PHYTOPLANKTON DIVERSITY, SEASONAL CHANGES AND LIMNOLOGY IN A STRETCH OF THE RIVER BURIGANGA NEAR DHAKA METROPOLIS

Ph.D. Thesis

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2008

DECLARATION

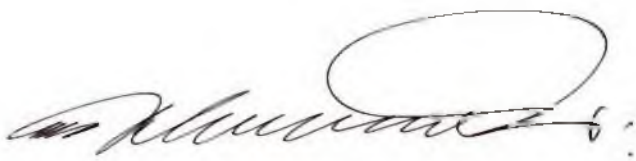
I do hereby declare that this thesis entitled **"Phytoplankton diversity, seasonal changes and limnology in a stretch of the river Buriganga near Dhaka Metropolis"** has been composed by myself and all the research works presented herein are my own. I do further declare that this work has not been submitted anywhere for any academic degree.

10 July, 2008

(Md. Shafiqul Islam)

CERTIFICATE

This is to certify that the research work presented in this thesis entitled "**Phytoplankton diversity, seasonal changes and limnology in a stretch of the river Buriganga near Dhaka Metropolis**" was carried out by Md. Shafiqul Islam bearing Registration no. 43/2004-05 under my supervision. It is further certified that the work presented here is original and suitable for submission as a Doctor of Philosophy (Ph.D.) thesis.



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ABSTRACT

ABSTRACT

A two year study (from September 2003 to August 2005) on the phytoplankton diversity, seasonal changes and limnology in a section of the river Buriganga adjacent to Dhaka Metropolis reveals a total of 180 species of phytoplankton belonging to 7 different algal classes. Highest number of species was obtained from the class Chlorophyceae (40% of the total species). Cryptophyceae represented least number of species (a maximum of 5 species) in the river. Among the total taxa of phytoplankton about 70 will be new report for Bangladesh. Seasonally the population density of phytoplankton community ranged 1.0×10^3 - 137.4×10^3 ind/L. Phytoplankton chl-a and its degraded product phaeopigment concentration ranged from 2.0-163 µg/L and 0-334 µg/L, respectively. The diversity index (H') varied from 1.4-4.7 byt/ind. This range indicates a moderate to heavy pollution of the river water along a 17 km stretch (the total length covered under ST-1 to ST-3 of the present investigation) of the river. The downstream station, ST-3 mostly enjoyed higher diversity of phytoplankton. A comparison with past studies carried out in this zone of the river Buriganga (nearly 30 years back) a greater shift in the community of phytoplankton has been observed i.e., from desmid and diatom dominated community to euglenoid and chlorococcoid dominated one. All other pollution related chemical and biological parameters such as SRP, SRS, alkalinity, conductivity, TDS and chl-a has increased to some extent. Data on 13 limnological variables recorded during the present investigation show almost clear picture about the water quality along 17 km stretch of the river Buriganga. Air and water temperature did not vary significantly. However water transparency as Secchi depth (Zs) showed gradual improvement from the upstream towards down stream stations (maximum Zs were at ST-1: 54, ST-2: 60 and ST-3: 83 cm). Zs improves only when the loading of suspended matter is low. But compared to 1995 Zs data (90 cm) water quality at ST-2 has deteriorated further in the recent time. pH maxima in all the studied stations was same (6.9) but shifted towards acidic range when compared with the data of 1995 at ST-2 (8.1). Improvement of water quality from upstream to downstream stations has also been observed in respect to alkalinity (maximas at ST-1: 7.6, ST-2: 6.6 and ST-3: 5.0 mg/L), conductivity (maximas at ST-1: 940, ST-2: 915 and ST-3: 713 µS/cm) and TDS (maximas at ST-1: 467, ST-2: 394 and ST-3: 316 mg/L). Similar trends have also been seen in respect of two important nutrient concentration. These are SRS (maximas at ST-1: 82, ST-2: 76 and ST-3: 34 mg/L) and SRP (maximas

at ST-1: 1443, ST-2: 1584 and ST-3: 466 µg/L). Anoxia is another indicator of bad water quality. Though DO maximas are almost closer in all the studied stations (ST-1: 9.4, ST-2: 9.4 and ST-3: 9.2 mg/L) complete anoxia was observed at ST-2 which is near to Sadarghat Jetty. At Shikder Medical College (ST-1) the minimum DO recorded was 0.5 mg/L while at ST-3 it was 4.3 mg/L. This shows clearly that ST-3 (further down to Sadarghat) DO improves quite a lot (4.3-9.2 mg/L). In the present study improved DO correlates improved NO_3-N concentration (0-2.5 mg/L). Similar trend was also seen by Zerin in 1995 (DO: 0.3-12.8 mg/L, NO_3-N: 0.4-10.9 mg/L) at ST-2. From this study it can be said that serious deterioration in the water quality has occurred after 1995 but there exists a trend of gradual recovery from upstream to downstream stretches in the river. Except river Turag the water quality of Shitalakhya (at certain station), Titas, Gumti, Havatia, and Meghna seems to be better when compared with the present study. Other international river such as Yamuna, India; Nile, Egypt and Kern, USA show lower range of alkalinity, TDS, SRS, SRP and NO_3-N and higher ranges in pH and DO when compared with the present study.

Excessive concentration of some nutrients and pollutant particles might be responsible for bringing damage and incomplete growth in some phytoplankton. Considering ST-2 as a reference point it could be said that within a span of 12 years (present research and that carried out by Zerin in 1995) Zs has dropped 37%, chl-a increased 11%, alkalinity increased 26%, conductivity increased 30%, SRS increased 50%, SRP increased 68%, NO_3-N dropped 90%, DO dropped 27.1%. All these parameters indicate an overall deterioration of water quality of the river Buriganga.

Chapter 1

INTRODUCTION AND AIMS AND OBJECTIVES

INTRODUCTION

Phytoplankton, the so called 'grasses of water' are an important component of the biodiversity of natural waters. Their principal function is to harvest light energy and to convert them into potential energy in the form of carbohydrate and at the same time to evolve some free oxygen in water. These are very fundamental processes related to the ecosystem functioning since phytoplankton are considered as the primary biological component in the free water to fix the energy and its subsequent transfer towards various other levels of the food chain and to make available pure oxygen for the use of others. Therefore, they do occupy the first trophic level of the whole energy flow systems in the aquatic habitats. Literally phytoplankton means 'drifting organisms'. More elaborately, they are microscopic plants which remain suspended in water and are drifted by strong wave and current actions and which complete in full or a part of their life cycle while remaining suspended in water. They are omni present in almost all natural water bodies and their existence can easily be proved by applying specialized limnological techniques. Apart from their very biological role in the aquatic food chain, their species richness, diversity, abundances and seasonal cycles are also a good indicator of water quality. This has been successfully applied by many aquatic ecosystem managers to forecast about water quality of lakes and other water bodies having tremendous economic and social impacts throughout the whole world.

Limnology is a discipline which deals with the physical and chemical water quality characteristics and the functional aspects of biological productivity in inland aquatic ecosystems. Lotic or running water and lentic or calm water are the two main domains of inland aquatic ecosystems.

The river Buriganga, a running water body, has been termed as the 'pulse' of Dhaka city because a number of activities related to trade, commerce, transportation, drainage, environment, etc. are controlled by the very existence of this river. It is also known to the historian that the city of Dhaka has expanded because of the river Buriganga. But on the other hand, the expansion and population increase in the city has created a threshold on the overall water quality and biology of the river. This has been considered as a serious concern for the existence and sustenance of the river Buriganga. The portion of the river flowing adjacent to the city of Dhaka has been vulnerable for dumping and discharging wastes and waste-water of almost all kinds.

Usually a river is a highly dynamic system in contrast to a lake (calm water body) because of the latter's longer retention time, except in the driest of seasons and in the most sluggish of streams. River water is constantly flowing having very little retention time. While the discharge of a waste at a given point may have catastrophic effects on the resident fish population, as well as the flora and fauna, and may also cause severe pollution for many miles downstream, the river - however much it has been damaged - has not been 'killed'.

One of the reasons is that, once the discharge has been stopped for good, a recovery process will begin. The residual waste will be diluted by clean water flowing downstream and carried away, the flora will recover, the fauna will recolonize, and the fish will return in time. This is not to excuse the uncontrolled discharge of effluents to river courses: rather, it should encourage pollution control bodies with polluted rivers to take those restorative steps which will ultimately result in the river regaining its pristine condition.

The above mentioned functions are best indicated by the quality and quantity of pelagic plankton population. Phytoplankton is one of the functional unit of the plankton community which includes micro-algae. The phytoplankton community

can be regarded as a complex machinery which derives its energy from the sun and its raw material from mineral salts and gases dissolved in the water. Theoretically, this machinery can be maintained by energy supply from the outside alone because nutrients can be recycled within the system. These community moves from place to place in a water body, causes its mode of nutrition and spatial biomass highly variable. It is interesting that this type of organism along with zooplankton covers 71% of the earth surface with a thickness of 3.8 km (Tilzer 1989).

Since the existence of algae suspended in river waters was acknowledged, nearly a century ago, the extent to which they may be regarded as a discrete, planktonic component of the river community has been controversial (Hynes 1970). Several reports suggests that *Stephanodiscus hantzschii*, *Melosira distans* var. *apligena* in Danube and in Severn; *Stephanodiscus hantzschii* and *Navicula* sp. are true river plankton (Reynolds 1988).

Literature survey on international basis reveals the fact that, no general attempts has ever been made to synthesize data on algal communities of river systems which can, however, develop larger populations. Ecological studies devoted to phytoplankton have been limited to particular river systems of Europe and America. Many studies are centered on particular aspects like primary production and biomass with little consideration of composition and population dynamics.

Bangladesh is a land of rivers most of which come from outside the neighbouring countries like India, Nepal, Bhutan and China. The country has a network of 250 rivers, the main three are Padma (Ganga), Jamuna (Brahmaputra) and Meghna (Mahboob 1995). About 90% of the flood water comes from outside the country due to downpour from the upstream of Ganges and Brahmaputra basin. Bangladesh has enormous water resources of about 7-8

million ha. The average annual discharge of water through this delta in the rainy season is >5 million cusecs.

In Bangladesh, freshwater is one of the most critical and valuable components of the natural resources. River system comprises nearly 13% of the total aquatic ecosystems but very few works have so far been conducted on the composition and dynamics of phytoplankton in these ecosystems.

Seasonal phytoplankton development is controlled by various physical, chemical and biological factors. Case studies proved (Descy 1993, Acs and Kiss 1993) that periodic disturbances caused by seasonal changes of discharge are important in understanding the development of riverine phytoplankton. On the otherhand questions related to the oligotrophic nature of some tropical rivers and the detail functioning of pelagic grazing food chain in running waters are some time difficult to answer.

Water pollution disturbs planktonic diversity through increased turbidity and altering nutrient status and other physico-chemical properties of water. Most of the water bodies situated in and around Dhaka city are organically enriched due to strong human influence causing serious water pollution. The polluted water bodies causes species diversity low. Concerning algal community and its ecology of the river Buriganga near Dhaka Metropolis, the remarkable research carried out 30 years back by Islam and his co-workers (Islam and Haroon 1975, Islam *et al.* 1974 and Islam and Zaman 1975) can be referred here as a milestone. But there was opportunity to do more to know the phytoplankton of the river till date as early workers carried out their study under a very limited laboratory facility. Despite, in recent times, water quality and pollution levels in the water of the river Buriganga have been debated so much in various forums that the present author deemed it necessary to carry out an investigation on the river water quality by judging its phytoplankton flora and measuring a number of water quality parameters in about a 17 km stretch adjacent to the city of Dhaka.

At present, so far its pollution status concerned, it could be labelled as one of the worst affected ecosystems. The river is dumped with tones of different wastes as well as its flow is impeded by the construction of illegal huts and houses. The river receives partially treated sewage effluents, sewage polluted surface runoff and untreated industrial effluents including tannery wastes and many other pollutants through direct human influence. All these have posed a great threat to the proper functions of the ecosystems. The upstream of the river Buriganga above the confluence of the river Turag dries up during the month of February to May when the waste assimilation capacity of the river is minimum (Ahmed 1993). Due to common pathway for most of the water transport, the water is turbid with floating oil lubricants released from the engines of the water transports. Due to lack of sufficient water flow during lean period these wastes cannot be removed and causes Buriganga a "death trap". It turns into a obnoxious large drain poses a great threat for the city dwellers. There is no regulatory body or appropriate law to protect the aquatic systems in the country. Whatever the laws formulated by the government is not enough to save the "life line" of Dhaka, the Buriganga as nobody care for it. There is no ray of hope to recover the Buriganga to its normal condition within next century due to reluctance of the authority for failing build up public awareness. Washington post published a report on Buriganga "A highly polluted river moving towards death". The river Buriganga is said to be the 'pulse' of Dhaka metropolis.

Buriganga is the sole ecosystem that receives tonnes of different wastes from 11 million inhabitants of Dhaka city. All storm sewerage falls at Buriganga. Interestingly city dwellers get their drinking and house hold uses water directly from Buriganga (Chadnighat) other than Saidabad water treatment plant. The DO (dissolved oxygen) at certain sections of the river was found less than the minimum level required for the survival of fish and other aquatic life (DEPC 1984). DO is the main criterion that represents status of a river receiving organic wastes for self purification. The DO concentration in river water is regulated by the hydrodynamic condition of the river and biological and chemical reactions

by the biota, suspended solids, plant debris and bottom sediments. Excessive depression of DO profile by heavy pollution may upset the aquatic environment of the natural stream. A complete absence of DO eliminates all aerobic flora and fauna in the natural water body.

Keeping all these forces and functions of a river ecosystems in mind the present piece of research work was undertaken to fulfill a number of objectives particularly on the diversity of its phytoplankton community and the factors regulating them.

Aims and objectives

Following are the aims and objectives of the present research on the river Buriganga:

1. What are the composition of phytoplankton?
2. What are the species richness and diversity of phytoplankton?
3. What is the trend between diversity of phytoplankton and water quality measuring index?
4. How the quantitative aspects of different species of phytoplankton do vary?
5. How the biomass of phytoplankton fluctuates over the season?
6. What are the trends of seasonal variation among the population densities of phytoplankton?
7. How the physical water quality parameters such as temperature, turbidity and flow vary over the seasons?
8. How the chemical water quality parameters such as nitrate, phosphorus, silicate, alkalinity and dissolved oxygen content of water shapes up?
9. Synergistic effect of all factors on the water quality of the river.
10. Temporal and spatial variation of the factors related to the water quality.
11. To foresee changes over historical perspective.

Chapter 2

LITERATURE REVIEW

LITERATURE REVIEW

National

The status of limnological research in Bangladesh has been reviewed by Khondker (1994). It is observed from the review that very few works on river system have been carried out in Bangladesh compared to pond ecosystems.

Islam (1969) studied the water samples collected from Sangu river (North Arakan Hill) and Rainkhyang lake. Phytoplankton and other algal flora were found to belong to Chlorophyceae, Cyanophyceae, Xanthophyceae and Bacillariophyceae. In his study from the group Bacillariophyceae 14 species belonging to 8 genera were recorded.

Islam *et al.* (1974) reported the physical and chemical limnology and their effects upon the general biological condition of the river Buriganga. They worked on air temperature, water temperature, sunshine hours, dissolved oxygen (DO), pH, total nitrogen and phospate content of the river water. Air temperature varied from 29-34°C. Water temperature was always less than the surrounding air temperature and varied within 2°C. DO content showed a high value (9.57 ml/L) in August 1973 but in other months remained 2.63-7.73 ml/L. They found quantitatively very low total nitrogen and phosphates (0.004-0.126 ppm). Water was alkaline in nature where pH was found 7.0-7.8. Phytoplankton density was recorded 4.2×10^5 . 100.0×10^5 ind/L and seasonally highest and lowest density occurred during the summer (250.4×10^5 ind/L) and spring (30.0×10^5 ind/L) respectively.

Islam and Haroon (1975) made a study on the biological aspects like algal flora, zooplankton composition, community pattern and seasonal variations for one year in the river Buriganga near Dhaka Metropolis. A total number of 59 genera

and 137 species of algae and 14 genera and 15 species of zooplankton were recorded. Percent composition of different groups of algae were Chlorophyta (62 species, 45.26%), Cyanophyta (18 species, 13.13%), Euglenophyta (2 species, 1.46%), Chrysophyta (1 species, 0.75%), (Bacillariophyceae 52 speceis, 37.96%) and Rhodophpyta (2 species, 1.46%). Their investigation showed that the member of species belonging to the class Cyanophyceae dominated in March. But the members of Bacillariophyceae and Chlorophyceae and other groups represent well from July to November. They identified 18 genera and 52 species of diatoms during their period of study, some of those were *Melosira varians*, *Cyclotella kuetzingiana*, *Synedra ulna* var. *oxyrhynchus*, *Surirella robusta* var. *splendida*, *Eunotia monodon*, *E. pectinalis* var. *undulata*, *Rhopalodia gibba*, *Navicula exigua*, *N. menisculus* fa., *Cymbella turgida*, *C. tumida*, *C. cistula*, *Gomphonema longiceps* var. *subclavata*, *G. augur*, and *G. lanceolatum* fa. *turis*.

Islam and Zaman (1975) studied the biological aspects i.e. the phytoplankton communities and their relative abundance in different seasons in the river Buriganga near Dhaka. During the study 72 genera including 194 species were encountered from the planktonic and benthic forms. The maximum number of species (about 56.19%) among the flora studied was represented by green algae. They found 29.90% of the total phyloplankton taxa belonged to the class Bacillariophyceae followed by Cyanophyceae (10.31%), Euglenophyceae, Rhodophyceae and Xanthophyceae (each represented by 1.03%) and Chrysophyceae (0.51%).

Islam and Aziz (1977) studied the phytoplankton of Karnaphuli river estuary. They have reported 23 genera and 42 species belonging to different classes.

Shafi *et al.* (1978) studied the limnology of the river Meghna for one year. They found that water was slightly alkaline and hard. DO contents showed favorable

condition for aquatic life. The nutrient value became high in summer and low in winter. Light penetration varied from 63-140 cm. Total nitrogen and phoshate concentration varied 0.1-0.42 ppm and 0.016-0.049 ppm, respectively. Plankton's numerical quantity varied from 83.34 $\times 10^4/m^3$ -171.50$\times 10^4/m^3$. The productivity was higher in summer than in winter. Among the phytoplankton, green algae flourished during summer and monsoon; desmids during spring and summer; blue green algae during spring and autumn, diatoms throughout the year. The major genera, which formed the main composition of different groups showed remarkable fluctuations *Spirogyra, Mougeotia* and *Closterium* were abundant genera in summer but rare in winter. *Microcystis* formed the bloom in spring which disappeared in monsoon and reappeared in autumn. *Pediastrum* was abundant only in spring. *Synedra, Melosira, Gomphonema, Nitzschia* and *Cosmarium* were more in monsoon. Though *Volvox* were found throughout the year, they were abundant in summer and autumn.

Safiullah *et al.* (1985) monitored the Padma (Ganges), the Jamuna (Brahmaputra) and the Baral in Bangladesh. They found that concentrations of suspended matter increased with increasing discharge in both the Padma (Ganges) and the Jamuna (Brahmaputra) as was also observed in 1981. Data on DO, alkalinity and hardness showed a very regular behaviour as those measured in 1981. DOC (dissolved organic carbon) concentrations decreased with increasing water discharge. POC (particulate organic carbon) contents found apparently different as in the river Padma POC percentage in suspended matter remained nearly constant throughout 1983 but POC in TSS (total suspended solids) decreases slightly with discharge in the Jamuna river.

Ittekot *et al.* (1985) studied the seasonal variability of organic matter in the dissolved and suspended loads in the river Ganges, Bangladesh during 1981 for over four years. They presented data on POC and DOC and their constituent fractions such as sugars, amino acids and *n*-alkanes. Organic matter associated

with peak sediment discharge appear to be dominated by a biodegraded fractions. They suggested that rivers such as the Ganges with their high sediment load are significant in terms of land derived organic carbon burial in marine sediments. Data on constituent fractions such as sugars, amino acids and *n*-alkanes of POC indicate that there are significant differences in the nature of POC transported during lean and high sediment discharge periods. Similar differences were also apparent in the DOC fraction. Its concentration varied between 1.4 and 9.3 mg/L. The peak value was observed in July.

Patra and Azadi (1987) carried out ecological studies on the planktonic organisms of the Halda River. Results of the qualitative and quantitative studies of plankton and the corresponding physicochemical conditions as well as seasonal distribution and abundance of various major taxa of phytoplankton were recorded.

Talukder and Khondker (1995) carried out limnological study of some water bodies in the Noakhali North flood prone areas of Bangladesh. On an average river water showed higher pH, DO, PO_4 and Si. Around 56% of aquatic algae from the country total occurred in the study area. Bloom formation by *Botryococcus braunii* and by some unicellular green flagellates was most common.

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

Talukder (1993) revealed water quality survey report on Gumti phase II sub-project. This work programme aims at water quality study for the river Meghna

in the upstream and downstream areas, river Salda at entering points near Indian border, internal rivers and *Khals*, confluences of main river and internal rivers, *Beels* and so on. A total number of twenty water bodies were included for that study. The pH values was found 7.6-7.7 for the Gumti river where as mean pH value for the Meghna and Titas river in the upstream represented by 7.5. DO concentration for all the sampling locations was measured sufficiently high (13.5-14.0 mg/L) in respect of 4-5 mg/L of Bangladesh standard. Maximum values for dry and wet seasons were recorded as 14 mg/L and 13.5 mg/L, respectively. Electrical conductivity for the river Meghna has an average of 98 µS/cm which is approximately one fifth of 500 µS/cm for Bangladesh standard. Nitrate for the Gumti and confluence of Titas river was measured 10 mg/L, whereas for the Meghna it varied from 5.6-9.0 mg/L. Meghna and Titas in the upstream areas contained higher concentration of phosphate in comparison to 6 mg/L of Bangladesh standard. Gumti rivers showed higher values for silica with an average concentration of 32.8 mg/L. Meghna showed slightly lower value than Gumti ranging from 20.4-27.2 mg/L of silica.

Ahmed (1993) studied the effect of bio-degradable organic pollutants on aquatic ecosystems of the river Buriganga during the lean period of the investigation year . This study focused on effluent characterstics, pollution loads and the parameters related to self-purification of the river Buriganga. The dissolved oxygen (DO) is the main criterion that represents status of a river receiving organic wastes for self purificaition. This DO concentration was found in the segment of the Buriganga river flowing by the densely populated area of Dhaka. below the desirable level of 4 mg/L for natural streams recommended by the Department of Environment of Bangladesh (1991).

Mahmud *et al.* (2007) studied on the abundance and distribution of Phytoplankton in Mouri river, Khulna. They identified 56 species of phytoplankton under 26 genera. The dominant class was Chlorophyceae (28

species) followed by Bacillariophyceae and the minimum number was represented by Euglenophyceae (7 species). The dominant species were *Navicula recta, Closterium microporum, Oscillatoria irrigua, Euglena viridis* and *Spirogyra mienningensis*. Density of phytoplankton ranged from 825-1630 ind/L.

International

Huq *et al.* (1978) studied the phytoplankton ecology of Shatt-al-Arab River at Basrah, Iraq. They studied some physico-chemical parameters as well as phytoplankton ecology. The water temperature ranged from 8.6-27.0°C, pH 7.7-8.0 and Secchi depth 0.56-1.56 m. The total number of phytoplankton ranged 0.563×10^6 - 4.479×10^6 ind/L. A total of 107 species was identified. Of these diatoms occupied 74.76% where green and blue greens constituted only 10.28% and 14.01%, respectively. The most commonly occurring species were *Bacillaria paradoxa, Cocconeis placentula, Diatoma vulgare, Rhoicosphenia curvata, Synedra ulna, S. ulna* var. *biceps, Spirogyra* sp., *Melosira granulata, M. varians, Gyrosigma tenuirostrum* and *Cyclotella meneghiniana.*

Ahmed *et al.* (1986) carried out field and laboratory studies on Nile phytoplankton in Egypt. They found that chlorophyll-a concentrations usually correlated well with phytoplankton density. The total phytoplankton exhibited higher counts in spring and summer than in autumn and winter. While diatoms exhibited the highest counts, green algae contributed more genera to the phytoplankton community. Sixty four genera were counted during the whole period of the investigation. Green algae were represented by 34 species, 20 to the diatoms and 10 to the blue-green algae.

Rai (1974) carried out limnological studies on the river Yamuna at Delhi, India part-I presents the results of physico-chemical observations to ascertain between water chemistry and the state of pollution in the River Yamuna. Part-II presents

the dynamics of potamoplankton populations in the river Yamuna. They identified 124 genera or species of phytoplankon. Dominance of Bacillariophyceae in the phytoplankton seems to be a characteristic of the river. Definite increase of Cyanophyceae group among the phytoplankton leads to pollution trends. Changes in phytoplankton related to the changes in discharge and turbidity. The greatest development of the potamoplankton occurred during the period of low discharges and turbidity and light penetration. Temperature and potamoplankton were directly related. The nitrate and phosphate concentration were increasingly related to phytoplankton yield.

Rai (1974) carried out (seven rivers) limnological observation on the different rivers and lakes in the Ivory Coast. River Do at Lakota showed that temperature varied between 21.0 and 25.9°C. The pH value varied only between 6.9 and 7.1. Nitrate nitrogen varied between 10 and 11 mg/L. Phosphate varied between 0.1 and 1.5 mg/L.

River Lonreni at Katiola showed that temperature varied between 23.5 and 26.9 °C. The pH value varied only between 7.2 and 8.1. This river is quite rich in nutrients, particularly nitrate and phosphate. The dissolved oxygen values were very low.

River Marahoue at Mankono showed that temperature did not vary very much during the period of investigation. Alkalinity was quite low with pH value (7.1). This river is quite low in nutrients and it is particularly poor in nitrate. The dissolved oxygen values were very low. Phosphate content of the water is generally low.

River Fon at Mankono showed that temperature varied between 22.0 and 26.8°C. The pH value ranged from 5.6-6.8. This river is quite rich in nutrients, particularly nitrate (10-15 mg/L) and phosphate (0-2.5 mg/L). The dissolved oxygen values were very low.

River Yani at Seguela showed that temperature varied between 21.0 and 32.2°C. The pH value remained at 7.1. This river is quite rich in nutrients, particularly in Nitrate nitrogen (0-27 mg/L) and phosphate (2.5-7.5 mg/L). The dissolved oxygen values were quite constant. River Nououri at Sinfra showed average temperature 25°C. The conductivity value was 278 µS/cm. This river is quite poor in nutrients, particularly nitrate nitrogen was found absent and phosphate was very low and these values were the lowest of the Ivory Coast rivers studied. In the River Kan at Tiebissou the pH value ranged from 6.5-7.0. The mean conductivity was 57 µS/cm. Nitrate nitrogen was usually the most concentrated (15-17 mg/L) and the phosphate content 0.4 mg/L. The mean dissolved oxygen recorded was 6 mg/L.

Golterman and Oude (1991) described the relation between algal biomass and phosphate loading in the eutrophication of lakes, rivers and coastal seas by using different statistical Models.

Descy (1993) revealed about riverine phytoplankton ecology that no general attempt has ever been made to synthesize data on potamoplankton which can however develop large populations. They often receive attention when they cause problems associated with river eutrophication: ecological studies devoted to phytoplankton have been limited to particular river systems, both temperate and tropical. Many studies are centred on particular aspects like primary production and biomass with little consideration of composition and population dynamics.

Reynolds (1988) expressed the phytoplankton ecology of shallow lakes and large rivers and as the difference between the two aquatic systems lies mainly in their physical structure. Case studies proved (Descy 1993, Acs and Kiss 1993) that periodic disturbances (attributed mostly to periodic changes of discharge) are

important in understanding the development of riverine phytoplankton and periphyton.

Gianesella *et. al.* (2001) studided on tidal effects on dissolved nutrients and phytoplankton distribution in Bertioga Channel, São Paulo, Brazil. They studied over a neap and a spring tide during the austral winter of 1991. Tidal influence and freshwater flow were the main forcing agents on the water column structure, nutrient availability and phytoplankton distribution as pointed out by the principal component analysis. The channel was vertically stratified during neap tide, but almost fully homogeneous during spring tide, especially in the flood phase. The inner area of the channel had high nutrient concentrations (up to 25 µM ammonium) and low dissolved oxygen saturation (minimum 20%). Phytoplankton biomass, measured as chlorophyll-a concentration, was low (maximum, 4.5 mg m^{-3}) considering the high nutrient availability. The highest chlorophyll-*a* levels were associated with waters of coastal origin and flood periods. The phytoplankton community was dominated by phytoflagellates but the contribution of diatoms became very significant during spring tide. The major microphytoplankton forms were *Skeletonema costatum* and *Pseudonitzschia* species. The noticeable presence of freshwater species (*Pinnularia*, *Synedra* and *Scenedesmus* species), indicated the important role of freshwater inflow in the composition of local phytoplankton community. Data suggest that the high flushing rates and hydrodynamic instability at Bertioga Channel accounted for the low phytoplankton biomass observed in the environment.

Hill and Rai (1984) studied on limnology of the Kern river (South California) for twenty months. They found that primary production in Kern river water is limited by nitrates and occasionally by phosphates. Planktonic biomass was highest in February-March and *Melosira granulata* was the dominant species. Chloraphyll-a averaged 4.17 µg/L.

Siddiqui *et al.* (1980) studied phytoplankton of the river Ganges, India. In all 125 algal species were recorded which included representatives of Cyanophyta, Bacillariophyta and Euglenophyta. The Chlorophyta specially chlorococcalean algae were the most prominent in composition and dominated during the summer.

Pahwa and Mehrotra (1966) carried out observations of fluctuations in the abundance of plankton in relation to certain hydrological conditions of river Ganga. Some physicochemical parameters along with distribution and seasonal fluctuation of phytoplankton.

Ahmed *et al.* (1986) carried out field and laboratory studies on Nile phytoplankton in Egypt. They recorded monthly variations of some physical and chemical characteristics of Nile waters. Their results revealed that the highest concentrations of dissolved oxygen recorded were always associated with increased phytoplankton populations which results in greater photosynthetic activity and accordingly higher oxygen production.

Ha *et al.* (2000) studied on vertical distribution of *Microcystis* population in the regulated Nakdong River, Korea. The vertical distribution of a bloom-forming *Microcystis* population was studied based on the limnological parameters obtained from the lower Nakdong River (Mulgum) during the summer 1994. Over three months (late June to late September), a high abundance of *Microcystis* population (mean ± SD, 2.9 ± 8.4 10^5 cells/ml, n= 40), algal biomass (mean ± SD, chlorophyll 131 ± 346 g/L, n=31) was persistent throughout the entire column (0-5 m, n=11). The vertical distribution of carbon content was uneven, with a high concentration near the surface (mean ± SD, total, 7.9 ± 7.8; *Microcystis*, 5.2 ± 8.3 g C/mL, n=15). Incorporating limnological and chlorophyll-a concentration was highest near the surface zone on a calm night but was evenly distributed on a windy day where wind velocity may have played

an important role in controlling the vertical distribution of *Microcystis* in the lower Nakadong River.

Okada and Watanabe (2002) studied on effect of physical factors on the distribution of filamentous green algae in the Tama river. The distribution of stream-specific filamentous green algae (SSFG) was investigated in the middle reach of the Tama river, Japan. *Cladophora glomerata* and *Stigeoclonium* sp. with five other taxa of algae were collected in the riverbed with fast currents. These two species were abundant in shallow (<20 cm) riffles with high current velocity (>30 cm/S), a habitat characterized by high light intensity and extensive aeration. The tufts of SSFG grown on riffle cobbles decreased rapidly when these cobbles were transferred to habitats with either deep water, low current velocity, or both. Their results suggests that the turbulent conditions of riffle habitats are important for the growth and survival of SSFG in the Tama river.

Katagami *et al.* (2003) made an analysis of the dynamics of the cyanobacterium *Microcystis* in the Tenryu river, Japan using an advection diffusion model. They studied seasonal changes in distribution of *Microcystis* cells in the Tenryu river flowing from lake Suwa. The results of advection-diffusion model simulation suggested that the pattern of decreases in the *Microcystis* cell concentration in the Tenryu river depended mostly on the seasonal variations in river discharge.

Takamura *et al.* (1990) discussed seasonal changes in species composition and photosynthesis of the periphyton community in an urban river (River Miyata, Japan) running the abandoned copper mining region. River Miyata polluted by copper (0.07-0.22 mg/L) and Zinc (0.13-0.55 mg/L). They measured pH, water temperature, dissolved organic carbon (DOC), dissolved inorganic nitrogen, soluble reactive phosphorus (SRP) and total copper. SRP was mostly below 0.01 mg/L, whereas nitrate-nitrogen were high, ranging 0.9-4.0 mg/L. The number of species in the river was restricted only 7-10. *Chamaesiphon subglobosus, Phormidium foveolarum, P. uncinatum, Achnanthes minutissima, Nitzschia*

palea and *Oocystis lacustris* found dominant. The diatoms tended to be abundant with a lower temperature and *Stigeoclonium* dominant under better illuminated conditions. Chlorophyll was high ranging from 31-1162 mg/m^2.

Ramberg *et al.* (2006) studied species diversity of the Okavango Delta, Botswana. They identified 1300 plant species. This level of species diversity is normal for the southern African region, and all analyzed aquatic groups are composed of ubiquitous species with an additional significant proportion of species originating from northern more tropical systems.

Kaiser *et al.* (2004) described sources and distribution of organic carbon and nitrogen in the Tagliamento river, Italy. Their investigations suggest that the major sources of fine particulate organic matter (FPOM) and solid phase extracted and ultrafilterd dissolved organic matter (DOM) in this river are a mixture of river-borne bacterial and micro algal biomass and soil-derived organic matter. Low C:N ratios of FPOM and bulk DOM, compared to DOM isolates, further indicate that FPOM is highly reactive and that its degradation releases bioavailable DOM compounds. Downstream abundance and distribution of organic C and N were also compared to inorganic nutrient concentrations and indicate that FPOM remineralization is a major pathway for the formation of inorganic nutrients in Tagliamento surface waters.

Hefny and Amer (2005) discussed Egypt and the Nile Basin. The Nile is Egypt's main source of water, and 96% of this water originates from outside of its territory. This explains why water is a key security issue for Egypt, and why, from Egypt's point of view, cooperation with the upstream Nile countries is the only way forward. Egypt's water policy focuses on demand management, environmental protection and international joint projects to increase the water supply.

Atazadeh *et al.* (2007) discussed water quality, diatom species composition and biomass estimation in the Gharasou river in western Iran. They measured physicochemical along with biological properties of the periphyton including biomass, chlorophyll-a concentration and taxonomic composition of diatom assemblages.

Bhatt *et al.* (2007) studied biotic communities in the Kishanganga river in Jammu and Kashmir to which a hydro-electric project is proposed. They carried out physical, chemical and biological characteristics of the river in two phases, monsoon and post-monsoon. They did not find any significant differences between two phases in the physical and chemical characteristics of the river water except water current velocity and turbidity. Among the biological components, significant differences were noticed in the density of phytoplankton and macro-invertebrates between two phases. Higher densities of these communities were observed during second phase with the exception of one site. Phytobenthos showed only a slight difference in the density between two phases. *Didymosphenia geminata* was the most common and abundant species in the phytoplankton as well as phytobenthos communities during both the phases. Their studies suggested that the river is unpolluted and supports a rich and diverse community composed of species that are mainly pollution tolerant. This study provides baseline data for the aquatic biodiversity of an unregulated Himalayan river and for preparation of an environment management plan for conserving the biotic communities of the river.

O'Farrel *et al.* (2001) studied on morphological variability of *Aulacoseira granulata* (Bacillariophyceae) in the Lower Paraná River (Argentina). In this paper they considered the morphological variation within a natural population of *Aulacoseira granulata* in relation to environmental factors. This species was dominant in the phytoplankton of the Lower Paraná River (Argentina) and exhibited seasonal fluctuations of cell dimensions. The mean cell diameter was

directly correlated with the river water level and inversely with pH and nitrate concentrations, whereas cell length was directly correlated with transparency and nitrate concentration and inversely with suspended solids. This pattern was similar to that observed for filament length. The cell length: diameter ratio was inversely related to water level and discharge and directly related to pH, transparency, and nitrate concentration. Maximum diameters did not coincide with maximum lengths. A tendency to maintain cell volume throughout the annual cycle was observed, which probably relates to both buoyancy and photosynthetic capacity. These results associate the water ascendancy and the size recovery phases to discharge. Cells become smaller on the ebbing of the flood phase, and the decreasing depth increases the probability that the alga will be disentrained from the turbulent field. The loss during low water would act as a stimulus for auxosporulation, contributing to the production of large cells to start off the next population.

Paidere *et al.* (2007) studied on impact of two different flood pulses on planktonic communities of the largest floodplain lakes of the Daugava River (Latvia). They observed an impact of two different flood pulses on phyto- and zooplankton communities of the two largest floodplain lakes of the Daugava River were studied in the spring and summer of 2005. Samples of phyto- and zooplankton were taken at weekly and biweekly intervals. At the end of March, a medium size pulse of spring flood was observed. At the beginning of May, it was followed by an unusually high pulse of flush floods caused by heavy rainstorms in the local drainage area. An overall increase of biomass and the number of taxa of planktonic communities during the filling and drainage phases of the spring floods was stated. The pulse of the flush floods resulted in a lower total biomass and higher species diversity, and can be regarded as a disturbance event. The high species diversity represented by a hump-shaped pattern caused by an intermediate disturbance that was measured by the rate of water level change during the floods according to Intermediate Disturbance Hypothesis

(IDH). This study reflected both linear and a slight hump-shaped relationships between the rate of water level change and the number of phytoplankton and zooplankton taxa.

Ndiritu *et al.* studied on characterization of environmental gradients using physico-chemical measurements and diatom densities in Nairobi River, Kenya. They described that diatom assemblages can serve as useful indicators of water quality in an urban environment, diversity of epilithic diatom communities on both natural and artificial substrates were sampled in Nairobi River, Kenya in 2000. Sampling of water and diatoms was carried in almost equidistant sites along 60 km stretch of Nairobi River. Their result suggested that diatom assemblages can reflect major types of environmental gradients and therefore can be used as indicators of ecological conditions in streams and rivers. Diatom assemblages, in both natural and artificial substrates, grouped together in similar environmental conditions. Consequently, satisfactory information can be obtained by the use of natural or artificial substrates.

Mitrovic *et al.* (2008) studied for long four years on development of blooms of *Cyclotella meneghiniana* and *Nitzschia* spp. in a shallow river and estimation of effective suppression flows in Hunter River, Australia. They described that blooms of *Cyclotella meneghiniana* and *Nitzschia* spp. coincided with water temperatures above 23°C and flows below 400 Ml/d that lasted for more than 12 days. Redundancy analysis showed that water temperature was positively related and antecedent flow was negatively related to the abundance of both taxa. Addition experiments indicated that nutrients are seldom limiting to growth. It suggested that a combination of faster growth rates at higher temperatures and longer retention times at low flows allows bloom populations to develop. Simulation modeling showed that flow regulation and water extraction have decreased flows in the river during summer, and consequently have probably

increased the number of diatom blooms. Environmental flows are not sufficient to prevent blooms but discharges required for bloom suppression.

Kennedy *et al.* (2008) studied for one year aimed at assessing seasonal patterns and controls on phytoplankton primary production and biomass (chl-a) in a fourth order section of the middle Cape Fear River in North Carolina, USA. This coastal river showed a mean concentrations of NO_3-N, NH_4^+-N and soluble reactive phosphorus (SRP) averaged 52.9, 6.0, and 3.6 µmol/L in monthly sampling, while the average light attenuation coefficient was 2.4/m. The average euphotic depth was 2.1 m. No seasonal pattern in physicochemical properties was apparent. Phytoplankton chl-a concentrations ranged from <1 to 36 µg/L. Biomass were consistently higher in May and June suggesting a seasonal effect, but values were otherwise similar such that overall means were not significantly different. Several factors pointed as the primary control on phytoplankton: high nutrient concentrations; a low ratio of euphotic: mixing depth (0.46); progressive increases in chl-a and radiocarbon uptake.

Lin *et al.* (2008) studied on nitrogen versus phosphorus limitation of phytoplankton growth in Ten Mile Creek (TMC), Florida, USA. Their goal of this study was to determine the nutrient-limiting status of the TMC outflow, which influenced by both agricultural input and urban development. Laboratory experiments were conducted by adding different concentrations of phosphorus (P) and nitrogen (N) under controlled conditions. The results showed that turbidity and phytoplankton biomass (in terms of chl-a) in TMC water samples were responsive to N additions. Turbidity and phytoplankton biomass increased with addition of available N, but were not affected by addition of reactive P. The result indicate that available N was the limiting nutrient for the growth of phytoplankton in the TMC.

Wyatt *et al.* (2008) studied the response of benthic algae to points of hyporheic-surface water exchange in the main channel of the Middle Fork Flathead River within the Nyack Flood Plain, Montana. They found that algal density and chl-a concentration were significantly higher at sites with hyporheic discharge compared to both sites with hyporheic recharge and sites with no hyporheic-surface water exchange. The assemblages of algae at upwelling sites were also significantly different from downwelling and neutral exchange sites. Filamentous green algae *Stigeoclonium* sp. and *Zygnema* sp. a chrysophyte, *Hydrurus foetidus* were abundant at upwelling sites, whereas an assemblage of diatoms *Achnanthidium minutissimum, Cymbella excisa, Diatoma moniliformis*, and *Gomphonema olivaceoides* were the most abundant taxa at downwelling and neutral exchange sites, occurring attached to, or in close association with the stalks of *Didymosphenia geminata*. These data showed that benthic algal communities were structured differently depending on the direction of hyporheic flux in the main channel of a large alluvial river, suggesting that hyporheic-surface exchange may influence the spatial distribution of main-channel benthic algae in rivers with hyporheic-surface water connectivity.

Fishar *et al.* (2008) described the development of a biotic pollution index for the river Nile in Egypt. They collect chemical data from 30 locations along the Nile from Aswan to Cairo and 21 sites within the river delta, incorporating a range of conditions from unpolluted to grossly polluted. Seven chemical variables were used to calculate a Nile chemical pollution index (NCPI) for each site. Biological data were collected primarily using artificial substrate samplers (ASS). The UK developed, Biological Monitoring Working Party (BMWP) biotic index and the BMWP-ASPT were applied to the data. A Nile Biotic Pollution Index (NBPI) and the NBPI-ASPT were obtained by incorporating more of the Nile taxa. There were highly significant regressions ($P < 0.001$) for both the UK and the Nile Pollution Index scores with the NCPI for the whole river. The modification of the UK indices improved the Nile indices increasing

the number of taxa recorded from 29 to 43 and the total number of recorded taxon occurrences from 377 to 490. The Nile indices provided better discrimination at both ends of the pollution spectrum. The NBPI-ASPT was best for the river as a whole, and particularly for the river from Aswan to Cairo. The NBPI was much better in the delta than from Aswan to Cairo. These differences in performance were attributed to the fact that the NBPI-ASPT excluded information on taxon diversity. In clean waters there was a wide range of NBPI score suggesting that the biodiversity of taxa is dependent on other aspects of habitat quality. Conversely in the polluted delta the high score of an individual taxon is critical for the NBPI-ASPT was the most consistent biotic index it is recommended as the regular biological assessment and regulatory tool for Egypt to meet the requirements of the convention for biodiversity.

From the above review it appears that limnological studies on river ecosystems, particularly focusing their pollutional status and diversity of phytoplankton are very rare. Very little attention has been given so far in this field of aquatic ecology. As a result only a very few species of phytoplankton are known now as true river plankton (potamoplankton). So, the discovery of more river plankton has been waiting as an arena in the field of running water limnology. Keeping all these facts under consideration the present piece of research has been undertaken.

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

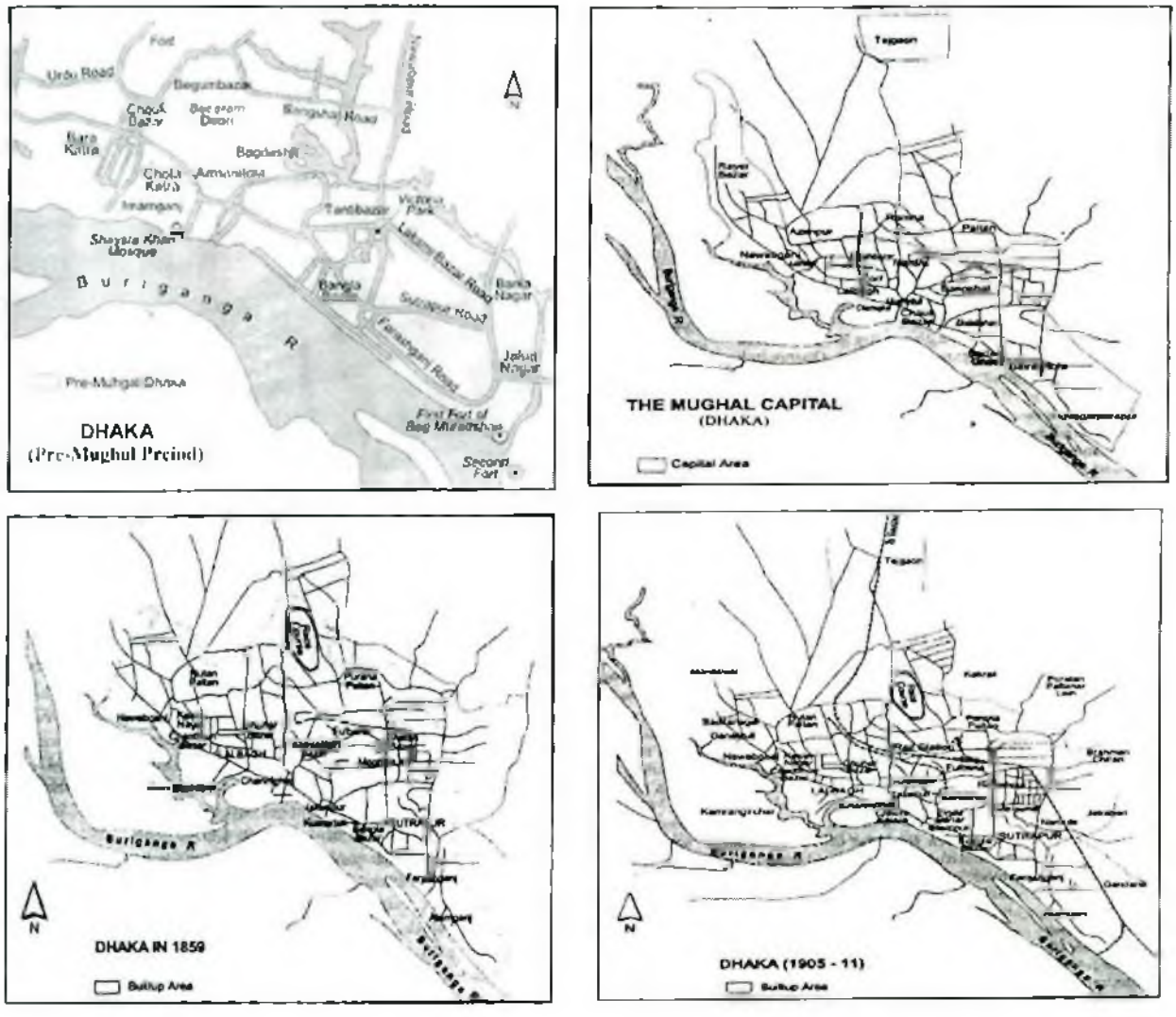
The present research work was carried out in a stretch of the river Buriganga adjacent to the capital city of Bangladesh, Dhaka. For the purpose the river was sampled for two years. A total of 47 samples were collected in between 2003 and 2005.

Study area

City of Dhaka and the river Buriganga

Dhaka, the capital city of Bangladesh was founded about 400 years ago by the side of the river Buriganga. Dhaka is situated about hundred and sixty km above the mouth of the Ganges in the very heart of a land, which is today the sovereign country of Bangladesh, one great wide-sweeping plain, low-lying and fertile, drained by some of the mightiest rivers of the East as they forge their impetuous way through many and ever-changing channels to the sea. The city of Dhaka, which lies 23°43' N and 90°24' E, stands on the northern bank of the river Buriganga, about 13 km above its confluence with the river Dhaleswari and this river-side situation not only gives a beautiful look to Dhaka city, but at the same time affords her a command over the water-routes. Through the Buriganga and the Dhaleswari, to which the former is a loop, Dhaka is connected by navigable waterways with the Padma, the Brahmaputra and the Meghna rivers and thus has the convenience of water carriage to and from any principal place.

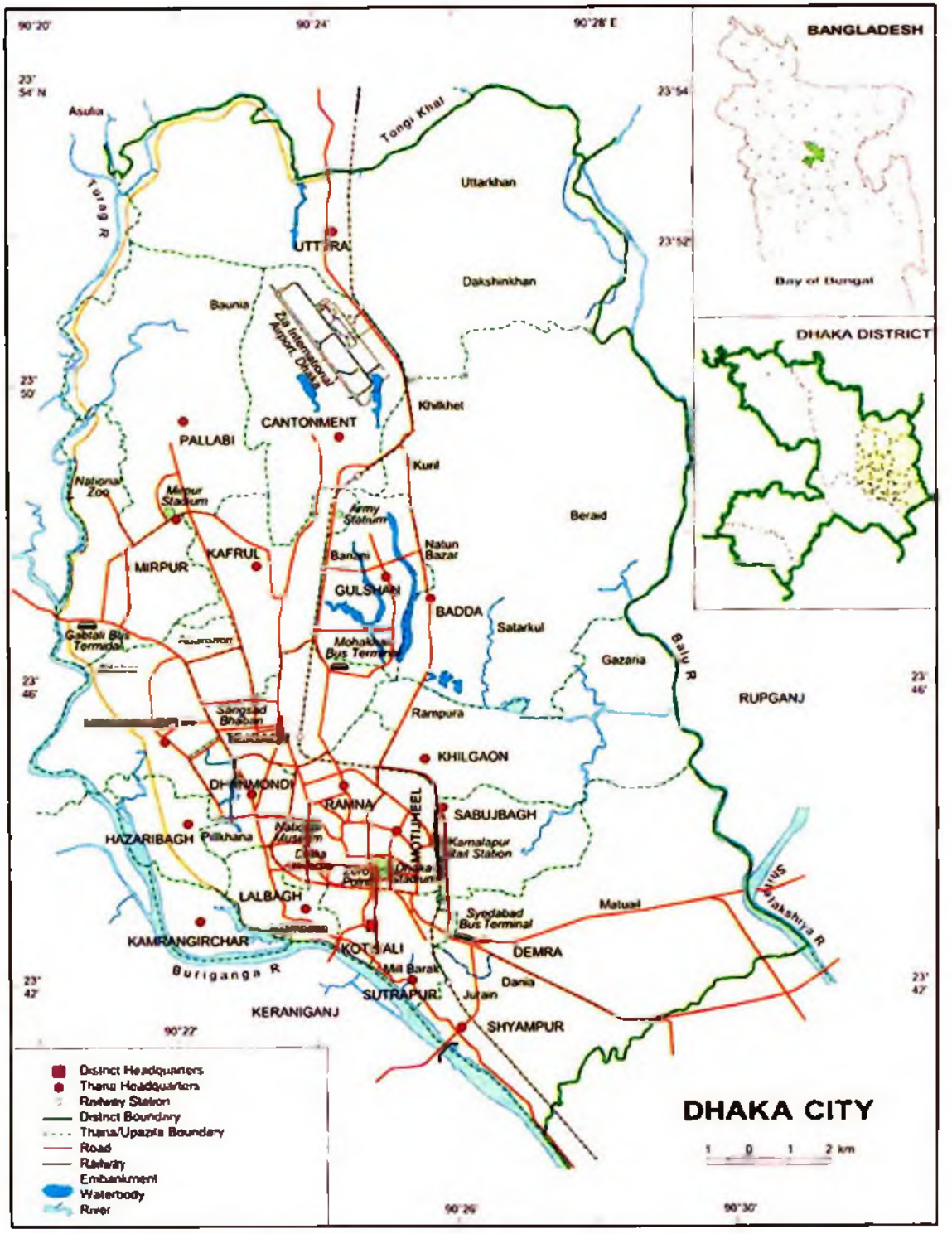
It was this geographical location of Dhaka, the topographical advantage of being situated on higher ground in a low-lying region, and above all its commanding position on the water-routes of the country, which motivated Islam Khan, the Mughal Subahdar, to transfer his capital there from Rajmahal, in 1610 AD, when it was named Jahangirnagar (Map 1).



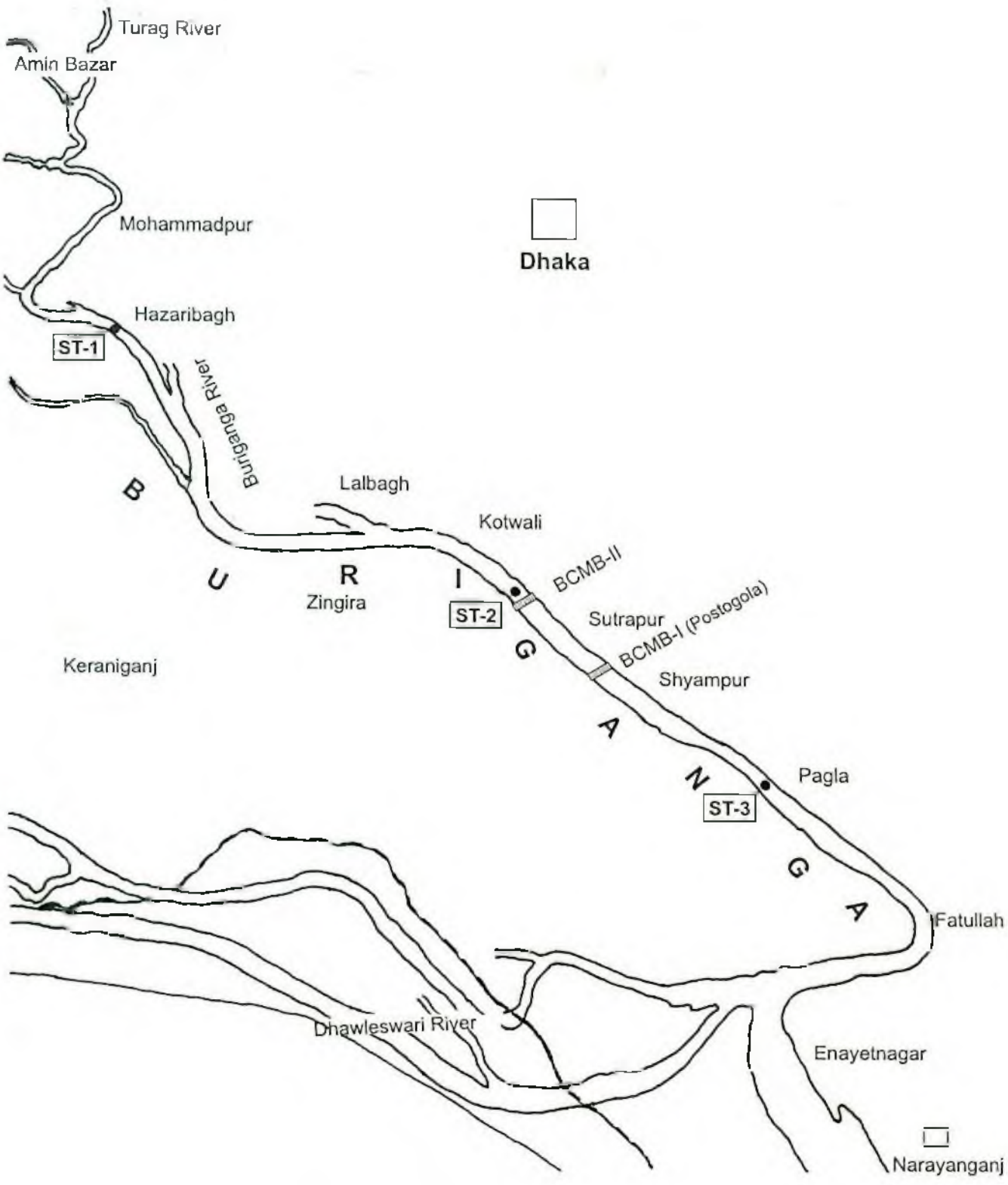
Map 1. The River Buriganga from Pre-Mughal to first partition phase (1911).

A number of water channels criss-crossed through and around the city giving hydrographic importance to the city. The most important of these channels was the Dulai. Islam Khan is credited to have excavated a canal joining the Buriganga near Babur Bazar with the Dulai *Khal* near Malitola-Tantibazar. This canal practically demarcated the 'Old Dhaka' with the 'New Dhaka' of Islam Khan. The development of Dhaka till the last quarter of the 19th century followed the banks of the river Buriganga where the wealthy citizens built their magnificient houses like the Ahsan Manzil and the Ruplal House. The embankment of the northern bank and the construction of a promenade on it by the energetic Divisional Commissionner C. E. Buckland made the river front a picturesque site and the Buckland Bund a rendezvous of the city's nature lovers in the 1880s (Chowdhury 2003).

The Buriganga river, branching off from the Dhaleswari little below Savar (Map 2), comes through the west-southern side of the city and curving rightward it again meets the Dhaleswari beyond Fatullah (Map 3). In fact it forms the southern and western boundary of the city. The Dulai river took off from the Baloo a little above Demra and flows south-west through the city and joins the Buriganga near modern Mill Barrack area. Another branch of the Dulai flowed north-westward crossing the Dhaka-Tejgaon road between Shahbagh and Kairowan Bazar and this river was called the Pandu river. At present all traces of this river are lost except west of the Mirpur road where the channel discernible flowing to the Turag river. This Pandu river sent two branches to the south going through the heart of the city to fall into the Dulai river or channel (Dulai Khal), which took off from the Buriganga near Babu Bazar, west north of Zindabahar and Goalnagar, crossed the Nawabpur Road and Narinda Road and flowed under the Iron Suspension Bridge (still the connecting link between Farashganj and Gandaria) to fall back into the Buriganga.



Map 2. The course of the river Buriganga along side the Dhaka city.



Map 3. The stretch of the river Buriganga showing the present sampling stations (boxed, ST-1 to ST-3).

These numerous water channels running through the length and breadth of the afforded easy drainage system in the city's initial period, but at the same time made it necessary to be bridged over the several points for construction of roads inside the city itself. Later on these channels with bridges and culverts posed a problem to the modern planners (Chowdhury and Faruqui 1991). This discussion actually reveals that though the city of Dhaka was once intersected by a number of river channels, at present almost all of them have become dead creating a severe pressure on Buriganga. Now all waste and storm water of the city must run via Buriganga.

Hydrology of the river Buriganga

Present status

The Buriganga is only 27 km long. Its average width and depth are 400 m and 10 m respectively. Unfortunately, it has turned up as the most polluted river in the country during the last two decades. Release of tremendous pollutant loads, arising out of domestic and industrial sources, into the Buriganga has changed the water quality to such a degree that sustainability of the aquatic ecosystem is the burning question, especially in the dry season when freshwater flow in the river becomes practically nil.

The headwaters of the river Buriganga have been gradually reducing during the past few decades due to siltation and channel shifting. The main source of water had been the spills of the Jamuna river. This has resulted currently to a situation where the flow is bare minimum in the dry season making the Buriganga not suitable for navigation and also deteriorating the quality of the river water. The depth of the river at Shikder medical college was 27 m (pers. com. WDB) at Bangladesh-China Friendship Bridge-II (BCMB-II) it was 16 m (pers. com. WDB) at Pagla (VIP Jetty) it was 10.5 m (pers. com. WDB).

Water regime and tidal effect

Dry period: The river receives water from the local rainfall and spill flows from the left bank of the Jamuna river during monsoon but during dry period the flow is totally dried off and only tidal water from Meghna enters into the river system.

Tidal effect: Tidal effect decreases with the increase of the river discharge, usually, the maximum tidal fluctuation in the river at Mirpur is <100 cm during no flow period of January to March. During mid June when the discharge was 300 cumec in 1998 the tidal fluctuation decreased to even < 0.1 m, which is practically negligible.

Through the ages these rivers have silted up and off takes from the main source of the Jamuna have been almost disconnected during the dry season causing obstructions to navigation through the surrounding rivers of the city due to reduced drafts.

Flow conditions

The rivers surrounding the Dhaka city receives water mainly from the Jamuna river including flood plain flows during monsoon but during dry period the flow is totally dried off and only the tidal water from Meghna enters into the river system. In the dry period (from November to May) all the peripheral rivers are completely tidal and reversal of flow occurs in these rivers (JICA).

During the last decades, the water flow of Buriganga declined significantly. Polluted due to industrial discharge indiscriminate disposal of toxic chemical and with the constant increase of population and sub-sequent socio-economic activities the inland ports in Dhaka become heavily congested. Earlier many of the *Khals*, lakes, channels were connected with the peripheral waterways, which have either been closed or disconnected through rising embankment or other interventions. As a result unhygienic environment developed over the years and make Dhaka city inhabitable. Serious environmental threat to the citizens and

other allied problems. Buriganga river was life line of Dhaka city during its early days turn into problematic one rather than a blessing to the citizen and surrounding areas.

Physiography

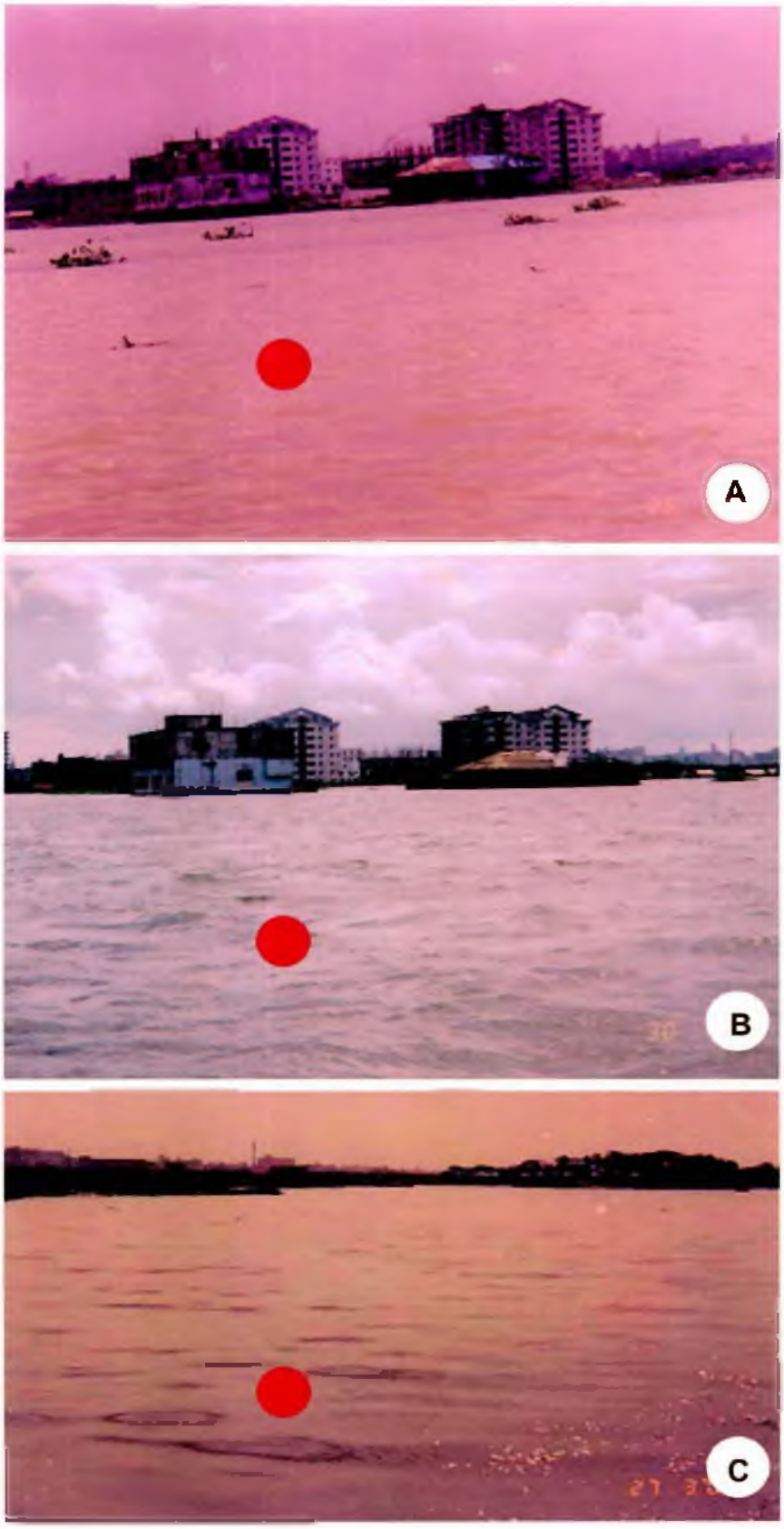
Dhaka, the capital city of Bangladesh was established on the banks of the river Buriganga in early 16^{th} century. The earliest available map shows Dhaka extending over an area of about 1.5 km^2 near the junction of the Dholai *Khal* and Buriganga river. The total population in Dhaka city grew from 0.1 million in 1906 to 9.9 million in 2000. Dhaka city is projected to be one of the four largest mega cities in the world by next 10 years. The Buriganga still remains the main gateway between Dhaka and the southern part of Bangladesh. It has thus promoted establishment of hundred of mills and factories, shops and business centres, boat terminals, dockyards, residential buildings etc. on both banks of the river.

The river Buriganga, a distributary of the river Dhaleswari, flows by Southwestern periphery of Dhaka city. The river Turag demarcating the western boundary of Dhaka city falls in the river Buriganga. From Kolatia to Fatullah 44 km long Buriganga has its history with Dhaka for thousand years.

Sampling and analyses

Setting of sampling stations

Three stations were set up along the selected part of the river Buriganga for sampling. These are: Station-1 (ST-1), Station-2 (ST-2) and Station-3 (ST-3). The stations covered a total stretch of 16.5 km distance of the river. ST-1 is situated near Shikder Medical College, Hazaribag, Dhaka (Fig. 1). ST-2 is located at near Bangladesh-China Friendship Bridge-II, near Sadarghat, Dhaka (Fig. 2) and is about 9 km away from ST-1. The distance between ST-2 and ST -3 is about 7.5 km and is situated at Pagla, Fatullah, Narayanganj (Fig. 3).



Figs. 1. Photographs of ST-1. A. Shikder Medical College in Monsoon. B. The same in rainy season, and C. Opposite view of the Shikder Medical College (red circle shows sampling point).

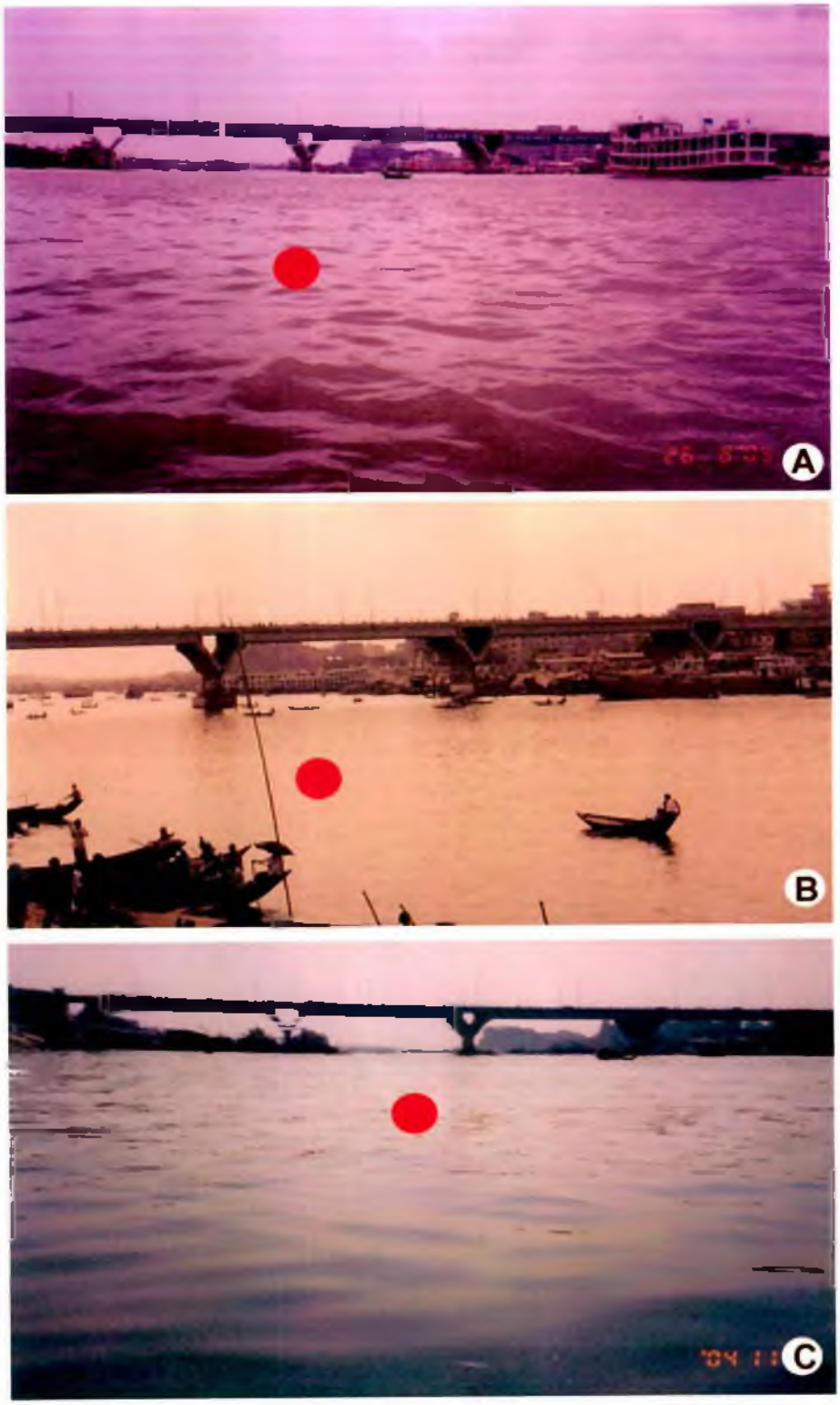


Fig. 2. Photographs shows ST-2, A. BCMB-II in Monsoon, B. The same in lean period. and C. Same in Autumn (red circle shows sampling point).

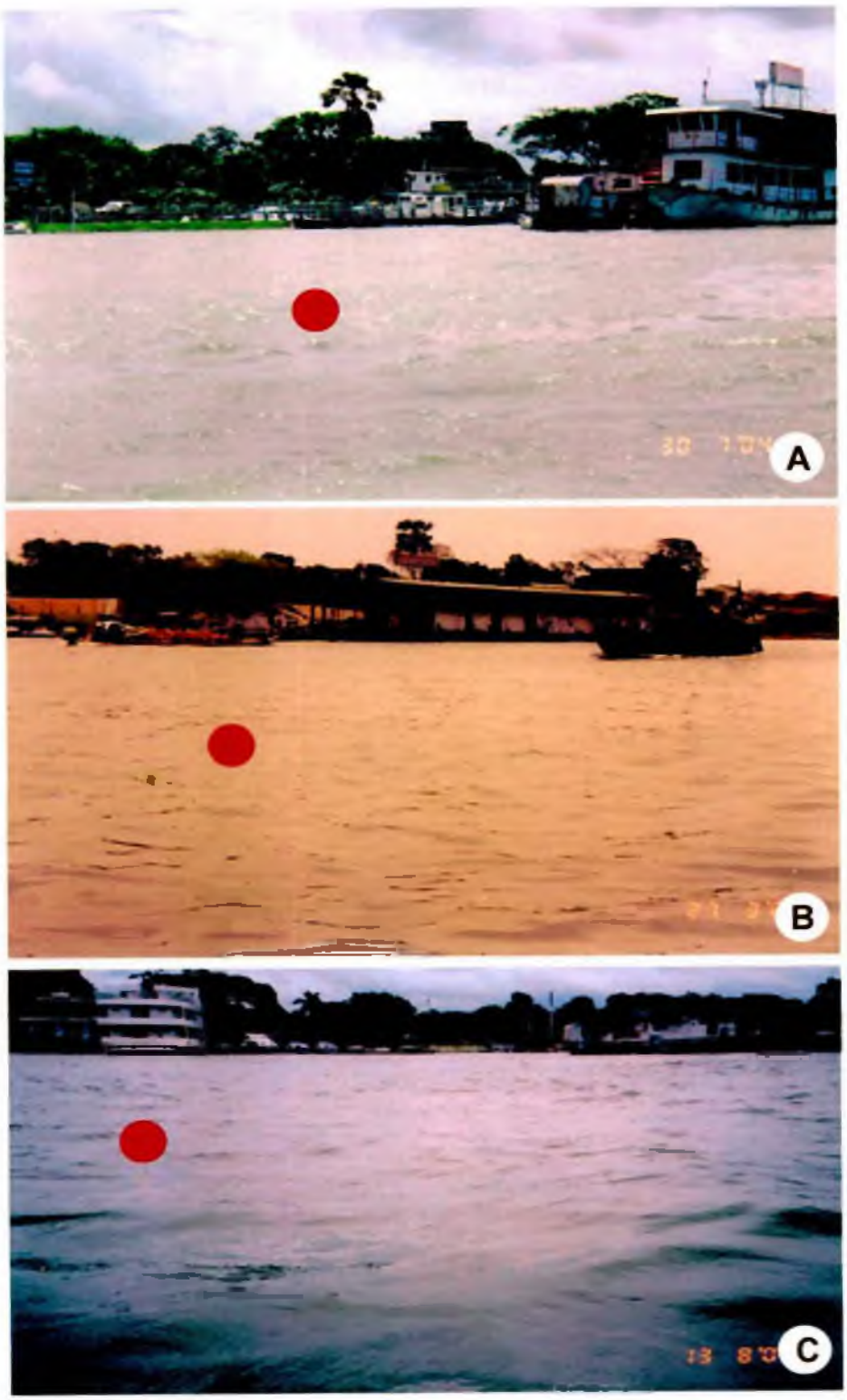


Fig. 3. Photographs shows ST-3, A. Mary Anderson, Pagla in Monsoon, B. The same in lean period, and C. The same in Monsoon (red circle shows sampling point).

Description of the three selected stations

ST-1 has been considered as the most upstream location for the present investigation. It is situated in the west part of Dhaka metropolis. Its geographical location is in between 23°44'16" N and 90°21'06" E. This station is surrounded by Basila a union of Mohammadpur Thana to the west, Rayerbazar *Buddhyabhumi Smritishoudho* to the north-east, Shikder Medical to the east. This part of the river Buriganga receives wastes and wastewater from the nearby residential areas and tanneries from Hazaribagh.

ST-2 lies in the mid-zone of the whole stretch considered for the present investigation. It is situated at the southern part of Dhaka metropolis popularly known as Old Dhaka. Its geographical location is in between 23°42'38'' N and 90°23'55" E. ST-2 is flanked by Sir Salimullah Medical College to the north, Bangladesh-China Friendship Bridge-II to the east and Keraniganj to the south. It is one of the busiest areas of Old Dhaka. The river bank is always crowded by country boats used to facilitate public to cross the river from both sides. About 400 m east Sadarghat Launch Terminal is situated where hundreds of watercrafts anchored and wait for depart. All water ways ended at Sadarghat those ply on to the south, south-east part of the country. Sadarghat is termed as gate way for the southern part of the country from Dhaka Metropolis.

ST-3 is to some extent away from the Dhaka city and considered as downstream for the present investigation. Its geographical location is in between 23°39'08" N and 90°27'40" E. This sampling point is situated near Pagla, Narayanganj. This place is famous for trading construction materials. Besides, a number of stone crusher factory established to the East of the riverside and brick fields to the west. Mary Anderson, a VIP jetty for anchoring tourist ship is situated in the eastern part. Many vessels with tourists are seen plying on the river at this point.

Sampling programs

Samples from the above mentioned three selected stations of the river Buriganga were collected over a period of two years between September 2003 and August 2005. Sample collections were carried out fortnightly mostly between 09:00 and 12:00 am. However, because of some unavoidable circumstances a single sample was collected in November 2003. So, there were altogether 141 samples collected over the study period. The field trip was arranged via road and waterways. Each time, the trip started at ST-1 which took about 45 minutes drive to reach Shikder Medical College from Dhaka University campus by Jeep. It needed another 10 minutes to reach the ST-1 by engine boat. From ST-1 another 20-30 minutes required to reach ST-2 by Jeep. After reaching ST-2 a country boat was hired to perform sampling. Finally, to reach the last station at Pagla (i.e., ST-3) it required another 30-40 minutes drive. From there a country boat was hired to complete the job at ST-3.

Collection of samples and field measurements

Water sample for chemical analysis

Integrated water samples were collected from each station from one meter depth by a PVC pipe fitted with a check valve at the end (Plate-14). The sampler had a capacity of 2.5 L. At each time the sampler was dipped slowly under water to 1 meter depth. After a few seconds the sampler was taken out of the water and trapped sample water was directly transferred to a 5 L capacity plastic carboy. The sampler was dipped two times to get 5 L capacity. The carboy was transported to the laboratory for further analysis. Care was taken to avoid jerking during transport of the samples.

Water sample for phytoplankton study

Pyrex flat glass bottles each having 1 L capacity were kept ready to collect phytoplankton samples for each station. One mL Lugol's solution was poured into each empty bottle just before sample water was added from the integrated

water sampler via a plastic funnel. After filling the bottle was sealed off by putting rubber cork on the mouth. After taking the sample to the laboratory the bottle was kept in the dark for the sedimentation of phytoplankton for counting.

In situ measurements

Temperature

After reaching the sampling station by boat, water temperature was recorded by an alcoholic thermometer graduated 0-50°C by manually immersing it to a depth of 10 cm below water surface. Air temperatures above the water surface were measured by the same mercury thermometer by rotating the bulb of the thermometer in the air by hand and thereafter recording the data.

Transparency

The transparency of water was measured with the help of a 20 cm diameter Secchi disc having the top surface painted black and white crosswise. The disc was slowly dipped into water and viewed from the top. The depth of disappearance and reappearance of white painted surface of the Secchi disk were noted. Average of the two depths were expressed as Secchi depth in centimeter.

Sample transport from field to the laboratory

All the collected samples were carefully transported to the laboratory by a jeep. The analyses were carried out in the Hydrobiology and Limnology Laboratory, Department of Botany, University of Dhaka. The time required from the collection of first sample up to the last one and to bring those in the laboratory was about 2-3 hours. Analyses of different parameters began immediately after reaching laboratory and were completed next day morning except the aspects of phytoplankton. The quantification work and taking of photomicrographs of phytoplankton diversity were completed before beginning the next sampling in the same month.

Laboratory procedure

Filtration and preservation

After reaching the laboratory, filtration of water samples for chemical analysis was carried out. A vacuum pump fitted to a Sartorius-Membrane Filter Holder (Gmbh, Göttingen, FRG) was used for the purpose. The water sample was shaken gently and then 100-250 mL of water was measured with the help of a graduated measuring cylinder and poured into the cup of the Sartorius device. Whatman GF/C 2.7 cm circles were used with the device to filter the water. After filtration the filter paper was rolled up with the help of a Millipore pincet and put into a screw capped Pyrex glass tube of 10 mL capacity. This sample was used for the determination of phytoplankton biomass as chl-a. The filtrate of each sample was transferred to a acid washed, clean screw capped polystyrene bottles (500 mL capacity) for nutrient analysis.

Chemical parameter measurements

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

pH

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

Alkalinity

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

Conductivity

90 mL of unfiltered sample water was measured with the help of a measuring cylinder (100 mL capacity). Conductivity meter Hanna instruments HI9033 (Singapore) was used to measure the conductivity of water. Electrode of the meter was cleaned with distilled water and dried with tissue paper. Scale indicator button was pushed for a probable value. Starting the meter the second knob was fixed at 20°C. Electrode was then put into the sample water slowly. Gentle stirring of electrode show movement of meter scale. Conductivity was then measured by keeping the electrode fixed in the sample water (Golterman *et al.* 1978).

Dissolved oxygen (DO)

Precipitation obtained after adding Winkler's reagent in all the oxygen samples those were treated with sulfuric acid and then transferred to a 250 mL capacity conical flask. To determine the end point one to two drops of starch solution was then added that turned the color of the sample to blue. The flask was put on a magnetic stirrer device and was titrated by adding very dilute (0.005 N) freshly prepared sodium thiosulphate solution until the blue color disappeared. With the help of the volume of thiosulphate consumed in the titration the DO was calculated after Wetzel and Likens (1979).

Total dissolved solids (TDS)

90 mL of unfiltered sample water was measured with the help of a measuring cylinder (100 mL capacity). TDS meter Hanna instruments code-HI9034W, URN 330067 I, D/N-413377, (Singapore) was used to measure the TDS of water. Electrode of the meter was cleaned with distilled water and dried with tissue paper. Scale indicator button was pushed for a probable value. By starting the meter the second knob was fixed at 20°C. Electrode was then put into the sample water slowly. Gentle stirring of electrode showed movement of meter scale. TDS was then measured by keeping the electrode fixed in the sample water (Golterman *et al.* 1978).

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 each used to determine SRS. Sequentially 5 mL 0.25N HCl, 5 mL of 5% ammonium molybdate and 5 mL 1% disodium EDTA was added to it. The sample was mixed properly and kept undisturbed for next five minutes. Then 10 mL of 17% sodium sulfite was added to each flask. Blue color developed according to the concentration of SRS in the sample. A reagent blank and standard series of silica was also treated in the same manner. Sub-samples from each of these were measured in a Schimadzu spectrophotometer (UV-120-02, Japan) at a wave length of 700 nm using 1cm path length quartz glass cuvette. Finally the values were calculated by regression analysis with the help of standard series.

Nitrate-nitrogen (NO_3-N)

The concentration of NO_3-N in the filtered sample water was determined following the method of Müller and Wiedemann (1955). To a 25 mL sample water in a 100 mL capacity Pyrex conical flask 1 mL of 5% sodium salicylate

was added and digested overnight to dryness in an oven (Eyela, Model- NDS-450D, Japan) set at 100°C temperature. 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 distilled water and then the sub-samples were measured in a Spectrophotometer (Schimadzu UV-120-02) using 1 cm path length quartz glass cuvette at a wave length of 420 nm. A distilled water plus reagent blank and a series of NO_3-N standards were also treated in the same manner in each batch. The values of NO_3-N were calculated by regression analysis later on with the help of standard series.

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 100 mL capacity Pyrex conical flasks. Then required amount of distilled water was added to each sample to make the volume 50 mL. 5 mL mixed reagent (a mixture of 30 mL ammonium molybdate, 75 mL H_2SO_4, 30 mL freshly prepared ascorbic acid and 15 mL potassium antimonyl tartarate) was dispensed in each flask. The solution of the flask was mixed properly and after 5 to 10 minutes blue color developed, then the extinctions were measured using 885 nm wavelength with the help of 4 cm path length quartz cuvettes.

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 collected from the pelagic zone of the river. The method of extraction was as follows: test tube containing rolled filter paper was treated with 5 mL hot 90% ethanol (kept boiling at 75°C in a water

bath, model Eycla, Thermopet NTT-211, Japan). Then the test tube containing filter paper dipped in to ethanol was given a hot and cold treatment by putting it firstly in the hot water bath for three minutes and then cooling in tap water carefully. After cooling, the pigment was extracted (1st) and was transferred to another glass tube while the filter paper was given second extraction treatment in the same manner as mentioned above. The extracted pigment solutions (1^{st} and 2^{nd}) were poured in 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 optical density (OD) was measured in a spectrophotometer at wave length 665 nm and 750 nm against 90% ethanol as blank. The acidification was done by adding in 3.7 µL HCl in each cuvette (for a volume c 3.7 mL). Finally the concentration of chl-a and phaeopigment were calculated after Marker *et al.* (1980).

Preparation of samples for the quantification and diversity analyses of phytoplankton

The Pyrex glass bottle containing one liter river water fixed with Lugol's solution was kept undisturbed in the dark for 48 h in order to facilitate sedimentation of phytoplankton individuals. After sedimentation, the overlying water from the bottle was withdrawn by using a vacuum pump in such a way that the accumulated layer of plankton sediment is not disturbed. After removing the water of the bottle successfully the sediment layer of phytoplankton was stirred up and the solution was transferred to a 50 mL screw capped glass vials for further handling. Here in after this solution is termed as 'plankton concentrates'.

Photomicrographs

A Helber Bacteria Counting Chamber (HBCC) (having a fixed volume 1.005 µL) was filled by a small volume of well mixed plankton concentrate and placed

under a Nikon (Optiphot, UFX-11A) microscope fitted with a camera (Nikon FX-35 WA, Japan). The field of the counting chamber was scanned under a magnification ranged from 10 × 40 to 10 × 100. Almost all individuals were photographed and their dimensions were measured with the help of a standardized oculometer fitted in the eye piece of the microscope.

Phytoplankton quantification

Counting of phytoplankton was also done with the help of a HBCC under a compound microscope (Nikon SE, Japan) at a magnification of 10 × 40. Each sample was counted three times. A minimum total of 100 cells (for three counts) were used for the identification of dominant phytoplankton taxa. Some taxa whose count fell below 100 were treated as present (p) only. Finally the cell density of phytoplankton was calculated as follows:

Density as ind/L = (v/3.015 µL × total count)

where,

v = volume of plankton concentrate in µL.

3.015 = volume of the counting chamber for three replicate counting (chamber volume = 1.05 µL).

total count = total number of individuals present in three replicate counting.

Qualitative analysis of phytoplankton

Before counting of the phytoplankton individual a random checking of the sedimented planktonic material was carried out under high magnification for identification up to species level. For identification, algal literatures as well as publications available for Bangladesh, other world monographs and books have been consulted (pl. see in the systematic part).

Creation of database

All measurements carried out *ex situ* and *in situ* for the selected stations were recorded properly. The values for different parameters were digitized in a PC and a data base was created in Excel programme. The values were then manipulated to calculate monthly, seasonal or annual means with standard error as applicable. Finally, time versus concentration figures were prepared for different variables.

Chapter 4
RESULTS

RESULTS

Physical parameters

Air temperature

Range of monthly average air temperatures for the period between September 2003 and August 2005 were recorded 16.5-34.8°C, 15.3-35.0°C and 18.0-34.0°C for ST-1, ST-2 and ST-3, respectively (Figs. 4-6). The highest air temperature was recorded in June whereas lowest temperature was obtained in January for all the three sampling points. Air temperature gives similar trends throughout the investigation period for all stations (Fig. 7). The average maximum air temperature were 18.3, 19.8 and 16°C for ST-1, ST-2 and ST-3, respectively. Air temperature starts increasing just after January and continues until May and thereafter the fluctuation takes an almost uniform shape with slight dropping tendency in July. The temperature starts falling in November.

Water temperature

During the study period, water temperature ranged 19.8-32.3°C, 19.8-32.8°C and 20.0-33.0°C for ST-1, ST-2 and ST-3, respectively (Figs. 8-10). The highest temperature recorded in June and the lowest in January for all the three stations. Water temperature followed a similar trend like air temperature throughout the investigation period (Fig. 11). The average maximum temperature were 12.5, 13.0 and 13.0°C for ST-1, ST-2 and ST-3, respectively. Water temperature was found higher than air temperature during winter period only by at least 1-4°C. In summer the water temperature differed by 1-2°C. The fluctuation of water temperature throughout the study period shows clear falls and rises. A gradual fall in the water temperature was evident in September until January, after January the water temperature started rising until May. From May to September the temperature remained almost uniform.

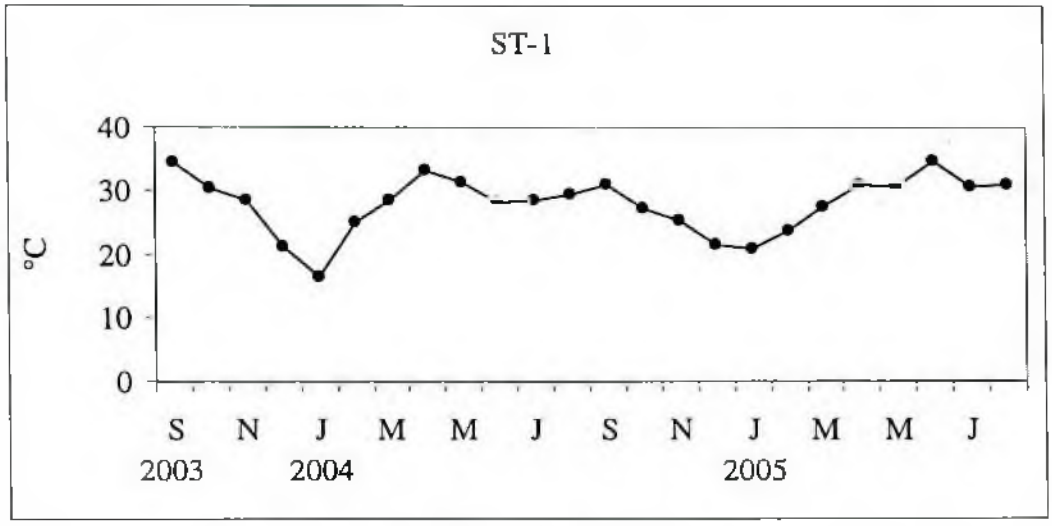


Fig. 4. Air temperature of ST-1.

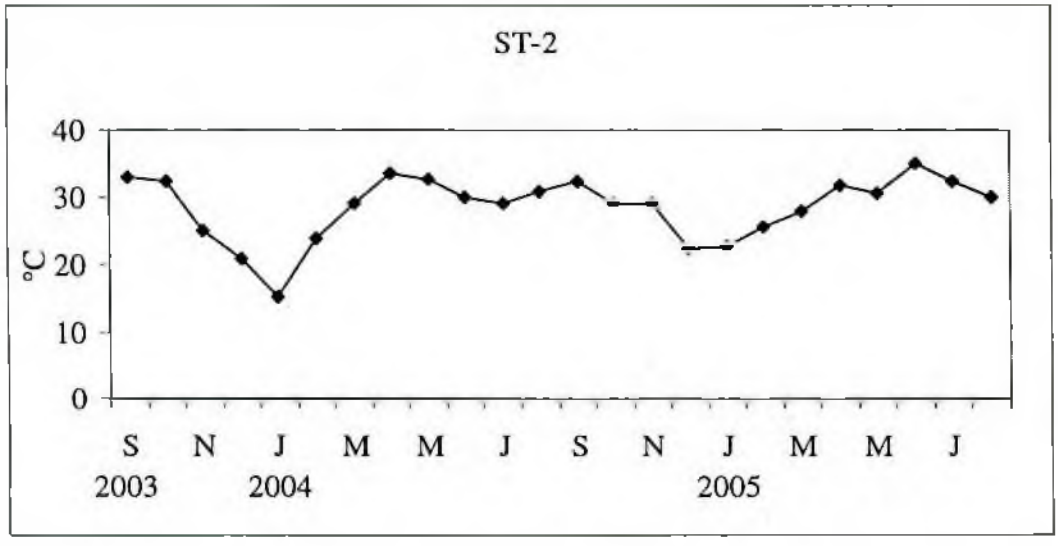


Fig. 5. Air temperature of ST-2.

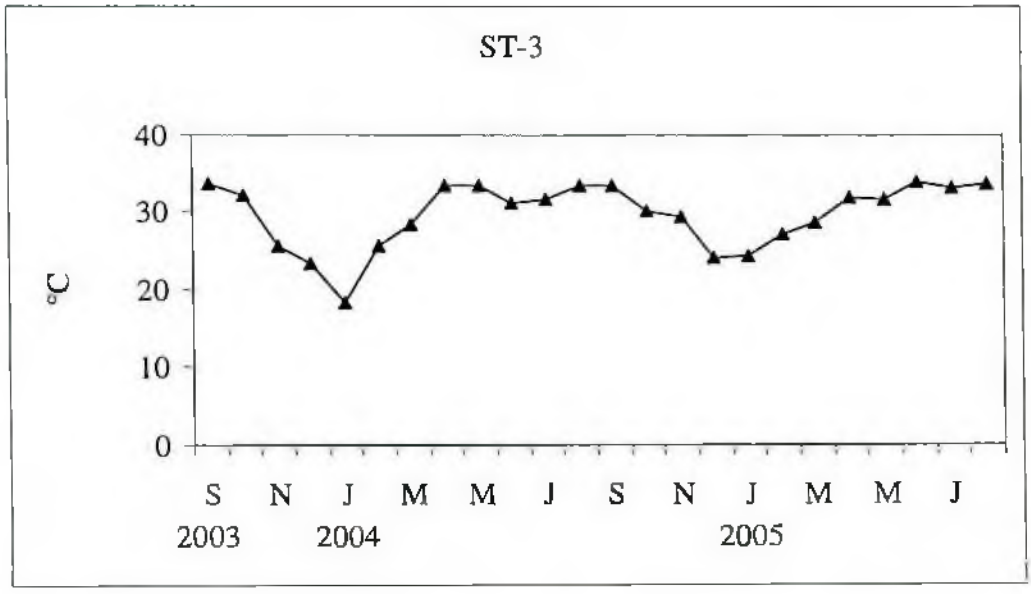


Fig. 6. Air temperature of ST-3.

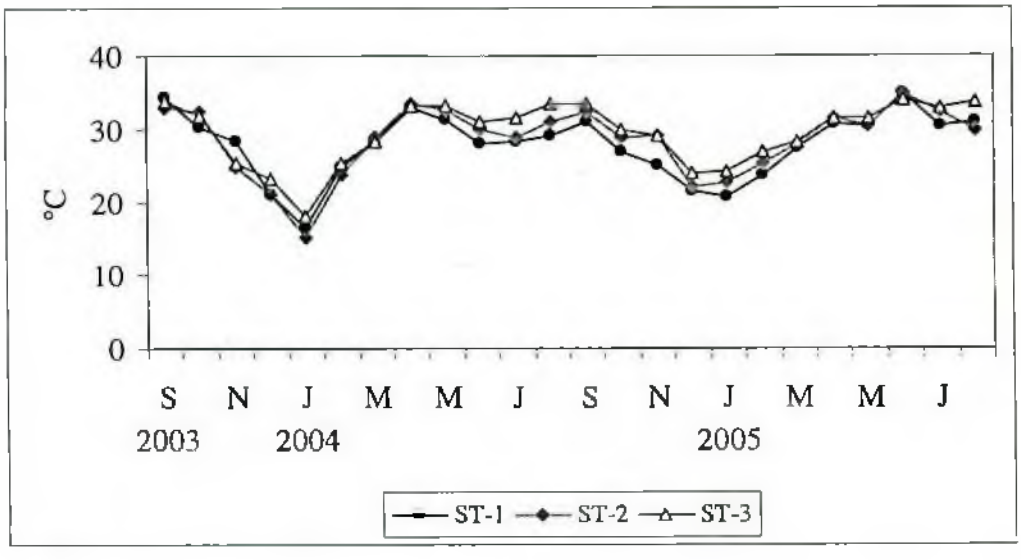


Fig. 7. Comparative air temperature among ST-1, ST-2 and ST-3.

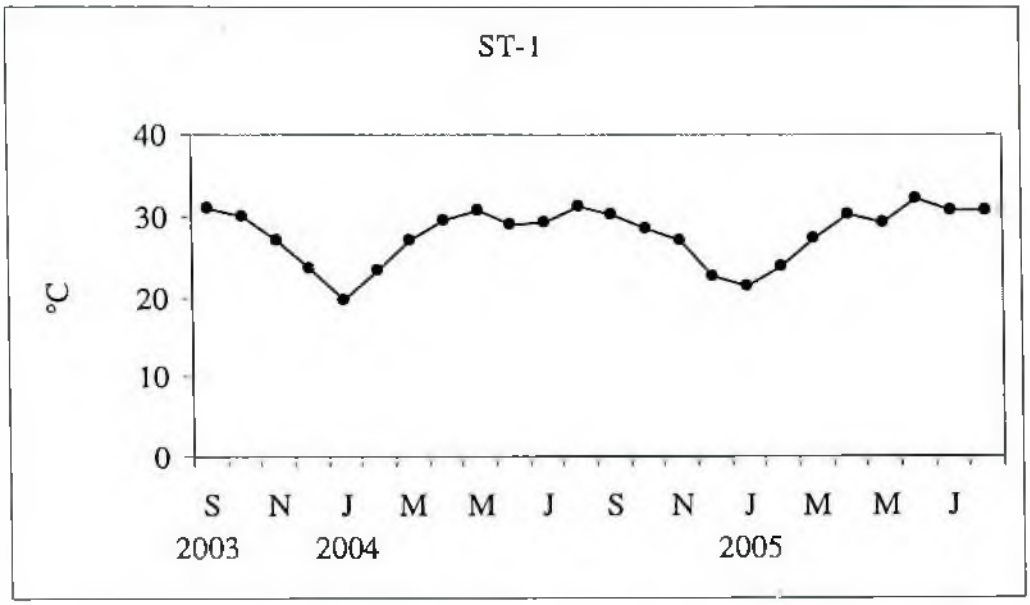


Fig. 8. Water temperature of ST-1.

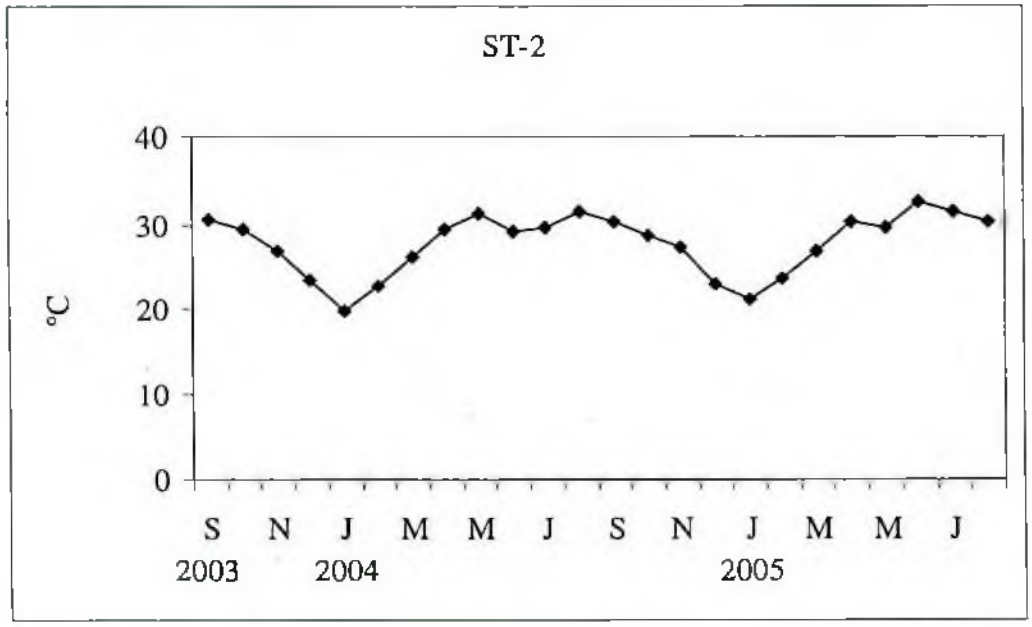


Fig. 9. Water temperature of ST-2.

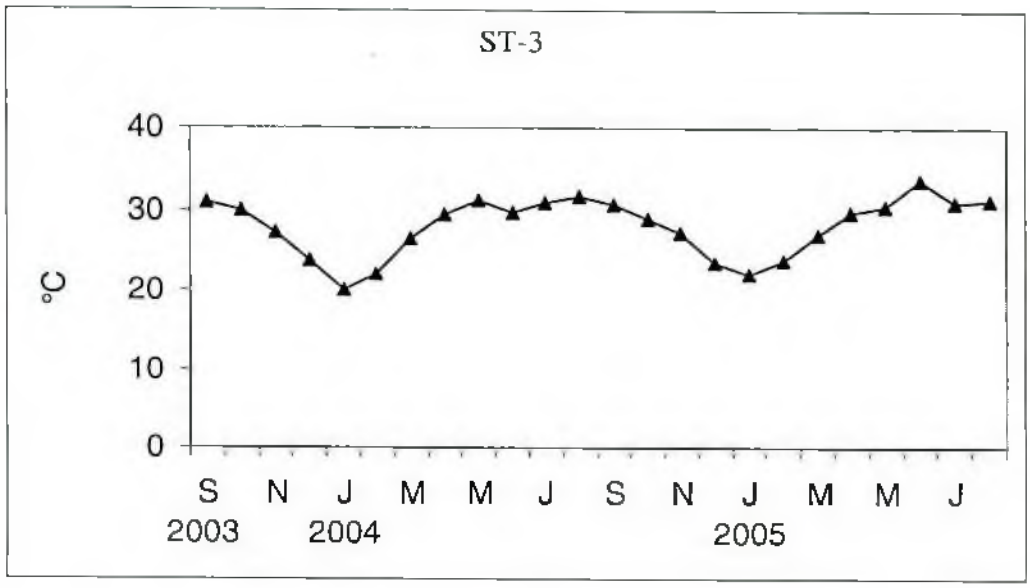


Fig. 10. Water temperature of ST-3.

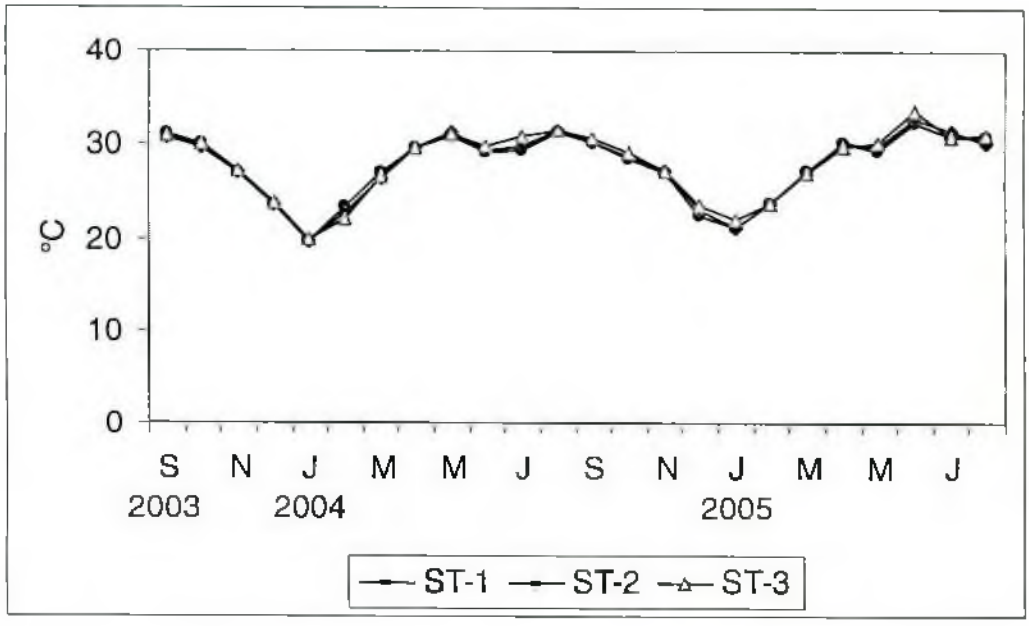


Fig. 11. Comparative water temperature among three stations.

Transparency

Secchi depth (Zs) varied from 11-54 cm in ST-1, 17-60 cm in ST-2, and 21-83 cm in ST-3 (Fig. 12). The highest values of Secchi depth were recorded in September (54 cm), in December (60 cm), and in April (83 cm) for ST-1, ST-2 and ST-3, respectively and lowest value was obtained in February (11 cm), July (17 cm), July (21 cm) for ST-1, ST-2 and ST-3, respectively. The monthly mean difference between highest and lowest Zs were 44 cm, 45 cm and 62 cm for ST-1, ST-2 and ST-3 respectively. The annual fluctuation of this light related parameter was highly variable in nature. Seasonally river water from ST-3 showed more transparent than the other two stations. The river water became gradually more transparent from upstream to downstream.

Chemical parameters

Hydrogen ion concentration (pH)

The mean pH fluctuated from 6.64-6.97 (ST-1), 6.7-6.9 (ST-2) and 6.69-6.9 (ST-3) for first year of the present study (Figs. 13-15). In the second year, it ranged from 6.62-6.84 (ST-1), 6.68-6.78 (ST-2) and 6.7-6.81 (ST-3). However, the pH of water was closer to neutral. In the two consecutive years of study, the pH shows a uniform fluctuations in all the three stations (Fig. 16). At ST-1, pH value started increasing from September reaching a peak in March. It then started falling until June and from June to October the value remained uniform. Similar trend of fluctuations has been observed by two other stations of study. The difference between highest and lowest value was 0.021 only. The peak value was generally recorded during lean period at all the three points.

Alkalinity

During the course of investigation, the highest monthly mean alkalinity was found in March for both ST-1 (7.65 meq/L) and ST-2 (6.55 meq/L) (Figs. 17-18). But at ST-3, the highest alkalinity was in February (5.05 meq/L) (Fig. 19). The lowest value was recorded during monsoon (June to October) for all the three stations ST-1 (1.25 meq/L), ST-2 (1.0 meq/L) and at ST-3 (1.1 meq/L) (Fig. 20). The annual trend of fluctuation of this parameter was almost similar in both the years of study and also in all the stations. Starting from September, the alkalinity began to rise gradually reaching a peak value in May thereafter it also fell until April. From April to October its concentration gave a plateau like picture then rose again to reach the peak.

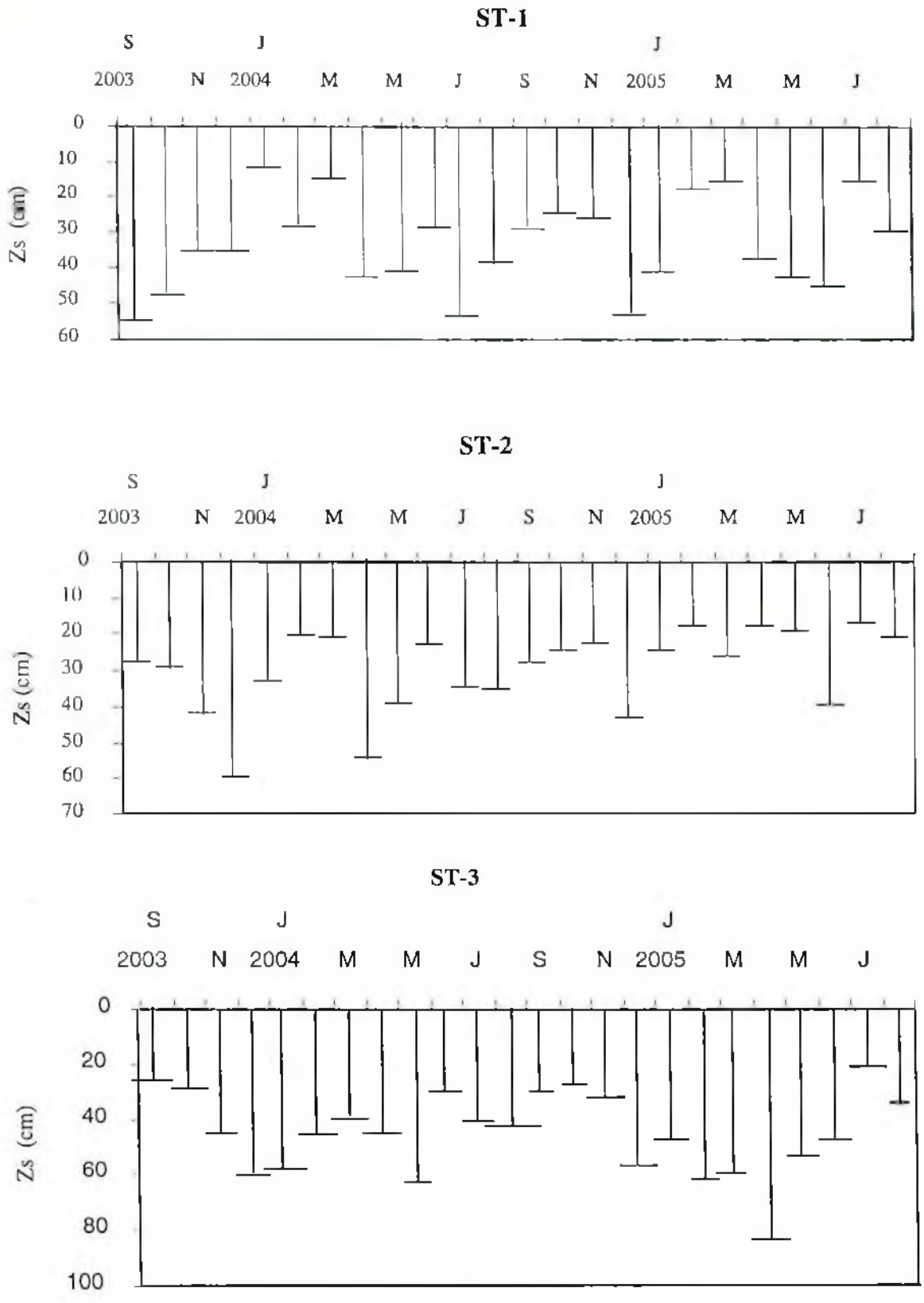


Fig. 12. Secchi depth at three different stations (ST-1 to ST-3).

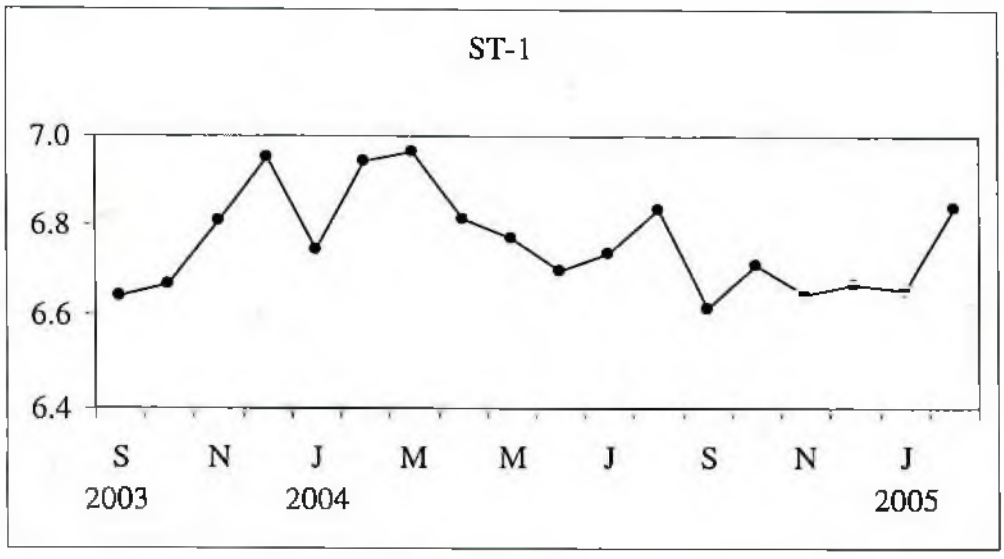


Fig. 13. pH of ST-1.

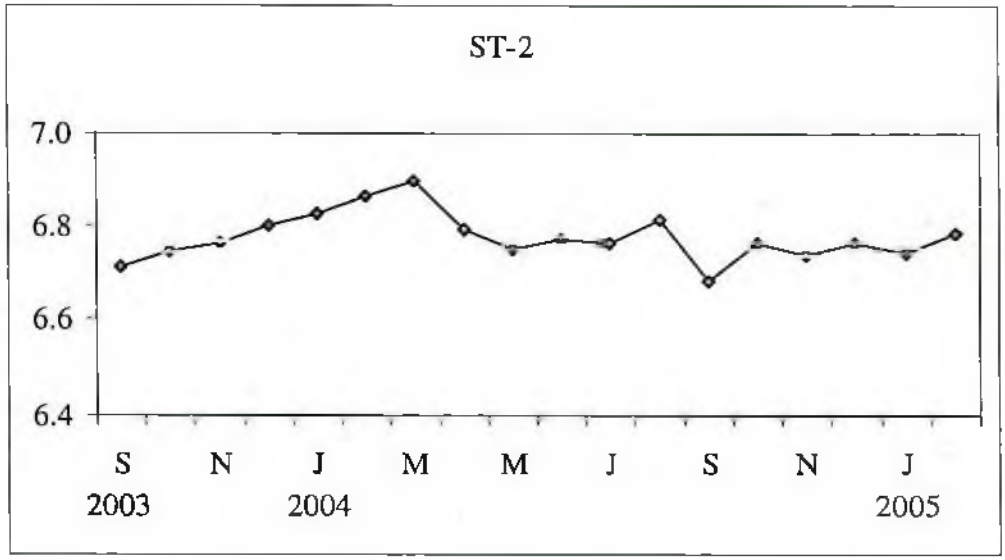


Fig. 14. pH of ST-2.

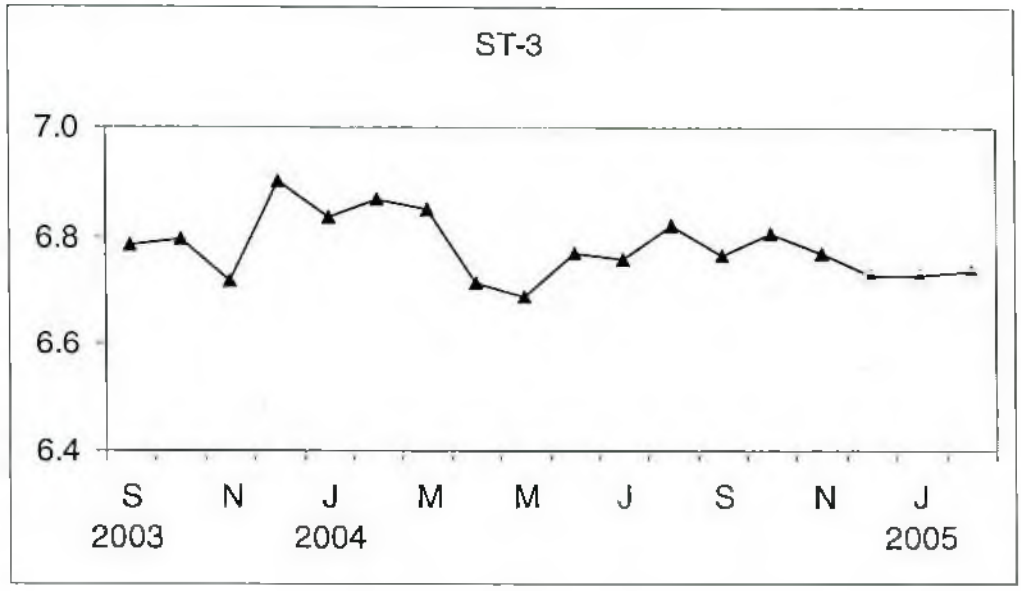


Fig. 15. pH of ST-3.

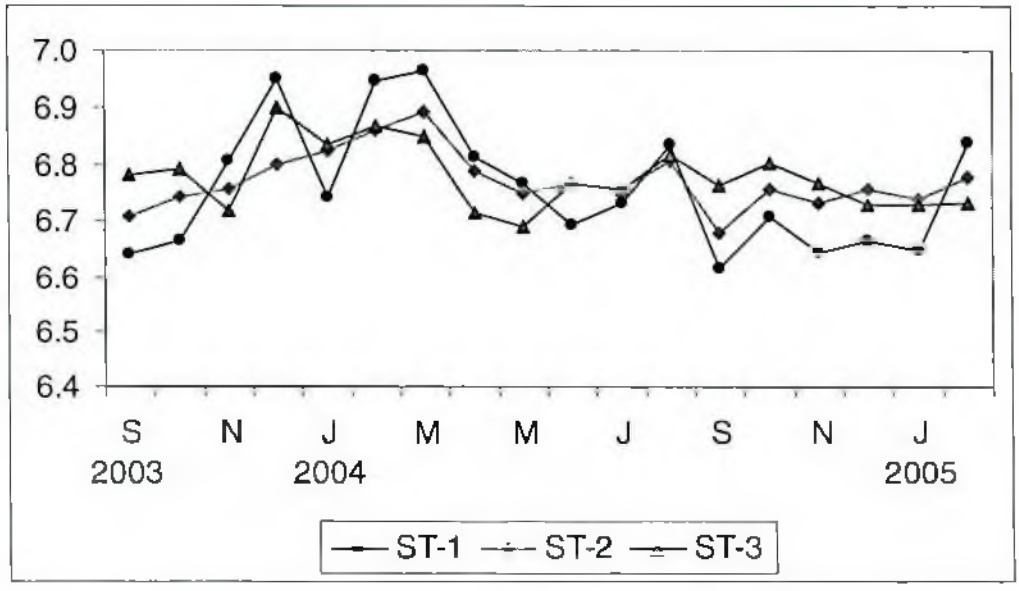


Fig. 16. Comparative pH among ST-1, ST-2 and ST-3.

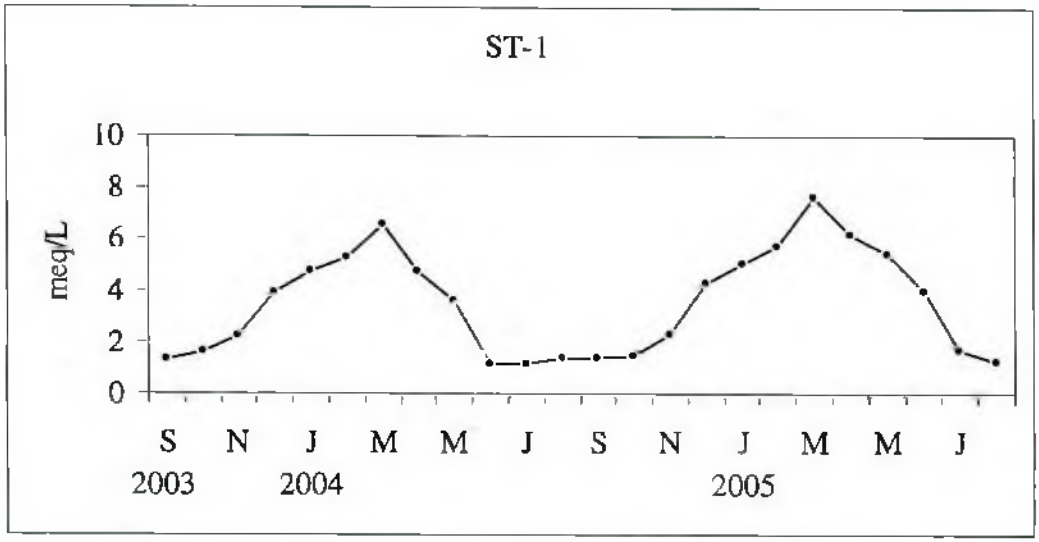


Fig. 17. Alkalinity of ST-1.

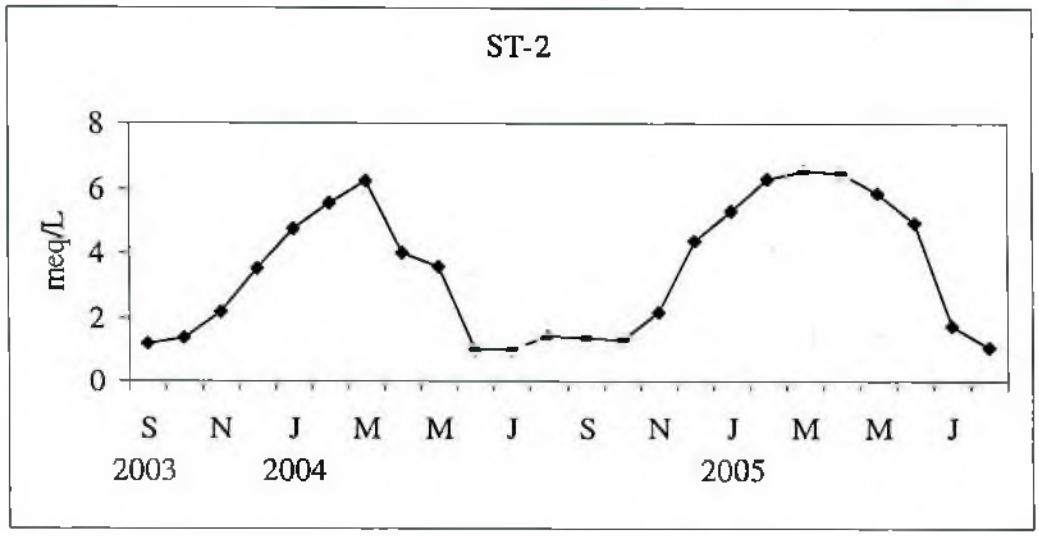


Fig. 18. Alkalinity of ST-2.

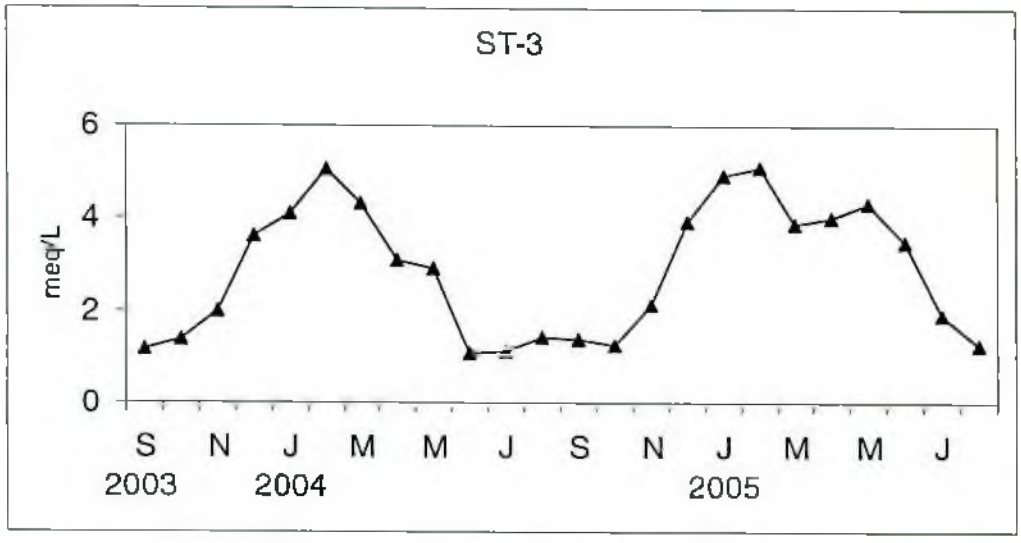


Fig. 19. Alkalinity of ST-3.

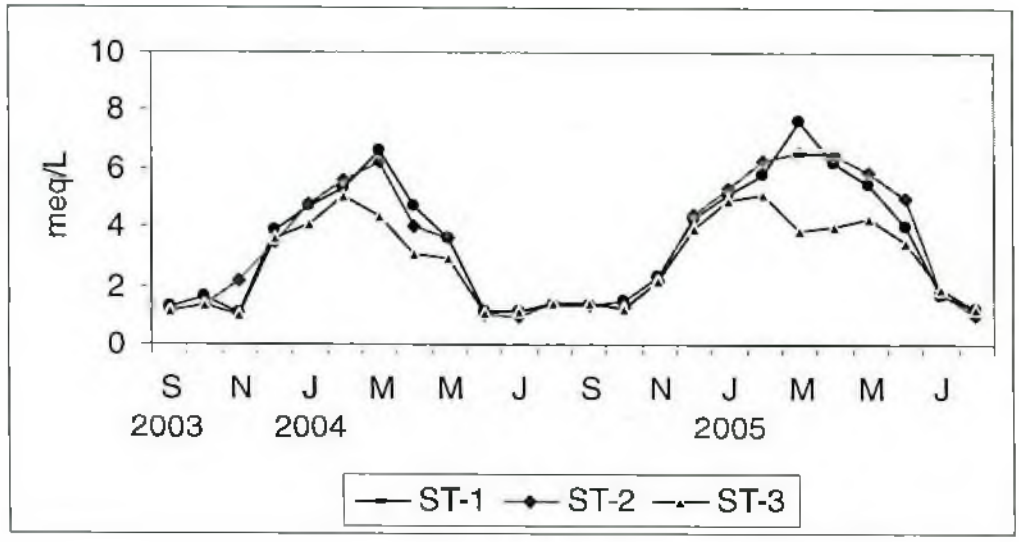


Fig. 20. Comparative alkalinity among three stations.

Conductivity

During the course of investigation, the highest monthly mean conductivity was recorded during May for all the three stations (Figs. 21-23). The values were ST-1: 940 µS/cm, ST-2: 915 µS/cm) and ST-3: 713 µS/cm, The lowest value was recorded during Monsoon (June to November) for all the three stations ST-1 (128 µS/cm), ST-2 (115 µS/cm) and at ST-3 (133 µS/cm) (Fig. 7). A sharp single peak was obtained every year at ST-1 but incase of ST-2 and ST-3, two peaks (one small and one big) was obtained for every single year. ST-2 and ST-3 exhibit similar trends having lower value than ST-1. For all the three stations higher values were recorded during lean period (November to June) and a lower stable value, throughout the Monsoon season (Fig. 24).

Dissolved oxygen (DO)

Dissolved oxygen concentration of the stations ranged from 0.5-9.0 mg/L, 0-9.4 mg/L and 4.3-9.2 mg/L in ST-1, ST-2 and ST-3, respectively (Figs. 25-27). The general pattern of fluctuation of DO in ST-1 and ST-2 is almost similar (Fig. 28). In these two stations the lowest value occurred always in March and highest in August. In May the concentration starts increasing and continues until October, thereafter it starts falling reaching to its lowest in March. However, in ST-3 the DO remains almost stable although the period of investigation except a slight fall in January (Fig. 27). The minimum value of DO is significant among stations. In ST-1 it was 0.5 mg/L while an anoxia was observed in ST-2. The minimum value of DO concentration in ST-3 was 4.3 mg/L. At ST-1 and ST-2 DO started increasing in April and continues until November thereafter it starts falling and reaching to its lowest value in March.

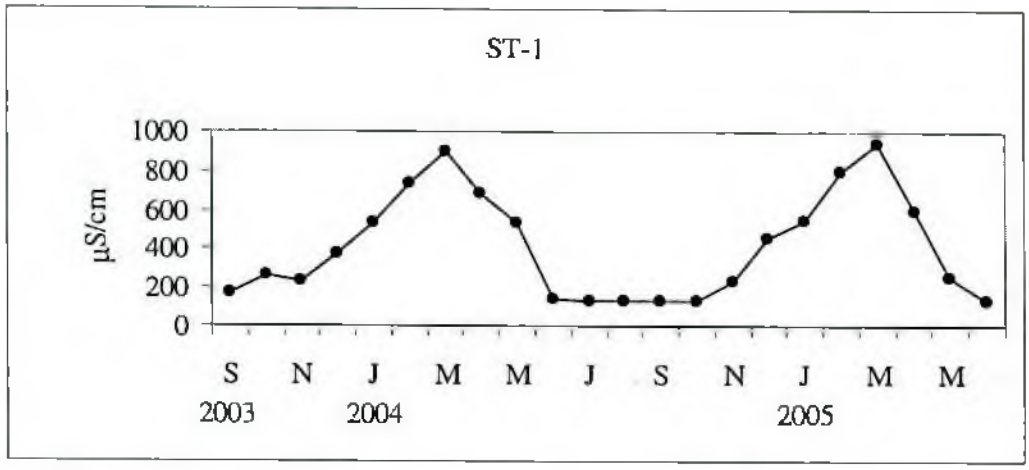


Fig. 21. Water conductivity of ST-1.

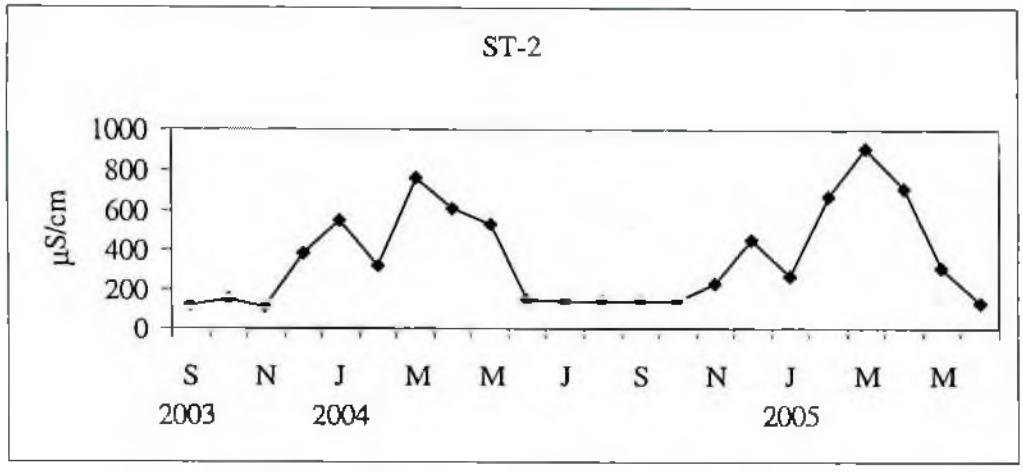


Fig. 22. Water conductivity of ST-2.

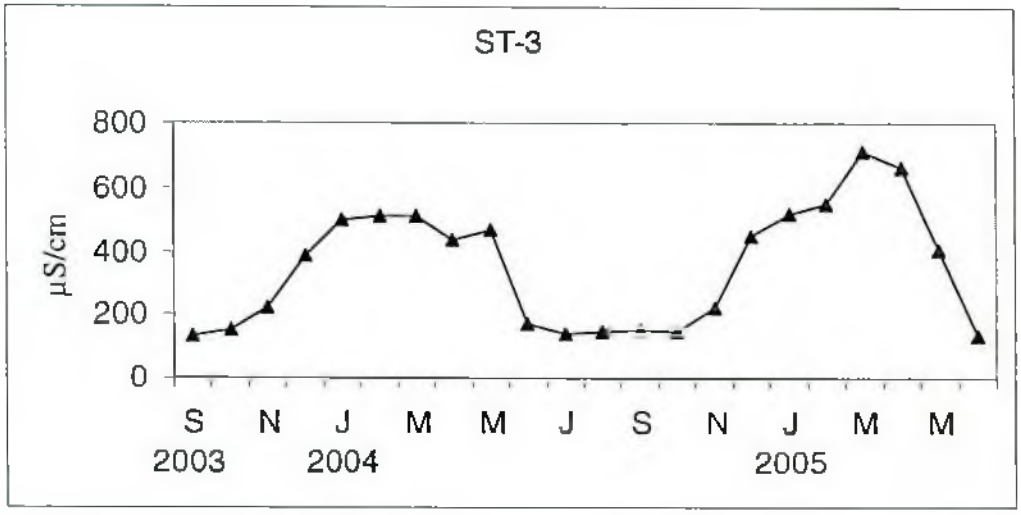


Fig. 23. Water conductivity of ST-3.

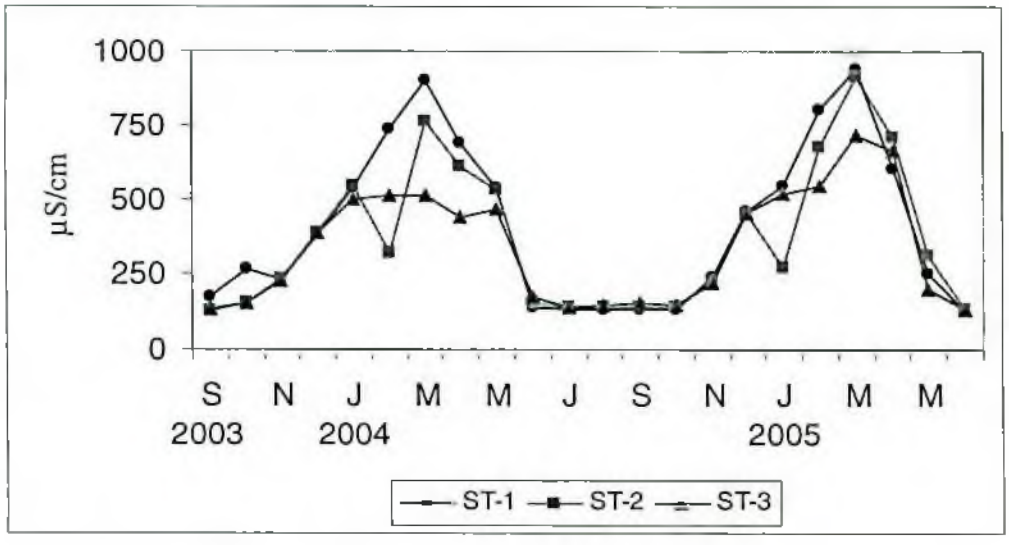


Fig. 24 Comparative water conductivity among ST-1, ST-2 and ST-3.

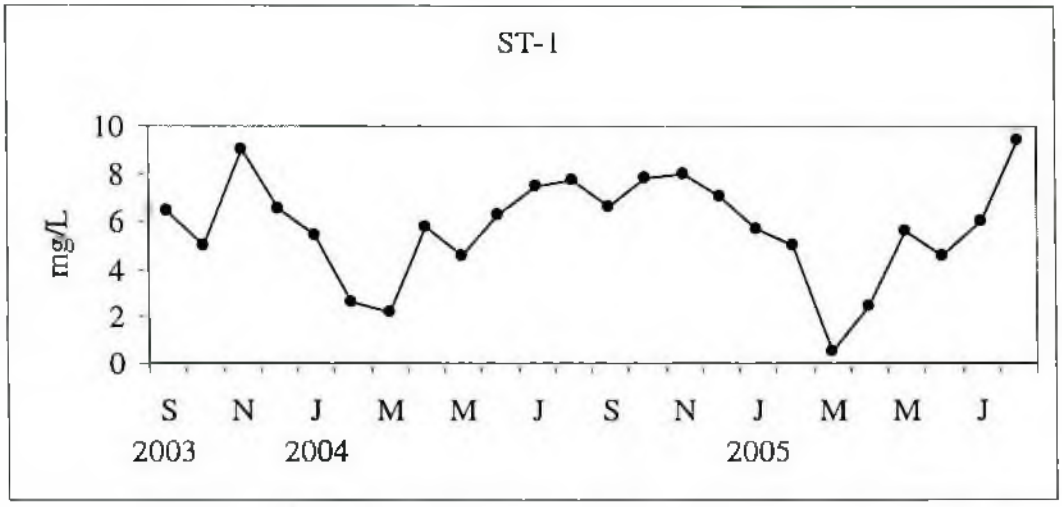


Fig. 25. Dissolved oxygen (DO) of ST-1.

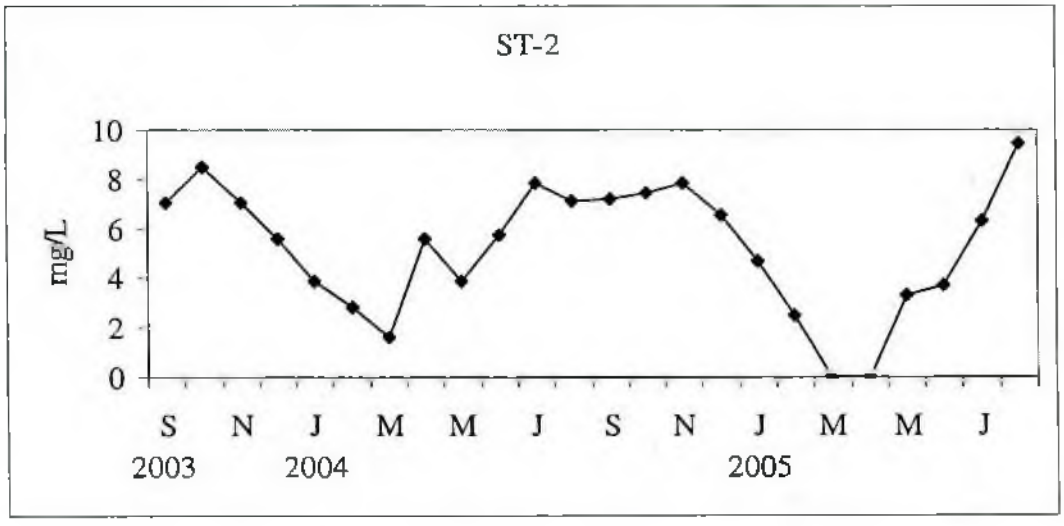


Fig. 26. Dissolved oxygen (DO) of ST-2.

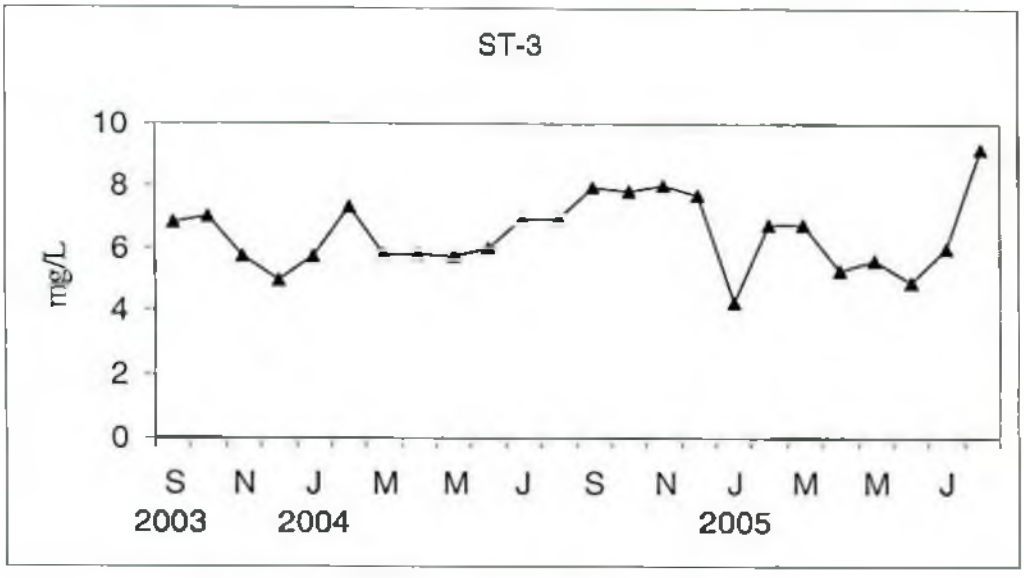


Fig. 27. Dissolved oxygen (DO) of ST-3.

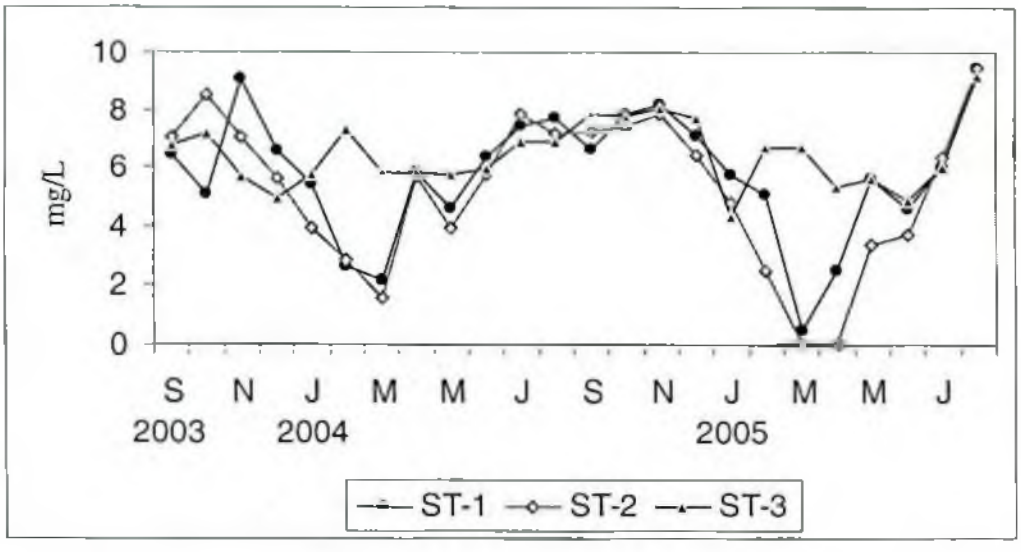


Fig. 28. Comparative dissolved oxygen (DO) among ST-1, ST-2 and ST-3.

Total dissolve solids (TDS)

The highest monthly mean TDS was recorded for ST-1: 466.5 mg/L, ST-2: 393.5 mg/L and ST-3: 301 mg/L, The lowest value was recorded during Monsoon (May to November) for all the three stations. i.e., ST-1: 56.5 mg/L, ST-2: 55 mg/L and at ST-3: 45 mg/L (Figs. 29-31). A sharp single peak was obtained in the same month (March) for every year at ST-1 but incase of ST-2 a single peak was obtained during first year but two peaks were recorded in the following year and at ST-3, two peaks (one small and one big) were obtained for every single year. ST-1, ST-2 and ST-3 exhibited similar trends throughout the investigation (Fig. 32). For ST-1 and ST-2 peak values were recorded in the same month (March) for both the years and for ST-3 it was February for the first year and June for the second year. In monsoon TDS concentration were uniform and in a lower range (May-November) for all the three stations.

SRS

In ST-1 it ranged from 3.0-82.0 mg/L and in ST-2 from 4.0-84.0 mg/L (Figs.33-34). However, in ST-3 SRS ranged from 2.0-34.0 mg/L over the period of investigation (Fig. 35). The general pattern of variation is a gradual depleting trend in the concentration of SRS during monsoon (May-October). Starting from November the concentration starts increasing showing a peak value in March for ST-1 and ST-2. But for ST-3, the peak concentration was recorded in January 2004. The concentration of soluble reactive silicate (SRS) in the river water fluctuated fairly in a similar manner in all the stations (Fig. 36).

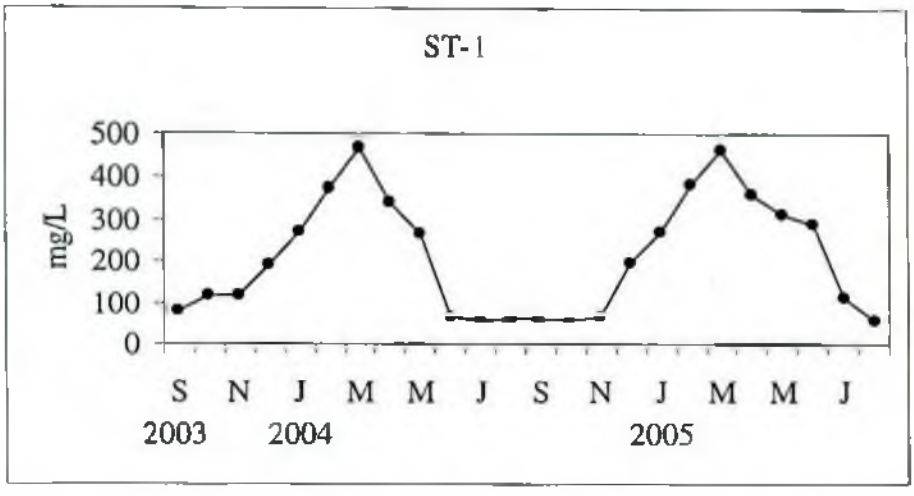


Fig. 29. Total dissolved solids (TDS) at ST-1.

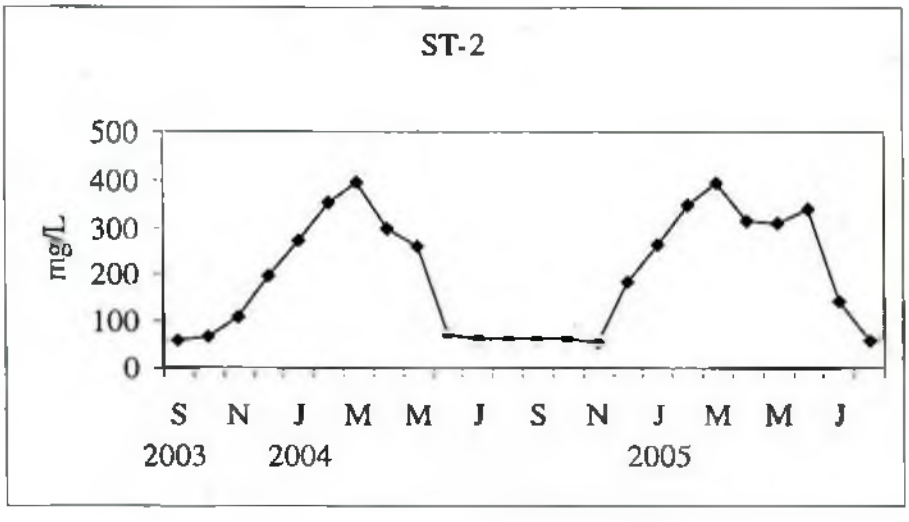


Fig. 30. Total dissolved solids (TDS) at ST-2.

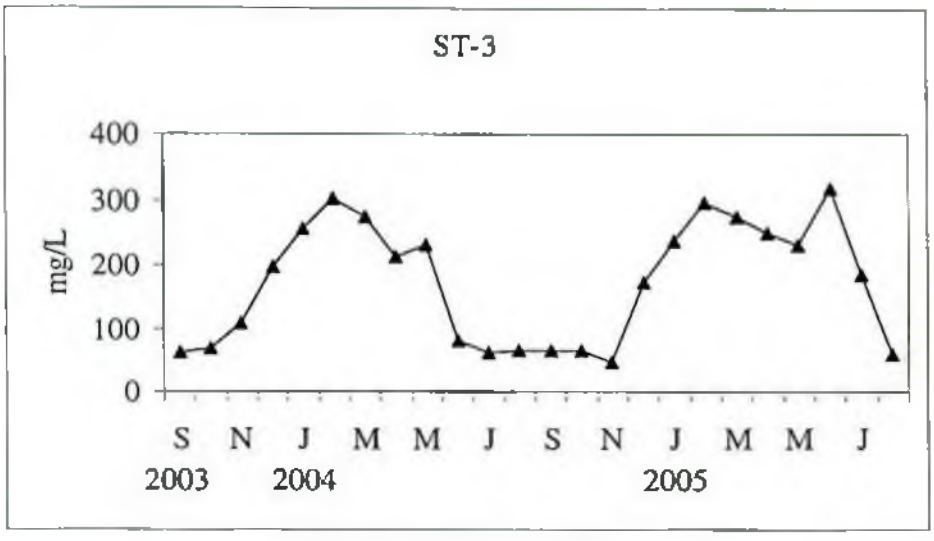


Fig. 31. Total dissolved solids (TDS) at ST-3.

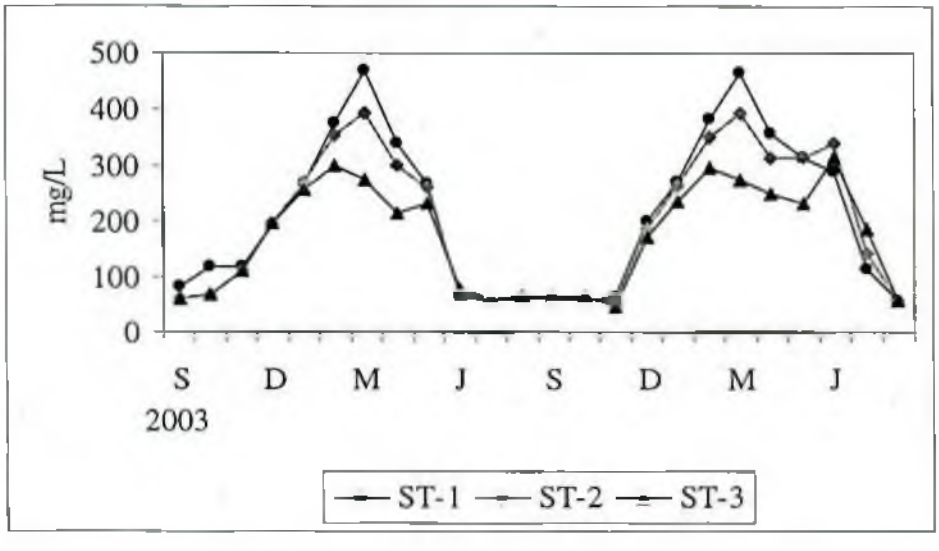


Fig. 32. Comparative total dissolved solids (TDS) among ST-1, ST-2 and ST-3.

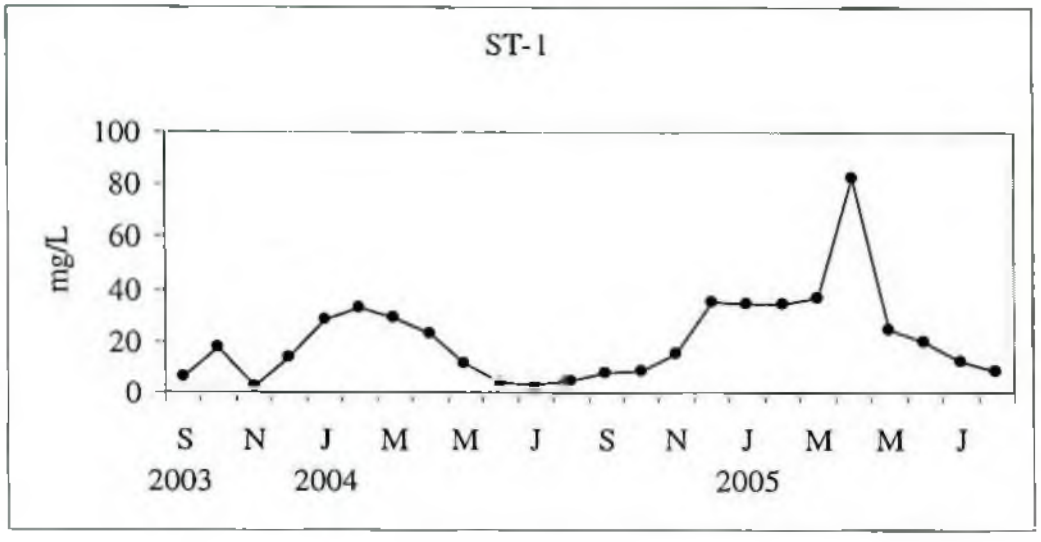


Fig. 33. Soluble reactive silicate (SRS) of ST-1.

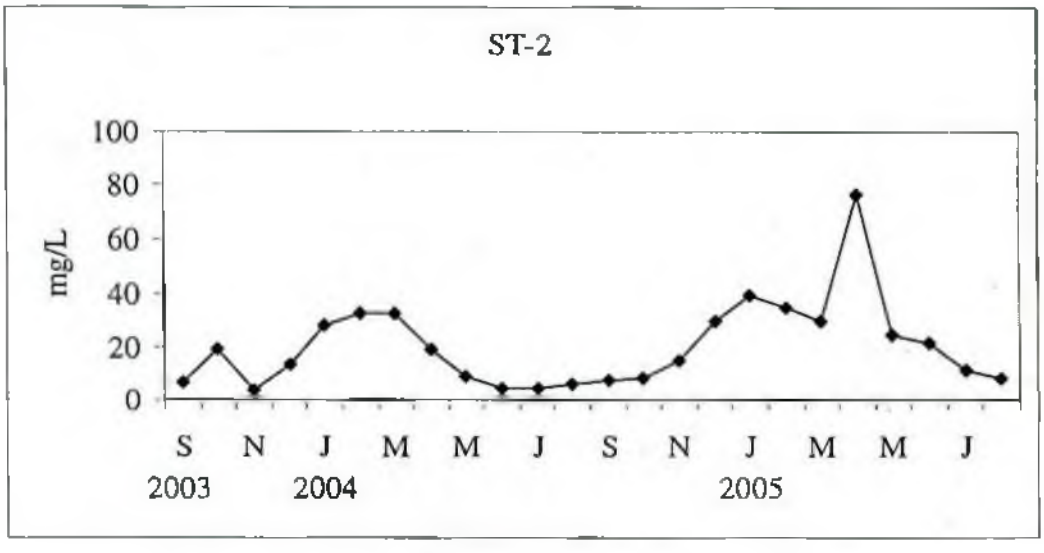


Fig. 34. Soluble reactive silicate (SRS) of ST-2.

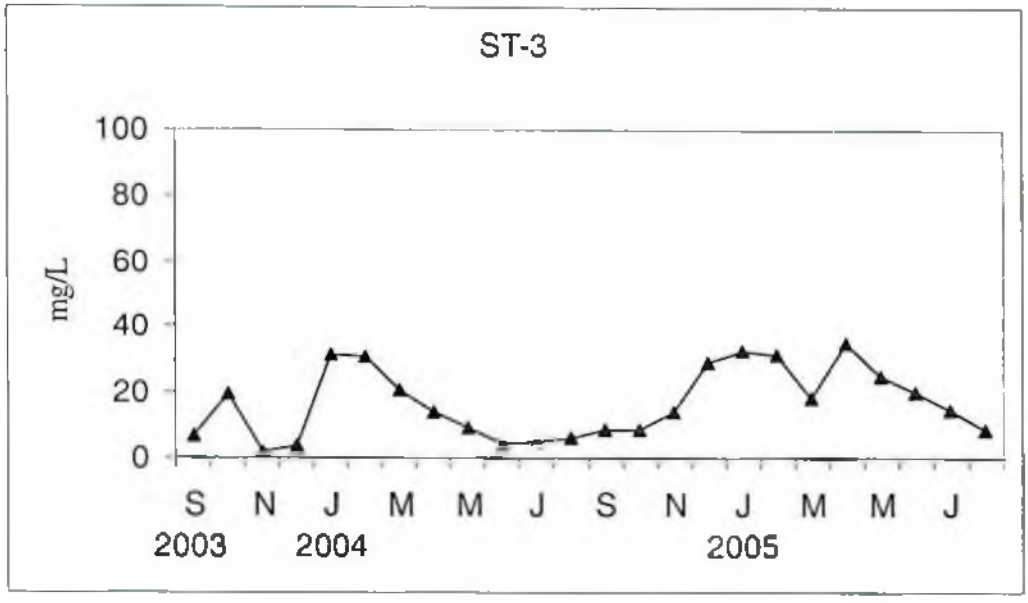


Fig. 35. Soluble reactive silicate (SRS) of ST-3.

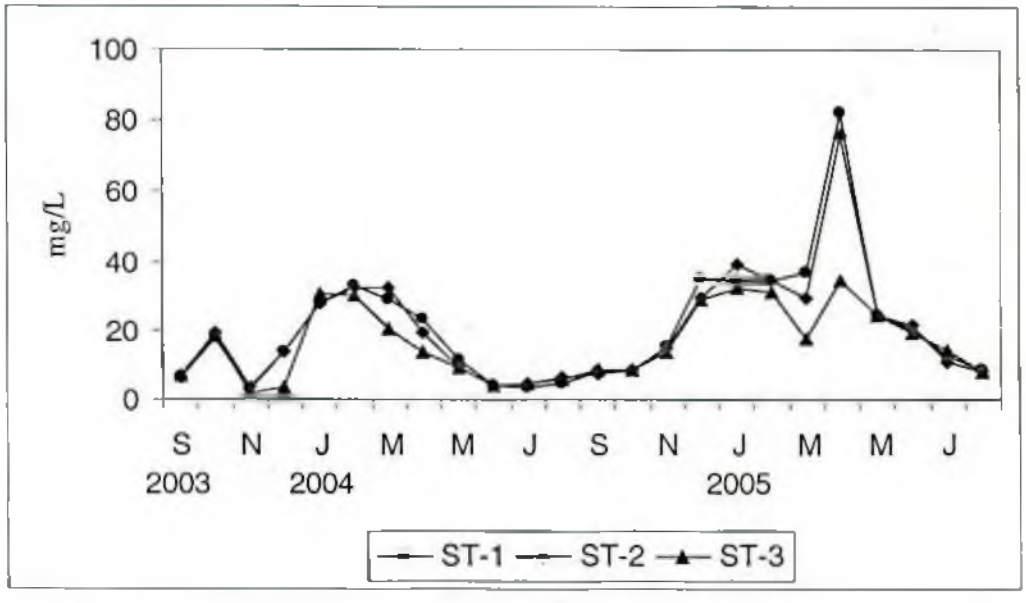


Fig. 36. Comparative soluble reactive silicate (SRS) among ST-1, ST-2 and ST-3.

Nitrate nitrogen (NO_3-N)

The concentration of NO_3-N varied from 0-0.3 mg/L, 0-0.27 mg/L and 0-2.52 mg/L in ST-1, ST-2 and ST-3, respectively. At ST-1 and ST-2 the NO_3-N dropped to zero in March and between February and May (Figs. 37-38). However, at ST-3 NO_3-N dropped to zero in November and August (Fig. 39). The annual fluctuation of this parameter among the studied stations were highly variable (Fig. 40). In ST-1, the peak was shown in July, 2005 whereas in ST-2 it was in October 2003. At ST-3 the peak concentration was observed in March 2005.

Soluble reactive phosphorus (SRP)

The concentration of soluble reactive phosphorus ranged 28-1443 µg/L, 34-1584 µg/L, 40-466 µg/L in ST-1, ST-2 and ST-3, respectively (Figs. 41-43). In between April and November the SRP concentration of the river water dropped in all the stations. However, between November and March SRP concentration elevated in the river water. The soluble reactive phosphorus exhibited an almost similar pattern of fluctuation over the study period and among the stations (Fig. 44).

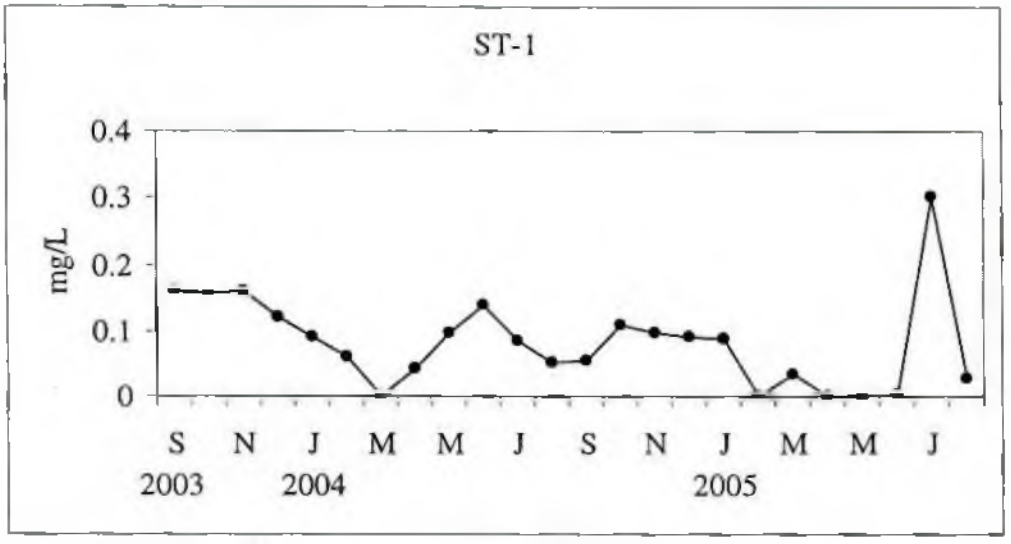


Fig. 37. Nitrate-nitrogen (NO_3-N) of ST-1.

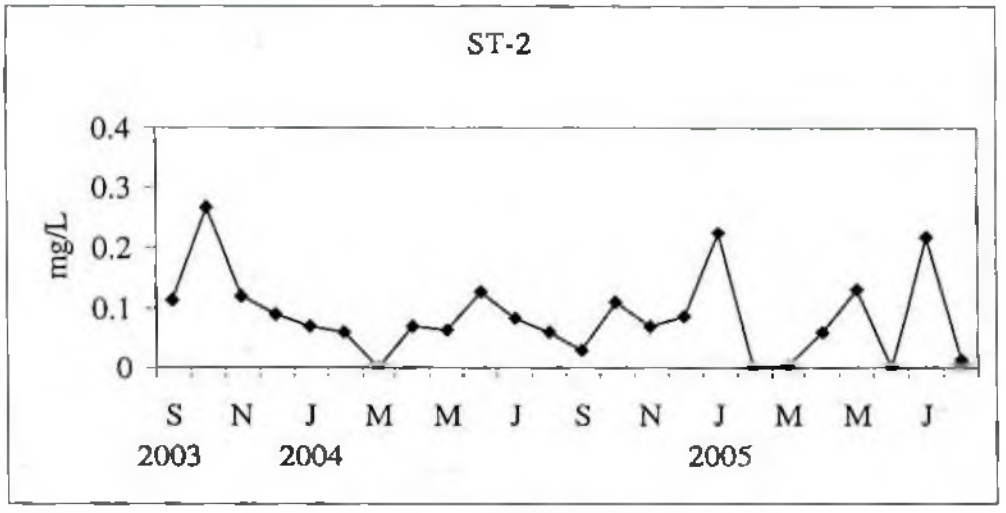


Fig. 38. Nitrate-nitrogen (NO_3-N) of ST-2.

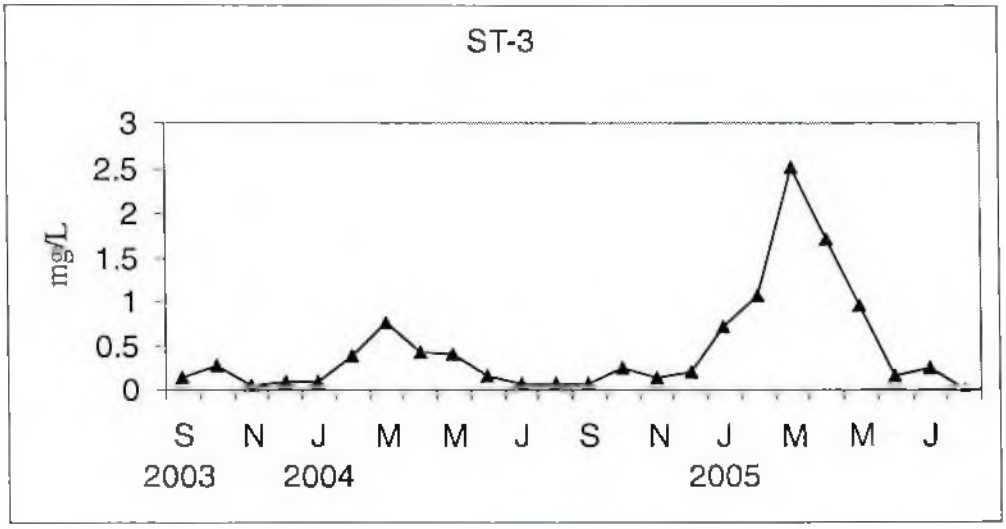


Fig. 39. Nitrate-nitrogen (NO_3-N) of ST-3.

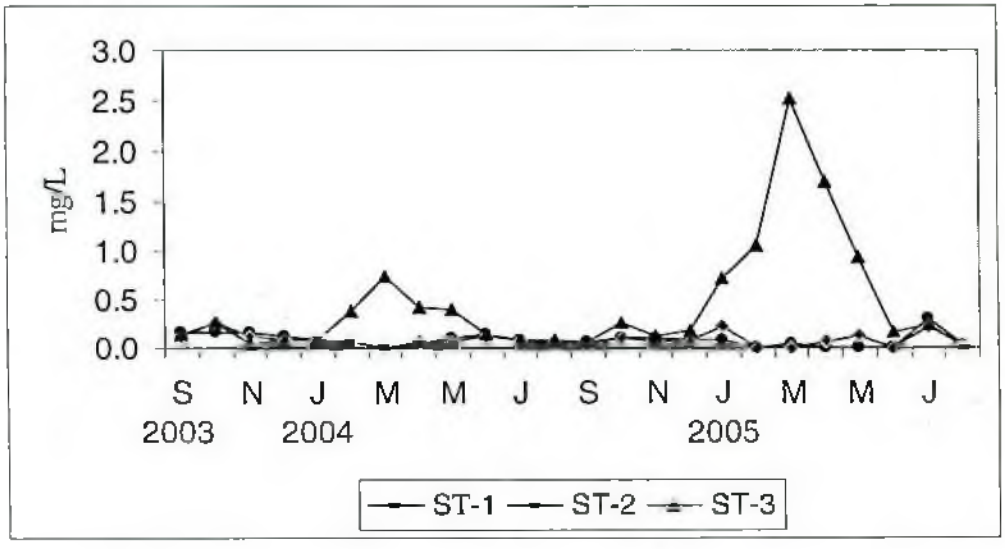


Fig. 40. Comparative nitrate-nitrogen (NO_3-N) among three stations.

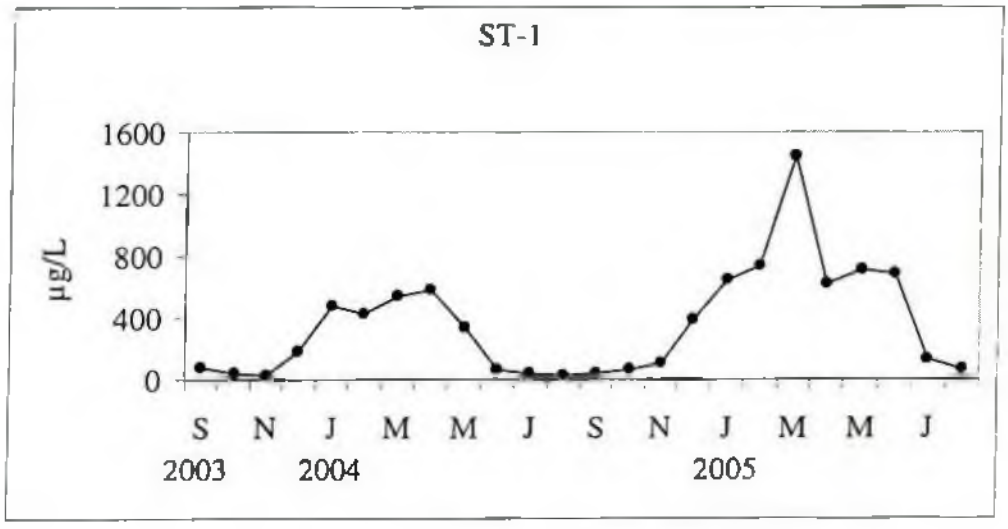


Fig. 41. Soluble reactive phosphorus (SRP) of ST-1.

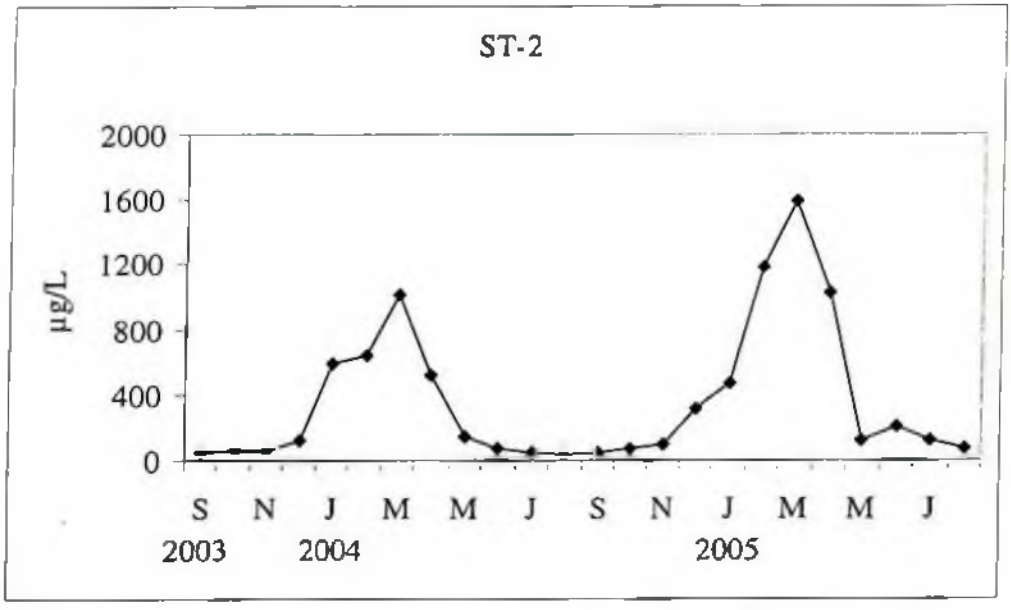


Fig. 42. Soluble reactive phosphorus (SRP) of ST-2.

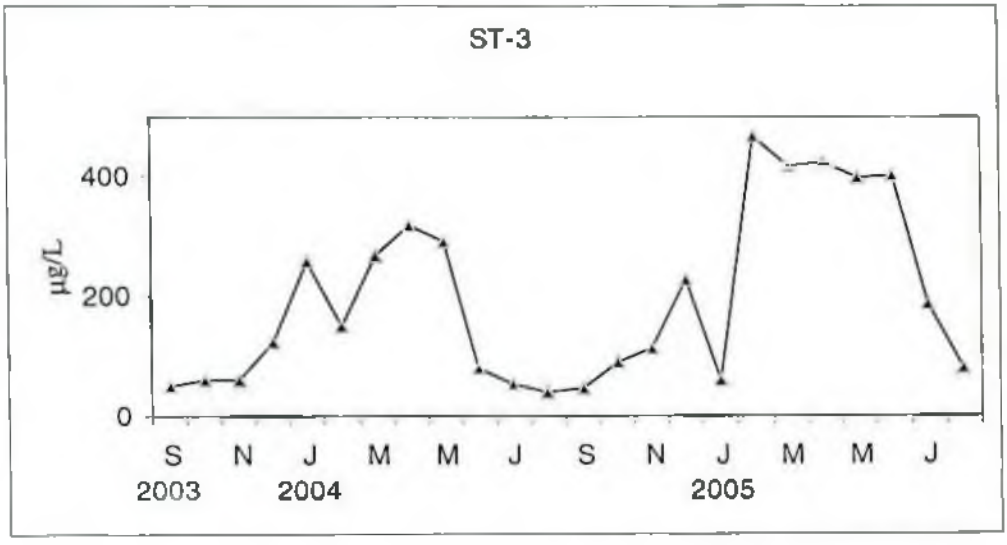


Fig. 43. Soluble reactive phosphorus (SRP) of ST-3.

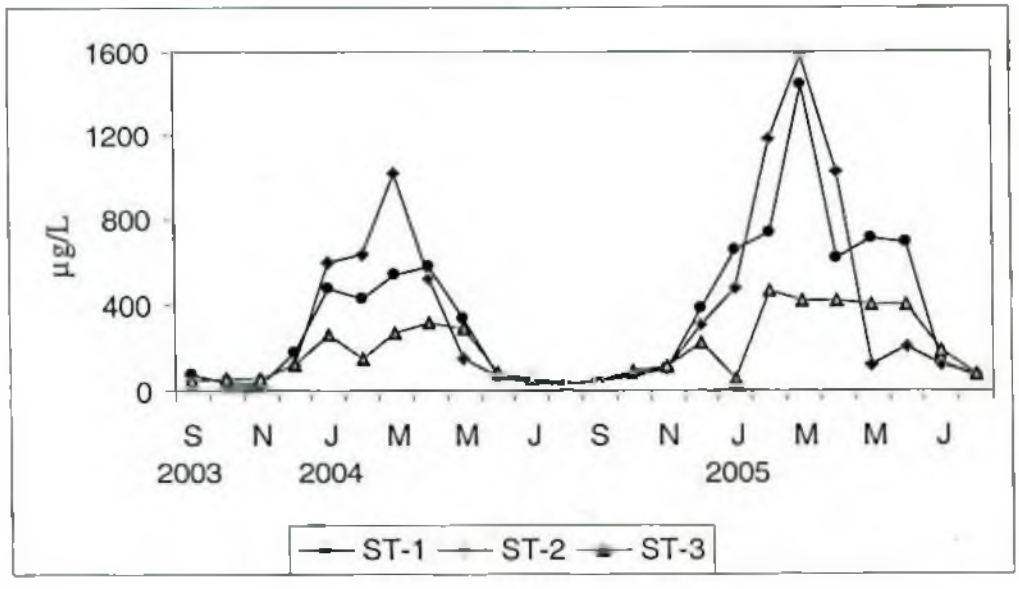


Fig. 44. Comparative soluble reactive phosphorus (SRP) among ST-1, ST-2 and ST-3.

Phytoplankton diversity

In the present investigation a total of 141 phytoplankton samples were collected for three stations. All these samples were studied for qualitative and quantitative data.

Qualitative

Composition

In the present investigation 65, 60 and 61 genera were represented in the phytoplankton communities for ST-1, ST-2 and ST-3, respectively. All these genera belonged to six classes (except ST-2 has one more class).

Genus level percentage composition shows that Chlorophyceae dominates all the three stations and occupied 44%, 43% and 43% for ST-1, ST-2 and ST-3, respectively followed by Cyanophyceae (22%) for ST-1, Bacillariophyceae (20%) for ST-2 and both Cyanophyceae and Bacillariophyceae (21%) for ST-3. Euglenophyceae can be treated as minor group (10%) recorded for all the three stations.

Principal components

Oscillatoria was found most dominant amongst blue green algae (BGA) followed by *Merismopedia* and *Pelonema* at ST-1 and ST-2. At ST-3 it was *Merismopedia* which was most dominant as BGA. *Monoraphidium*, *Scenedesmus* and *Cosmarium* were found considerably abundant than other green algae at ST-1 and ST-2. At ST- 3 *Cosmarium* only was found dominant. *Cyclotella* and *Melosira* were found most dominant as Bacillariophyceae at ST-2 and ST-3. *Euglena* was found in a large number at ST-1 and ST-2 other than any representative of its group. At ST-3 both *Euglena* and *Trachelomonas* were recorded as most dominant from Euglenophyceae.

Recorded common species

The total number of phytoplankton species recorded under the present study were 180 of which 110 species were common for Bangladesh. Classwise distribution of these species were Euglenophyceae 25, Chlorophyceae 41, Bacillariophyceae 16, Cyanophyceae 23 and Cryptophyceae 5. (Plate 1 to Plate 5). A brief systematic description of the species are as follows.

A brief systematic description of the recorded common species of phytoplankton from the river Buriganga

(Species are alphabetized under each genus)

Class **Euglenophyceae;** Order **Euglenales;** Family **Euglenaceae**

1. **Euglena acus** Ehrb. **(Pl. 1, Figs. 2, 10, 15)**
(Huber-Pestalozzi 1955, 98, 16: 75 a; Islam *et al.* 1991, 8, 1: 5)
Cell 88.9 × 7.6 µm.

2. **Euglena chlamydophora** Mainx **(Pl. 1, Figs. 6, 9, 11,16)**
(Huber-Pestalozzi 1955, 95, 45: 74; Islam *et al.* 1991, 10, 1: 3)
Cell 38.1 × 11.4 µm.

3. **Euglena geniculata** Dujardin **(Pl. 1, Fig. 5)**
(Dillard 1989, 24, 1: 12; Islam *et al.* 1991, 11, 1: 4)
Cell 60.9 × 17.8 µm.

4. **Euglena hemichromata** Skuja **(Pl. 1, Fig. 7)**
(Dillard 1989, 27, 5: 6; Khondker *et al.* 2008, 41, 7c)
Cell 116.8 × 20.3 µm.]

5. **Euglena polymorpha** Dang.
(Huber-Pestalozzi 1955, 85, 14: 62a; Islam and Khatun 1966, 101, 2: 25)
Cell 43.1 × 15.2 µm.

6. **Euglena retronata** Johnson. **(Pl. 1, Figs. 4, 8)**
(Huber-Pestalozzi 1955, 95, 15: 74a; Khondker *et al.* 2008, 44, 17)
Cell 17.8 × 9.7 µm.

7. **Euglena sanguinea** Ehrb
(Huber-Pestalozzi 1955, 90, 15: 70a; Islam *et al.* 1991, 12, 2: 27)
Cell 116.8 × 58.4 µm.

8. **Lepocinclis ovum** var. **dimido-minor** Defl.
(Huber-Pestalozzi 1955, 151, 30: 151a; Bhuiyan 2006, 55, 323)
Cell 15.2 × 10.1 µm.

9. **Lepocinclis playfairiana** Deflandre **(Pl. 1, Fig. 12-14)**
(Dillard 1989, 43, 7: 13; Islam and Irfanullah 2005, 40, 4: 49)
Length of the cell 40.6 µm, maximum width 20.3 µm.

10. **Phacus caudatus** Hübner **(Pl. 2, Fig. 6)**
(Dillard 1989, 54, 12: 1; Islam and Irfanullah 2005, 40, 4: 54)
Cell 45.7 × 20.3 µm.

11. **Phacus curvicauda** Swirenko **(Pl. 2, Fig. 7)**
(Dillard 1989, 56, 11: 8; Islam and Irfanullah 2005, 41, 4: 55)
Cell 34.0 × 26.0 µm.

12. **Phacus ephippion** Pochm. **(Pl. 2, Figs. 1, 9)**
(Huber-Pestalozzi 1955, 224, 50: 308b; Khondker *et al.* 2008, 57, 2)
Cell 73.6 × 33.0 µm.

13. **Phacus lismorensis** Playf.
(Huber-Pestalozzi 1955, 219, 48: 297b; Islam and Al-fasane 2002, 10, 4: 45)
Cell 53.3 × 22.9 µm.

14. **Phacus longicauda** var. **attenuata** (Pochm.) H.-P. **(Pl. 2, Fig. 4)**
(Huber-Pestalozzi 1955, 222, 49: 301; Islam and Al-fasane 2002, 12, 3: 36)
Cell 116.8 × 43.2 µm.

15. **Phacus meson** Pochm. **(Pl. 2, Fig. 12)**
(Huber-Pestalozzi 1955, 218, 68: 294c; Islam and Al-fasane 2002, 14, 4: 43)
Cell 101.6 × 45.7 µm, paramylum 13.9 µm long.

16. **Phacus platalea** Drez. **(Pl. 2, Fig. 11)**
(Huber-Pestalozzi 1955, 210, 65: 274b; Islam and Irfanullah 2005, 41, 4: 52)
Cell 50.9 × 30.4 µm, flagellum 71.1 µm.

17. **Phacus tortus** (Lemm.) Skv. **(Pl. 2, Figs. 3, 5, 8, 10)**
(Huber-Pestalozzi 1955, 225, 51: 319b; Islam and Al-Tasane 2002, 16, 4: 52)
Cell 71.1 × 40.6 µm.

18. **Phacus undulatus** (Skv.) Pochm. **(Pl. 2, Fig. 2)**
(Huber-Pestalozzi 1955, 214, 47: 287b; Khondker *et al.* 2008, 59, 19)
Cell 76.2 × 40.6 µm.

19. **Strombomonas verrucosa** var. **borystheniensis** (Roll) Defl. **(Pl. 2, Figs. 13-14)**
(Huber-Pestalozzi 1955, 369, 77: 793; Bhuiyan 2006, 58, 604)
Cell 30.4 × 20.3 µm.

20. **Trachelomonas dybowskii** Drezepolski. **(Pl. 2, Fig. 17)**
(Prescott 1982(reprint), 412 , 83: 21; Islam and Zaman 1981, 114, 1: 39)
Cell 20.3 × 15.2 µm with lorica.

21. **Trachelomonas planctonica** Swirenko. **(Pl. 2, Fig. 18)**
(Dillard 1989, 96, 19: 16; Islam and Zaman 1981, 118, 3: 98)
Cell 21.0 × 18.0 µm.

22. **Trachelomonas pulcherrima** var. **minor** Playfair
(Dillard 1989, 97, 19: 7; Islam and Zaman 1981, 118, 2: 48)
Cell 15.2 × 7.6 µm.

23. **Trachelomanas superba** (Swir.) Deflandre **(Pl. 2, Fig. 16)**
(Prescott 1982(reprint), 417, 84: 10; Islam and Zaman 1981,120, 4: 128)
Cell dia 38.1 µm with lorica, cell wall spiny.

Family **Astasiaceae**

24. **Astasia longa** Pringsh. **(Pl. 2, Fig. 15)**
(Huber-Pestalozzi 1955, 435, 88: 899c; Aziz and Islam 1979, 112, 2: 29)
Cell 35.5 × 7.6 µm.

Class **Chlorophyceae;** Order **Chlorococcales;** Family **Scenedesmaceae**

25. **Actinastrum hantzschii** var. **subtile** Wolosz. **(Pl. 3, Fig. 10)**
(Huber-Pestalozzi 1983, 742, 207: 3; Aziz 2008 in press)
8 cell colony, individual cell 17.0 × 3.0 µm.

26. **Actinastrum gracillimum** var. **gracillimum** (nach. GM. Smith)
(Huber-Pestalozzi 1983, 746, 3: 3; Islam and Khatun 1966, 97, 4: 93)
Colony 10.1 µm, individual cell 5.0 × 2.5 µm.

27. **Scenedesmus acuminatus** (Lag.) Chod. **(Pl. 3, Fig. 17)**
(Huber-Pestalozzi 1983, 844, 229: 1; Islam and Khatun 1966, 3:79)
Colony 45.7 × 30.4 µm.

28. **Scenedesmus dimorphus** (Turpin) Kütz.
(Huber-Pestalozzi 1983, 842, 228: 3; Islam and Khatun 1966, 100, 3: 72)
Colony 20.3 × 12.7 µm.

29. **Scenedesmus obliquus** (Turp) Kütz .
(Huber-Pestalozzi 1983, 837, 227: 3; Islam and Khatun 1966, 100, 3:67)
Colony 10.1 × 10.1 µm, individual cell 10.1 × 2.5 µm.

30. **Scenedesmus opoliensis** Richter **(Pl. 3, Fig. 8)**
(Huber-Pestalozzi 1983, 906, 224: 7; Islam and Khatun 1966, 100, 3: 44)
Colony 40.6 × 15.2 µm.

Family **Volvocaceae**

31. **Carteria globosa** Korsch.
(Huber-Pestalozzi 1961, 85, 16: 59e; Khondker *et al.* 2007, 3, 1b)
Cell measures 17.7 µm long, 12.7 µm broad.

32. **Eudorina elegans** Ehrenberg **(Pl. 3, Fig. 16)**
(Ling and Tyler 2000 , 123, 55: 5); (Islam and Khatun 1966, 96,1: 11)
Colony 12.0 × 9.0 µm, individual cell 7.0 × 4.0 µm.

33. **Gonium pectorale** Müller **(Pl. 3, Fig. 3)**
(Huber-Pestalozzi 1961, 624, 107: 877; Islam and Khatun 1966, 97,1: 1)
Cells 10.0 × 8.0 µm, flagella 20 µm long.

34. **Pandorina morum** Bory
(Dillard 1989 , 32, 6: 3; Islam and Khatun 1966, 97,1: 5)
Colony 12.0 × 10.0 µm.

35. **Pyrobotrys gracilis** Korsch. **(Pl. 3, Fig. 2)**
(Huber-Pestalozzi 1961, 614, 115: 871c; Islam and Khatun 1966, 97, 2: 14)
Colony 40.0 × 30.0 µm, individual cell 12.0 × 8.0 µm, flagella 36 µm long.

Family **Micractiniaceae**

36. **Micractinium pusillum** Fresenius **(Pl. 3, Fig. 9)**
(Huber-Pestalozzi 1961,322, 97: 1; Islam and Khatun 1966, 98, 7:144)
Colony three in number 9.0 × 10.0 µm in diameter, chaete 13 µm long.

Family **Characiaceae**

37. **Characium ornithocephalum** A Brown
(Huber-Pestalozzi 1961, 206, 59: 8a; Islam and Begum 1970, 237, 1: 44)
Cell 35.5 µm long and 7.6 µm broad.

Family **Oocystaceae**

38. **Ankistrodesmus bibraianus** (Reinsch) Kors. **(Pl. 3, Fig. 1)**
(Huber-Pestalozzi 1983, 688, 194: 3f; Islam and Khatun 1966, 100, 4: 88; recorded as *Selenestrum bibraianum*
Colony 25.4 × 20.3 µm, individual cell 12.7 × 2.5 µm.

39. **Ankistrodesmus densus** Kors. **(Pl. 3, Fig. 19)**
(Huber-Pestalozzi 1983, 687, 193: 2; Khondker *et al.* 2007, 89, 18)
Colony 66.0 × 5.0 µm, 6 cell colony.

40. **Crucigenia quadrata** Morren **(Pl. 3, Fig. 4)**
(Huber-Pestalozzi 1983, 788, 219: 4d; Islam and Begum 1970, 249, 4: 115)
4 celled colony 15.2 × 15.2 µm.

41. **Crucigenia tetrapedia** (Kirch.)West and West **(Pl. 3, Fig. 13)**
(Huber-Pestalozzi 1983, 787, 218: 7; Islam and Begum 1970, 250, 4: 117)
Colony 12.0 × 10.0 µm, individual cell 5.0 × 5.0 µm.

42. **Dictyosphaerium tetrachotomum** Printz **(Pl. 3, Fig. 12)**
(Huber-Pestalozzi 1983, 768, 214: 2; Khondker *et al.* 2007, 87, 10)
Larger cell measures 8.0 × 5.0 µm, smaller cell 4.0 × 3.0 µm.

43. **Hyaloraphidium contortum** Pascher and Koršikov
(Huber-Pestalozzi 1983, 694, 194: 6; Islam and Begum 1970, 246, 3: 94)
Cell 36.9 × 5.0 µm.

44. **Kirchneriella irregularis** (Smith) Kors.
(Dillard 1989, 80, 20: 8; Khondker *et al.* 2007, 89, 20)
Colony measures 30.4 × 27.9 µm.

45. **Kirchneriella lunaris** (Kirch) Moeb.
(Huber-Pestalozzi 1983, 669, 187: 3d; Islam and Khatun 1966, 98, 4:103)
Larger cell measures 8.0 × 6.0 µm, smaller cell 5.0 × 4.0 µm.

46. **Kirchneriella obesa** (W. West) Schmidle **(Pl. 3, Fig. 21)**
(Ling and Tyler 2000, 104, 46: 12; Islam and Khatun 1966, 98, 4: 97)
16 celled colony 25.4 µm in diameter, 4 celled colony 12.7 µm, individual cell 5.0 µm long.

47. **Monoraphidium arcuatum** (Kors.) Hind. **(Pl. 3, Fig. 14)**
(Huber-Pestalozzi 1983, 634, 178: 7a; Khondker *et al.* 2007, 88, 136)
Cell 25.4 × 2.5 µm.

48. **Monoraphidium subclavatum** Nygaard
(Ling and Tyler 2000, 105, 42: 13; Khondker *et al.* 2007, 88, 13)
Cell 28.0 × 2.0 µm.

49. **Nephrochlamys subsolitaria** (G. S. West) Kors **(Pl. 3, Fig. 11)**
(Yamagishi 1998, 73; Islam and Irfanullah 2000,116, 1: 45)
Colony measures 10.0 × 10.0 µm.

50. **Schroederia antillarum** Komarek
(Huber-Pestalozzi 1983, 251, 74: 2; Khondker *et al.* 2007, 86, 3)
Cell 36.9 × 5.0 µm.

51. **Tetraedron gracile** (Reinsch) Hansg. **(Pl. 3, Fig. 15)**
(Dillard 1989, 14:1; Islam and Khatun 1966, 100, 5: 125)
Cell 38.1 × 25.4 µm.

52. **Tetrastrum heteracanthum** (Nordst) Chod. **(Pl. 3, Fig. 22)**
(Huber-Pestalozzi 1983, 770, 214: 5; Islam and Begum 1970, 250, 4: 120)
Colony 12.7 µm in diameter, individual cell 5.0 µm long, chacte 7.6 µm long.

Family **Coelastraceae**

53. **Coelastrum microporum** Nägeli **(Pl. 3, Fig. 20)**
(Huber-Pestalozzi 1983, 726, 202: 1; Islam and Khatun 1966, 107, 5: 111)
Maximum colony diameter 15.2 µm, cell 5.0 µm in diameter.

Family **Hydrodictyaceae**

54. **Pediastrum duplex** Meyen **(Pl. 3, Figs. 5, 23)**
(Dillard 1989, 126, 35: 7; Islam and Khatun 1966, 99, 6: 141)
Colony 30.4 × 27.9 µm.

55. **Pediastrum duplex** var. **reticulatum** Lager
(Huber-Pestalozzi 1983, 300, 89: 3b; Islam and Khatun 1966, 99, 6: 140)
Colony 38.1 µm in diameter, individual cell 12.7 × 7.60 µm.

56. **Pediastrum simplex** (Meyen) Lemm. **(Pl. 3, Fig. 18)**
(Huber-Pestalozzi 1983, 288, 84: 1f; Islam and Zaman 1975, 50, 3: 24)
Colony 75.2 × 66.0 µm.

57. **Pediastrum tetras** (Ehr.) Ralfs. **(Pl. 3, Fig. 7)**
(Huber-Pestalozzi 1983, 93, 41: 8; Islam and Begum 1970, 262, 7: 224)
Colony 25.4 × 15.2 µm.

Order **Zygnematales;** Family **Desmidiaceae**

58. **Closterium calosporum** Wittrock **(Pl. 3, Fig. 26)**
(Ling and Tyler 2000, 135, 61: 1; Akter 1991, 52, 15: 90)
Cell 112.0 × 7.0 µm.

59. **Closterium dianae** var. **minus** Hieron.
(Huber-Pestalozzi 1983, 137, 61: 12; Islam and Irfanullah 2005, 52, 2: 13)
Cell 112.0 × 7.0 µm.

60. **Closterium limneticum** Ehr. **(Pl. 3, Fig. 24)**
(Huber-Pestalozzi 1983, 143, 60: 6; Khondker *et al.* 2007)
Cell 226.0 × 10.1 µm.

61. **Closterium macilentum** Breb. **(Pl. 3, Fig. 25)**
(Huber-Pestalozzi 1983, 142, 64: 2; Islam and Haroon 1980, 554, 3: 38)
Cell 152.4 × 7.6 µm.

62. **Closterium navicula** (Breb.) Luetk **(Pl. 3, Fig. 6)**
(Ling and Tyler 2000, 142, 58: 6; Akter 1991, 56, 14: 71-75)
Cell 76.2 × 12.7 µm.

63. **Cosmarium impressulum** Elf.
(Ling and Tyler 2000, 172, 77: 9; Islam 1970, 924, 11: 6-8)
Length 25 µm, median diameter 18.1 µm, isthmus 3.6 µm, tip 5.4-7.2 µm.

Class **Dinophyceae;** Order **Gymnodiniales**
Family **Gymnodiniaceae**

64. **Peridinium volzi** Lemm. **(Pl. 3, Figs. 27-28)**
(Huber-Pestalozzi 1983, 195, 30: 177b; Bhuiyan 2006, 60, 432)
Cell 22.8 × 25.4 µm.

Class **Bacillariophyceae;** Order **Centrales**
Family **Coscinodiscaceae**

65. **Coscinodiscus lacustris** Grun. **(Pl. 4, Figs. 5, 24-25)**
(Germain 1981, 42,11: 1; Islam and Haroon 1975, 29, 1: 19)
Cell 50.8 µm in diameter.

66. **Cyclotella comta** var. **affinis** (Ehr.) Kütz. **(Pl. 4, Fig. 4)**
(Germain 1981, 40, 9: 15 ; Khair and Chowdhury 1983, 79, 1:10)
Cell 17.7 µm in diameter.

67. **Cyclotella meneghiniana** Kütz. **(Pl. 4, Fig. 11)**
(Germain 1981, 32, 7: 1 ; Nahar 2001, 82, 1:12)
Cell 25.4 µm in diameter, 8 spike in every 10 µm.

68. **Cyclotella stelligera** Cleve *et* Grunow **(Pl. 4, Fig. 12)**
(Germain 1981, 34, 8:16 ; Nahar 2001, 82, 1:15)
Cell 22.8 µm in diameter.

69. **Melosira granulata** (Ehr.) Ralfs **(Pl. 4, Figs. 10, 13-14)**
(Germain 1981, 24, 3: 2; Islam and Haroon 1975, 48, 1: 3)
Filament 210.8 µm long, 10.1 µm broad, 12 puncti per 10 µm.

Order **Pennales;** Family **Nitzschiaceae**

70. **Nitzschia acicularis** Smith **(Pl. 4, Figs. 3, 18)**
(Germain 1981, 362, 136: 7; Khondker *et al.* 2006
Cell 93.9 µm long, maximum width 7.6 µm.

71. **Nitzchia fruticosa** Hustedt. **(Pl. 4, Figs. 4, 26)**
(Pascher 1930, 352, 133: 9; Nahar 2001, 96, 14: 209)
Cell in colony (6 in number) individual cell 45.7 µm long, maximum width 7.6 µm.

72. **Synedra acus** Kütz. **(Pl. 4, Fig. 4)**
(Germain 1981, 78, 27: 2; Islam and Haroon 1975, 29, 1: 10)
Cell 86.3 × 7.6 µm.

73. **Synedra tabulata** Ag. **(Pl. 4, Fig. 22)**
(Germain 1981, 78, 26: 8; Aziz and Ara 2000, 8, 4)
Cell 111.7 × 7.6 µm.

74. **Synedra ulna** var. **oxyrhynchus** (Nitzsch) Ehr. **(Pl. 4, Fig. 23)**
(Germain 1981, 76, 25: 2; Islam and Haroon 1975, 29, 1: 8)
Cell 66.0 µm long, maximum width 7.6 µm.

Family **Naviculaceae**

75. **Gyrosig[illegible] acuminatum** Kütz. **(Pl. 4, Fig. 7)**
(Germa[illegible]981, 118, 49: 3; Bhuiyan 2006, 51, 163)
Cell 93[illegible]× 15.2 µm.

76. **Navicula pupula** Kütz. **(Pl. 4, Fig. 15)**
(Germain 1981,180, 68: 6; Islam and Irfanullah 2005, 49)
Cell 45.7 µm long, maximum width 10.7 µm.

77. **Navicula radiosa** Kütz. **(Pl. 4, Figs. 2, 19)**
(Germain 1981,118, 49: 3; Aziz and Yasmin 1997, 182, 15)
Cell 38.1 × 7.6 µm.

Family **Surirellaceae**

78. **Surirella robusta** var. **splendida** (Ehr.) Van Huerek **(Pl. 4, Fig. 21)**
(Germain 1981, 384, 149: 3; Islam and Haroon 1975, 35, 1: 17)
Cell 68.5 µm long, maximum width 25.5 µm.

Family **Gomphonemataceae**

79. **Gomphonema acuminatum** (Ehr.) **(Pl. 4, Fig. 27)**
(Germain 1981, 301, 111: 1; Nahar 2001, 93, 11:163)

Cell 45.7 µm long, maximum width 15.2 µm, tip 2.5 µm, valve heteropolar.

80. **Gomphonema angustatum** (Kutz.) Rab. **(Pl. 4, Figs. 9, 20)**
(Germain 1981, 306, 114: 14; Nahar 2001, 93, 11:171)
Cell 40.6 µm long, maximum width 7.6 µm.

Family **Achnanthaceae**

81. **Achnanthes minutissima** Kutz. **(Pl. 4, Figs. 6, 16)**
(Germain 1981, 109, 41: 10; Aziz and Tanbir 2003, 72, 29-30)
Cell 17 µm long, maximum width 2.5 µm.

Class **Cyanophyceae**; Order **Oscillatoriales**
Family **Oscillatoriaceae**

82. **Arthrospira platensis** (Nordst.) Gomont
(Desikachary 1959, 190, 35: 2; Islam and Nahar 1967, 147, 4: 8)
Filament length 160.0 µm and broad 45.7 µm.

83. **Arthrospira platensis** var. **non-constricta** (Banerji) Desik. **(Pl. 5, Fig. 16)**
(Desikachary 1959, 191, 36: 2; Islam *et al.* 2002, 4, 23; recorded as *Spirulina platensis* var. *non-constricta*)
Filament length 101.6 µm, width 33.0 µm, distance between one coil to another one 25.4 µm.

84. **Lyngbya limnetica** Lemm.
(Desikachary 1959,294, 50: 11; Islam and Khundker 2003, 66, 1: 25)
Filament 1.6 µm broad, cells 1.5 µm broad, nonconstricted, end cell rounded.

85. **Oscillatoria acutissima** Kufferath. **(Pl. 5, Fig. 11)**
(Starmach 1966, 354, 520; Islam and Uddin 1969, 75, 1: 12)
Length of trichome 203.2 µm, median cell 5.0 to 40.6 µm, width 10.1 µm, tip cell 50.8 × 2.5 µm.

86. **Oscillatoria agardhii** Gomont **(Pl. 5, Fig. 2)**
(Starmach 1966, 350, 615; Islam and Nahar 1967, 146, 2: 6)
Filament 152.4 × 5.0 µm.

87. **Oscillatoria amphibia** Vaucher *ex* Gomont
(Desikachary 1959, 229, 37: 6; Khondker *et al.* 2006, 176, 8)
Filament size 78.0 × 3.0 µm, individual cell 8.0 × 3.0 µm.

88. **Oscillatoria chalybea** (Mertens) Gomont
(Desikachary 1959, 218, 38: 3; Islam and Zaman 1975, 55, 8: 125)
Length of trichome 279.4 µm, width 10.1 µm, tip slightly taper.

89. **Oscillatoria geitleriana** Elenkin
(Desikachary 1959, 230, 40: 9; Islam and Khundker 2003, 62, 1: 23)
Each cell 7.6 × 2.5 µm.

90. **Oscillatora raoi** De Toni **(Pl. 5, Fig. 7)**
(Desikachary 1959, 223, 42: 17; Islam and Uddin 1969, 78, 1: 20)
Cell 7.6 × 5.0 µm.

91. **Oscillatoria tenuis** (Ag.) *ex* Gomont **(Pl. 5, Fig. 1)**
(Desikachary 1959, 227, 39: 19; Islam and Uddin 1969, 78, 1: 19)
Bigger cell size 7.6 × 5.0 µm, smaller cell size 5.0 × 2.5 µm.

Family **Nostocaceae**

92. **Anabaena constricta** (Szafer) Geitler **(Pl. 5, Fig. 17)**
(Desikachary 1959,394, 71: 3; Islam and Nahar 1967, 149, 4: 16)
Tip cell 10.1 µm wide and 9.3 µm long, median cell 12.7 × 10.1 µm, no heterocyst and no akinete.

93. **Anabaenopsis arnoldii** var. **indica** Raman **(Pl. 5, Figs. 3, 4)**
(Desikachary 1959, 356, 63: 2; Islam 1973, 134, 1: 15)
Dia of each coil 30.4 × 20.3 µm.

94. **Gomposphaeria lacustris** Chodat **(Pl. 5, Fig. 10)**
(Ling and Tyler 2000, 17, 1: 7; Khondker *et al.* 2006, 176, 4)
Colony 12.7 × 12.7 µm.

95. **Hyella fontana** Huber *et* Jadin
(Starmach 1966, 212, 267; Islam and Khundker 2003, 60, 4: 64)
Colony 35.5 × 33.0 µm, individual cell 5.0 × 2.5 µm, cell crescent shape.

96. **Pelonema aphane** Skuja **(Pl. 5, Fig. 15)**
(Skuja 1956, 91, 10: 7; Islam and Irfanullah 2000, 115, 1: 1)
Filament 60.0 µm long, 2.0 µm width, individual cell 7.0 µm long.

97. **Pseudanabaena mucicola** (H-P. and Naumann) Bourr. emend Chang **(Pl. 5, Fig. 14)**
(Ling and Tyler 2000, 31, 14: 2; Khondker *et al.* 2006, 178, 13 a)
Cell larger one 5.0 × 2.5 µm; smaller one 2.5 × 2.5 µm.

98. **Pseudanabaena schmidlei** Jaag **(Pl. 5, Fig. 6)**
(Starmach 1966, 447, 663; Gafur *et al.* 2000, 185, 29: 2)
Filament 165.1 µm long, 5.0 µm width, individual cell size 5.0 µm.

99. **Raphidiopsis indica** Singh, R. N. **(Pl. 5, Fig. 19)**
(Desikachary 1959, 422, 79: 1; Khondker *et al.* 2006, 178, 15c)
Trichome solitary 89 µm long, straight, long; tip lanceolate, tip 5 × 2 µm,

100. **Synechocystis aquatilis** Sauv. **(Pl. 5, Fig. 13)**
(Desikachary 1959,144, 25: 9; Islam and Uddin 1969, 90)
Cell round to oval, larger one 7.0 × 7.0 µm; smaller one 7.0 × 6.0 µm.

Order **Chroococcales;** Family **Chroococcaceae**

101. **Chroococcus dispersus** (Keissler) Lemm. **(Pl. 5, Fig. 12)**
(Ling and Tyler 2000, 13, 4: 3; Khondker *et al.* 2006, 175, 3)
Two celled colony, larger cell 7.0 × 7.0 µm, smaller one 7.0 × 6.0 µm.

102. **Gloeocapsa tenax** (Kirchn.)
(Desikachary 1959,103, 26: 7; Aziz and Yasmin 1997, 13, 13)
Two celled colony 14.0 × 6.0 µm, larger cell 8.0 × 6.0 µm, smaller 6.0 × 6.0 µm.

103. Merismopedia glauca (Ehrenb.) Näg. **(Pl. 5, Fig. 8)**
(Starmach 1966, 71, 59; Desikachary 1959, 155, 29: 5; Islam and Zaman 1975, 54, 8: 124)
Colony 8.0 × 7.0 µm.

104. Merismopedia minima Beck **(Pl. 5, Fig. 9)**
(Desikachary 1959, 154, 29: 11; Islam and Nahar 1967, 144, 3: 4)
Colony 9.0 × 3.0 µm.

105. Microcystis aeruginosa f. flos-aquae (Wittr.) Kirch. **(Pl. 5, Fig. 5)**
(Ling and Tyler 2000, 19, 2: 3-5 ; Islam and Nahar 1967, 143, 1: 6)
Colony 300.0 × 217.0 µm.

Class **Cryptophyceae;** Order **Cryptomonadales**
Family **Cryptochrysidaceae**

106. Cryptomonas erosa Ehr. **(Pl. 4, Fig. 17)**
(Huber-Pestalozzi 1968, 51, 5: 28; Khondker *et al.* 2007, 56, 7b)
Cell 27.9 × 15.2 µm.

107. Cryptomonas marssonii Skuja
(Huber-Pestalozzi 1968, 58, 7: 39; Khondker *et al.* 2007, 56, 12a)
Cell 28.0 × 13.0 µm, two unequal flagella, long one15 µm and short one 12 µm.

108. Cryptomonas reflexa Skuja
(Huber-Pestalozzi 1968, 59, 7: 40; Khondker *et al.* 2007, 58, 13b)
Cell 38.1 × 15.2 µm.

109. Rhodomonas minuta Skuja **(Pl. 4, Fig. 8)**
(Huber-Pestalozzi 1968, 23, 2: 9; Khondker *et al.* 2007, 54, 16b)
Cell 15.2 × 7.6 µm.

110. Rhodomonas minuta var. **nannoplanktica** Skuja
(Huber-Pestalozzi 1968, 23, 2: 10; Khondker *et al.* 2007, 54, 15a)
Cell 10.1 × 7.6 µm.

Recorded unreported species for Bangladesh

Out of 180 recorded species of phytoplankton 70 species were found unreported for Bangladesh. Classwise distribution of these species are Euglenophyceae 27, Chlorophyceae 29, Bacillariophyceae 4, Cyanophyceae 10, and Cryptophyceae 3 (Plates 6-12). In the following section a brief systematic description of the species has been furnished.

A brief systematic description of the phytoplankton species recorded from the river Buriganga but unreported for Bangladesh
(Species are alphabetized under each genus)

Class **Euglenophyceae**; Order **Euglenales**
Family **Euglenaceae**

1. **Euglena acus** var. **angularis** Johnson **(Pl. 6, Fig. 10)**
(Huber-Pestalozzi 1955, 98, 16: 75a-e)
Cell 88.9 × 7.6 µm.
ST-1, 30.04.2004

2. **Euglena acus** var. **detonii** (Van oye) H.-P. **(Pl. 6, Fig. 11)**
(Huber-Pestalozzi 1955, 97, 16: 75B)
Length of the cell 106.6 µm; maximum width 5.0 µm.
ST-2, 30.04.2004

3. **Euglena anabaena** var. **minor** Mainx. **(Pl. 6, Fig. 6)**
(Dillard 2000, 18, 6: 9)
Cell 53.3 × 17.8 µm.
ST-1, 08.04.2005

4. **Euglena convoluta** Kors. **(Pl. 6, Fig. 3)**
(Dillard 2000, 21, 3: 13)
Length of the cell 167.6 µm; maximum width 12.7 µm.
ST-3, 03.06.2005

5. **Euglena gracilis** Klebs. **(Pl. 6, Fig. 8)**
(Huber-Pestalozzi 1955, 71, 9: 48g)
Length of the cell 55.8 µm; width 12.7 µm; flagellum 22.8 µm long.
ST-1, 25.02.2005

6. **Euglena klebsii** (Lemm) Mainx **(Pl. 6, Fig. 1)**
(Huber-Pestalozzi 1955, 78, 12: 54)
Length of the cell 121.9 µm; maximum width 12.7 µm.
ST-1, 16.04.2004.

7. **Euglena longoflagellata** Gröenbled **(Pl. 6, Fig. 5)**
(Schiller 1956, 561, 5: 24a-d)
Length of the cell 43.1 µm; width 15.2 µm; flagellum 27.9 µm long.
ST-1, 16.04.2004.

8. **Euglena megalithus** Skuja **(Pl. 6, Fig. 2)**
(Huber-Pestalozzi 1955, 100, 17: 8a)
Length of the cell 83.8 µm; maximum width 17.7 µm.
ST-1, 16.04.2004

9. **Euglena simulacra** Walton **(Pl. 6, Fig. 9)**
(Huber-Pestalozzi 1955, 71, 9: 47)
Cell length 55.8 µm, width 7.6 µm; paramylon two, 10.1 × 5.0 µm in size.
ST-1, 20.05.2005

10. **Euglena stellata** Mainx **(Pl. 6, Fig. 4)**
(Dillard 1989, 36, 1: 8)
Cell 71.10 × 20.30 µm.
ST-1, 20.05.2005

11. **Euglena tristella** Chu **(Pl. 6, Fig. 12)**
(Pringsheim 1956, 116, 36)
Cell 58.4 µm long and 25.40 µm width.
ST-2, 14.05.2004

12. **Euglana velata** Klebs. **(Pl. 6, Fig. 7)**
(Huber-Pestalozzi 1955, 82, 13: 58a)
Cell length 71.1 µm; maximum width 20.3 µm; paramylon 1, 17.7 × 12.7 µm in size.
ST-1, 08.04.2005

13. **Lepocinclis glabra** Drez. **(Pl. 6, Figs. 19-20)**
(Ling and Tyler 2000, 78, 37: 1-6)
Length of the cell 38.1 µm; maximum width 22.8 µm.
ST-3, 03.06.2005

14. **Lepocinclis gracillima** Kufferath. **(Pl. 6, Figs. 21-22)**
(Huber-Pestalozzi 1955, 156, 31: 172)
Cell 20.0 × 8.0 µm.
ST-1, 03.06.2005

15. **Lepocinclis ovum** fa. **typica** H.-P. **(Pl. 6, Fig. 18)**
(Huber-Pestalozzi 1955, 149, 29: 143 b)
Length of the cell 33.0 µm; maximum width 22.8 µm.
ST-1, 27.02.2004

16. **Phacus angulatus** Pochm. **(Pl. 7, Fig. 4)**
(Huber-Pestalozzi 1955, 207, 44: 266)
Cell 33.0 × 30.50 µm.
ST-3, 27.03.2004

17. **Phacus glaber** (Defl.) Pochm. **(Pl. 7, Fig. 6)**
(Huber-Pestalozzi 1955, 238, 55: 340)
Length of the cell 43.1 µm; maximum width 22.8 µm.
ST-2, 03.06.2005

18. **Phacus longicauda** (E.) Duj. **(Pl. 7, Fig. 3)**
(Huber-Pestalozzi 1955, 220, 49: 299b)
Length of the cell 91.4 µm; maximum width 48.2 µm.
ST-3, 30.04.2004

19. **Phacus prunoideus** Roll **(Pl. 7, Fig. 1)**
(Huber-Pestalozzi 1955, 208, 44: 268)
Cell length 35.0 µm; maximum width 25.0 µm; central paramylon 8 × 8 µm.
ST-1, 30.04.2004

20. **Phacus pseudoplataica** Pochm. **(Pl. 7, Figs. 11-12)**
(Huber-Pestalozzi 1955, 199, 40: 247)
Cell 22.9 × 10.10 µm.
ST-1, 16.04.2004

21. **Phacus suecicus** Lemm. **(Pl. 7, Fig. 2)**
(Huber-Pestalozzi 1955, 559, 114: 1135)
Length of the cell 30.4 µm; maximum width 22.8 µm.

ST-3, 27.02.2004

22. **Phacus tortus** (Lemm.) var. **1** var.nov. **(Pl. 7, Figs. 5, 10)**
(Huber-Pestalozzi 1955, 94, 51: 309 d)
Cell 66.0 × 30.50 µm.
ST-2, 30.04.2004

23. **Phacus tortus** (Lemm.) var. **2** var.nov. **(Pl. 7, Figs. 7-8)**
(Huber-Pestalozzi 1955, 225, 51: 309 c)
Cell 43.2 × 25.40 µm.
ST-2, 30.04.2004

24. **Phacus trimarginatus** Allerge *et* Jahn **(Pl. 7, Fig. 9)**
(Huber-Pestalozzi 1955, 218, 48: 295 b)
Length of the cell 43.1 µm; maximum width 20.3 µm; flagellum 12.7 µm.
ST-1, 16.04.2004

25. **Strombomonas costata** Defl. **(Pl. 6, Figs. 14-16)**
(Huber-Pestalozzi 1955, 386, 80: 840a)
Cell 58.4 × 27.9 µm.
ST-1, 26.11.2004

26. **Strombomonas ovalis** (Playf.) Defl. **(Pl. 6, Fig. 13)**
(Huber-Pestalozzi 1955, 378, 78: 811)
Cell 48.0 × 26.0 µm.
ST-2, 30.04.2004

27. **Strombomonas undulata** Conr. **(Pl. 6, Fig. 17)**
(Huber-Pestalozzi 1955, 387, 80: 844a)
Cell 20.3 × 20.30 µm.
ST-1, 26.11.2004

Class **Chlorophyceae;** Order **Chlorococcales**
Family **Scenedesmaceae**

28. **Scenedesmus acuminatus** var. **acuminatus** nach Philipose **(Pl. 8, Flg. 9)**
(Huber-Pestalozzi 1983, 867, 234: 5)
Colony 27.0 × 23.0 µm, individual cell 23.0 × 5.0 µm.
ST-1, 08.04.2005

29. **Scenedesmus acuminatus** var. **elongatus** G. M. Smith **(Pl. 8, Fig. 7)**
(Huber-Pestalozzi 1983, 844, 229: 1)
Colony 35.5 × 33.0 µm.
ST-2, 03.06.2005

30. **Scenedsmus bicaudatus** (Hortob.) Hindak **(Pl. 8, Fig. 12)**
(Huber-Pestalozzi 1983, 882, 238: 5)
Colony 25.4 × 12.7 µm.
ST-3, 03.06.2005.

31. **Scenedesmus lunatus** (W and G.S. West) Chod. **(Pl. 8, Fig. 10)**
(Huber-Pestalozzi 1983, 867, 234: 5)
Colony 20.3 × 10.1 µm, single cell 5.0, each cell have two short spine at each end.
ST-2, 08.04.2005

32. **Scenedesmus obtusus** Meyen **(Pl. 8, Figs. 2, 11)**
(Huber-Pestalozzi 1983, 828, 225: 8)
Colony measures 22.8 × 12.7 µm; cell arranged in two rows.
ST-1, 17.06.2005

33. **Scenedesmus opoliensis** var. **polycostatus** Hortob. and Nemeth**(Pl. 8, Fig. 8)**
(Huber-Pestalozzi 1983, 908, 245: 5)
Colony measures 27 × 23 µm; individual cell 23 × 5 µm.
ST-2, 03.06.2005

34. **Scenedsmus opoliensis** var. **mononensis** (nach Hortobagy) Komarek
(Huber-Pestalozzi 1983, 908, 244: 7) **(Pl. 8, Fig. 3)**
Colony 15.2 µm, individual cell 10.1 × 2.5 µm.
ST-1, 25.02.2005

35. **Scenedesmus ovalternus** Chod. **(Pl. 8, Figs. 4, 6)**
(Huber-Pestalozzi 1956, 826, 225: 4a)
8 cell colony (1 cell missing), colony measures 20 × 15 µm; individual cell 9 × 3 µm.
ST-3, 03.06.2005

36. **Scenedesmus verrucosus** Roll **(Pl. 8, Figs. 1, 5)**
(Huber-Pestalozzi 1983, 864, 233: 4b)
Colony measures 16 × 11 µm; individual cell 11 × 4 µm.
Dhaka, ST-1, 17.06.2005

Family **Oocystaceae**

37. **Kirchneriella contorta** (Schmid.) Bohl. **(Pl. 9, Fig. 3)**
(Huber-Pestalozzi 1983, 662, 185: 2)
Colony measures 15.2 × 15.2 µm; individual cell 5.0 × 2.5 µm.
ST-1, 26.11.2004

38. **Monoraphidium griffithii** (Berk.) Kom.-Legn. **(Pl. 9, Fig. 5)**
(Huber-Pestalozzi 1983, 634, 177: 1a)
Cell length 63.5 µm and width 5.0 µm.
ST-1, 25.02.2005

39. **Oocystis irregularis** (Petkoff) Printz **(Pl. 9, Fig. 1)**
(Huber-Pestalozzi 1983, 516, 151: 4)
Colony measures 25.4 × 20.3 µm; individual cell 10.1 × 7.6 µm.
ST-3, 30.04.2004

40. **Oocystis natans** var. **major** G.M. Smith **(Pl. 9, Fig. 2)**
(Huber-Pestalozzi 1983, 507, 148: 5)
Colony 23.0 × 27.9 µm; individual cell inside the colony 23.0 × 27.9 µm.
ST-1, 08.04.2005

41. **Radiococcus planctonicus** Lund **(Pl. 9, Fig. 10)**
(Huber-Pestalozzi 1983, 399, 120: 1)
Colony measures 33.0 × 25.40 µm, individual cell 5.0 × 5.0 µm.
ST-3, 30.04.2004

42. **Tetraedron triangulare** Kors. **(Pl. 9, Fig. 4)**
(Huber-Pestalozzi 1983, 696, 195: 5c)
Maximum width with spine 17.7 µm; without spine 11.4 µm.
ST-1, 20.05.2005

43. **Hyaliella polytomoides** **(Pl. 10, Fig. 3)**
(Huber-Pestalozzi 1983, 767, 213: 4)
Cell measures 25.0 × 16.0 µm (maximum dia), flagella two, 29 µm long.
ST-2, 03.06.2005

44. **Trochiscia sp.** Kütz **(Pl. 9, Fig. 11)**
(Huber-Pestalozzi 1983, 767, 213: 4)
Cell dia 33.0 × 33.0 µm; chaetae 10.1 µm.
ST-2, 30.04.2004

Family **Hydrodictyaceae**

45. **Pediastrum duplex** var. **subgranulatum** Raciborski **(Pl. 9, Figs. 8-9)**
(Ling and Tyler 2000, 91, 42: 21)
8 celled colony dia 30.8 µm, individual cell 7.60 µm.
ST-1, 25.02.2005

Order **Volvocales;** Family **Polyblepharidaceae**

46. **Pyramidimonas quadricauda** Pasch. **(Pl. 10, Fig. 2)**
(Huber-Pestalozzi 1961, 22, 3: 17)
Cell measures 25.0 × 16.0 µm (maximum dia), flagella 29 µm long.
ST-1, 20.05.2005

Family **Chlamydomonadaceae**

47. **Chlamydomonas impressa** Pasch. **(Pl. 10, Fig. 1)**
(Huber-Pestalozzi 1961, 160, 28: 140 a)
Cell biflagellate, anterior end flat, maximum dia 21µm, length 20 µm, flagella 20 µm.
ST-1, 20.05.2005

48. **Lagerheimia balatonica** (Scherff in Kol) Hiwd **(Pl. 10, Figs. 12-13)**
(Huber-Pestalozzi 1961, 472, 140: 3)
Egg shaped cell, cell measures 10 µm long, 4 µm width, chaete 10µm.
ST-2, 25.12.2004

Order **Chlorococcales;** Family **Coelastraceae**

49. **Coelastrum astroideum** De-Not **(Pl. 9, Fig. 7)**
(Huber-Pestalozzi 1983, 725, 202: 4)
Cell measures 30.0 × 30.0 µm, individual cell measures 11.0 × 8.0 µm.
ST-1, 03.06.2005

50. **Coelastrum microporum** var. **octaedricum** (Skuja) Sodomk **(Pl. 9, Fig. 6)**
(Huber-Pestalozzi 1983, 725, 202: 1)
Colony measures 14.0 × 12.0 µm.
ST-3, 03.06.2005

Order **Zygnematales;** Family **Desmidiaceae**

51. **Closterium acutum** var. **variable** (Lemmermann) Krieger. **(Pl. 11, Fig. 2)**
(Ling and Tyler 2000, 134, 65: 7)
Cell 76.2 × 5.0 µm.
ST-3, 30.04.2004

52. **Closterium gracile** Breb. **(Pl. 11, Figs. 4-6)**
(Ling and Tyler 2000, 138, 65: 4-5)
Cell 114.3 × 5.0 µm.
ST-1, 30.04.2004

53. **Closterium idiosporum** West and West **(Pl. 11, Fig. 3)**
(Ling and Tyler 2000, 139, 65: 8)
Cell 261.6 × 10.1 µm.
ST-1, 08.04.2005

54. **Closterium pseudospirotaenium** var. **variable** (Lemm.) **(Pl. 11, Fig. 1)**
(Ling and Tyler 2000, 134, 65: 7)
Cell length 68.5 µm width 5 µm, 10 pyrenoids in both semicell.
ST-1, 06.05.2005

Class **Bacillariophyceae;** Order **Pennales**
Family **Nitzschiaceae**

55. **Nitzschia dissipata** (Kütz.) Grun. 429908 **(Pl. 10, Figs. 6-7)**
(Germain 1981, 344, 130: 1)
Cell measures 20.3 µm long, 7.6 µm broad.
ST-1, 25.03.2005

56. **Nitzchia elgei** Lange-Bertalot **(Pl. 10, Fig. 5)**
Internet.(www. Algaebase.org)
Cell measures 104.1 µm long, 10.1 µm broad.
ST-3, 27.03.2004

Order **Pennales;** Family **Eunotiaceae**

57. **Synedra acus** var. **angustissima** Grunow. **(Pl. 10, Fig. 4)**
(Germain 1981, 78, 27: 10)
Cell measures 58.4 µm long, 5.0 µm broad.
ST-2, 13.08.2004

Family **Naviculaceae**

58. **Navicula festiva** Krasske. **(Pl. 10, Fig. 13)**
(Germain 1981, 233, 85: 46)
Cell 20.0 µm long, maximum 10.0 µm broad.
ST-1, 12.03.2004

Class **Cyanophyceae;** Order **Oscillatoriales**
Family **Oscillatoriaceae**

59. **Arthrospira khannae** Drouet *et* Strickland **(Pl. 12, Fig. 1)**
(Desikachary 1959, 188, 35: 12)
Trichome length 165.4 µm, width 5.0 µm, length of another one 113.7 µm, width 5.0 µm.
ST-1, 20.05.2005

60. **Arthrospira spirulinodes** Ghose **(Pl. 12, Fig. 10)**
(Desikachary 1959, 189, 35: 1)
Trichome length 33.0 µm, width 10.10 µm, distance between coil 3.8 µm.
ST-3, 14.05.2004

Order **Nostocales;** Family **Nostocaceae**

61. **Anabaena macrospora** Klebahn var. **gracilis** Lemmermann **(Pl. 12, Fig. 6)**
(Ling and Tayler 2000, 24, 8: 2)
Filament 261.6 × 10.1 µm, individual cell 10.0 × 7.6 µm, heterocyst 10.1 × 10.1 µm.
ST-2, 14.05.2004

62. **Pelonema tenue** Lauterborn **(Pl. 12, Fig. 5)**
(Starmach 1966, 442, 654)
Organism 112 µm long , maximum width 7.0 µm.
ST-3, 17.06.2005

63. **Pseudanabaena crassa** Vozzhennikova **(Pl. 12, Fig. 3)**
(Starmach 1966, 448, 665)
Organism 134.6 µm long, maximum width 7.6 µm, intercalary and terminal cell 5.0 µm.
ST-2, 25.12.2004

64. **Pseudanabaena constricta** (Szafer) **(Pl. 12, Fig. 4)**
(Starmach 1966, 448, 662)
Organism 88.9 µm long, maximum width 5.0 µm, median cell 5.0 µm long, tip cell 2.5 µm long.
ST-2, 25.12.2004

65. **Raphidiopsis mediterranea** Skuja. **(Pl. 12, Fig. 2)**
(Starmach 1966, 456, 679)
Organism 81.2 µm long, width 2.5 µm, measurement at intercalary position 5.0 × 2.5 µm, tip cell 5.0 µm having pointed end.
ST-3, 14.05.2004

Order **Chroococcales;** Family **Chroococcaceae**

66. **Chroococcidiopsis indica** Geitler **(Pl. 12, Figs. 7-8)**
(Desikachary 1959, 167, 31: 29)
Two celled colony 7.6 × 7.6 µm, individual cell 5.0 × 2.5 µm.
ST-3, 22.04.2005

67. **Synechococcus cedrorum** (Wedlug Sauvageau) Ercegovic **(Pl. 12, Fig. 9)**
(Desikachary 1959, 145, 25: 11; Starmach 1966, 56, 23)
Colony 10.0 × 7.0 µm, individual cell larger one 8.0 × 6.0 µm and smaller one 6.0 × 6.0 µm.
ST-3, 03.06.2005

Class **Cryptophyceae:** Order **Cryptomonadales**
Family **Cryptochrysidaceae**

68. **Chroomonas breviciliata** Nygaard **(Pl. 10, Figs. 8-9)**
(Huber-Pestalozzi 1968, 35, 22 A)
Cell 17.7 µm long and 7.60 µm wide.
ST-1, 26.11.2004

69. **Chroomonas nordstedtii** Hansgirg **(Pl. 10, Figs. 10-11)**
(Huber-Pestalozzi 1968, 28, 3: 13)
Cell 12.7 µm long and 7.60 µm wide.
ST-2, 16.04.2004

70. **Cryptomonas erosa** var. **reflexa** Ehr. **(Pl. 10, Fig. 12)**
(Huber-Pestalozzi 1968, 53, 5: 29)
Cell 17.7 × 10.1 µm.
ST-1, 26.11.2004

Quantitative

Genus number

Table 1 shows the number of phytoplankton genera recorded under each class and station. The number of algal genera recorded are almost closer to each other in all the stations (Table 1). At ST-1 the number of genera recorded was little higher (65) compared to ST-2 (60) and ST-3 (61).

Species number

At species level a total of 108, 82 and 91 species were recovered from ST-1, ST-2 and ST-3 respectively (Table 2). Maximum number of species 40% (ST-1), 41% (ST-2) and 36% (ST-3) among the flora studied was represented by the green algae (Chlorophyceae) (Fig. 45). Next was Euglenophyceae 22% at ST-1, Cyanophyceae 16% and 23% for ST-2 and ST-3, respectively followed by Bacillariophyceae 15%,16% and 18% for ST-1, ST-2 and ST-3, respectively. Cryptophyceae represents 5% for ST-1 and ST-2 as well as 3% for ST-3. Chrysophyceae was represented by a single species at ST-2 where as one species of Dinophyceae was represented at ST-1, ST-2 and ST-3 (Table 2).

Table 1. Number of genera recorded from different classes of algae as phytoplankton from the three stations of the river Buriganga.

Class	No. of genera		
	ST-1	ST-2	ST-3
Chlorophyceae	29	26	26
Chrysophyceae	0	1	0
Cryptophyceae	3	3	2
Bacillariophyceae	12	12	13
Euglenophyceae	6	6	6
Cyanophyceae	14	11	13
Dinophyceae	1	1	1
Total	65	60	61

Table 2. Number of species recorded from different classes of algae as phytoplankton from the three stations of the river Buriganga.

Class	No. of species		
	ST-1	ST-2	ST-3
Chlorophyceae	44	34	33
Chrysophyceae	0	1	0
Cryptophyceae	5	4	3
Bacillariophyceae	16	13	16
Euglenophyceae	24	13	17
Cyanophyceae	18	16	21
Dinophyceae	1	1	1
Total	108	82	91

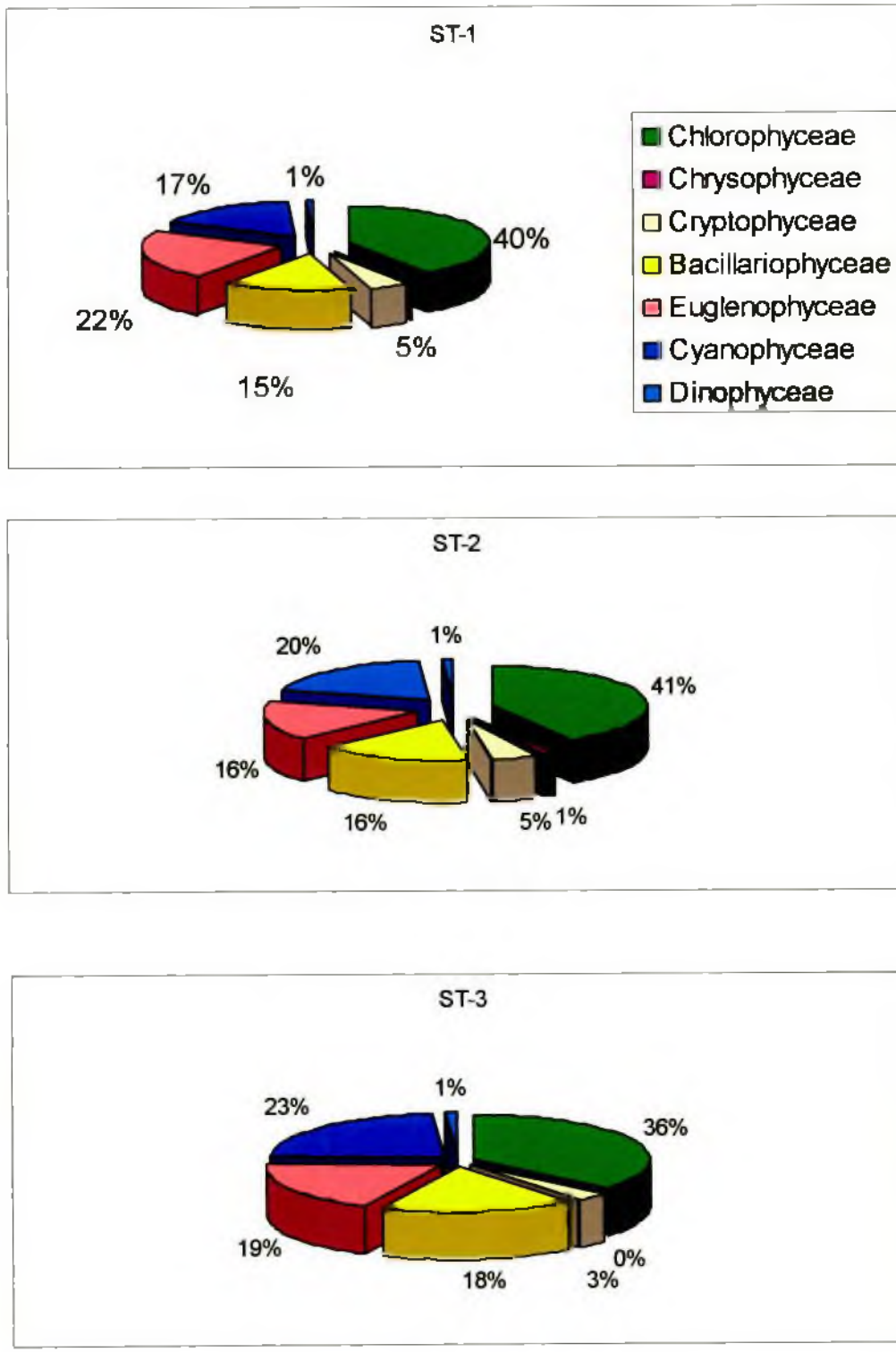


Fig. 45. Percentage composition of phytoplankton species under different algal classes (ST-1 to ST-3).

Density

The fluctuations in the quantities of mean total phytoplankton density at three different stations are shown in Figs. 46-48 . It is evident that the number of phytoplankton was higher in summer and monsoon than autumn (Fig. 49). At ST-1 during the first year the highest phytoplankton concentration was recorded in April (87 $\times 10^3$ ind/L). The lowest was in September (0.9 $\times 10^3$ ind/L). In the second year the highest cell concentration was found in May (236 $\times 10^3$ ind/L) and a lowest in July (1.4 $\times 10^3$ ind/L). At ST-2 and ST-3 the range between lowest and highest density was (1.0-197.0 $\times 10^3$ ind/L) and (0.55-250.0 $\times 10^3$ ind/L), respectively. During peak time considering high density, members from Cyanophyceae found dominant in most of the occasions followed by Bacillariophyceae and Chlorophyceeae at ST-1 (Fig. 50). At ST-2 Cyanophyceae was found dominant followed by Chlorophyeceae and Bacillariophyceae for the first year and in the second year it was Chlorophyceae which occupied top position followed by Cyanophyceae and Bacillariophyceae. At ST-3 Chlorophyeceae become dominant followed by Bacillariophyceae and Cyanophyceae for both first and second year of the study period. Cyanophyceae occupied highest single peak once (mid June) during second year summer period (Fig. 50).

Diversity index

The species diversity (Figs. 51-54), expressed as Shanon-Weaver index, exhibited a clear seasonality in the river Buriganga (Figs. 55-57). The index varied from 2.0-4.6 byt/ind, 1.8-4.2 byt/ind, and 1.4-4.7 byt/ind, in ST-1, ST-2 and ST-3, respectively. Lowest index obtained in the monsoon season of both the years for all the three stations throughout the period of investigation (Fig. 58). The maximum index was obtained during winter season for both ST-1 (November for first year, December for the second year), and ST-2 (December for both the year). At ST-3 it was winter season (December) for the first year and Summer (April) for the second year (Fig. 57).

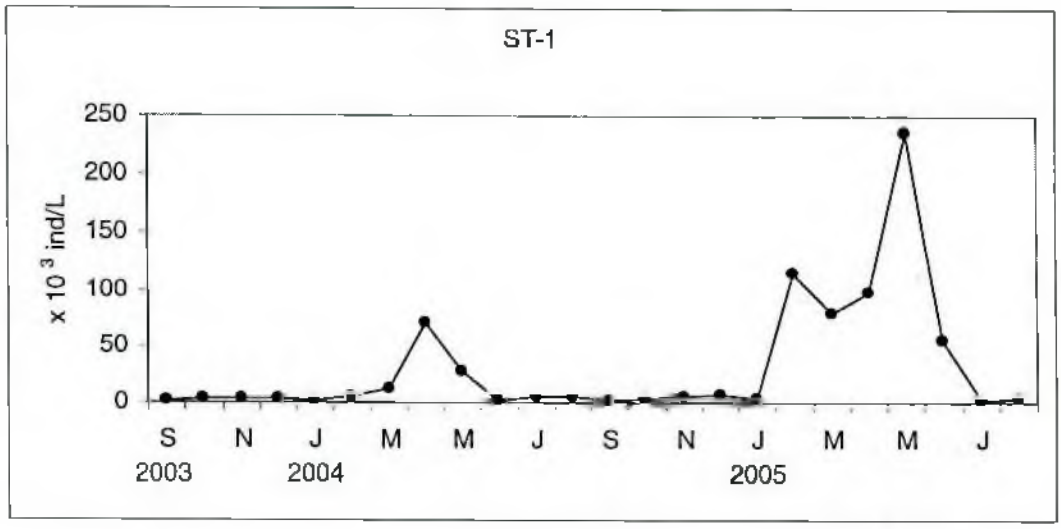


Fig. 46. Frequency occurrence of mean total phytoplankton at ST-1.

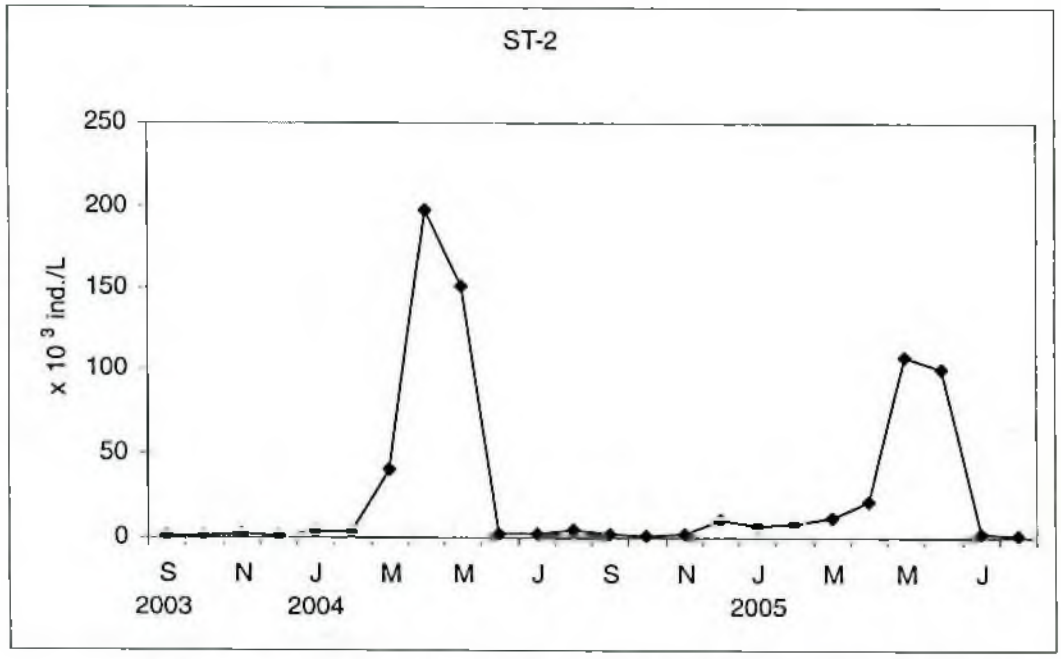


Fig. 47. Frequency occurrence of mean total phytoplankton at ST-2.

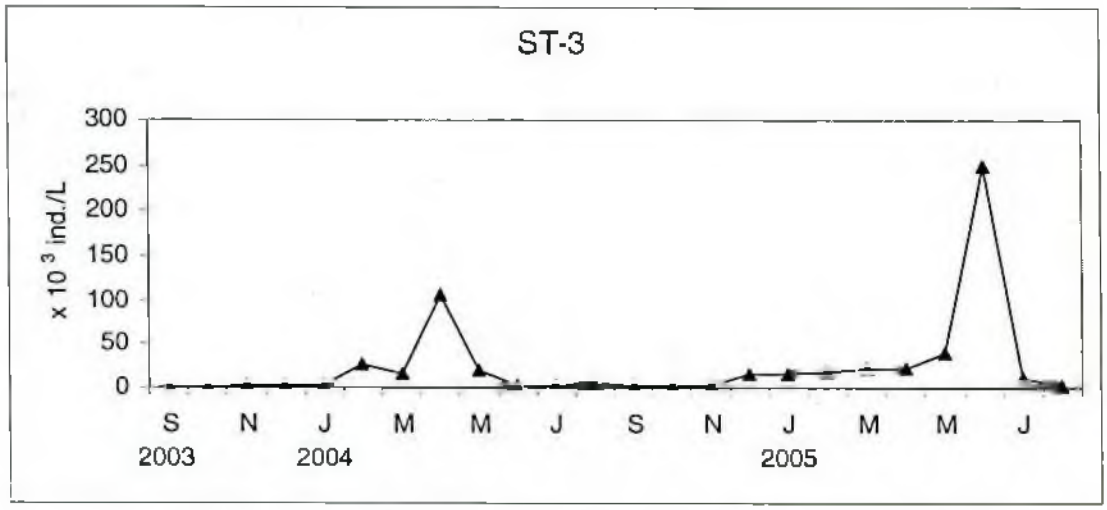


Fig. 48. Frequency occurence of mean total phytoplankton at ST-3.

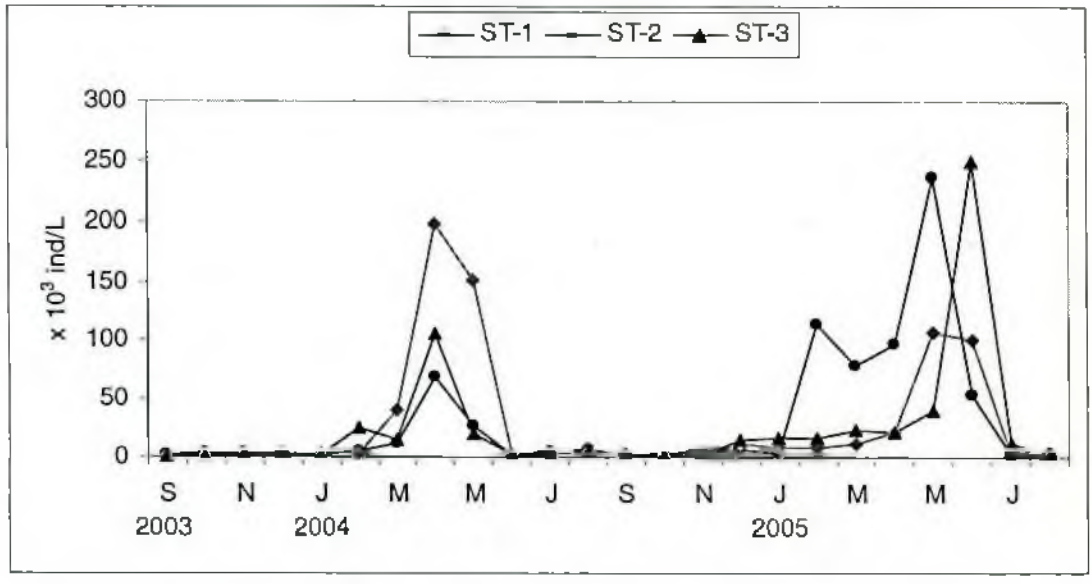


Fig. 49. Comparative mean total phytoplankton among ST-1, ST-2 and ST-3.

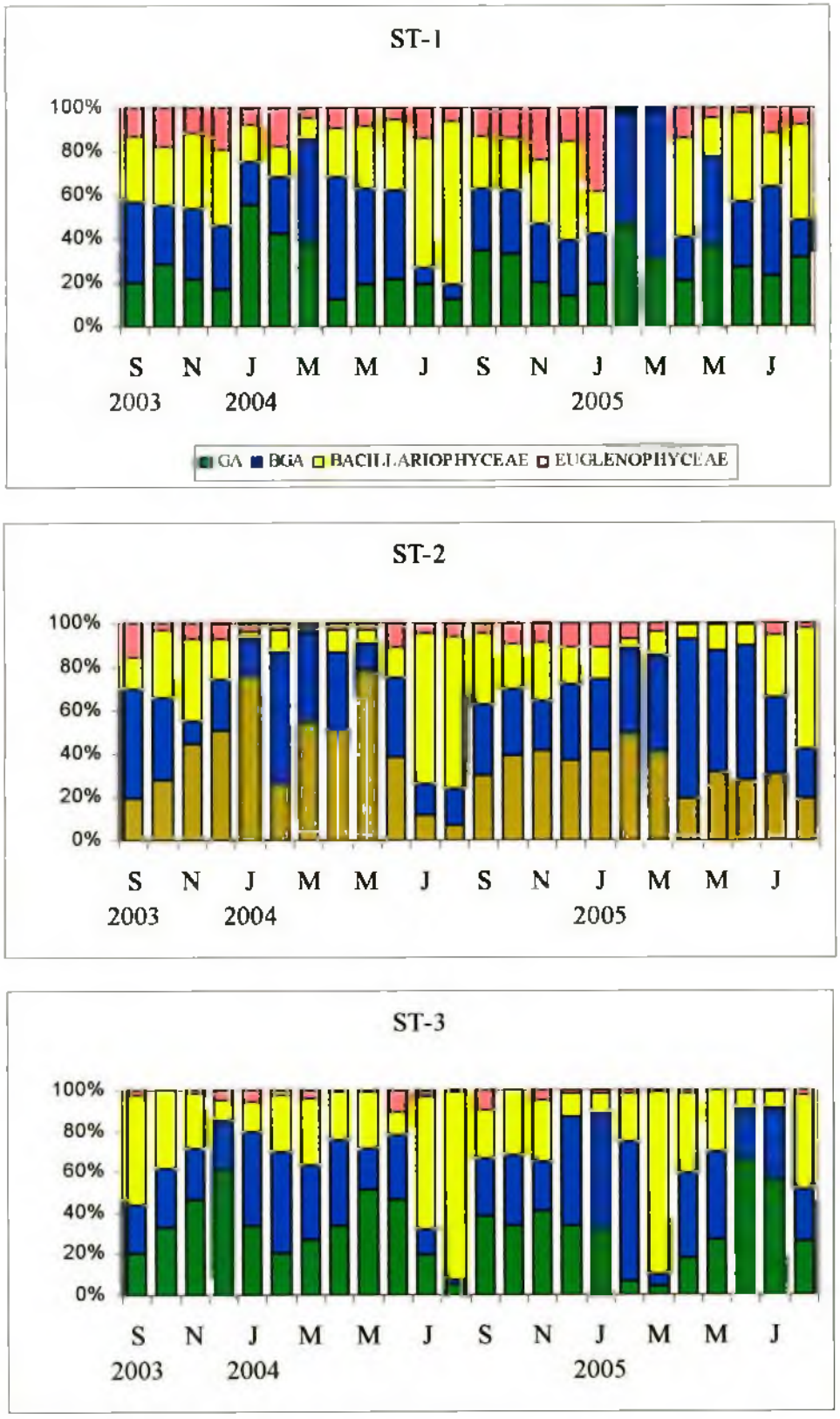


Fig. 50. Monthly distribution of phytoplankton species under four different algal classes (ST-1 to ST-3).

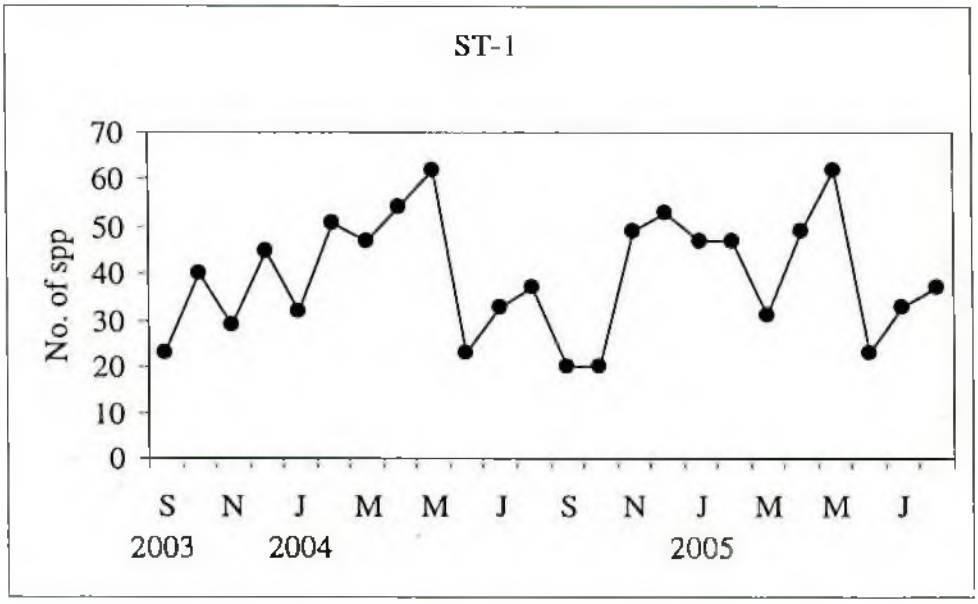


Fig. 51. Species number recovered from ST-1.

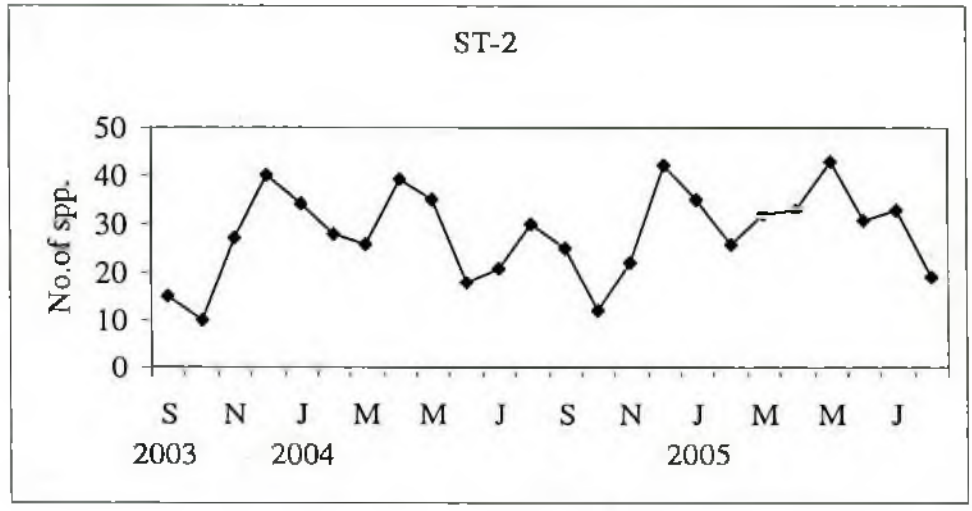


Fig. 52. Species number recovered from ST-2.

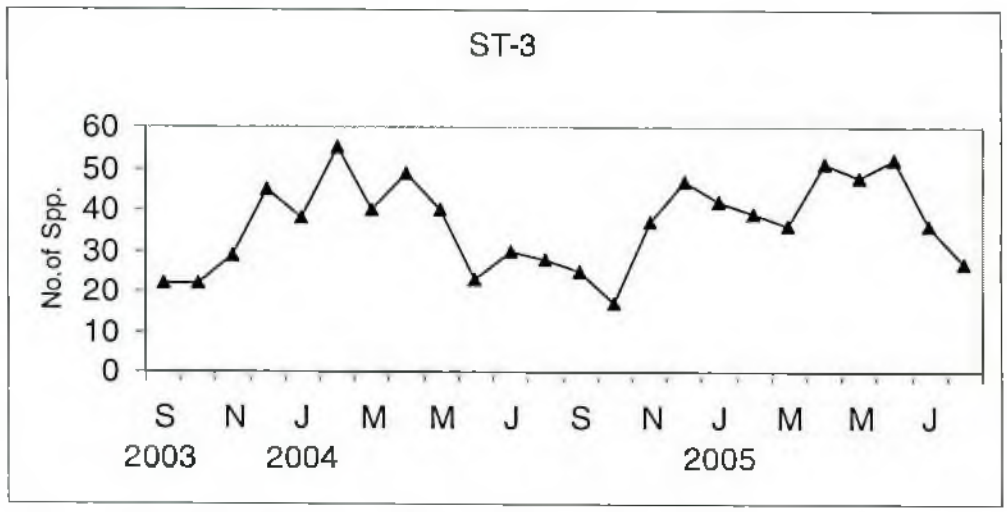


Fig. 53. Species number recovered from ST-3.

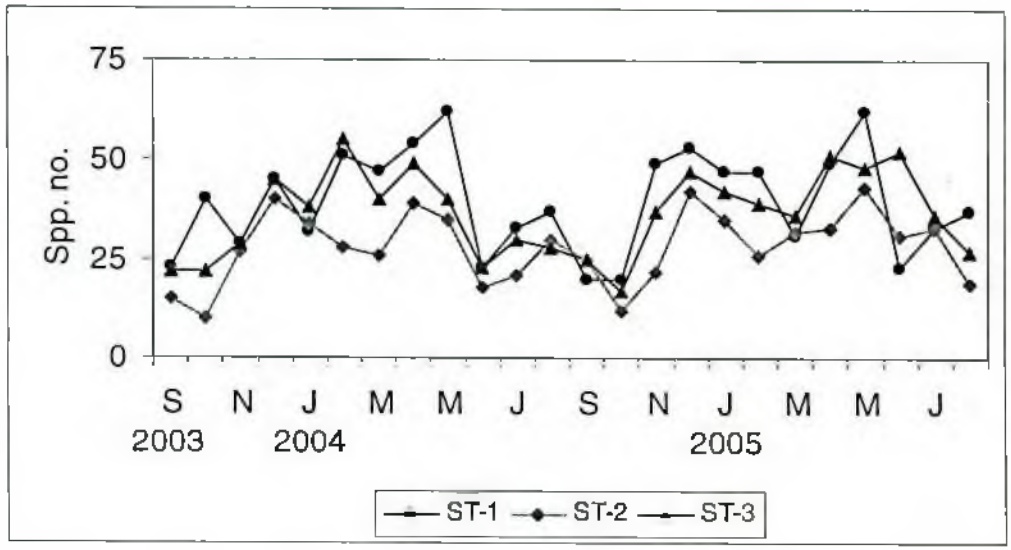


Fig. 54. Comparative species number recovered from different stations (ST-1 to ST-3).

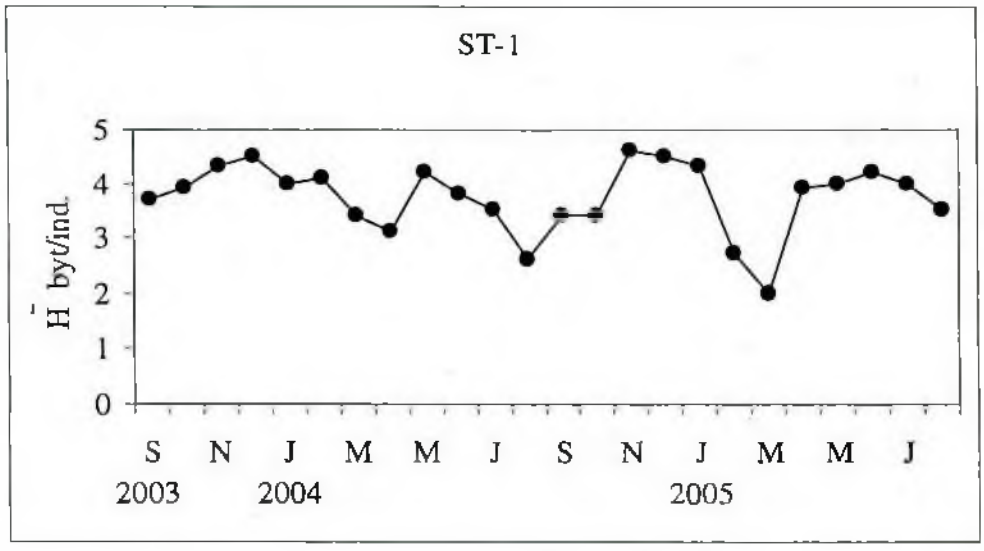


Fig. 55. Shanon-Weaver diversity index (H') for ST-1.

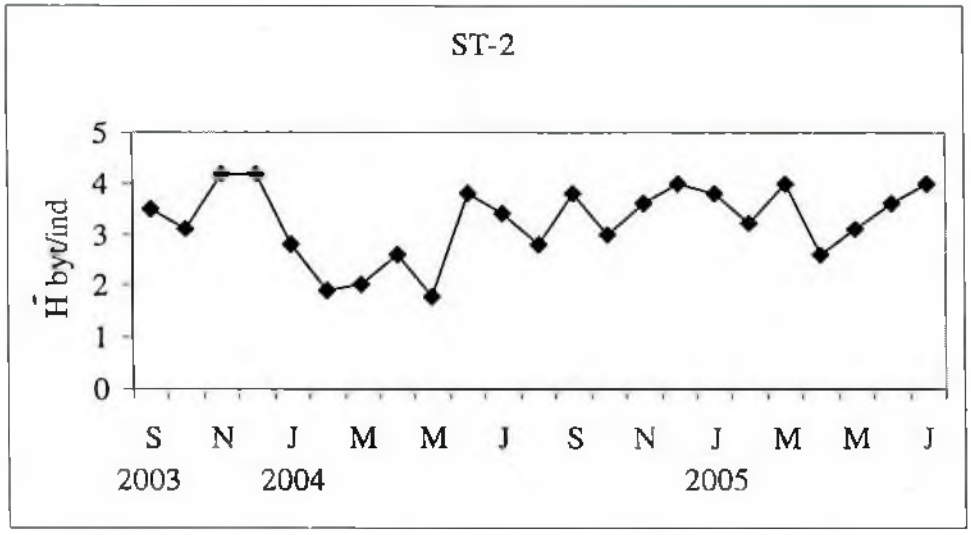


Fig. 56. Shanon-Weaver diversity index (H') ST-2.

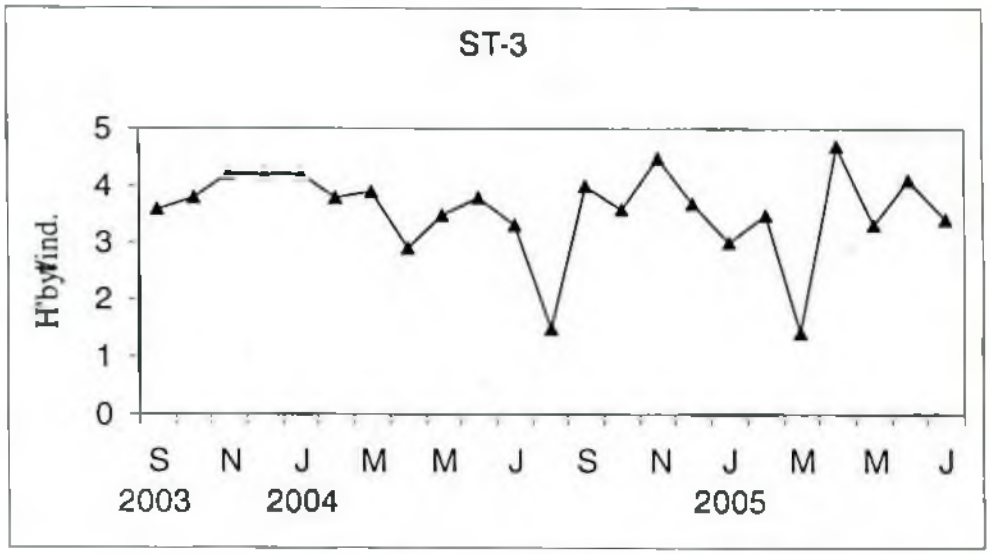


Fig. 57. Shanon-Weaver diversity index (H') at ST-3.

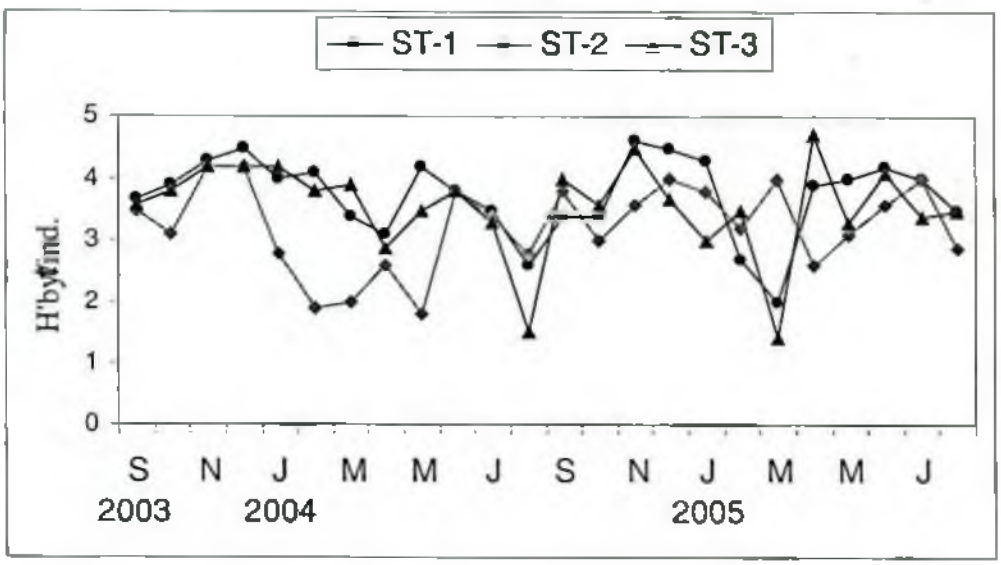


Fig. 58. Comparative diversity index (H') among ST-1, ST-2 and ST-3.

Periodicity and seasonality

The major genera recovered were *Arthrospira, Merismopedia, Pelonema* and *Oscillatoria* as BGA, *Closterium, Monoraphidium* and *Scencedesmus* as green algae, *Cyclotella, Melosira, Nitzschia,* and *Navicula* as diatom *Phacus, Euglena* and *Trachelomonas* as Euglenoid, for ST-1 (Figs. 59-60). At ST-2 *Arthrospira, Merismopedia* and *Oscillatoria* as BGA, *Cosmarium, Monoraphidium, Crucigenia* and *Scencedesmus* as green algae, *Cyclotella, Melosira, Nitzschia* and *Synedra* as diatom, *Phacus, Euglena* and *Trachelomonas* as Euglenoid formed the main bulk of the composition among different groups (Figs. 61-62). At ST-3 major genera represented from different groups were *Arthrospira, Merismopedia, Pelonema* and *Oscillatoria* from BGA, *Cosmarium, Monoraphidium, Crucigenia,* and *Scencedesmus* from green algae, *Cyclotella, Melosira* and *Nitzschia* from diatom, and *Phacus, Euglena, Lepocinclis* and *Trachelomonas* as Euglenoid algae (Figs. 63-64). All the major groups did not show any remarkable fluctuations. BGA were abundant in summer (April-June) but rare in early monsoon for all the three stations. Green algae were abundant in late winter (January-February) and summer (April-June), the quantity fell sharply from monsoon and continued until winter. Bacillariophyceae were found abundant in summer and monsoon. *Cyclotella* and *Melosira* remain peaked during April-May and April-August, respectively at ST-1 and ST-2. At ST-3 Bacillariophyceae were found abundant in late winter (February) and summer (April-June). *Cyclotella,* fell sharply unlike *Melosira* after attaining a peak. Euglenophyceae showed its peak value during winter (December-February) and summer. *Trachelomonas* fell sharply after its peak value unlike *Euglena* (Figs. 59-64).

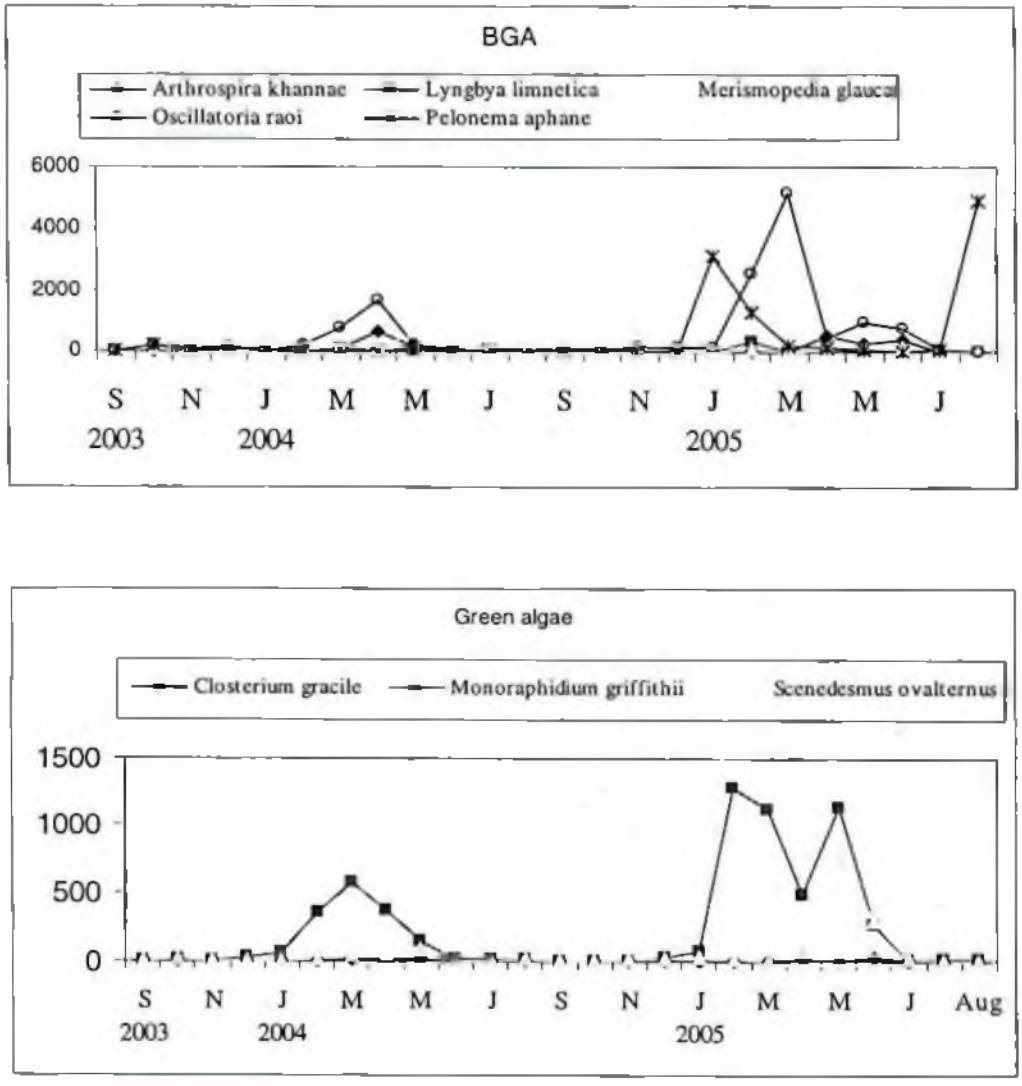


Fig. 59. Relative mean abundance of dominant phytoplankton at ST-1.

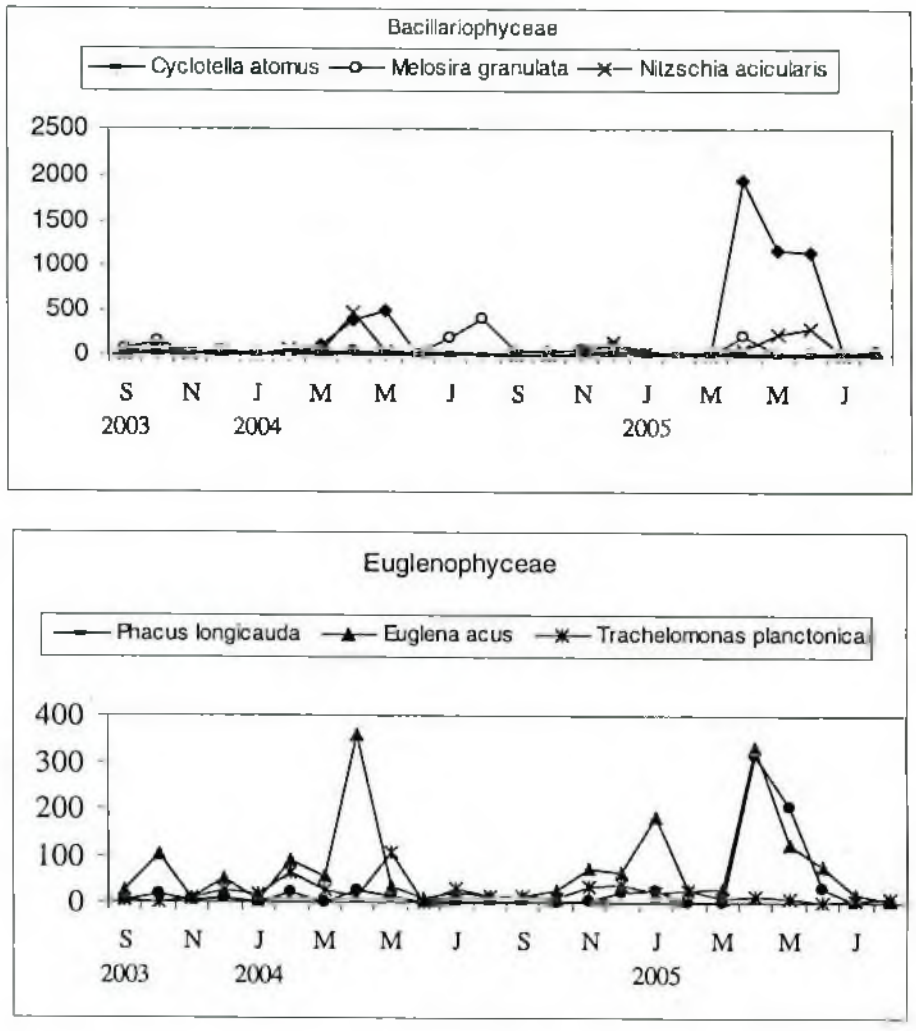


Fig. 60. Relative mean abundance of dominant phytoplankton at ST-1.

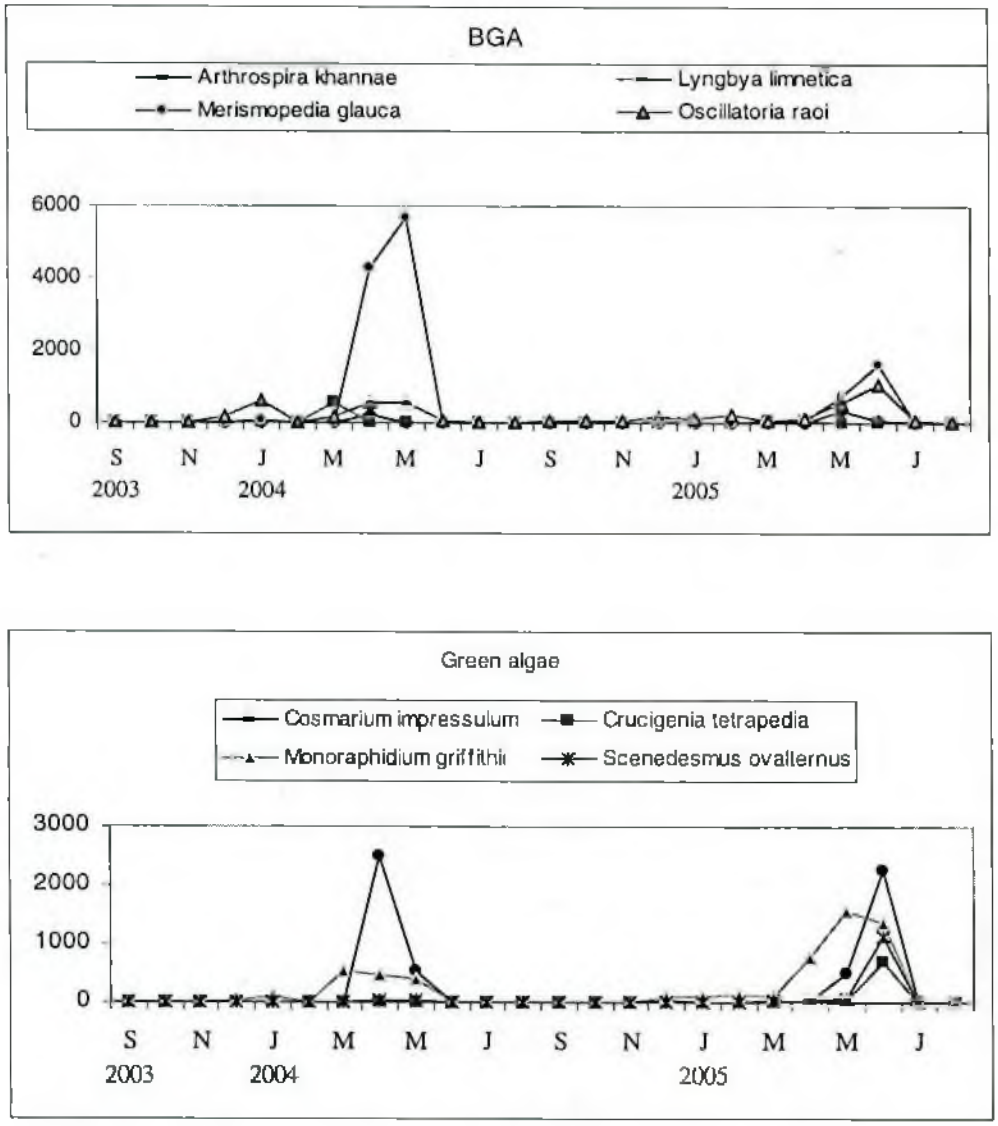


Fig. 61. Relative mean abundance of dominant phytoplankton at ST-2.

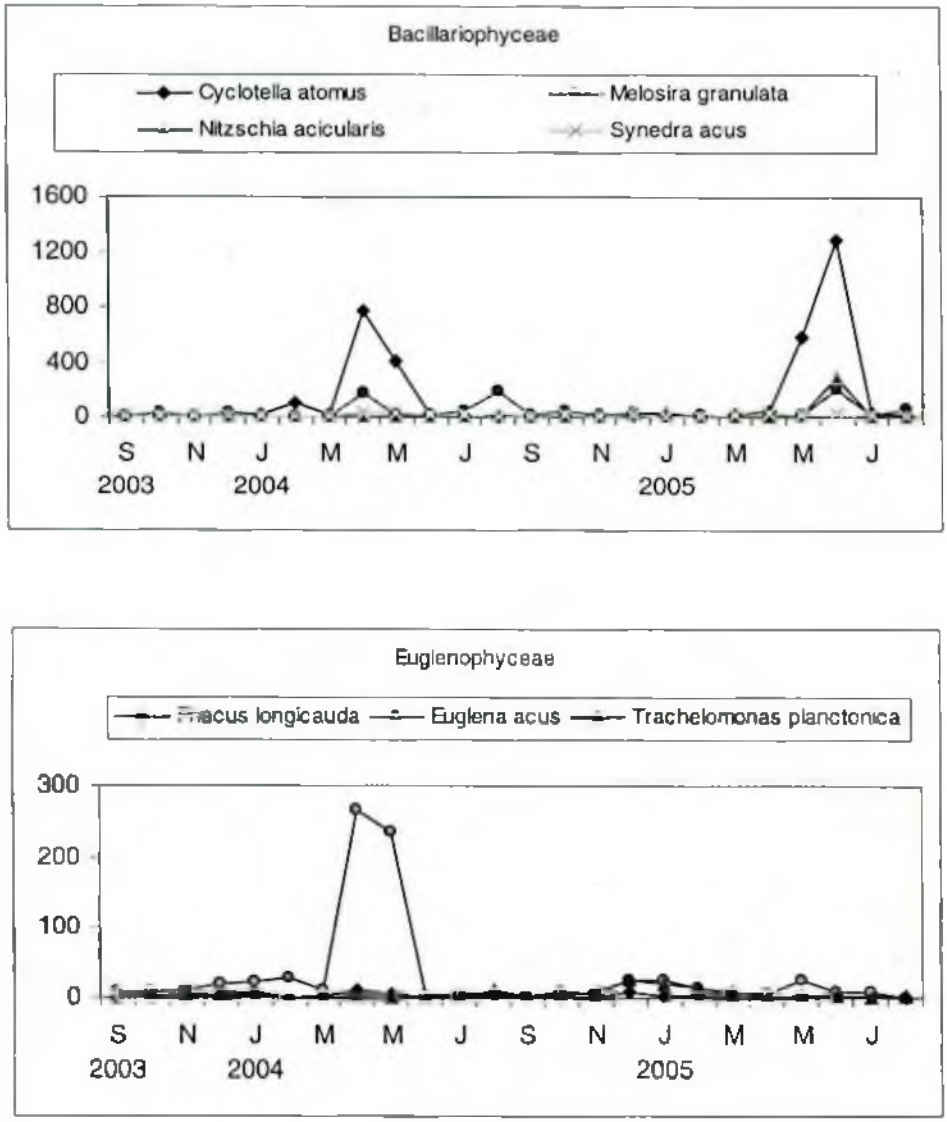


Fig. 62. Relative mean abundance of dominant phytoplankton at ST-2.

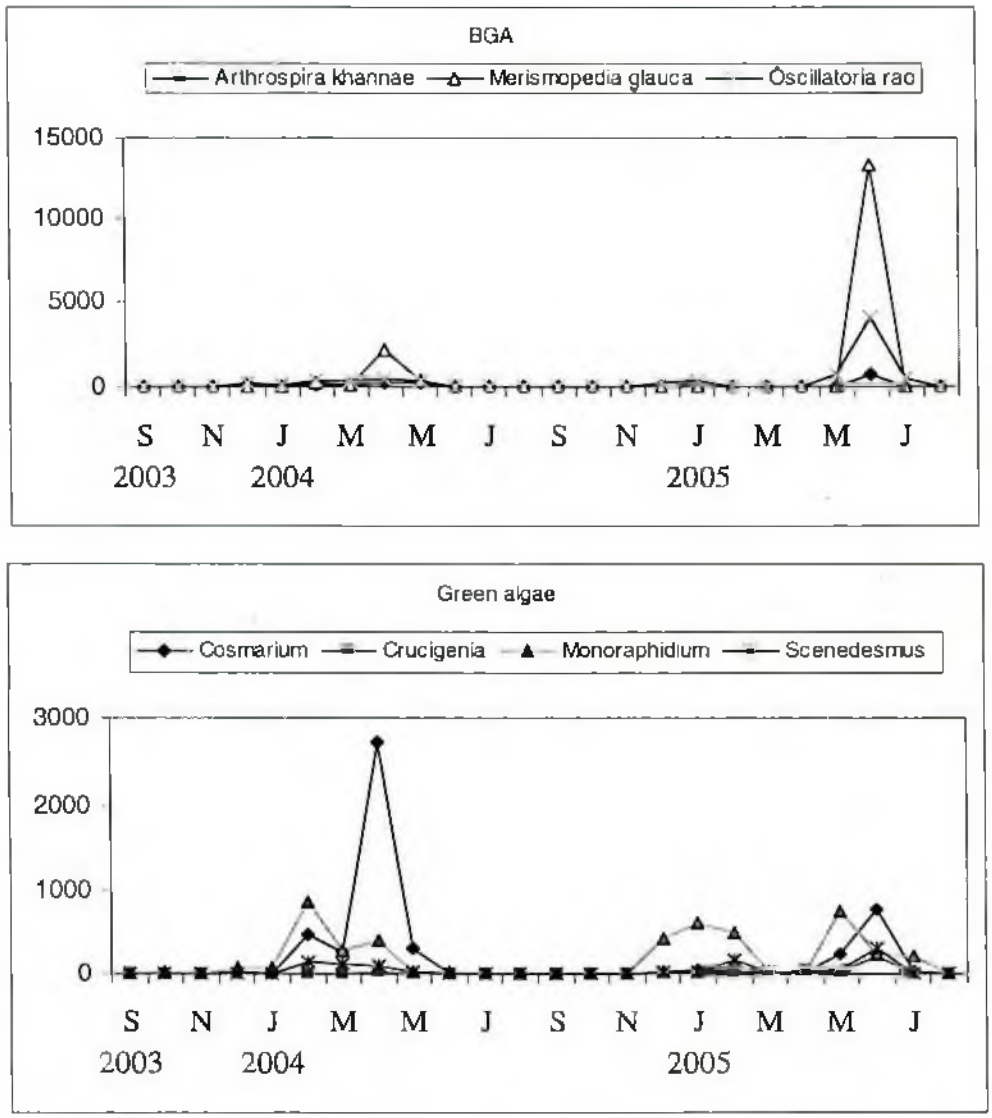


Fig. 63. Relative mean abundance of dominant phytoplankton at ST-3.

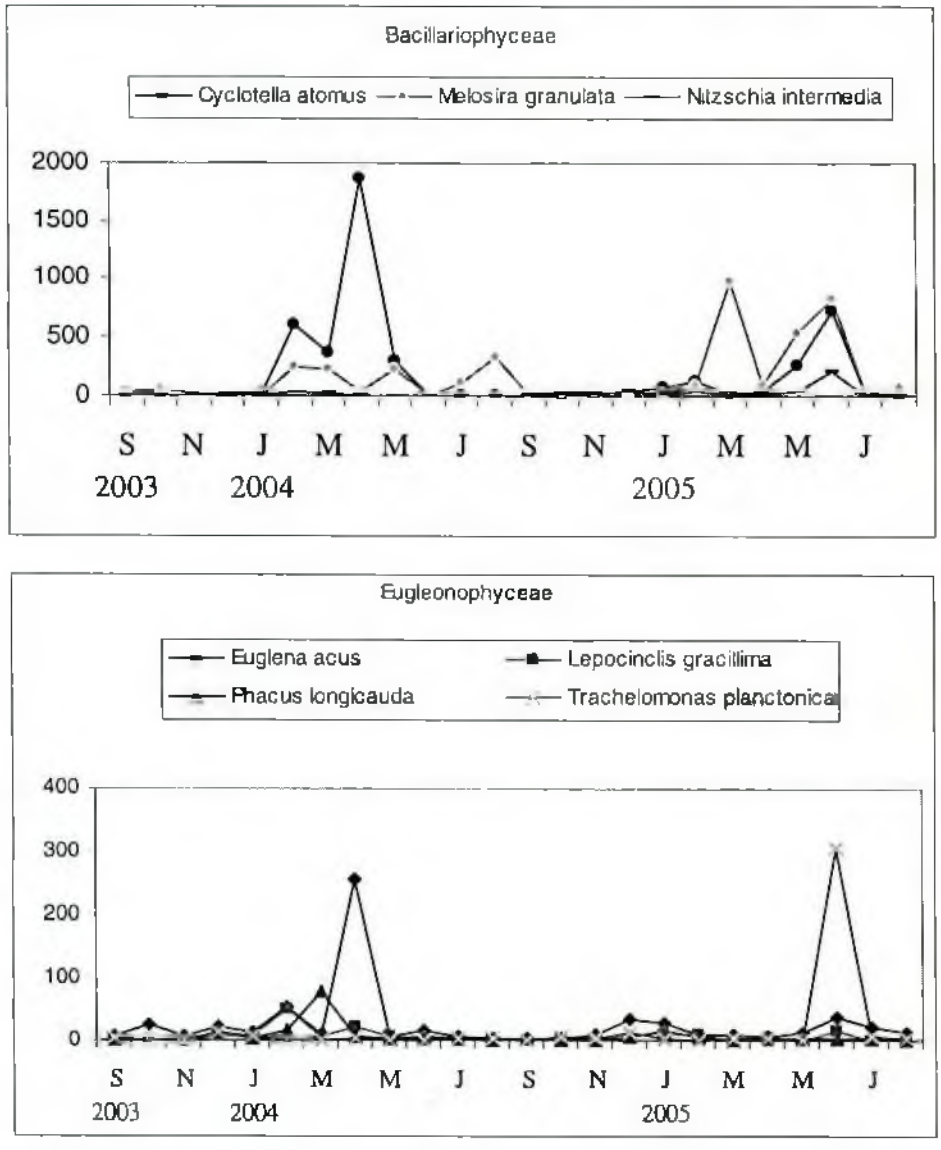


Fig. 64. Relative mean abundance of dominant phytoplankton at ST-3.

Abnormal growth in phytoplankton

During the compound microscopy of phytoplankton samples abnormality in the growth of phytoplankton cells were noticed. These were incomplete colony development, damaged cells, cell surface and mucilage crowded with debris and dirt particles. All these plankton cells were photographed and presented in Plate 13. Figs 1 and 2 show the incomplete colony of *Gonium* sp. and *Scenedesmus* sp. Dissolution of siliceous wall and accumulation of debris have been noticed in the frustules of *Coscinodiscus* sp. (Plate 13, Fig. 3). Figs. 4-6 show damaged cell content of different euglenoid cells. Accumulation of pollutant particles was evident on the wall of *Tetraedron* sp. (Plate 13, Fig. 7). The mucilage of *Anabaena* sp. has been found completely blocked with pollutant particles (Plate 13, Fig. 8). Excessive pollutant load in water actually blocks the cell surface thereby causing a severe stress in the metabolic process and kill the plankton. Some times incomplete growth also occurs because of toxic effect of some chemicals.

Biomass

Chlorophyll-a

The concentration of chlorophyll-a (chl-a) varied from 4.0-133.0 µg/L, 2.0-163.0 µg/L and 2.0-126.0 µg/L in ST-1, ST-2 and ST-3 respectively (Figs. 65-67). This parameter showed identical fluctuating pattern in ST-1 and ST-2 throughout the period of investigation (Fig. 68). From September to January the concentration remained lower but closer to each other in different months. After January the concentration increased and attained a peak between March and May and then fell. From June to November the concentration droped again until it started rising in December. The second peak of chl-a in the study year was observed in May for ST-1 and ST-2. In ST-3, the fluctuation trend of chl-a was different compared to ST-1 and ST-2. At least three smaller peaks and one high peak were observed during the study period. The three smaller peaks occurred in February, April and December and the large peak occurred in June.

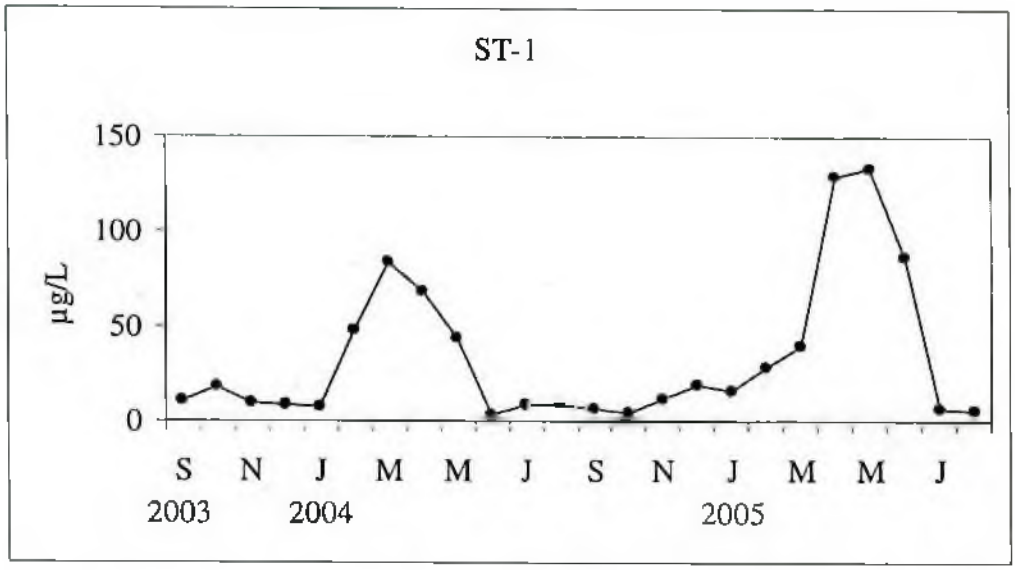


Fig. 65. Seasonal variation in chlorophyll a concentration at ST-1.

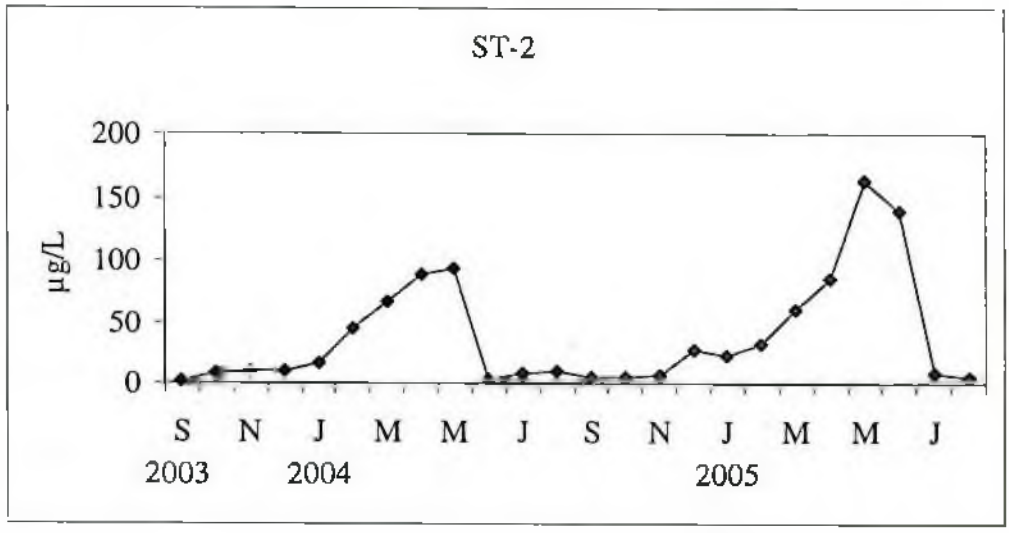


Fig. 66. Seasonal variation in chlorophyll a concentration at ST-2.

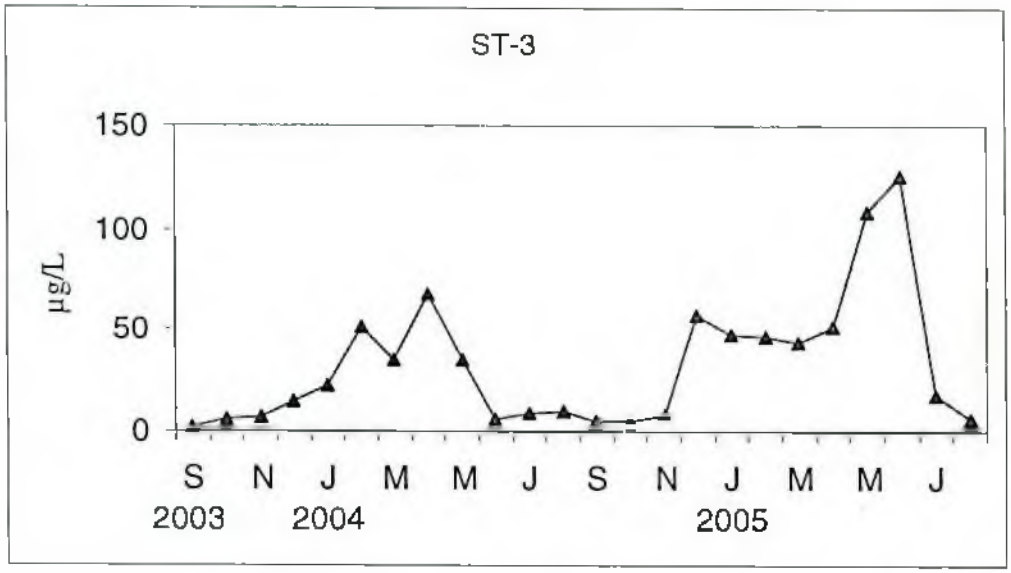


Fig. 67. Seasonal variation in chlorophyll-a concentration at ST-3.

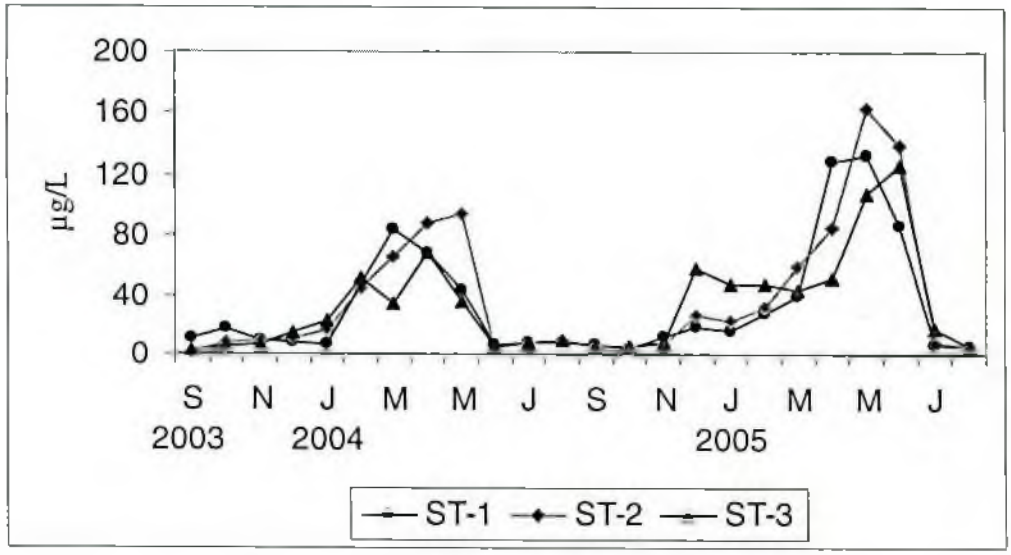


Fig. 68. Comparative seasonal variation in chlorophyll-a among ST-1, ST-2 and ST-3.

Phaeopigment

Phaeopigment concentration varied from 0-334 µg/L, 0-212 µg/L and 0.31-38 µg/L in ST-1, ST- 2 and ST-3, respectively (Figs. 69-71). The pattern of fluctuation of this parameter in the river water was almost identical for ST-1 and ST-2. The highest phaeopigment concentration in this two stations occurred in March 2004. During all other periods of measurement this parameter showed almost closer concentration except May for ST-1 and June for ST-2 during which the concentration elevated to a little. In ST-3 phaeopigment concentration showed three peaks throughout the period of investigation. These were in April 2004, January and June 2005. In this station the phaeopigment concentration on either side of the peak in April fell gradually (Fig. 71). A gradual fall was also observed between the peaks of January and June but the concentration did not attain a lower range (Fig.71).

Seasonal changes

According to Rashid (1991) four distinct seasons prevail in Bangladesh. These are: winter (late November to February), summer (March to May), monsoon (June to early October) and autumn (late October to November). Depending upon the above mentioned classification, seasonal changes of different limnological parameters were calculated for the river and presented in Table 3 and Table 4 among stations and between years of study.

Among stations and between years of study

Physical factors

Physical factors like air and water temperature along with Secchi depth data obtained from the present investigation was consolidated seasonally to observe the variations among the mean value (Table 3). Eventually all data was compiled to assess the difference between annual mean value.

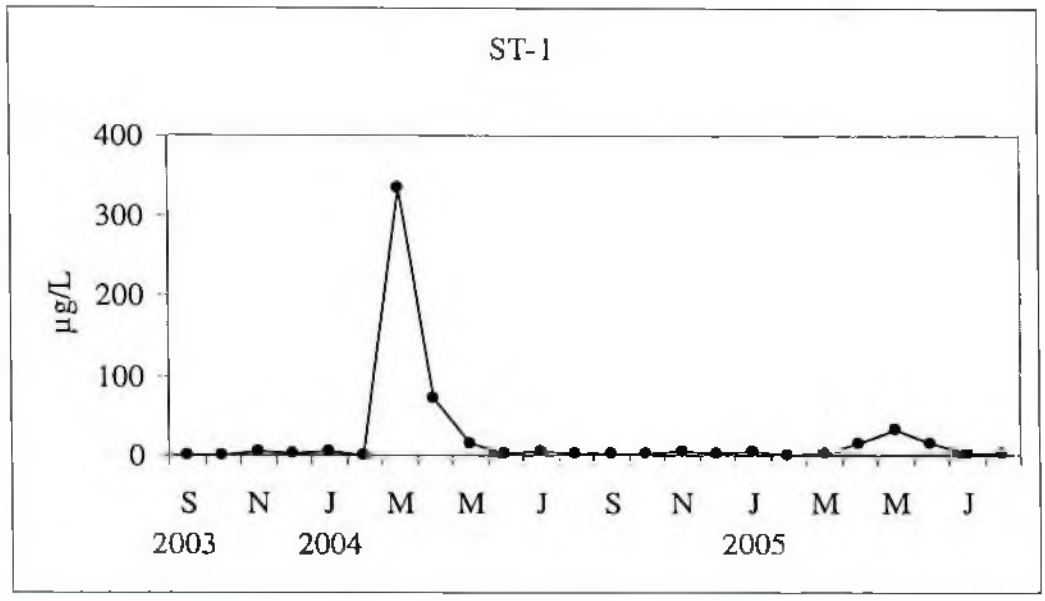


Fig. 69. Seasonal variation in phaeopigment concentration at ST-1.

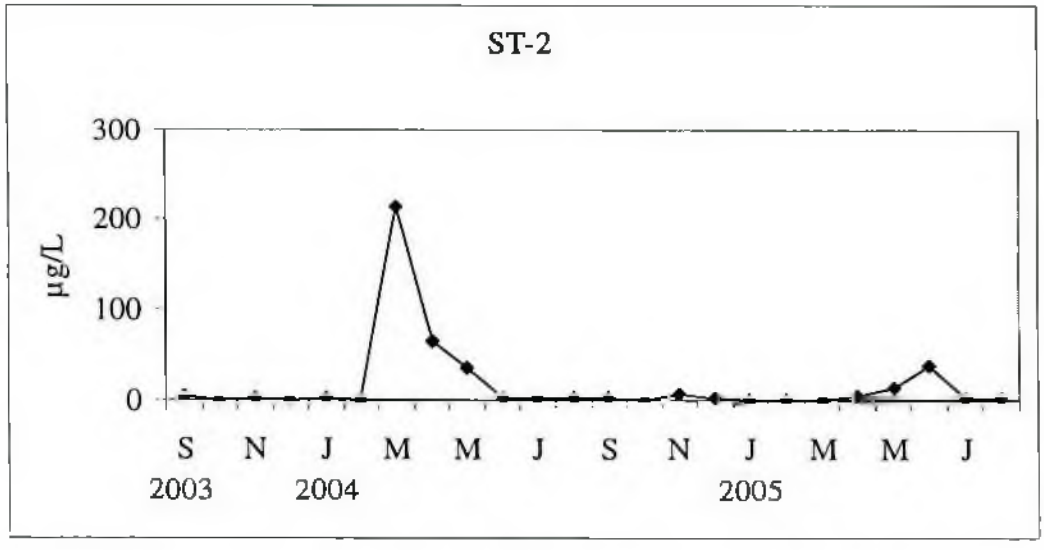


Fig. 70. Seasonal variation in phaeopigment concentration at ST-2.

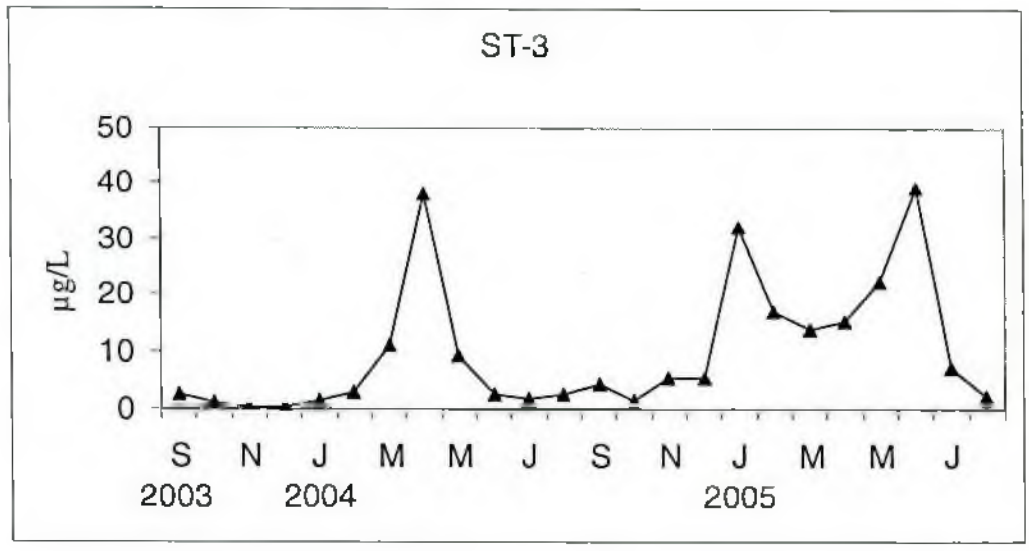


Fig. 71. Seasonal variation in phaeopigment concentration at ST-3.

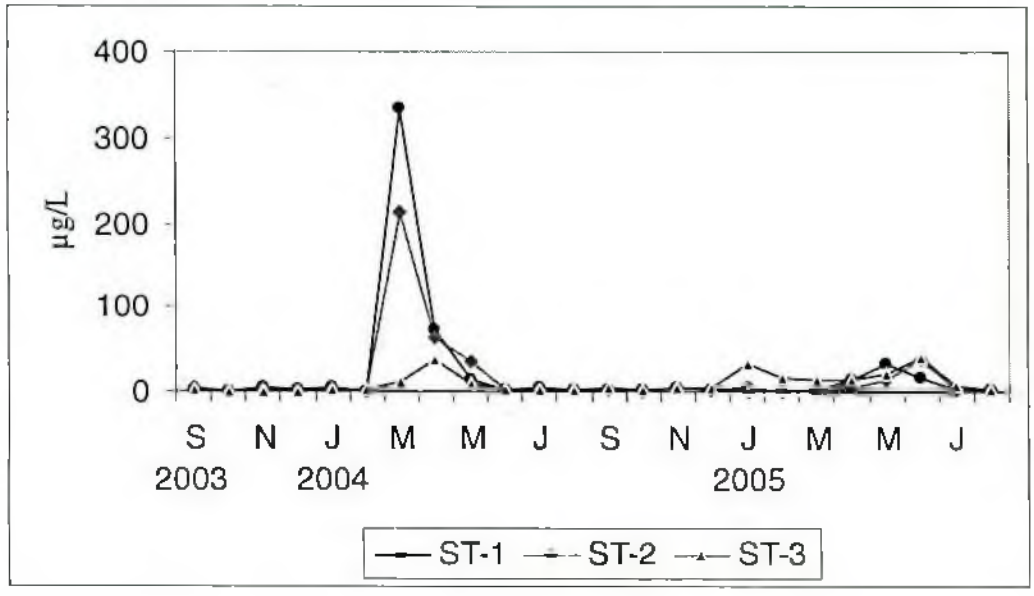


Fig. 72. Comparative seasonal variation in phaeopigment among ST-1, ST-2 and ST-3.

In running water habitats physical factors namely temperature usually produce marked effect on the biota. Seasonal averages of various parameters as presented in Table 3 implicates a major difference in water temperature during monsoon and winter. In monsoon marked increase in temperature was observed. On the other hand factor like transparency showed higher value during autumn and lower value during monsoon (Table 3).

Chemical factors

Chemical factors like pH, conductivity, alkalinity, TDS, SRS, NO_3-N, SRP and DO data obtained from the present investigation were consolidated to seasonal mean values to observe the variations among the stations (Table 3).

Seasonally pH did not show any noticeable change among four seasons, but conductivity, alkalinity, and TDS remained higher during summer and become lower during monsoon. SRS and SRP found higher during summer and lower in monsoon. DO showed higher value during monsoon with an increase in temperature but declined to lower value in summer.

Biological factors

Biological factors like chl-a, phaeopigment, density of the phytoplankton, number of species along with diversity index data obtained from the present investigation were also pulled to seasonal mean values to observe the variations among the stations (Table 4). Phytoplankton biomass, density and their diversity showed that highest density occurred during summer and lowest during autumn. Biomass remained high in summer and lower in winter as well as species diversity become higher in summer and lower in monsoon (Table 4).

Table 3. Seasonal variations in the physico-chemical characteristics of water in the river Buriganga (mean value).

Parameters		Autumn		Winter		Summer		Monsoon	
		Late Oct.-Nov.		Late Nov-Feb		Mar-May		June-early Oct.	June-*Aug.
	Station	2003	2004	2003-04	2004-05	2004	2005	2004	2005
Physical factors									
Zs (cm)	ST-1	41	41.1	27.2	37.1	32.5	31.6	28.3	29.8
	ST-2	36.5	35.6	38.8	28.6	38.6	21	26.1	26.5
	ST-3	37	36.7	52.6	54.9	49.5	54.9	32.5	34.1
Air temp. (°C)	ST-1	28.75	26.1	20.75	22	30.9	29.6	28.7	31.5
	ST-2	28.75	29.1	20	23.5	31.7	30	30.3	32.5
	ST-3	28.75	29.6	22.25	25	31.6	30.6	32.4	32.6
Water temp. (°C)	ST-1	28.1	28.5	22.1	22.5	29	29	29.6	31.5
	ST-2	28.2	28.2	22	22.7	29	29	29.9	31.5
	ST-3	28.4	28.6	21.9	23.1	29	29	30.6	31.7
Chemical factors									
pH	ST-1	6.7	6.7	6.9	6.7	6.8	-	6.7	-
	ST-2	6.7	6.7	6.8	6.8	6.8	-	6.8	-
	ST-3	6.7	6.8	6.9	6.7	6.8	-	6.8	-
Conductivity (µS/cm)	ST-1	278	184	551	599	710	597	134	128
	ST-2	199	183	417	465	633	645	141	131
	ST-3	188	182	465	504	470	525	151	132
Alkalinity (meq/L)	ST-1	1.9	1.9	4.6	5	4.9	6.4	1.3	2.3
	ST-2	1.7	1.7	4.6	5.3	4.6	6.2	1.2	2.5
	ST-3	1.7	1.7	4.2	4.6	3.4	4	1.3	2.2
TDS (mg/L)	ST-1	133	62	279	284	358	378	59	154
	ST-2	94	59	274	267	318	340	64	180
	ST-3	89	55	251	234	239	251	67	186
SRP (µg/L)	ST-1	35	76	277	468	485	923	48	296
	ST-2	61	81	350	515	561	908	55	135
	ST-3	65	90	148	216	291	412	62	196
NO_3-N (mg/L)	ST-1	0.19	0.1	0.09	0.06	0.05	0.01	0.09	0.11
	ST-2	0.31	0.08	0.07	0.1	0.04	0.06	0.08	0.07
	ST-3	0.25	0.19	0.18	0.65	0.5	1.7	0.12	0.13
SRS (mg/L)	ST-1	6.2	12	25	35	21	48	6	14
	ST-2	6.1	12	25	35	20	43	6	14
	ST-3	10.3	11	22	31	15	26	6	14
DO (mg/L)	ST-1	7	8	4.9	6	4.2	2.9	7.2	6.7
	ST-2	7.8	7.6	4.1	4.6	3.7	1.1	7.1	6.5
	ST-3	6.4	7.9	6	6.2	5.8	5.9	7.1	6.7

Table 4. Seasonal variations in the biological characteristics of water in the river Buriganga (mean value).

Parameters		Autumn		Winter		Summer		Monsoon	
		Late Oct.-Nov.		Late Nov-Feb		Mar-May		June - early Oct.	June-*Aug.
	Station	2003	2004	2003-04	2004-05	2004	2005	2004	2005
Biological factors									
Chl-a (µg/L)	ST-1	16	7.7	20.8	20.6	65.4	100.79	6.5	33
	ST-2	8	6.1	23.2	26.9	83	102.9	6.4	50.6
	ST-3	9.4	6.3	29.6	50.5	45.8	67.9	6.8	50.1
Phaeopigment (µg/L)	ST-1	2	3.2	2.2	2.6	140	17	2.4	6.3
	ST-2	0.81	3.4	1	1	104	5	1.8	14
	ST-3	0.39	3.2	1.5	18	19.4	16.9	2.5	16
Phytoplankton density ($\times 10^3$ ind/L)	ST-1	3.7	4.1	3.5	41.8	36.1	137.4	3.5	19.8
	ST-2	2.4	1.7	2.9	9.1	129.4	46.8	3.1	34.5
	ST-3	1.1	2.0	10.1	15.8	47.1	28.0	2.5	88.0
Number of species	ST-1	35	35	46	49	54	47	28	31
	ST-2	19	17	34	34	33	36	24	28
	ST-3	26	27	46	43	43	45	27	38
Shanon-Weaver index (H')	ST-1	4.1	4	4.2	3.8	3.6	3.3	3.2	3.9
	ST-2	3.7	3.3	3	3.7	2.1	3.2	3.5	3.5
	ST-3	4	4.1	4.1	3.4	3.4	3.1	3.2	3.7

Correlation matrix

Different physicochemical parameters and biological variables recorded from the river Buriganga was analyzed to determine their effect on the phytoplankton diversity and their seasonal changes and over all limnology of the river water. A correlation matrix was prepared with the help of Statistical programme for Social Sciences (SPSS) following Pearson correlation method. Multiple correlation analysis has been made among 15 physical, chemical and biological parameters obtained from the three sampling stations in the river Buriganga. The matrix has been presented in Table 5-7 for ST-1, ST-2 and ST-3, respectively.

At ST-1 water temperature showed highly significant positive correlation with air temperature. pH had significant positive correlation with alkalinity, chl-a, phaeopigment, and TDS but pH showed negative correlation with DO. Conductivity showed highly significant positive correlation with alkalinity, biomass, pH, SRP, SRS, TDS and negatively correlated with DO and NO_3-N. DO and NO_3-N both showed identically negative correlation with alkalinity, conductivity, biomass, SRP, SRS and TDS. SRP showed positive correlation with alkalinity, conductivity, chl-a, TDS and SRS where as SRP exhibit negative correlation with DO and NO_3-N. SRS showed strong positive correlation with alkalinity, conductivity, chl-a, SRP and TDS and maintained negative correlation with DO and NO_3-N.

At ST-2 Water temperature showed highly significant positive correlation with air temperature and negatively correlated with alkalinity. pH had significant positive correlation with alkalinity, conductivity, SRP, phaeopigment, and TDS, pH showed negative correlation with DO. Conductivity showed highly significant positive correlation with alkalinity, biomass, pH, SRP, SRS, TDS and phytoplankton density, and negatively correlated with DO. DO showed negative correlation with pH, alkalinity, conductivity, chl-a, SRP, SRS and TDS. NO_3-N showed negative correlation with SRP. SRP showed positive correlation with alkalinity, conductivity, TDS and SRS where as SRP exhibit negative correlation with DO and NO_3-N. SRS showed strong positive correlation with alkalinity, conductivity, TDS, SRP and chl-a.

Table 5. Matrix of Product moment correlation (r) among different physicochemical and biological variables recorded from ST-1.

		Air Temp (oC)	water temp.(oC)	Transparency(Zs)	pH	Alkalinity (mg/L)	Cond. (µS/cm)	DO (mg/L)	TDS (mg/L)	SRS (mg/L)	NO3-N (mg/L)	SRP (µg/L)	Density (ind/L)	Diversity index(H')	Chl. a (µg/L)	Pheeo (µg/L)
Air Temp (oC)	Pearson Correlatic	1	.841**	.338	-.129	-.281	-.153	-.022	-.139	-.203	-.043	-.117	.201	-.223	.347	.109
	Sig. (2-tailed)	.	.000	.106	.609	.183	.497	.919	.516	.342	.842	.586	.347	.295	.097	.611
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
water temp.(oC)	Pearson Correlatic	.841**	1	.288	-.205	-.447*	-.363	.107	-.336	-.301	.043	-.262	.114	-.234	.208	.006
	Sig. (2-tailed)	.000	.	.172	.414	.028	.096	.620	.109	.153	.842	.217	.596	.270	.329	.979
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Transparency(Zs	Pearson Correlatic	.338	.288	1	-.364	-.288	-.152	.278	-.282	-.118	.009	-.248	.042	.306	.115	-.249
	Sig. (2-tailed)	.106	.172	.	.737	.172	.501	.189	.182	.584	.966	.242	.844	.146	.592	.241
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
pH	Pearson Correlatic	-.129	-.205	-.364	1	.568*	.590**	-.481*	.626**	.231	-.453	.340	.256	-.185	.566*	.474*
	Sig. (2-tailed)	.609	.414	.137	.	.014	.010	.044	.005	.256	.059	.167	.305	.463	.014	.047
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Alkalinity (meq/L	Pearson Correlatic	-.281	-.447*	-.288	.568*	1	.960**	-.779**	.967**	.773**	-.577**	.901**	.547*	-.174	.645**	.378
	Sig. (2-tailed)	.183	.028	.172	.014	.	.000	.000	.000	.000	.003	.000	.006	.416	.001	.069
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Cond. (µS/cm)	Pearson Correlatic	-.153	-.363	-.152	.590**	.960**	1	-.734**	.968**	.803**	-.544**	.917**	.641**	.026	.808**	.490*
	Sig. (2-tailed)	.497	.096	.501	.010	.000	.	.000	.000	.000	.009	.000	.001	.907	.000	.021
	N	22	22	22	18	22	22	22	22	22	22	22	22	22	22	22
DO (mg/L)	Pearson Correlatic	-.022	.107	.278	-.481*	-.779**	-.734**	1	-.839**	-.656**	.352	-.753**	-.332	.265	-.391*	-.364
	Sig. (2-tailed)	.919	.620	.189	.044	.000	.000	.	.000	.000	.092	.000	.113	.178	.004	.080
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
TDS (mg/L)	Pearson Correlatic	-.139	-.336	-.282	.626**	.967**	.968**	-.839**	1	.804**	-.556**	.873**	.517**	-.219	.672**	.457*
	Sig. (2-tailed)	.516	.109	.182	.005	.000	.000	.000	.	.000	.005	.000	.010	.304	.000	.025
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
SRS (mg/L)	Pearson Correlatic	-.203	-.301	-.118	.231	.773**	.803**	-.656**	.804**	1	-.459*	.647**	.429*	-.021	.632**	.133
	Sig. (2-tailed)	.342	.153	.584	.356	.000	.000	.000	.000	.	.024	.001	.037	.921	.001	.536
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
NO3-N (mg/L)	Pearson Correlatic	-.043	.043	.009	-.453	-.577**	-.544**	.352	-.556**	-.459*	1	-.549**	-.527**	.258	-.600**	-.311
	Sig. (2-tailed)	.842	.842	.966	.059	.003	.009	.092	.005	.024	.	.005	.008	.086	.002	.139
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
SRP (µg/L)	Pearson Correlatic	-.117	-.262	-.248	.340	.901**	.917**	-.753**	.873**	.647**	-.549**	1	.599**	-.365	.565**	.177
	Sig. (2-tailed)	.586	.217	.242	.167	.000	.000	.000	.000	.001	.005	.	.002	.080	.004	.407
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Density (ind/L)	Pearson Correlatic	.201	.114	.042	.256	.547**	.641**	-.332	.517**	.429*	-.527**	.599**	1	-.212	.762**	.039
	Sig. (2-tailed)	.347	.596	.844	.305	.006	.001	.113	.010	.037	.008	.002	.	.320	.000	.855
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Diversity index(H	Pearson Correlatic	-.223	-.234	.306	-.185	-.174	.026	.265	-.219	-.021	.258	-.365	-.212	1	.003	-.126
	Sig. (2-tailed)	.295	.270	.146	.463	.416	.907	.178	.304	.921	.086	.080	.320	.	.988	.557
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Chl. a (µg/L)	Pearson Correlatic	.347	.208	.115	.566*	.645**	.808**	-.571**	.672**	.632**	-.600**	.565**	.762**	.003	1	.394
	Sig. (2-tailed)	.097	.329	.592	.014	.001	.000	.004	.000	.001	.002	.004	.000	.988	.	.057
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Pheeo (µg/L)	Pearson Correlatic	.109	.006	-.249	.474*	.378	.490*	-.364	.457*	.133	-.311	.177	.039	-.126	.394	1
	Sig. (2-tailed)	.611	.979	.241	.047	.069	.021	.080	.025	.536	.139	.407	.855	.557	.057	.
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24

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

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

Table 6. Matrix of Product moment correlations coefficient (r) among different physicochemical and biological variables recorded from ST-2.

		Air Temp (oC)	Water temp (oC)	Transparancy (Ts	pH	Alkalinity (meq / L)	Cond. (µS/ cm)	DO (mg/ L)	TDS (mg/ L)	SRS (mg/ L)	NO3-N (mg/ L)	SRP (µg/ L)	Density (ind. / L)	Diversity index (H)	Chlorophyll-a (µg/ L)	Phoeopig ments(µg/ L)
Air Temp (oC)	Pearson Correlation	1	.934**	-.155	-.377	-.305	-.059	.107	-.196	-.201	-.002	-.229	.404	-.143	.107	.173
	Sig. (2-tailed)	.	.000	.469	.123	.148	.795	.623	.360	.347	.994	.282	.051	.506	.620	.419
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Water temp.(oC)	Pearson Correlation	.934**	1	-.088	-.296	-.452*	-.157	.245	-.343	-.347	-.015	-.385	.320	-.062	.008	.039
	Sig. (2-tailed)	.000	.	.753	.103	.026	.485	.246	.101	.097	.946	.064	.128	.775	.972	.856
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Transparancy (Zs)	Pearson Correlation	-.155	-.088	1	-.018	-.116	.052	.224	-.049	-.302	-.063	-.160	.377	.191	.066	.020
	Sig. (2-tailed)	.469	.753	.	.942	.589	.819	.293	.820	.151	.768	.220	.070	.372	.761	.926
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
pH	Pearson Correlation	-.377	-.396	-.018	1	.698**	.576*	-.672**	.632**	.452*	-.360	.608**	.082	-.573*	.371	.576*
	Sig. (2-tailed)	.123	.103	.942	.	.009	.012	.002	.003	.060	.143	.007	.746	.013	.129	.012
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Alkalinity (meq / L)	Pearson Correlation	-.305	-.452*	-.116	.698**	1	.647**	.900**	.957**	.800**	-.247	.608**	.295	-.265	.709**	.320
	Sig. (2-tailed)	.148	.026	.589	.009	.	.000	.000	.000	.000	.097	.000	.161	.210	.000	.127
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Cond. (µS/ cm)	Pearson Correlation	-.059	-.157	.052	.576*	.647**	1	-.304*	.669**	.615**	.333	.589**	.629**	.335	.605**	.506*
	Sig. (2-tailed)	.795	.485	.819	.012	.000	.	.000	.000	.002	.130	.004	.002	.127	.000	.016
	N	22	22	22	18	22	22	22	22	22	22	22	22	22	22	22
DO (mg/ L)	Pearson Correlation	.107	.245	.224	-.672**	-.900**	-.704**	1	-.902**	-.737**	.385	-.636**	-.244	.297	-.562**	-.321
	Sig. (2-tailed)	.623	.246	.293	.002	.000	.000	.	.000	.000	.064	.000	.250	.159	.004	.116
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
TDS (mg/ L)	Pearson Correlation	-.196	.343	-.049	.632**	.957**	.669**	-.902**	1	.675**	-.377	.783**	.436*	-.352	.732**	.420*
	Sig. (2-tailed)	.360	.101	.820	.003	.000	.000	.000	.	.000	.070	.000	.033	.091	.000	.041
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
SRS (mg/ L)	Pearson Correlation	-.201	-.347	-.302	.452	.800**	.615**	.737**	.675**	1	-.123	.710**	.032	-.262	.463*	.136
	Sig. (2-tailed)	.347	.097	.151	.060	.000	.002	.000	.000	.	.566	.000	.884	.217	.023	.526
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
NO3-N (mg/ L)	Pearson Correlation	-.002	-.015	-.063	-.360	-.247	-.333	.385	-.377	-.123	1	-.439*	-.177	.281	-.230	-.312
	Sig. (2-tailed)	.994	.946	.768	.143	.097	.130	.064	.070	.566	.	.032	.409	.183	.279	.138
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
SRP (µg/ L)	Pearson Correlation	-.229	-.385	-.160	.608**	.608**	.589**	-.636**	.783**	.710**	-.439*	1	.029	-.212	.308	.289
	Sig. (2-tailed)	.282	.064	.220	.007	.000	.004	.000	.000	.000	.032	.	.891	.319	.142	.171
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Density (ind./ L)	Pearson Correlation	.404	.320	.377	.082	.295	.629**	-.244	.436*	.032	-.177	.029	1	-.412*	.618**	.375
	Sig. (2-tailed)	.051	.128	.070	.746	.161	.002	.250	.033	.884	.409	.891	.	.045	.001	.071
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Diversity index (H)	Pearson Correlation	-.143	-.062	.191	-.573*	-.265	-.335	.297	-.352	-.262	.281	-.212	-.412*	1	-.143	-.460*
	Sig. (2-tailed)	.506	.775	.372	.013	.210	.127	.159	.091	.217	.183	.319	.045	.	.506	.024
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Chlorophyll-a (µg/ L)	Pearson Correlation	.107	.008	.066	.371	.709**	.605**	-.562**	.732**	.463*	-.230	.308	.618**	-.143	1	.201
	Sig. (2-tailed)	.620	.972	.761	.129	.000	.000	.004	.000	.023	.279	.142	.001	.506	.	.347
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Phoeopigments(µg/ L)	Pearson Correlation	.173	.039	.020	.576*	.320	.506*	-.321	.420*	.136	-.312	.289	.375	-.460*	.201	1
	Sig. (2-tailed)	.419	.856	.926	.012	.127	.016	.128	.041	.526	.138	.171	.071	.024	.347	.
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24

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

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

Table 7. Matrix of Product moment correlation coefficient (r) among different physicochemical and biological variables recorded from ST-3.

		Air Temp(oC)	Water temp (oC)	Transparency (Zs)	pH	Alkalinity (meq/ L)	Conductivity (µS/cm)	DO (mg/ L)	TDS (mg/ L)	SRS (mg/ L)	NO3-N (mg/ L)	SRP (µg/ L)	Density (ind./ L)	Diversity index(H)	Chl.a (µg/ L)	Pheo (µg/ L)
Air Temp(oC)	Pearson Correlation	1	.543**	-.377	-.406	-.565**	-.361	.223	-.355	-.423*	-.105	-.037	.266	-.208	.026	.172
	Sig. (2-tailed)	.	.000	.070	.094	.004	.089	.295	.089	.040	.671	.866	.209	.330	.904	.422
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Water temp (oC)	Pearson Correlation	.543**	1	-.355	-.429	-.460*	-.390	.135	-.462*	-.344*	-.115	-.063	.305	-.138	.012	.099
	Sig. (2-tailed)	.000	.	.088	.075	.000	.072	.528	.045	.006	.592	.770	.147	.521	.955	.645
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Transparency (Zs)	Pearson Correlation	-.377	-.355	1	.344	.695**	.527*	-.421*	.652**	.518**	.571**	.679**	.131	.029	.465*	.277
	Sig. (2-tailed)	.070	.088	.	.162	.000	.000	.040	.001	.010	.004	.000	.543	.891	.022	.190
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
pH	Pearson Correlation	-.406	-.429	.344	1	.537*	.556*	-.259	.630**	.393	.506*	.392	.205	-.068	.371	.018
	Sig. (2-tailed)	.094	.075	.162	.	.021	.022	.300	.005	.174	.217	.108	.416	.790	.129	.944
	N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Alkalinity(meq/ L)	Pearson Correlation	-.565**	-.460*	.695**	.537*	1	.605**	-.462*	.889**	.606**	.513*	.687**	.207	.037	.659**	.486*
	Sig. (2-tailed)	.004	.000	.000	.021	.	.000	.023	.000	.000	.010	.000	.268	.864	.001	.016
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Conductivity (µS/cm)	Pearson Correlation	-.361	-.390	.527**	.556*	.605**	1	-.561**	.916**	.712**	.691**	.819**	.522**	.102	.866**	.652**
	Sig. (2-tailed)	.099	.072	.000	.022	.000	.	.007	.000	.000	.001	.000	.013	.651	.000	.001
	N	22	22	22	18	22	22	22	22	22	22	22	22	22	22	22
DO (mg/ L)	Pearson Correlation	.223	.135	-.421*	-.259	-.462*	-.561**	1	-.586**	-.286	-.220	.350	-.369	-.063	-.481*	-.530**
	Sig. (2-tailed)	.295	.528	.040	.300	.023	.007	.	.003	.381	.302	.093	.076	.768	.027	.008
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
TDS (mg/ L)	Pearson Correlation	-.355	-.462*	.652**	.630**	.889**	.916**	-.586**	1	.688**	.584**	.793**	.470*	-.062	.782**	.577**
	Sig. (2-tailed)	.089	.045	.001	.005	.000	.000	.003	.	.000	.007	.000	.021	.956	.000	.003
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
SRS (mg/ L)	Pearson Correlation	-.423*	-.344*	.518**	.393	.606**	.712**	-.286	.688**	1	.483*	.585**	.157	.130	.548**	.404
	Sig. (2-tailed)	.040	.006	.010	.174	.000	.000	.381	.000	.	.019	.003	.480	.545	.006	.050
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
NO3-N (mg/ L)	Pearson Correlation	-.105	-.115	.571**	.506*	.513*	.691**	-.220	.584**	.470*	1	.674**	.026	-.357	.364	.339
	Sig. (2-tailed)	.671	.592	.004	.217	.010	.001	.302	.007	.019	.	.000	.904	.086	.080	.105
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
SRP (µg/ L)	Pearson Correlation	-.037	.063	.679**	.392	.687**	.819**	-.350	.793**	.585**	.674**	1	.481*	-.041	.740**	.580**
	Sig. (2-tailed)	.866	.770	.000	.108	.000	.000	.093	.000	.003	.000	.	.017	.851	.000	.000
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Density (ind./ L)	Pearson Correlation	.266	.305	.131	.205	.207	.522*	-.369	.470*	.157	.026	.481*	1	.029	.777**	.765**
	Sig. (2-tailed)	.209	.147	.543	.416	.268	.013	.076	.021	.463	.904	.017	.	.892	.000	.000
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Diversity index(H)	Pearson Correlation	-.208	-.138	.029	-.068	.037	.102	-.063	-.062	.130	-.357	-.041	.029	1	-.040	-.161
	Sig. (2-tailed)	.330	.521	.891	.790	.864	.651	.768	.956	.545	.086	.851	.892	.	.853	.453
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Chl.a (µg/ L)	Pearson Correlation	.026	.012	.465*	.371	.659**	.866**	-.481*	.782**	.548**	.364	.740**	.777**	-.040	1	.805**
	Sig. (2-tailed)	.904	.955	.022	.129	.001	.000	.027	.000	.006	.080	.000	.000	.853	.	.000
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24
Pheo (µg/ L)	Pearson Correlation	.172	.099	.277	.018	.486*	.652**	-.530**	.577**	.404	.339	.580**	.765**	-.161	.805**	1
	Sig. (2-tailed)	.422	.645	.190	.944	.016	.001	.008	.003	.050	.105	.003	.000	.453	.000	.
	N	24	24	24	18	24	22	24	24	24	24	24	24	24	24	24

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

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

At ST-3 water temperature showed highly significant positive correlation with air temperature and negatively correlated with alkalinity and SRS. pH had significant positive correlation with alkalinity, conductivity and TDS. Conductivity showed highly significant positive correlation with alkalinity, biomass, pH, SRP, SRS, NO_3-N, TDS, Secchi depth and phytoplankton density, and negatively correlated with DO. DO showed negative correlation with Secchi depth, alkalinity, conductivity, biomass, and TDS. NO_3-N showed positive correlation with alkalinity, Secchi depth, conductivity, TDS, SRP and SRS. SRP showed positive correlation with Secchi depth, alkalinity, conductivity, TDS, NO_3-N, SRS, density of phytoplankton and biomas. SRS showed strong positive correlation with alkalinity, conductivity, TDS, SRP, chl-a, and Secchi depth. It showed negative correlation with water temperature.

Comparison with other river ecosystems

A comparative limnology of different rivers in both domestic and international river ecosystems was obtained by consulting available data from various sources.

Domestic river ecosystems

Past data available for the river Buriganga at different period of study was consulted. through. Data from some other important domestic rivers like Turag, Meghna, Titas, Gumti, Havatia, Karnaphuli, Sitalakhya, Balu, Halda, Padma etc. were also compiled to understand the present status of the river Buriganga (Table 8-11).

International river ecosystems

Data from some international rivers like Yamuna, India; Nile river, Egypt; Kern River, South California and some rivers from Ivory Coast also consulted and compared with the results obtained in the present investigation (Table 8-11).

Table 8. Comparison among the ranges of air and water temperature, Secchi depth, chl-a and phaeopigment concentration from some river waters.

Rivers	Air temp. °C	Water temp. °C	Secchi depth cm	Chl-a µg/L	Phaeopig-ment µg/L	Reference
Buriganga						
ST-1	17-35	20-32	11-54	4-133	0-334	Present study
ST-2	15-35	20-33	17-60	2-160	0-212	"
ST-3	18-34	20-34	21-83	2-126	0-39	"
BCMB-II	-	20-32	17-95	2-142	0.1-43	Zerin (1995)
Other rivers						
Turag	-	20-32	20-50	1-163	0.1-37	Abed (1995)
Sitalakhya	-	21-32	<25-<55	-	-	DOE (2003)
Halda	23-33	20-32	13-29	-	-	Patra and Azadi (1987)
Meghna	-	20-31	20-140	-	-	Shafi *et al.* (1978)
Nile, Egypt	-	14-27	-	-	-	Ahmed *et al.* (1986)
Kern, S. Cal.	-	10-22	-	1.3-13.8	1.3-4.3	Hill and Rai (1984)

Table 9. Comparison of phytoplankton quality and quantity from some river waters.

Rivers	No. of genera	No. of species	Dominant class	Density $\times 10^3$ ind/L	Reference
Buriganga					
ST-1	65	108	Chlorophyceae (40%)	1-236	Present study
ST-2	60	82	Chlorophyceae (41%)	1-197	"
ST-3	61	91	Chlorophyceae (36%)	1-250	"
BCMB-II	28		Cyanophyceae (33%)	1-2130	Zerin (1995)
Buriganga	-	-	-	.32-25000	Islam *et al.* (1974)
Buriganga	72	194	Chlorophyceae (56%)	-	Islam and Zaman (1975)
Other rivers					
Mouri, Khulna	26	56	Chlorophyceae (50%)	.082-1.630	Mahmud *et al.* (2007)
Ganges, India	19	125	Chlorophyceae		Siddiqui *et al.* (1980)
Nile, Egypt	64	141	Chlorophyceae	4800-10000	Ahmed *et al.* (1986)
Shatt-al-Arab	6	107	Diatom (75%)	500-4400	Huq *et al.* (1978)

Table 10. Comparison among the ranges of pH, alkalinity, conductivity and total dissolved solids from some river waters.

Rivers	pH	Alkalinity meq/L	Conductivity µS/cm	TDS mg/L	Reference
Buriganga					
ST-1	6.6-6.9	1.1-7.6	128-940	57-467	Present study
ST-2	6.7-6.9	1.0-6.6	115-915	55-394	"
ST-3	6.7-6.9	1.1-5.0	133-713	45-316	"
BCMB-II	6.8-8.1	1.0-4.9	110-640	-	Zerin (1995)
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	"
Other rivers					
Turag	6.6-8.2	1.0-5.4	100-890	-	Abed (1995)
Balu	7.2-7.3	-	244-335	170-248	DOE (1993)
Sitalakhya	7.3-7.6	-	117-333	117-196	"
Halda	6.6-7.6	-	52-148	-	Patra and Azadi (1987)
Karnaphuli	6.2-7.8	-	-	-	DOE (1993)
Yamuna, India	7.2-8.3	1.6-3.7	-	-	Rai (1974)
Fon, Ivory coast	5.6-6.9	0.6-1.0			Rai (1974)
Nile, Egypt	7.4-8.5	2.5-3.7	-	-	Ahmed *et al.* (1986)
Kern, S. Cal.	7.9-8.0	1.0-1.2	-	62-114	Hill and Rai (1984)

Table 11. Comparison among ranges of dissolved oxygen (DO) and nutrient concentrations from some river waters.

Rivers	SRS mg/L	SRP µg/L	NO_3-N mg/L	DO mg/L	Reference
Buriganga					
ST-1	3-82	28-1443	0-0.3	0.5-9.4	Present study
ST-2	4-76	34-1584	0-0.3	0-9.4	"
ST-3	2-34	40-466	0-2.5	4.3-9.2	"
BCMB-II	3-38	38-508	0.4-10.9	0.3-12.8	Zerin (1995)
Other rivers					
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 (1993)
Gumti	-	-	9-12.5	-	"
Havatia	-	-	-	8-11	"
Meghna	-	-	-	6.5-10.5	Shafi *et al.* (1978)
Yamuna, India	2-38.2	20-170	0.03-0.6	3.8-10.1	Rai (1974)
Nile, Egypt	4.5-10.0	35-68	0.03-3.0	6.8-13.6	Ahmed *et al.* (1986)
Kern, S. Cal.	-	14-35	0.03-1.0	7.1-10.6	Hill and Rai (1984)

PLATES
(PHOTOMICROGRAPHS OF PHYTOPLANKTON)

PLATE 1
(Photomicrographs)

Figs. 1, 3.	*Euglena sanguinea*
Figs. 2, 10, 15.	*Euglena acus*
Figs. 4, 8.	*Euglena retronata*
Fig. 5.	*Euglena geniculata*
Figs. 6, 9, 11, 16.	*Euglena chlamydophora*
Fig. 7.	*Euglena hemichromata*
Fig. 10.	*Euglena minima*
Figs. 12, 13, 14.	*Lepocinclis playfairiana*

All bars = 10 μm

Plate 1

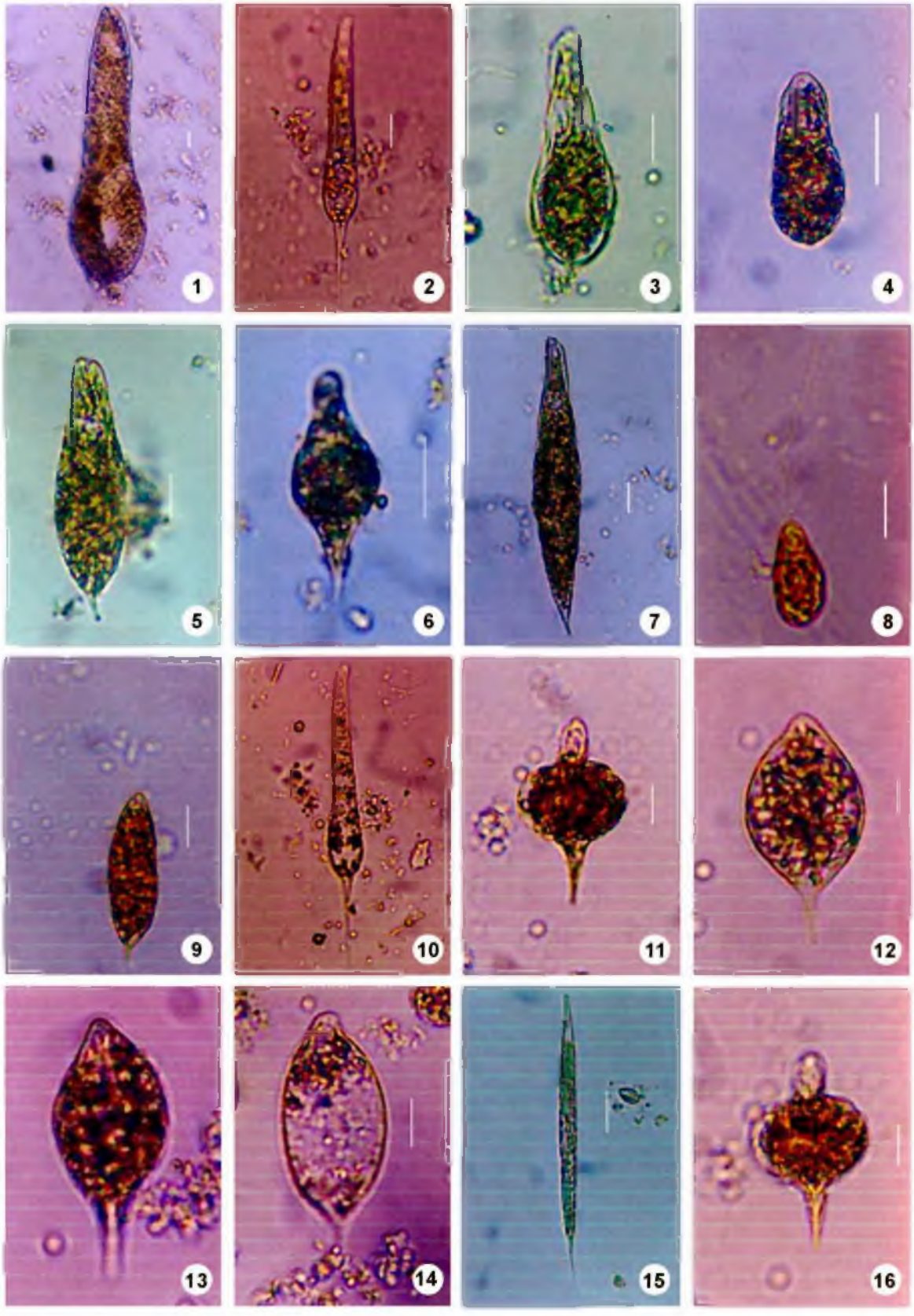


PLATE 2
(Photomicrographs)

Figs. 1, 9.	*Phacus ephippion*
Fig 2.	*Phacus undulatus*
Figs. 3, 5, 8, 10.	*Phacus tortus*
Fig. 4.	*Phacus longicauda* var. *attenuata*
Fig. 6.	*Phacus caudatus*
Fig. 7.	*Phacus curvicauda*
Fig. 11.	*Phacus platalea*
Fig. 12.	*Phacus meson*
Figs. 13, 14.	*Strombomonas verrucosa* var. *borystheniensis*
Fig. 15.	*Astasia longa*
Fig. 16.	*Trachelomanas superba*
Fig. 17.	*Trachelomonas dybowskii*
Fig. 18.	*Trachelomonas planctonica*

Plate 2

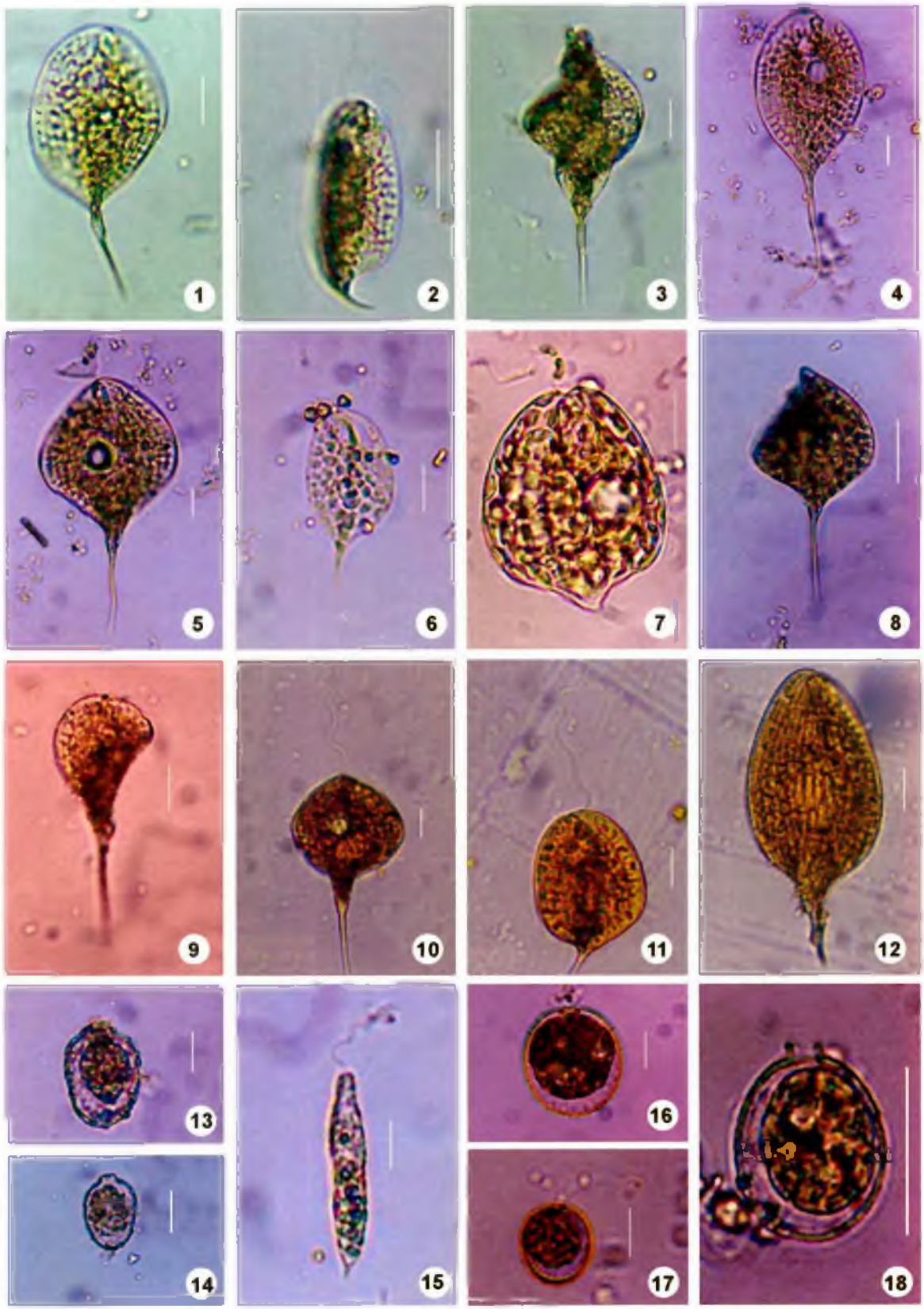


PLATE 3
(Photomicrographs)

Fig. 1. *Ankistrodesmus bibraianus*
Fig 2. *Pyrobotrys gracilis*
Fig 3. *Gonium pectorale* (Broken colony)
Fig 4. *Crucigenia quadrata*
Fig. 5. *Pediastrum duplex*
Fig. 6. *Closterium navicula*
Fig. 7. *Pediastrum tetras*
Fig. 8. *Scenedesmus opoliensis*
Fig. 9. *Micractinium pusillum*
Fig. 10. *Actinastrum hantzschii* var. *subtile*
Fig. 11. *Nephrochlamys subsolitaria*
Fig. 12. *Dictyosphaerium tetrachotomum*
Fig. 13. *Crucigenia tetrapedia*
Fig. 14. *Monoraphidium arcuatum*
Fig. 15. *Tetraedron gracile*
Fig. 16. *Eudorina elegans*
Fig. 17. *Scenedesmus acuminatus*
Fig. 18. *Pediastrum simplex*
Fig. 19. *Ankistrodesmus densus*
Fig. 20. *Coelastrum microporum*
Fig. 21. *Kirchneriella obesa*
Fig. 22. *Tetrastrum heteracanthum*
Fig. 23. *Pediastrum duplex*
Fig. 24. *Closterium limneticum*
Fig. 25. *Closterium macilentum*
Fig. 26. *Closterium calosporum*
Figs. 27-28. *Peridinium volzii*

Plate 3

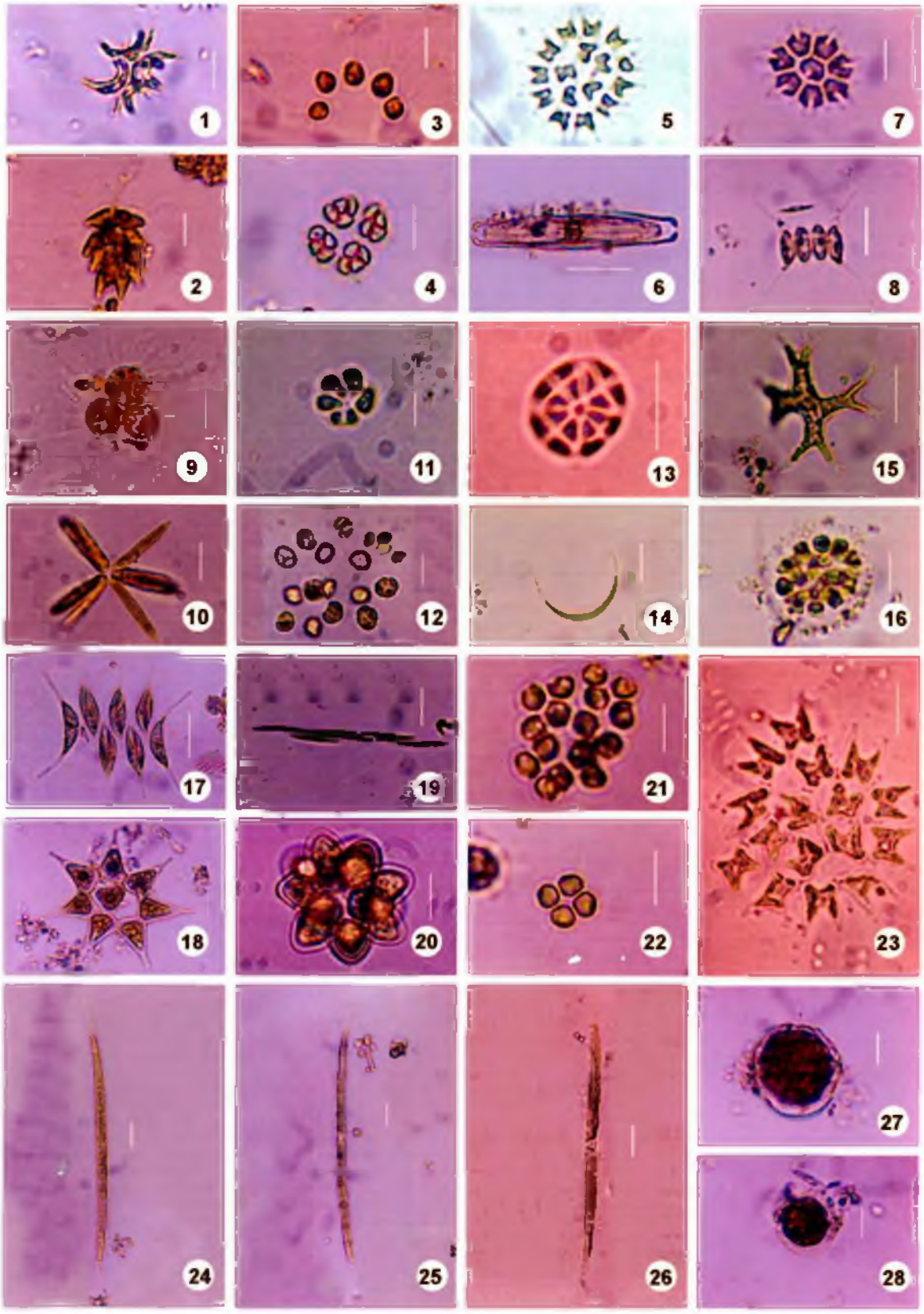


PLATE 4
(Photomicrographs)

Fig. 1.	*Cyclotella comta* var. *affinis*
Fig 2, 19.	*Navicula radiosa*
Fig 3, 18.	*Nitzschia acicularis*
Fig 4.	*Synedra acus*
Figs. 5, 24, 25.	*Coscinodiscus lacustris*
Figs. 6, 16.	*Achnanthes minutissima*
Fig. 7.	*Gyrosigma acuminatum*
Fig. 8.	*Rhodomonas minuta*
Figs. 9, 20.	*Gomphonema angustatum*
Figs. 10, 13-14.	*Melosira granulata*
Fig. 11.	*Cyclotella meneghiniana*
Fig. 12.	*Cycltella stelligera*
Fig. 15.	*Navicula pupula*
Fig. 17.	*Cryptomonas erosa*
Fig. 21.	*Surirella robusta* var. *splendida*
Fig. 22.	*Synedra tabulata*
Fig. 23.	*Synedra ulna* var. *oxyrhynchus*
Fig. 26.	*Nitzschia fruticosa*
Fig. 27.	*Gomphonema acuminatum*
Fig. 28.	*Navicula* sp. (Girdle view)

Plate 4

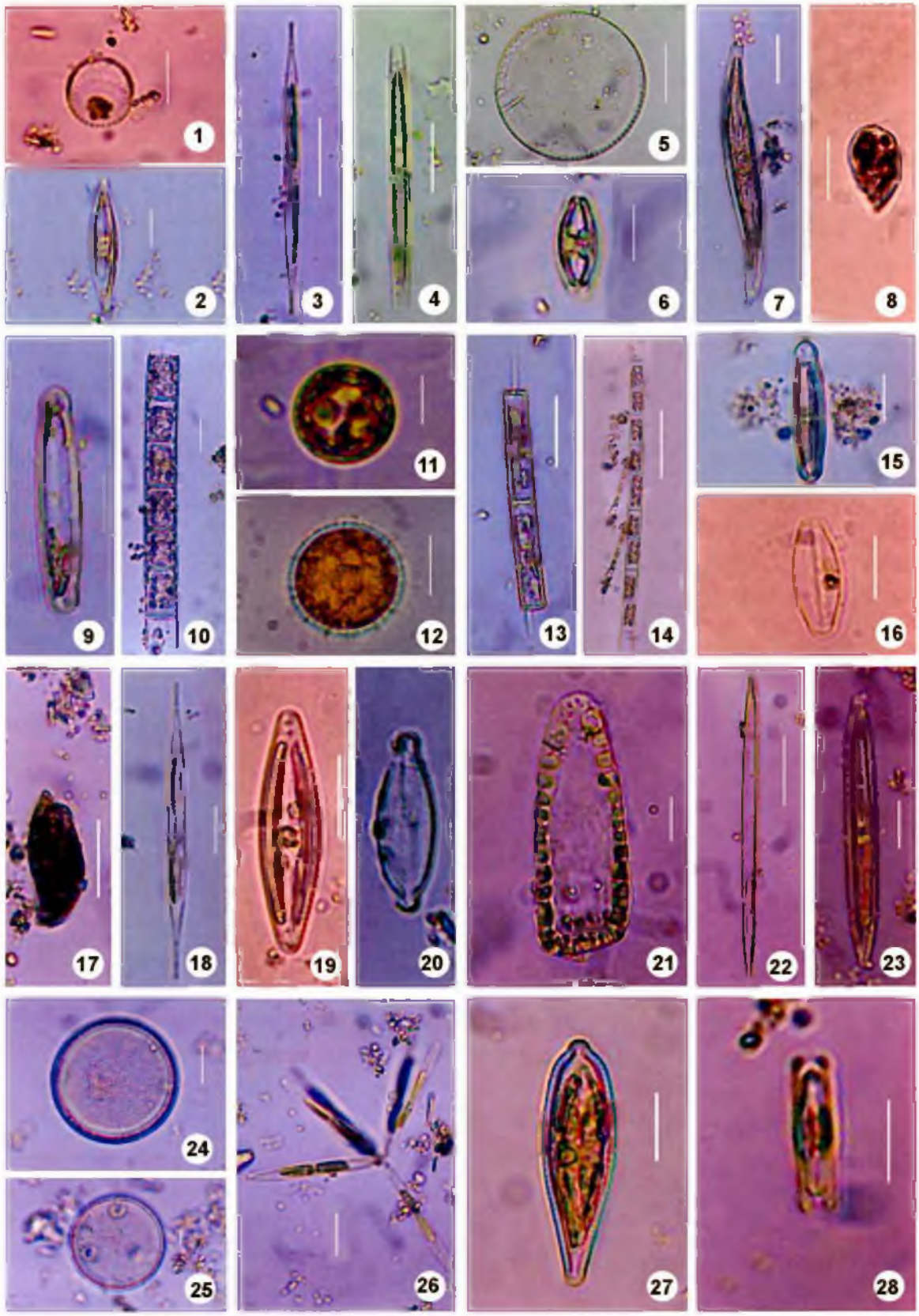


PLATE 5
(Photomicrographs)

Fig. 1. *Oscillatoria tenuis*
Fig. 2. *Oscillatoria agardhii*
Figs. 3, 4. *Anabaenopsis arnoldii* var. *indica*
Fig. 5. *Microcystis aeruginosa* f. *flos-aquae*
Fig. 6. *Pseudanabaena schmidlei*
Fig. 7. *Oscillatora raoi*
Fig. 8. *Merismopedia glauca*
Fig. 9. *Merismopedia minima*
Fig. 10. *Gomposphaeria lacustris*
Fig. 11. *Oscillatoria acutissima*
Fig. 12. *Chroococcus dispersus*
Fig. 13. *Synechocystis aquatilis*
Fig. 14. *Pseudanabaena mucicola*
Fig. 15. *Pelonema aphane*
Fig. 16. *Arthrospira platensis* var. *non-constricta*
Fig. 17. *Anabaena constricta*
Fig. 18. *Raphidiopsis indica*

Plate 5

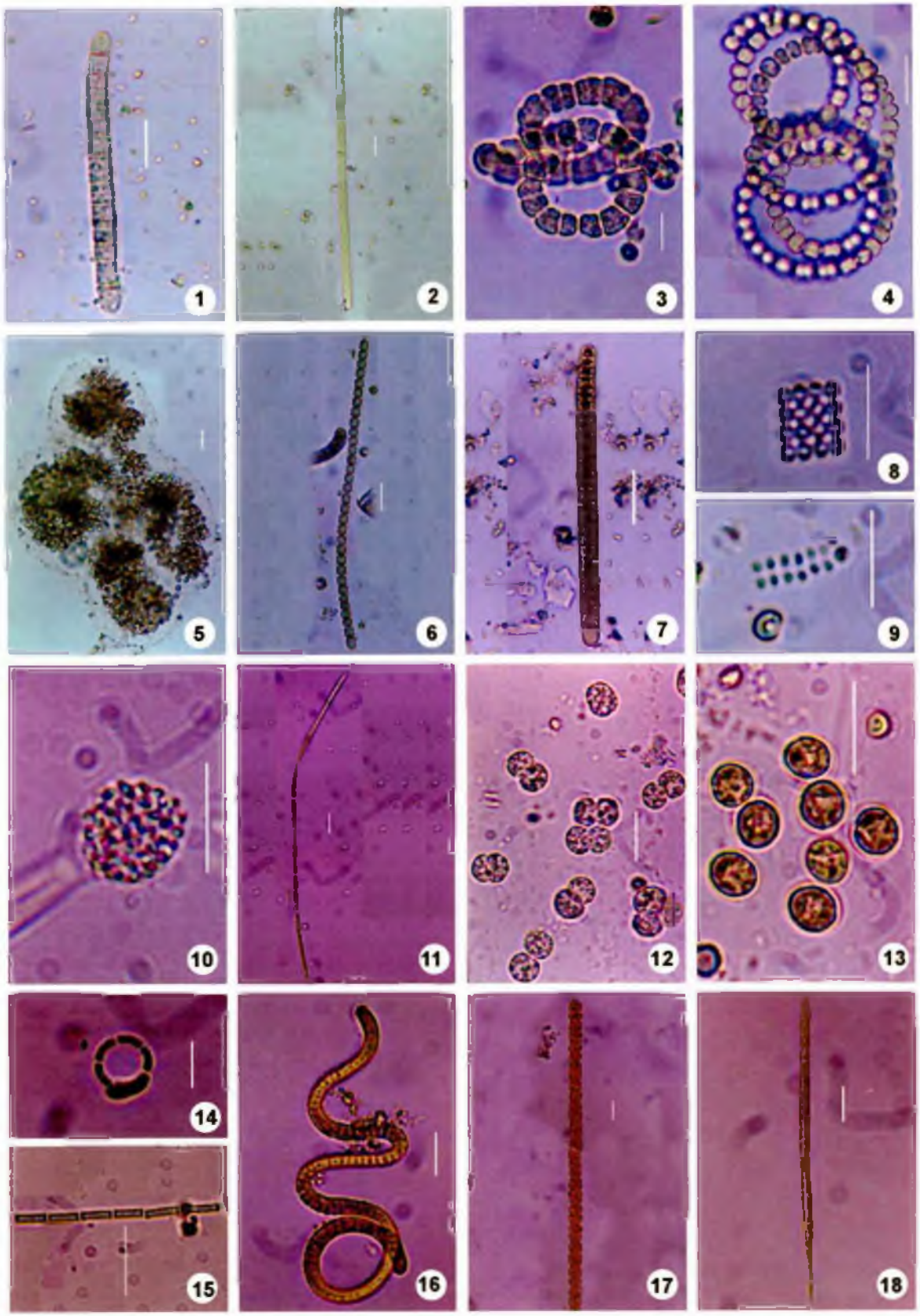


Plate 6
(Photomicrographs)

Fig. 1. *Euglena klebsii*
Fig. 2. *Euglena megalithus*
Fig. 3. *Euglena convoluta*
Fig. 4. *Euglena stellata*
Fig. 5. *Euglena longoflagellata*
Fig. 6. *Euglena anabaena* var. *minor*
Fig. 7. *Euglana velata*
Fig 8. *Euglena gracilis*
Fig 9. *Euglena simulacra*
Fig. 10. *Euglena acus* var. *angularis*
Fig . 11. *Euglena acus* var. *detonii*
Fig. 12. *Euglena tristella*
Fig . 13. *Strombomonas ovalis*
Figs 14-16. *Strombomonas costata*
Fig 17. *Strombomonas undulata*
Fig. 18. *Lepocinclis ovum* fa. *Typica*
Figs 19-20. *Lepocinclis glabra*
Figs 21-22. *Lepocinclis gracillima*

Plate 6

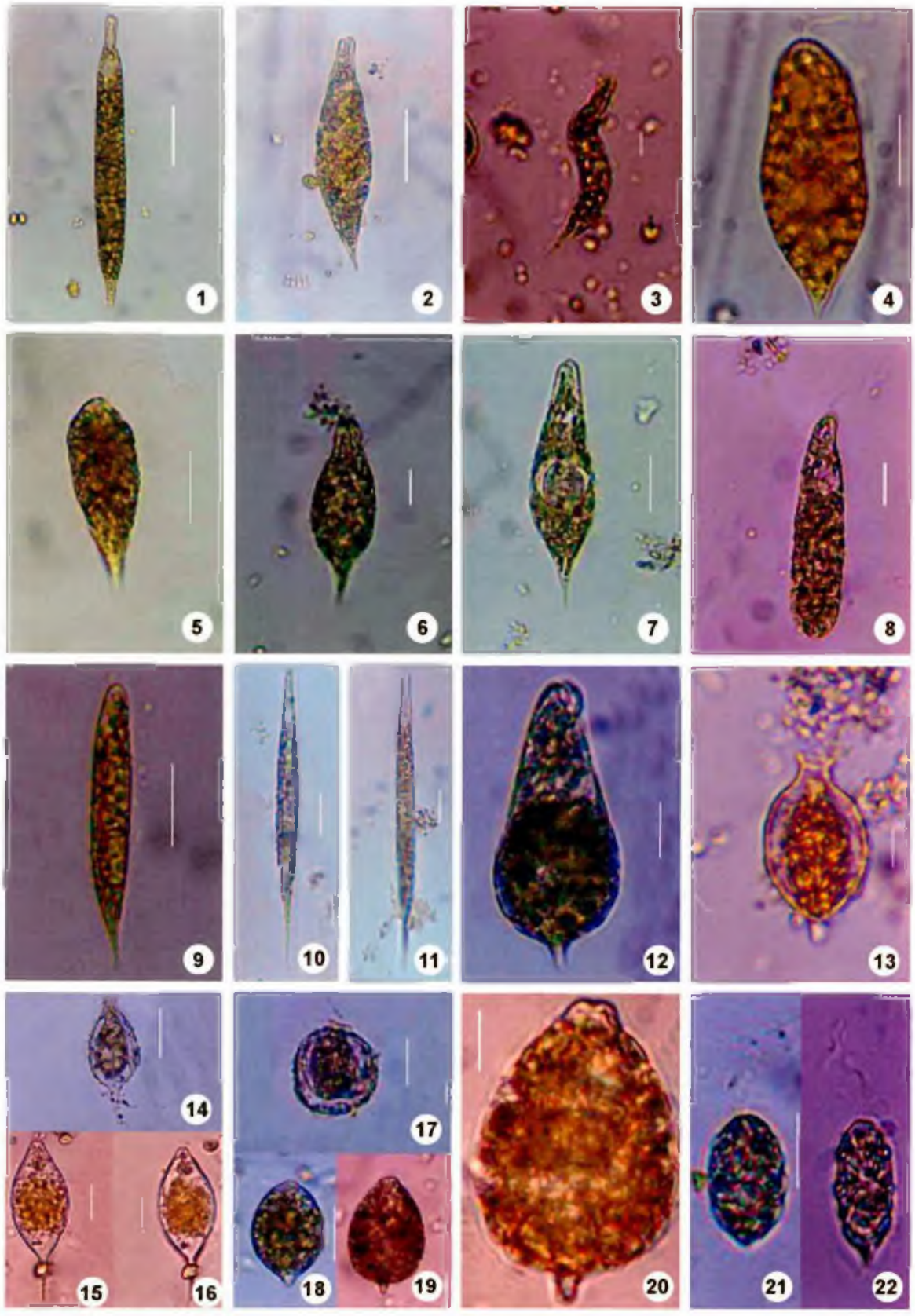


Plate 7
(Photomicrographs)

Fig 1. *Phacus prunoideus*
Fig 2. *Phacus suecicus*
Fig 3. *Phacus longicauda*
Fig 4. *Phacus angulatus*
Figs. 5, 10. *Phacus tortus* var. 1 var. nov.
Fig. 6. *Phacus glaber*
Figs. 7-8. *Phacus tortus* var. 2 var. nov.
Fig. 9. *Phacus trimarginatus*
Figs. 11-12. *Phacus pseudoplatalea*

Plate 7

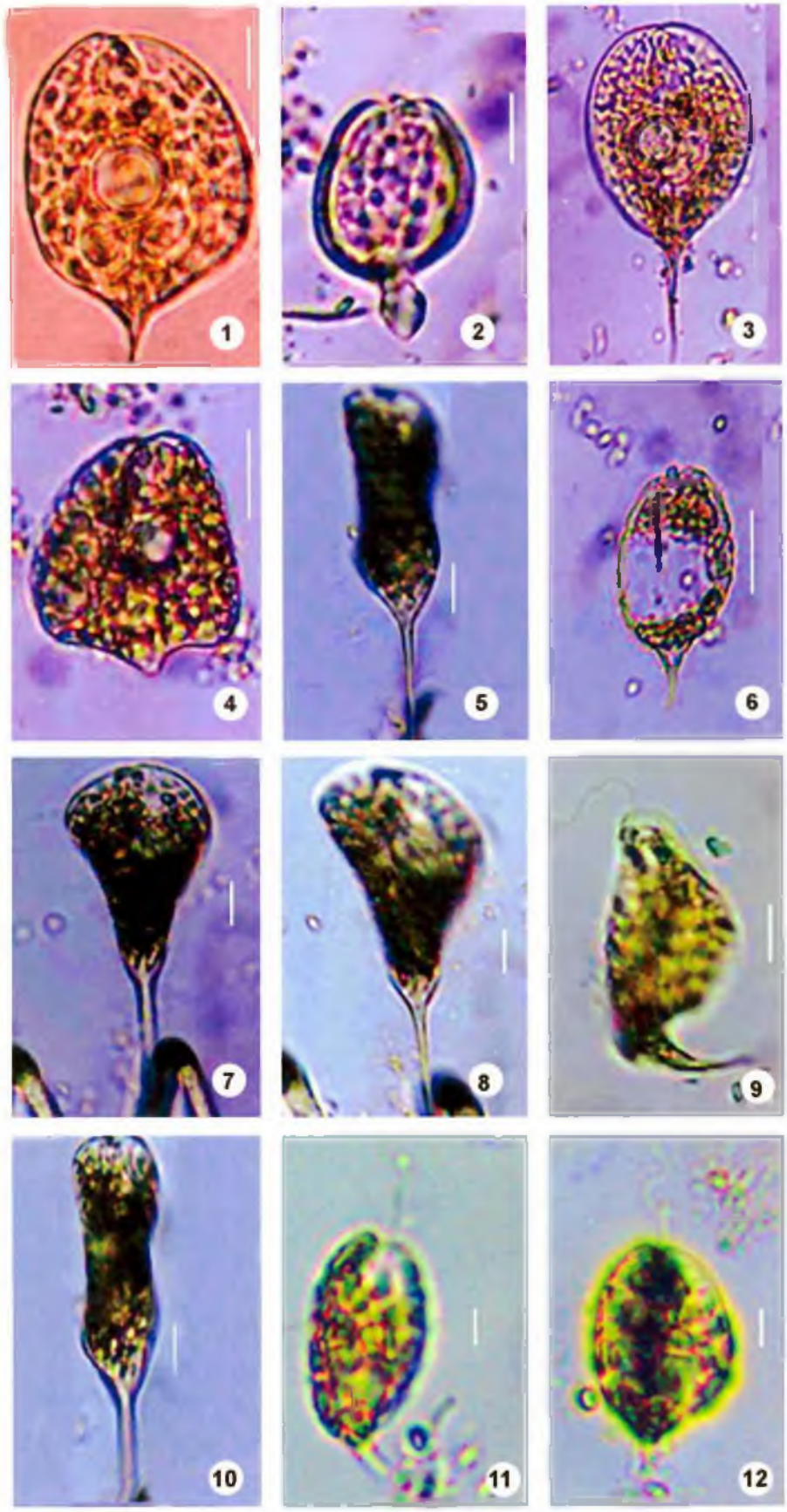


Plate 8
(Photomicrographs)

Figs. 1, 5. *Scenedesmus verrucosus*
Figs. 2, 11. *Scenedesmus obtusus*
Fig. 3. *Scenedesmus opoliensis* var. *mononensis*
Figs. 4, 6. *Scenedesmus ovalternus*
Fig. 7. *Scenedesmus acuminatus* var. *elongatus*
Fig. 8. *Scenedesmus opoliensis* var. *polycostatus*
Fig. 9. *Scenedesmus acuminatus* var. *acuminatus*
Fig. 10. *Scenedesmus lunatus*
Fig. 12. *Scenedesmus bicaudatus*

Plate 8

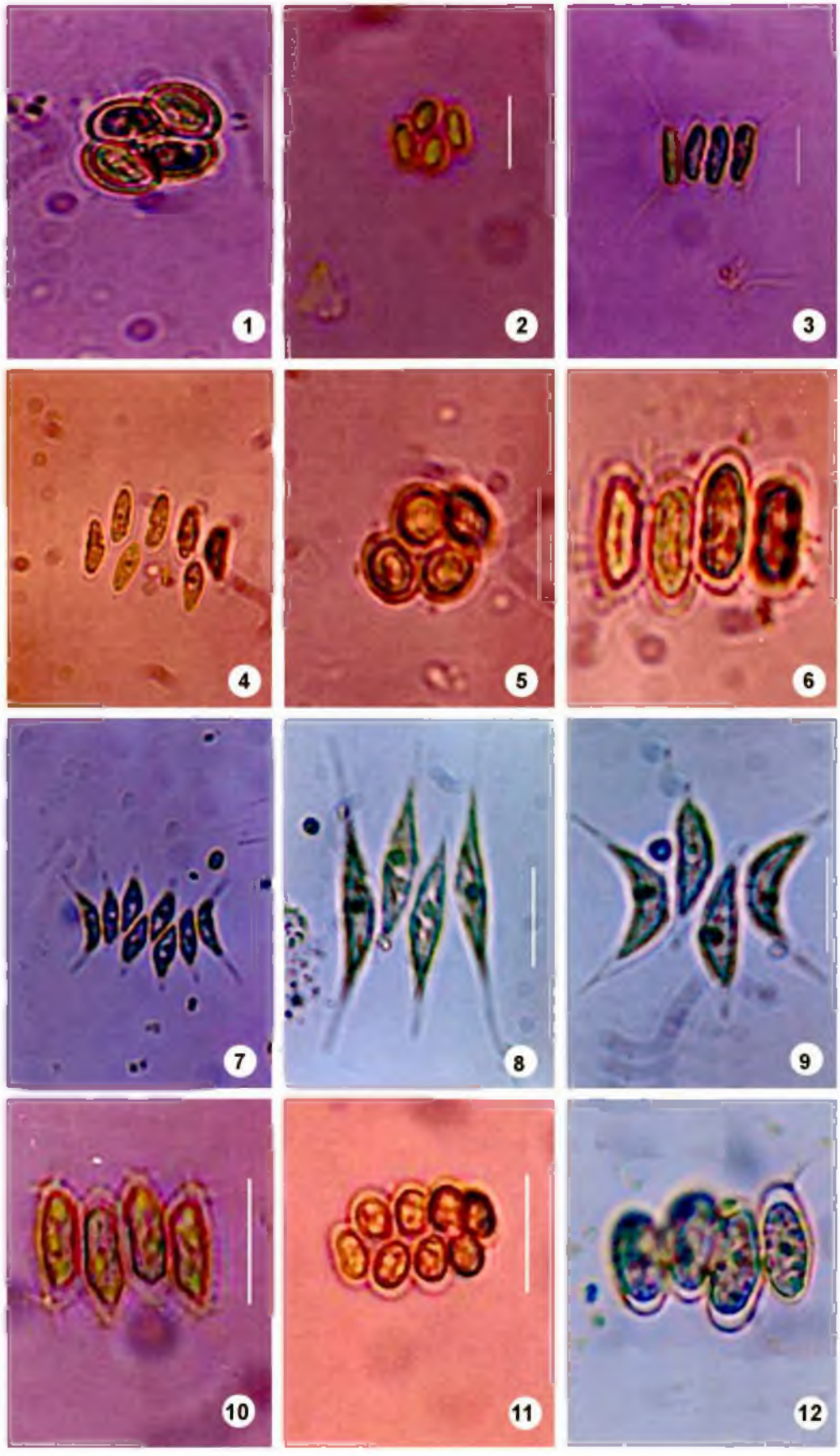


Plate 9
(Photomicrographs)

Fig. 1.	*Oocystis irregularis*
Fig. 2.	*Oocystis natans* var. *major*
Fig. 3.	*Kirchneriella contorta*
Fig. 4.	*Tetraedron triangulare*
Fig. 5.	*Monoraphidium griffithii*
Fig. 6.	*Coelastrum microporum* var. *octaedricum*
Fig. 7.	*Coelastrum astroideum*
Figs. 8-9.	*Pediastrum duplex* var. *subgranulatum*
Fig. 10.	*Radiococcus planctonicus*
Fig. 11.	*Troischia* sp.
Figs. 12-13.	*Lagerheimia balatonica*

Plate 9

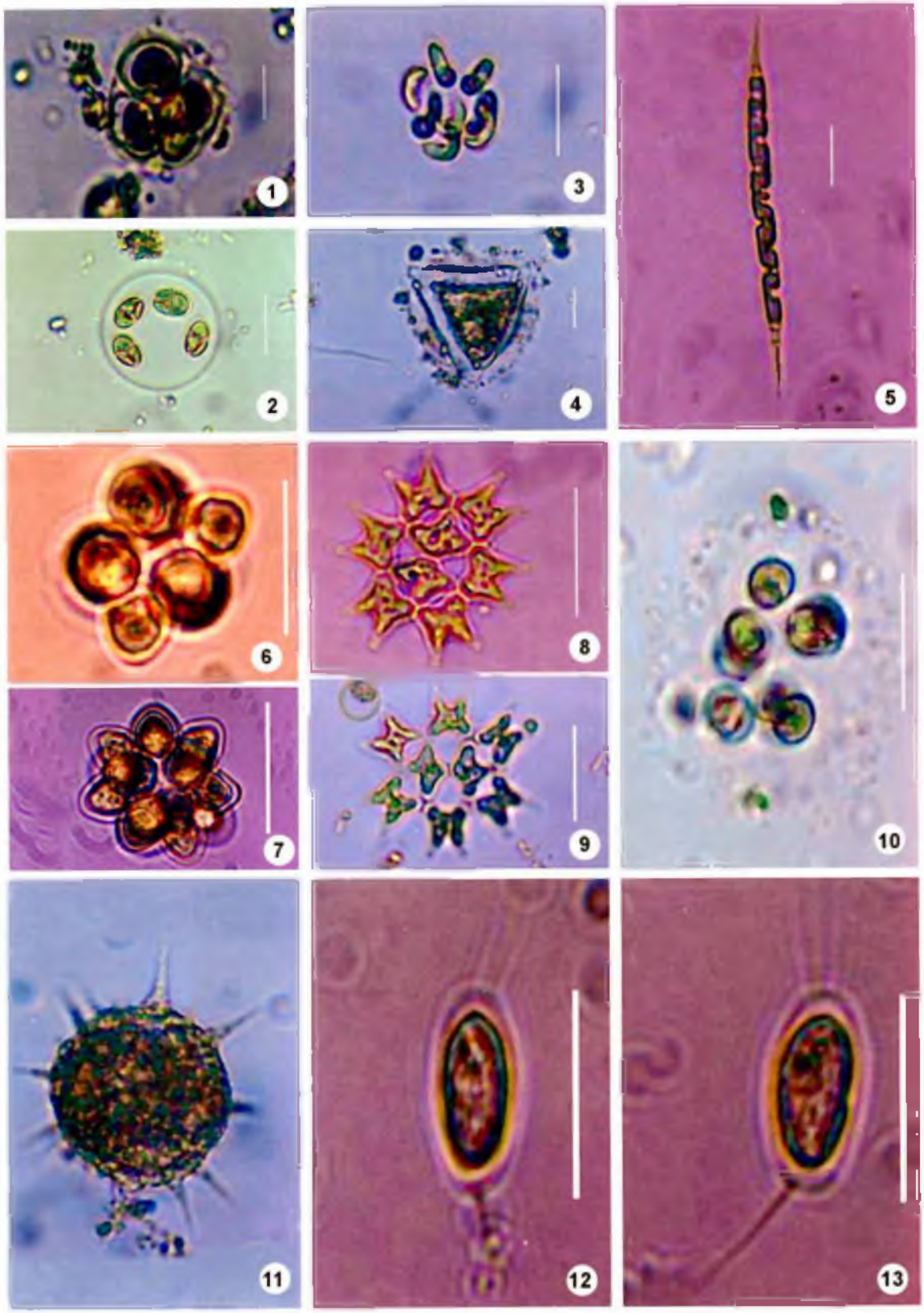


Plate 10
(Photomicrographs)

Fig 1.	*Chlamydomanas impressa*
Fig 2.	*Pyramidimonas quadricauda*
Fig 3.	*Hyaliella polytomoides*
Fig 4.	*Synedra acus* var. *angustissima*
Fig 5.	*Nitzchia elgei*
Figs. 6-7.	*Nitzschia dissipata*
Figs. 8-9.	*Cryptomonas erosa* var. *reflexa*
Figs. 10-11.	*Chroomonas breviciliata*
Fig 12.	*Chroomonas nordstedtii*
Fig 13.	*Navicula festiva*

Plate 10

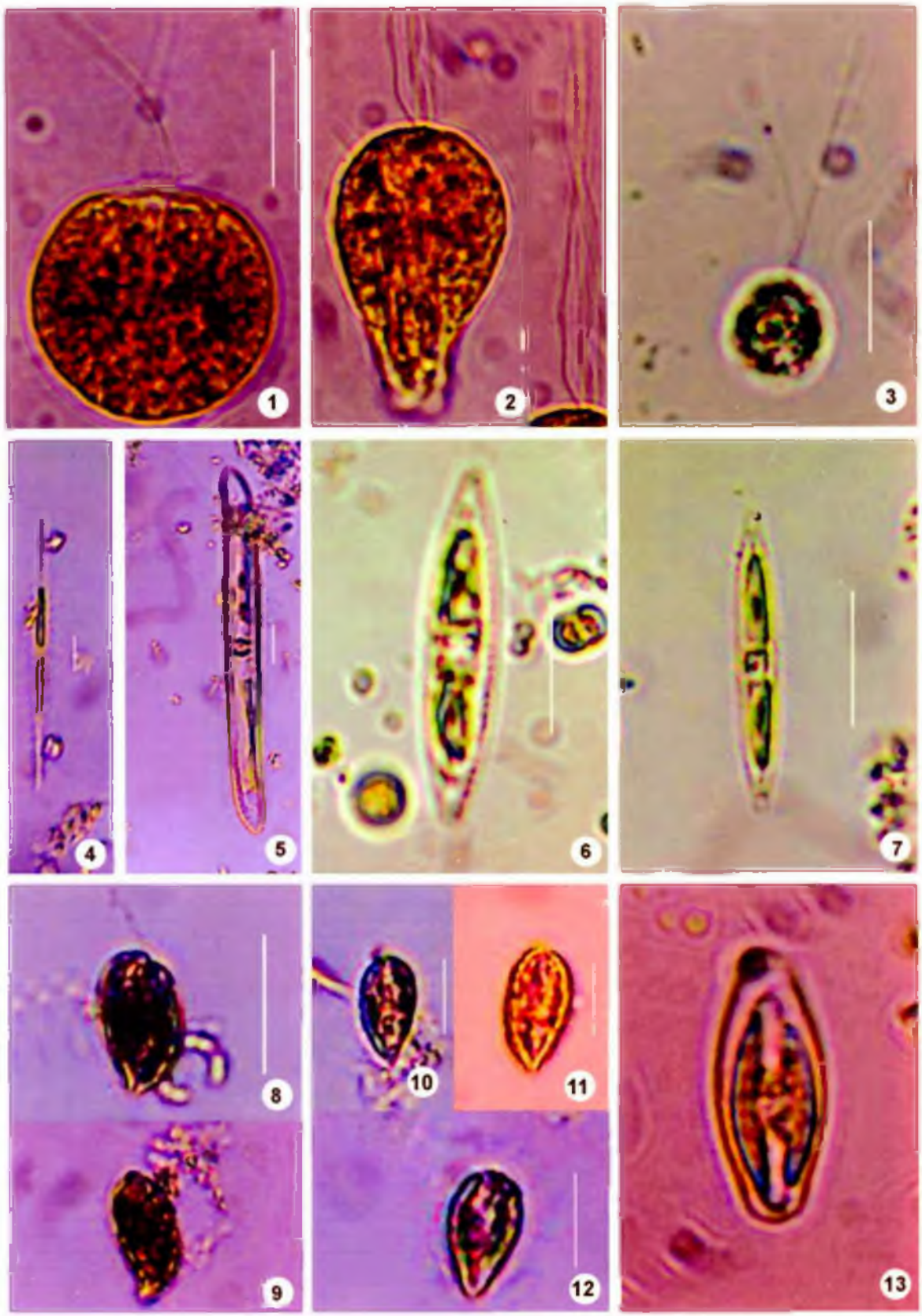


Plate 11
(Photomicrographs)

Fig 1. *Closterium pseudospirotaenium* var. *variable*
Fig 2. *Closterium acutum* var. *variable*
Fig 3. *Closterium idiosporum*
Figs 4-6. *Closterium gracile*

Plate 11

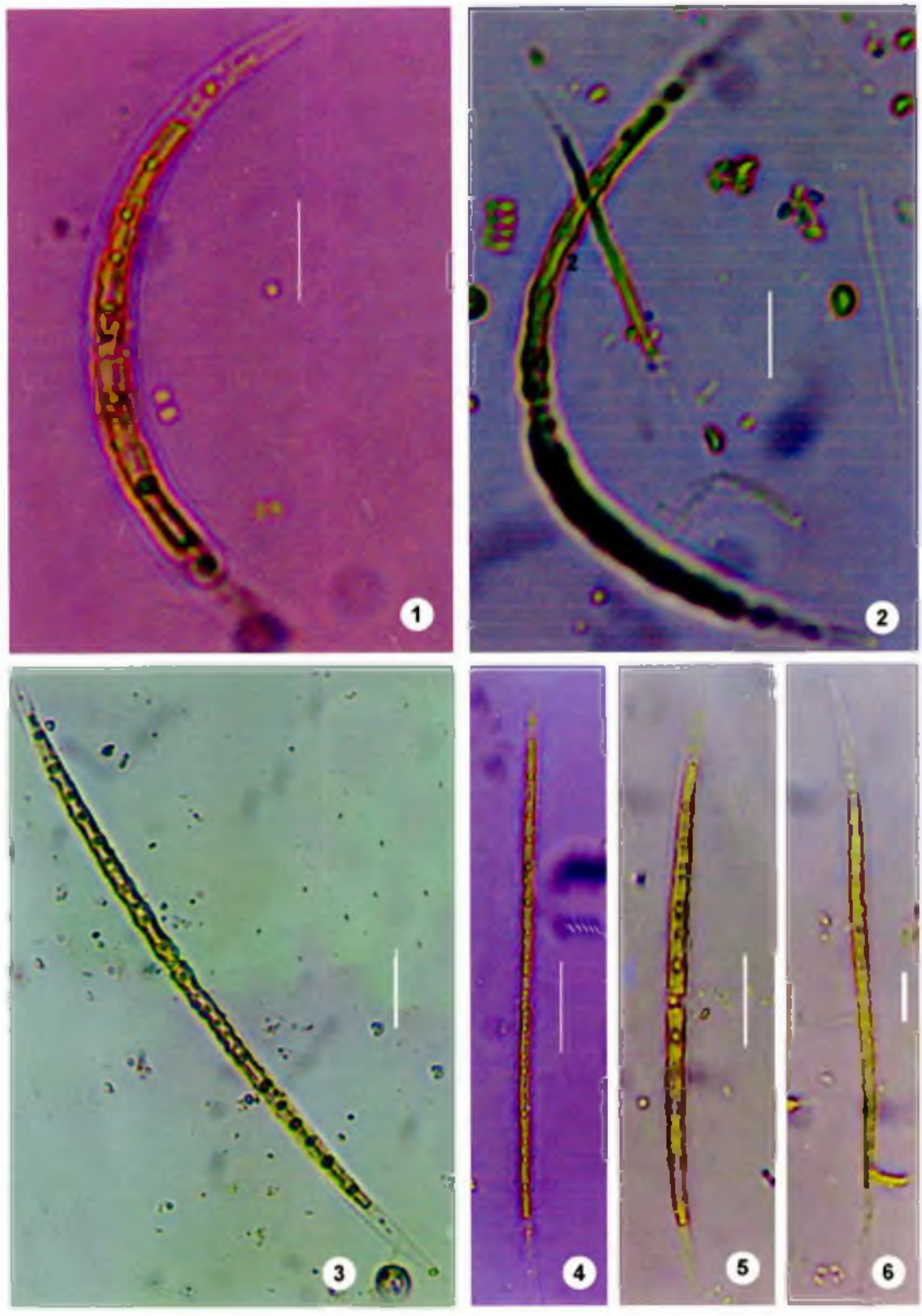


Plate 12
(Photomicrographs)

Fig 1. *Arthrospira khannae*
Fig 2. *Raphidiopsis mediterranea*
Fig 3. *Pseudanabaena crassa*
Fig 4. *Pseudanabaena constricta*
Fig 5. *Pelonema tenue*
Fig 6. *Anabaena macrospora* var. *gracilis*
Figs 7-8. *Chroococcidiopsis indica*
Fig 9. *Synechococcus cedrorum*
Fig 10. *Arthrospira spirulinodes*

Plate 12

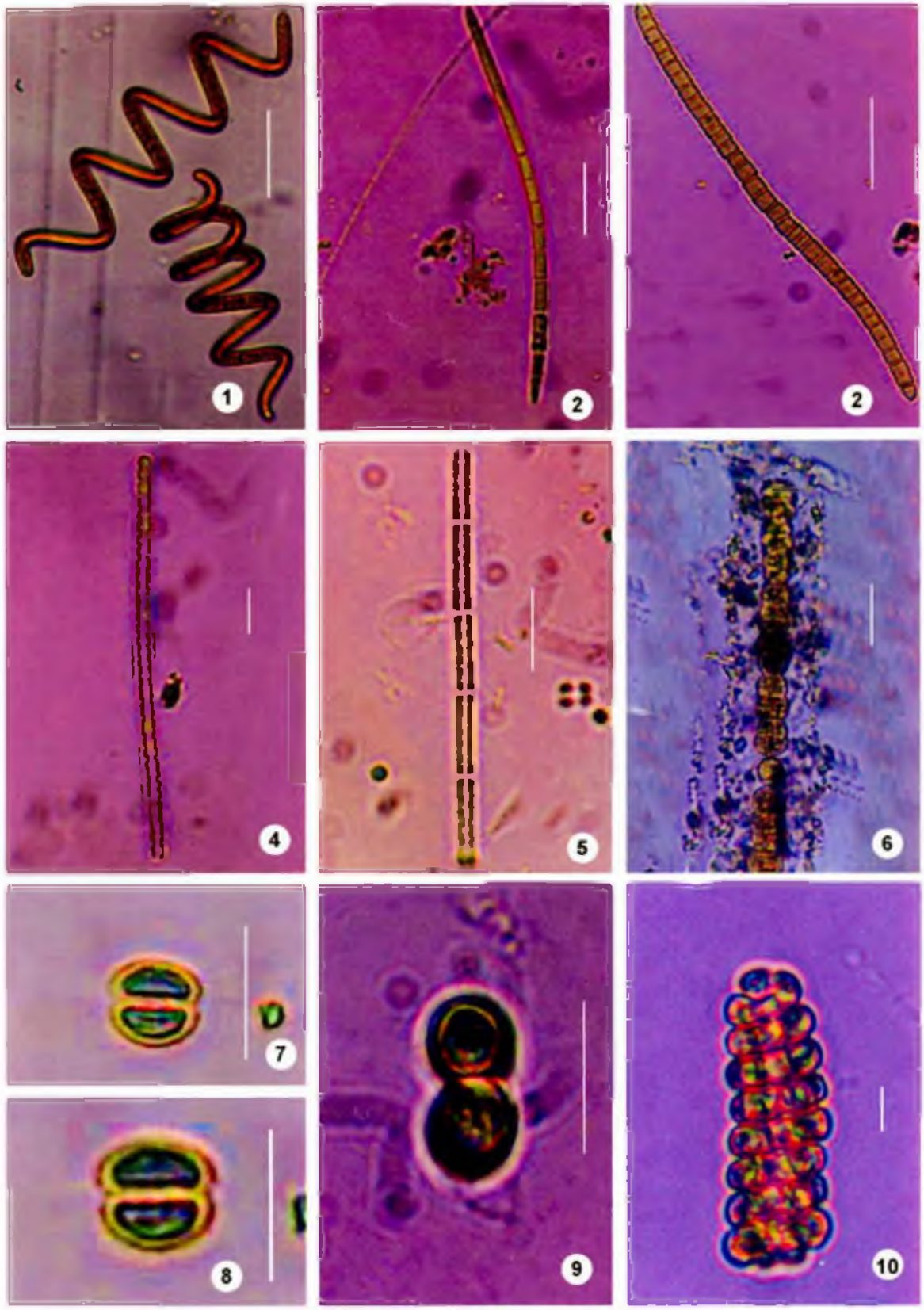
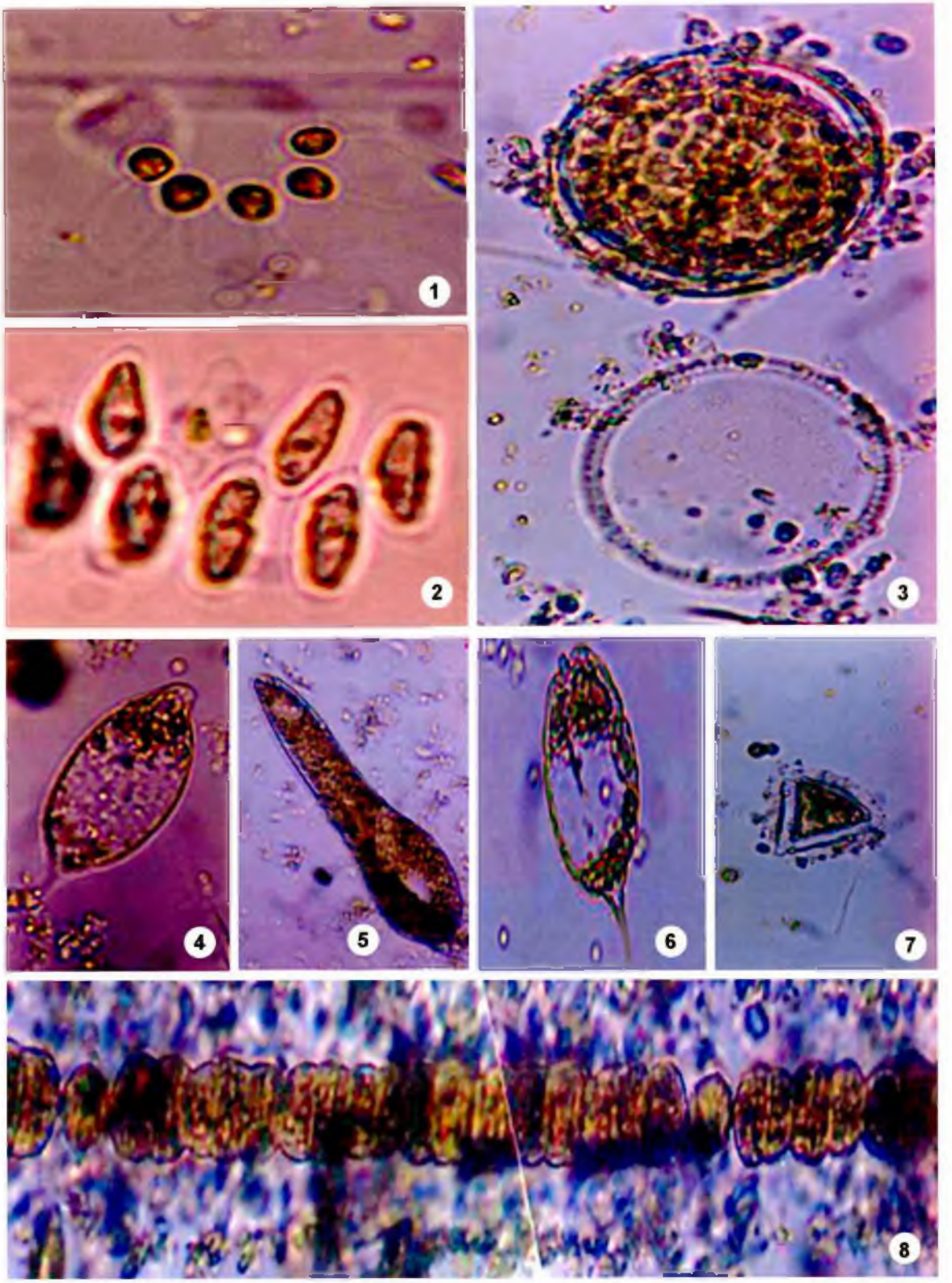


Plate 13
(Photomicrographs)

Showing the abnormal growth of phytoplankton due to excessive pollutant load.

1. Incomplete growth of *Gonium pectorale* colony
2. Incomplete growth in the colony of *Scendesmus* sp.
3. Frustule of a diatom *Coscinodiscus* sp. with attached debris, Lose of photosynthetic surface.
4. Abnormal growth of *Lepocinclis* sp.
5. Abnormal growth of *Euglena* sp.
6. A broken cell of *Phacus* sp.
7. A cell of *Tetraedron* sp. surrounded by particulate matter losing photosynthetic surface.
8. A filament of *Anabaena* sp. crowded by particulate matter losing photosynthetic surface.

Plate 13



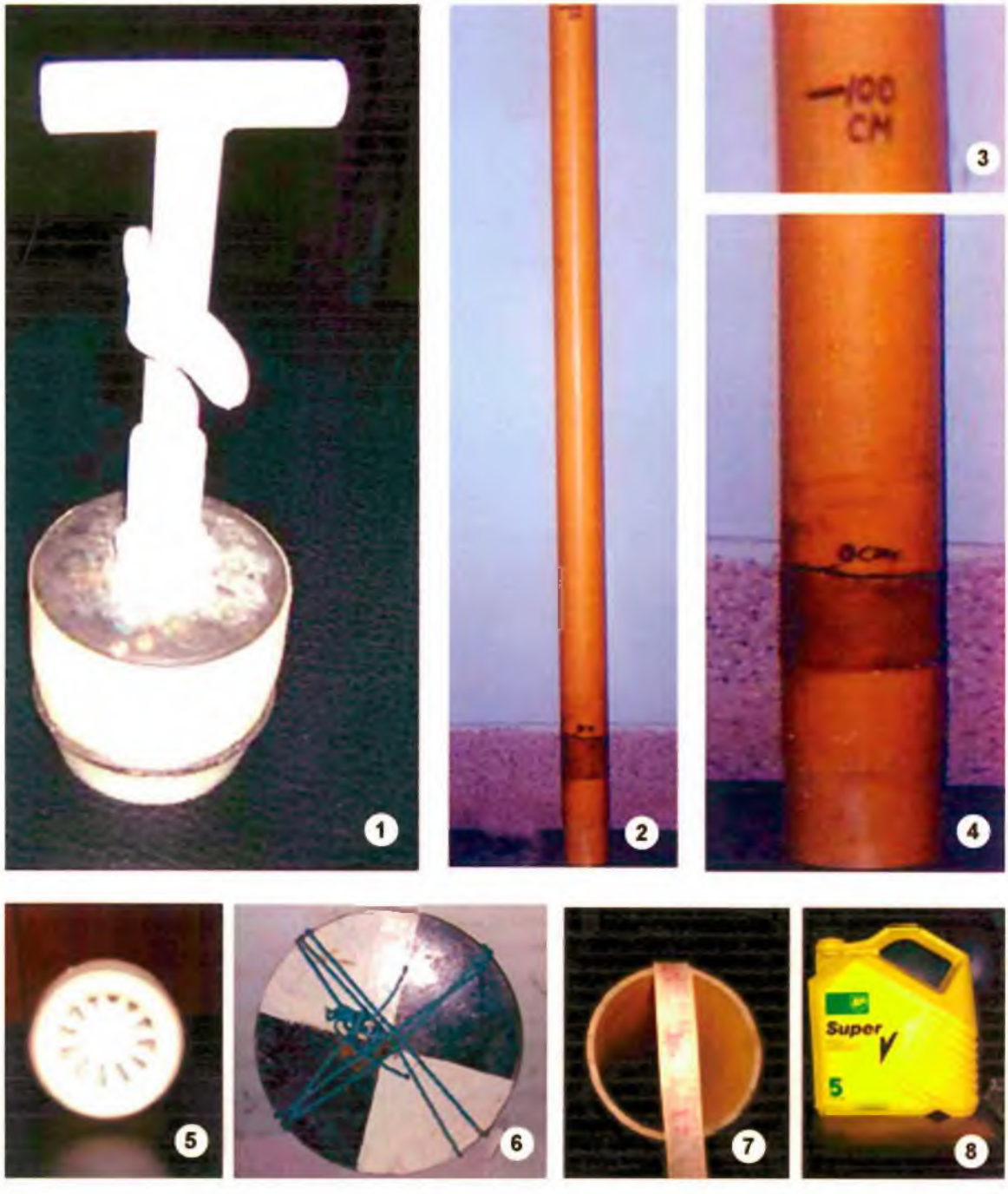
PLATE

(PHOTOGRAPHS OF SOME EQUIPMENTS)

Plate 14
(Photographs of some *in situ* sampling equipments)

Fig. 1, 5. Check valve (1-side view, 5- inner bottom view).
Fig. 2-4, 7. PVC pipe (2-4 side view, 7- dia of the pipe).
Fig. 6. Secchi disc.
Fig. 8. 5 L capacity plastic carboy for collecting water sample.

Plate 14



Chapter 5

DISCUSSION

DISCUSSION

The present research work has been undertaken at a time when there was a great awareness among public regarding the severe deterioration of physical, chemical and biological water quality of the rivers surrounding Dhaka Metropolis. The studied river Buriganga is one of those affected rivers and the stations from where the present data were collected were subjected to direct threats of water pollution. To assess the water quality at the stations concerned, a total of 15 parameters were regularly measured from the three stations for 2 years. These are phytoplankton quality and quantity, biomass of chl-a and phaeopigment, air and water temperature, Secchi depth, pH, conductivity and alkalinity, DO, TDS, SRS, NO_3-N and SRP. The present discussion is based on the composition, concentration, seasonality and diversity of the above mentioned parameters together with their relationships among themselves and their comparison with other similar environments studied else where.

The phytoplankton diversity in the river Buriganga is represented by 7 algal classes under which a total of 180 species were recorded. Islam and Zaman (1975) recorded 194 species from the same localities. Quantitatively nearly a 7% drop in the species number has been evident from this study when the result is compared with Islam and Zaman (1975). However, qualitatively a big difference is observed when the results from these two studies (present study and Islam and Zaman, 1975) are compared. On an average basis, phytoplankton recorded from the three studied stations under the present investigation, Chlorophyceae (green algae) occupied 39% where as in the study of 1975 by Islam and Zaman Chlorophyceae dominated nearly 56% (Table 9). Even in the composition, dominant phytoplankton taxa of Chlorophyceae under the present investigation were represented mainly by the members of chlorococcoid and volvocalean forms. On the other hand in 1975 the class was represented mostly by desmids.

In the present investigation only 9 species of desmids were recorded. The total number of desmids recorded by Islam and Zaman (1975) were about 54. From this, it is clear that though a shift in the total number of species is small, a bigger shift has been occurred in the quality of phytoplankton species in the river Buriganga during the last near about 30 years. The total number of phytoplankton species was recorded in Mouri river Khulna; Ganges, India; Nile, Egypt and Shatt-al-Arab, Iraq were 56, 125, 141 and 107, respectively (Mahmud *et al.* 2007, Siddique *et al.* 1980, Ahmed *et al.* 1986, Huq *et al.* 1978). Table 9 also depicts that among those rivers except Shatt-al-Arab all were dominated by Chlorophyceae, the former river is dominated by diatoms only. So, the total number of species recorded in the river Buriganga (180) is closer to Ganges and Nile (125 and 141).

At different stations of Buriganga itself, a total of 65, 60 and 61 genera were recorded from ST-1, ST-2 and ST-3, respectively (Table 1). From this result it is evident that the total number of species recorded in each station decreased chronologically i.e., 108, 82 and 91 in ST-1, ST-2 and ST-3, respectively. A gradual decrease in the species number in the downstream might be due to the improvement in the self purifying capacity of the river. Zerin (1995) reported 28 genera of phytoplankton under five classes from the ST-2 of the present investigation. The percentage distribution was Cyanophyceae 33%, Bacillariophyceae 27%, Chlorophyceae 23%, Euglenophyceae 11% and Cryptophyceae 5%. In the present investigation the number of genera collected at ST-2 was 60 and the percentage distribution was Chlorophyceae 43%, Cyanophyceae 22%, Bacillariophyceae 20%, Euglenophyceae 10% and Cryptophyceae 5%. In the study of Zerin (1995) Cyanophyceae yielded highest number of phytoplankton genera but in the present investigation it was Chlorophyceae.

Among different classes of phytoplankton, Chlorophyceae dominated all the three stations and occupied closer to 40% of the total. *Oscillatoria raoi*, *Merismopedia glauca*, and *Pelonema aphane* from Cyanophyceae; *Monoraphidium griffithii*, *Scenedesmus ovalternus* and *Cosmarium impressulum* from Chlorophyceae; *Cyclotella atoma* and *Melosira distans* from Bacillariophyceae and *Euglena acus* from Euglenophyceae were recorded as most dominant phytoplankton in all the sampling stations. Out of the 180 recorded species of phytoplankton in the present investigation, 110 species were found as common for Bangladesh and 70 species will be new report for Bangladesh. The unreported species for Bangladesh belongs to 27 species each for Euglenophyceae and Chlorophyceae, 4 species for Bacillariophyceae, 9 species for Cyanophyceae and 3 species for Cryptophyceae.

The seasonal high density of phytoplankton was found 137×10^3 ind/L at ST-1 in summer and 87×10^3 ind/L at ST-3 in monsoon and 1×10^3 ind/L at ST-3 in autumn. Monthly mean species number recovered shows wide range of variation (ST 1: 28-54; ST 2: 17-36, ST 3: 27-45). Phytoplankton belonging to green and blue-green were found dominant on most of the occasions at there sampling points except mid summer (July-August) when the members of Bacillariophyceae showed their dominance. Islam *et al.* (1974) recorded total phytoplankton an overall range of 0.3-25000 ind/L in the river Buriganga. Maximum production was recorded during summer and monsoon and minimum was recorded during autumn and winter. They described that high light intensity causes increase of depth of illuminated region resulting the increase of photosynthetic activity of 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 lack of upwelling of the nutrients and increase of organic load.

To determine the water condition of the river by using algal flora as indicator, a relationships between species and individuals in aquatic environments have frequently been summarized by using diversity index (H') (Shanon and Weaver 1963). The diversity index (H') of phytoplankton as has been calculated for different stations in the present investigation showed a range of 2.0-4.6 byt/ind, 1.8-4.2 byt/ind, 1.4-4.7 byt/ind in ST-1, ST-2 and ST-3, respectively. The mean values for individual stations were ST-1: 3.80 byt/ind, ST-2: 3.25 byt/ind and ST-3: 3.63 byt/ind. According to Wilhm and Dorris (1968) there exists a relationship between (H') and the pollution status of river ecosystems. A (H') index value > 3 will indicate 'Clean water', 1 - <3 indicates moderate pollution and <1 indicates heavy pollution (Wilhm and Dorris 1968). The reduction in number of species and the increase in number of individuals that characterized polluted areas results in significant decrease in values of diversity (Wilhm 1970). Applying this concept in the diversity index data of present investigation it could be said that on an average basis the diversity index (H') was little above 3 for all the stations. However, their seasonality showed a minimum value closer to 1. So, a moderate to high pollution level has been prevailing in the three studied stations of the river Buriganga. Islam *et al.* (1974) reported mildly to moderately polluted state considering the amount of pollution and the algal population for the river Buriganga.

The monsoon is a flow pattern of general atmospheric circulation prevailing in southern Asia. Bangladesh enjoys a single but comparatively long (c 5 months duration) monsoon with an annual mean rainfall 2500 mm. A well marked reduction in alkalinity, conductivity, TDS, SRP, SRS and biomass has been observed during monsoon (Table 3 and Table 4). This means heavy monsoonal rainfall actually dilutes the river water, help to increase water flow and might have enhancing the self purification capacity as well.

The maximum range of air temperature in the present study area was 18-35°C. Zaman (1991) showed the annual mean values of some climatological variables for Dhaka station, where air temperature was recorded as 21.8-30.3°C. In Halda river air temperature was obtained between 23.0-33.0°C. So, it could be said that air temperature does vary 3-5°C among the places as discussed above.

The range of water temperature in all the three studied stations was 20-34°C. Abed (1995) recorded 20-32°C from the river Turag. DOE (1993) recorded 21-32°C from the river Sitalakhya, 20-31°C from the river Meghna. Ahmed et al. (1986) recorded a range of water temperature from 14-27°C from the river Nile in Egypt. Hill and Rai (1984) recorded water temperature ranging from 10-22°C for the river Kern, USA. Considering ranges of water temperature as mentioned above it has been seen that the difference between the maximum and minimum record of water temperature ranged from 11-14°C.

The water transparency (Zs) of the river Buriganga ranged 11-54 cm at ST-1, 17-60 cm at ST-2, and 21-83 cm at ST-3. Abed (1995) recorded 20-50 cm from the river Turag. Zerin (1995) recorded 17-95 cm from the river Buriganga near at ST-2 of the present investigation. This comparison reveals that at least at ST-2 of the present investigation there is slight drop in the transparency after 1995. Transparency of water (Zs) is affected mainly due to the increase in the seston load. So, it could be said that the seston load in the form of pollutants might have increased in the river water. However, a gradual improvement in the loading of pollutants has been noticed from upstream towards downstream zones of the river as it has been indicated by a gradual improvement of Zs from ST-1 to ST-3 (Table 8). Shafi *et al.* (1978) recorded Secchi depth a range of 20-140 cm in Meghna river near Dhaudkandi. So, under water light climate is poorer in Buriganga when data compared with Meghna river.

The biomass of phytoplankton as chl-a concentration showed a range of 2-160 µg/L. Abed (1995) recorded 1-163 µg/L from the river Turag. Zerin (1995) recorded 2-142 µg/L from the river Buriganga at ST-2 of the present investigation. These values are very close to each other refelecting a general trend of phytoplankton biomass in Turag and Buriganga. The highest biomass value (142-163 µg/L) indicates an eutrophic nature of the above mentioned rivers. Contrary to this an oligotrophic nature is being evident in the river Kern, USA (chl-a 1.3-13.8 µg/L) (Hill and Rai 1984).

Phaeopigment concentration in the present investigation ranges from 0-334 µg/L. Abed (1995) recorded 0.1-37 µg/L from the river Turag. Zerin (1995) recorded 0.1-43 µg/L from the river Buriganga at ST-2 of the present investigation. The present value showed about 9 times higher in concentration than previous study discussed above except ST-1 (0-39 µg/L) where the value showed similarity with the data presented in Abed (1995) and Zerin (1995). So, there are noticeable difference in the phaeopigment concentration (ST-1 and ST-2). Hill and Rai (1984) found 1.3-4.3 µg/L phaeopigment the maximum of which is 82 times lower than the present record at ST-1 and ST-2.

Conductivity of water in the river Buriganga showed more or less similar trends for all the sampling points. Conductivity remains low during monsoon and attained higher during lean period when no flow condition prevail in the river. Seasonally highest conductivity value 710 µS/cm was found during summer while lowest 128 µS/cm recorded during monsoon. The conductivity values recorded at ST-2 by Zerin (1995) and in river Turag by Abed (1995) were 110-640 µS/cm and 100-890 µS/cm, respectively. From this observation it could be said that at ST-2 of the present investigation an increase in the conductivity of water has occurred. This clearly indicates an increased loading of ions in the river water. However, a decrease in the conductivity value from ST-1 to ST-3 (Table 10) indicates an improvement in the loading of ions in the river water from upstream to downstream. Mean alkalinity value of the river Buriganga as

obtained in the present investigtion showed a high value in ST-1 and ST-2. In ST-3 a fall in alkalinity by 1.6-2.6 meq/L has been observed. This also indicates a gradual recovering nature of the river from up to the downsteams. Mean pH value always remain close to neutral. The pH value remains more or less consistent throughout the sampling period in all the stations studied (Table 10). However, Zerin (1995) recorded a range of pH 6.8-8.1 at ST-2 of the present investigation.

The overall range of Total dissolved solids (TDS) for all the stations were 45-467 mg/L (Table 10). However, a gradual decrease in the concentration of the TDS was observed through out upstream to downstream stations (ST-1: 57-467 mg/L, ST-2: 55-394 mg/L, ST-3: 45-316 mg/L). This data also indicates a self purification status of the river from upstream to downstream stretches. Zerin (1995) recorded a value of TDS 160-290 mg/L at ST-2 of the present investigation. The maximum value of TDS recorded in the present investigation is about 26% higher than that recorded by Zerin (1995). This might be due to an increase in the pollution level of the river. A lower range of TDS value 170-248 mg/L, 117-196 mg/L has been recorded for Balu and Sitalakhya rivers respectively (DOE 1993). DOE (1993) recorded 85-266 mg/L at Chadni Ghat of the river Buriganga. River Kern, USA yielded a range of TDS from 62-114 mg/L (Hill and Rai 1984).

Soluble reactive silicate concentration in the water of the river Buriganga was found very high at ST-1 and ST-2 (3-82 mg/L, 4-76 mg/L, respectively). ST-3 yielded a value of 2-34 mg/L. A gradual decrease in the concentration of this parameter has also been observed from upstream zone to downstream zone of the river Burignaga. Zerin (1995) recorded a range of 3-38 mg/L at ST-2 of the present investigation. The maximum value of SRS recorded in the present investigation at ST-2 is 2 times higher than that recorded by Zerin (1995). The maximum SRS concentration recorded in the present investigation at ST-1 and ST-2 is higher than Turag and Titas (Table 11). River Yamuna, India and Nile,

Egypt yielded SRS concentration from 2-38 mg/L and 4.5-10.0 mg/L, respectively (Rai 1974, Ahmed *et al.* 1986).

The concentration of NO_3-N as recorded in the present investigation shows a gradual increase from upstream to downstream stations (Table 11). This is just in a reverse order as has been found in case of pH, alkalinity, conductivity, TDS, SRS and Secchi depth of the present investigation. The overall range of NO_3-N concentration was 0-2.5 mg/L for all the stations. In the individual stations this parameter ranged from 0-0.3 mg/L for ST-1 and ST-2. In ST-3 the range was 0-2.5 mg/L. But a very high value was recorded (0.4-10.9 mg/L) at ST-2 by Zerin (1995). River Turag yielded a range of 0.3-9.0 mg/L (Abed 1995). The other rivers of Bangladesh such as Titas and Gumti showed a range of 4.7-5.6 mg/L and 9.0-12.5 mg/L (Talukder *et al.* 1993). River Yamuna, India; Nile, Egypt and Kern, USA showed a range of NO_3-N concentration from 0.03-0.6 mg/L and 0.03-3.0 mg/L, 0.03-1.0 mg/L, respecitively.

SRP concentration in the river Buriganga was found extremely high (28-1584 µg/L) that exceeded the mandatory phosphate limit (22-300 µg/L) specified in the surface water regulations in the EU. The concentration of SRP at ST-1 was 28-1443 µg/L. At ST-2 a higher range of SRP (34-1584 µg/L) compared to ST-1 was observed. ST-3 showed an improvement in the concentration of SRP (40-466 µg/L). High SRP at ST-2 might be because of excessive human interferences at Sadarghat Terminal where all the marine vessels stops and stay for loading the passengers. At this station (ST-2) Zerin (1995) recorded a range of 38-508 µg/L. The maximum SRP concentration recorded at this station in the present investigation is three times higher than the concentration recorded by Zerin (1995). This finding indicates a tremendous pollutant load of organic origin in the river water. Other rivers of Bangladesh such as Turag and Titas showed a range of 30-797 µg/L, 1-10 µg/L, respectively (Table 11). The river Yamuna, India; Nile, Egypt and Kern, USA show a range of SRP 20-170 µg/L, 35-68 µg/L and 14-35 µg/L, respectively. All these data when compared with the

river Buriganga indicate that the water of the latter is strongly polluted with organic pollutants.

Dissolved oxygen (DO) is a very good indicator of water condition. The range of this parameter as recorded in 3 different stations of the river Buriganga show an overall range of 0-9.4 mg/L. Among the stations studied, ST-1 and ST-2 were anoxic at different times whereas at ST-3 the minimum DO recorded was 4.3 mg/L. This DO data also proves a gradual improvement of water quality from upstream to downstream zones. At ST-2 of the present investigation, Zerin (1995) recorded a range of 0.3-12.8 mg/L. The maximum of which is about 30% higher than the present record at this station. Other rivers of Bangladesh such as 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 (Table 11). River Yamuna, India; Nile, Egypt and Kern, USA showed DO ranges as 3.8-10.1 mg/L, 6.8-13.6 mg/L and 7.1-10.6 mg/L, respectively (Rai, 1974, Ahmed *et al.* 1986, Hill and Rai 1984).

Chlorophyll-a (chl-a) shows a trend exactly similar with SRP i.e., an increased value at ST-2 and then a decline towards ST-3 (Table 11). This also indicates the effect of high organic load near at ST-2 i.e., at Sadarghat region. An increase by 11% in the concentration of chl-a at ST-2 was obtained compared to that recorded by Zerin (1995). In river Turag the concentration of chl-a ranged from 1-163 µg/L (Abed 1995). River Kern, USA showed a value 1.3-13.8 µg/L (Hill and Rai 1984). The degraded product of chl-a i.e., phaeopigment concentration varied from 0-334 µg/L as a whole. A gradual decrease in the concentration has been observed from upstream zone to downstream zone of the river (Table 8). At ST-2 concentration of this pigment is about 5 times higher when compared with the result as obtained by Zerin (1995). Abed (1995) recorded phaeopigment concentration 0.1-37.0 µg/L in river Turag (Table 8). In river Kern, USA it was 1.3-4.3 µg/L (Hill and Rai 1984).

All the data obtained in the present investigation were fed in a SPSS programme and Pearson Correlation studies were performed. Phytoplankton diversity related parameters such as cell density, diversity index, chl-a and phaeopigment concentration showed significant correlation with a number of limnological parameters. The cell density (ind/L) showed significant positive correlation with conductivity, TDS and chl-a in all the three studied stations. SRP showed a positive correlation with cell density at ST-1 and ST-3. This indicates that SRP did not play any significant role at ST-2. SRP data recorded in the present investigation indicate that its concentration was high in ST-2 compared to ST-1 and ST-3 and at these two stations phytoplankton population density related with SRP concentration. This finding also indicate that the diversity of phytoplankton is dependent on the concentration of SRP in the river water. Chl-a and phaeopigment concentration of the river water related positively with alkalinity, conductivity, TDS and SRS in almost all the three stations of the present investigation (Table 5-7). Chl-a also related negatively with DO in all the three studied stations of the river Buriganga. Zerin (1995) performed multiple correlation analysis with 21 physical, chemical and biological variables at ST-2 of the present investigation. It was observed from her findings that water temperature negatively correlated total phytoplankton. Alkalinity positively related with pH, SRP, total phytoplankton and chl-a. Conductivity showed positive correlation with SRP, total phytoplankton and chl-a.

A two year study on the phytoplankton diversity and limnology in a section of the river Buriganga adjacent to Dhaka Metropolis reveals a total of 180 species of phytoplankton belonging to 7 different algal classes. Highest number of species was obtained from the class Chlorophyceae (40% of the total species). Cryptophyceae represented least number of species (a maximum of 5 species) in the river. Among the total taxa of phytoplankton about 70 will be new report for Bangladesh. The population density of phytoplankton community ranged 1.1×10^3- 250.0×10^3 ind/L. Phytoplankton chl-a and its degraded product phaeopigment concentration ranged from 2.0-163 µg/L and 0-334 µg/L,

respectively. The diversity index (H') varied from 1.4-4.7 byt/ind. This range indicates a heavy to moderate pollution of the river water along a 17 km stretch (the total length covered under ST-1 to ST-3 of the present investigation) of the river. The downstream station (ST-3) mostly enjoyed higher diversity of phytoplankton. A comparison with past studies carried out in this zone of the river Buriganga (nearly 30 years back) a greater shift in the community of phytoplankton has been observed i.e., from desmid and diatom dominated community to euglenoid and chlorococcoid dominated one. All other pollution related parameters such as SRP, SRS, chl-a, conductivity, TDS and alkalinity has increased to some extent. The concentration of DO showed a strong fluctuation seasonally. This indicates highly variable loading of organic pollution in the river water. However, analysis of data among all the three stations shows that the river recovers from the effect of pollution from upstream to downwards. Heavy loading of organic pollutants actually occurs near ST-1 and ST-2. As it has been observed from the different indicator parameters a moderate recovery was evident in ST-3.

Data on 13 limnological variables recorded during the present investigation show and almost clear picture about the water quality along 17 km stretch of the river Buriganga adjacent to Dhaka Metropolis. Air and water temperature did not vary significantly. However water transparency as Secchi depth (Zs) showed gradual improvement from the upstream towards down stream stations (maximum Zs were at ST-1: 54, ST-2: 60 and ST-3: 83 cm). Zs improves only when the loading of suspended matter is low. But compared to 1995 Zs data (90 cm) water quality at ST-2 has deteriorated further in the recent time. pH maxima in all the studied stations was same (6.9) but shifted towards acidic range when compared with the data of 1995 at ST-2 (8.1). Improvement of water quality from upstream to downstream stations has also been observed in respect to alkalinity (maximas at ST-1: 7.6, ST-2: 6.6 and ST-3: 5.0 mg/L), Conductivity (maximas at ST-1: 940, ST-2: 915 and ST-3: 713 µS/cm) and TDS (maximas at ST-1: 467, ST-2: 394 and ST-3: 316 mg/L). Similar trends have also been seen

in respect of two important nutrient concentration. These are SRS (maximas at ST-1: 82, ST-2: 76 and ST-3: 34 mg/L) and SRP (maximas at ST-1: 1443, ST-2: 1584 and ST-3: 466 µg/L). Anoxia is another indicator of bad water quality. Though DO maximas are almost closer in all the studied stations (ST-1: 9.4, ST-2: 9.4 and ST-3: 9.2 mg/L) complete anoxia was observed at ST-2 which is near to Sadarghat Jetty. At Shikder Medical College (ST-1) the minimum DO recorded was 0.5 mg/L while at ST-3 it was 4.3 mg/L. This shows clearly that ST-3 (further down to Sadarghat) DO improves quite a lot (4.3-9.2 mg/L). In the present study improved DO correlates improved NO_3-N concentration (0-2.5 mg/L). Similar trend was also seen by Zerin in 1995 (DO: 0.3-12.8 mg/L, NO_3-N: 0.4-10.9 mg/L) at ST-2. From this study it can be said that serious deterioration in the water quality has occurred after 1995 but there exists a trend of gradual recovery from upstream to downstream stretches in the river. Except river Turag the water quality of Shitalakhya (at certain station), Titas, Gumti, Havatia, and Meghna seems to be better when compared with the present study. Other international river such as Yamuna, India; Nile, Egypt and Kern, USA show lower range of alkalinity, TDS, SRS, SRP and NO_3-N and higher ranges in pH and DO when compared with the present study.

Excessive concentration of some nutrients and pollutant particles might be responsible for bringing damage and incomplete growth in some phytoplankton. Considering ST-2 as a references point it could be said that with in a span of 12 years (present research and that carried out by Zerin in 1995) Zs has dropped 37%, chl-a increased 11%, alkalinity increased 26%, conductivity increased 30%, SRS increased 50%, SRP increased 68%, NO_3-N dropped 90%, DO dropped 27.1%. All these parameters indicate an overall deterioration of water quality of the river Buriganga.

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ABBREVIATION

LIST OF ABBREVIATION

A	Area
BCMB II	Bangladesh-China Maitry Bridge II
BGA	Blue green algae
C	Circa (about)
°C	Degree centigrade
Chl-a	Chlorophyll-a
Cond.	Conductivity
DEPC	Department of Environment Pollution Control
dia	Diameter
DOE	Department of Environment
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DOM	Dissolved organic matter
E	East
EU	European Union
fa.	Forma
Fig.	Figure
Figs.	Figures
FPOM	Fine particulate organic matter
GOB	Government of Bangladesh

H	Hour
H'	Shanon-Weaver index
Hcl	Hydrochloric acid
H_2So_4	Sulfuric acid
IDH	Intermediate disturbance hypothesis
JICA	Japan international cooperation agencies
km	Kilometer
km^2	Square kilometer
L	Litre
meq/L	Milliequivalent per litre
MFP	Mutagen formation potential
mg	Milligram
ml	Millilitre
mm	Millimeter
µg	Micro gram
µS/cm	Micro-Siemens per centimeter
N	Normality
NO_3-N	Nitrate-nitrogen
OD	Optical density
Phaeo.	Phaeopigment
POC	Particulate organic carbon
SRP	Soluble reactive phosphorus

Spp.	Species
SPSS	Statistical programme for social sciences
SSFG	Stream specific filamentous green algae
ST	Station
TDS	Total dissolved solids
Temp.	Temperature
THMFP	Trihalomethane formation potential
TSS	Total suspended solids
USA	United States of America
Var.	Variety
WDB	Water development board
Z_s	Secchi depth transparency