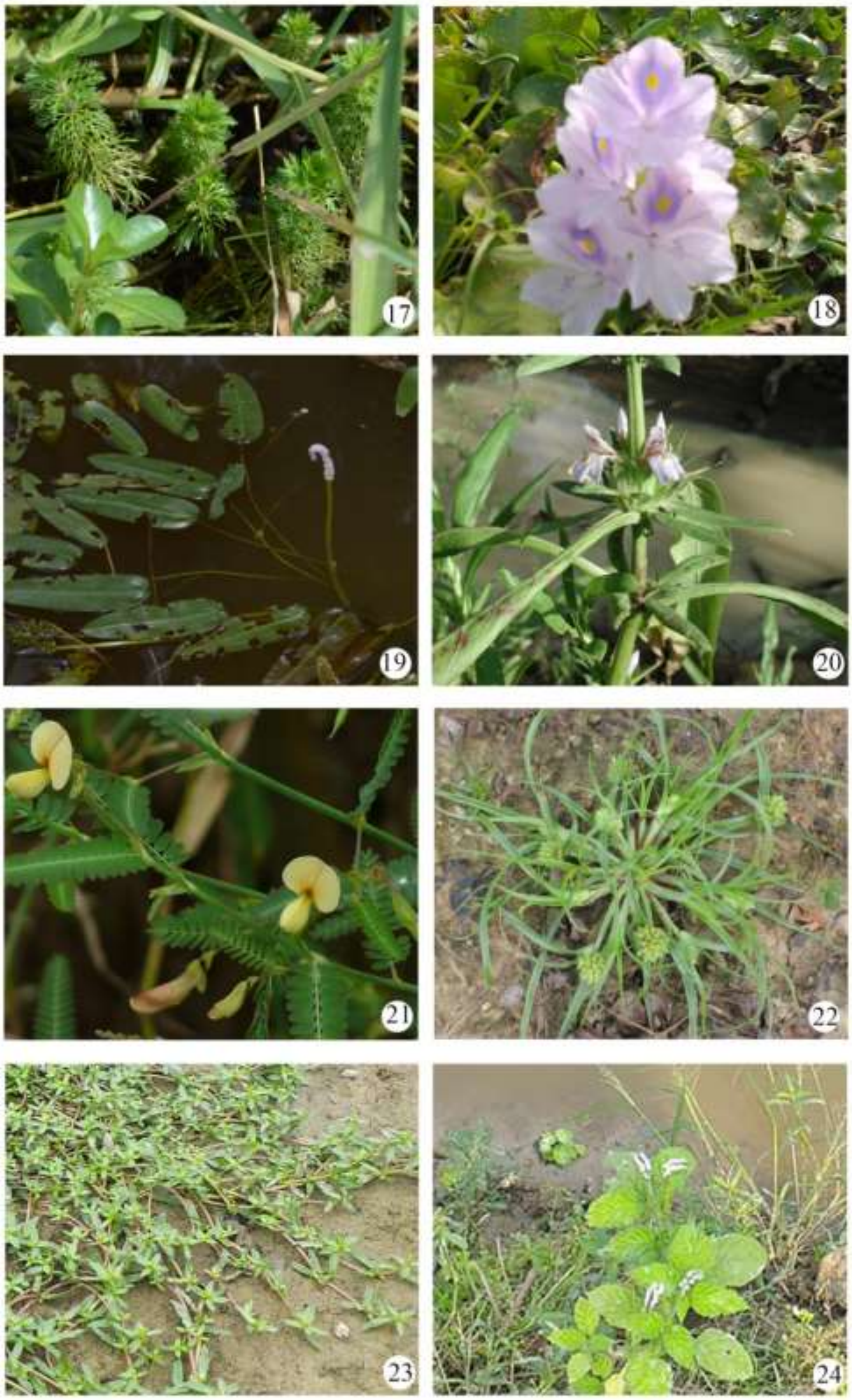


Plate 4

No.	Name of the species
25.	*Potamogeton* sp.
26.	*Utricularia geminiscapa* Benj.
27.	*Ceratophyllum* sp.
28.	*Nymphoides indica* L.
29.	*Nitella* sp.
30.	*Ottelia alismoides* L.
31.	*Ludwigia adcendens* L.
32.	*Nymphaea naucheli* N. L. Burman

Plate 4

Chapter-7

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REFERENCES

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APPENDICES

Appendix I

List of some reported phytoplankton species together dimensions and sources of identification.

Division: Cyanophyta

Species	Dimension (µm)	References
Anabaena affinis Lemm.	Cells 7 × 4 µm, heterocyst 7.5 ×5.5 µm	Islam and Mannan, 1986; Desikachary, 1959
A. ballyganglii J. C. Banerji	Cells 5 × 4 µm	Khandker *et al.*, 2006; Desikachary, 1959
A. california O. Borge	Cells 5.5 × 4 µm	Islam and Hossain, 1978; Desikachary. 1959
A. circinalis Rab. ex Bornet & Flah.	Cells 6 × 8 µm	Islam and Nahar, 1967; Desikachary. 1959
A. fertilissima Rao	Cells 5 × 7 µm	Islam and Begum, 1981; Desikachary. 1959
A. orientalis Dixit	Cells 6 × 5 µm	Islam and Nahar, 1967; Desikachary. 1959
A. oryzae Fritsch	Cell 3 µm, heterocyst 4.5 × 4 µm	Islam and Uddin, 1969; Desikachary. 1959
A. oscillarioides Bory ex Born	Cells 5×4 µm	Islam and Irfanullah, 2005; Desikachary. 1959
A. torulosa (Cram.) Larger	Cells 3 µm in diameter	Islam and Aziz, 1979; Desikachary. 1959
A. utermöhlii Geitler	Vegetative cells 5 µm in diameter	Khandker *et al.*, 2006; Desikachary. 1959
A. variabilis Kuetz *ex* Born	Cells 5.5 ×5 µm	Islam 1973; Desikachary. 1959
Anabaenopsis arnoldii Aptkerj	Cells 6.5 ×5 µm	Islam and Uddin, 1969; Desikachary. 1959
An. elenkinii Miller	Cells 12 × 1 µm	Khandker *et al.*, 2006; Desikachary. 1959

An. raciborskii Wolosz.	Cells 6.5 × 3 µm	Islam and Mannan, 1986; Desikachary. 1959
An. tanganikae (West) Wol.	Cells 7 × 3.5 µm	Islam and Saha, 1975; Desikachary. 1959
Cylindrospermopsis raciborskii (Wolosz.) Seenayya & Subba Raju	Cell 3.4 × 3 µm	Khandker *et al.*, 2006; Desikachary. 1959
Cylindrospermum doryphorum Brühl	Cells 6 × 3 µm	Islam and Uddin, 1969; Desikachary. 1959
Gomphosphaeria lacustris Chodat	Colony 8 µm in diameter	Khandker et al., 2006; Desikachary. 1959
Merismopedia elegans A. Br. ex Kütz.	Cell 5 × 3.5 µm	Islam and Aziz, 1979; Desikachary. 1959
Me. minima Beck	Cell 2.5 µm in diameter	Islam and Nahar, 1967; Desikachary. 1959
Me. punctata Meyen	Cells 9 ×5 µm	Khandker et al., 2006; Desikachary. 1959
Microcystis aeruginosa Kütz.	Cell 5 µm in diameter	Islam and Nahar, 1967; Desikachary. 1959
Mic. flos-aquae (Wittr.) Kirch.	Cells 4.5 µm in diameter	Islam and Nahar, 1967; Desikachary. 1959
Mic. marginata (Menegh.) Kütz.	Colony 145 × 75 µm	Islam and Nahar, 1967; Desikachary. 1959
Mic. robusta (Clark) Nygaard	Cells 7.5 µmin diameter	Islam and Aziz, 1977; Desikachary. 1959
Mic. roseana (de Bary) Elenkin	Cells 8.5 µm diameter	Aziz and Yasmin, 1997; Desikachary. 1959
Oscillatoria geitleriana Elenkin	Cells 2 µm	Islam and Khundker, 2003; Desikachary. 1959
O. geminata Menegh.	Cells 12 × 3.5 µm	Islam and Uddin, 1969; Desikachary. 1959
O. irrigua (Kütz.) Gomont	Cells 8 × 2.5 µm	Islam and Uddin, 1969, Ling and Tyler, 2000

O. limosa Ag. *ex* Gomont	Cells 14 × 3 µm long	Islam and Hossain, 1979, Desikachary, 1959
O. margaritifera (Kütz.) Gomont	Cells 12 µm in diameter	Islam, 1976; Desikachary. 1959
O. minnesotensis Tilden	Cell 3 ×4 µm	Islam and Khundker, 2003; Desikachary. 1959
O. perornata Skuja	Cell 14 × 4 µm	Islam and Uddin, 1969; Desikachary, 1959
O. planktonica Wolosz.	Cells 2.5 ×10 µm	Islam and Uddin, 1969; Desikachary. 1959
O. proteus Skuja	Cells 3 × 5 µm	Islam and Aziz, 1977; Desikachary. 1959
O. pseudogeminata G. Schmid.	Cells 5 ×2.5 µm	Khandker et al., 2006; Desikachary. 1959
Pelonema aphane Skuja	Cells 5 × 1.5 µm	Islam and Irfanullah, 2000; Desikachary. 1959
Spirulina gigantea Schmidle	Cells 10 µm	Islam and Uddin, 1969; Desikachary. 1959
Sp. laxa G. M. Smith	Cells 1.5 µm in diameter	Islam and Irfanullah, 2005; Desikachary. 1959

Division: Chrysophyta

Species	Dimension (µm)	References
Amphora veneta Kütz.	Cells 73 ×d 13 µm	Aziz and Ara, 2000, Germain, 1981
Cymbella affinis Kütz.	Frustules 86 × 16,5 µm	Islam and Haroon, 1975; Hustedt, 1930
Cym. cistula (Hemp. and Ehr,) Kirch.	Frustules 81 × 19 µm	Islam and Haroon, 1975; Hustedt, 1930
Diatoma vulgare var. *linearis* (W. Smith) Heurck	Frustules 37 × 7 µm	Islam and Aziz, 1975; Hustedt, 1930

Eunotia alpina (Näg.) Hust.	Cells 144 × 6 µm	Aziz and Ara, 2000; Hustedt, 1930
Eu. lunaris (Ehren.) Grun.	Frustules 109 × 7 µm	Islam and Haroon, 1975; Hustedt, 1930
Eu. monodon Ehrenberg	Frustules 55 × 18 µm	Islam and Haroon, 1975; Hustedt, 1930
Eu. pectinalis fa. *minor* (Kuetz.) Muel.	Frustules 44 × 4 µm	Islam and Haroon, 1975; Hustedt, 1930
Eu. pectinalis var. *valvariae* (Kuetz.) Rabh.	Frustules 119 × 7 µm	Nahar, 2001; Hustedt, 1930
Eu. veneris (Kuetz.) De Tony	Frustules 69 × 7 µm	Nahar, 2001; Hustedt, 1930
Fragillaria crotonensis Kitton	Frustules 143 × 43 µm	Aziz and Tanbir, 2003; Hustedt, 1930
Gomphonema lanceolatum var. *insignis* (Greg,) Cleve	Frustules 68 × 4 µm	Nahar, 2001; Hustedt, 1930
G. lanceolatum var. *turnis* (Ehr.) Hust.	Frustules 65 × 14 µm	Islam and Haroon, 1975; Hustedt, 1930
G. longiceps var. *subclavata* Grun.	Frustules 60 × 9 µm	Islam and Haroon, 1975; Hustedt, 1930
G. pervulum (Kütz.) Van Heurck	Frustules 33 × 6 µm	Islam and Chowdhury, 1979; Hustedt, 1930
G. sphaerophorum Ehren.	Frustules 44 × 15 µm	Aziz and Yasmin, 1997; Hustedt, 1930
Gyrosigma attenuatum (Kütz,) Rab.	Frustules 144 × 22 µm	Aziz and Islam, 1966; Hustedt, 1930
Gy. scalproides (Rab.) Cleve	Frustules 65 × 15 µm	Islam and Haroon, 1980; Hustedt, 1930
Melosira distans var. *alpigena* Grunow	Cells 6 × 10 µm	Nahar, 2001; Hustedt, 1930
M. granulata (Ehrenberg) Ralfs	Cells 14.5 × 7 µm	Islam, 1974; Hustedt, 1930
M. granulata var. *angustissima* Müller	Cells 24.5 × 5 µm	Islam, 1974; Hustedt, 1930
Navicula americana Ehrenberg	Cells 134 × 25 µm	Nahar, 2001; Hustedt, 1930

N. bacillum Ehrenberg	Cells 134 × 19 µm	Islam and Aziz, 1979; Hustedt, 1930
N. exigua (Dujardin) Nouv.	Cells 29 × 8 µm	Islam and Haroon, 1975; Hustedt, 1930
N. grimmei Krasske	Cells 18 × 10 µm	Aziz and Ara, 2000; Hustedt, 1930
N. integra (W. Sm.) Ralfs	Cells 95 × 17 µm	Islam and Haroon, 1975; Hustedt, 1930
N. menisculus Schum.	Cells 34 × 8 µm	Islam and Haroon, 1975; Hustedt, 1930
N. placentula var. *rostrata* Backman and Cleve-Euler	Cells 31.5 × 9.25 µm	Aziz and Tanvir, 2003; Hustedt, 1930
N. pseudohalophila Cholnoky	Cells 24 × 5 µm	Aziz and Ara, 2000; Hustedt, 1930
N. pupula Kütz.	Cells 39 × 7.25 µm	Islam and Irfanullah, 2005; Hustedt, 1930
N. pupula var. *capitata* Hust.	Cells 44 × 8 µm	Nahar, 2001; Hustedt, 1930
N. radiosa Kütz.	Cells 67 × 9 µm	Begum and Hadi, 1994; Hustedt, 1930
N. spicula Hickey	Cells 64 × 7 µm	Aziz and Ara, 2000; Hustedt, 1930
Nitzschia acicularis (Kuetz.) G.M.Smith	Frustules 78 × 3.5 µm	Nahar, 2001; Hustedt, 1930
Nitz. acicularis var. *closteroides* Grun.	Frustules 139 × 6 µm	Islam and Aziz, 1979; Hustedt, 1930
Nitz. alpina (Naeg.) Hustedt	Frustules 40 × 5 µm	Aziz and Tanvir, 2003; Hustedt, 1930
Nitz.gracilis Hantz. in Raben.	Frustules 101 × 5 µm	Islam and Irfanullah, 2000; Hustedt, 1930
Nitz.longissima (Brėb.) Grunow	Frustules 35 × 6 µm	Aziz and Tanvir, 2003; Hustedt, 1930
Nitz.pungens Grunow	Frustules 125 × 6 µm	Islam and Aziz, 1975; Hustedt, 1930

Nitz.subtubicola H. Germain	Frustules 39 × 4 µm	Nahar, 2001; Hustedt, 1930
Pinnularia acrosphaeria (Brėb.) Rab.	Cells 75 × 12 µm	Nahar, 2001; Hustedt, 1930
Pin. gibba var. *mesogonglya* (Ehr.) Hust.	Cells 47 × 8.5 µm	Islam and Haroon, 1975; Hustedt, 1930
Pin. gibba var. *parva* (Grun.) Fre.	Cells 41 × 8.3 µm	Islam and Haroon, 1975; Hustedt, 1930
Pin. karelica var. *tibetana* (Hust.) Cleve	Cells 66 × 12.5 µm	Islam and Haroon, 1975; Hustedt, 1930
Pin. krookii (Grun.) Cleve	Cells 134 × 18.5 µm	Nahar, 2001; Hustedt, 1930
Pin. microstauron (Ehr.) Cleve	Cells 75 × 12 µm	Aziz and Tanbir, 2003; Hustedt, 1930
Pin. stauroptera (Grun.) Rab.	Cells 131 × 15 µm	Nahar, 2001; Hustedt, 1930
Stauroneis anceps fa. *gracilis* (Ehr.) Hust.	Cells 104 × 14 µm	Aziz and Ara, 2000; Hustedt, 1930
Synedra acus Kütz.	Frustules 143 × 6 µm	Islam and Haroon, 1975; Hustedt, 1930
Syn. rumpens var. *familiaris* (Kütz.) Poretzky	Frustules 93 × 4 µm	Nahar, 2001; Hustedt, 1930
Syn. tabulate (Ag.) Kütz.	Frustules 99 × 5 µm	Aziz and Ara, 2000; Hustedt, 1930
Syn. ulna var. *danica* (Kütz.) Heurck	Frustules 176 × 4.5 µm	Nahar, 2001; Hustedt, 1930
Syn. ulna var. *oxyrhynchus* (Kütz.) O'Meara	Frustules 199 × 12 µm	Islam and Aziz, 1975; Hustedt, 1930
Syn. vaucheriae Kütz.	Frustules 39 × 3.5 µm	Nahar, 2001; Hustedt, 1930

Division: Chlorophyta

Species	Dimension (µm)	References
Actinastrum gracillimum var. *gracillimum* Smith	Cells 3.5 × 14 µm long	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ac. hantzschii Lager.	Cells 3 µm wide and 15 µm long	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ac. hantzschii var. *subtile* Wolosz.	Cells 3 µm wide and 18 µm long	Aziz, 2008; Huber-Pestalozzi, 1983
Ankistrodesmus barnardii Kom.	Cells 1 × 32.5 µm long	Khondker *et al.*, 2007; Huber-Pestalozzi, 1983
Ank. blibraianus (Rein.) Kors.	Cells 3 × 12.5 µm long	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ank. densus Kors.	Colony 5 × 95 µm long	Khondker *et al.*, 2007; Huber-Pestalozzi, 1983
Ank. falcatus var. *radiatus* (Chod.) Lemm.	Cells 3 × 65 µm long	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ank. spiralis (Turner) Lemm.	Cells 2 × 30.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ank. stipitatus (Chod.) Kom.	Cells 1.5 × 41 µm	Khondker *et al.*, 2007; Huber-Pestalozzi, 1983
Arthrodesmus curvatus Turne	Cells 65 × 35 µm, isthmus 8 µm	Islam and Irfanullah, 2006; Huber-Pestalozzi, 1983
Chlamydomonas globosa Snow	Cells 7 µm in diameter	Khandker *et al.*,2007; Huber-Pestalozzi, 1961
Chl. gracilis Snow	Cells 5 × 7 µm	Islam and Khondker, 1993; Huber-Pestalozzi, 1961
Chl. pertyi Gor.	Cells 20 × 22 µm	Khandker *et al.*,2007; Huber-Pestalozzi, 1961

Chl. pulchra Skvortz.	Cells 10 × 12 µm	Khandker *et al.*,2007; Huber-Pestalozzi, 1961
Chlorogonium elongatum (Dang.) France	Cells 3.5 × 32 µm	Khandker *et al.*,2007; Huber-Pestalozzi, 1961
Chlorotetraedron polymorphum Mc Entee	Cells 17.5 µm in diameter	Khandker *et al.*,2007; Huber-Pestalozzi, 1983
Closterium angustum var. *angustum* Kutz. ex Ralfs	Cells 30 × 216 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
Cl. diane var. *pseudodiane* (Roy) Krieg.	Cells 18 × 164 µm	Islam and Akter, 1999; Ling and Tyler, 2000
Cl. limneticum Lemm.	Cells 8.5 × 156 µm	Yeasmin, 2006; Ling and Tyler, 2000
Cl. pitchardianum var. *angustum* Bor.	Cells 33.5 × 284 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
Cl. praelongum var. *praelongum* Brėb.	Cells 23.5 × 400 µm	Islam and Irfanullah, 2003; Ling and Tyler, 2000
Cl. subulatum var. *striolatum* Islam	Cells 2.54 × 103 µm	Akter, 1991; Ling and Tyler, 2000
Cl. toxon var. *toxon* W. West	Cells 16 × 204 µm	Islam and Akter, 1999; Ling and Tyler, 2000
Cl. venus var. *venus* Kuetzing	Cells 10.5 × 87 µm	Islam and Akter, 1999; Ling and Tyler, 2000
Coelastrum indicum Turner	Colony 15 µm in diameter	Khondker et al., 2007; Ling and Tyler, 2000
Coel. microphorum Nägeli	Colony 26 µm in diameter	Islam and Khatun, 1966; Ling and Tyler, 2000
Coel. pulchellum var. *pulchellum* Schmid.	Cells 22 µm in diameter	Islam and Irfanullah, 2005; Ling and Tyler, 2000

Coel. sphaericum Nägeli	Cells 12 µm in diameter colony 35 µm in diameter	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cosmarium birame var. *berbadense* G.S. West	Cells 12 × 9 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cos. clepsydra Nordst.	Cells 13.5 × 14 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cos. contractum var. *cracoviense* fa. *angulatus* Islam and Irfanullah	Cells 29 × 43 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cos. contractum var. *reductum* Islam	Cells 11 × 16 µm	Islam and Begum, 1999; Ling and Tyler, 2000
Cos. laeve var. *octangulare* (Wille) West	Cells 13 × 15 µm	Islam and Aziz, 1979; Ling and Tyler, 2000
Cos. moniliforme var. *moniliforme* (Turp.) Ralfs	Cells 23.5 × 33.5 µm	Islam, 1970; Ling and Tyler, 2000
Cos. pachydermum var. *pachydermum* Lundell	Cells 87 × 145 µm	Islam and Chowdhury, 1979; Ling and Tyler, 2000
Cos. phaseolus var. *minutum* (Bis.) Kr.	Cells 10 × 9 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cos. pseudopyramidatum var. *extensum* (Nordst.) Krieg.	Cells 45 × 94 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
Cos. subcostatum Nordst.	Cells 25 × 34 µm	Islam and Zaman, 1975; Ling and Tyler, 2000
Cos. trachypleurum var. *minus* Racib.	Cells 30 × 33 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000

Crucigenia quadrata Morren	Cells 5 × 8 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Cru. lauterbournii (Schim.) Schim.	Cells 5 × 8 µm	Islam, 1969; Huber-Pestalozzi, 1983
Cru. rectangularis (Näg.) Gay	Cells 3 × 7 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Cru. truncate G.M. Smith	Cells 3 × 6.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Crucigeniella apiculata (Lemm.) Kom.	Cells 5 × 10 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Cruci. crucifera (Wolle) Kom.	Cells 9 × 14 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Cruci. rectangularis (Näg.) Kom.	Cells 3.5 × 6 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Dictyosphaerium granulatum Hind.	Colony 35 µm in diameter and cell 5 µm in diameter	Khondker et al., 2007; Huber-Pestalozzi, 1983
Dic. pulchellum Wood	Colony 53 µm in diameter and cell 4 µm in diameter	Islam and Aziz, 1977; Huber-Pestalozzi, 1983
Dic. tetrachotomum Printz	Colony 30 µm in diameter and cell 3 µm in diameter	Khondker et al., 2007; Huber-Pestalozzi, 1983
Euastrum denticulatum (Kirch.) Gay	Cells 16 × 20 µm	Islam and Begum, 1999; Ling and Tyler, 2000
Eua. spinolosum var. *burmense* (W.&W.) Krieg.	Cells 47 × 54 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000

Eudorina elegans Ehrenberg	Cells 17.5 µm in diameter	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Eud. unicocca G.M. Smith	Cells 11 µm in diameter	Islam and Aziz, 1979; Huber-Pestalozzi, 1983
Golenkinia pausispina West & West	Cells 14.5 × 20 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Gonium pectorale Müller	Cells 13 × 17 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
Hyaloraphidium contortum Pascher and Kors.	Cells 2.5 × 24 µm	Islam, 1969; Huber-Pestalozzi, 1983
Lagerheimia wratislaviensis Schroeder	Cells 5.5 × 6 µm	Islam, 1969; Huber-Pestalozzi, 1983
Monoraphidium arcuatum (Kors.) Hind.	Cells 1.5 × 27 µm	Khondker et al., 2007; Huber-Pestalozzi, 1983
Mon. fontinale Hind.	Cells 5 × 19 µm	Khondker et al., 2007; Huber-Pestalozzi, 1983
Mon. griffithi (Berkeley) Kom.	Cells 2 × 58.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Mon. tortile (W. & W.) Kom.	Cells 2.5 × 21 µm	Khondker et al., 2007; Huber-Pestalozzi, 1983
Oocystis borgei Snow	Cells 15 × 19 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Oo. elliptica W. West	Cells 13 × 29 µm	Islam, 1973; Huber-Pestalozzi, 1983
Oo. granulata Hortob.	Cells 4.5 × 6 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1983
Oo. nägelli A. Br.	Cells 11 × 23 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1983

Oo. pusilla Hansg.	Cells 33 × 43 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Oo. solitaria Wittr.	Cells 14.5 × 29.5 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1983
Oo. submarina Lagerheim	Cells 33.5 × 37.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Pandorina morum (Müller) Bory	Cells 7.5 × 28.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
Pediastrum biradiatum Meyen	Vegetative cell 7.5 × 12 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ped. boryanum var. *brevicorne* A. Br.	Cells 10 × 12 µm	Khondker et al., 2007; Huber-Pestalozzi, 1983
Ped. duplex Meyen	Cells 15 × 18 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ped. duplex var. *clathratum* (A. Br.) Lag.	Cells 12 × 17 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ped. duplex var. *gracillimum* W & W	Cells 10.5 × 12 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ped. duplex var. *rogulosum* Racib.	Cells 15 × 19 µm	Islam, 1973; Huber-Pestalozzi, 1983
Ped. tetras (Ehrenberg) Ralfs	Cells 5 × 8.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ped. tetras var. tetraedron (Corda) Hansg.	Cells 7.5 × 12.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
Phacotus angustus Pascher	Cells 16 × 33 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1961
Ph. lenticularis (Ehren.) Diesing	Cells 13 × 18 µm	Islam and Alfasane, 2001; Huber-Pestalozzi, 1961

Pyrobotrys gracilis (Kors.) Kors.	Cells 11.5 × 17.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
Scenedesmus acuminatus (Lag.) Chodat	Cells 4 × 18 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. acuminatus var. *minor* G.M. Smith	Cells 2.5 × 15 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. acutiformis Schroeder	Cells 2 × 6 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. acutus var. *acutus* Meyen	Cells 3 × 16 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. arcuatus Lemm.	Cells 7 × 13 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. arcuatus var. *platydiscus* G.M. Smith	Cells 4.5 × 7.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. bijuga var. *irregularis* (Wolle) G.M. Smith	Cells 5.5 × 9.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. brevispina (G.M. Smith) Chodat	Cells 6.5 × 16.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. denticulatus Lag.	Cells 8.5 × 19.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. denticulatus fa. *maximus* Uhrek	Cells 7.5 × 18 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1961
S. dimorphus (Trup.) Kütz.	Cells 5.5 × 9.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. ecornis var. *ecornis* (Ehr.) Chodat	Cells 5.5 × 15.5 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1961
S. incrassatulus Bohlin	Cells 3.5 × 18.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961

S. longispina var. *asymmetricus* Hort.	Cells 5.4 × 12.5 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1961
S. longus var. *apiculatus* Meyen	Cells 4.2 × 7.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. magnus Meyen	Cells 7.5 × 27 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. opoliensis var. *contacta* Prescott	Cells 7.5 × 28.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
S. perforatus Lemm.	Cells 7 × 26 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
S. quadricauda (Turp.) de Breb.	Cells 6 × 17 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
S. quadricauda var. *longispina* (Chod.) G.M. Smith	Cells 6 × 25 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
S. quadricauda var. *quadrispina* (Chod.) G.M. Smith	Cells 8 × 23 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
S. quadricauda var. *rectangularis* West	Cells 8.5 × 17.5 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1983
S. regularis Svir.	Cells 8 × 23.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Schroederia setigera (Schroeder) Lemm.	Cells 4.5 ×102 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Sch. spiralis (Printz.) Kors.	Cells 3.5 × 32 µm	Khondker et al., 2007; Huber-Pestalozzi, 1983
Staurastrum acanthocephalum Skuja	Cells 14 × 23 µm	Islam and Zaman, 1975; Ling and Tyler, 2000
St. chaetoceros (Schroeder) Smith	Cells 13 × 23 µm	Islam and Aziz, 1977; Ling and Tyler, 2000

St. gladiosum Turner	Cells 38 × 45 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
St. johnsonii West and West	Cell 36 × 43 µm	Islam and Akter, 2004; Ling and Tyler, 2000
St. paradoxum Meyen	Cell 29 × 22 µm	Islam and Chawdhury, 1979; Ling and Tyler, 2000
St. parundulatum Groen.	Cell 13 × 29 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
St. pinnatum Turner	Cell 36 × 23 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
St. polymorphum var. *polymorphum* Bréb.	Cell 25 × 28 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
Tetraedron constrictum G. M. Smith	Cells 29 µm in diameter	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Tet. limneticum var. *gracile* Prescott	Cells 34.5 µm in diameter	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Tet. minimum (A. Br.) Hansgirg	Cells 6 µm in diameter	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Tet. muticum (A. Br.) Hansgirg	Cells 9.5 µm in diameter	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Tet. regulare Kuetz.	Cells 45 × 52 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Tet. trigonum (Naeg.) Hansgirg	Cells 13.5 × 18 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Tet. verrucosum G. M. Smith	Cells 20.5 × 25 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Tetrastrum elegans Playfair	Cells 3.5 × 5.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983

Treubaria setigera (Archer) G. M. Smith	Cells 15 µm in diameter	Islam and Alfasane, 2001; Huber-Pestalozzi, 1983

Division: Euglenophyta

Species	Dimension (µm)	References
Euglena acus (Müller) Ehrenberg	Cell 143.25 × 13 µm	Islam and Khatun, 1966, Huber-Pestalozzi, 1955
E. acus var. *longissima* Defl.	Cell 148 × 15 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. agilis var. *praecxicisa* Schiller	Cell 19 × 6 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. allorgei Defl.	Cell 128 × 13 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. australica Playfair	Cell 42 × 22 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. australica var. *claviformis* Palyfair	Cell 22 × 14 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. chlamydophora Mainx	Cell 58 × 20 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. clavata Skuja	Cell 104 × 19 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. ehrenbergii Klebs	Cell 78 × 13 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. exilis Gojdics	Cell 50 × 12 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. granulata (Klebs) Fr. Schmitz	Cell 71 × 25 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. güntheri Gojdics	Cell 92 × 16 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. hemichromata Skuja	Cell 97 × 23 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. limnophila Lemm.	Cell 48 × 8 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955

E. mutabilis var. *lafevri* Chadef.	Cell 54 × 6 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. oblonga Schmitz	Cell 72 × 23 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. oxyuris var. *charkowiensis* (Swir.) Chu	Cell 143 × 25 µm	Islam and Aziz, 1977; Huber-Pestalozzi, 1955
E. oxyuris var. *minor* Prescott	Cell 155 × 23 µm	Huber-Pestalozzi, 1955
E. platydesma Skuja	Cell 124 × 8 µm	Islam et al., 1991; Huber-Pestalozzi, 1955
E. pseudospiroides Svir.	Cell 128 × 20 µm	Islam et al., 1991; Huber-Pestalozzi, 1955
E. rubra Hardy	Cell 98 × 31 µm	Islam et al., 1991; Huber-Pestalozzi, 1955
E. sociabilis Dangeard	Cell 72 × 7 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1955
E. spathirhyncha Skuja	Cell 116 × 24 µm	Khondker et al., 2008; Huber-Pestalozzi, 1955
E. tripteris (Dujardin) Klebs	Cell 98 × 17 µm	Islam et al., 1991; Huber-Pestalozzi, 1955
Lepocinclis acuta Prescott	Cell 39 × 18 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
L. cymbiformis Playfair	Cell 34.22 × 12 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1955
L. ovum var. *bütschlii* (Lemm.) Conr.	Cell 32 × 19 µm	Khondker et al., 2008; Huber-Pestalozzi, 1955

L. playfairiana Defl.	Cell 40 × 29 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1955
L. salina Fritsch	Cell 38 × 29 µm	Khondker et al., 2008; Huber-Pestalozzi, 1955
L. salina fa. *obtusa* (H.-P) Conr.	Cell 44 × 24 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
L. texta fa. *minor* Conr.	Cell 30 × 21 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
Phacus acuminatus var. *acuminatus* Stokes	Cell 39 × 20 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. bicarinatus Weik	Cell 39 × 25 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. circumflexus Pochm.	Cell 79 × 38 µm	Islam et al., 1991, Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. curvicauda Swirenko	Cell 39 × 27 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. hamelii Allorge and Lafevre	Cell 70 × 30 µm	Khondker et al., 2008; Huber-Pestalozzi, 1955
P. helicoides Pochm.	Cell 76 × 34 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955

P. horridus Pochm.	Cell 48 × 28 µm	Alfasane and Khondker, 2007; Huber-Pestalozzi, 1955
P. inflatus var. *petrophora* Skuja	Cell 50 × 32 µm	Khondker et al., 2008a; Huber-Pestalozzi, 1955
P. lismorensis Playf.	Cell 145 × 40 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. longicauda var. *attenuata* (Pochm.) Huber-Pest.	Cell 99 × 46 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. longicauda var. *major* Svir.	Cell 144 × 38 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. longicauda var. *rotunda* (Pochm.) Huber-Pest.	Cell 92 × 45 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. orbicularis var. *caudatus* Skvr.	Cell 55 × 35 µm	Islam and Irfanullah, 2000; Huber-Pestalozzi, 1955
P. pleuronectes (O.F.M) Dujardin	Cell 67 × 40 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. ranula Pochm.	Cell 104 × 42 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955

P. suecious var. *oidion* Pochm.	Cell 45 × 22 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
Strombomonas gibberosa (Playf.) Defl.	Cell 76 × 42 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
Str. gibberosa var. *longicollis* (Playf.) Defl.	Cell 54 × 24 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
Str. napiformis var. *brevicollis* (Playf.) Defl.	Cell 44 × 23 µm	Khondker et al., 2008d; Huber-Pestalozzi, 1955
Trachelomonas abrupta var. *arcuata (*Playf.) comb. Defl.	Cell 30 × 21 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. anguste-ovata var. *ellipsoidea* Islam	Cell 50 × 27 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. anguste-ovata fa. *minor* Islam	Cell 27 × 11.5 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. anulifera var. *semi-ornata* (Conrad) Huber-Pest.	Cell 10 µm in diameter	Khondker et al., 2008d; Huber-Pestalozzi, 1955
Tr. armata (Ehren.) Stein	Cell 28.5 × 12.5 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955

Tr. armata var. *longispina* (Playf.) Defl.	Cell 51 × 30 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. armata var. *rangpurense* Islam	Cell 37 × 29 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. dybowskii Drez.	Cell 17 × 9.5 µm	Islam and Moniruzzaman, 1981, Dillard, 2000; Huber-Pestalozzi, 1955
Tr. hispida var. *punctata* Lemm.	Cell 28 × 23 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. intermedia Dang.	Cell 25 ×18 µm	Islam and Moniruzzaman, 1981, Dillard, 2000; Huber-Pestalozzi, 1955
Tr. lacustris var. *ovalis* Drez.	Cell 26 × 15 µm	Khondker et al., 2008b; Huber-Pestalozzi, 1955
Tr. lismorensis var. *inermis* Playfair	Cell 12 × 15 µm	Khondker et al., 2008b; Huber-Pestalozzi, 1955
Tr. mirabilis var. *minor* Woron.	Cell 31 × 21 µm	Khondker et al., 2008b; Huber-Pestalozzi, 1955
Tr. mucosa var. *brevicollis* Skv.	Cell 18 × 13 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. nadsoni Skv.	Cell 69 × 19 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955

Tr. nadsoni var. *acuta* Islam	Cell 66 × 21 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
Tr. oblonga Lemm.	Cell 15 × 12 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. oblonga var. *truncata* Lemm.	Cell 12 × 7.5 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. planctonica Swir.	Cell 29 × 20 µm	Islam and Moniruzzaman, 1981, Dillard, 2000
Tr. planctonica var. *oblonga* Drez.	Cell 27 × 14 µm	Khondker et al., 2008b; Huber-Pestalozzi, 1955
Tr. playfairii Defl.	Cell 24 × 17 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. raciborskii Wolosz.	Cell 28 × 15 µm	Khondker et al., 2008b; Huber-Pestalozzi, 1955
Tr. rogulosa Stein	Lorica 24 µm in diameter	Islam and Alfasane, 2003, Dillard, 2000
Tr. sydneyensis Playfair	Cell 40.5 × 23 µm	Islam and Irfanullah, 2003, Dillard, 2000
Tr. volvocina Ehrenberg	Lorica 22 µm in diameter	Islam and Moniruzzaman, 1981, Dillard, 2000
Tr. volvocina var. *derephora* Conrad	Lorica 25 µm in diameter	Islam and Moniruzzaman, 1981, Dillard, 2000
Tr. volvocina var. *punctata* Playf.	Lorica 16 µm in diameter	Khondker et al., 2008b; Huber-Pestalozzi, 1955
Tr. volvocinopsis Swirenko	Lorica 34 µm in diameter	Islam and Irfanullah, 2003, Dillard, 2000

Tr. volvocinopsis var. *khanne* (Skv.) Bour.	Lorica 33 µm in diameter	Islam and Alfasane, 2004; Huber-Pestalozzi, 1955
Tr. volzii Lemmermann	Cell 32 × 17 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955

Division: Cryptophyta

Species	Dimension (µm)	References
Chilomonas acuta var. *insignis* Skuja	Cell 24.22 × 7.88 µm	Islam and Khondker, 1997
Chil. paramaecium Ehreberg	Cell 38.45 × 11.32 µm	Islam and Khondker, 1997
Chroomonas acuta Utermöhi	Cell 10.24 × 4.42 µm	Khondker *et al.*, 2007
Cryptomonas erosa Ehreberg	Cell 30 × 12 µm	Khondker *et al.*, 2007
Cryp. lucens Skuja	Cell 13 × 7 µm	Khondker *et al.*, 2007
Cryp. obovata Czosnowski	Cell 24.25 × 12 µm	Khondker *et al.*, 2007
Cryp. ovata Ehreberg	Cell 35 × 13 µm	Islam and Khondker, 1993
Cryp. phaseolus Skuja	Cell 14 × 7µm	Khondker *et al.*, 2007
Cryp. reflexa Skuja	Cell 36 × 15 µm	Khondker *et al.*, 2007
Cryp. reflexa var. *recurva* Islam *et* Khondker	Cell 48 × 21 µm	Islam and Khondker, 1993
Rhodomonas lacustris Pascher *et* Ruttner	Cell 15 × 6.55 µm	Islam and Khondker, 1993
R. minuta Skuja	Cell 14 × 7 µm	Khondker *et al.*, 2007
R. minuta var. *nanoplanktica* Skuja	Cell 7.25 × 3 µm	Khondker *et al.*, 2007

Division: Pyrrhophyta

Species	Dimension (µm)	References
Peridinium abei Paulsen	Cells 62 × 54 µm	Islam and Aziz 1977, Subrahmanyan 1968
Ceratium hirundinella (Ehrenberg) Claprède *et* Lachmann	Cell proper 40-44 × 32.5 µm	Islam and Aziz 1975, Subrahmanyan 1968

Appendix II

List of some probationary new phytoplankton species together with dimensions and sources of identification.

Division: Cyanophyta

Species	Dimension (µm)	References
Anabaena spiroides (Woronichin) Elenkin	Vegetative cells 8.07 µm in diameter and heterocyst 7.27 µm in diameter	Ling and Tyler 2000; Pl. 10; fig. 2
Pseudoanabaena constricta (Szafar) Lauterborn	Cell 16.80 × 13.63 µm, terminal cell 20.49 × 14.95 µm	Starmach, 1966; pp. 448; fig.663
Cylindrospermopsis curvispora M. Watanabe	Filament 5.81 µm wide, heterocyst not found	Yamagishi, 1995; p. 39; fig. 20: 27-28
Lingbya contorta fa.	Cell 4.71 × 2.35 µm	Desikachary, 1959; pp. 295; Pl. 50; fig. 5, 9
Gomphosphaeria fusca Skuja	Colony 42.21 × 35.45 µm, individual cell 6.76 µm in diameter	Starmach, 1966; p. 137; fig. 160
Xenococcus minimus fa. *starmarchii* Geitler	Colony 32.54 µm in diameter, individual cells 6.71 µm in diameter	Starmach, 1966; p.204; fig. 255
Spirulina subsalsa Oersted ex Gomont	Coil 5.73 µm	Desikachary, 1959
Gomphosphaeria nageliana (Unger) Lemm.	Colony 87.75 µm in diameter	Starmach, 1966; p. 140; fig. 166
Gomphosphaeria rosea (Snow) Lemm.	Colony 67.35 × 58.29 µm	Starmach, 1966; p. 137; fig. 164
Arthrospira platensis fa. g*ranulata* Gomont	Coil 3.07 µm	Desikachary, 1959; p. 190; Pl. 35; fig. 6
Lingbya contorta var. contorta Lemm.	Filament 4.10 µm	Yamagishi, 1995; p. 40; fig. 3:55

Division: Chlorophyta

Species	Dimension (µm)	References
Crucigenia mucronata (Smith) Kom.	Cell 8.81 × 6.97 µm	Yamagishi and Akiama 1995
Keratococcus bicaudatus (Br. ex Rab.) Petersen	Cell 75.21 × 7.79 µm	Huber-Pestalozzi 1983
Pediastrum duplex var. *asperum* Meyen	Colony 91.80 × 90.16 µm; cell 17 × 14 µm	Huber-Pestalozzi 1983
Tetrastrum heteracanthum (Nordst.) Chodat	Colony 59.22 × 54.30 µm; spine 17 µm long	Huber-Pestalozzi 1983
T. triangulare (Chodat) Kom.	Colony 20.59 µm in diameter	Huber-Pestalozzi 1983
Scenedesmus aquatus var. *globosus*	Cell 21.72 × 11.48 µm	Huber-Pestalozzi 1983
S. javanensis Chodat	Cell 52.87 × 5.74 µm	Yamagishi and Akiama 1995; Bourelly 1965
S. bernardii G. M. Smith	Cell 65.16 × 11.68 µm	Ling and Tyler 2000
S. indicus Philipis ex Hegewald	Cell 23.57 × 9.02 µm	Huber-Pestalozzi 1983
S. bicaudatus var. *brevicaudatus* Hortob.	Cell 23.57 × 7.79 µm	Huber-Pestalozzi 1983
S. apiculatus var. *apiculatus* Corda	Cell 31.15 × 19.88 µm	Huber-Pestalozzi 1983
S. productocapitatus Schmula	Cell 29.30 × 12.91 µm	Huber-Pestalozzi 1983
S. verrucosus Y.V. Roll	Cell 22.95 × 11.89 µm	Huber-Pestalozzi 1983
Euastrum denticulatum var. *quqdriferium* F. Gay	Cell 19.06 × 30.94 µm; isthmus 6.87 µm wide	Ling and Tyler 2000

Division: Euglenophyta

Species	Dimension (µm)	References
Euglena limnophila var. *lammermanii* Lemm.	Cell 110.45 × 19.06 µm	Huber-Pestalozzi, 1955; pl. 13; fig. 59A
E. klebsii (Lemm.) Mainx	Cell 131.15 × 12.50 µm	Huber-Pestalozzi, 1955; pl. 12; fig. 54
E. lucens E. K.F. Günther	Cell 89.75 × 31.35 µm	Huber-Pestalozzi, 1955; pl. 5; fig. 31
Phacus aenigmaticus Drez.	Cell 80.84-100.31 × 33.60 µm	Huber-Pestalozzi, 1955; pl. 37; fig. 217
P. monilatus (Stokes) Lemm.	Cell 31.35 × 23.98 µm	Huber-Pestalozzi, 1955, pl., 55; fig. 335
E. mespiliformis Skv.	Cell 60.24 × 39.14 µm	Huber-Pestalozzi, 1955; pl. 27; fig. 128
Lepocinclis caudata var. *nasuta* (Chunha) Pascher	Cell 66.19 × 27.25 µm	Huber-Pestalozzi, 1955; pl. 28; fig. 134
E. neustonica F. Gessner	Cell 109.85 × 45.49 µm	Gojdics, 1967; pl. 39; fig. 7
Lepocinclis caudata (Chunha) Pascher	Cell 107.17 × 54.10 µm	Huber-Pestalozzi, 1955; pl. 28; fig. 133
L. paxilliformis Playfair	Cell 52.86 × 20.08 µm	Huber-Pestalozzi, 1955; pl. 33; fig. 190
Phacus inflatus Playfair	Cell 46.11 × 33.38 µm	Huber-Pestalozzi, 1955; pl. 112; fig. 1118
Strombomonas vermonti (Defl.) Defl.	Cell 26.03 × 20.90 µm	Huber-Pestalozzi, 1955; pl. 81 fig. 850
Trachelomonas bulla F. Stein	Cell 77.05 × 44.67 µm	Huber-Pestalozzi, 1955; pl. 73 fig. 719b
Tr. crispa Balech	Cell 42.42 × 17.01 µm	Huber-Pestalozzi, 1955; pl. 63 fig. 510b
Tr. hexangulare fa. *lata* Svir.	Cell 38.93 × 24.80 µm	Huber-Pestalozzi, 1955; pl. 72 fig. 703

Appendix III

Correlation matrix for Station 1 (N=24).

	AT	WT	SD	pH	TDS	Cond.	Alk.	DO	NO_3-N	SRP	SRS	Chla	PP	PD
AT	1	0.920**	0.123	-.164	-.485*	-.26	-.308	-.511*	-.138	0.169	0.173	-.088	-.046	-.027
WT	0.920**	1	-.053	-.323	-.537**	-.374	-.202	-.283	-.072	0.130	0.361	0.133	0.143	0.162
SD	0.123	-.053	1	0.308	0.011	0.242	-.518**	-.504*	-.200	0.360	-.551**	-.636**	-.693**	-.588**
pH	-.164	-.323	0.308	1	0.364	0.373	-.140	-.425*	0.373	0.056	-.467*	-.439*	-.367	-.412*
TDS	-.485*	-.537**	0.011	0.364	1	0.780**	.430*	-.077	-.009	-.284	-.090	0.028	0.075	0.276
Cond.	-.26	-.374	0.242	0.373	0.780**	1	0.092	-.223	0.028	0.004	-.271	-.335	-.191	-.044
Alk.	-.308	-.202	-.518**	-.140	.430*	0.092	1	0.272	-.319	-.670**	0.635**	0.546**	0.570**	0.564**
DO	-.511*	-.283	-.504*	-.425*	-.077	-.223	0.272	1	0.176	-.268	0.299	0.382	.586**	0.321
NO_3-N	-.138	-.072	-.2	0.373	-.009	0.028	-.319	0.176	1	0.174	-.109	-.102	0.017	-.064
SRP	0.169	0.130	0.36	0.056	-.284	0.004	-.670**	-.268	0.174	1	-.498*	-.523**	-.473*	-.508*
SRS	0.173	0.361	-.551**	-.467*	-.09	-.271	0.635**	0.299	-.109	-.498*	1	0.554**	0.499*	0.563**
Chla	-.088	0.133	-.636**	-.439*	0.028	-.335	0.546**	0.382	-.102	-.523**	.554**	1	0.567**	0.841**
PP	-.046	0.143	-.693**	-.367	0.075	-.191	0.570**	0.586**	0.017	-.473*	.499*	0.567**	1	0.632**
PD	-.027	0.162	-.588**	-.412*	0.276	-.044	.564**	0.321	-.064	-.508*	0.563**	0.841**	.632**	1

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

Appendix IV

Correlation matrix for Station 2 (N=24).

	AT	WT	SD	pH	TDS	Cond.	Alk.	DO	NO_3-N	SRP	SRS	Chla	PP	PD
AT	1	0.938**	0.201	0.397	0.429	0.366	0.102	-.812**	-.155	0.464	-.610*	0.118	-.022	-.190
WT	0.938**	1	0.337	0.267	0.362	0.418	0.252	-.799**	-.121	0.360	-.663*	0.121	0.155	-.092
SD	0.201	0.337	1	-.051	-.276	0.251	-.145	-.099	0.061	-.370	-.422	-.458	-.232	0.086
pH	0.397	0.267	-.051	1	0.539	0.548	0.145	-.240	-.731**	0.159	0.054	-.060	-.185	-.669*
TDS	0.429	0.362	-.276	0.539	1	0.625*	0.176	-.202	-.096	0.345	-.172	0.074	-.137	-.254
Cond.	0.366	0.418	0.251	0.548	.625*	1	0.119	-.237	-.264	0.318	-.167	-.018	-.175	-.290
Alk.	0.102	0.252	-.145	0.145	0.176	0.119	1	-.103	-.273	-.051	-.160	-.025	0.205	-.314
DO	-.812**	-.799**	-.099	-.24	-.202	-.237	-.103	1	0.313	-.612*	0.562	-.228	-.311	0.407
NO_3-N	-.155	-.121	0.061	-.731**	-.096	-.264	-.273	0.313	1	-.119	0.027	-.210	-.152	0.771**
SRP	0.464	0.360	-.37	0.159	0.345	0.318	-.051	-.612*	-.119	1	-.234	0.261	0.179	-.189
SRS	-.610*	-.663*	-.422	0.054	-.172	-.167	-.160	0.562	0.027	-.234	1	-.125	-.125	0.051
Chla	0.118	0.121	-.458	-.060	0.074	-.018	-.025	-.228	-.210	0.261	-.125	1	0.506	0.099
PP	-.022	0.155	-.232	-.185	-.137	-.175	0.205	-.311	-.152	0.179	-.125	0.506	1	0.119
PD	-.190	-.092	0.086	-.669*	-.254	-.290	-.314	0.407	0.771**	-.189	0.051	0.099	0.119	1

** 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)

Appendix V

Correlation matrix for Station 3 (N=24).

	AT	WT	SD	pH	TDS	Cond.	Alk.	DO	NO_3-N	SRP	SRS	Chla	PP	PD
AT	1	0.928**	0.284	-.052	0.267	0.343	0.120	-.179	0.066	0.143	0.255	-.358	-.146	-.471*
WT	0.928**	1	0.278	-.012	0.190	0.271	0.001	-.322	0.110	0.132	0.200	-.249	0.013	-.456*
SD	0.284	0.278	1	.503*	-.209	-.078	-.345	0.165	-.030	-.111	-.326	-.184	-.173	0.001
pH	-.052	-.012	.503*	1	-.423*	-.249	-.726**	-.224	-.066	0.107	-.571**	0.495*	-.032	.460*
TDS	0.267	0.190	-.209	-.423*	1	.827**	0.665**	0.299	0.225	-.024	0.278	-.293	-.200	-.313
Cond.	0.343	0.271	-.078	-.249	.827**	1	0.383	0.107	0.330	0.043	.409*	-.339	-.255	-.312
Alk.	0.120	0.001	-.345	-.726**	.665**	0.383	1	0.449*	-.126	-.224	.415*	-.450*	-.025	-.405*
DO	-.179	-.322	0.165	-.224	0.299	0.107	.449*	1	-.007	-.239	0.146	-.270	-.181	0.117
NO_3-N	0.066	0.110	-.030	-.066	0.225	0.330	-.126	-.007	1	0.016	0.118	-.274	-.358	-.262
SRP	0.143	0.132	-.111	0.107	-.024	0.043	-.224	-.239	0.016	1	0.071	-.204	-.206	-.288
SRS	0.255	0.200	-.326	-.571**	0.278	0.409*	.415*	0.146	0.118	0.071	1	-.467*	-.179	-.394
Chla	-.358	-.249	-.184	.495*	-.293	-.339	-.450*	-.270	-.274	-.204	-.467*	1	0.399	.770**
PP	-.146	0.013	-.173	-.032	-.200	-.255	-.025	-.181	-.358	-.206	-.179	0.399	1	0.193
PD	-.471*	-.456*	0.001	.460*	-.313	-.312	-.405*	0.117	-.262	-.288	-.394	.770**	0.193	1

** 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)

Appendix VI

Correlation matrix for Station 4 (N=24).

	AT	WT	SD	pH	TDS	Cond.	Alk.	DO	NO3N	SRP	SRS	Chla	PP	PD
AT	1	0.924**	0.167	0.207	0.348	0.306	0.330	-.539**	0.013	0.201	-.205	-.126	-.187	-.362
WT	0.924**	1	0.141	0.122	0.246	0.188	0.255	-.400	-.013	0.100	-.207	-.011	-.046	-.198
SD	0.167	0.141	1	0.290	.494*	.557**	.601**	-.342	0.154	0.039	-.249	-.346	-.279	-.405*
pH	0.207	0.122	0.29	1	0.246	0.231	0.285	-.353	-.266	0.031	-.021	0.224	-.241	-.327
TDS	0.348	0.246	.494*	0.246	1	.938**	.692**	-.369	0.147	.527**	0.324	-.414*	-.372	-.706**
Cond.	0.306	0.188	0.557**	0.231	.938**	1	.674**	-.390	0.080	0.404	0.230	-.403	-.279	-.665**
Alk.	0.33	0.255	0.601**	0.285	.692**	.674**	1	-.351	0.320	0.187	0.033	-.372	-.267	-.658**
DO	-.539**	-.400	-.342	-.353	-.369	-.390	-.351	1	0.098	-.274	0.394	-.114	-.036	0.398
NO_3-N	0.013	-.013	0.154	-.266	0.147	0.080	0.320	0.098	1	-.074	0.072	-.307	-.117	0.078
SRP	0.201	0.100	0.039	0.031	.527**	0.404	0.187	-.274	-.074	1	0.224	-.316	-.292	-.427*
SRS	-.205	-.207	-.249	-.021	0.324	0.230	0.033	0.394	0.072	0.224	1	-.260	-.284	-.176
Chla	-.126	-.011	-.346	0.224	-.414*	-.403	-.372	-.114	-.307	-.316	-.260	1	0.527**	0.459*
PP	-.187	-.046	-.279	-.241	-.372	-.279	-.267	-.036	-.117	-.292	-.284	0.527**	1	0.304
PD	-.362	-.198	-.405*	-.327	-.706**	-.665**	-.658**	0.398	0.078	-.427*	-.176	.459*	0.304	1

** 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)

Appendix VII

Correlation matrix for Station 5 (N=24).

	AT	WT	SD	pH	TDS	Cond.	Alk.	DO	NO_3-N	SRP	SRS	Chla	PP	PD
AT	1	0.923**	0.382	0.139	0.010	-.315	-.554**	-.266	-.267	0.051	-.058	0.104	0.314	-.171
WT	0.923**	1	0.284	0.004	0.025	-.409*	-.602**	-.320	-.196	0.183	0.025	0.140	0.294	-.279
SD	0.382	0.284	1	0.630**	-.127	0.005	-.350	-.108	-.157	0.122	-.487*	-.358	-.199	0.039
pH	0.139	0.004	0.630**	1	-.100	0.243	-.227	-.099	-.053	0.246	-.391	-.292	0.022	0.063
TDS	0.010	0.025	-.127	-.100	1	0.278	.458*	0.116	-.150	-.231	-.154	.501*	0.547**	0.297
Cond.	-.315	-.409*	0.005	0.243	0.278	1	0.599**	-.134	-.206	-.320	0.019	0.083	0.221	-.013
Alk.	-.554**	-.602**	-.350	-.227	.458*	0.599**	1	0.135	-.212	-.381	0.040	0.218	0.192	0.246
DO	-.266	-.320	-.108	-.099	0.116	-.134	0.135	1	0.174	-.361	0.171	0.033	-.080	0.705**
NO_3-N	-.267	-.196	-.157	-.053	-.150	-.206	-.212	0.174	1	.436*	0.147	-.402	-.245	-.103
SRP	0.051	0.183	0.122	0.246	-.231	-.320	-.381	-.361	.436*	1	-.305	-.149	-.260	-.392
SRS	-.058	0.025	-.487*	-.391	-.154	0.019	0.040	0.171	0.147	-.305	1	0.083	0.241	0.124
Chla	0.104	0.140	-.358	-.292	.501*	0.083	0.218	0.033	-.402	-.149	0.083	1	0.551**	0.377
PP	0.314	0.294	-.199	0.022	0.547**	0.221	0.192	-.080	-.245	-.260	0.241	0.551**	1	0.272
PD	-.171	-.279	0.039	0.063	0.297	-.013	0.246	0.705**	-.103	-.392	0.124	0.377	0.272	1

** 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)

Appendix VIII

Correlation matrix for Station 6 (N=24).

	AT	WT	SD	pH	TDS	Cond.	Alk.	DO	NO_3-N	SRP	SRS	Chla	PP	PD
AT	1	0.873**	.455*	0.393	-.058	0.217	0.002	-.556**	-.014	0.210	-.222	-.077	0.255	0.006
WT	0.873**	1	0.385	0.192	-.203	-.049	-.151	-.565**	-.006	0.259	-.424*	-.284	0.177	-.176
SD	0.455*	0.385	1	0.646**	-.278	0.038	-.052	-.208	0.590**	0.046	0.007	0.122	0.355	0.171
pH	0.393	0.192	0.646**	1	0.154	0.315	0.208	-.155	0.328	0.244	0.133	0.355	0.366	0.357
TDS	-.058	-.203	-.278	0.154	1	0.681**	0.818**	0.363	-.185	-.018	0.110	0.178	0.006	0.278
Cond.	0.217	-.049	0.038	0.315	0.681**	1	0.638**	0.002	-.095	0.099	0.289	.429*	.405*	.405*
Alkalinity	0.002	-.151	-.052	0.208	0.818**	0.638**	1	0.316	-.164	0.041	0.079	0.360	0.358	0.524**
DO	-.556**	-.565**	-.208	-.155	0.363	0.002	0.316	1	0.243	-.483*	-.042	-.220	-.397	-.082
NO_3-N	-.014	-.006	.590**	0.328	-.185	-.095	-.164	0.243	1	-.217	0.226	-.054	0.058	-.052
SRP	0.210	0.259	0.046	0.244	-.018	0.099	0.041	-.483*	-.217	1	-.170	0.590**	0.489*	0.458*
SRS	-.222	-.424*	0.007	0.133	0.110	0.289	0.079	-.042	0.226	-.170	1	0.398	0.083	0.329
Chla	-.077	-.284	0.122	0.355	0.178	0.429*	0.360	-.220	-.054	0.590**	0.398	1	0.686**	0.827**
PP	0.255	0.177	0.355	0.366	0.006	.405*	0.358	-.397	0.058	0.489*	0.083	0.686**	1	0.586**
PD	0.006	-.176	0.171	0.357	0.278	0.405*	0.524**	-.082	-.052	0.458*	0.329	0.827**	0.586**	1

** 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)

Appendix IX

Correlation matrix for Station 7 (N=24).

	AT	WT	SD	pH	TDS	Cond.	Alk.	DO	NO_3-N	SRP	SRS	Chla	PP	PD
AT	1	0.849**	0.476*	0.236	0.284	0.445*	0.020	-.556**	-.148	0.034	-.251	-.031	-.004	-.012
WT	0.849**	1	0.410*	0.028	0.104	0.189	-.040	-.602**	-.074	-.048	-.400	-.194	-.154	-.179
SD	0.476*	0.410*	1	0.610**	0.179	0.357	0.174	-.051	0.187	0.059	-.123	0.275	0.321	0.308
pH	0.236	0.028	0.610**	1	0.273	0.318	0.319	-.093	0.105	0.340	-.111	0.469*	0.484*	0.446*
TDS	0.284	0.104	0.179	0.273	1	0.707**	0.655**	-.049	0.122	-.147	0.208	.422*	0.397	0.310
Cond.	0.445*	0.189	0.357	0.318	0.707**	1	0.691**	-.350	0.122	-.184	0.384	0.573**	0.553**	0.526**
Alk.	0.020	-.040	0.174	0.319	0.655**	0.691**	1	-.361	0.317	-.0320	0.369	0.665**	0.582**	0.436*
DO	-.556**	-.602**	-.051	-.093	-.049	-.350	-.361	1	-.065	-.079	0.000	-.173	-.149	-.125
NO_3-N	-.148	-.074	0.187	0.105	0.122	0.122	0.317	-.065	1	0.048	0.102	0.099	0.046	-.061
SRP	0.034	-.048	0.059	0.340	-.147	-.184	-.032	-.079	0.048	1	-.417*	0.264	0.143	0.156
SRS	-.251	-.400	-.123	-.111	0.208	0.384	0.369	0.000	0.102	-.417*	1	0.442*	0.431*	0.486*
Chla	-.031	-.194	0.275	0.469*	0.422*	0.573**	0.665**	-.173	0.099	0.264	.442*	1	0.933**	0.891**
PP	-.004	-.154	0.321	0.484*	0.397	0.553**	0.582**	-.149	0.046	0.143	0.431*	0.933**	1	0.873**
PD	-.012	-.179	0.308	0.446*	0.310	0.526**	0.436*	-.125	-.061	0.156	0.486*	0.891**	0.873**	1

** 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