BIOMONITORING OF A FLOODPLAIN WETLAND USING PLANKTON AND PROTOZOAN PARASITE

A Thesis
Submitted to the
West Bengal University of Animal and Fishery Sciences,
in partial fulfilment of the requirements for the Degree of

Master of Fishery Science
in
Fisheries Environment

By

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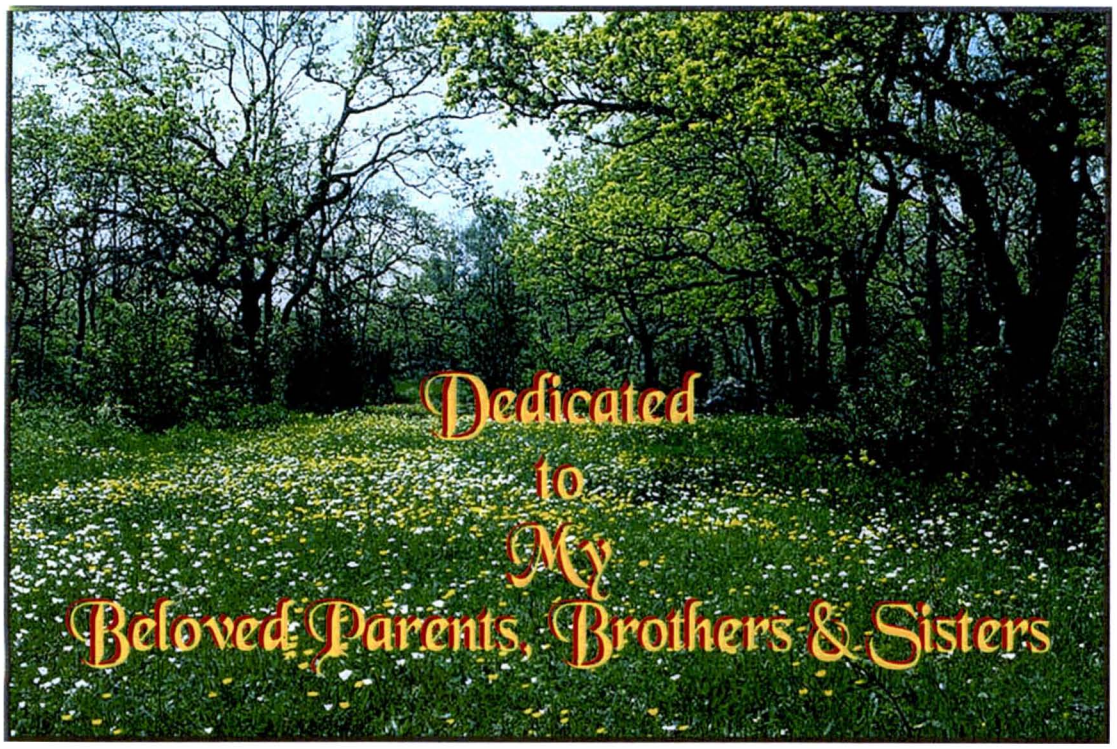
Dedicated
to
My
Beloved Parents, Brothers & Sisters

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Certificate

This is to certify that the work embodied in the thesis entitled "***Biomonitoring of a floodplain wetland using plankton and protozoan parasite***" submitted by **Mr. Vivekenand Safi**, in partial fulfilment of the requirements for the Degree of Master of Fishery Science in Fisheries Environment in the Faculty of Fishery Sciences, West Bengal University of Animal and Fishery Sciences, Mohanpur Campus, Nadia, West Bengal, India, is a faithful and bonafide research work carried out by him under my supervision and guidance. The results of the investigation reported in this thesis have not so far been submitted for any other degree or diploma. The assistance and help received during the course of investigation have been duly acknowledged.

Dated : 22nd. July..., **2005**
Mohanpur, Nadia (W. B.)

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Chairman, Advisory Committee

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APPROVAL SHEET

APPROVAL OF EXAMINERS FOR THE AWARD OF THE DEGREE OF MASTER OF FISHERY SCIENCE (FISHERIES ENVIRONMENT)

We, the undersigned, have been satisfied with the performance of **Mr. Vivekanand Safi,** in the viva-voce examination, conducted today, the September 19 ,2005, recommended that the thesis be accepted for the award of the Degree of Master of Fishery Science in Fisheries Environment.

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Place : Mohanpur, Nadia (W.B.)

Dated : 2005

Vivekanand safi

Vivekanand Safi

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CHAPTER - 1

INTRODUCTION

INTRODUCTION

Biological monitoring in its most rudimentary form probably had its origin in the mind of fish wardens, river keepers and minders of lakes and ponds. Biomonitoring or biological monitoring is the systematic use of biological responses to evaluate changes in the environment with the intent to use this information in quality control programme. It is no more a tool box of technique that one can use to keep tabs on integrity and water quality of the aquatic system. It makes use of existing, synthesized information already present in the form of animal and plant in an aquatic ecosystem. It provides a quicker, cheaper and more integrated picture of water quality or ecosystem integrity than expensive routine monitoring of water chemistry (Dey, 2000). The idea that certain species can be used to indicate certain types of environmental conditions is well established.

India has extensive flood plain wetlands which are an integral component of the Ganga and Brahmaputra basin covering an area of about 0.2 million hectares. These water bodies are locally known as beels in Gangetic West Bengal which has more then 150 numbers of its kinds covering an area of 42,000 hectare and constituting 22% of the total freshwater area of the state. These beels are an important natural resource which play a vital role in the fisheries, rural economy and environment of the state. Thousands of poor fishermen are dependent on these important fisheries resource for their livelihood. These water bodies are considered as biologically sensitive habitat and they are extremely rich in plant nutrient having high productivity. The biological productivity of these water bodies depends on the suitability of physico-chemical parameters of its soil and water (Sugunan, 2000).

The quality of water in flood plain wetlands is influenced by soil and water quality, atmosphere and to a great extent by the metabolic processes of the plant and animal living in the water bodies, particularly the

luxuriant growth of aquatic macrophytes. It is also influenced by the plant nutrients pesticides and silt, regularly washed into it by surface run off from the surrounding agricultural lands. Pesticides cause severe pollution problem by outright killing of fish by entering into the food chain while nutrients cause eutrophication over a period of time and silts cause the siltation problem, which is the main focussing point for all the water bodies. Thus, monitoring the quality of water of the flood plain wetlands is essential in order to assess their production potential. Biomonitoring of aquatic ecosystem is an input and reliable method for assessing the water quality, where both plant and animal are used to monitor water quality, besides the physical and chemical parameters. Biological monitoring provides a more integrated view of the state of ecosystem and quality of their water. The living organism can provide information about the quality of water in which they live, about the amount of water available to them in the environment and about the integrity of the ecosystem as a whole.

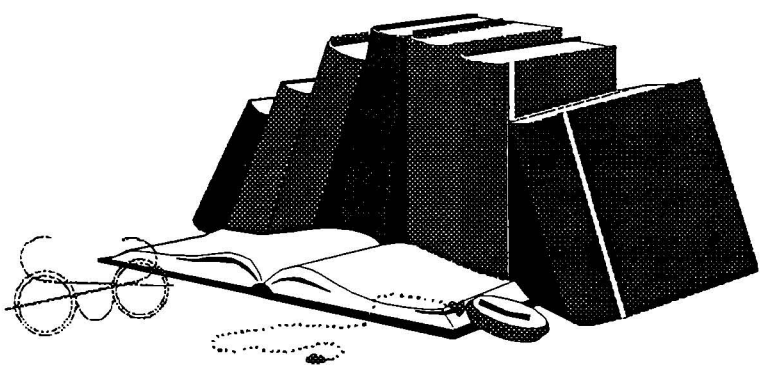
Biotic communities in general and plankton and parasite in particular play an important role in monitoring the water quality. Plankton communities are highly sensitive to the environmental condition as a result changes in their abundance species diversity and community composition can provide important indications of environmental changes or disturbances. Similarly more rapid response to environmental charges is likely to be observed by monitoring water quality using parasites as they are highly sensitive indicators.

Considering the above facts, the present study was initiated for monitoring the water quality with the following broad objectives.

Objectives

1. To estimate the hydrobiological parameters of water, sediment and macrophytes.
2. To know the responses of the various stress factors on biotic communities in lentic water bodies.
3. To study the protozoan parasitic load and their potential use as water pollution indicator.
4. To analyse qualitatively and quantitatively the plankton communities and their effective role in water quality assessment.

CHAPTER - 2



REVIEW OF LITERATURE

REVIEW OF LITERATURE

An attempt has been made to review the available literature related to the present work and has been presented as per the following heads.

2.1 PHYSICO-CHEMICAL PARAMETERS OF WATER

Various physico-chemical parameters of water bodies have been studied by different workers.

Rana *et al.* (1996) has made an attempt to asses the limnological characteristics of two tropical beels of Nadia (West Bengal) in relation to the fish growth and observed a positive correlation between water temperature, pH, $NH_4(N)$ and primary productivity with fish growth performance.

Chakrabarthy (1998), studied various physico-chemical and hydrobiological variations in the lake of Darjeeling district during pre-monsoon, monsoon and post monsoon period, and found wide variations in the physico-chemical parameters and also in the occurrence of biotic communities.

Limnology and productivity of two reservoirs in the northeastern India and nine reservoirs of Andhra Pradesh was studied by Ahmed and Sarkar (1997) and Das (2000) respectively. Both of these studies revealed that the nutrients were very meagre in water. Limnology of tropical reservoir in Kerala was studied by Thomas and Azis (2000) who concluded that the reservoir is an ideal site for aquaculture and fishery development. Pathak (1979) evaluated primary productivity in Nagarjuna Sagar reservoir as a function of hydrological and limno-chemical parameters.

Limnological annual cycle inferred from physical and chemical fluctuations of lake Tanganiyaka was studied by Plisnier *et al.* (1999). They

observed that the annual limnological cycle of lake appears closely linked to the climatic condition.

Paria and Konar (2000) studied 56 impounded water bodies in Jalpaiguri district of West Bengal to assess the ecological status in relation to fish production and reported that the pH of water was acidic to neutral, total nitrate and phosphate contents were high, dissolved oxygen, alkalinity and hardness were normal.

Impact of human activities on the selected water quality parameters of five water bodies of Southern Rajasthan were assessed by Sharma and Sharma (1994). They concluded that the water body was more affected by pollution but aquatic weeds infestation in lake receiving sewage were found to reduce the pollution levels substantially.

Trophic status of Mathura beel in West Bengal was studied by Chakraborthy and Chattopadhyaya (2003). Their study revealed a marked deviation in the physico-chemical characteristics of water and sediment.

Izaguirre *et al.* (2003) studied the variation in phytoplankton composition and limnological features in a lower Parana Basin (Argentina). Subsurface hydrology of a woodland stream was studied by Tillman *et al.* (2001). They stated that the subsurface zones may function as organic matter in the reservoirs.

Badkhal lake was investigated by Kaushal and Sharma (2001) for its limnochemical features and productivity status on seasonal basis. They highlighted the significant findings on eco-dynamics of lake vis-à-vis and suggested about eco-frendly exercises for management of fisheries in Badkhal lake. Interrelationship of certain physico-chemical parameters and plankton community of Tesel lake of Meghalaya was studied by Hazarika and Dutta (1998) who concluded that the plankton community was depended greatly on different physico-chemical parameters.

Seasonal variations in physico-chemical parameters and plankton of a lake of Madhya pradesh was studied by Mathew (1985). He observed that the transparency of the water level and dissolved oxygen both showed an inverse relationship with water temperature. pH showed only very little fluctuation, total alkalinity showed inverse correlation with water. Arizhagavan and Kamalaveni (1997) observed that the seasonal variation in physico-chemical parameters and plankton of Kurichi pond.

Bhatt *et al.* (1999) studied physico-chemical characteristics and phytoplankton biomass of a lake in Nepal and observed that the lake water was rich in nitrogen (nitrate and ammonia) and orthophosphate opining the lake to be moderately polluted. Throat and Sultana (2000) did chemical analysis of a lake of Aurangabad and encountered higher values of total hardness, BOD and organic nitrogen indicating organic pollution. Similar studies were carried out by Patil and Tizare (2001), on water quality of Gadchiroli lake.

Singh *et al.* (1998) conducted hydrobiological studies of some eutrophic ponds of Bihar and observed correlation in between plankton density and high levels of nutrient content in both pond water and soil even after utilization by the primary producers. Some limnological parameters of an acidic swamp in Assam which is surrounded by human habitats and being thickly covered with *Eichhornia* sp. throughout the year was studied by Pal and Singh (1983) and poor productivity of the swamp was reported. Pahari *et al.* (2001) studied two wetlands of Midnapore district in respect to their water quality macrophytes and phytoplankton components.

Verma and Paul (1998) assessed primary production in relation to nutrient status of tropical standing water body of Gulbarga and few observations recorded were like temperature of water exhibited seasonal trend towards summer, fluctuations in dissolved oxygen level noticed, free CO_2 was nil during July and September and the major nutrients namely

phosphate phosphorus and nitrate nitrogen showed highest values during rainy season, ammonical-nitrogen, showed highest values during summer.

Basheer *et al.* (1996) studied seasonal variations in the primary productivity of a pond receiving sewage effluents and observed wide fluctuations in the primary productivity and other physico-chemical characteristics.

Productivity of Dighali beel was evaluated by Acharjee *et al.* (1999) as a function of limnochemical parameters who stated that the rich nutrient status of the soil was not reflected in the water phase. Similar works on limnological parameters in Assam were carried out by Singh *et al.* (1997) and Baruah *et al.* (1998b).

Francis *et al.* (1997) investigated pollution and its influence on the biomass of a monsoon fed freshwater pond and stated that it was rich in organic and inorganic substances there by harbouring a big biomass community of plants and animals.

The physico-chemical characteristics of any water body or aquatic ecosystem and the nature and distribution of its biota are directly related to and influenced by each other and controlled by a multiplicity of natural regulatory mechanisms. Limnological studies on water bodies were stimulated to assess the deterioration of water quality due to pollution (Hazarika and Dutta, 1998).

Unni *et al.* (1998) studied limnology and eutrophication of Tawa reservoir. During their study they observed wide fluctuations in total hardness, phsophate and ammonia nitrogen, indicating the impact of ash effluents. The role of wetland on water quality was estimated in a natural lake by Marion and Brient (1998). Based on their observations they concluded that the lake is not able to counter balance the dramatic increase of agricultural and sewage inputs, which induce its eutrophication and siltation.

Limnology of polluted urban pond was studied by Bath and Singh (1998) who reported that the concentrations of total alkalinity, nitrate, and phosphate were sometimes more than the permissible limits.

2.2. SEDIMENT

Sediments are not well defined but rather are a complex heterogenous mixture of different gaseous/liquid/solid, inorganic/organic, and living components derived from various source and controlled by numerous physical, chemical and biological factors. Sediments may also act as a source of contamination when environmental conditions change. Quality of sediment play major role in maintaining the physico-chemical qualities of water bodies.

Sediment plays various roles in production of phytoplankton. Trivedi (1988) investigated the soil characteristics of three waterbodies of Karnataka and correlated with the physico-chemical and biological characteristics of water. The co-relationship between the sediment and water were worked out by Lerman and Brunskill (1971) and Raghavan (1973) reporting a strong interaction between the physico-chemical characteristics.

Seasonal soil and water samples of Adhartal pond were studied for physico-chemical characteristics by Mahajan and Mandlio (1998). The study showed that nutrient availability of soil was higher in monsoon season and lower in summer.

Nutrient contents of the bottom soil of lake Badkhal in Haryana was estimated by Kaushal and Sharma (2001). They reported that the soil organic content was moderate but available nitrogen and available phosphorus contents were varied from low to medium range.

Physico-chemical parameters of soil of Baghla reservoir was studied by Khan *et al.* (1996). Similar studies conducted by Paria and Konar (2000) on pond ecosystem in Jalpaiguri district. They reported that available

nitrogen and available phosphorus of soil also takes part in controlling the pond environmental conditions.

Acharjee *et al.* (1999) analysed the nutrient status of soil of Dighali beel, Assam which was acidic in pH, rich in organic matter, available nitrogen and available phosphorus. But the rich nutrient status of soil was not replicated in the water phase. Saha and Pandit (1987) compared between soil properties of standing and running waterbodies with relation to water factor.

Singh *et al,* (2000) analysed soil properties of the polluted and unpolluted tanks of Sasaram, Bihar. The also compared between the two ponds by the parameters like organic carbon, pH, Ca, Mg, conductivity and available phosphorus.

The co-relationships between the sediment and water were worked out by Lerman and Brunskill (1971) and Vihayaraghavan (1973) who reported a strong interaction between the physico-chemical characteristics.

Weldung *et al,* (1977) investigated the sediment phosphorus status in a eutropic lake and related that the exchange of phosphorus from water to soil and vice-versa depends on the physico-chemical characteristics like temperature, pH, redox potential and organic matter.

Rai (1994) studied some soil parameters of six non-drainable sewage fed ponds for a period of six years and reported an increase in the level of organic carbon and phosphorus and a marginal increase in available nitrogen.

Mitchell and Haldwin (1999) studied the effects of sediment desiccation on the potential for nitrification, denitrification and methanogenesis in a Australian reservoir.

2.3. AQUATIC MACROPHYTES

Aquatic macrophytes are the common occurrence in shallow ponds, tanks, margins of lakes and reservoirs in tropical and subtropical climates (Kumaraiah and Rao, 2000). Aquatic macrophytes posses an outstanding ability of assimilating nutrients and creating favourable environment for organic decomposition (Mohanty and Sinha, 1999). The accumulation of nutrients in macrophyte tissues determine the ability of these plants to form a protective barrier (Alaez *et al.*, 1999). A large number of publications contributes data on nutrient levels in the plant tissues of a variety of wetlands, but comparisons among different plant groups, growth forms and functional groups are still scare. (Durate, 1992).

Gopal and Sharma (1981) reported that water hyacinth generally absorb 5-10 times nitrogen as readily as phosphorus. The average nitrogen content was reported to be decreased during the period from June to September. They further reported that the concentration of nitrogen and phosphorus in the dried sample of water hyacinth ranged from 1.2-5.6% and 0.1-0.8% respectively.

Gossett and Norris (1971) found a positive correlation between nitrogen, phosphorus and potassium in between habitat water and water hyacinth plant tissues. Reza and Khan (1981) reported that the nutrient content of water hyacinth varies from type to type and parts to parts within type.

Trivedy and Gopal (1981) reported about the seasonal variation in elemental compositions of water hyacinth, they observed the presence of maximum nutrients in water hyacinth plant tissues at the time of maximum growth of *Eichhornia crassipes.*

Absorption and subsequent bioaccumulation of nutrients in the plant *Eichhornia crassipes* solms, growing luxuriantly in a wetland receiving untreated and partially treated domestic sewage was studied by Mohan and

Hosetti (1998). They reported that the highest accumulation of nutrients were recorded during pre monsoon followed by post monsoon and the monsoon months.

Several scientists tried to work out the viability of aquatic weeds in controlling the extent of the pollutant effects on the water bodies (Lazaridon et *al.*, 1997; Yu *et al.*, 2000; Joseph and Joseph, 2001).

Wilcock *et al.* (1999) observed that weed choked streams typically have wide diurnal variations in dissolved oxygen, temperature and pH and extreme values which can influence habitat suitability and ammonia toxicity for aquatic organisms. Melzer (1999) investigated the submerged vegetation of Bavarian lakes to evaluate the state of nutrient pollution. During their study they observed that the successful restoration of lakes in upper Bavaria has been obtained from the distribution patterns of submerged vegetation. Similar type of observations have been reported by Lachavanae *et al.* (1992) and Simons *et al.*(1994).

The effects of macrophytes on hydraulic and physico-chemical variables were examined by Wilcock *et al.* (1999) on NewZealand low land stream. Stream showed more pronounced diurnal variations in dissolved oxygen levels and even be anoxic at times.

Collier *et al.* (1999) observed that the biomass of macrophytes increased significantly from June to March. Their study suggested that the creation of patchy shade conditions may be useful tool where the management aim is to enhance condition of aquatic biota by encouraging the development of intermediate biomass macrophyte patches. Aquatic macrophyte community distribution along the casters shoreline of the Itaipur reservoir is described in relation to limnological and sedimentological factors by Bini *et al.* (1999). They studied macrophyte community composition and species covered at 30 sites in relation to sediment, total phosphorus, organic matter, water total phosphorus and Kjeldhal nitrogen concentration. They

concluded that the floating macrophyte assemblage was closely related to the concentration of nutrients in both water and sediment.

Inorganic nitrogen and soluble reactive phosphate concentration were measured in the water of a marshiland in its interstitial water at two sites by Villar *et al.* (1999). These values were compared with the nitrogen and phosphorus concentration in sediments and macrophyte biomass in order to assess nutrient availability, fate and storage capacity. They observed that pore water showed a pronounced minimum ammonium concentration close to (March) or relatively soon after (May), the end of the macrophyte-growing season. Soluble phosphate showed a large variation without any discernible seasonal pattern.

Scheffer (1999) analysed the effect of aquatic vegetation on turbidity. He suggested that aquatic macrophytes can enhance water clarity and reduce phytoplankton biomass, nutrient availability and resuspention. But studies of Perrow *et al.*, (1994) showed unaltered or even increased ortho phosphorus levels in the water column. Similar studies were conducted by Cullery and Epps (1973), Culley *et al.* (1981) observed that the values of nutrients and elements in the plants were sufficiently higher in the plant than in the water to indicate that the plant was concentrating these materials inside it and was therefore purifying the water.

Pahari *et al.*, (2001) studied two wetlands in Midnapore district in respect to their water quality, macrophytes and planktonic components. Their study concluded that macrophytes play a vital role in physico - chemical nature of wetlands and phytoplanktonic and zooplanktonic abundance. During their study they observed lower temperature and higher transparency, lower concentrations for potassium and iron in one site and stated that it may be due to the presence of macrophytes.

Macrophytes are considered as an important component of any aquatic ecosystem as far as the primary productivity is concerned. (Barnett

and Schneider, 1974). Primary production of macrophytes in a domestically polluted tropical pond was assessed by Varghese (1993). He observed that summer period exhibited maximum biomass production and rainy period showed minimum.

Studies on macrophytes of two ecologically distinctive ponds at Patna were carried out for two consecutive years by Kumar (1997). During his study he observed that, the presence of macrophytes in shallow pond resulted in poor primary productivity and extreme diurnal pulses of dissolved oxygen along with the elevation of CO_2 in water. In shallow pond macrophyte biomass reached maximum level by August to October and minimum by December to March. He concluded that the shallow pond experienced drastic changes in its hydrological features due to luxuriant growth of macrophytes.

Vegetational profile of macrophyte of Jagatdev reservoir was studied by Singh *et al.* (1999). They stated that due to the rich floristic account, the nature of Jagatdev reservoir is changed and gradually becomes more eutrophic. Growth performance of selected emergent macrophytes present in different wetlands around Jaipur was studied by Sharma and Sharma (1994). They observed that density of macrophytes was maximum in lower depth.

Sinha *et al.* (1994) studied the biodiversity and pollutional status of Kawar lake, North Bihar in relation to the hydrobiological factors and reported about the ecological deterioration of lake due to eutrophication, siltation, luxuriant macrophytic growth, soil erosion and anthropogenic pressures.

Aquatic weed production in a perennial irrigation tank in Andhra Pradesh was observed by Kumariah and Rao (2000). The biomass production was maximum in post monsoon period and minimum in pre monsoon period.

2.4. PLANKTON

Yoshida (1997) studied the north basin of lake Biwa and observed that algae is a common species in early May and their growth is suppresed under abnormal water quality and meteorological conditions.

Caroppa *et al.* (1994) investigated the waters of Taranto, Italy and obtained a high correlation between organic pollution and phyloplankton population. Yoshida *et al.* (1996) studied the south basin of lake Biwa and reported that the abnomally abundance of *Phormidium tenue* bloom occurred when the concentration of total nitrogen, dissolved inorganic nitrogen and total phosphorus and dissolved inorganic phosphorus was high.

Sinha *et al.* (1994) investigated in detail the Kawar lake wetland (Begusarai), North Bihar and reported that ecological deterioration was due to luxuriant growth of macrophytes, siltation, sedimentation, soil erosion, eutrophication, anthropogenic pressure and poor conservation and management strategies.

Nair, (1999) studied the village pond at Imalia (Vidisha), India and observed that phytoplankton (total plankton) showed positive correlation with transparency, pH, hardness, total alkalinity and dissolved oxygen, and negative correlation with water temperature, turbidity, conductivity, free carbondioxide, chloride, ammonia, nitrate, phosphate, sulphate and silicate. The Chlorophyceae showed correlation similar to phytoplankton (Total phytoplankton) with the physico/chemical factors but the correlations of Myxophyceae, Bacilloriophyceae and Eyglenineae with physico-chemical factors deffered from the correlations of total phytoplankton and physico/chemical factors. It was found that the seasonal variations of phytoplankton are influenced by the seasonal variations of physico-chemical factors of the pond ecosystem.

Akbay *et al.* (1999) studied the Keban dam reservoir of Anatolia and reported that the overall phytoplankton density is low during the fall and winter months.

Battarbee *et al.*(1997) studied the surface water quality in the Hoeylandert area of Nord - Troendelag, Norway and reported that pH and water colour were the principal water chemistry variables influencing species composition of periphytic diatoms.

Lecterq *et al.* (1996) studied the fresh water of the Belgian semois catchment area and found that Diatoms seem to be the most reliable bioindicator of increasing mineralization and various levels of pollution and eutrophication.

Socha, (1997) investigated the heated lake of Koninskie District (Poland) and reported that mass development of phytoplankton in summer was limited by intensive water mixing within and between lakes and phytoplankton proved to be a sensitive indicator of the change in water ecosystem and in the adjacent watershed.

Guo *et al.* (1997) studied the water quality of Dongping lake using the phytoplankton.

Conttingham and Carpenter (1998) studied the lake and observed that reliable indicators of phytoplankton responses to enrichment were very different from reliable indicators of animal response to toxic stressors and it may be difficult to make generalization regarding the use of phytoplankton population, community and ecosystem variates as indicators of a wide array of perturbations.

Brook (1965) investigated the trophic status of a fresh water lake of Britain and reported that many taxa of Desmieliaceae supposedly oligotrophic algal group are most frequently associated with eutrophic waters.

Chaturvedi *et al.*, (1999) studied the plankton community of polluted waters around Sanganer, Jaipur and reported that *Aphlanocapsa, chlorella* and *closterium* are considered as indicator of organic pollution in the water.

Billen *et al.*, (1999) reported that the oxygen level closely depends the balance between phytosynthesis, bacterial degradation of organic material (either produced by algal or brought in with waste water) and ammonium oxidation by nitrification as studied in seine.

Wessels *et al.*,(1999) studied the pelagic zone of lake Constance, Germany and observed that oligotrophic condition of lake was indicated by the dominance of various *Cyclotella* taxa. Increasing abundance of *Tabellaria fenestratra* showed oligotrophic to mesotrophic conditions and increasing *Stephanodiscus bantzschii* and disappearing Cyclotella indicated advanced eutrophication.

Vgreethiah and Haniffa (1998) reported *Anabaena sp., Oscillatoria sp.*, and *Spirogyra sp.* as indicator species from polluted coir rotting area in Anadan Victoria Martandavarman canal (A.V. canal) South-West coast of India.

Wu. (1999) studied the Keelung river of Taiwan which is heavily polluted by domestic, industrial and agricultural wastes and reported that water quality particularly in ammonium, nitrite, silicate and turbidity, was negatively correlated with dissolved oxygen and generic index of diatom assemblages used as bioindicator of pollution.

Strueder and Schoenborn. (1999) reported *Periphyton* and *Sphagnicolous* protists from dystrophic bog lakes (Brandenburg, Germany).

Kuemmerlin (1980) investigated the phytoplankton community of upper lake constance (Bodensee-obersee) and suggested that taxanomical composition of phytoplankton species is corelated to environmental changes.

Fallu and Pieniz (1999) studied the diatoms of Jamesie - Hudsonie (ceuebec) and reported that freshwater diatoms are more and more frequenctly used in paleoenvironmental studies.

Lepistoe (1999) investigated the ecological status of lakes in Finland and reported that phytoplankton quantity use to reflect the water quality of the reservoirs. In the mesoeutrophic Lokka reservoir, cyanophytes became abundant especially during warm weather condition.

Krienitz (2000) observed that the phytoplankton of inland water exhibit a high structural and functional biodiversity and offer a good opportunity to evaluate water quality by means of biological approaches.

Starkel *et al.* (1988) reported that lake phytoplankton was dominated by algae which is associated with nutrient enrichment, organic pollution and other nuisance categories.

Vass, (1997) studied in detail on flood plain lakes and small reservoirs of india and reported that methods used in bimonitoring include ecotaxonomical methods (indicator species, community structure) and physio -biochemical methods (biological function analysis, toxicity testing).

Makarewicz *et al.* (1998) observed that mesotrophic diatom accounted for 47.2% of the total phytoplankton biomass of lake Michigan during spring and summer. Sazonova *et al.* (1997) reported that *Daphnia magna* and *Cerioaphnia affinis* and unicellutar protozoan were used to monitor the quality of purified municipal and industrial waste water and unicellular organisms can be used successfully for analysis of water quality.

Wei, (2000) studied lake Kasumigaura, Japan which is contaminated and found that Chlorophill - a was suitable as one biological indicator to show the trend of eutrophication.

Yoshida *et al.* (2000) reported that occurrence of *microcystis* blooms occurred where high level of dissolved inorganic phosphate and dissolved

organic phosphate and low level of dissolved inorganic nitrogen were present as studied in lake Biwa and ponds of Kiniki district in Japan.

Cronberg (1999) studied the Ringsjoen, Scania, Sweden and reported that lake was developed into a hypertrophic status with extensive blooms of blue green algae from May to October, including high biomass of mainly *Microcystis* sp. This severe pollution started with increased usage of the lake, increased tourism and recreation, intensified farming with the introduction of artificial fertilization, and also the diversion of sewage water from a sewage treatment plant.

Rai and Kumar (1977) studied the seasonal variations of algal population in a pond polluted with fertilizer factor effluent. Hutchinson (1957) observed that the majority of the species of *Euglena* and *Phacus* are found in small bodies of water which often have high organic contents. Prasadam (1977) studied influence of washing clothes and irrigation activity on the zooplankton composition in some tanks of Karnataka Ramaswamy and Somashekhar (1982) and Srivastava (1990) studied the effectiveness of algae in abatement of water pollution.

A detailed ecological survey of phytoplankton of polluted habitats of Warangal city Andhra Pradesh done by Suvarna and Simgaracharya (1995). Ahmed, (1996) studied the algal flora of polluted habitats of Dharbhanga, Bihar. Sharma and Kaushal (2004) carried out detailed studies on biotic communities of Khari reservoir and found that *Anabaena, Phormidium* and *Rotifers* are the pollution indicator species.

Sharma and Kaushal (2004) investigated the biotic communities or Kothari reservoir , Rajasthan and found that occurrence of *Anabaena Oscillatoria, Microcystis, Scenedesmus* and *Pediastrum* indicated eutrophic tendency of reservoir.

An attempt to study the plankton diversity of different kinds of waterbodies of Rajasthan affected by textile mills and heavy metal pollution was made by Chaturvedi *et al.* (1999) and Sharma *et al.* (2000).

Sharma and Kaushal (2004) carried out the investigation on Udaisagar reservoir, Rajasthan and recorded that high organic loads favoured the abundance of rotifers, copepods (Cyclops, Diaptomus).

Holopainen and Letanskaya (1999) studied the phytoplankton species composition, total biomass and primary production and evaluated the human impact and state of eutrophication in lake lodaga.

Singh *et al.* (1998) studied the hydrobiology of eutrophic ponds and concluded that higher percentage of rotifers indicate the eutrophic condition in freshwater.

Sharma and Kaushal (2004) investigated the Nandsamand, Soma Kamla Amba, West Banas and Jawai reservoir, Rajasthan and concluded that ocurence of *Anabaena, Oscillatoria, Microcystis, Scenedesmus* and *Pediastrum* indicated eutrophic tendency of the reservoir.

The seasonal and vertical distribution of planktonic algal in the solar lake (Taba-Egypt) and their relation with some aquatic environmental factor were investigated by Ali (2001). Certain groups of plankton to be used as indicators of pollution can be found in the works of Rao and Mohan (1977), Dzyban and Kuenetsova (1978), Paramsivam and Sreenivasan (1981) and Nikunen and Miettinen (1985).

Bath and Singh (1998) studied the polluted urban pond and observed that *Paramecium caudatum, Halteria grandinella, Brachionus calyciflorus, Keratella tropica* and *Pilinia terminalis* are indicator species.

Pandey et *at.* (2004) studied on phytoplankton and its correlation with physico-chemical parameters and recorded that diatoms like *Navicula, Cyclotella* and *Fragilaria* and Blue-green algal like *Eyglena, Phacus, Trachelomns* and *Lepocinclis* are pollution indicator.

Sharma and Kaushal (2004) carried out detail investigation on biotic communities of Badkhal reservoir of Haryana and recorded pollution indicator species such as *Pediastrum* under Bacillariophceae and *Oscillatoria, Nostoc* under Myxophyceae which indicate eutrophic tendency of the water body. Partick (1973) used algae especially diatoms for the assessment of water quality.

Certain algal forms grow in the special type of polluted water and these species are characteristic features for the particular environment. These forms are the indicator of water pollution. *Microcystis aeruginos* is the best single indicator of organic pollution (Singh, 1999). *Euglena* and *Oscillatoria* could also be reliable indicators of eutrophication (Partick, 1973).

Palmer (1969) in his valuable review on algal as biological indicators of pollution and found certain algae tolerant to relatively raw sewage or organic waste and the listed genera most tolerant to organic pollution were *Euglena, Oscillatoria, Chlamydsmonas, Scenedesmus, Chlorella, Nitzschia, Navicula* and *Stigeoclonium.*

Rai and Kumar (1977) observed that *Oscillatoria* and *Stigeoclonium* exhibit considerable tolerance to pollution.

Hong *et al.* (1994) studied in detail the of zooplankton comunities in Pusan harbor, Korea and observed a relationship of zooplankton communities and distribution of copepods as indicator species to environmental variables such as temperature salinity, chemical oxygen demand (COD) and total inorganic nitrogen. Guentzel and Rocha (1998) studied the Caconde lake, Osoria, RS Brazil and reported that zooplankton communities were trophic indicator species.

Beaver *et al.* (1998) investigated the four types of wetlands in the upper midwest, USA and observed that abiotic factors which are known to directly affect phytoplankton, may indirectly affect zooplankton composition

in such a way as to use zooplankton assemblages as indicator of water quality.

Armengol and Miracle (1999) studied the zooplankton communities from several lakes and pool of a karstic area in Central Spain and observed that zooplankton diversity was higher in autumn than in spring, and variation of zooplankton data were depended upon the shallowness and type of water feeding and flux.

Vandish, (2000) studied the role of the zooplankton community as a pollution indicator of subarctic lake Imandra, which is subjected to the impact of complex anthropogenic pollution. Starkel and Chimney (1988) and Chimney (1988) used zooplankton for biological monitoring of a L- Lake Steel Creek.

Ostoji (2000) investigated the Grosnica Reservoir (Serbia, Yugoslavia) and founded that abundance of zooplankton increased markedly which is a case of intensification of eutrophication processes.

Swierzpwski *et al.* (2000) studied the Solina reservoir and reported that maximal concentrations of zooplanktons were observed in a well illuminated surface layer at the highest temperature and oxygen concentration.

Caleffi (1998) reported that the spatial distribution of the zooplankton community was influenced directly and indirectly by changes in water quality due to eutrophication.

Baruah *et al.* (1998a) investigated a detailed water quality and planktonic population assessment of both urban and rural waterbodies and observed that excessive anthropogenic activities in urban areas affected the water quality as well as plankton population.

2.5. PROTOZOAN PARASITES

According to Acharya and Dutta (2004) fishes grown in poorer quality of water remain stressed and if stress continues for long it make way for the protozoan parasites to attack.

Blazer *et al.* (2003) observed that infection rate (*Mlyxobolus cerebralis*) also can be directly influenced by environmental factors. Khan (1990) reported that immuno-suppression and changes in the gill habitat caused by pollutant may account for the increase in parasitism.

Das and Shrivastava (1984) observed the protozoan *Trichodina domergulei* and *Chilonodella cylorini* on gills of *Puntius sp.* from Uttar Pradesh lake (India) which frequently received industrial waste, detergents, domestic sewage, silt from soil erosion. Paperna and Overstreet (1981) reported the Myxosporean *Myxobolus esiguun* found on gills of mullet (*Mugil cephalus* and *M. auratus)* from Crimea (Marine) where low level of dissolved oxygen, possibly caused by pollutants might be the reason.

Dabrowska (1974) recorded Trichodinids from gills of several fish species, which is living in Municipal polluted water body. Lehtinen *et al.*, (1984) reported ciliate *Trichodina* sp. from the gills of *Platichthys fiesus* from Baltic (Marine) which frequently received pulp mill effluent.

Detail study on protozoan parasite was done by Dabrowska (1974) Lehtinen *et al.* (1984) and Das and Shrivasta (1984) who observed that increased trichodinid infection was associated with exposure to pollutant other than oil.

Mohan and Sommerville (1988) experimented that the response of gill tissue to copper exposure was important in determining susceptibility of fish to the protozoan.

According to Khan (1990) the prevalence and intensity of infection by *Trichodinid gill ciliates* of cod and longhorn sculpin *Myoxocephalus*

octodecemspinmosces was significantly higher in oil exposed fish than in controls.

Pal (1982) reported the seasonal occurrence of *Myxobolus sp.* and *Thelohanellus sp.* from fishes of the nurseries and rearing ponds in the district of Midnapur, Hoogly and 24 parganas of West Bengal.

Das *et al.* (1989) observed the Myxozoan infection mainly found in youngones of carps and infection was mostly prevalent in summer and monsoon months which also synchronise with the spawning season of the carps in India.

Sarkar and Haldar (1990), Saha *et al.* (1995) and Mitra and Haldar (2003) observed that urceolariid ciliates are mostly prevalent on the gills and body surfaces of various fishes extensively in colder months. Joshi (1979) reported that haemoflagelate (Trypanosomes) infections were found only during the colder months.

Kalavati *et al.*, (1992) reported new species of Myxosporidians from the skin and scales of fish from Chilka lake, Orissa. Saha and Haldar (1996) recorded a new species of paratrichodina Lom,1963 (Protozoa Ureceolaridae) on the gill of the teleost, *Heteropneustes fossilin* (Bloch) collected at Kalyani, West Bengal.

Houjan (1998) investigated the Meiliang Bay of Taihu lake and reported that ciliated protozoan was a good indicative community for the lake eutrophication and mean volume of the the ciliated protozoans in eutrophic lake region was larger than that in mesotrophic region with significance difference and mean monthly abundancl and biomass of total ciliates were positiveluy correlated with the trophic gradient.

Sawyer *et al.* (1996) investigated the deeploater sediment at Eudson Canyon which frequently receive sewage water and reported protozozan as an indicator of sewage contamination.

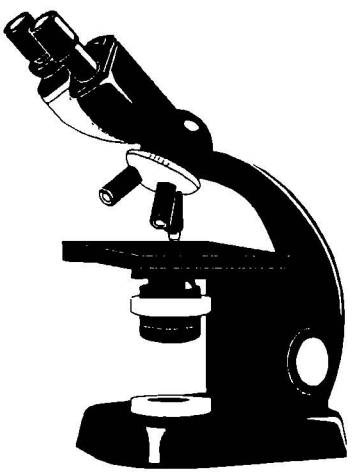
Katiyar and Belsare (1997) reported the freshwater protozoan community as indicator of organic pollution from the Bhopal city lake which is highly organic polluted.

Yeomans *et al.* (1997) studied the chronic organic polluted small river of south east England and reported that *Trichodinid* ciliates act as a potential bioindicator and also found the increased intensity of trichodinid infestation with increased concentration of sewage.

Finlay (1997) reported that aerobic protozoa thrive at low oxygen tensions and in anaerobic environments, they are the only phagotrophic organisms, and they live in unique symbiotic consortia with methanogens sulphate reducers and non-sulphur purple baeteria.

Karr (1999) reported that biological monitoring and biological endpoints provide the most integrative view of river condition or river health and multimetric bioligical indices are an important and relatively new approach to measuring river condition.

CHAPTER - 3



MATERIALS AND METHODS

MATERIALS AND METHODS

3.1. STUDY AREA AND ITS ENVIRONMENT

The water body considered for study is a flood plain wetland locally known as Mathura beel spreading across the districts of Nadia and 24 Parganas(N), West Bengal.

The water body is unique in its type having the agricultural fields and human settlements surroundings it, thus contributing varied qualities of sediment and water. Though the beel has no point source of waste water, it mainly receives domestic sewage of railway and military quarters from the national highway zone. The beel receives heavy run-off of silt, chemicals and fertilizers from the agricultural land which is the most threatening effect on beel productivity in near future. It is a perennial water body receiving water through ground water seepage, rainwater, surface run-off from the surrounding vicinity. The water of the beel is used by residents of the surrounding for washing, bathing and household purposes as well as for irrigation of agricultural lands and mainly for fish culture practices.

The varied and diverse nature of water body in terms of input enticed me to monitor using biotic communities.

3.2. PHYSIOGRAPHIC FEATURES OF MATHURA BEEL (Fig.1)

Area	:	264 ha
Total length	:	9 km.
Shape	:	Crescent
Category	:	Ox bow lakes
Soil type	:	Sand-clay-loamy
Source of water	:	Rain fed
Type of water body	:	Perennial
Average depth at monsoon		5ft - 6ft.
Average depth at lean season		3ft - 4 ft.

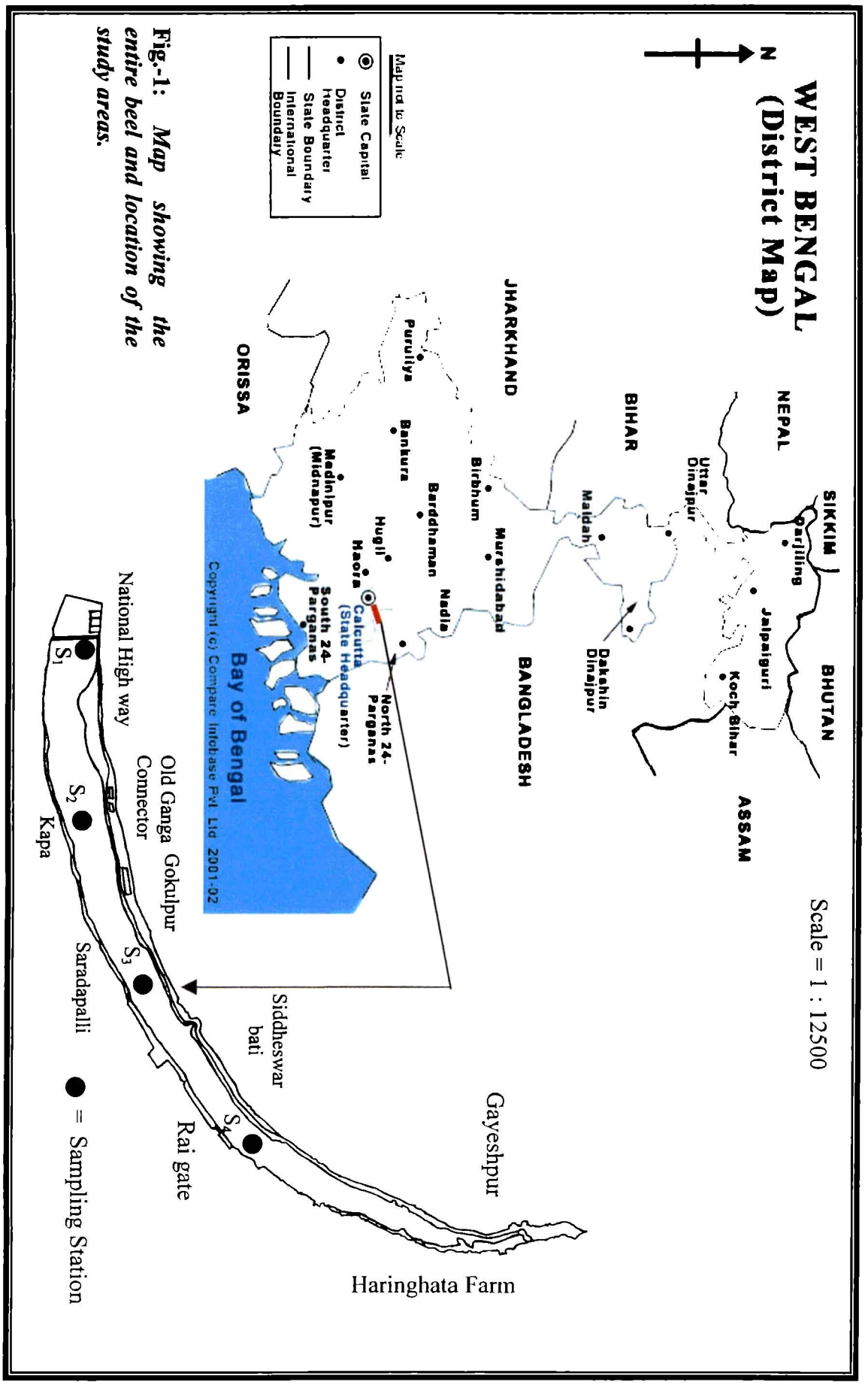


Fig.-1: ***Map showing the entire beel and location of the study areas.***

Plate 1. A general view of Mathura beel

Plate 2. A view of the beel showing siltation

Plate 3. A view of beel showing anthropogenic activities

Plate 4. A patch of the beel with heavily macrophytic infestation

Plate 5. A patch of beel converted into agricultural land

Plate 6. A view of beel showing shrinkage of its area at terminal portion due to silation

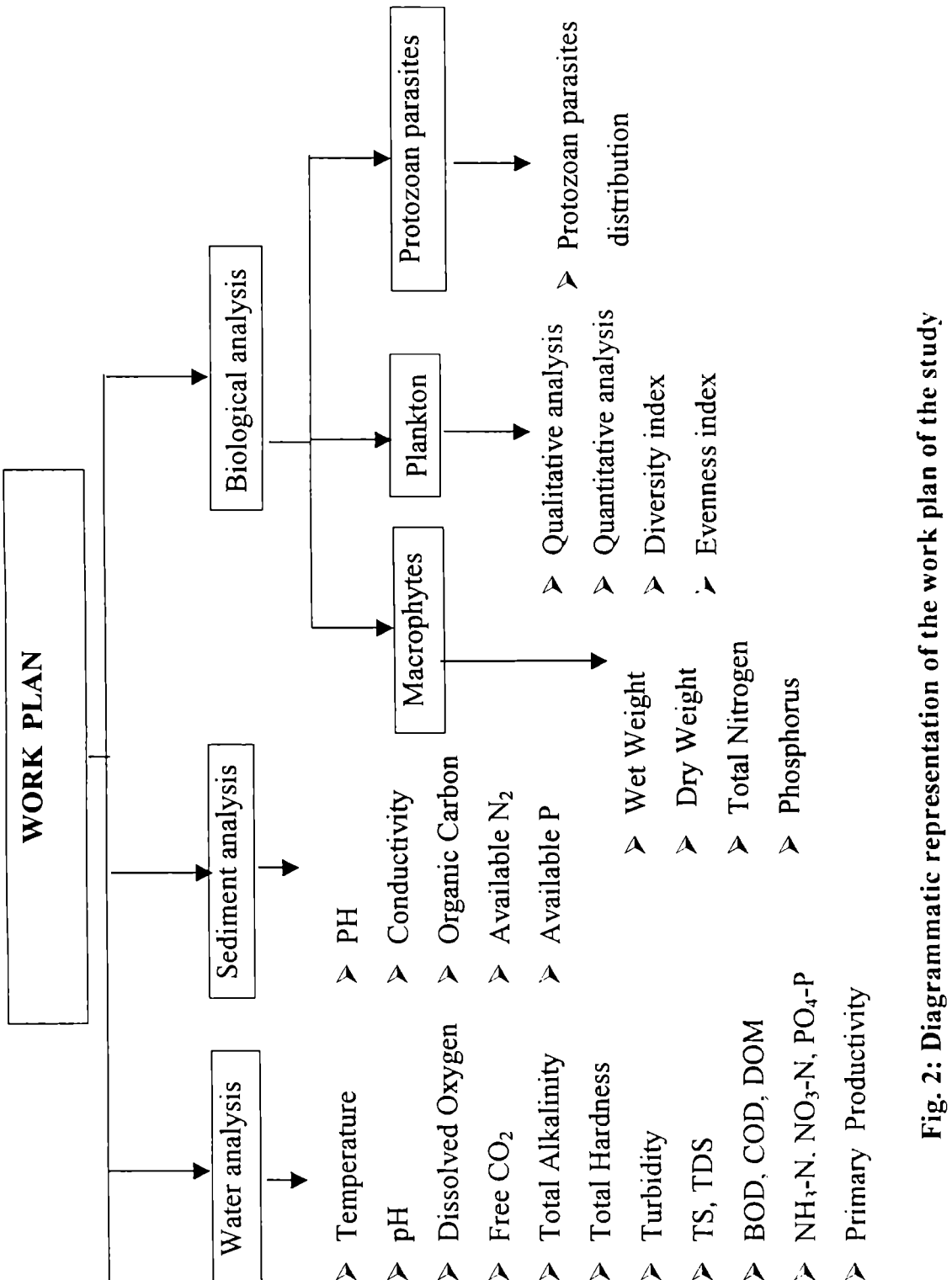


Fig. 2: Diagrammatic representation of the work plan of the study

3.3. WORK PLAN OF THE STUDY

For biomonitoring of this floodplain wetland, an investigation was carried out for a period of twelve months starting from May 2004 to April 2005. To get the detailed status of water quality, four sampling stations were fixed randomly considering the whole water body into one and stations were denoted as S_1, S_2, S_3 and S_4. The station S_1 is situated near national highway. It receives domestic sewage of military and railway staff quarters of Kanchrapara and it is highly silted and weed choked zone. The station S_2 is locally known as Mandir of Kampa. It is used for washing and bathing of the local people. The station S_3 is known as Saradapalli. Water of this zone is frequently used for washing-bathing and agricultural purposes by the residents. The station S_4 is known as Raigate. The salient feature of this zone is that it is silted zone and bathing and washing activities observed during study period.

3.3.1. Sampling procedure

From each sampling station compound samples for water sample, sediment, macrophytes and plankton were collected randomly in labeled and clean containers once in a month and were analysed. Fishes from each and every station were collected and brought to the laboratory in every month for protozoan parasite studies. Samples were collected in the early morning (between 7 to 8 a.m.) at the last week of every month from each stations. Monthly air temperature, rainfall and humidity data were computed from the daily data gathered from the records of the department of Agro-meteorology & Physics of the Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal.

3.3.2. Sample collection

Compound water samples were collected monthly from four selected stations for determining the physico-chemical parameters. The sensitive water parameters like temperature, dissolved oxygen, total

alkalinity and pH were analysed on the spot and for other parameters the samples were brought to the laboratory for analysis. The primary productivity was conducted by dark and light bottle method. Compound sediment samples were collected from each station in clean, dry labeled polythene bags and brought to the laboratory for analysis.

Compound macrophyte samples from each sampling station were collected by 1 m^2 wooden frame. The samples collected, were washed, extra water was drained and wet weight was taken on spot by standard balance. Then the samples were brought to the laboratory for other analysis.

Plankton samples were collected by filtering fifty liters of water from each station. The samples were preserved in labeled bottle in 5% formalin for further analysis.

Live fish from each station as per the availability were brought to the laboratory for protozoan parasite analysis.

3.4. METHODS

3.4.1 Physico-chemical parameters of water

3.4.1.1 Temperature (Adoni *et al.*, 1985)

Water temperature was recorded by using centigrade thermometer to the nearest of 0.1^0C atfield it self.

3.4.1.2 pH (Adoni *et al.*, 1985)

pH of water was estimated by using direct water sample in digital pH meter (Systronics India model Mk IV).

3.4.1.3 Dissolved oxygen (APHA, 1998)

Dissolved oxygen was estimated by Winkler's Iodometric method. Samples were fixed with Winkler's reagents at field itself and fixed samples were titrated against 0.025N $Na_2S_2O_3$, where starch was used as indicator.

3.4.1.4 Free carbon dioxide (APHA, 1998)

The free carbon dioxide of water sample was estimated by titrating against standard sodium hydroxide (0.0227N) and phenolphthalein as indicator at field itself.

3.4.1.5. Specific conductivity (APHA, 1998)

The conductivity of the water samples were measured in the laboratory using digital conductivity meter (Systronics, India, model : 306) and the result was expressed as mS/cm^2 .

3.4.1.6 Total alkalinity (APHA, 1998)

Total alkalinity of water sample was estimated by titrimetric method, using 0.02N sulphuric acid solution as titrant and alcoholic phenolphthalein and methyl orange as indicators. The estimation was done at field itself.

3.4.1.7 Total hardness (APHA, 1998)

Total hardness of water sample was estimated by titrimetric method. Sample was titrated against 0.1N ethelene diamine tetra acetic acid (EDTA), after the addition of ammonium buffer. Erichrome black-T was used as indicator.

3.4.1.8 Total solids (APHA, 1998)

Water sample (50 ml) was evaporated in hot air oven at 103^0C for 24 hours and the weight difference of beaker was taken by electronic mono pan balance to find out the total solids.

3.4.1.9 Total dissolved solids (APHA, 1998)

Water sample (50 ml) was filtered by Whatman No-1 filter paper and evaporated in hot air oven explained as above to estimate the total dissolved solids.

3.4.1.10 Biological oxygen demand (APHA, 1998)

Biological oxygen demand (BOD_5) of water sample was estimated as follows. After a thorough aeration at 20^0C water sample was collected in BOD bottle and was incubated at 20^0C in BOD incubator for 5 days. Initial and final dissolved oxygen levels were estimated by Winkler's Iodometric method. BOD_5 value was calculated from the difference between initial and final values.

3.4.1.11 Chemical oxygen demand (APHA, 1998)

For the estimation of chemical oxygen demand (COD), water sample was digested with 0.25N standard potassium dichromate (5 ml) and sulphuric acid reagent (15 ml) by using COD digestion distillation unit then diluted with distilled water (15 ml) and titrated against 0.2N ferrous ammonium sulphate prepared freshly. Here, phenonthroline was used as indicator.

3.4.1.12 Dissolved organic matter (APHA, 1998)

The release of nascent oxygen by standard 0.1N potassium permanganate in the presence of acid and its subsequent utilization by dissolved organic matter in the water for stabilization was estimated. Filtered water sample (50 ml) along with 0.1N $KMnO_4$ (10 ml) solution and 1:3 ratio of H_2SO_4 solution (5 ml) was water bathed at 60^0C for 1 hour. 0.1N ammonium oxalate (10 ml) was added to discolour the sample. Resultant was titrated against 0.1N $KMnO_4$ till pink colour reappears.

3.4.1.13 Turbidity (APHA, 1998)

Turbidity was estimated by using direct water sample in digital Nephelo turbidity meter (Systronics India model 132).

3.4.1.14 Ammonia nitrogen (APHA, 1998)

Ammonia-nitrogen concentration in water was estimated by phenate method. Samples were fixed with indophenol reagents at field itself.

To the fixed sample (25 ml) phenol solution (1 ml), sodium nitroprusside (1 ml) and oxidizing solution (2.5 ml) was added. In the presence of phenol, ammonia and hypochlorite solutions react to give blue coloured indophenol compound after 30 min., which is stable for 24 hours. This colour was read at 640 nm in digital spectrophotometer (Systonics India model No-MK 166).

3.4.1.15 Nitrate nitrogen (Strickland and Parsons, 1960)

Nitrate nitrogen in the sample (50 ml) was reduced to nitrite with hydrazine and copper which is used as catalyst. To the reduced sample sulphonylamide solution (1 ml) and N-naphthylene diamine dihydrochloride (1 ml) were added. Developed pink colour was read at 543 nm in digital spectrophotometer (Systonics India model No-MK 166).

3.4.1.16 Phosphate phosphorus (APHA, 1998)

Phosphate-phosphorus was estimated by stannous chloride method. To the water sample (100 ml), ammonium molybdate (4 ml) and stannous chloride (0.5 ml) reagents were added. Optical density of developed blue colour was read after 10 minutes but before 12 minutes at 690 nm in digital spectrophotometer (Systonics India model No-MK 166).

3.4.1.16. Primary productivity (light and dark bottle technique)

The light and dark bottle technique described by Winberg (1963) was followed for the estimation of primary productivity. Water samples were collected in 250ml light and dark glass bottles and were incubated in same environment for a period of 4 hours. Dissolve oxygen (DO) in the samples before exposure to light were estimated by the Winkler's method. The differences of DO content in different bottles were used to estimate the primary productivity. The result of the primary production in terms of O_2 was converted into carbon by multiplying with a factor 0.375 (Boyd, 1992). The calculation described by Vollenwider (1974), was used to measure the rate of primary productivity as follows :

***Gross primary productivity** ($mgC/m^3/day^1$)=(LB-DB)/T x 0.375/PQ x 1000 x 12

***Net primary productivity** ($mgC/m^3/day^1$) = (LB-IB)/T x 0.375/PQ x 1000 x 12

3.5. SEDIMENT

Shade dried sediment samples were grounded and seived with 0.425 mm meshed standard test sieve. The sieved samples were used for the estimation of pH, conductivity organic carbon, available nitrogen and available phosphorus.

3.5.1 pH (Tan, 1996)

Sediment suspension in water (1:5) was used for the determination of pH by digital pH meter (Systronics India molel No-MK IV).

3.5.2 Organic carbon (El Wakeela and Riley, 1957)

1 gm. sediment was digested with 1N $K_2Cr_2O_7$ (10 ml) and concentrated sulphuric acid (20 ml). After digestion that was diluted with distilled water (200 ml). To that phosphoric acid (10 ml) was added and titrated against 1N ferrous ammonium sulphate using diphenylamine as indicator.

3.5.3. Available nitrogen (Subbaiah and Asija, 1956)

Sediment (20 g) was taken in 800 ml Kjeldhal flask, then distilled water (20 ml), liquid paraffin (1 ml), 0.32% $KMnO_4$ (100 ml) and 2.5% NaOH (100 ml) were added. Immediately, flask was connected to the distillation unit. Tip of the delivery tube was dipped into erlenmeyer flask which contain boric acid (20 ml) solution, and mixed indicator. Collected distillate was titrated against 0.02N H_2SO_4 till the sample become colourless.

3.5.4. Available phosphorus (Bray and Kurtz, 1945)

Available phosphorus content of sediment was estimated by following Bray-I method. To the shaked sediment (1 g), (0.5N HCL + 1N NH_4F) extracting solution (10 ml) was added and centrifuged mechanically. The supernatant (5 ml) was separated and transferred into 500 ml volumetric flask then diluted with distilled water upto the mark. To that solution ammonium molybdate (40 ml) and stannous chloride (0.25 ml) were added.

The colour developed was read at 660 nm were length in spectrophotometer (Systonics India model No. MK-166).

3.6. MACROPHYTE

3.6.1. Wet weight and dry weight (Tandon, 1995)

Plant samples were washed thoroughly and the excess water was drained out. Wet weight of macrophytes was recorded at station itself by using minimum 5 g grade automatic pan balance. About one fourth (not less than 1 kg.) of the plant sample was collected and brought to the laboratory for other analysis. Plant samples were dried in hot air oven at 65^0C for over night. Dry weight of plants was recorded by using same balance.

After drying total plants were grounded properly using homogenizer and used for the estimation of total nitrogen and phosphorus.

3.6.2. Total nitrogen (AOAC, 1995)

Total nitrogen in plant sample was determined by Kjeldhal method. Sample (0.5 g) was taken in 100 ml digestion flask and digested by adding (10-15 ml) concentrated sulphuric acid and a pinch of digestion mixture till the solution become colourless. After digestion, sample was cooled and diluted with distilled water up to the mark. Aliquot was distillated with 40% sodium hydroxide (10 ml) and 2% boric acid (5 ml). Here bromocresol green and methyl red were used as mixed indicator. After distillation, resultant was titrated against N/70 hydrochloric acid solution. The appearance of pink colour of solution indicates the end point of the titration.

3.6.3. Phosphorus (Tandon, 1995)

Grounded plant sample (1 g) was digested by adding a mixture of (10 ml) concentrated nitric acid and perchloric acid at a ratio of 9:4, till the sample become colourless. After digestion, the volume was made up to the mark of the volumetric flask with distilled water and the solution was filtered through Whatman No-1 filter paper. Aliquot was used for determination of phosphorus.

Plant phosphorus was estimated by using Vanadomolybdate reagent. Aliquot (10 ml) was taken in 50 ml volumetric flask. To the aliquot Vanadomolybdate reagent (10 ml) was added and the volume was make with distilled water. Vanadate, molybdate and orthophosphates react together to give a yellow colour complex in acidic medium after 30 minutes. which is stable for 2-8 weeks. The colour was read at 420 nm in spectrophotometer (Systonics India model No-MK 166). Analytical grade of KH_2PO_4 was used for the standard solution.

3.7. PLANKTON

3.7.1. Qualitative and quantitative analysis of plankton

The preserved plankton samples were examined under research microscope for qualitative and quantitative analysis following drop method (Battish, 1992). In this method, one drop of well-shaken concentrated plankton samples was transferred to a slide and covered with a cover glass, carefully. The individual phytoplankton and zooplankton were counted under microscope using high power magnification (40X) and the species were identified following (APHA, 1998). Ten drops of each sample were counted in the same manner and the total numbers of phytoplankton and zooplankton were calculated as follows (APHA, 1998).

$$\text{Plankton (Nos./l)} = R \times \frac{1}{p} \times \frac{n}{N}$$

Where,

R = Average number of phytoplankton or zooplankton per drop.

P= volume of one drop.

N= volume of original sample.

n= Total volume of concentrated sample.

3.7.2. Diversity index and Evenness index

The diversity index of plankton was assessed by the Shannon-Weaver index ($\bar{H}$) (1964) calculated as :

$$\bar{H} = \sum_{i=1}^{S} Pi \, (\ln Pi)$$

Where Pi is the proportion of individuals belonging to species - i and S is total number of species in the community.

The evenness index of plankton was calculated by Pielou's (1966) evenness index (E) as :

$$E = \frac{\bar{H}}{\ln S}$$

Where, $\bar{H}$ is the observed species diversity and S is the total number of species.

3.8. PROTOZOAN PARASITE

3.8.1. Collection of samples for parasitic examination

The methods for collection and preservation of the samples for protozoan parasitic examination were followed as described by Mandal and Nandi (1980). Monthly samples of host fish (10-20 numbers) ranged from 100-200 gm were brought to the laboratory in live condition.

3.8.2. Preparation of smear and fixing of parasite

The scrapings were taken from gills, body surface and other body parts separately with the help of scalpel and a pair of forceps. Then the scrapings on the slides were diluted by 0.7% NaCl and thin smears were made on greese free clean glass slides. The smears were then semidried with Bouins's fluid and sometimes Schaudion's fluid was used for fixation. However, to avoid specimens form becoming hard and brittle, after 15-20 minutes of fixation, slides were washed and placed in a preservative (70% ethyl alcohol). After washing the slides were dipped in couplin jars containing 70% ethyl alcohol for further preservation.

3.8.3. Staining

The collected smears were stained by hematoxylin and eosin and giemsa and some slide were also stained by Klein dry silver impregation technique.

3.8.4. Microscopic Examination

Prepared slides were observed under microscope to note the presence and types of protozoan parasite. Different types of protozoan parasites were identified based on their individual characteristics features (Kudo, 1954; Nandi and Das, 1995; Rosemarie, 1998; Jayakumar and Ramasamy, 1999).

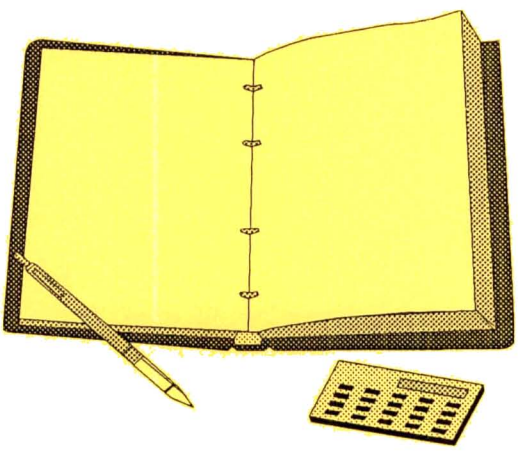
3.8.5. Determination of parasitic frequency index (PFI)

Parasitic frequency index was calculated by taking the percentage of the number of hosts infected by an individual parasite species against the total number of host examined (Smears from gills, body surfaces).

Statistical Analysis

The data generated from the investigation were tested for significance of variance among the stations during different months of the year through two factors (ANOVA) analysis of variance based on RCB (Randomised Complete Block) design. The interactions between the different parameters of water and sediment and stress factors were tested through the correlation analysis. All the statistical procedures were followed after Gomez and Gomez (1984) and with the help of a statistical software (Microsoft Excel-2000).

CHAPTER - 4



RESULTS

The entire results obtained were presented as figurers in the chapter. The tabulated data of the results obtained are given in Annexure for easy reference.

4.1. METEOROLOGICAL CONDITIONS

The average monthly records of different meteorological parameters like rainfall, relative humidity and atmospheric temperature (minimum and maximum) were collected from the department of Agricultural Meteorology and Physics, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The air temperature during the study period varied from 8.5^{0}C (January) to 38.8^{0}C (May). It was recorded that air temperature was in decreasing trend from June to January. The monthly rainfall throughout the study period ranged from nil to 104.0 mm. There was no rainfall in December and February. Average monthly relative humidity of air at 13:35 hours was fluctuated from 85.83±12.59% to 46.33±14.82%.

4.2. PHYSICO CHEMICAL PARAMETERS OF WATER

The monitoring of aquatic environment can be assessed by physical, chemical and biological methods. The physico-chemical analysis has direct or indirect relation with the biotic community of aquatic ecosystem. Considering the fact the following physico-chemical parameter were analysed and the results were described below. The tabulated data of the physico-chemical parameters have been depicted as Annexure - I.

4.2.1. Temperature :

Water temperature readings of four sampling station of water body at the time of sampling are given in Fig - 3(a). During the study period the highest temperature was recorded as 30.4^{0}C in the month of May at station S_4 and the lowest value recorded was 16.0^{0}C in the month of

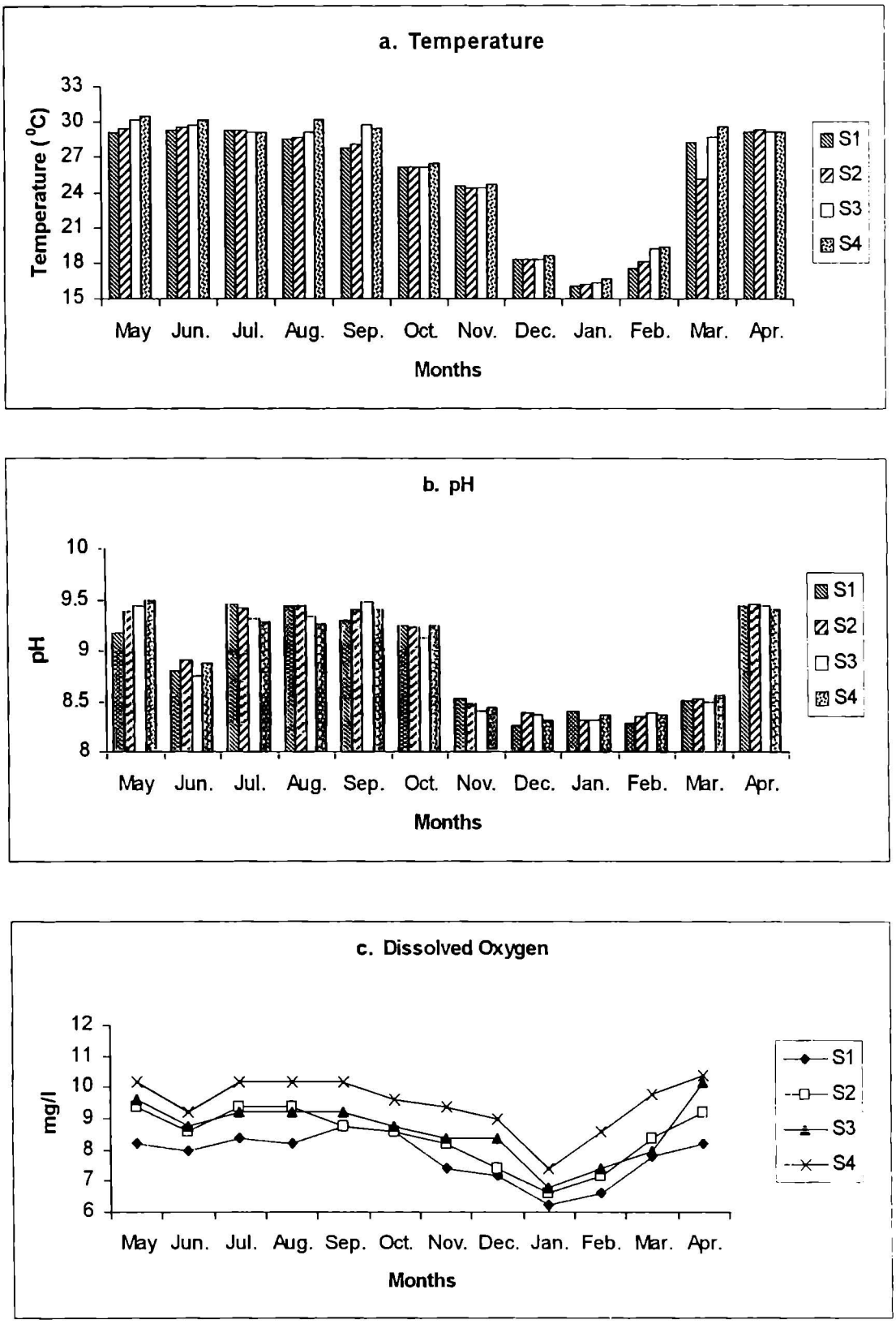


Fig. 3 : Monthly fluctuations in (a)Temperature (b)pH and (c) Dissolved oxygen of water

January at station S_1. Average values recorded were 25.37^{0}C, 25.22^{0}C, 24.68^{0}C and 23.72^{0}C at S_1, S_2 S_3 and S_4 respectively. The air temperature showed similarity in distribution with water temperature.

4.2.2. pH :

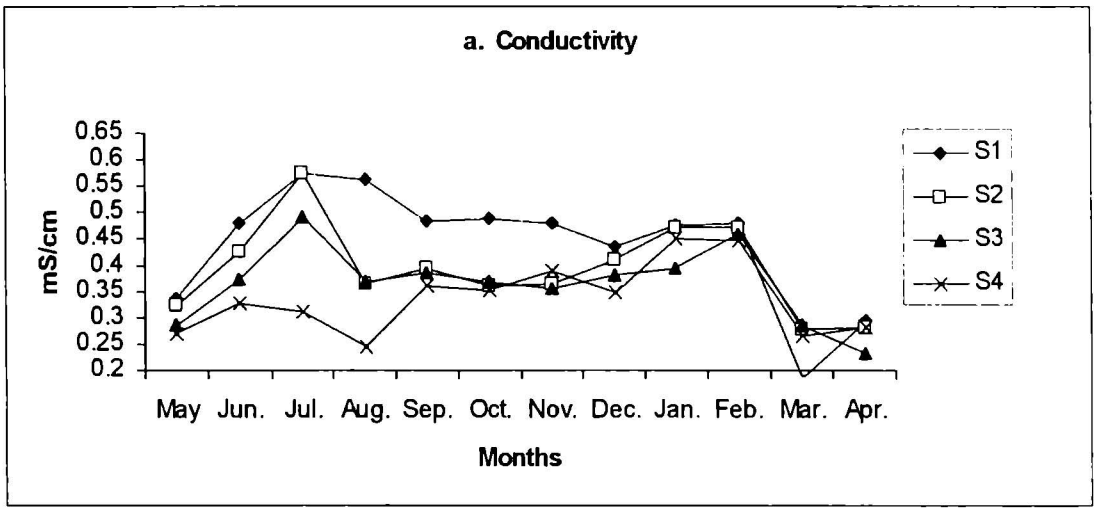
The pH fluctuations recorded at four different stations is depicted in Fig - 3(b). The pH range was seen to be from 8.28 (in February) to 9.50 (in September) at S_2 and S_4 respectively. pH recorded in all the stations were alkaline throughout the year. The average values of S_1, S_2, S_3 and S_4 were 8.91, 8.86, 8.74 and 8.92 respectively. pH of water decreased during November to March in all the stations of the water body. In the present investigation, pH showed a highly significant positive correlation with alkalinity, Hardness, Nitrate, Phosphate in all the stations.

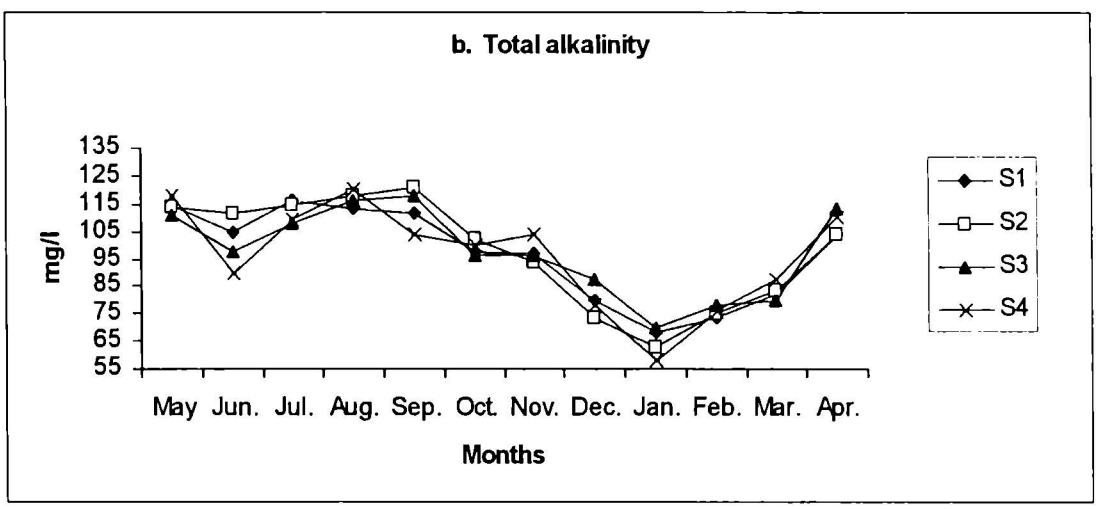
4.2.3. Dissolved oxygen

Dissolved oxygen as seen in Fig 3(c) varied between a range of 6.2 mg/l (January, S_1) and 10.4mg/l (April, S_4). The lower and higher values of dissolved oxygen at S_1, S_2, S_3 and S_4 were 6.2 mg/l (Jan) and 8.8 mg/l (Sept.), 6.6 mg/l (Jan.) and 9.4 mg/l (May), 6.8 mg/l (Jan) and 10.2 mg/l (May), 7.4 mg/l (April) and 10.4 mg/l (January) and average values were 7.8 mg/l, 8.4 mg/l, 8.6 mg/l and 8.5 mg/l respectively. The dissolved oxygen fluctuation occurred during post monsoon and winter season. All the stations show minimum dissolved concentration during winter season and maximum values in pre-monsoon and during monsoon month. Dissolved oxygen showed a significant variation among four stations of the water body and a significant positive correlation with BOD, COD and primary productivity.

4.2.4. Conductivity :

From the conductivity values of four stations shown in Fig. 4(a). The minimum and maximum values of conductivity recorded during study are 0.131mS/cm of S_3 (April) and 0.576 mS/cm at S_2 (July). The S_4 shows some





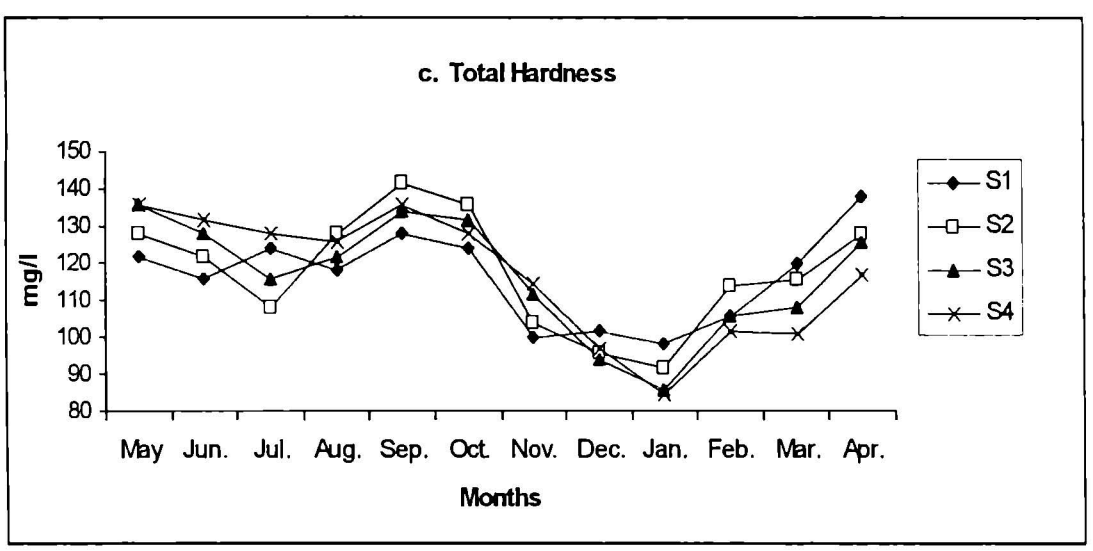


Fig. 4 : Monthly fluctuations in(a) Conductivity (b) Total Alkalinity and (c) Total Hardness of water

lower values of conductivity compared to other three stations. Its minimum value was 0.260 mS/cm and maximum value was 0.448 mS/cm in February. The average values recorded were 0.441 mS/cm, 0.394 mS/cm, 0.370 mS/cm and 0.338 mS/cm of stations S_1, S_2, S_3 and S_4 respectively. ANOVA for conductivity revealed that the variation between months and between stations were significant at 5% level.

4.2.5. Total alkalinity :

The minimum and maximum values of total alkalinity and maximum values recorded among four stations Fig - 4(b) were 58 mg/l (S_4, Jan) and 120 mg/l (S_4, August). In case of S_1 minimum value was 68 mg/l (January) and maximum value was 116mg/l (July) with an average value of 97 mg/l. The minimum and maximum values of total alkalinity of S_2, S_3, S_4 recorded were 63 mg/l (Jan.) and 121 mg/l (Sept), 70 mg/l (Jan) and 118 mg/l (Sept.) and 58 mg/l (January) and 120 mg/l (August) and average values were 98.00 mg/l, 97.67 mg/l and 96.25 mg/l respectively. The lowest value of total alkalinity was observed during January and there was an increasing trend upto May. Alkalinity was positively correlated with hardness. ANOVA for total alkalinity revealed that the variations between months varied significantly at 5% level.

4.2.6. Total hardness :

The values of total hardness recorded from four sampling stations were presented in Fig - 4(c). The readings of total hardness more or less showed similar trend of fluctuation . Values of total hardness (minimum and maximum) recorded during study were 85mg/l (S_4, January) and 142mg/l (S_2, September). Average values were 116.33mg/l, 117.83mg/l, 116.67mg/l and 116.92mg/l at stations S_1, S_2, S_3 and S_4 respectively. All the sampling stations recorded lowest values during January month. ANOVA for the total hardness revealed that the variation between months varied significantly at 5% level.

4.2.7. Turbidity

The values of turbidity taken from four sampling stations were presented in Fig - 5(a). Turbidity values for S_1 station showed decreasing trend from July to January and from February onwards a gradual increasing trend was observed. The minimum turbidity recorded was 17.11NTU (October) in case of S4 and maximum was 46.84 NTU (April) in case of S_1. Average values of S_1, S_2, S_3 and S_4 were 33.83 NTU, 30.53 NTU, 27.59 NTU and 25.46 NTU respectively. The annual variations of turbidity followed higher values during monsoon season and lower values in winter seasons. The ANOVA for turbidity revealed that the variations between months and between the stations were significant at 5% level.

4.2.8. Total solids:

Total solids values were given in Fig - 5(b). The minimum and maximum value of total solids recorded at S_1, S_2, S_3 and S_4 were 268mg/l (December) and 548mg/l (October), 274mg/l (February) and 4.22mg/l (July), 236mg/l (January) and 373mg/l (July) and 234mg/l (November) and 371mg/l (July) and average values recorded were 369.92mg/l, 336.33mg/l, 298.17mg/l and 300.25mg/l at stations S_1, S_2, S_3 and S_4 respectively. The overall values of all the four sampling stations showed a decreasing trend from July to December. The variations were significant at 5% level.

4.2.9. Total dissolved solids (TDS) :

The variation in the total dissolved solids (TDS) from the four sampling stations of the water body were shown in Fig - 5(c). In this study, TDS values were ranged from 152mg/l (May) to 270mg/l (October), 164mg/l (May) to 260mg/l (October), 105mg/l (November) to 160mg/l (September) and 114mg/l (November) to 166mg/l (September) and average values were 206.67mg/l, 188.85mg/l, 126.67mg/l and 129.83mg/l in S_1, S_2, S_3 and S_4 respectively. The trend of fluctuation was same as in the case of total solids. The values were significantly different in between months and between stations of 5% level.

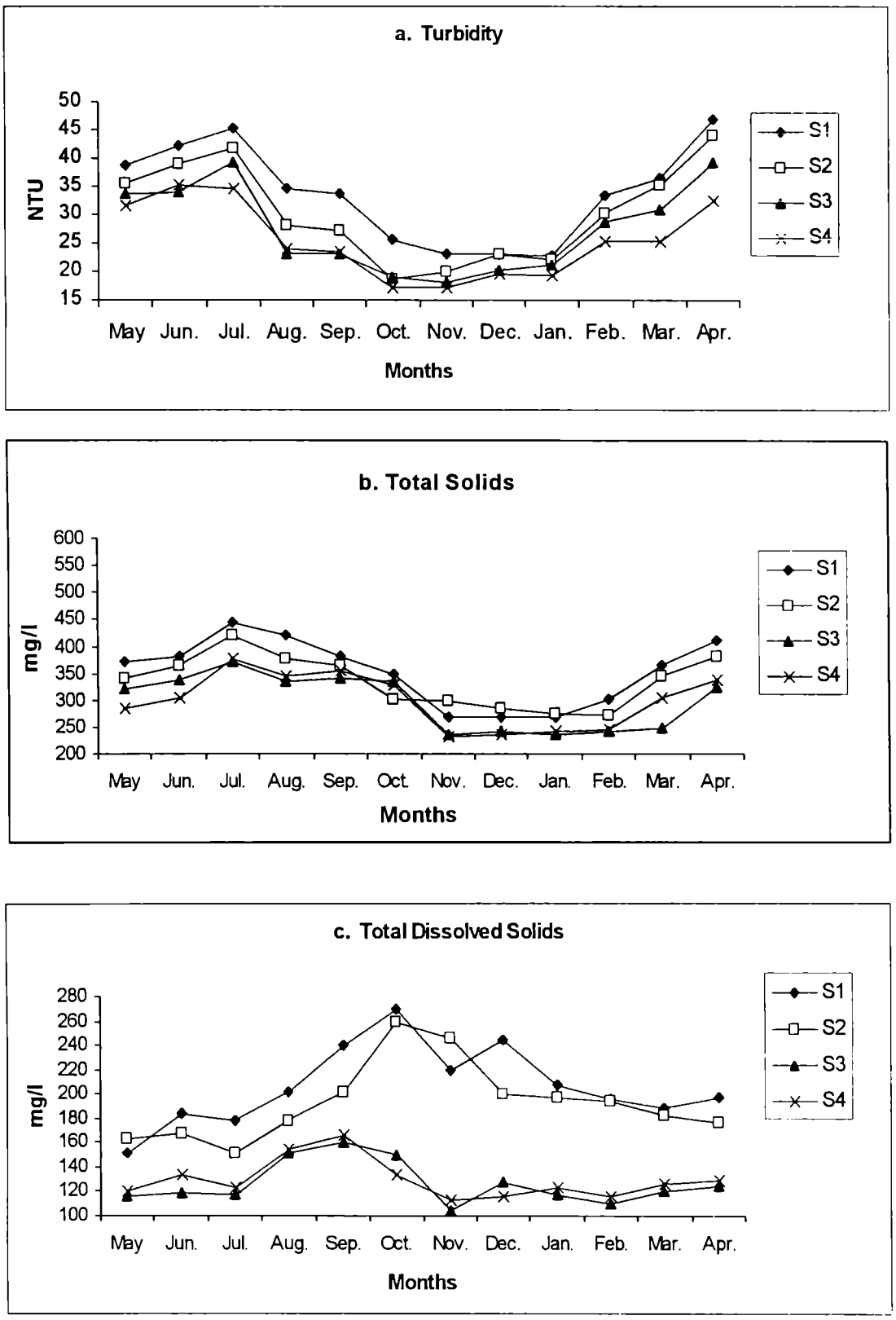


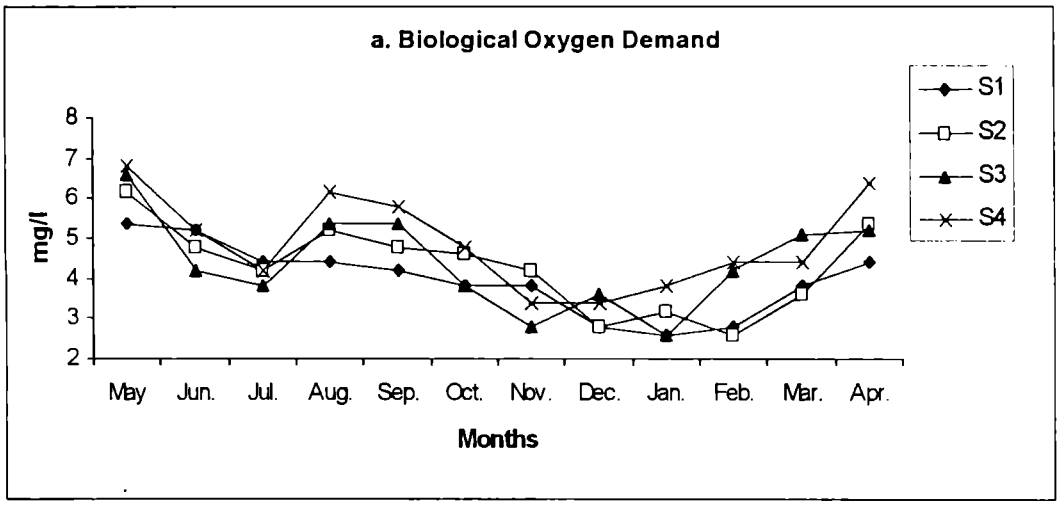
Fig. 5 : Monthly fluctuations in (a) Turbidity (b)Total Solids and (c) Total Dissolved Solids of water

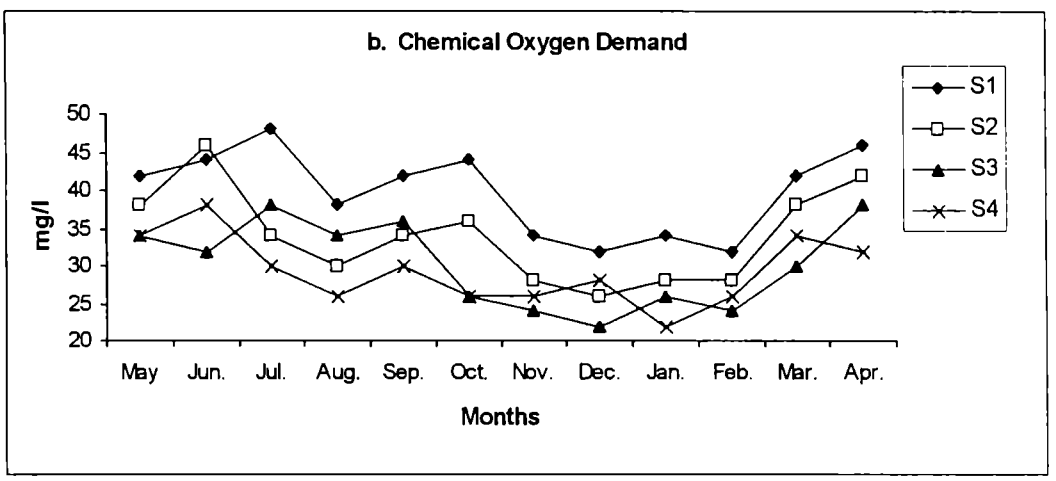
4.2.10. Biological oxygen demand (BOD_5) :

The biological oxygen demand (BOD_5), one of the important pollution indicator, varied between a minimum value of 2.6mg/l (S_1, January) to a maximum of 6.8mg/l (S_4, May) [Fig - 6(a)]. The fluctuations in the BOD_5 level were within the normal range and did not exceed the threshold level at any of the stations studied. It was comparatively higher in S_4 then S_1, S_2 and S_3. The minimum and maximum values at the stations S_1, S_2 S_3 and S_4 were 2.6mg/l (January) and 5.4mg/l (May), 2.6mg/l (February) and 6.2mg/l (May), 2.6mg/l (Jan) and 6.6mg/l (May) and 3.4mg/l (December) and 6.8mg/l (May) and average values were S_1, S_2, S_3 and S_4 were 4.4mg/l, 5.4mg/l, 5.2mg/l and 3.4mg/l respectively. ANOVA for the BOD_5 showed that the variation between months and BOD_5 also was between stations were significant at 5% level and significantly correlated with dissolved oxygen.

4.2.11. Chemical oxygen demand (COD) :

The chemical oxygen demand (COD) values of the water at different stations were presented in Fig 6(b). The minimum values of 22.0mg/l was recorded at S_3 (December), whereas the maximum COD level of 48.0mg/l was observed at S_1 (July). The overall trend of fluctuation was almost similar to that of BOD. The minimum and maximum values at S_1, S_2, S_3 and S_4 were varied from 32mg/l (Dec-Feb) to 48mg/l (July), 28mg/l (Nov-Jan-Feb) to 46mg/l (June), 22mg/l. (December) to 38mg/l (April) and 22mg/l (January) to 38mg/l (June) and the average values were 39.83mg/l, 34.00mg/l, 30.73mg/l and 29.33mg/l respectively, reflecting more or less similar fluctuations. From statistical analysis the variations in chemical oxygen demand values were found to be significant at 5% level and COD values were significantly positive correlated with dissolved oxygen.





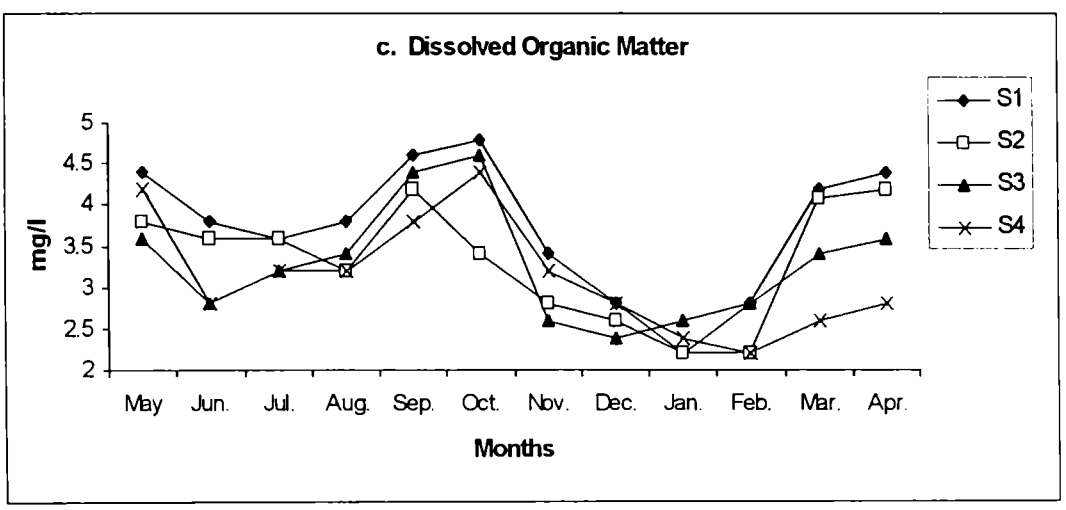


Fig. 6 : Monthly fluctuations in (a) Biological Oxygen Demand (b) Chemical Oxygen Demand and (c) Dissolved Organic Matter of water

4.2.12. Dissolved organic matter (DOM) :

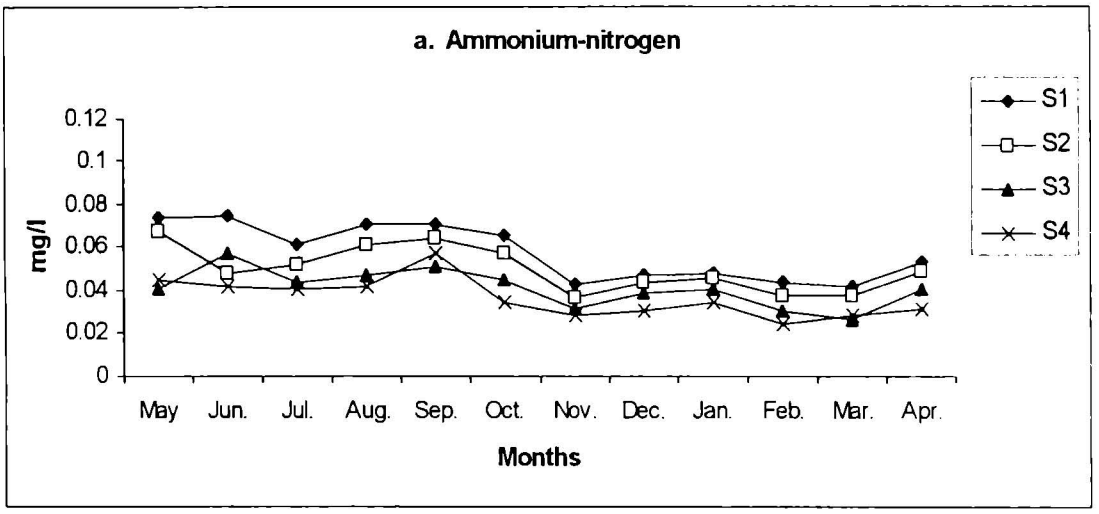
Among four stations the dissolved organic matter (DOM) values recorded at S_4 were [Fig - 6(c)] all time higher in comparison to that of S_1, S_2 and S_3. DOM values of four stations showed a similar increasing trend during post monsoon and summer months comparing to the monsoon months. The minimum and maximum values of DOM at S_1, S_2, S_3 and S_4 recorded were varied from 2.2mg/l (January) to 4.8mg/l (October), 2.2mg/l (Jan-Feb) to 4.2mg/l (September and April), 2.4mg/l (December) to 4.6mg/l (October) and 2.2mg/l (February) to 4.4mg/l (October) and average values recorded were 3.7mg/l, 3.3mg/l, 3.3mg/l and 3.1mg/l respectively. ANOVA for the DOM showed that the variations between stations and between months were significant at 5% level.

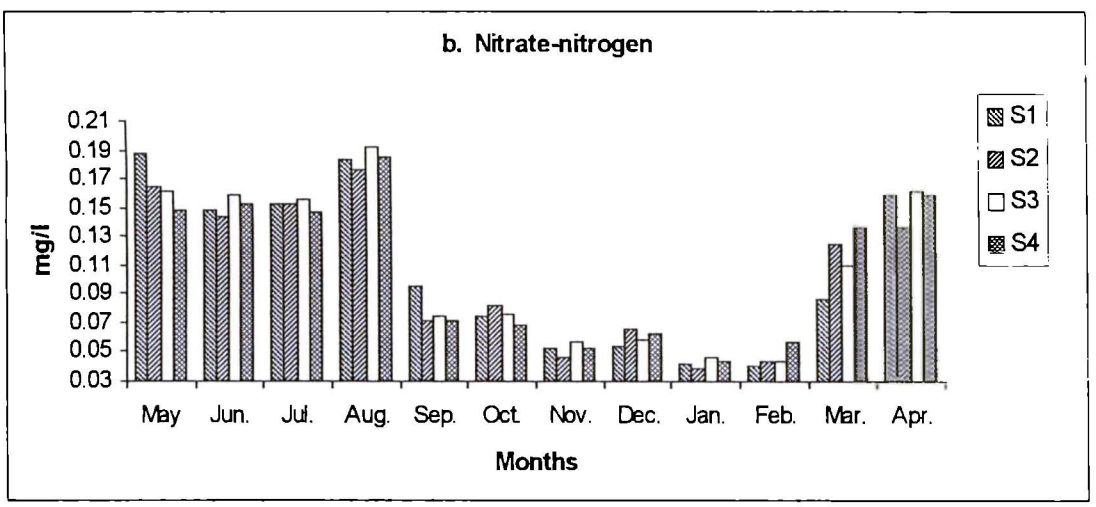
4.2.13. Ammonia nitrogen :

The values of ammonia nitrogen from four sampling stations of the water body was presented in Fig - 7(a). Higher values were recorded in all the stations during monsoon month but S_1 showed comparatively higher value than other three stations. The minimum and maximum values recorded for S_1, S_2, S_3 and S_4 were from 0.042mg/l (March) to 0.075mg/l (June), 0.037mg/l (November) to 0.068mg/l (May), 0.027mg/l (March) to 0.057mg/l (March) and 0.025mg/l (February) to 0.057mg/l (September) and average values were 0.058mg/l, 0.050mg/l, 0.049mg/l and 0.037mg/l respectively. Statistical analysis showed that the variations in the ammonia nitrogen concentration between months and between stations were significant at 5% level.

4.2.14. Nitrate nitrogen :

The Fig - 7(b) gives the variations in the nitrate nitrogen content at different stations of the water body studied. An uniformity in the fluctuations were noticed at all the sampling stations. Higher values were observed during the early period of study and the lower values during





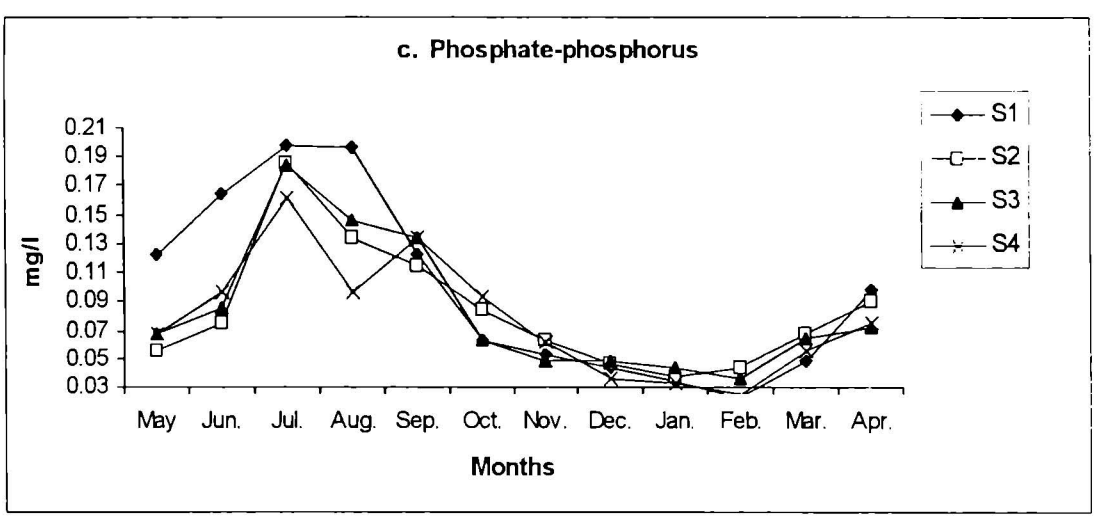


Fig. 7 : Monthly fluctuations in (a)Ammonia-Nitrogen(b)Nitrate-Nitrogen(c) Phosphate-Phosphorus of water

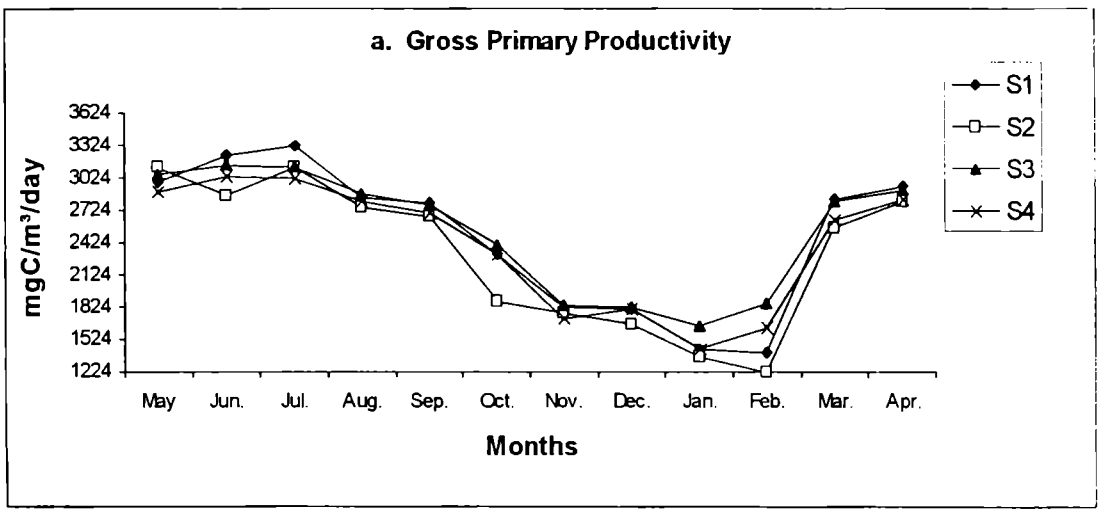
middle phase of the study with one or two exceptions. The minimum and maximum values at S_1, S_2, S_3 and S_4 recorded were 0.041mg/l (February) to 0.188mg/l (May), 0.039mg/l (February) to 0.176mg/l (August), 0.044mg/l (February) to 0.192mg/l (August) and 0.044mg/l (January) to 0.185mg/l (August) and average values were 0.106mg/l, 0.104mg/l, 0.106mg/l and 0.107mg/l respectively. Statistical analysis for nitrate-nitrogen revealed that the variations between months varied significantly at 5% level and nitrate nitrogen was also positively correlated with pH of water.

4.2.15. Phosphate phosphorus :

The monthly variations of phosphate phosphorus of water from four sampling stations were presented in Fig - 7(c). which revealed a higher value in case of S_1 than that of S_2, S_3 and S_4. In case of S_1 the level of phosphate phosphorus is relatively higher during monsoon season compared to other stations. The values of phosphate phosphorus varied from 0.022mg/l (February) to 0.198mg/l (July), 0.038mg/l (January) to 0.186mg/l (July), 0.036mg/l (February) to 0.184mg/l (July) and 0.026mg/l (February) to 0.162mg/l (July) and average values recorded were 0.097mg/l, 0.083mg/l, 0.083mg/l and 0.078mg/l at stations S_1, S_2, S_3 and S_4 respectively. Statistical analysis showed that the variations in phosphate phosphorus concentration between months and between stations varied significantly at 5% level.

4.2.16. Gross primary productivity (GPP) :

The GPP values of four sampling stations were represented in Fig 8(a). The minimum and maximum GPP values recorded were 1360 $mgC/m^3/d$ at S_3 in February and 3318 $mgC/m^3/d$ at S_1 in July. The minimum and maximum value of GPP at S_1, S_2, S_3 and S_4 varied from 1398 $mgC/m^3/d$ (February) to 3318 mgC/m3/d (July), 1222 $mgC/m^3/d$ (February) to 3126 $mgC/m^3/d$ (July), 1654 $mgC/m^3/d$ (January) to 3152 $mgC/m^3/d$ (June) and 1432 $mgC/m^3/d$ (January) to 3046 $mgC/m^3/d$



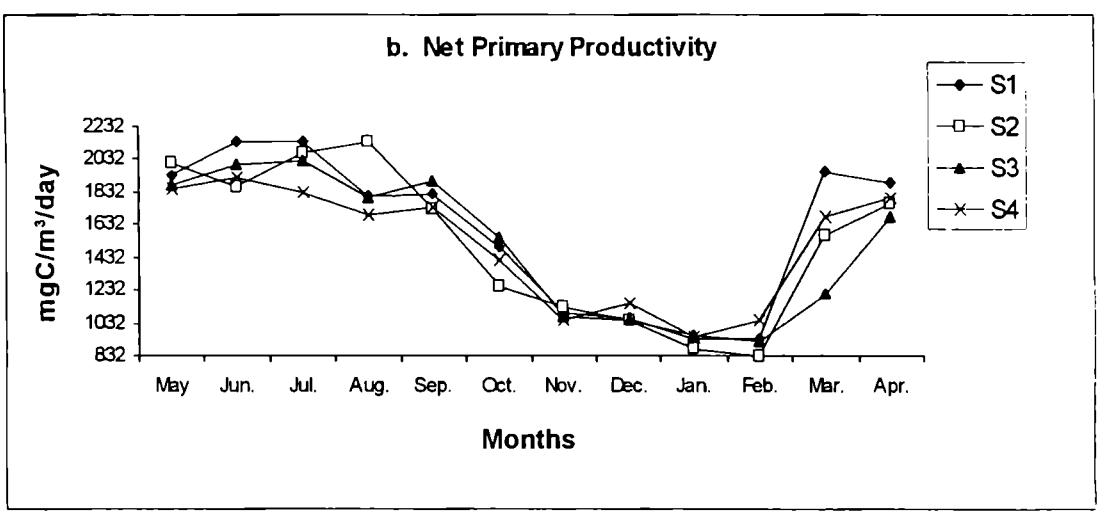


Fig. 8 : Monthly fluctuations in (a) Gross Primary Productivity and (b)Net Primary Productivity of water

(June) and average value recorded were 27 mgC/m^3/d 2478.33 mgC/m3/d, 2321.50 mgC/m^3/d, 2525.00 mgC/m^3/d and 2505.00 mgC/m^3/d at S_1 , S_2 , S_3 and S_4 respectively. The GPP values were maximum during monsoon season in all the sampling stations and lower values were recorded during winter and summer season. Statistical analysis showed that the variation in GPP between months and between stations were significant at 5% level.

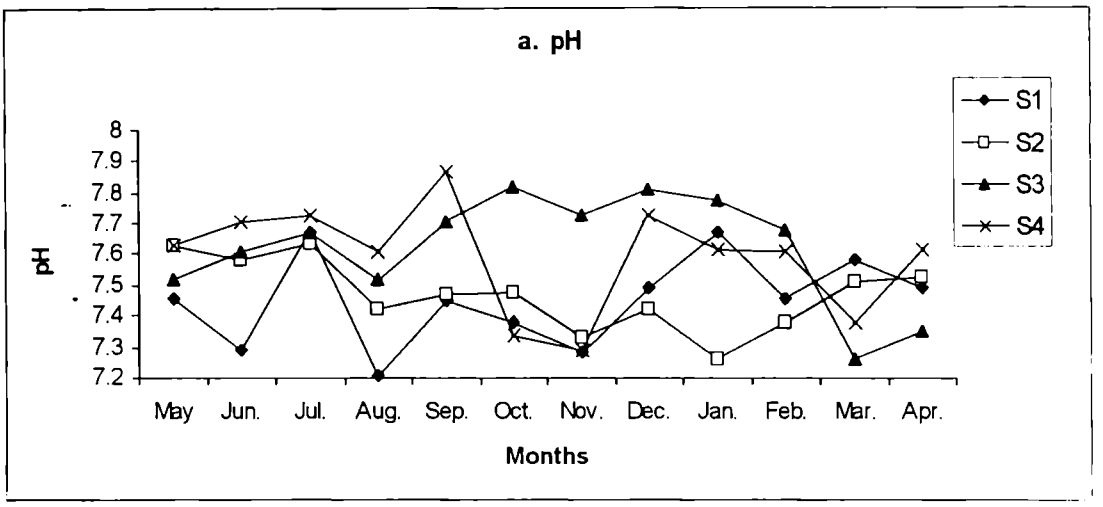
4.2.17. Net primary productivity (NPP) :

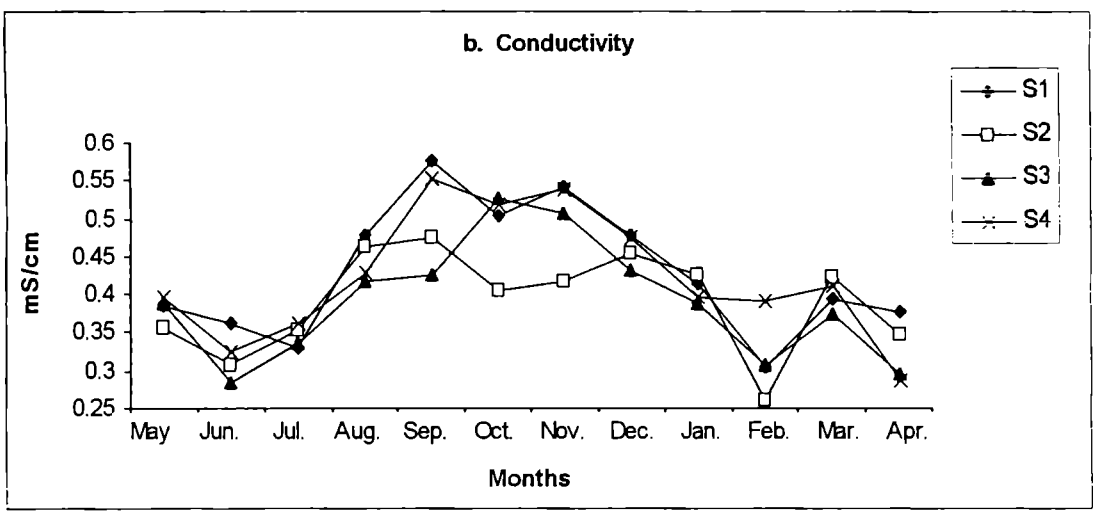
NPP values of four sampling stations of a water body was shown in Fig - 8(b). The minimum and maximum values of NPP recorded were 1834 mgC/m^3/d (Feb, S_2) and 2138 mgC/m^3/d (July, S_1 and August, S_2). The minimum and maximum values of S_1, S_2, S_3 and S_4 varied from 936 mgC/m^3/d (Feb) to 2138 mgC/m^3/d (July), 834 mgC/m^3/d (Feb) to 2138 mgC/m^3/d (August), 922 mgC/m^3/d (Feb) to 2098 mgC/m^3/d (May) and 948 mgC/m^3/d (Jan) to 1918 mgC/m^3/d (June) and average values recorded were 1600.17 mgC/m^3/d, 1525.33 mgC/m^3/d, 1505.00 mgC/m^3/d and 1511.17 mgC/m^3/d respectively. The NPP showed similar trend as in case of GPP. NPP showed significant positive correlation with the dissolved oxygen.

4.3. SEDIMENT

4.3.1. pH

The values of sediment pH from four sampling stations of the water body [Fig - 9(a)] replicates uniform fluctuation values in all the sampling stations. The minimum and maximum values for S_1, S_2, S_3 and S_4 were from 7.21 (August) to 7.67 (July, Jan), 7.26 (Jan) to 7.64 (July), 7.26 (March) to 7.82 (October) and 7.38 (March) to 7.87 (September) and average values were 7.45, 7.47, 7.62 and 7.59 respectively. ANOVA for the sediment pH reflects a significant difference in pH variations between sampling stations and the months at 5% level.





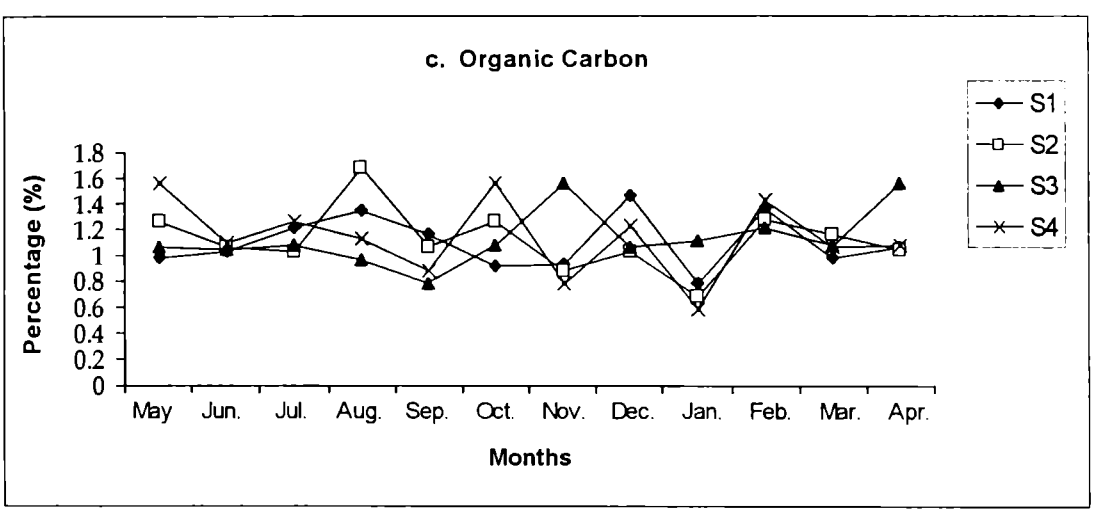


Fig. 9 : Monthly fluctuations in (a) pH (b) Conductivity and (c) Organic Carbons of sediment

4.3.2. Conductivity

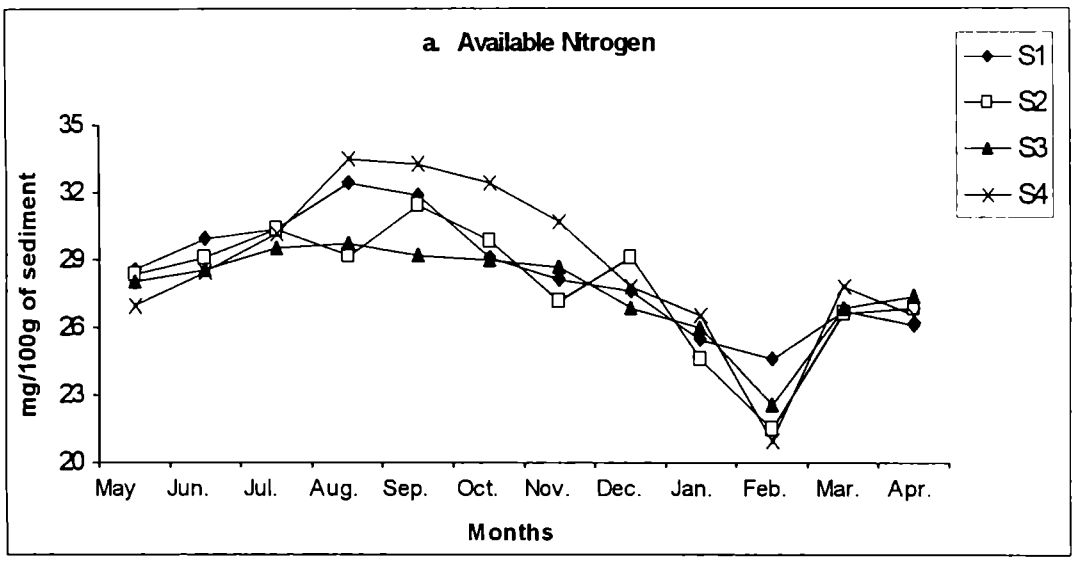
Conductivity of sediment at four sampling stations of the water body was shown in Fig - 9(b). The minimum and maximum values of conductivity recorded during study were 0.263 mS/cm(S_2, Feb) and 0.578 mS/cm (S_1, Sep). The lower and higher values at S_1, S_2, S_3 and S_4 recorded were 0.305 $mScm^{-1}$ (Feb) to 0.578 mS/cm (September), 0.263 mS/cm (Feb) to 0.477 mS/cm (Sep), 0.285 mS/cm (June) to 0.529 mS/cm (Oct) and 0.289 mS/cm (April) to 0554 mS/cm (Sep) and average values recorded were 0.430 mS/cm, 0.390 mS/cm, 0.390 mS/cm and 0.42 mS/cm respectively. Statistical analysis showed that the variation between months and between stations were significant at 5% level.

4.3.3. Organic carbon

The organic carbon content of the sediment recorded from four sampling stations was presented in Fig - 9(c). The maximum values of organic carbon of four sampling stations were recorded during monsoon period and minimum during winter period. The minimum and maximum values of organic carbon for S_1, S_2, S_3 and S_4 were recorded as 0.78%/100g (Jan) to 1.78%/100g (December), 0.68%/100g (Jan) to 1.68%/100g (August), 0.78%/100g (September) to 1.56%/100g (Nov- Aprl.) and 0.26%/100g (Jan) to 1.56%/100g (May-Oct) and average values were 1.10%/100g, 1.12%/100g, 1.13%/100g and 1.115/100g respectively.

4.3.4. Available nitrogen

The available nitrogen content of sediment collected from four sampling stations were represented in Fig - 10(a). The available nitrogen content of S1, S2, S_3 and S_4 showed a minimum and maximum value of 24.62mg/100g (Feb.) and 32.42mg/100g, 21.54mg/100g (Feb) and 31.42mg/100g (Sep), 22.58mg/100g (Feb) and 29.78mg/100g (August) and



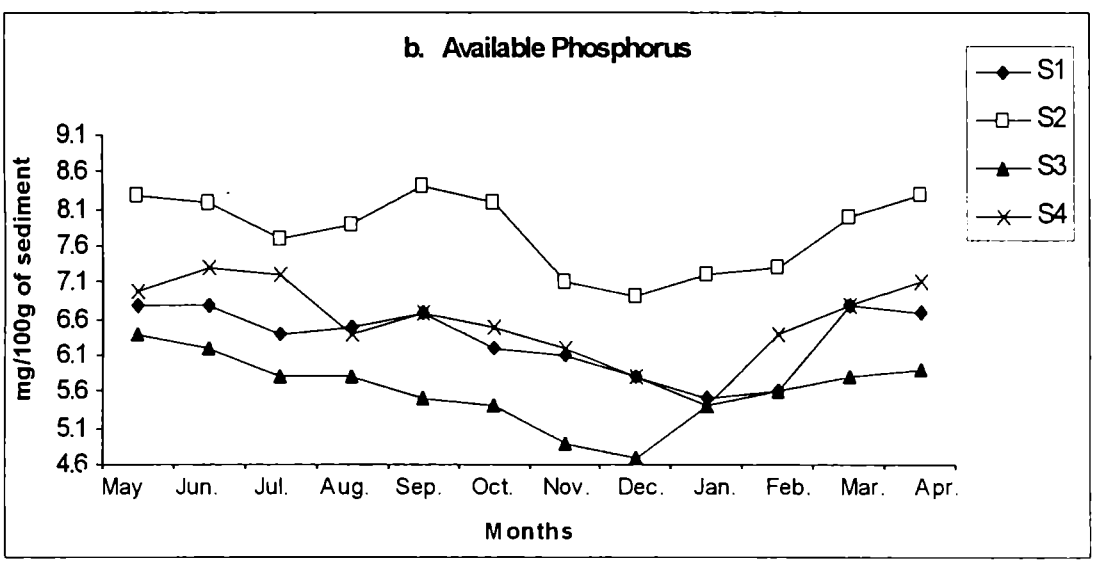


Fig. 10 : Monthly fluctuation in (a) Available Nitrogen and (b) Available Phosphorus of sediment

20.92mg/100g (Feb) and 34.54mg/100g (August) and average values recorded were 28.42mg/100g, 27.85mg/100 g, 27.71mg/100g and 28.86mg/100g respectively. The annual fluctuation of available nitrogen is not so much remarkable but the values are slightly towards higher side during monsoon and post-monsoon whereas lower during winter season. Statistical analysis of the sediment available nitrogen revealed that the variations between month and stations were significant at 5% level.

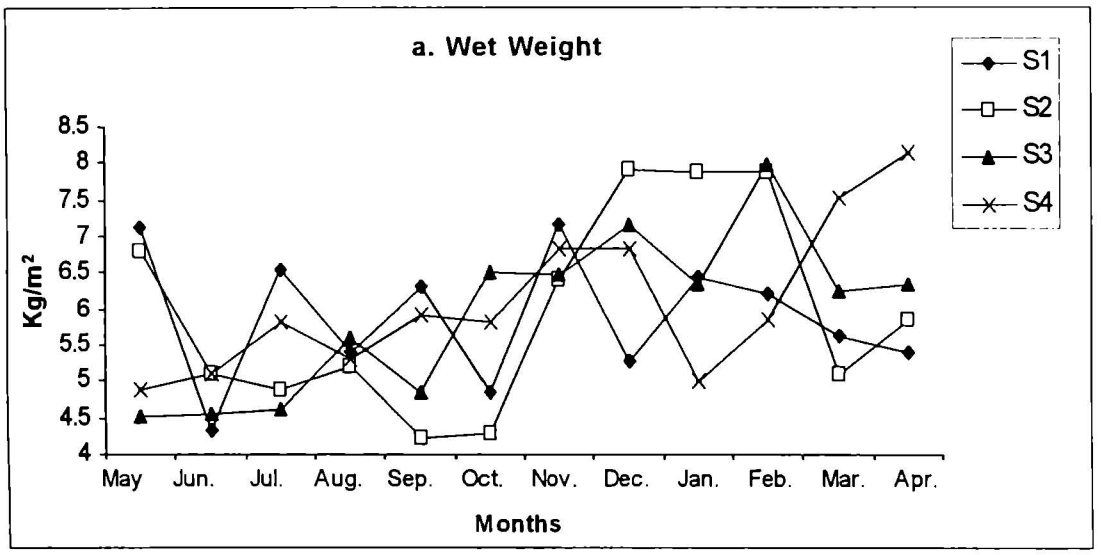
4.3.5. Available phosphorus

The available phosphorus of sediment of four sampling stations was represented in Fig - 10(b). Among four stations, S_2 showed higher values of available phosphorus compared to that of S_1, S_3 and S_4. The minimum and maximum values recorded for S_1, S_2, S_3 and S_4 were from 5.5mg/100g (January) to 6.8mg/100g (March-May-June), 6.9mg/100g (December) to 8.4mg/100g (Sep), 4.7mg/100g (December) to 6.4mg/100g (May) and 5.4mg/100g (Jan) to 7.3mg/100g (June) and the average values were 6.3mg/100g, 7.8mg/100g, 5.6mg/100g and 6.6mg/100g respectively. The available phosphorus content of sediment showed a similar pattern of fluctuation with that of available nitrogen having a higher value during monsoon months and lower during winter season. Statistical analysis showed that the variations in the available phosphorus concentration between stations and between months were significant at 5% level.

4.4. MACROPHYTE

4.4.1. Wet weight

The wet weight of macrophyte collected from four sampling stations of a water body was presented in Fig - 11(a). The minimum and maximum value of macrophyte biomass as wet weight varied from 4.34kg/m^2 (June) to 7.16 kg/m^2 (November), 4.23 kg/m^2 (Sep) to 7.91 kg/m^2 (Dec), 4.52 kg/m^2 (May) to 7.99 kg/m^2 (Feb) and 4.87 kg/m^2 (May) to 8.15 kg/m^2 (April) and average values recorded were 5.89 kg/m^2, 5.96 kg/m^2,



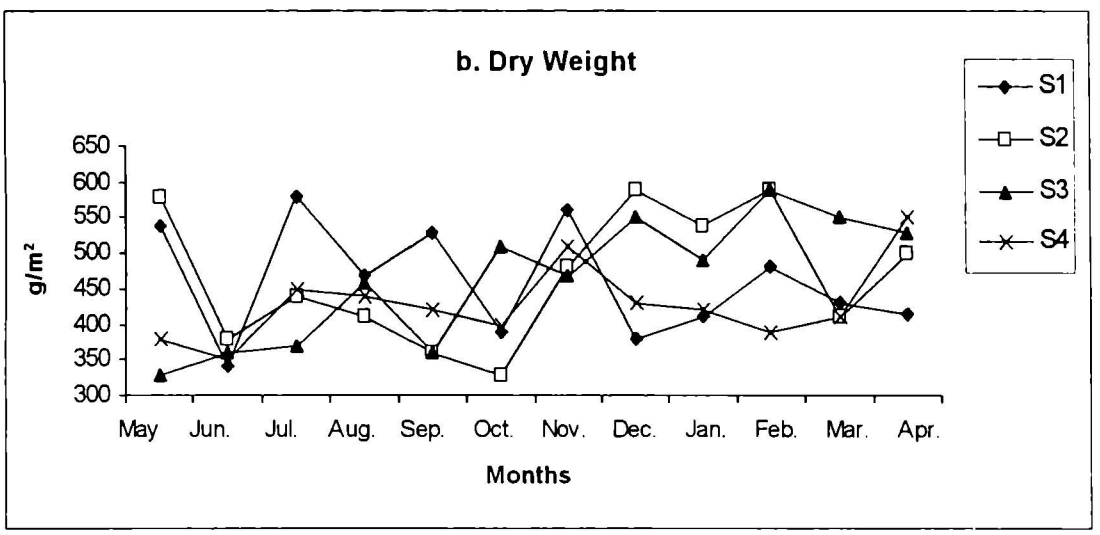


Fig. 11 : Monthly fluctuations in (a) Wet Weight and (b) Dry Weight of Macrophytes

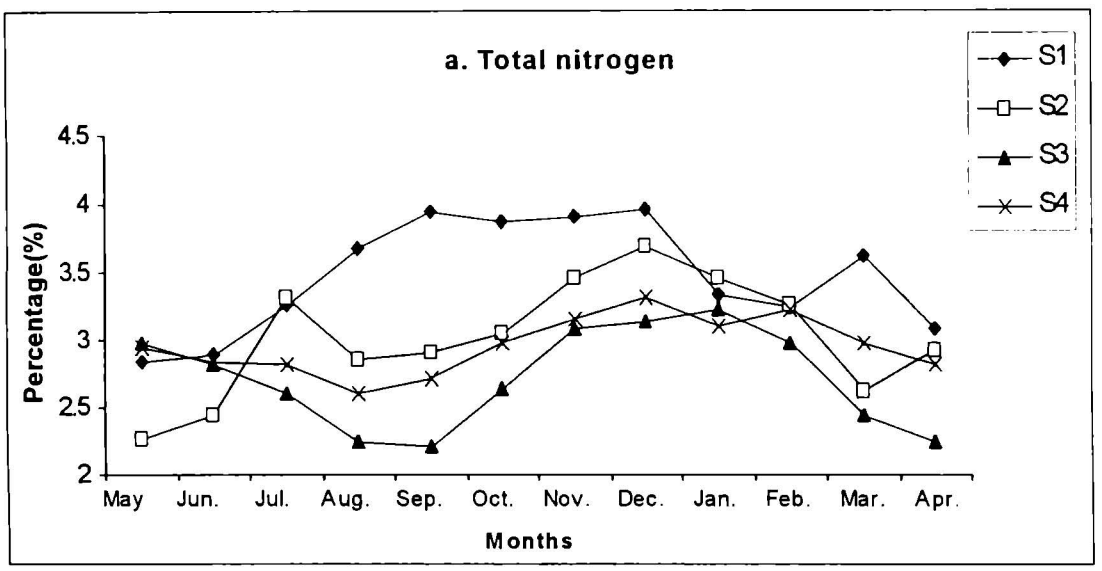
5.94 kg/m^2 and 6.09 kg/m^2 in S_1, S_2, S_3 and S_4 respectively. The higher values were observed in peak summer where as lower values in early winter. The macrophyte biomass was higher in S_1, moderate in S_4 and comparatively low in S_2 and S_3. In case of some periods of study the wet weight is very low due to manual removal of macrophyte by co-operative labour from time to time.

4.4.2. Dry weight

Dry weight of macrophyte collected during the present study was represented in Fig - 11(b). Dry weight of macrophyte ranged from 340 g/m^2(June) to 540 g/m^2 (May), 330 g/m^2 (October) to 590 g/m^2 (Feb-Dec), 330 g/m^2 (May) to 590 g/m^2 (Feb) and 390 g/m^2 (Feb) to 550 g/m^2 (April) and average values were 460.42 g/m^2, 567.50 g/m^2, 464.17 g/m^2 and 429.17 g/m^2 in S_1, S_2, S_3 and S_4 respectively. The overall trend of fluctuations are same as in the case of wet weight.

4.4.3. Total nitrogen

The estimated total nitrogen content of whole plant tissue of macrophyte collected from four sampling stations of a water body was given in Fig - 12(a). The total nitrogen varied from 2.834mg/100g (May) to 3.962mg/100g (Sep), 2.068mg/100g (May) to 3.716mg/100g (July), 2.218mg/100g (Sep) to 3.238mg/100g (Dec) and 2.612mg/100g (Aug) to 3.236mg/100g (Feb) and average values were 3.472mg/100g, 3.040mg/100g, 2.721mg/100g and 2.959mg/100g respectively. Higher values of total nitrogen were observed in S_1. Higher value were observed during summer and lower average values during winter. Analysis of variance revealed that the variation in the total nitrogen content of macrophytes between stations and between months were significant at 5% level.



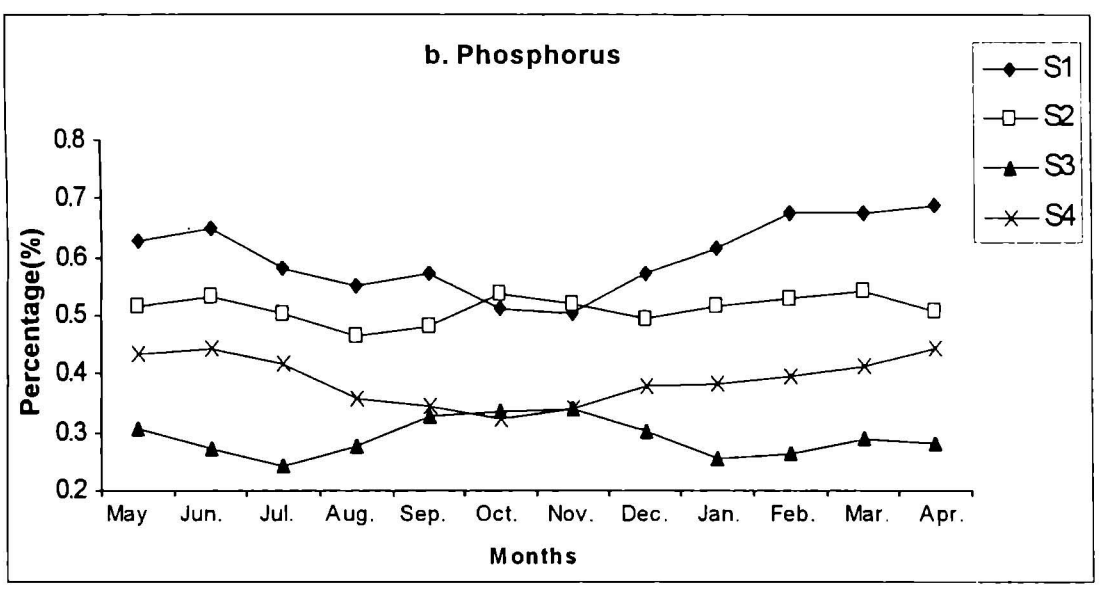


Fig. 12: Monthly fluctuations in (a) Total nitrogen and (b) Phosphorus of Macrophytes

4.4.4. Phosphorus

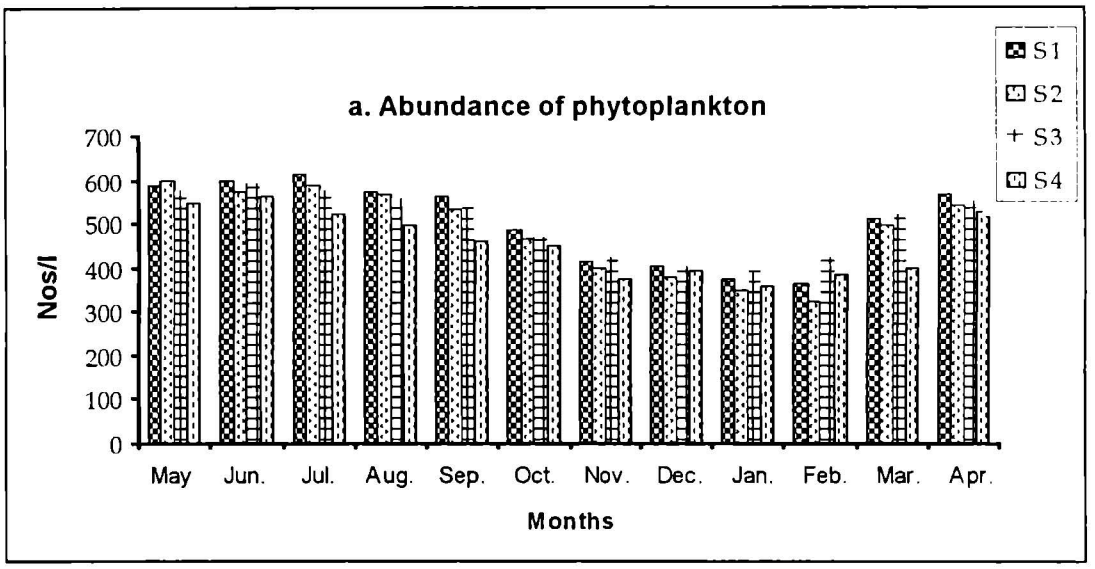
Results of the phosphorus content of the whole plant tissue collected from your sampling stations of a water body are given in Fig - 12(b). The phosphorus content ranged from 0.505mg/100g (Nov) to 0.687mg/100g (April), 0.464mg/100g (Aug) to 0.544mg/100g (March), 0.256mg/100g (Jan) to 0.342mg/100g (Nov) and 0.326mg/100g (Oct) to 0.446mg/100g (April) in S_1, S_2, S_3 and S_4 respectively. Maximum total phosphorus content of macrophytes was recorded in the month of November, October, March and April in S_1, S_2, S_3 and S_4 respectively. ANOVA for the total phosphorus content of macrophyte shows variation between months and between stations was significant at 5% level.

4.5. PLANKTON

4.5.1. Phytoplankton

The quantitative contribution of phytoplankton (nos/l) count was worked out for all the sampling stations and was presented in Fig - 13 (a) and table-1. The total plankton count varied from minimum of 439 nos/l (station 2, Feb.) to a maximum of 763 nos/l (station 1, May). Station 1 and 4 recorded comparatively lower values which ranged from 536 nos/l to 734 nos/l and 506 nos/l to 683 nos/l respectively. In general the percentage contribution of the total phytoplankton count over total plankton varied between 60 to 88%.

The phytoplankton community of Mathur beel exhibited a diverse assemblege of members belonging to Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae. The highest peak of phytoplankton was observed during May-July and lowest in winter month (Dec-Jan). Seasonal variations of different groups of phytoplankton was given in Table 2 & 3. Phytoplankton number gradually decreased from October to February and flourished during pre-monsoon month (April-June). Among the groups the Cyanophyceae shared 37.56-42.39%, Chlorophceae 31.23-36.45%, Bacillariophyceae 14-14.19% and Euglenophyceae shared 10.32-14.03%.



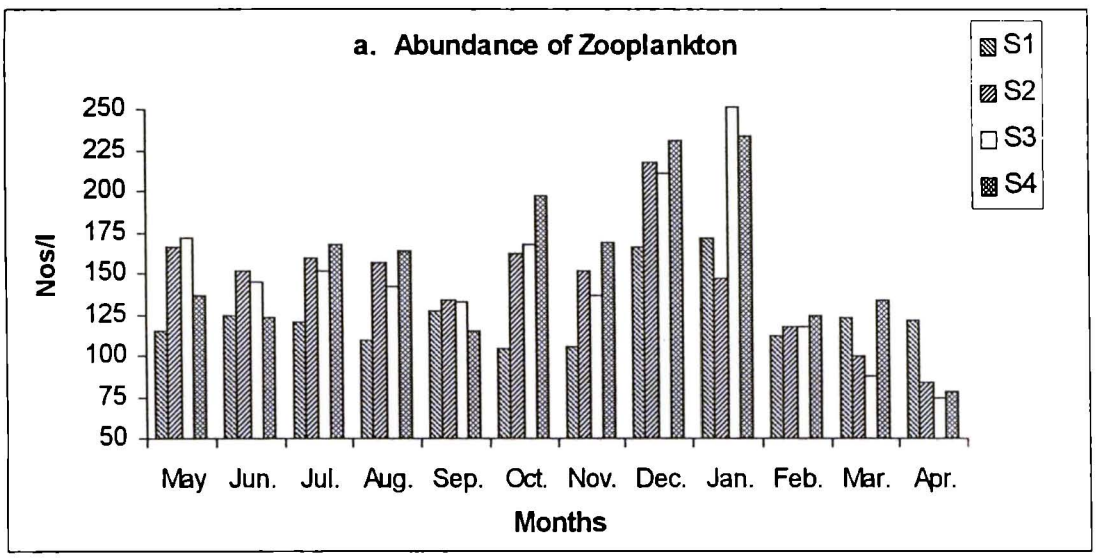


Fig. 13 : Monthly fluctuations in abundance of (a) Phytoplankton and (b) Zooplankton

The percentage composition of phytoplankton is show in Fig (14). At all the stations Cyanophyceae were represented by *Anabaena* sp, *Anacystis* sp, *Microcystis* sp, *Oscillatoria* sp, *Spirulina* sp and *Spirogyra* sp. Among the *Microcystis* sp, *Anabaena* sp were dominated. The number was increased from March to August due to algal bloom of *Microcystis, Anabaena* sp and Oscillatoria sp. It is positively correlated with Temp., pH, D.O., Hardness, Turbidity, BOD, COD, Nitrate, Phosphate. The green algae of Chlorophyceae was represented by *Ankistrodesmus* sp, *Cosmerium* sp, *Closterium* sp, *Pediastrum* sp, *Pandorina* sp, *Scenedesmus* sp, *Ulothrix* sp and *Volvox* sp, *Pediastrum* sp, dominated and its peak was from August to September andwas positively correlated with Temp., D.O., BOD, COD, Nitrate, Ammonia. Bacillariophyceae species encountered were *Cymbella* sp, *Diatoma* sp, *Fragillaria* sp, *Melosira* sp, *Navicula* sp, *Nitzschia* sp. and *Synedra* sp. Among them *Melosira* sp, *Navicula* sp, *Fragillaria* sp. dominated and number was increased during August and September and they showed positively correlation with Temp., D.O., pH, BOD, COD, Nitrate, Phosphate, Ammonia. *Phacus* sp. was sole representative of Euglenophyceae.. Its peak was also observed in the months of May-June and positively correlated with Temp. pH, Alkalinity, Hardness, Turbidity, Nitrate, Phosphate. Amog the value of phytoplankton Cyanophyceae was the dominant group at all the stations. The contribution of the plankton belonging to Euglenophyceae is very meagre.

The Shanan-Weaver index of phytoplankton ranged between 2.011 at station 1 (March) to 2.982 at station 3 (May) and Eveness index ranged between 0.779 (S_1, July) to 0.989 (S_2, May). Chlorophyceae was positively correlated with temperature, D.O, BOD, Ammonia at 1% level of significance and with Alkalinity and COD at 5% level of significance. Cyanophyceae, Bacillariophyceae were positively correlated with 1% level with temperature, pH, D.O, alkalinity, hardness, BOD, COD, ammonia, nitrate, phosphate,

Euglenophyceae also showed 1% level of significance with the temperature, pH, D.O, alkalinity, hardness, turbidity, BOD, COD, nitrate and phosphate.

4.5.2. Zooplankton

The spatial and temporal fluctuation in the biomass of zooplankton (total counts) was presented in Fig - 13(b) and their percentage contribution at four sampling stations are given in Fig - 15. It is evident from the table no.1 that considerable fluctuation occurred in the population on from time to time and from place to place. Among the four stations, the lowest count was 75 nos/l at station 3 (April), where as the highest zooplankton biomass was recorded at station 3 in the month of January (251 nos/l).

The percentage contribution of zooplankton in the total plankton was lowest in most of times. The percentage range of zooplankton to the total plankton count range between 10.50 to 40.90%. The percentage composition of S_1, S_2, S_3 and S_4 varied between 16.01% to 31.49%, 13.40% to 41.58%, 11.94% to 35.36% and 12.87% to 39.46% respectively.

The major zooplankton groups were represented in Table (2 & 3). At all the stations rotifer was mainly represented by *Brachionus* sp., *Keratella* sp., *Filinia* sp. and *Asplanchna* sp., *Brachionus* sp. is dominated species in rotifers and the less number of *Keratella* sp. and *Filinia* sp. were recorded. Their peak was observed in winter season (Dec-Jan) and they were positively correlated with nitrate nitrogen of water. The rotifers range between 19 nos/l (Station - 3, April) to 156 nos/l (Station 3, January). Rotifers represent the dominant group among zooplankton of the water body. *Moina* sp., *Daphniosoma* sp., *Daphnia* sp., *Bosmina* sp. were the representative of Cladoceran. and among them *Moina* sp. was dominant. They appeared at their peak in Nov-Dec and showed positive correlation with hardness, nitrate nitrogen of water. Copepod number varied between 3 nos/l (station 3, January) to 96 nos/l (station 4, October). Higher number of copepods were recorded at Station 1 and station 4 as compared to rest of the stations.

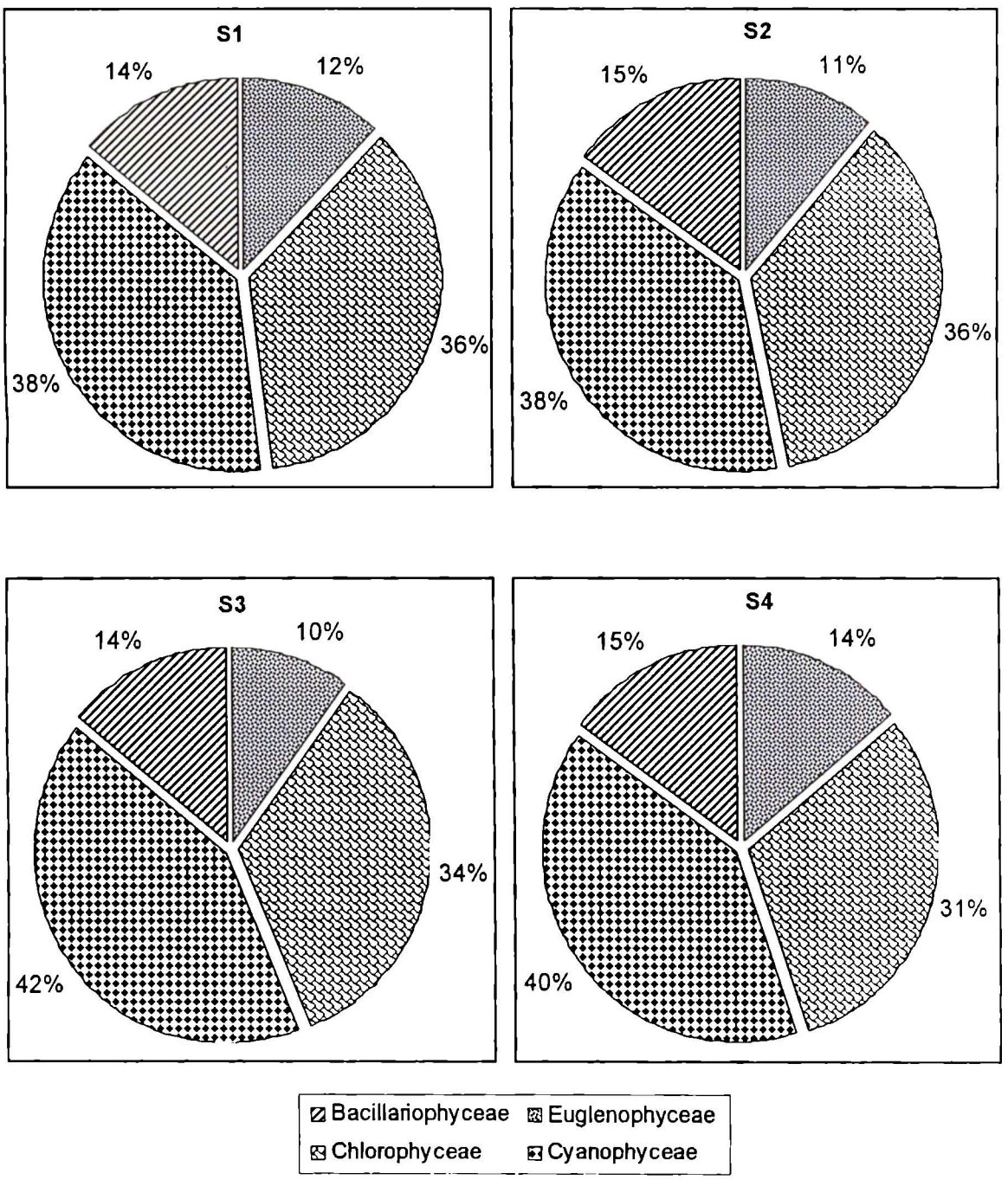


Fig. 14: Phytoplankton dominance pattern at different stations

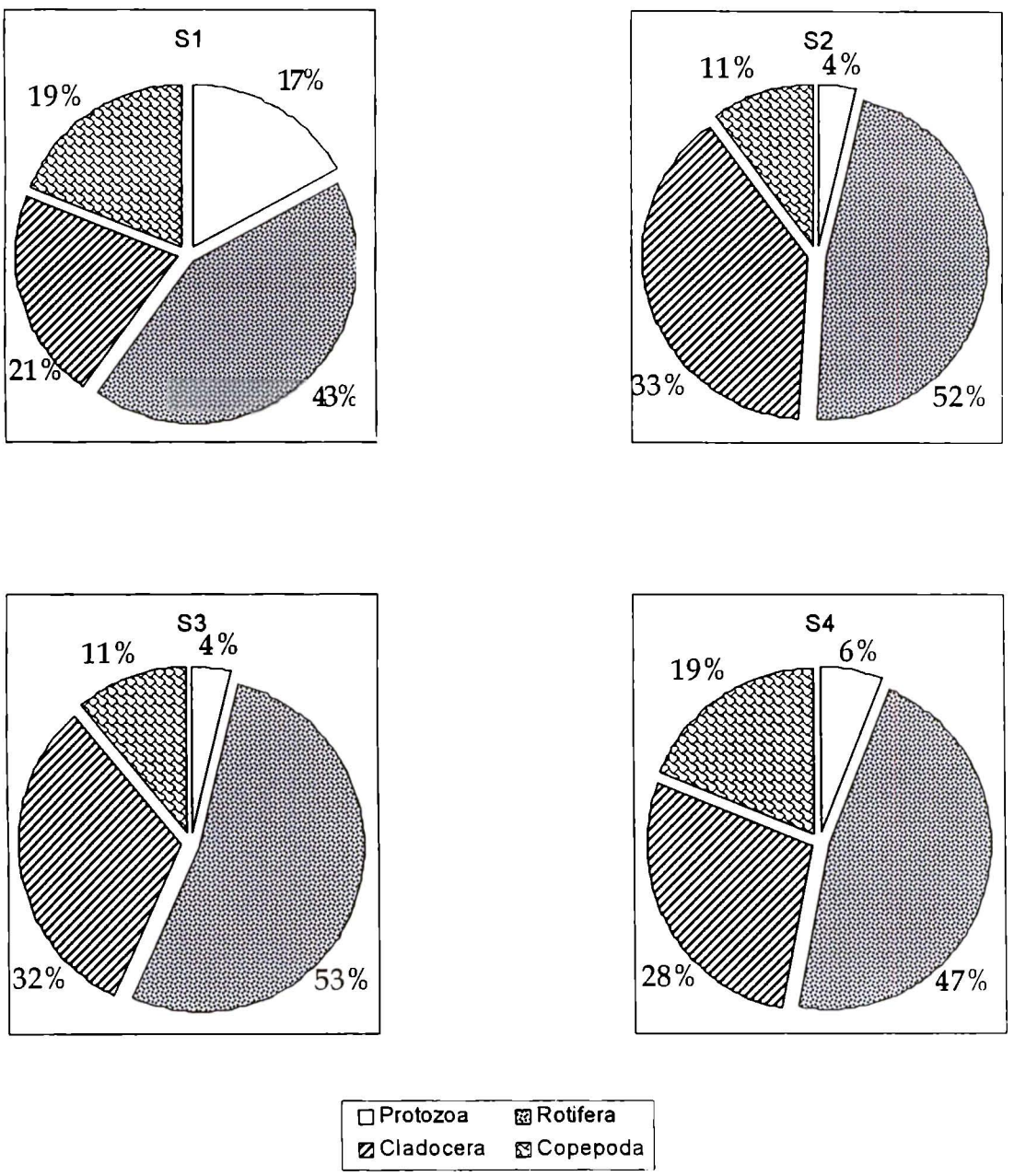


Fig. 15: Zooplankton dominance pattern at different stations

Shanon-Weaver index ($\overline{H}$) for the zooplankton ranged between 1.045 (S_1, March) to 1.925 (S_3, May) and Evenness index (e) ranged between 0.578 (S_4, April) to 0.971 (S_2, Dec.). Rotifora showed 5% level of significance with the hardness and 1% level of significance with nitrate only but negatively correlated with pH, D.O, BOD, COD. Cladocera positively correlated with temperature, hardness, Nitrate and phosphate with 1% level of significance. In general most of the zooplanktonic groups were negatively correlated with physico/chemical parameters.

4.6. PROTOZOAN PARASITE

The randomly host fishes like, *Labeo rohita, Lebeo batta, Catla catla, Cirrhinus mrigala, Channa punctatus, Tilapia mosumbica* of weight group ranging from 100-200 g were brought for the examination of protozoan parasites. The total percentage of infection by the parasites in the fish in each station was 25.90, 24.43, 19.84 and 13.77 in S_1, S_2, S_3 and S_4 respectively which was presented in Table (6-10).Three species of myxozoans viz., *Henneguya, Myxobolus* and *Thelohanellus* and one species of trichodinid ciliophorans like *Tripartiella* were found. The maximum percentage of incidence was observed during May-September and December - February. The highest percentage of infection was observed at station 1 and lowest at the station 4. A trend of gradually decreasing in percentage of infection was fond from station 1 to 4.

The physico-chemical parameters like D.O, ammonia and phosphate were positively correlated with parasitic frequency index at the station 2 and with phosphate and ammonia at station 3 and 4 but all the parameters showed positive correlation at station 1. In general most of the physico-chemical parameters were negatively correlated with the parasitic frequency index.

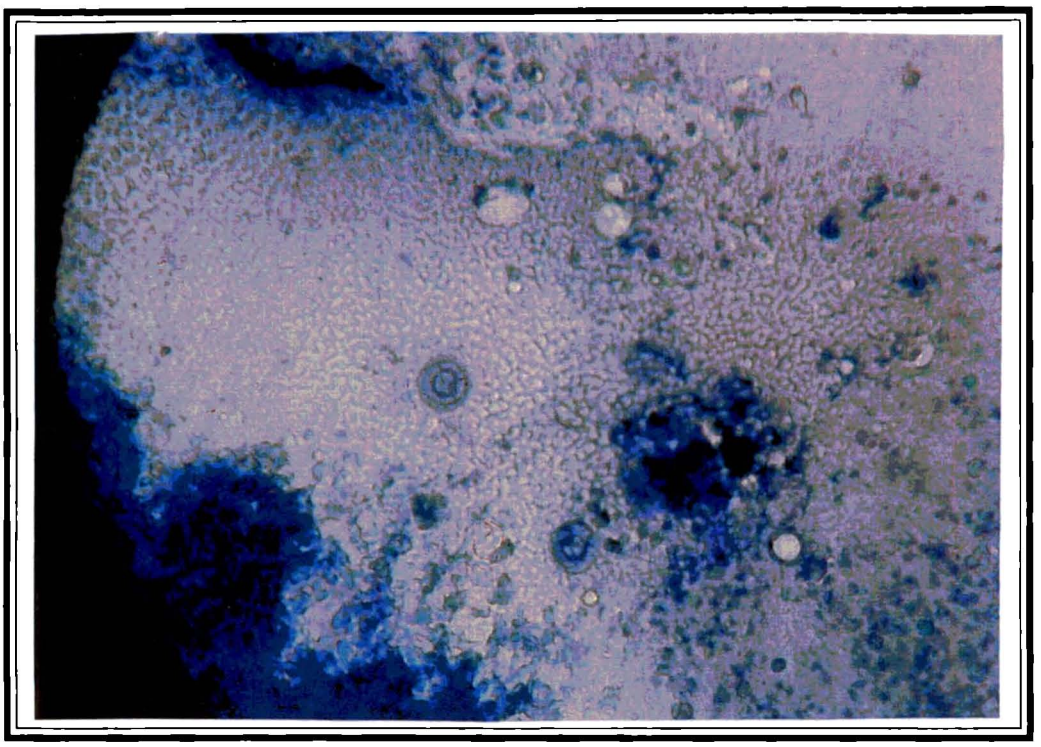


Plate 7. Photomicrograph of the *Tripartiella* from skin of fish by silver impregnation (x40)

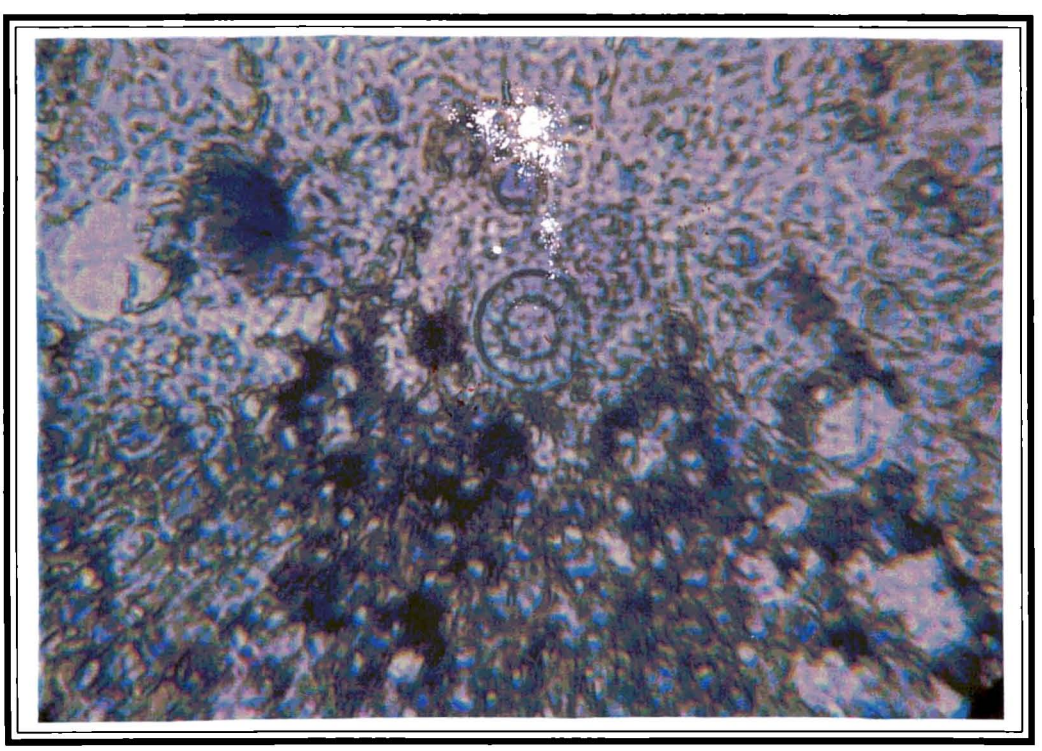


Plate 8. Photomicrograph of the *Tripartiella* from gills of fish by silver impregnation (x100)

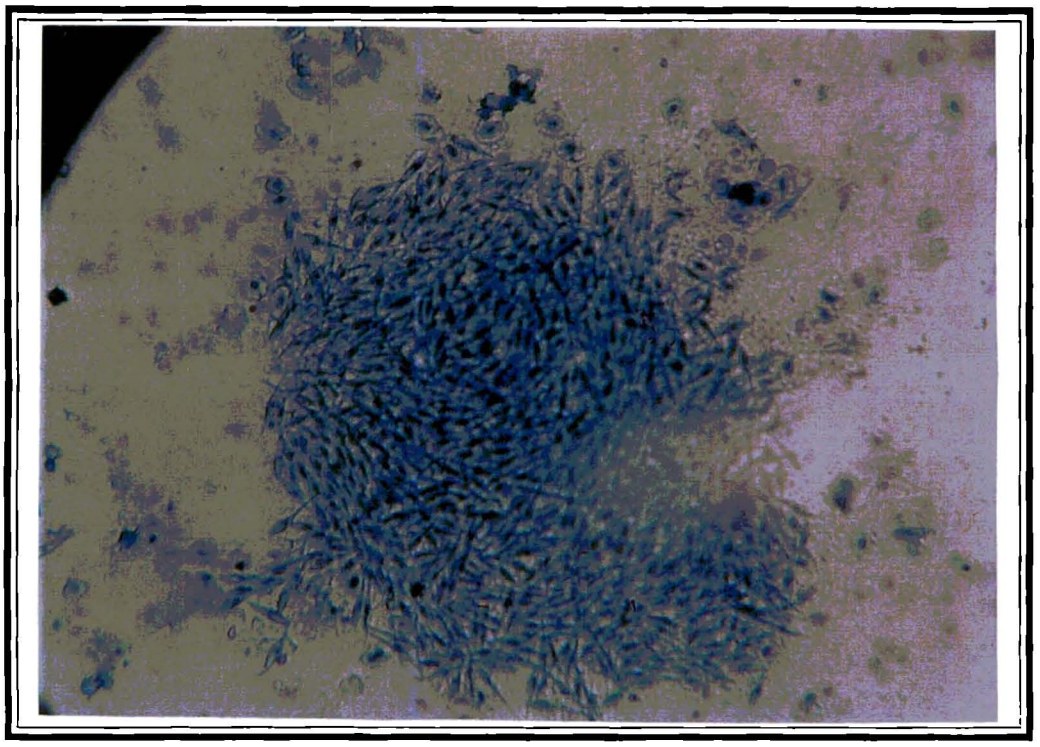


Plate 9. Photomicrograph of the *Henneguya* from gills of fish using giemsa stain (x40)

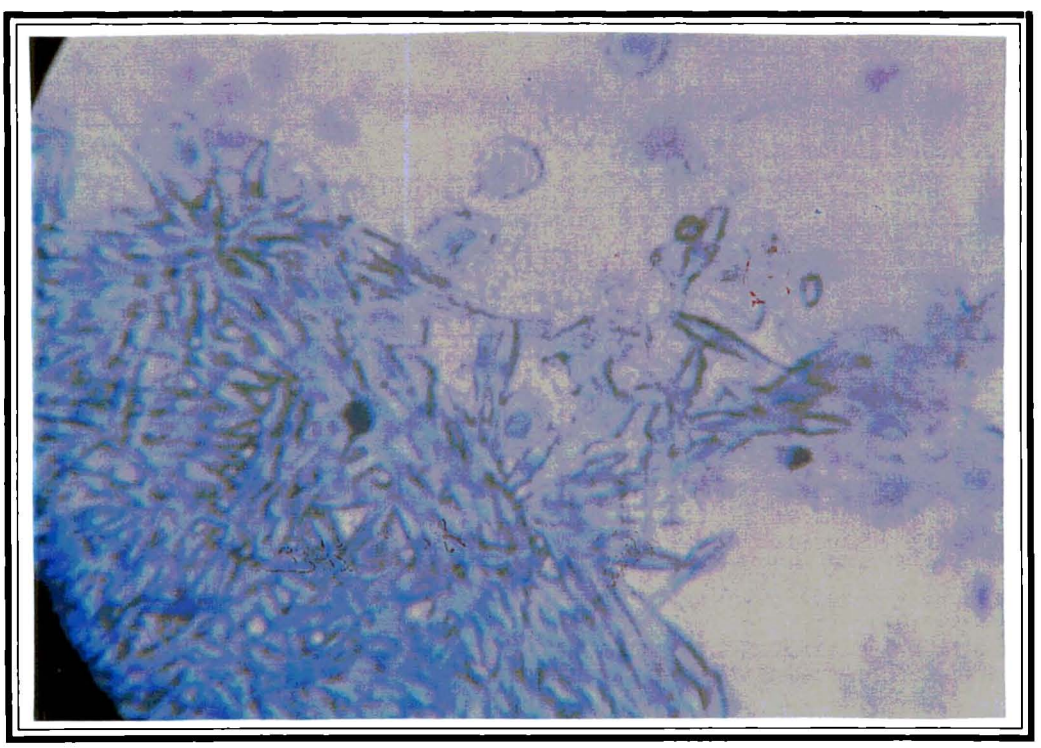


Plate 10. Photomicrograph of the *Henneguya* from gills of fish using giemsa stain (x100)

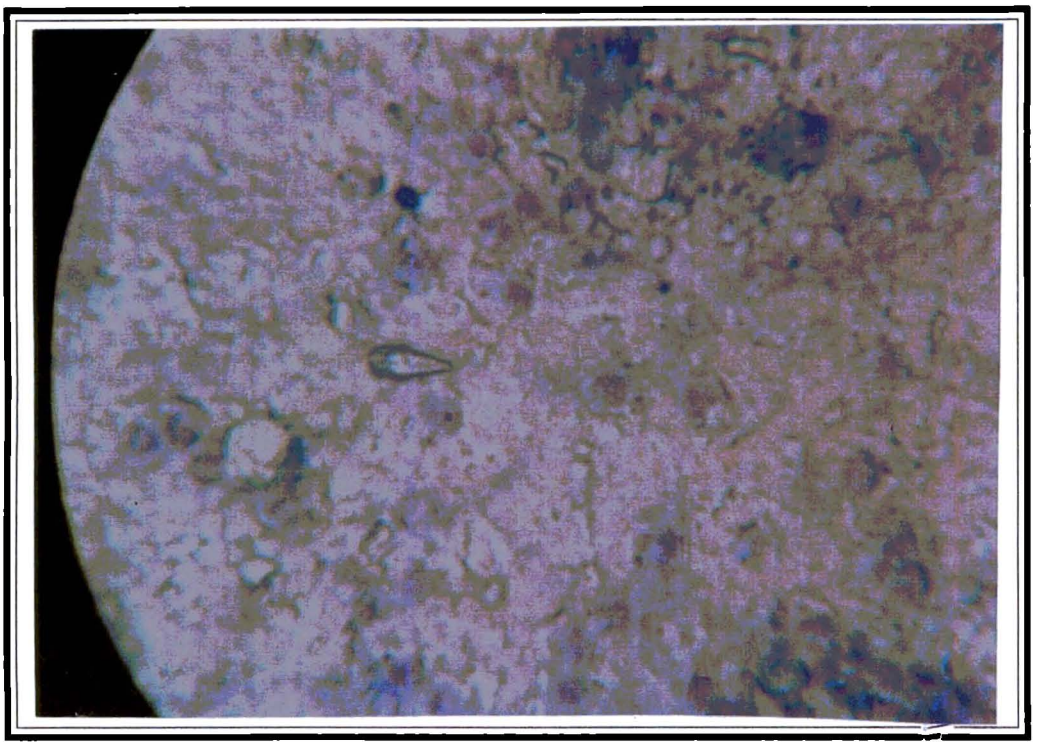


Plate 11. Photomicrograph of the *Myxobolus* from gills of fish using giemsa stain (x100)

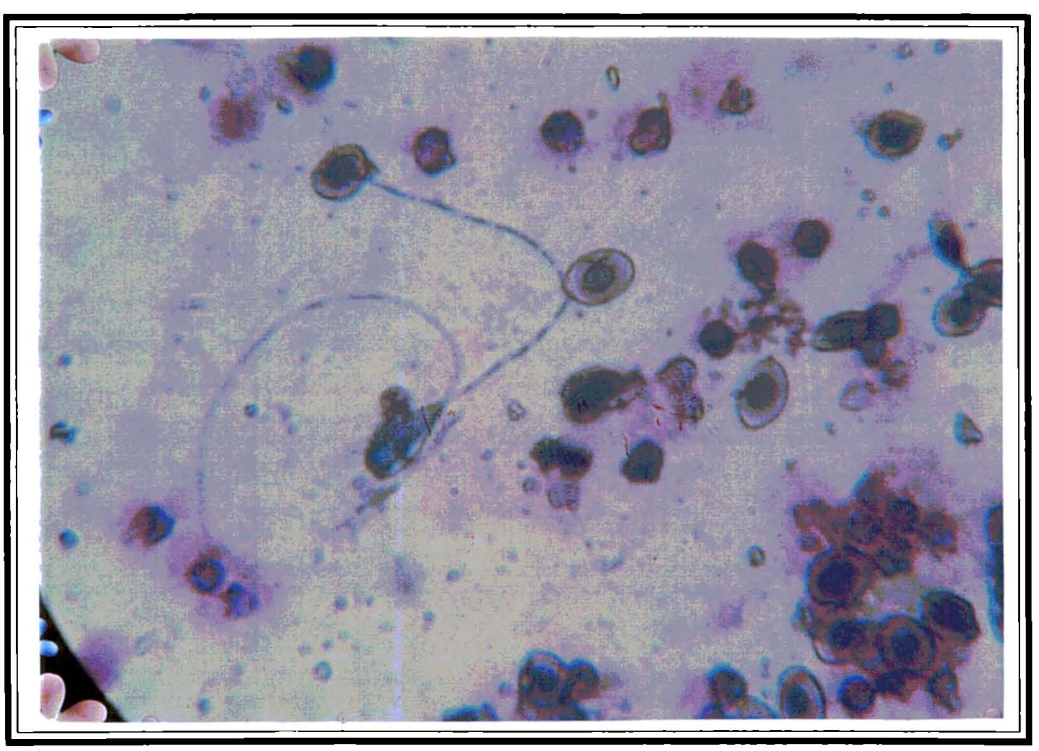


Plate 12. Photomicrograph of the *Thelohanellus* from gills of fish using giemsa stain (x100)

Table.1 : a. Phytoplankton and Zooplankton (nos/l) found in station S1, S2, S3 and S4. b. Total plankton counts (nos/l) at four sampling stations.

a. Plankton (Nos/l)

Month	S_1		S_2		S_3		S_4	
	PP	ZP	PP	ZP	PP	ZP	PP	ZP
May	589 (83.66)	115 (16.34)	597 (78.24)	166 (21.76)	578 (77.17)	171 (22.83)	547 (80.09)	136 (19.91)
June	597 (82.69)	125 (17.31)	573 (79.14)	151 (20.86)	593 (80.46)	144 (19.54)	564 (82.10)	123 (17.90)
July	614 (83.65)	120 (16.35)	588 (78.61)	160 (21.39)	576 (79.12)	152 (20.88)	522 (75.76)	167 (24.24)
August	572 (84.00)	109 (16.01)	568 (78.34)	157 (21.66)	558 (79.71)	142 (20.29)	498 (75.34)	163 (24.66)
September	562 (81.58)	127 (18.43)	529 (79.79)	134 (20.21)	537 (80.15)	133 (19.85)	461 (80.03)	115 (19.97)
October	485 (82.34)	104 (17.66)	465 (74.16)	162 (25.84)	471 (73.71)	168 (26.29)	449 (69.50)	197 (30.50)
November	413 (79.73)	105 (20.27)	398 (72.36)	152 (27.64)	422 (75.49)	137 (24.51)	372 (68.76)	169 (31.24)
December	405 (70.93)	166 (29.07)	379 (63.59)	217 (34.41)	402 (65.58)	211 (34.42)	395 (63.10)	231 (36.90)
January	372 (68.51)	171 (31.49)	347 (58.42)	247 (41.58)	393 (64.64)	251 (35.36)	359 (60.54)	234 (39.46)
February	365 (76.52)	112 (23.48)	321 (73.12)	118 (26.88)	426 (78.45)	117 (21.55)	381 (75.30)	125 (24.70)
March	513 (80.66)	123 (19.34)	498 (83.28)	100 (16.72)	521 (85.55)	88 (14.44)	401 (74.95)	134 (25.05)
April	568 (82.44)	121 (17.56)	543 (86.60)	84 (13.40)	553 (88.06)	75 (11.94)	528 (87.13)	78 (12.87)

b. Total plankton (nos/l)

Month	S_1	S_2	S_3	S_4
May	704	763	749	683
June	722	724	737	687
July	734	748	728	689
August	681	725	700	661
September	689	663	670	576
October	589	627	639	646
November	518	550	559	541
December	571	596	613	626
January	543	594	608	593
February	577	439	543	506
March	536	598	609	535
April	689	627	628	606

Table.2 : Monthly fluctuations in different groups of phytoplankton and zooplankton abundance (nos/l) during May 2004 to April 2005 in station 1 and station 2 of water body in Mathura Beel.

S1

Month	Phytoplankton					Zooplankton				
	Chloroph-yceae	Cyanophy-ceae	Bacillario-phyceae	Euglено-phyceae	Total	Proto-zoa	Roti-fera	Clad-ocera	Cope-pods	Total
May	185	234	89	79	589	24	58	15	14	115
June	199	245	85	68	597	21	47	39	18	125
July	188	276	78	72	614	27	46	26	21	120
Aug	158	231	125	58	572	28	49	19	13	109
Sept	220	173	89	80	562	32	43	23	29	127
Oct	210	145	66	64	485	12	35	21	36	104
Nov	195	199	68	51	413	11	34	14	46	105
Dec	178	121	57	49	405	37	79	18	32	166
Jan	153	150	31	38	372	29	93	34	15	171
Feb	168	120	42	35	365	10	45	39	18	12
Mar.	182	239	40	52	513	07	53	37	26	123
Apr	156	238	91	83	568	11	62	27	21	121

S2

Month	Phytoplankton					Zooplankton				
	Chloroph-yceae	Cyanophy-ceae	Bacillario-phyceae	Euglено-phyceae	Total	Proto-zoa	Roti-fera	Clad-ocera	Cope-pods	Total
May	159	275	86	77	597	08	89	53	16	166
June	180	259	72	62	573	05	82	50	14	151
July	177	267	85	59	588	04	87	42	27	160
Aug	223	163	135	47	568	02	78	55	22	157
Sept	215	161	103	50	529	04	60	57	13	134
Oct	201	107	95	62	465	02	76	63	21	162
Nov	155	129	53	61	398	09	69	41	33	152
Dec	153	108	55	63	379	12	123	59	23	217
Jan	137	131	33	46	347	09	145	88	05	247
Feb	145	116	39	21	321	04	63	42	09	118
Mar.	175	206	49	68	498	08	45	34	13	100
Apr	197	259	36	51	543	03	23	21	07	84

Table.3 : Monthly fluctuations in different groups of phytoplankton and zooplankton abundance (nos/lit) during May 2004 to April 2005 in station 3 and station 4 of water body in Mathura Beel.

S3

Month	Phytoplankton					Zooplankton				
	Chlorophyceae	Cyanophyceae	Bacillariophyceae	Euglenophyceae	Total	Protozoa	Rotifera	Cladocera	Copepods	Total
May	188	235	83	72	578	10	95	48	18	171
June	195	278	75	45	593	05	84	43	12	144
July	203	246	73	54	576	03	88	38	23	152
Aug	217	201	111	29	558	04	72	47	19	142
Sept	235	192	80	30	537	05	63	56	09	133
Oct	241	153	42	35	471	01	74	68	25	168
Nov	112	195	58	57	422	08	56	38	37	137
Dec	110	175	51	66	402	13	130	49	79	211
Jan	119	192	31	51	393	07	156	85	03	251
Feb	118	214	65	29	426	04	68	38	07	117
Mar.	109	223	101	88	521	06	39	28	15	88
Apr	146	258	84	65	553	02	19	23	11	75

S4

Month	Phytoplankton					Zooplankton				
	Chlorophyceae	Cyanophyceae	Bacillariophyceae	Euglenophyceae	Total	Protozoa	Rotifera	Cladocera	Copepods	Total
May	139	257	68	83	547	10	71	43	12	136
June	141	268	64	91	564	07	68	39	09	123
July	110	252	71	89	522	05	79	48	35	167
Aug	121	212	95	70	498	08	82	41	32	163
Sept	153	181	74	53	461	03	43	28	41	115
Oct	185	161	56	47	449	02	76	63	56	197
Nov	162	117	45	48	372	09	59	72	29	169
Dec	175	109	52	59	395	18	114	53	46	231
Jan	177	111	37	34	359	11	133	69	21	234
Feb	133	148	51	49	381	06	62	42	16	125
Mar.	102	158	69	72	401	13	52	21	48	134
Apr	115	147	93	73	528	05	31	26	16	78

Table.4: a. Shanon-Weaver index (H) and Eveness index (e) for phytoplankton and b. zooplankton at four sampling stations.

a. phytoplankton

Month	S_1		S_2		S_3		S_4	
	H	e	H	e	H	e	H	E
May	2.656	0.907	2.819	0.941	2.982	0.989	2.976	0.939
June	2.221	0.820	2.863	0.984	2.611	0.964	2.695	0.972
July	2.115	0.779	2.213	0.839	2.723	0.972	2.511	0.898
August	2.761	0.975	2.982	0.981	2.691	0.949	2.621	0.892
September	2.698	0.966	2.481	0.916	2.592	0.915	2.501	0.826
October	2.236	0.826	2.681	0.967	2.516	0.908	2.763	0.949
November	2.484	0.843	2.623	0.926	2.683	0.911	2.529	0.872
December	2.621	0.928	2.571	0.974	2.321	0.905	2.416	0.856
January	2.392	0.903	2.411	0.970	2.281	0.960	2.813	0.988
February	2.340	0.870	2.619	0.934	2.240	0.925	2.401	0.848
March	2.011	0.789	2.312	0.802	2.256	0.871	2.391	0.846
April	2.316	0.791	2.623	0.994	2.486	0.864	2.444	0.842

b. Zooplanton

Month	S_1		S_2		S_3		S_4	
	H	e	H	e	H	e	H	e
May	1.665	0.929	1.656	0.923	1.925	0.925	1.625	0.9.7
June	1.613	0.900	1.617	0.912	1.481	0.920	1.563	0.971
July	1.545	0.862	1.583	0.825	1.962	0.932	1.792	0.967
August	1.965	0.984	1.946	0.984	1.972	0.989	1.930	0.992
Sept.	1.873	0.962	1.673	0.946	1.840	0.946	1.761	0.983
Oct.	1.996	0.960	1.827	0.981	1.826	0.932	1.875	0.934
Nov.	1.573	0.878	1.679	0.829	1.473	0.915	1.935	0.941
Dec.	1.369	0.986	1.366	0.998	1.125	0.687	1.092	0.679
Janu.	1.087	0.989	1.181	0.978	1.102	0.935	1.064	0.921
Feb	1.355	0.977	1.365	0.987	1.392	0.962	1.597	0.997
March	1.045	0.992	1.061	0.996	1.095	0.590	1.061	0.810
Aprl.	1.508	0.937	1.861	0.928	1.565	0.942	1.041	0.578

Table.5 : a. Correlation coefficients between phytoplankton and physico-chemical parameters. b. Correlation coefficients between zooplankton and physico-chemical parameters

a.

Parameters	Chlorophyceae	Cyanophceae	Bacillariophycea	Eugleninae
Temperature	0.69479**	0.73062**	0.5386**	0.51007**
PH	0.20226	0.59186**	0.80194**	0.84215**
DO	0.71114**	0.67656**	0.64934**	0.43446**
Alkalinity	0.39276*	0.67549**	0.57733**	0.85607**
Hardness	0.21742	0.53788**	0.61197**	0.66213**
Turbidity	0.06818	0.77141**	0.46613*	0.65387**
BOD	0.58270**	0.62967**	0.54989**	0.46459*
COD	0.38289*	0.76315**	0.70159**	0.40574*
Ammonia	0.59137**	0.30096**	0.77897**	0.25911
Nitrate	0.50714**	0.79438**	0.91126**	0.79838**
Phosphate	0.13144	0.73261**	0.82008**	0.62865**

b.

Parameters	Protozoa	Rotifera	Cladocera	Copepods
Temperature	0.48776*	-0.60305**	0.52221**	0.20968
PH	0.11110	-0.37090*	-0.32791*	-0.21990
DO	-0.53254**	-0.53276**	-0.48857*	0.30742*
Alkalinity	0.17170	-0.51721**	-0.47010*	-0.08633
Hardness	0.50873**	0.44033*	0.52169**	0.52342**
Turbidity	-0.15586*	-0.21196	0.28977	-0.52196**
BOD	-0.41649*	-0.36079*	-0.21470	0.72137**
COD	-0.37577*	-0.49487*	-0.41259*	-0.29575
Ammonia	-0.40710*	0.03490	0.26423	-0.00570
Nitrate	0.78242**	0.68353**	0.77285**	0.79562**
Phosphate	0.79191**	0.25812	0.54827**	0.33195*

** 1% level of significance, * 5% level of significance .

Table. 6 : Monthwise data of number of host examined, number of host infected and protozoan parasite found, at station 1.

Month	No. of host examined	No. of host infected	Parasitic frequency index (PFI)	Name of parasite
May	10	3	30	*Myxobolus* sp.
June	12	3	25	*Myxobolus* sp. *Thelohanellus* sp.
July	18	4	22	*Myxobolus* sp., *Thelohanellus* sp., *Tripatiella* sp.
August	20	6	27	*Myxobolus* sp., *Thelohanelles* sp., *Tripatiella* sp.
September	20	5	25	*Myxobolus* sp., *Thelohenelles* sp., *Tripatiella* sp.
October	20	4	20	*Tripatiella* sp., *Myxobolus* sp.
November	20	3	15	*Myxobolus* sp., *Thelohenelles* sp., *Tripatiella* sp.
December	16	7	43.75	*Tripatiella* sp., *Henneguya* sp.
January	12	5	41.66	*Tripatiella* sp., *Henneguya* sp., *Myxobolus* sp.
February	11	3	27.27	*Myxobolus* sp., *Tripatiella* sp.
March	16	3	18.57	*Myxobolus* sp., *Tripatiella* sp.
April	18	4	22.22	*Myxobolus* sp., *Tripatiella* sp.

Total number of host examined = 193

Total number of host infected = 50

Percentage of infection = 25.90

Table. 7 : Monthwise data of number of host examined, number of host infected and protozoan parasite found, at station 2.

Month	No. of host examined	No. of host infected	Parasitic frequency index (PFI)	Name of parasite
May	8	2	25	*Myxobolus* sp.
June	10	2	20	*Myxobolus* sp. *Thelohanellus* sp.
July	16	5	31.25	*Thelohanellus* sp., *Tripatiella* sp.
August	17	4	35.29	*Myxobolus* sp., *Thelohanellus* sp., *Tripatiella* sp.
September	20	5	25	*Myxobolus* sp., *Thelohanellus* sp., *Tripatiella* sp.
October	20	4	20	*Tripatiella* sp.
November	19	4	21.05	*Myxobolus* sp., *Thelohanellus* sp., *Tripatiella* sp.
December	14	5	35.71	*Tripatiella* sp., *Henneguya* sp. *Myxobolus* sp.
January	10	4	14	*Tripatiella* sp., *Henneguya* sp., *Myxobolus* sp.
February	12	3	25	*Myxobolus* sp., *Tripatiella* sp.
March	14	3	21.42	*Myxobolus* sp., *Tripatiella* sp.
April	16	2	12.5	*Myxobolus* sp., *Tripatiella* sp.

Total number of host examined = 176

Total number of host infected = 43

Percentage of infection = 24.43

Table. 8 : Monthwise data of number of host examined, number of host infected and protozoan parasite found, at station 3.

Month	No. of host examined	No. of host infected	Parasitic frequency index (PFI)	Name of parasite
May	5	1	20	*Myxobolus* sp. *Thelohanellus* sp.
June	9	2	22.22	*Myxobolus* sp. *Thelohanellus* sp.
July	14	4	28.57	*Thelohanellus* sp., *Tripatiella* sp.
August	16	3	18.75	*Myxobolus* sp., *Thelohanellus* sp., *Henneguya* sp.
September	14	2	14.29	*Myxobolus* sp., *Thelohanellus* sp., *Henneguya* sp.
October	12	2	16.67	*Henneguya* sp., *Tripatiella* sp., *Myxobolus* sp.
November	15	3	20.00	*Myxobolus* sp., *Tripatiella* sp.
December	12	4	33.33	*Tripatiella* sp., *Henneguya* sp.
January	10	2	20	*Tripatiella* sp., *Myxobolus* sp.
February	6	1	16	*Myxobolus* sp., *Tripatiella* sp.
March	8	1	12.5	*Myxobolus* sp.
April	10	1	10	*Myxobolus* sp.

Total number of host examined = 131

Total number of host infected = 26

Percentage of infection = 19.84

Table. 10 : **Monthwise data of number of host examined, number of host infected and protozoan parasite found, at station 4.**

Month	No. of host examined	No. of host infected	Parasitic frequency index (PFI)	Name of parasite
May	8	1	12.5	*Myxobolus* sp. *Thelohanellus* sp.
June	10	1	10	*Myxobolus* sp. *Thelohanellus* sp.
July	8	2	25	*Thelohanellus* sp., *Tripatiella* sp.
August	10	1	10	*Myxobolus* sp., *Thelohanellus* sp., *Henneguya* sp.
September	8	1	12.5	*Myxobolus* sp., *Tripatiella* sp. *Henneguya* sp.
October	12	2	16.66	*Henneguya* sp. *Tripatiella* sp., *Myxobolus* sp.
November	14	2	14.20	*Henneguya* sp. *Tripatiella* sp.
December	16	2	12.5	*Tripatiella* sp.,
January	16	3	18.75	*Tripatiella* sp., *Myxobolus* sp.
February	10	1	10	*Myxobolus* sp., *Tripatiella* sp.
March	12	2	16	*Myxobolus* sp.,
April	14	1	7.14	*Myxobolus* sp., *Tripatiella* sp.

Total number of host examined = 138

Total number of host infected = 19

Percentage of infection = 13.77

Table. 11 : a. Correlation coefficients between parasitic frequency index (PFI) and physico-chemical parameters. b. Correlation coefficients between total plankton and parasitic frequency index (PFI).

a.

Parameters	S 1	S 2	S 3	S 4
Temperature	-0.65591	-0.50617	-0.32459	-0.10761
pH	-0.38851	-0.04337	-0.24478	-0.07557
DO	-0.53573	0.55464	-0.11975	-0.14363
Alkalinity	-0.44532	-0.32778	-0.09997	-0.15255
Hardness	-0.46487	-0.54787	-0.36983	-0.11900
Turbidity	-0.35742	-0.37318	-0.12738	-0.08836
BOD	-0.44817	-0.40328	-0.39946	-0.50191
COD	-0.50791	-0.68305	-0.27264	-0.23458
Ammonia	-0.06911	0.09483	0.17053	0.03229
Nitrate	-0.20114	-0.14858	-0.06148	-0.17753
Phosphate	-0.20988	0.04320	0.15846	0.34908

b.

Parasitic frequency index (PFI) / Plankton	S 1	S 2	S 3	S 4
S-1	-0.0962			
S-2		0.08831		
S-3			0.23880	
S-4				0.15469

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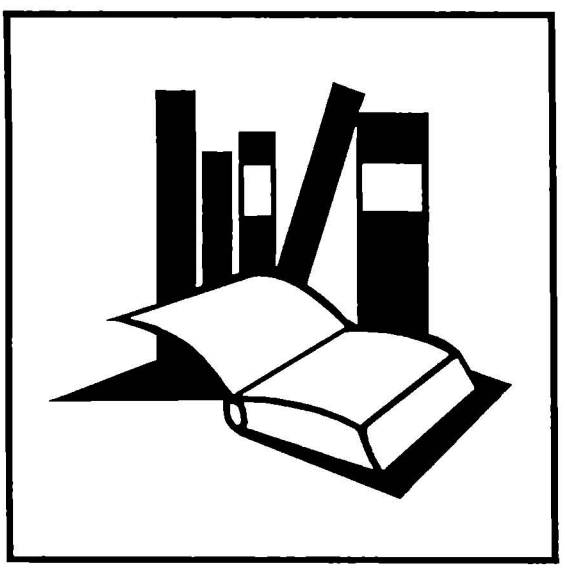


DISCUSSION

DISCUSSION

Scientific management of beel waters requires an understanding of the physico-chemical and biological condition of the water body. Quality of an aquatic ecosystem depends on physico-chemical qualities of water and also on biological diversity of the system. Cairns and Dickson (1971) stated that the analysis of biological material along with the chemical characteristics of water forms a valid method of water quality assessment. Hence the physico-chemical characteristics, macrophyte plankton and protozoan parasitics from four stations of Mathura beel were observed for 12 months in the present investigation which has been scientifically discussed below.

5.1 PHYSICO - CHEMICAL PARAMETERS

5.1.1. Temperature

It is well known that the fluctuation in water temperature is the resultant effect of different environmental parameters, particularly air temperature of the immediate surroundings. Such a situation was also observed during present investigation. The water temperature varied between 16.0^{0}C and 30.4^{0}C. These results are comparable with the observation of Anupama (2003), Paul (2003), Rana *et al* (1990) and Saha *et al* (1990)

5.1.2. pH

pH is the index of water quality. During present study pH values ranged between 8.27 and 9.50. The pH values between different stations did not varied significantly on most of the occasions. The pH value range from 6.8 to 9.8 in the beels of West Bengal which has been reported by Sugunan *et. al.* (2000), which is in agreement with the present study. Lower value of pH observed during winter might be due to high infestation of aquatic macrophytes. The higher value of pH might be due to trace amount of free carbon dioxide for high photosynthetic rate (Ayyappan and Gupta, 1981;

Kumar, 1998). Hutchinson (1957) and Welch (1952) reported that the normal range of pH of inland waters are in between 6.0 to 9.0. Paria and Konar (2000) also reported the pH range of 6.3 to 8.6 in the pond waters of Jalpaiguri district of West Bengal. Degaonkar and Saksena (1992) and Kaushik and Saksena (1991) reported that the maximum pH values were in summer and rainy seasons while the minimum in winter season in some natural water bodies. All the above findings are quite similar with the present study.

5.1.3. Dissolved oxygen

Dissolved oxygen is an important critical factor in natural water bodies. It is regulated by both abiotic and biotic factors and susceptible to frequent changes. The DO range in the present investigation is comparable with Pathak (1990) and Rana *et al.* (1996), who reported dissolved oxygen range between 5.5 and 8.6 mg/l in beels of West Bengal. Higher values of dissolved oxygen might be due to the high eutrophic conditions (Das, 2000), showing nil amount of free carbon dioxide due to high photosynthetic rate. A low content of dissolved oxygen observed during the winter season (6.2 to 7.4 mg/l) at all the stations might be due to high infestation of macrophyte (Kumar, 1997 and Singh *et al.* 1998) and also might be attributed due to decaying organic matter and pollution of water (Pal and Singh, 1983). At S_1 dissolved oxygen level observed was lower in comparison to rest of the stations and this might be due to discharge of domestic waste to fresh water system (Kumari and Kumar, 1997) and decomposition of organic matter (Badge and Varma, 1985, Bhatt *et. al.*, 1999; Ranjan and Raj, 1997; Bandyopadhyaya and Das, 1998). Singh *et al.* (1998) observed the infestation of *Eichhornia crassipes* in some eutrophic ponds of Bihar which resulted in low abundance of phytoplankton and dissolved oxygen by the less percentage of the sunlight penetration.

5.1.4. Free carbon dioxide

In the present study the free CO_2 was absent in all the stations throughout the study period. It might be due to enhanced photosynthetic rate and increasing dissolved oxygen level. This result is comparable with the result of Sharma and Kaushal (2004). In the present study pH value always showed above 8.3 in all the stations throughout the study period and this might be the reason of absence of CO_2. The enhanced growth of algae due to the increased nitrogen and phosphorus and other nutrients resulted in the increase in the dissolved oxygen level and decrease in CO_2 (Boyd, 1979a). A direct relation between free carbon dioxide and bicarbonate alkalinity has been reported by Zafar (1964), Munawar (1970) which has been reflected in this study. Free CO_2 is inversely correlated with the pH of water.

5.1.5. Conductivity

Conductivity is used by limnologists to estimate total ionic concentration of water, which in turn is related to the fertility of water.

Lind (1979) stated that the relationship varies with both quality and quantity of ions present. He recommended specific conductivity value as quick check for alteration of the total quality of water because of the addition of many nutrients. In the present investigation, conductivity ranged between 0.213 and 0.576 mS/cm. Vass and Langer (1990) found conductivity between 198 mS/cm and 638 mS/cm in an oxbow lake of Kashmir. Pathak *et al.* (2004) reported the conductivity of the wetlands of Uttar Pradesh varied from 121 to 706 mS/cm. The above results were comparable with the present investigation. Ayyappan (1987) observed a positive correlation between conductivity and gross primary productivity and also observed an increasing in DOM affecting the value of conductance.

5.1.6. Total alkalinity

The total alkalinity or acid combining capacity, is generally due to carbonate and bicarbonate of calcium and magnesium. The total alkalinity range is comparable with Rana *et al* (1996) who also observed alkalinity range of 68.75 to 145.5 mg/l in Kalyani lake and Sugunan *et al.* (2000) reported that total alkalinity of West Bengal beels ranged from 7.8-192 mg/l. A more or less higher value of total alkalinity was observed during summer period which might be due to partial stagnation which was also reported by Blum (1957).

5.1.7.Total Hardness

The total hardness refers to the concentration of divalent metal ions in water (Paria and Konar, 2000). In the present study, the hardness range is comparable with Suganan *et al.* (2000) who reported the average total hardness of West Bengal beels as 56.4 to 372.2 mg/l. Bath and Sigh (1998) reported the alkalinity in a polluted urban pond with a range from 110 to 220 mg/l and stated that the high value of alkalinity during summer has been attributed to high temperature which increases concentration of salt by excessive evaporation. Comparatively lower values of hardness recorded in all the stations during winter season might be due to luxuriant growth of macrophytes (Jebanesan, 1997).

5.1.8. Turbidity

During the present investigation, higher average values of turbidity were observed during monsoon period which might be due to influx of rain water (Pal and Singh, 1983, Chandrasekhar and Jafer, 1998) and also might be due to the presence of plankton population (Pahari *et al.* 2000 and Das, 2002). Lower average value of turbidity was observed from November to January in all the stations which might be due to the presence of aquatic macrophytes which enhance water clarity and which are able to remove suspended solids from water (Scheffer, 1999).

5.1.9. Total solids and total dissolved solids

The total solids and total dissolved solids concentration were significantly higher in all the stations during summer and monsoon period and lower value during winter season. Mishra and Saksena (1991) encountered very high total solids and total dissolved solids and inferred that it was mainly due to organic matter, silts and debris. Higher values might also be due to large quantity of surface run-off and rain water getting drained into the water body near this station. According to Schwoerbel (1991), the total dissolved solids increases with temperature. Bhatt *et al.* (1999) have said that the higher the value of dissolved solids, greater will be the amounts of ions in water. The total dissolved solids and total solids of S_1 is relatively higher than S_2, S_3 and S_4. The total dissolved solids value might get influenced by discharge of domestic effluents (Rao *et al.*, 1999). It might be due to large quantity of surface run-off and rain water getting drained into the water body near this station.

5.1.10. Biological oxygen demand (BOD_5)

The biological oxygen demand (BOD_5) gives an idea about the measure of biodegradable organic matter present in any aquatic system which is subjected to aerobic decomposition by microbes. Both BOD and COD are reliable for judging the extent of pollution in water (Mishra and Saksena, 1991; Singh, 1999).

The BOD values of four sampling stations observed were comparable with Varghese *et. al.* (1992) who observed an average BOD value of 3.8 mg /l while conducting the hydrobiological study of a domestically polluted tropical water body and Abbasi and Vinithan (1999) who reported BOD ranging from 0.3 to 7.2 mg /l in water bodies of Pondicherry and Pradhan (2002) who reported BOD ranged from 0.4 to 4.5 mg /l in Kulia beel.

5.1.11. Chemical oxygen demand (COD)

Chemical oxygen demand is a measure of the oxygen equivalent to the organic matter content of the water that is susceptible to oxidation by strong chemical oxidant (APHA, 1998). In the present investigation the COD values are comparable with Abbasi and Vinthan (1999), Pradhan (2002) and Das (2002) who reported COD ranging from 0.8 to 76 mg/l, 12.5 to 45 mg/l and 20.5 to 46.8 mg/l respectively. Patel and Sinha (1998) attributed higher values of COD to algal biomass present in ponds. Kumar (1998) said that lower COD values were due to decreased light intensity and retarded bacterial activity and less load of organic materials which has also been reflected in the present study during winter season at S_1, S_2, S_3 and S_4 which are having more macrophytic infestation. It is reported that COD values are higher than BOD values when organic matter contain a large amount of biologically resistant substance (Ogunrombi and Onuoha, 1982, Zanoni, 1986).

5.1.12. Dissolved organic matter (DOM)

Depending on the accumulation of different wastes along with oxidation of different flora and fauna in lentic water brought in by the inflowing water, the spatial and temporal variations in the quality of dissolved organic matter is noticed. The results of DOM in the present study were in accordance with the results of Pathak (1990) and Acharjee *et. al* (1999) who recorded the DOM values of beels of North Eastern states including Assam varying between 1.0 to 4.8 mg/l and 2.0 to 1.16 mg/l respectively and Pathak *et. al.* (2004) reported the DOM content of wetlands of U.P. (India) ranging from 1.6 to 4.3 mg/l. Higher vales of DOM during the summer for all the stations of water body might be due to decomposition which release other soluble organic compound (Parvateesam and Gupta, 1994). Sinha *et. al.* (1973) reported the DOM values ranges 4.2 to 6 mg /l in a fish culture pond of Kalyani (W.B.) Trivedi (1988) reported the DOM value between 3.75 to 38.22 mg /l in the water body of Karnataka. All these results are in agreement with the findings of the present investigation.

5.1.13. Nutrients in water

Nutrients are the most important abiotic factors, which influence the components of ecosystem. Dissolved inorganic nitrogen (NH_3, NO_2, NO_3) forms in the range of 0.2 to 0.5 mg/l and phosphate phosphorus in the range of 0.05 to 0.2 mg/l are considered favourable for aquatic productivity (Moyle, 1946).

5.1.13.1. Ammonia nitrogen

The ammonia nitrogen is either released from proteinaceous organic matter and urea or is synthesized after the fixation of atmospheric nitrogen (Train, 1979). A range more than 1 mg/l may be described to the microbial decomposition of organic matter which release CO_2 and NH_3 (Parvateesam and Gupta, 1994). Ellis *et. al.* (1946) suggested that a concentration of more than 1 mg/l of ammonia nitrogen indicate pollution by organic matter. In the present study the average ammonia nitrogen was below 1 mg/l for all the stations. A comparatively lower value during winter and higher value during summer in all the four Stations seems to be directly proportional to the rate of decomposition (Varma and Paul, 1998). The higher values might be due to higher microbial activities and higher excretory products of aquatic animal (Bhatt *et. al.*, 1999). Rana *et. al.*, (1996) recorded high ammonia nitrogen values in trophic beel. Das (2000) opined that aquatic autotrophs quickly utilize ammonia - ions preferring over nitrates, accordingly ammonia does not reach the harmful concentrations.

5.1.13.2. Nitrate nitrogen

Welch (1952) opined that nitrate in natural waters will be in a continuously changing state due to the relation of nitrate with nitrifying bacteria and demand by nitrate consuming organisms such as phytoplankton and higher aquatic plants. In the present investigation the nitrate nitrogen content is supported by the findings of Das (2002), Anupama (2003) and Paul (2003). Saha *et. al.* (1990) reported the variations of nitrate-nitrogen

values from 0.08 to 1.8 mg/l during their study (1981-82) in Kulia beel which is closely similar to present investigation. Chandrasekhar and Jafar (1998) reported that the chief source of nitrate is domestic sewage, agriculture run-off, metabolic waste of aquatic community and dead organisms. Higher values of nitrate-nitrogen was observed during summer and monsoon season. (Bhowmik, 1987; Rao, 1987; Badge and Verma, 1985 and Singh *et al.*, 1980). Comparatively lower values of nitrate-nitrogen was observed during the post monsoon and winter seasons. The low values of nitrate might be due to the insufficiency in the system to oxidize biologically the ammonia to increase the nitrate levels (Chandrasekhar and Jafar, 1998). Hannan (1979) reported that the decrease in NO_3-N content is due to increase in atmospheric association or stratification. Ajmal *et. al.*, (1985) reported a lowest content of nitrate during winter and highest during summer. The lower concentration during winter probably might be due to rapid absorption of NO_3 - N for excessive growth of macrophytes (Paul, 2003).

5.1.13.3. Phosphate - Phosphorus

Phosphorus is always available in the form of phosphate in natural waters and is considered as one of the limiting nutrient regulating plant production in aquatic system. The present results are in agreement with the findings of Sugunan *et. al.*, (2000) who reported a phosphate range of trace to 0.63 mg/l in the beels of West Bengal. Ganapati (1956) stated more than 0.5 mg/l is an indicator of pollution. The highest phosphate phosphorus value was observed during rainy season which might be due to inflow of rain water, and lower values were recorded during winter which might be due to utilization by phytoplankton and macrophytes (Varma and Paul, 1998 and Coeltho and Greco, 1999;). The rise in phosphorus level might be attributed to monsoon rain (Blum, 1957, Hutchinson, 1957; Swingle, 1967). Low concentration of phosphate in post monsoon might be due to the dilution of the ditch water with rain water as the only source (Chakraborthy,

1998). Mishra and Sakesena (1991) stated that the major source of phosphate in water is domestic sewage, agricultural effluent with fertilizers, Industrial waste water etc. Phosphorus is the principle nutrient in determining eutrophication in freshwater (Vollenwider, 1968 and Lee, 1973).

5.1.14.Primary productivity

Primary productivity is an important index for production as well as the biodiversity of the aquatic ecosystem. It is directly or indirectly controlled by the biotic and abiotic factors and nutrient status of the waterbody. In the present investigation, both NPP and GPP showed the maximum values during summer and monsoon periods and the minimum values were recorded during winter period (October to February) in all the stations. The result is comparable with the finding of Paul (2003) who reported that during summer the temperature is raising which accelerates the nutrients release from the sediment through microbial decomposition. The excessive amount of nutrients along with higher temperature favours the maximum concentrations of NPP and GPP values during summer. Present investigation showed the peakness of high production in July when the temperature was high, which is correlated with the findings of Basheer *et. al.*, (1996). Ali and Khan (1978) reported higher values of production in spring and lower in winter. Kumar (1997) reported that the presence of macrophyte in shallow pond resulted in poor primary productivity. The sources of nutrients were restricted only from autochthonous release and some times autochthonous inputs through human activities. So the productivity of beel varied due to seasonal fluctuations of temperature corresponding with its availability of nutrients. In addition major parts of the water body was covered by dense macrophytes during the month of November to February, which impaired the penetration of light into the water body and also obstructed to produce phytoplankton. For these reasons, the primary productivity was limited during these month.

5.2. SEDIMENT

Sediment plays important role in maintaining the productivity of a waterbody and has the ability to store the nutrients and release them into waters through different mechanisms under different conditions. Quality of water in a floodplain wetland is influenced by the soil quality which differ considerably from those of catchment areas.

5.2.1. Sediment pH

pH of the soil like the overlying water, is controlled by many environmental parameters and undergoes fluctuations depending upon the nature of soil. In the present investigation the soil pH ranged between 7.21 and 7.87. Sugunan *et. al.,* (2000) while studying in detail about the beels of West Bengal encountered the pH range of 6.70 to 7.83. Sinha and Jha (1997) observed a pH range of 7.7 and 8.2 in the four oxbow lakes of North Bihar. The results of recent investigation are comparable with the above. Singh *et. al.* (2000) observed a soil pH range of 7.0 to 8.2. Pathak *el. al.,* (2004) reported the pH range of wetlands of Uttarpradesh in between 7.0 - 8.2. The above findings are also comparable with the present study.

5.2.2. Sediment conductivity

Specific conductivity reflects the nutrient level of the soil of beels. High value of conductivity of the sediments of beel was due to rich in plant nutrient in the soil and its range in beel of West Bengal varying between 162 to 2455 μmho (Sugunan *el. al.* 2000). In the present study conductivity ranged between 0.263 and 0.580 mS/cm. Which is in comparable with the present study.

5.2.3. Organic carbon

Organic carbon content of sediment are important constituents of lakes. The organic carbon of lake sediments get influenced by amount of detritus, surface run off, lake again process, presence of other organic matter,

sewage and effluents discharges. During this investigation, organic carbon content in the soil of Mathura beel was found to be in between 0.26% and 1.68%. Sinha and Jha (1997) reported the organic carbon varying between 0.32 and 2.8% while working on the ecology and fisheries of oxbow lakes of North Bihar. Banerjee and Ghosh (1970) while working on the relation between soil reaction and phosphorus in fish pond soils observed organic carbon to vary from 0.21 to 2.86%. Das (2002) reported organic carbon content in the sediments of Kulia beel to be in between 0.74 and 2.64% with an average value of 1.64%. The organic carbon recorded during present study agrees with the above findings. According to Sugunan and Bhattachariya (2000) the variations in organic carbon is mainly dependent on the quality of macrophyte present in the beels and their magnitude of decomposition.

5.2.4. Available nitrogen

Available soil nitrogen status represents the easily oxidisable form of total nitrogen in the soil and its level is influenced largely by the organic matter content of soil. Sugunan *et. al.,* (2000) reported available nitrogen ranging from 2.35 to 83.44 mg/100g. Bandyopadhyaya and Das (1998) reported the available nitrogen content of Kole beel ranging from 26.65 to 58.75mg/100g with a higher value during monsoon and lower value during summer. The available nitrogen content observed in range of present investigation is correlated with the above findings. Ayyappan and Gupta (1980) attributed the rise in the nitrogen content of the sediment to increased water levels due to incursion of surface run-off. Ahmed (1996) reported that soil available nitrogen is beneficial for higher aquatic productivity and the main source of nitrogen is by run-off water which bring huge quantity of sewage from catchment areas. Paul (2003) observed the maximum concentration of available nitrogen during monsoon and summer due to increased temperature and light intensity, which accelerates the rate of

mineralization process and/or allochthonous input through run off during monsoon. This is in comparable with present study. Sugunan and Bhattachariya (2000) stated that the available N_2 status reflects the oxidizable form of total nitrogen in the soil and its level is influenced largely by the aquatic carbon of the water body.

5.2.5. Available phosphorus

Available phosphorus in the soil during the period of investigation ranged from 4.7 to 7.98 mg/100g. Sugunan *et. al.,* (2000) reported the available phosphorus value ranging from traces to 10.08 mg/100g in the beels of West Bengal. The result of present study are correlated with the above works. The lower value of available phosphorus might be due to its being the limiting nutrient for plant growth, is used off mostly by the rooted aquatic macrophytes (Sugunan *et. al.,* 2000; Sugunan and Bhattachriaya, 2000). Comparatively higher values of phosphorus during monsoon season might be due to increased surface run-off from surroundings were amongest the region attributed for compaling higher value (Ayyappan and Gupta, (1980). Paul (2003) observed the higher concentration of available phosphorus during summer and monsoon and lower values during winter. The result of present investigation co-related with the above findings.

5.3. AQUATIC MACROPHYTES

Macrophytes have the capability to absorb pollutants and make the environment clean and thus act as environmental indicators. It is serve as useful indicators of water pollution along the littoral of lakes (Melur 1999). Scheffer (1999) observed that macrophytes can enhance water clarity and reduce phytoplankton biomass through shading and reduction of nutrients availability. The dominance of macrophytes in wetland ecosystems is reflected in the aquatic productivity process (Mitra, 1997). During the present investigation, the wet weight of macrophytes ranged from 3.61 and

8.15 kg/m^2. This is in agreement with the result of Sinha and Jha (1997) who reported wet weight range of 4 to 25 kg/m^2 in the oxbow lakes of Bihar. Varghese (1993) observed the floating macrophytes biomass increasing from December to the maximum in April and showing the decline from June. This observation also is correlated with the present findings. The dry wet of macrophytes ranged from 330 and 590 gm/m^2. Singh and Jha (1997) have reported the average dry weight from the ox-bow lakes of North Bihar ranging from 0.30 to 3.80 kg/m^2. Sugunan *el. al.*, (2000) reported the dry weight range of macrophytes between 18.44 g/m^2 to 726.67 g/m^2 in the beels of West Bengal. These results are correlated with the present investigation.

5.3.1. Total nitrogen

In the present investigation the total nitrogen content of macrophytes ranged from 2.084 to 3.952%. Gopal and Sharma (1981) reported that the concentration of nitrogen ranged from 5.6 to 1.2% in macrophyte plant tissues. Chatterjee and Hya (1938) also estimated nutrient content of macrophyte, whose observations are also similar to the present investigation.

5.3.2. Phosphorus

The phosphorus content of macrophyte of water hyacinth ranged between 0.280 and 0.676%. These results are correlated with the observations of Gopal and Sharma (1981), Surat and Singh (1980), Coelho and Greco (1999) and Mohan and Hossetti (1998) who reported phosphorus content in macrophyte to be 0.1 to 0.8%, 0.59%, 30.1 to 0.37% and 0.52 to 0.623% respectively. During the present investigation, estimated nutrient contents of macrophyte like total nitrogen, phosphorus in aquatic macrophyte varied significantly between four stations. These observations are coinciding with the findings of Podder (1989), who concluded that the concentration of nutrients vary in the macrophytes belongs to various habitats.

5.4. PLANKTON

Plankton constitute a vital link in the food chain and its production directly depend on physicochemical features of the water. The quantum and taxa of plankton and their respective importance have widely being recognised throughout the globe and remain a matter of attraction for fishery scientists. It is well know fact that plankton are ubiquitous in distribution and are the most desirable organism in grazing food chain in aquatic ecosystem.

5.4.1. Phytoplankton

Phytoplankton are primary producers which form base of an autotrophic food chain. Use of phytoplankton community structure to analyse water quality monitoring for evaluation of the pollution potential of the waterbodies has become a popular method, as phytoplankton are the important biotic components of an aquatic ecosystem (Bais *et al.*,1993). Twenty two species of phytoplankton belonging to Chlorphyceae (Eight), Cyanophyceae (Six), Baillariophyceae (Seven) and Englenphyceae (One) are observed during the study. The present observations regarding density of various phytoplnkton groups are comparable to the observation of Saha *et al.* (1971), Saha and Chaudhary (1985) and Kanungo and Nayek (1987). Jana (1979), Sugunon (1980) and Pant *et al.* (1982) have reported peaks of diatoms during same period. Among diatoms, *Fragillaria* and *Navicula* were dominated species. Similar results were reported by Jana (1979) and Bhatt and Nagi (1985). Among twenty two species of phytoplnakton, the indicator species recorded were *Anabaena, Microcystis, Oscillatoria* from Cynophyceae, *Pediastrum, Scenedesmus, Pandorina, Volvox* from Chlorophyceae, *Fragillaria, Nitzia, Navicula, Synedra* and *Phacus* from *Eugleninae.*

According to Sinha and Jha (1997) the plankton population of the lakes, both in terms of abundance and texture, get adversely affected with the greater infestation of macrophytes. Based on the average and percentage

composition, the dominant phytoplankton groups were categorized in order of Cyanophyceae> Chlorophyceae> Bacillariophyceae> Euglenophyceae.

Sharma and Kaushal (2004) found that occurrence of *Anabaena, Oscillatoria, Microcystis, Scenedesmus* and *Pediastrum* indicated entrophic tendency of the reservoir. Presence of most pollution tolerant species of phytoplankton - *Oscillatoria, Scenedesmus* and *Euglena* indicates high degree of organic pollution (Nandan and Patel, 1992). Sharma and Kaushal (2004) found that abundance of pollution indicator species such as *Pediastrum* under Chlorophyceae, *Cymbella, Fragillaria* under Bacillariophyceae and *Oscillatoria, Nostoc* under Myxophyceae indicated eutrophic tendency of the water body. Vasisht and Sara (1979) observed that dominance and regular presence of *Microystis* sp scts as an indicative of pollution and eutrophication of water body. Pandey *et al.,* (2004) have found several pollution indicator diatoms like *Navicula, Cyclotella* and *Fragillaria.* During this study *Oscillatoria, Anabaena, Microcystis, Fratgillaria, Navicula, Nitzia, Synendra, Scenedesmus* and *Phacus* were recorded. Sugunan and Bhattachariya (2000) observed that Chlorophyceae use to be a dominant species in the beel of Assam. Sharma and Kaushal (2004) and Patralekh and Patralekh (2004) found Chlorophceae to be a dominant species in the Mall reservoir of Haryana and Bihar respectively. Pandey *et. al.* (2004) also observed the same in the Ramjan river Bihar. According to Zuthshi (1975) and Trivedi *et al.,*(1985), pollution leads to the development of green algae and blue green algae. Presence of pollution tolerant phytoplankton like *Englena* has also being considered indicative of enriched waters (Khan *et. al.,* 1988). Franklin (1972) and Rao *et al.,* (1978) have also designated blue green algae to be the indicative of highly polluted water. Species of *Englena, Phacus, Trachelomns* and *Lepocinclis* are always encountered due to rich oxidizable matter in water (Rameswamy *et al.,* (1982). The use of diatom as indicators of pollution has been emphasized by many workers (Patrick, 1973, Reynolds, 1973, Stockner and Benson, 1967

and Stoemer *et al.*, 1967). *Chydones* is also an indicator of eutrophication (Singh *et al.*, 1998). Bandyopadhyay and Das (1998) have recorded ten pollution indicting species as *Oscillatoria chlorina, Pandorina morum, Ankitrodesmus falcatus, Phacus longicaudata, Scenedesmus quadricands, Microcystis aeruginosa, synedra ulna, Ceratium hirundinella, Nitzschia acicularis, Navicula frustutum and Euglena acus* from Kole beel, West Bengal. Garg and Garg (2003) recorded *Merismopedia punctata* as eutrophic form among Cyanophytes, which was able to withstand large nutrient variations and *Microcystis aeneginosa,* was evolved as a dominant eutrophic form. During the present study *Microcystis, Oscillatoria, Anabaena, Scenedesmus, Pediastrum, Cymbella,* Frayillaria, *Synedra, Ankistrodoesmus, Pandorina* were encountered. Saify *et al.*, (1986) have attributed the Chlorophycean dominance to the eutrophic condition of water bodies. Moderate to high level of infestation of various categories of macrovegetation are associated with low plankton count (Sugunan and Bhattachariya, 2000). Slightly higher numbers of phytoplankton count were observed at stations- 2 and stations- 3 compared to other stations, which might be due to lower infestation of macrophytes. Statistical analysis reflected that Cyanophyceae, Baccillariophyceae and Euglenophyceae were positively correlated with phosphate. Nair (1999) also found same result when working on phytoplankton of vilage pond at Imalia (India) with relation to physico-chemical factors.

5.4.2. Zooplankton

A total number of eleven zooplankton species were recorded with the highest total of 251 and the lowest at 75 nos/l. Percentage wise its contribution to the total plankton was higher at stations 2 and 3 compared to stations 1 and 4. Zooplankton is secondary producer linking the phytoplankton with the community occupying higher trophic levels. According to Sugunan *el al.*, (2000) generally population of phyto and zooplankton in the floodplain wetland is low during monsoon season. A

total of eleven zooplankton species with the average density of 260 and 214 nos/l during summer and monsoon seasons, respectively, were recorded by Bandyopadhyay and Das (1998) during their study of Kole beel in West Bengal. Choudhary and Singh (1999) found a poor concentration of zooplankton during rainy season and attributed it to heavy rain causing severe disturbance in zooplankton biota.

The animal component of plankton was mainly constituted by *Protozoan, Rotifers, Cladocerans* and *Copepods*. The order of domination of zooplankton in Mathura beel was *Rotifers>Cladocera>Copepods> Protozoa.* Like phytoplankton a few zooplankton species are also considered by many ecologists as indicator of organic pollution. During study the indicator Zooplankton species recorded were *Branchionus, Keratella, Filinia.* Zooplankton population remained lower than phytoplankton throughout the stretches of beel. Singh *et al* (1998) reported rotifers in higher percentage as an indicator of eutrophy. Bandyopadhyay and Das (1998) reported certain pollution indicator species viz *Daphnia carinata, Brachionus rubens, Moina bracheata, Voticella convularia and Rotatoria* sp. from Kole beel of West Bengal Khan and Rao (1981) labelled *Paramaecium candatum, Halteria grandinella, Brachionus calcyciforus, Keratella tropica and Filinia terminalis* as indicators of pollution. According to Bath (1997) copepods and cladocerans are abundant groups in Harike wetlands. Syal (1991) referred these groups as tolerant groups. Among *Copepods, Cyclopoids* were the dominant group. Kurasawa (1975) from his studies on several Japanese lakes showed that in oligotrophic lakes there if dominance of copepod and in eutrophic lake there was dominance of *Cladocera* or *Rotifer*, but according to Varghese *et al.*, (1992), in tropical eutrophic lakes Cyclopoid and Copepods are dominant. The dominance of *Copepods* have also been reported by Seenayya (1973) and Ayyappan and Gupta (1980).

Rotifers were found in high number in all the stations. However Stations- 1 showed comparatively higher numbers. According to Ruttnor (1974), rotifers are highly sensitive to low oxygen and in the eutrophic condition deficient of oxygen in general contained only very few species in spite of the great amount of food available. During the present work also Stations- 1 and Stations- 2 had comparative lowered dissolved oxygen than station - 3 and station- 4. Among the rotifers *Brachionus* sp was the dominant species. Lillieroth (1950) and Das (2002) designated *Brachionus* sp as an indicator of eutrophy. The fluctuation in abundance of phyto and zooplankton is due to the combined and complex effects of different physico-chemical characteristics, which intern may directly influence the food of planktor.

5.4.3. Diversity index

Species diversity is a function of the number of species present (species richness or species abundance) and evenness with which the individuals are distributed among these species (Margalet 1958; Pielou, 1966). Various definitions have been put forward for diversity indices. Odum (1971) has defined the species diversity as the ration between the number of species and number of individuals. Hulbert (1971) said that species diversity is a combined function of the number of species and the eveness. Thus diversity can increase as eveness increases, while species number decreases marginally. Various species diversity indices respond differently to different environmental and bio chemical factors of biotic communities. In recent years, emphasis have been given to evaluate the environment based on different diversity indices (Laal *et al.*, 1982; Singh, 1988; Jhingran *et al.*, 1989; Acharjee *et al.*, 1995). During the present investigation an attempt has been made to evaluate the waterbody through Shannun - Weaver index (Shannon - Weaver, 1949) and Evenness index (Pielou, 1966).

The concept of species diversity is based on the theory that aquatic communities living in a pollution free habitat are characterized by occurrence of a wide variety of species, but only by a moderate number of individuals. A change in the community structure resulting in less species, but greater abundance of tolerant numbers indicates onset of an environmental stress (Das, 2002). Wilhm and Dorris (1968) gave the value of Shannon - Weaver index (H) more than 3 as clean water, 1 to 3 moderately polluted and less than 1 heavily polluted. Staub *et al.*, (1970) suggested another scale of evaluating pollution in terms of species diversity as follows.

Species diversity	Pollution Status
3.0 - 4.5	Slight pollution
2.0 - 3.0	Light pollution
1.0 - 2.0	Moderate pollution
0.0 - 1.0	Heavy pollution

In the present study H values for phytoplankton were found to vary between 2.011 to 2.982. Acharjee *el al.*, (1995) reported an overall phytoplankton diversity index of 1.79497 in Dighali beel of Assam. Rana *el. al.* (1996) also found H value varying between 1.0414 and 1.0932 for unmanaged beel and between 0.4318 and 0.7418 in managed beel of West Bengal. However the Shanon Weaver diversity index was found to vary between 1.4 and 2.7 in the Kole beel of West Bengal by Bandoyopadhyay and Das (1998). Khan *et al.*, calculated the values for middle stretch of river Ganga and reported it to vary between 0.205 and 2.433. During present investigation station 3 had the highest average phytoplankton H of 2.982 indicating of comparatively lesser polluted station than others but no significant difference in values observed among the stations. However the Stations 1 had lowest value indicating of comparatively increased pollution.

The Evenness index for different stations ranged between 0.779 and 0.989. The highest value was recorded for station 3 and lowest for

station 1. Acharjee *et al.*, (1995) have reported the average Evenness index for a beel to be 0.8969 and also reported significant direct correlation between index and evenness index.

In case of zooplankton the diversity was found to vary between 1.045 and 1.972. The H value was higher in stations 3 and the lower for stations- 1. Bandyopadhyay and Das (1998) have reported the species diversity index of zooplankton for Kole beel of West Bengal to vary from 2.6 to 2.9. A variation in H value of zooplankton from 1.0677 to 1.0750 for an unmanaged beel and 0.9580 to 1.0699 for managed beel have been reported by Rana *et al.*, (1996) and Das (2002). For zooplankton the evenness index was found to vary from 0.602 to 0.989 with the highest Evenness index at stations 3. Odom (1971) observed that when stress occurred in a community dominated by a few species, a large number of dominant species was eliminated and evenness increase.

Based on the suggestions given by Wilhm and Dorris (1968), Staub *et al.*, (1970) and Das (2002) the present waterbody can be grouped under modrately polluted category with stations 2, 3 and 4 are being least affected whereas stations 1 having comparatively higher pollution effect. The presence of indicator species and species diversity indices of plankton community also confirmed this waterbody to be moderately affected.

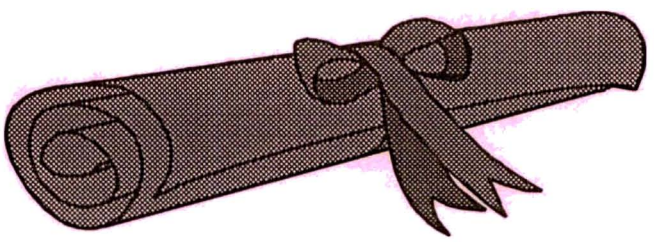
5.5. PROTOZOAN PARASITE

The protozoan parasites recorded during investigations were *Tripartiella, Thelohanellus, Myxobolus* and *Henneguya.* Sarkar and Haldar (1990) suggested that the urceolariid ciliates are most prevalence in the gills and body surface of various fishes in different physico-chemical factors. A peak in intensity was noticed during December and January by Saha *et al.* (1995). A similar observation was found by Pal (1975). The present observation also was comparable with Saha *et al.* (1995) and Pal's (1975). Yeomans *et al.* (1997) identified *Trichodinid* ciliates as a potential bioindicator,

recorded from the highly organic polluted river of south east England. Das and Shrivastava (1984) showed increased *Trichodinid* infection associated with exposure to pollutant other than oil. Voltonen and Koskinaara (1987, 1989) reported the skin ciliate *Trichodina* sp from Finland lake which frequently was receiving paper and pulp mill effluent and similar observation also observed by Lentinen (1984). Das and Shrivastava (1984) reported *Trichodina domergulei* on gills of *Puntius* sp from a lake, frequently receiving industrial waste, detergent, domestic sewage, silt from soil erosion. Similar results also were observed by Dabrowka (1974). Paperna and Overstreet (1981) reported myxosporozoan *Myxobolus* on gills of mullet where low level of dissolved oxygen, possibly caused by pollutants was present. Blazer (2003) suggested that infection rate *Myxobolus cerabralis* also can be directly influenced by environmental factors. Acharya (2004) also reported the high percentage of *Tripartiella* sp, *Thelohanellus* sp and *Myxobolus* sp from sewage fed fish farm compare to managed fish farm. Above reference were closely related to our investigation which confirming the water body to be moderately polluted.

According to different ecologists as cited in discussion part of plankton and protozoon parasites, the Bio-indicator species of plankton recorded during investigation were *Anabaena, Microcystis, Oscillatoria* from Cyanophyceae, *Volvox, Pediastrum, Sceredesmus, Pandorina* in case of Chlorophyceae. Under Bacillariophyceae Synedra, Fragillaria and Nitzia recorded. Only one species of Euglenophyceae recorded was *Phacus.* In case of zooplankton, indicator species were *Branchionus,* Keratella and Filinia recorded. On the other hand *Myxobolus, Tripartiella, Thelohanellus* and *Henneguya* recorded from protozoan parasites which also indicate different pollution levels in water bodies.

CHAPTER - 6



SUMMARY

SUMMARY

The present study was an attempt to investigate the ecological status of beel with reference to macrophytes, plankton and protozoan parasites. The studies were conducted for a period of twelve months, from May 2004 to April 2005.

Review of literature provides an over view of available literature related to the present study.

Selection and description of sampling stations, the materials used and methodology followed. The results obtained on different physico-chemical parameters of water, nutrient, of macrophyte, nutrient status of sediment, plankton composition and protozoan parasites are presented in chapter 'Result'.

The variation in temperature at different stations was in accordance with air temperature. Station 1 and Station 2 had the significantly higher average pH (8.91 and 8.92) than other stations. Station 1 had the lowest and Station 4 had the highest (9.5 mg/1) dissolve oxygen concentration. No presence of any amount of CO_2 recorded during the study period. Alkalinity and hardness were uniformly distributed and showed somewhat similar trends. Station 4 had lowest turbidity recorded than other three stations.

Station 3 and station 4 recorded significantly lowest average total solids and total dissolved solids. The highest average dissolved organic matter was recorded at station 1.

The average biological oxygen demand was highest at station 4 and the lowest average chemical oxygen demand was recorded at station 4.

Among the nutrients the concentration of ammonia nitrogen was low in Station 4 among all the stations. Station 4 had the highest average

phosphate concentration (0.097 mg/l). The average conductivity was recorded highest at station 1 (0.441 mS/cm) compared to other three stations.

Gross primary productivity and net primary productivity were lowest in station 2 and no significant difference observed in other station.

The average pH and organic carbon content of the sediment was highest at station 4 and station 3 respectively. The average available nitrogen was highest recorded at station 4 and other three stations showed more or less similar values. In case of available phosphorus lowest value (5.62 mg/100 g) was recorded at station 3 and highest value was recorded at station 2 (7.79 mg/100 g). The average specific conductivity of sediments varied between 0.39 and 0.43 m S/cm and did not show any clear-cut seasonal trends.

The phytoplankton and zooplankton counts was were of optimum level at all the stations. Among phytoplankton Cyanophyceae and among zooplankton Rolifers were the dominant groups. The Shannon-Weaver index calculated was lowest (2.001) and the highest (2.982) at station 1 and station 2, respectively and for zooplankton the respectives values were between 1.045 (station 1) and 1.972 (station 3). The evenness index (e) followed the same trend.

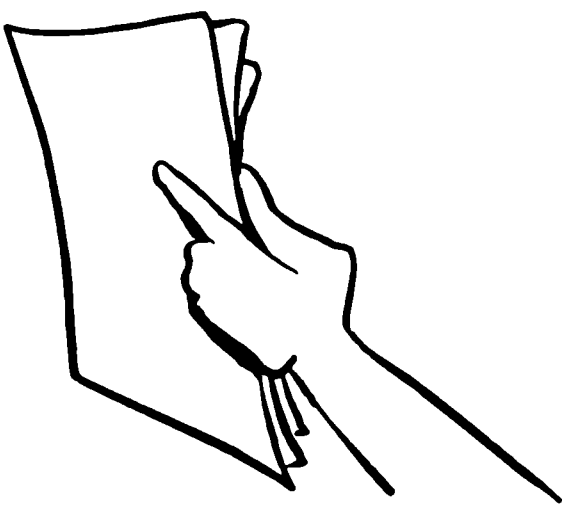
The indicator species recorded from different groups of phytoplankton *viz., Anabaena, Microcystis* and *Oscillatoria* from Cyanophyceae, *Volvox, Pediastrum, Scenedesmus* from Chlorophyceae, *Nitzia, Fragillaria, Synedra* from Bacillariophyceae and *Phacus* from *Euglenophyceae.*

In case of zooplankton *Branchionus, Keratilla* and *Filinia* were recorded. The highest wet weight was recorded from stations 4 and dry weight from station 2. The highest concentration of phosphate and total nitrogen were recorded from station 1.

Four different protozoan parasites such as *Myxobolus, Thelohanellus, Tripartiella* and *Henneguya* were found on different fishes of Mathura beel.

Two way ANOVA was analysed to find out the variation of observed parameters in between months and between stations. Most of the parameters are significantly varying at 5% level. The correlation between different parameters and plankton analysed. Most of the parameters were significantly correlated.

CHAPTER - 7



CONCLUSION

CONCLUSION

From the data gathered and analysed, it can be concluded that

- The hydrobiological conditions of the water body were more or less within the permissible limits except for one two instances like BOD, COD.
- The plankton population were dominated by pollution tolerant species and in terms of planktonic diversity and quality assessment this water body is found to be moderately polluted. It is also confirmed by Shannon - weaver index and evenness index values
- The macrophytes, especially *Eichhornia* sp covered most of the sampling stations confirming the organic polluted nature of waterbody.
- The protozoan parasites recorded from different fishes were confirmed that water body is in verge of pollution.

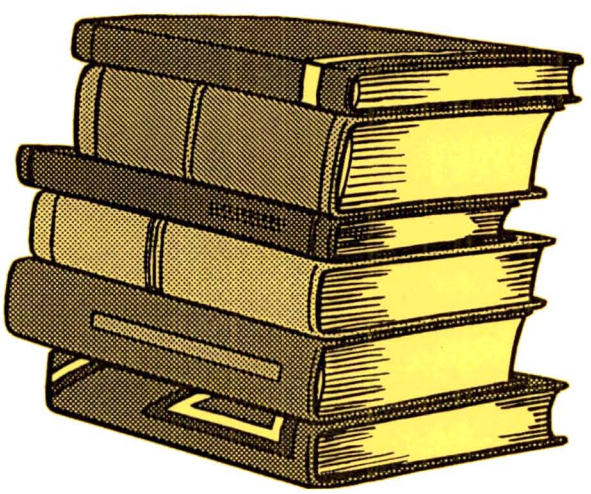
Suggestions

In order to restore the hydrobiological conditions of flood plain wetland, the following aspects need to be addressed properly -

- Complete ban on the use of chemical fertilizer in surrounding field by educating the farmers.
- Management practices such as control of macrophytes and liming, bottom racking, strengthening of the bundhs and control of flow of polluted water should be taken care.
- More and more ecological research as well as continuous monitoring should be carried out.

Though the water quality is not indicating the pollution level but through biomonitoring it is concluded that the vast waterbody is under stress and is moderately polluted which will be reflected by water quality within certain periods, if proper management will not be followed.

CHAPTER - 8



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ANNEXURE

Annexure - I

A. PHYSICO-CHEMICAL PARAMETERS OF WATER

Table 12. Monthly Variations In (a) Temperature (b) PH And (c) Do of Water During May, 2004 To April, 2005 In Mathura Beel.

a. Temperature (in ^{0}C)

Months	S1	S2	S3	S4
May	29.2	29.5	30.2	30.4
June	29.3	29.6	29.7	30.2
July	29.3	29.3	29.2	29.2
August	28.5	28.7	29.1	30.2
September	27.8	28.1	29.8	29.5
October	26.2	26.1	26.1	26.4
November	24.5	24.4	24.3	24.6
December	18.3	18.2	18.3	18.6
January	16.0	16.2	16.4	16.6
February	17.6	18.1	19.2	19.3
March	28.3	25.1	28.7	29.6
April	29.4	29.3	29.1	29.4
Average	25.37	25.22	24.68	23.72

b. pH

Months	S1	S2	S3	S4
May	9.18	9.38	9.44	9.50
June	8.89	8.91	8.76	8.87
July	9.46	9.42	9.32	9.28
August	9.43	9.43	9.33	9.27
September	9.30	9.41	9.48	9.41
October	9.24	9.24	9.13	9.24
November	8.52	8.48	8.41	8.41
December	8.27	8.38	8.36	8.31
January	8.40	8.32	8.31	8.37
February	8.28	8.35	8.38	8.38
March	8.51	8.52	8.49	8.57
April	9.43	8.45	9.43	9.41
Average	8.91	8.86	8.74	8.92

c. Dissolved oxygen (in mg/l)

Months	S1	S2	S3	S4
May	8.2	9.4	9.6	10.2
June	8.0	8.6	8.8	9.2
July	8.4	9.4	9.2	10.2
August	8.2	9.4	9.2	10.2
September	8.8	8.8	9.2	10.2
October	8.6	8.6	8.8	9.6
November	7.4	8.2	8.4	9.4
December	7.2	7.4	8.4	9.0
January	6.2	6.6	6.8	7.4
February	6.6	7.2	7.4	8.6
March	7.8	8.4	8.0	9.8
April	8.2	9.2	10.2	10.4
Average	7.8	8.4	8.6	8.5

Table.13: Monthly variations in (a) Conductivity (b) Total alkalinity and (c) Total hardness of water during May, 2004 to April, 2005 in Mathura Beel.

a. Conductivity of water (in mS/cm)

Months	S1	S2	S3	S4
May	0.336	0.324	0.286	0.269
June	0.482	0.428	0.372	0.326
July	0.576	0.576	0.492	0.311
August	0.562	0.366	0.371	0.244
September	0.486	0.394	0.384	0.362
October	0.488	0.363	0.368	0.353
November	0.482	0.364	0.358	0.389
December	0.435	0.412	0.381	0.349
January	0.476	0.471	0.396	0.452
February	0.482	0.472	0.461	0.448
March	0.188	0.278	0.286	0.265
April	0.295	0.282	0.231	0.282
Average	0.441	0.394	0.370	0.338

b. Total alkalinity (in mg/l)

Months	S1	S2	S3	S4
May	115	114	111	118
June	105	112	98	90
July	116	115	108	109
August	113	118	116	120
September	112	121	118	104
October	98	102	96	100
November	97	94	96	104
December	80	74	88	78
January	68	63	70	58
February	74	75	78	76
March	82	84	80	88
April	104	104	113	110
Average	97.00	98.00	97.67	96.25

c. Total hardness (in mg/l)

Months	S1	S2	S3	S4
May	122	128	136	136
June	116	122	128	132
July	124	108	116	128
August	118	128	122	126
September	128	142	134	136
October	124	136	132	128
November	100	104	112	115
December	102	96	94	97
January	98	92	86	85
February	106	114	106	102
March	120	116	108	101
April	138	128	126	117
Average	116.33	117.83	116.67	116.92

Table. 14 : Monthly variations in (a) Turbidity (b) Total solids and (c) Total dissolved solids of water during May, 2004 to April, 2005 in Mathura Beel.

a. Turbidity (in NTU)

Months	S1	S2	S3	S4
May	38.86	35.68	33.68	31.64
June	42.33	39.01	33.92	35.35
July	45.32	41.98	39.45	34.66
August	34.64	28.19	23.15	24.01
September	33.68	27.11	23.25	23.35
October	25.57	18.69	18.94	17.11
November	23.01	19.93	18.22	17.25
December	23.06	22.98	20.19	19.67
January	22.86	22.08	21.27	19.38
February	33.37	30.38	28.67	25.26
March	36.43	35.25	30.82	25.27
April	46.84	44.05	39.47	32.61
Average	33.83	30.53	27.59	25.46

b. Total solids (in mg/l)

Months	S1	S2	S3	S4
May	371	342	321	286
June	382	366	338	306
July	445	422	373	378
August	421	378	336	346
September	381	365	343	356
October	548	304	336	328
November	270	298	237	234
December	268	285	244	236
January	271	276	236	244
February	304	274	242	246
March	366	345	248	305
April	412	381	324	338
Average	369.92	336.33	298.17	300.25

c. Total dissolved solid (in mg/l)

	S1	S2	S3	S4
May	152	164	116	120
June	184	168	119	134
July	178	152	118	124
August	202	178	152	154
September	240	202	160	166
October	270	260	150	134
November	220	246	105	114
December	244	148	128	116
January	208	198	117	124
February	196	194	110	116
March	188	182	120	126
April	198	176	125	130
Average	206.67	188.83	126.67	129.83

Table. 15 : Monthly variations in (a) Biological oxygen demand (b) Chemical oxygen demand and (c) Dissolved organic matter of water during May, 2004 to April, 2005 in Mathura Beel.

a. Biological oxygen demand (in mg/l)

Months	S1	S2	S3	S4
May	5.4	6.2	6.6	6.8
June	5.2	4.8	4.2	5.2
July	4.4	4.2	3.8	4.2
August	4.4	5.2	5.4	6.2
September	4.2	4.8	5.4	5.8
October	3.8	4.6	3.8	4.8
November	3.8	4.2	2.8	3.4
December	2.8	2.8	3.6	3.4
January	2.6	3.2	2.6	3.8
February	2.8	2.6	4.2	4.4
March	3.8	3.6	5.1	4.4
April	4.4	5.4	5.2	6.4

b. Chemical oxygen demand (in mg/l)

Months	S1	S2	S3	S4
May	42	38	34	34
June	44	46	32	38
July	48	34	38	30
August	38	30	34	26
September	42	34	36	30
October	44	36	26	26
November	34	28	24	26
December	32	26	22	28
January	34	28	26	22
February	32	28	24	26
March	42	38	30	34
April	46	42	38	32
Average	39.83	34.00	30.33	29.33

c. Dissolved organic matter (in mg/l)

Months	S1	S2	S3	S4
May	4.4	3.8	3.6	4.2
June	3.8	3.6	2.8	2.8
July	3.6	3.6	3.2	3.2
August	3.8	3.2	3.4	3.2
September	4.6	4.2	4.4	3.8
October	4.8	3.4	4.6	4.4
November	3.4	2.8	2.6	3.2
December	2.8	2.6	2.4	2.8
January	2.2	2.2	2.6	2.4
February	2.8	2.2	2.8	2.2
March	4.2	4.1	3.4	2.6
April	4.4	4.2	3.6	2.8
Average	3.7	3.33	3.3	3.1

Table. 16 : **Monthly variations in (a) Ammonium nitrogen (b) Nitrate nitrogen and (c) Phosphate phosphorus of water during May, 2004 to April, 2005 in Mathura Beel.**

a. Ammonia nitrogen (in mg/l)

Months	S1	S2	S3	S4
May	0.074	0.068	0.041	0.045
June	0.075	0.048	0.057	0.042
July	0.062	0.052	0.044	0.041
August	0.071	0.062	0.047	0.042
September	0.071	0.065	0.051	0.057
October	0.066	0.057	0.045	0.035
November	0.043	0.037	0.032	0.029
December	0.047	0.044	0.039	0.031
January	0.048	0.046	0.041	0.035
February	0.044	0.038	0.031	0.025
March	0.042	0.038	0.027	0.029
April	0.053	0.049	0.041	0.032
Average	0.058	0.050	0.049	0.037

b. Nitrate nitrogen (in mg/l)

	S1	S2	S3	S4
May	0.188	0.164	0.162	0.148
June	0.148	0.144	0.158	0.152
July	0.152	0.152	0.156	0.146
August	0.184	0.176	0.192	0.185
September	0.095	0.072	0.074	0.072
October	0.074	0.081	0.076	0.068
November	0.052	0.046	0.056	0.052
December	0.054	0.066	0.058	0.062
January	0.042	0.039	0.046	0.044
February	0.041	0.044	0.044	0.056
March	0.086	0.124	0.109	0.136
April	0.158	0.136	0.162	0.158
Average	0.106	0.104	0.108	0.107

c. Phosphate phosphorus (in mg/l)

Months	S1	S2	S3	S4
May	0.122	0.056	0.068	0.068
June	0.164	0.076	0.086	0.096
July	0.198	0.186	0.184	0.162
August	0.196	0.134	0.146	0.096
September	0.122	0.114	0.134	0.134
October	0.064	0.084	0.064	0.094
November	0.052	0.064	0.048	0.062
December	0.044	0.046	0.048	0.036
January	0.034	0.038	0.044	0.033
February	0.022	0.044	0.036	0.026
March	0.048	0.068	0.065	0.056
April	0.098	0.090	0.072	0.076
Average	0.097	0.083	0.083	0.078

Table. 17 : Monthly variations in (a) Gross primary productivity and (b) Net primary productivity of water during May, 2004 to April, 2005 in Mathura Beel.

a. Gross primary productivity (in mgC/m³/d)

Months	S1	S2	S3	S4
May	2986	3122	3064	2904
June	3244	2874	3152	3046
July	3318	3126	3122	3028
August	2844	2764	2876	2812
September	2802	2674	2772	2704
October	2316	1874	2398	2312
November	1818	1772	1838	1712
December	1804	1668	1826	1814
January	1438	1372	1654	1432
February	1398	1222	1860	1630
March	2826	2572	2812	2628
April	2946	2818	2926	2826
Average	2478.33	2321.50	2525.00	2504.00

b. Net primary productivity (in mgC/m³/d)

Months	S1	S2	S3	S4
May	1934	2014	1882	1854
June	2136	1868	1998	1918
July	2138	2074	2028	1834
August	1812	2138	1798	1694
September	1816	1732	1894	1734
October	1494	1256	1553	1422
November	1094	1134	1071	1048
December	1058	1048	1054	1148
January	938	874	958	948
February	936	834	922	1054
March	1962	1568	1216	1682
April	1884	1764	1686	1798
Average	1600.17	1525.33	1505.00	1511.17

B. SEDIMENT

Table. 17 : Monthly variations in (a) pH (b) Conductivity and (c) Organic carbon of sediment during May, 2004 to April, 2005 in Mathura Beel.

a. pH

Months	S1	S2	S3	S4
May	7.46	7.63	7.52	7.63
June	7.29	7.58	7.61	7.71
July	7.67	7.64	7.67	7.73
August	7.21	7.42	7.52	7.61
September	7.45	7.47	7.71	7.87
October	7.38	7.48	7.82	7.34
November	7.28	7.33	7.73	7.29
December	7.49	7.42	7.81	7.73
January	7.67	7.26	7.78	7.62
February	7.46	7.38	7.68	7.61
March	7.58	7.51	7.26	7.38
April	7.49	7.53	7.35	7.62
Average	7.45	7.47	7.62	7.59

b. Conductivity (mS/cm)

Months	S1	S2	S3	S4
May	0.386	0.358	0.389	0.398
June	0.362	0.309	0.285	0.326
July	0.331	0.353	0.337	0.364
August	0.478	0.464	0.418	0.428
September	0.578	0.477	0.426	0.554
October	0.505	0.405	0.529	0.518
November	0.542	0.419	0.508	0.538
December	0.478	0.456	0.433	0.477
January	0.416	0.427	0.388	0.397
February	0.305	0.263	0.308	0.391
March	0.396	0.423	0.373	0.412
April	0.376	0.347	0.297	0.289
Average	0.43	0.39	0.39	0.42

c. Organic carbon (in %)

Months	S1	S2	S3	S4
May	0.98	1.26	1.06	1.56
June	1.03	1.06	1.04	1.09
July	1.22	1.04	1.08	1.26
August	1.35	1.68	0.96	1.14
September	1.16	1.06	0.78	0.88
October	0.91	1.26	1.08	1.56
November	0.94	0.88	1.56	0.78
December	1.46	1.04	1.06	1.24
January	0.78	0.68	1.12	0.26
February	1.36	1.28	1.22	1.44
March	0.98	1.16	1.08	1.06
April	1.06	1.05	1.56	1.08
Average	1.10	1.12	1.13	1.11

Table . 18 : Monthly variations in (a) Available nitrogen and (b) Available phosphorus of sediment during May, 2004 to April, 2005 in Mathura Beel.

a. Available nitrogen (in mg/100g)

Months	S1	S2	S3	S4
May	28.62	28.36	28.02	26.98
June	29.96	29.16	28.56	28.42
July	30.42	30.34	29.58	30.22
August	32.42	29.26	29.78	34.54
September	31.86	31.42	29.22	33.32
October	29.16	29.82	28.98	32.44
November	28.12	27.14	28.72	30.72
December	27.66	29.16	26.88	27.82
January	25.42	24.58	25.96	26.58
February	24.62	21.54	22.58	20.92
March	26.70	26.62	26.84	27.78
April	26.14	26.82	27.42	26.58
Average	28.42	27.85	27.71	28.86

b. Available phosphorus (in mg/100g)

Months	S1	S2	S3	S4
May	6.8	8.3	6.4	6.98
June	6.8	8.2	6.2	7.3
July	6.4	7.7	5.8	7.2
August	6.5	7.9	5.8	6.4
September	6.7	8.4	5.5	6.7
October	6.2	8.2	5.4	6.5
November	6.1	7.1	4.9	6.2
December	5.8	6.9	4.7	5.8
January	5.5	7.2	5.4	5.4
February	5.6	7.3	5.6	6.4
March	6.8	7.98	5.8	6.8
April	6.7	8.3	5.9	7.1
Average	6.32	7.79	5.62	6.56

C. AQUATIC MACROPHYTES

Table 19. Monthly variations in (a) Wet weight and (b) Dry weight of macrophytes during May, 2004 to April, 2005 in Mathura Beel.

a. Wet weight (in kg/m²)

Months	S1	S2	S3	S4
May	7.12	6.81	4.52	4.87
June	4.34	5.11	4.56	5.12
July	6.53	4.89	4.63	5.84
August	5.41	5.21	5.61	5.29
September	6.31	4.23	4.85	5.92
October	4.85	4.28	6.52	5.83
November	7.16	6.42	6.48	6.84
December	5.26	7.91	7.15	6.83
January	6.43	7.89	6.34	5.01
February	6.22	7.87	7.99	5.85
March	5.62	5.11	6.26	7.51
April	5.41	5.85	6.35	8.15
Average	5.89	5.96	5.94	6.09

b. Dry weight (in g/m²)

Months	S1	S2	S3	S4
May	540	580	330	380
June	340	380	360	350
July	580	440	370	450
August	470	410	460	440
September	530	360	360	420
October	390	330	510	400
November	560	480	470	510
December	380	590	550	430
January	410	540	490	420
February	480	590	590	390
March	430	410	550	410
April	415	500	530	550
Average	460.42	467.50	464.17	429.17

Table 20. Monthly variations in (a) Total nitrogen and (b) Phosphorus of macrophytes during May, 2004 to April, 2005 in Mathura Beel.

a. Total nitrogen (in %)

Months	S1	S2	S3	S4
May	2.834	2.068	2.984	2.946
June	2.884	2.452	2.816	2.842
July	3.264	3.716	2.612	2.816
August	3.684	2.862	2.244	2.612
September	3.952	2.914	2.218	2.708
October	3.876	3.052	2.648	2.986
November	3.916	3.462	3.092	3.158
December	3.962	3.688	3.134	3.314
January	3.332	3.456	3.238	3.102
February	3.252	3.266	2.978	3.236
March	3.624	2.626	2.448	2.976
April	3.084	2.922	2.244	2.816
Average	3.472	3.040	2.721	2.959

b. Phosphorus (in %)

Months	S1	S2	S3	S4
May	0.628	0.517	0.308	0.437
June	0.652	0.534	0.271	0.444
July	0.582	0.503	0.244	0.418
August	0.552	0.464	0.276	0.358
September	0.573	0.482	0.328	0.345
October	0.512	0.538	0.338	0.326
November	0.505	0.523	0.342	0.342
December	0.574	0.494	0.303	0.378
January	0.615	0.517	0.256	0.384
February	0.676	0.528	0.265	0.396
March	0.676	0.544	0.288	0.414
April	0.687	0.508	0.282	0.446
Average	0.603	0.513	0.292	0.391

Annexure - II

Table. 21 : Summary of analysis of variance (ANOVA) for different parameters of (a) water, (b) sediment and (c) macrophytes

Sl. No.	Parameter	Source of variation	SS	df	MS	F	P-Value
a. Water							
1.	Temperature	Between Stations	6.8606	3	2.2868	5.6648*	0.0030
		Between Months	1120.617	11	101.8743	252.3558*	1.55E-28
2.	pH	Between Stations	0.0264	3	0.0088	0.3409	0.7958
		Between Months	9.4547	11	0.8595	33.2463*	1.1E-14
3.	Dissolved Oxygen	Between Stations	18.1491	3	6.0497	67.8858*	3.33E-14
		Between Months	31.9091	11	2.9008	32.5511*	1.51E-14
4.	Conductivity	Between Stations	0.0698	3	0.0232	8.1819(	0.0003
		Between Months	0.2351	11	0.0213	7.5140*	2.88E-06
5.	Total Alkalinity	Between Stations	21.5625	3	7.1871	0.2671	0.8485
		Between Months	13209.23	11	1200.839	44.6414*	1.33E-16
6.	Total Hardness	Between Stations	14.8958	3	4.9652	0.1058	0.9560
		Between Months	8828.063	11	802.5511	17.1102*	1.34E-10
7.	Turbidity	Between Stations	473.905	3	157.9684	44.4301*	1.09E-11
		Between Months	2695.882	11	245.0802	68.9311*	1.63E-19
8.	Total Solids	Between Stations	41677.97	3	13892.39	13.5598*	6.25E-06
		Between Months	126046.2	11	11458.74	11.18444*	3.09E-08
9.	Total Dissolved Solids	Between Stations	60034.92	3	20011.64	44.6685*	1.02E-11
		Between Months	15988.92	11	1453.538	3.2444*	0.0042
10.	Biological Oxygen Demand	Between Stations	5.3689	3	1.7896	6.4555	0.0014
		Between Months	43.1672	11	3.9242	14.1554*	1.62E-09
11.	Chemical Oxygen Demand	Between Stations	812.25	3	270.75	28.0305*	3.38E-09
		Between Months	1054.25	11	95.8409	9.9223*	1.29E-07
12.	Dissolved Organic Matter	Between Stations	2.3706	3	0.7902	5.27113*	0.0044
		Between Months	18.7656	11	1.7059	11.3802*	2.51E-08
13.	Ammonia-nitrogen	Between Stations	0.0031	3	0.0010	43.1949*	1.58E-11
		Between Months	0.0040	11	0.003	14.8007*	9.11E-10
14.	Nitrate-nitrogen	Between Stations	0.001	3	3.55E-05	0.3276	0.8054
		Between Months	0.1217	11	0.0110	102.2196*	4.25E-22
15.	Phosphate-phosphorus	Between Stations	0.0023	3	0.007	1.9770	0.1465
		Between Months	0.0934	11	0.0084	21.4190*	6.19E-12
16.	Gross Primary Productivity	Between Stations	285478	3	95159.42	7.5928*	0.0005
		Between Months	17702	11	16093	128.4113*	8.5E-24
17.	Net Primary Productivity	Between Stations	69689.67	3	23229.89	1.3639	0.2708
		Between Months	78671	11	715199.7	41.9930*	3.35E-16
b. Sediment							
18.	PH	Between Stations	02644	3	0.0881	3.8091*	0.0189
		Between Months	0.3022	11	0.0274	1.1872	0.3329
19.	Conductivity	Between Stations	0.0153	3	0.0051	3.8648*	0.0178
		Between Months	0.2274	11	0.0206	15.6509*	4.38E-10

Sl. No.	Parameter	Source of variation	SS	df	MS	F	P-Value
20.	Organic Carbon	Between Stations	0.0061	3	0.0020	0.0349*	0.9910
		Between Months	1.199023	11	0.1090	1.8628	0.0824
21.	Available Nitrogen	Between Stations	10.1453	3	3.3817	2.2763	0.0979
		Between Months	294.2433	11	26.7493	18.0055*	8.74E-11
22.	Available Phosphorus	Between Stations	29.4867	3	9.8289	147.9108*	3.31E-19
		Between Months	9.6971	11	0.8815	13.2662*	3.72E-09
c. Macrophytes							
23.	Wet Weight	Between Stations	0.2604	3	0.0868	0.0866	0.9668
		Between Months	22.0273	11	2.0024	1.9982	0.0614
24.	Dry Weight	Between Stations	11239.06	3	3746.354	0.6414	0.5937
		Between Months	88801.56	11	8072.869	1.3822	0.2270
25.	Total Nitrogen	Between Stations	3.5328	3	1.1776	10.8708*	4.04E-05
		Between Months	3.1628	11	0.2875	2.6542*	0.0148
26.	Phosphorus	Between Stations	0.6695	3	0.2231	133.6244*	1.56E-18
		Between Months	0.0253	11	0.0023	1.3810	0.2276
d. Plankton							
27	Phytoplankton	Between Stations	17806.23	3	5935.41	9.1810*	0.0001
		Between Months	313729.7	11	28520.88	44.1168*	1.59E-16
28.	Zooplankton	Between Stations	6479.229	3	2159.743	3.7961*	0.0192
		Between Months	49624.73	11	4511.339	7.9295*	1.62E-06

F-crit (Between Stations) = 2.891568

F-crit (Between Months) = 2.093252

***5% level of significance**

Annexure -III

Table 22. Correlation co-efficient (r) between different physico-chemical and biological characteristics in water of Mathura beel during May 2005 to April 2005.

Sl. No.	Parameters	Correlation Co-efficient (r)			
		S_1	S_2	S_3	S_4
1.	Temperature VS Do	0.88166**	0.89614**	0.79466**	0.87133**
2.	Tubidity VS TS	0.42349*	0.55336**	0.46039*	0.48681*
3.	PH VS Alkalinity	0.88342**	0.86076**	0.96698**	0.80925**
4.	PH VS Hardness	0.83613**	0.65035**	0.82114**	0.83452**
5.	Alkalinity VS Ltardness	0.67702**	0.75092**	0.80004**	0.82220**
6.	PH VS NO_3-N	0.78796**	0.59657**	0.68124**	0.61165**
7.	PH VS PO_4-P	0.78505**	0.70253**	0.67780**	0.72225**
8.	BOD VS COD	0.76244**	0.61194**	0.62714**	0.44353*
9.	BOD VS DO	0.74423**	0.84658**	0.63167**	0.63133**
10.	COD VS DO	0.80043**	0.56562**	0.73673**	0.50613**
11.	DO VS NPP	0.79195**	0.92023**	0.78953**	0.78803**
12.	DO VS GPP	0.82179**	0.90087**	0.74184**	0.80549**
13.	NPP VS Soil N	0.57037**	0.62823**	0.71881**	0.33253*
14.	NPP VS Soil P	0.92070**	0.70481**	0.66290**	0.88095**
15.	Water pH VS Soil pH	-0.16804	0.57853**	-0.26305	0.28434
16.	Soil N VS NO_3-N oP Water	0.54541**	0.43925*	0.52860**	0.21504
17.	Soil No VS NH_4-N of water	0.77328**	0.62764**	0.57331**	0.58126**
18.	Soil P VS water P	0.61079**	0.36035*	0.31337*	0.61527**
19.	Temp VS Plankton	0.67090**	0.75305**	0.68299**	0.43257*
20.	Alkalinity VS Palnkton	0.81743**	0.75621**	0.63427**	0.43672*
21.	Hardness VS Plankton	0.67476**	0.36240**	0.59234**	0.56868**
22.	NH_4 -N of water VS Plankton	0.81236**	0.73534**	0.72214**	0.50719**
23.	NO_3 -N of water VS Plankton	0.85134**	0.81043**	0.77893**	0.56797**
24.	PO_4P of water VS Plankton	0.87294**	0.58649**	0.65898**	0.53007**
2.5	Soil N VS Plankton	0.59898**	0.75015**	0.64376**	0.39357*
26.	Soil P VS Plankton	0.62626**	0.57807	0.67853**	0.37998*
27.	Soil OC VS Plankton	0.22196	0.24038**	- 0.51316**	0.30674*
28.	GPP VS Plankton	0.80797**	0.85621**	0.81696**	0.62313**

** 1% level of significance, * 5% level of significance