ALGAL DIVERSITY IN THE COASTAL WETLANDS OF COX'S BAZAR IN RELATION TO ENVIRONMENTAL VARIABLES AND ECOLOGICAL NICHE

Ph.D. Thesis

Submitted by

JESMIN AKHTER JOLLY

REGISTRATION NO: 96/2017-18
SESSION 2017-18

National Professor AKM Nurul Islam Phycology, Limnology and Hydrobiology Laboratory
Department of Botany
University of Dhaka,
Dhaka-1000, Bangladesh

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

BY

JESMIN AKHTER JOLLY
REGISTRATION NO: 96/2017-18
SESSION 2017-18

National Professor A.K.M. Nurul Islam
Phycology, Limnology and Hydrobiology Laboratory
Department of Botany
University of Dhaka,
Dhaka-1000, Bangladesh

September 2022

DECLARATION

I, do hereby declare that this thesis entitled **"Algal diversity in the coastal wetlands of Cox's Bazar in relation to environmental variables and ecological niche"** 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.

September 2022 (**Jesmin Akhter Jolly**)

Certificate

This is to certify that the research work presented in this thesis entitled '**Algal diversity in the coastal wetlands of Cox's Bazar in relation to environmental variables and ecological niche**' has been carried out by **Jesmin Akhter Jolly,** bearing Registration No. 96/2017-18 under our supervision in the National Professor A.K.M. Nurul Islam Phycology, Limnology and Hydrobiology 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.

Mohammed Almujaddade Alfasane, Ph.D.
Professor
Department of Botany
University of Dhaka
Dhaka 1000, Bangladesh
Email: mujaddade@yahoo.com

Moniruzzaman Khondker, Ph.D.
Supernumerary Professor
Department of Botany
University of Dhaka
Dhaka 1000, Bangladesh
Emil: mkhondker@yahoo.com

Dr. Md. Sabbir Mostafa Khan
Professor
Department of Water Resources Engineering
Bangladesh University of Engineering and Technology, (BUET), Dhaka-1000

September 2022

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Author

Dedicated to My Husband

Dr. Mohammad Sadrul Anam

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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
DO	Dissolved oxygen
E	East
EDTA	Ethylenediaminetetraacetic acid
FAO	Food and Agricultural Organization
Fig.	Figure
Figs.	Figures
ft.	Feet
GF/C	Glass microfiber filter per circles
GOB	Government of Bangladesh
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
St.	Station

ABSTRACT

ABSTRACT

Algae have amazing diversities in respect to their habit, habitat, and taxonomic characters. Coastal wetlands are semi saline water bodies of varying length and dimension and in Bangladesh are present in the vicinity of the Bay of Bengal. Among the diversities of algae of the coastal wetlands, phytoplankton are major occupants and contribute cellularly built vital food elements to the trophic cascades. In those wetlands, the faunal diversity is fully dependent upon the productivity of phytoplankton. The qualitative and quantitative aspects of phytoplankton community, on the other hand, reflect the water quality status of a habitat. In the present research, a two-year study (2018-2020) on the assessment of the water quality of two coastal wetlands namely, Bakkhali River and Reju Canal, of Cox's Bazar city area was carried out. Cox's Bazar, a significantly famous maritime touristic spot of Bangladesh, where the aquatic ecosystems are routinely threatened by strong anthropogenic activities. So, the goal of the present research was to accumulate field data on water quality governing parameters as well as the quality, quantity, and seasonality of algal diversity of the two major coastal wetlands. Relevant to this, data collection was done on air- and water temperature (AT and WT, respectively), Secchi depth, salinity, total dissolved solids (TDS), electric conductivity, dissolved oxygen (DO), pH, alkalinity, NO_3-N, soluble reactive phosphorus (SRP), soluble reactive silicate (SRS), chlorophyll-a (chl-a), phaeopigment, and phytoplankton density.

A total of six (3 in each wetland) sampling stations were fixed to collect samples. Due to the remoteness of the study habitats from Dhaka, the sampling was done monthly once. The collected samples were processed following the standard procedures as available. The digital database thus created based on the analytical results was used to perform multivariate statistical analysis for predicting the ecological niche of the two wetland ecosystems. Besides, the dynamics of phytoplankton density (PD) variable with respect to the study stations and seasons were done via box-plot diagram. Impact on PD by AT, WT, water transparency (Secchi depth), biomass (chl-a), phaeopigment, and NO_3-N were made via simple linear regression. To see the water quality, trophic diatom index was calculated. To predict PD using all the variables, advanced machine learning model, Random Forest, Support Vector (SVM) was used. Taxonomy of phytoplankton community was worked out and the species as new reports for Bangladesh and some new species were screened and reported.

All the nutrients like nitrate (NO_3-N), phosphate (PO_4^{3-}) and silicate (SiO^{4-}_4) showed seasonal as well as spatial variation. Higher values of nitrate were observed during the pre-monsoon period than the other times of the year. The DO content of the water exhibited high degree of variation throughout the year especially during post monsoon and winter. Results of multiple correlation analysis reveal significant positive correlation between phytoplankton and

different physicochemical parameters. Phytoplankton biomass as chl-a is also compared to the study sites. Physicochemical variables of both the studied ecosystems are almost similar only exceptions could be observed in case of phytoplankton density. In Reju Canal the density of phytoplankton is nearly 5-fold higher than the Bakkhali River. The phytoplankton was found to be a function of temperature factor. Both the ecosystem has a dynamic equilibrium and therefore the ranges of the concentration of dissolved nutrients were wide. The upper limit of DO concentration in Bakkhali River and Reju Canal was 9.8 and 7.9 mg/L, respectively. The present hydrobiological condition is ideal for the growth of phytoplankton and species richness of *Chaetoceros* throughout the year for Reju canal on the other hand excessive nutrient load create negative impact on phytoplankton growth in Bakkhali river for some samplings due to higher conductivity and salinity. During monsoon, the dilution of nutrients promotes quality of phytoplankton for richness rather than quantity. Heavy precipitation favored the growth of phytoplankton as well as chl-a concentration. Among all the studied parameters, conductivity showed significant role for the growth and distribution of phytoplankton. Nitrate nitrogen was found as the limiting factor for phytoplankton growth. In the present study, Reju Canal habitiat showed 1.5 times higher NO_3-N than that of Bakhkhali river. So, phytoplankton diversity is higher in Reju canal. On the other hand, microbial degradation and chemical pollution helps to retard the growth of the phytoplankton in Bakhkhali River. Different hydrobiological parameters and presence of *Chaetoceros* and *Cyclotella* differentiate two ecological niches of the studied wetlands. Trophic diatom values indicate a moderate to good water quality of the studied ecosystems. As coastal wetlands, the Bakkhali river and Reju canal supports a significantly large phytoplankton diversity dominated by diatoms. Its self-purification capacity might be still high to lead a fairly good water quality. The niche defining characters of two dominant centric diatoms namely, *Chaetoceros* and *Cyclotella* could be as those by water transparency, water temperature, salinity and other nutrients. The study may contribute 48 new reports of phytoplankton for Bangladesh, which awaits a further detail address on a preliminarily identified source-list as new contribution.

Chapter-1

INTRODUCTION

Since long, algae have been used as water quality indicators. Nearly over a century ago, algal biomass and their biproducts were used as indicator of particular aquatic ecosystem (Kolkwitz and Marsson 1908). From the knitting of different algal communities in water supply systems (drinking water, swimming pool, etc.) it is possible to predict the condition of water (Stevenson 2014). In case of costal ecosystem, algae play a vital role for oxygen production. Phytoplankton, attached micro and macroalgae all together make the composition of algal diversity. They play a major role in the production of organic carbon, which further enters into the nutrient cycle via food chain. These are some of the basic functions related to the algal plants in our environment.

Algae show a high diversity in their body forms, habitat, size and shape, eco-physiological balances, etc. Other than cyanobacteria, there are nearly 28,550-140,600 species of algae are present in our earth (Botkin and Keller 2007). According to Guiry (2012), the estimated total algal species might be 72,500. However, AlageBase supports 33,248 species. In Bangladesh, so far, a little above 2300 species of algae have been recorded (Khondker 2022). Majority of these species were worked out from the freshwater terrestrial, and aquatic, and marine habitats (Islam *et al*. 1991, Ahmed *et al*. 2008, 2009; Khondker 2022).

Algal taxa were differentiated by ecological abundance and overall environment. It is also influenced by the physicochemical properties of an ecosystem. Zelinka and Marvan (1961) found a reliable method to identify human effects on aquatic resources by counting the total algae and their abundance (Watanabe *et al*. 1986, Wang *et al*. 2009, Chessman *et al*. 2007, Kelly *et al*. 2009, Kireta *et al*. 2012). Using algal species-composition in an aquatic habitat, it is possible to characterize the deviations from an original growing environment even to a slightly disturbed condition also (Passy and Bode 2004, Kelly *et al*. 2008, Stevenson *et al*. 2013). This technique has been used to protecting water quality in many countries around the world.

Concerning coastal wetlands, algal diversity in a mangrove ecosystem can be used as an indicator of climate change (Gao and Guanghui 2018). Both in polluted and unpolluted water we can find characteristic forms of algae growing there. So, we can easily use algae as a water quality indicator to forecast if it is polluted or not (Trivedy and Goel 1986). We also can determine the toxic level of the water body by the presence of some special algae (Joubert 1980). Occurrences of different algal blooms in coastal water indicates the rate of

climate change elements and the impact of human disturbance on coastal water (Anderson *et al*. 2002, Smol and Douglas 2007, Stevenson *et al*. 2013).

Recently, diversity or biodiversity is a well-known word for modern society. Nowadays this term is widely used to record the variety of life existing on this earth. This term is applied rapidly in different culture to study life science and its importance (Jeffries 1997). The word 'diversity' actually means the variations. The diversity among plants can be called as phyto-diversity. The same concept may also be applied to designate the animal diversity. There are three types of diversity, namely, species diversity, genetic diversity, and ecosystem diversity (Hassan 2000). Plants are a very diverse group and among plants, algae have the most diverse characters. It can be eukaryotic to prokaryotic and are cosmopolitan in distribution. Study of aquatic macrophytes and phytoplankton are commonly known as phytodiversity of wetlands. But the algal components of the free water of wetland ecosystems, i.e., phytoplankton means microscopic drifting algal communities. These are autotrophic tiny organisms found both in fresh water and marine water. Phytoplankton also have chlorophyll a to capture sunlight which they further turn into chemical energy by photosynthesis (Behrenfeld *et al*. 2005). Ecological condition of a water body can be calculated by encountered phytoplankton and it might be used as a water quality indicator (Bhatt *et al*. 1999).

Wetlands have been considered universally as important assets for biological conservation because they support a rich biodiversity and high productivity (Mitsch and Gosselink 2000). The term Wetland was first used in 1950, for describing the seasonally of shallow-flooded habitats. Nowadays, these wetlands are divided into many types i.e.; swamp, bog, fen, mire, moor, marshes, estuaries and so on. Each wetland type plays a significant role to host a number of algal communities of flora and fauna.

Wetlands are named so, because they contain land mass inundated by water, thus having a shallow basin and the depth of which should not exceed 6 m in the direction to the seas. These are the most important inland ecosystem which supports a wide range of biotic diversity. For many developing countries the wetlands are used as a waste dumping ground, so it also remains in endangered condition. However, wetlands regulate the whole local ecosystem on a particular area. There are 90 different names prevail to designate wetland in the USA (Hatvany 2009). Wetland diversity and aquatic diversity depends on water so, it will depend upon the pattern of rainfall and other sorts of wet precipitation. Bangladesh is blessed with a rainfall amount of around 2200 mm per year. Most part of the country receive at least

1500 mm and northeastern border area receive 5000 mm of rain fall per year. More than 64-66% rainfall mostly occurs during monsoon, followed by pre-monsoon (22-29%), post-monsoon (5-11%) and winter (1-2%) (BWDB report 2019). The water of a wetland may be varied like fresh, brackish or saline, it may be standing or may be flowing. The organisms in these habitats may vary from smallest microscopic to huge gigantic size. Wetlands are found in all climates and from sea level to more than 5500 m ASL like Himalaya.

About 50% land of Bangladesh consider as wetlands and they support a wide range of species including endanger plant and animals (IUCN 2005). Among all, the coastal wetlands have become more valuable and more productive zone in the universe. In our country, coastal wetlands have many ecological values. Coastal zone is the most dynamic and diverse zone on earth because in this land ocean and atmosphere both interact with each other. Seasonally this zone continuously faces by different natural disaster like cyclones, tsunami, hurricane, sea level rise, etc. So, coastal wetlands need to be preserved and protected for all time because coastal zone has many natural resources and minerals upon which depend the livelihood of a large number of people. It has much more potential to explore usable resources and as of tourism site.

Coastal wetlands include both salt- and freshwater ecosystems which are located within coastal watersheds and support rich biodiversity and high productivity (Mitsch and Gosselink 2000). Bangladesh has an extensive longest coastline of about 710 km. Along with environmental benefits, those water bodies are important for fisheries, coastal aquaculture, acquisition of mangrove forest resources, and many more economic and social activities. In Bangladesh, coastal zone plays a vital role in economic development. The area of this zone covers 47,201 km^2, which means a total of 32% of the country. Among total number of populations, 29% live in coastal zones of Bangladesh. There are 19 coastal districts in our country. They are Jessore, Narail, Gopalganj, Shariatpur, Chandpur, Satkhira, Khulna, Bagerhat, Pirozpur, Jhalakati, Barguna, Barisal, Patuakhali, Bhola, Lakshmipur, Noakhali, Feni, Chittagong, and Cox's Bazar. Coastal Bangladesh is divided into three distinct zone, these are: 1. Eastern coastal zone, 2. Central coastal zone and 3. Western coastal zone (Ahmad 2019). Cox’s bazar located in eastern coastal zone of Bangladesh. This is a narrow coastal zone. Karnafully, Sangu, and Matamuhury River are flowing through this zone. The Naf River divided Bangladesh and Myanmar. Soil type of this zone are dominated by submerged sands and mudflats (Islam 1993).

Bangladesh is a riverine country where river serves a large portion of wetlands. A river can cover a large area by flowing through the landmass into the ocean. There are 700 rivers present in Bangladesh. Most of the rivers originated from the Himalayan ranges and flowing through south. All river falls into the Bay of Bengal. So, rivers are playing an important role to build coastal ecosystems and estuaries. River estuaries are the transition zones between sea and freshwater where we find both freshwater and marine species (Claridge *et al*. 1986). Estuaries are not only important for transportation, industry, and tourism but also serve as drainage of wastewater originated from the domestic and industrial sources (Heip and Herman 1995). This zone also supports a specialized marine ecosystem where large number of marine species might live or spend at least some stages of their life cycle through migration (Cowley and Whitfield 2002). Marine phytoplankton can contribute half of the total global production (Chavez *et al*. 2011). The coastal wetlands have great contribution to marine nutrient sources and functioning of marine ecosystems (Naeem 2012). It is very important to know the relationship between the phytoplankton diversity and the environmental factors of the whole ecosystem.

The variation in the ecosystem functioning of the coastal wetlands of Bangladesh occurs over a seasonal cycle. According to Brammer (2000), four typical climatic seasons are found to prevail in Bangladesh. These are, pre-monsoon, monsoon, post-monsoon and winter. Growth of phytoplankton depends on season. Phytoplankton grow luxuriantly during winter and pre-monsoon. Biological parameters and others physicochemical parameters have also great impact on phytoplankton density and their growth. As physicochemical parameters are responsible for phytoplankton growth, so they can be used as a water quality indicator (Brettum and Andersen 2005). Along with diatoms other algal species can be used as excellent proxies for detecting changes in the water column as a result of anthropogenic activities. So, we can monitor water quality and save fish community, drinking water, domestic uses, agriculture, and overall ecosystem by observed phytoplankton content present in that ecosystem (Imhoff and Albrecht 1982).

Plankton are drifting organisms present both in the fresh- and marine water ecosystems (Reynolds 1984) and constitute an important vegetation in the coastal wetlands. In aquatic ecosystem, their presence mostly depends on seasons and water quality. Of the plankton components phytoplankton has been regarded as the primary producer while the zooplankton as primary consumer (Battish 1992). So, plankton serve as main components of food chain in

wetlands (Boyd 1982, Hossain *et al*. 2007). Phytoplankton donate nearly 0.5-92% of aquatic primary production (Vadeboncoeur *et al*. 2002, Vander Zanden *et al*. 2011).

The population dynamics of phytoplankton depends on concentration of dissolved nutrients, ranges of temperature, availability of light and weather condition (Vaulot 2001). But sometimes self-shading, as produced by their vigorous growth in water, the so-called algal bloom formation, sometimes inhibit the rate of primary production. It is not only the nutrient supported bloom of phytoplankton, interactions of phytoplankton with other aquatic organisms can affect the ecosystem functioning too. Such relationships can be designated as niche function of a particular species.

Ecological niche is a term for the position of a species within an ecosystem, describing both the range of conditions necessary for persistence of the species, and its ecological role in the ecosystem. For studying the ecological niche, it is important to assess the pattern of water quality and biological and physical variables which can bring changes through pollution and other man-made causes. Ecological niche is recognized from the interrelationship among the organisms and the surrounding environmental variables (Grinnell 1917). The cumulative function of niche characteristics actually determines the fragility of an ecosystem via predator and prey relationships which catches the attention of ecologists. Nowadays, niche has been considered as the key element of ecology. So, by the proper concept of ecological niche we can find out relation of a species with all other reliable data of that ecosystem and also with other species.

In Bangladesh and throughout the world, Cox's Bazaar is well known for its longest sea beach situated along the shore of northern Bay of Bengal. Over many years, it has been an attraction to both international and domestic tourists and playing a vital role in the economy of Bangladesh. The success of the tourist industry in those areas is often associated with an intact natural environment both in the sea as well as in the land and estuarine areas. So, water quality of rivers and channels in the coastal area serves as an important factor for tourists in their choice of destination, and should not be underestimated. The Bakkhali River and Reju Canal maintain the flow of entire watershed area of Cox’s Bazar. So, it is important to protect this zone for not only ecological aspects but also for a sustainable functioning of tourist industry.

Bakkhali river estuary is located in most southern part of Cox’s bazar. This river originated from south-eastern hill of Mizoram, India. It flows through Naikhongchhari of

Bandarban district of Bangladesh then further it enters into the territory of Cox's Bazar through Ramu and then it falls into Moheshkhali channel of the Bay of Bengal. This is the most wide and longest river of Cox's Bazar. Length of Bakkhali river within Cox's Bazar district is about 67 km. Salinity of the water varied with tidal zone. Cox's bazar fish landing center located in the bank of this river. City wastewater and all sorts of drainage discharges are dumped in this river causing public nuisances via water pollution. Besides, discharges of burnt oil from fishing trawlers by fishing boats also cause a severe threat towards plankton population and water quality deterioration.

Reju canal is another important river of Cox's bazar originated from north Arakan Mountain of Mayanmar, which then enters into Bandarban district of Bangladesh and flows over Ukhia of Cox's Bazar district. This river produces huge fish and named famous for its marvelous scenario. Many eco-resorts are made in the bank of this river. Salinity of this river was lower than Bakkhali river and also depends on high tide and low tide.

In Bangladesh, so far, much attention has been given to study the diversity of freshwater aquatic microalgae and phytoplankton, and were focused mainly in the central and northern part and in and around Dhaka Metropolis (Alfasane *et al*. 2010, 2012; Islam and Zaman 1975, Khondker 2022). From the Chittagong division and the coastal belt there are only very few studies present. The plankton of Karnafully river estuary and Halda river were studied by Islam and Aziz (1977), Patra and Azadi (1985) and Hossen *et al*. (2019). There are a number of studies conducted on water quality of Bakkhali river (Rashed-Un-Nabi *et al*. 2011, Siddique *et al*. 2012, Hasan *et al*. 2019), but excluding the diversity of phytoplankton studies. Recently, the zooplankton productivity and fisheries resources of Reju canal were studied (Parvez *et al.* 2018, Iqbal *et al.* 2017, Zakaria *et al*. 2016). In aquatic habitats, the terminal biological production as fish as well as zooplankton productivity are dependent chiefly on the primary production by phytoplankton. So, to know the pattern of kinetic energy flow to potential food energy in the wetlands, the communities of phytoplankton must be addressed. On the other hand, the diversity and productivity of phytoplankton depend upon the physical availability of light, temperature and many more physicochemical factors. So, to work out this interaction strategies in this region is highly important. To fulfil this knowledge gaps in these coastal wetlands of Bangladesh, the present research was undertaken. The results of this study will be helpful for management and planning for water quality monitoring in the two coastal wetlands namely, Bakkhali River and Reju Canal, Cox's Bazar. It is suggested that frequent monitoring of the hydrobiological recourses of the river systems

is very necessary for near future to detect the shifting of baselines, assisting ecosystems-based monitoring and enhancing restoration efforts.

Under this preamble, the objectives of the present research have been set forth. The research goal thus attempted, is to find out the intrinsic environmental factors governing the algal diversity in the pelagic region of the two selected coastal wetlands of Cox's Bazar along with their niche functionality and characteristics. The system approach of these two ecosystems should then be assessed via measuring environmental and algal variables over a qualitative and quantitative range as well as their variations on spatial and temporal scale. The results would thus focus the role of algal diversity on the fisheries resource as well as the events of water quality forecast via algal indicators.

Objective of the research work:

- To study the physicochemical characteristics of two coastal wetland habitats of Cox's Bazar district.
- To study the total phytoplankton of two coastal wetlands
- To find algal biomass as well as cell number
- To address the interrelationships between the physical, chemical and biological aspects of coastal wetlands of Cox's Bazar district.
- To study the relationships between the selected environmental variables such as air and water temperature, secchi depth, salinity, pH, dissolved oxygen (DO), total dissolved solids (TDS), conductivity, alkalinity, soluble reactive phosphorus (SRP), soluble reactive silicate (SRS) and NO_3-N with algae.
- To find out the seasonal variation of physicochemical parameters and phytoplankton density of two different wetlands of Cox's Bazar
- To calculate total Phytoplankton qualitative and quantitative aspects
- To study the community composition and abundance over the array of physicochemical water quality factors
- To study the indicatives are spatial and seasonal phytoplankton density distribution as niche response
- To determining the niche governing physical factors i.e., habitat temperature and transparency concentration
- Determining chemical environment of water as dissolved ions and chemicals i.e., salinity, TDS, electric conductivity, DO, pH, alkalinity, NO_3-N, SRP, SRS
- To find out the spatial and seasonal distribution of biomass parameter such as chl-a, phaeopigments, and phytoplankton density
- To detect the responsible niche variables done many multiple correlation analyses
- To inferring the water quality status of the studied habitats over national and global scales
- To detecting the effects of salinity and nutrients on phytoplankton species abundance, diversity, and distribution
- To predicting cumulative ecological niche effects on two different studied habitats
- To finding relationship between phytoplankton and different physicochemical parameters via multivariate statistical analysis

Chapter-2

LITERATURE REVIEW

Literature review

In Bangladesh, several researches on the relationship between physicochemical parameters and algal communities were carried out. In those, the ecology, biology, primary productivity and systematics of phytoplankton, micro- and macroalgae growing in different wetland habitats were emphasized. Khondker (1994) had reviewed the detailed status of the limnological researches in Bangladesh. He mentioned in his review that few researches on running water ecosystems of Bangladesh were addressed in the past. In comparison, limnology of natural and artificial lakes of Bangladesh, ponds, *beels*, and *haor* ecosystems were prioritized. Besides, in a latest review on the earlier phycological research and its current trend in Bangladesh, Khondker (2022) has provided a statistical background of the systematics of algal species recorded along with their autecological significance. In addition, he has also provided an account on the new taxa reported from Bangladesh by various authors from both the aquatic and terrestrial habitats (Khondker 2022). Consulting those two reviews, it could be said that compared to the lentic inland aquatic habitats, the estuarine and running waters of Bangladesh are less studied. The important researches so far carried out in the running water habitats of Bangladesh are reviewed below.

Islam (1969) studied algal flora of Sangu river (North Arakan Hill) and Rainkhyang lake. He reported that the river Sangu was rich in nitrogen which was judged by the presence of indicator species belonging to the cyanophyte-diatom communities of the river. The algal flora of desmids was very poor, rather the species of *Cladophora* and *Spirogyra* were dominant in the Sangu river. The recorded algal flora belonged to the family Chlorophyceae, Cyanophyceae, Xanthophyceae, and Bacillariophyceae.

Islam *et al.* (1974) studied the relationship between physicochemical parameters and biological parameters of the river Buriganga near Dhaka Metropolis. They considered the parameters on rainfall, duration of sun-shine, water temperature, dissolved oxygen (DO), pH, total N_2, permanent hardness as $CaCO_3$, and phosphate contents of the river water. The range of air temperature of the river showed 29-34°C. DO ranges from 2.63-7.73 ml/L and annual rainfall ranged from 1.02-645.67 mm. Relative humidity was ranged from 61.00-88.66%.

From the studied chemical parameters, pH, total nitrogen, and phosphate ranged from 7.0-7.8, 0.026-0.44 mg/L and 0.004-0.126 ppm, respectively. However, from the biological parameters, the density of phytoplankton ranged from 4.2 - 100.0 $\times 10^5$ ind/L and the zooplankton population density from 2 - 42 $\times 10^5$ ind/L. They also reported some species of phytoplankton and benthic algae as indicator to the pollution status of the river water.

Islam and Haroon (1975) studied the biological aspects of the river Buriganga where they had illustrated and provided systematic enumeration of 137 algal and 15 zooplankton species. All the reported algal species belonged to 59 genera and the species of zooplankton what they reported were 15 under 14 genera. The percentage composition of different classes of algae were 45.26, 13.13, 1.46, 0.73, 87.26, and 1.46% respectively for Chlorophyta, Cyanophyta, Euglenophyta, Chrysophyta, Bacillariophyceae, and Rhodophpyta. In their study, marked seasonality of the population dynamics of the algal flora was observed. Among the studied species *Hydrodictyon reticulatum* (L.) Bory (water net) appeared in the community more than one time. They also observed some discontinuous distribution of both phyto- and zoo- plankton species in the community.

Islam and Zaman (1975) studied the biological aspects *i.e.,* algal communities and their relative abundance in different seasons in zone II of the river Buriganga near Dhaka. During their study, 194 species of algae (under 72 genera) were recorded from both the planktonic and benthic communities. In that zone, the percentage composition of Chlorophyceae, Bacillariophyceae, Cyanophyceae, Euglenophyceae, Rhodophyceae, Xanthophyceae, and Chrysophyceae were 56.19, 29.90, 10.31, 1.03, 1.03, 1.03, and 0.51%, respectively. They had also showed the relative abundance of phytoplankton as minimum and maximum during monsoon and autumn seasons, respectively.

Islam and Aziz (1977) studied the phytoplankton of Karnaphuli river estuary. They have reported 23 genera and 42 species belonging to different classes. The class wise distribution of the number of phytoplankton species were 12, 1, 1, 17, 5, and 6, respectively from Chlorophyceae, Euglenophyceae, Chrysophyceae, Bacillariophyceae, Dinophyceae, and Cyanophyceae.

Patra and Azadi (1987) carried out one limnological investigation of the Halda river. They studied physicochemical characteristics of the river with respect to their annual variation and the degree of correlation among them. The relationships, among the physicochemical parameters had showed relatively a complex trend during summer and monsoon due to the high current, turbidity, and water temperature. On the other hand, these measurements showed high values during the winter season. Significant positive and negative correlations were found between and among the factors studied from the river.

Water quality studies conducted by GOB (1993) and Ahmed (1993) in some rivers adjacent to the city of Dhaka, namely, Baloo, Buriganga, Sitalakhya, and Dhaleshwari had revealed clearly a polluted condition of their water. However, an increased flow of the river water during monsoon created a dilute condition of the water and had caused a reduction in the pollution status (Hasan *et al*. 2013). The higher concentrations of some harmful heavy metals e.g., Cd, Pb, and Cr were found in different stations in the studied Burignaga, Sitalakhya, and Turag rivers (Alam *et al*. 1993).

Talukder *et al*. (1994) reported water quality parameters under environmental perspective of north western regions of Bangladesh where they carried out measurements on temperature, pH, NH_3-N, Cl^-, $SO4^{-2}$, Fe, DO, BOD_5, COD, total coliform, As, and Cr. They considered different water bodies including rivers. The pollution of the Nandakuja river occurred from different discharges of adjacent areas. High BOD_5, COD, and total coliform density in this river were found responsible for fish-kill.

Talukder and Khondker (1995) carried out limnological studies of 20 water bodies in the Noakhali North flood prone areas of Bangladesh. They observed higher pH, DO, PO_4, and Si in the river water and nearly 56% of the total aquatic algae and 51% of the total aquatic macrophytes of Bangladesh were reported from this area. Bloom forming phytoplankton (which has a high prospect of bio-diesel extraction) *Botryococcus braunii* Kutz. and other unicellular green flagellates were most common.

Khondker and Talukder (1995) studied limnological assessment of some water bodies within Gumti floodplain, Comilla. They found that the concentration of dissolved gaseous substances (O_2 and CO_2) and nutrients (nitrate, phosphate, and silicate) were higher in the river water than in the pond and *Beel* ecosystems. Around 50% of the total aquatic algae and macrophytes were found to grow in those ecosystems.

Chakraborty and Mirza (2010) studied the aquatic resources in Someshwari river in northern Bangladesh. They showed phytoplankton was dominant in the lower region of the river where Someswari met with the Kangsha river. On the other hand, phytoplankton population was much less in the upper region of the river. The floristic composition of phytoplankton revealed 27 genera under the classes of Chlorophyceae, Bacillariophyceae, Cyanophyceae, and Euglenophyceae. Chlorophyceae included the genera *Protococcus*, *Mougeotia*, *Microspora*, *Mesotaenium*, *Closterium*, *Eremesphaera*, *Chlorococcum*, *Ophiocytium*, *Penium*, *Spyrogyra*, *Zygnema*, *Kirchneriella*, *Gonatozygon*, *Pediastrum*, *Oocystis*, *Tetraedron*, and *Volvox*. Bacillariophyceae contained the genera namely, *Melosira*, *Diatoma*, *Fragilaria*, and *Navicula*. However, *Anabaena*, *Chroococcus*, *Merismopedia*, *Microcystis*, and *Oscillatoria* did belong to the class Cyanophyceae. Euglenophyceae included only the genus *Euglena*. Chlorophyceae and Bacillariophyceae were the dominant group (P<0.05) during the five-year study period. Hossain (2016) also reported the status of biodiversity in the Transboudary River Someshwari.

Alfasane *et al*. (2011) reported the relationship between phytoplankton and limnological parameters in Tulatali river of Bakerganj. Among the major groups of phytoplankton, they showed the member of the class Bacillariophyceae as dominant (61.63%) followed by Cyanophyceae (27.83%), Euglenophyceae (9.71%) and Chlorophyceae (0.81%). Diatom genera like *Cyclotella*, *Stephanodiscus*, *Coscinodiscus*, *Navicula*, *Synedra*, *Melosira*, *Gyrosigma*, *Fragilaria*, *Nitzschia* and *Gomphonema* were reported as prevalent taxa. Among green algae, genera like *Eudorina*, *Pandorina*, *Scenedesmus*, *Pediastrum*, *Closterium*, *Cosmarium* and *Zygnema* were common. Cyanophyceae was represented by *Microcystis*, *Oscillatoria*, *Anabaena*, *Arthrospira*, *Merismopedia*, and *Nostoc*. *Euglena*, *Phacus* and *Trachelomonas* were the principal genera from Euglenophyceae. While the members of the class Cryptophyceae were reported to be present in 4, out of 24 samples. Under this class, the species like *Cryptomonas ovata* Ehr. and *Rhodomonas lacustris* Pascher & Ruttner were most common.

Ahsan *et al*. (2012) studied the composition of plankton, their abundance, and diversity in the *Tenualosa ilisha* (Hamilton 1822), from their migratory rivers of Bangladesh during spawning season. They studied plankton from the Padma, Meghna, and Tetulia rivers where a total of 58 taxa of plankton were present. Of which, 19 taxa (32.76%) were of phytoplankton which belonged to the algal classes of Cyanophyceae (6 taxa), Chlorophyceae (7 taxa), and Bacillariophyceae (6 taxa).

Khondker and Abed (2013) studied the seasonality of phytoplankton productivity of Turag River, Dhaka in relation to its water quality parameters. They measured 16 water quality variables together with the phytoplankton biomass where potential primary productivity ranged from 6.22 - 199.7 μgC/l/hr. On the other hand, the phytoplankton biomass chlorophyll a (chl a), phosphate-phosphorus, and nitrate-nitrogen concentration were in the range of 1.84 - 162.8, 30.28 - 796.54, and 27.02 - 905.04 μg/l, respectively. A decrease in the mean concentration of these parameters was observed in monsoon compared to their high concentration in pre-monsoon, post-monsoon, and winter. Strong positive correlation was found between primary productivity and chl a, on the other hand chl a showed strong positive correlation with PO_4-P and NO_3-N. Significant negative correlation was observed between DO and PO_4-P which indicated the eutrophic nature of the river. Concentrations of PO_4-P, NO_3-N and chl a were high in pre-monsoon but lowered by 90, 87, and 97%, respectively in monsoon.

Flura *et al*. (2016) studied the physicochemical and biological parameters of Meghna River. They measured nineteen physicochemical parameters of water namely, water depth, water temperature, air temperature, water colour, odour of water, bottom type, transparency, conductivity, turbidity, TDS, DO, free carbon dioxide, pH, NH_3, total alkalinity, total hardness, BOD, COD, and phytoplankton and zooplankton population density. The recorded highest concentration of dissolved oxygen and free CO_2 were 7.5 and 3.7 mg/L, respectively. In the study, the major groups of phytoplankton belonged to the classes of Chlorophyceae, Bacillariophyceae, Dinophyceae, and Cyanophyceae. Results on the concentration values of various physicochemical and biological parameters studied for the river water had indicated that the river water were safe for aquatic lives, but the trend of continuous sewage disposal into the river water might become detrimental to this valuable running water ecosystem of Bangladesh.

Uddin *et al*. (2016) reported the status of heavy metals in water and sediment of the canals and rivers around the Dhaka city of Bangladesh and their subsequent transfer to crops. They analyzed water, sediment, soil, and plant samples for the evaluation of heavy metals *i.e.*, lead, cadmium, copper, and zinc contents. The findings show that heavy metal concentrations revealed a trend like Tejgaon Khal>Rampura canal>Shitalakhya river. The pH, DO, BOD, COD, TDS, and NH_3 values showed higher concentration compared to the values recommended by the DoE (Bangladesh) for irrigation water standards. The heavy metals trend had followed the order Pb>Cd>Zn>Cu. The concentrations of heavy metals in soil and sediment samples were found higher than the U.S. Environmental Protection Agency (USEPA) recommended standards and follow the trend Zn>Cu>Pb>Cd. In most of the cases chemical parameters showed significant variations (at 1% level) from Tejgaon river samples with others.

Parvez *et al*. (2018) made a hydrobiological study on Reju Khal estuary with emphasis on fish diversity. They investigated different physicochemical and biological variables. The recorded values for surface water temperature, pH, salinity, DO, TDS, and Secchi depth were 16-26 °C, 7- 8, 8-29 PSU, 3-4 mg/L, 33- 35 mg/L, 21-45 cm, respectively. In their study, the density of zooplankton and phytoplankton population were 27-45 ind/m^3 and 9400-17100 cells/L, respectively. During the study period, a total of 6706 individuals of the faunal population were worked out which belonged to 36 species under 23 families. The qualitative aspects of the species recorded in the study were comparable to the subtropical coastal ecosystem compositions.

Parvez *et al.* (2019) carried out one study on the water quality of the tidal river Halda, India. The studied stations were namely, Gorduara, Sattarghat, and Kalurghat. They considered different physicochemical and biological variables namely, temperature, pH, transparency, EC, DO, TDS, SS, salinity, and plankton communities. Among all the physicochemical parameter lower concentration of DO indicated pollution of Kalurghat station. On the basis of 11 algal genera. They also prepared 'Palmer pollution index' which could help to measure Kalurghat station is highly polluted zone among three stations.

Islam *et al.* (2021) studied the assessment of physicochemical properties and comparative pollution status of the Dhaleshwari river in Bangladesh. They showed that the threatened condition of the river was developing due to the continuous input of industrial wastes from the leather tanning industries. They found that the total dissolved solids,

biochemical oxygen demand, and chemical oxygen demand for the Dhaleshwari river deviated as much as 90% from the WHO standards in certain instances due to direct discharge of the untreated wastes into the river water. They had compared their results on the concentration of different toxic heavy metals such as chromium (Cr), cadmium (Cd), and nickel (Ni) with the standard chart of the FAO and found that the river system in Dhaka city can be termed as severely polluted in respect to organic and solid discharges. Therefore, the ecological risk indices are in high category.

From the above review on the estuarine and freshwater rivers and wetlands of Bangladesh and India it has been found that the algal diversity in relation to environmental factors in the coastal wetlands, and ecological niche character's assessment are very rare. A very few attentions have been given in this coastal ecology study disciplines with special emphasis on river ecology. So, the present attempt has been made to carry out a detail study on phytoplankton diversity, physico-chemical aspects of the coastal river water of Cox's Bazar along with a study on their ecological niche. This information will help to fulfill the knowledge gaps of river ecology of wetland habitats with particular reference to the algae and will also become useful for adopting conservation and management programs of this water body in the near future.

Chapter-3

MATERIALS AND METHODS

MATERIALS AND METHODS

The present research was carried out in Bakkhali River and Reju Canal of Cox's Bazar district. A total of 6 stations were selected from both the studied wetland ecosystems. The selected stations were B1, B2, B3 and R1, R2, R3 for Bakkhali River, and Reju Canal, respectively. Samples, for analyzing 15 water quality parameters were collected monthly from three stations set up in each of the studied running water ecosystems. The study sites were investigated from September 2018 to August 2020. Monthly mean values of 15 physicochemical parameters of the water quality and the diversity of phytoplankton were calculated from all the samples collected from three stations of each study site.

Study sites

The sampling sites for the present investigation i.e., the Cox's Bazar city are situated nearly 395 km south east of Dhaka Metropolis, the capital city of Bangladesh. Details on the geographical location of Cox's bazar together with some physiographic features and sampling events of the studied stations have been presented in Table 1, and Figs. 1-12.

Bakkhali River

Bakkhali river estuary is located in the most southern part of Cox's bazar. This river is originated from south-eastern hill of Mizoram located in India and then flowing through Naikhongchhari of Bandarban district of Bangladesh. From Naikhongchhari it enters into Cox's bazar through Ramu and then it falls into Moheshkhali channel of the Bay of Bengal. This is the widest and longest river of Cox's Bazar. Length of Bakkhali river within Cox's bazar district is about 67 km. Salinity of the water varied with tidal zone. My study stations were situated in the Maheshkhali channel of Bakkhali river. There are several fish landing centers and motor launch stations locally known as Ghat. Collection of samples were started from the Ghat No. 6 which is one of the busiest places for water transport vehicles and markets. The GPS data of the study stations of this site has been presented in Table 1.

Table 1. GPS data of the studied stations.

Bakkhali river		Reju canal	
Station	GPS	Station	GPS
B1	21° 45' 19 " N, 91° 97' 11 " E	R1	21° 29' 45 " N, 92° 05' 11 " E
B2	21° 45' 22 " N, 91° 97' 49 " E	R2	21° 29' 35 " N, 92° 05' 14 " E
B3	21° 45' 17 " N, 91° 98' 03 " E	R3	21° 29' 07 " N, 92° 05' 27 " E

Reju canal

Reju canal is another important river of Cox's bazar. It has importance from both economical and geographical point of view. This is a beautiful hilly stream flows over Cox's Bazar which rises from the hill of North Arakan. Reju canal originated from north Arakan Mountain of Mayanmar then it enters through Bandarban district of Bangladesh and flows over the Ukhia of Cox's bazar. A beautiful bridge over Reju canal connect Inani, Nhila, and Teknaf sea beaches with Cox's Bazar and Himchari sea beaches. This river produces huge fish. Coral reef formation and large rocks are found in the bottom part of the river. This river also famous for its marvelous scenario. Many eco-resorts are made in the bank of this river. It has a huge variation of diversity may be due to longshore sediment movement. Its GPS location has been presented in Table 1.

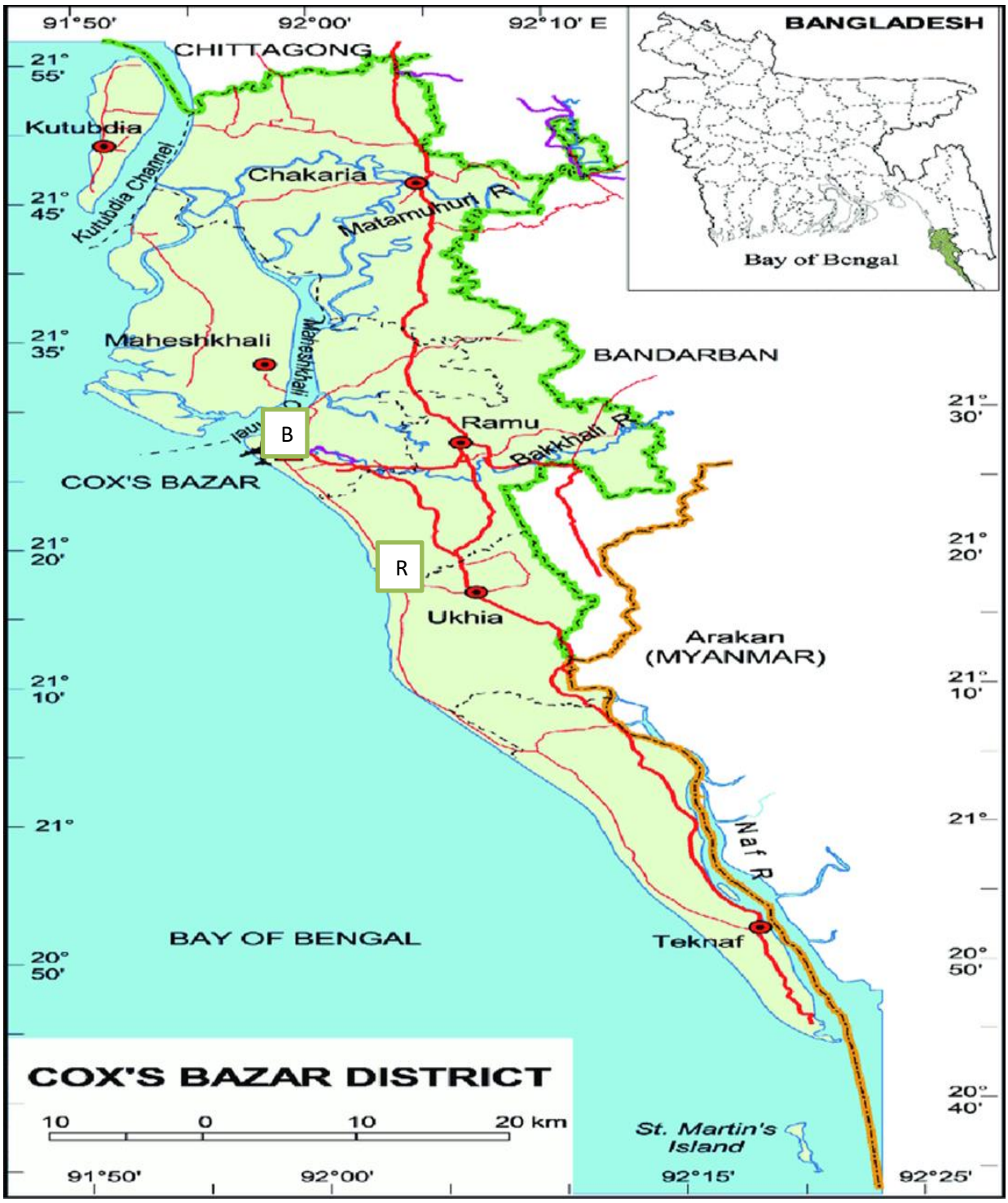


Fig. 1. District map of study area showing different places along with the studied areas of Cox's Bazar (source google).

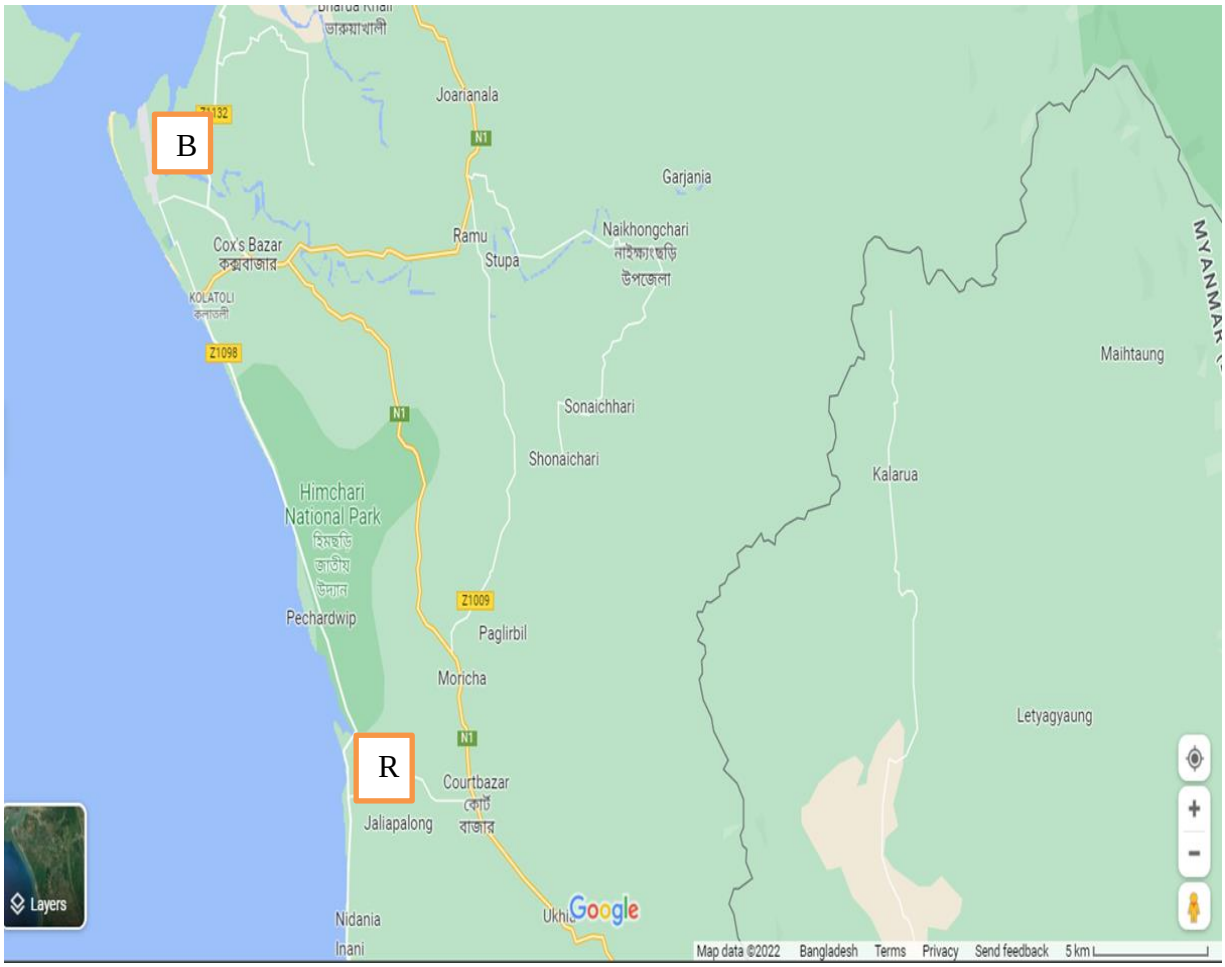


Fig. 2. Google map of Cox's Bazar showing Bakkhali river (B) and Reju canal (R).

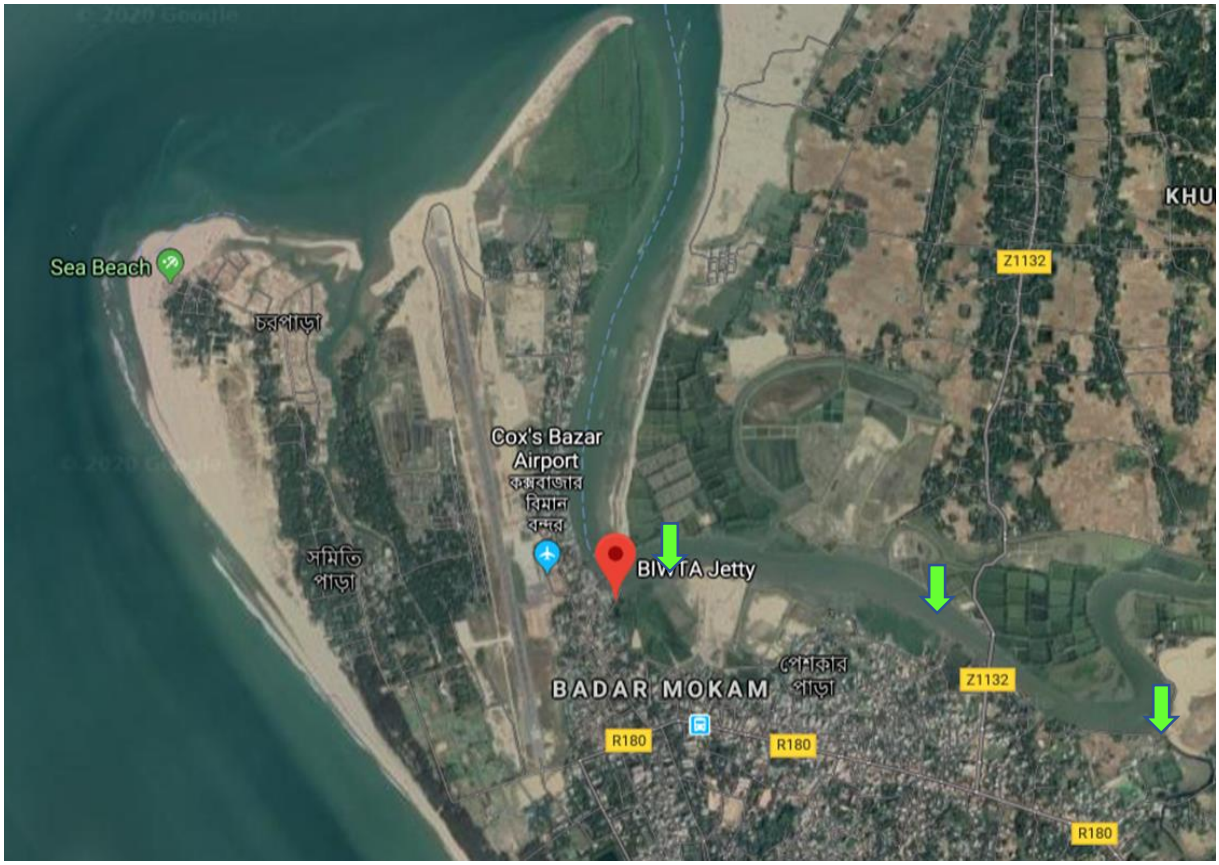


Fig. 3. Bakkhali river with B1, B2, B3 sampling stations which pointed by arrow sign (↓).

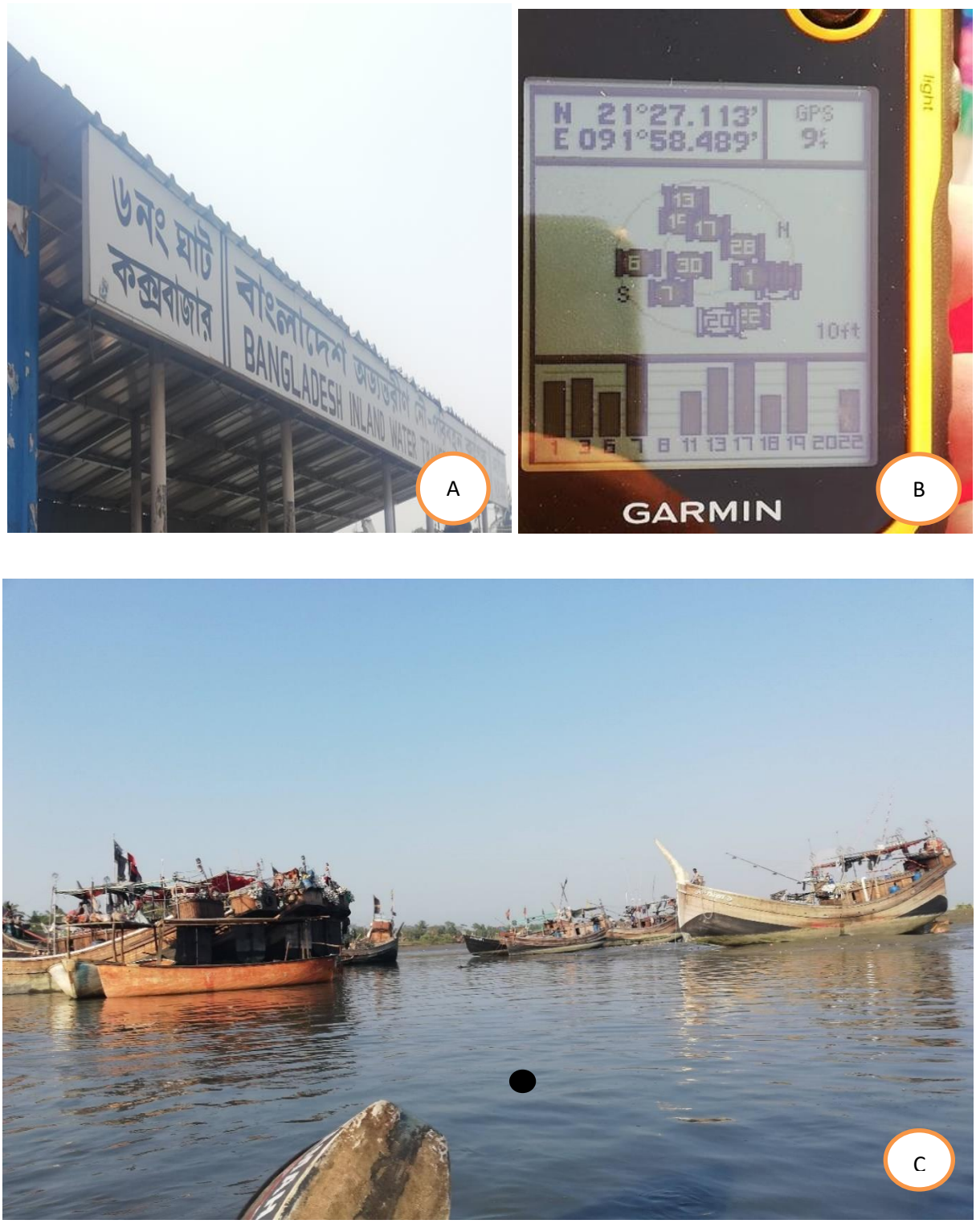


Fig. 4. A-C, Sampling station B1. A, 6 No. Ghat; B, GPS meter; C, sampling station (sampling station, ●).

Fig. 5. B2 sampling station from Bakkhali river (sampling station, ●).

Fig. 6. B3 sampling station from Bakkhali river (sampling station, ●).

Fig. 7. Reju canal with R1, R2, R3 sampling stations which pointed by arrow (↓) sign.

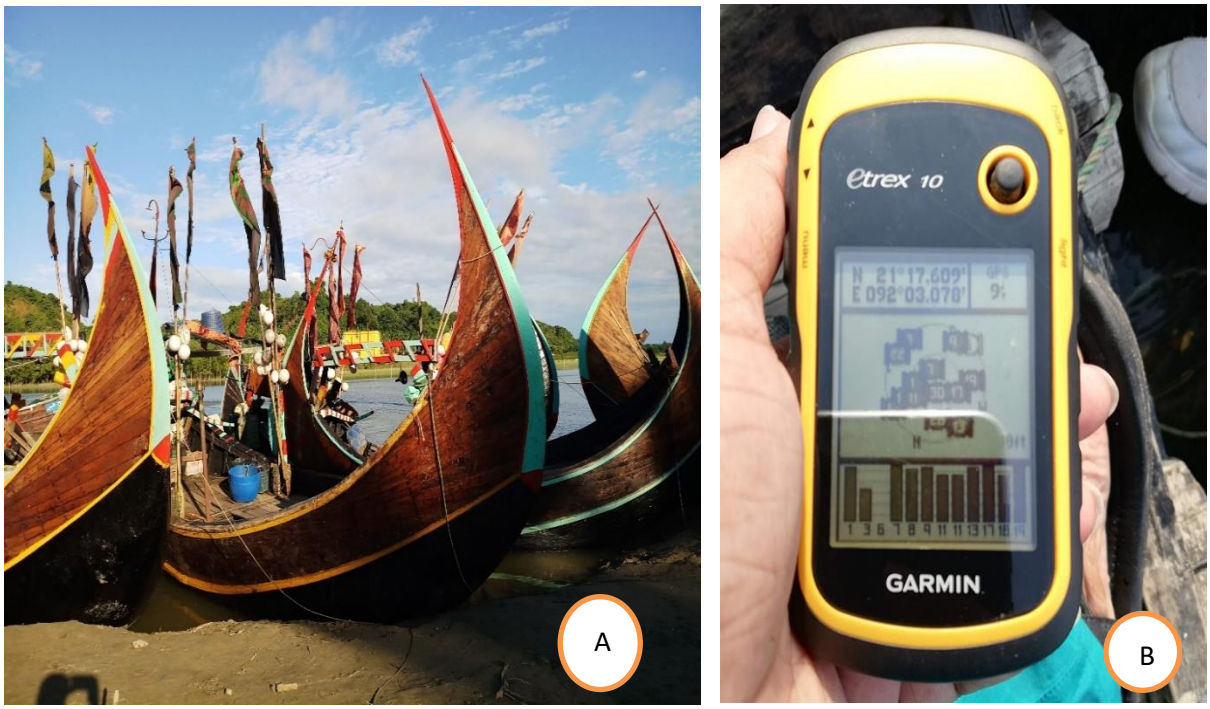


Fig. 8. A, B, Sampling station Reju canal. A, Traditional fishing boat; B, GPS meter.

Fig. 9. R1 sampling station from Reju Canal (sampling station, ●).

Fig. 10. R2 sampling station from Reju Canal (sampling station, ●).

Fig. 11. R3 sampling station from Reju Canal (sampling station, ●).

In situ sample collection

Collection of water and phytoplankton samples

The sampling was carried out from 09.00 AM - 2.00 PM. A Schindler-Patalas water sampler (5 l capacity) was used to collect integrated water sample from 50 cm depth of each study station. Sampler was dripped under water very slowly then pulled out. After confirming the closure of the sampler, it was taken out and two 1 l capacity acid washed polystyrene bottle was filled with the collected water which were frozen in a locally available deep freeze. Another one-liter capacity polystyrene bottle containing 1 ml Lugol's iodine was then filled with the same water for phytoplankton qualitative and quantitative study.

During the time of sample collection, *in situ* measurements of some physicochemical water quality parameters were carried out. Air temperature was measured with the help of a mercury centigrade thermometer and water temperature was recorded from a thermometer fixed inside the Schindler-Patalas sampler. Secchi depth was measured with the help of a black and white painted Secchi disc. Conductivity, TDS, DO, pH and salinity of the sample water were measured *in situ* with the help of respective field meters (Table 2). After the collection was complete, all the samples were put transported to the laboratory of the University of Dhaka for further analysis within 24 h following standard procedure (please see in the next).

Other physicochemical parameters i.e., chlorophyll a (chl-a), soluble reactive phosphorus (SRP), soluble reactive silicate (SRS), and alkalinity were determined on the next day at laboratory (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. Detail description of the measurement of all the parameters are provided below.

In situ measurements

Air temperature

The air temperature was measured with the help of a mercury centigrade thermometer (Gallenkamp UK) graduated from 0-60°C. The system of temperature record is, holding thermometer in hand and keeping the bulb in upward direction then rotated in the air slowly for a minute. Finally, the reading of temperature was recorded in my field record book. The procedure was repeated thrice and a mean value was calculated in °C.

Water temperature

In the Schindler-Patalas depth sampler, one alcoholic centigrade thermometer is fixed inside. During the collection of water sample with the help of this apparatus, the temperature of the collected water was displayed by the thermometer. This value was recorded at each sampling station during collection procedure.

Secchi depth

The depth of visibility was determined with the help of a Secchi depth (20 cm diameter) disc which is crosswise-painted black and white. The Secchi disc was tied at the end of a strong rope and was hanged vertically by holding the rope and then slowly dipped into water. By observing at the painted black and white 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.

Hydrogen ion concentration (pH)

The pH was determined with the help of a Griffin pH meter. 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 cleaned and checked every time with standard buffer before the measurement of other sample.

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 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. Before using it in another sample the meter was washed and dried.

Conductivity

From unfiltered sample water, 90 ml was measured with the help of a measuring cylinder and poured it in a 100 mL 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). The meter was clean and dried before it was used for another sample water.

Dissolved oxygen (DO)

In a 100 ml capacity measuring cylinder 90 ml of sample water was taken. Then the electrode of the DO meter 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. Repeat the cleaning process for each and every reading.

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 24 hours 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 24 hours.

Sedimentation of phytoplankton sample

In a plastic bottle of 1-litre capacity, sample water collected by myself 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×.

Laboratory processing

Filtration and preservation

With the help of a vacuum pump fitted to a Sartorius-Membrane Filter Holder (Gmbh, Göttingen, FRG), filtration of the sample water was done in the laboratory. At first water sample were shaken gently for 2 - 3 times for avoiding any sedimentation. Then 250 mL of water measured with measuring cylinder and poured into the cup of the filtration machine. In this filtration process Whatman GF/F 47 mm circles of filter paper were used to filter the sample water. After filtration, the filter paper was rolled up with the help of a Sartorius pincer and put into a screw-capped Pyrex glass tube of 10 ml capacity. The filter paper carrying the residue was used for the determination of phytoplankton biomass as chl-a and phaeopigment. The filtrate 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). 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 2.

Table 2. Methodology, equipments, units of measurement and relevant references used for various limnological parameters

Parameter	Method	Unit	Equipment
AT	Gallenkamp, UK	°C	Mercury centigrade thermometer
WT	Housed in Schindler's-Patalas Sampler	°C	Alcoholic thermometer
SD	Nil	cm	20 cm diameter crosswise-painted black and white Secchi disc
Alkalinity	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	mS/cm	Hanna instruments HI9033W, UOM EA, D/N 048053, URN 315625Y, S/N: 1414153, Singapore
TDS	TDS meter	g/l	Hanna instrument HI9034W, UOM EA, D/N 413377, URN 330067T, S/N: 1391748, Singapore
DO	*In situ* measurement	mg/l	Hanna instrument HI9034W, UOM EA, D/N 413377, URN 330067T, S/N: 1391748, Singapore
Salinity	Salinity refractrometer	ppm	Refractrometer, WL0020-ATC
SRP	Spectrophotometric method (Murphy and Riley, 1962)	µg/l	Spectrophotometer Shimadzu UV-0120-01, Japan
SRS	Spectrophotometric method (Wetzel and Likens 1979)	mg/l	-ditto-

Table 2. (Contd.)

Parameter	Method	Unit	Equipment
NO_3-N	Spectrophotometric (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	Compound microscopy	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, American, Bangladesh and other standard literatures on microalgae and phytoplankton		

Chemical parameters

Alkalinity

From the unfiltered sample water, 50 ml was measured with the help of a measuring cylinder, 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 color 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 orange. Finally, the alkalinity was calculated after Mackereth *et al.* (1978) with the help of the total volume of acid consumed in the titration.

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 m. After it, 5 ml mixed reagents (a mixture of 15 ml ammonium molybdate, 37.5 ml H_2SO_4, 15 ml freshly prepared ascorbic acid and 7.5 ml potassium 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 wave length 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, 1983 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; Subrahmanyan 1946; Bogopocam 1951; Al-kandari *et al*., 2009; Bourelly, 1981; Cupp, 1943; Doan-Nhu *et al*., 2014; Cleve 1894; Hustedt 1930).

Statistical analysis

The statistical analyses were made to study the relationship between and among the different Physicochemical and biological variables, namely, Pearson correlation (SPSS v16.0), the Shannon-Weiner diversity index, Trophic Diatom Index (TDI) and Jaccard index have been applied. Machine learning (python) method also applied for regression analysis and making decision tree.

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 6). Species richness is the most commonly used measure of diversity, but H is a strong indicator of diversity.

Shannon-Weiner Diversity Indices Calculation:

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

b) Based on 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)

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

The value of TDI indicate the effect of organic nutrients on the wetland that already nutrient-rich, and the measurement of large increase in the proportion of organic pollution & tolerant taxa (Whitton & Kelly, 1995).

The value of TDI can range from 1 (very low nutrient concentrations) to 5 (very high nutrient concentrations) (Zelinka and Marvan, 1961)

Methodology

WMS = ∑asv÷∑av

Trophic diatom index (TDI) = (WMS×25)-25

Here, a = total counts of diatom species

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

V= indicator values

Machine learning (Python):

Machine learning (ML) is the logical ponder of calculations and statistical models that computer frameworks utilize to perform a particular task without being explicitly programmed. Learning algorithms in numerous applications that has been make use of every day. These algorithms are utilized for different purposes like data analysis, classification problem, predictive analytics, etc. The most advantage of utilizing machine learning is that, once an algorithm learns what to do with information, it can do its work automatically. (Alex and Vishwanathan 2008).

Exploratory Data Analysis (EDA)

Exploratory Data Analysis is a method of evaluating or comprehending data in order to derive insights or key characteristics. EDA can be divided into two categories, graphical analysis and non-graphical analysis. EDA is a critical component of any data science or machine learning process. The data must be explored to understand the relationships between variables, and the underlying structure of the data in order to build a reliable and valuable output based on it (Brillinger and Finney 2014).

The EDA stages has been carried out in the research by preparing box plots, linear regression, decision tree model and ecosystem health model using the Python programming language.

Box Plot

In descriptive statistics, a box plot (also known as box and whisker plot) is a type of chart often used in EDA. Box plots graphically show the distribution of numerical data and skewness through displaying the data quartiles and median (Williamson *et al*. 1989).
Box plots show the five-number summary of a set of data: including the minimum score, first (lower) quartile, median, third (upper) quartile, and maximum score.

Linear regression

Linear regression endeavors to demonstrate the relationship between two variables by fitting a linear equation to observed information. One variable is considered to be an explanatory variable, and the other is considered to be a dependent variable (Gupta *et al*. 2017). The linear equation assigns one scale factor to each input value or column, called a coefficient. One additional coefficient is also added, giving the line an additional degree of freedom and is often called the intercept or the bias coefficient.

A linear regression line has an equation of the form:

$$Y = a + bX + €$$

where X is the explanatory variable and Y is the dependent variable. The slope of the line is b, and a is the intercept, here € is the error term.

Support Vector Machine (SVM)

SVM is a supervised learning model along with learning algorithm which analyzed data and recognized patterns that is used for classification and regression analysis. SVM can be extended into a nonlinear classifier by mapping the space of the objects into a high dimensional (possibly infinite- dimensional) space. In general, the whole procedure is to make the data dimension raising and linearization (Durgesh and lekha 2010). In this study two commonly used kernel functions for SVM have been used.

Polynomial kernel function:

$$K(X_i, X_j) = \left(\gamma {X_i}^T, X_j + r\right)^d, \gamma > 0$$

Radial basis function (RBF) kernel:

$$K(X_i, X_j) = \exp(-\gamma ||X_i - X_j||^2), \gamma > 0$$

Where, γ and d, are kernel specific parameters.

Random Forest (RF)

Random forests or random decision forests are an ensemble learning method for classification, regression and other tasks that operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees. Random decision forests correct for decision trees' habit of overfitting to their training set (Cutler *et al*. 2012).

For b = 1 to B:

(a) Draw a bootstrap sample Z∗ of size N from the training data.

(b) Grow a random-forest tree Tb to the bootstrapped data, by recursively repeating the following steps for each terminal node of the tree, until the minimum node size nmin is reached. Which is done by selecting m variables at random from the p variables then pick the best variable/split-point among the m. Finally split the node into two daughter nodes.

To make a prediction at a new point x:

$$f_{rf}^{B}(x) = \frac{1}{B}\sum_{b=1}^{B} T_b(x)$$

Where, T_b is the output of ensemble trees.

Test Train Split

For machine learning purpose the data set have been split into two set, Training set and Testing set. Training set have been used for the learning purpose of the machine whereas testing set have been used to evaluate the model efficiency. In this study 70% data have been used for training the model and rest 30% have been used for model evaluation.

Chapter-4

RESULTS

RESULTS

In the present investigation, a total of 15 (3 physical, 9 chemicals, and 3 biological) environemental parameters were measured for the seven studied staions of the selected wetlands. The data collection was continued for two years (2018-2020). In the study, both the qualitative and quantitative analyses of phytoplankton were made. The interrelationships among the different physical, chemical, and biological parameters were also carried out.

Physical parameters

Air temperature (°C)

The annual trend of air temperature almost was similar among the stations. During the study period, the ranges of air temperature were 20.0-33.1, 20.0-33.0, 20.0-33.0, 22.0-33.7, 22.0-33.5, and 22.0-33.1 ºC for Station B1, B2, B3, R1, R2, and R3, respectively. The highest monthly mean air temperature was recorded in August for the first study period and that for the 2nd study-period it is found in the month of October. Tthe lowest mean air temperature was obtained for all the stations in the month of December for 1st study year and January for 2nd study year (Table 3). Air temperature followed a distinct trend throughout the investigation period.

The seasonal dynamics of air temperature has been presented in Fig. 12. From the figure it is evident that air temperature showed the highest value during pre-monsoon and the lowest in post monsoon in all the stations during 1st study period. Seasonal variation for 2nd study year has shown the highest in post-monsoon and lowest in winter. So, as it located in coastal zone it has showing different pattern in 2 different year (Fig. 12).

Air temperature started to increase from March and continued to August then it starts to decrease. Fig. 13 shows a comparison of air temperature fluctuations between 2018-2019 and 2019-2020. Temperature ups and downs among the stations showed a gradually pattern.

Mean air temperature (29.99 ºC) was the highest in Station R3 for both the study year and also the lowest mean air temperature (26.58 ºC) was recorded in B2 station for both the study year (Table 3).

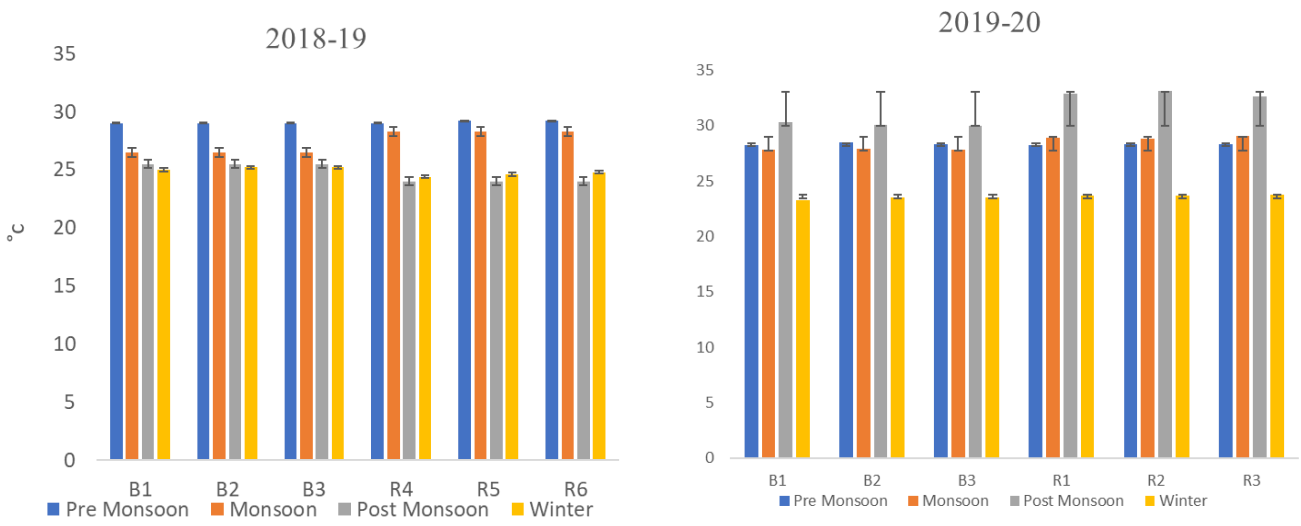


Fig. 12. Seasonal dynamics of air temperature (ºC).

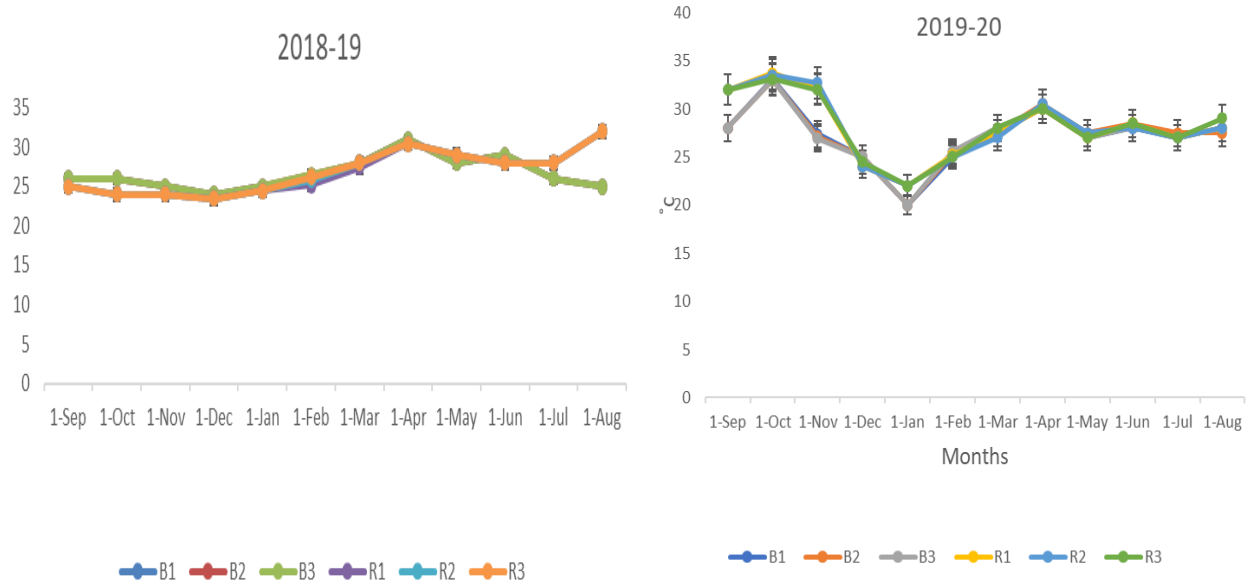


Fig. 13. Comparison of monthly values of air temperature from two study years.

Table 3. Monthly values with (±SD) of air temperature (°C).

Months	B1	B2	B3	R1	R2	R3
Sep-18	26±0.55	26±0.55	26±0.55	25±0.55	25±0.55	25±0.55
Oct-18	26±1.1	26±1.1	26±1.1	24±1.1	24±1.1	24±1.1
Nov-18	25±0.55	25±0.55	25±0.55	24±0.55	24±0.55	24±0.55
Dec-18	24±0.27	24±0.27	24±0.27	23.5±0.27	23.5±0.27	23.5±0.27
Jan-19	25±0.27	25±0.27	25±0.27	24.5±0.27	24.5±0.27	24.5±0.27
Feb-19	26±0.49	26.5±0.49	26.5±0.49	25.2±0.49	25.8±0.49	26.2±0.49
Mar-19	28±0.2	28±0.2	28±0.2	27.5±0.2	28±0.2	28±0.2
Apr-19	31±0.274	31±0.274	31±0.274	30.5±0.274	30.5±0.274	30.5±0.274
May-19	28±0.548	28±0.548	28±0.548	29±0.548	29±0.548	29±0.548
Jun-19	29±0.548	29±0.548	29±0.548	28±0.548	28±0.548	28±0.548
Jul-19	26±1.095	26±1.095	26±1.095	28±1.095	28±1.095	28±1.095
Aug-19	25±3.834	25±3.834	25±3.834	32±3.834	32±3.834	32±3.834
Sep-19	28±2.2	28±2.2	28±2.2	32±2.2	32±2.2	32±2.2
Oct-19	33.1±0.29	33±0.29	33±0.29	33.7±0.29	33.5±0.29	33.1±0.29
Nov-19	27.4±2.83	27.1±2.83	26.9±2.83	32.1±2.83	32.7±2.83	32±2.83
Dec-19	25±0.49	25±0.49	25±0.49	24±0.49	24±0.49	24.5±0.49
Jan-20	20±1.1	20±1.1	20±1.1	22±1.1	22±1.1	22±1.1
Feb-20	25±0.25	25.4±0.25	25.6±0.25	25.2±0.25	25±0.25	25±0.25
Mar-20	27.5±0.38	27.5±0.38	28±0.38	27.5±0.38	27±0.38	28±0.38
Apr-20	30±0.26	30.5±0.26	30±0.26	30±0.26	30.5±0.26	30±0.26
May-20	27±0.26	27.5±0.26	27±0.26	27±0.26	27.5±0.26	27±0.26
Jun-20	28±0.27	28.5±0.27	28±0.27	28.5±0.27	28±0.27	28.5±0.27
Jul-20	27±0.2	27.5±0.2	27±0.2	27±0.2	27±0.2	27±0.2
Aug-20	28±0.49	27.5±0.49	28±0.49	28±0.49	28±0.49	29±0.49
Mean	29.01	29.6	26.79	27.58	28.71	29.99

Water temperature (°C)

The ranges of water temperature were 19.8-33.5, 19.5-32.4, 19.4-32.0, 21.0-31.0, 21.2-31.5 and 21.4-33.0 ºC for Station B2, B2, B3, R1, R2 and R3, respectively. The highest water temperature (33.5 ºC) was recorded in April, 2019 for R3 station, whereas the lowest water temperature (19.4 ºC) was obtained for B3 station in the month of January 2020 (Table 4). 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 pre-monsoon and the lowest in post monsoon in all the stations during 1st study period. However, for the 2nd study year the seasonal trend of water temperature showed highest value in post-monsoon and lowest value in winter (Fig. 14). So, the temperature pattern is different for the both years.

Water temperature starts increasing just after January and continues until July and thereafter a gradual fall was evident from August to December (Fig. 15). Fig. 15 compares water temperature of 2018-2019 and 2019-2020.

There was a sudden fall of water temperature in August 2019 for B1, B2, and B3 stations. The trend of annual fluctuation of water temperature is almost same in both study years except the sudden fall. The highest mean water temperature (27.57 ºC) was recorded in R1 Station and the lowest mean water temperature was (27.03 ºC) recorded in B3 Station (Table 4).

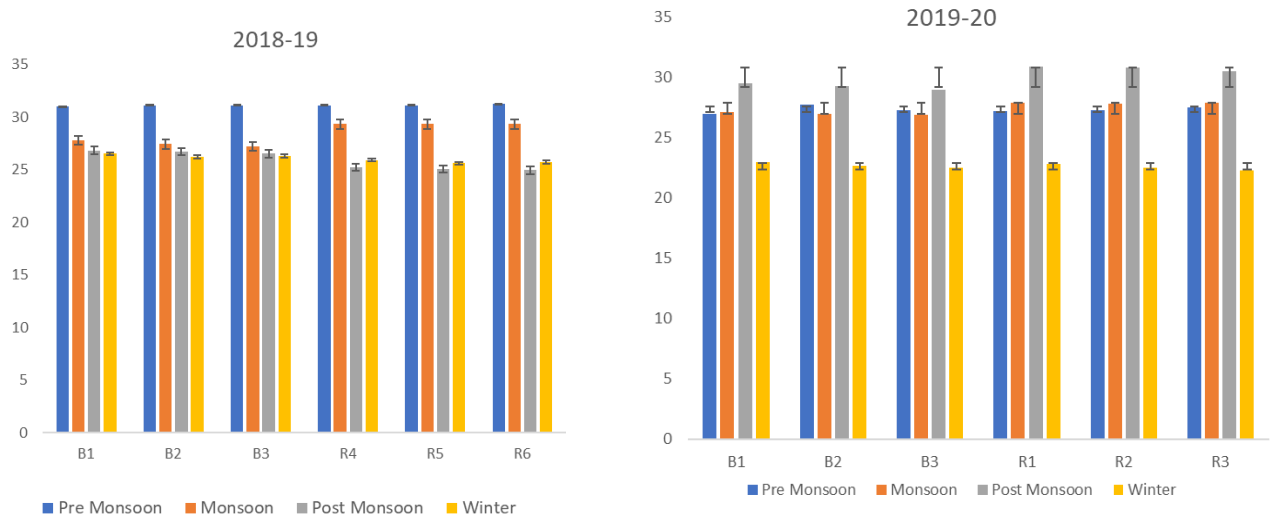


Fig. 14. Seasonal dynamics of water temperature (ºC).

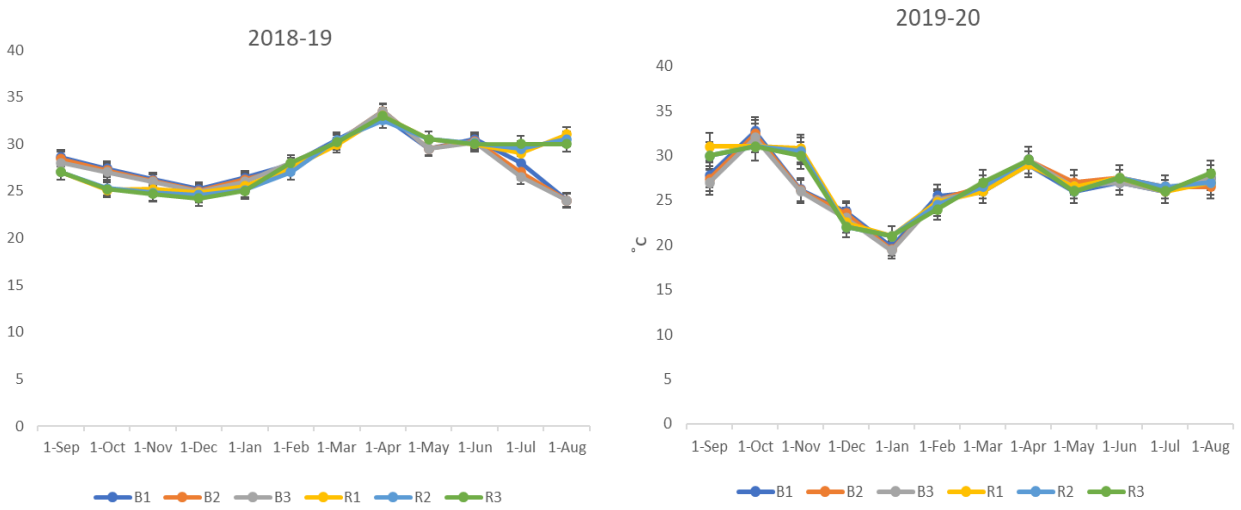


Fig. 15. Comparison of monthly values of water temperature from two study years.

Table 4. Monthly values with (±SD) of water temperature (ºC).

Months	B1	B2	B3	R1	R2	R3
18-Sep	28.6±0.76	28.4±0.76	28±0.76	27±0.76	27±0.76	27±0.76
18-Oct	27.4±1.1	27.2±1.1	27±1.1	25.1±1.1	25.3±1.1	25.2±1.1
18-Nov	26.2±0.68	26.1±0.68	26±0.68	25.2±0.68	24.8±0.68	24.7±0.68
18-Dec	25.2±0.35	25±0.35	24.9±0.35	24.8±0.35	24.6±0.35	24.2±0.35
19-Jan	26.4±0.59	26.2±0.59	26±0.59	25.5±0.59	25.1±0.59	25±0.59
19-Feb	27.8±0.38	27.5±0.38	28±0.38	27.5±0.38	27±0.38	28±0.38
19-Mar	30.4±0.18	30.2±0.18	30.2±0.18	29.9±0.18	30.4±0.18	30.2±0.18
19-Apr	33±0.38	33.5±0.38	33.5±0.38	33±0.38	32.5±0.38	33±0.38
19-May	29.5±0.55	29.5±0.55	29.5±0.55	30.5±0.55	30.5±0.55	30.5±0.55
19-Jun	30.5±0.19	30.3±0.19	30.2±0.19	30±0.19	30.1±0.19	30±0.19
19-Jul	28±1.4	27±1.4	26.5±1.4	29±1.4	29.5±1.4	30±1.4
19-Aug	24±3.6	24±3.6	24±3.6	31±3.6	30.5±3.6	30±3.6
19-Sep	27.8±1.7	27.4±1.7	27±1.7	31±1.7	30±1.7	30±1.7
19-Oct	32.7±0.78	32.4±0.78	32±0.78	31±0.78	31±0.78	31±0.78
19-Nov	26.2±2.4	26.1±2.4	26±2.4	30.8±2.4	30.5±2.4	30±2.4
19-Dec	23.7±0.74	23.5±0.74	23±0.74	22.5±0.74	22±0.74	22±0.74
20-Jan	19.8±0.8	19.5±0.8	19.4±0.8	21±0.8	21±0.8	21±0.8
20-Feb	25.5±0.5	25±0.5	25±0.5	24.8±0.5	24.5±0.5	24±0.5
20-Mar	26±0.41	26.5±0.41	26±0.41	26±0.41	26.5±0.41	27±0.41
20-Apr	29±0.26	29.5±0.26	29.5±0.26	29±0.26	29.5±0.26	29.5±0.26
20-May	26±0.41	27±0.41	26.5±0.41	26.5±0.41	26±0.41	26±0.41
20-Jun	27±0.26	27.5±0.26	27±0.26	27.5±0.26	27.5±0.26	27.5±0.26
20-Jul	26±0.26	26.5±0.26	26±0.26	26±0.26	26.5±0.26	26±0.26
20-Aug	27.5±0.52	26.5±0.52	27.5±0.52	27±0.52	27±0.52	28±0.52
Mean	27.26	27.18	27.03	27.57	27.47	27.49

Secchi depth

The ranges of Secchi depth were 16.4-62.0, 18.0-59.0, 19.0-60.0, 24.5-63.0, 25.0-65.0 and 26.0-61.0 cm for Station B1, B2, B3, R1, R2 and R3, respectively. For the 1st study year, the highest monthly mean Secchi depth was recorded in May, 2020 for B2 stations, whereas the lowest mean Secchi depth was obtained for Station B1 in the month of October, 2018 (Table 5). For the 2nd study period, highest Secchi depth obtained in June, 2020 in B1 station and lowest was recorded in B2 station in October, 2019. Secchi depth followed a same trend throughout the investigation period, it was highest during May, June, and lowest in September, and October (Fig.17).

In the present research, the seasonal variation of Secchi depth showed the highest value during pre-monsoon and the lowest in post-monsoon in 2018-2019 and for 2019-2020 study period. Over the seasons, the mean values of Secchi depth followed a pattern of pre-monsoon>winter> monsoon> post-monsoon for all the Station 1st study year and the pattern was pre-monsoon>winter> monsoon> post-monsoon for the 2nd study year (Fig. 16).

So, Secchi depth followed a fix pattern in both the study year and for both the coastal rivers. Mean Secchi depth (46.08 cm) was the highest in Station B2 and the lowest mean Secchi depth (40.67 cm) was recorded in Station R1 (Table 5).

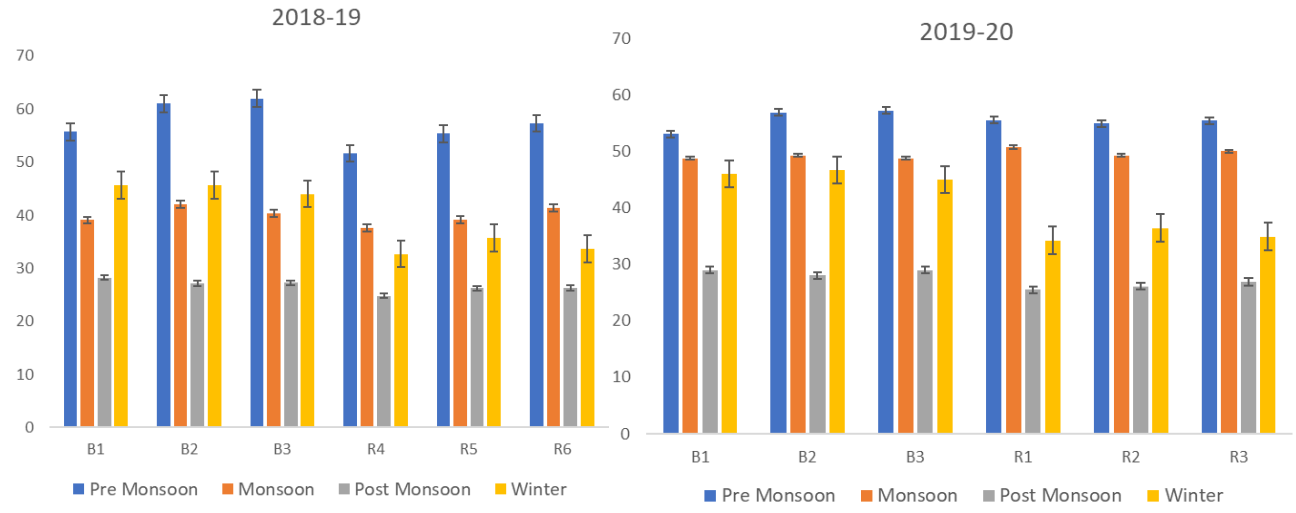


Fig. 16. Seasonal dynamics of Secchi depth (cm).

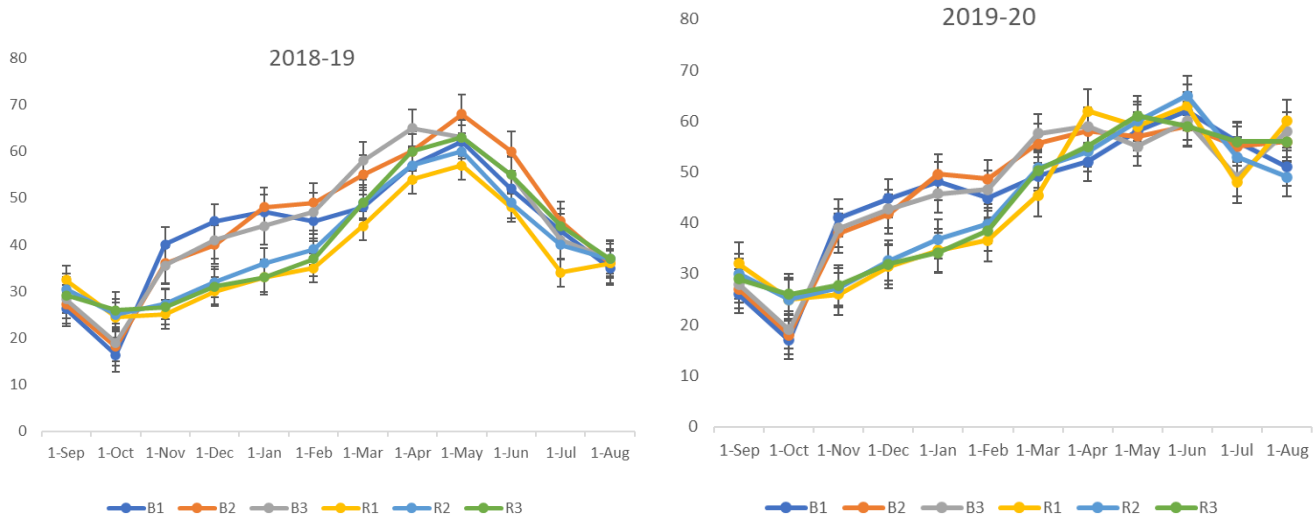


Fig. 17. Comparison of monthly values of Secchi depth from two study years.

Table 5. Monthly values with (±SD) of Secchi depth (cm).

Months	B1	B2	B3	R1	R2	R3
18-Sep	26.2±2.25	27.2±2.25	28.3±2.25	32.4±2.25	30.5±2.25	29.2±2.25
18-Oct	16.4±4.11	18.2±4.11	19±4.11	24.5±4.11	25±4.11	26±4.11
18-Nov	40.1±6.2	36±6.2	35.5±6.2	25.1±6.2	27.3±6.2	26.6±6.2
18-Dec	45±6.3	40±6.3	41±6.3	30±6.3	32±6.3	31±6.3
19-Jan	47±6.97	48±6.97	44±6.97	33±6.97	36±6.97	33±6.97
19-Feb	45±5.76	49±5.76	47±5.76	35±5.76	39±5.76	37±5.76
19-Mar	48±5.09	55±5.09	58±5.09	44±5.09	49±5.09	49±5.09
19-Apr	57±3.76	60±3.76	65±3.76	54±3.76	57±3.76	60±3.76
19-May	62±3.66	68±3.66	63±3.66	57±3.66	60±3.66	63±3.66
19-Jun	52±4.45	60±4.45	55±4.45	48±4.45	49±4.45	55±4.45
19-Jul	43±3.97	45±3.97	41±3.97	34±3.97	40±3.97	44±3.97
19-Aug	35±0.82	36±0.82	37±0.82	36±0.82	37±0.82	37±0.82
19-Sep	26±2.16	27±2.16	28±2.16	32±2.16	30±2.16	29±2.16
19-Oct	17±4.08	18±4.08	19±4.08	25±4.08	25±4.08	26±4.08
19-Nov	41±6.85	38±6.85	39±6.85	26±6.85	27.2±6.85	27.8±6.85
19-Dec	44.8±6.19	41.8±6.19	42.7±6.19	31.4±6.19	32.6±6.19	31.9±6.19
20-Jan	48.2±7.09	49.6±7.09	45.7±7.09	34.6±7.09	36.8±7.09	34.2±7.09
20-Feb	44.9±4.9	48.6±4.9	46.6±4.9	36.6±4.9	39.8±4.9	38.5±4.9
20-Mar	49.2±4.44	55.6±4.44	57.6±4.44	45.4±4.44	50.8±4.44	50.3±4.44
20-Apr	52±3.67	58±3.67	59±3.67	62±3.67	54±3.67	55±3.67
20-May	58±2.16	57±2.16	55±2.16	59±2.16	60±2.16	61±2.16
20-Jun	62±2.4	59±2.4	60±2.4	63±2.4	65±2.4	59±2.4
20-Jul	56±3.5	55±3.5	49±3.5	48±3.5	53±3.5	56±3.5
20-Aug	51±4.2	56±4.2	58±4.2	60±4.2	49±4.2	56±4.2
Mean	**44.45**	**46.08**	**45.56**	**40.67**	**41.88**	**42.318**

Chemical parameters

Alkalinity

The ranges of alkalinity were 1.2-4.8, 0.7-4.6, 1.0-4.9, 1.0-4.9, 0.9-4.9 and 0.8-4.7 meq/l for Station B1, B2, and B3, and R1, R2, and R3, respectively. The highest monthly alkalinity was recorded in May, 2019 for Station R1 and R2, whereas the lowest mean alkalinity was obtained for Station B2 in the month of November 2018 (Table 6). Alkalinity followed a distinct trend throughout the investigation period.

The seasonal variation of alkalinity in the first study year showed the highest value during pre-monsoon in all the Stations and the lowest was recorded in the post-monsoon in all the studied stations. For the second study year, the highest value observed in pre-monsoon for all the study stations but incase of lowest value, B1, B2, and B3 stations showed lowest value in monsoon and R1, R2, and R3 stations showed the lowest value in winter (Fig. 18).

In general, over the seasons the mean values of alkalinity followed a pattern of pre-monsoon> winter> monsoon>post-monsoon. Station R1, R2, and R3 showed lower values of alkalinity in both the study years (Fig. 18).

Annual trends of alkalinity fluctuation for most of the stations showed a fall from September to October and then a rise from November to May, which fell further in the month of May. (Fig. 19). Mean of alkalinity (3.29 meq. /l) was the highest in Station B2 whereas the lowest mean alkalinity (2.8 meq. /l) was recorded in Station R3 (Table 6).

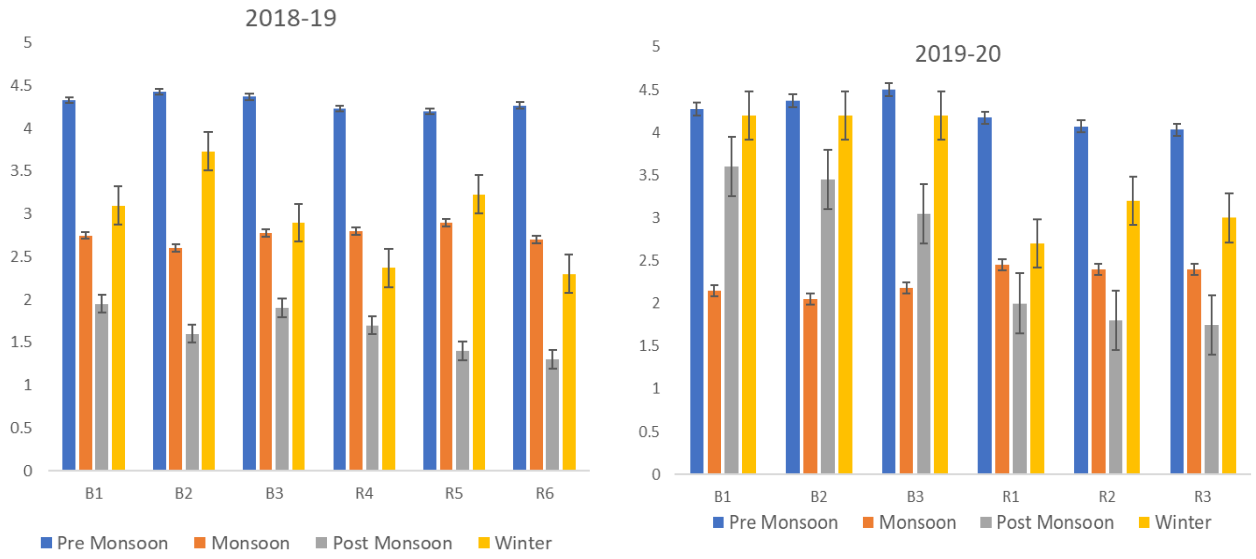


Fig. 18. Seasonal dynamics of alkalinity (meq/l).

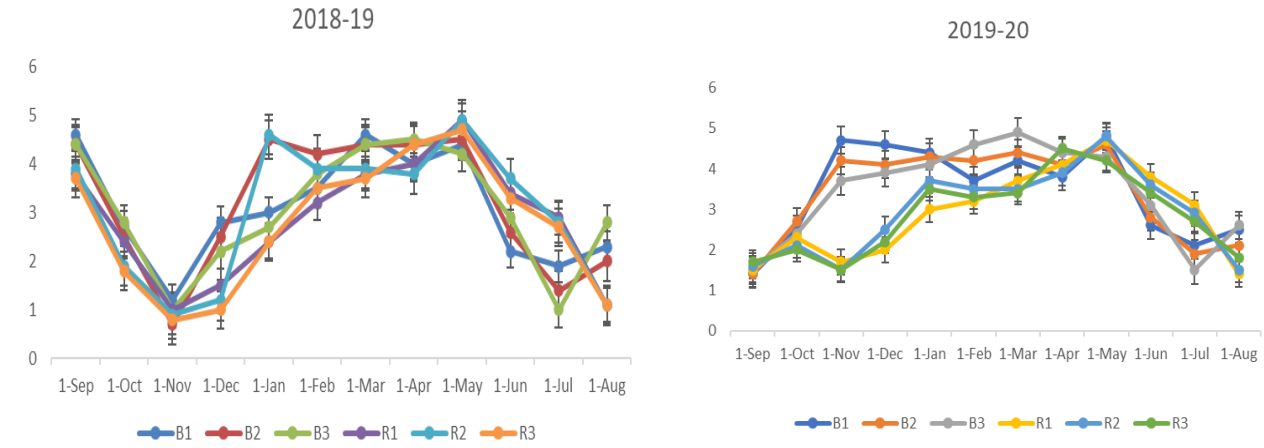


Fig. 19. Comparison of monthly values of alkalinity from two study years.

Table 6 Monthly values with (±SD) of alkalinity (meq/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	4.6±0.38	4.4±0.38	4.4±0.38	3.8±0.38	3.9±0.38	3.7±0.38
18-Oct	2.7±0.41	2.5±0.41	2.8±0.41	2.4±0.41	1.9±0.41	1.8±0.41
18-Nov	1.2±0.18	0.7±0.18	1±0.18	1±0.18	0.9±0.18	0.8±0.18
18-Dec	2.8±0.74	2.5±0.74	2.2±0.74	1.5±0.74	1.2±0.74	1±0.74
19-Jan	3±1.02	4.5±1.02	2.7±1.02	2.4±1.02	4.6±1.02	2.4±1.02
19-Feb	3.5±0.35	4.2±0.35	3.8±0.35	3.2±0.35	3.9±0.35	3.5±0.35
19-Mar	4.6±0.38	4.4±0.38	4.4±0.38	3.8±0.38	3.9±0.38	3.7±0.38
19-Apr	4±0.29	4.4±0.29	4.5±0.29	4±0.29	3.8±0.29	4.4±0.29
19-May	4.4±0.28	4.5±0.28	4.2±0.28	4.9±0.28	4.9±0.28	4.7±0.28
19-Jun	2.2±0.56	2.6±0.56	2.9±0.56	3.4±0.56	3.7±0.56	3.3±0.56
19-Jul	1.9±0.80	1.4±0.80	1±0.80	2.9±0.80	2.8±0.80	2.7±0.80
19-Aug	2.3±0.74	2±0.74	2.8±0.74	1.1±0.74	1.1±0.74	1.1±0.74
19-Sep	1.4±0.12	1.4±0.12	1.5±0.12	1.5±0.12	1.6±0.12	1.7±0.12
19-Oct	2.5±0.26	2.7±0.26	2.4±0.26	2.3±0.26	2.1±0.26	2±0.26
19-Nov	4.7±1.5	4.2±1.5	3.7±1.5	1.7±1.5	1.5±1.5	1.5±1.5
19-Dec	4.6±1.11	4.1±1.11	3.9±1.11	2±1.11	2.5±1.11	2.2±1.11
20-Jan	4.4±0.54	4.3±0.54	4.1±0.54	3±0.54	3.7±0.54	3.5±0.54
20-Feb	3.7±0.55	4.2±0.55	4.6±0.55	3.2±0.55	3.5±0.55	3.3±0.55
20-Mar	4.2±0.58	4.4±0.58	4.9±0.58	3.7±0.58	3.5±0.58	3.4±0.58
20-Apr	3.8±0.27	4.1±0.27	4.4±0.27	4.1±0.27	3.9±0.27	4.5±0.27
20-May	4.8±0.26	4.6±0.26	4.3±0.26	4.7±0.26	4.8±0.26	4.2±0.26
20-Jun	2.6±0.47	2.8±0.47	3.1±0.47	3.8±0.47	3.6±0.47	3.4±0.47
20-Jul	2.1±0.63	1.9±0.63	1.5±0.63	3.1±0.63	2.9±0.63	2.7±0.63
20-Aug	2.5±0.50	2.1±0.50	2.6±0.50	1.4±0.50	1.5±0.50	1.8±0.50
Mean	3.271	3.2875	3.238	2.871	2.988	2.804

Hydrogen ion concentration (pH)

The ranges of pH were 7.2-8.8, 7.5-8.8, 6.8-8.6, 7.4-8.4, 7.4-8.5 and 7.2-8.8 for Station B1, B2, and B3, and R1, R2, and R3, respectively. The highest monthly mean pH was recorded in January, 2019 for B1 Station and in June-2019 for B2 station, whereas the lowest mean pH was obtained for Station R3 in July-2020. The trend of alkalinity was more or less same throughout the investigation period.

In 2018-19 study year, the seasonal variation of pH showed the highest value during winter in B1, B2, and B3 station and during monsoon in R1, and R2 station. While a highest value was obtained for R3 station in pre-monsoon. The lowest pH was recorded in B1, B2, and B3 stations during monsoon and for R1, R2, and R3 stations during winter.

In case of the 2nd study year, the highest value was recorded during pre-monsoon for B1, B2, and B3 stations and for R1, and R2 stations. Lowest value was recorded during winter for B1, B2, and B3 stations and R1, R2, and R3 stations showed lowest value during post-monsoon. So, during the study years, the pH did not show uniform distribution over seasons, but for an annual scale it showed similar trend (Fig. 20). Fig. 21 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 (Fig. 21).

Table 7 showed the annual mean value of the stations. Whereas, the highest monthly mean pH was recorded in January, 2019 for B1 Station and in June 2019 for B2 station, whereas the lowest mean pH was obtained for Station R3 in July 2020. Mean of pH (8.15) was the highest in Station B1 whereas the lowest mean alkalinity (7.99) was recorded in Station R1 (Table 7).

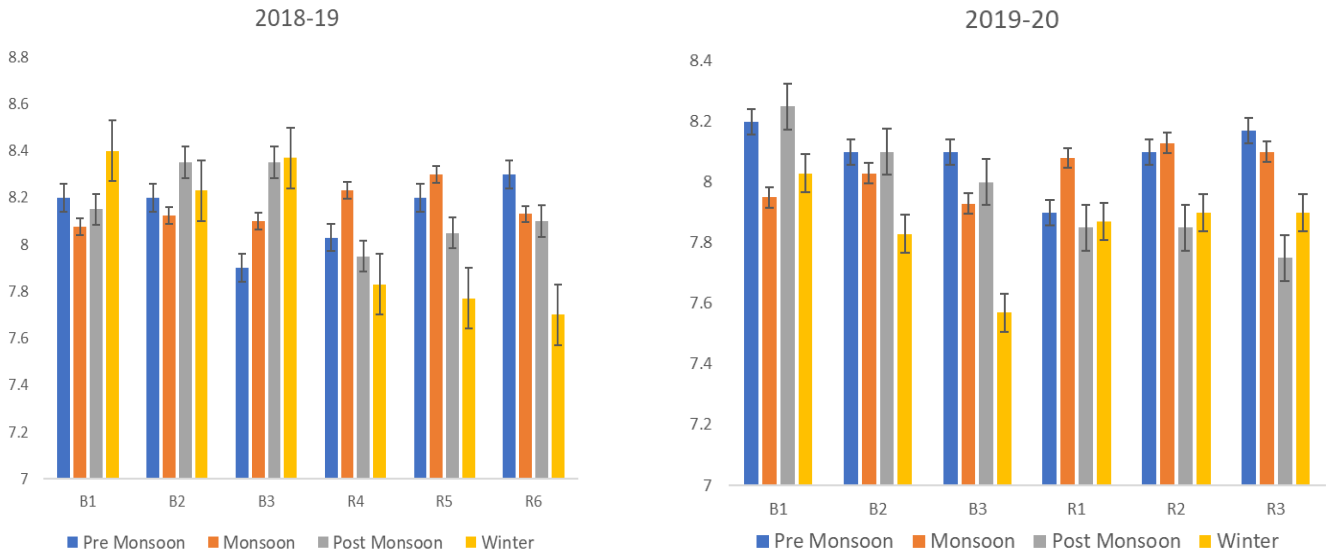


Fig. 20. Seasonal dynamics of pH.

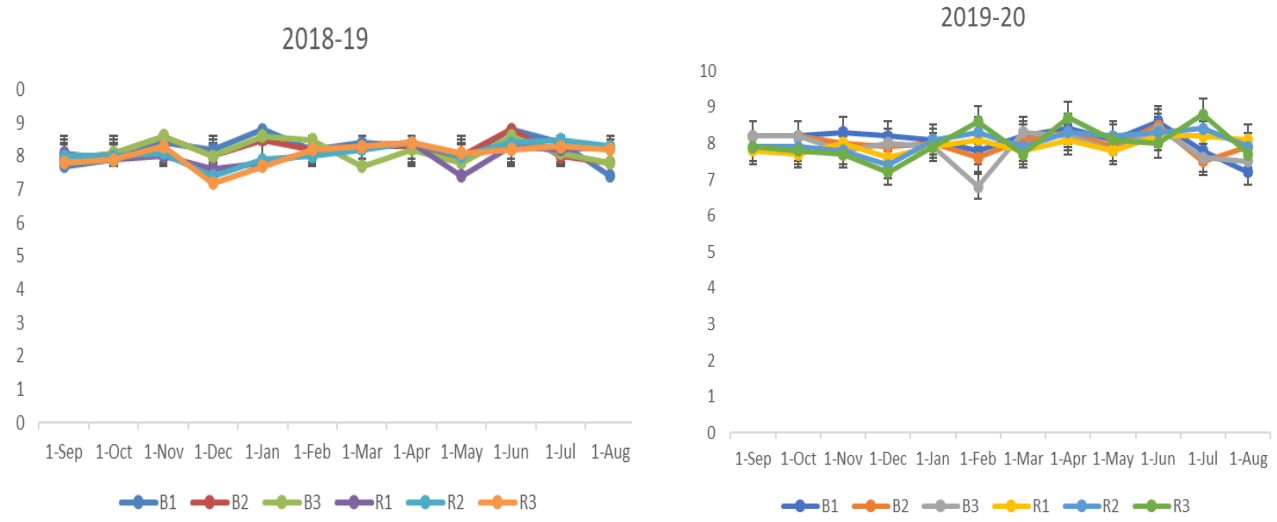


Fig. 21. Comparison of monthly values of pH from two study years.

Table 7. Monthly values with (±SD) of pH.

Months	B1	B2	B3	R1	R2	R3
18-Sep	7.7±0.141	7.9±0.141	7.9±0.141	8.1±0.141	8±0.141	7.8±0.141
18-Oct	7.9±0.098	8.1±0.098	8.1±0.098	7.9±0.098	8±0.098	7.9±0.098
18-Nov	8.4±0.25	8.6±0.25	8.6±0.25	8±0.25	8.1±0.25	8.3±0.25
18-Dec	8.2±0.39	8±0.39	8±0.39	7.6±0.39	7.4±0.39	7.2±0.39
19-Jan	8.8±0.47	8.5±0.47	8.6±0.47	7.8±0.47	7.9±0.47	7.7±0.47
19-Feb	8.2±0.167	8.2±0.167	8.5±0.167	8.1±0.167	8±0.167	8.2±0.167
19-Mar	8.4±0.253	8.3±0.253	7.7±0.253	8.3±0.253	8.2±0.253	8.3±0.253
19-Apr	8.3±0.082	8.3±0.082	8.2±0.082	8.4±0.082	8.4±0.082	8.4±0.082
19-May	7.9±0.25	8±0.25	7.8±0.25	7.4±0.25	8±0.25	8.1±0.25
19-Jun	8.8±0.256	8.8±0.256	8.6±0.256	8.3±0.256	8.4±0.256	8.2±0.256
19-Jul	8.4±0.187	8±0.187	8.1±0.187	8.2±0.187	8.5±0.187	8.3±0.187
19-Aug	7.4±0.361	7.8±0.361	7.8±0.361	8.3±0.361	8.3±0.361	8.2±0.361
19-Sep	8.2±0.186	8.2±0.186	8.2±0.186	7.8±0.186	7.9±0.186	7.9±0.186
19-Oct	8.2±0.228	8.2±0.228	8.2±0.228	7.7±0.228	7.9±0.228	7.8±0.228
19-Nov	8.3±0.216	8±0.216	7.8±0.216	8±0.216	7.8±0.216	7.7±0.216
19-Dec	8.2±0.382	7.9±0.382	8±0.382	7.6±0.382	7.4±0.382	7.2±0.382
20-Jan	8.1±0.098	8±0.098	7.9±0.098	7.9±0.098	8.1±0.098	7.9±0.098
20-Feb	7.8±0.631	7.6±0.631	6.8±0.631	8.1±0.631	8.3±0.631	8.6±0.631
20-Mar	8.2±0.237	8.1±0.237	8.3±0.237	7.8±0.237	7.9±0.237	7.7±0.237
20-Apr	8.4±0.207	8.3±0.207	8.2±0.207	8.1±0.207	8.3±0.207	8.7±0.207
20-May	8.1±0.172	7.9±0.172	7.8±0.172	7.8±0.172	8.2±0.172	8.1±0.172
20-Jun	8.6±0.216	8.5±0.216	8.4±0.216	8.2±0.216	8.3±0.216	8±0.216
20-Jul	7.8±0.505	7.5±0.505	7.6±0.505	8.2±0.505	8.4±0.505	8.8±0.505
20-Aug	7.2±0.325	7.9±0.325	7.5±0.325	8.1±0.325	7.9±0.325	7.7±0.325
Mean	8.15	8.108	8.025	7.9875	8.067	8.0292

Conductivity

The ranges of electrical conductivity were 226-2650, 136-1950, 114-1940, 3.44-206, 1.88-113.8 and 0.98-258 mScm-¹ for Station B1, B2, B3, R1, R2, and R3, respectively. There is a clear difference between two coastal rivers. Bakkhali river is very high in conductivity level and Reju khal has average conductivity value compared to all other dtudied rivers of Bangladesh.

For 1st study year, the seasonal variation of EC showed the highest value during pre-monsoon for all the six stations but lowest value found in monsoon for B1, B2, B3, stations but for R1, R2, R3 stations, lowest was found during winter. For the 2nd study year, the seasonal variation of conductivity was highest during monsoon and lowest during winter for B1, B2, B3 stations and for the R1, R2, and R3 stations, conductivity was higher during pre-monsoon and lower during winter.

So, over the seasons, the mean values of EC followed a pattern of monsoon> pre-monsoon> post-monsoon> winter for B1, B2, and B3 stations and the pattern is pre-monsoon> monsoon> post-monsoon> winter for the R1, R2, R3 stations. In both years of investigation EC concentrations remained very low in Reju canal than the Bakkhali river (Fig. 22).

Fig. 22 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 the years of investigation. In the first year, the annual trend showed a zig zag pattern for Station B1, B2, and B3 but Station R1, R2, and R3 remained flatly linear horizontal line in the both study years. Annual trends of conductivity fluctuation for most of the stations showed a fall from September to November then rest of the year remain same but following another small fall which was observed in June. However, in case of R1, R2, and R3 all the year remained same annually but with a slightly uprising value in May (Fig. 23).

For Bakkhali river the highest monthly mean electrical conductivity (2650 mS/cm) was recorded in September 2019 for B1 station whereas the lowest mean EC (114 mS/cm) was obtained in October, 2018 for B3 station. In case of Reju canal the highest value obtained in May 2020 and lowest in October 2018 and both highest and lowest values were recorded from R3 (Table 8).

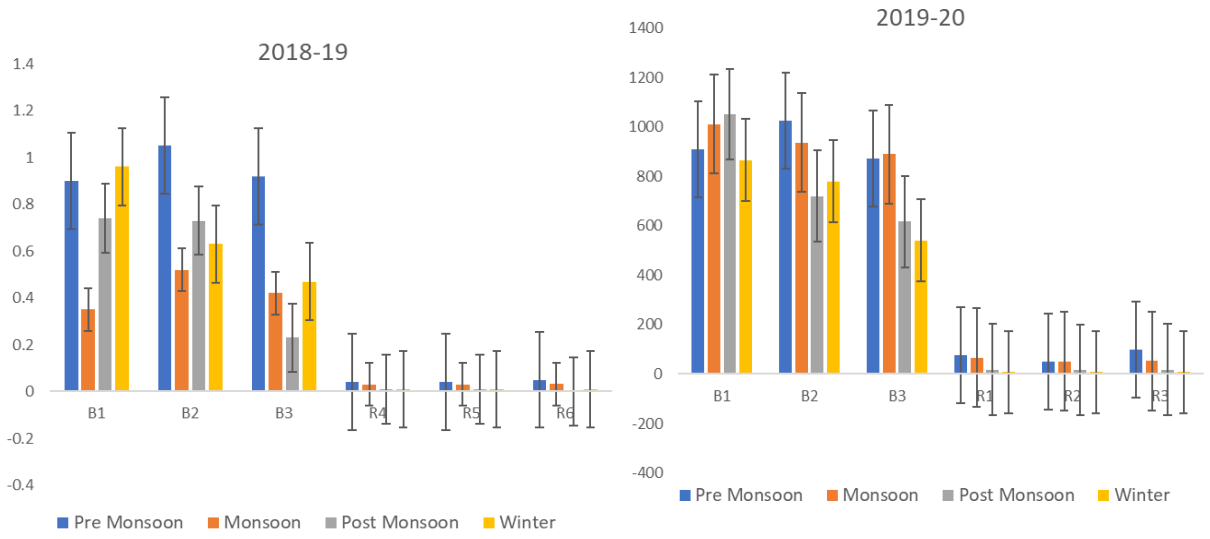


Fig. 22. Seasonal dynamics of electrical conductivity (mS/cm).

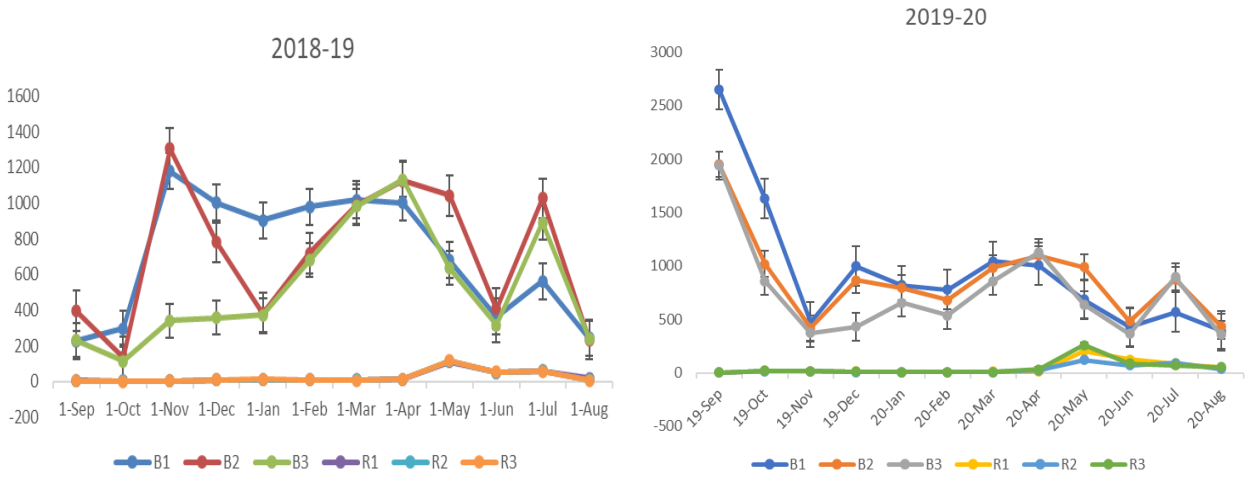


Fig. 23. Comparison of monthly values of electrical conductivity from two study years.

Table 8. Monthly values with (±SD) of electrical conductivity (mS/cm).

Months	B1	B2	B3	R1	R2	R3
18-Sep	226±165.10	396±165.10	232±165.10	7.27±165.10	3.24±165.10	3.24±165.10
18-Oct	298±117.6	136±117.6	114±117.6	3.44±117.6	1.88±117.6	0.98±117.6
18-Nov	1180±612.3	1306±612.3	340±612.3	4.44±612.3	2.68±612.3	1.67±612.3
18-Dec	1002±437.5	780±437.5	358±437.5	8.9±437.5	9.8±437.5	10±437.5
19-Jan	904±353.8	382±353.8	372±353.8	10±353.8	10±353.8	11.8±353.8
19-Feb	980±441.7	720±441.7	680±441.7	9.1±441.7	8.72±441.7	9.52±441.7
19-Mar	1019±541.9	990±541.9	982±541.9	8.47±541.9	7.81±541.9	7.35±541.9
19-Apr	1002±590.6	1125±590.6	1133±590.6	11.77±590.6	11.23±590.6	11.92±590.6
19-May	679±394.6	1043±394.6	635±394.6	110.2±394.6	113.8±394.6	115.5±394.6
19-Jun	364±173.3	408±173.3	316±173.3	50±173.3	49.8±173.3	52.4±173.3
19-Jul	561±446.5	1026±446.5	890±446.5	58.4±446.5	60±446.5	57.8±446.5
19-Aug	243±125.5	235±125.5	241±125.5	18±125.5	8.32±125.5	6±125.5
19-Sep	2650±1219.7	950±1219.7	1940±1219.7	3.35±1219.7	3.37±1219.7	3.04±1219.7
19-Oct	1630±680.9	1020±680.9	860±680.9	18.7±680.9	17.3±680.9	20.4±680.9
19-Nov	475±225.4	421±225.4	373±225.4	17±225.4	15.2±225.4	15±225.4
19-Dec	998±454.3	865±454.3	432±454.3	9.7±454.3	8.6±454.3	9.2±454.3
20-Jan	820±414.98	794±414.98	655±414.98	6.18±414.98	5.5±414.98	5.23±414.98
20-Feb	780±367.998	680±367.998	536±367.998	8.7±367.998	8.53±367.998	8.46±367.998
20-Mar	1042±525.25	986±525.25	856±525.25	9.56±525.25	8.59±525.25	7.98±525.25
20-Apr	1004±578.9	1098±578.9	1126±578.9	10.89±578.9	22.58±578.9	31.58±578.9
20-May	685±340.3	989±340.3	637±340.3	206±340.3	121±340.3	258±340.3
20-Jun	432±187.5	485±187.5	367±187.5	125±187.5	71±187.5	86±187.5
20-Jul	569±399.86	876±399.86	898±399.86	87±399.86	92±399.86	69±399.86
20-Aug	394±193.44	436±193.44	356±193.44	48±193.44	36±193.44	52±193.44
Mean	830.708	797.792	638.708	35.4196	29.0396	35.586

Total dissolved solids (TDS)

TDS ranged from 0.056-13.39, 0.066-19.9, 0.052-9.87, 0.226-19.9, 0.102-18.88 and 0.076-18.6 g/l for B1, B2, and B3, and R1, R2, and R3, respectively. The highest monthly mean TDS (19.9 g/l) was recorded in May 2019 for B2 and R1, whereas the lowest mean TDS (0.052 g/l) was obtained in September 2018 for B3 station.

The seasonal variation of TDS in the 1st study period showed the highest value during pre-monsoon in all the stations and the lowest in monsoon for all the stations except B2 and B3 station. The TDS showed the lowest in post-monsoon and for 2nd study year the highest value was observed in pre-monsoon and lowest in winter season (Fig. 24).

Over the seasons, the mean values of alkalinity followed a pattern of pre-monsoon> post-monsoon> winter > monsoon for the first study year and for the second study year it showed a pattern pre-monsoon> post-monsoon> monsoon> winter. In both the years of investigation, TDS concentrations remained similar for both the rivers (Fig. 24).

Fig. 25 shows the annual range of TDS for the two consecutive years of study. The trend 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 May for both the study year (Fig. 25).

Mean value of TDS 2.85 (g/l) was the highest in R1 whereas the lowest mean value of TDS (1.76 g/l) was recorded in Station B3 (Table 9).

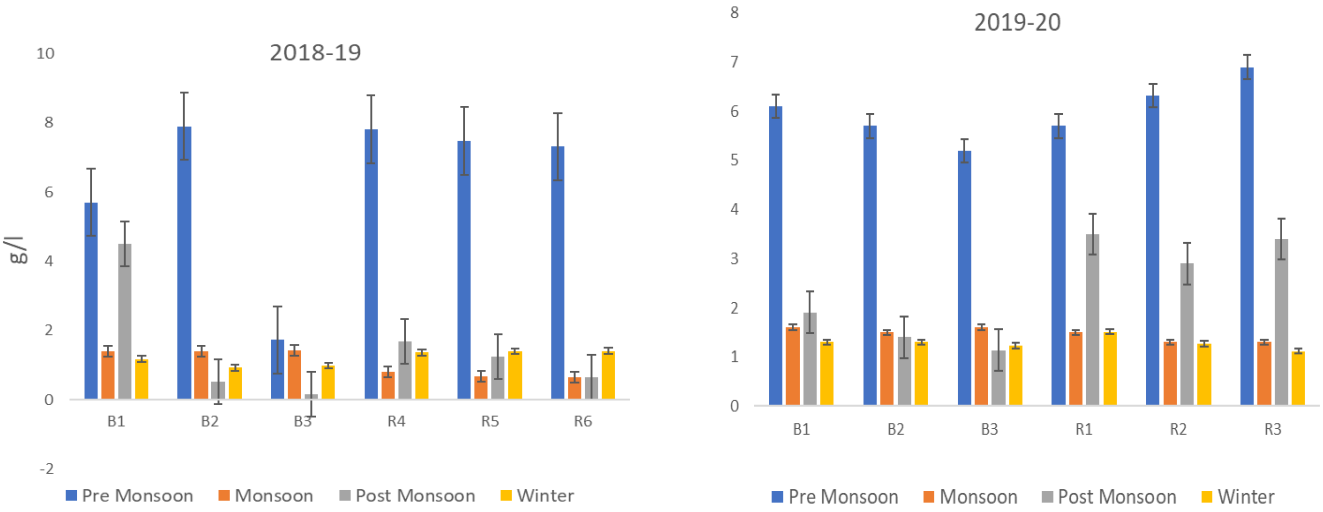


Fig. 24. Seasonal dynamics of TDS (g/l).

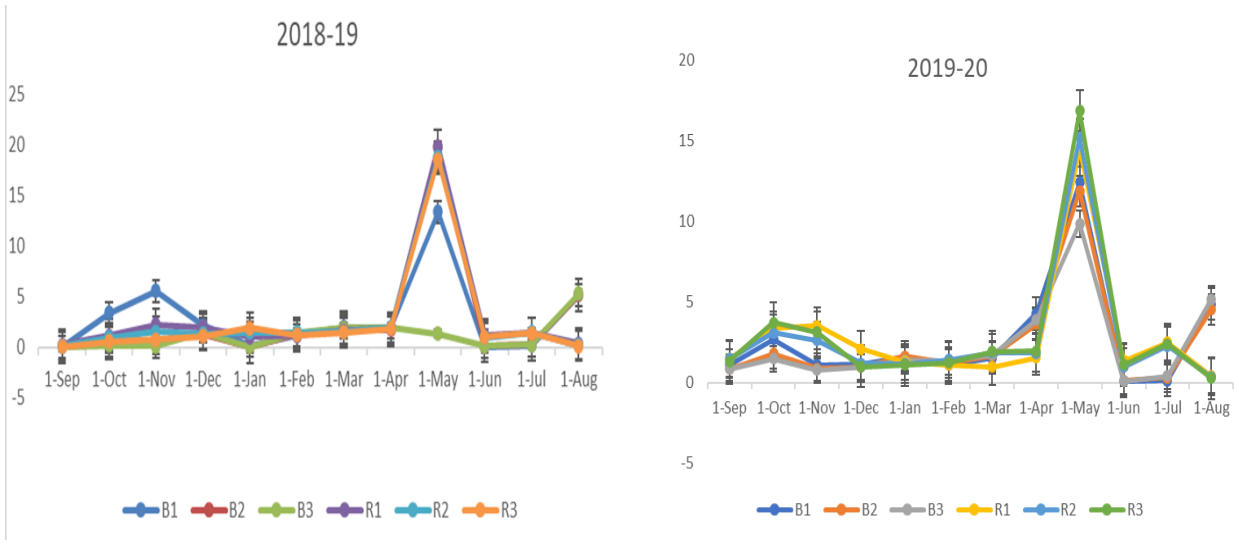


Fig. 25. Comparison of monthly values of TDS from two study years.

Table 9. Monthly mean values (±SD) of TDS (g/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	0.056±0.066	0.066±0.066	0.052±0.06	0.226±0.066	0.102±0.066	0.076±0.066
18-Oct	3.38±1.16	0.442±1.16	0.196±1.16	1.16±1.16	0.96±1.16	0.54±1.16
18-Nov	5.58±1.99	0.6±1.99	0.127±1.99	2.21±1.99	1.52±1.99	0.77±1.99
18-Dec	2.148±0.41	1.358±0.41	1.468±0.41	2±0.41	1.32±0.41	1.11±0.41
19-Jan	0.184±0.78	0.083±0.78	0.081±0.78	1±0.78	1.443±0.78	1.888±0.78
19-Feb	1.215±0.13	1.352±0.13	1.425±0.13	1.116±0.13	1.445±0.13	1.228±0.13
19-Mar	1.951±0.21	1.935±0.21	1.924±0.21	1.671±0.21	1.559±0.21	1.466±0.21
19-Apr	1.89±0.08	1.745±0.08	1.906±0.08	1.867±0.08	1.993±0.08	1.877±0.08
19-May	13.39±7.27	19.9±7.27	1.36±7.27	19.9±7.27	18.88±7.27	18.6±7.27
19-Jun	0.076±0.54	0.096±0.54	0.085±0.54	1.225±0.54	0.969±0.54	0.999±0.54
19-Jul	0.15±0.65	0.284±0.65	0.245±0.65	1.409±0.65	1.438±0.65	1.376±0.65
19-Aug	5.21±2.74	5.17±2.74	5.29±2.74	0.371±2.74	0.191±2.74	0.133±2.74
19-Sep	1.124±0.29	0.854±0.29	0.849±0.29	1.484±0.29	1.49±0.29	1.341±0.29
19-Oct	2.71±0.89	1.8±0.89	1.48±0.89	3.35±0.89	3.11±0.89	3.73±0.89
19-Nov	1.106±1.23	0.909±1.23	0.805±1.23	3.55±1.23	2.63±1.23	3.14±1.23
19-Dec	1.148±0.44	0.988±0.44	0.976±0.44	2.11±0.44	1.2±0.44	1±0.44
20-Jan	1.589±0.22	1.657±0.22	1.396±0.22	1.3±0.22	1.172±0.22	1.12±0.22
20-Feb	1.115±0.13	1.252±0.13	1.325±0.13	1.116±0.13	1.445±0.13	1.228±0.13
20-Mar	1.524±0.35	1.682±0.35	1.742±0.35	0.987±0.35	1.877±0.35	1.943±0.35
20-Apr	4.31±1.2	3.65±1.2	3.89±1.2	1.567±1.2	1.853±1.2	1.977±1.2
20-May	12.435±2.55	11.894±2.55	9.87±2.55	14.53±2.55	15.24±2.55	16.88±2.55
20-Jun	0.102±0.58	0.124±0.58	0.097±0.58	1.356±0.58	0.989±0.58	1.102±0.58
20-Jul	0.146±1.16	0.329±1.16	0.426±1.16	2.5±1.16	2.3±1.16	2.4±1.16
20-Aug	4.87±2.48	4.56±2.48	5.21±2.48	0.426±2.48	0.359±2.48	0.294±2.48
Mean	2.809	2.614	1.76	2.852	2.729	2.759

Dissolved oxygen (DO)

During the study period (2018-2020), the ranges of DO were 1.9-9.8, 1.8-8.6, 1.5-8.4, 3.3-7.9, 2.2-7.6, 1.5-6.9 mg/l for Station B1, B2, B3, R1, R2, and R3, respectively. The highest monthly DO (9.8 mg/l) was recorded in September, 2018 for Station B1 whereas the lowest mean DO (1.5 mg/l) was obtained in November, 2019 for Station R3 and June, 2020 for station B3. The trend of DO fluctuation showed a distinctly variable pattern over the two years of investigation.

The seasonal variation of DO doesn't maintain any pattern. In the first study year, the seasonal variation of DO was high in post-monsoon for B1 and B3 station but for B2 station it was high during pre-monsoon. In case of R2 and R3 station DO concentration was high during winter and for R1 station it was highest during monsoon. In second year, it was highest during winter for B1, B2, and B3 stations and the lowest during post-monsoon. DO concentration in R1 station was high in monsoon and in R2, and R3 station the value was high in monsoon and low in post-monsoon for all the station of Reju canal (Fig. 26)

Fig. 27 shows the annual range of DO for the two years of study. The DO concentration was strongly fluctuating among all the studied stations. DO was the highest during September in the 1st year but in March of the 2nd year of study and in June in both the year of study the value was low.

Mean DO (5.42 mg/l) was high in Station R1 whereas it was low (4.15 mg/l) in B2 (Table 10).

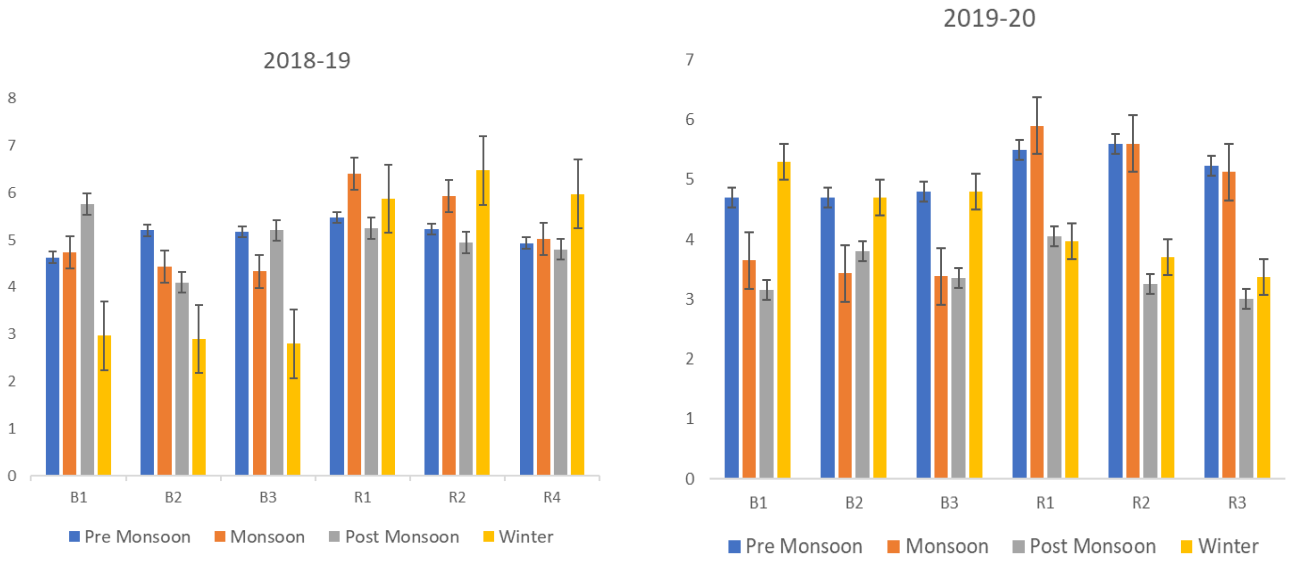


Fig. 26. Seasonal dynamics of DO (mg/l).

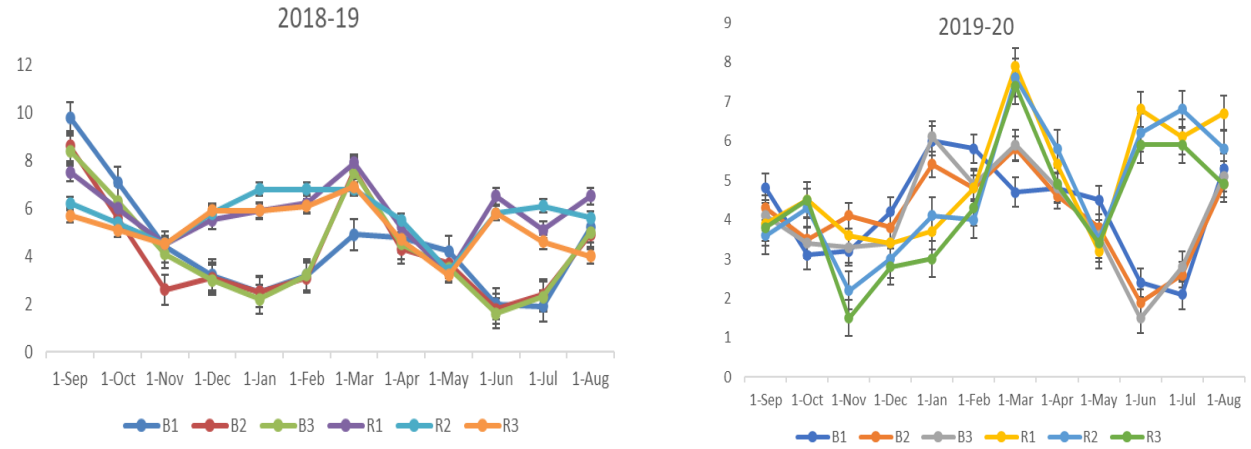


Fig. 27. Comparison of monthly values of DO from two study years.

Table 10. Monthly mean values (±SD) of DO (mg/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	9.8±1.55	8.6±1.55	8.4±1.55	7.5±1.55	6.2±1.55	5.7±1.55
18-Oct	7.1±0.72	5.6±0.72	6.3±0.72	6±0.72	5.4±0.72	5.1±0.72
18-Nov	4.4±0.75	2.6±0.75	4.1±0.75	4.5±0.75	4.5±0.75	4.5±0.75
18-Dec	3.2±1.45	3.1±1.45	3±1.45	5.5±1.45	5.8±1.45	5.9±1.45
19-Jan	2.5±2.11	2.5±2.11	2.2±2.11	5.9±2.11	6.8±2.11	5.9±2.11
19-Feb	3.2±1.77	3.1±1.77	3.2±1.77	6.2±1.77	6.8±1.77	6.1±1.77
19-Mar	4.9±1.08	7.6±1.08	7.5±1.08	7.9±1.08	6.8±1.08	6.9±1.08
19-Apr	4.8±0.45	4.3±0.45	4.5±0.45	5.2±0.45	5.5±0.45	4.7±0.45
19-May	4.2±0.36	3.7±0.36	3.5±0.36	3.3±0.36	3.4±0.36	3.2±0.36
19-Jun	2±0.36	1.8±0.36	1.6±0.36	6.5±0.36	5.8±0.36	5.8±0.36
19-Jul	1.9±1.76	2.4±1.76	2.3±1.76	5.1±1.76	6.1±1.76	4.6±1.76
19-Aug	5.2±0.83	4.9±0.83	5±0.83	6.5±0.83	5.6±0.83	4±0.83
19-Sep	4.8±0.43	4.3±0.43	4.1±0.43	3.9±0.43	3.6±0.43	3.8±0.43
19-Oct	3.1±0.62	3.5±0.62	3.4±0.62	4.5±0.62	4.3±0.62	4.5±0.62
19-Nov	3.2±0.96	4.1±0.96	3.3±0.96	3.6±0.96	2.2±0.96	1.5±0.96
19-Dec	4.2±0.51	3.8±0.51	3.4±0.51	3.4±0.51	3±0.51	2.8±0.51
20-Jan	6±1.3	5.4±1.3	6.1±1.3	3.7±1.3	4.1±1.3	3±1.3
20-Feb	5.8±0.62	4.8±0.62	4.9±0.62	4.8±0.62	4±0.62	4.3±0.62
20-Mar	4.7±1.27	5.8±1.27	5.9±1.27	7.9±1.27	7.6±1.27	7.4±1.27
20-Apr	4.8±0.45	4.6±0.45	4.8±0.45	5.4±0.45	5.8±0.45	4.9±0.45
20-May	4.5±0.45	3.8±0.45	3.6±0.45	3.2±0.45	3.5±0.45	3.4±0.45
20-Jun	2.4±2.43	1.9±2.43	1.5±2.43	6.8±2.43	6.2±2.43	5.9±2.43
20-Jul	2.1±2.1	2.6±2.1	2.8±2.1	6.1±2.1	6.8±2.1	5.9±2.1
20-Aug	5.3±0.7	4.9±0.7	5.1±0.7	6.7±0.7	5.8±0.7	4.9±0.7
Mean	4.34	4.15	4.19	5.42	5.23	4.78

Salinity (ppm)

During the study period (2018-2020), the ranges of salinity were 0-15, 0-28, 0-15, 0-30, 0-28, and 0-27 ppm for Station B1, B2, B3, R1, R2, and R3, respectively. Salinity depends on high tide and low tide time. The highest rate of salinity during my sampling period (30 ppm) was recorded in May, 2019 for Station R1 whereas the lowest salinity (0 ppm) was obtained in several months and in different stations.

The seasonal variation of salinity does did not maintain any pattern. In the first study year the seasonal variation of salinity was high in pre-monsoon for all, except B3 station, this station showed high salinity in winter. For the second study year the highest salinity was obtained in winter and the lowest in monsoon for all the studied stations (Fig. 28)

There were a number of fluxes in the salinity among the six stations. Salinity was highest in May but lowest in different months for the 1st year of study. And for the 2nd year, the peak was found in the month of January. The lowest salinity was recorded at different times of the study period (Fig. 29)

The highest mean value of salinity (6.96 ppm) was recorded in R1 station and the lowest mean value (2.48 ppm) was recorded in B3 station (Table 11).

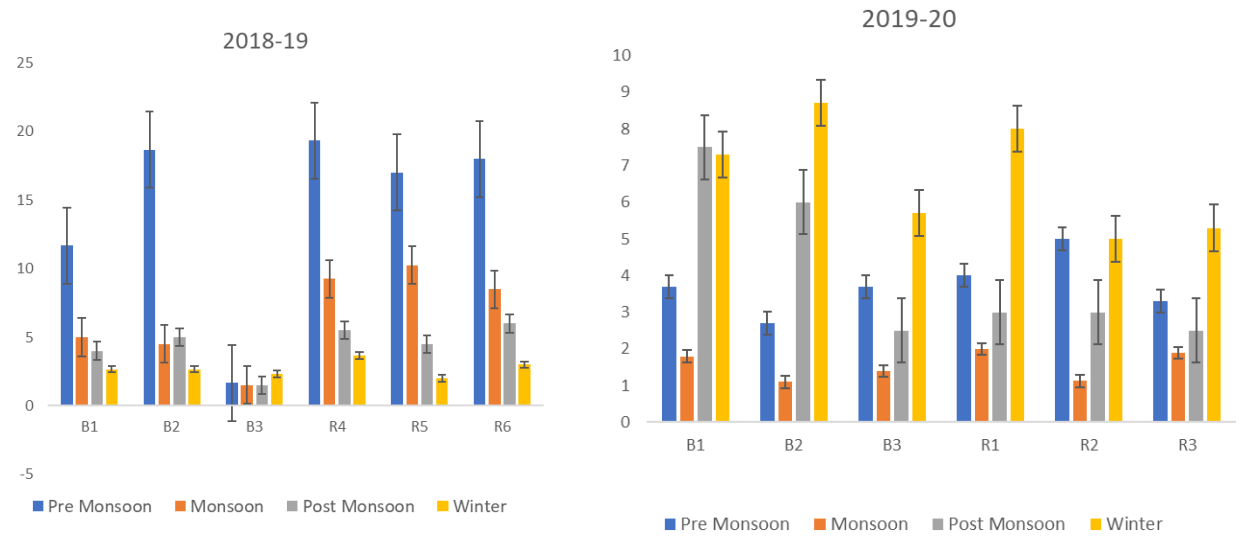


Fig. 28. Seasonal dynamics of Salinity (ppm).

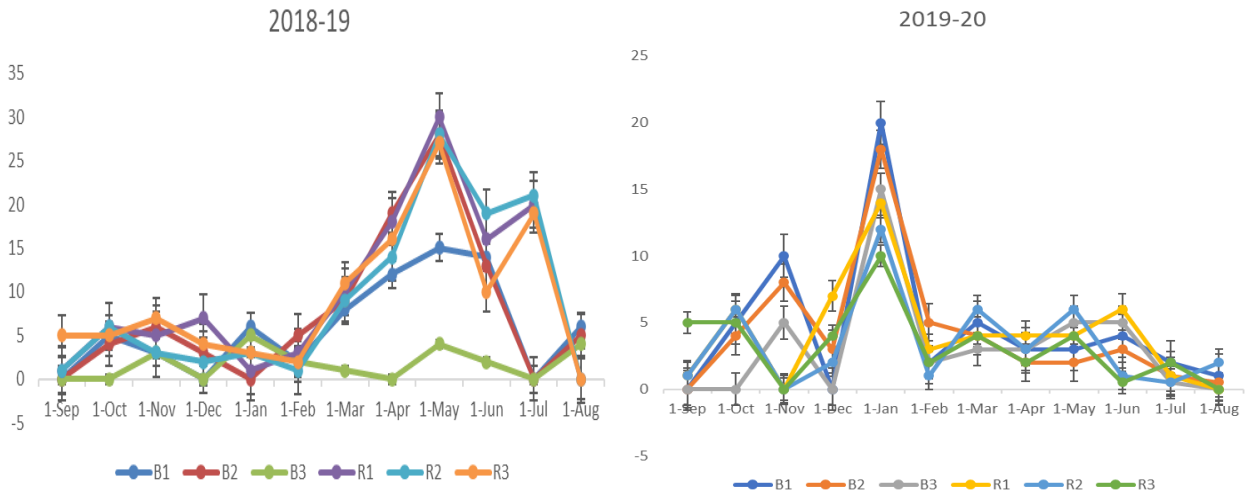


Fig. 29. Comparison of monthly values of salinity from two study years.

Table11. Monthly mean values (±SD) of Salinity (ppm).

Months	B1	B2	B3	R1	R2	R3
18-Sep	0±1.9	0±1.9	0±1.9	1±1.9	1±1.9	5±1.9
18-Oct	5±2.3	4±2.3	0±2.3	6±2.3	6±2.3	5±2.3
18-Nov	3±1.8	6±1.8	3±1.8	5±1.8	3±1.8	7±1.8
18-Dec	0±2.7	3±2.7	0±2.7	7±2.7	2±2.7	4±2.7
19-Jan	6±2.3	0±2.3	5±2.3	1±2.3	3±2.3	3±2.3
19-Feb	2±1.4	5±1.4	2±1.4	3±1.4	1±1.4	2±1.4
19-Mar	8±3.6	9±3.6	1±3.6	10±3.6	9±3.6	11±3.6
19-Apr	12±6.9	19±6.9	0±6.9	18±6.9	14±6.9	16±6.9
19-May	15±10.3	28±10.3	4±10.3	30±10.3	28±10.3	27±10.3
19-Jun	14±5.9	13±5.9	2±5.9	16±5.9	19±5.9	10±5.9
19-Jul	0±10.97	0±10.97	0±10.97	20±10.97	21±10.97	19±10.97
19-Aug	6±2.8	5±2.8	4±2.8	0±2.8	0±2.8	0±2.8
19-Sep	0±1.9	0±1.9	0±1.9	1±1.9	1±1.9	5±1.9
19-Oct	5±2.3	4±2.3	0±2.3	6±2.3	6±2.3	5±2.3
19-Nov	10±4.5	8±4.5	5±4.5	0±4.5	0±4.5	0±4.5
19-Dec	0±2.7	3±2.7	0±2.7	7±2.7	2±2.7	4±2.7
20-Jan	20±3.7	18±3.7	15±3.7	14±3.7	12±3.7	10±3.7
20-Feb	2±1.4	5±1.4	2±1.4	3±1.4	1±1.4	2±1.4
20-Mar	5±1.03	4±1.03	3±1.03	4±1.03	6±1.03	4±1.03
20-Apr	3±0.75	2±0.75	3±0.75	4±0.75	3±0.75	2±0.75
20-May	3±1.4	2±1.4	5±1.4	4±1.4	6±1.4	4±1.4
20-Jun	4±2.2	3±2.2	5±2.2	6±2.2	1±2.2	0.5±2.2
20-Jul	2±0.68	1±0.68	0.5±0.68	1±0.68	0.5±0.68	2±0.68
20-Aug	1±0.8	0.5±0.8	0±0.8	0±0.8	2±0.8	0±0.8
Mean	5.25	5.94	2.48	6.96	6.15	6.15

Soluble reactive phosphorus (SRP)

During the study period (2018-2020), the ranges of SRP were 11.58-98.60, 6.33-86.30, 10.93-242.42, 4.19-196.9, 6.84-142.58, and 0.86-75.62 µg/l for Station B1, B2, B3, R1, R2, and R3 respectively. The highest monthly mean SRP (242.42 µg/l) was recorded in May, 2019 for Station B3 whereas the lowest mean SRP (0.86 µg/l) was recorded in October, 2019 for Station R3. The trend of SRP fluctuation was distinct but different in two years of investigation.

The seasonal variation of SRP showed the highest value during pre-monsoon for Station B1, B2, B3 and R3 station but during post-monsoon for Station R2 and in winter for Station R3 in the first year of study and the lowest was recorded in monsoon for B2, R1, R2 and R3 stattions but for B1 it was lowest during post-monsoon and winter for B3 station in the first year of study and in second year it was highest during pre-monsoon for all the studied Station and the lowest during winter for Station B1, B2 and B3 and during post-monsoon for R1, R2 and R3 station. Over the seasons, the mean values of SRP did not follow any distinct trend or pattern. Usually, the highest value was observed in pre-monsoon but in-case of the lowest value it does not follow any specific seasonal trend (Fig. 30).

Fig. 31 shows a number of fluctuations, which were observed throughout the year. In the month of May, SRP values were observed high in May in both the years of study and low in July in the 1st year and in October of the 2nd study year.

Mean value of SRP (46.3 µg/l) was the highest in Station B1 whereas the lowest mean value of SRP (29.7 µg/l) was recorded in Station R3 (Table 12).

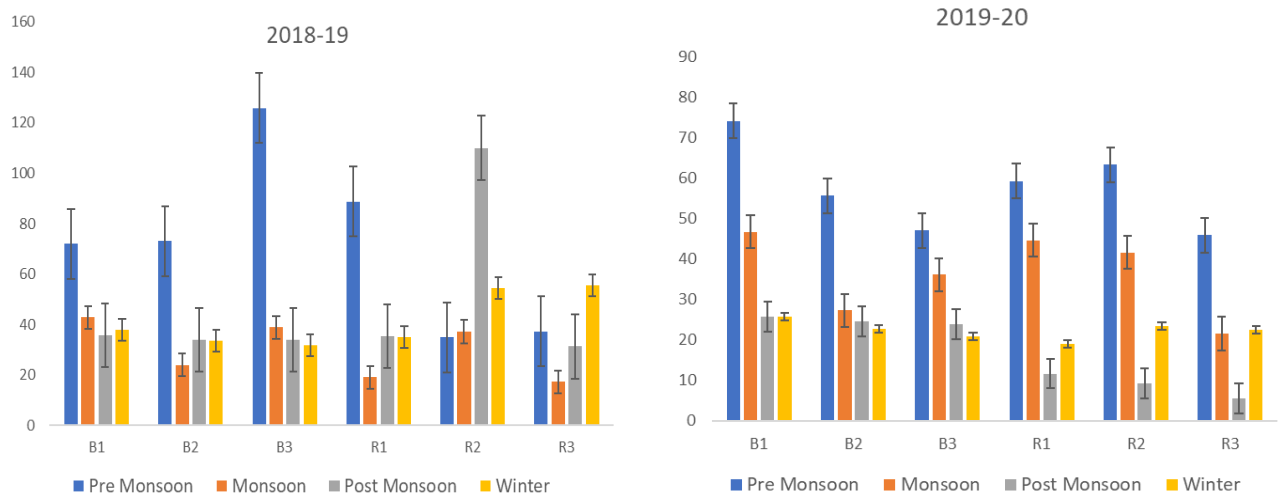


Fig. 30. Seasonal dynamics of SRP (µg/l).

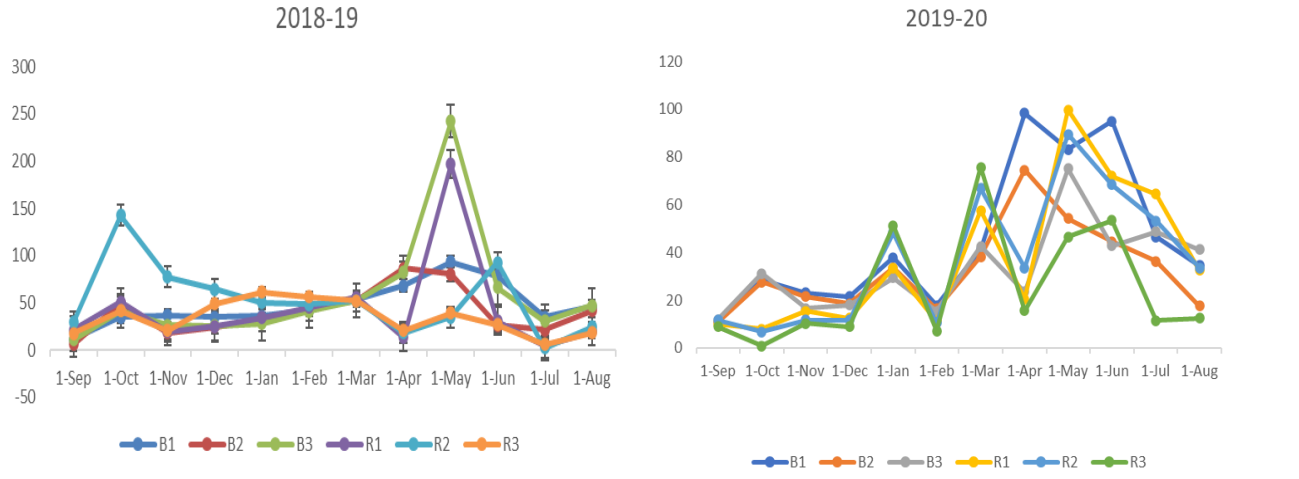


Fig. 31. Comparison of monthly values of SRP from two study years.

Table 12. Monthly mean values (±SD) of SRP (µg/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	11.58±8.3	6.33±8.3	10.93±8.3	21.42±8.3	29.29±8.3	17.48±8.3
18-Oct	34.95±40.8	49.75±40.8	41.7±40.8	51.09±40.8	142.58±40.8	41.7±40.8
18-Nov	36.66±40.8	18.23±40.8	26.13±40.8	19.55±40.8	77.5±40.8	20.9±40.8
18-Dec	34.65±16.2	24.68±16.2	25.9±16.2	24.8±16.2	64.2±16.2	48.8±16.2
19-Jan	36.12±12.5	32.99±12.5	28.297±12.5	34.56±12.5	50.2±12.5	61.16±12.5
19-Feb	42.54±5.5	43.28±5.5	41.26±5.5	45.22±5.5	48.52±5.5	56.22±5.5
19-Mar	54.2±1.5	52.74±1.5	52.7±1.5	55.83±1.5	52.09±1.5	52.05±1.5
19-Apr	68.21±34.3	86.3±34.3	82.08±34.3	13.33±34.3	18.15±34.3	20.6±34.3
19-May	93.6±85.8	80.2±85.8	242.4±85.8	196.9±85.8	34.7±85.8	39.32±85.8
19-Jun	78.7±29.4	26.3±29.4	66.4±29.4	30.9±29.4	92.84±29.4	26.8±29.4
19-Jul	34.9±14.4	21.5±14.4	30.9±14.4	4.2±14.4	2.2±14.4	6.19±14.4
19-Aug	46.1±13.6	41.4±13.6	47.4±13.6	19.6±13.6	24.2±13.6	18.3±13.6
19-Sep	10.99±1.2	10.9±1.2	11.96±1.2	9.9±1.2	11.6±1.2	8.9±1.2
19-Oct	28.5±13.4	27.6±13.4	31.3±13.4	7.9±13.4	6.84±13.4	0.9±13.4
19-Nov	23.12±5.1	21.46±5.1	16.54±5.1	15.46±5.1	11.67±5.1	10.26±5.1
19-Dec	21.46±4.8	18.63±4.8	17.89±4.8	12.46±4.8	11.68±4.8	8.96±4.8
20-Jan	37.8±8.8	33.56±8.8	29.4±8.8	33.56±8.8	48.2±8.8	51.23±8.8
20-Feb	17.86±4.1	16.31±4.1	15.42±4.1	11.22±4.1	10.52±4.1	7.22±4.1
20-Mar	41.2±15.4	38.23±15.4	42.62±15.4	57.62±15.4	66.84±15.4	75.62±15.4
20-Apr	98.23±33.9	74.6±33.9	23.56±33.9	20.58±33.9	33.59±33.9	15.67±33.9
20-May	83.15±20.6	54.26±20.6	74.97±20.6	99.68±20.6	89.53±20.6	46.52±20.6
20-Jun	94.96±19.8	44.53±19.8	42.86±19.8	71.85±19.8	68.32±19.8	53.48±19.8
20-Jul	46.53±18.2	36.34±18.2	48.62±18.2	64.52±18.2	53.14±18.2	11.46±18.2
20-Aug	34.58±11.1	17.52±11.1	41.23±11.1	32.53±11.1	33.48±11.1	12.39±11.1
Mean	46.3	36.6	45.5	39.8	45.1	29.7

Soluble reactive silicate (SRS)

During the study period (2018-2020), the ranges of SRS were 1.35-13.23, 1.13-14.52, 2.01-14.24, 1.55-7.53, 2.28-7.13, and 1.96-7.91 mg/l for Station B1, B2, B3, R1, R2 and R3, respectively. The highest monthly mean SRS (14.52 mg/l) was recorded in July, 2020 for Station B2 and the lowest mean value (1.13 mg/l) was in November, 2018 and for also in Station B2. The trend of SRS was distinct but different in two

The seasonal variation of SRS showed the highest value during monsoon for B1, B2, and B3 but in winter for Station R1, R2, and R3. The lowest was recorded during post-monsoon for Station B2, B3, R1, R2, and R3 but during pre-monsoon for B1 station in the first year of study. In the second year it was highest during post-monsoon for Station B2. But during monsoon for B1 and B3 and during pre-monsoon for R1, R2, and R3. The lowest value was recorded during pre-monsoon for Station B1 and B2 and during winter for B3 station and during monsoon for R1, R2 and R3 stations. Over the seasons, the mean values of SRP did not follow any distinct pattern (Fig. 32).

An interesting pattern of fluctuation of SRS in was found in three different stations (Fig. 33). Wherein, SRS value was maximum in July for B3 station and minimum in November for B2 station in case of 1st year of study and for 2nd year of study it is high in July for B2 station and low in March for B2 station (Fig. 33).

Mean value of SRS (6.1 mg/l) was the highest in Station B1 whereas the lowest mean value of SRS (4.6 mg/l) was recorded in Station R1 and R3 (Table 13).

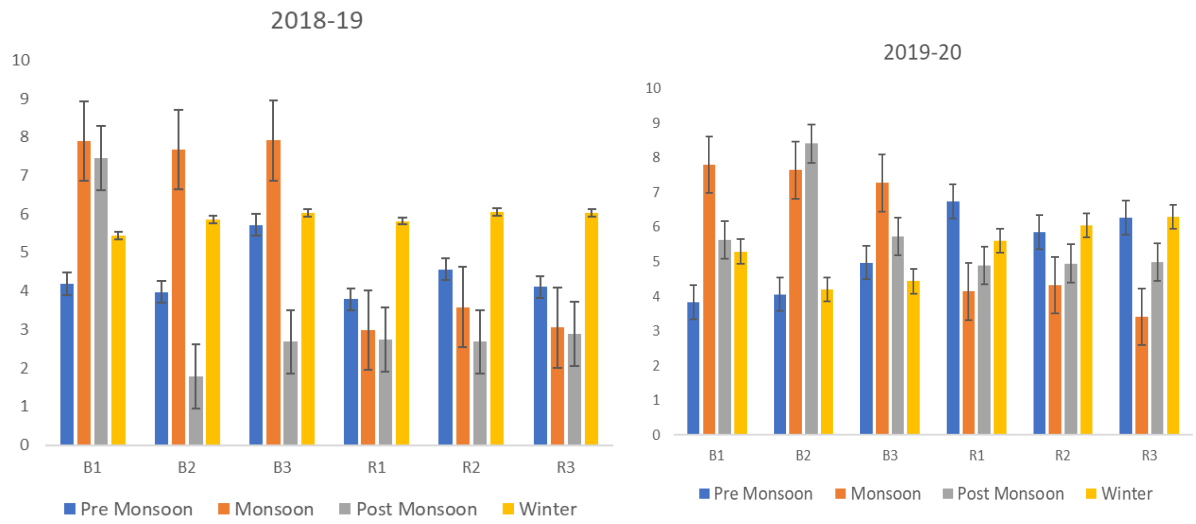


Fig. 32. Seasonal dynamics of SRS (mg/l).

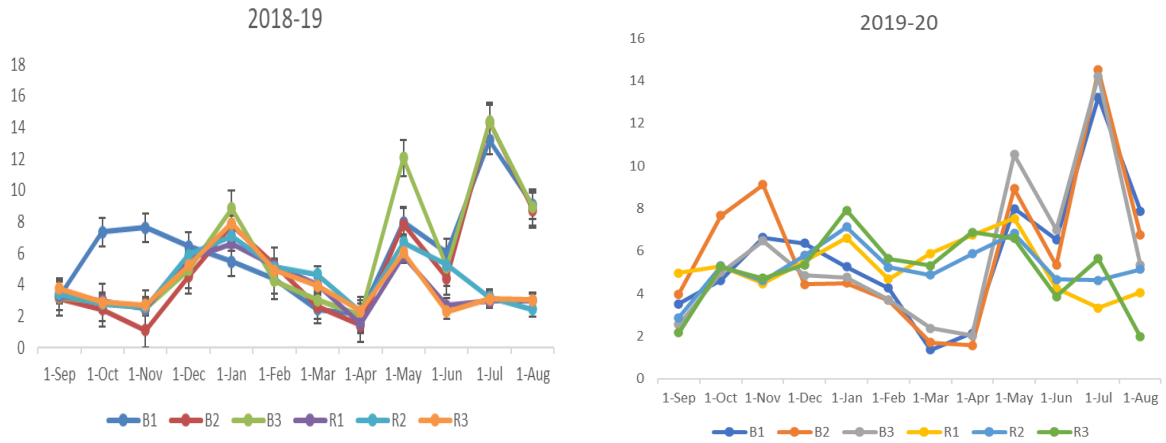


Fig. 33. Comparison of monthly values of SRS from two study years.

Table 13. Monthly mean values (±SD) of SRS (mg/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	3.27±0.22	3.14±0.22	3.21±0.22	3.27±0.22	3.41±0.22	3.75±0.22
18-Oct	7.35±1.9	2.43±1.9	2.89±1.9	3±1.9	2.77±1.9	2.89±1.9
18-Nov	7.64±2.3	1.13±2.3	2.48±2.3	2.48±2.3	2.6±2.3	2.7±2.3
18-Dec	6.5±0.69	4.5±0.69	4.96±0.69	5.6±0.69	5.9±0.69	5.25±0.69
19-Jan	5.46±1.2	7.8±1.2	8.85±1.2	6.62±1.2	7.13±1.2	7.91±1.2
19-Feb	4.36±0.44	5.26±0.44	4.26±0.44	5.21±0.44	5.12±0.44	4.93±0.44
19-Mar	2.46±0.88	2.63±0.88	3.03±0.88	3.9997±0.88	4.69±0.88	3.94±0.88
19-Apr	2.13±0.38	1.44±0.38	2.07±0.38	1.55±0.38	2.28±0.38	2.34±0.38
19-May	7.98±2.29	7.84±2.29	12.06±2.29	5.83±2.29	6.7±2.29	6.06±2.29
19-Jun	6.043±1.5	4.44±1.5	5.12±1.5	2.69±1.5	5.27±1.5	2.3±1.5
19-Jul	13.1699±5.98	14.34±5.98	14.39±5.98	2.96±5.98	3.19±5.98	3.099±5.98
19-Aug	9.075±3.34	8.749±3.34	8.912±3.34	2.99±3.34	2.44±3.34	3.039±3.34
19-Sep	3.515±1.03	3.98±1.03	2.54±1.03	4.96±1.03	2.86±1.03	2.16±1.03
19-Oct	4.62±1.08	7.67±1.08	4.99±1.08	5.3±1.08	5.3±1.08	5.26±1.08
19-Nov	6.64±±1.8	9.13±1.8	6.48±1.8	4.48±1.8	4.6±1.8	4.7±1.8
19-Dec	6.36±0.68	4.42±0.68	4.86±0.68	5.52±0.68	5.796±0.68	5.35±0.68
20-Jan	5.262±1.39	4.48±1.39	4.75±1.39	6.62±1.39	7.13±1.39	7.91±1.39
20-Feb	4.263±0.8	3.684±0.8	3.698±0.8	4.689±0.8	5.234±0.8	5.629±0.8
20-Mar	1.356±2.0	1.689±2.0	2.356±2.0	5.892±2.0	4.864±2.0	5.314±2.0
20-Apr	2.143±2.55	1.564±2.55	2.013±2.55	6.75±2.55	5.86±2.55	6.89±2.55
20-May	7.99±1.5	8.92±1.5	10.53±1.5	7.53±1.5	6.83±1.5	6.596±1.5
20-Jun	6.528±1.26	5.32±1.26	6.99±1.26	4.23±1.26	4.65±1.26	3.86±1.26
20-Jul	13.23±5.26	14.52±5.26	14.24±5.26	3.31±5.26	4.63±5.26	5.65±5.26
20-Aug	7.88±2.07	6.75±2.07	5.32±2.07	4.05±2.07	5.13±2.07	1.96±2.07
Mean	6.1	5.7	5.9	4.6	4.8	4.6

Nitrate-nitrogen (NO_3-N)

The ranges of nitrate-nitrogen (NO_3-N) were 0.013-1.69, 0.0012-2.81, 0.02-1.36, 0.02-1.26, 0.048-1.62, and 0.04-1.45 mg/l for Station B1, B2, B3, R1, R2 and R3, respectively. The highest monthly value of NO_3-N (2.81 mg/l) was recorded in September, 2018 for Station B2 whereas the lowest mean NO_3-N (0.0012 mg/l) was recorded also for B2 station in January 2019 and January 2020.

The seasonal variation of NO_3-N shows the highest value during pre-monsoon for B1, B3, R1, R2, and R3 but during monsoon for Station B2. The lowest concentration of nitrate was recorded during winter for B1, B2, R2, and R3 stations and during post monsoon for B3 and R1 stations in the first year of study. In the second year it was highest during pre-monsoon for Station B1, B3, R1, R2 and R3 and during monsoon for Station B2. However, the lowest was recorded during winter for Station B1, B2, R1, R2 and R3 and during monsoon in the B3 station. Over the seasons, the mean values of NO_3-N did not follow any distinct pattern (Fig. 34).

Fig. 35 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. The NO_3-N values shows high values in the month of September, some picks were found in the month of march, April and September in B3, R2 and B2 station respectively in the 1st year and in April for R2 station in 2nd year. The lowest value was recorded in the month of January for both year and for all studied station. (Fig. 35).

Mean value of NO_3-N (0.42 mg/l) was the highest in Station B2 whereas the lowest mean value of NO_3-N (0.33 mg/l) was recorded in Station B3 (Table 14).

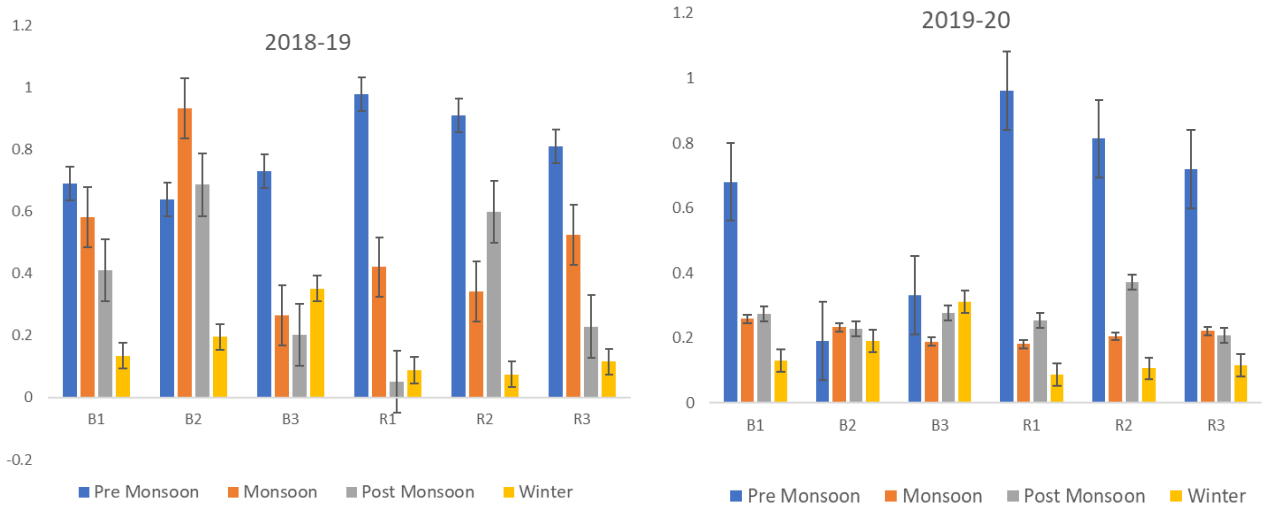


Fig 34. Seasonal dynamics of NO_3-N (mg/l).

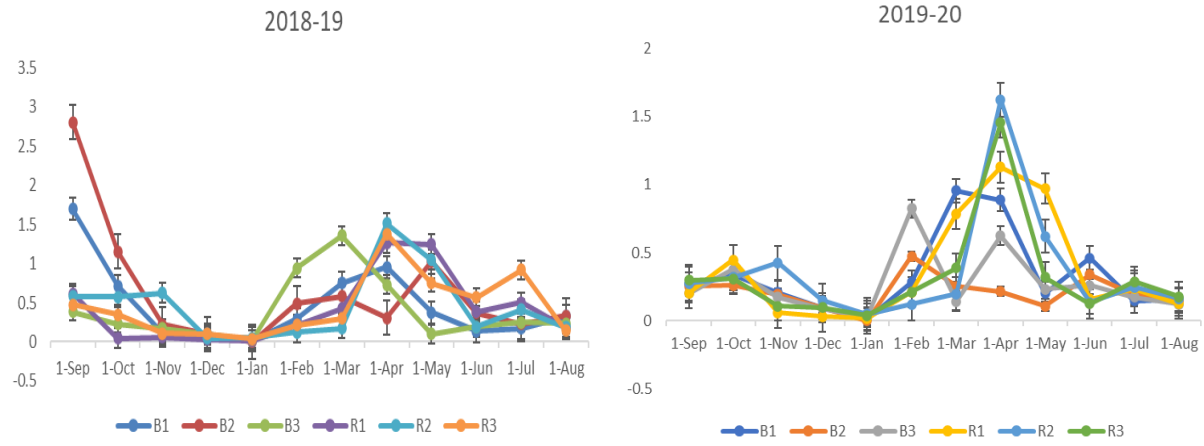


Fig. 35. Comparison of monthly values of NO_3-N from two study years.

Table 14. Monthly mean values (±SD) of NO_3-N (mg/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	1.69±0.97	2.81±0.97	0.39±0.97	0.62±0.97	0.58±0.97	0.47±0.97
18-Oct	0.71±0.39	1.15±0.39	0.23±0.39	0.04±0.39	0.57±0.39	0.35±0.39
18-Nov	0.11±0.21	0.22±0.21	0.17±0.21	0.06±0.21	0.63±0.21	0.11±0.21
18-Dec	0.098±0.03	0.095±0.03	0.09±0.03	0.032±0.03	0.05±0.03	0.098±0.03
19-Jan	0.013±0.02	0.0012±0.02	0.02±0.02	0.02±0.02	0.05±0.02	0.04±0.02
19-Feb	0.29±0.30	0.49±0.30	0.94±0.30	0.21±0.30	0.12±0.30	0.21±0.30
19-Mar	0.75±0.42	0.58±0.42	1.36±0.42	0.43±0.42	0.17±0.42	0.297±0.42
19-Apr	0.95±0.45	0.305±0.45	0.73±0.45	1.26±0.45	1.51±0.45	1.38±0.45
19-May	0.38±0.44	1.03±0.44	0.099±0.44	1.24±0.44	1.05±0.44	0.75±0.44
19-Jun	0.14±0.16	0.37±0.16	0.191±0.16	0.39±0.16	0.191±0.16	0.57±0.16
19-Jul	0.17±0.28	0.23±0.28	0.25±0.28	0.5±0.28	0.41±0.28	0.92±0.28
19-Aug	0.33±0.08	0.33±0.08	0.24±0.08	0.18±0.08	0.19±0.08	0.15±0.08
19-Sep	0.27±0.04	0.25±0.04	0.2±0.04	0.21±0.04	0.27±0.04	0.299±0.04
19-Oct	0.34±0.07	0.26±0.07	0.38±0.07	0.45±0.07	0.32±0.07	0.31±0.07
19-Nov	0.21±0.13	0.195±0.13	0.17±0.13	0.06±0.13	0.43±0.13	0.11±0.13
19-Dec	0.098±0.04	0.095±0.04	0.09±0.04	0.032±0.04	0.15±0.04	0.098±0.04
20-Jan	0.013±0.02	0.0021±0.02	0.024±0.02	0.017±0.02	0.048±0.02	0.038±0.02
20-Feb	0.28±0.26	0.47±0.26	0.82±0.26	0.21±0.26	0.12±0.26	0.21±0.26
20-Mar	0.95±0.34	0.25±0.34	0.14±0.34	0.79±0.34	0.198±0.34	0.39±0.34
20-Apr	0.89±0.53	0.215±0.53	0.62±0.53	1.126±0.53	1.62±0.53	1.45±0.53
20-May	0.201±0.33	0.11±0.33	0.23±0.33	0.97±0.33	0.62±0.33	0.32±0.33
20-Jun	0.46±0.13	0.34±0.13	0.26±0.13	0.16±0.13	0.14±0.13	0.12±0.13
20-Jul	0.15±0.05	0.19±0.05	0.17±0.05	0.23±0.05	0.25±0.05	0.29±0.05
20-Aug	0.16±0.02	0.15±0.02	0.12±0.02	0.12±0.02	0.16±0.02	0.18±0.02
Mean	0.40	0.42	0.33	0.39	0.41	0.38

Biological parameters

Chlorophyll a (chl-a)

The ranges of chl-a were 1.184-8.29, 1.184-9.47, 1.184-6.78, 3.55-13.024, 2.37-13.024 and 3.55-14.84 µg/l for Station B1, B2, B3, R1, R2 and R3, respectively. The highest monthly chl-a (14.84 µg/l) was recorded in September, 2019 for Station R3 whereas the lowest mean chl-a (1.184 µg/l) was recorded for several times for Station B1, and B2 but for B3 it was in October, 2019.

The seasonal variation of chl-a shows the highest value during winter for Station B1, B3, and R2 but for Station B1 and R3 it occurred during monsoon. For R1 highest chl-a was recorded during pre-monsoon. The lowest chl-a was recorded during pre-monsoon for Station B1, B2, and B3 but during post-monsoon for Station R1, R2, and R3 in the first year of study. However, in the second year it was highest during pre-monsoon for Station B1, B2, B3, and R3. Chl-a showed its highest concentration during monsoon for the R1 and R2, while all the stations showed lowest values during post-monsoon. Over the seasons, the mean values of chl-a did not follow any distinct pattern (Fig. 36).

Fig. 37 shows the annual range of chl-a for the two consecutive years of study for all the studied stations. At least two to three peaks of chl-a concentration were noticed during the two years of study. Otherwise, the values showed a highly fluctuating trend among the stations. Chl-a was the highest in April and the lowest in March for 1st year and lowest value found during October and highest showed in September for the next year (Fig. 37).

Mean value of chl-a (7.5 µg/l) was the highest in Station R1 whereas, the lowest mean value of chl-a (4.5 µg/l) was recorded in Station B3 (Table 15).

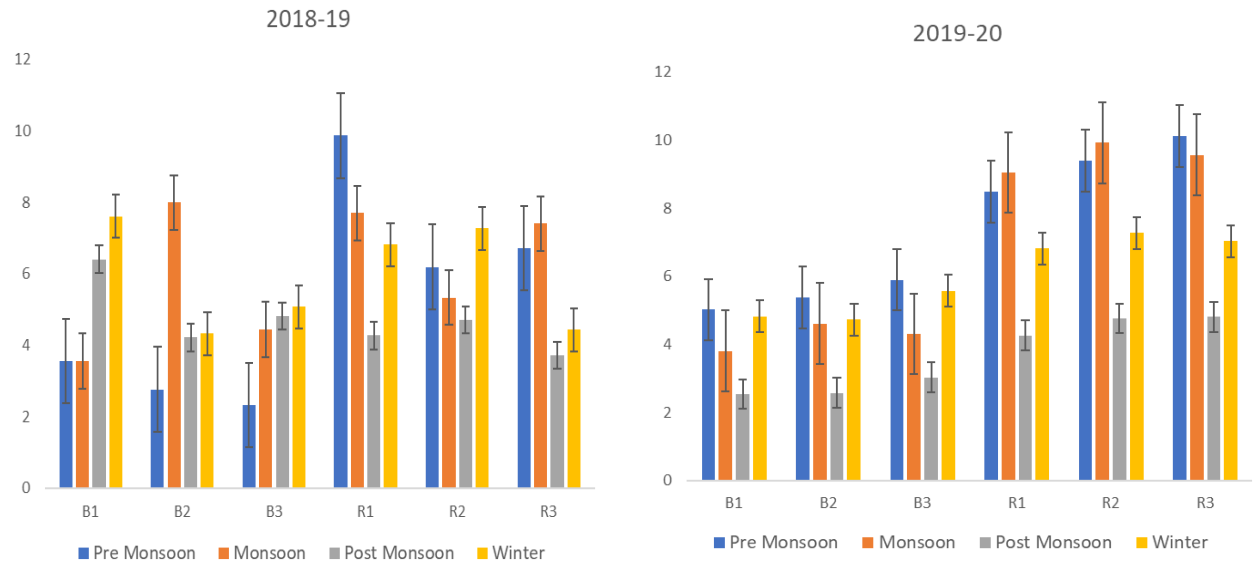


Fig. 36. Seasonal dynamics of chl-a (µg/l).

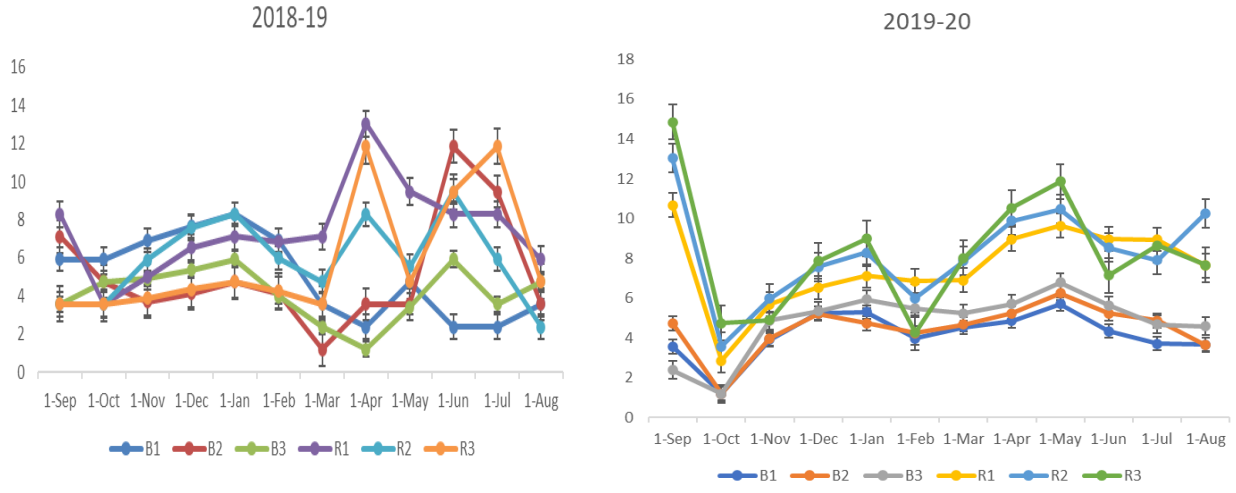


Fig. 37. Comparison of monthly values of chl-a from two study years.

Table 15. Showing monthly mean values (±SD) of chl-a (µg/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	5.92±2.08	7.10±2.08	3.55±2.08	8.29±2.08	3.55±2.08	3.55±2.08
18-Oct	5.92±0.97	4.74±0.97	4.74±0.97	3.55±0.97	3.55±0.97	3.55±0.97
18-Nov	6.89±1.21	3.69±1.21	4.89±1.21	4.99±1.21	5.88±1.21	3.88±1.21
18-Dec	7.64±1.56	4.12±1.56	5.34±1.56	6.52±1.56	7.56±1.56	4.33±1.56
19-Jan	8.29±1.63	4.74±1.63	5.92±1.63	7.104±1.63	8.29±1.63	4.74±1.63
19-Feb	6.89±1.39	4.12±1.39	3.96±1.39	6.84±1.39	5.98±1.39	4.25±1.39
19-Mar	3.55±2.04	1.18±2.04	2.37±2.04	7.10±2.04	4.74±2.04	3.55±2.04
19-Apr	2.37±5.06	3.55±5.06	1.18±5.06	13.02±5.06	8.29±5.06	11.84±5.06
19-May	4.74±2.22	3.55±2.22	3.42±2.22	9.47±2.22	5.55±2.22	4.74±2.22
19-Jun	2.37±3.32	11.84±3.32	5.92±3.32	8.29±3.32	9.47±3.32	9.47±3.32
19-Jul	2.37±3.62	9.47±3.62	3.55±3.62	8.29±3.62	5.92±3.62	11.84±3.62
19-Aug	3.55±1.24	3.55±1.24	4.74±1.24	5.92±1.24	2.37±1.24	4.74±1.24
19-Sep	3.55±5.31	4.74±5.31	2.37±5.31	10.66±5.31	13.02±5.31	14.84±5.31
19-Oct	1.18±1.51	1.18±1.51	1.18±1.51	2.85±1.51	3.55±1.51	4.74±1.51
19-Nov	3.89±0.85	3.96±0.85	4.87±0.85	5.67±0.85	5.96±0.85	4.88±0.85
19-Dec	5.23±1.21	5.21±1.21	5.34±1.21	6.52±1.21	7.56±1.21	7.86±1.21
20-Jan	5.29±1.69	4.74±1.69	5.92±1.69	7.10±1.69	8.29±1.69	8.99±1.69
20-Feb	3.96±1.16	4.23±1.16	5.46±1.16	6.84±1.16	5.98±1.16	4.25±1.16
20-Mar	4.52±1.59	4.65±1.59	5.21±1.59	6.89±1.59	7.86±1.59	7.99±1.59
20-Apr	4.84±2.55	5.23±2.55	5.69±2.55	8.96±2.55	9.86±2.55	10.53±2.55
20-May	5.697±2.54	6.24±2.54	6.78±2.54	9.63±2.54	10.46±2.54	11.85±2.54
20-Jun	4.32±1.87	5.23±1.87	5.63±1.87	8.96±1.87	8.52±1.87	7.12±1.87
20-Jul	3.69±2.30	4.86±2.30	4.67±2.30	8.94±2.30	7.89±2.30	8.64±2.30
20-Aug	3.65±2.70	3.62±2.70	4.57±2.70	7.63±2.70	10.26±2.70	7.65±2.70
Mean	4.6	4.8	4.5	7.5	7.1	7.1

Phaeopigment (PP)

During the study period (2018 – 2020), the ranges of phaeopigment (PP) were 0.59-10.11, 0.024-7.97, 0.096-10.12, 0.512-9.184, 1.12-12.384 and 0.608-8.098 µg/l for Station B1, B2, B3, R1, R2, and R3 respectively. The highest monthly phaeopigment (12.38 µg/l) was recorded in July, 2019 for Station R2 whereas the lowest mean phaeopigment (0.02 µg/l) was recorded for Station B2 in March, 2020. The trend of phaeopigment was as like as chl-a in two years of investigation.

The seasonal variation of phaeopigment shows the highest value during pre-monsoon at Station B2 and B3, but at post-monsoon for Station R1 and R3. During winter for B1 station and during monsoon for R2 station the concentration of PP was also higher. On the otherhand, the lowest value was recorded during post-monsoon for Station B1, R1, R2, and R3 but during winter for Station B2. In the first year of study the lowest value of chl-a was recorded at B3 during monsoon. In second year of study, it was highest during winter for Station B1 and during monsoon in B2 and R3. PP was also highest during the post-monsoon in B3 and R2 and during pre-monsoon for R1. However, the lowest value of PP was recorded during post-monsoon for B2, B3 and during monsoon for B1 and R2. PP was also low during post-monsoon for R1 station and during winter for R3 station. The higher amount of PP prevails in post monsoon in the 1st year of study and pre monsoon in the 2nd year of study. Here we found a clear difference in Bakkhali river and Reju canal in respect to the dynamics of PP. In Reju canal comparatively higher PP was recorded than Bakkhali river. Over the seasons, the mean values of phaeopigment did not follow any distinct pattern. Amount of phaeopigment was comparatively higher during the second year of investigation (Fig. 38).

Fig. 39 shows the annual range of PP for the two consecutive years of study, The graph shows a that PP concentration was the highest in July for both the year and the lowest in January for 1st year and March for 2nd year (Fig. 39).

Mean value of PP (4.25 µg/l) was the highest in Station R1 whereas the lowest mean value of PP (2.06 µg/l) was recorded in Station B2 (Table 16).

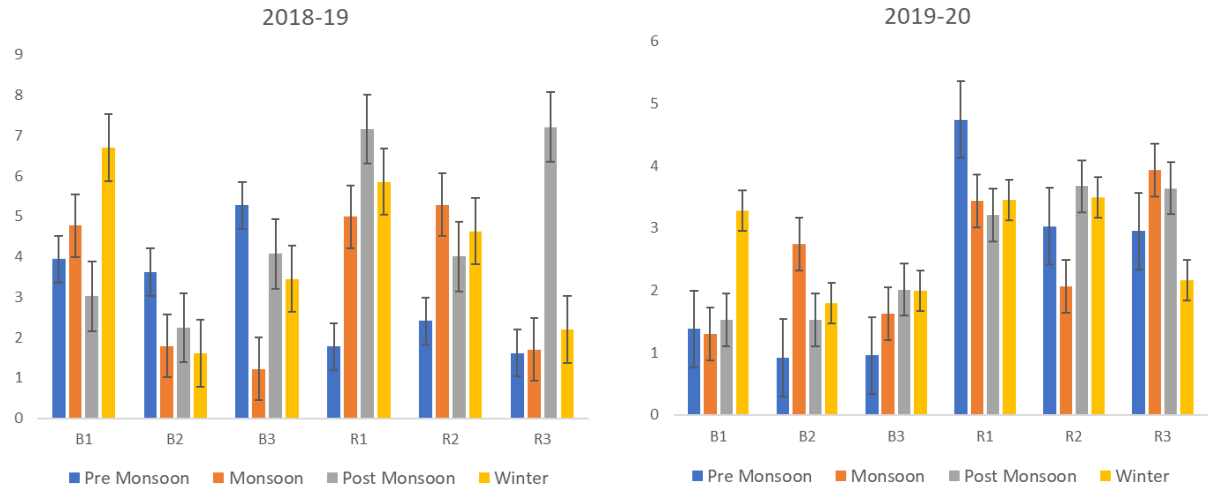


Fig. 38. Seasonal dynamics of phaeopigment (µg/l).

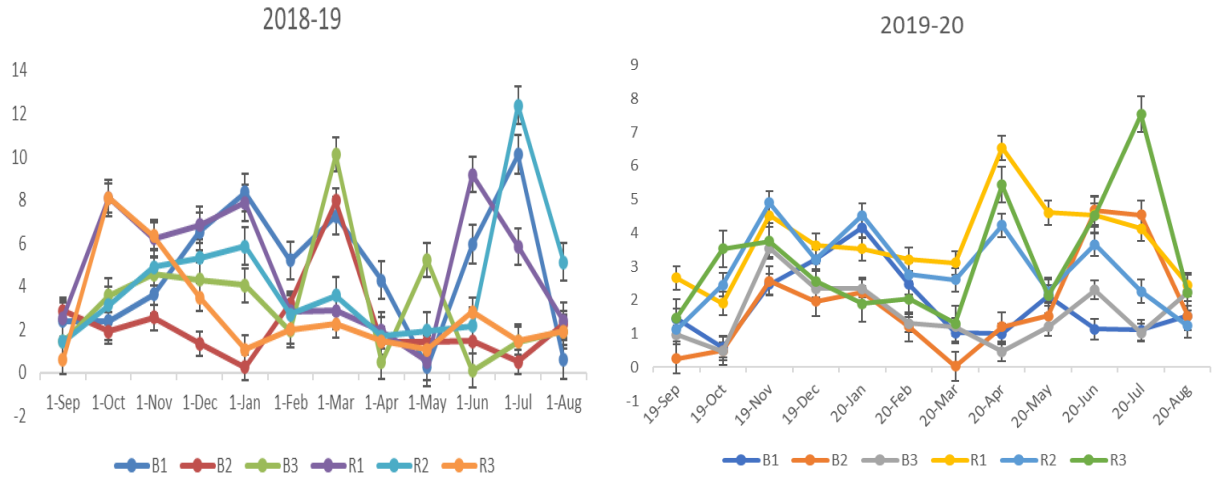


Fig. 39. Comparison of monthly values of phaeopigment from two study years.

Table 16. Monthly mean values (±SD) of phaeopigment (µg/l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	2.4±0.86	2.88±0.86	1.44±0.86	2.528±0.86	1.44±0.86	0.608±0.86
18-Oct	2.4±2.82	1.92±2.82	3.58±2.82	8.098±2.82	3.12±2.82	8.098±2.82
18-Nov	3.64±1.46	2.56±1.46	4.56±1.46	6.23±1.46	4.89±1.46	6.32±1.46
18-Dec	6.54±2.06	1.35±2.06	4.32±2.06	6.85±2.06	5.31±2.06	3.5±2.06
19-Jan	8.35±3.4	0.252±3.4	4.064±3.4	7.872±3.4	5.856±3.4	1.088±3.4
19-Feb	5.21±1.19	3.21±1.19	1.96±1.19	2.84±1.19	2.72±1.19	2.01±1.19
19-Mar	7.26±3.2	7.968±3.2	10.12±3.2	2.88±3.2	3.584±3.2	2.272±3.2
19-Apr	4.288±1.28	1.44±1.28	0.48±1.28	1.952±1.28	1.696±1.28	1.472±1.28
19-May	0.256±1.81	1.44±1.81	5.218±1.81	0.512±1.81	1.936±1.81	1.088±1.81
19-Jun	5.952±3.35	1.472±3.35	0.096±3.35	9.184±3.35	2.176±3.35	2.816±3.35
19-Jul	10.11±5.02	0.512±5.02	1.44±5.02	5.856±5.02	12.384±5.02	1.472±5.02
19-Aug	0.608±1.49	2.272±1.49	1.92±1.49	2.4±1.49	5.12±1.49	1.92±1.49
19-Sep	1.44±0.79	0.254±0.79	0.96±0.79	2.656±0.79	1.12±0.79	1.472±0.79
19-Oct	0.59±1.27	0.49±1.27	0.48±1.27	1.897±1.27	2.45±1.27	3.521±1.27
19-Nov	2.46±0.99	2.56±0.99	3.54±0.99	4.52±0.99	4.89±0.99	3.75±0.99
19-Dec	3.21±0.63	1.96±0.63	2.34±0.63	3.62±0.63	3.21±0.63	2.56±0.63
20-Jan	4.16±1.11	2.23±1.11	2.34±1.11	3.52±1.11	4.52±1.11	1.89±1.11
20-Feb	2.46±0.80	1.2±0.80	1.3±0.80	3.21±0.80	2.75±0.80	2.03±0.80
20-Mar	1.02±1.12	0.024±1.12	1.2±1.12	3.1±1.12	2.6±1.12	1.3±1.12
20-Apr	0.987±2.59	1.2±2.59	0.456±2.59	6.53±2.59	4.23±2.59	5.43±2.59
20-May	2.13±1.20	1.53±1.20	1.2±1.20	4.6±1.20	2.253±1.20	2.13±1.20
20-Jun	1.13±1.45	4.67±1.45	2.3±1.45	4.53±1.45	3.65±1.45	4.52±1.45
20-Jul	1.1±2.50	4.53±2.50	1.02±2.50	4.126±2.50	2.25±2.50	7.53±2.50
20-Aug	1.523±0.50	1.532±0.50	2.236±0.50	2.45±0.50	1.23±0.50	2.21±0.50
Mean	3.301	2.06	2.44	4.25	3.56	2.96

Qualitative and quantitative analysis of phytoplankton

Phytoplankton diversity

In the present investigation a total of 144 phytoplankton samples were collected from two coastal river of Cox's Bazar, Bangladesh. All these samples were studied for qualitative and quantitative aspects.

Qualitative data

Composition

In the present investigation, 112 genera were represented in the phytoplankton from all the six stations and those belonged to the six divisions of algae namely. Cyanophyta, Chlorophyta, Euglenophyta, Bacillariophyta, Pyrrophyta and Cryptophyta (Table 16).

Genus level percentage composition shows that Bacillariophyta dominates in all the stations and occupied 10 (16.13%), 16 (25.8%), 14 (22.58%), 28 (45.16%), 24 (38.7%) and 18 (29.03%) for Station B1, B2, B3, R1, R2 and R3, respectively, followed by Chlorophyta 4 (6.5%), 5 (8.06%), 3 (4.8%), 14 (22.58%), 15 (24.2%) and 12 (19.35%) for Station B1, B2, B3, R1, R2 and R3, respectively, Euglenophyta 2 (3.2%), 1 (1.6%), 1 (1.6%), 4 (6.5%), 3 (4.8%) and 5 (8.06%) for Station B1, B2, B3, R1, R2 and R3, respectively, Cyanophyta 2 (3.2%), 1 (1.6%), 2 (3.2%), 3 (4.8%), 4 (6.5%), 3 (4.8%) for Station B1, B2, B3, R1, R2 and R3, respectively, Pyrrophyta 1 (1.6%), 2 ((3.2%), 1 (1.6%), 0, 1 (1.6%), 1 (1.6%) for Station B1, B2, B3, R1, R2 and R3, respectively; Cryptophyta 0, 0, 0, 1 (1.6%), 1 (1.6%), 1 (1.6%) for Station B1, B2, B3, R1, R2 and R3, respectively and Cryptophyta can be treated as a minor group for all the stations (Table 17).

At the species level, 402 species from different classes were recorded from all the stations. Maximum percentage of species (53.24%) in Station R3 found in the division Bacillariophyta but in total count maximum number (101) was recorded in station R2 and the minimum number of species (0 % in Station B1, B2, B3) was recorded from the division Cryptophyta and station R1 from the division Pyrrophyta. Bacillariophyta was dominant followed by Chlorophyta, Euglenophyta, Cyanophyta, Pyrrophyta and Cryptophyta (Table 18)

Table 17. The number of genera recorded from different divisions of phytoplankton (percentage values are given in the parenthesis).

Division	No of genera					
	B1	B2	B3	R1	R2	R3
Cyanophyta	2((3.2%)	1(1.6%)	2(3.2%)	3(4.8%)	4(6.5%)	3(4.8%)
Chlorophyta	4(6.5%)	5(8.06%)	3(4.8%)	14(22.58%)	15(24.2%)	12(19.35%)
Euglenophyta	2(3.2%)	1(1.6%)	1(1.6%)	4(6.5%)	3(4.8%)	5(8.06%)
Pyrrophyta	1(1.6%)	2((3.2%)	1(1.6%)	0	1(1.6%)	1(1.6%)
Cryptophyta	0	0	0	1(1.6%)	1(1.6%)	1(1.6%)
Bacillariophyta	10(16.13%)	16(25.8%)	14(22.58%)	28(45.16%)	24(38.7%)	18(29.03%)
Total	19	25	21	40	48	40

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

Division	No of species					
	B1	B2	B3	R1	R2	R3
Cyanophyta	3 (2.9%)	2 (1.9%)	3 (2.9%)	4 (3.9%)	6 (5.7%)	5 (4.8%)
Chlorophyta	9 (8.6%)	10 (9.5%)	5 (4.8%)	21 (20%)	26 (24.8%)	19 (18.1%)
Euglenophyta	5 (4.8%)	3 (2.9%)	2 (1.9%)	10 (9.5%)	12 (11.43%)	14 (13.3%)
Pyrrophyta	2 (1.9%)	2 (1.9%)	3 (2.9%)	0	2 (1.9%)	2 (1.9%)
Cryptophyta	0	0	0	2 (1.9%)	4 (3.9%)	3 (2.9%)
Bacillariophyta	21 (20%)	32 (30.48%)	33 (31.7%)	54 (51.53%)	51 (48.57%)	56 (53.24%)
Total	40	49	46	91	101	99

Dominant phytoplankton flora

Table 20 to Table 25 show the dominant phytoplankton genera and their individual density of studied six stations. In these stations, dominant genera of phytoplankton are described along with their density.

Station-B1

Table 20 shows the most dominant phytoplankton genera and their individual density of Station B1. In this station, *Euglena, Gyrosigma, Nitzschia, Cyclotella, Navicula, Trachaelomonas, Chaetoceros, Amphiprora, Melosira, Fragillaria, Peridinium, Cryptomonas, Pinnularia, Synedra, Surirella, Eunotia, Chlorella, Oscillatoria, Ulothrix, Scenedesmus, Pelonema, Centritactus,* were dominant. In this station, Ulothrix, *Melosira, Cyclotella, Chaetoceros, Navicula* was dominant genus for most of the months throughout the period of investigation.

Station-B2

Table 21 shows the dominant phytoplankton genera and their individual density of Station B2. In this station, *Cyclotella, Crucigenia, Coscinodiscus, Gyrosigma, Pinnularia, Synedra, Navicula, Achnanthes, Ulothrix, Closterium, Euglena, Rhodomonas, Oscillatoria, Nitzschia, Amphiprora, Eunotia, Melosira, Trachaelomonas, Scenedesmus, Chlamydomonas, Peridinium, Chaetoceros, Melosira, Rhizosolenia, Pithophora, Anabaena, Cosmarium, Monoraphidium,* were dominant in this station. In this station, *Synedra, Cyclotellla, Melosira, Euglena, Ulothrix,* and *Amphiprora* were dominant genera for most of the months throughout the period of investigation.

Station B3

Table 22 shows the dominant phytoplankton genera and their individual density of Station B3. In this station *Euglena, Coscinodiscus, Cyclotella, Synedra, Fragilaria, Ulothrix, Eunotia, Melosira, Navicula, Centritectus, Trachaelomonas, Cryptomonas, Oscillatoria, Scenedesmus, Croomonas, Phacus, Chaetoceros, Nitzschia, Pelonema, Cylindrocystis, Peridinium, Rhodomonas, Chlamydomonas, Lapocinclis, Schroederia, Cosmerium, Crusigenia, Plankospheria,* were dominant in this station. In this station, *Cyclotella, Ulothrix, Euglena, Trachaelomonas, Melosira, Nitzschia and Synedra* were the dominant genera for most of the months throughout the period of investigation.

Station-R1

Table 23 shows the dominant phytoplankton genera and their individual density of Station R1. In this station, *Chaetoceros, Navicula, Gyrosigma, Synedra, Pinnularia, Gomphonema, Surirella, Cyclotella, Monoraphidium, Closteriopsis, Amphiprora, Strombomonas, Navicula, Cosmarium, Trachaelomonas, Chlamydomonas, Oocystis, Euglena, Rhodomonas, Lepocinclis, Peridinium, Schroederia, Chroomonas, Phacus, Cryptomonas, Cymbella, Crusigenia, Fragilaria, Centritractus, Ceratium, Asterionella, Lepocinclis, Melosira, Ditylum,* were dominant in this station. In this station, *Cyclotella, Amphiprora, Trachaelomonas, Euglena, Rhodomonas, Chaetoceros, Nitzschia, Peridinium and Ulothrix* were dominant genera for most of the months throughout the period of investigation.

Station-R2

Table 24 shows the dominant phytoplankton genera and their individual density of Station R2. In this station, *Navicula, Rhodomonas, Cosmerium, Pinnularia, Oscillatoria, Symbella, Trachaelomonas, Closterium, Amphiprora, Scenedesmus, Closteriopsis, Euglena, Surirella, Cyclotella, Gyrosigma, Synedra, Peridinium, Tetredon, Peridinium, Scenedesmus, Monoraphidium, Croomonas, Lepoinclis, Cryptomonas, Nitzschia, Phacus, Cymbella, Chlamydononas, Asterionella, Ceracium, Melosira, Tretridon, Crucigenia, Ditylum* were dominant in this station throughout the investigation period. In this station, *Rhodomonas, Trachelomonas, Amphiprora, Peridinium, Asterionella* and *Euglena* were the most dominant genera for most of the months throughout the period of investigation.

Station R3

Table 25 shows the dominant phytoplankton genera and their individual density of Station R3. In this station *Trachelomonas, Navicula, Rhodomonas, Cosmerium, Pinnularia, Euglena, Cymbella, Cyclotella, Gyrosigma, Synedra, Scenedesmus, Oosystis, Oscillatoria, Ceratium, Amphiprora, Phacus, Cryptomonas, Coscinodiscus, Chroomonas, Closterium, Nitzschia, Asterionella, Schroederia, Peridinium, Micrasterias, Surirella, Fragilaria, Oscillatoria, Melosira, Tetraedon, Chlorella, Coscinodiscus and Chlamydomonas* were dominant in this station. In this station, *Cyclotella, Nitzschia, Chlorella, Peridinium, Euglena, Closterium, Rhodomonas, Asterionella, Oscillatoria and Ulothrix* were the most dominant genera for most of the months throughout the period of investigation.

Density of phytoplankton (PD)

During the study period (2018 – 2020), the ranges of density of phytoplankton (PD) were 0.5-2.5×10^6, 0.27-5.62×10^6, 0.28-1.8×10^6, 0.504-27.8×10^6, 0.39-12.46×10^6, and 1.04-18.71×10^6 ind./l for Station B1, B2, B3, R1, R2 and R3, respectively. The highest monthly mean PD (27.8×10^6 ind./l) was recorded in October, 2018 for Station R1 whereas the lowest mean PD (0.27×10^6 ind./l) was recorded in July, 2019 for Station B2. The trend of PD was unique and distinct in two years of investigation and related with PP.

In the present research, the seasonal variation of PD shows the highest value during pre-monsoon for Station B1, B2, and B3, during post-monsoon for Station R1, during winter for Station R2 and during monsoon for station R3. The lowest PD was recorded during post-monsoon for B1, during winter for B2 and B3. While the R1, R2, and R3 yielded the lowest during pre-monsoon in the first year of investigation. And in the second year it was highest during post-monsoon for Station B1 and B3 and during pre-monsoon for B2 station and during monsoon for R1, R2, and R3. But the lowest PD was recorded during monsoon for B1, B2, and B3 and during pre-monsoon for R1, R2, and R3. Over the seasons, the mean values of PD did not follow any distinct pattern. PD was comparatively higher in Reju canal (R1, R2, R3) than the Bakkhali River (B1, B2, B3) station (Fig. 40).

Fig. 41 shows the annual range of PD for the two consecutive years of study, the PD of all the stations fluctuated, but with two to three clear developmental peaks. Number of phytoplankton varied among stations and different months of the year. The highest value was found in the month of October in R1 and the lowest was recorded in July in B2 for the 1st and for 2nd year but it showed a peak growth in June in R3 station. PD however lowered in July for B2 station (Fig. 41).

Mean value of PD (5.95×10^6 ind./l) was the highest in Station R1 whereas the lowest mean value of PD (1.09×10^6 ind./l) was recorded in Station B3 (Table 19).

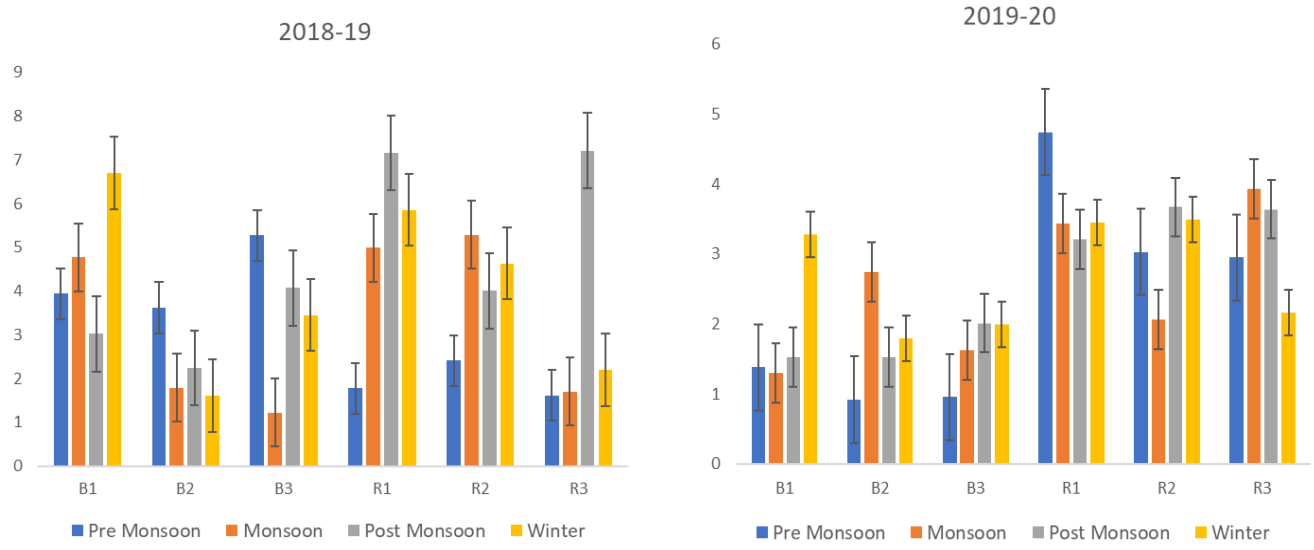


Fig. 40. Seasonal dynamics of phytoplankton density (×10^6 ind./l).

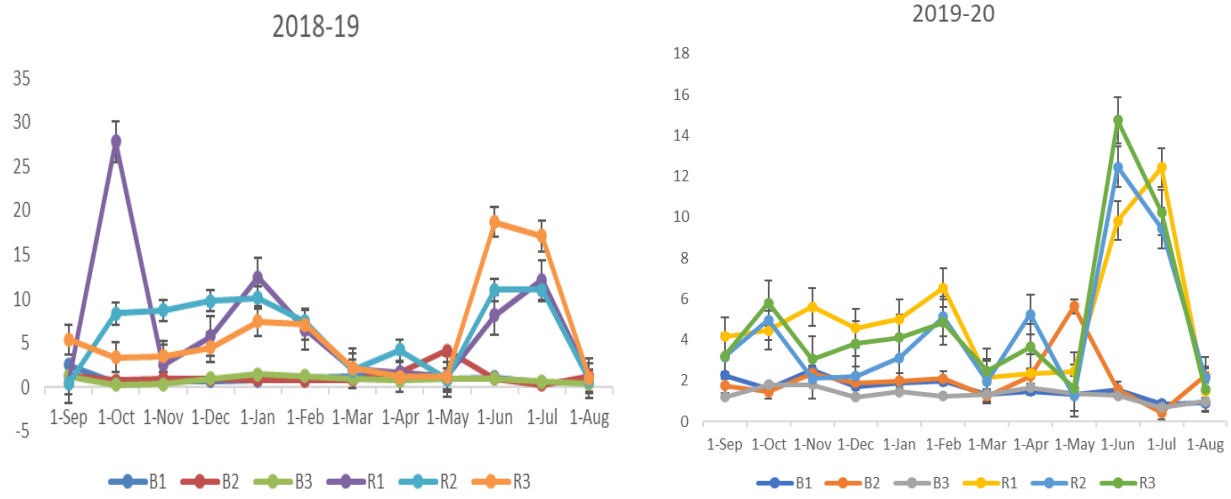


Fig. 41. Comparison of monthly values of phytoplankton density from two study years.

Table 19. Monthly mean values (±SD) of phytoplankton density (×10^6 ind./l).

Months	B1	B2	B3	R1	R2	R3
18-Sep	2.5±1.88	1.33±1.88	1.23±1.88	0.504±1.88	0.39±1.88	5.4±1.88
18-Oct	0.59±10.70	0.78±10.70	0.28±10.70	27.8±10.70	8.36±10.70	3.39±10.70
18-Nov	0.72±3.14	0.96±3.14	0.32±3.14	2.5±3.14	8.7±3.14	3.5±3.14
18-Dec	0.71±3.64	0.88±3.64	0.97±3.64	5.74±3.64	9.8±3.64	4.5±3.64
19-Jan	0.77±5.17	0.84±5.17	1.48±5.17	12.44±5.17	10.12±5.17	7.48±5.17
19-Feb	1.1±3.30	0.78±3.30	1.23±3.30	6.54±3.30	7.45±3.30	7.12±3.30
19-Mar	1.19±0.60	0.81±0.60	1±0.60	2.12±0.60	1.89±0.60	2.15±0.60
19-Apr	1.23±1.23	1.65±1.23	0.78±1.23	1.7±1.23	4.19±1.23	1.16±1.23
19-May	0.88±1.28	4.14±1.28	0.92±1.28	1.23±1.28	0.92±1.28	1.19±1.28
19-Jun	1.09±7.24	0.96±7.24	0.96±7.24	8.16±7.24	11.01±7.24	18.71±7.24
19-Jul	0.58±7.37	0.27±7.37	0.66±7.37	12.14±7.37	11.01±7.37	17.13±7.37
19-Aug	0.5±0.33	1.24±0.33	0.42±0.33	1.05±0.33	0.77±0.33	1.04±0.33
19-Sep	2.25±1.08	1.75±1.08	1.2±1.08	4.15±1.08	3.15±1.08	3.2±1.08
19-Oct	1.6±1.94	1.45±1.94	1.8±1.94	4.45±1.94	4.95±1.94	5.8±1.94
19-Nov	2.5±1.39	2.35±1.39	1.8±1.39	5.6±1.39	2.1±1.39	3.05±1.39
19-Dec	1.71±1.32	1.89±1.32	1.2±1.32	4.56±1.32	2.2±1.32	3.8±1.32
20-Jan	1.89±1.41	1.98±1.41	1.45±1.41	5.01±1.41	3.1±1.41	4.1±1.41
20-Feb	1.95±2.15	2.1±2.15	1.23±2.15	6.54±2.15	5.12±2.15	4.85±2.15
20-Mar	1.34±0.51	1.23±0.51	1.34±0.51	2.13±0.51	1.96±0.51	2.46±0.51
20-Apr	1.46±1.43	2.21±1.43	1.65±1.43	2.34±1.43	5.23±1.43	3.64±1.43
20-May	1.32±1.70	5.62±1.70	1.35±1.70	2.43±1.70	1.23±1.70	1.64±1.70
20-Jun	1.53±6.16	1.57±6.16	1.25±6.16	9.82±6.16	12.46±6.16	14.73±6.16
20-Jul	0.87±5.59	0.43±5.59	0.68±5.59	12.43±5.59	9.45±5.59	10.23±5.59
20-Aug	0.89±0.56	2.24±0.56	0.99±0.56	1.46±0.56	2.15±0.56	1.57±0.56
Mean	1.299	1.645	1.091	5.952	5.321	5.493

Density of dominant genera of phytoplankton

Table 20. Monthly density of dominant genus of phytoplankton (×10^6 ind./l) in Station B1.

Month	Dominant 1	Dominant 2	Dominant 3	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
18-Sep	*Nitzschia*	*Navicula*	*Gyrosigma*	1.35	1.15	2.5
18-Oct	*Peridinium*	*Euglena*	*Melosira*	0.41	0.18	0.59
18-Nov	*Peridinium*	*Euglena*	*Oscillatoria*	0.50	0.22	0.72
18-Dec	*Ulothrix*	*Synedra*	*Scenedesmus*	0.50	0.21	0.71
19-Jan	*Peridinium*	*Cyclotella*	*Synedra*	0.51	0.26	0.77
19-Feb	*Cyclotella*	*Ulothrix*	*Synedra*	0.7	0.4	1.1
19-Mar	*Oscillatoria*	*Euglena*	*Pelonema*	0.91	0.28	1.19
19-Apr	*Nitzschia*	*Euglena*	*Pelonema*	0.75	0.48	1.23
19-May	*Oscillatoria*	*Trachaelomonas*	*Nitzschia*	0.35	0.53	0.88
19-Jun	*Euglena*	*Synedra*	*Navicula*	0.62	0.47	1.09
19-Jul	*Ulothrix*	*Oschillatoria*	*Navicula*	0.45	0.13	0.58
19-Aug	*Ulothrix*	*Naviculla*	*Synedra*	0.32	0.18	0.5
19-Sep	*Trachaelomonas*	*Euglena*	*Eunotia*	1.15	1.1	2.25
19-Oct	*Chlorella*	*Amphiprora*	*Cyclotella*	0.7	0.9	1.6
19-Nov	*Melosira*	*Gyrosigma*	*Peridinium*	1.8	0.7	2.5
19-Dec	*Ulothrix*	*Eunotia*	*Pinnularia*	0.85	0.86	1.71
20-Jan	*Chaetoceros*	*Melosira*	*Cyclotella*	1.12	0.75	1.89
20-Feb	*Ulothrix*	*Cyclotella*	*Coscinodiscus*	1.15	0.80	1.95
20-Mar	*Euglena*	*Oscillatoria*	*Trachelomonas*	0.75	0.59	1.34
20-Apr	*Chlamydomonas*	*Peridinium*	*Nitzschia*	0.86	0.60	1.46
20-May	*Oscillatoria*	*Cryptomonas*	*Trachaelomonas*	0.74	0.58	1.32
20-Jun	*Euglena*	*Scenedesmus*	*Navicula*	0.86	0.67	1.53
20-Jul	*Nitzschia*	*Cyclotella*	*Ulothrix*	0.45	0.42	0.87
20-Aug	*Gyrosigma*	*Peridinium*	*Navicula*	0.56	0.33	0.89

Table 21. Monthly density of dominant genus of phytoplankton (×10^6 ind./l) in Station B2.

Month	Dominant 1	Dominant 2	Dominant 3	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
18-Sep	*Cyclotella*	*Synedra*	*Navicula*	0.98	0.35	1.33
18-Oct	*Oscillatoria*	*Euglena*	*Nitzschia*	0.46	0.32	0.78
18-Nov	*Oscillatoria*	*Euglena*	*Nitzschia*	0.72	0.24	0.96
18-Dec	*Trachaelomonas*	*Ulothrix*	*Navicula*	0.45	0.43	0.88
19-Jan	*Chlamydomonas*	*Peridinium*	*Rhodomonas*	0.62	0.22	0.84
19-Feb	*Rhizosolenia*	*Cyclotella*	*Chaetoceros*	0.46	0.32	0.78
19-Mar	*Oscillatoria*	*Euglena*	*Pelonema*	0.51	0.3	0.81
19-Apr	*Pithophora*	*Anabaena*	*Cosmarium*	1.21	0.44	1.65
19-May	*Amphiprora*	*Synedra*	*Cyclotella*	2.46	1.68	4.14
19-Jun	*Oscillatoria*	*Synedra*	*Monoraphidium*	0.51	0.45	0.96
19-Jul	*Ulothrix*	*Synedra*	*Cyclotella*	0.15	0.12	0.27
19-Aug	*Ulothrix*	*Navicula*	*Nitzschia*	0.97	0.27	1.24
19-Sep	*Euglena*	*Rhodomonas*	*Cyclotella*	1.46	0.29	1.75
19-Oct	*Cyclotella*	*Amphiprora*	*Eunotia*	1.23	0.22	1.45
19-Nov	*Cyclotella*	*Melosira*	*Oscillatoria*	1.98	0.37	2.35
19-Dec	*Trachaelomonas*	*Scenedesmus*	*Ulothrix*	1.05	0.84	1.89
20-Jan	*Chaetoceros*	*Melosira*	*Gyrosigma*	1.23	0.75	1.98
20-Feb	*Cyclotella*	*Coscinodiscus*	*Chlorella*	1.8	0.30	2.1
20-Mar	*Euglena*	*Cyclotella*	*Synedra*	0.81	0.42	1.23
20-Apr	*Gyrosigma*	*Euglena*	*Synedra*	1.23	0.98	2.21
20-May	*Cyclotella*	*Gyrosigma*	*Euglena*	3.46	2.16	5.62
20-Jun	*Synedra*	*Euglena*	*Oscillatoria*	0.86	0.71	1.57
20-Jul	*Cyclotella*	*Ulothrix*	*Nitzschia*	0.21	0.22	0.43
20-Aug	*Ulothrix*	*Navicula*	*Cyclotella*	1.76	0.48	2.24

Table 22. Monthly density of dominant genera of phytoplankton (×10^6 ind./l) in Station B3.

Month	Dominant 1	Dominant 2	Dominant 3	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
18-Sep	*Cyclotella*	*Coscinodiscua*	*Ulothrix*	0.72	0.51	1.23
18-Oct	*Trachaelomonas*	*Euglena*	*Synedra*	0.13	0.15	0.28
18-Nov	*Peridinium*	*Trachaelomonas*	*Euglena*	0.18	0.14	0.32
18-Dec	*Trachaelomonas*	*Euglena*	*Peridinium*	0.54	0.43	0.97
19-Jan	*Peridinium*	*Synedra*	*Phacus*	1.06	0.42	1.48
19-Feb	*Croomonas*	*Chlamydomonas*	*Melosira*	0.87	0.36	1.23
19-Mar	*Pelonema*	*Carteria*	*Euglena*	0.64	0.36	1.0
19-Apr	*Trachaelomonas*	*Chaetoceros*	*Closterium*	0.12	0.66	0.78
19-May	*Synedra*	*Navicula*	*Gyrosigma*	0.28	0.64	0.92
19-Jun	*Pelonema*	*Euglena*	*Oscillatoria*	0.33	0.63	0.96
19-Jul	*Melosira*	*Cyclotella*	*Strombomonas*	0.20	0.46	0.66
19-Aug	*Trachaelomonas*	*Chlorella*	*Melosira*	0.13	0.29	0.42
19-Sep	*Cyclotella*	*Oscillatoria*	*Euglena*	0.85	0.35	1.2
19-Oct	*Cyclotella*	*Trachaelomonas*	*Cryptomonas*	1.03	0.77	1.8
19-Nov	*Cyclotella*	*Melosira*	*Oscillatoria*	0.97	0.83	1.8
19-Dec	*Scenedesmus*	*Ulothrix*	*Eunotia*	0.77	0.43	1.2
20-Jan	*Chaetoceros*	*Melosira*	*Scenedesmus*	0.86	0.59	1.45
20-Feb	*Cyclotella*	*Ulothrix*	*Nitzschia*	0.84	0.39	1.23
20-Mar	*Pelonema*	*Euglena*	*Oscillatoria*	0.96	0.38	1.34
20-Apr	*Trachaelomonas*	*Cyclotella*	*Euglena*	1.46	0.19	1.65
20-May	*Gyrosigma*	*Synedra*	*Nitzschia*	0.89	0.46	1.35
20-Jun	*Synedra*	*Oscillatoria*	*Euglena*	0.76	0.49	1.25
20-Jul	*Ulothrix*	*Cyclotella*	*Nitzschia*	0.46	0.22	0.68
20-Aug	*Ulothrix*	*Navicula*	*Cyclotella*	0.52	0.47	0.99

Table 23. Monthly density of dominant genera of phytoplankton (×10^6 ind./l) in Station R1.

Month	Dominant 1	Dominant 2	Dominant 3	Total dominant × 10⁶ ind./l	Other ×10⁶ ind./l	Total PD ×10⁶ ind./l
18-Sep	*Pinnularia*	*Gyrosigma*	*Synedra*	0.41	0.094	0.504
18-Oct	*Cyclotella*	*Amphiprora*	*Trachaelomonas*	19.1	8.7	27.8
18-Nov	*Cyclotella*	*Amphiprora*	*Trachaelomonas*	1.8	0.7	2.5
18-Dec	*Amphiprora*	*Cyclotella*	*Coscinodiscus*	3.84	1.9	5.74
19-Jan	*Euglena*	*Rhodomonas*	*Peridinium*	9.21	3.23	12.44
19-Feb	*Chaetoceros*	*Rhizosolenia*	*Nitzschia*	4.86	1.68	6.54
19-Mar	*Scenedesmus*	*Rhodomonas*	*Cryptomonas*	1.20	0.92	2.12
19-Apr	*Peridinium*	*Synedra*	*Fragillaria*	0.98	0.72	1.7
19-May	*Ulothrix*	*Cyclotella*	*Scenedesmus*	0.76	0.47	1.23
19-Jun	*Cyclotella*	*Nitzschia*	*Peridinium*	6.68	1.48	8.16
19-Jul	*Ulothrix*	*Chaetoceros*	*Ditylum*	9.16	2.98	12.14
19-Aug	*Euglena*	*Navicula*	*Amphiprora*	0.67	0.38	1.05
19-Sep	*Cyclotella*	*Ditylum*	*Chlamydomonas*	2.6	1.55	4.15
19-Oct	*Cyclotella*	*Peridinium*	*Chlamydomonas*	2.7	1.75	4.45
19-Nov	*Cyclotella*	*Trachaelomonas*	*Amphiprora*	3.1	2.5	5.6
19-Dec	*Cyclotella*	*Coscinodiscus*	*Amphiprora*	2.4	2.16	4.56
20-Jan	*Melosira*	*Surirella*	*Ulothrix*	3.6	1.41	5.01
20-Feb	*Ulothrix*	*Surirella*	*Cyclotella*	3.89	2.65	6.54
20-Mar	*Rhodomonas*	*Ditylum*	*Trachaelomonas*	1.13	1.0	2.13
20-Apr	*Peridinium*	*Asterionella*	*Synedra*	1.24	1.1	2.34
20-May	*Ulothrix*	*Synedra*	*Melosira*	1.20	1.23	2.43
20-Jun	*Peridinium*	*Ulothrix*	*Nitzschia*	7.41	2.41	9.82
20-Jul	*Gyrosigma*	*Nitzschia*	*Chaetoceros*	9.72	2.71	12.43
20-Aug	*Amphiprora*	*Chaetoceros*	*surirella*	0.67	0.79	1.46

Table 24. Monthly density of dominant genera of phytoplankton (×10^6 ind./l) in Station R2.

Month	Dominant 1	Dominant 2	Dominant 3	Total dominant × 10^6 ind./l	Other ×10^6 ind./l	Total PD ×10^6 ind./l
18-Sep	*Oscillatoria*	*Pinnularia*	*Navicula*	0.21	0.18	0.39
18-Oct	*Nefrocytium*	*Amphiprora*	*Euglena*	7.98	0.38	8.36
18-Nov	*Nefrocytium*	*Euglena*	*Amphiprora*	7.82	0.88	8.7
18-Dec	*Trachelomonas*	*Cyclotella*	*Amphiprora*	8.21	1.59	9.8
19-Jan	*Euglena*	*Rhodomonas*	*Croomonas*	8.76	1.36	10.12
19-Feb	*Chaetoceros*	*Asterionella*	*Rhizosolenia*	6.84	0.61	7.45
19-Mar	*Rhodomonas*	*Cryptomonas*	*Scenedesmus*	1.21	0.68	1.89
19-Apr	*Micrasterias*	*Peridinium*	*Asterionella*	3.87	0.32	4.19
19-May	*Oscillatoria*	*Cyclotella*	*Synedra*	0.43	0.49	0.92
19-Jun	*Cyclotella*	*Nitzschia*	*Peridinkium*	9.81	1.2	11.01
19-Jul	*Ulothrix*	*Nitzschia*	*Ditylum*	10.1	0.91	11.01
19-Aug	*Euglena*	*Rhodomonas*	*Amphiprora*	0.67	0.10	0.77
19-Sep	*Cyclotella*	*Nitzschia*	*Chlorella*	2.2	0.95	3.15
19-Oct	*Cyclotella*	*Synedra*	*Trachelomonas*	3.41	1.54	4.95
19-Nov	*Rhodomonas*	*Cryptomonas*	*Trachelomonas*	1.4	0.7	2.1
19-Dec	*Cyclotella*	*Trachaelomonas*	*Navicula*	1.5	0.7	2.2
20-Jan	*Melosira*	*Gyrosigma*	*Cyclotella*	1.7	1.4	3.1
20-Feb	*Gyrisigma*	*Rhodomonas*	*Euglena*	3.12	2.0	5.12
20-Mar	*Trachelomonas*	*Phacotus*	*Rhodomonas*	1.21	0.75	1.96
20-Apr	*Trachelomonas*	*Cryptomonas*	*Phacus*	3.78	1.45	5.23
20-May	*Trachelomonas*	*Euglena*	*Oscillatoria*	0.98	0.25	1.23
20-Jun	*Cyclotella*	*Peridinium*	*Trachaelomonas*	10.87	1.59	12.46
20-Jul	*Rhodomonas*	*Euglena*	*Melosira*	7.86	1.59	9.453
20-Aug	*Navicula*	*Amphiprora*	*Euglena*	1.46	0.69	2.15

Table 25. Monthly density of dominant genera of phytoplankton (×10^6 ind./l) in Station R3.

Month	Dominant 1	Dominant 2	Dominant 3	Total dominant × 10⁶ ind./l	Other ×10⁶ ind./l	Total PD ×10⁶ ind./l
18-Sep	*Navicula*	*Oosystis*	*Gyrosigma*	4.12	1.28	5.4
18-Oct	*Nefrocytium*	*Euglena*	*Amphiprora*	1.86	1.53	3.39
18-Nov	*Nefrocytium*	*Amphiprora*	*Euglena*	1.98	1.52	3.5
18-Dec	*Amphiprora*	*Scenedesmus*	*Synedra*	2.8	1.7	4.5
19-Jan	*Euglena*	*Rhodomonas*	*Peridinium*	6.21	1.27	7.48
19-Feb	*Chaetoceros*	*Asterionella*	*Rhizosolenia*	5.98	1.14	7.12
19-Mar	*Nitzschia*	*Rhodomonas*	*Cryptomonas*	1.74	0.41	2.15
19-Apr	*Micrasterias*	*Asterionella*	*Fragillaria*	0.84	0.32	1.16
19-May	*Oscillatoria*	*Cyclotella*	*Synedra*	0.85	0.34	1.19
19-Jun	*Cyclotella*	*Nitzschia*	*Peridinium*	16.89	1.82	18.71
19-Jul	*Ulothrix*	*Nitzschia*	*Asterionella*	16.52	0.61	17.13
19-Aug	*Oscillatoria*	*Euglena*	*Ulothrix*	0.6	0.44	1.04
19-Sep	*Cyclotella*	*Nitzschia*	*Chlorella*	1.8	1.4	3.2
19-Oct	*Cyclotella*	*Peridinium*	*Trachaelomonas*	3.9	1.9	5.8
19-Nov	*Cyclotella*	*Melosira*	*Nitzschia*	1.78	1.27	3.05
19-Dec	*Cyclotella*	*Amphiprora*	*Scenedesmus*	2.1	1.7	3.8
20-Jan	*Navicula*	*Scenedesmus*	*Cyclotella*	3.7	0.4	4.1
20-Feb	*Chaetoceros*	*Rhizosolenia*	*Ceratium*	3.98	0.87	4.85
20-Mar	*Rhodomonas*	*Trachelomonas*	*Cryptomonas*	1.98	0.48	2.46
20-Apr	*Asterionella*	*Trachelomonas*	*Rhodomonas*	2.89	0.75	3.64
20-May	*Trachelomonas*	*Cyclotella*	*Oscillatoria*	1.1	0.54	1.64
20-Jun	*Cyclotella*	*Oscillatoria*	*Peridinium*	13.98	0.75	14.73
20-Jul	*Chaetoceros*	*Euglena*	*Rhizosolenia*	8.89	1.34	10.23
20-Aug	*Ulothrix*	*Euglena*	*Chaetoceros*	1.1	0.47	1.57

Seasonal variation of dominant phytoplankton at genus level

Station B1

In this station, dominant phytoplankton were *Euglena*, *Trachaelomonas,* belonging to Euglenophyta; *Gyrosigma, Nitzschia, Cyclotella, Navicula, Chaetoceros, Amphiprora, Melosira, Fragillaria Pinnularia, Synedra, Eunotia, Centritactus,* belonging to Bacillariophyta; *Peridinium, Ceratium* belonging to Pyrrophyta; *Cryptomonas* belonging to Cryptophyta; *Surirella, Chlorella, Oscillatoria, Ulothrix, Scenedesmus,* belonging to Chlorophyta; *Pelonema* belonging to Cyanophyta; were observed.

During pre-monsoon, the genera *Oscillatoria,* and *Euglena* were dominant followed by *Pelonema, Synedra, Nitzschia, Trachaelomonas,* and *Gyrosigma* in the first year but in second year *Ulothrix* was dominant followed by *Eunotia, Pinnularia, Fragillaria, Melosira, Surirella* and *Amphiprora*.

During monsoon, the genus *Euglena* was dominant followed by *Chaetoceros, Amphora, Gyrosigma, Navicula, Nitzschia* and *Pinnularia* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Cyclotella, Euglena,* and *Eunotia*.

During post-monsoon the genus *Euglena* was dominant followed by *Peridinium, Melosira, Nitzschia, Gyrosigma, Navicula* and *Amphora* in first year but in second year, the genus *Cyclotella* was most dominant followed by *Amphiprora, Chlorella, Centritectus, Melosira* and *Eunotia*.

Winter was dominated by the genus *Melosira* and *Cyclotella* followed by *Chlorella, Amphiprora, Centritectus, Gyrosigma, Coscinodiscus* and *Peridinium* in the first year where as in second year, *Synedra* was dominant followed by *Oscillatoria, Peridinium,* and *Euglena* (Table 26).

In theis station, the dominant Phytoplankton species with their density are shown in Table 32.

Station B2

In this station, dominant phytoplankton were *Euglena, Trachaelomonas,* belonging to Euglenophyceae; *Gyrosigma, Nitzschia, Cyclotella, Navicula, Chaetoceros, Amphiprora, Melosira, Fragillaria Pinnularia, Synedra, Eunotia, Centritactus, Coscinodiscus, Synedra, Achnanthes, Rhodomonas, Amphiprora, Melosira, Rhizosolenia, Scenedesmus* belonging to Bacillariophyta; *Peridinium, Ceratium* belonging to Pyrrophyta; *Cryptomonas* belonging to Cryptophyta; *Surirella, Chlorella, Oscillatoria, Ulothrix, Scenedesmus, Closterium, Crusigenia, Cosmarium, Monoraphidium, Chlamydomonas* belonging to Chlorophyta; *Pelonema, Oscillatoria, Pithophora, Anabaena,* belonging to Cyanophyta; were observed.

During pre-monsoon, the genus *Euglena* was dominant followed by *Oscillatoria, Anabaena, Cyclotella, Pelonema, Synedra, Nitzschia, Trachaelomonas* and *Nitzschia* in the first year but in second year *Trachaelomonas* was dominant followed by *Ulothrix, Scenedesmus, Eunotia, Chaetoceros, Fragillaria, Melosira, Surirella* and *Synedra*.

During monsoon, the genus *Oscillatoria* was dominant followed by *Synedra, Nitzschia, Amphiprora, Cyclotella* and *Monoraphidium* in the first year but in second year, the genus *Trachelomonas* was dominant followed by *Chaetoceros, Amphora, Gyrosigma, Navicula, Nitzschia, Pinnularia, Cyclotella, Euglena*, and *Eunotia.*

During post-monsoon the genus *Oscillatoria* was dominant followed by *Euglena, Trachaelomonas, Peridinium, Melosira, Nitzschia, Gyrosigma, Navicula, Pinnularia* and *Cymbella* in first year but in second year, the genus *Euglena* was most dominant followed by *Amphiprora, Rhodomonas, Peridinium, Chlorella, Centritectus, Melosira, Eunotia, Cyclotella, Merismopedia* and *Oscillatoria*.

Winter was dominated by the genus *Chlamydomonas* followed by *Scenedesmus, Rhodomonas, Cryptomonas,* and *Peridinium* in the first year where as in second year, *Cyclotella* was dominant followed by *Amphiprora, Merismopedia, Eunotia, Oscillatoria, Peridinium,* and *Nitzschia* (Table 27).

In theis station, the dominant Phytoplankton species with their density are shown in Table 33.

Station-B3

In this Station, dominant phytoplankton were *Oscillatoria, Pelonema* belonging to Cyanophyta*; Cyclotella, Coscinodiscus, Ulothrix* and *Chlorella* belonging to Chlorophyta; *Euglena, Trachelomonas, Pelonema* and *Phacus* belonging to Euglenophyta; *Synedra, Cyclotella, Gyrosigma, Nitzschia, Amphiprora, Navicula, Mellosira, Scenedesmus, Chaetoceros, Padiastrum, Ditonula, Melosira* and *Coscinodiscus* belonging to Bacillariophyta; *Peridinium* belonging to Pyrrophyta; *Rhodomonas, Chroomonas,* and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Euglena* was dominant followed by *Synedra, Gyrosigma, Scenedesmus, Pelonama, Nitzschia* and *Trachaelomonas* in the first year but in second year, the genus *Scenedesmus* was dominant followed by *Ditonula, Rhodomonas, Cryptomonas, Melosira* and *Coscinodiscus*.

During monsoon the genus *Synedra* was dominant followed by *Euglena, Oscillaria, Scenedesmus, Peridinium, Nitzschia* and *Cyclotella* in the first year but in second year, the genus *Scenedesmus* was dominant followed by *Rhodomonas, Coscinodiscus, Euglena, Synedra* and *Melosira*.

In Post-monsoon, the genus *Trachaelomonas* was dominant followed by *Synedra, Euglena, Cylindrocystis* and *Navicula* in the first year but in second year, the genus *Euglena* was dominant followed by *Cyclotella, Oscillatoria, Scenedesmus, Peridinium, Amphiprora, Navicula* and *Cryptomonas*.

During winter the genus *Euglena* was dominant followed by *Trachaelomonas Microcystis, Oscillatoria, Croomonas, Phacus, Peridinium* and *Synedra* in the first year but in second year, the genus *Cyclotella* was dominant followed by *Cruptomonas, Amphiprora, Oscillatoria, Navicula, Melosira, Chlorella*, and *Pediastrum* (Table 28).

In theis station, the dominant Phytoplankton species with their density are shown in Table 34.

Station-R1

In this Station, dominant phytoplankton were *Surirella, Ulothrix, Chlamydomonas, Cryptomonas, Monoraphidium,* and *Scenedesmus* belonging to Chlorophyta; *Euglena and Trachelomonas,* belonging to Euglenophyta; *Chaetoceros, Pinnularia, Gyrosigma, Cyclotella, Amphiprora, Muniera, Hamiaulus, Synedra, Nitzschia, Coscinodiscus, Melosira, Gyrosigma, Surirella, Ditylum, Navicula* belonging to Bacillariophyta; *Oocystis* belonging to Chlorophyta; *Peridinium* belonging to Pyrrhophyta and *Rhodomonas, Fragillaria,* and *Cryptomonas* belonging to Cryptophyta were observed.

In pre-monsoon, the genus *Muniera* was dominant followed by *Rhodomonas, Scenedesmus, Hamiaulius, Chaetocros, Nitzschia* and *Cryptomonas* in the first year but in second year, the genus *Cyclortella* and *Chaetoceros* were dominant followed by *Melosira, Scenedesmus, Peridinium, Rhodomonas, Surirella, Ulothrix, Amphiprora, Coscinodiscus* and *Fragillaria*.

During monsoon the genus *Chaetoceros* was dominant followed by *Cyclotella, Ulothrix, Gyrosigma, Nitzschia, Peridinium,* and *Scenedesmus* in the first year but in second year, the genus *Ulothrix* was dominant followed by *Chaetoceros, Scenedesmus, Ditylum, Rhodomonas, Navicula, Oscillatoria, Amphiprora, Melosira, Surirella* and *Euglena*.

In post-monsoon, the genus *Amphiprora* was dominant followed by *Trachaelomonas, Cyclotella, Scenedesmus, Surirella Pinnularia, and Gyrosigma* in the first year but in second year, *Cyclotella* and *Oocystis* were dominant followed by *Chlamydomonas, Nitzschia, Coscinodiscus, Peridinium, Cryptomonas, Monoraphidium and Trachelomonas*.

During winter, the genus *Amphiprora, Euglena* were dominant followed by *Trachaelomonas, Cyclotella, Scenedesmus, Rhodomonas* and *Peridinium* in the first year but in second year, the genus *Cyclotella* and *Peridinium* were dominant followed by *Chlamydomonas, Cryptomonas, Monoraphidium, Melosira,* and *Gyrosigma* (Table 29).

In theis station, the dominant Phytoplankton species with their density are shown in Table 35.

Station-R2

In this Station, dominant phytoplankton were *Oocystis* of Chlorophyta and *Oscillatoria* of Cyanophyta; *Scenedesmus, Surirella, Ulothrix, Chlamydomonas, Cryptomonas, Monoraphidium* and *Cosmarium* belonging to Chlorophyta; *Euglena, Trachelomonas* and *Lepocinclis* belonging to Euglenophyta; *Peridinium* belonging to Pyrrhophyta; *Rhodomonas*, and *Cryptomonas* belonging to Cryptophyta and *Pinnularia, Gyrosigma, Cyclotella, Amphiprora, Chaetoceros, Muniera, Hamiaulus, Synedra, Nitzschia, Coscinodiscus, Melosira, Navicula, Asterionella* and *Fragillaria* belonging to Bacillariophyta were observed.

In pre-monsoon, the genus *Peridinium* was dominant followed by *Euglena, Rhodomonas, Scenedesmus, Asterionella, Synedra, Cosmarium, Cyclotella, Oscillatoria* and *Cryoptomonas* in the first year but in second year, the genus *Cyclotella* was dominant followed by *Trachaelomonas, Navicula, Amphiprora,* and *Centritactus*.

During monsoon the genus *Cyclotella* and *Nitzschia* were dominant followed by *Synedra, Oscillatoria, Trachaelomonas, Amphiprora, Rhodomonas,* and *Peridinium* in the first year but in second year, the genus *Ulothrix* was dominant followed by *Navicula, Euglena, Amphiprora, Ditylum, Nitzschia* and *Bidulphia*.

In post-monsoon, the genus *Amphiprora* and *Cyclotella* were dominant followed by *Oscillatoria, Navicula, Cryptomonas, Euglena, Closterium and Ulothrix* in the first year but in second year, the genus *Cyclotella* was dominant followed by *Trachaelomonas, Synedra, Nitzschia, Amphiprora, Peridinium, Oocystis, Chlamydomonas* and *Navicula*.

During winter *Euglena* was dominant followed by *Rhodomonas, Amphiprora, Cyclotella, Lepocinclis, Cryptomonas,* and *Rhodomonas* in the first year but in second year, the genus *Cyclotella* was dominant followed by *Nitzschia, Melosira, Chlamydomonas, Synedra, Peridinium* and *Trachaelomonas* (Table 30).

In theis station, the dominant Phytoplankton species with their density are shown in Table 36.

Station-R3

In this Station, dominant phytoplankton were *Pinnularia, Gyrosigma, Cyclotella, Amphiprora, Chaetoceros, Muniera, Hamiaulus, Synedra, Nitzschia, Coscinodiscus, Melosira, Gyrosigma, Surirella, Ditylum* and *Navicula* belonging to Bacillariophyta; *Surirella, Ulothrix, Chlamydomonas, Cryptomonas, Oocystis* and *Monoraphidium* belonging to Chlorophyta; *Euglena* and *Trachelomonas,* belonging to Euglenophyta; *Rhodomonas, Cryptomonas* and *Fragillaria* belonging to Cryptophyta; *Peridinium* and *Ceratium* belonging to Pyrrhophyta and were observed.

In pre-monsoon, the genus *Rhodomonas* was dominant followed by *Trachaelomonas, Euglena, Cryptomonas, Cosmarium, Asterionella, Fragillaria, Oscillatoria, Cyclotella, Synedra* and *Rhodomonas* in the first year but in second year, the genus *Chaetoceros* was do77minant followed by *Amphiprora, Peridinium, Navicula, Ulothrix, Scenedesmus, Cyclotella, Synedra* and *Rhodomonas*.

During monsoon the genus *Cyclotella* was dominant followed by *Nitzschia, Euglena, Coscinodiscus, Oscillatoria, Synedra, Chlamydomonas, Chlorella, Chlorococcus* and *Peridinium* in the first year but in second year, the genus *Ulothrix* was dominant followed by *Euglena, Nitzschia, Oscillatoria, Asterionella* and *Navicula*.

In post-monsoon, the genus *Ceratium* was dominant followed by *Euglena, Gyrosigma, Synedra, Pinnularia* and *Navicula* in the first year but in second year, *Trachelomonas, Cyclotella* were dominant followed by *Peridinium, Synedra, Navicula, Chlamydomonas, Chlorella, Chlorococcus* and *Microcystis.*

During winter, *Euglena* was dominant followed by *Trachelomonas, Amphiprora, Ceratium, Peridinium* and *Oscillatoria* in first year but in second year, the genus *Trachaelomonas* was dominant followed by *Cyclotella, Peridinium, Synedra, Navicula, Microcystis, Melosira, Monoraphidium, Nitzschia* and *Gyrosigma* (Table 31).

In theis station, the dominant Phytoplankton species with their density are shown in Table 37.

Table 26. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station B1.

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			
2018-2019	Pre-monsoon	*Oscillatoria*	*Euglena*	*Pelonema*	*Synedra*	0.75	0.35	1.1
	Monsoon	*Euglena*	*Chaetoceros*	*Amphora*	*Gyrosigma*	0.85	0.32	1.17
	Post-monsoon	*Euglena*	*Peridinium*	*Melosira*	*Nitzschia*	0.37	0.29	0.66
	Winter	*Melosira*	*Cyclotella*	*Chlorella*	*Amphora*	0.49	0.37	0.86
2019-2020	Pre-monsoon	*Ulothrix*	*Eunotia*	*Pinnularia*	*Melosia*	1.12	0.25	1.37
	Monsoon	*Trachelomonas*	*Cyclotella*	*Euglena*	*Eunotia*	1.08	0.31	1.39
	Post-monsoon	*Cyclotella*	*Amphiprora*	*Chlorella*	*Centritectus*	1.87	0.35	2.05
	Winter	*Synedra*	*Oscillatoria*	*Peridinium*	*Euglena*	1.34	0.51	1.85

Table 27. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station B2.

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			
2018-2019	Pre-monsoon	*Pithophora*	*Euglena*	*Oscillatoria*	*Anabaena*	1.68	0.52	2.2
	Monsoon	*Oscillatoria*	*Synedra*	*Nitzschia*	*Amphiprora*	0.72	0.23	0.95
	Post-monsoon	*Oscillatoria*	*Euglena*	*Nitzschia*	*Gyrosigma*	0.56	0.31	0.87
	Winter	*Chamydomonas*	*Scenedesmus*	*Rhodomonas*	*Cryptomonas*	0.48	0.35	0.83
2019-2020	Pre-monsoon	*Trachelomonas*	*Ulothrix*	*Scenedesmus*	*Eunotia*	2.12	0.9	3.02
	Monsoon	*Trachelomonas*	*Amphora*	*Navicula*	*Cyclotella*	1.08	0.42	1.50
	Post-monsoon	*Euglena*	*Amphiprora*	*Rhodomonas*	*Peridinium*	1.1	0.8	1.9
	Winter	*Cyclotella*	*Amphiprora*	*Merismopedia*	*Eunotia*	1.67	0.32	1.99

Table 28. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station B3.

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			
2018-2019	Pre-monsoon	*Euglena*	*Synedra*	*Gyrosigma*	*Scenedesmus*	0.34	0.56	0.90
	Monsoon	*Synedra*	*Euglena*	*Oscillatoria*	*Scenedesmus*	0.29	0.55	0.84
	Post-monsoon	*Trachaelomonas*	*Synedra*	*Euglena*	*Phacus*	0.37	0.5	0.87
	Winter	*Euglena*	*Trachaelomonas*	*Microcystis*	*Phacus*	0.34	0.49	0.83
2019-2020	Pre-monsoon	*Scenedesmus*	*Ditonula*	*Rhodomonas*	*Cryptomonas*	1.37	0.08	1.45
	Monsoon	*Scenedesmus*	*Rhodomonas*	*Coscinodiscus*	*Euglena*	0.87	0.16	1.03
	Post-monsoon	*Euglena*	*Cyclotella*	*Oscillatoria*	*Scenedesmus*	1.23	0.57	1.80
	Winter	*Cyclotella*	*Cryptomonas*	*Amphiprora*	*Navicula*	0.87	0.43	1.30

Table 29. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station R1.

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			
2018-2019	Pre-monsoon	*Muniera*	*Rhodomonas*	*Scenedesmus*	*Hamiaulus*	1.46	0.22	1.68
	Monsoon	*Chaetoceros*	*Ulothrix*	*Gyrosigma*	*Nitzschia*	4.96	0.54	5.5
	Post-monsoon	*Amphiprora*	*Trachaelomonas*	*Cyclotella*	*Scenedesmus*	13.97	1.18	15.15
	Winter	*Amphiprora*	*Euglena*	*Trachaelomonas*	*Cyclotella*	7.86	0.38	8.24
2019-2020	Pre-monsoon	*Cyclotella*	*Chaetoceros*	*Melosira*	*Scenedesmus*	1.94	0.36	2.3
	Monsoon	*Ulothrix*	*Chaetoceros*	*Scenedesmus*	*Ditylum*	6.12	0.85	6.97
	Post-monsoon	*Cyclotella*	*Ditylum*	*Chaetoceros*	*Nitzschia*	4.67	0.36	5.03
	Winter	*Cyclotella*	*Surrirella*	*Melosira*	*Navicula*	4.61	0.76	5.37

Table 30. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station R2

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			
2018-2019	Pre-monsoon	*Cosmarium*	*Euglena*	*Rhodomonas*	*Scenedesmus*	1.98	0.35	2.33
	Monsoon	*Chaetoceros*	*Nitzschia*	*Synedra*	*Cyclotella*	4.98	0.82	5.8
	Post-monsoon	*Amphiprora*	*Cyclotella*	*Merismopedia*	*Navicula*	7.86	0.67	8.53
	Winter	*Rhodomonas*	*Amphiprora*	*Euglena*	*Lepocinclis*	8.23	0.89	9.12
2019-2020	Pre-monsoon	*Cyclotella*	*Trachelomonas*	*Navicula*	*Amphiprora*	2.13	0.68	2.81
	Monsoon	*Ulothrix*	*Rhizosolenia*	*Euglena*	*Amphiprora*	6.23	0.57	6.8
	Post-monsoon	*Cyclotella*	*Trachelomonas*	*Synedra*	*Nitzschia*	1.87	1.66	3.53
	Winter	*Cyclotella*	*Nitzschia*	*Melosira*	*Chlamydomonas*	2.13	1.34	3.47

Table 31. Seasonal density of dominant genera of phytoplankton (×10^6 ind./l) in Station R3.

Year	Seasons	Dominant genus of phytoplankton				Total Dominant ×10^6 ind./l	Others ×10^6 ind./l	Total ×10^6 ind./l
		Genus 1	Genus 2	Genus 3	Genus 4			
2018-2019	Pre-monsoon	*Rhodomonas*	*Trachelomonas*	*Euglena*	*Cryptomonas*	1.13	0.37	1.5
	Monsoon	*Cyclotella*	*Nitzschia*	*Euglena*	*Coscinodiscus*	9.86	0.71	10.57
	Post-monsoon	*Ceratium*	*Euglena*	*Gyrosigma*	*Synedra*	2.98	0.47	3.45
	Winter	*Euglena*	*Trachelomonas*	*Ceratium*	*Peridinium*	5.97	0.4	6.37
2019-2020	Pre-monsoon	*Chaetoceros*	*Amphiprora*	*Peridinium*	*Navicula*	1.97	0.61	2.58
	Monsoon	*Ulothrix*	*Euglena*	*Nitzschia*	*Microcystis*	6.76	0.67	7.43
	Post-monsoon	*Trachelomonas*	*Cyclotella*	*Peridinium*	*Bacteriastrum*	3.87	0.56	4.43
	Winter	*Trachelomonas*	*Cyclotella*	*Peridinium*	*Microcystis*	3.96	0.29	4.25

Table 32. Density of dominant species of phytoplankton (×10^3 ind./l) in Station B1.

Division	Species	Density (×10^3 ind./l)
Cyanophyta	*Arthrospira indica*	1.78
	A. erdosensis	0.82
	Cylindrospermopsis raciborskii	1.61
	Merismopedia punctata	0.81
	Microcystis aeruginosa	1.88
	Oscillatoria pseudogeminata	1.86
	Pelonema aphane	0.68
	Anabaenopsis elenkinii	0.42
	Anabaenopsis arnoldii	0.96
Bacillariophyta	*Gyrosigma distortus*	1.15
	G. acumina	0.69
	Pleurosigma salinarum	1.57
	P. elongatum	0.92
	P. cuspidatum	1.06
	Nitzschia longisima	2.25
	Nitzschia closterium	1.22
	Chaetoceros costatus	0.09
	Chaetoceros diversus	1.2
	Cymbella hustedtii	1.02
	Rhizosolenia setigera	0.17
	Rhizosolenia bergonii	1.54
	R. calcar-avis	1.20
	Amphora ovalis	0.18
	Navicula spicula	0.12
	Coscinodiscus lineatus	0.36
	Biddulphia mobiliencis	0.24
	Pinnularia krookii	0.67
	Thellassionema nitzschiodes	0.46
	Melosira distans	0.23
	Cyclotella bodanica	1.21
	Cyclotella comensis	1.14
	Amphiprora costata	0.76
	Actinocyclus octonarius	0.39
	Actinastrum graccilium	0.58
	Actinastrum raphidioides	0.57

Table 32. (Contd.)

Division	Species	Density ($\times 10^3$ ind./l)
Euglenophyta	*Euglena agilis*	2.34
	E. gojdicsae	0.24
	E. limnophila	0.59
	E. flava	1.93
	E. acus	0.67
	E. deses	0.78
	E. chlamydophora	1.47
	E. allorgei	0.23
	Phacus acuminatus	0.77
	P. circumflexus	0.53
	P. contortus	1.52
	P. latas	0.34
	Lepocinclis ovum	1.12
	Trachelomonas hispida	0.41
	Tr. intermedia Dang.	0.86
Chlorophyta	*Cosmarium botrytis*	0.38
	Eunotia veneris	0.49
	Ulothrix aequalis	0.71
	Ulothrix moniliformis	0.19
	Surirella arctica	0.82
	Chlorella coloniales	0.10
	Chlorella minutissima	0.16
	Oscillatoria princep	0.12
	Scenedesmus arcuatus	1.36
	Scenedesmus acuminatus	0.18
	Scenedesmus dimorphus	0.27
	Tetrastrum elegans	0.35
Cryptophyta	*Chroomonas acuta*	1.13
	Cryptomonas erosa	0.90
	Rhodomonas lacustris	0.58
Pyrrophyta	*Ceratium hirundinella*	0.12
	Peridinium abei	0.18

Table 33. Density of dominant species of phytoplankton (×10^3 ind./l) in Station B2.

Division	Species	Density (×10^3 ind./l)
Cyanophyta	*Chroococcus limneticus*	1.78
	Chroococcus minor	0.82
	Merismopedia punctata	1.61
	Microcystis ramosa	0.81
	Microcystis aeruginosa	1.88
	Pelonema aphane	1.86
	Anabaena flos-aquae	0.87
	Anabaenopsis arnoldii	0.78
	Anabaenopsis elenkinii	0.96
Bacillariophyta	*Acanthes lacunarum*	1.15
	Nitzschia fruticosa	0.69
	Nitzschia longisima	1.57
	Biddulphia mobiliensis	0.92
	Cymbella stuxbergii	1.06
	Cymbella parva	2.25
	Eucampia cornuta	1.22
	Chaetoceros costatus	0.09
	Chaetoceros diversus	1.2
	Chaetoceros diadema	1.02
	Rhizosolenia setigera	0.17
	Rhizosolenia bergonii	1.54
	Gyrosigma distortus	
	R. calcar-avis	1.20
	Amphora ovalis	2.18
	Amphiprora costata	0.56
	Asterionella formosa	0.12
	Coscinodiscus lineatus	0.36
	Biddulphia mobiliencis	0.26
	Pinnularia krookii	0.46
	Scenedesmus arcuatus	1.36
	Thellassionema nitzschiodes	1.48
	Synedra acus	1.56
	Synedra ulna	1.32
	Melosira distans	0.97
	Coscinodiscus stellaris	1.21
	Hamiaulus membranaceus	0.87
	Gyrosigma acuminatum	0.62

Table 33. (Contd.)

Division	Species	Density ($\times 10^3$ ind./l)
	Rhizosolenia alata	0.53
	Navicula radiosa	0.89
	Navicula spicula	0.76
Euglenophyta	*Euglena agilis*	2.34
	E. gojdicsae	0.24
	E. limnophila	0.59
	E. flava	1.93
	E. acus	0.67
	E. deses	0.89
	E. chlamydophora	1.47
	E. allorgei	1.23
	E. oblonga	0.23
	Phacus acuminatus	0.77
	P. circumflexus	0.53
	P. contortus	1.52
	P. latas	0.34
	Lepocinclis ovum	0.87
	Trachaelomonas abrupta	1.12
Chlorophyta	*Chlamydomonas cylindrica*	0.38
	Dicanthos belenophorus	0.69
	Eunotia veneris	1.64
	Hyaloraphidium contortum	0.52
	Schroederia spiralis	0.49
	Schroederia setigera	0.71
	Ulothrix aequalis	1.46
	Ulothrix moniliformis	1.37
	Actinotaenium cucurbita	0.19
	Cosmarium pseudomatum	0.82
Cryptophyta	*Chroomonas acuta*	1.13
	Cryptomonas erosa	0.90
	Rhodomonas lacustris	0.57
	Rhodomonas minuta	0.58
Pyrrhophyta	*Ceratium hirundinella*	0.12
	Peridinium abei	0.18

Table 34. Density of dominant species of phytoplankton (×10^3 ind./l) in Station B3.

Division	Species	Density (×10^3 ind./l)
Cyanophyta	*Merismopedia minima*	1.78
	Chroococcus minor	0.82
	Microcystis ramosa	0.81
	Microcystis aeruginosa	1.88
	Oscillatoria pseudogeminata	
	Pelonema aphane	1.86
	Anabaena flos-aquae	0.89
	Anabaenopsis arnoldii	0.78
Bacillariophyta	*Acanthes Minutissima*	1.15
	Nitzschia fruticosa	0.69
	Nitzschia longisima	1.57
	Bacteriastrum hyalinum	0.92
	Cymbella gracilis	1.06
	Eunotia lunaris	2.25
	Eucampia cornuta	1.22
	Chaetoceros costatus	0.09
	Chaetoceros diversus	1.2
	Chaetoceros diadema	1.02
	Rhizosolenia setigera	0.17
	Rhizosolenia bergonii	1.54
	Gomphonema acuminatum	1.20
	Amphora ovalis	0.18
	Amphiprora costata	1.56
	Asterionella formosa	0.12
	Melosira granulata	0.36
	Biddulphia mobiliencis	0.13
	Thellassionema nitzschiodes	1.46
	Synedra acus	2.25
	Synedra ulna	2.21
	Melosira distans	2.64
	Coscinodiscus lineatus	1.78
	Hamiaulus membranaceus	1.20
	Gyrosigma acuminatum	1.56
	Rhizosolenia alata	1.87
	Rhizosolenia robusta	1.89
	Surirella robusta	0.98

Table 34. (Contd.)

Division	Species	Density ($\times 10^3$ ind./l)
	Navicula radiosa	1.21
	Navicula spicula	1.12
Euglenophyta	*Euglena agilis*	2.34
	E. gojdicsae	0.24
	E. limnophila	0.59
	E. flava	1.93
	E. acus	0.67
	E. deses	0.62
	Phacus acuminatus	0.77
	P. circumflexus	0.53
	P. contortus	1.52
	P. latas	0.34
	Lepocinclis ovum	0.87
	Trachaelomonas abrupta	1.12
Chlorophyta	*Chlamydomonas cylindrica*	0.38
	Dicanthos belenophorus	0.48
	Hyaloraphidium contortum	0.56
	Scenedesmus arcuatus	1.36
	Schroederia spiralis	0.49
	Schroederia setigera	0.71
	Actinotaenium cucurbita	0.19
	Cosmarium pseudomatum	0.82
Cryptophyta	*Chroomonas acuta*	1.13
	Cryptomonas ovata	0.90
	Cryptomonas erosa	1.43
	Rhodomonas lacustris	0.98
	Rhodomonas minuta	0.58
Pyrrhophyta	*Ceratium hirundinella*	0.12
	Peridinium abei	0.18
	Peridinium brochi	0.21

Table 35. Density of dominant species of phytoplankton (×10^3 ind./l) in Station R1.

Division	Species	Density (×10^3 ind./l)
Cyanophyta	*Chroococcus minutus*	1.78
	Merismopedia punctata	0.82
	Microcystis roeseana	1.61
	Lyngbya limnetica	0.81
Bacillariophyta	*Achnanthes minutissima*	1.15
	Cocconeis placentula	0.69
	Nitschia longissima	1.57
	Nitzschia sigmoidea	0.92
	Biddulphia granulata	1.06
	Bacteriastrum hyalinum	2.25
	Chaetoceros brevis	1.22
	Chaetoceros costatus	0.09
	Chaetoceros diversus	1.2
	Chaetoceros diadema	1.87
	Chaetoceros curvisetum	1.23
	Chaetoceros lorenzianus	0.98
	Coscinodiscus stellaris	1.64
	Amphora commutata	0.87
	Amphora ovalis	0.78
	Cymbella affinis	1.02
	Rhizosolenia setigera	0.17
	Rhizosolenia bergonii	1.54
	R. calcar-avis	1.20
	Asterionella formosa	0.18
	Navicula spicula	0.12
	Fragilaria virescens	0.36
	Biddulphia mobiliencis	0.78
	Pinnularia krookii	0.87
	Ditylum brightwellii	1.21
	Ditylum sol	1.14
	Thellassionema nitzschiodes	0.98
	Actinocyclus octonarius	0.78
	Actinastrum graccilium	0.97
	Actinastrum raphidioides	0.84
	Hemiaulus membranaceus	1.21
	Hemiaulus sinensis	1.03
	Synura curtispina	0.56

Table 35. (Contd.)

Division	Species	Density ($\times 10^3$ ind./l)
	Melosira granulata	0.68
	Amphiprora costata	0.78
	Surirella robusta	0.82
	Surirella tenera	0.21
Euglenophyta	*Euglena agilis*	2.34
	E. gojdicsae	0.24
	E. limnophila	0.59
	E. flava	1.93
	E. acus	0.67
	Phacus acuminatus	0.77
	P. circumflexus	0.53
	P. contortus	1.52
	P. latas	0.34
	Lepocinclis ovum	1.12
	Trachelomonas hispida	0.41
Chlorophyta	*Hyaloraphidium contortum*	0.38
	Tetraedron caudatum	0.49
	Schroederia spiralis	0.71
	Schroederia setigera	0.19
	Actinastrum hantzschii	0.82
	Actinotaenium subglobosum	0.10
	Closterium setaceum	0.13
	Cosmarium angulatum	0.12
	Cosmarium dorsifruneatum	0.18
	Ulothrix aequalis	1.21
	Staurastrum chaetoceros	0.27
	Crusigenia tetrapedia	0.86
	Scenedesmus arcuatus	1.36
	Scenedesmus quadricauda	0.98
Cryptophyta	*Chroomonas acuta*	1.13
	Rhodomonas minuta	0.58
Pyrrophyta	*Ceratium hirundinella*	0.12
	Ceratium inflatum	0.16
	Peridinium abei	0.18

Table 36. Density of dominant species of phytoplankton (×10^3 ind./l) in Station R2.

Division	Species	Density (×10^3 ind./l)
Cyanophyta	*Chroococcus minutus*	1.78
	Merismopedia punctata	0.82
	Microcystis roeseana	1.61
	Lyngbia contorta	1.23
	Lyngbia allorgei	1.34
	Lyngbya limnetica	0.81
Bacillariophyta	*Achnanthes minutissima*	1.15
	Cocconeis placentula	0.69
	Nitschia longissima	1.57
	Nitzschia sigmoidea	0.92
	Biddulphia granulata	1.06
	Bacteriastrum hyalinum	2.25
	Chaetoceros brevis	1.22
	Chaetoceros costatus	0.09
	Chaetoceros diversus	1.2
	Chaetoceros diadema	0.98
	Chaetoceros curvisetum	0.87
	Chaetoceros lorenzianus	0.79
	Coscinodiscus lineatus	1.56
	Ditylum brightwellii	1.23
	Ditylum sol	1.13
	Amphora commutata	0.86
	Amphora ovalis	1.54
	Cymbella affinis	1.02
	Rhizosolenia setigera	0.17
	Rhizosolenia bergonii	1.54
	Asterionella formosa	0.18
	Navicula spicula	0.12
	Fragilaria virescens	0.36
	Pinnularia krookii	1.23
	Hemiaulus membranaceus	1.56
	Thellassionema nitzschiodes	0.87
	Actinastrum raphidioides	0.68
	Actinocyclus octonarius	0.23
	Actinastrum graccilium	0.98
	Synura curtispina	0.87
	Melosira granulata	0.46

Table 36. (Contd.)

Division	Species	Density ($\times 10^3$ ind./l)
	Amphiprora costata	0.49
	Surirella robusta	1.78
	Surirella tenera	1.89
Euglenophyta	*Euglena agilis*	2.34
	E. gojdicsae	0.24
	E. limnophila	0.59
	E. flava	1.93
	E. acus	0.67
	Phacus acuminatus	0.77
	P. circumflexus	0.53
	P. contortus	1.52
	P. latas	0.34
	Lepocinclis ovum	1.12
	Trachelomonas hispida	0.41
Chlorophyta	*Hyaloraphidium contortum*	0.38
	Tetraedron caudatum	0.49
	Schroederia spiralis	0.71
	Schroederia setigera	0.19
	Actinastrum hantzschii	0.82
	Actinotaenium subglobosum	0.10
	Closterium setaceum	0.23
	Cosmarium angulatum	0.12
	Straurastrum chaetoceros	0.27
	Crusigenia tetrapedia	0.54
	Scenedesmus arcuatus	1.36
	Scenedesmus quadricauda	0.61
Cryptophyta	*Chroomonas acuta*	1.13
	Rhodomonas minuta	0.58
Pyrrophyta	*Ceratium hirundinella*	0.12
	Ceratium inflatum	0.46
	Peridinium abei	0.18

Table 37. Density of dominant species of phytoplankton (×10^3 ind./l) in Station R3.

Division	Species	Density (×10^3 ind./l)
Cyanophyta	*Chroococcus minutus*	1.78
	Merismopedia punctata	0.82
	Microcystis roeseana	1.61
	Lyngbya limnetica	0.81
Bacillariophyta	*Achnanthes minutissima*	1.15
	Cocconeis placentula	0.69
	Nitschia longissima	1.57
	Nitzschia sigmoidea	0.92
	Biddulphia granulata	1.06
	Bacteriastrum hyalinum	2.25
	Ditylum brightwellii	0.87
	Ditylum sol	1.21
	Chaetoceros brevis	1.22
	Chaetoceros costatus	0.09
	Chaetoceros diversus	1.2
	Chaetoceros diadema	1.32
	Chaetoceros curvisetum	0.89
	Chaetoceros lorenzianus	0.76
	Coscinodiscus lineatus	0.87
	Coscinodiscus stellaris	0.97
	Amphora commutata	0.84
	Amphora ovalis	0.89
	Cymbella affinis	1.02
	Rhizosolenia setigera	0.17
	Rhizosolenia bergonii	1.54
	R. calcar-avis	1.20
	Asterionella formosa	0.18
	Navicula spicula	0.12
	Fragilaria virescens	0.36
	Biddulphia mobiliencis	0.43
	Pinnularia krookii	0.56
	Thellassionema nitzschiodes	1.23
	Actinocyclus octonarius	0.78
	Actinastrum graccilium	0.65
	Actinastrum raphidioides	0.89
	Synura curtispina	0.98
	Melosira granulata	0.79

Table 37. (Contd.)

Division	Species	Density ($\times 10^3$ ind./l)
	Amphiprora costata	1.64
	Surirella robusta	1.23
	Surirella tenera	1.64
Euglenophyta	*Euglena agilis*	2.34
	E. gojdicsae	0.24
	E. limnophila	0.59
	E. flava	1.93
	E. acus	0.67
	Phacus acuminatus	0.77
	P. circumflexus	0.53
	P. contortus	1.52
	P. latas	0.34
	Lepocinclis ovum	1.12
	Trachelomonas hispida	0.41
Chlorophyta	*Hyaloraphidium contortum*	0.38
	Tetraedron caudatum	0.49
	Schroederia spiralis	0.71
	Schroederia setigera	0.19
	Actinastrum hantzschii	0.82
	Actinotaenium subglobosum	0.10
	Closterium setaceum	0.76
	Cosmarium angulatum	0.12
	Cosmarium dorsifruneatum	0.18
	Straurastrum chaetoceros	0.27
	Crusigenia tetrapedia	0.34
	Scenedesmus arcuatus	1.36
	Scenedesmus quadricauda	0.46
Cryptophyta	*Chroomonas acuta*	1.13
	Rhodomonas minuta	0.58
Pyrrophyta	*Ceratium hirundinella*	0.12
	Ceratium inflatum	0.13
	Peridinium abei	0.18

Seasonal variation of dominant phytoplankton in species level

Station B1

In this station, dominant phytoplankton species were *Arthrospira indica, A. erdosensis, Cylindrospermopsis raciborskii, Merismopedia punctata, Microcystis aeruginosa, Oscillatoria pseudogeminata, Pelonema aphane, Anabaenopsis elenkinii* and *Anabaenopsis arnoldii* belonging to Cyanophyta; *Cosmarium botrytis, Eunotia veneris, Ulothrix aequalis, Ulothrix moniliformis, Surirella arctica, Chlorella colonials, Chlorella minutissima, Oscillatoria prince, Scenedesmus acuminatus, Scenedesmus dimorphus* and *Tetrastrum elegans* belonging to Chlorophyta; *Euglena agilis, E. gojdicsae, E. limnophila, E. flava, E. acus, Phacus acuminatus, P. circumflexus, P. contortus, P. latas, Lepocinclis ovum, Trachelomonas hispida* belonging to Euglenophyta; *Gyrosigma distortus, G. acumina, Pleurosigma salinarum, P. elongatum, P. cuspidatum, Nitzschia longisima, Nitzschia Closterium, Chaetoceros costatus, Chaetoceros diversus, Cymbella hustedtii, Rhizosolenia setigera, Rhizosolenia bergonii, R. calcar-avis, Amphora ovalis, Synedra acus, Navicula spicula, Coscinodiscus lineatus, Biddulphia mobiliencis, Pinnularia krookii, Scenedesmus arcuatus, Thellassionema nitzschiodes, Amphiprora costata, Melosira distans, Actinocyclus octonarius, Actinastrum graccilium, Actinastrum raphidioides, Cyclotella comensis* and *Cyclotella bodanica* belonging to Bacillariophyta, *Chroomonas acuta, Cryptomonas erosa* and *Rhodomonas lacustris* belonging to Cryptophyta were observed.

During pre-monsoon *Euglena gojdicsae* was dominant in the first year and in the second year, *Ulothrix simplex* was dominant.

In the monsoon *Euglena agilis* was dominant in the first year and in second year, *Trachelomonas oblonga* was dominant.

During post-monsoon *Euglena alata* was dominant in the first year and in second year, *Cyclotella comensis* was dominant.

In the winter, *Melosira distans* was dominant in the first year and in second year, *Synedra acus* was dominant. (Table 38).

Station B2

In this station, dominant phytoplankton species were *Chroococcus limneticus, Chroococcus minor, Merismopedia punctata, Microcystis ramose, Microcystis aeruginosa, Pelonema aphane, Anabaena flos-aquae, Anabaenopsis arnoldii* and *Anabaenopsis elenkinii* belonging to Cyanophyta; *Chlamydomonas cylindrica, Dicanthos belenophorus, Hyaloraphidium contortum, Schroederia spiralis, Ulothrix aequalis, Ulothrix moniliformis, Schroederia setigera, Actinotaenium cucurbita and Cosmarium pseudomatum* belonging to Chlorophyta; *Euglena agilis, E. gojdicsae, E. limnophila, E. flava, E. acus, E. deses, E. chlamydophora, E. allorgei, E. oblonga, Phacus acuminatus, P. circumflexus, P. contortus, P. latas, Lepocinclis ovum* and *Trachaelomonas abrupta* belonging to Euglenophyta; *Acanthes lacunarum, Nitzschia fruticose, Nitzschia longisima, Biddulphia mobiliensis, Cymbella stuxbergii, Cymbella parva, Eucampia cornuta, Chaetoceros costatus, Chaetoceros diversus, Chaetoceros diadema, Rhizosolenia setigera, Rhizosolenia bergonii, R. calcar-avis, Gyrosigma distortus, Amphora ovalis, Amphiprora costata, Asterionella Formosa, Coscinodiscus lineatus, Biddulphia mobiliencis, Pinnularia krookii, Scenedesmus arcuatus, Thellassionema nitzschiodes, Synedra acus, Synedra ulna, Melosira distans, Hamiaulus membranaceus, Gyrosigma acuminatum, Rhizosolenia alata, Navicula radiosa* and *Navicula spicula* belonging to Bacillariophyta, *Ceratium hirundinella* and *Peridinium abei* belonging to Pyrrhophyta and *Chroomonas acuta, Cryptomonas erosa, Rhodomonas lacustris* and *Rhodomonas minuta* belonging to Cryptophyta were observed.

During pre-monsoon *Pithophora zelleri* was dominant in the first year and in the second year, *Trachaelomonas anulifera* was dominant.

In the monsoon *Oscillatoria agardhii* was dominant in the first year and in second year, *Amphora ovalis* was dominant.

During post-monsoon *Oscillatoria amphibia* was dominant in the first year and in second year, *Euglena allorgei* was dominant.

In the winter, *Chlamydomonas gloeopara* was dominant in the first year and in second year, *Cyclotella comensis* was dominant. (Table 39).

Station-B3

In this station, dominant phytoplankton species were *Chroococcus minutus, Merismopedia punctata, Oscillatoria pseudogeminata, Microcystis roeseana* and *Lyngbya limnetica* belonging to Cyanophyta; *Hyaloraphidium contortum, Tetraedron caudatum, Schroederia spiralis, Schroederia setigera, Actinastrum hantzschii, Actinotaenium subglobosum, Closterium setaceum, Cosmarium angulatum, Cosmarium dorsifruneatum, Straurastrum chaetoceros, Crusigenia tetrapedia* and *Scenedesmus quadricauda* belonging to Chlorophyta; *Euglena agilis, E. gojdicsae, E. limnophila, E. flava, E. acus, Phacus acuminatus, P. circumflexus, P. contortus, P. latas, Lepocinclis ovum and Trachelomonas hispida* belonging to Euglenophyta; *Achnanthes minutissima, Cocconeis placentula, Detonula pumila, Nitschia longissimi, Nitzschia sigmoidea, Biddulphia granulate, Bacteriastrum hyalinum, Chaetoceros brevis, Chaetoceros costatus, Chaetoceros diversus, Chaetoceros diadema, Chaetoceros curvisetum, Chaetoceros lorenzianus, Coscinodiscus lineatus, Amphora commutate, Amphora ovalis, Amphiprora costata, Cymbella affinis, Rhizosolenia setigera, Rhizosolenia bergonii, R. calcar-avis, Asterionella Formosa, Navicula spicula, Fragilaria virescens, Biddulphia mobiliencis, Pinnularia krookii, Scenedesmus arcuatus, Thellassionema nitzschiodes, Actinocyclus octonarius, Actinastrum graccilium, Actinastrum raphidioides, Synura curtispina, Navicula radiosa, Melosira granulate, Amphiprora costata, Surirella robusta* and *Surirella tenera* belonging to Bacillariophyta; *Ceratium hirundinella, Ceratium inflatum* and *Peridinium abei* belonging to Pyrrhophyta and *Chroomonas acuta* and *Rhodomonas minuta* belonging to Cryptophyta were observed.

During pre-monsoon *Euglena acus var. longissima* was dominant in the first year and in the second year, *Scenedesmus acuminatus var. minor* was dominant.

In the monsoon *Synedra ulna* (Nitzsch) was dominant in the first year and in second year, *Scenedesmus acuminatus var. minor* was dominant.

During post-monsoon *Trachaelomonas armata* was dominant in the first year and in second year, *Euglena archaeoplastidiata* was dominant.

In the winter, *Euglena agilis* var. *praeexicisa* was dominant in the first year and in second year, *Cyclotella comensis* was dominant. (Table 40).

Station-R1

In this station, dominant phytoplankton species were *Chroococcus minutus, Merismopedia punctata, Microcystis roeseana* and *Lyngbya limnetica* belonging to Cyanophyta; *Hyaloraphidium contortum, Tetraedron caudatum, Schroederia spiralis, Schroederia setigera, Actinastrum hantzschii, Actinotaenium subglobosum, Closterium setaceum, Cosmarium angulatum, Cosmarium dorsifruneatum, Straurastrum chaetoceros, Crusigenia tetrapedia, Ulothrix aequalis* and *Scenedesmus quadricauda* belonging to Chlorophyta; *Euglena agilis, E. gojdicsae, E. limnophila, E. flava, E. acus, Phacus acuminatus, P. circumflexus, P. contortus, P. latas, Lepocinclis ovum and Trachelomonas hispida* belonging to Euglenophyta; *Achnanthes minutissima, Cocconeis placentula, Nitschia longissimi, Nitzschia sigmoidea, Biddulphia granulate, Hemiaulus membranaceus, Bacteriastrum hyalinum, Chaetoceros brevis, Chaetoceros costatus, Chaetoceros diversus, Chaetoceros diadema, Chaetoceros curvisetum, Chaetoceros lorenzianus, Amphora commutate, Amphora ovalis, Cymbella affinis, Rhizosolenia setigera, Rhizosolenia bergonii, R. calcar-avis, Asterionella Formosa, Navicula spicula, Fragilaria virescens, Biddulphia mobiliencis, Pinnularia krookii, Scenedesmus arcuatus, Thellassionema nitzschiodes, Actinocyclus octonarius, Actinastrum graccilium, Actinastrum raphidioides, Synura curtispina, Melosira granulate, Amphiprora costata, Surirella robusta* and *Surirella tenera* belonging to Bacillariophyta; *Ceratium hirundinella, Ceratium inflatum* and *Peridinium abei* belonging to Pyrrhophyta and *Chroomonas acuta and Rhodomonas minuta* belonging to Cryptophyta were observed.

In pre-monsoon *Muniera membranaceae* was higher in the first year but in second year, *Chaetoceros peruvianus* was higher.

In the monsoon *Chaetoceros peruvianus* was dominant in the first year and in second year, *Ulothrix aequalis* was dominant.

During post-monsoon *Amphiprora costata* was dominant in the first year and in second year, *Cyclotella comensis* was dominant.

In the winter, *Amphiprora costata* was dominant in the first year and in second year, *Cyclotella comensis* was dominant (Table 41).

Station-R2

In this station, dominant phytoplankton species were *Chroococcus minutus, Merismopedia punctata, Microcystis roeseana, Lyngbia contorta, Lyngbia allorgei* and *Lyngbya limnetica* belonging to Cyanophyta; *Hyaloraphidium contortum, Tetraedron caudatum, Schroederia spiralis, Schroederia setigera, Ulothrix simplex, Actinastrum hantzschii, Actinotaenium subglobosum, Closterium setaceum, Cosmarium angulatum, Straurastrum chaetoceros, Crusigenia tetrapedia* and *Scenedesmus quadricauda* belonging to Chlorophyta; *Euglena agilis, E. gojdicsae, E. limnophila, E. flava, E. acus, Phacus acuminatus, P. circumflexus, P. contortus, P. latas, Lepocinclis ovum* and *Trachelomonas hispida* belonging to Euglenophyta; *Achnanthes minutissima, Cyclotella bodanica, Cocconeis placentula, Nitschia longissimi, Nitzschia sigmoidea, Biddulphia granulate, Bacteriastrum hyalinum, Hemiaulus membranaceus, Chaetoceros brevis, Chaetoceros costatus, Chaetoceros diversus, Chaetoceros diadema, Chaetoceros curvisetum, Chaetoceros lorenzianus, Amphora commutate, Amphora ovalis, Cymbella affinis, Rhizosolenia setigera, Rhizosolenia bergonii, Asterionella Formosa, Navicula spicula, Fragilaria virescens, Pinnularia krookii, Scenedesmus arcuatus, Thellassionema nitzschiodes, Actinastrum raphidioides, Actinocyclus octonarius, Actinastrum graccilium, Synura curtispina, Melosira granulate, Amphiprora costata, Surirella robusta* and *Surirella tenera* belonging to Bacillariophyta; *Ceratium hirundinella, Ceratium inflatum* and *Peridinium abei* belonging to Pyrrhophyta and *Chroomonas acuta* and *Rhodomonas minuta* belonging to Cryptophyta were observed.

During pre-monsoon *Cosmarium angulatum* was dominant in the first year and in the second year, *Trachelomonas hispida* was dominant.

In the monsoon *Chaetoceros curvisetum* was dominant in the first year and in second year, *Rhizosolenia bergonii* was dominant.

During post-monsoon *Amphiprora costata* was dominant in the first year and in second year, *Cyclotella bodanica* was dominant.

In the winter, *Euglena agilis* var. *praeexicisa* was dominant in the first year and in second year, *Cyclotella bodanica* was dominant. (Table 42).

Station-R3

In this station, dominant phytoplankton species *Chroococcus minutus, Merismopedia punctata, Microcystis roeseana* and *Lyngbya limnetica* belonging to Cyanophyta, *Hyaloraphidium contortum, Tetraedron caudatum, Schroederia spiralis, Schroederia setigera, Ulothrix simplex, Actinastrum hantzschii, Actinotaenium subglobosum, Closterium setaceum, Cosmarium angulatum, Cosmarium dorsifruneatum, Straurastrum chaetoceros, Crusigenia tetrapedia* and *Scenedesmus quadricauda* belonging to Chlorophyta, *Euglena agilis, E. gojdicsae, E. limnophila, E. flava, E. acus, Phacus acuminatus, P. circumflexus, P. contortus, P. latas, Lepocinclis ovum* and *Trachelomonas hispida* belonging to Euglenophyta, *Achnanthes minutissima, Cyclotella bodanica, Cocconeis placentula, Nitschia longissimi, Nitzschia sigmoidea, Biddulphia granulate, Bacteriastrum hyalinum, Chaetoceros brevis, Chaetoceros costatus, Chaetoceros diversus, Chaetoceros diadema, Chaetoceros curvisetum, Chaetoceros lorenzianus, Amphora commutate, Amphora ovalis, Cymbella affinis, Rhizosolenia setigera, Rhizosolenia bergonii, R. calcar-avis, Asterionella Formosa, Navicula spicula, Fragilaria virescens, Biddulphia mobiliencis, Pinnularia krookii, Scenedesmus arcuatus, Thellassionema nitzschiodes, Actinocyclus octonarius, Actinastrum graccilium, Actinastrum raphidioides, Synura curtispina, Melosira granulate, Amphiprora costata, Surirella robusta* and *Surirella tenera* belonging to Bacillariophyta; *Chroomonas acuta* and *Rhodomonas minuta* belonging to Pyrrhophyta and *Ceratium hirundinella, Ceratium inflatum* and *Peridinium abei* belonging to Cryptophyta were observed.

During pre-monsoon *Euglena acus* var. *longissima* was dominant in the first year and in the second year, *Chaetoceros diadema* was dominant.

In the monsoon *Cyclotella bodanica* was dominant in the first year and in second year, *Ulothrix simplex* was dominant.

During post-monsoon *Ceratium hirundinella* was dominant in the first year and in second year, *Trachelomonas hispida* was dominant.

In the winter, *Euglena gojdicsae* was dominant in the first year and in second year, *Trachelomonas hispida* was dominant (Table 43).

Table 38. Seasonal density of dominant species of phytoplankton (×10^6 ind./l) in Station B1.

Year	Seasons	Dominant species of phytoplankton				Total dominant × 10⁶ ind./l	Other ×10⁶ ind./l	Total PD ×10⁶ ind./l
		Species 1	Species 2	Species 3	Species 4			
2018-2019	Pre-monsoon	*Euglena gojdicsae*	*Oscillatoria pseudogeminata*	*Pelonema aphane*	*Synedra acus*	0.75	0.35	1.1
	Monsoon	*Euglena agilis*	*Chaetoceros costatus*	*Amphora ovalis*	*Gyrosigma distortus*	0.85	0.32	1.17
	Post-monsoon	*Euglena alata*	*Nitzschia longisima*	*Peridinium abei*	*Melosira distans*	0.37	0.29	0.66
	Winter	*Melosira distans*	*Cyclotella bodanica*	*Chlorella minutissima*	*Amphora ovalis*	0.49	0.37	0.86
2019-2020	Pre-monsoon	*Ulothrix simplex*	*Eunotia veneris*	*Pinnularia krookii*	*Melosira distans*	1.12	0.25	1.37
	Monsoon	*Trachaelomonas oblonga*	*Cyclotella comensis*	*Euglena gojdicsae*	*Eunotia veneris*	1.08	0.31	1.39
	Post-monsoon	*Cyclotella comensis*	*Amphiprora costata*	*Chlorella minutissima*	*Eunotia veneris*	1.87	0.35	2.05
	Winter	*Synedra acus*	*Oscillatoria pseudogeminata*	*Peridinium abei*	*Euglena agilis*	1.34	0.51	1.85

Table 39. Seasonal density of dominant species of phytoplankton (×10^6 ind./l) in Station B2.

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			
2018-2019	Pre-monsoon	*Pithophora zelleri*	*Euglena oblonga*	*Oscillatoria amphibia*	*Anabaena flos-aquae*	1.68	0.52	2.2
	Monsoon	*Oscillatoria agardhii*	*Synedra acus*	*Nitzschia closterium*	*Amphiprora costata*	0.72	0.23	0.95
	Post-monsoon	*Oscillatoria amphibia*	*Euglena oblonga*	*Nitzschia closterium*	*Gyrosigma distortus*	0.56	0.31	0.87
	Winter	*Chlamydomonas gloeopara*	*Scenedesmus arcuatus*	*Rhodomonas minuta*	*Chroomonas acuta*	0.48	0.35	0.83
2019-2020	Pre-monsoon	*Trachaelomonas anulifera*	*Ulothrix moniliformis*	*Scenedesmus arcuatus*	*Eunotia veneris*	2.12	0.9	3.02
	Monsoon	*Amphora ovalis*	*Trachaelomonas abrupta*	*Navicula radiosa*	*Cyclotella comensis*	1.08	0.42	1.50
	Post-monsoon	*Euglena allorgei*	*Amphiprora costata*	*Rhodomonas minuta*	*Peridinium abei*	1.1	0.8	1.9
	Winter	*Cyclotella comensis*	*Amphiprora costata*	*Merismopedia punctata*	*Eunotia veneris*	1.67	0.32	1.99

Table 40. Seasonal density of dominant species of phytoplankton (×10^{6}ind./l) in Station B3.

Year	Seasons	Dominant species of phytoplankton				Total dominant × 10⁶ ind./l	Other ×10⁶ ind./l	Total PD ×10⁶ ind./l
		Species 1	Species 2	Species 3	Species 4			
2018-2019	Pre-monsoon	*Euglena acus* var. *longissima*	*Synedra ulna*	*Gyrosigma distortus*	*Scenedesmus acuminatus*	7.42	6.41	13.83
	Monsoon	*Synedra ulna*	*Euglena agilis var. praeexicisa*	*Oscillatoria amphibia*	*Scenedesmus acuminatus var. minor*	3.27	2.82	6.09
	Post-monsoon	*Trachaelomonas armata*	*Synedra ulna*	*Euglena agilis var. praeexicisa*	*Phacus contortus*	4.53	3.49	8.02
	Winter	*Euglena agilis* var. *praeexicisa*	*Euglena acus var. longissimi*	*Trachaelomonas armata*	*Microcystis roeseana*	5.50	4.61	10.39
2019-2020	Pre-monsoon	*Scenedesmus acuminatus*	*Detonula pumila*	*Rhodomonas minuta*	*Cryptomonas erosa*	10.85	6.13	17.05
	Monsoon	*Scenedesmus acuminatus* var. *minor*	*Rhodomonas minuta*	*Coscinodiscus lineatus*	*Euglena acus var. longissimi*	3.49	2.55	6.03
	Post-monsoon	*Euglena archaeoplastidiata*	*Cyclotella comensis*	*Oscillatoria pseudogeminata*	*Scenedesmus acuminatus*	3.87	2.14	6.01
	Winter	*Cyclotella comensis*	*Cryptomonas erosa*	*Amphiprora costata*	*Navicula spicula*	7.17	4.17	11.34

Table 41. Seasonal density of dominant species of phytoplankton (×10^{6}ind./l) in Station R1.

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			
2018-2019	Pre-monsoon	*Muniera membranaceae*	*Rhodomonas minuta*	*Scenedesmus arcuatus*	*Hemiaulus membranaceus*	1.46	0.22	1.68
	Monsoon	*Chaetoceros peruvianus*	*Ulothrix aequalis*	*Gyrosigma distortus*	*Nitzschia sigmoidea*	4.96	0.54	5.5
	Post-monsoon	*Amphiprora costata*	*Trachaelomonas hispida*	*Cyclotella bodanica*	*Chaetoceros peruvianus*	13.97	1.18	15.15
	Winter	*Amphiprora costata*	*Euglena gojdicsae*	*Trachaelomonas hispida*	*Cyclotella bodanica*	7.86	0.38	8.24
2019-2020	Pre-monsoon	*Chaetoceros peruvianus*	*Cyclotella bodanica*	*Melosira granulata*	*Scenedesmus arcuatus*	1.94	0.36	2.3
	Monsoon	*Ulothrix aegualis*	*Chaetoceros peruvianus*	*Scenedesmus arcuatus*	*Ditylum brightwellii*	6.12	0.85	6.97
	Post-monsoon	*Cyclotella comensis*	*Ditylum sol*	*Chaetoceros peruvianus*	*Nitzschia sigmoidea*	4.67	0.36	5.03
	Winter	*Cyclotella comensis*	*Surirella robusta*	*Melosira granulata*	*Navicula spicula*	4.61	0.76	5.37

Table 42. Seasonal density of dominant species of phytoplankton (×10^{6}ind./l) in Station R2.

Year	Seasons	Dominant species of phytoplankton				Total dominant × 10⁶ ind./l	Other ×10⁶ ind./l	Total PD ×10⁶ ind./l
		Species 1	Species 2	Species 3	Species 4			
2018-2019	Pre-monsoon	*Cosmarium angulatum*	*Euglena agilis var. praeexicisa*	*Rhodomonas minuta*	*Chaetoceros peruvianus*	1.98	0.35	2.33
	Monsoon	*Chaetoceros curvisetum*	*Nitzschia sigmoidea*	*Synedra ulna*	*Cyclotella bodanica*	4.98	0.82	5.8
	Post-monsoon	*Amphiprora costata*	*Cyclotella bodanica*	*Merismopedia punctata*	*Navicula radiosa*	7.86	0.67	8.53
	Winter	*Euglena agilis* var. *praeexicisa*	*Rhodomonas minuta*	*Amphiprora costata*	*Lepocinclis ovum*	8.23	0.89	9.12
2019-2020	Pre-monsoon	*Navicula radiosa*	*Cyclotella bodanica*	*Trachaelomonas hispida*	*Amphiprora costata*	2.13	0.68	2.81
	Monsoon	*Rhizosolenia bergonii*	*Ulothrix aegualis*	*Euglena agilis var. praeexicisa*	*Amphiprora costata*	6.23	0.57	6.8
	Post-monsoon	*Cyclotella bodanica*	*Trachaelomonas hispida*	*Synedra ulna*	*Nitzschia sigmoidea*	1.87	1.66	3.53
	Winter	*Cyclotella bodanica*	*Nitzschia sigmoidea*	*Melosira granulate*	*Chlamydomonas gloeopara*	2.13	1.34	3.47

Table 43. Seasonal density of dominant species of phytoplankton (×10^6 ind./l) in Station R3.

Year	Seasons	Dominant species of phytoplankton				Total dominant × 10⁶ ind./l	Other ×10⁶ ind./l	Total PD ×10⁶ ind./l
		Species 1	Species 2	Species 3	Species 4			
2018-2019	Pre-monsoon	*Euglena acus* var. *longissima*	*Rhodomonas minuta*	*Trachaelomonas hispida*	*Cryptomonas erosa*	1.13	0.37	1.5
	Monsoon	*Cyclotella bodanica*	*Nitzschia sigmoidea*	*Euglena acus var. longissima*	*Coscinodiscus lineatus*	9.86	0.71	10.57
	Post-monsoon	*Ceratium hirundinella*	*Euglena acus var. longissima*	*Gyrosigma acumina*	*Synedra ulna*	2.98	0.47	3.45
	Winter	*Euglena gojdicsae*	*Trachaelomonas hispida*	*Ceratium hirundinella*	*Peridinium abei*	5.97	0.4	6.37
2019-2020	Pre-monsoon	*Chaetoceros diadema*	*Amphiprora costata*	*Peridinium abei*	*Navicula radiosa*	1.97	0.61	2.58
	Monsoon	*Ulothrix simplex*	*Euglena gojdicsae*	*Nitzschia sigmoidea*	*Microcystis roeseana*	6.76	0.67	7.43
	Post-monsoon	*Trachaelomonas hispida*	*Cyclotella bodanica*	*Peridinium abei*	*Bacteriastrum hyalinum*	3.87	0.56	4.43
	Winter	*Trachaelomonas hispida*	*Cyclotella bodanica*	*Peridinium abei*	*Microcystis roeseana*	3.96	0.29	4.25

Cummulative phytoplankton species list from the present investigation from Bakkhali River and Reju canal.

During the present investigation, a total of 402 species of phytoplankton were identified from 1-6 study Stations. Among them, 354 species were previously reported for Bangladesh which are appended in Appendix I and 48 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, a total of 48 species of phytoplankton may be considered as the new record for Bangladesh. (Appendix II).

Comparison of ranges of physicochemical factors and biological factors among two sampling year

Comparative study between two years among the ranges of different physicochemical and biological factors was quite interesting. Some data were higher and found in the 1st year and some were higher in the 2nd study year (Table 44).

Air temperature and Water temperature were comparatively higher in 1st year of study also salinity, total dissolved solids (TDS), dissolved oxygen (DO), pH, nitrate nitrogen (NO_3-N), soluble reactive phosphate (SRP), chlorophyll a (chl-a), PP= phaeopigments were higher in 1st study year.

On the other hand, Secchi depth (SD), conductivity, alkalinity, soluble reactive silicate (SRS), phytoplankton density (PD) was higher in 2nd study period. (Table 44)

Table 44. Showing a comparison of ranges of physicochemical factors and biological factors among two sampling year.

Parameters	Unit	N	YEAR 2018-2019	YEAR 2019-2020
AT	°C	24	24.0-31.0	20.0-33.0
WT	°C	24	24.0-33.5	19.4-32.7
SD	cm	24	16.4-68.0	17.0-62.0
Salinity	ppm	24	0.0-28.0	0.0-20.0
TDS	mg/l	24	0.052-19.90	0.097-12.435
Conductivity	µS/cm	24	235-1318	356-2650
DO	mg/l	24	1.6-9.8	1.5-6.1
pH	-	24	7.4-8.8	6.8-8.6
Alkalinity	meq/l	24	0.7-4.6	1.4-4.9
NO_3-N	mg/l	24	0.0012-2.81	0.0021-0.954
SRP	µg/l	24	6.33-242.42	10.851-98.23
SRS	mg/l	24	1.13-14.39	1.356-14.523
Chl-a	µg/l	24	1.18-11.84	1.18-6.784
PP	µg/l	24	0.25-11.11	0.24-4.67
PD	x 10^6 ind/l	24	0.27-4.14	0.43-5.62

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

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 B1, B2, B3, R1, R2 and R3 reveals that the range of air temperature and water temperature is more or less equal for most of the stations (Tables 45 - 50). But the average air temperature is higher in Station R1 and the lower is found in station B1. The highest mean value of water temperature was observed in R1 whereas, the lowest was recorded in B3. The average mean value of Secchi depth is higher in s B2 and lower in R1. Mean values of salinity were depending on high tide and low tide time. But the highest value is recorded in R1 station and the lowest in B3. TDS was higher in station R1 and lower in station B3. Conductivity was higher in station B1 and the lower was found in R2. DO was found higher in R1 and the lower value was recorded in B3. At B1, pH values were higher but was lower at R1. A higher range of alkalinity is recorded at Station B2, and a lower was recorded at R3. Nitrate concentration was higher at the Station B2 but lower was at B3. Mean concentration of SRP was recorded higher in Station B3 whereas the lowest was found in station R3. SRS value was recorded higher in Station B1, whereas the lowest was found in R1. Phytoplankton biomass as chl-a was recorded higher in Station R1 and phaeopigment was also found higher in Station R1 than the other stations. And also, Phytoplankton density was recorded higher in Station R1 than the other stations and comparatively a lower value was recorded in B1, B2, and B3 (Table 51).

Table 45. Annual mean values of physicochemical and biological parameters in Station B1.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	20.00	33.10	26.8750	9.26	20.0-33.10
WT	°C	24	19.80	33.00	27.2583	9.33	19.80-33.0
SD	cm	24	16.40	62.00	44.4500	32.24	16.40-62.0
Salinity	ppm	24	.00	20.00	5.2500	14.14	0.0-20.0
TDS	g/l	24	.06	13.39	2.8087	9.43	0.06-13.39
Cond.	mS/cm	24	226.00	2650.00	1438	1714.0	226.0-2650.0
DO	mg/l	24	1.90	9.80	4.3375	5.59	1.90-9.80
pH	-	24	7.20	8.80	8.1458	1.13	7.20-8.80
Alk.	meq/l	24	1.20	4.80	3.2708	2.55	1.20-4.80
NO_3-N	mg/l	24	.01	1.69	.4023	1.19	0.01-1.69
SRP	µg/l	24	10.99	98.23	46.2716	61.69	10.99-98.23
SRS	mg/l	24	1.36	13.23	6.0491	8.40	1.36-13.23
Chl-a	µg/l	24	1.18	8.29	4.5965	5.03	1.18-8.29
PP	µg/l	24	.26	10.11	3.3013	6.97	0.26-10.11
PD	x 10^6 ind./l	24	.50	2.50	1.2987	1.41	0.50-2.50

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

Table 46. Annual mean values of physicochemical and biological parameters of station B2.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	20.00	31.00	26.96	2.59	20.0-31.00
WT	°C	24	19.50	33.50	27.18	2.92	19.50-33.50
SD	cm	24	18.00	68.00	46.08	13.65	18.0-68.0
Salinity	ppm	24	0.00	28.00	5.94	7.02	0.0-28.0
TDS	g/l	24	.07	19.9	2.61	4.46	0.07-19.9
Cond.	mS/cm	24	136	1950	797.79	400.87	136-1950
DO	mg/l	24	1.8	8.6	4.15	1.67	1.8-8.6
pH	-	24	7.5	8.80	8.11	0.30	7.5-8.80
Alk.	meq/l	24	0.7	4.6	3.29	1.24	0.7-4.6
NO_3-N	mg/l	24	0.00	2.81	0.42	0.58	0.00-2.81
SRP	µg/l	24	6.33	86.3	36.56	21.38	6.33-86.3
SRS	mg/l	24	1.13	14.34	5.66	3.67	1.13-14.34
Chl-a	µg/l	24	1.18	11.84	4.82	2.23	1.18-11.84
PP	µg/l	24	0.024	7.97	2.06	1.74	0.024-7.97
PD	x 10^6 ind./l	24	0.27	5.62	1.64	1.18	0.27-5.62

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

Table 47. Annual mean values of physicochemical and biological parameters in Station B3.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	20.00	33.00	26.917	2.55	20.0-33.00
WT	°C	24	19.40	33.50	27.029	2.94	19.40-33.50
SD	cm	24	19.00	65.00	45.558	13.20	19.0-65.0
Salinity	ppm	24	0.00	15.00	2.479	3.30	0.0-15.0
TDS	g/l	24	.052	9.87	1.759	2.27	0.052-9.87
Cond.	mS/cm	24	114.00	1940.00	638.708	403.32	114.0-1940.0
DO	mg/l	24	1.60	8.40	4.188	1.76	1.60-8.40
pH	-	24	7.50	8.60	8.025	0.41	7.50-8.60
Alk.	meq/l	24	1.00	4.90	3.238	1.20	1.00-4.90
NO_3-N	mg/l	24	0.024	1.358	0.331	0.33	0.024-1.358
SRP	µg/l	24	10.93	242.4	45.509	45.96	10.93-242.4
SRS	mg/l	24	2.013	14.388	5.874	3.75	2.013-14.388
Chl-a	µg/l	24	1.184	6.784	4.470	1.50	1.18-6.784
PP	µg/l	24	0.096	10.11	2.440	2.17	0.096-10.11
PD	x 10^6 ind./l	24	0.28	1.8	1.091	0.42	0.28-1.8

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

Table 48. Annual mean values of physicochemical and biological parameters in Station R1.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	22.00	33.70	27.58	3.13	22.0-33.70
WT	°C	24	21.0	33.00	27.57	2.9	21.0-33.0
SD	cm	24	24.5	63.00	40.67	12.58	24.5-63.0
Salinity	ppm	24	.00	30.00	6.96	6.62	0.0-30.0
TDS	g/l	24	0.226	19.9	2.852	4.599	0.226-19.9
Cond.	mS/cm	24	3.35	206	35.42	47.67	3.35-206
DO	mg/l	24	3.2	7.9	5.42	1.41	3.2-7.9
pH	-	24	7.40	8.40	7.99	0.255	7.40-8.40
Alk.	meq/l	24	1.00	4.90	2.871	1.16	1.00-4.90
NO3-N	mg/l	24	0.017	1.26	0.39	0.412	0.017-1.26
SRP	µg/l	24	4.2	196.9	39.8	40.44	4.2-196.9
SRS	mg/l	24	1.55	7.53	4.6	1.42	1.55-7.53
Chl-a	µg/l	24	2.85	13.02	7.5	2.23	2.85-13.02
PP	µg/l	24	0.512	9.184	4.25	2.06	0.512-9.184
PD	x 106 ind./l	24	0.504	27.8	5.95	5.54	0.504-27.8

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, DO= Dissolve Oxygen, NO3-N= Nitrate Nitrogen, SRP= Soluble Reactive Phosphate. SRS= Soluble reactive silicate, chl a= Chlorophyll a, PP= Phaeopigments, PD= Phytoplankton density

Table 49. Annual mean values of physicochemical and biological parameters in Station R2.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	22.0	33.50	27.479	3.182	22.0-33.5
WT	°C	24	21.0	31.00	27.471	2.996	21.0-31.0
SD	cm	24	25.0	65.0	41.875	12.291	25.0-65.0
Salinity	ppm	24	0.00	28.00	6.146	7.485	0.0-28.0
TDS	g/l	24	0.102	18.88	2.729	4.500	0.102-18.88
Cond.	mS/cm	24	1.88	121	29.040	36.167	1.88-121
DO	mg/l	24	2.2	7.6	5.233	1.429	2.2-7.6
pH	-	24	7.4	8.5	8.067	0.287	7.4-8.5
Alk.	meq/l	24	0.9	4.9	2.988	1.237	0.9-4.9
NO_3-N	mg/l	24	0.048	1.622	0.410	0.429	0.048-1.62
SRP	µg/l	24	2.19	142.6	45.078	33.612	2.19-142.6
SRS	mg/l	24	2.28	7.13	4.766	1.504	2.28-7.13
Chl-a	µg/l	24	2.37	10.46	7.098	2.574	2.37-10.46
PP	µg/l	24	1.12	12.38	3.558	2.329	1.12-12.38
PD	x 10^6 ind./l	24	0.39	12.46	5.321	3.882	0.39-12.46

AT=Air temperature, WT=Water temperature, SD= Secchi depth, TDS= Total dissolve solids, DO= Dissolve Oxygen, NO_3-N= Nitrate Nitrogen, SRP= Soluble Reactive Phosphate. 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 R3.

Parameter	Unit	N	Minimum	Maximum	Mean	(±SD)	Range
AT	°C	24	22.00	33.10	27.533	3.074	20.0-33.10
WT	°C	24	21.0	33.00	27.492	3.054	21.0-33.0
SD	cm	24	26.0	63.00	42.313	13.147	26.0-63.00
Salinity	ppm	24	0.00	27.00	6.146	6.590	0.0-27.0
TDS	g/l	24	0.08	18.60	2.759	4.700	0.08-18.60
Cond.	mS/cm	24	0.98	258.0	35.586	56.310	0.98-258.0
DO	mg/l	24	1.50	7.4	4.779	1.389	1.50-7.4
pH	-	24	7.20	8.80	8.029	0.406	7.20-8.80
Alk.	meq/l	24	0.8	4.70	2.804	1.162	0.8-4.7
NO_3-N	mg/l	24	0.04	1.45	0.381	0.385	0.04-1.45
SRP	µg/l	24	0.86	75.62	29.665	21.493	0.86-75.62
SRS	mg/l	24	1.96	7.91	4.562	1.789	1.96-7.91
Chl-a	µg/l	24	3.55	14.84	7.075	3.309	3.55-14.84
PP	µg/l	24	0.21	8.10	2.959	2.045	0.21-8.10
PD	x 10^6 ind./l	24	1.04	18.71	5.493	4.941	0.50-2.50

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

Table 51. A comparison on mean values of limnological data of studied six Stations.

Parameter	Unit	N	B1	B2	B3	R1	R2	R3
AT	°C	24	26.88	26.96	26.92	27.58	27.479	27.533
WT	°C	24	27.26	27.18	27.03	27.57	27.471	27.492
SD	cm	24	44.45	46.08	45.56	40.67	41.875	42.313
Salinity	ppm	24	5.25	5.94	2.48	6.96	6.146	6.146
TDS	g/l	24	2.81	2.61	1.76	2.852	2.729	2.759
Cond.	mS/cm	24	1438.00	797.79	638.71	35.42	29.040	35.586
DO	mg/l	24	4.34	4.15	4.19	5.42	5.233	4.779
pH	-	24	8.15	8.11	8.03	7.99	8.067	8.029
Alka.	meq/l	24	3.27	3.29	3.24	2.871	2.988	2.804
NO_3-N	mg/l	24	0.40	0.42	0.33	0.39	0.410	0.381
SRP	µg/l	24	46.27	36.56	45.51	39.8	45.078	29.665
SRS	mg/l	24	6.05	5.66	5.87	4.6	4.766	4.562
Chl-*a*	µg/l	24	4.60	4.82	4.47	7.5	7.098	7.075
PP	µg/l	24	3.30	2.06	2.44	4.25	3.558	2.959
PD	x 10^6 ind./l	24	1.30	1.64	1.09	5.95	5.321	5.493

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

Seasonal changes (mean values) of different limnological parameters

According to Brammer (2002) four distinct climatic 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 Tables 52-57.

At the station and between years of study physical factors like air and water temperature along with a Secchi depth and chemical factors like pH, conductivity, alkalinity, DO, TDS, SRS, SRP, NO_3-N and biological factors like chl-a, PP, PD from the present investigation a clear seasonal trend in the fluctuation was observed.

Table 52. Seasonal mean values of different limnological parameters for Station B1.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
Physical factors					
AT	°C	28.6	27.15	27.9	24.15
WT	°C	28.99	27.45	28.15	24.75
SD	cm	54.39	43.93	28.63	45.84
Chemical factors					
Salinity	ppm	7.685	3.4	5.75	4.985
TDS	g/l	4.7	1.6	6	4.24
Cond.	mS/cm	905.15	679.88	895.75	914
DO	mg/l	4.67	4.19	4.45	4.14
pH	-	8.2	8.01	8.2	8.22
Alk.	meq/l	4.3	2.45	2.78	3.65
NO_3-N	mg/l	0.685	0.421	0.342	0.133
SRP	µg/l	73.11	44.78	30.795	31.75
SRS	mg/l	4.01	7.84	6.54	5.36
Biological factors					
chl-a	µg/l	4.286	3.678	4.471	6.219
PP	µg/l	2.658	3.033	2.273	4.989
PD	$\times 10^6$ ind./l	1.235	1.278	1.353	1.355

Table 53. Seasonal mean values of different limnological parameters for Station B2.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
Physical factors					
AT	°C	28.75	27.2	27.8	24.35
WT	°C	29.4	27.2	28	24.45
SD	cm	44	38.35	27.35	36.45
Chemical factors					
Salinity	ppm	10.685	2.8	5.5	5.685
TDS	g/l	5.3	1.25	3.261	4.816
Cond.	mS/cm	1038.49	726.5	720.75	703.52
DO	mg/l	4.95	3.93	3.95	3.8
pH	-	8.15	8.0775	8.225	8.03
Alk.	meq/l	4.4	2.33	2.53	3.97
NO_3-N	mg/l	0.415	0.583	0.457	0.193
SRP	µg/l	64.38	25.595	29.27	28.23
SRS	mg/l	4.015	7.655	5.0895	5.028
Biological factors					
chl-a	µg/l	4.069	6.303	3.393	4.527
PP	µg/l	2.269	2.266	1.883	1.701
PD	$\times 10^6$ ind./l	2.610	1.224	1.385	1.412

Table 54. Seasonal mean values of different limnological parameters for Station B3.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
Physical factors					
AT	°C	28.65	27.15	27.725	24.35
WT	°C	29.2	27.05	27.75	24.4
SD	cm	42.75	38.3	29.475	34.25
Chemical factors					
Salinity	ppm	2.685	1.45	2	4.015
TDS	g/l	2.715	1.41	1.331	3.345
Cond.	mS/cm	894.835	655	421.75	505.5
DO	mg/l	4.985	3.855	4.275	3.8
pH	-	8	8.015	8.175	7.97
Alk.	meq/l	4.435	2.48	2.475	3.55
NO_3-N	mg/l	0.531	0.227	0.239	0.332
SRP	µg/l	86.390	37.520	28.900	26.355
SRS	mg/l	5.345	7.590	4.205	5.229
Biological factors					
chl-a	µg/l	4.110	4.375	3.921	5.323
PP	µg/l	3.111	1.427	3.040	2.721
PD	$\times 10^6$ ind./l	1.174	0.935	1.335	1.062

Table 55. Seasonal mean values of different limnological parameters for Station R1

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
Physical factors					
AT	°C	28.6	28.6	28.45	24.05
WT	°C	29.15	28.6	28.05	24.35
SD	cm	43.3	40.05	25.35	30.05
Chemical factors					
Salinity	ppm	11.665	5.625	4.25	5.835
TDS	g/l	5.905	1.405	2.345	4.685
Cond.	mS/cm	59.49	49.61	10.895	8.765
DO	mg/l	5.485	6.15	4.65	4.92
pH	-	7.965	8.155	7.9	7.85
Alk.	meq/l	4.2	2.625	1.85	2.535
NO_3-N	mg/l	0.970	0.301	0.152	0.088
SRP	µg/l	73.990	31.865	23.490	26.970
SRS	mg/l	5.260	3.560	3.815	5.715
Biological factors					
chl-a	µg/l	9.180	8.372	4.265	6.821
PP	µg/l	3.262	4.216	5.187	4.652
PD	$\times 10^6$ ind./l	1.990	6.233	10.088	6.805

Table 56. Seasonal mean values of different limnological parameters for Station R2.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
Physical factors					
AT	°C	28.75	28.55	28.55	24.15
WT	°C	29.2	28.55	27.925	24.05
SD	cm	43	39.3	25.575	31
Chemical factors					
Salinity	ppm	11	5.6875	3.75	3.5
TDS	g/l	6.24	0.9	2.12	3.2
Cond.	mS/cm	47.49	40.47	9.265	8.525
DO	mg/l	5.415	5.765	4.1	5.085
pH	-	8.15	8.215	7.95	7.835
Alk.	meq/l	4.135	2.65	1.6	3.215
NO_3-N	mg/l	0.862	0.273	0.485	0.091
SRP	µg/l	49.145	39.390	59.641	38.890
SRS	mg/l	5.205	3.950	3.815	6.050
Biological factors					
chl-a	µg/l	7.791	7.626	4.735	7.276
PP	µg/l	2.719	3.672	3.838	4.060
PD	$\times 10^6$ ind./l	2.569	6.300	6.028	6.298

Table 57. Seasonal mean values of different limnological parameters for Station R3.

Parameters	Unit	Pre-monsoon (Mar-May)	Monsoon (Jun-Sept)	Post-monsoon (Oct -Nov)	Winter (Dec-Feb)
Physical factors					
AT	°C	28.75	28.7	28.3	24.3
WT	°C	29.35	28.6	27.725	24
SD	cm	43.3	39.65	25.925	30.3
Chemical factors					
Salinity	ppm	10.65	5.2	4.25	4.15
TDS	g/l	5.305	1.273	1.5775	3.355
Cond.	mS/cm	72.06	41.185	9.5125	9.035
DO	mg/l	5.08	5.075	3.9	4.67
pH	-	8.235	8.115	7.925	7.8
Alk.	meq/l	4.15	2.55	1.525	2.65
NO_3-N	mg/l	0.765	0.374	0.219	0.116
SRP	µg/l	41.630	19.370	18.415	38.930
SRS	mg/l	5.190	3.230	3.935	6.163
Biological factors					
chl-a	µg/l	8.417	8.482	4.262	5.735
PP	µg/l	2.280	2.819	5.423	2.180
PD	$\times 10^6$ ind./l	2.040	9.002	3.935	5.309

Statistical Analysis

Correlation matrix

Correlation matrix was prepared with the help of SPSS (Statistical program for the Social Science) following Pearsons's correlation (version 20.0) method to observe the relationship among physical, chemical and biological parameters of all the selected sampling stations. Analysis has been performed among 15 physical, chemical, and biological parameters of six stations of the two study sites. The extract of the matrix has been presented in Tables 58 - 63 for Station B1, B2, B3, R1, R2 and R3, respectively and the detailed tables of the matrix have been appended in Appendix III-VIII

Study Stations

Station-B1

Air temperature showed a positive correlation with water temperature (at 5% significant level) and negative correlation with chl-a (at 5% significant level). Water temperature showed a positive correlation with NO_3-N and negative correlation with chl-a (at 1% significant level). Secchi depth showed positive relation with SRP (at 5% significant level) and negative correlation with DO (at 1% significant level).

TDS showed positive correlation with SRP (at 1% significant level). DO showed positive correlation with NO_3-N (at 5% significant level) and negative relation with SD (at 1% significant level) and pH (at 1% significant level). pH showed positive relation with PP and negative with DO (at 5% significant level). Alkalinity showed positive correlation with PD but negative correlation with SRS (at 1% significant level). NO_3-N showed positive relation with DO and negative relation with SRS (at 5% significant level).

Chl-a showed negative relation with AT (at 5% significant level) and WT (at 1% significant level). PP showed positive relation with pH (at 5% significant level) and PD showed positive relation with Alkalinity and negative with SRS (at 1% significant level) (Table 58).

Station-B2

Air temperature showed positive correlation with water temperature (at 5% significant level). Water temperature also showed positive correlation with pH and SRP. SD showed positive relation with salinity, TDS (at 1% significant level) and with SRP (at 5% significant level).

Salinity showed positive correlation with TDS and SRP (at 5% significant level). TDS showed positive correlation with SRP and PD (at 5% significant level). DO showed positive relation with NO_3-N (at 5% significant level) and negative relation with SRS (at 1% significant level)

Phytoplankton density showed positive correlation with TDS (at 5% significant level). But there is no noticeable significant correlation among physical, chemical or biological parameters (Table 59).

Station-B3

Air temperature showed positive correlation with water temperature (at 5% significant level) and negative correlation with salinity, chl-a (at 5% significant level). Water temperature showed positive relation with NO_3-N (at 1% significant level) and negative relation with salinity and chl-a (at 1% significant level). SD showed positive relation with Alkalinity and SRP (at 1% significant level).

Salinity showed positive correlation with Chl-a (at 1% significant level). Conductivity showed negative relation with Chl-a (at 1% significant level). DO showed positive relation with Alkalinity and negative relation with SRS (at 1% significant level). Alkalinity showed positive correlation with PD (at 1% significant level).

Chlorophyl-a showed positive correlation with salinity (at 1% significant level) and negative correlation with AT, WT (at 5% significant level) and with conductivity and Alkalinity (at 1% significant level). Phytoplankton density showed positive relation with Alkalinity (at 1% significant level) (Table 60).

Station-R1

AT showed positive correlation with WT (at 5% significant level). WT showed positive correlation with NO_3-N (at 1% significant level). SD showed strong positive correlation with Conductivity, Alkalinity, NO_3-N, Chl-*a* (at 5% significant level) and with SRP (at 1% significant level).

Salinity showed positive correlation with TDS, Alkalinity, NO_3-N and SRP (at 1% significant level). TDS showed positive correlation with Conductivity, SRP and NO_3-N (at 5% significant level) whereas with salinity and Alkalinity (at 1% significant level). TDS also showed highly significant negative correlation with DO and pH (at 5% significant level). In addition, conductivity showed positive correlation with Alkalinity (at 1% significant level). DO showed highly positive correlation with pH (at 5% significant level). pH showed negative relation with SRS (at 5% significant level). Alkalinity showed positive relation with NO_3-N, SRP and Chl-a (at 5% significant level). NO_3-N showed highly positive correlation with Chl-a (at 5% significant level) and with SRP (at 1% significant level).

Chlorophyll-a showed highly significant positive correlation with SD, Alkalinity NO_3-N (at 5% significant level). PP showed highly positive PD (at 5% significant level) (Table 61).

Station-R2

Air temperature showed highly significant positive correlation with water temperature (at 5% significant level) and negative correlation with SRP (at 1% significant level). Water temperature also showed positive correlation with NO_3-N (at 1% significant level). SD showed highly significant positive correlation with Conductivity and Alkalinity (at 5% significant level) and positive correlation with TDS and pH (at 1% significant level).

Salinity showed positive correlation with TDS, Conductivity and Alkalinity (at 1% significant level). TDS showed highly significant positive correlation with Conductivity (at 5% significant level) and also positive correlation with Alkalinity and SRS (at 1% significant level) and showed negative correlation with DO (at 1% significant level). Alkalinity showed strongly significant positive correlation with SRS (at 5% significant level).

The biological parameter Phaeopigment (PP) showed positive correlation with PD (Table 62).

Station-R3

Air temperature showed highly significant positive correlation with water temperature (at 5% significant level). WT showed strong significant positive correlation with NO3-N (at 5% significant level) and only negative correlation with SRS (at 1% significant level). SD showed highly significant positive correlation with Conductivity and Alkalinity (at 1% significant level).

Salinity showed positive relation with TDS, Alkalinity and NO3-N (at 1% significant level). TDS showed highly strong significant positive correlation with conductivity (at 5% significant level) and with Alkalinity (at 1% significant level). Conductivity showed positive correlation with Alkalinity (at 1% significant level). DO showed positive correlation with SRP (at 1% significant level). pH showed positive correlation with Alkalinity and NO_3-N (at 1% significant level). Alkalinity showed strong significant positive correlation with NO_3-N (at 5% significant level) and with TDS (at 1% significant level).

The biological parameter chl-a showed positive correlation with SD and NO_3-N (at 1% significant level). (Table 63).

Table 58. Results of significant correlation between pairs of studied variables (n=24) in Station B1.

Parameters	Correlation value (r)
AT vs WT	.880**
AT vs chl-a	-.606**
WT vs NO_3-N	.419*
WT vs chl-*a*	-.469*
SD vs DO	-.405*
SD vs SRP	.681**
TDS vs SRP	.469*
DO vs pH	-.545**
DO vs NO_3-N	.649**
pH vs PP	.520**
Alk. vs SRS	-.431*
Alk. vs PD	.445*
NO_3-N vs SRS	-.534**
SRS vs PD	-.491*
Chl-a vs AT	-.606**
Chl-a vs WT	-.469*
PP vs pH	.520**
PD vs Alk.	.445*
PD vs SRS	-.491*

Table 59. Results of significant correlation between pairs of studied variables (n=24) in Station B2.

Parameters	Correlation value (r)
AT vs WT	.899**
WT vs pH	.407*
WT vs SRP	.440*
SD vs Salinity	.425*
SD vs TDS	.408*
SD vs SRP	.528**
Salinity vs SD	.425*
Salinity vs TDS	.518**
Salinity vs SRP	.553**
TDS vs SRP	.527**
DO vs NO_3-N	.602**
DO vs SRS	-.416*
pH. vs SRS	-.439*
Alk. vs SRP	.407*
NO_3-N vs DO	.602**
PD vs TDS	.788**
PD vs Alk.	.427*

Table 60. Results of significant correlation between pairs of studied variables (n=24) in Station B3

Parameters	Correlation value (r)
AT vs WT	.894**
AT vs Salinity	-.529**
AT vs Chl-a	-.545**
WT vs Salinity	-.545**
WT vs NO_3-N	.472*
WT vs Chl-a	-.630**
SD vs Alkalinity	.456*
SD vs SRP	.470*
Salinity vs Chl-a	.478*
Cond. vs Chl-a	-.508*
DO vs Alkalinity	.452*
DO vs SRS	-.500*
Chl-a vs AT	-.545**
Chl-a vs WT	-.630**
Chl-a vs Salinity	.478*
Chl-a vs Cond.	-.508*
Chl-a vs NO_3-N	-.419*
PD vs Alkalinity	.439*

Table 61. Results of significant correlation between pairs of studied variables (n=24) in Station R1

Parameters	Correlation value (r)
AT vs WT	.876**
WT vs NO_3-N	.486*
SD vs Cond.	.620**
SD vs Alk.	.630**
SD vs NO_3-N	.598**
SD vs SRP	.501*
SD vs Chl-a	.661**
Salinity vs TDS	.494*
Salinity vs Alk.	.469*
Salinity vs NO_3-N	.486*
Salinity vs SRP	.458*
TDS vs Cond.	.684**
TDS vs DO	-.534**
TDS vs pH	-.527**
TDS vs Alk.	.486*
TDS vs NO_3-N	.539**
TDS vs SRP	.836**
Cond. vs Alk.	.495*
Cond. vs SRP	.643**
DO vs pH	.531**
pH vs SRS	-.652**
Alk. vs NO_3-N	.757**
Alk. vs SRP	.582**
Alk. vs Chl-a	.516**
NO_3-N vs SRP	.431*
NO_3-N vs Chl-a	.578**
Chl-a vs SD	.661**
Chl-a vs Alk.	.516**
Chl-a vs NO_3-N	.578**
PP vs PD	.596**

Table 62. Results of significant correlation between pairs of studied variables (n=24) in Station R2

Parameters	Correlation value (r)
AT vs WT	.875**
AT vs SRP	-.450*
WT vs NO_3-N	.445*
SD vs TDS	.440*
SD vs Cond.	.683**
SD vs pH	.496*
SD vs Alk.	.619**
Salinity vs TDS	.497*
Salinity vs Cond.	.426*
Salinity vs Alk	.417*
TDS vs Cond.	.745**
TDS vs DO	-.410*
TDS vs Alk.	.459*
TDS vs SRS	.422*
Cond. vs Alk.	.420*
DO vs TDS	-.410*
Alk. vs SRS	.521**
PP vs PD	.417*

Table 63. Results of significant correlation between pairs of studied variables (n=24) in Station R3

Parameters	Correlation value (r)
AT vs WT	.858**
WT vs NO_3-N	.577**
WT vs SRS	-.463*
SD vs TDS	.455*
SD vs Cond.	.625**
SD vs Alk.	.677**
pH vs SD	.444*
pH vs Alk.	.423*
pH vs NO_3-N	.488*
Salinity vs TDS	.458*
Salinity vs Alk.	.428*
Salinity vs NO_3-N	.495*
TDS vs Cond.	.799**
TDS vs Alk.	.447*
Cond. vs Alk.	.405*
DO vs SRP	.488*
Alk. vs NO_3-N	.583**
NO_3-N vs SD	.488*
NO_3-N vs Alk.	.583**
NO_3-N vs chl-a	.455*
Chl-a vs SD	.409*
Chl-a vs NO_3-N	.455*

Correlation between variables for all dataset in Bakkhali river

In this graph we actually show the correlation between all the variables of Bakkhali river. The main focus of the graph is the relationship between PD and other variables to understand the association among them. Here PD shows negative correlation with conductivity and positive correlation with Phaeopigments, DO, Chl-a and negative correlation with SRS. Reddish colour represent the positive correlation and Bluish colour indicate the negative correlation among all the variables with Phytoplankton density (PD) (Fig.42)

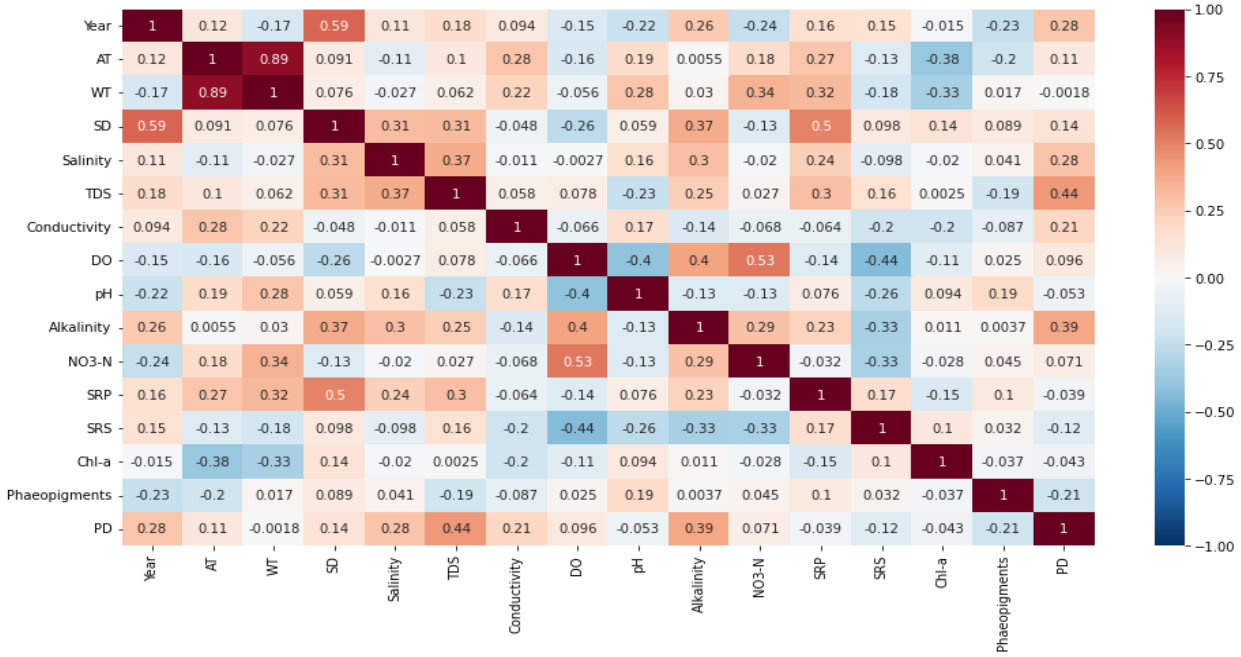


Fig.42. Correlation between variables for all dataset in Bakkhali river.

Correlation between variables for all dataset in Reju canal

In this graph we actually show the correlation between all the variables of Reju canal. The main focus of the graph is the relationship between PD and other variables to understand the association among them. Here PD shows negative correlation with NO_3-N, TDS, AT, SRS and positive correlation with Phaeopigments, DO, Chl-a and pH. Reddish colour represent the positive correlation and Bluish colour indicate the negative correlation among all the variables with Phytoplankton density (PD) (Fig.43)

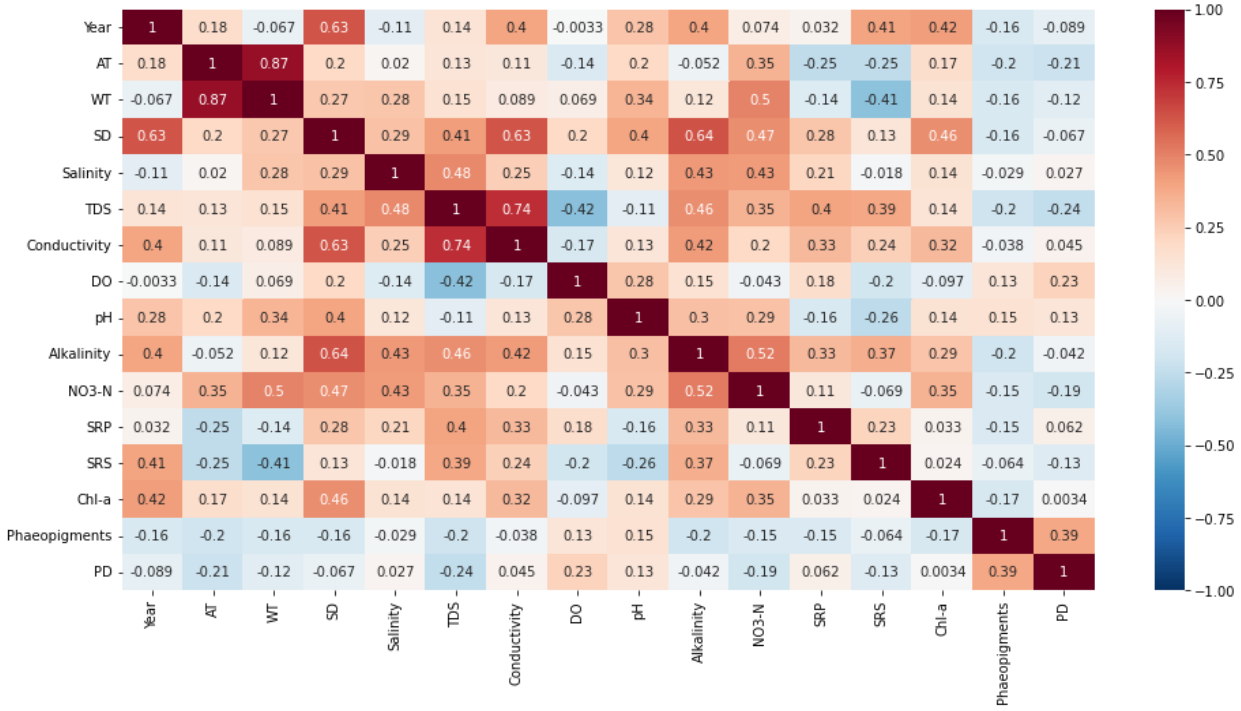


Fig.43. Correlation between variables for all dataset in Bakkhali river.

Shannon-Wiener diversity index

Shannon-Wiener diversity index is an index that is generally used to describe species diversity in a community. Here, stations R1, R2, R3, belong to Reju canal showed more diverse in Shannon-Wiener diversity index than the Bakkhali River. The highest diversity (0.5597) occurs in Station R1 on November 2018 and the lowest diversity (0.014) was obtained in Station B3 in November, 2018 (Table 64) in the 1st year of investigation. In the second year of investigation, Reju canal also showed more diversity, according to Shannon-Wiener diversity index and the highest diversity (0.548) occurs in the month of July 2020 in station R2 but the lowest diversity (0.017) was observed in Station B3 in the in March 2020 (Table 65).

Table 64. Shannon-Wiener Diversity Index (2018-19) for phytoplankton

2018-2019	B1	B2	B3	R1	R2	R3
Sep-18	0.343	0.247	0.163	0.096	0.066	0.084
Oct-18	0.033	0.044	0.015	0.5596	0.187	0.1615
Nov-18	0.032	0.043	0.014	0.5597	0.1943	0.157
Dec-18	0.026	0.032	0.026	0.475	0.3621	0.166
Jan-19	0.021	0.026	0.045	0.3797	0.321	0.2076
Feb-19	0.132	0.114	0.093	0.233	0.2458	0.1822
Mar-19	0.121	0.126	0.086	0.225	0.257	0.1623
Apr-19	0.1195	0.146	0.106	0.212	0.288	0.128
May-19	0.087	0.409	0.1	0.1696	0.1	0.135
Jun-19	0.023	0.024	0.024	0.185	0.276	0.468
Jul-19	0.225	0.258	0.167	0.425	0.516	0.473
Aug-19	0.287	0.213	0.198	0.342	0.246	0.313

Table 65. Shannon-Wiener Diversity Index (2019-20) for phytoplankton

2019-2020	B1	B2	B3	R1	R2	R3
Sep-19	0.143	0.1143	0.076	0.263	0.2	0.203
Oct-19	0.0798	0.0723	0.0898	0.2219	0.2469	0.2893
Nov-19	0.144	0.135	0.1034	0.322	0.121	0.175
Dec-19	0.1263	0.118	0.0856	0.487	0.234	0.191
Jan-20	0.1174	0.136	0.0631	0.516	0.533	0.412
Feb-20	0.031	0.042	0.021	0.232	0.211	0.194
Mar-20	0.028	0.022	0.017	0.187	0.172	0.161
Apr-20	0.105	0.112	0.107	0.174	0.214	0.112
May-20	0.077	0.084	0.098	0.145	0.137	0.122
Jun-20	0.035	0.038	0.041	0.164	0.264	0.158
Jul-20	0.312	0.289	0.309	0.536	0.548	0.492
Aug-20	0.271	0.163	0.213	0.412	0.315	0.354

Jaccard Index

Bakkhali River (Station B1, B2, B3)

Jaccard index is also called Jaccard Similarity Coefficient index. It is a measure of similarity for the two sets of data with a range from 0%-100%. The Jaccard Index shows that all the stations of Bakkhali River (B1, B2, B3) are highest 7.62% similar in September 2019 and their intersecting members are 8. In Jaccard index, it indicates that higher the percentage, the more similar are the stations. It equivalences members for two sets to see which members are shared and which are distinct. So, the Bakkhali River showed more similarities in September 2019 throughout the two years of investigation (Table 66).

Table 66. Jaccard index for phytoplankton analysis for Bakkhali River.

2018-2019	Number of intersecting species	Jaccard coefficient (%)	2019-2020	Number of intersecting species	Jaccard coefficient (%)
Sep-18	7	5.6%	Sep-19	8	7.62%
Oct-18	2	4.1%	Oct-19	7	7.2%
Nov-18	3	4.6%	Nov-19	2	4.3%
Dec-18	2	2.6%	Dec-19	3	4.6%
Jan-19	4	5.3%	Jan-20	9	5.7%
Feb-19	5	6.25%	Feb-20	7	4.8%
Mar-19	5	5.95%	Mar-20	5	5.1%
Apr-19	4	2.9%	Apr-20	5	5.2%
May-19	4	5.4%	May-20	4	4.7%
Jun-19	5	6.2%	Jun-20	5	6.4%
Jul-19	4	4.12%	Jul-20	4	5.9%
Aug-19	5	6.4%	Aug-20	5	5.3%

Reju canal (Station R1, R2, R3)

The Jaccard Index shows that among two years of study all the stations of Reju canal (R1, R2, R3) are highest 9.3% similar in January 2020 and their intersecting members are 8. In Jaccard index, it indicates the higher the percentage, the more similar are the stations. It equivalences members for two sets to see which members are shared and which are distinct. So, the Reju canal showed more similarities in January 2020 throughout the two years of investigation (Table 67).

Table 67. Jaccard index for phytoplankton analysis for Reju canal.

2018-2019	Number of intersecting species	Jaccard coefficient (%)	2019-2020	Number of intersecting species	Jaccard coefficient (%)
Sep-18	4	4.9%	Sep-19	8	3.8%
Oct-18	8	1.6%	Oct-19	6	1.97%
Nov-18	8	1.57%	Nov-19	7	3.3%
Dec-18	12	1.6%	Dec-19	6	7.7%
Jan-19	7	4.5%	Jan-20	8	9.3%
Feb-19	8	4.9%	Feb-20	4	7.7%
Mar-19	10	5.4%	Mar-20	4	5.97%
Apr-19	9	6.3%	Apr-20	5	5.88%
May-19	4	4.3%	May-20	4	4.1%
Jun-19	9	1.04%	Jun-20	6	5.6%
Jul-19	7	1.35%	Jul-20	9	1.1%
Aug-19	9	1.85%	Aug-20	10	1.3%

Month wise PD Boxplot Graph

The graph describes the month wise minimum and maximum values, Inter Quartile Range (IQR) and outliers of phytoplankton density (PD). From the figure, we can say in the month of October, November, December, January, April and May have outliers. Maximum range of phytoplankton density (PD) is shown in the month of June and July. So, maximum diversity also found in these two months (Fig.44).

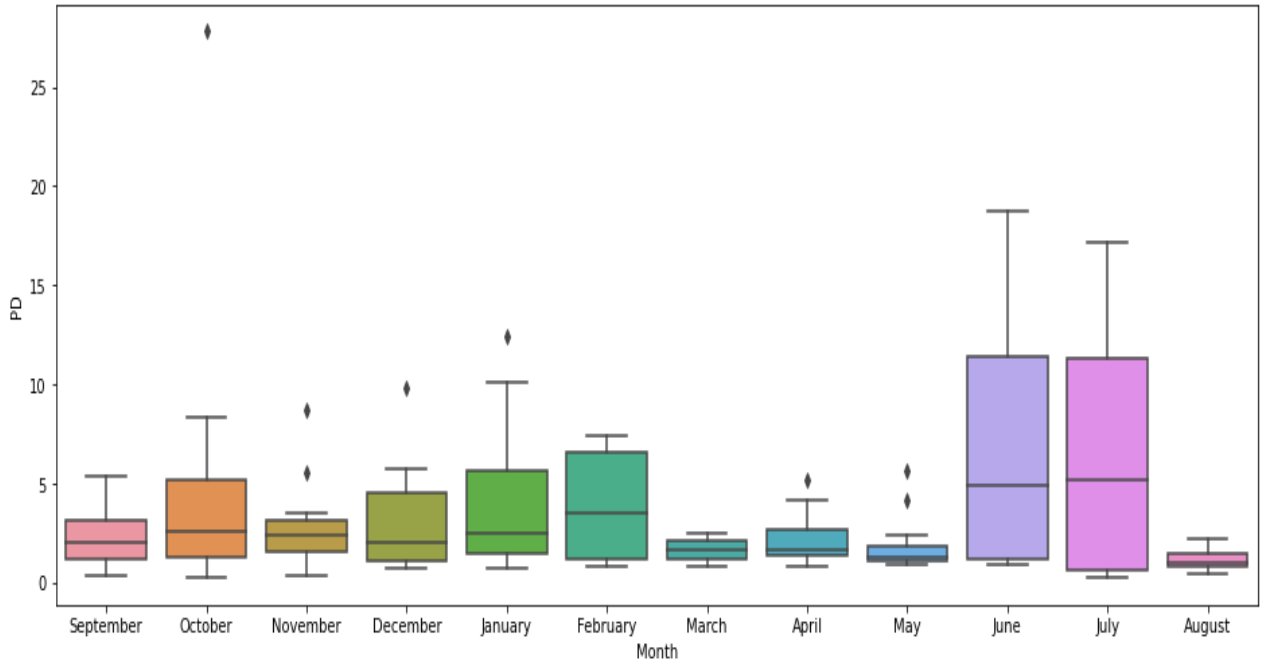


Fig. 44. Month wise Phytoplankton density (PD) Boxplot Graph.

Station wise PD Boxplot Graph

The graph describes the station wise minimum and maximum values, Inter Quartile Range (IQR) and outliers of Phytoplankton density (PD). From the figure, we can say that PD is high in R1, R2, R3 than the B1, B2, B3 station. From the figure, we can say in B2, R1 and R3 stations have outliers and station R2 rich in diversity (Fig.45).

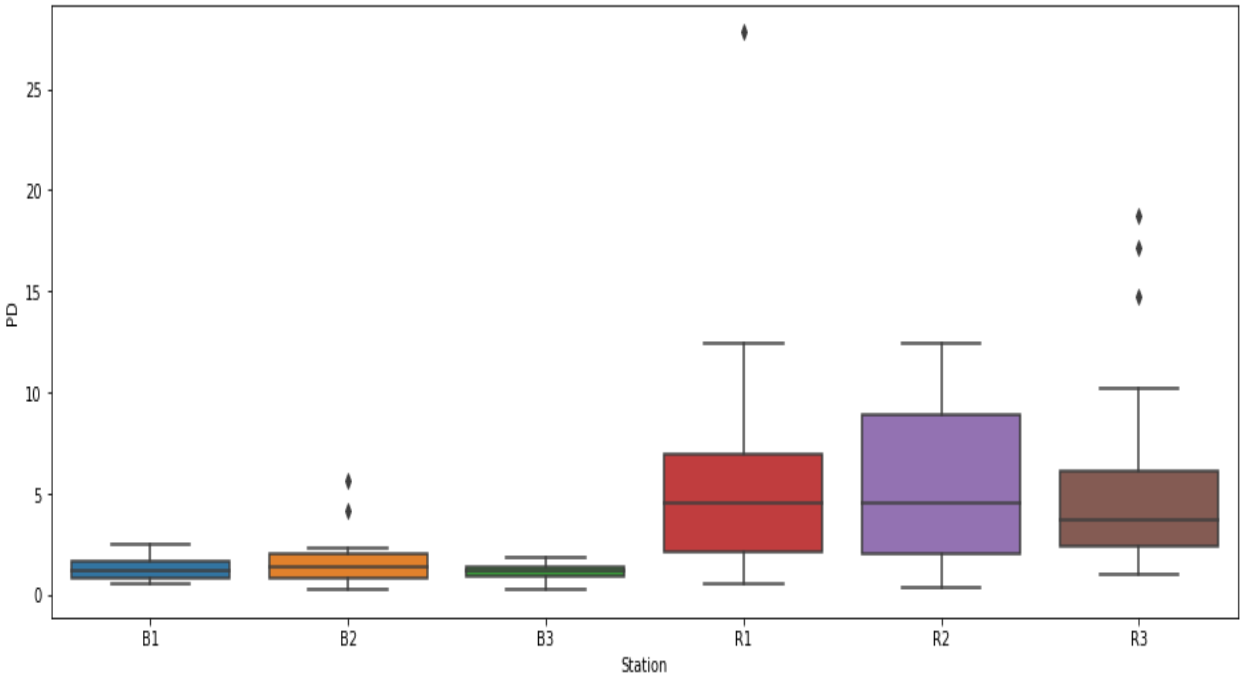


Fig. 45. Station wise Phytoplankton density (PD) Boxplot Graph.

Simple linear regression between Phaeopigments and PD

This is the simple linear regression between phaeopigments and PD. Where phaeopigments is an independent variable and PD is dependent variable. The straight line represents the regression line. In this figure we can also see the distribution of those parameters. In the right-hand side, we can see the distribution of phaeopigments and in the above part is PDs' distribution (Fig.46).

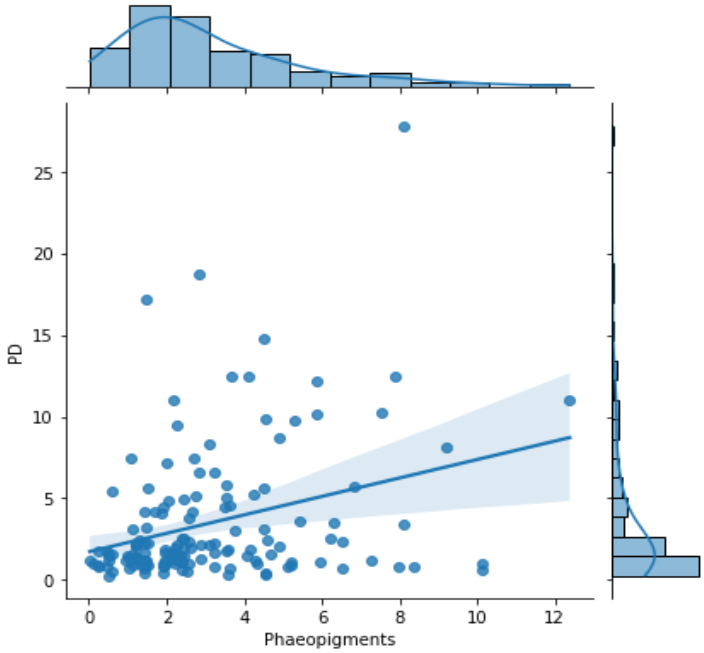


Fig.46**.** Linear regression between Phaeopigments and PD.

Simple linear regression between chl-a and phytoplankton density (PD)

This is the simple linear regression between chl-a and PD. Where chl-a is an independent variable and PD is dependent variable. The straight line represents the regression line. In this figure we can also see the distribution of chl-a in the above part, and in the right-hand side is PDs' distribution (Fig. 47).

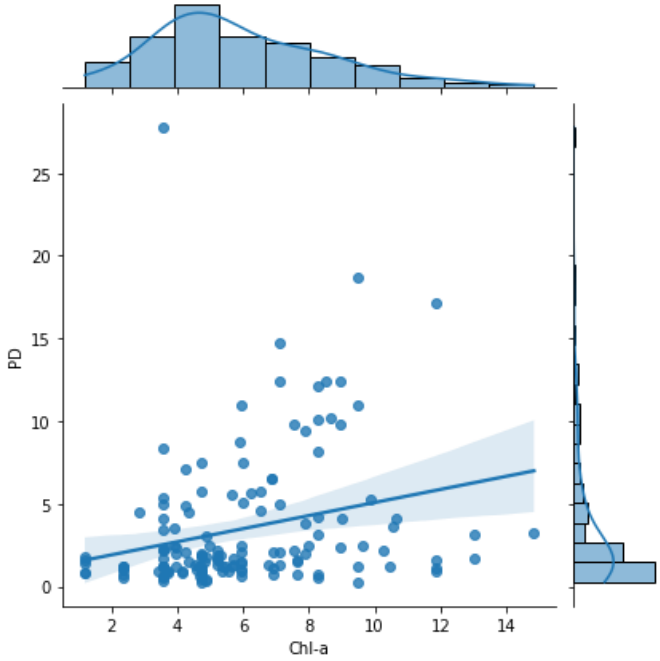


Fig. 47. Linear regression between Chl-a and Phytoplankton density (PD).

Simple linear regression between NO_3-N and Phytoplankton density (PD)

This is the simple linear regression between NO_3-N and PD. Where NO_3-N is an independent variable and PD is dependent variable. The straight line represents the regression line. In this figure we can also see the distribution of NO_3-N in the above part, and in the right-hand side is PDs' distribution (Fig. 48).

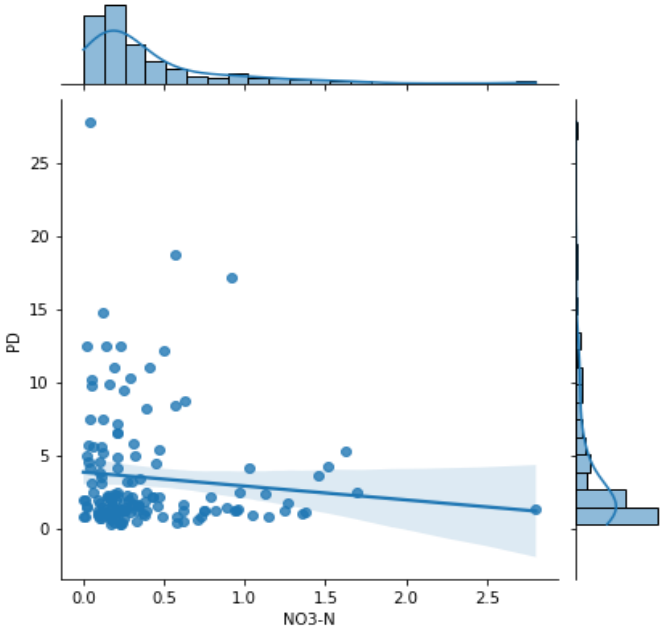


Fig. 48. Linear regression between NO_3-N and Phytoplankton density (PD).

Simple linear regression between Secchi depth (SD) and phytoplankton density (PD)

This is the simple linear regression between SD and PD. Where SD is an independent variable and PD is dependent variable. The straight line represents the regression line. In this figure we can also see the distribution of SD in the above part, and in the right-hand side is PDs' distribution (Fig. 49).

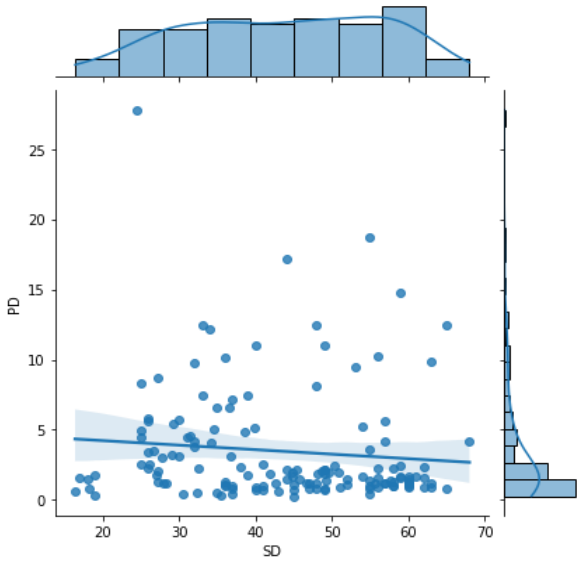


Fig. 49. Linear regression between Secchi depth (SD) and Phytoplankton density (PD).

Simple linear regression between water temperature (WT) and PD

This is the simple linear regression between WT and PD. Where WT is an independent variable and PD is dependent variable. The straight line represents the regression line. In this figure we can also see the distribution of WT in the above part, and in the right-hand side is PDs' distribution (Fig. 50).

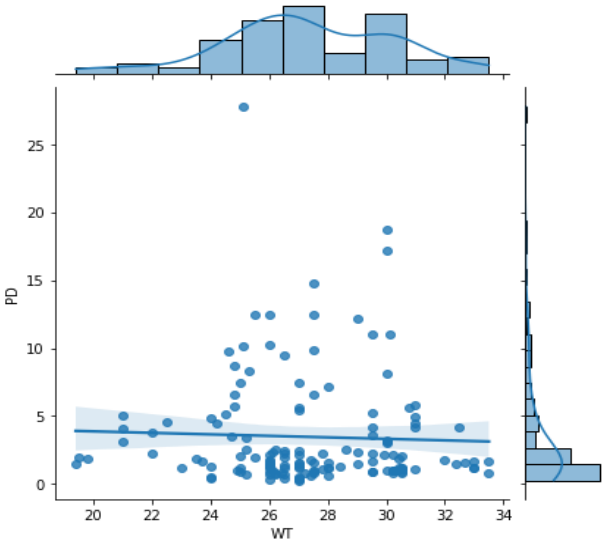


Fig. 50. Linear regression between Water temperature (WT) and Phytoplankton density (PD).

Simple linear regression between air temperature (AT) and PD

This is the simple linear regression between AT and PD. Where AT is an independent variable and PD is dependent variable. The straight line represents the regression line. In this figure we can also see the distribution of AT in the above part, and in the right-hand side is PDs' distribution (Fig. 51).

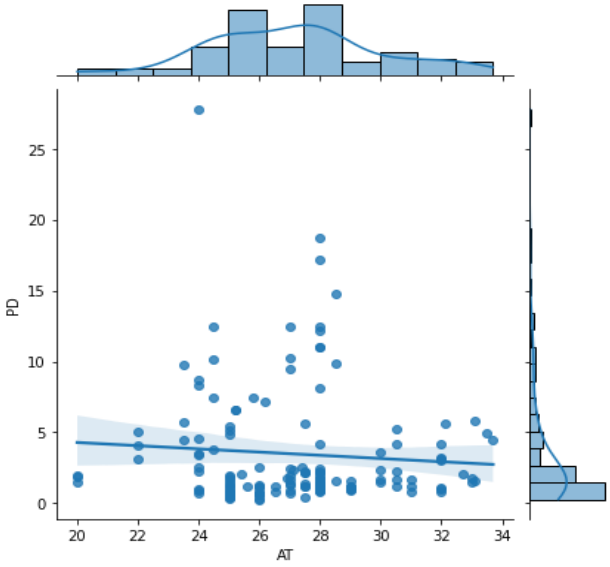


Fig. 51. Linear regression between Air temperature (AT) and Phytoplankton density (PD).

Simple linear regression between salinity and PD

This is the simple linear regression between Salinity and PD. Where Salinity is an independent variable and PD is dependent variable. The straight line represents the regression line. In this figure we can also see the distribution of Salinity in the above part, and in the right-hand side is PDs' distribution (Fig. 52).

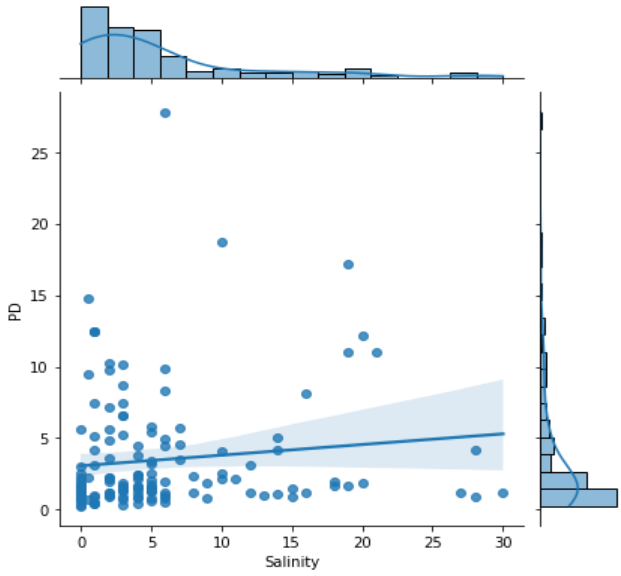


Fig. 52. Linear regression between Salinity and Phytoplankton density (PD).

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

It is experimentaly proved that diatom taxa have sensitivities to decrease of environmental condition. So, a measurement of the health of the particular environment can be diagnosed by using diatom communities of that ecosystem (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, Tables 68-69).

Methodology

$$WMS = \sum asv \div \sum av$$

$$\text{Trophic diatom index (TDI)} = (WMS \times 25) - 25$$

Here, a = total counts of diatom species

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

V= indicator values

Table 68. Showing pollution status of wetlands of Cox's Bazar District, through TDI (Trophic diatom index), contd. Data sheet.

No	*Taxon*	*Count(a)*	*Sensitivities(s)*	*Indicator values (v)*	*asv*	*av*
1	*Achnanthes ploenensis*	6	4	2	48	12
2	*Achnenthes (others)*	6	3	1	18	6
3	*Amphora pediculus*	5	5	1	50	5
4	*Asterionella*	4	0	0	0	0
5	*Aulacosira*	1	0	0	0	0
6	*Chaetoceros*	24	0	0	0	0
7	*Cocconeis placentula*	6	3	1	36	6
8	*Cyclotella*	4	0	0	0	0
9	*Cymbella delicatula*	8	2	1	48	8
10	*Cymbella microcephala*	7	2	1	28	7
11	*Cymbella (large forms)*	7	4	2	56	14
12	*Cyclotella* other	4	2	1	8	4
13	*Diatoma tenue*	6	5	2	60	12
14	*Diploneis*	1	4	1	4	1
15	*Epithemia*	1	4	2	8	2
16	*Eunotia alpina*	4	3	1	12	4
17	*Eunotia lunaris*	4	2	1	8	4
18	*Eunotia monodon*	2	4	1	8	2
19	*Fragilaria brevistriata*	2	2	2	8	4
20	*Fragilaria brevistriata*	2	2	2	8	4
21	*Fragilaria crotonensis*	4	2	0	0	0
22	*Frustulia*	2	1	2	4	4
23	*Gomphoneis*	2	3	1	6	2
24	*Gomphonema minutum*	6	4	2	48	12

Trophic diatom index (contd.)

25	*Gyrosigma*	8	5	2	80	16
26	*Hantzschia*	3	5	1	15	3
27	*Melosira varians*	4	4	2	32	8
28	*Navicula capitoradiata*	5	3	1	30	10
29	*Navicula tripunctata*	3	4	2	24	6
30	*Nitzschia acicularis*	4	4	2	32	8
31	*Pinnularia*	5	2	1	30	5
32	*Pseudostraurosira brevistriata*	2	5	1	10	2
33	*Rhizosolenia*	10	0	0	0	0
34	*Skeletonema*	4	0	0	0	0
35	*Synedra ulna*	5	4	1	20	5
36	*Synedra* other sp	6	4	1	24	6
37	*Tabelaria*	2	4	1	24	2
38	*Urosolenia*	4	0	0	0	0

Calculation of TDI

Total counts (a) = 179

Sum of asv = 787

Sum of av = 182

Trophic diatom index (TDI) was calculated from,

WMS = ∑asv÷∑av = 787÷182 =4.324

So, Trophic diatom index (TDI) = (WMS*25)-25= (4.324*25)-25=83.1

Table. 69 Water quality index classification according to National Sanitation Foundation Water Quality Index (NSF-WQI) (Brown *el al*. 1970).

Water Quality	Index
Excellent	91-100
Good	71-90
Medium	51-70
Unsuitable	26-50
Very Unsuitable	0-25

The TDI index showed the the water quality of the wetlands is fairly good.

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

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

chl-a concentration is higher in pre-monsoon and lower in post-monsoon. SRS and NO_3-N concentration give a linear line relation with chl-a. In case of SRP concentration, it does not maintain any linear relation with them. SRP value is very high among them. (Fig. 53).

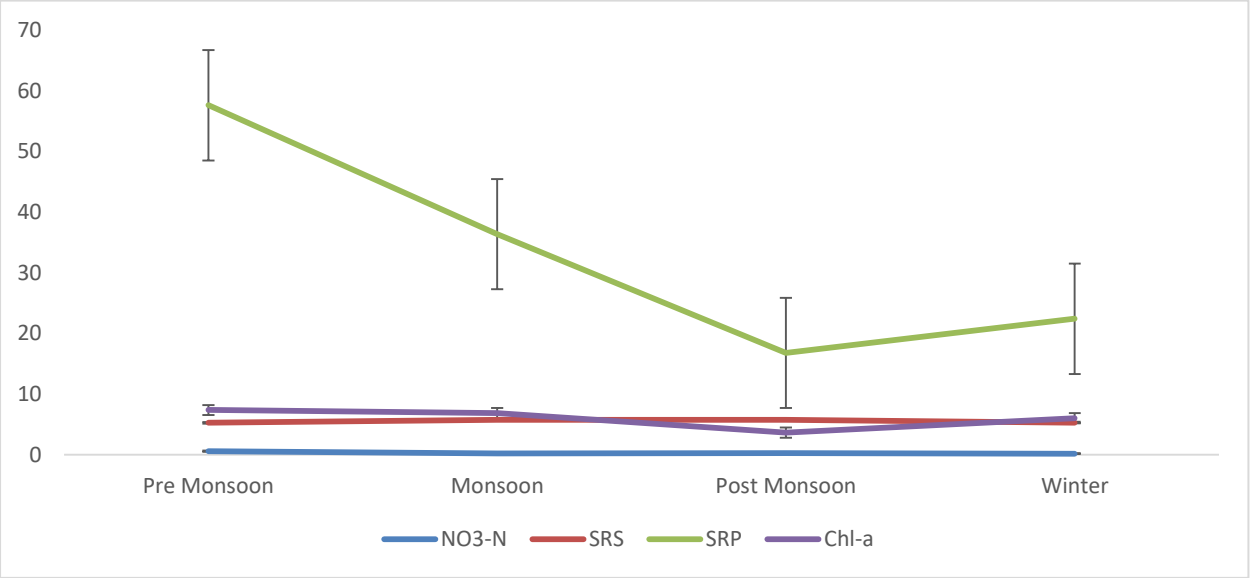


Fig. 53. Relationships among nutrient concentrations with Chl-a.

Effect of Physical variables on phytoplankton biomass as chl-a.

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 Secchi depth and all others value showed a positive relation with each other. (Fig.54)

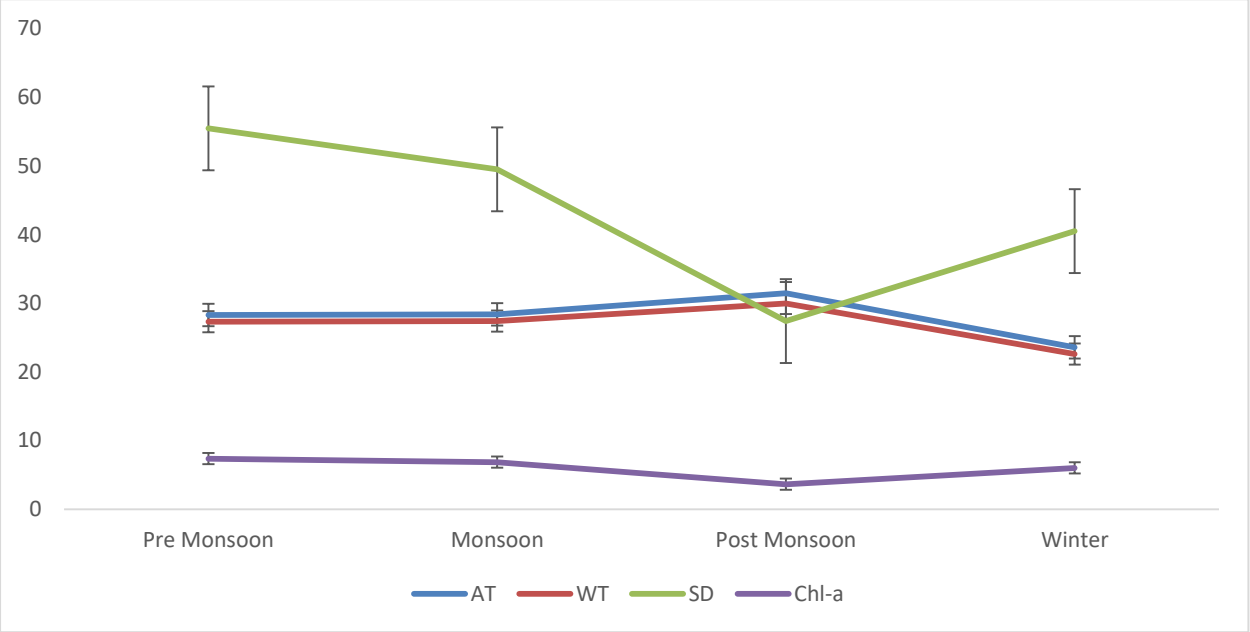


Fig. 54. Showing the comparison among physical variables with Chl-a

Effects of chemical variables on phytoplankton biomass as Chl-a:

Chl-a, DO and TDS showed almost similar trend from pre monsoon to winter and did not show any such type of trend. They showed a linear relation to each other. Conductivity remained higher in respect of the other chemical parameters throughout the year. (Fig.55)

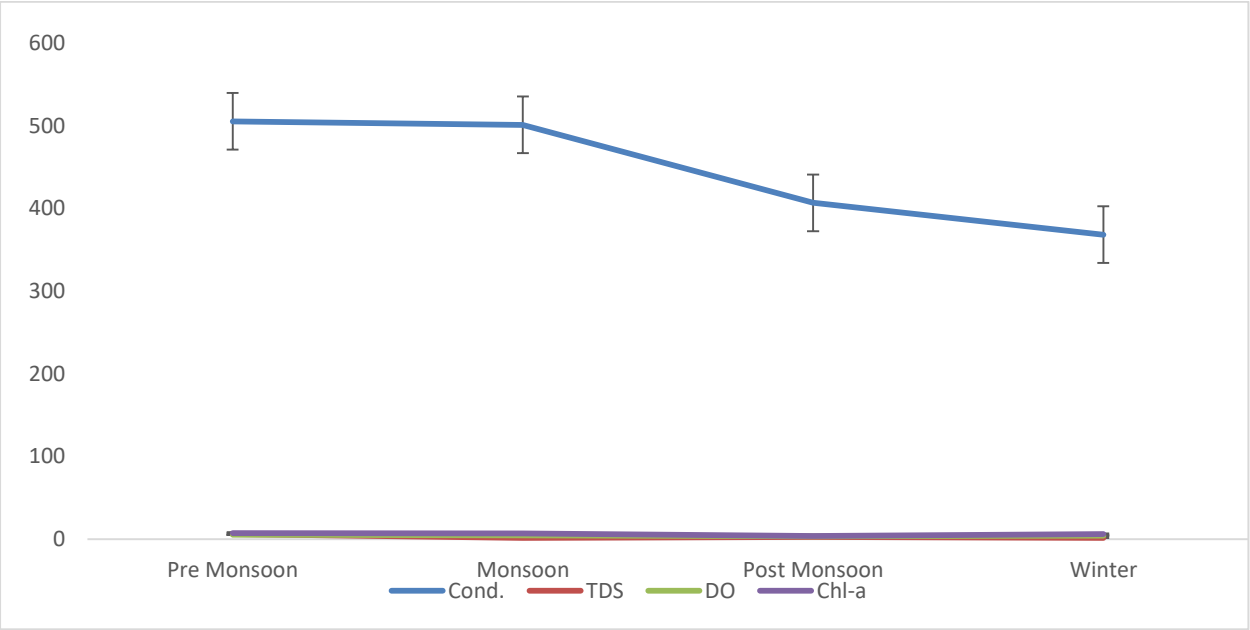


Fig. 55. Showing the comparison among chemical variables with Chl-a

Effect of biological variables on phytoplankton biomass as chl-a:

Phaeopigment is the function of chl-a. The graph shows that there is a positive relation among these three biological variables, chl-a value decreased in post monsoon (Fig. 56).

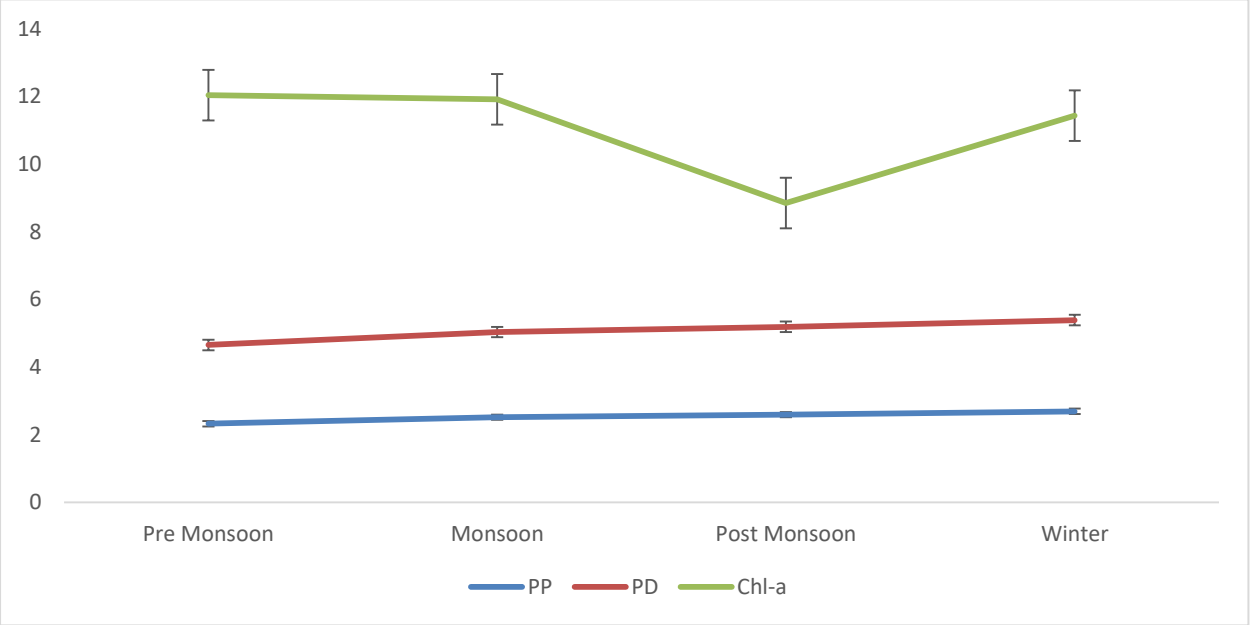


Fig. 56. Showing the comparison among biological variables with Chl-a.

Proposed Decision Tree model:

This is a machine learning data model where we can see conductivity is the major element for the growth and distribution of phytoplankton. The other parameters namely SD, Alkalinity, Chl-a are also the key elements for algal growth. These 3 parameters are closely related with conductivity at different concentration. (Fig. 57).

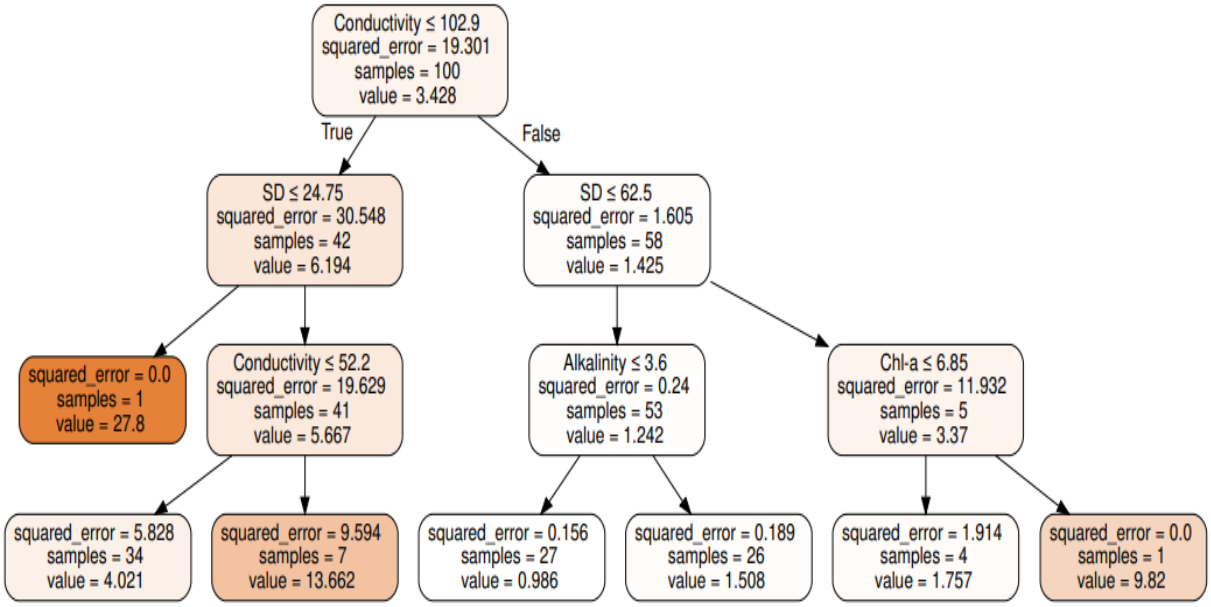


Fig. 57. Machine learning data model where key element influence the growth and distribution of phytoplankton.

Machine Learning models' performance to predict PD:

Here we used three advanced machine learning model named Random Forest, Support Vector Machine (SVM) with two different kernels (Random Basis Function and Polynomial Function) to predict the PD using all others variables.

SL NO	model	mean squared error	mean absolute error	max error
1	random_forest	16.658681	2.308959	14.214760
2	support_vector_rbf	24.852751	2.636241	15.802575
3	support_vector_poly	27.876774	2.788022	16.552725

Here in this graph blue color line represents the actual PD, orange one represents the random forest, green represent the SVM with RBF kernel and finally red represent SVM with polynomial function. Among the three-machine learning model we can see random forest works better as it shows the lower error. (Fig. 58).

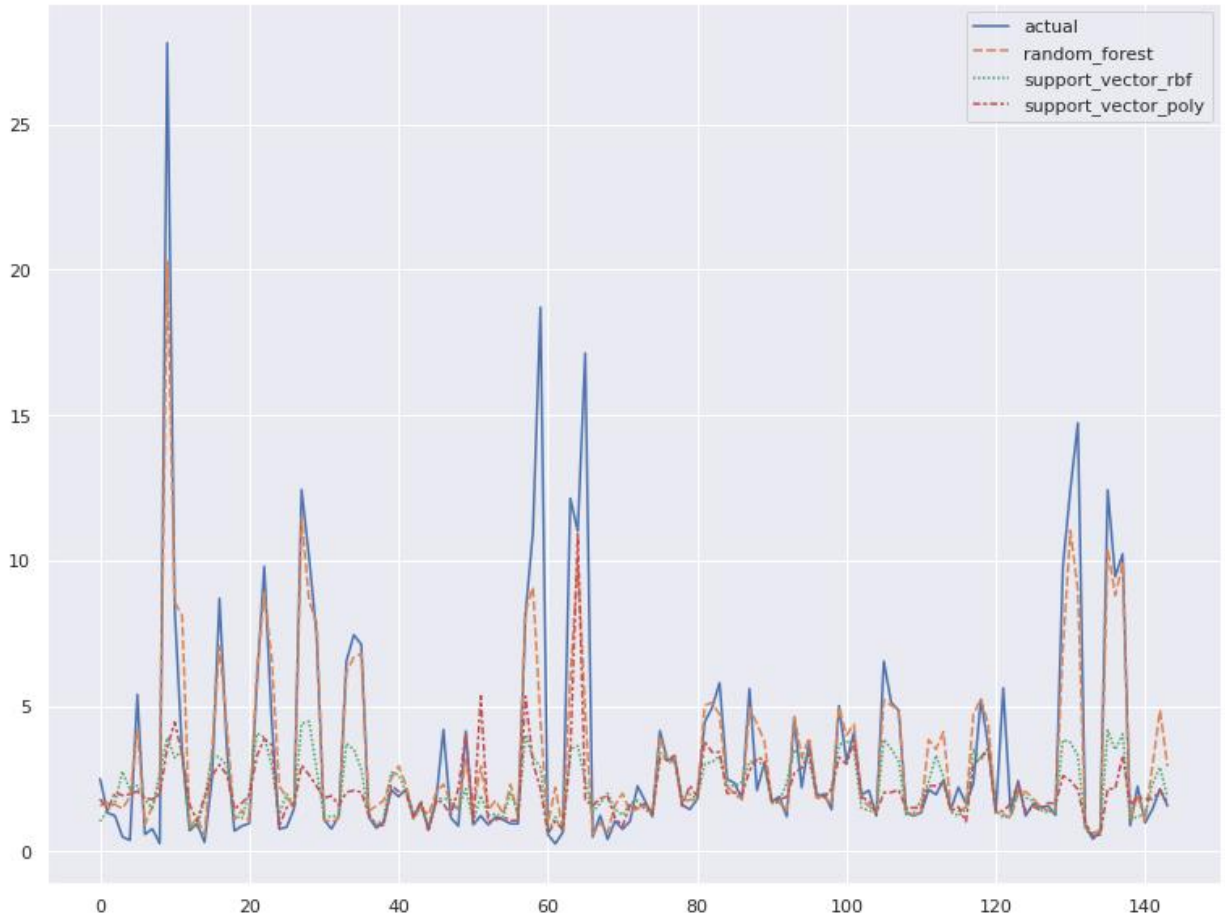


Fig.58. Showing data fitted perfectly in Random Forest model.

Comparative analysis of the results with other running water ecosystems

Results from the physicochemical and biological water quality data from the present study have been compared with those carried out eslwhere and the information have been provided in Tables 70-74.

Table 70. Comparison showing of air and water temperature, Secchi depth, chl-a and phaeopigment concentrations from different river waters.

Rivers	Air temp. °C	Water temp. °C	Secchi depth cm	Chl-a µg/L	Phaeopigment µg/L	Reference
Bakkhali	20-33.10	19.4-33.5	16.4-68.0	1.18-11.84	0.024-10.11	Present study
Reju canal	22-33.70	19.8-33.0	16.4-65.0	2.37-14.84	0.21-12.38	Present study
Meghna	-	20-31	20-140	-	-	Shafi *et al.* (1978)
Halda	23-33	20-32	13-29	-	-	Patra and Azadi (1987)
Buriganga BCMB-II	-	20-32	17-95	2-142	0.1-43	Zerin (1995)
Turag	-	20-32	20-50	1-163	0.1-37	Abed (1995)
Sitalakkhya	-	21-32	<25-<55	-	-	DOE (1993)
Buriganga ST (1-3)	15-35	20-34	11-83	2-160	0-334	Islam *et al.* (2006)

Table 71. Comparison showing the ranges of pH, alkalinity, conductivity and total dissolved solids from different river waters.

Rivers	pH	Alkalinity meq/L	Conductivity µS/cm	TDS mg/L	Reference
Bakkhali	7.2-8.8	0.7-4.9	114-2650 mS/cm	0.052-19.90 g/l	Present study
Reju canal	7.2-8.8	0.8-4.9	0.98-258.0 mS/cm	0.08-19.9 g/l	Present study (2018-2020)
Halda	6.6-7.6	-	52-148	-	Patra and Azadi (1987)
Hazaribagh	6.3-6.6	1.4-3.5	-	160-290	DOE (1993)
Chandni Ghat	6.0-7.0	1.8-3.6	-	85-266	DOE (1993)
Balu	7.2-7.3	-	244-335	170-248	DOE (1993)
Sitalakhya	7.3-7.6	-	117-333	117-196	DOE (1993)
Karnaphuli	6.2-7.8	-	-	-	DOE (1993)
Turag	6.6-8.2	1.0-5.4	100-890	-	Abed (1995)
Buriganga BCMB-II	6.8-8.1	1.0-4.9	110-640	-	Zerin (1995)
Buriganga ST 1-3	6.6-6.9	1-7.6	115-940	45-467	Islam *et al*. (2006)

Table 72. Comparison of dissolved oxygen (DO) and nutrient parameters of different river waters.

Rivers	SRS mg/L	SRP µg/L	NO_3-N mg/L	DO mg/L	Reference
Bakkhali	1.13-14.388	6.33-242.4	0.00-2.81	1.6-9.8	Present study
Reju canal	1.55-7.91	0.86-196.9	0.017-1.622	1.5-7.9	Present study
Meghna	-	-	-	6.5-10.5	Shafi *et al.* (1978)
Buriganga BCMB-II	3-38	38-508	0.4-10.9	0.3-12.8	Zerin (1995)
Turag	3-38	30-797	0.3-9.0	0.5-13.3	Abed (1995)
Sitalakhya	-	-	-	6.4-6.8	"
Titas	3-24	1-10	4.7-5.6	-	Talukdar *et al.* (1994)
Gumti	-	-	9-12.5	-	"
Havatia	-	-	-	8-11	"
Buriganga ST 1-3	2-76	28-1584	0-2.5	0-9.4	Islam *et al.* (2006)

Table 73. Comparison of qualitative and quantitative estimation of phytoplankton in different river waters.

Rivers	No. of genera	No. of species	Dominant class	Density $\times 10^3$ ind/L	Reference
Bakkhali	33	215	Bacillariophyceae (16.13-45.16%)	$0.27\text{-}5.62\times 10^6$	Present study
Reju canal	52	386	Bacillariophyceae (21-54%)	$0.504\text{-}27.8\times 10^6$	Present study (2018-2020)
Buriganga	-	-	-	.32-25000	Islam *et al*. (1974)
Buriganga	72	194	Chlorophyceae (56%)	-	Islam and Zaman (1975)
Shatt-al-Arab	6	107	Diatom (75%)	500-4400	Huq *et al*. (1978)
Ganges, India	19	125	Chlorophyceae		Siddiqui *et al*. (1980)
Nile, Egypt	64	141	Chlorophyceae	4800-10000	Ahmed *et al*. (1986)
Buriganga BCMB-II	28		Cyanophyceae (33%)	1-2130	Zerin (1995)
Mouri, Khulna	26	56	Chlorophyceae (50%)	.082-1.630	Mahmud *et al*. (2007)
Buriganga ST 1-3	60-65	82-108	Chlorophyceae (36-41%)	1-250	Islam *et al*. (2006)

From the comparison, marked differences among the physicochemical and biological water quality variables were seen. The water temperature maxima of the presently studied two rivers were seen higher but comparable with some polluted rivers of Dhaka area (Buriganga, Sitalakhsya, Turag). Similar was with the transparency values, *i.e*., the upper maxia in the ranges are quite comparable with the rivers of Dhaka area. But the phytoplankton biomass as chl-a was higher in the rivers of Dhaka (Table 70). pH, alkalinity and salinity all were higher in the Bakkhali River and Reju Canal (Table 71). The studied habitats support low DO but with higher to moderate loading of nutrients (Table 72). The phytoplankton species composition shows a higher species number predominantly with the members of Bacilariophyta compared to all other studied running water habitats of Bangladesh (Table 73).

Chapter-5

DISCUSSION

The present research work has been undertaken to increase the awareness among public regarding the deterioration of water quality of the rivers, particularly in a heavily touristic zone Cox's Bazar, Bangladesh. Water quality of rivers and channels in the coastal area serves as an important factor for tourists and also the surrounding areas as well as support the life of wetland population. The Bakkhali River and Reju Canal maintain the flow of entire watershed area of Cox's Bazar. Nowadays the studied wetlands are affected with different sources of pollution. So, it is important to protect this zone for not only ecological reasons but also for a sustainable functioning of tourist industry and to maintain the ecological health of the two wetland habitats.

In the present research, a two-year (24 months) study on the assessment of the water quality of Bakkhali River and Reju Canal, Cox's Bazar has created an accumulation of field data on their water quality. Data on phytoplankton quality and quantity, biomass as chl-a, degraded product phaeopigment, air and water temperature, Secchi depth, pH, conductivity, salinity, alkalinity, DO, TDS, SRS, NO_3-N and SRP were analyzed on the basis of their courses on annual and seasosnal dynamics. The results, thus obtained are henceforth discussed in the light of identical researches carried out elsewhere. In addition, a comparative study on different parameters of river ecosystems of Bangladesh was obtained by consulting available literature (Tables 70-73).

The annual range of different measured water quality variables for two years in Bakkhali River has revealed: air temperature 20.0-33.1 ºC; water temperature 19.4-33.5 ºC; Secchi depth 16.4-68 cm; salinity 0-28 ppm; TDS 0.052-19.9 g/l; conductivity 114-2650 mScm-¹; dissolved oxygen 1.6-9.8 mg/l; pH 7.2-8.8; alkalinity 0.7-4.9 meq/l; NO_3-N 0.00-2.81 mg/l; SRP 6.33-142.4 µg/l; SRS 1.13-14.388 mg/l; chl-a 1.18-11.84 µg/l; phaeopigments 0.024-10.11 µg/l and phytoplankton density 0.27-5.62 $\times 10^6$ ind/l.

In the Reju Canal study, the water quality parameters ranged: air temperature 22.0-33.7 ºC; water temperature 21-33 ºC; Secchi depth 24.5-65 cm; salinity 0-30 ppm; TDS 0.08-19.9 g/l; conductivity 0.98-258 mScm-¹; dissolved oxygen 1.5-7.9 mg/l; pH 7.2-8.8; alkalinity 0.8-4.9 meq/l; NO3-N 0.0174-1.622 mg/l; SRP 0.862-196.9 µg/l; SRS 1.55-7.91 mg/l; chl-a 2.37-14.84 µg/l; phaeopigments 0.21-12.38 µg/l and phytoplankton density 0.39-27.8 $\times 10^6$ ind/l.

In a nearby river of Cox's Bazar area Halda, Zaman (1991) showed the annual mean values of air temperature from 21.8-30.3°C, while the annual range was 23.0-33.0°C. The ranges of water temperature were 20-34°C. Abed (1995) recorded 20-32°C from the river Turag. DOE (1993) reported 21-32°C from the river Sitalakhya, 20-31°C from the river Meghna. Considering ranges of water temperature, it has been found that the temperature ranges of the present study have similarity with that of Halda but not with the rivers of greater Dhaka district regions (Abed 1995, DOE 1993). The reason might be that the currently studied habitats are closer to maritime. Shafi *et al*. (1978) recorded Secchi depth at a range of 20-140 cm in Meghna River. But in the present study, the ranges showed by Bakkhali river, and Reju canal were 16.4-68 and 24.5-65 cm, respectively. The maximum transparency of Meghna River is ~ 2-fold higher compared to the mean maximum transparency of Bakkhali river and Reju canal ecosystems. It indicates a higher loading of particles in the studied rivers. The effect of tides as well as release of wastewater into the river systems might have caused this turbidity of water.

Some truly freshwater parts of rivers studied in Bangladesh, show physicochemical and biological characteristics in a different manner compared to those of present in estuarine habitats. The recorded chlorophyll value by Abed (1995) was 1-163 µg/l from the river Turag and Zerin (1995) recorded 2-142 µg/l from the river Buriganga. Abed (1995) reported the phaeopigment concentration 0.1-37 µg/L from the river Turag and Zerin (1995) reported 0.1-43 µg/L from the river Buriganga.The recorded value of conductivity by Zerin (1995) in Buriganga and in river Turag by Abed (1995) were 110-640 µS/cm and 100-890 µS/cm, respectively. Zerin (1995) had recorded a range of pH 6.8-8.1 she also reported the range of TDS values from 160-290 mg/l. A lower ranges of TDS value were also reported as 170-248 mg/l, 117-196 mg/l for Balu and Sitalakhya rivers, respectively (DOE 1993). DOE (1993) was also reported 85-266 mg/l at Chadni Ghat of the river Buriganga. Zerin (1995) recorded SRS values ranges from 3-38 mg/l. The NO_3-N value was recorded 0.4-10.9 mg/l in Buriganga by Zerin (1995) and 0.3-9.0 mg/l in Turag by Abed 1995. The NO_3-N value of Titas and Gumti showed a range of 4.7-5.6 mg/l and 9.0-12.5 mg/l (Talukder *et al*. 1993). Zerin (1995) recorded SRP at range of 38-508 µg/l. Turag and Titas showed a range of 30-797 µg/l, 1-10 µg/l, respectively. Zerin (1995) recorded DO at a range of 0.3-12.8 mg/l. Turag, Sitalakhya, Havatia and Meghna showed a range of dissolved oxygen as 0.5-13.3 mg/l, 6.4-6.8 mg/l, 8-11 mg/l, 6.5-10.5 mg/l, respectively. In river Turag the concentration of

chl-a ranged from 1-163 µg/l by Abed 1995. Abed (1995) also recorded the phaeopigment concentration 0.1-37.0 µg/l in river Turag.

In the present investigation a total of 144 phytoplankton samples were collected from two coastal river of Cox's Bazar, Bangladesh. All these samples were studied for qualitative and quantitative aspects. In the present investigation 112 genera were represented in the phytoplankton from all the six stations was identified which belonged to six divisions (Cyanophyta, Chlorophyta, Euglenophyta, Bacillariophyta, Pyrrophyta and Cryptophyta, Table 17). Islam and Zaman (1975) were also recorded 194 species from Buriganga.

Genus level percentage composition shows that Bacillariophyta dominates in all the stations and occupied 10 (16.13%), 16 (25.8%), 14 (22.58%), 28 (45.16%), 24 (38.7%) and 18 (29.03%) for Station B1, B2, B3, R1, R2 and R3, respectively, followed by Chlorophyta 4 (6.5%), 5 (8.06%), 3 (4.8%), 14 (22.58%), 15 (24.2%) and 12 (19.35%) for Station B1, B2, B3, R1, R2 and R3, respectively, Euglenophyta 2 (3.2%), 1 (1.6%), 1 (1.6%), 4 (6.5%), 3 (4.8%) and 5 (8.06%) for Station B1, B2, B3, R1, R2 and R3, respectively, Cyanophyta 2 ((3.2%), 1 (1.6%), 2 (3.2%), 3 (4.8%), 4 (6.5%), 3 (4.8%) for Station B1, B2, B3, R1, R2 and R3, respectively, Pyrrophyta 1 (1.6%), 2 ((3.2%), 1 (1.6%), 0, 1 (1.6%), 1 (1.6%) for Station B1, B2, B3, R1, R2 and R3, respectively; Cryptophyta 0, 0, 0, 1 (1.6%), 1 (1.6%), 1 (1.6%) for Station B1, B2, B3, R1, R2 and R3, respectively and Cryptophyta can be treated as a minor group for all the stations (Table 17). Islam and Zaman (1975) reported Chlorophyceae occupied nearly 56% of the total population in Buriganga. They also recorded the Chlorophyceae was represented mostly by desmids. A total of 54 species of desmids were recorded by Islam and Zaman (1975). Zerin (1995) reported 28 genera of phytoplankton under five classes from a station of Buriganga and the percentage composition was Cyanophyceae 33%, Bacillariophyceae 27%, Chlorophyceae 23%, Euglenophyceae 11% and Cryptophyceae 5%. In this study of Zerin (1995) showed that Cyanophyceae occupied highest in number of phytoplankton genera in contrast to the present investigation it was Bacillariophyceae.

At the species level, 402 species from different classes were recorded from all the stations. Maximum percentage of species (53.24% in Station R3) found in the division Bacillariophyta but in total count maximum number (101) was recorded in station R2 and the minimum number of species (0 % in Station B1, B2, B3) was recorded from the division Cryptophyta and station R1 from the division Pyrrophyta. Bacillariophyta was dominant

followed by Chlorophyta, Euglenophyta, Cyanophyta, Pyrrophyta and Cryptophyta (Table 18). During the study period, the ranges of density of phytoplankton (PD) were 0.5-2.5×10^6, 0.27-5.62×10^6, 0.28-1.8×10^6, 0.504-27.8×10^6, 0.39-12.46×10^6, and 1.04-18.71×10^6 ind./l for Station B1, B2, B3, R1, R2 and R3, respectively. The total number of phytoplankton species was recorded in Mouri river Khulna and Ganges were 56, 125, respectively (Mahmud *et al*. 2007, Siddique *et al*. 1980). On the basis of preliminary identification, 48 species of phytoplankton may be considered as new records. The distribution is as follows: dominated by Bacillariophyta (Appendix II).

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 6, the range of air temperature and water temperature is more or less equal for most of the stations (Tables 45-50) but the average air temperature is higher in Station R1 and the lower is found in station B1 and highest mean value of water temperature observed in R1 station whereas the lowest was recorded in B3 station. The average mean value of Secchi depth is higher in station B2 and lower in station R1. Mean values of salinity were depending on high tide and low tide time, but the highest value is recorded in R1 station and lowest is recorded in B3 station. TDS was higher in station R1 and lower in station B3. Conductivity was higher in station B1 and the lower was found in R2. DO was found higher in Stations R1 and lower was recorded in station B3. pH values were higher in station B1 whereas the lowest was in station R1. Range of alkalinity is recorded the higher in the Station B2 and the lower was recorded in R3. The higher value of NO3-N was recorded in Station B2 and lowest was recorded in station B3. Mean concentration of SRP was recorded higher in Station B3 whereas the lowest was found in station R3. SRS value was recorded higher in Station B1, whereas the lowest was found in R1. Phytoplankton biomass as chlorophyll-a was recorded higher in Station R1 and phaeopigment was also found higher in Station R1 than the other stations and also Phytoplankton density was recorded higher in station R1 than the other stations and comparatively lowest was recorded in B1, B2 and B3 station (Table 51). Islam *et al*. (1974) were recorded the total phytoplankton ranges from 0.3-25000 ind/l in the river Buriganga. In summer and monsoon maximum production was recorded on the otherhand minimum production was recorded during autumn and winter. They described that high light intensity covers maximum depth of illuminated area resulting photosynthetic activity increased in phytoplankton, wind and wave causes upwelling of water also influenced the density of phytoplankton. During winter and autumn density of phytoplankton become low

due to minium illuminated light as well as intensity of light, lack of upwelling of the nutrients and organic load.

Chl-a concentration is higher in pre-monsoon and lower in post-monsoon. SRS and NO3-N concentration give a linear line relation with Chl-a. In case of SRP concentration, it does not maintain any linear relation with them. SRP value is very high among them. (Fig. 53). 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 Secchi depth and all others value showed a positive relation with each other (Fig. 54). Chl-a and TDS showed almost similar trend from post monsoon to winter but DO did not show any such type of trend. Conductivity remained higher in respect of the other chemical parameters throughout the year. Phaeopigment is the function of chl-a. The graph shows that there is a positive relation among these three biological variables. Chl-a value decreased in post monsoon (Fig. 56). The machine learning data model where we can see conductivity is the major element for the growth and distribution of phytoplankton. The other parameters namely SD, Alkalinity, Chl-a are also the key elements for algal growth. These 3 parameters are closely related with conductivity at different concentration (Fig. 57).

Shannon-Wiener diversity index is an index that is generally used to describe species diversity in a community. Here, stations R1, R2, R3 belongs to Reju canal showed more diverse in Shannon-Wiener diversity index than the Bakkhali River. The highest diversity (0.5597) occurs in Station R1 on November 2018 and the lowest diversity (0.014) was obtained in Station B3 in November, 2018 (Table 64) In case of 1st year of investigation. In the second year of investigation, Reju canal also showed more diversity, according to Shannon-Winner diversity index and the highest diversity (0.548) occurs in the month of July 2020 in station R2 but the lowest diversity (0.017) was observed in Station B3 in the in March 2020 (Table 65).

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 of Bakkhali River (B1, B2, B3) are highest 7.62% similar in September 2019 and their intersecting members are 8. 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 Bakkhali River showed more similarities in September 2019 throughout the two years of investigation (Table 66).

The Jaccard Index shows that among two years of study all the stations of Reju canal (R1, R2, R3) are highest 9.3% similar in January 2020 and their intersecting members are 8. 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 Reju canal showed more similarities in January 2020 throughout the two years of investigation (Table 67).

It is experimented proved that diatom taxa have sensitivities to decrease of environmental condition. So, a measurement of the health of the particular environment can be diagnosed by using diatom communities of that ecosystem (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, Tables 68-69). During the present study the TDI index of two wetland habitats showed the water quality of is fairly good. Which is the normal range. Multiple correlation analysis was carried out among the different measured variable and the results showed: significant positive correlation between phytoplankton and air temperature, water temperature, DO (at 5% significant level), alkalinity (at 5% significant level), and NO_3-N (at 1% significant level) and negative correlation between phytoplankton and Secchi depth, salinity, TDS, conductivity, pH, SRP, SRS (at 5% significant level), chl-a, phaeopigments for station B1. In the station B2, phytoplankton density showed positive correlation with air temperature, water temperature, Secchi depth, salinity (at 1% significant level), TDS (at 1% significant level), conductivity, DO, alkalinity, NO_3-N and SRP (at 5% significant level) and on the other hand showed negative correlation with pH, chl-a and phaeopigments. At B3,

phytoplankton showed positive correlation with air temperature, water temperature, Secchi depth, salinity, conductivity, pH, alkalinity, NO_3-N, SRP, chl-a and phaeopigment and also showed negative correlation with TDS and DO.

In Reju canal, phytoplankton showed positive correlation with DO, SRS, and phaeopigment (at 5% significant level); on the other hand, showed negative correlation with air and water temperature, Secchi depth, salinity, TDS, conductivity, pH, alkalinity, NO_3-N, SRP and chl-a at station R1. However, at station R2 the density of phytoplankton related positively with salinity, DO, SRP, SRS, chl-a (at 5% significant level) and phaeopigment and negatively related with air and water temperature, Secchi depth, TDS, conductivity, pH, alkalinity and NO_3-N. At R3 location the density of phytoplankton related positively with water temperature, Secchi depth, salinity, conductivity, DO, pH, alkalinity, NO_3-N and chl-a on the other hand phytoplankton related negatively with air temperature, TDS, SRP, SRS and phaeopigments.

All the nutrients like nitrate (NO_3N), phosphate (PO_4^{3-}) and silicate (SiO^{4-}_4) showed seasonal as well as spatial variation. Higher values of nitrate were observed during the pre-monsoon period than the other times of the year. The DO content of the water exhibited very high degree of variation throughout the year especially during post monsoon and winter. Phytoplankton biomass as chlorophyll *a* is also compared to the study sites. Physicochemical variables of both the studied ecosystems are almost similar only exceptions could be observed in case of phytoplankton density. In Reju Canal the density of phytoplankton is nearly 5-fold higher than the Bakkhali River. The phytoplankton was found to be a function of temperature factor. Both the ecosystem has a dynamic equilibrium and therefore the ranges of the concentration of dissolved nutrients were wide. The upper limit of DO concentration in Bakkhali River and Reju Canal was 9.8 and 7.9 mg/L, respectively. DO in the wetland areas were higher in monsoon than the other seasons. During monsoon due to heavy rainfall, the surface and volume of water of the wetland areas increased ameliorating the contents of water resulting higher DO. Increased DO supports the aquatic life in the water body during the monsoon greatly. The number of observed values of pH ranged from 6.8-8.7. This kind of pH is preferable for the growth of phytoplankton, macrophytes and other fresh water species. 30 new texa have been reported as new record of Bangladesh.

The present hydrobiological condition is ideal for the growth of phytoplankton and species richness of *Chaetoceros* throughout the year for Reju canal on the other hand excessive nutrient load create negative impact on phytoplankton growth in Bakkhali river for some samplings due to higher conductivity and salinity. During monsoon, the dilution of nutrients promotes quality of phytoplankton for richness rather than quantity. Heavy precipitation favored the growth of phytoplankton as well as Chlorophyll concentration. Among all the studied parameters conductivity showed great role for the growth and distribution of phytoplankton. The nutrient nitrogen is the great limiting factors for phytoplankton growth. In the present study showed near about 1.5 times higher NO_3-N in Reju canal than that of Bakhkhali river. So, phytoplankton diversity is higher in Reju canal. On the other hand, microbial degradation and chemical pollution helps to retard the growth of the phytoplankton in Bakhkhali River. Different hydrobiological parameters and presence of *Chaetoceros* and *Cyclotella* differentiate into two ecological niches of the studied two wetlands. This value indicates a moderate to good water quality of the studied ecosystems.

From the ecosystem principle, the array of physicochemical quality and quantity factors present in any habitat must reflect the characteristic biological diversity and production. The studied habitats included under the present research has got maritime as well as strong anthropogenic effects. The water temperature maxima of the ranges obtained in the studied habitats is nearly one degree centigrade upper compared to the other studied running water habitats of Bangladesh (Table 70). Turbidity value is nearly 2-fold lower than other studies (Table 70). The chl-a maxima obtained in Bakkhali river and Reju canal are 11.84 and 14.84 μg/L, respectively. But the maximas of chl-a recorded in the river Buriganga and Turag is nearly 10-11 times higher (Table 70). Low transparency of water and tidal effects might be the reason for it. The range-maximas of pH, alkalinity, and conductivity as recorded in the Bakkhali river and Reju canal are higher than the other studied running water habitats of Bangldesh (Table 71). pH range fall in the estuarine characteristics and higher conductivity indicates the strong salinity condition of the habitat but the range is wide (Table 71). Because of high salinity and conductivity, the DO content is low in the studied habitats compared to other studies carried out in Bangladesh (Table 72). Among nutrients, silicate and nitrate concentrations are low but SRP shows ranges which are almost similar to other studied polluted sections of rivers in around Dhaka (Table 72). This condition of Bakkhali river and Reju canal actually reflects the strong anthropogenic effects on them.

Phytoplankton are the beneficiary components of aquatic ecosystems towards the array of physicochemical factors. Table 73 shows a comparative account on the phytoplankton

floristic composition of different rivers of Bangladesh and some other parts of the world along with the presently studied river ecosystems. The dominancy of Bacilariophyceae range maxima 45.16 and 54%, respectively for Bakkhali river and Reju canal could be compared with Shatt-al-Arab ecosystem (Huq *et al*. 1978). The latter habitat supprts nearly 75% of diatom population (Table 73). However, all other studied rivers of Bangladesh showed a dominancy by green and/or blue green algal phytoplankton (Table 73).

Highest phytoplankton density (27.28×10^6 ind/L) was recorded from Reju canal. Box plot diagram prepared to show the relationship between PD and sampling stations and months reveal the occurrence of high phytoplankton density at R1, R2, and R3 with a growing season of June and July (Figs. 44-45). Since PD (phytoplankton density) is a culminating primary biological factor, its simple linear regression was drawn with environmental variables like tempertarure, water transparency, biomass, and nutrients (Figs. 46-52). All those variables were seen to act as governing elements to the PD in the Bakkhali river and Reju canal study stations. To reveal the pollution status of the studied habitats, and since diatoms (Bacilariophyceae) were dominant in the population of PD, trophic diatom index (TDI) was calculated (Table 68). The TDI assay reveals the fact that the studied habitats support a fairly good water, means the organic pollutional load is rather minimal. So, low transparency as discussed earlier might have resulted due to the non degradable particles or rather the self-purification capacity of the studied habitats is high.

The concept of 'Decision Tree Model' has been applied to reveal the key elemental factors responsible for the growth of phytoplankton (PD). The model successfully shows that three elements namely, Secchi depth, alkalinity, chl-a are relevant factors to PD.

All the nutrients like nitrate (NO_3N), phosphate (PO_4^{3-}) and silicate (SiO^{4-}_4) showed seasonal as well as spatial variation. Higher values of nitrate were observed during the pre-monsoon period than the other times of the year. The DO content of the water exhibited very high degree of variation throughout the year especially during post monsoon and winter. Phytoplankton biomass as chlorophyll a is also compared to the study sites. Physicochemical variables of both the studied ecosystems are almost similar only exceptions could be observed in case of phytoplankton density. In Reju Canal the density of phytoplankton is nearly 5-fold higher than the Bakkhali River. The phytoplankton was found to be a function of temperature factor. Both the ecosystem has a dynamic equilibrium and therefore the ranges of the concentration of dissolved nutrients were wide. The upper limit of DO concentration in

Bakkhali River and Reju Canal was 9.8 and 7.9 mg/L respectively.The present hydrobiological condition is ideal for the growth of phytoplankton and species richness of *Chaetoceros* throughout the year for Reju canal on the other hand excessive nutrient load create negative impact on phytoplankton growth in Bakkhali river for some samplings due to higher conductivity and salinity.During monsoon, the dilution of nutrients promotes quality of phytoplankton for richness rather than quantity. Heavy precipitation favored the growth of phytoplankton as well as Chlorophyll concentration. Among all the studied parameters conductivity showed great role for the growth and distribution of phytoplankton. The nutrient nitrogen is the great limiting factors for phytoplankton growth. In the present study showed near about 1.5 times higher NO_3-N in Reju canal than that of Bakhkhali river. So, phytoplankton diversity is higher in Reju canal. On the other hand, microbial degradation and chemical pollution helps to retard the growth of the phytoplankton in Bakhkhali River. Different hydrobiological parameters and presence of *Chaetoceros* and *Cyclotella* differentiate into two ecological niches of the studied two wetlands. These values indicate a moderate to good water quality of the studied ecosystems. As coastal wetlands, the Bakkhali river and Reju canal supports a significantly large phytoplankton diversity dominated by diatoms. Its self-purification capacity might be still high to lead a fairly good water quality. The niche defining characters of two dominant centric diatoms namely, *Chaetoceros* and *Cyclotella* could be as those by water transparency, water temperature, salinity and other nutrients. The study may contribute some new reports of phytoplankton for Bangladesh, which awaits a further detail address on a preliminarily identified source-list as a contribution via the present research.

PHOTOMICROGRAPHS

OF

PHYTOPLANKTON

Photomicrographs of reported phytoplankton

(Magnification of the images range 400-1000×)

Division: Bacillariophyta

Plate-1

No.	Name of the species
1.	*Chaetoceros brevis*
2.	*C. peruvianus*
3.	*C. affinis* var. *willei*
4.	*C.laciniosus*
5.	*C. curvicetus*
6.	*C. costatus*
7.	*C. lauderi*
8.	*C.laciniosus*
9.	*Bloom of Chaetoceros*

Plate 1

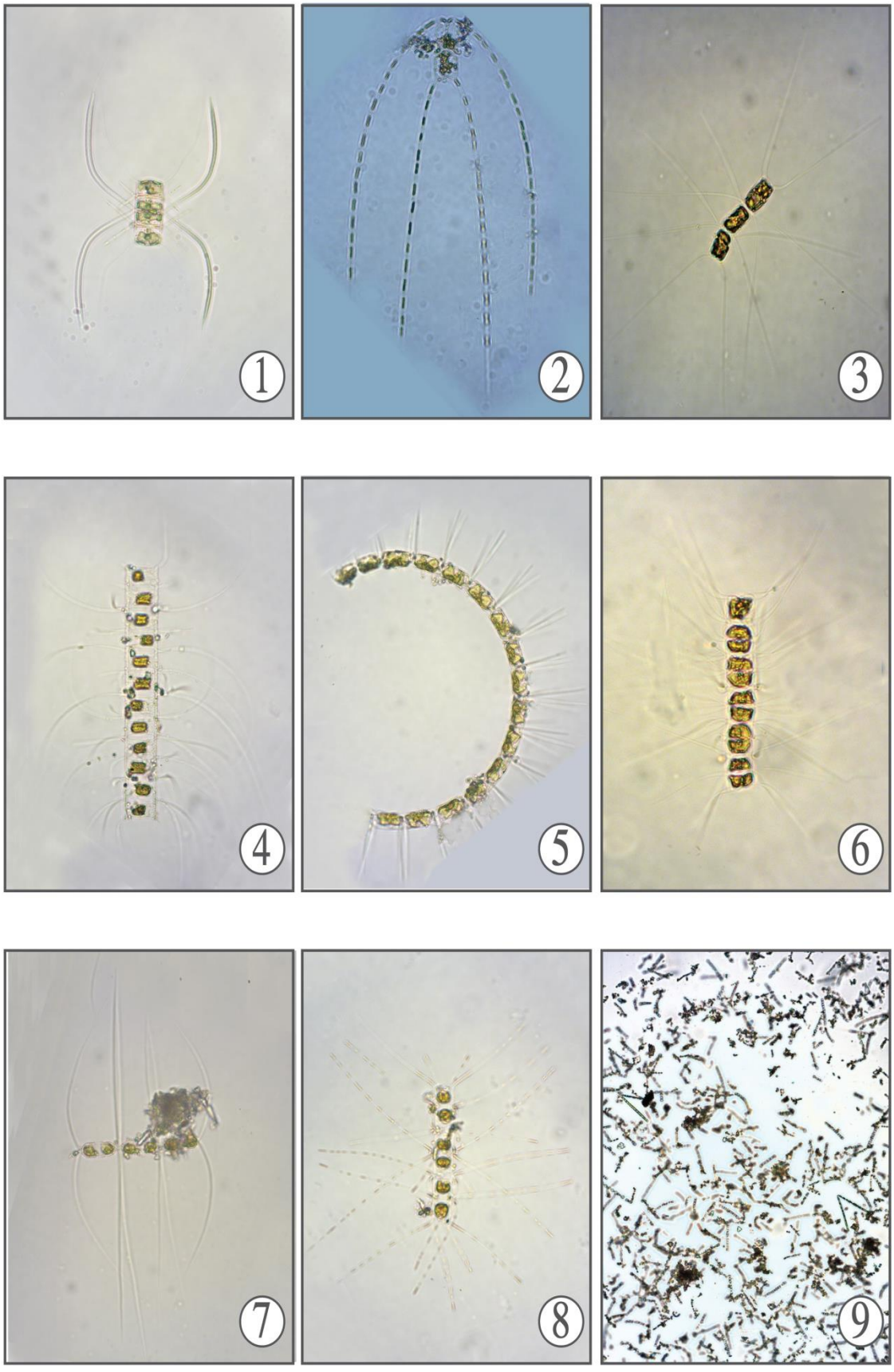


Plate 2

No.	Name of the species
1.	*Bacteriastrum hyalinum*
2.	*B. delicatulum*
3.	*B. hyalinum*
4.	*Eucampia cornula*
5.	*Coscinodiscus lineatus*
6.	*C. stellaris*
7.	*Hamiaulus membrenaceae*
8.	*H. sinensis*
9.	*Biddulphia mobiliensis*

Plate 2

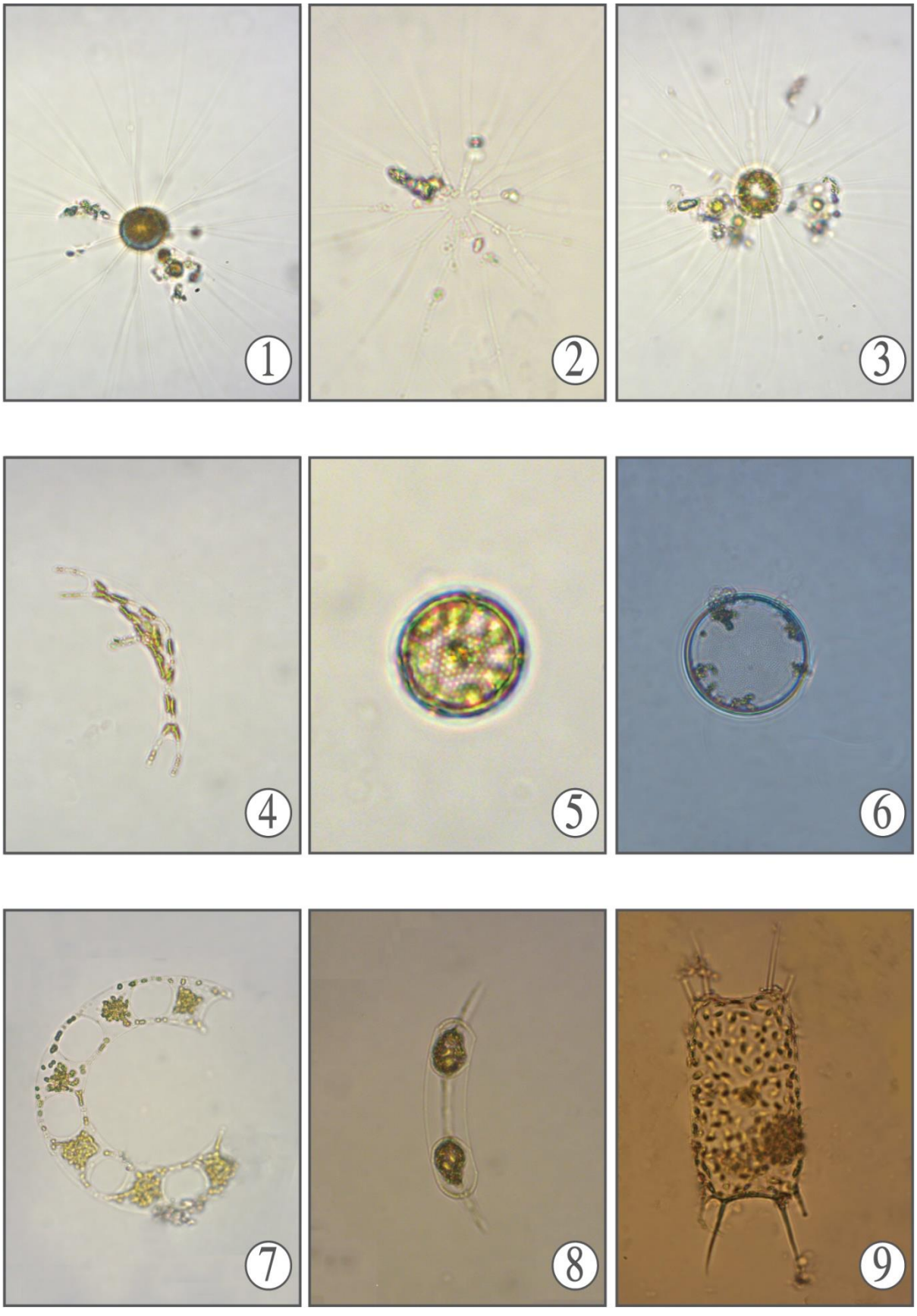


Plate 3

No.	Name of Species
1.	*Ceratium hirnundinella*
2.	*Amphora ovalis*
3.	*Cymbella hutedtii*
4.	*C. stuxbergii*
5.	*Amphora veneta*
6.	*Amphiprora costata*
7.	*Asterionella glacialis*
8.	*Asterionella glacialis*
9.	*Asterionella japonica*

Plate 3

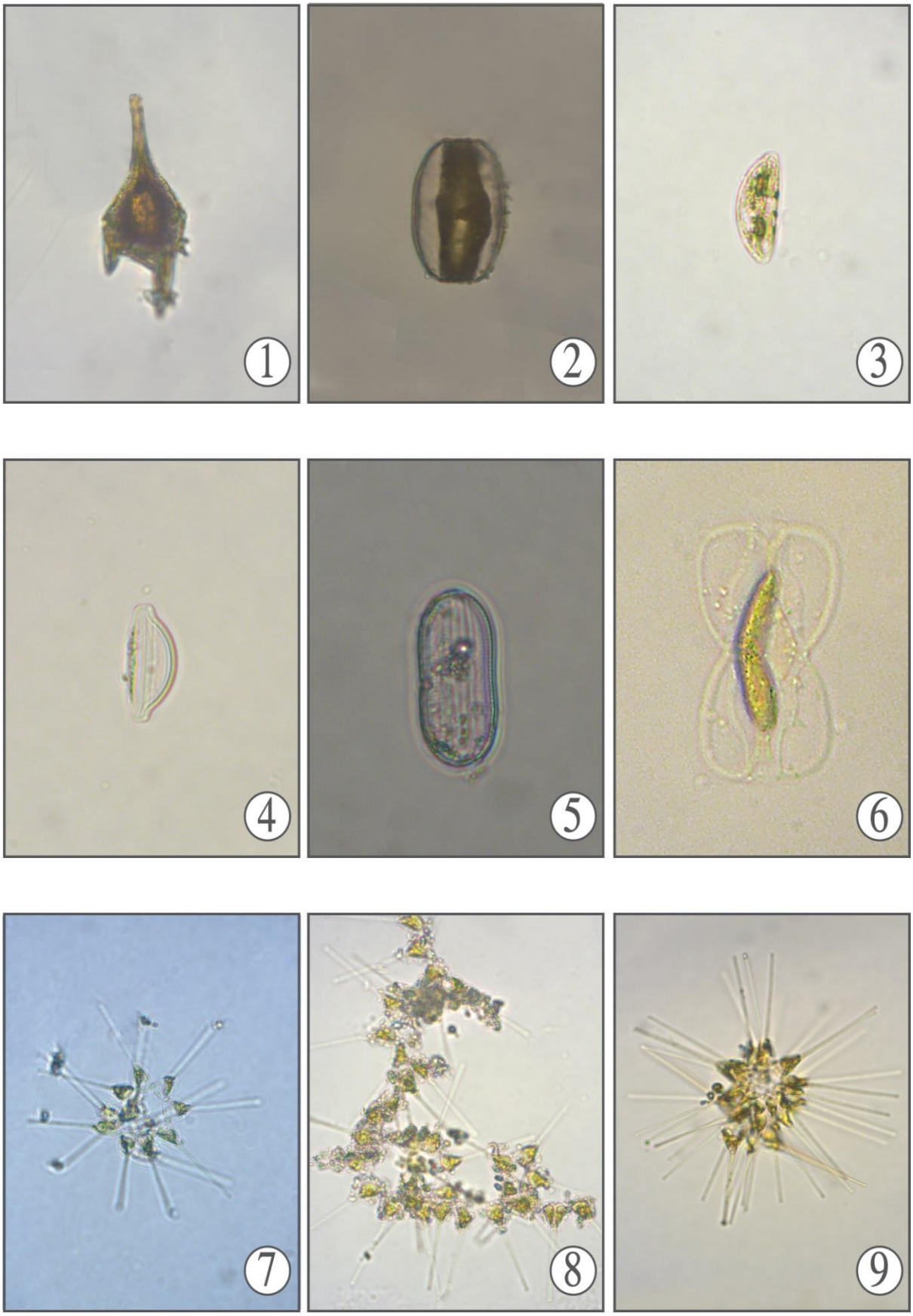


Plate 4

No.	Name of the species
1.	*Gyrosigma distortus*
2.	*Gyrosigma acumina*
3.	*Nitzschia longissima*
4.	*Surirella tenera*
5.	*Nitzschia longissima*
6.	*Nitzschia pungens*
7.	*Ditylum sol*
8.	*Ditylum sol*
9.	*Ditylum sol*

Plate 4

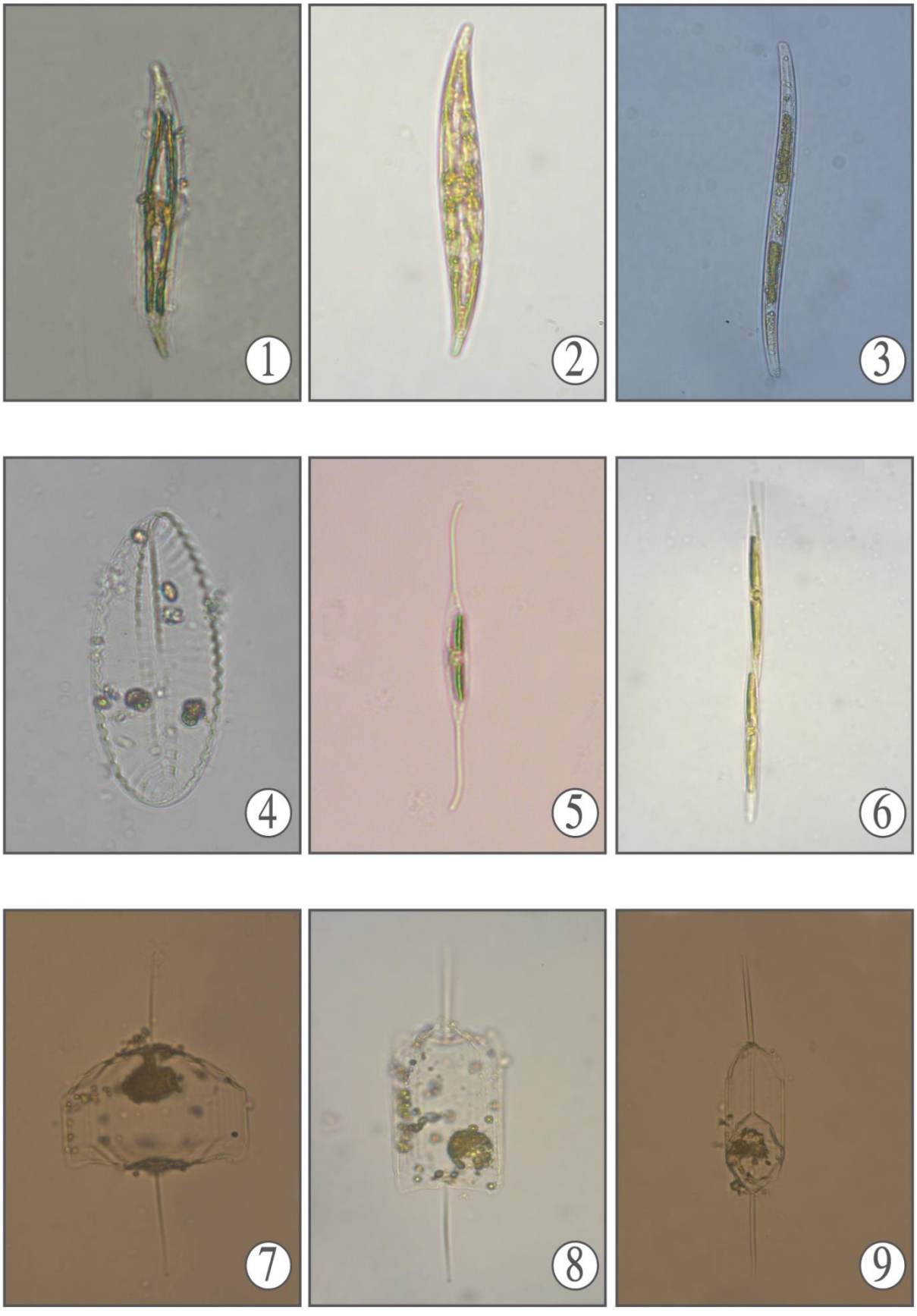


Plate 5

No.	Name of the species
1.	*Rhizosolenia setigera*
2.	*R. bergonii*
3.	*R. calcar-avis*
4.	*R. setigera*
5.	*R. Styliformis*
6.	*Asterionella formosa*
7.	*Diatoma vulgare* var. *linearis*
8.	*Ditylum brighwellii*
9	*Ditylum brighwellii*

Plate 5

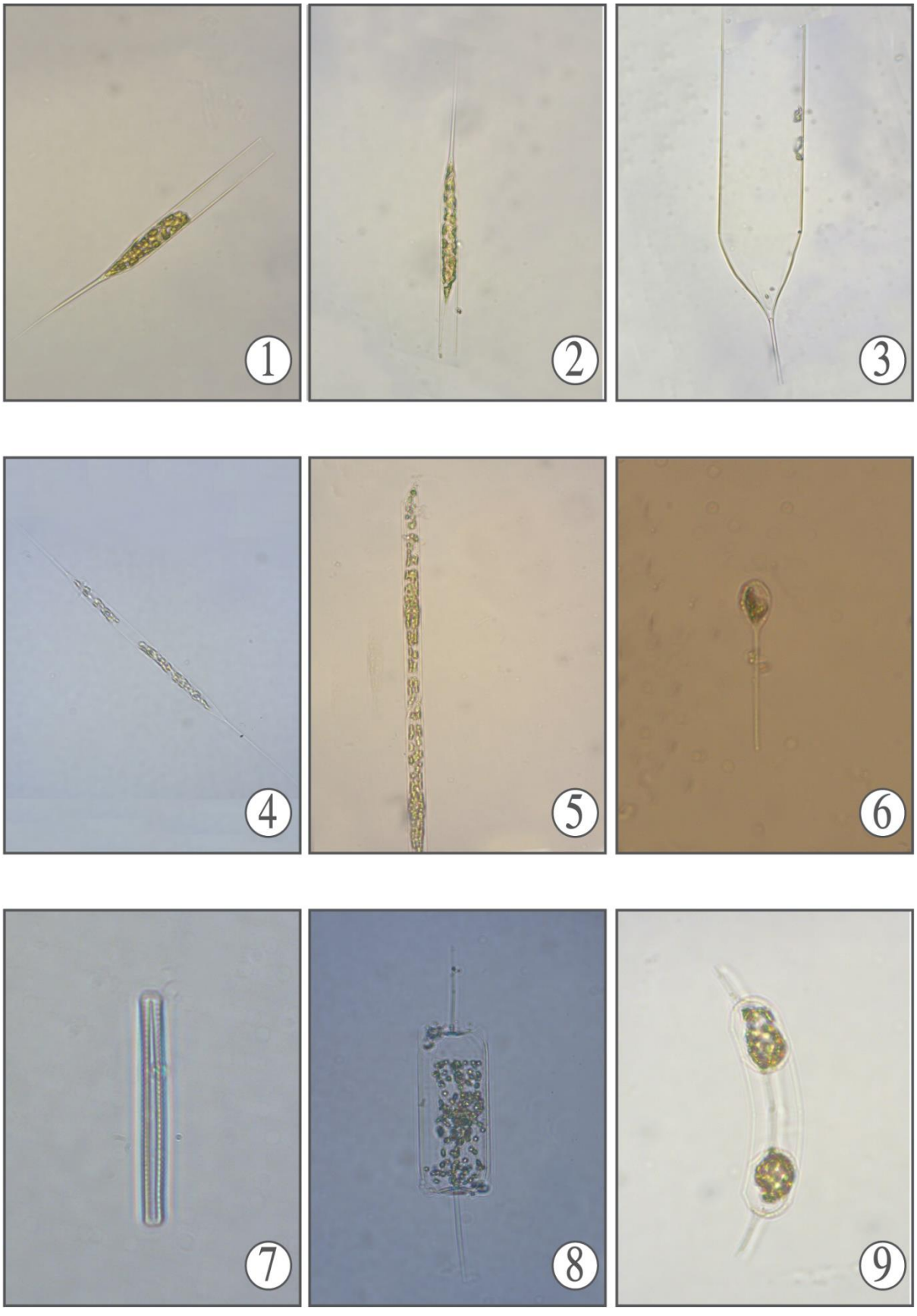


Plate 6

No.	Name of the species
1	*Cyclotella comensis*
2	*Cy. comta*
3	*Cy. meneghiana*
4	*Coscinodiscus granii*
5	*Fragillaria virenscens*
6	*Fragillaria virenscens* var. *capitata*
7	*Fragillaria crotonensis*
8	*Navicula exigua*
9	*Navicula cuspidata*

Plate 6

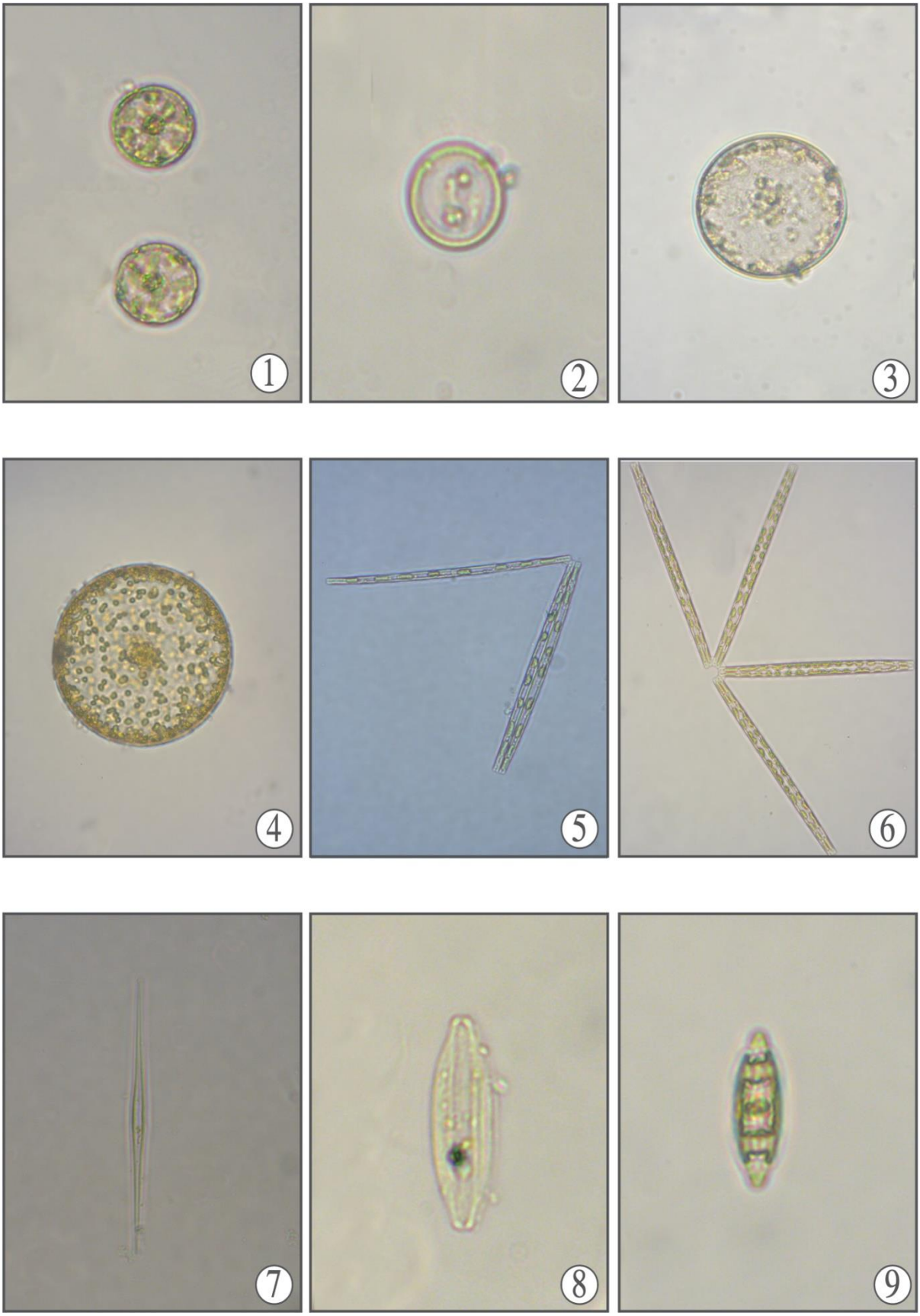
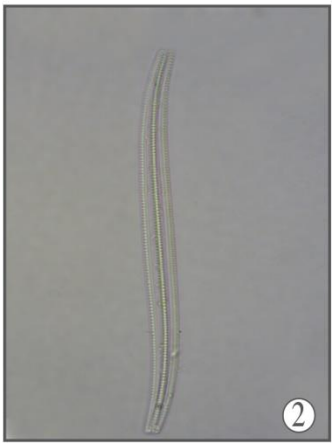


Plate 7

No.	Name of the species
1	*Epithemia zebra*
2	*Thellassionema nitzschioides*

Plate 7



Division Chlorophyta

Plate 8

No.	Name of the species
1	*Crucigenia terapedia*
2	*Actiotaenium*
3	*Actinastrum gracillium*
4	*A. hantzschii* var. *subtile*
5	*A. gracillimum*
6	*Closterium kuetzingii*

Plate 8

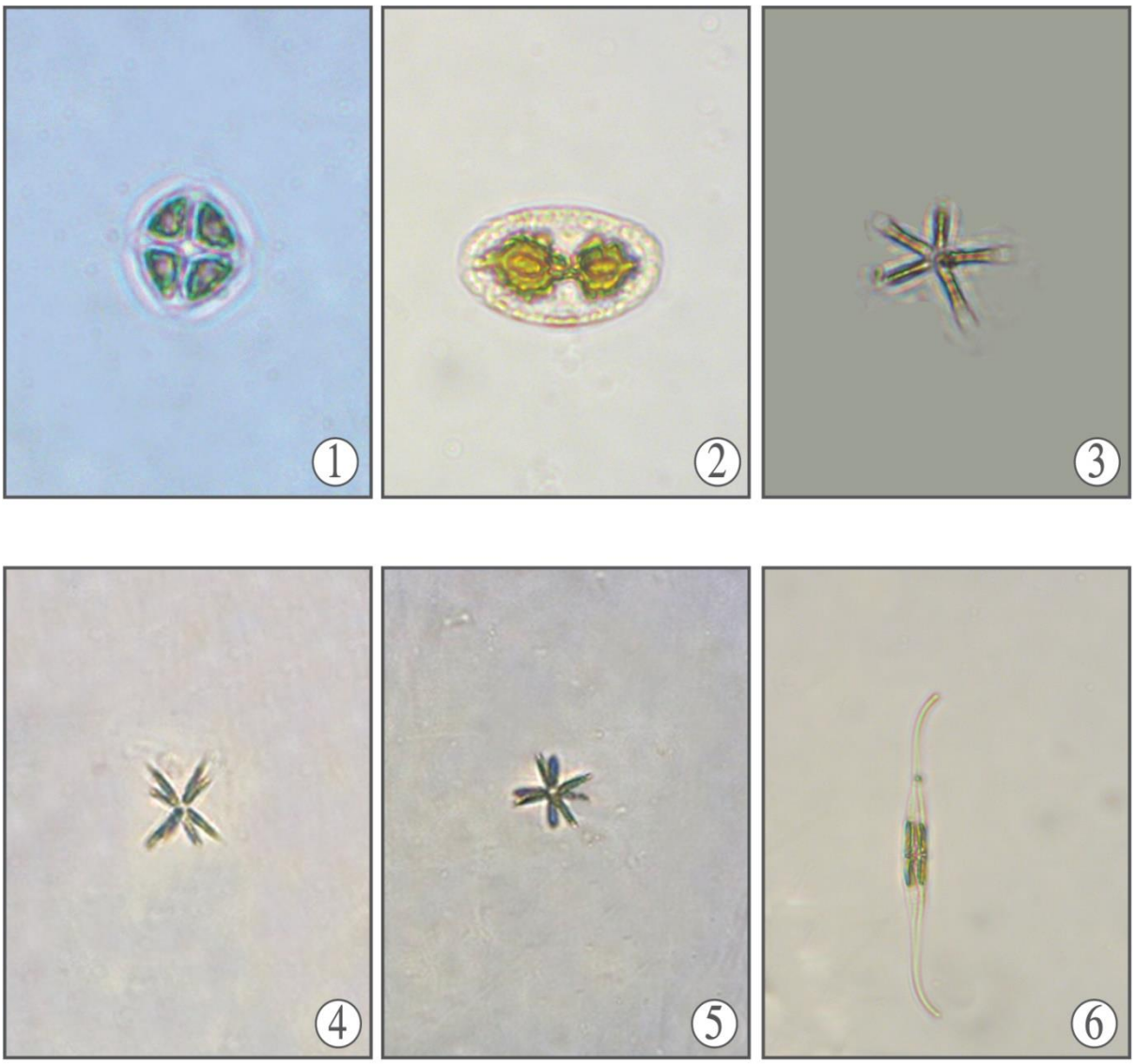
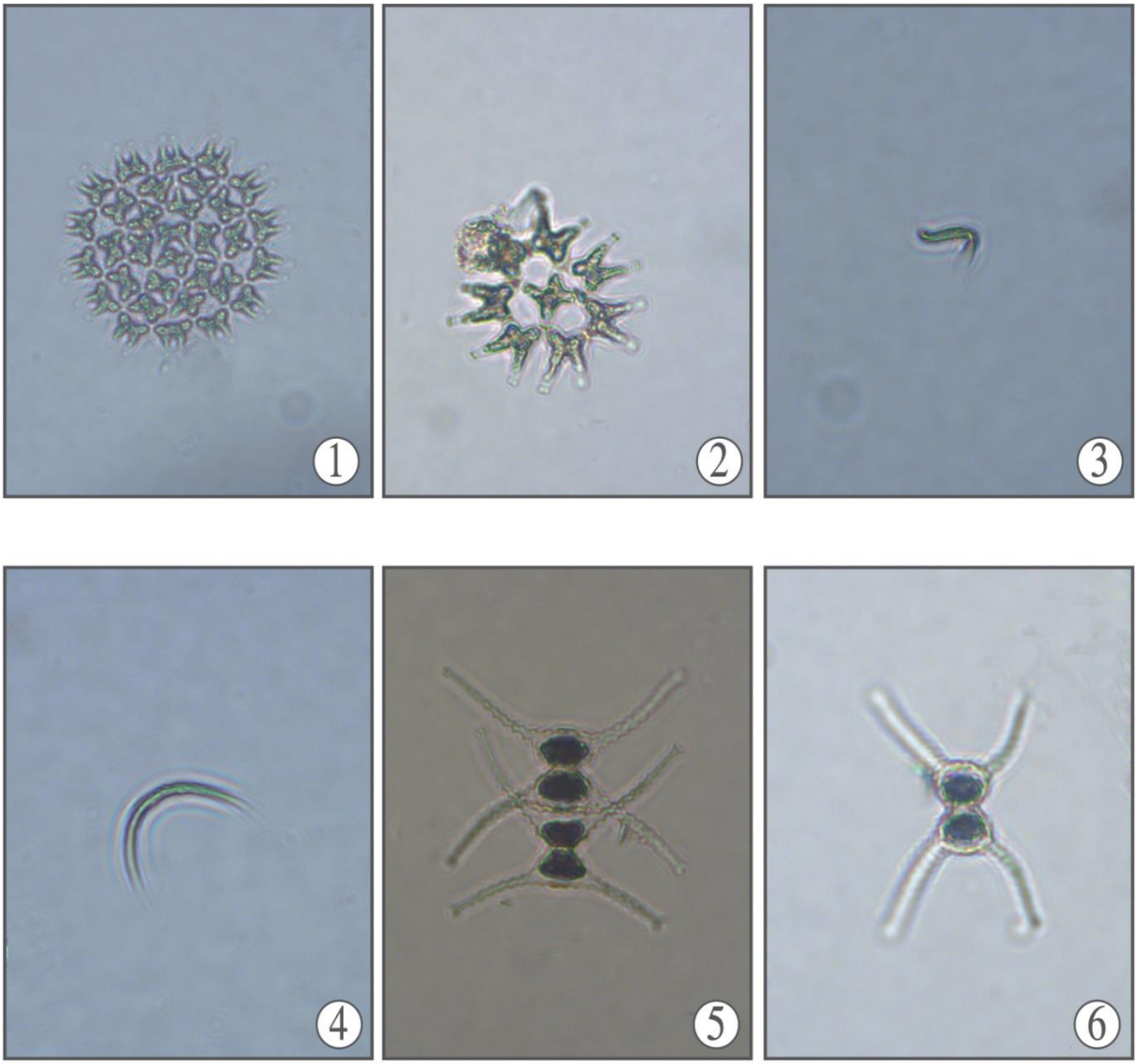


Plate 9

No.	Name of the species
1	*Padiustrum duplex*
2	*Padiustrum duplex*
3	*Schroederia spiralis*
4	*Hyaloraphidium contortum*
5	*Straurastrum chaetoceros*
6	*Straurastrum indestatum*

Plate 9



Division Cyarophyta

and

Division Pyrrhophyta

Plate 10

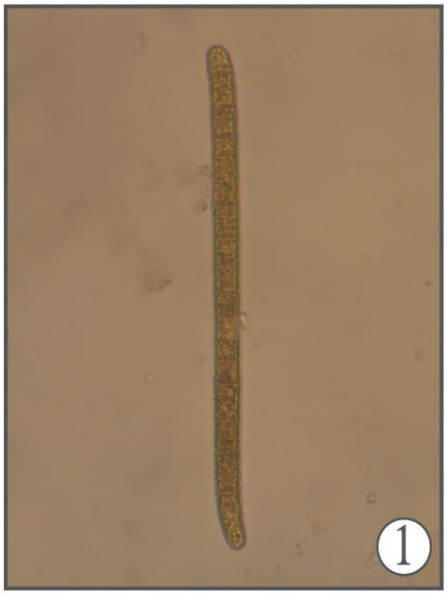
Division Cyanophyta

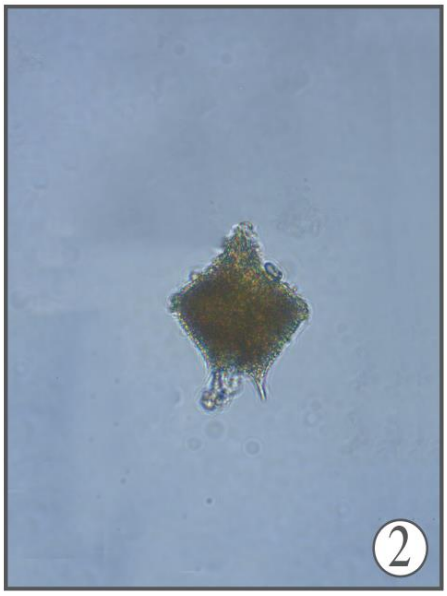
No.	Name of the species
1	*Oscillatoria formosa*

Division Pyrrhophyta

No.	Name of the species
2	*Peridinium granii*

Plate 10



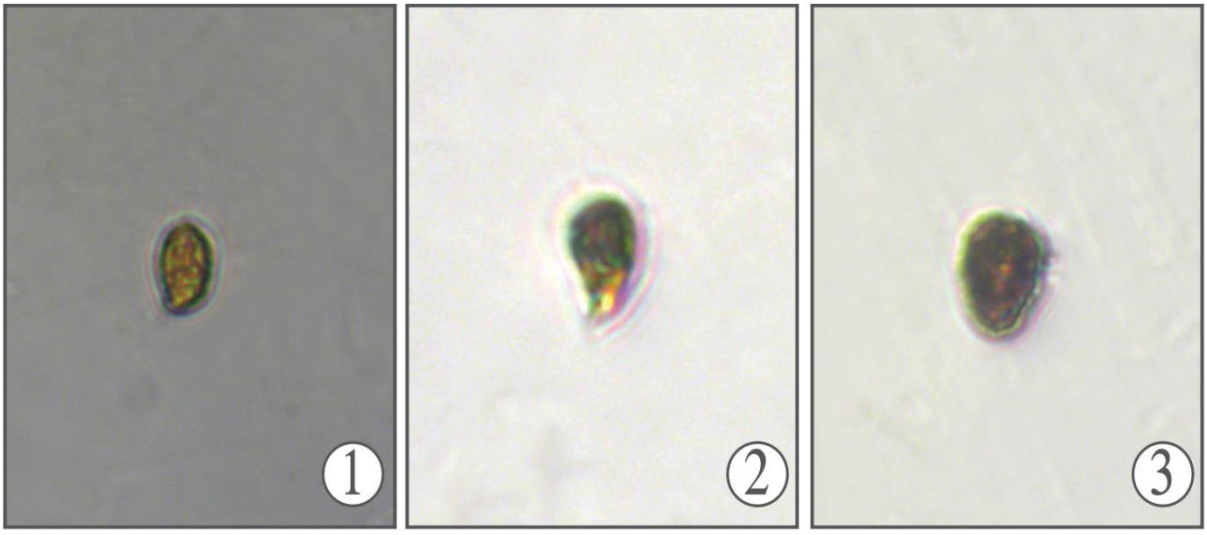


Division Cryptophyta

Plate 11

No.	Name of the species
1	*Chroomonas acula*
2	*Cryptomonas marsonii*
3	*Cryptomonas obovata*

Plate 11

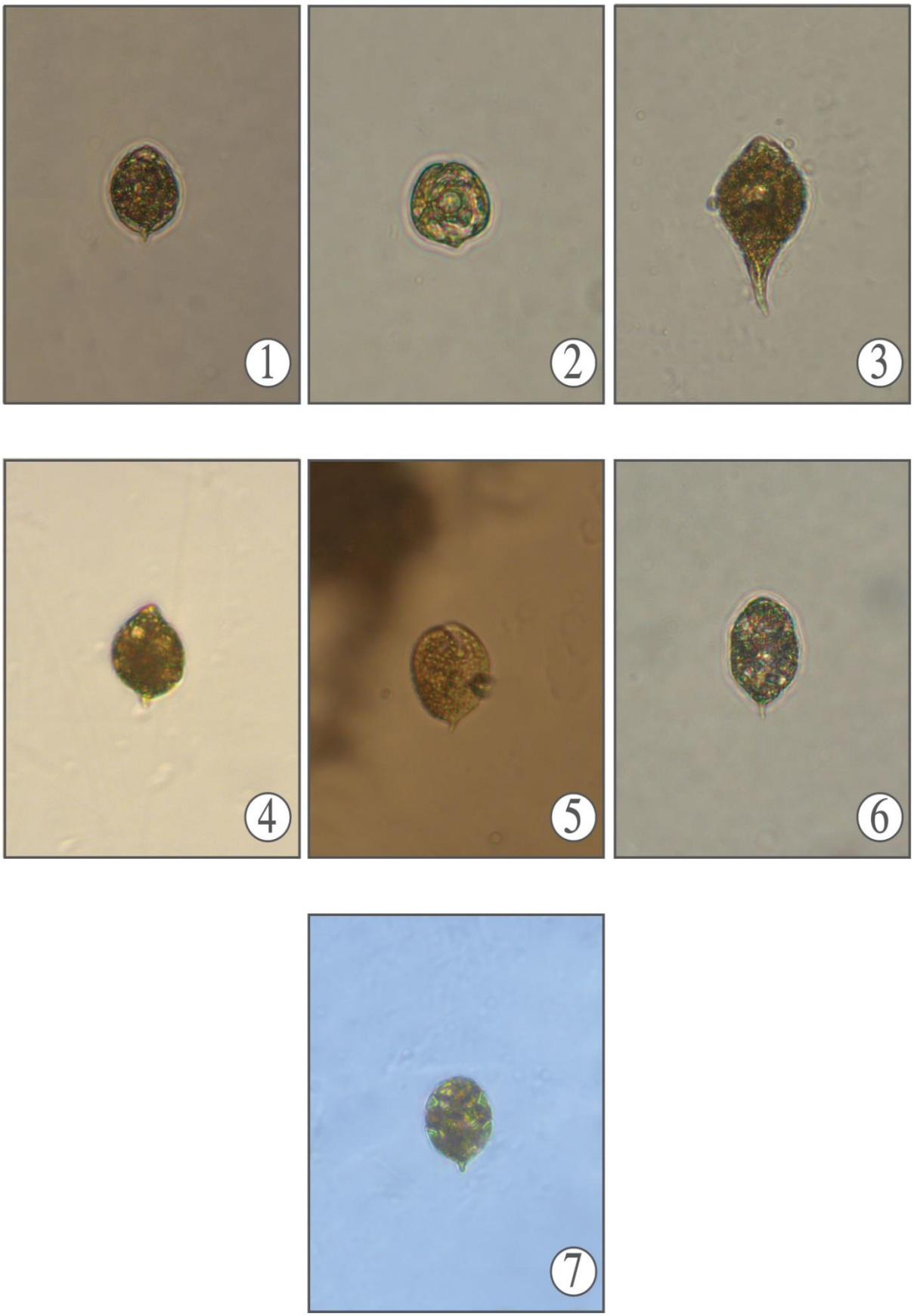


Division Euglenophyta

Plate 12

No.	Name of the species
1	*Lepocinclis ovum*
2	*Phacus acuminatus*
3	*Phacus circumflexus*
4	*PhacusContortus*
5	*Phacus Latus*
6	*Phacus warszewiczii*
7	*Lepocinclis ovum*

Plate 12



Photomicrographs of the probitionary new list of phytoplankton for Bangladesh

Division Bacillariophyta

Plate 1

No.	Name of the species
1	*Chaetoceros decipiens*
2	*Chaetoceros denicus*
3	*Chaetoceros pendulus*
4	*Chaetoceros tetrastichon*

Plate 1

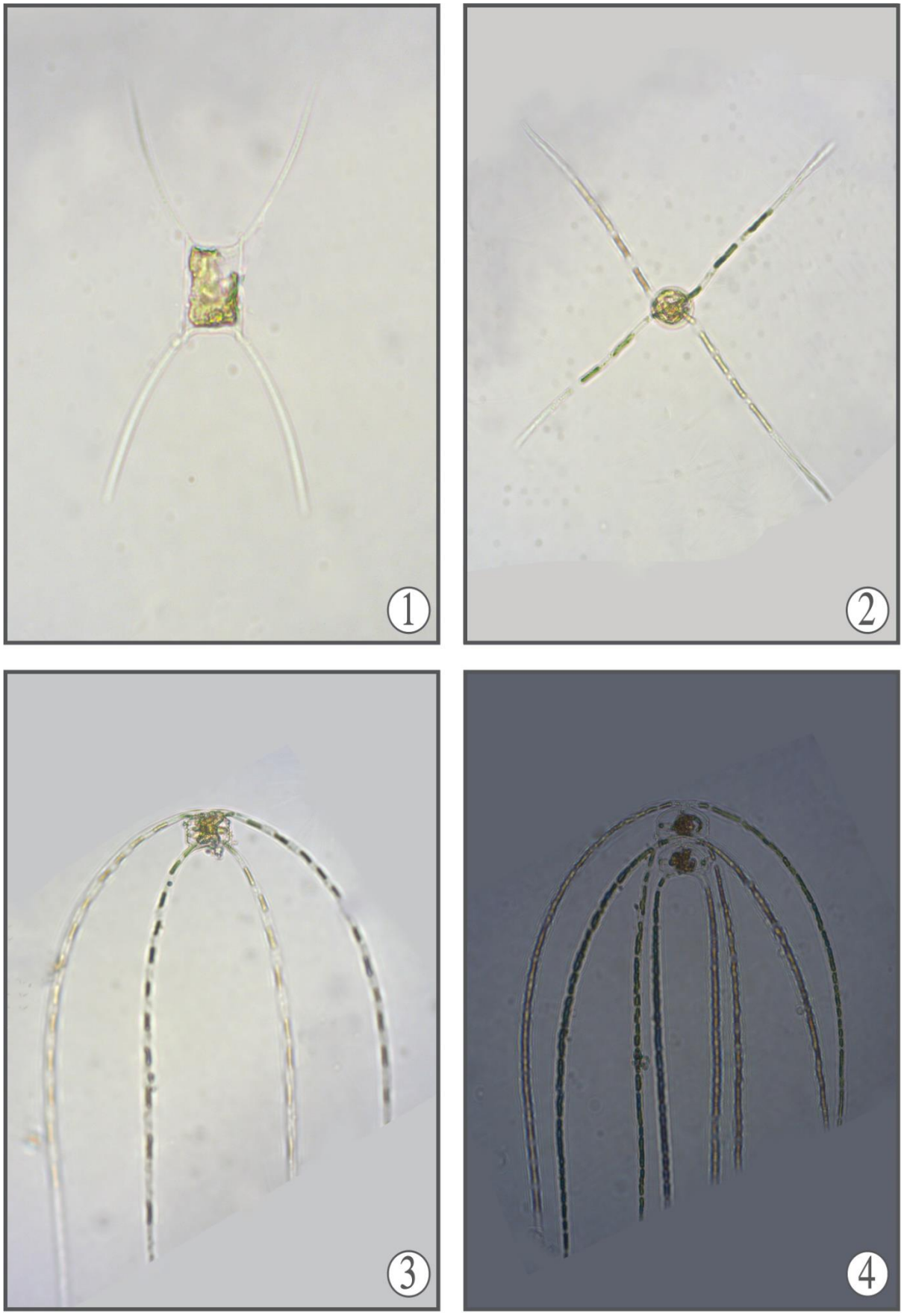


Plate 2

No.	Name of the species
1	*Chaetoceros tetrastichon*
2	*C. Pseudobrevis*
3	*C. pelagicus*
4	*C. aequatorialis*

Plate 2

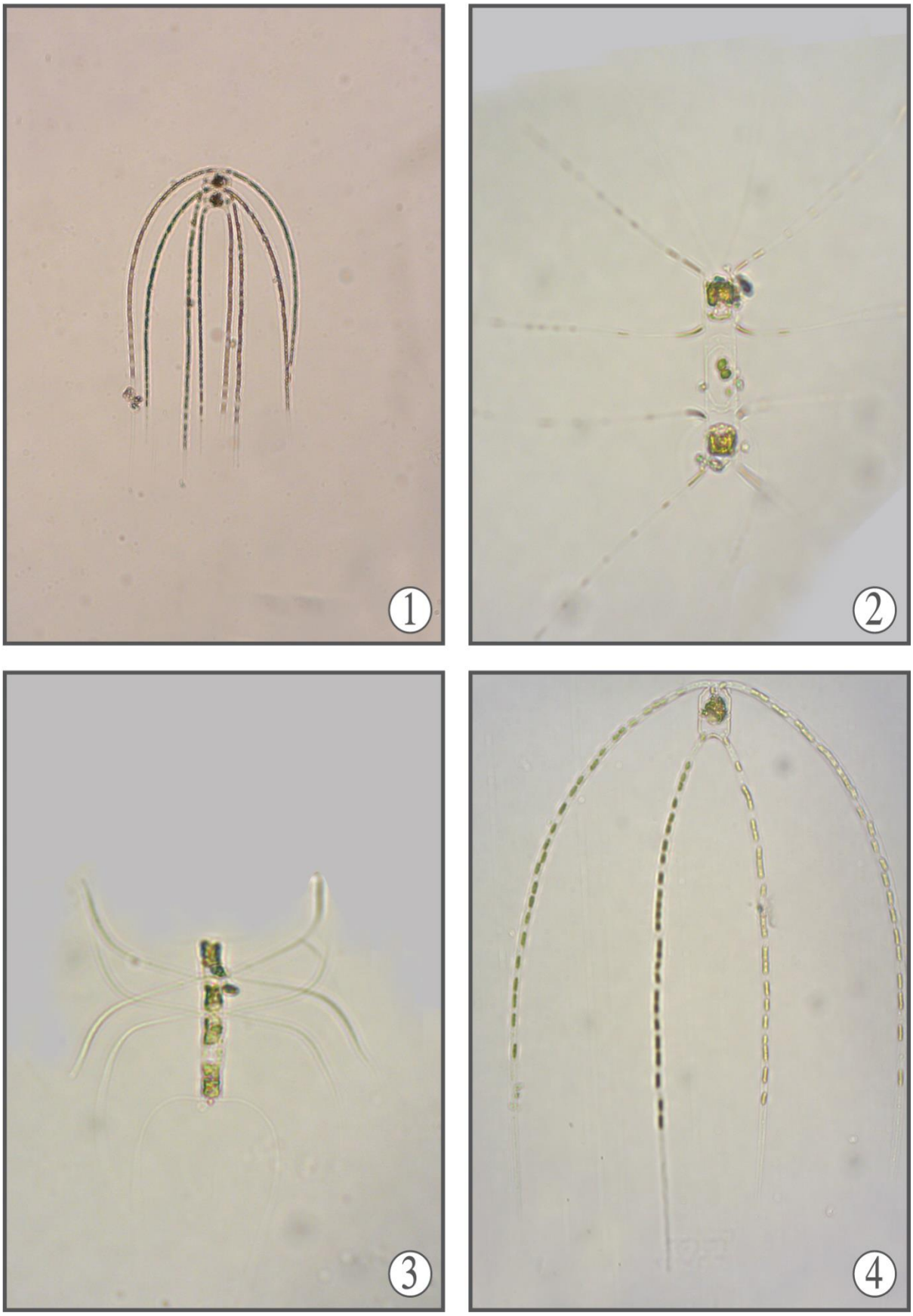
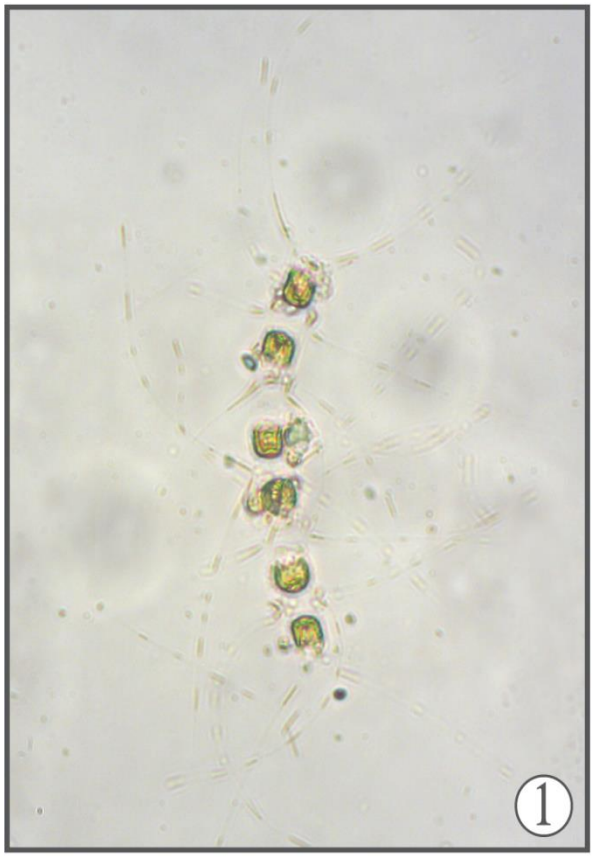
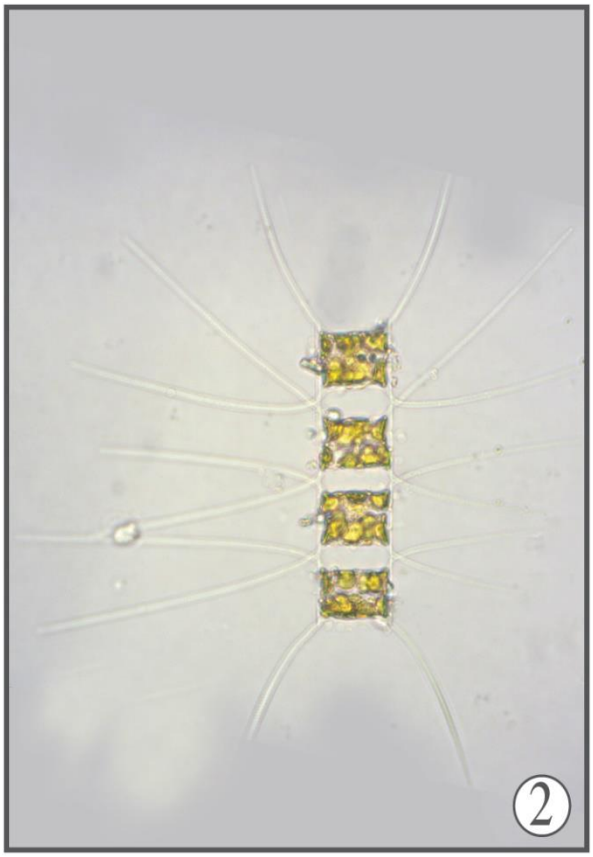


Plate 3

No.	Name of the species
1	*C. contortus*
2	*C. constrictus*
3	*C. decipiens*
4	*C. dedymus*

Plate 3





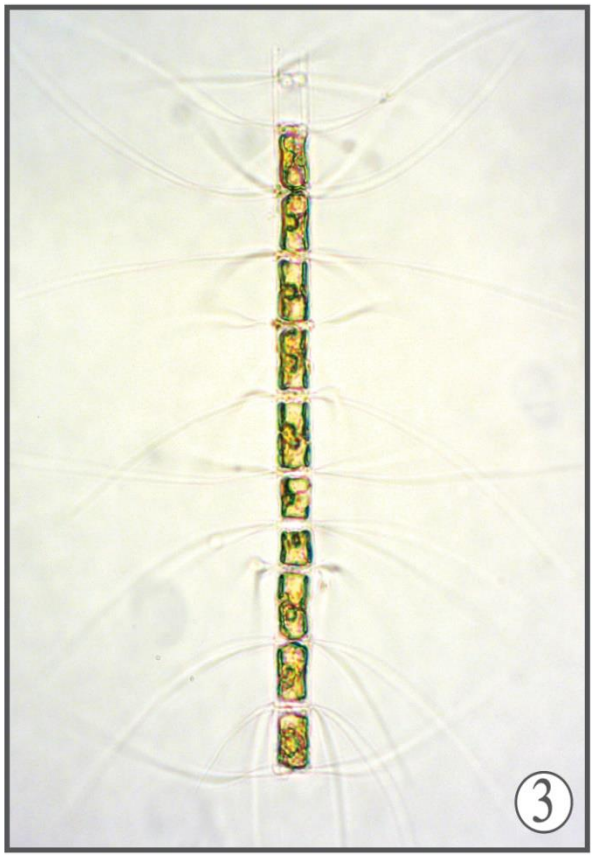


Plate-4

No.	Name of the species
1	*Nitzschia* cf. *sigma*
2	*Stenapterobia sigmatella*
3	*Entomoneis sulcata*
4	*Muniera membranaceae*

Plate-4

Plate-5

No.	Name of the species
1	*Odontella sinensis*
2	*Odontella sinensis*
3	*Chaaetoceros decipiens*
4	*Muniera membranaceae*

Plate-5

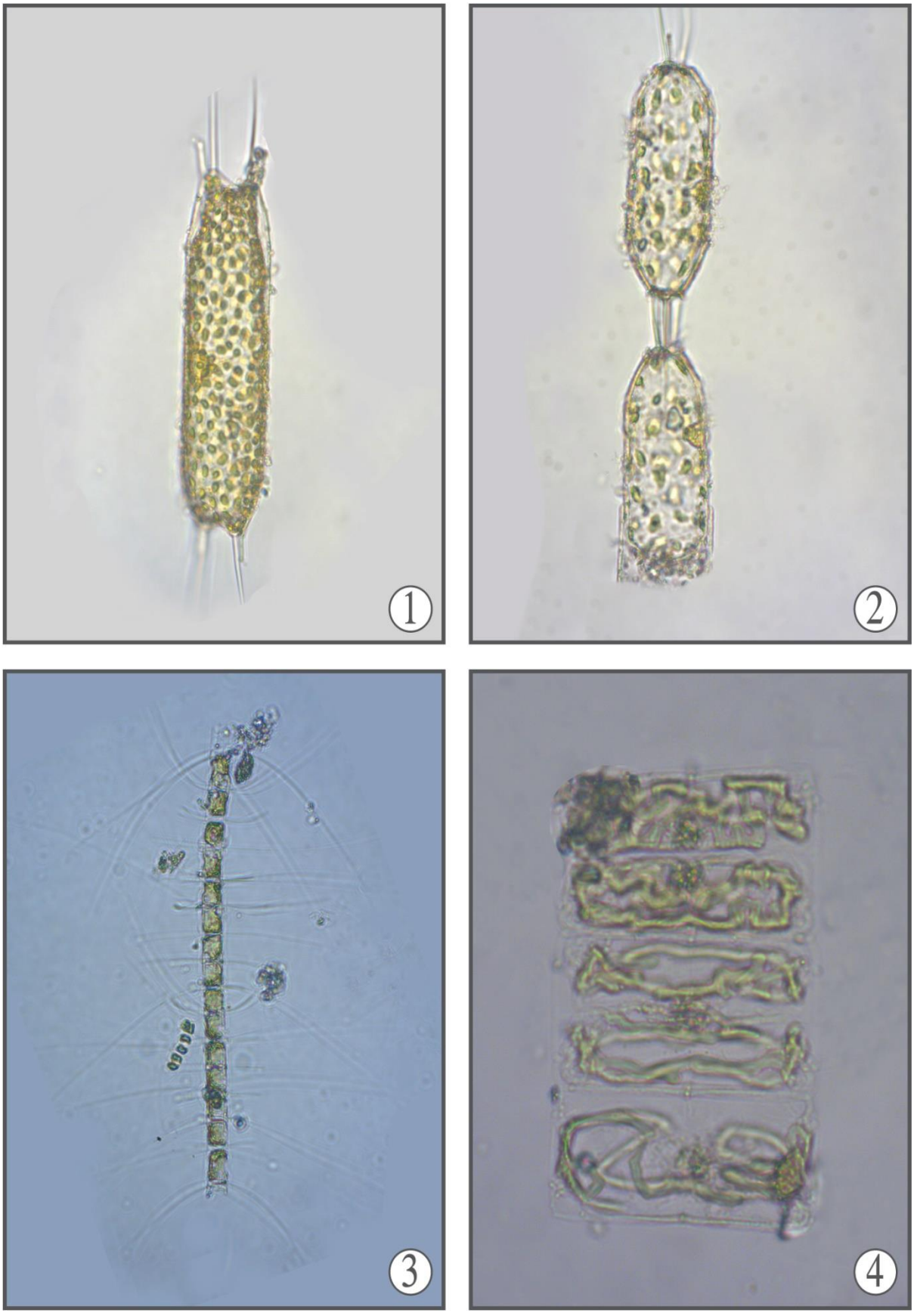


Plate-6

No.	Name of the species
1	*Lamriscus shadholtianum*
2	*Guinardia striata*
3	*Guinardia striata*
4	*Chaetoceros diversus*

Plate 6

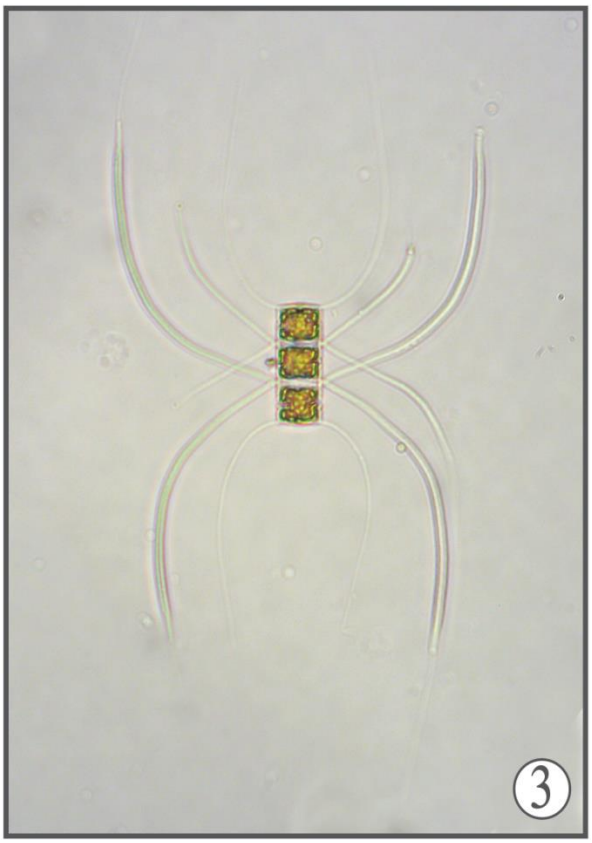


Plate 7

No.	Name of the species
1	*Actinocyclus octonarius*
2	*Actinocyclus octonarius*
3	*Nitzschia Closterium*

Plate 7

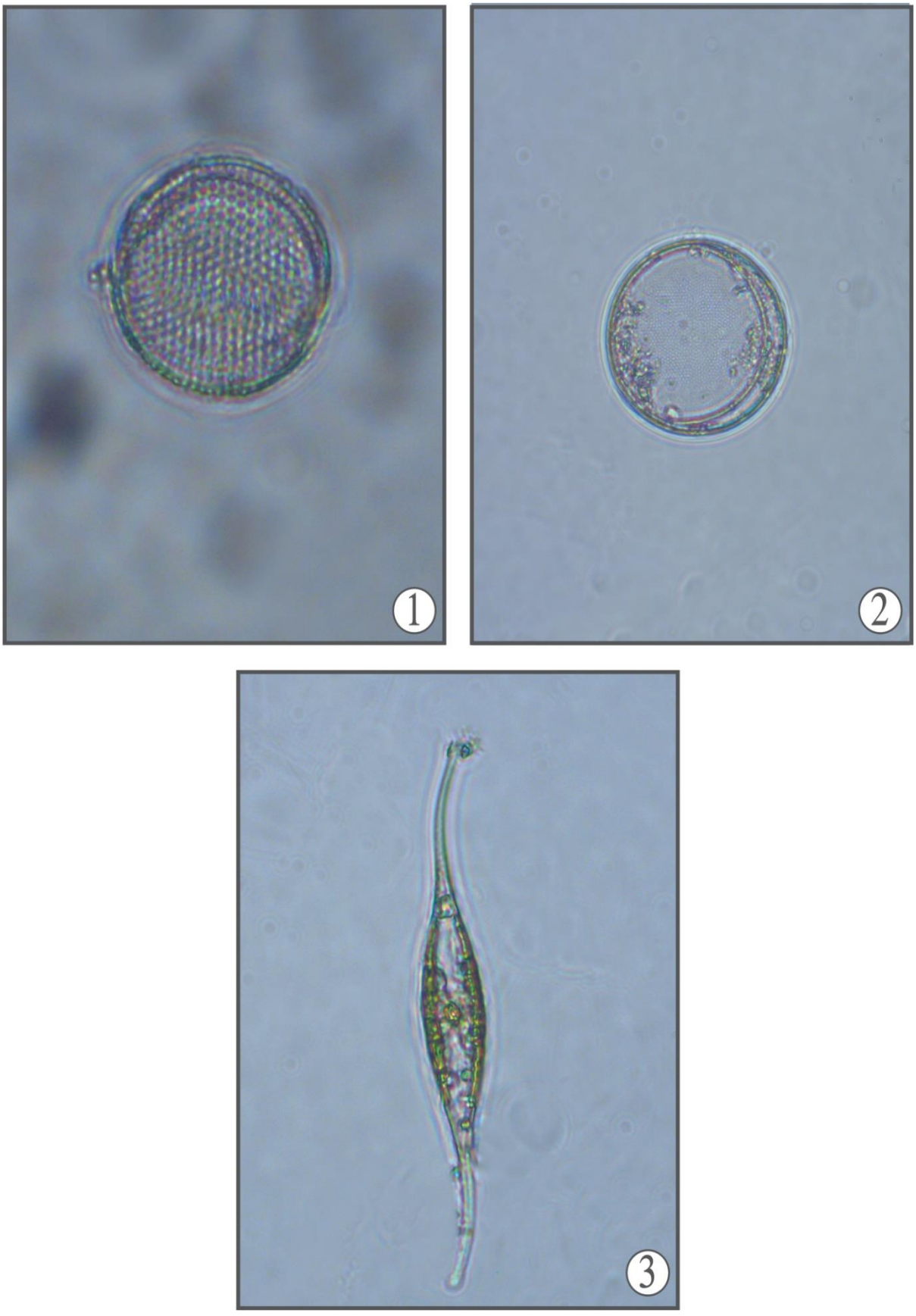


Plate 8

No.	Name of the species
1	*Tropidoneis lepidoptera*
2	*Amphiprora alata*
3	*Thalassiosira oestrupii*
4	*Thalassiosira oestrupii*

Plate 8

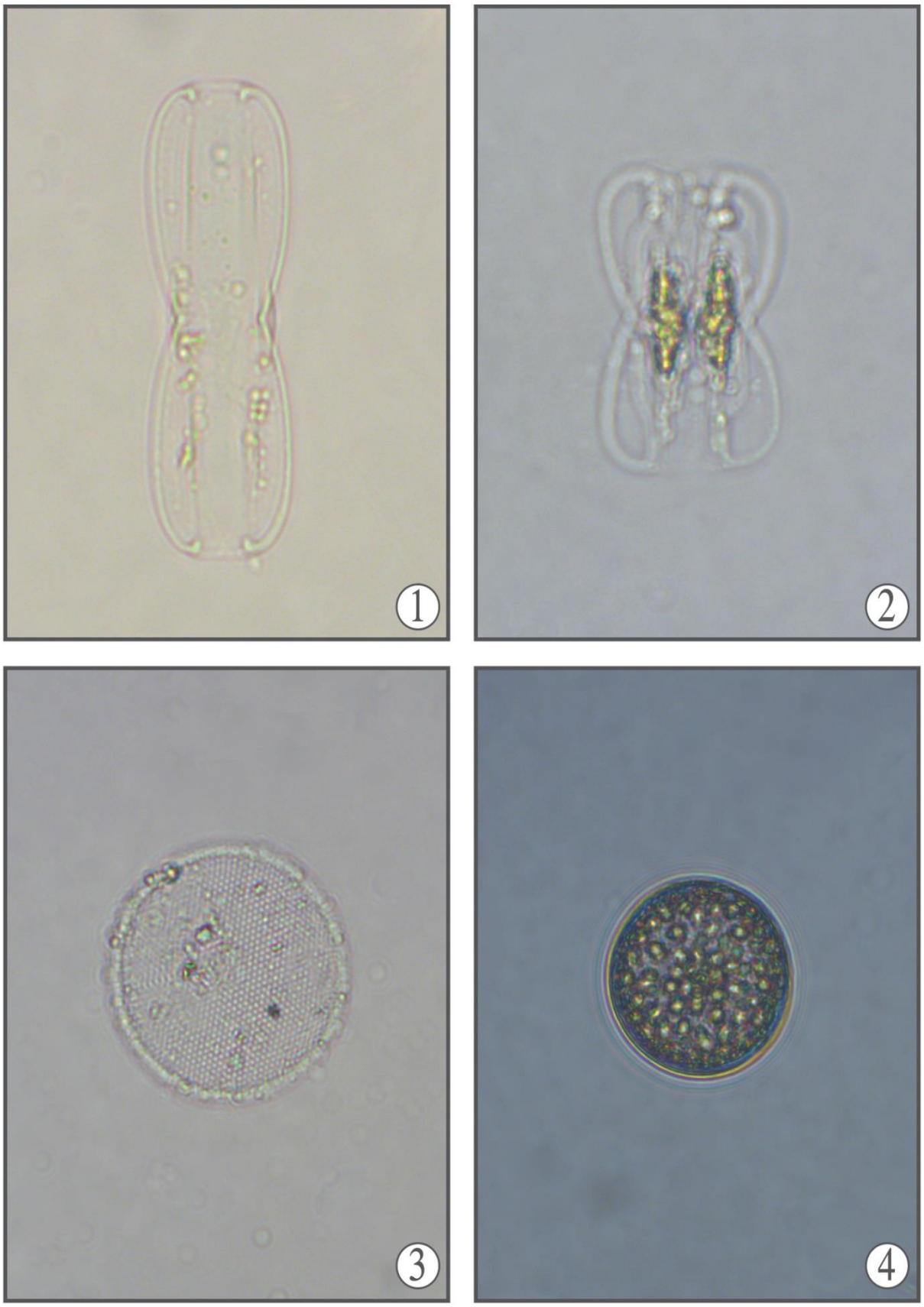


Plate 9

No.	Name of the species
1	*Surirella fastuosa*
2	*Surirella ovalis*
3	*Lyrella spectabilis*
4	*lyrella* cf. *abrupta*

Plate 9

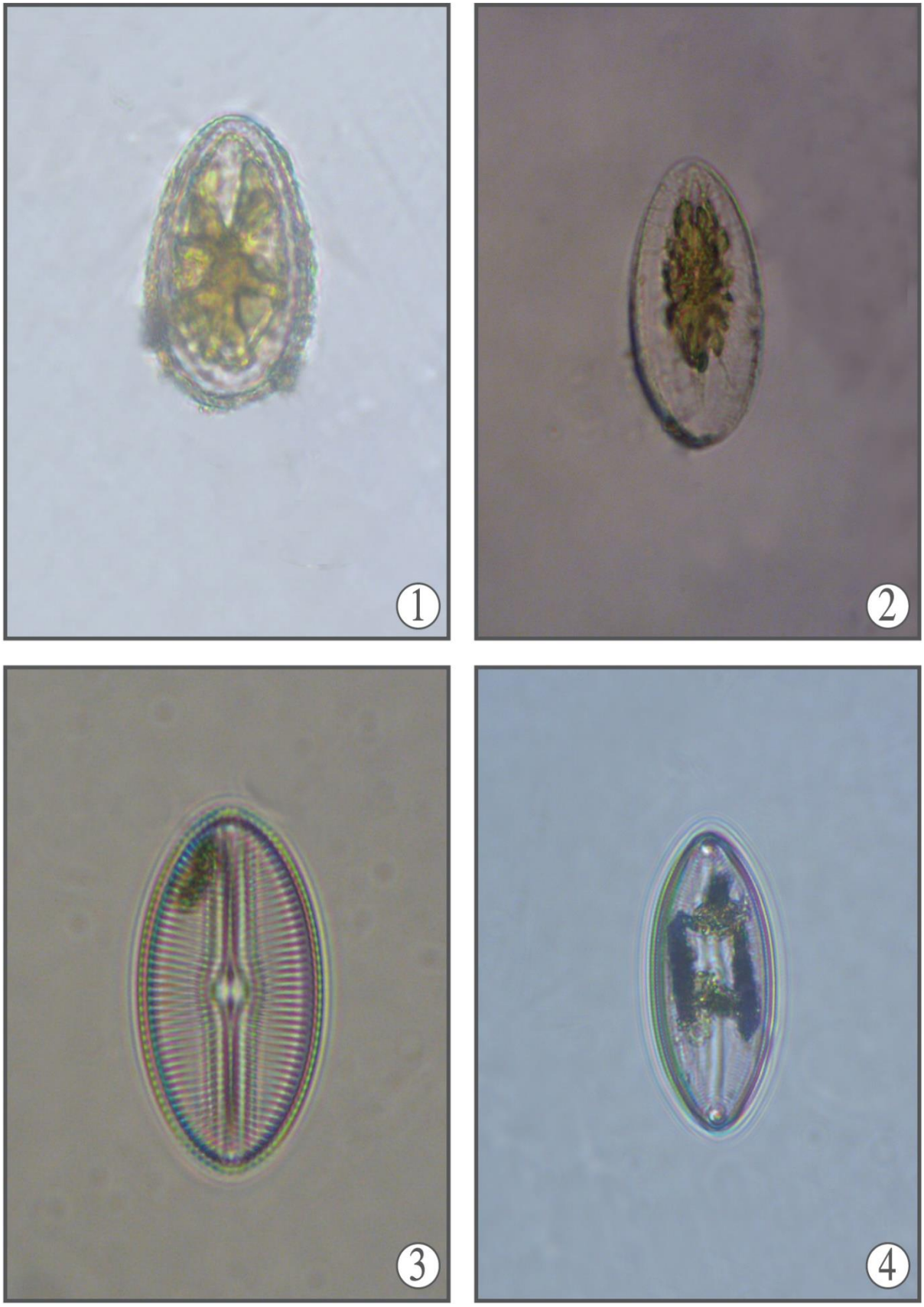


Plate 10

No.	Name of the species
1	*Mastogloia smithii*
2	*Entomoneis sulcata*
3	*Helicotheca thamensis*
4	*Helicotheca thamensis*

Plate 10

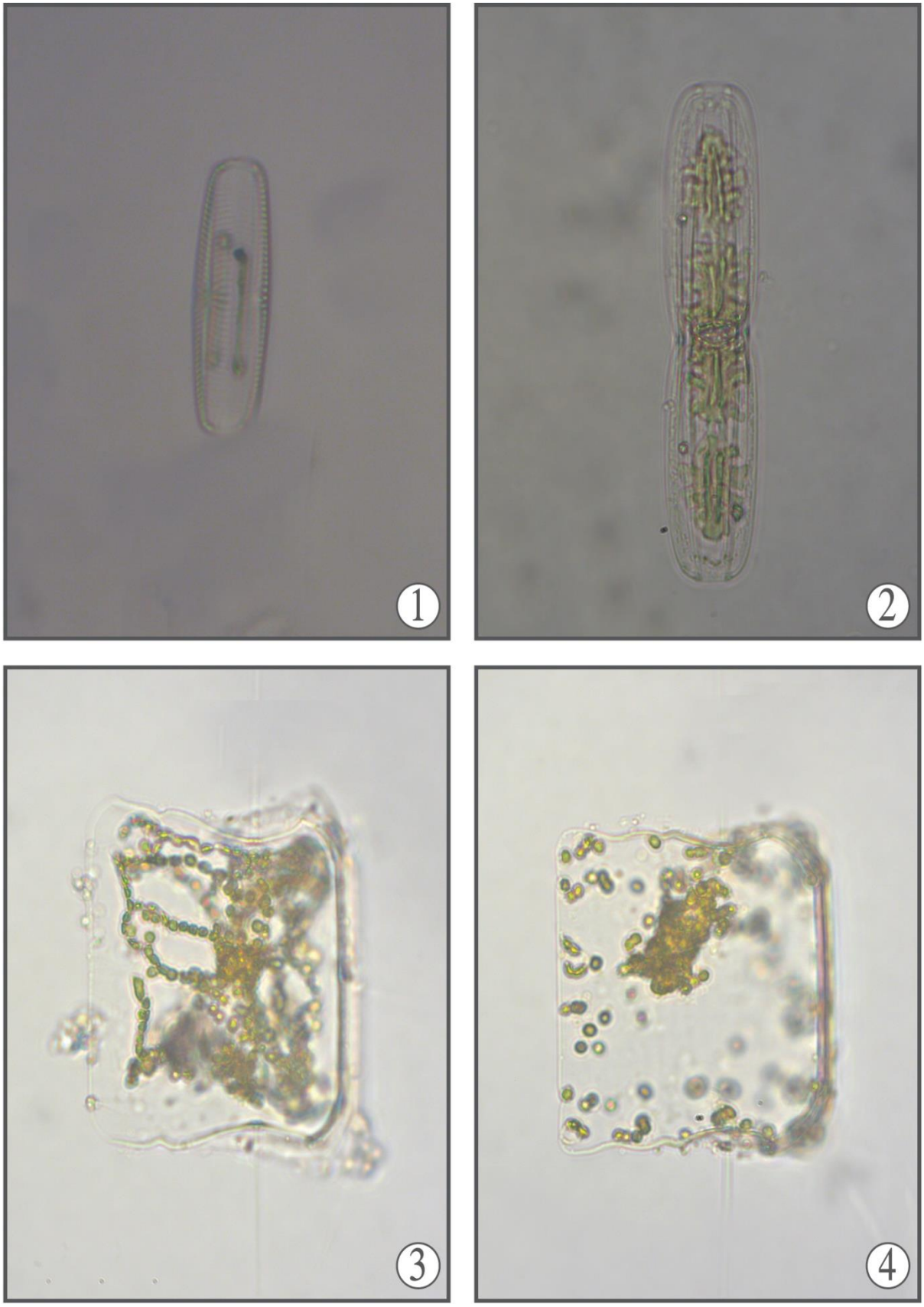


Plate 11

No.	Name of the species
1.	*Fragillaria capitellata*
2.	*Pinnularia lata* fa*. thuringiaca*
3.	*Pinnularia interupta* fa. *minutissima*
4.	*Striatella unipunctata*

Plate 11

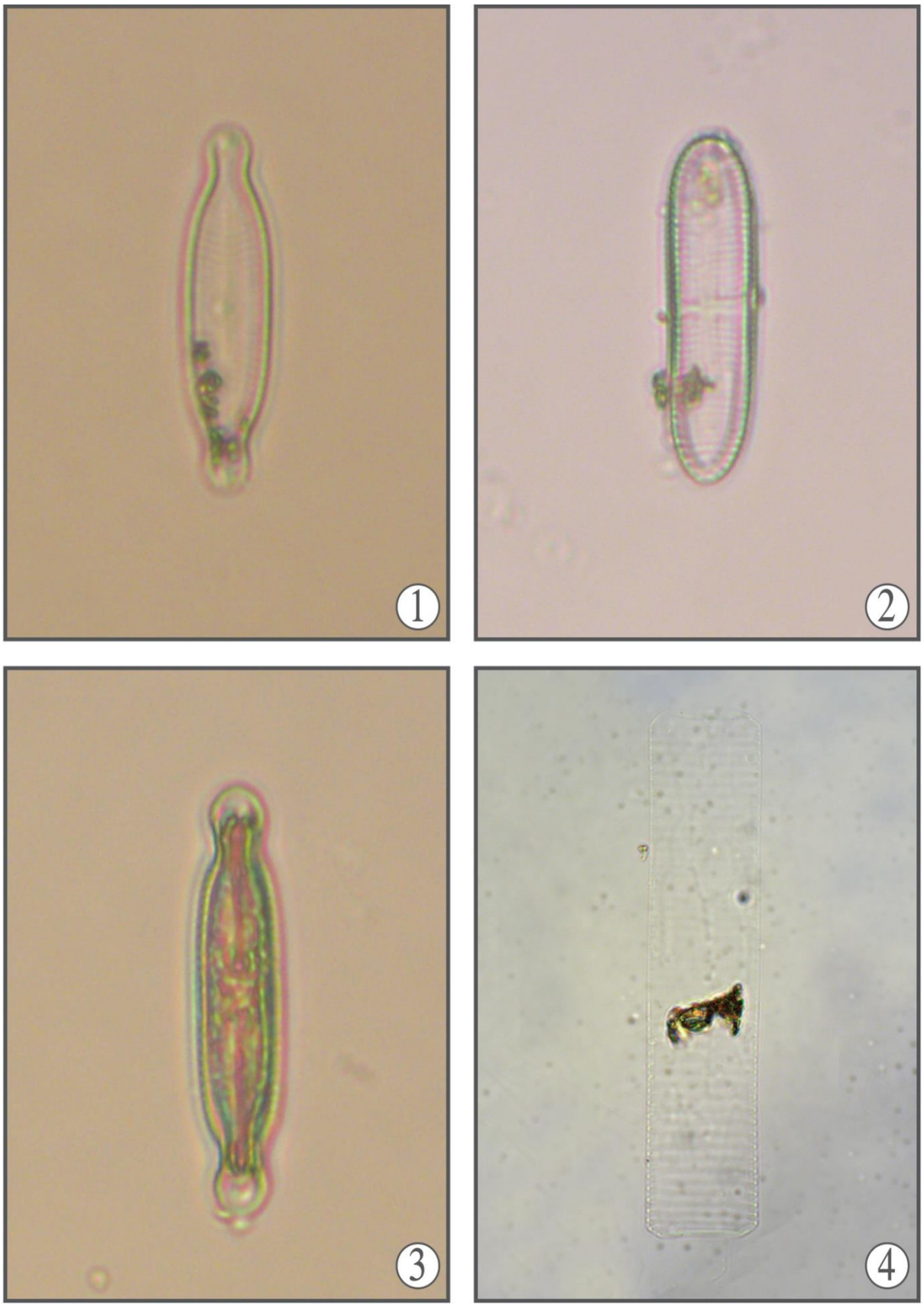


Plate 12

No.	Name of the species
1.	*Aulacodiscus orbiculatus*
2.	*Cyclotella stylorum*
3.	*Navicula dicephala*
4.	*Thalassiosira eccentrica*

Plate 12

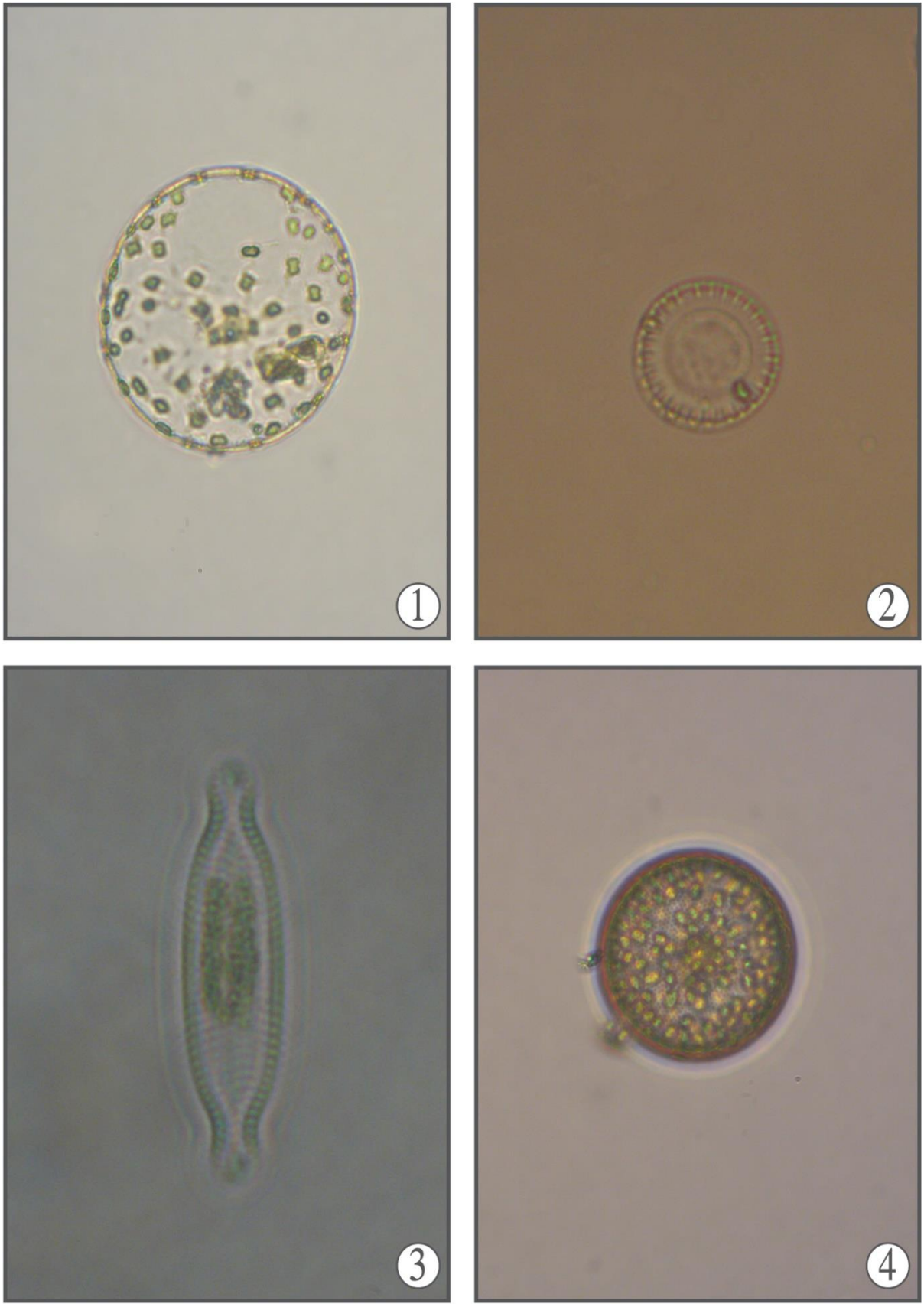


Plate 13

No.	Name of the species
1.	*Pleurosigma* cf. *elongatum*
2.	*Pleurosigma longum*
3.	*Pleurosigma salinarum*
4.	*Pleurosigma elongatum*

Plate 13

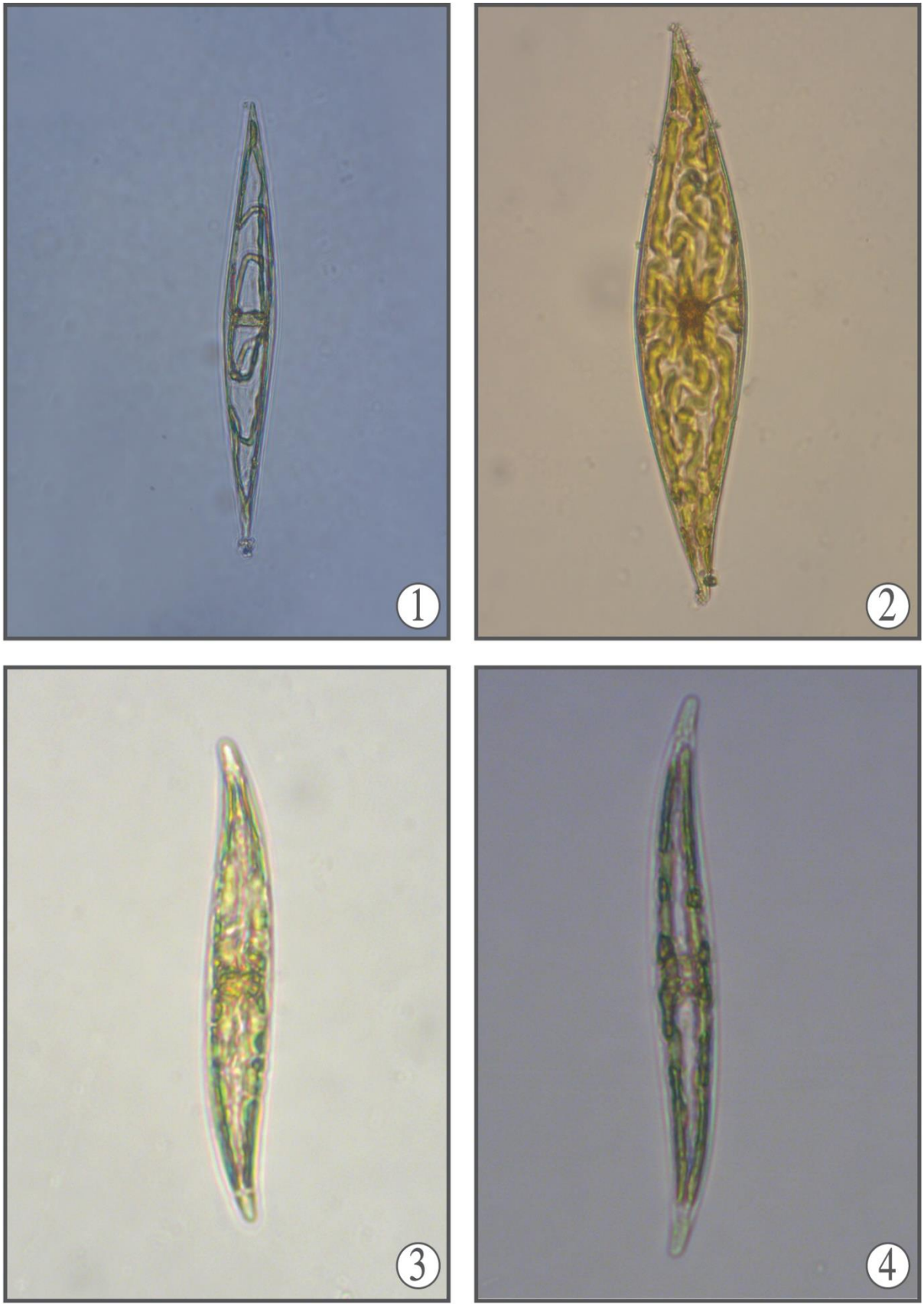
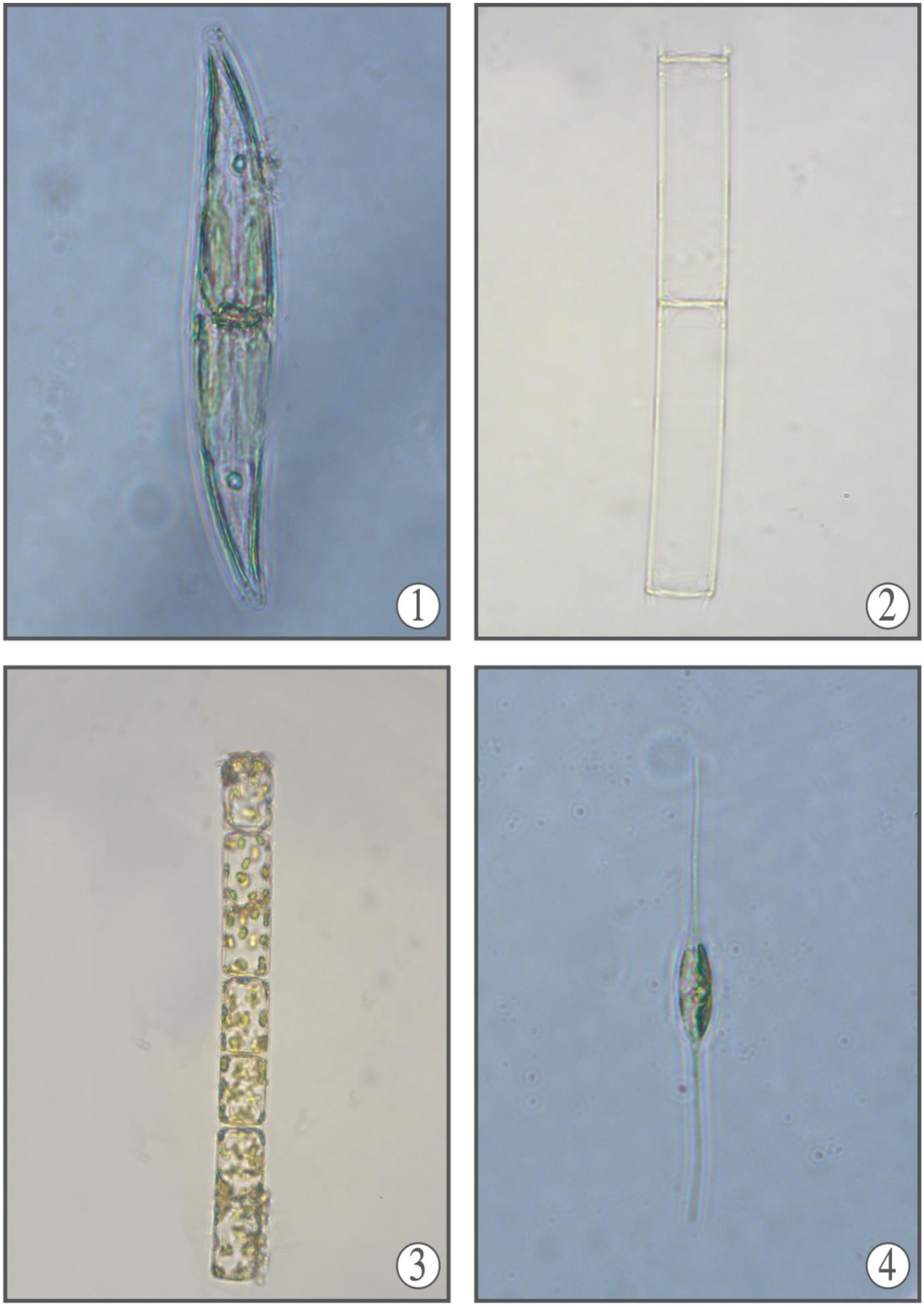


Plate 14

No.	Name of the species
1.	*Pleurosigma cuspidatum*
2.	*Cerataulina dentala*
3.	*Lauderia annulata*
4.	*Cylindrotheca closterium*

Plate 14

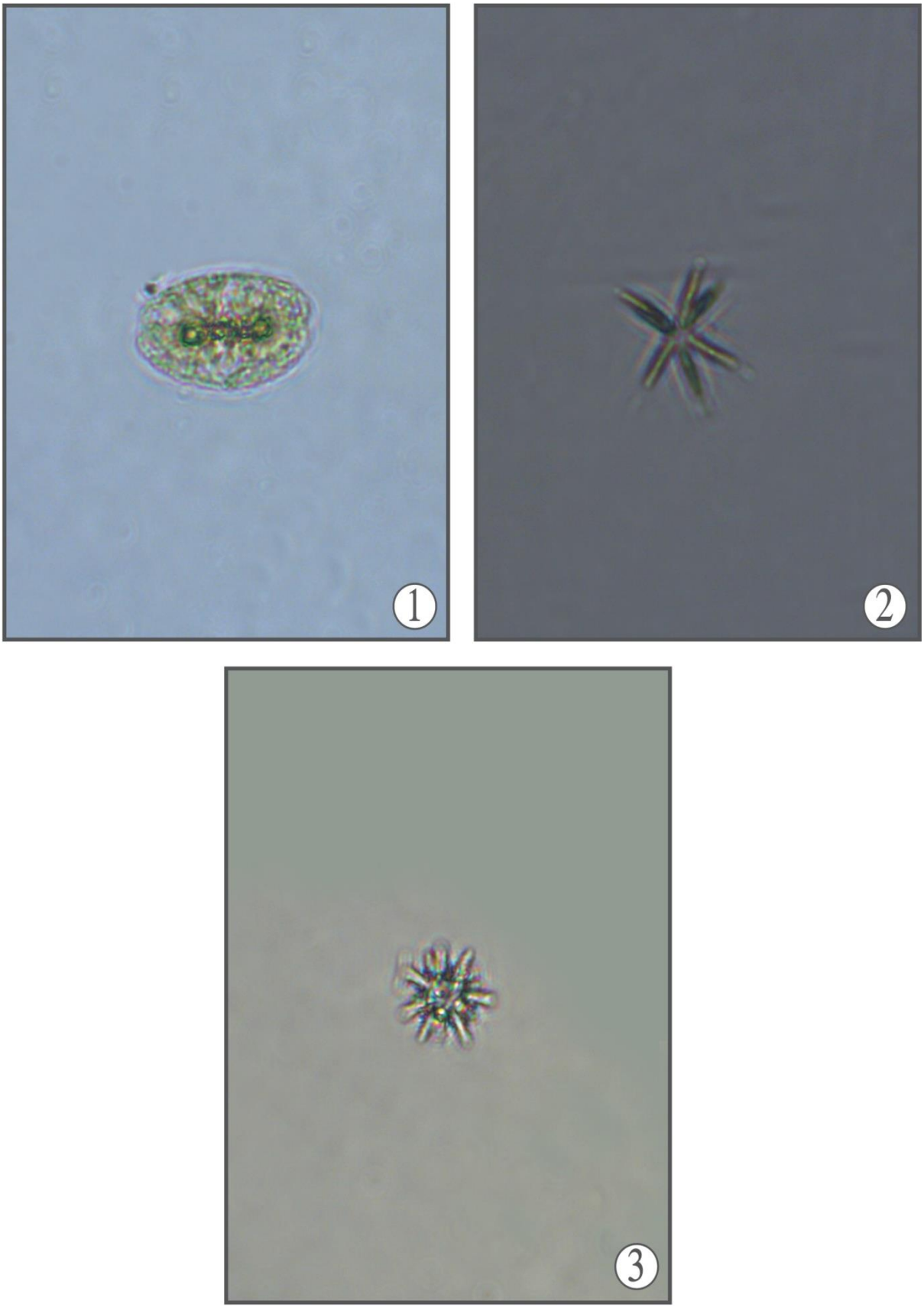


Division Chlorophyta

Plate 15

No.	Name of the species
1.	*Cosmarium dorsifruneatum*
2.	*Actinastrum raphidioides*
3.	*Conococcus elongatus*

Plate 15



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APPENDICES

Appendix I

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

Division: Cyanophyta

Species	Dimension (µm) (wide × length)	References
Aphanocapsa littoralis Hansg. Var. *macrococca*	Cells 12.5 × 6.8 µm	Islam and Aziz, 1979; Desikachary. 1959
Anabaena torulosa (Cram.) Larger	Cells 3.3 µm in diameter	Islam and Aziz, 1979; Desikachary. 1959
Arthospira platensis (Nordst.)	Cells 9.8 × 4µm	Islam and Nahar, 1967; Desikachary. 1959
Aulosira laxa Kirchner *ex* Born. *et* Flah	Cells 6.8 × 4.5µm	Islam and Irfanullah, 2003; Desikachary. 1959
Chroococcus disperses (V. Keissler) Lemm.	Cells 3.5 µm in diameter	Khondker *et al*. 2006; Prescott, 1982
Gloeocapsa atrata (Trup.)	Cells 13.8 × 5.6µm with seath	Islam and Uddin, 1977; Desikachary. 1959
Gloeocapsa decorticans Richer ex. Wille	Cells 18.2 × 17.8µm with seath	Aziz and Yasmin, 1997; Ling and Tylor, 2000
Gl. Turgida fa. maxima	Colony 31 × 46 µm	Aziz and Yasmin, 1997; Desikachary. 1959
Lyngbya allorgei Fremy	Filament 7.9-10.8 µm	Islam, 1976; Desikachary. 1959
Lyn. ceylanica Wille var. *constricta* Fremy	Filament 7.9-10.8 µm with sheath	Islam and Irfanullah, 2003; Desikachary. 1959
Lyn. Contorta Lemm	Cells 4.8 × 1.8 µm	Islam and khondker, 2003; Desikachary. 1959
Merismopedia minima	Cells 0.5-0.7 µm broad	Islam and Nahar, 1967; Skuja, 1949
Merismopedia punctata	Colony 8.4-4.7 µm broad	Khondker *et al*., 2006; Desikachary. 1959
Microcystis elongata	Cells 3.5-4.7 µm broad	Islam and Aziz, 1977; Desikachary. 1959

Oscillatoria bonnemaisonii (Gomont)	Cells 2.1 × 12.5 µm	Islam, 1976; Pham-Hang, 1969
Oscillatoria chlorina Kutz. *Ex* Gomont	Cells 5.1 × 13 µm	Islam and Irnanullah, 2003; Desikachary. 1959
Oscillatoria formosa Bory. *Ex* Gomont	Cells 4.3 × 6.8 µm	Aziz and Islam, 1986; Desikachary. 1959
Oscillatoria margaritifera Kütz.	Cells 3.5 × 6.2 µm	Islam, 1976; Crow, 1923
Oscillatoria minnesotensis Tilden	Cells 3.1 × 4.9 µm	Islam and Khundker, 2003; Desikachary. 1959
Spirulina nordstedtii Gomont	Spiral width 3.7 µm	Islam and Khundker, 2003; Prescott, 1982
Spirulina subtilissima Kütz.	Spiral width 2.7 µm	Aziz and Islam, 1986; Desikachary. 1959
Merismopedia elegans A. Br. ex Kütz.	Cell 5 × 3.5 µm	Islam and Aziz, 1979; Desikachary. 1959
Merismopedia glauca Ehrenb.	Cell 7.4 × 4.2 µm	Islam and Aziz, 1979; Rao, 1939
Me. minima Beck	Cell 2.5 µm in diameter	Islam and Nahar, 1967; Desikachary. 1959
Me. punctata Meyen	Cells 5 × 9 µm	Khandker et al., 2006; Desikachary. 1959
Microcystis flos-aquae (Wittr.) Kirch.	Cells 4.5 µm in diameter	Islam and Nahar, 1967; Desikachary. 1959
Mic. robusta (Clark) Nygaard	Cells 7.5 µm in diameter	Islam and Aziz, 1977; Desikachary. 1959
Mic. roseana (de Bary) Elenkin	Cells 8.5 µm in diameter	Aziz and Yasmin, 1997; Desikachary. 1959
Pelonema aphane Skuja	Cells 1.5 × 5 µm	Islam and Irfanullah, 2000; Desikachary. 1959

Division: Bacillariophyta

Species	Dimension (µm)	References
Acnanthes minutissima Kütz.	Frustules 14.8 × 2.5 µm	Aziz and Tanbir, 2003; Hustedt, 1930
Amphora ovalis	Cell 41 ×29 µm	Islam and Aziz, 1979; Germain, 1981
Amphora commutate Grun.	Cell 58.2 × 13 µm	Nahar, 2001; Hustedt, 1930
Amphora veneta	Cell 69 × 16µm	Aziz and Ara, 2000; Germain, 1981
Amphiprora costata	Cell 64 × 31 µm	Yeasmin, 2006; Hustedt, 1930
Asterionella Formosa Hasall	Frustules 82 × 1.8 µm	Nahar, 2001; Day *et al*., 1995
Asterionella glacialis Castracane	Frustules 54 ×12 µm	Islam and Aziz, 1975
Biddulphia mobiliensis (Bailey)	Frustules 131.2 × 90 µm	Islam and Aziz, 1975
Bacteriastrum hyalinum Lauder	Cell 28.8 × 36 µm	Islam and Aziz, 1975; Cupp, 1943
Bac. delicatulum Cleve	Cell 25 × 14 µm	Islam and Aziz, 1975; Cupp, 1943
Corethron hystrix Hensen	Apical axis 69.8 µm	Islam and Aziz, 1980; Cupp, 1943
Cocconeis placentula Ehr.	Cell 17.9 × 9.8 µm	Islam and Haroon, 1975; Hustedt, 1930
Climacodium frauenfeldianum Grun.	Frustules 130 × 13 µm	Islam and Aziz, 1975
Cymbella stuxbergii Cleve	Frustules 62.7 × 20 µm	Islam and Haroon, 1975
Cym. hustedtii Krasske	Cells 32.7 × 9.8 µm	Islam and Haroon, 1975; Day *et al*., 1995

Ceratium hirundinella	Cells 1.5 × 5 µm	Islam and Haroon, 1975
Ceratualina bergonii H. Peragallo	Axis 87 × 22 µm	Islam and Aziz, 1980; Cupp, 1943
Chaetoceros affinis Lauder var. *Wellei*	Cells 25 × 11 µm	Islam and Aziz, 1975; Cupp, 1943
Chaetoceros lorenzianus Grunow	Cells 28 × 36 µm	Islam and Aziz, 1975; Subrahmanyan,1946
C. costatus Pavillard	Cells 41 × 24 µm	Islam and Aziz, 1975
C. peruvianus Brightwell fa. *depressus*	Cells 20.1 × 24.8 µm	Islam and Aziz, 1980
C. coarctatus Lauder	Cells 55 × 49 µm	Islam and Aziz, 1975;
C. denticulatum Lauder	Cells 32 × 19 µm	Islam and Aziz, 1975
C. laciniosus Schutt	Frustules 10 × 19 µm	Islam and Aziz, 1975
C. compressus Lauder	Cells 19 × 13 µm	Islam and Aziz, 1975; Subrahmanyan,1946
C. brevis Schutt	Cells 32 × 30 µm	Islam and Aziz, 1975; Cupp, 1943
C. curvisetus Cleve	Cells 15 × 13 µm	Islam and Aziz, 1975; Caraus, 2002
C. diadema (Ehr.)	Frustules 21 × 13 µm	Islam and Aziz, 1975; Shevchenko *et al.*, 2006
C.Costatus Pavillard	Cells 42.5 × 24.8 µm	Islam and Aziz, 1975
C. distans Cleve	Frustules 17 × 13 µm	Islam and Aziz, 1975
C. eibenii Grunow	Cells 28 × 32 µm	Islam and Aziz, 1975; Caraus, 2002
C. flexuosus Mangin	Cells 12 × 27 µm	Islam and Aziz, 1975; Cupp, 1943
C. hendyi Mangin	Cells 12 × 27 µm	Islam and Aziz, 1975; Cupp, 1943

Coscinodiscus lineatus	Valves 41 µm in diameter	Islam and Aziz, 1977; Day *et al*., 1995
Cos. Stellaris var. *symbolophorus* Grunow	Valves 72 µm in diameter	Islam and Aziz, 1977
Cos. Excentricus Ehr.	Valves 38 µm in diameter	Islam and Aziz, 1975
Centritractus belanophorus (Schmidle)	Cells 17.8 × 7 µm	Aziz and Tanbir, 2003; Prescott, 1982
Botrydiopsis arhiza Borzi	Cells 8.8 µm	Islam and Irfanullah, 2000; Prescott, 1982
Cyclotella bodanica Eulenstein ex. Grunow	Valves 65 µm in diameter	Islam and Aziz, 1977; Hustedt, 1930
Cy. comensis Grunow	Valves 6.5 µm in diameter	Islam and Aziz, 1977; Hustedt, 1930
Cy. comta (Ehr.) Kütz.	Valves 43 µm in diameter	Khair and Chowdhury, 1983
Cy. meneghianiana Kütz.	Cells 12.8 µm in diameter	Nahar, 2001; Hustedt, 1930
Cy. Stelligera Cleve	Frustules 13 µm in diameter	Nahar, 2001; Germain, 1981
Diploneis ovalis (Hilse) Cleve	Cells 38 × 22 µm	Nahar, 2001; Day *et al*., 1995
Diatoma vulgare Bory var. *linearis*	Frustules 33 × 7 µm	Islam and Aziz, 1975
Ditylum brightwellii (West) Grunow	Frustules 148 × 42 µm	Islam and Aziz, 1975; Cupp, 1943
Ditylum sol (Grunow)	Frustules 152 × 42 µm	Islam and Aziz, 1975; Cupp, 1943
Epithemia zebra (Ehr.)	Cells 34.5 × 6.5 µm	Nahar, 2001; Day *et al*., 1995
Epithemia argus Ehrenberg	Cells 21.5 × 15.5 µm	Aziz and Yasmin, 1997; Germain, 1981
Eucampia balaustium Castr.	Cells 31 × 43 µm	Islam and Aziz, 1975
Eucampia cornuta Cleve	Cells 45 × 31 µm	Islam and Aziz, 1975; Cupp, 1943

Eunotia alpina (Näg.) Hust.	Cells 97 × 7 µm	Aziz and Ara, 2000; Germain, 1981
Eunotia lunaris (Ehren.) Grun.	Frustules 87 × 6.4 µm	Islam and Haroon, 1975; Caraus, 2002
Eunotia sudetica O. Muller.	Frustules 29.7 × 13.4 µm	Islam and Haroon, 1975; Day *et al.* 1995
Eunotia pectinalis (Kütz.)	Frustules 73 × 8.4 µm	Islam and Haroon, 1975
Fragillaria crotonensis Kitton	Frustules 143 × 43 µm	Aziz and Tanbir, 2003; Hustedt, 1930
Fragillaria virescens Ralfs	Frustules 415 × 12 µm	Islam and Aziz, 1977; Germain, 1981
Fragillaria virescens var. *capitata* Ostrup	Cells 110 × 7 µm	Aziz and Yasmin, 1997; Varela, 1982
Hemiaulus membranaceus Cleve.	Axis 35 µm	Islam and Aziz, 1980; Cupp, 1943
H. sinensis	Frustules 60 × 34 µm	Islam and Aziz, 1975; Cupp, 1943
Hemidiscus hardmannianus Greville	Valve 238 µm	Islam and Aziz, 1975; Subrahmanyan,1946
Lauderia borealis Grun.	Frustules 37 × 38 µm	Islam and Aziz, 1975; Cupp, 1943
Rhizosolenia setigera	Frustules 310 × 58 µm	Islam and Aziz, 1975; Cupp, 1943
R. imbricata Brightwell	Frustules 289 × 33 µm	Islam and Aziz, 1975; Cupp, 1943
R. imbricata Brightwell var. *shrubsolei*	Frustules 700 × 50 µm	Islam and Aziz, 1975; Cupp, 1943
R. alata fa. *gracillima*	Frustules 372 × 8 µm	Islam and Aziz, 1980; Cupp, 1943
R. alata fa. *indica*	Frustules 472 × 25.8 µm	Islam and Aziz, 1980; Cupp, 1943
R. alata Brightwell fa. *intermis*	Frustules 510 × 18 µm	Islam and Aziz, 1975; Cupp, 1943
R. calcar-avis M. Schultze	Frustules 310 × 98 µm	Islam and Aziz, 1975; Cupp, 1943

R. bergonii Peragallo	Frustules 970 × 150 µm	Islam and Aziz, 1975; Cupp, 1943
R. styliformis Brightwell	Frustules 327 × 18.5 µm	Islam and Aziz, 1975; Cupp, 1943
R. styliformis var. *longispina*	Frustules 227 × 30 µm	Islam and Aziz, 1975; Cupp, 1943
R. truncate Karsten	Frustules 352 × 89 µm	Islam and Aziz, 1975; Cupp, 1943
Skeletonema costatum Grev.	Frustules 14 × 6.8 µm	Islam and Aziz, 1975; Cupp, 1943
Gyrosigma scalproides (Rabh.)	Cells 112 × 16 µm	Islam and Haroon, 1975; Hustedt, 1930
Gyrosigma distortum var. *parkeri* (Harison)	Cells 118 × 17 µm	Islam and Mannan, 1986; Day *et al.* 1995
Gy. Acuminatum (Kütz.)	Frustules 150 × 24 µm	Aziz and Islam, 1986; Germain, 1981
Gy. Attenuatum (Kütz.)	Frustules 243 × 25 µm	Islam and Aziz, 1986; Germain, 1981
Gomphonema lanceolatum var. *insignis* (Greg,) Cleve	Frustules 4 × 68 µm	Nahar, 2001; Hustedt, 1930
G. lanceolatum var. *turnis* (Ehr.) Hust.	Frustules 14 × 65 µm	Islam and Haroon, 1975; Hustedt, 1930
Melosira juergensii Ag.	Cells 61 × 24.4 µm	Islam and Aziz, 1975; Cupp, 1943
Melosira arenaria Moore	Cells 33 × 18 µm	Islam and Aziz, 1975; Cupp, 1943
Melosira distans var. *alpigena* Grunow	Cells 6 × 10 µm	Nahar, 2001; Hustedt, 1930
Mel. granulata (Ehrenberg) Ralfs	Cells 14.8 × 6.8 µm	Islam, 1974; Hustedt, 1930
Mel. granulata var. *angustissima* Müller	Cells 25.5 × 5 µm	Islam, 1974; Hustedt, 1930
Nitzschia longissima	Cell 4 × 48.7 µm	Aziz and Tanbir, 2003; Germain, 1981
Nitzschia clausii Hantzsch	Frustules 350 × 13.4 µm	Islam and Aziz, 1979; Day *et al.* 1995

Nitzschia fruticosa Hust.	Frustules 28 × 4 µm	Nahar, 2001; Germain, 1981
Nitzschia acicularis var. closterioides Grunow	Frustules 78 × 4 µm	Islam and Aziz, 1979; Hustedt, 1930
Nitzschia pungens Grunow	Frustules 121 × 6 µm	Islam and Aziz, 1975; Cupp, 1943
Surirella tenera Gregory	Frustules 101 × 34 µm	Nahar, 2001; Hustedt, 1930
Su. angustata Kütz.	Frustules 40 × 10 µm	Aziz and Tanbir, 2003; Hustedt, 1930
Su. capronii Brébisson	Frustules 300 × 90 µm	Nahar, 2001; Hustedt, 1930
Su. ovata var. *apiculate* W. Smith	Frustules 90 × 19 µm	Aziz and Tanbir, 2003; Germain, 1981
Su. ovata var. *pinnata*	Frustules 75 × 15 µm	Aziz and Tanbir, 2003; Hustedt, 1930
Su. obusta var. *splendida* (Ehrenberg)	Frustules 145 × 65 µm	Islam and Haroon, 1975; Hustedt, 1930
Stephanopyxis palmeriana (Greville)	Cells 87 × 70 µm	Islam and Aziz, 1975; Cupp, 1943
Navicula americana Ehrenberg	Cells 143 × 25.8 µm	Nahar, 2001; Hustedt, 1930
N. bacillum Ehrenberg	Cells 128 × 20 µm	Islam and Aziz, 1979; Hustedt, 1930
N. exigua (Dujardin) Nouv.	Cells 27 × 7.8 µm	Islam and Haroon, 1975; Hustedt, 1930
N. grimmei Krasske	Cells 23 × 7.5 µm	Aziz and Ara, 2000; Hustedt, 1930
N. laevissima Kutzing	Cells 33 × 9 µm	Islam and Haroon, 1975; Hustedt, 1930
N. menisculus Schum.	Cells 27 × 7 µm	Islam and Haroon, 1975; Hustedt, 1930
N. placentula var. *rostrata* Backman and Cleve-Euler	Cells 30 × 10 µm	Aziz and Tanvir, 2003; Hustedt, 1930
N. pseudohalophila Cholnoky	Cells 25 × 5.8 µm	Aziz and Ara, 2000; Hustedt, 1930

N. pupula Kütz.	Cells 7.25 × 39 µm	Islam and Irfanullah, 2005; Hustedt, 1930
Navicula pupula var. *capitata* Hust.	Cells 40 × 9 µm	Nahar, 2001; Hustedt, 1930
N. radiosa Kütz.	Cells 68 × 8 µm	Begum and Hadi, 1994; Hustedt, 1930
N. spicula Hickey	Cells 58 × 7 µm	Aziz and Ara, 2000; Hustedt, 1930
Nitzschia acicularis (Kuetz.) G.M. Smith	Frustules 3.5 × 78 µm	Nahar, 2001; Hustedt, 1930
Nitz. acicularis var. *closteroides* Grun.	Frustules 6 × 139 µm	Islam and Aziz, 1979; Hustedt, 1930
Nitz. alpina (Naeg.) Hustedt	Frustules 5 × 40 µm	Aziz and Tanvir, 2003; Hustedt, 1930
Nitz.gracilis Hantz. in Raben.	Frustules 5 × 101 µm	Islam and Irfanullah, 2000; Hustedt, 1930
Nitz.longissima (Brėb.) Grunow	Frustules 6 × 35 µm	Aziz and Tanvir, 2003; Hustedt, 1930
Nitz.pungens Grunow	Frustules 6 × 125 µm	Islam and Aziz, 1975; Hustedt, 1930
Nitz.subtubicola H. Germain	Frustules 4 × 39 µm	Nahar, 2001; Hustedt, 1930
Stauroneis anceps fa. *gracilis* (Ehr.) Hust.	Cells 130 × 13 µm	Aziz and Ara, 2000; Hustedt, 1930
Synedra acus Kütz.	Frustules 6 × 143 µm	Islam and Haroon, 1975; Hustedt, 1930
Syn. rumpens var. *familiaris* (Kütz.) Poretzky	Frustules 4 × 93 µm	Nahar, 2001; Hustedt, 1930
Syn. tabulate (Ag.) Kütz.	Frustules 5 × 99 µm	Aziz and Ara, 2000; Hustedt, 1930
Syn. ulna var. *danica* (Kütz.) Heurck	Frustules 4.5 × 176 µm	Nahar, 2001; Hustedt, 1930
Syn. ulna var. *oxyrhynchus* (Kütz.) O'Meara	Frustules 12 × 199 µm	Islam and Aziz, 1975; Hustedt, 1930

Syn. vaucheriae Kütz.	Frustules 3.5 × 39 µm	Nahar, 2001; Hustedt, 1930
Pinnularia acrosphaeria (Brėb.) Rab.	Cells 68 × 12.4 µm	Nahar, 2001; Hustedt, 1930
Pin. brevicostata Cleve	Frustules 112 × 14.8 µm	Nahar, 2001; Caraus, 2002
Pin. divergens W. Smith	Frustules 80 × 11.5 µm	Nahar, 2001; Day *et al.* 1995
Pin. gibba var. *mesogonglya* (Ehr.) Hust.	Cells 42 × 10 µm	Islam and Haroon, 1975; Hustedt, 1930
Pin. gibba var. *parva* (Grun.) Fre.	Cells 40 × 9 µm	Islam and Haroon, 1975; Hustedt, 1930
Pin. karelica var. *tibetana* (Hust.) Cleve	Cells 65 × 13.8 µm	Islam and Haroon, 1975; Hustedt, 1930
Pin. krookii (Grun.) Cleve	Cells 135 × 19 µm	Nahar, 2001; Hustedt, 1930
Pin. microstauron (Ehr.) Cleve	Cells 78 × 12.8 µm	Aziz and Tanbir, 2003; Hustedt, 1930
Pin. stauroptera (Grun.) Rab.	Cells 132 × 16.8 µm	Nahar, 2001; Hustedt, 1930
Pleurosigma normanii Ralfs	Valves 240 × 38 µm	Islam and Aziz, 1975; Cupp, 1943
Thalassiosira subtilis (Ostenfeld)	Valves 5 µm in diameter	Islam and Aziz, 1980; Subrahmanyan,1946
Thellasionema nitzschiodes Grunow	Frustules 34 × 5 µm	Islam and Aziz, 1975; Yamaji, 1968
Thalassiothrix frauenfeldii Grun.	Frustules 250 × 6 µm	Islam and Aziz, 1975; Yamaji, 1968

Division: Chlorophyta

Species	Dimension (µm)	References
Actinastrum gracillimum var. *gracillimum* Smith	Cells 13 × 3.4 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ac. hantzschii Lager.	Cells 15 × 3 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ac. hantzschii var. *subtile* Wolosz.	Cells 18 × 3 µm	Aziz, 2008; Huber-Pestalozzi, 1983
Actinotaenium cruciferum (De Bary)	Cells length 20 µm	Islam and Irfanullah, 1999; Prescott, 1957
Actinotaenium cucurbita (Bréb)	Cells length 35 µm	Islam and Irfanullah, 1999; Skuja, 1949
Actinotaenium cucurbitium var. *cucurbitinium* (Biss)	Cells length 70 µm	Islam and Irfanullah, 2006;
Actinotaenium pseudoconnatum var. *attenuatum* Nordst	Cells length 84 µm	Islam and Begum, 1999;
Ankistrodesmus barnardii Kom.	Cells 32.5 × 1.2 µm	Khondker *et al.*, 2007; Huber-Pestalozzi, 1983
Ank. blibraianus (Rein.) Kors.	Cells 12.5 × 3 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ank. densus Kors.	Colony 95 × 5 µm	Khondker *et al.*, 2007; Huber-Pestalozzi, 1983
Ank. falcatus var. *radiatus* (Chod.) Lemm.	Cells 65 × 3 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ank. spiralis (Turner) Lemm.	Cells 30.5 × 2 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ank. stipitatus (Chod.) Kom.	Cells 41 × 1.5 µm	Khondker *et al.*, 2007; Huber-Pestalozzi, 1983

Arthrodesmus curvatus Turne	Cells 65 × 35 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 7 × 5 µm	Islam and Khondker, 1993; Iyengar and Desikachary, 1973
Chl. pulchra Skvortz.	Cells 12 × 10 µm	Khandker *et al.*,2007; Huber-Pestalozzi, 1961
Closteriopsis acicularis var. *acicularis* (G.M. Smith)	Cells 54 × 1 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Closteriopsis longissimi var. tropica	Cells 87 × 3.8 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Chlorogonium elongatum (Dang.) France	Cells 32 × 3.5 µm	Khandker *et al.*,2007; Huber-Pestalozzi, 1961
Closterium angustum var. *angustum* Kutz. ex Ralfs	Cells 316 × 29 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
Cl. abruptum var. *abruptum* W.	Cells 216 × 12 µm	Islam and Haroon, 1980; Prescott *et al*., 1975
Cl. archerianum var. *archerianum*	Cells 120 × 11 µm	Islam and Haroon, 1980; Prescott *et al*., 1975
Cl. diane var. *pseudodiane* (Roy) Krieg.	Cells 164 × 18 µm	Islam and Akter, 1999; Ling and Tyler, 2000
Cl. limneticum Lemm.	Cells 156 × 8.5 µm	Yeasmin, 2006; Ling and Tyler, 2000
Cl. pitchardianum var. *angustum* Bor.	Cells 284 × 33.5 µm	Islam and Haroon, 1980; Ling and Tyler, 2000
Cl. closteroides (Ralfs)	Cells 400 × 23.5 µm	Islam and Irfanullah, 2005; Prescott *et al*., 1975

Cl. costatum Corda	Cells 250 × 25 µm	Islam and Chowdhury, 1979; Prescott *et al*., 1975
Cl. praelongum var. *praelongum* Brėb.	Cells 400 × 23.5 µm	Islam and Irfanullah, 2003; Ling and Tyler, 2000
Cl. toxon var. *toxon* W. West	Cells 204 × 16 µm	Islam and Akter, 1999; Ling and Tyler, 2000
Cl. kuetzingii var. *kuetzingii*	Cells 456 × 14.5 µm	Islam, 1970; Prescott *et al*., 1975
Cl. venus var. *venus* Kuetzing	Cells 87 × 10.5 µm	Islam and Akter, 1999; Ling and Tyler, 2000
Cl. limneticum Lemmermann	Cells 87 × 10.5 µm	Yeasmin, 2006;
Cylindrocystis brebisonii Meneghini	Cells 12 × 32 µm	Bhuiyan, 2006; 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	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cosmarium birame var. *berbadense* G.S. West	Cells 9 × 12 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cos. clepsydra Nordst.	Cells 14 × 13.5 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cos. contractum var. *reductum* Islam	Cells 16 × 11 µm	Islam and Begum, 1999; Ling and Tyler, 2000

Cos. laeve var. *octangulare* (Wille) West	Cells 14.8 × 12 µm	Islam and Aziz, 1979; Ling and Tyler, 2000
Cos. moniliforme var. *moniliforme* (Turp.) Ralfs	Cells 32 × 22 µm	Islam, 1970; Ling and Tyler, 2000
Cos. pachydermum var. *pachydermum* Lundell	Cells 132 × 78 µm	Islam and Chowdhury, 1979; Ling and Tyler, 2000
Cos. subcostatum Nordst.	Cells 29 × 23 µm	Islam and Zaman, 1975; Ling and Tyler, 2000
Cos. trachypleurum var. *minus* Racib.	Cells 31 × 29 µm	Islam and Irfanullah, 2006; Ling and Tyler, 2000
Cos. Depressum (Näg.)	Cells 21 × 23 µm	Islam and Irfanullah, 2006; Hirano, 1956
Crusigenia tetrapedia (Kirchner)	Cells 6.5 × 4.8 µm	Islam and Begum, 1970;
Crucigeniella apiculata (Lemm.) Kom.	Cells 10 × 5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Cruci. crucifera (Wolle) Kom.	Cells 14 × 9 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Cruci. rectangularis (Näg.) Kom.	Cells 6 × 3.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Dictyosphaerium granulatum Hind.	Colony 35 × 5 µm	Khondker *et al*., 2007; Huber-Pestalozzi, 1983
Dic. tetrachotomum Printz	Colony 30 × 3 µm	Khondker *et al*., 2007; Huber-Pestalozzi, 1983
Desmidium aptogonum Bréb.	Cells 30 × 16 µm	Islam and Irfanullah, 2005

Desmidium baileyi (Ralfs)	Cells 21 × 22 µm	Islam and Irfanullah, 2005; Ling and Tyler, 2000
Euastrum denticulatum (Kirch.) Gay	Cells 20 × 16 µm	Islam and Begum, 1999; Ling and Tyler, 2000
Eua. spinolosum var. *burmense* (W.&W.) Krieg.	Cells 54 × 47 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
Golenkinia pausispina West & West	Cells 20 × 14.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Hyaloraphidium contortum Pascher and Kors.	Cells 24 × 2.5 µm	Islam, 1969; Huber-Pestalozzi, 1983
Lagerheimia wratislaviensis Schroeder	Cells 6 × 5.5 µm	Islam, 1969; Huber-Pestalozzi, 1983
Monoraphidium arcuatum (Kors.) Hind.	Cells 27 × 1.5 µm	Khondker *et al*., 2007; Huber-Pestalozzi, 1983
Mon. fontinale Hind.	Cells 19 × 5 µm	Khondker *et al*., 2007; Huber-Pestalozzi, 1983
Mon. tortile (W. & W.) Kom.	Cells 21 × 2.5 µm	Khondker *et al*., 2007; Huber-Pestalozzi, 1983
Oocystis borgei Snow	Cells 19 × 15 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Pandorina morum (Müller) Bory	Cells 28.5 × 7.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
Pediastrum duplex Meyen	Cells 16 × 21 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Ped. duplex var. *gracillimum* W & W	Cells 12 × 10.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983

Ped. duplex var. *rogulosum* Racib.	Cells 19 × 15 µm	Islam, 1973; Huber-Pestalozzi, 1983
Ped. tetras (Ehrenberg) Ralfs	Cells 8.5 × 5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Ped. tetras var. tetraedron (Corda) Hansg.	Cells 12.5 × 7.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
Phacotus angustus Pascher	Cells 33 × 16 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1961
Ph. lenticularis (Ehren.) Diesing	Cells 18 × 13 µm	Islam and Alfasane, 2001; Huber-Pestalozzi, 1961
Pyrobotrys gracilis (Kors.) Kors.	Cells 17.5 × 11.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
Scenedesmus acuminatus (Lag.) Chodat	Cells 18 × 4 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. acuminatus var. *minor* G.M. Smith	Cells 15 × 2.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. acutiformis Schroeder	Cells 6 × 2 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. acutus var. *acutus* Meyen	Cells 16 × 3 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. arcuatus Lemm.	Cells 13 × 7 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. arcuatus var. *platydiscus* G.M. Smith	Cells 7.5 × 4.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. bijuga var. *irregularis* (Wolle) G.M. Smith	Cells 9.5 × 5.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. brevispina (G.M. Smith) Chodat	Cells 16.5 × 6.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961

S. denticulatus Lag.	Cells 19.5 × 8.5 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1961
S. denticulatus fa. *maximus* Uhrek	Cells 18 × 7.5 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1961
S. incrassatulus Bohlin	Cells 18.5 × 3.5 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. longispina var. *asymmetricus* Hort.	Cells 12.5 × 5.4 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1961
S. longus var. *apiculatus* Meyen	Cells 7.5 × 4.2 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1961
S. regularis Svir.	Cells 23.5 × 8 µm	Islam and Khatun, 1966; Huber-Pestalozzi, 1983
Schroederia setigera (Schroeder) Lemm.	Cells 97 × 4.1 µm	Islam and Begum, 1970; Huber-Pestalozzi, 1983
Sch. spiralis (Printz.) Kors.	Cells 32 × 3.5 µm	Khondker *et al*., 2007; Huber-Pestalozzi, 1961
Staurastrum acanthocephalum Skuja	Cells 23 × 14 µm	Islam and Zaman, 1975; Ling and Tyler, 2000
St. indentatum fa. *minus* West	Cells 36 × 15 µm	Islam and Akter, 2006; Scott and Prescott, 1961
St. chaetoceros (Schroeder) Smith	Cells 23 × 13 µm	Islam and Aziz, 1977; Ling and Tyler, 2000
Tetrastrum elegans Playfair	Cells 3.5 × 5.5 × 3.5 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) (length × wide)	References
Euglena acus (Müller) Ehrenberg	Cell 148 × 13.2 µm	Islam and Khatun, 1966, Huber-Pestalozzi, 1955
E. acus var. *longissima* Defl.	Cell 250 × 15 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. agilis var. *praecxicisa* Schiller	Cell 17.8 × 6.2 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. allorgei Defl.	Cell 115 × 12 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. australica var. *claviformis* Palyfair	Cell 20 × 13.8 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. australica var. *gibberosa* Palyfair	Cell 19 × 14 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. caudata Hübner	Cell 84.4 × 19.8 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. clavata Skuja	Cell 90 × 14.8 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. ehrenbergii Klebs	Cell 74 × 13.5 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. fusca Klebs	Cell 190 × 24.5 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. gojdicsae Prescott	Cell 36.8 × 11.8 µm	Islam *et al.*, 1991, Huber-Pestalozzi, 1955
E. limnophila Lemm.	Cell 47 × 7.8 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955
E. limnophila var. *minor*	Cell 37 × 7.8 µm	Khondker *et al.*, 2008, Huber-Pestalozzi, 1955

E. mainxii Defl.	Cell 37 × 14 µm	Khondker *et al*., 2008, Huber-Pestalozzi, 1955
E. mutabilis var. *lafevri* Chadef.	Cell 52.2 × 6.2 µm	Khondker *et al*., 2008, Huber-Pestalozzi, 1955
E. oblonga Schmitz	Cell 71 × 20.2 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
E. oxyuris var. *minor* Prescott	Cell 150 × 21 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
E. rostrifera Johnson	Cell 102 × 26 µm	Islam *et al*., 1991; Huber-Pestalozzi, 1955
Lepocinclis acuta Prescott	Cell 29 × 18 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
L. cymbiformis Playfair	Cell 33 × 11.8 µm	Islam and Irfanullah, 2005; Huber-Pestalozzi, 1955
L. ovum var. *bütschlii* (Lemm.) Conr.	Cell 31.8 × 18.8 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
L. ovum var. *dimido-minor* (Defl.)	Cells 17.8 × 11.8 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
L. ovum var. *major*	Cells 35 × 23.5 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
L. salina Fritsch	Cell 37.8 × 28 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
L. salina fa. *obtusa* (H.-P) Conr.	Cell 41 × 24 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
L. teres fa. *parvula*	Cell 35 × 21.8 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
L. texta (Duj.)	Cell 45 × 31 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955

L. texta fa. *minor* Conr.	Cell 30 × 21 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
Phacus acutus Pochm.	Cell 68 × 16 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955
Phacus acuminatus var. *acuminatus* Stokes	Cell 37 × 21.5 µm	Islam and Alfasane, 2002
P. acuminatus var. *granulate* (Roll)	Cell 29 × 18 µm	Khondker *et al*., 2008; Huber-Pestalozzi, 1955
P. latus (Roll) Pochm.	Cell 29 × 20 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
P. contortus var. *complicates* Bourr.	Cell 41 × 21 µm	Khondker *et al*., 2008; 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. 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. ranula Pochm.	Cell 104 × 42 µm	Islam and Alfasane, 2002; Huber-Pestalozzi, 1955
Strombomonas gibberosa (Playf.) Defl.	Cell 76 × 42 µm	Islam and Alfasane, 2003; Huber-Pestalozzi, 1955

Str. Acuminata var. deflandreana	Cell 28 × 17 µm	Khondker *et al*., 2008d; Day *et al*., 1995
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
Str. Fluviatilis (Lemn.)	Cell 29 × 12 µm	Khondker *et al*., 2008d; Huber-Pestalozzi, 1955
Str. Girardiana (Playf.)	Cell 41 × 21 µm	Khondker *et al*., 2008d; Huber-Pestalozzi, 1955
Str. islamii Khondker	Cell 71 × 20 µm	Khondker *et al*., 2008d
Str. rotunda (Playf.)	Cell 26 × 19 µm	Khondker *et al*., 2008d; Huber-Pestalozzi, 1955
Str. triquetra (Playf.)	Cell 29 × 14 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. Allorgei var. madaripurense	Cell 68 × 17 µm	Islam and Moniruzzaman, 1981
Tr. armata (Ehren.) Stein	Cell 28.5 × 12.5 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. anguste-ovata var. *ellipsoidea*	Cell 48 × 28 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955

Tr. angusta-ovata fa. *minor*	Cell 24 × 11 µm	Islam and Moniruzzaman, 1981
Tr. armata (Ehr.)	Cell 13 × 28 µm	Islam and Moniruzzaman, 1981; Huber-Pestalozzi, 1955
Tr. hystrix Teiling	Cell 34 × 15 µm	Khondker *et al*., 2008d; 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. 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
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
Tr. sydneyensis Playfair	Cell 40.5 × 23 µm	Islam and Irfanullah, 2003
Tr. volvocina Ehrenberg	Lorica 22 µm in diameter	Islam and Moniruzzaman, 1981
Tr. volvocina var. *punctata* Playf.	Lorica 16 µm in diameter	Khondker *et al*., 2008; Huber-Pestalozzi, 1955

Division: Cryptophyta

Species	Dimension (µm) (length × wide)	References
Astasia longa E.G.Pringsheim	Cell 19 × 78 µm	Islam and Aziz, 1979
Astasia longa var. *truncata* Pringsheim	Cell 19 × 78 µm	Islam and Aziz, 1979
Chroomonas acuta Utermöhi	Cell 4 × 10 µm	Khondker *et al.*, 2007
Chroomonas coerulea (Geitl.)	Cell 5 × 7 µm	Khondker *et al.*, 2007
Cryptomonas ovata Ehreberg	Cell 12.8 × 34 µm	Islam and Khondker, 1993
Cryptomonas erosa Ehreberg	Cell 14 × 28 µm	Khondker *et al.*, 2007
Cryp. lucens Skuja	Cell 7.1 × 10 µm	Khondker *et al.*, 2007
Cryp. obovata Czosnowski	Cell 12.2 × 24.8 µm	Khondker *et al.*, 2007
Rhodomonas lacustris Pascher *et* Ruttner	Cell 7 × 15 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) (length × wide)	References
Peridinium abei Paulsen	Cells 62 × 54 µm	Islam and Aziz 1977, Subrahmanyan 1968
Peri. granii Ostenfeld	Cells 62 × 54 µm	Islam and Aziz 1977, Parke and Dixon, 1976
Protoperidinium brochi (Kofaid and Swezy)	Cells 52 ×31 µm	Aziz and Islam, 1979; Subrahmanyan 1968
Pro. Subinerme (Paulsen)	Cells 63 ×69 µm	Aziz and Islam, 1979
Ceratium furca (Ehrenberg)	Cell proper 43 × 31 µm	Islam and Aziz 1975, Subrahmanyan 1968
Ceratium horridum Gran	Cell proper 45 ×41µm	Islam and Aziz 1975, 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: Chlorophyta

Species	Dimension (µm) (length × wide)	References
Actinastrum raphidioides (Reinsch)	Cell 6.7×2.2 µm	Huber-Pestalozzi, 1983
Conococcus elongatus CART.	Cell 4.7×1.8µm	Huber-Pestalozzi, 1983; Carter, 1869
Cosmarium dorsitruncatum (Nordst.) West	Cell 43.7-33.9 µm	Bogopocam, 1982;

Division: Bacillariophyta

Species	Dimension (µm) (length × wide)	References
Actinocyclus octonarius var. *octonarius* Ehrenberg	Valve 140× 80.4 µm	Al-Kandari *et al*., 2009
Amphiprora alata Kütz.	Valve 148 × 42.8 µm	Bourrelly, 1981
Aulacodiscus orbiculatus Ehrenberg	Cell 77-112 µm	Subrahmanyan, 1946
Cheatoceros pendulus Karsten	Cell 17 µm width	Cupp, 1943
C. diversus Cleve	Apical axis 9-11.8 µm	Cupp, 1943
C. pelagicus Cleve.	Cell 16.2 µm broad	Subrahmanyan, 1946; Cupp, 1943
C. decipiens Cleve.	Cell 75 × 80 µm	Cupp, 1943; Doan-Nhu *et al*., 2014
C. pseudobrevis Pavillard	Apical axis 32.8 µm	Doan-Nhu *et al*., 2014; Cupp, 1943
C. tetrastichon Cleve	Cell 19 µm width	Cupp, 1943
C. didymus Ehrenberg	Chain 31 µm wide	Cupp, 1943; Simonsen, 1974
C. denicus Cleve	Cell 7 µm width	Doan-Nhu *et al*., 2014
C. aequatorialis Cleve	Apical axis 29.4 µm	Cupp, 1943; Doan-Nhu *et al*., 2014
C. contortrus Schütt	Apical axis 19.2 µm	Doan-Nhu *et al*., 2014; Cupp, 1943
C. constrictus Gran	Chain 34 µm wide	Doan-Nhu *et al*., 2014
Cyclotella stylorum Brightwell	Diameter 30.7 µm	Al-Kandari *et al*., 2009; Hustedt, 1930
Cerataulina dentata Hasle	Diameter 10-12 µm	Al-Kandari *et al*., 2009; Hasle and Syvertson, 1997

Species	Dimension (µm) (length × wide)	References
Cylindrotheca Closterium (Ehrenberg)	Valve 72.5 × 21.5 µm	Al-Kandari *et al*., 2009
Fragilaria capitellata Grun	Cell 23.6 × 4.8 µm	Bogopocam, 1951
Helicotheca thamensis (Shrubsole) Ricard	Axis 91 × 108.2 µm	Al-Kandari *et al*., 2009; Pavillard, 1925
Odontella sinensis (Greville) Grunow	Cell 300 × 178 µm	Pavillard, 1925; Cupp, 1943
Meuniera membranacea Cleve	Cell 35-49 µm	Pavillard, 1925; Cupp, 1943
Entomoneis sulcata Müller	Valves 148.2 × 58.7 µm	Al-Kandari *et al*., 2009
Pleurosigma salinarum Grun.	Cells 120.8 × 16.8 µm	Hustedt, 1930
Pl. longum Cleve	Cells 350 × 42.8 µm	Hustedt, 1930
Pl. elongatum W. Smith	Cells 312.8 × 34.4 µm	Subrahmanyan, 1946
Pl. cf. elongatum Smith	Cells 358 × 28.5 µm	Al-Kandari *et al*., 2009
Pl. cuspidatum Cleve (Peragallo)	Valves 87.8 × 22.5 µm	Al-Kandari *et al*., 2009
Lampriscus shadboltianum (Greville)	Cells 51 × 26 µm	Hustedt, 1930; Round *et al*., 1990
Lyrella cf. *abrupta* (Gregory) Mann	Valves 56.8 × 22.5 µm	Al-Kandari *et al*., 2009
Lyrella spectabilis (Gregory) Mann	Valves 47.3 × 26.5 µm	Al-Kandari *et al*., 2009
Lauderia annulata Cleve	Valves 42-44.8 µm in diameter	Al-Kandari *et al*., 2009; Pavillard, 1925
Nitzschia Closterium (Ehrenberg) W. Smith	Cells 86.8 µm long	Cupp, 1943
Nitzschia cf. *sigma* (Kützing)	Cells 300 × 21.4 µm	Al-Kandari *et al*., 2009

Species	**Dimension (µm) (length × wide)**	**References**
Thalassionema nitzschioides Grunow	Cells 110 × 25.8 µm	Cupp, 1943
Thalassiosira oestrupii (Ostenfeld) Hasle	Valve 14.8-16.8 µm in diameter	Al-Kandari *et al*., 2009
Thalassiosira eccentrica (Ehrenberg) Cleve	Valve 56-58 µm in diameter	Al-Kandari *et al*., 2009
Tropidoneis lepidoptera (Greg.) Cleve	Valve 110 × 25.8 µm	Cleve, 1894
Guinardia striata (Stolterfoth)	Cells 110 × 25.8 µm	Cupp, 1943; Hendey, 1964
Mastogloia smithii Thwaites	Valve 48.2 × 12.5 µm	Bourrelly, 1981
Surirella fastuosa (Ehrenberg)	Valve 71 × 42 µm	Al-Kandari *et al*., 2009
Surirella ovalis (de Brebisson)	Valve 94 × 39.8 µm	Bourrelly, 1981
Striatella unipunctata (Lyngbye)	Valve 98.8 × 32.8 µm	Al-Kandari *et al*., 2009
Stenopterobia sigmatella (Gregory) Ross	Cells 298 × 24.8 µm	Hustedt, 1930
Navicula dicephala (Ehr.)	Cells 30 × 10.5 µm	Bogopocam, 1951;
Pinnularia lata fo. *Thuringiaca* (Rabh.)	Cells 7.8× 2.2 µm	Hustedt, 1930
Pinnularia interrupta fo. *minutissima* (W.Sm.)	Cells 60× 12.5 µm	Bogopocam, 1951; Hustedt, 1924

Appendix III

Correlation matrix for Station B1 (N=24).

	AT	WT	SD	Salinity	TDS	Cond.	DO	pH	Alk.	NO_3N	SRP	SRS	Chl*a*	Phaeo	PD
AT	1	.880**	-.015	-.048	.092	.229	-.216	.152	-.077	.323	.351	-.247	-.606**	-.294	.060
WT	.880**	1	-.076	.008	.036	.167	-.112	.228	-.088	.419*	.285	-.270	-.469*	.033	-.055
SD	-.015	-.076	1	.285	.245	-.263	-.405*	.196	.278	-.192	.681**	.108	.041	.077	-.186
Salinity	-.048	.008	.285	1	.175	-.170	-.035	.204	.314	-.085	.373	-.148	-.192	.019	.034
TDS	.092	.036	.245	.175	1	-.067	.128	-.303	.211	-.088	.469*	.166	.117	-.377	-.270
Cond.	.229	.167	-.263	-.170	-.067	1	-.121	.268	-.223	-.134	-.250	-.401	-.073	-.047	.265
DO	-.216	-.112	-.405*	-.035	.128	-.121	1	-.545**	.364	.649**	-.299	-.397	.177	-.321	.356
pH	.152	.228	.196	.204	-.303	.268	-.545**	1	-.043	-.138	.290	-.235	.093	.520**	.028
Alk.	-.077	-.088	.278	.314	.211	-.223	.364	-.043	1	.375	.140	-.431*	.143	-.082	.445*
NO_3N	.323	.419*	-.192	-.085	-.088	-.134	.649**	-.138	.375	1	.063	-.534**	-.072	-.229	.297
SRP	.351	.285	.681**	.373	.469*	-.250	-.299	.290	.140	.063	1	.008	-.094	-.139	-.310
SRS	-.247	-.270	.108	-.148	.166	-.401	-.397	-.235	-.431*	-.534**	.008	1	-.067	.104	-.491*
Chl*a*	-.606**	-.469*	.041	-.192	.117	-.073	.177	.093	.143	-.072	-.094	-.067	1	.199	-.149
Phaeo	-.294	.033	.077	.019	-.377	-.047	-.321	.520**	-.082	-.229	-.139	.104	.199	1	-.303
PD	.060	-.055	-.186	.034	-.270	.265	.356	.028	.445*	.297	-.310	-.491*	-.149	-.303	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 B2 (N=24).

	AT	WT	SD	Salinity	TDS	Cond	DO	pH	Alk	NO_3N	SRP	SRS	Chl*a*	PP	PD
AT	1	.899**	.108	.018	.123	.251	-.111	.279	.010	.018	.385	-.030	-.109	-.038	.116
WT	.899**	1	.101	.168	.117	.209	-.014	.407*	.069	.239	.440*	-.138	-.049	.045	.003
SD	.108	.101	1	.425*	.408*	.051	-.227	.095	.374	-.287	.528**	.066	.171	.179	.326
Salinity	.018	.168	.425*	1	.518**	.077	.010	.155	.342	.032	.553**	-.170	-.112	.067	.304
TDS	.123	.117	.408*	.518**	1	.139	.013	-.208	.280	.065	.527**	.178	-.159	-.110	.788**
Cond.	.251	.209	.051	.077	.139	1	-.092	.092	-.165	-.266	.091	-.127	-.172	-.154	.160
DO	-.111	-.014	-.227	.010	.013	-.092	1	-.312	.394	.602**	-.005	-.416*	-.292	.251	.057
pH	.279	.407*	.095	.155	-.208	.092	-.312	1	-.084	-.122	.149	-.439*	.195	.000	-.212
Alk.	.010	.069	.374	.342	.280	-.165	.394	-.084	1	.192	.407*	-.248	-.145	.074	.427*
NO_3N	.018	.239	-.287	.032	.065	-.266	.602**	-.122	.192	1	-.072	-.213	.133	.180	-.033
SRP	.385	.440*	.528**	.553**	.527**	.091	-.005	.149	.407*	-.072	1	-.132	-.229	.130	.331
SRS	-.030	-.138	.066	-.170	.178	-.127	-.416*	-.439*	-.248	-.213	-.132	1	.186	-.017	.043
Chl*a*	-.109	-.049	.171	-.112	-.159	-.172	-.292	.195	-.145	.133	-.229	.186	1	-.262	-.074
PP	-.038	.045	.179	.067	-.110	-.154	.251	.000	.074	.180	.130	-.017	-.262	1	-.184
PD	.116	.003	.326	.304	.788**	.160	.057	-.212	.427*	-.033	.331	.043	-.074	-.184	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 B3 (N=24).

	AT	WT	SD	Sal.	TDS	Cond	DO	pH	Alk	NO_3N	SRP	SRS	Chl*a*	PP	PD
AT	1	.894**	.173	-.529**	.096	.393	-.145	.158	.079	.325	.220	-.128	-.545**	-.247	.206
WT	.894**	1	.196	-.545**	-.014	.293	-.042	.227	.098	.472*	.334	-.163	-.630**	-.035	.027
SD	.173	.196	1	.201	.291	.121	-.161	-.079	.456*	.218	.470*	.132	.200	.082	.082
Sal.	-.529**	-.545**	.201	1	.129	-.146	.015	.033	.270	-.256	.088	.094	.478*	.061	.304
TDS	.096	-.014	.291	.129	1	.036	.124	-.303	.274	.047	.140	.132	.227	-.129	.096
Cond.	.393	.293	.121	-.146	.036	1	.013	.039	-.046	.288	.003	-.102	-.508*	-.172	.214
DO	-.145	-.042	-.161	.015	.124	.013	1	-.357	.452*	.349	-.131	-.500*	-.219	.260	-.078
pH	.158	.227	-.079	.033	-.303	.039	-.357	1	-.267	-.202	-.051	-.172	-.018	-.091	-.003
Alk.	.079	.098	.456*	.270	.274	-.046	.452*	-.267	1	.402	.223	-.344	.098	.047	.439*
NO_3N	.325	.472*	.218	-.256	.047	.288	.349	-.202	.402	1	-.056	-.357	-.419*	.281	.046
SRP	.220	.334	.470*	.088	.140	.003	-.131	-.051	.223	-.056	1	.390	-.158	.224	-.200
SRS	-.128	-.163	.132	.094	.132	-.102	-.500*	-.172	-.344	-.357	.390	1	.158	-.028	-.163
Chl*a*	-.545**	-.630**	.200	.478*	.227	-.508*	-.219	-.018	.098	-.419*	-.158	.158	1	-.093	.081
PP	-.247	-.035	.082	.061	-.129	-.172	.260	-.091	.047	.281	.224	-.028	-.093	1	-.189
PD	.206	.027	.082	.304	.096	.214	-.078	-.003	.439*	.046	-.200	-.163	.081	-.189	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 R1 (N=24).

	AT	WT	SD	Sal.	TDS	Cond.	DO	pH	Alk.	NO_3N	SRP	SRS	Chl*a*	Phaeo	PD
AT	1	.876**	.214	-.005	.125	.115	-.061	.181	-.006	.367	-.043	-.148	.176	-.361	-.297
WT	.876**	1	.220	.210	.157	.067	.081	.327	.134	.486*	.038	-.359	.319	-.275	-.265
SD	.214	.220	1	.233	.353	.620**	.168	.233	.630**	.598**	.501*	.142	.661**	-.163	-.290
Sal.	-.005	.210	.233	1	.494*	.211	-.257	-.129	.469*	.486*	.458*	-.112	.318	-.085	-.027
TDS	.125	.157	.353	.494*	1	.684**	-.534**	-.527**	.486*	.539**	.836**	.383	.238	-.270	-.207
Cond.	.115	.067	.620**	.211	.684**	1	-.218	-.084	.495*	.346	.643**	.223	.371	-.049	-.023
DO	-.061	.081	.168	-.257	-.534**	-.218	1	.531**	.087	-.054	-.112	-.356	-.052	.095	.080
pH	.181	.327	.233	-.129	-.527**	-.084	.531**	1	.067	.008	-.384	-.652**	.251	.088	.022
Alk.	-.006	.134	.630**	.469*	.486*	.495*	.087	.067	1	.757**	.582**	.234	.516**	-.166	-.108
NO_3N	.367	.486*	.598**	.486*	.539**	.346	-.054	.008	.757**	1	.431*	.096	.578**	-.312	-.401
SRP	-.043	.038	.501*	.458*	.836**	.643**	-.112	-.384	.582**	.431*	1	.301	.231	-.237	-.035
SRS	-.148	-.359	.142	-.112	.383	.223	-.356	-.652**	.234	.096	.301	1	-.045	-.046	-.182
Chl*a*	.176	.319	.661**	.318	.238	.371	-.052	.251	.516**	.578**	.231	-.045	1	-.215	-.316
Phaeo	-.361	-.275	-.163	-.085	-.270	-.049	.095	.088	-.166	-.312	-.237	-.046	-.215	1	.596**
PD	-.297	-.265	-.290	-.027	-.207	-.023	.080	.022	-.108	-.401	-.035	-.182	-.316	.596**	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 R2 (N=24).

	AT	WT	SD	Sal.	TDS	Cond.	DO	pH	Alk.	NO_3N	SRP	SRS	Chl*a*	Phaeo	PD
AT	1	.875**	.148	.057	.141	.149	-.191	.240	-.150	.330	-.450*	-.277	.028	-.107	-.269
WT	.875**	1	.246	.313	.146	.159	.061	.398	.019	.445*	-.301	-.393	-.097	-.052	-.122
SD	.148	.246	1	.345	.440*	.683**	.270	.496*	.619**	.323	.117	.266	.397	-.202	.010
Sal.	.057	.313	.345	1	.497*	.426*	-.063	.321	.417*	.319	.029	.131	-.029	.202	.040
TDS	.141	.146	.440*	.497*	1	.745**	-.410*	.019	.459*	.346	.090	.422*	.081	-.187	-.317
Cond.	.149	.159	.683**	.426*	.745**	1	-.102	.347	.420*	.171	.147	.336	.242	-.032	.093
DO	-.191	.061	.270	-.063	-.410*	-.102	1	.295	.205	-.131	.279	-.135	-.079	.116	.389
pH	.240	.398	.496*	.321	.019	.347	.295	1	.338	.308	.053	-.291	-.013	.154	.229
Alk.	-.150	.019	.619**	.417*	.459*	.420*	.205	.338	1	.251	.082	.521**	.160	-.157	-.060
NO_3N	.330	.445*	.323	.319	.346	.171	-.131	.308	.251	1	-.067	-.189	.062	-.110	-.186
SRP	-.450*	-.301	.117	.029	.090	.147	.279	.053	.082	-.067	1	.049	.025	-.155	.352
SRS	-.277	-.393	.266	.131	.422*	.336	-.135	-.291	.521**	-.189	.049	1	.297	-.076	-.044
Chl*a*	.028	-.097	.397	-.029	.081	.242	-.079	-.013	.160	.062	.025	.297	1	-.222	.109
Phaeo	-.107	-.052	-.202	.202	-.187	-.032	.116	.154	-.157	-.110	-.155	-.076	-.222	1	.417*
PD	-.269	-.122	.010	.040	-.317	.093	.389	.229	-.060	-.186	.352	-.044	.109	.417*	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 R3 (N=24).

	AT	WT	SD	Sal.	TDS	Cond.	DO	pH	Alk.	NO_3N	SRP	SRS	Chl*a*	Phaeo	PD
AT	1	.858**	.238	.010	.132	.091	-.177	.192	.010	.345	-.400	-.332	.295	-.131	-.077
WT	.858**	1	.349	.320	.143	.066	.065	.328	.212	.577**	-.256	-.463*	.216	-.192	.055
SD	.238	.349	1	.312	.455*	.625**	.210	.444*	.677**	.488*	.184	.020	.409*	-.099	.142
Sal.	.010	.320	.312	1	.458*	.167	-.114	.169	.428*	.495*	.027	-.061	.168	-.301	.083
TDS	.132	.143	.455*	.458*	1	.799**	-.346	.069	.447*	.157	.161	.365	.114	-.180	-.244
Cond.	.091	.066	.625**	.167	.799**	1	-.183	.164	.405*	.104	.120	.215	.344	-.037	.088
DO	-.177	.065	.210	-.114	-.346	-.183	1	.139	.154	.059	.488*	-.121	-.179	.062	.295
pH	.192	.328	.444*	.169	.069	.164	.139	1	.423*	.488*	-.216	-.050	.195	.258	.183
Alk.	.010	.212	.677**	.428*	.447*	.405*	.154	.423*	1	.583**	.276	.341	.265	-.313	.052
NO_3N	.345	.577**	.488*	.495*	.157	.104	.059	.488*	.583**	1	-.225	-.117	.455*	-.046	.050
SRP	-.400	-.256	.184	.027	.161	.120	.488*	-.216	.276	-.225	1	.358	-.205	-.137	-.053
SRS	-.332	-.463*	.020	-.061	.365	.215	-.121	-.050	.341	-.117	.358	1	-.109	-.075	-.137
Chl*a*	.295	.216	.409*	.168	.114	.344	-.179	.195	.265	.455*	-.205	-.109	1	-.159	.184
Phaeo	-.131	-.192	-.099	-.301	-.180	-.037	.062	.258	-.313	-.046	-.137	-.075	-.159	1	.113
PD	-.077	.055	.142	.083	-.244	.088	.295	.183	.052	.050	-.053	-.137	.184	.113	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)