

**AN ECOLOGICAL INVESTIGATION ON THE
PHYSICO-CHEMICAL AND BIOLOGICAL
CHARACTERISTICS
OF SHANTISAGAR LAKE**

Thesis submitted to
Kuvempu University
for the award of
degree of

**DOCTOR OF PHILOSOPHY
in
ENVIRONMENTAL SCIENCE**

BY

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Dedicated to
my
beloved parents

DECLARATION

I do hereby declare that the thesis entitled "AN ECOLOGICAL INVESTIGATION ON THE PHYSICO-CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF SHANTISAGAR LAKE", which is submitted herewith for the award of the degree of DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE of Kuvempu University is the result of the work carried out by me in the Department of Post Graduate Studies and Research in Environmental Science, Kuvempu University, Jnana Sahyadri under the guidance of Dr. E.T. PUTTAIAH, Professor and Chairman, Department of Post Graduate Studies and Research in Environmental Science, Kuvempu University, Shankaraghatta - 577 451 during the period 1995-97.

I further declare that the results of the work are not submitted for the award of any other degree or diploma either in this or in any other university or institute.

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CERTIFICATE

I certify that the thesis entitled “AN ECOLOGICAL INVESTIGATION ON THE PHYSICO-CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF SHANTISAGAR LAKE” submitted to the Kuvempu University for the award of DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE by Ms. HINA KOUSAR is the result of the work carried out by her in the Department of Post Graduate Studies and Research in Environmental Science, Kuvempu University, Jnana Sahyadri, Shankaraghatta – 577 451, under my guidance during the period 1995-97.

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(Dr. E.T. PUTTAIAH)
(Guide)

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Place: Shankaraghatta

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ABBREVIATIONS USED

mg/l	- Milligrams per litre
o/l	- organisms per litre
kms	- kilometers
m	- metre
mm	- millimetre
mcft	- million cubic feet
Sq. kms	- Square kilometers
ha	- hectare
NTU	- Nephelometric turbidity unit
BOD	- Biochemical oxygen demand
COD	- Chemical oxygen demand
μ mho	- micro mhos/ centimeter

All the physico-chemical parameters under study are represented in mg/l except pH, temperature in °C, turbidity in NTU and conductivity in μ mho. The density of phytoplankton is represented in o/l.

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CHAPTER I

INTRODUCTION

"A thing of beauty is a joy for ever". This famous phrase augurs with anything beautiful in nature, more so ever if the sight is as enthralling as a clear and pure waterbody.

The general survey reveals that the total surface area of the earth is 51 crore sq.km. out of which 36.1 crore km. is covered by the sea. In addition to this, we get water from tanks, rivers, lakes and snow on hills. About 15 crore cubic km. of water is also found in the different layers of the earth.

Water is one of the prime necessities of life. A person is capable of surviving without food for several days but can't do without water for long. 70% of man's body is composed of water. Blood, cells and bones contain 18%, 75% and 22% of water respectively. This indicates the extent to which we are dependent on water.

The importance of fresh waterbodies around human habitation is well known. They have been the cause for the rise and fall of many civilisations. Many civilisations had flourished along fresh waterbodies and the same have perished when the rivers had dried up.

In olden days man was content to survive and exist with the basic needs. However, as the civilizations progressed his needs also increased. Man began to crave for more luxuries and comforts and in his greed for these, he began to destroy his surroundings indiscriminately. Thus began the downfall of our environment. As every biological science student is aware that environment comprises of the surroundings in which we live, which also encompasses the waterbodies along with other things. Thus rivers, lakes, ponds and streams which were hitherto free from any foreign material began to be loaded with

matter which changed the quality of water. The problem further intensified with the advent of industrialisation.

The 18th century is associated with industrial revolution which brought along with it, lots of prosperity and economic success to nations world-wide. Consequently, nations began to prosper and increase their wealth. But today, one can witness the repercussions of industrial revolution. Our environment has been degraded to such an extent that it seems a Herculean task if not an impossible one to bring it back to its former glory. The forests which were once dense have a sparse look since trees are being felled at a rapid rate to meet the increasing demand for fuel wood and other purposes. Same is the case with waterbodies too. The waterbodies which from time immemorial had an aesthetic look, quenching the thirst of crores of people and animals have today been loaded with toxic materials and chemicals which have rendered them almost useless.

Although several drastic measures have been taken during the last few years, the problem of pollution continues to pose as serious a challenge as the threat of nuclear war. In the evolution of human race, man has reached a stage where he has acquired the power to harness and transform nature in various ways. Through sheer negligence or apathy we can do irreparable harm to the environment on which depends our life and well-being. We are yet to recognise that good environment is the fundamental right of every citizen as it is essential for his physical, moral and social health.

The waterbodies, the world over, are threatened. They are being used as dumping grounds for various chemicals, solid wastes, toxic materials and radio-active wastes. The major rivers of the world like The Volga, The Euphrates, The Tigris, The Nile, The Colorado, The Congo, The Potomac, The Thames etc, have been used as dumping sites.

Nevertheless, owing to the process of self-purification these rivers clean themselves. The cleaning process is further aggravated owing to the huge quantity of water the year round. But the same cannot be said in case of the rivers of our country. Excepting a few like The Bramhaputra and The Jhelum which always house huge quantity of water, the others usually have very little water in summer. Hence the problem intensifies with the discharge of chemicals from industrial effluents, agricultural wastes, dumping of solid wastes and radio-active wastes.

Water pollution is turning India's famous lakes too into sewers. Several famous lakes which once attracted thousands of tourists from world over are now virtually on the brink. To cite a few, The Dal lake, Hussien Sagar lake, Chilka lake, The Picchola lake and The Nagin lake, which were known for their scenic location, the Shikaras and the purity of their water have now acquired the title of being the most polluted lakes in the world. The water is almost black, no aquatic fauna exists now and the stench emanating is unbearable. William Shakespeare inspired by clear and pure water had once written in his sonnet.,

"Full many a glorious morning have I seen,
Flatter the mountain tops with sovereign
eye,
Kissing with golden face the meadows green;
Gilding pale streams with heavenly alchemy."

The alchemy which he was referring to was the hue of the morning sun which when it falls on the water, splits the water into several colors. But ironically the alchemy

occurring in the waterbodies these days is quite different i.e. that from chemicals and other effluents. Such is the situation now.

Much attention has been given to the famous lakes and tanks and also sufficient literature is available on them. But there are several lakes and tanks which have escaped the public eye. One such waterbody is the Shantisagar lake, situated near the foot hills of Davanagere at a place called Kerebilchi, a village under Channagiri taluk, Davanagere district, Karnataka state.

Limnology deals with the study of fresh waterbodies. Fresh waterbodies include rivers, lakes, ponds, streams and springs. The study of lotic waterbodies deals with the flowing/running water and study of lentic water deals with the water which is standing or which stagnates. Several books and journals have been published on the famous lakes and tanks of our country. Ours being an agricultural country, depends heavily on fresh waterbodies. Hence, it is imperative that a clear cut knowledge on the availability of water and its proper utilisation is absolutely essential. Also, information on the physico-chemical and biological characteristics of water is a pre-requisite. A critical perusal of the available literature has revealed that no scientific work on the Shantisagar lake has been carried out. Hence, it is with this strong background, the present study on Shantisagar lake has been carried out which is considered to be the second biggest lake in South India, the first being Khambham lake in Andhra Pradesh.

SCOPE OF THE PRESENT WORK

The present work has been carried out with the following objectives:

The lake, inspite of being considered as the second largest in South India, has not been studied for its physico-chemical characteristics although such studies have been extensively carried out on other famous lakes of our country.

The tropical status of the lake could be assessed by evaluating its physico-chemical and biological characteristics.

Since no information is available regarding the physico-chemical characteristics, it is hoped that the data so collected would help in proper utilisation of water. Also, it could be of enormous use in assessing the extent of pollution.

Further, information regarding the inter-relationship between different chemical factors is a pre-requisite and it is equally important to establish the relationship between the physico-chemical and biological components.

The other objective is to know the seasonal variations with respect to physico-chemical and biological components.

It is depressing to note that the lake could be a major tourist attraction of the state but sadly, the government has not paid much attention to it. Hence, it is imperative that environmental organisations come forward and pressurise the government to take necessary steps to convert it into a tourist resort.

REVIEW OF LITERATURE

The history of limnology spans a period of barely 100 years. Eventhough special studies on certain water-based organisms, their feeding habits, propagation and behaviour in water had been undertaken in the 17th and 18th centuries by certain authors (Otto Friedrich Muller, Johann Christian Schaffer, Johann Abraham Trembly, Johann Conrad Eichorn, Karl Bonnet, Johann August Ephraim Goetze and others), studies on their relationships to natural waters were still wanting. This was hydrobiology not limnology. Junge (1885) and Forbes (1887) were the first to treat natural waters as a 'microcosm.'

From this hydrobiological prelude limnology emerged slowly at first, following the discovery by Johannes Muller in 1845 of sea-water plankton which gave the subject of fresh-water biology a fresh impulse.

The decisive forward step from hydrobiology to limnology was taken by F.A. Forel (1901) in Lausanne who investigated Lake Geneva not merely from biological, but also from the physical and chemical aspects and formulated the first concept of lake types. He named his area of study "Limnology" and published his findings under the title "Lake Geneva a Limnological Monograph" (in French). In 1901 he published "Handbook of the science of Lakes; General Limnology (in German) the first text book on this subject.

From 1880 onwards, stimulated by the earlier work of Forel (1901) there commenced in Europe and America an upsurge in the study of limnology which quickly established itself at several fresh-water research stations. In 1901 Otto Zacharias established the celebrated station in Plon which later exerted a decisive influence on the progress of limnology. In America, E.A. Birge (1911) together with C. Juday (1911) set up a limnological station on lake Mendota in Wisconsin, which rapidly developed into a centre

for classical limnological research. Birge (1911) and his associate Juday (1911) can be regarded as the pioneers of scientific limnology in N. America which has today assumed a position of eminence rivalling that in Europe.

The contributions to the field of limnology in the succeeding decades include those of: West and West (1912) who observed the periodicity of phytoplankton of some British lakes; Pearsall (1921) worked on the development of vegetation of English lake considered in relation to general evolution of glacial and rock basins; Storm (1924) investigated the ecology and geographical distribution of fresh water algae and plankton; Uspenskle (1927) made extensive studies on Iron as a factor in the distribution of lower aquatic plants; Howland and Lucy (1931) made extensive investigation on a pond at Hertford Shire; Pearsall (1932) observed the composition of the phytoplankton in the dissolved substances in English lakes; Hutchinson and Pickford (1932) made limnological observations on Mountain lake, Virginia; Ggdward (1934) investigated the distribution of algal epiphytes; Lund (1934) made extensive studies on Danish fresh water phycomycetes and made a note on their occurrence particularly relative to the hydrogen ion concentration of water; Prescott (1938) recorded the objectionable algae and their control in lakes and reservoirs; Lund (1938) recorded the periodicity of algae in the Bean Chief ponds, Sheffield; Gojdicks (1939) made observation on Euglena sanguinea; Burr (1941) investigated the photosynthesis of algae and other aquatic plants; Hameed (1942) worked on the Indian water moulds. Gonzalves and Joshi (1946) worked on the seasonal accession of the algae in tank at Bandra, Bombay; Patrick (1948) observed the factors affecting the distribution of diatoms; Rao (1953) investigated the distribution of algae in a group of small six ponds. Gandhi (1955) worked on the fresh water diatoms of Pratabgarh, Rajasthan; Philipose

(1959) worked on the fresh water phytoplankton of Inland fisheries; Singh (1960) who recorded the phytoplankton ecology of the inland waters of Uttar Pradesh; Subramanyan and Sahay (1964) who made observations on nitrogen fixation by some blue-green algae and remarked on its potentialities in rice culture; Talling and Talling (1965) recorded the chemical composition of an African lake water; Zafar (1967) worked on the ecology of algae in certain fish ponds of Hyderabad.

The presentations of factors interfering algal blooms by Verma and Shukla (1968) was a break-through in the study of lentic waterbodies for the ecological characteristics. This encouraged Vyas (1968) for phytoplanktonic study of Pichola lake. Later, Seenayya (1972) studied ecological aspects of certain Indian lakes at Hyderabad and its surrounding areas with special reference to its plankton composition. Further, Adoni (1975) made detailed investigation on Sagar lake microbes and the factors influencing their existence.

Further, Santisi and Salvatar (1979) while investigating on the ecology of three lentic waterbodies of Montesirino (Basilicata, Italy) discussed the phytoplankton distribution. Contemporary works include those of Adam-czak *et al.*, (1979) on the primary production of lake Tynwald (Poland); Grygierek *et al.*, (1979) on the influence of ammonia on bacteria, phytoplankton and zooplankton in the lakes of Ponds. A detailed study on the physico-chemical and microbiological parameters of Central Amazon lakes was conducted by Rai *et al.*, (1980) who classified these lakes into oligotrophic and eutrophic waterbodies characterised by the bacterial density, electrical conductivity, dissolved oxygen, pH, iron, silica and phosphate content. Simultaneously, Koschel and Rainer (1980) while working on lake Meckelenburger See concluded that a high phosphate content limited the plankton composition. Charlton (1980) found hypolimnion

oxygen consumption in Laurentian and Erie lakes of Canada and further stated that oxygen depletion is related to chlorophyll thickness and temperature. Various exhaustive studies on phytoplankton include those of Yamamoto *et al.*, (1980) in the lake of Ono dammed in Japan who collected 129 species of phytoplankton except diatoms and studied their distribution pattern; Imhoff *et al.*, (1980) carried out studies on the physico-chemical and biological parameters of eutrophic desert lakes of Egypt and indicated that sulphate, carbonate, chloride, sodium and other trace elements like magnesium, calcium and potassium play a pivotal role in algal and bacterial distribution.

Later, Parra *et al.*, (1981) working on some lentic water-bodies of Concepcion in Chile noted the seasonal succession of phytoplankton; Studies on limnology of Perched lake, south-west Tasmania by King and Tyler (1981) showed that the oxygen of the hypolimnion declines late in the stratification period which results in low productivity.

The other contemporaries involved in limnological studies include Schulz and Liselotte (1981) who conducted studies on nutrient input by bathers in Klagenfurt lake and Woerthersee pond; Lindpear and Aini (1981) working on the bottom sediments of Estonian lake observed the major components like silica, aluminium, iron and calcium; Takahashi and Eiji (1981) made observations on the algal distribution in lake Saroma Hokkaido of Japan and noted high diatomic population in the sea ice lagoon as well as in lake water.

Beaver (1981) working on lakes of Florida, observed that the productivity pattern is greatly influenced by water temperature. At home the Indian researchers too did not lag behind. Zutshi and Khan (1982) studied the limnological aspects of Dal lake while Divakaran *et al.*, (1982) working on Ashtamudi lake observed the zooplankton

composition. Rao et al., (1982) investigated the phytoplankton production of Nainital lake.

Conway (1982) investigated the vertical distribution of lentic forms in lake Michigan. Lake Baikal was extensively investigated with respect to its ecology by Sakharov (1982). Karydis et al., (1982) investigating Saronicos, Gulf and Greece lakes observed the vertical distribution of nutrients and phytoplankton distribution in relation to water stability. Smith and Val (1982) observed the algal biomass yield in relation to nitrogen and phosphorus concentration in lake Montreal. Goeltenboth (1982) conducted studies on the physico-chemical and biological parameters including macrophytes and heavy metal tracers in Lake Rawa Pening of Central Jawa. Leach (1982) investigated the physico-chemical parameters of St. Clair lake, Canada. Similar observations were made by Heathcote et al., (1982) on Lake Erie, Canada.

Other noteworthy publications on lentic water bodies include those of Kaul and Siddarth (1983) on Lalpari Talab at Rajkot, India; Chandra Prakash (1983) on water quality of Keetham lake and Pant and Sharma (1983) worked on the primary producers of lake Nainital.

Shapiro et al., (1983) observed a sharp decline in silica in the treatment plant of lake Michigan, U.S.A.; Maes (1983) analysed the water quality of an aerated polluted low land brook by Evan's technique and observed the distribution pattern of diatoms and their production. Campos et al., (1983) investigated the physico-chemical and biological parameters on Villarrica lake, Chile and observed phytoplankton like diatoms and species of Chlorella. Schroeder et al., (1983) recorded biogenetic calcium carbonate production in the Oligotrophic lake Attersee, Salzkam-mergut, Austria.

In continuity with the work of the above researchers, others such as Hindak et al., (1983) recorded the phytoplankton distribution in gravelpit lake near Kosice, Czechoslovakia. The other significant studies include those of Gorham et al., (1983) who observed the chemical composition of North Central lakes of U.S.A.; Forsyth et al., (1983) worked on the limnological aspects of Rotangaio lake of New Zealand; Koschel et al., (1983) pointed out that calcite precipitation decreases the phytoplankton population, dissolved oxygen and total phosphate in lake Breiber, Lucin, Germany.

Inspired by researchers abroad the noteworthy investigations in India include those of Dakshini and Gupta (1984) on the ecological characteristics of three lakes in Union territory of Delhi. Roy and Verma (1984) worked on the limnological studies of Motipur lake while Singh and Rai (1984) investigated the ecology of Jabalpur lake (Madhya Pradesh).

Puttaiah and Somashekar (1985) conducted extensive investigations on the limnology of Mysore city lakes. Kaul and Nirmala Saraf (1985) recorded the weed composition of Dal lake and Kanungo et al., (1985) worked on the chemical characteristics of lake Nainital.

Researchers such as Sharma et al., (1986); Chitranshi and Bilgrami (1986); Sarwar and Zutshi (1987); Singh and Mahajani (1987); Sinha Minakumari et al., (1987) have investigated the lentic water ecosystems and reported the importance of physico-chemical characteristics of water in relation to phytoplankton distribution. Mainly, they have considered pH, temperature, potassium, sodium, dissolved oxygen and phosphate as the chief physico-chemical characteristics that play a vital role by either increasing or decreasing certain phytoplanktonic groups in different waterbodies. Further,

Akhmetova (1986) pointed out that seasonal changes do not affect the composition of diatoms, rather diatomic population is determined by temperature. Several other investigations in the field of limnology include those of Basterrechea and Manuel (1986) on limnological characteristics of lake Amatitlan, Guatemala; Lyubezhov et al., (1986) recorded the phytoplankton of Kopet Dag storage lake, USSR., Kumagi et al., (1986) noted vertical circulation and formation of anoxic layer in southern basin of lake Biwa, Japan.

Later, Sarwar and Zutshi (1987) investigated Himalayan lakes for the physico-chemical and biological characteristics and reported that diatoms dominate the total bulk of plankton, although the lakes studied slightly differ with regard to the water quality parameters. Singh (1987) and Tripathi et al., (1987) have made similar observations. Sinha Minakumari et al., (1987) have also recorded the distribution of phytoplankton in North Indian lakes. Further, Puttaiah and Somashekar (1987) reported that higher carbon dioxide and lower oxygen concentration contribute significantly for the abundance of euglenoids in the lakes of Mysore city. Singh (1987) working on Ox-bow lake has investigated the phytoplankton primary production and concluded that high temperature coupled with higher concentration of phosphate enhance the higher rate of production of Microcystis aeruginosa, a cyanophycean alga. Berbert et al., (1987) recorded the residual BHC in the rivers and lakes of Cacao regions of Southern Bahia (Brazil) and noted that the aeration of the whole lake of Central Florida eliminated thermal stratification and increased the dissolved oxygen concentration significantly while turbidity, pH, alkalinity, total nitrogen, hydrogen sulphide and iron concentration decreased correspondingly with no effect on the phytoplankton analysed. Other noteworthy

publications during the same period include those of Schelske et al., (1987) who investigated the limnological aspects such as biogenic silica and silica bio-geo chemistry in lake St. Moritz and lake Zurich, Switzerland; June and Fred (1987) made observation on physico-chemical and biological characteristics of lake Sharpe, South Dakota (USA); Jensen et al., (1987) who recorded the pattern of sulphate reduction and Pelagic oxygen uptake in coastal lake during summer stratification.

The next year witnessed researchers like Zutshi and Khan (1988); Anand (1988); Bhattacharya et al., (1988); Saifullah et al., (1988) who have worked extensively on the chemical composition of lentic waterbodies and concluded that the physical and chemical characteristics of water significantly affect the algal population and they stressed the importance of pH, total alkalinity and carbon dioxide concentration of water on the succession of phytoplankton leading to eutrophication. Hurghisu and Ileana (1988) recorded the dynamics of nitrogen, phosphorus concentration, organic and mineral matter in the lakes of Puiu-Rosu and Motita lake, Nimenton, Finland. Croome and Tyler (1988) recorded the appearance of phytoplankton and the associated factors in the polyhumic lake of Tasmania.

The year 1989, in the history of limnology, commenced with commendable work on Indian lakes by Ahluwalia et al., (1989); Srivasthava et al., (1989); Unni and Naugoriya (1989); Ghosh and George (1989); Parimala Varadaraj and Ayyappan (1989) who have investigated the polluted waterbodies and inferred that chloride, sulphate and organic carbon play a vital role in the formation of blooms. They have also concluded that the phosphate concentration in water has a direct bearing on the development of water blooms. Other noteworthy works on the ecology and taxonomy of lentic waterbodies include those

of Madhusudan et al., (1989) on the lake of Mayeni, Goa; Mansoor Ali and Tiwari (1989) on Hussain sagar lake; Sharma and Rai (1989) on the biomass production of Dal lake, Panda et al., (1989) on Chilka lake and Tripathi and Pandey (1989) on Chandari Pond.

Further investigations include those of Krishna Rao (1990) on periphyton production in Peninsular lakes; Saha (1990) on Hazaribagh lake; Bhunya and Mohanty (1990) on the hydrobiological status of NandanKannan lake; Singh (1990) on the correlation between certain physico-chemical parameters and primary production of phytoplankton at Jamalpur lake, Munger, India and characterisation of 151 small lakes in eastern Finland based on their water chemistry, land use on catchment and phytoplankton communities by Ilmavirta et al., (1990).

Further research in the limnological field includes contributions by Sarwar and Wazir (1991) on the physico-chemical characteristics of fresh water ponds near Srinagar. They opined that alkaline water with calcium, bicarbonate, phosphorus and nitrates in higher concentration trigger the water blooms in waterbodies and together tend to increase the eutrophic nature. Swarnalatha and Narasingarao (1991) observed that cyanophycean blooms which are common in highly polluted waterbodies are indicators of water pollution as they deteriorate the water quality.

Rautray et al., (1991) have worked on the lakes of Berhampur for their physico-chemical characteristics. Usha Kumari et al., (1991) investigating on Basman and Motihari lakes, Bihar could not establish any clearcut correlation between temperature and plankton distribution. Surendra Kumar and Sharma (1991) working on Picchola lake revealed that electrical conductance, pH, total alkalinity and nitrates at higher concentration increase the productivity status of the lake and these parameters could act as

indicators in establishing the trophic level of waterbodies. Molot and Dillon (1991) investigating on the lakes of Central Ontario recorded the nitrogen and phosphorus ratios and chlorophyll production.

Other limnological investigations include those of Nygaard (1991) on the seasonal periodicity of planktonic desmids in oligotrophic lake, Grane Langso, Denmark; Vaquer and EL Hafa (1991) on the primary production of phytoplankton in an oligo mesotrophic lake; Tugrul and Morkoc (1991) on the determination of limnological characteristics of Sapanca lake.

The succeeding contributions to the field of fresh water ecology include those of Vaishya and Adoni (1992) on Sagar lake who inferred the lake as hyper eutrophic based on the physico-chemical properties. Chatterjee (1992) investigating on the lake Nandankannan recorded that temperature with slightly alkaline pH, conductivity, chloride, calcium and magnesium do not seem to vary much indicating the insignificant influence of organic and inorganic matter from outside to the lake. Swarnalatha and Narsingarao (1992) working on Hyderabad lakes discussed the occurrence of cyanophycean bloom and recorded a permanent bloom of Microcystis aeruginosa and indicated that bright sunlight associated with high temperature are the factors responsible for the development of the bloom. Adikary and Sahu (1992) revealed the occurrence of Trichodesmium bloom in Chilka lake during summer and concluded that the temperature above 20°C together with an alkaline pH are responsible for the bloom.

Other contributions to the limnological studies include those of Belsare et al., (1992) on numerical and volumetric variation in plankton population of a polymictic tropical lake, Bhopal; Rask. et al., (1992) on the lakes of Evo forest area; Van Den Brink

et al., (1992) on the impact of hydrology on the chemistry and phytoplankton development in flood plain lakes along the Lower Rhine and Meuse; Eckartz Nolden (1992) on the phytoplankton of lake Laachersee: Species composition and seasonal periodicity.

Recent investigation by Nayak (1993) on Mathyal lake indicated the physico-chemical characteristics and associated biological components and he has opined that the temperature and carbon dioxide are negatively correlated with each other while there is an inverse relationship between water transparency and bicarbonate content. Morgan and Pickup (1993) concluded that the greater range of microbial enzyme activity increased the trophic status of the water in the English lake, Cumbria (U.K.). Parvateesam and Mishra (1993) working on man made lake located near temple town, Pushkar, recorded 88 algal forms belonging to Chlorophyceae, Euglenaceae and Bacillariophyceae. Swarnalatha and Narsingarao (1993) investigated Banjara lake near Hyderabad and concluded that Microcystis aeruginosa occur as a continuous bloom in summer and attributed factors such as pH, total solids and total hardness as the factors responsible for the appearance of such a bloom. Bodre et al., (1993) worked on the physico-chemical and biological characteristics of lake Lonar of Maharashtra and categorised it as eutrophic based on the biological composition.

The year 1994 in the history of limnology saw an extensive research in limnological field. Contributions include those of: Begum and Hadi (1994) on the comparative abundance of phytoplankton, periphyton, epipelagic algae and some related physico-chemical parameters in two shrimp culture ponds; Perrow et al., (1994) on the trophic interactions in a shallow lake following a reduction in nutrient loading: A long term study; Alvarez et al., (1994) on the time course of phytoplankton biomass and related

limnological factors in shallow and deep lakes; Tryfon et al., on the phytoplankton, physical and chemical features of the shallow lake Mikri Prespa, Macedonia, Greece.

Olila et al., (1995) recorded the distribution of inorganic phosphorus in sediments of two shallow lakes of Florida; Druvietis (1995) worked on the phytoplankton periodicity in different trophic state lakes in Latvia; Larson et al., (1995) observed the limnology of isolated and connected high mountain lakes in Olympic National Park, Washington State, USA and Agbeti and Smol (1995) worked on the physical, chemical and biological characteristics of two temperate lakes during ice cover.

The year 1996 commenced with extensive research on fresh waterbodies both in India and abroad. Frenette et al., (1996) worked on the size dependent changes in phytoplankton carbon and nitrogen uptake in the dynamic mixed layer of Lake Biwa; Khan (1996) recorded the phytoplankton periodicities of two warm climate lakes subjected to marked seasonal variability; Holopainen (1996) recorded the trophic state of lake Ladoga and observed the summer phytoplankton and Sarkka (1996) recorded the meiofauna ratios in the profundal depths of large lakes.

Recent investigation includes research conducted by Swarnalatha and Narasingarao (1997) on the ecological studies of two lentic waterbodies with reference to cyanobacteria.

STUDY AREA

Shantisagar lake ranked the second biggest lake in South India is situated in Channagiri Taluk of Davangere District in Karnataka State. It is about 33km. from Davangere city and 256km. from Bangalore and about 50 kms away from the Kuvempu University where the work was carried out. The lake was previously known as Sulekere and lies 20km. north of Channagiri Town. It was constructed in the 11-12th century A.D. across two valleys Hirehalla and Soppinhalla.

A historical panorama indicates that the lake had derived its former name "Sulekere" which literary means "Whore's lake" on the lady who designed it. One story goes that some of the whores in the Maharaja's Kingdom were given respectable positions and one lady among them designed the lake. Hence the name. Another story is that Princess Shantamma, the daughter of King Vikramaraya later turned into a whore. She was the one who designed it. Hence the name Sulekere was given. Another story according to the localites is that the region received huge amount of rain - fall during monsoon but experienced severe scarcity of water during summer. One lady called Shantamma devised an idea of constructing a bund across the two valleys Hirehalla and Soppinahalla to hold water. No doubt huge quantity of water was held but simultaneously with the onset of monsoon the surrounding villages were submerged and there was a heavy loss of life and property. Hence, the outraged people called the lady "Sule" and hence the name.

Later, the name was changed into Shantisagar in fond memory of the lady who designed it. It is learnt that the Government of Karnataka has changed "Shantisagar" to its former name "Sulekere".

There is a temple here dedicated to Lord Siddeshwara on a small hillock which has a garbhagriha, a shukanasi, a navaranga, a front porch and it is enclosed by a prakara. The temple has preserved the Hoysala and Keladi traditions of architecture. The Durga temple which is to the south-west of the main temple has a garbhagriha and a porch of rude pillars of Dravidian style while the doorway is in Hoysala style. The image is in rough relieve of Kapalika form. The temple commands an enchanting view of Shantisagar lake and its surrounding areas.

Shantisagar lake prior to 1971 was under the Department of Public Works but subsequently it was handed over to the Department of Irrigation. The lake has an irregular shaped bund in north-east direction constructed between two hillocks. Further details of the lake are furnished below:

1. Total water spread area	64kms.
2. Total depth when full	8.25m.
3. Total catchment area	896.92 Sq. kms.
4. Intercepted catchment area	330.72 Sq. kms.
5. Independent catchment area	566.19 Sq. kms.
6. Total area benefitted	1380 ha.
7. Average rainfall	25 inch per annum
8. Lake capacity	2611 mcft.
9. Bund length	60.96 m.
10. Bund breadth	30.48 m-49.37 m.
11. Submerged area	2651 ha.
12. Irrigated area	2976 ha.

13. Total villages benefitted 28 No's

The villages surrounding the lake include

- | | |
|---------------|-------------------|
| 1. Sulekere | 8. Kagatur |
| 2. Kerebilchi | 9. Hatti |
| 3. Somlapura | 10. Itige |
| 4. Chikkoda | 11. Arasinagatta |
| 5. Jatli | 12. Basavarajpura |
| 6. Hiredou | 13. Sevanagar |
| 7. Nimbapura | |

The lake has six canals. They are

- | | |
|-------------------|---------------------|
| a) Siddana nala | d) Belalgere nala |
| b) Basavana nala | e) Kattalagere nala |
| c) Tyavanagi nala | f) Kariganur nala |

During summer, about 500 - 600 acres of land surrounding the lake will be encroached for cultivation of crops like paddy, cotton and vegetables. Sparse macrophytic vegetation includes trees like Pongamia glabra, Canthium Parviflora, Capparis pinosa, Dodonia viscosa, Brynia racemosa, Azadirachta indica, Ficus bengalensis and Samania saman which are seen around the lake. Along the bund 8-10 Acacia aphylla trees are seen. Fish farming is practiced in an area adjacent to the bund.

Stations selected for the investigation:

Four stations were selected for the present investigation to get the overall ecological status of the lake. The stations selected are as follows:

Station I: It is situated adjacent to a village called Kerebilchi. The villagers however, do not utilise the lake water for drinking purpose, but to cultivate crops like maize, paddy etc. The station is disturbed mostly during day time either by cattle or people washing clothes.

The macrophytic vegetation consists of Pongamia glabra, Canthium parviflora, Capparis spinosa, Dodonia viscosa, Cassia floribanda and Ipomea fistulosa. (Photo I).

Station II: This station is situated about a kilometer away from station I and is located along the bund. One can have a spectacular view of the lake from this spot. Few years back tourists had enjoyed a boating ride which has now been stopped. Just a few yards away is a temple dedicated to Lord Siddeshwara which is situated atop a hillock. From here one can enjoy a panoramic view of the lake. The reason for selecting this station is that the water color is quite different here as compared to the other stations. This could be attributed to the fact that due to wind action the planktonic forms get carried away towards the bund side and impart color to the water.

The macrophytic vegetation comprise of Acacia aphylla, Ficus bengalensis and Samania samana. (Photo II).

Station III: This station is located about 1.5 Km. away from station II at a village called Arasinaghatta. It is easily accessible to all vehicles and is thus used for their washing and

cleaning. Hence the water remains turbid most of the day due to continuous human interference. Acacia aphylla trees are abundantly grown on the bank of the lake at this spot. (Photo III).

Station IV: This station is located at a village called Basavarajpura. Several crops like cotton, maize etc. are cultivated on the bank of the lake. During rainy season the runoff from the agricultural fields tend to bring in high amount of fertilizers, chemicals and organic matter. (Photo IV).

The macrophytic vegetation consists of Acacia aphylla, Azadirachta indica, Stachitarpita indica, Vitis ve-nifera, Euphorbia thirucalli, Dodonia viscosa, Cassia floribanda and Pongamia pinnata.



Station I



Station II



Station III



Station IV



Photograph exhibiting the surrounding hillocks of the lake



Photograph displaying the fishing activity in the lake



Photograph showing human settlement and crop cultivation near the lake



An overview of the lake



A panoramic view of the lake



A view of the lake from atop the hillock

CHAPTER II

MATERIALS AND METHODS

Four different spots each a kilometer apart were selected for collecting water samples for chemical analysis. The samples collected at an interval of 30 days were brought to the laboratory in 3 litre capacity black carbuoys. Certain factors like air temperature, water temperature and pH were recorded on the spot. Dissolved oxygen was fixed at the spot using Winkler's reagent. The samples were kept in air cooled chambers after being brought to the laboratory for estimating other chemical parameters. The final result was calculated after obtaining three concurrent readings.

The factors estimated were :

1. Color
2. Temperature
3. pH
4. Electrical conductivity
5. Turbidity
6. Free carbon dioxide
7. Dissolved oxygen
8. Carbonates
9. Bicarbonates
10. Total hardness
11. Calcium
12. Magnesium
13. Chloride
14. Sulphate

15. Dissolved organic matter
16. Total solids
17. Ammonia nitrogen
18. Total kjeldahl nitrogen
19. Organic nitrogen
20. Phosphates
21. Nitrates
22. Nitrites
23. Silica
24. Iron
25. Potassium
26. Sodium
27. Biochemical oxygen demand
28. Chemical oxygen demand.

The methods employed for the estimation of the above chemical factors are as follows:

Temperature :- The temperature of water at each spot was recorded at a depth of 10 to 12 cms with the help of a mercury thermometer.

Electrical conductivity :- Conductivity readings were taken in the laboratory using conductivity meter (systronics make).

Turbidity :- Readings were obtained by using Nephelometric turbidity meter.

pH :- pH was recorded at the place of collection using universal pH paper and was later confirmed in the laboratory using Global digital pH meter (DPH 500).

Free Carbon dioxide :- Free carbon dioxide was estimated by titrimetric method, APHA 1976, pp. 298-300.

Dissolved oxygen :- To estimate dissolved oxygen Winkler's modified method (Chemical analysis for fresh waters, 1971 :128) was employed.

Carbonates :- It was determined by method discussed by Wilcox and Hatcher, 1950, Para 16.

Bicarbonates :- (Op. cit.)

Total hardness :- EDTA titrimetric method, ISI.

Calcium :- EDTA titrimetric method, ISI.

Magnesium :- (Op. cit.)

Chlorides :- Argentometric method, APHA, 1976, pp.303-304.

Sulphates :- Volumetric method, ISI.

Dissolved organic matter :- Standard methods, 1965, pp. 244-245.

Total solids :- Standard methods, APHA, 1976, pp. 91-92.

Ammonia nitrogen:- Volumetric method, R. Pitchai and V.S.Govindan, "Determination of Water quality parameters," Anna University, Madras, 1989, pp. 68-69.

Total kjeldahl nitrogen :- (Op. cit.) pp. 73-75.

Organic nitrogen :- (Op. cit.) p. 76.

Phosphates :- Stannous chloride method, Standard methods; 1965, pp. 234-236.

Nitrates :- Estimated by Phenol disulphonic acid method, APHA, 1976, pp. 485-487.

Nitrites :- Standard methods, 1965, pp. 205-208.

Silica :- Colorimetric molybdosilicate method, APHA, 1976, pp. 485-487.

Iron :- Phenanthroline method, APHA, 1976, pp. 208-212.

Potassium :- Flame photometer method, APHA, 1976, pp. 234-235.

Sodium :- Flame photometer method, APHA, 1976, pp. 234-235.

Biochemical oxygen demand :- Direct method; Standard methods for the estimation of water and waste water analysis, 1976, 14th edition, APHA, AWWA and WPCF, Washington DC.

Chemical oxygen demand :- APHA, 1976, pp. 550-554.

For colorimetric estimations, spectrophotometer (Systronics) was employed with respective calibrations.

Estimation of Phytoplankton :-

Plankton forms were collected by using a plankton net made of bolting silk cloth of meshes of 10mm fixing a conical flask of 100 ml at a narrow end. For taking the samples for qualitative analysis, the net was towed for 5 minutes just below the surface of water (Green and Holden, 1960). Tows were restricted to a small area around each sampling point. The samples were immediately transferred to other bottles and preserved by adding 4% formalin as per the practice of Welch (1958). The qualitative estimation was carried out by taking one ml of sample from the stock samples at each time and repeated 5 times. Uniform distribution was made by agitating the sample thoroughly. Identification of planktonic organisms was conducted with the help of monographs and phytoplankton are identified upto species level. Camera lucida drawings were made to identify the phytoplankton. Since no new organism was identified the plates of camera lucida drawings have been deleted in the thesis.

CHAPTER III

PHYSICO-CHEMICAL CHARACTERISTICS

Temperature: (Figs. 1 and 2)

(Temperature of the surface waters often has a direct bearing on chemical concentration. It plays a vital role in either increasing or decreasing a particular chemical factor or a set of factors. Diurnal and seasonal variation of temperature are very much evidenced in fresh water environment than in marine environment. Hence, fluctuations in temperature of the aquatic medium regulate the biological composition of that ecosystem.)

Air temperature during the period of study is found to be minimum in the month of January 1996 at station I and it was recorded to be 26°C while it reached its maximum of 39.8° C at stations III and IV during the month of May 1996. If the yearly averages are taken into account, the temperature is found to be high during the first year of study. Further, if the seasonal variations are considered, summer experienced high temperature reaching up to 39.8° C [Tables. 6, 6.1 and 6.2]. On the contrary, the ranges for water temperature vary from a minimum of 22° C at station II to a maximum of 38° C at station I.

It is very interesting to note that always the water temperature remained lower than air temperature at all stations in all the seasons. Munawar (1970); Ambasht (1971); Petre (1975) and Shardendu *et al.*, (1988) are of the opinion that water and air temperature vary to a great extent. A similar observation has also been made by Chandan Bohra (1990); Parvateesam *et al.*, (1991) and Borkar *et al.*, (1992). Based on the data generated by them, they have concluded that air and water temperature show much variation when the waterbody under study is relatively small. When this contention is

applied to the present study it is observed that air and water temperature vary with each other by about 5 °C (Tables. 2, 3, 4 and 5).

Hence, our observations are in conformity with the above researchers. Nevertheless, Hodgetts (1922) has never seen such a range of variation between air and water temperature in respect of waterbodies that he has investigated.

The statistical synopsis (correlation matrix -1) has revealed that air temperature is in no way correlated with pH, carbonates, bicarbonates and iron. However, its positive and negative correlation with other parameters is represented in correlation matrix I.

On a general consideration, the data recorded reveals that the dissolved oxygen and temperature are inversely related. Such a relationship between these aforesaid parameters has been recorded by Dakshini and Gupta (1984) ; Hegde (1985) and Ouellet *et al.*, (1989).

A similar behaviour with respect to water temperature with other parameters has been observed and recorded in correlation matrix I. However, water temperature did not show any kind of relationship with pH, free carbon dioxide, magnesium, carbonates, bicarbonates, nitrates and iron.

P^H : (Fig. 3)

One inherent property of water is to be either acidic, alkaline or neutral. Based on the affinity of the organisms towards a particular range of pH they are either classified as acidophilic or alkaliphilic. Furthermore, pH is an important parameter which determines the suitability of water for various purposes.

Ambasht (1971), Petre (1975), Rai and Hill (1982), Shardendu and Ambasht (1988), Swarnalatha and Narasingarao (1993), Gibson et al. (1995) and Sinha (1995) have recorded alkaline pH in their studies on surface waterbodies. On the contrary, Chatterjee (1992) working on Nandankannan lake of Bhubhaneshwar recorded a pH range between 5.0 and 6.0 and concluded that leaching of soil and decomposition of plankton are responsible for acidity in water.

In the present study the pH ranged from 7.0 to 7.5 at all stations. Nevertheless, when the monthly values are considered it is observed that the pH reached a value of 7.5 at station I during Feb 1995, at station II during Sep 1995, at station III during Sep 1995 and 1996 and at station IV during Sep 1995 and 1996. Furthermore, in many of the collections the pH remained exactly neutral at all the stations. However, when the average values for two years are taken into account it crosses the neutral range denoting that the waterbody under study is slightly alkaline [Tables 2, 3, 4 and 5]. Hence, our observations are in accordance with Ambasht (1971), Peter (1975), Rai and Hill (1982), Shardendu and Ambasht (1988), Swarnalatha and Narasingarao (1993) and Sinha (1995).

Many investigators [Zafar (1964), Sankaran Unni(1985), Zutshi and Khan (1988), Shardendu and Ambasht (1988), Swarnalatha and Narasingarao (1993) and Sinha (1995)] have pointed out that pH and carbonates go hand in hand while it is inversely proportional to bicarbonates and calcium. In the present investigation, it is noted that pH and bicarbonates go hand in hand while no relation could be established with any other parameter which is also supported from the statistical analysis (correlation matrix I). Hence, our observations are not in agreement with the above mentioned researchers.

Turbidity:(Fig. 4)

(The turbidity of water is due to the presence of suspended matter that interferes with the passage of light through the water. Clay, mud, silica, calcium carbonate, algae and bacteria are common substances found suspended in water. Therefore, turbidity of water plays an important role in determining the type of biotic communities in the water.)

(Turbidity is found to be maximum at station I during June 1995 and it was recorded to be 40.21 NTU and the same was found to possess a minimum of 13.14 NTU at station II during November 1995.) The yearly averages indicate the maximum turbidity at station III during the second year of study. The seasonal average shows high turbidity in the rainy season at station II. However, when monthly collections are taken into consideration the turbidity is comparatively high during summer and decreases drastically during winter at all the stations [Tables 6, 6.1 and 6.2]

(Zutshi and Khan (1988) working on Dal Lake have recorded maximum turbidity during rainy season compared to summer. But the present observations reveal that the turbidity was highest during rainy season when seasonal average is taken into account while the monthly collections point out that turbidity was maximum during summer. Hence, the foregoing observations are in partial agreement with the aforesaid researchers.

Satyakala et al., (1986) and (Vaishya and Adoni (1992) opined that turbidity has a positive correlation with electrical conductivity, free carbon dioxide, free ammonia, organic nitrogen and sodium and has negative correlation with total solids, total Kjeldahl nitrogen, air temperature and chemical oxygen demand. However, it is quite interesting to note that the present investigation deviates from the observations of the aforesaid researchers i.e. turbidity has a significant positive correlation with air

temperature, water temperature, biochemical oxygen demand, chemical oxygen demand, bicarbonates, sulphates, chlorides, nitrates, phosphate and silica and a negative correlation with dissolved oxygen, calcium, magnesium, sodium, potassium, dissolved organic matter, nitrates, ammonia nitrogen, total Kjeldahl nitrogen, iron, total hardness and total solids. (correlation matrix I).

Turbidity in water is of paramount importance since it interferes with the easy passage of light. In other words, it hinders with the photosynthetic process thus decreasing the productivity. /

Color:

Normally the color of an undisturbed waterbody would be clear and colorless. However, the water gains color as a consequence of human interference, formation of water blooms or due to some specific mineral constituents. In the present study, however, the color of water remained clear and colorless for the major part of the year except in rainy season when it turned muddy due to leaching of soil from the adjoining areas. Occasionally, as a result of wind action the planktonic forms get transferred towards the bund side of the lake imparting golden brown color owing to the presence of diatomic population.

The foregoing observations reveal that the color of the water remained colorless except during rainy season.

Electrical Conductivity: (Fig. 5)

The electrical conductance is of paramount importance in evaluating the quality of water. The conductivity of a solution is the measure of its ability to carry an electrical current and it varies with the number and type of ions present in the solution. Sreenivasan (1969) while investigating on Ooty lake recorded the electrical conductivity which ranged between 145-475 μmhos and in the other lake, the Pykara lake, the recorded value was found to be relatively less and ranged between 14-45 μmhos .

The present study has revealed that the values of electrical conductance fluctuated between a minimum of 43 μmhos during April 1996 and a maximum of 397 μmhos during November 1996. The values observed in the present study are, by and large, similar to the observation made in Ooty lake by Sreenivasan (1969). Seasonally, the electrical conductivity value rised appreciably during winter at all the four stations and the value was recorded to be low during summer (Tables 6, 6.1 and 6.2). This observation. is contrary to the observation made by Shardendu and Ambasht (1988) who have recorded high conductance value during rainy season and low during other seasons. Further, they have also pointed out that the lakes situated in the vicinity of urban settlements receiving domestic wastes contain high electrical conductivity than the lakes of rural areas. Nevertheless, Shantisagar lake situated in a rural sector shows a high conductance value due to the inflow of agricultural run-off.

Unni(1985); Patil et al., (1986); Chatterjee (1992); Gibson et al., (1995) have also made similar observations.

The positive and negative correlation of electrical conductance with other parameters is presented in correlation matrix I.

Total solids: (Fig. 6)

The natural waters never occur in pure form but always have a variable quantity of dissolved salts. The commonly occurring natural salts are comprised mostly of nitrogen.

Verma and Shukla (1968) while investigating on Devikunda lake of Uttar Pradesh, recorded a range of total solids that varied from 180 mg/l to 512 mg/l. A similar observation has been made by Shastry *et al.*, (1970) in a lake of Bhopal city (188-588 mg/l). However, Dakshini and Gupta (1984) and Swarnalatha and Narasingarao (1993) have reported a high concentration of total solids in Peacock lake of Delhi and Banjara lake of Hyderabad respectively that reached upto 1500 mg/l.

The values recorded during the present investigation are more or less similar to the observations made by Verma and Shukla (1968) and Shastry *et al.*, (1970) which ranged between 486 mg/l at station I and 857 mg/l at station III.

Sreenivasan (1969) and Dakshini and Gupta (1984) have opined that lakes receiving sewage possess high value of total solids. In the present study since there is no discharge of sewage or any effluent, the value of total solids remained, by and large, moderate.

Seasonwise, it has been found that the concentration of total solids was always more during winter at all stations (Tables 6.9, 7 and 7.1). Zafar *et al.*, (1964); Sreenivasan (1969); Shastry *et al.*, (1970) and Swarnalatha and Narasingarao (1993) have opined that total solids and pH are inversely related while Singh and Singh (1990) and Tripathy and Adhikary (1990) have noted a direct relationship between them.

However, in the present investigation no such correlation could be established as total solids behaved rather independently (correlation matrix I).

Dissolved oxygen: (Fig. 7)

The concentration of dissolved oxygen in a natural water body regulates the distribution of the aquatic flora and fauna. It also alters the chemical characteristics of a particular aquatic body. The dissolved oxygen test is generally conducted to assess the quality of water for drinking purpose. As per the WHO and ISI standards drinking water should contain dissolved oxygen not less than 5 mg/l. A large number of researchers have pointed out that polluted water generally contains lower amount of dissolved oxygen (Bowling and Tyler (1988); Ghosh and George (1989); Chatterjee (1992); Swarnalatha and Narasingarao (1993)).

In the present study, the concentration of dissolved oxygen ranged from a minimum of 5.02 mg/l at station I during March 1997 to a maximum of 8.01 mg/l at station III during September 1996. Hence, if dissolved oxygen concentration as a parameter is taken alone for quality criteria the water of Shantisagar is potable. With regard to the seasonal variation, at stations I and II, the dissolved oxygen was found to be more during winter while at the remaining stations it was found to be more during rainy season (Tables 6, 6.1 and 6.2). Nevertheless, at all the stations the concentration of dissolved oxygen was low during summer. The variation in the concentration of dissolved oxygen during rainy and winter months is attributed to various interferences caused by human activities like fishing and washing coupled with agricultural runoff.

Reddy *et al.*, (1982); Ghosh and George (1989); Swarnalatha and Narasingarao (1993) and Venkateswarlu (1993) have concluded that the dissolved oxygen concentration rises appreciably during monsoon and reduces during summer. Hence, our observations are in partial agreement with that of the above researchers.

Swarnalatha and Narasingarao (1993) have pointed out that dissolved oxygen and free carbon dioxide exhibit an inverse relationship with each other. However, in the present investigation, no such relationship could be established between the two since both of them behave rather independent of each other. On the contrary, dissolved oxygen showed a negative correlation with temperature, pH, biochemical oxygen demand, chemical oxygen demand, sulphate and chloride (correlation matrix I). Such observations have also been made by Dakshini and Gupta (1984); Hegde *et al.*, (1985) and Ouellet *et al.*, (1989).

In general, the concentration of dissolved oxygen is on par with ISI standard. Seasonally, the behaviour of dissolved oxygen is rather irregular except in summer. Dissolved oxygen and free carbon dioxide behave independently.

Free carbondioxide: (Fig. 8)

The importance of free carbondioxide for autotrophic plants is very well known. It is the basic raw material for the photosynthetic process. The two important sources of carbondioxide in aquatic medium are:(a) The physiological process of photosynthesis. (b) Diffusion from atmosphere. This gas on reacting with water forms carbonic acid which further dissociates into carbonates and bicarbonates and alters the pH of water. Hence the estimation of free carbondioxide in the aquatic medium is of great importance.

Adhikary and Jayanthi Sahu (1988) have pointed out that there is always a close relationship between free carbondioxide and pH and recorded the absence of free carbondioxide whenever pH was alkaline.

In the present investigation the concentration of carbondioxide varies from a minimum of 23.4 mg/l at station II to a maximum of 61.96 mg/l at station IV and further, it was found to be absent during certain months of collection. In accordance with the observations made by Adhikary and Jayanthi Sahu (1988) the absence of free carbondioxide was noted whenever pH was either neutral or alkaline.

Kratz et al., (1987) have observed acidic pH in Wisconsin lake due to increased concentration of free carbondioxide as a consequence of stray acid input. Lerman et al., (1989) have observed high alkalinity in certain fresh water lakes and attributed it to carbonate mineral dissolution or input of chemical bases. In the present investigation, pH remained either neutral or alkaline even in the absence of carbondioxide or without the addition of chemical bases.

Seasonwise, free carbondioxide was found to be more during winter at stations I and II and during rainy season at stations III and IV (Tables 6, 6.1 and 6.2). Shardendu and Ambasht (1988) have observed high carbondioxide concentration during monsoon and summer seasons in a pond located in Banaras University campus. Therefore, our observations are in partial agreement with that of the above researchers. Hegde et al., (1985) have reported an inverse relationship between oxygen and carbondioxide. Such a relationship has not been observed in the present observation.

The interrelationship of free carbondioxide with other parameters is appended in correlation matrix I.

Carbonates: (Fig. 9)

The occurrence of carbonates in a waterbody is of immense relevance so much so that most of the physico-chemical parameters have a direct bearing with it. In fact, it is the prime contributor for maintaining pH of a waterbody and hence its role is of vital importance.

The present study reveals that the carbonate concentration was high at station III with a value of 4.1 mg/l during March 1997 and was found to be absent during the other months. A similar situation was recorded at all the other stations too.

A look into the seasonal average indicates that carbonates were absent during rainy season at stations I, II, and III and at station IV their absence was recorded both in rainy and winter season. However, the concentration of carbonates was maximum in summer at all the four stations (Tables 6.3, 6.4 and 6.5).

Verma and Shukla (1968); Kaul *et al.* (1980); Rekha Purohit and Singh (1981) and Hegde *et al.* (1985) have observed that carbonate concentration is low compared to bicarbonates. The present study too conforms with their observation.

Further, Verma and Shukha (1968) recorded the presence of carbonate only during the absence of carbondioxide. However, no such observation has been made in the present study. Rekha purohit and Singh (1981) have observed the absence of carbonate during winter. Prasad (1990) while studying the Upper lake of Bhopal has recorded a high carbonate concentration during winter and summer months and its absence during rainy season. The present investigation too conforms with their observations. The absence of carbonate during rainy season could be attributed to the

fact that rain water increases the carbondioxide concentration of water thereby reducing the carbonate concentration.

The statistical analysis points out that carbonate has no significant correlation with any parameters and is negatively correlated with free carbondioxide and nitrates. However, it behaves independently with respect to other parameters (correlation matrix I).

In general, it can be concluded that the behaviour of carbonate in the present study is rather irregular.

Bicarbonates: (Fig. 10)

Bicarbonates varied between 1.6 mg/l to 12 mg/l during the entire period of investigation. Seasonally, bicarbonates were high during summer at all stations. Nevertheless, stations II, III and IV recorded low concentration of bicarbonates in rainy season while at station I it was found to be low in winter (Tables 6.6, 6.7 and 6.8). When the average values are taken into account, the behavior of bicarbonates was not uniform.

Bicarbonates were found to be present in all the months during the entire period of study.

Verma and Shukla (1968) have also recorded the presence of bicarbonates throughout the period of their investigation and pointed out that the concentration of bicarbonate increases during rainy season compared to winter and summer seasons. The present study reveals that the concentration of bicarbonates increases during summer and decreases towards rainy season which is in direct contrast with the observations of the above researchers. The reason for this could be due to varied geological and weather

conditions. Moreover, Rekha Purohit and Singh (1981) while investigating on Nainital lake have observed maximum bicarbonate concentration during dry season and attributed the same reason. A similar observation has also been made by Zafar (1964); Seenayya (1971) and Narendra Babu *et al.* (1993).

It is rather very interesting to note that the bicarbonates did not have any negative correlation with the other parameters studied. On the other hand, a positive relationship has been observed with pH, turbidity, chlorides and silica (correlation matrix I). A similar such observation has been made by Dakshini and Gupta (1984) and Swarnalatha and Narasingarao (1993). Furthermore, Swarnalatha and Narasingarao (1993) have stated that the factor bicarbonate behaved independently with the other parameters, apart from the parameters mentioned above. This inference also coincides with the present investigation.

Calcium: (Fig. 11)

Calcium is one of the important cations that greatly influences the distribution of phytoplankton in an aquatic environment. Phytoplankton need calcium for growth and other physiological activities. Therefore, inadequate amount of calcium in water may interfere with their normal physiological activities. Thus, it plays a vital role in the biological productivity also.

Dakshini and Gupta (1984) are of the opinion that the concentration of calcium increases during monsoon. While investigating on Peacock lake of Delhi, they were able to record a range of calcium concentration which fluctuated between 12-32 mg/l. In the

present investigation, a relatively high concentration of calcium has been noted which ranged between 20.4 mg/l and 49.78 mg/l.

Contrary to the present observations, Ouellet *et al.*, (1989) have recorded as low as 10 mg/l of calcium. On the other hand, Zutshi and Khan (1988) have recorded as high as 87.6 mg/l of calcium in Dal lake and concluded that the concentration increases during monsoon season. In the above context, when the results obtained in the present study are compared with the data generated by the above researchers, the calcium concentration was found to be intermediate. When the seasonal variations are taken into account, stations III and IV registered a high concentration during monsoon and low during summer while the other stations showed a high concentration during winter (Tables 6.3, 6.4 and 6.5).

In general the seasonal behavior of calcium is quite irregular.

The statistical correlation of calcium with other parameters is appended in correlation matrix I.

Magnesium: (Fig. 12)

Magnesium is a component of chlorophyll and is necessary for its proper development. It is rather very interesting to note that magnesium stands next to calcium in its concentration and ranges between 18.4 mg/l at stations I and II and 39.6 mg/l at station IV. Unlike calcium, seasonwise, it was found to be more during rainy season and low during summer except at station IV (Tables 6.3, 6.4 and 6.5).

Dakshini and Gupta (1984); Zutshi and Khan (1988) and Shardendu and Ambasht (1991) have also recorded magnesium concentration lesser than calcium. Therefore, the

present observations are in total agreement with the above researchers. Seasonwise observations also coincide with their findings.

Shastry *et al.*, (1970) have observed a negative correlation between calcium and magnesium while the present study indicates a positive correlation (Correlation matrix I).

Sulphates: (Fig. 13)

The major sources of sulphate in natural waters are rocks, fertilizers and waste discharges from industries. The amount of sulphate in waters is a factor of concern in determining the magnitude of problems that can arise from reduction of it into hydrogen sulphides. In the present investigation, the sulphate ranged from 65 mg/l to 162 mg/l. Seasonwise, sulphates were recorded in high concentration during summer and low during winter at all the stations thus correlating negatively with the quantum of water (Tables 6.6, 6.7 and 6.8). This is in conformity with the findings of Lavendier and Decamps (1984).

Satyakala *et al.*, (1986) while investigating on Banjara lake, Hyderabad, have also reported higher concentration of sulphates during summer. Hickel (1973) and Zutshi and Khan (1988) have opined that polluted waters are always rich in sulphates. If this is taken into account, the lake under study, has recorded a maximum concentration of 162 mg/l of sulphate which is well within the tolerance limit prescribed by ISI standards (Table 1). Hence, it can be concluded that the lake under study is oligotrophic. The statistical correlation of sulphates in relation to other parameters is presented in correlation matrix I.

Chloride: (Fig. 14)

It is one of the most important parameters in assessing the water quality. Munawar (1970) is of the opinion that higher concentration of chlorides indicate higher degree of organic pollution. His opinion has been supported by Deshmukh *et al.*, (1964); Ramakrishna Rao (1990) and Shardendu and Amabasht (1991). In the present study, the concentration of chloride varied between a minimum of 14.85 mg/l at station I during February 1996 to a maximum of 89.14 mg/l at station IV during May 1995 with an average of 38.61 mg/l. Seasonally, chloride was found to be high in summer at all the stations reaching upto a maximum of 89.14 mg/l and there was a corresponding decrease in its concentration during winter (Tables 6.6, 6.7 and 6.8). A similar such behaviour of chlorides has been observed by Zafar (1964). Verma and Shukla (1968); Shastry *et al.*, (1970), Patil *et al.*, (1989); Ouellet *et al.*, (1989) Swarnalatha and Narasingarao (1993) and Sinha (1995) have attributed to the evaporation of water due to extreme heat during summer. Also, due to anthropogenic activities like washing of domestic animals, washing of clothes, churning of water the chloride concentration builds up during summer. The statistical correlation of chlorides with other parameters is presented in correlation matrix I.

Dissolved organic matter: (Fig. 15)

The three basic sources of dissolved organic matter in a fresh waterbody are:

- 1) Decomposition of dead organisms,
- 2) Extra cellular substances liberated into water by the living organisms.

3) Decomposed organic matter of the catchment area brought in partly with surface runoff and partly by wind.

Welch (1952) is of the opinion that dissolved organic matter does not show any variation in its concentration qualitatively or quantitatively either with respect to seasons or depth. Fogg (1960) stated that the concentration of dissolved organic matter rises appreciably as a consequence of liberation of extracellular products or substances from biotic communities during growth phase. On the other hand, Clarke (1965) has observed higher concentration of dissolved organic matter during summer and states that the regeneration of organic matter is always associated with high temperature. When all the above observations are taken into account the present study shows a high concentration of dissolved organic matter during winter indicating that the present investigations are not in agreement with that of above researchers. Hegde (1980) and Narendra Babu *et al.*, (1993) reported that discharge of water through any outlet dilutes the dissolved organic matter concentration which is quite true in the present investigation too especially at station I where the excess of water is being discharged during rainy season.

If the range of values recorded during the period of study are taken into consideration, the concentration of dissolved organic matter fluctuated between a minimum of 0.29 mg/l at station I to a maximum of 3.89 mg/l at station IV thus within the ISI specifications.

Narendra Babu *et al.*, (1993) working on polluted ponds of Hyderabad city concluded that nitrates and dissolved organic matter are inversely related while Clarke (1964) and Hegde (1985) have pointed out that the dissolved organic matter is always

inversely proportional to carbondioxide (correlation matrix I). The present statistical analysis reveals that nitrates and dissolved organic matter are positively correlated whereas it doesn't show any relationship with free carbondioxide. Lalman and Dixit (1989) have also arrived at the same conclusion.

Chemical oxygen demand: (Fig. 16)

Chemical oxygen demand is a rapid test carried out for determination of total oxygen demand by organic material present in the samples. (In this test, organic matter is oxidized by making use of a strong chemical oxidizing agent. Chemical oxygen demand measures a large portion of the ultimate oxygen demand of the sample and remains greater than biochemical oxygen demand. In the present study also always the chemical oxygen demand values remained greater than bio-chemical oxygen demand (Tables 2, 3, 4 and 5) at all the stations during the entire period of investigation) and the range falls between 4.0 and 10.9 mg/l. (Seasonally, like biochemical oxygen demand, chemical oxygen demand values too were high during summer and low during winter)(Tables 6.3, 6.4 and 6.5).

Dakshini and Gupta (1984); Shardendu and Ambasht (1988) and Venkateshwaran et al., (1993) have also made similar observations.

Statistical analysis indicates that chemical oxygen demand is positively correlated with temperature, turbidity, biochemical oxygen demand and negatively correlated with dissolved oxygen (correlation matrix I)

Biochemical oxygen demand: (Fig. 17)

All oxidizable organic matter when degraded by aerobic microorganisms consume oxygen present in water. The respiratory demand for oxygen exerted by microorganisms while stabilising the organic matter under aerobic condition is called biochemical oxygen demand popularly abbreviated as BOD. Generally, biochemical oxygen demand test is conducted to assess the organic load in the given waterbody. Many researchers have recorded higher biochemical oxygen demand values in polluted water.

The ISI specifies that drinking water should be devoid of biochemical oxygen demand.

Shardendu and Ambasht (1988) have recorded BOD values that ranged between 4.8 and 33 mg/l in an urban pond which continuously receives domestic waste water. Further, they have recorded a low biochemical oxygen demand value from 1-3 mg/l in another pond which virtually does not receive any sewage indicating that the inflow of sewage contributes to a high biochemical oxygen demand load.

In the present investigation no sewage or domestic waste is discharged into the lake. Hence, the BOD concentration remained very low ranging between 1.2 - 2.9 mg/l indicating the fact that the lake is not eutrophic.

Dakshini and Gupta (1984) and Chatterjee (1992) have observed that BOD concentration increases during summer as a consequence of high temperature which triggers the microbial population. In the present investigation too, the BOD value rises appreciably during summer which is coupled with high temperature (Tables 6.3, 6.4 and 6.5)

The statistical correlation points out that biochemical oxygen demand has a significant positive correlation with temperature and a negative correlation with dissolved oxygen (correlation matrix I).

Nitrogen complexes:

Nitrogen in fresh water ecosystem exists either in the form of ammonia-nitrogen, nitrates and nitrites or organic nitrogen.

Ammonia nitrogen: (Fig. 18)

The concentration of ammonia-nitrogen varied between 0.52 mg/l at station I and 2.96 mg/l at station II. Seasonwise, it was found to be at its peak during winter and lowest during summer at all stations (Tables 6.9, 7 and 7.1).

Kaul et al., (1980) have reported the increasing trend of ammoniacal nitrogen during summer (Nilnag lake) while Shastry et al., (1970) pointed out that it increases during monsoon. Contrary to the above, the present investigation has revealed that ammoniacal nitrogen reaches its maximum concentration during the post monsoon months.

The statistical correlation of ammonia-nitrogen with the other parameters has been appended in the correlation matrix I.

Total kjeldahl nitrogen: (Fig. 19)

The concentration of total kjeldahl nitrogen varied from a minimum of 4.3 mg/l at stations I and II to a maximum of 9.6 mg/l at station IV.

Gibson *et al.*, (1995) have pointed out that total kjeldahl nitrogen increases in its concentration during monsoon as a consequence of inflow of runoff water. In the present study it was also found to be true save station I in which the maximum concentration of total kjeldahl nitrogen was recorded in winter season (Tables 6.9, 7 and 7.1). When the first year and second year average values are taken into account not much of variation has been observed (Tables 2, 3, 4 and 5).

If the relationship of total kjeldahl nitrogen with that of organic nitrogen is considered both behave rather independent of each other (correlation matrix I).

Organic nitrogen: (Fig. 20)

Organic nitrogen is an important parameter in determining the status of eutrophication of any waterbody. Sreenivasan (1969) concluded that the organic nitrogen in high concentration is responsible for eutrophication. Thomas (1966) reported that algal blooms are triggered by the higher concentration of organic nitrogen in the waterbody.

Anon (1968) is of the opinion that the persistence of water blooms for more than one year is due to the high organic matter load in the waterbody. In the present investigation, the lake is rated as oligotrophic with less concentration of organic nitrogen. Hence, formation of continuous water blooms was not recorded.

In general, the organic nitrogen values varied between a minimum of 0.52 mg/l at stations I and IV and a maximum of 0.99 mg/l at all the stations.

Seasonally, it was found to be at its maximum during rainy period at all the stations (Tables 6.6, 6.7 and 6.8). When the correlation of organic nitrogen with other parameters is taken into account it is observed that there is a positive correlation with magnesium while its relationship with ammonia-nitrogen, calcium and phosphate is rather independent and shows a negative correlation with nitrites (correlation matrix I). This observation is in partial agreement with Anon (1968) and Sreenivasan (1969).

Phosphates: (Fig. 21)

The importance of phosphates in waterbodies is well established. Phosphates along with other salts are the prime contributors for the degradation of water quality. The present scenario is such that due to the formation of algal blooms because of high phosphorous concentration which lead to eutrophication, several waterbodies have perished. Hence, the amount of phosphate which enter the waterbody through agricultural runoff and sewage has to be studied in order to assess the quality of water.

In the present study, phosphate was found to be in a maximum concentration which varied from 2.1 mg/l at station IV during May 1995 to a minimum of 0.61 mg/l at station II during November 1996. The seasonal averages indicate that the phosphate concentration was higher during summer at all the stations and least in winter (Tables 6.9, 7 and 7.1).

Verma and Shukla (1968) while investigating on temple tanks, Kaul *et al.*, (1980) working on Nilnag lake in Kashmir, Zutshi and Khan (1988) investigating on Dal lake have recorded high amount of phosphate during summer. Hence, the present observation is in conformity with the above said researchers.

Dakshini and Gupta (1984), Zutshi and Khan (1988); Swarnalatha and Narasinga rao (1993) have opined that phosphates and iron have an inverse relationship. However, the present study does not reveal any such relationship and that phosphate behaves rather independently with organic nitrogen and iron (correlation matrix. I).

Hence, it can be inferred that the phosphate concentration raises appreciably during summer and decreases drastically during winter. This could be attributed to the fact that due to evaporation during summer the concentration of phosphate builds up.

Nitrate: (Fig. 22)

The presence of nitrates in any aquatic ecosystem depends on the activity of nitrifying bacteria, the chemical content of catchment area and the adjoining agricultural land. The conversion of nitrates from ammonia by nitrobacter and nitrosomonas chiefly depends upon the presence of oxygen.

In the present investigation, the range of nitrate fluctuated from a minimum of 2.0 mg/l to a maximum of 4.1 mg/l at station III itself.

Verma and Shukla (1968); Kaul *et al.*, (1980); Shardendu and Ambasht (1991) are of the opinion that nitrates rise appreciably during rainy and winter season. In the present study also nitrate peaks were observed during rainy season (Tables 6.6, 6.7 and 6.8) as the rain water brings in more nitrates from the adjoining agricultural fields.

Whitton (1976) has also arrived at the same conclusion. The data obtained by Venkateswarlu (1969 A) and Manikya Reddy (1984) also confirms the above statement. Further, Verma and Shukla (1968); Kaul *et al.*, (1980) and Shardendu and Ambasht (1991) have opined that nitrates and dissolved organic matter are inversely related while the present study shows a positive relationship between them (correlation matrix I). Venkateswarlu (1969 a) and Manikya Reddy (1984) have also arrived at the same conclusion.

Nitrite: (Fig. 23)

Nitrite is an intermediate state of nitrogen in the bio-chemical oxidation of ammonia to nitrates. Surface waters unless badly polluted with sewage effluent seldom contain more than 0.1 mg/l of nitrite.

In the present investigation the concentration of nitrites fluctuated between a minimum of 0.001 mg/l and a maximum of 0.003 mg/l at all the stations. In general, nitrites and nitrates exhibit an inverse relationship with each other at all stations.

Singh *et al.*, (1969) reported dominance of nitrates over nitrites in aquatic ecosystem. This is also true in the present study.

The interrelationship of nitrites with other parameters is appended in correlation matrix I.

Iron: (Fig. 24)

Iron is known to be a limiting nutrient factor in a number of fresh water ecosystems and occurs in very low concentrations (Cole (1983); Chavez et al., (1991); Duce and Tindale (1991) and Price et al., (1991)).

In the present investigation, iron ranged between a minimum of 0.01 mg/l at station I and a maximum of 0.031 mg/l at station II. On the contrary, Zutshi and Khan (1988) have recorded a very high iron concentration in lakes which ranged between 16-200 mg/l. A similar observation has also been made by Rao et al., (1992) in certain lakes of Bangalore district wherein the concentration of iron reached upto a maximum of 25 mg/l which could be probably due to the discharge of iron containing waste water. However, Chatterjee (1992) has observed lower concentration of iron in Nandankannan lake in which it fluctuated between 0.16 - 0.29 mg/l. Therefore, our observations coincide with that of Hegde et al., (1985) and Chatterjee (1992).

Seasonally, iron was found to be at its maximum during winter (Tables 6.9, 7 and 7.1) at all the stations whereas the lowest value fluctuated for other seasons. A similar observation has been made by Hegde et al., (1985).

The statistical analysis reveals that iron is positively correlated with dissolved oxygen and total solids and negatively correlated with turbidity. However, it behaves independently with respect to other parameters (correlation matrix I).

Silica: (Fig. 25)

It has been considered as an important parameter regulating the diatomic population in fresh water ecosystems. The presence or absence of dissolved silicates

often determine the quality of diatomic population. Infact, the frustules of diatoms are siliceous. Beaty and Parker (1994) while working on Mountain lake, Virginia have recorded the concentration of silica which varied between 0.13 mg/l to 3.59 mg/l. Hurley *et al.*, (1985) have reported higher concentration of silica in certain oligotrophic lakes of Wisconsin and pointed out that the mixing of ground water with that of lake water is responsible for this. Hegde (1985) has reported a fairly higher concentration of silica reaching upto 10.5 mg/l in some lakes of Dharwad district, Karnataka and held the sandy nature of the bed responsible.

In the present investigation the silica concentration was found to be relatively low ranging from 0.04 mg/l to 0.19 mg/l which could be probably due to non-sandy nature of the lake bed or non-intrusion of ground water as postulated by others.

Munawar (1970) has opined that silica concentration increases towards summer which is true in the present investigation too. However, in all the stations it was found to be low during winter (Tables 6.9, 7 and 7.1).

The statistical correlation is appended in matrix I.

Sodium and Potassium: (Figs. 26 and 27)

Sodium and Potassium are the two cations needed as macro nutrients for the growth of aquatic organisms. Shardendu and Ambasht (1991) have recorded sodium in the range of 2.4 - 4.6 mg/l and concluded that the concentration increases towards winter. In the present investigation, the concentration of sodium fluctuated between 3 mg/l and 26 mg/l in station I itself and it was found to be at its peak during winter (Tables 6.3, 6.4 and 6.5). A similar observation has also been made by Sinha (1995) in respect of

some rural ponds of Bihar. The positive and negative correlation of sodium with other parameters is presented in correlation matrix I.

Unlike sodium the concentration of potassium was recorded to be very low in the present study ranging from 1.0 mg/l to 3.3 mg/l. Seasonwise, it was highest during winter and was fairly consistent at all the stations during the remaining seasons (Tables 6.3, 6.4 and 6.5).

Shardendu and Ambasht (1991) have observed as low as 1.8 mg/l of potassium in their studies and concluded that its concentration increases during winter. Hence, the present investigations are in essential agreement with the above researchers. Contrary to this, Dakshini and Gupta (1984) and Zutshi and Khan (1988) concluded that potassium behaves rather independently during different seasons which is contrary to our observations.

The interrelationship of potassium with other parameters is appended in correlation matrix I.

Total hardness: (Fig. 28)

Hardness is usually expressed in terms of equivalent quantity of calcium carbonate. Water quality association has provided a general scale of hardness demarcating the limits for soft and hard water (Lehr et al., (1980)).

Table: General scale of hardness provided by water quality association (Lehr et al., (1980)).

Hardness of water mg/l as calcium carbonate	Description
0-17	Soft
17-60	Slightly hard
60-120	Moderately hard
120-180	Hard
more than 180	Very hard

The values recorded for hardness in the present study clearly indicate that the water is moderately hard to very hard in nature with a range of 64 mg/l at station I to 290 mg/l at station IV. Deshmukh et al., (1964); Shastry et al., (1970); Patil and Unni (1976); Zutshi and Khan (1988) and Swarnalatha and Narasingarao (1993) have recorded the concentration of total hardness and concluded that it is subjected to variation. Sreenivasan (1969) and Patil et al., (1986) have pointed out that total hardness of water was found to be more during monsoon as a consequence of inflow of rainwater carrying high amount of salts. The same holds true in the present investigation also wherein monsoon recorded high hardness (Tables 6.9, 7 and 7.1). The inter-relationship of total hardness with other parameters is appended in correlation matrix I.

Fig. 1. Air Temperature

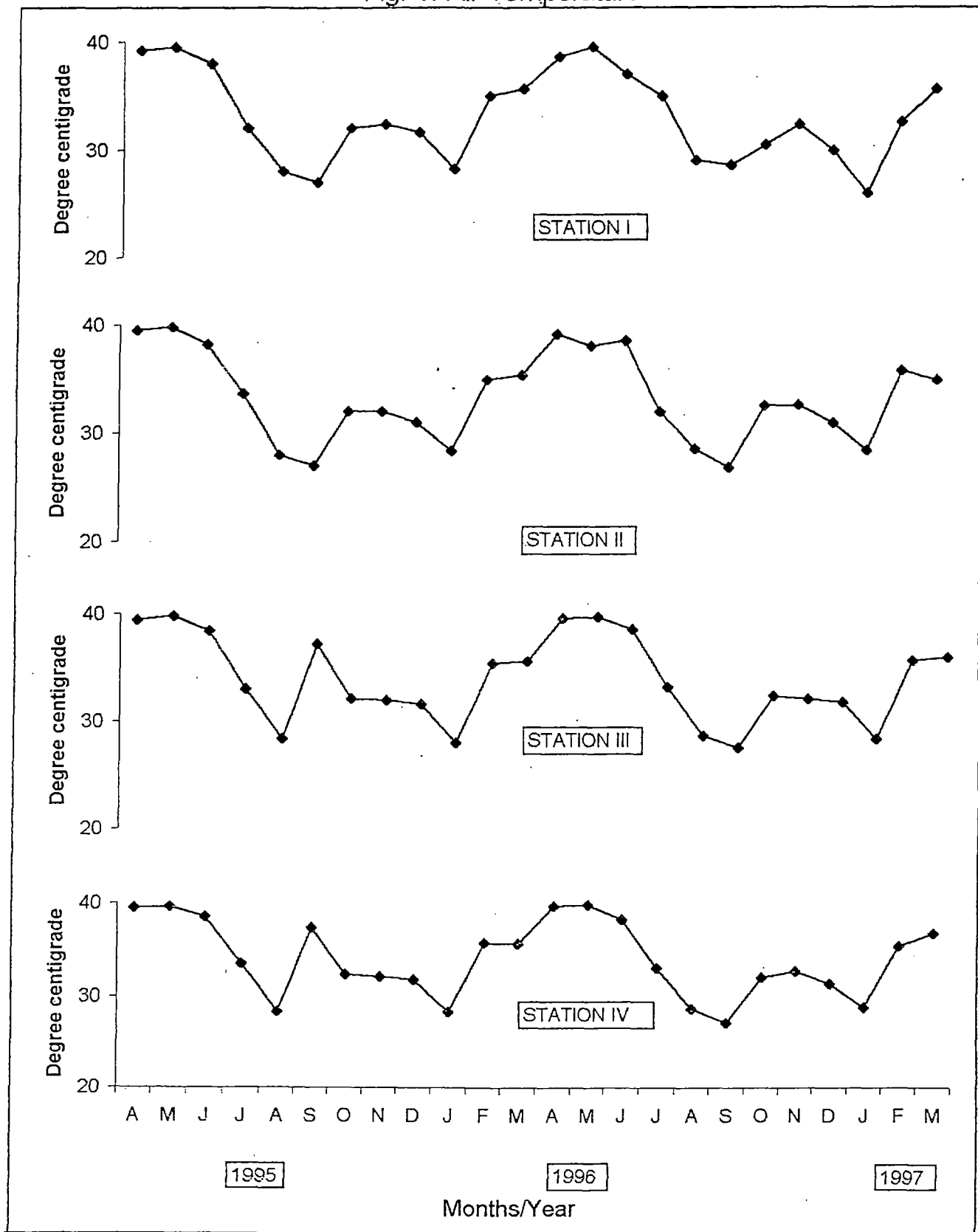


Fig. 2. Water Temperature

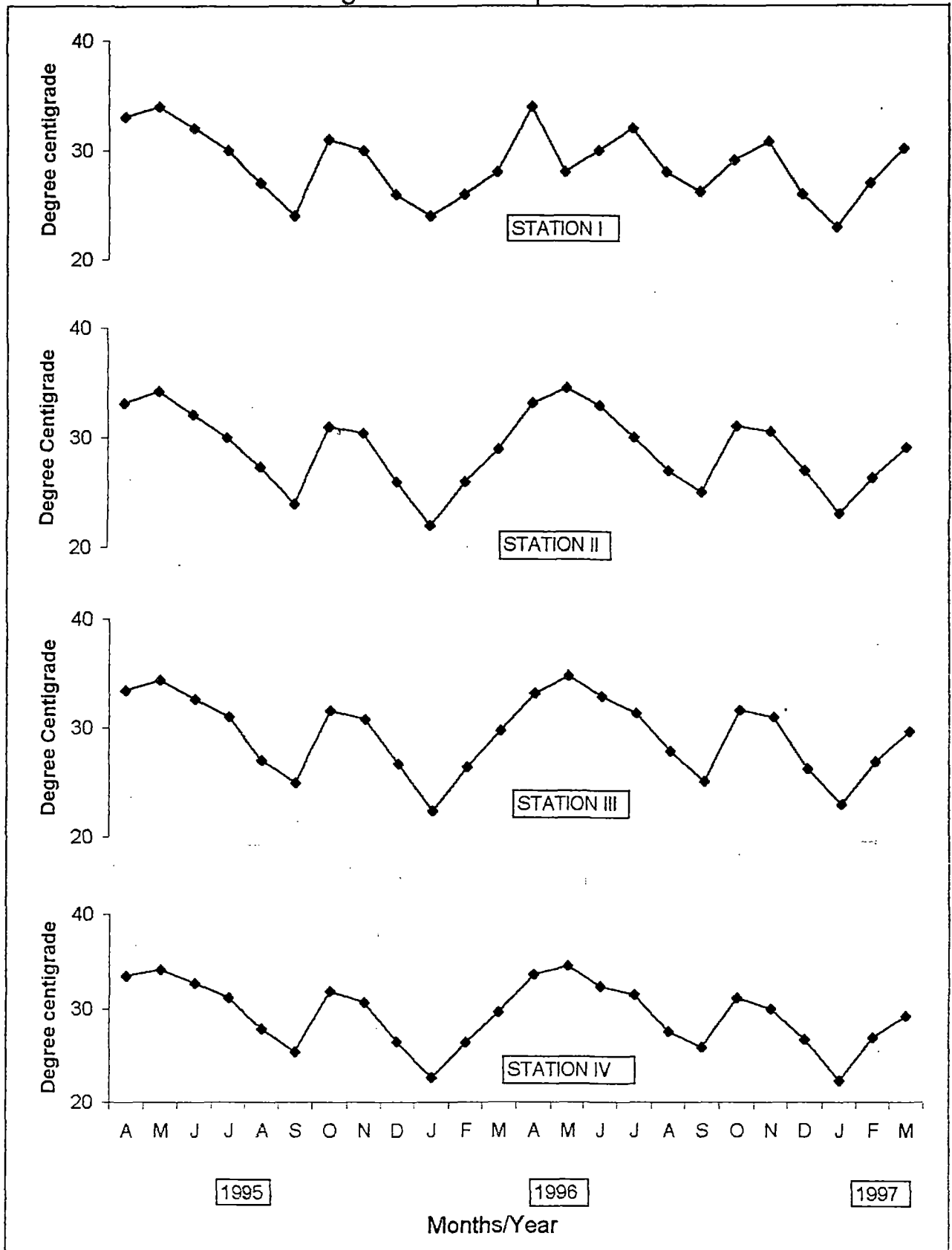


Fig. 3 pH

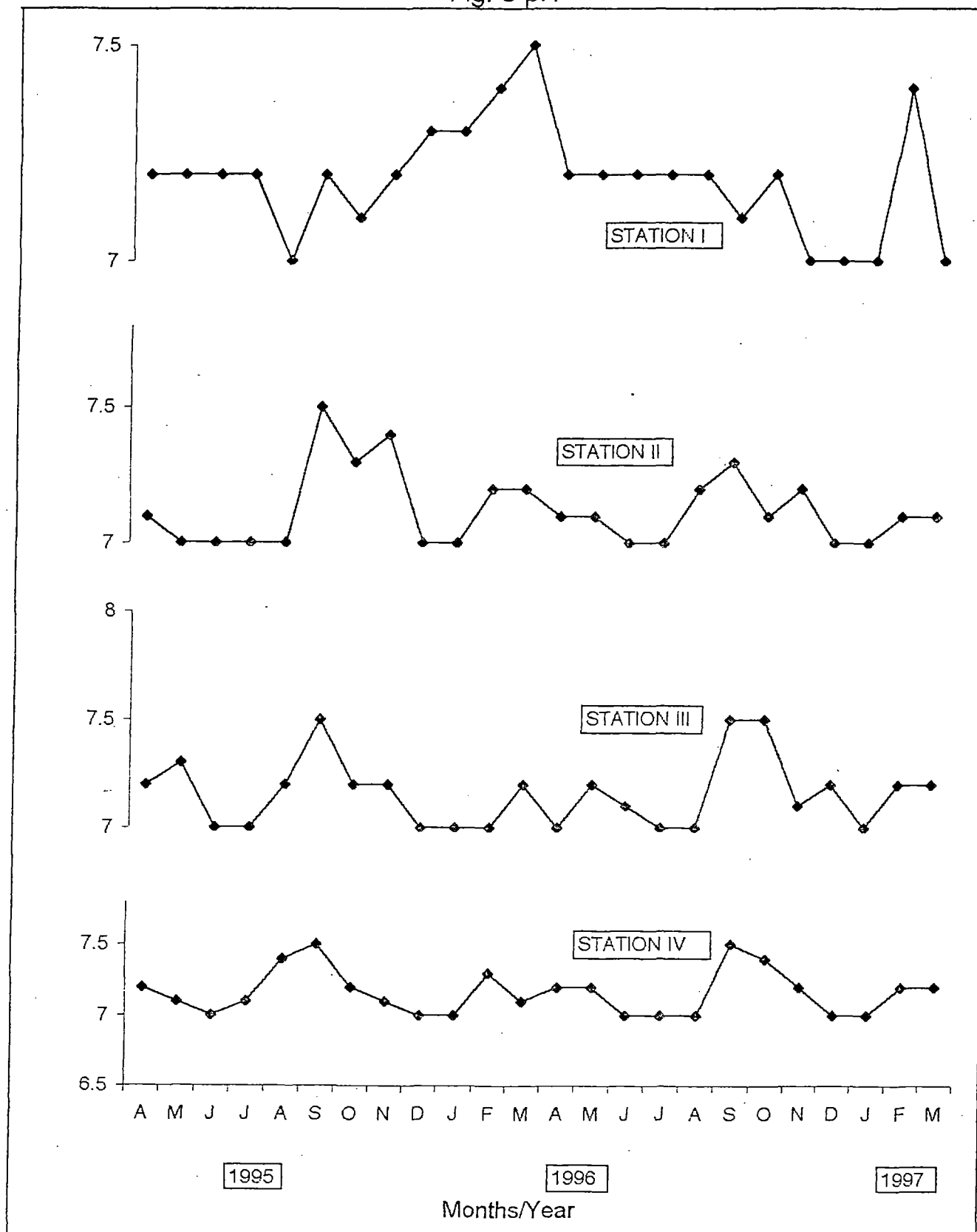


Fig. 4. Turbidity

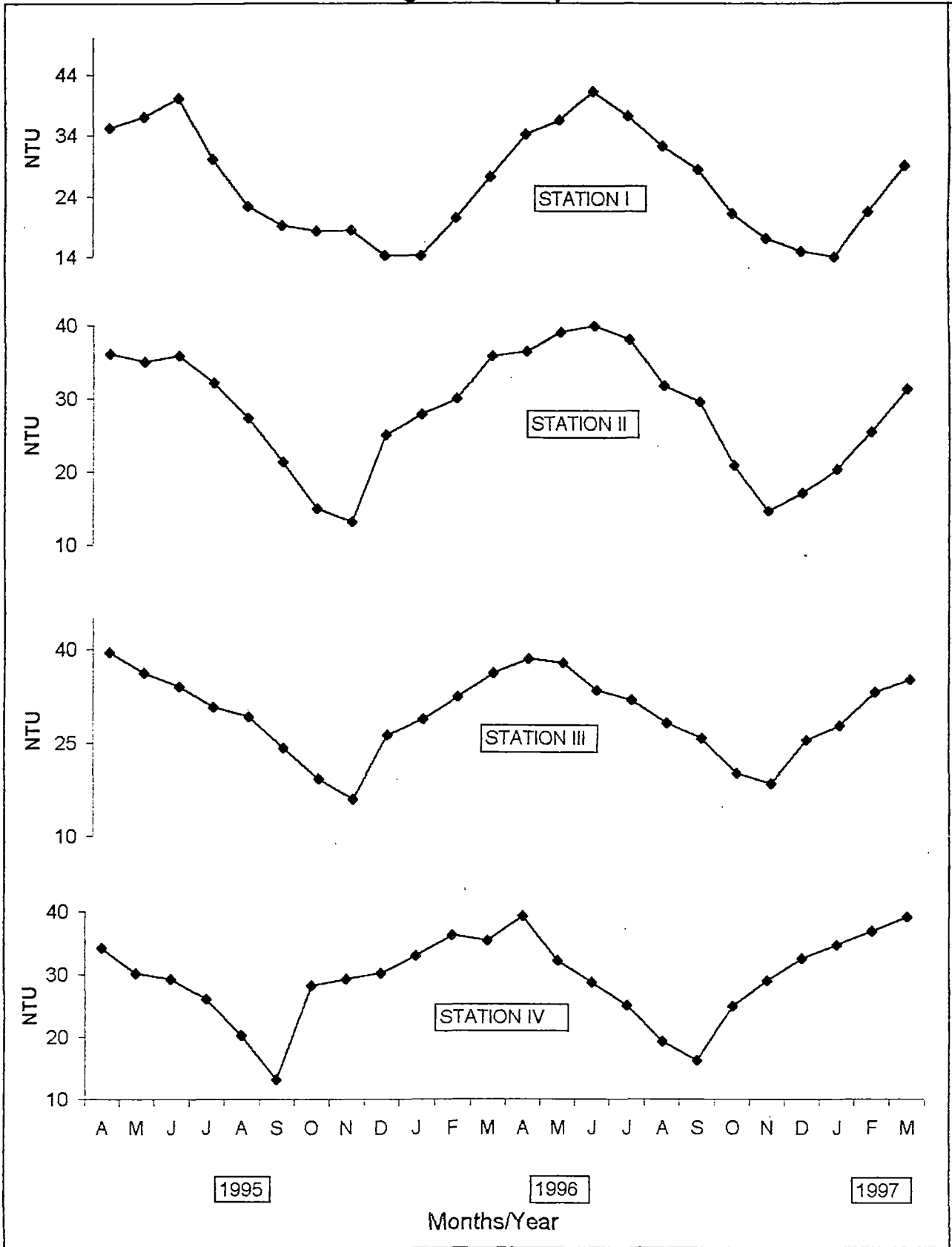


Fig. 5. Conductivity

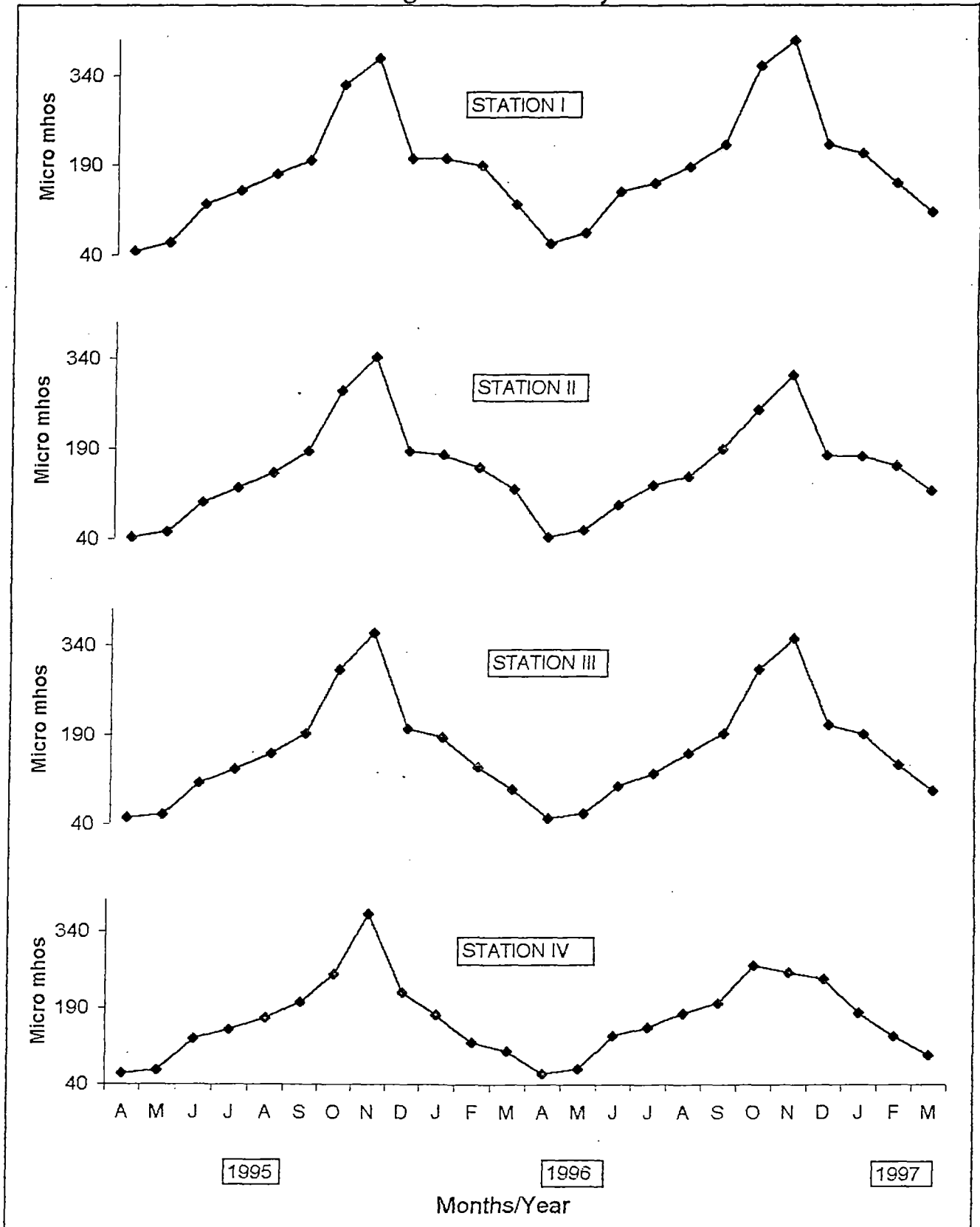


Fig. 6. Total solids

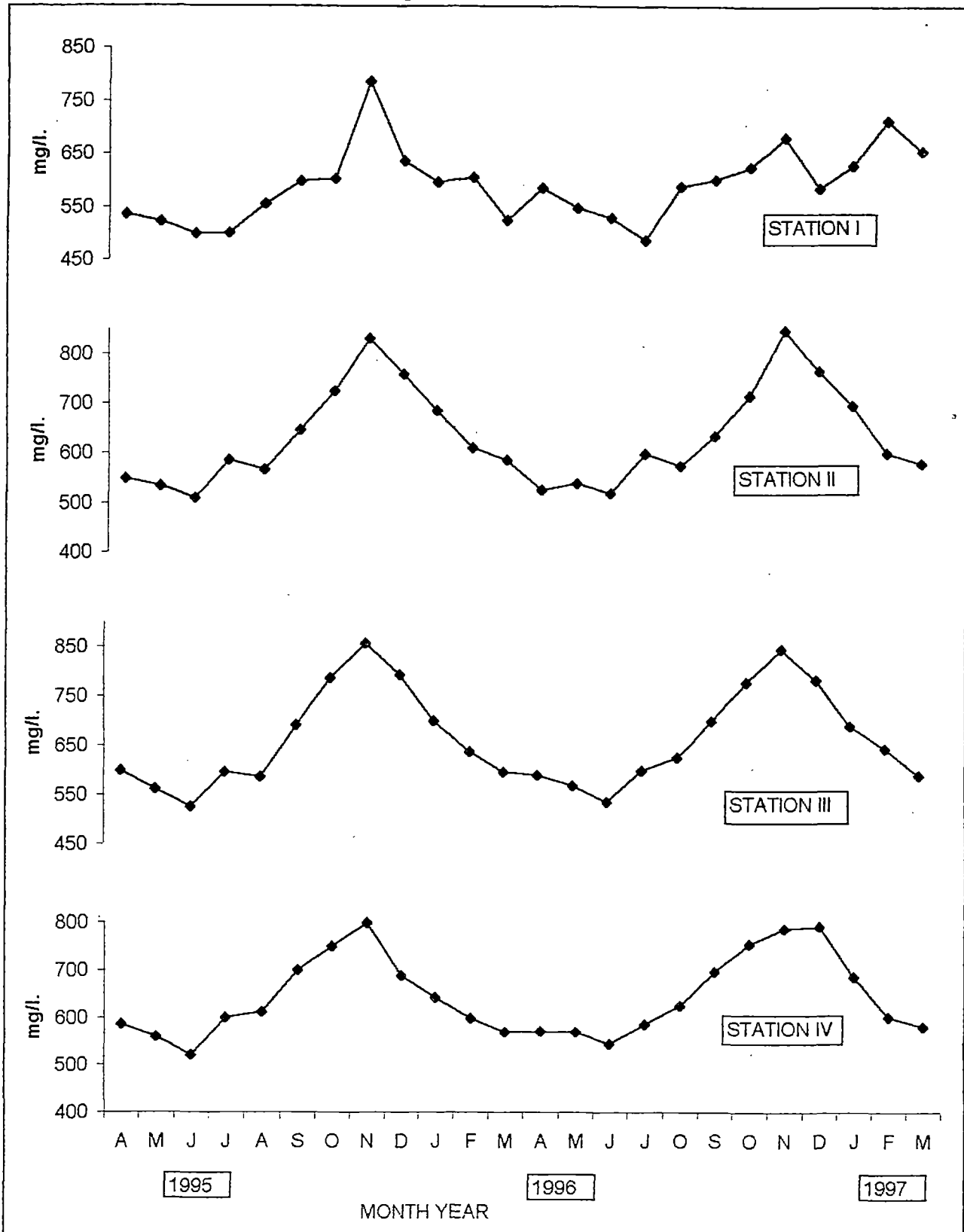


Fig. 7 Dissolved Oxygen

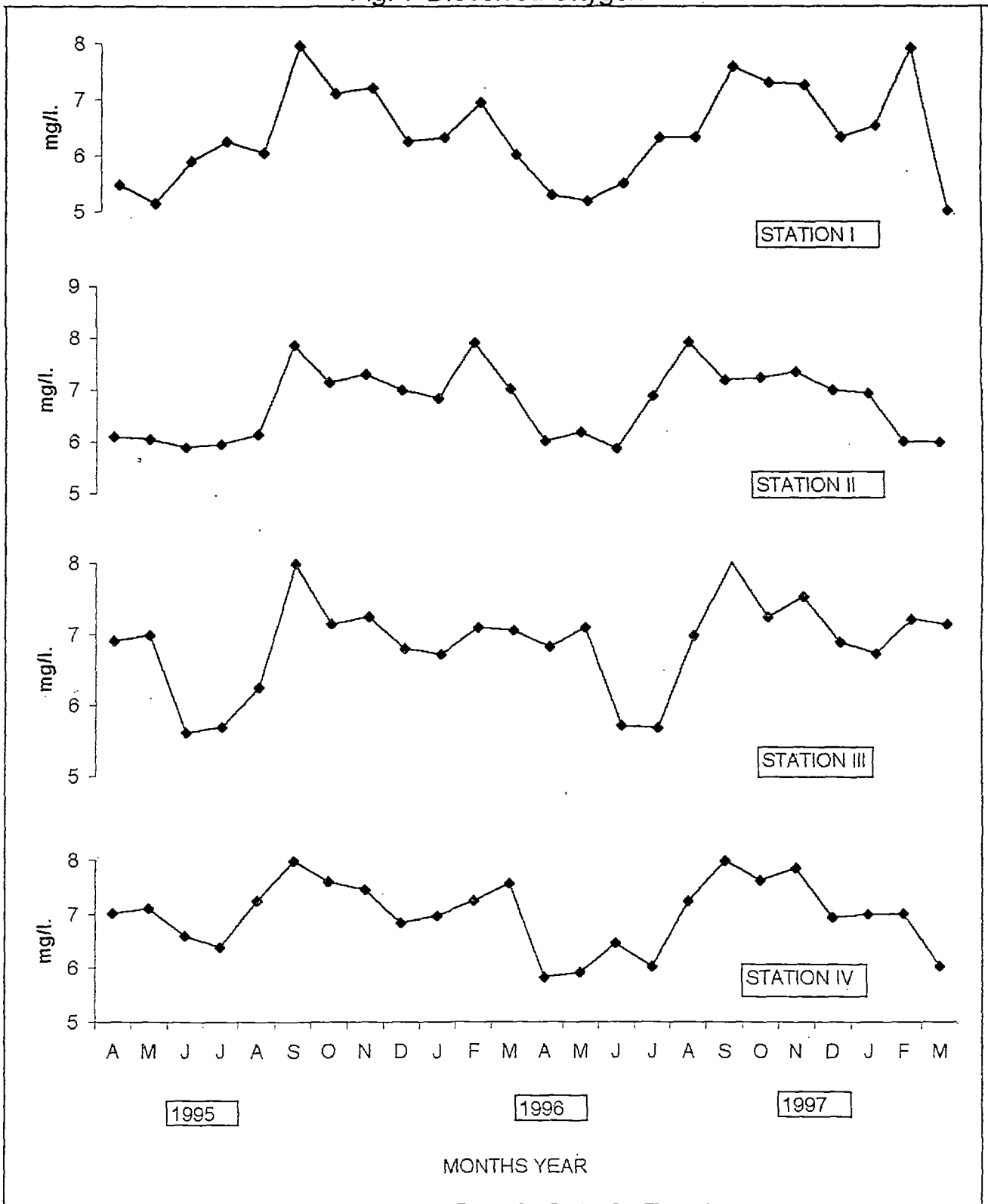


Fig. 8. Free Carbon Dioxide

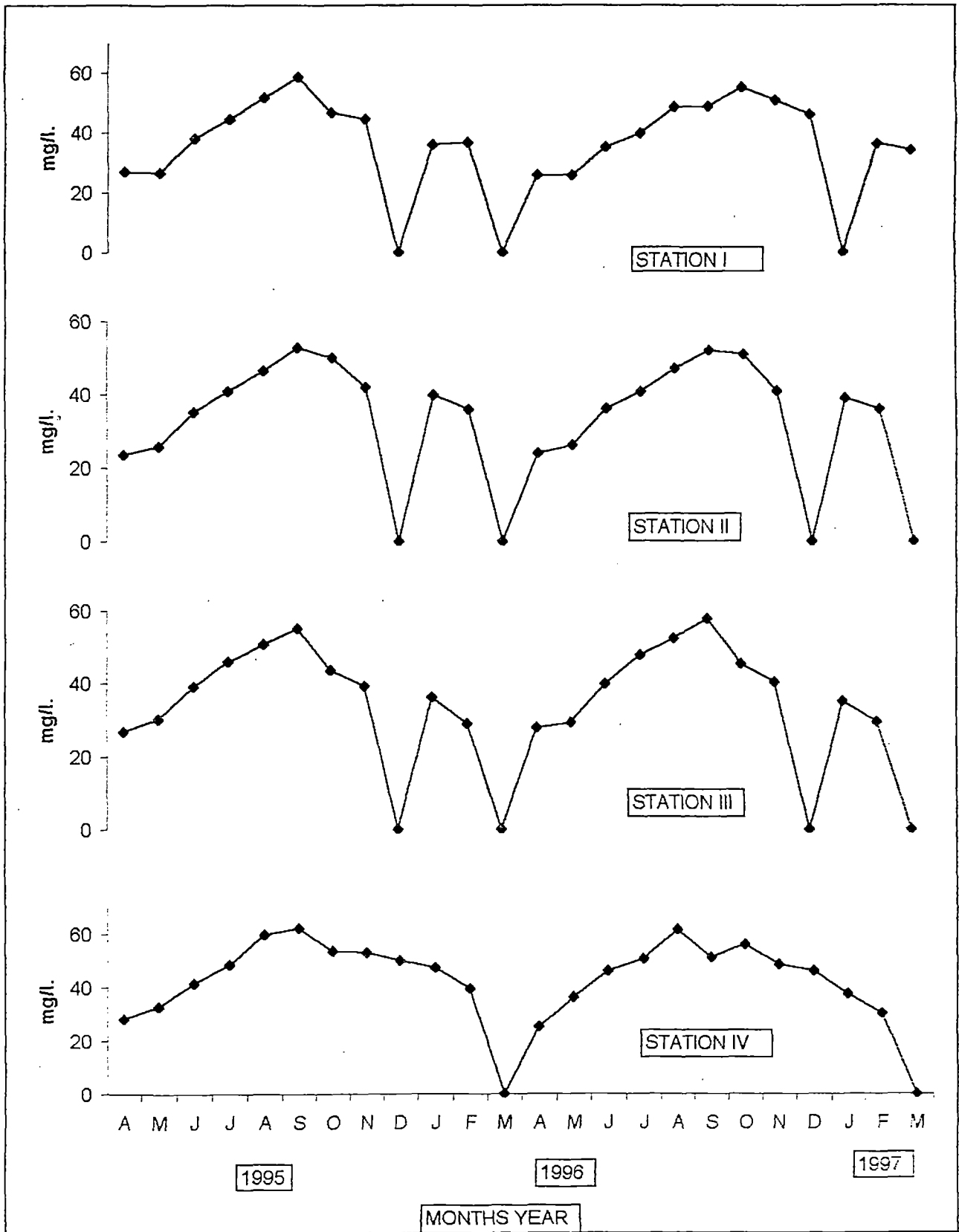


Fig. 9. Carbonates

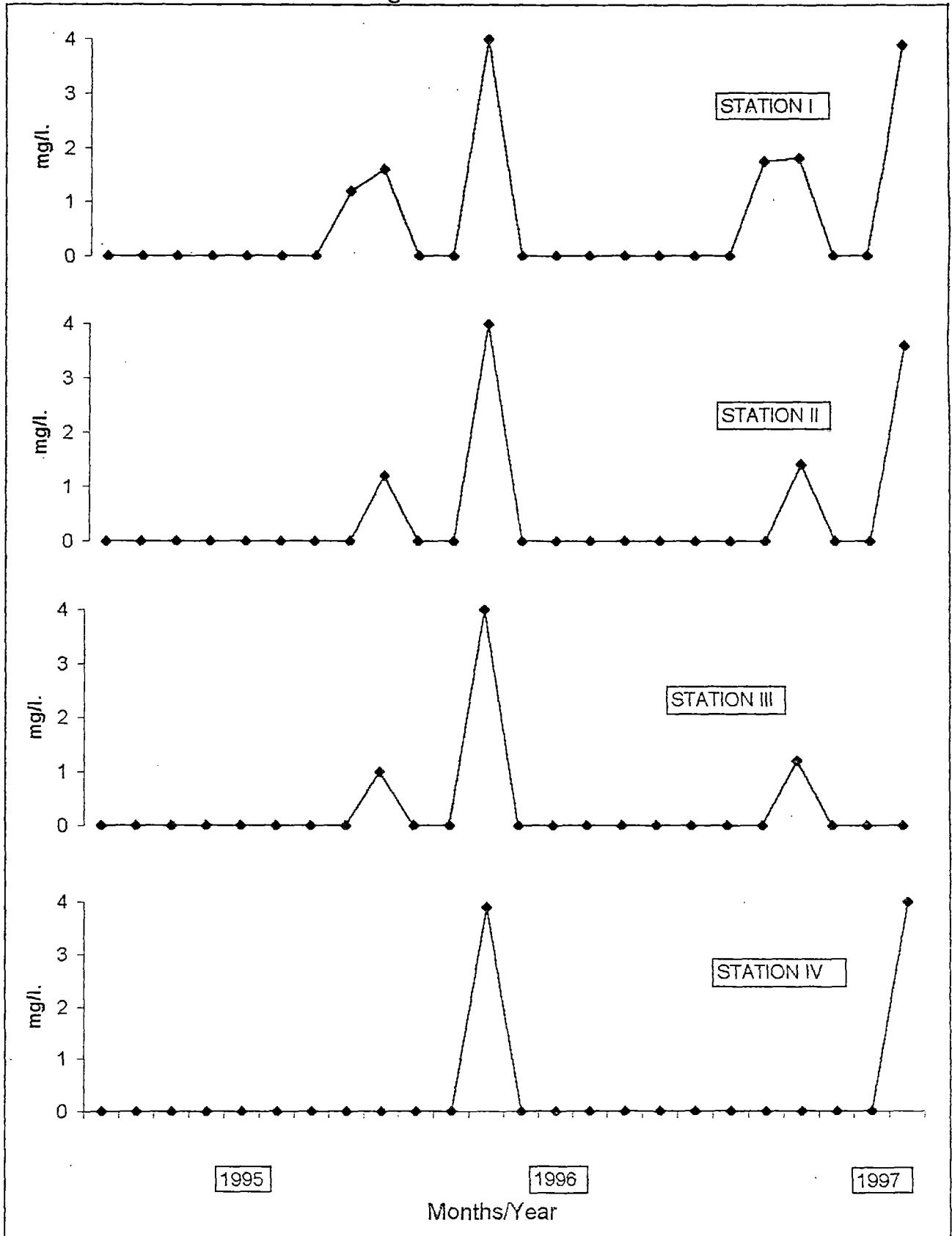


Fig. 10. Bicarbonates

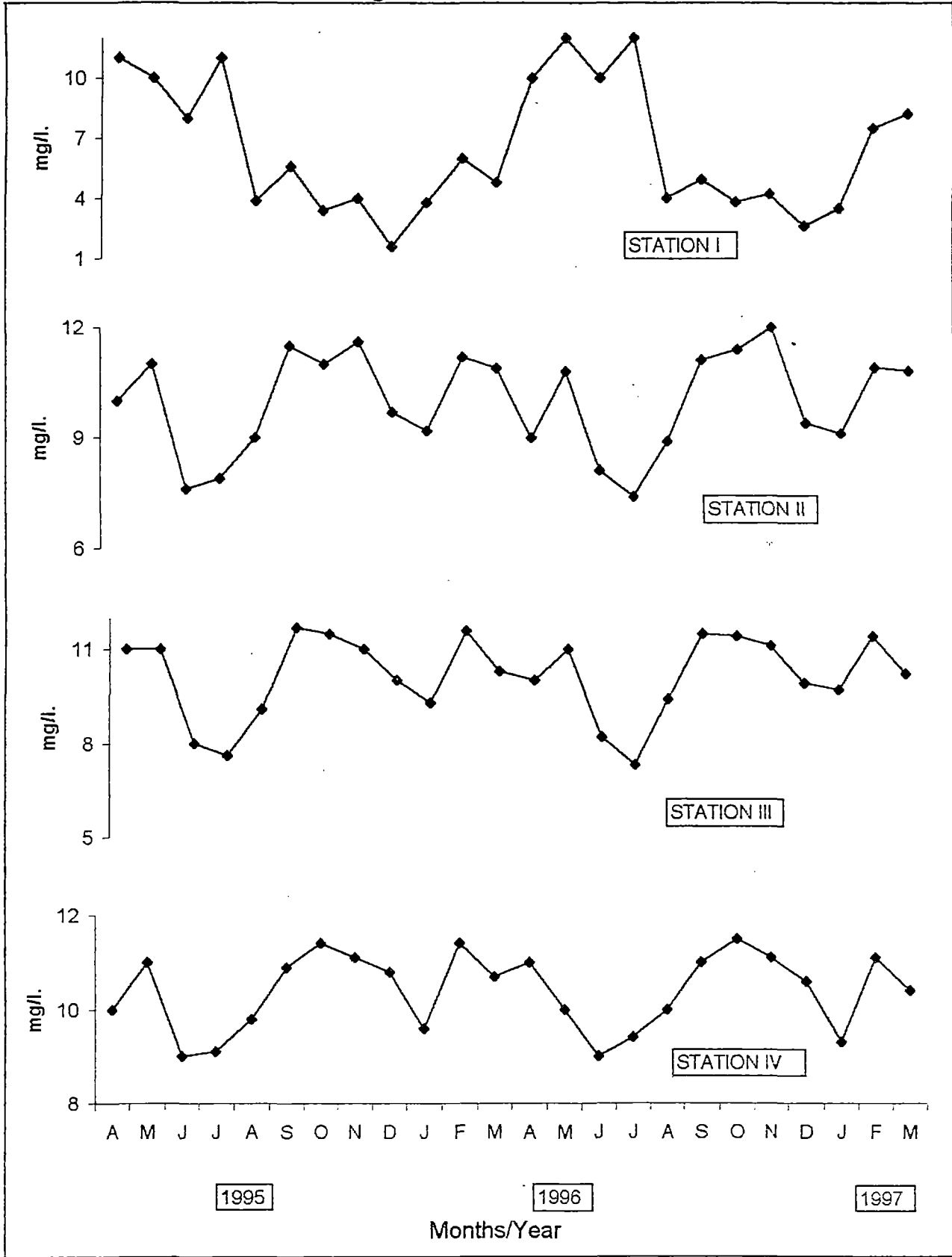


Fig. 11. Calcium

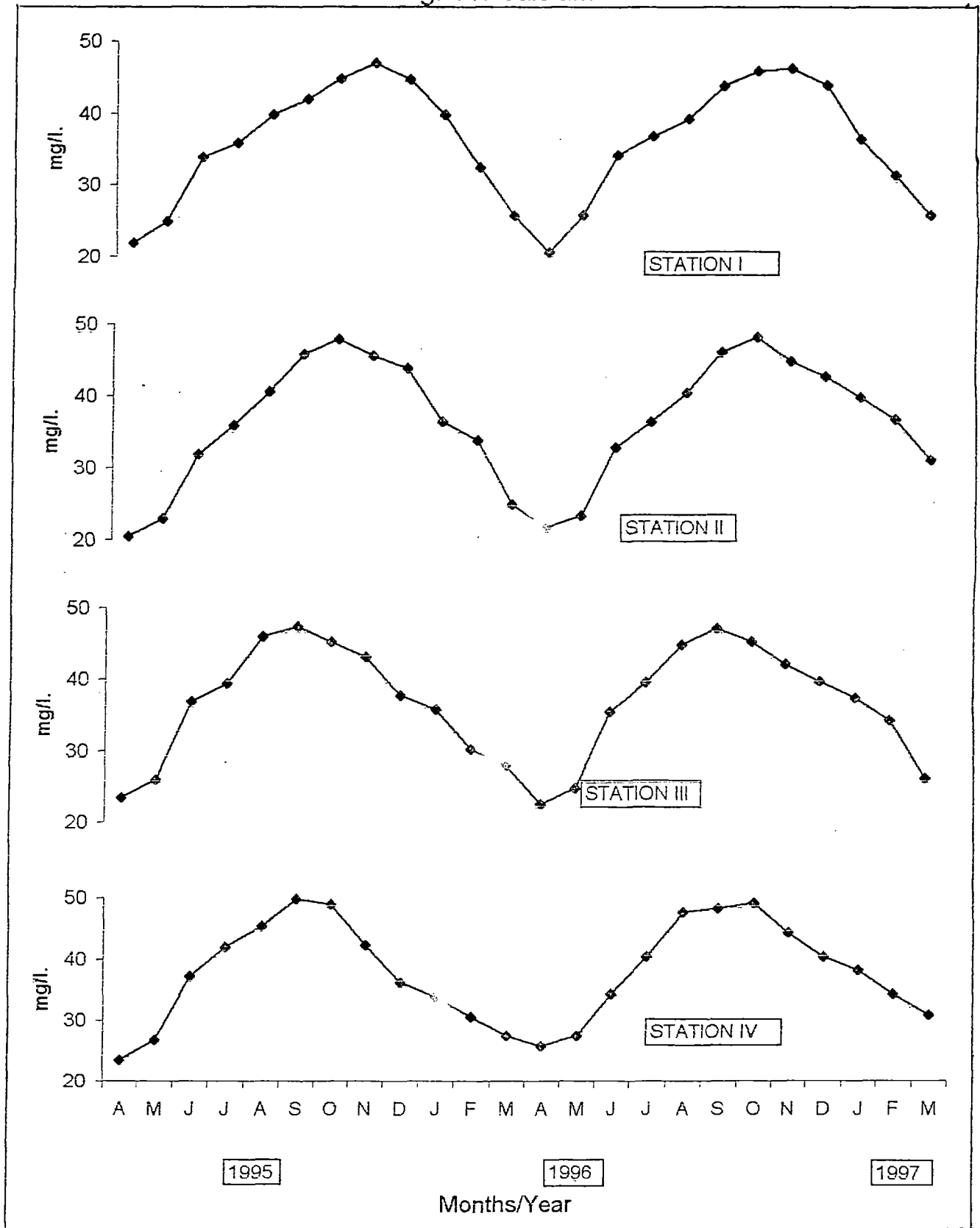


Fig. 12. Magnesium

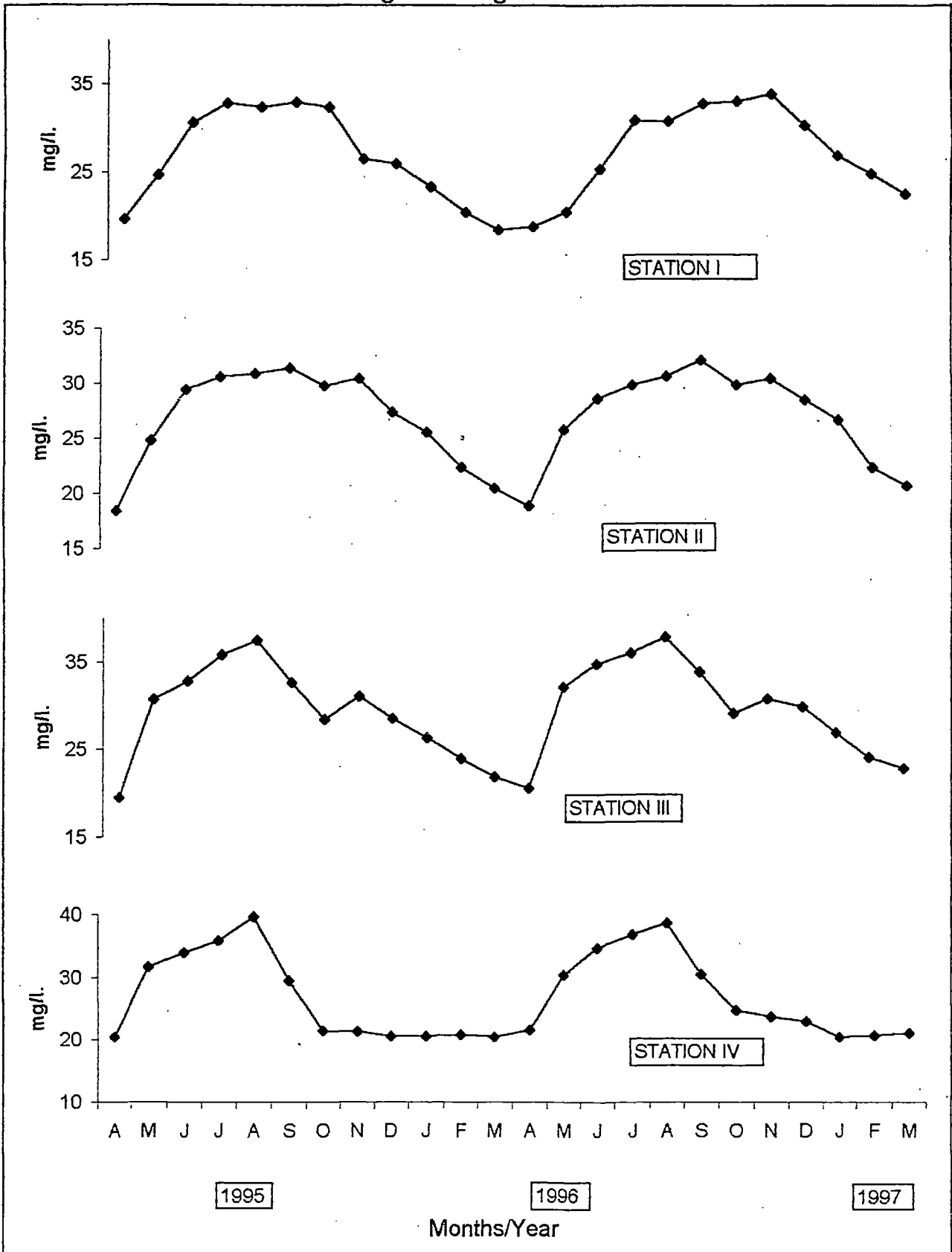


Fig. 13. Sulphate

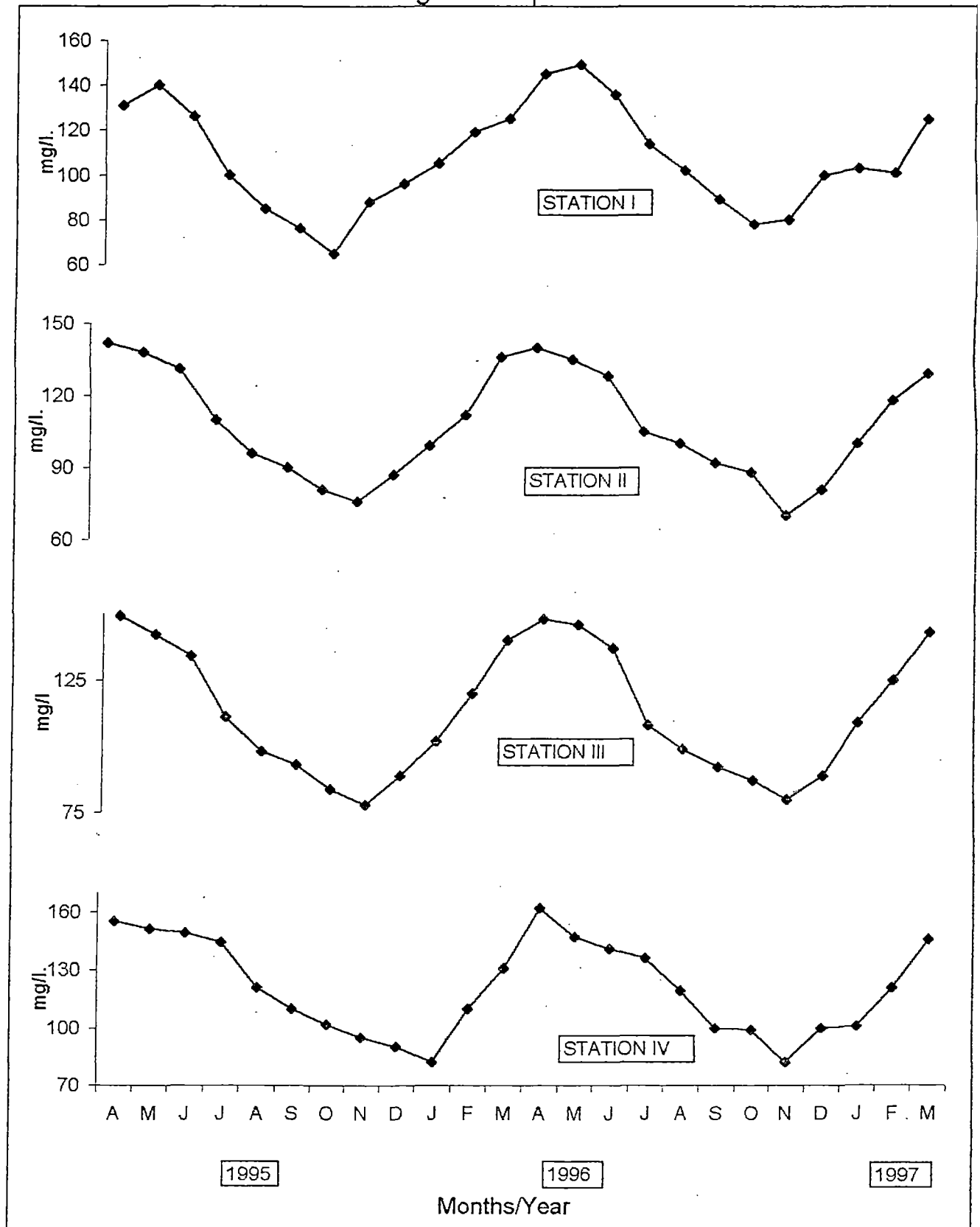


Fig. 14. Chlorides

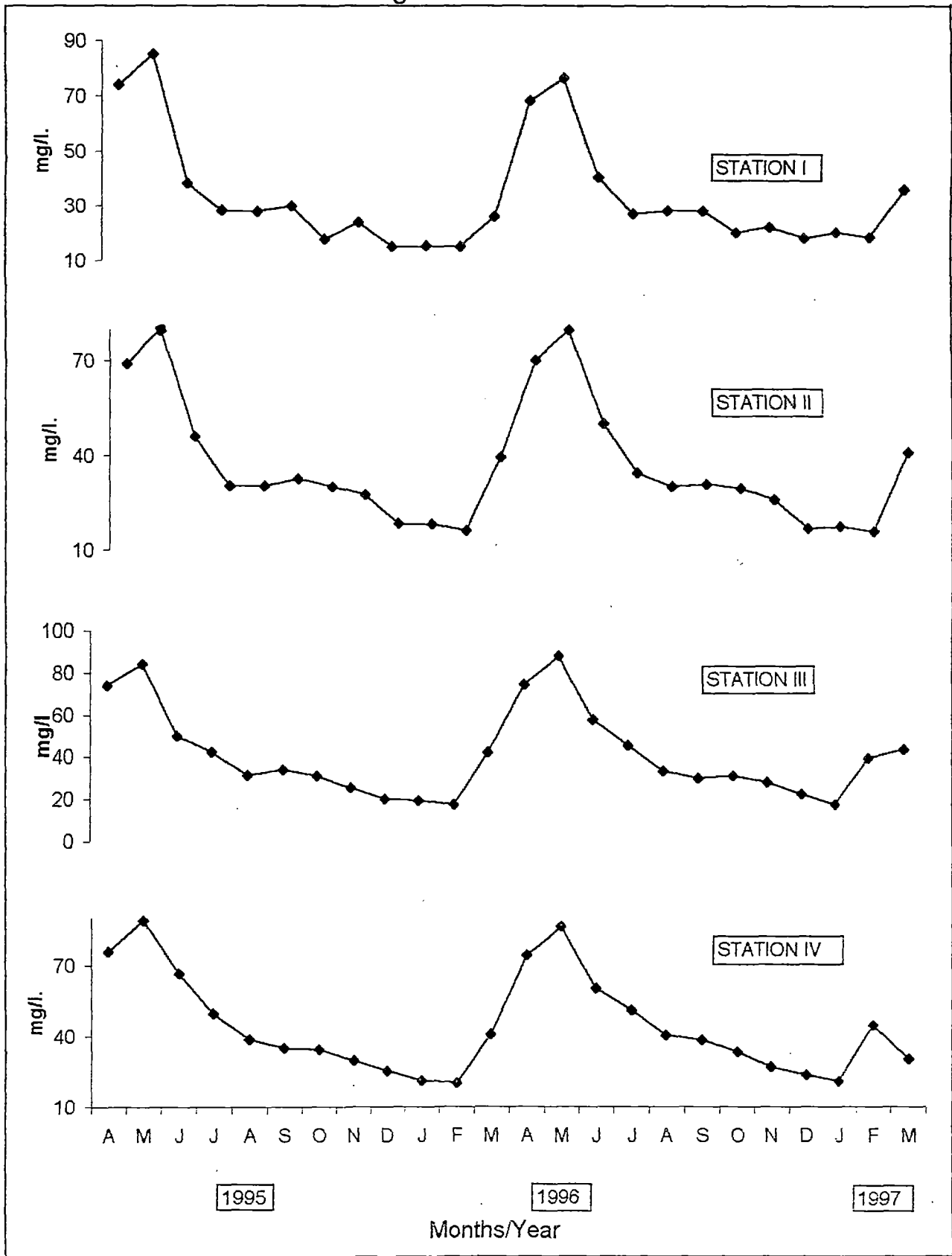


Fig. 15. Dissolved Organic Matter

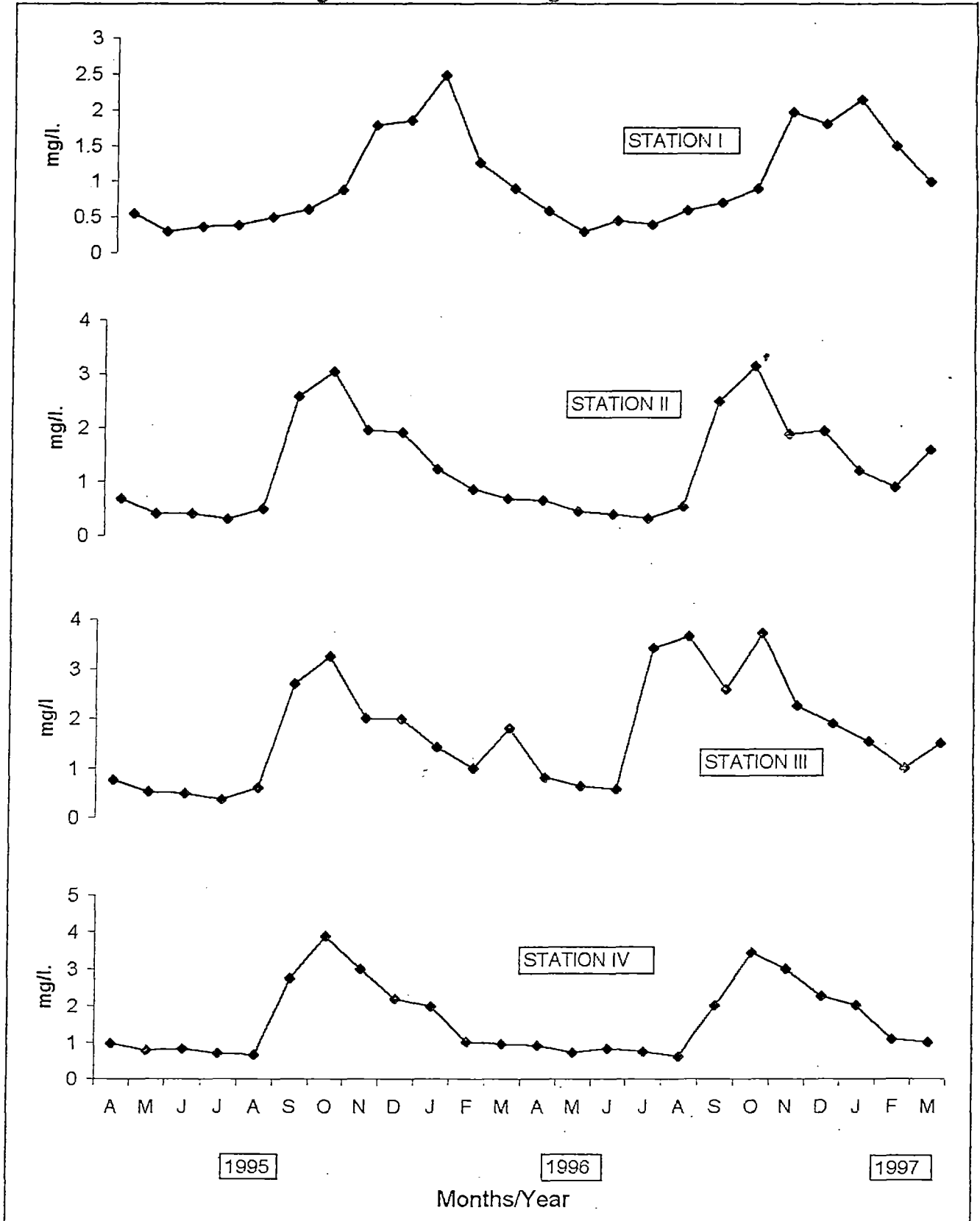


Fig. 16. Chemical Oxygen Demand

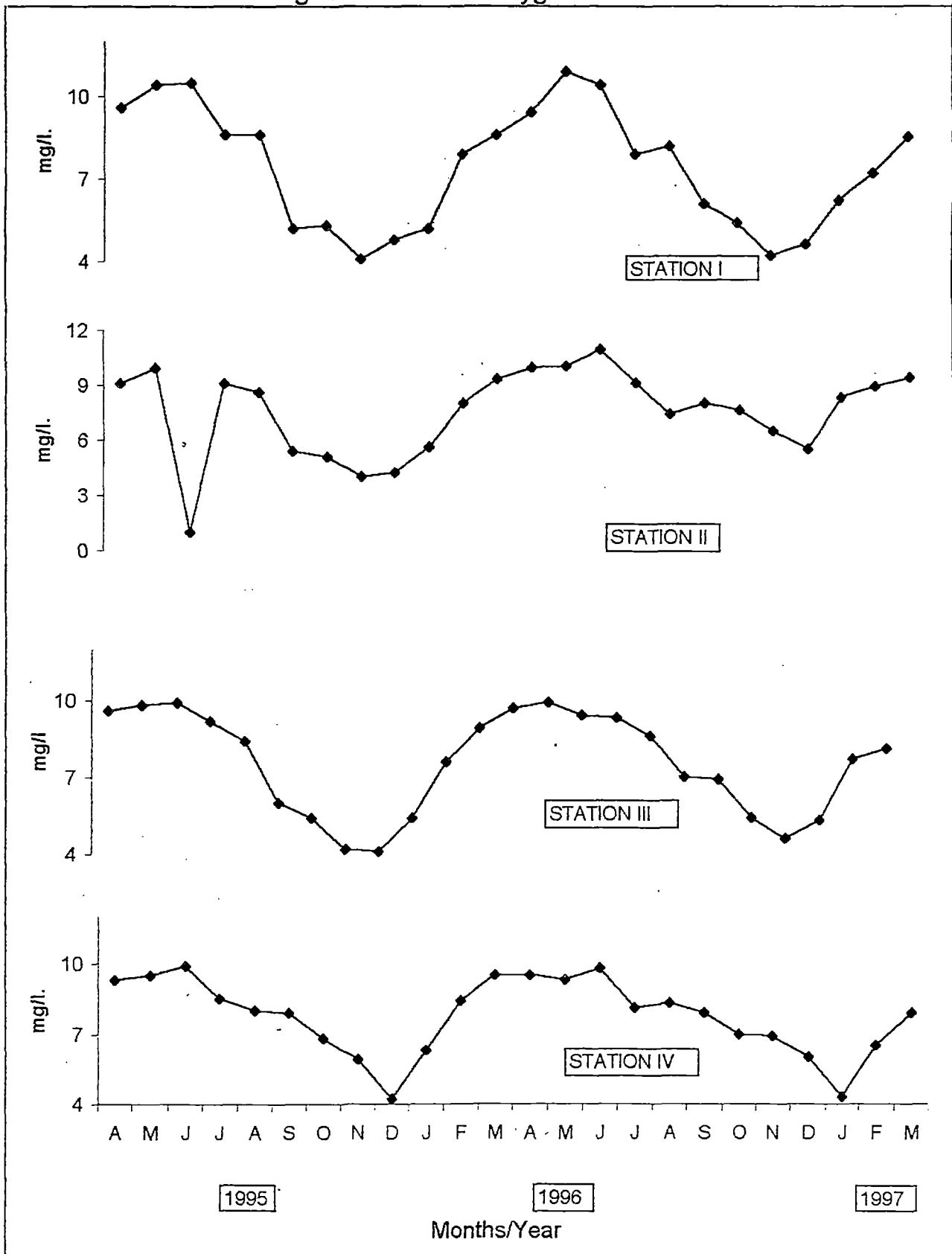


Fig. 17. Bio chemical Oxygen Demand

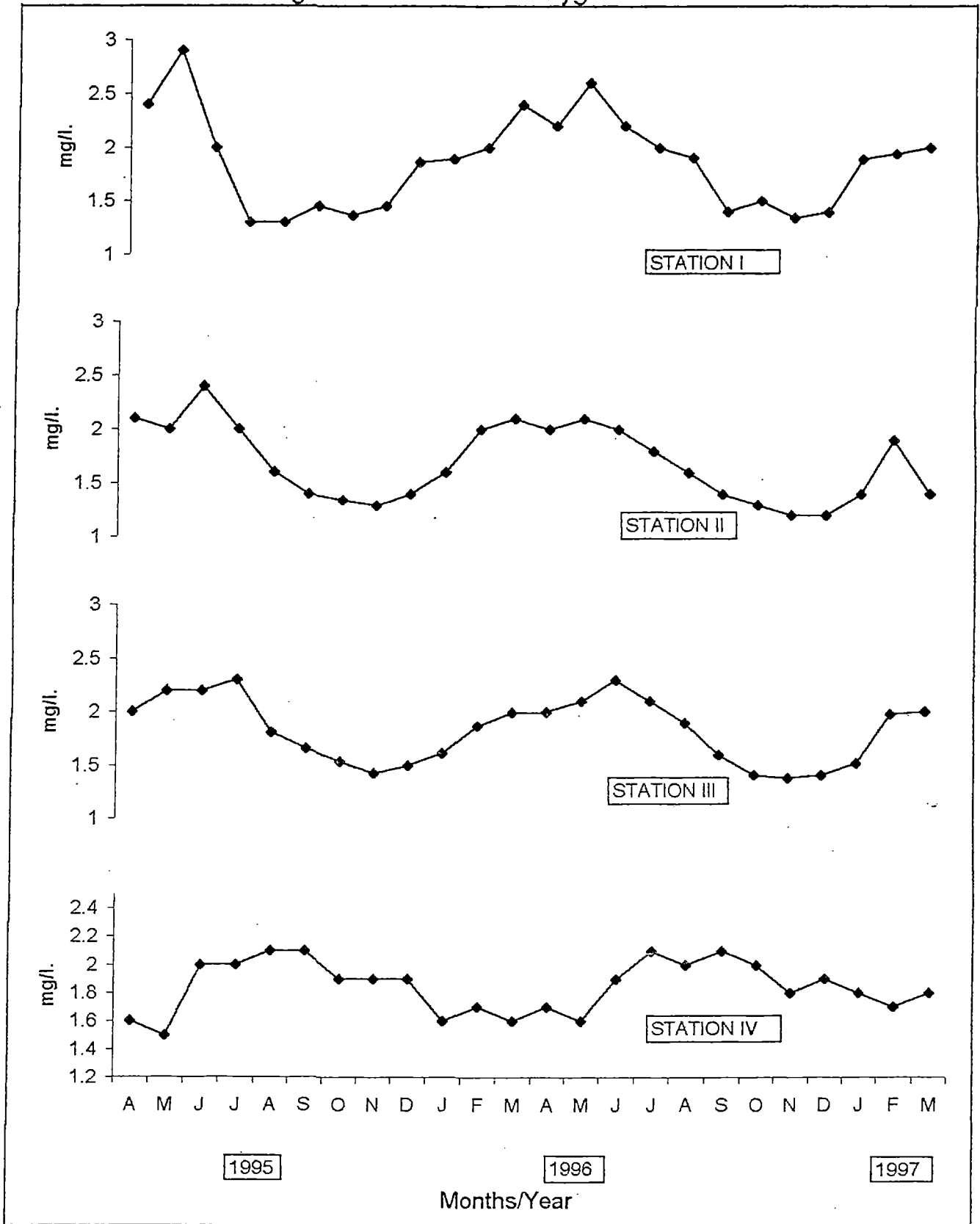


Fig. 18. Ammonia Nitrogen

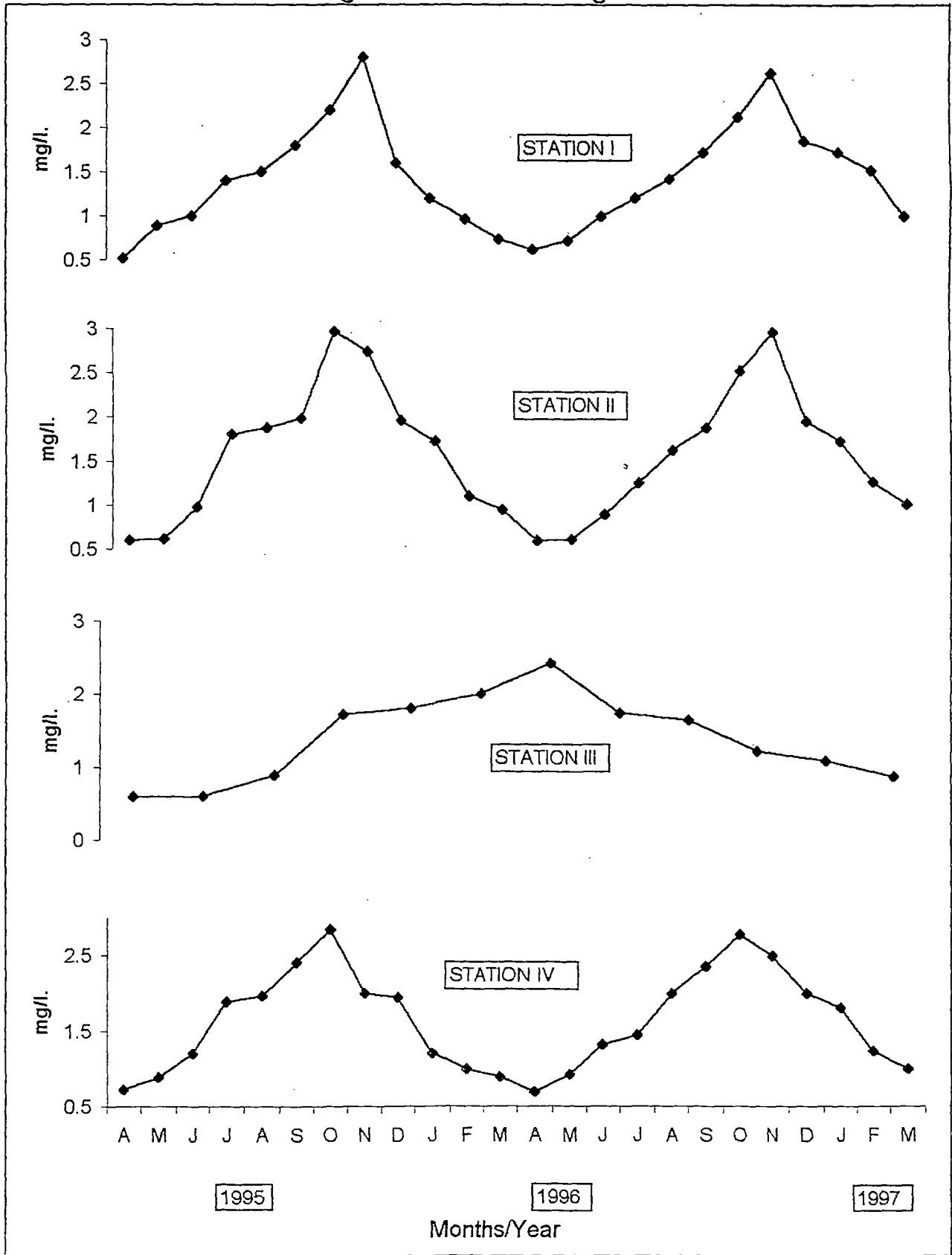


Fig. 19. Total kjeldahl nitrogen

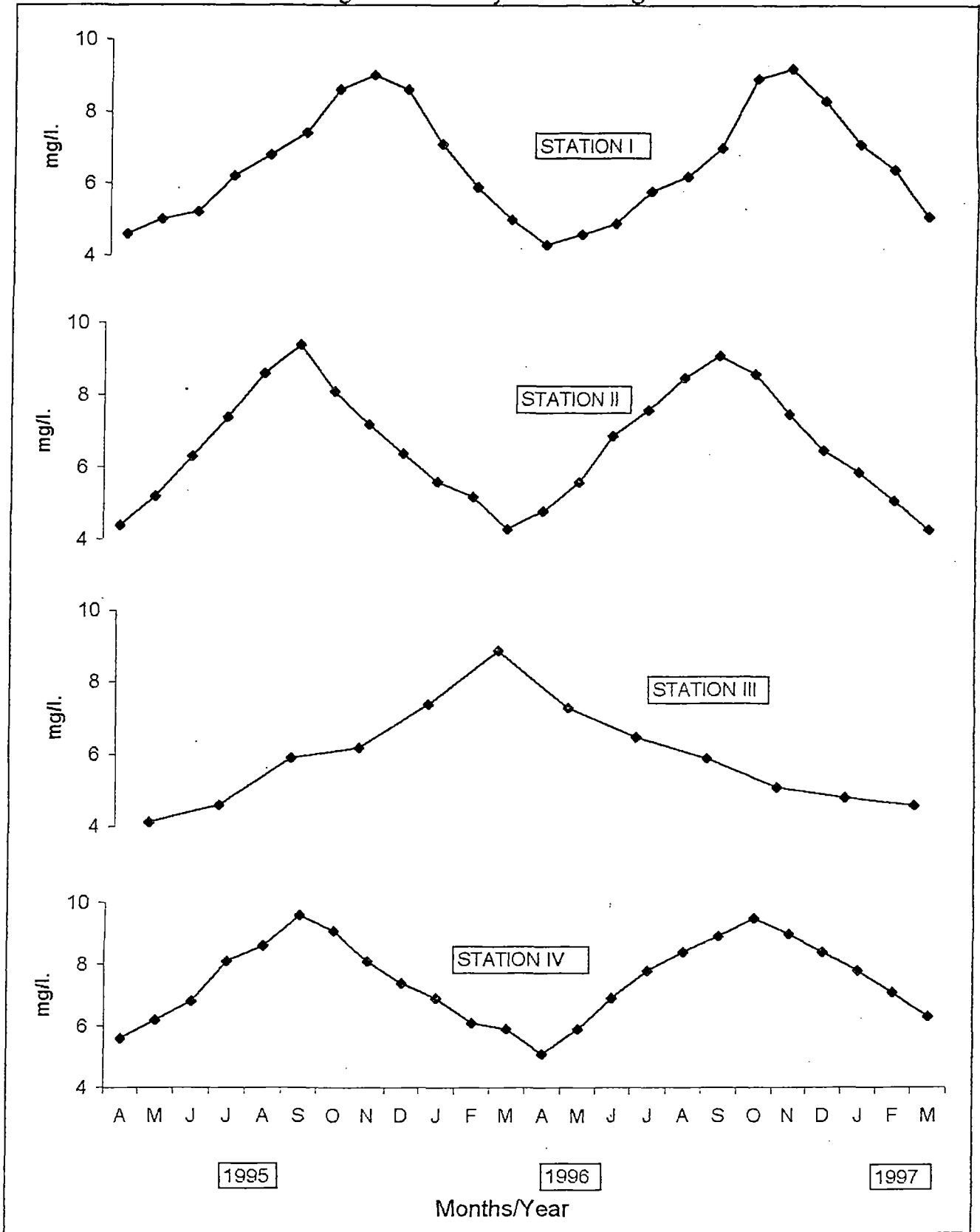


Fig. 20. Organic Nitrogen

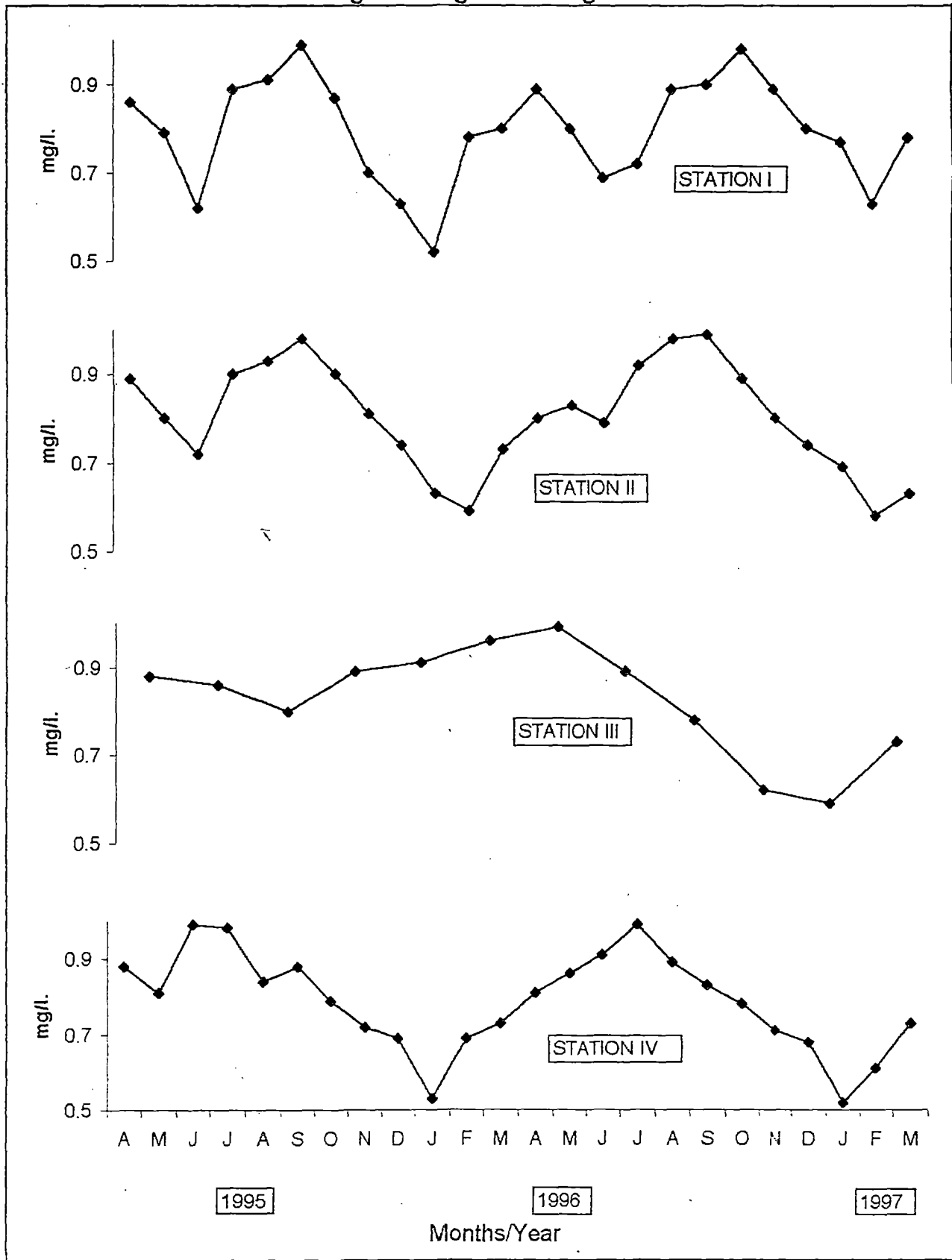


Fig. 21. Phosphate

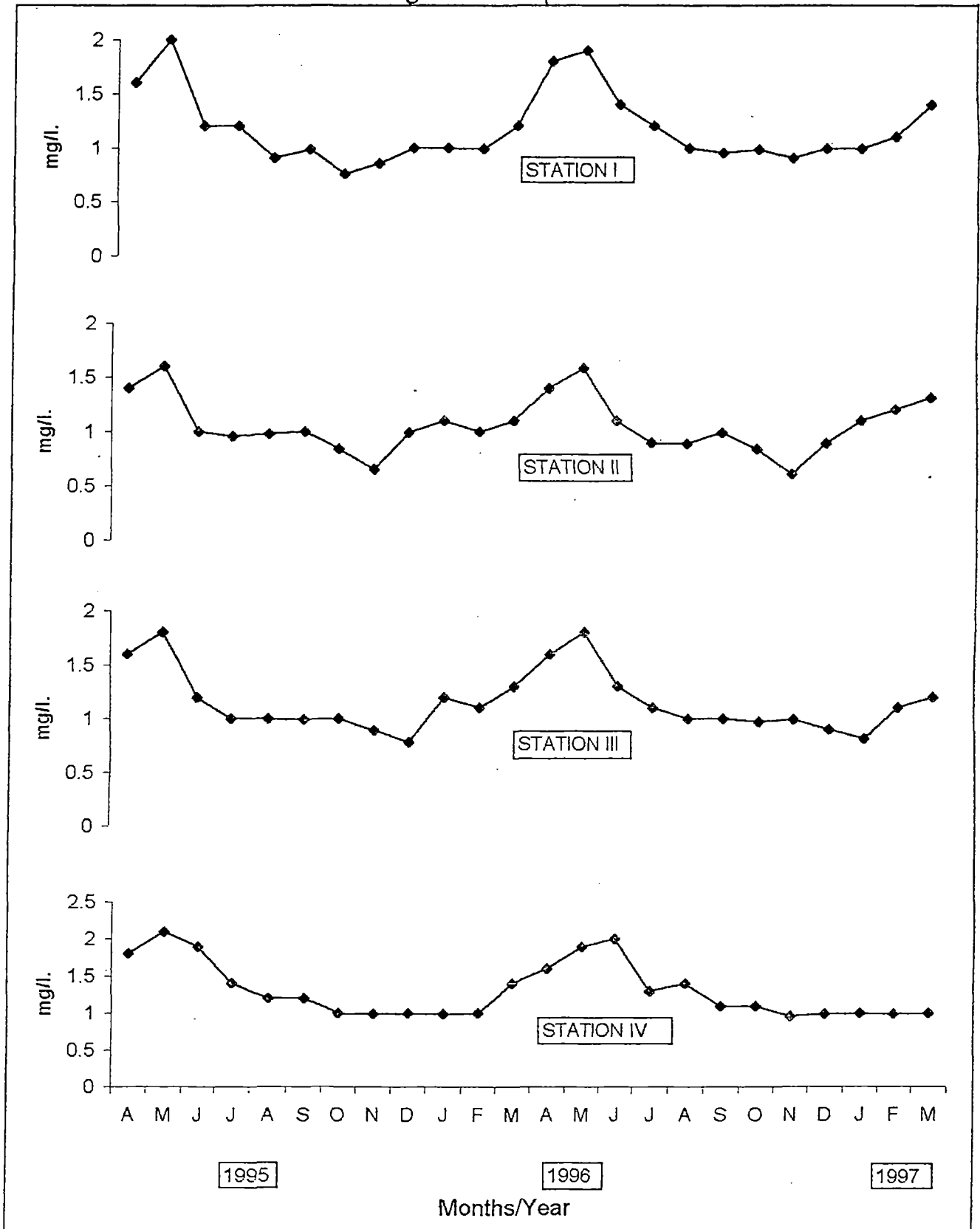


Fig. 22. Nitrate

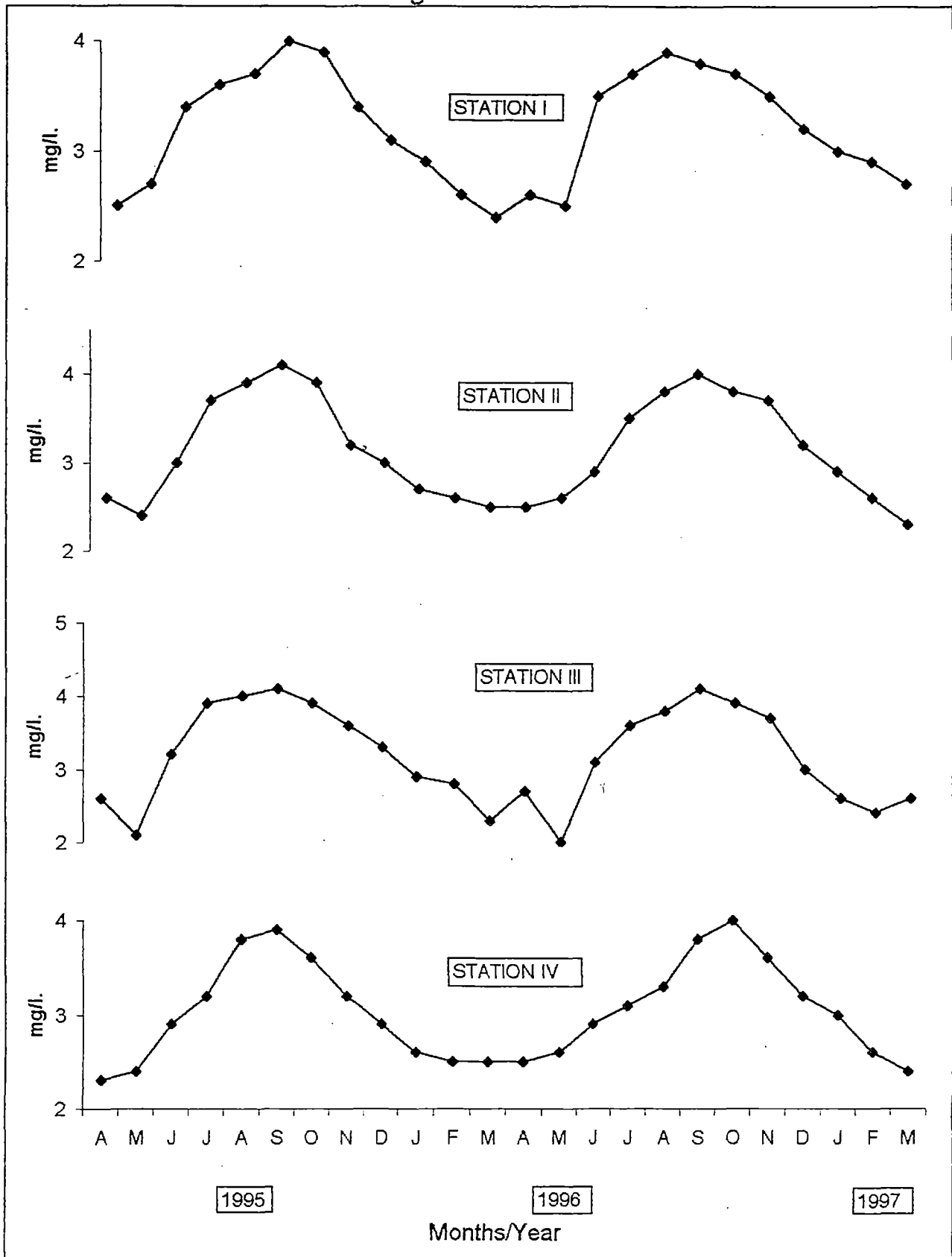


Fig. 23. Nitrite

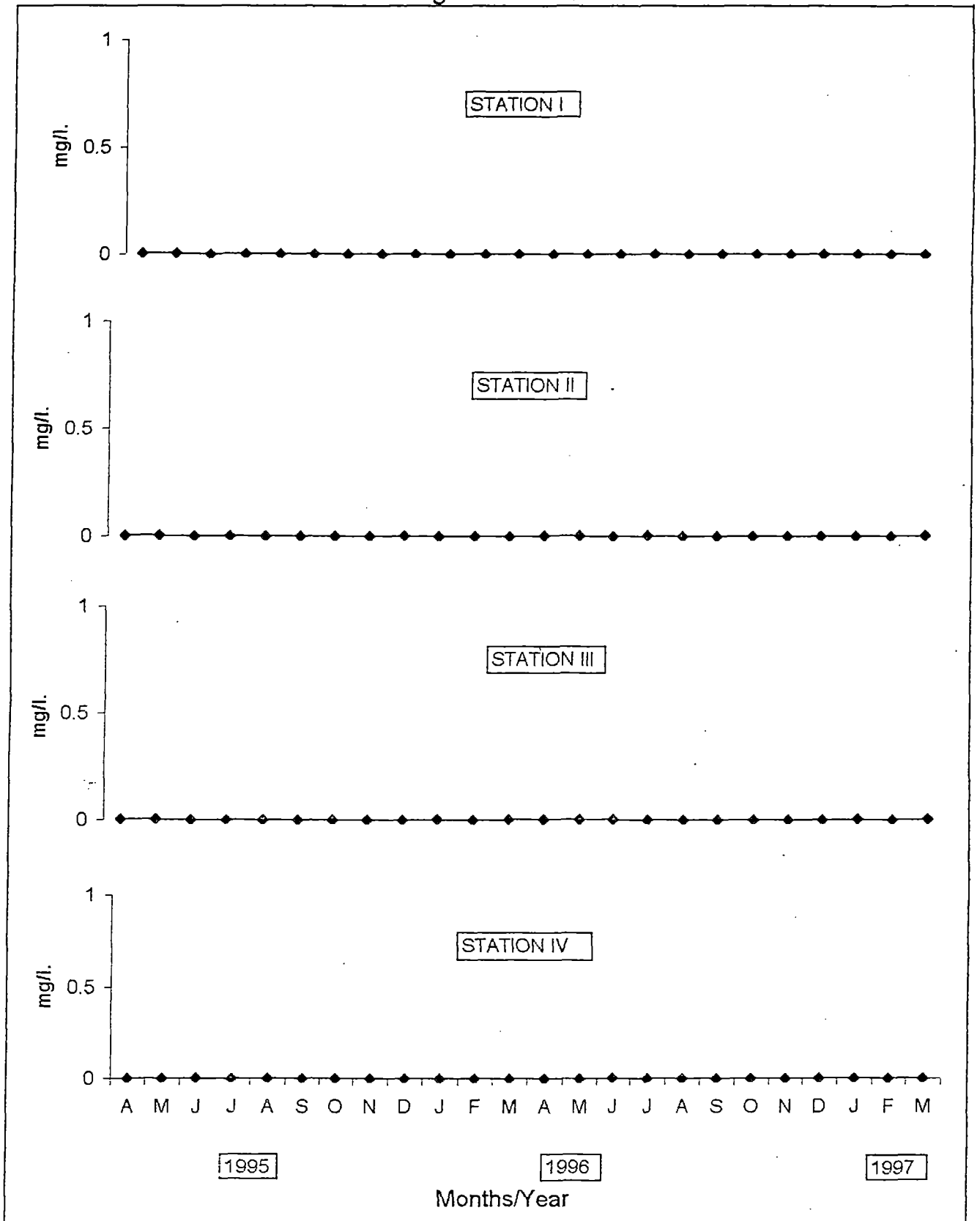


Fig. 24. Iron

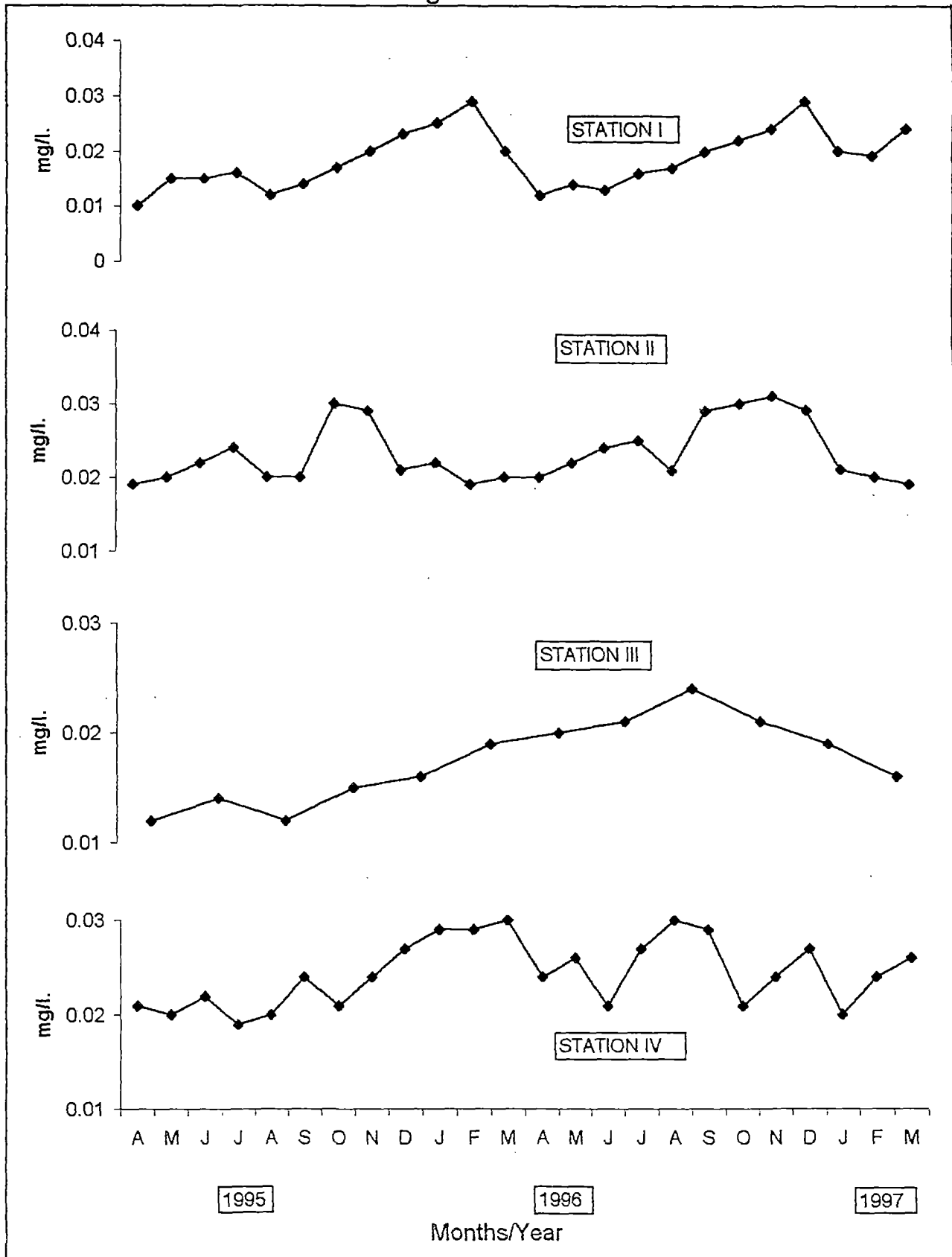


Fig. 25. Silica

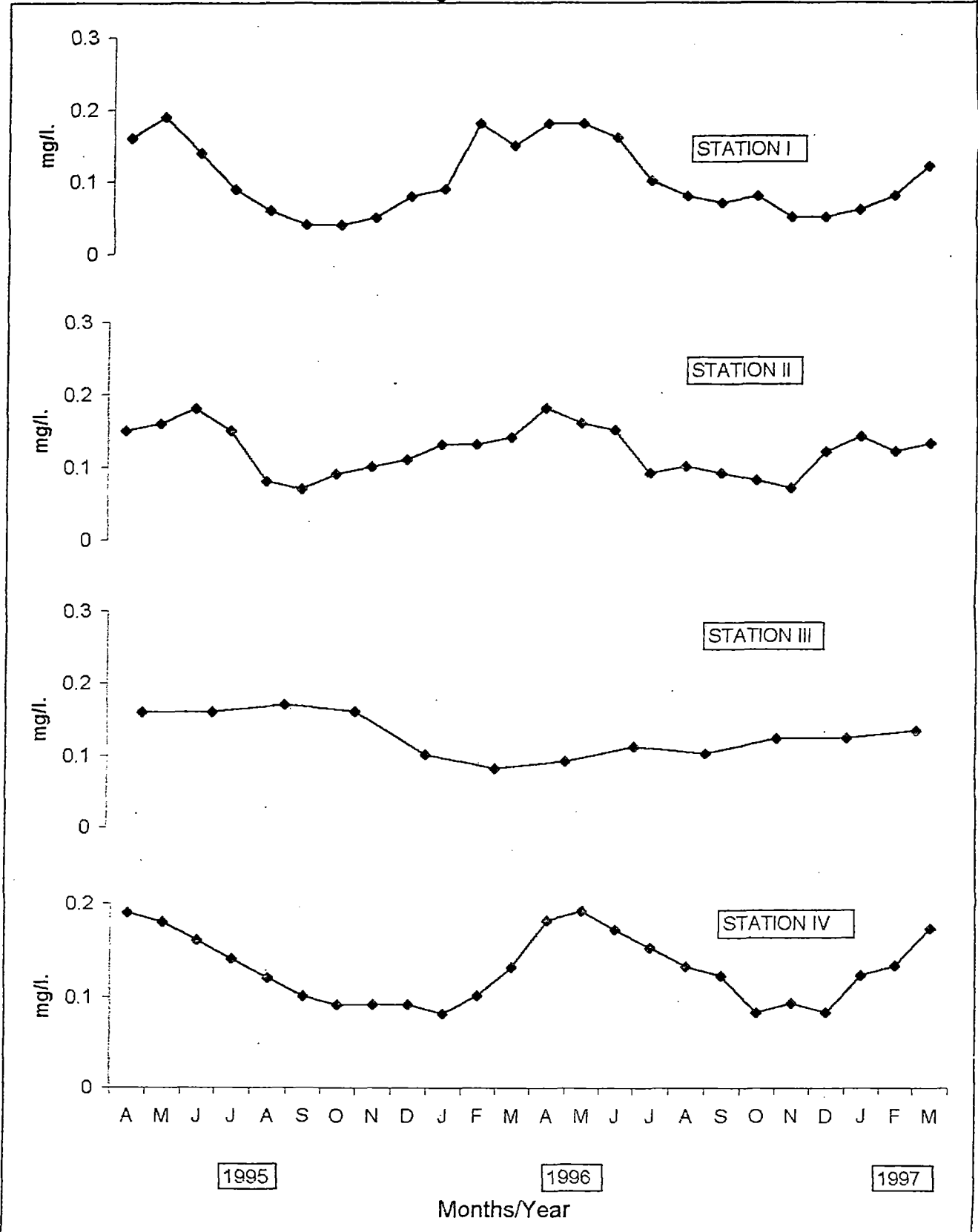


Fig. 26. Sodium

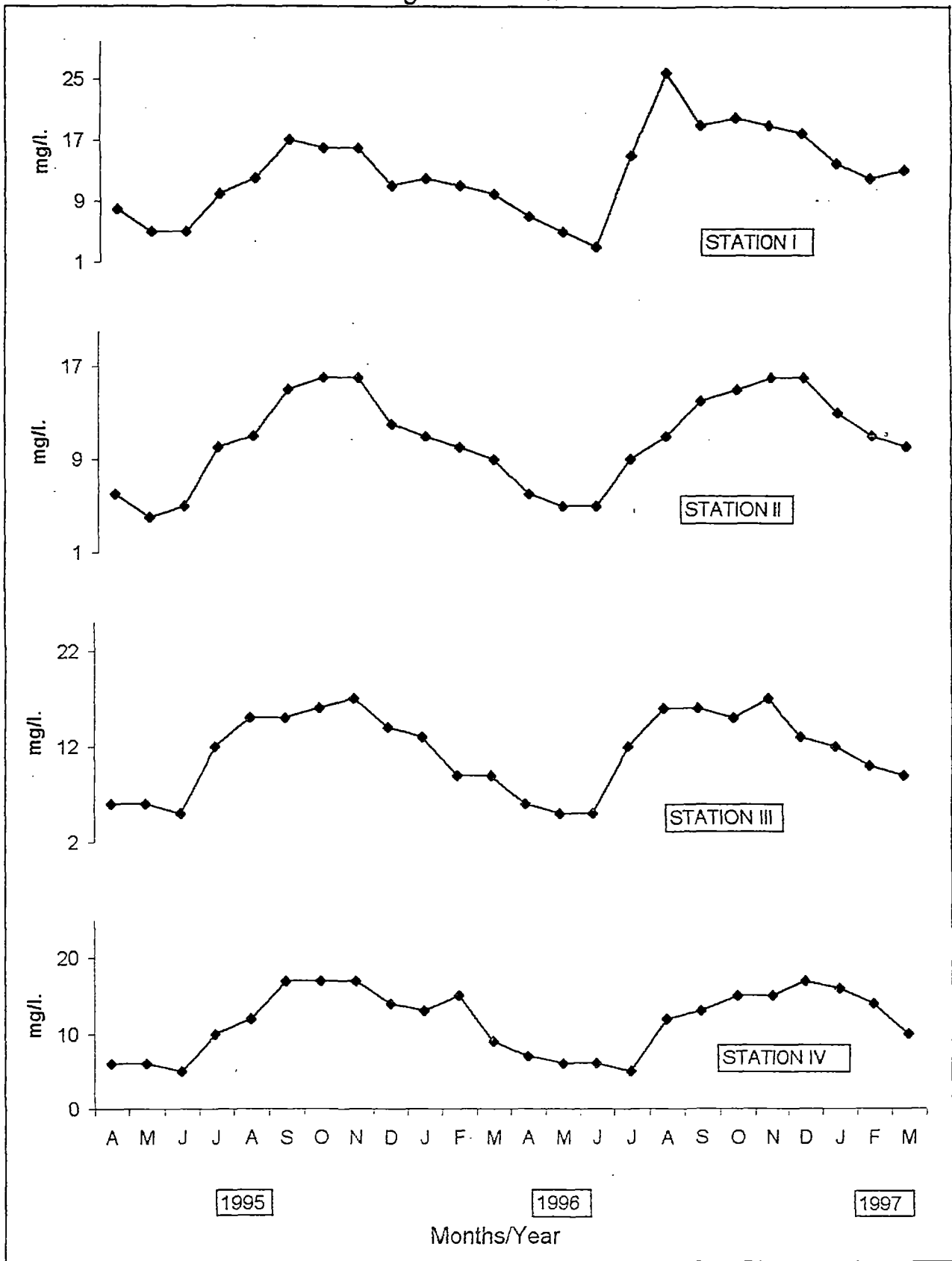


Fig. 27. Potassium

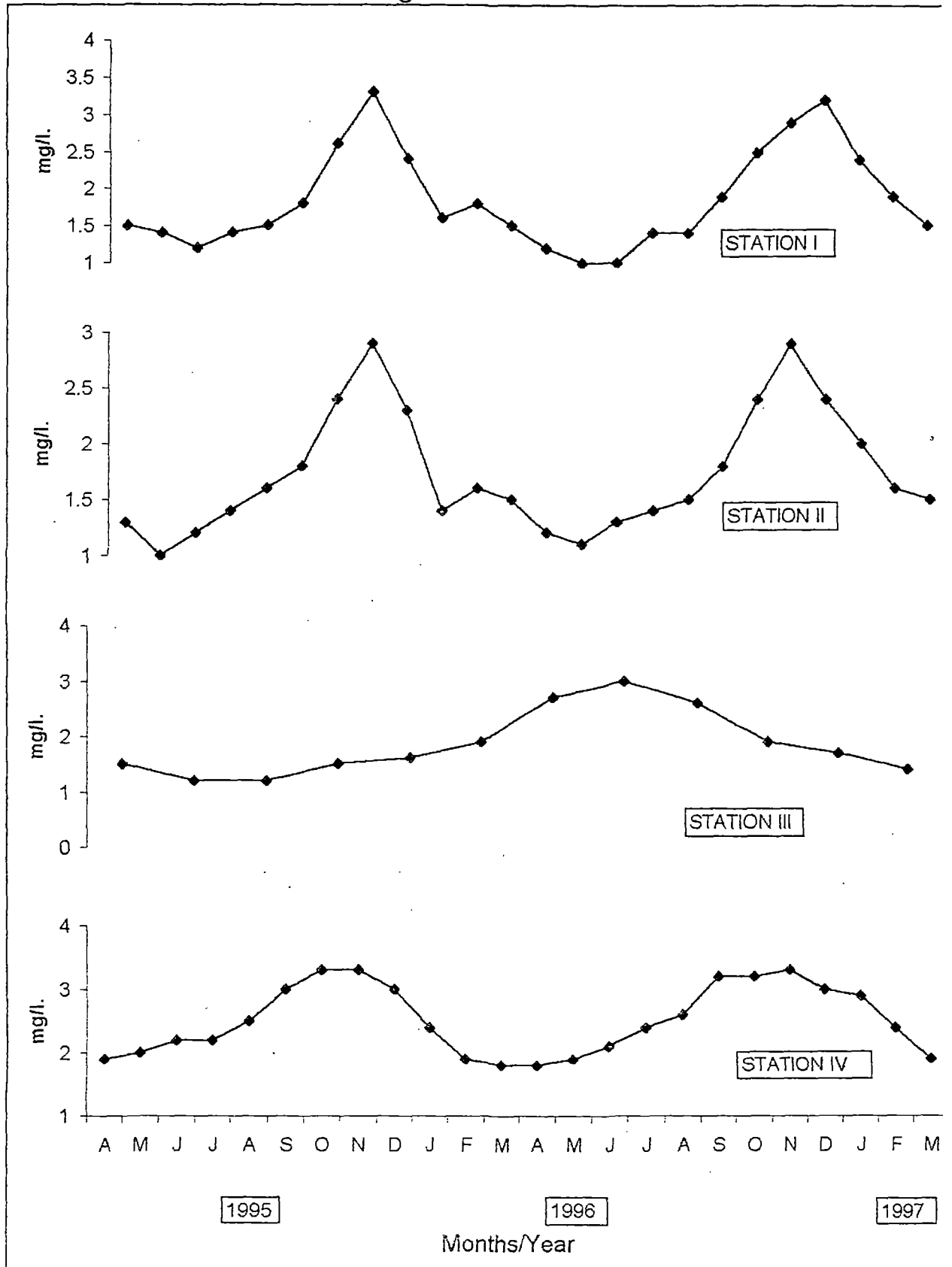


Fig. 28. Total Hardness

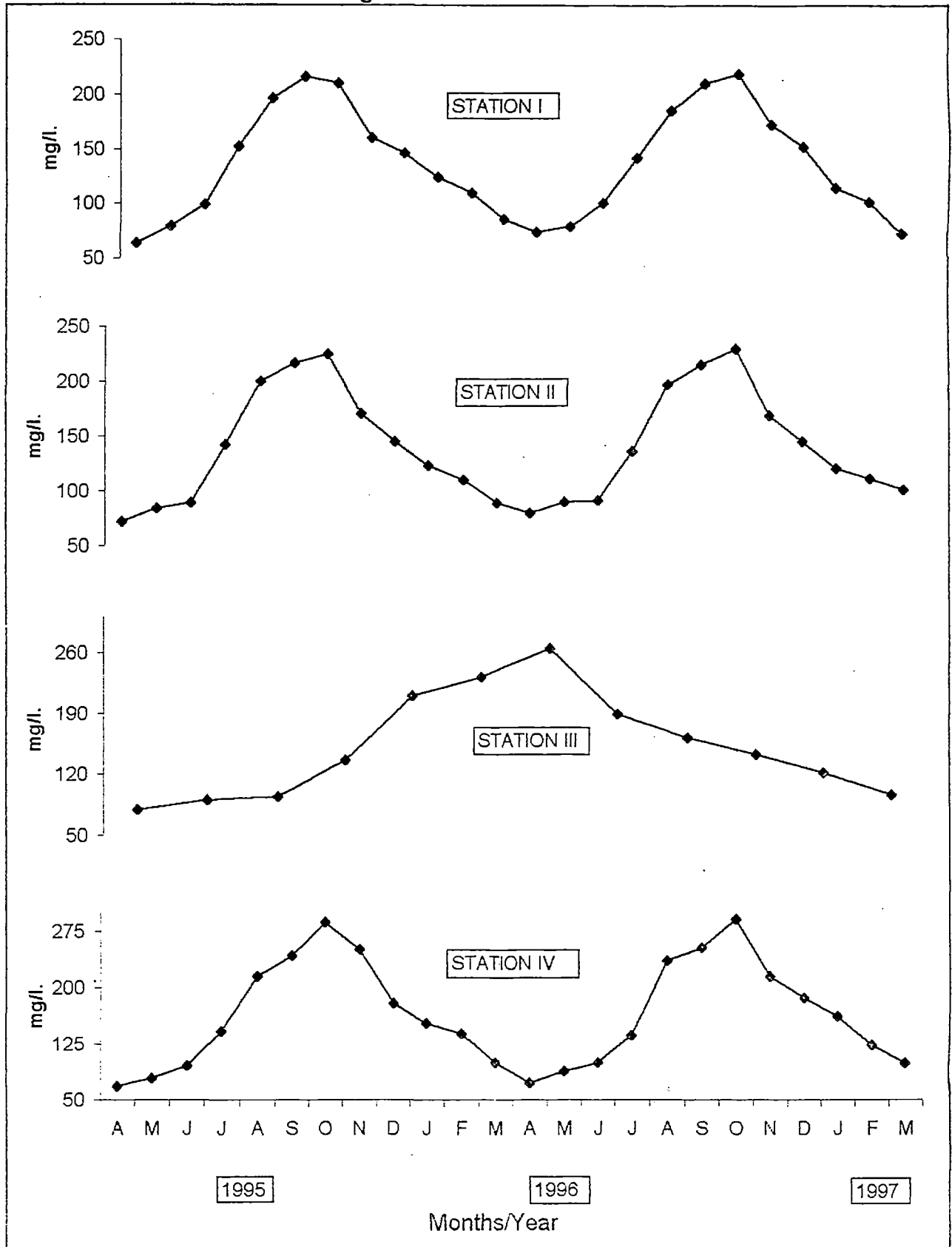


Table 1
ISI Specifications for potable water.

Sl.No.	Characteristics	Generally acceptable to consumer	Maximum limit (above which supply should be rejected)
1.	Turbidity ppm (JTU scale)	2.5	10
2	Colour (units on platinum-cobalt scale)	5.0	25
3	Taste and odour	Unobjectionable	Unobjectionable threshold number 3
4	Temperature	10°C	15.6°C
5	pH	7.0 to 8.5	6.5 to 9.2
6	Total solids (mg/l)	500	1500
7	Total hardness as CaCo ₃ (mg/l)	200	600
8	Chlorides as Cl (mg/l)	200	1000
9	Sulphates as SO ₄ (mg/l)	200	400
10	Fluorides as F (mg/l)	1.0	1.5
11	Nitrates as NO ₂ (mg/l)	45	45
12	Calcium as Ca (mg/l)	75	200
13	Magnesium as Mg (mg/l)	30	150
14	Iron as Fe (mg/l)	0.1	0.1
15	Zinc as Zn (mg/l)	5.0	15.0
16	Mineral oil (mg/l)	0.01	0.3
17	Copper as Cu (mg/l)	0.05	1.5
Toxic materials			
18	Arsenic as As (mg/l)	0.05	0.05
19	Cadmium as Cd (mg/l)	0.01	0.01
20	Lead as Pb (mg/l)	0.1	0.1

Table 2

**Averages of the physico-chemical parameters of Shantisagar lake
STATION I (1995-1997)**

Sl.No.	Parameters	Averages for first year 1995-96	Averages for second year 1996-97	Total Averages
1.	Air Temperature	33.20	32.9	33.05
2.	Water Temperature	28.75	29.5	29.12
3.	pH	7.2	7.1	7.15
4.	Turbidity	24.74	27.29	26.01
5.	Electrical Conductivity	180.16	193.25	186.70
6.	Dissolved oxygen	6.38	6.38	6.38
7.	Free Carbondioxide	41.15	35.21	38.18
8.	Biological oxygen demand	1.85	1.86	1.85
9.	Chemical oxygen demand	7.4	7.41	7.405
10.	Calcium	36.03	35.84	35.93
11.	Magnesium	26.65	27.55	27.10
12.	Sodium	11.08	14.25	12.66
13.	Potassium	1.833	1.85	1.84
14.	Carbonates	2.26	2.3	2.28
15.	Bicarbonates	6.09	6.89	6.49
16.	Sulphates	104.66	110.16	107.41
17.	Chlorides	33.03	33.54	33.28
18.	Dissolved organic matter	0.979	1.02	0.999
19.	Nitrates	3.18	3.25	3.21
20.	Nitrites	0.0013	0.0016	0.0014
21.	Organic nitrogen	0.78	0.811	0.795
22.	Ammonia nitrogen	1.38	1.45	1.41
23.	Total kjeldahl nitrogen	6.61	6.48	6.54
24.	Phos pates	1.145	1.21	1.17
25.	Silica	0.10	0.10	1.41
26.	Iron	0.018	0.019	0.0185
27.	Total hardness	136.83	135	135.91
28.	Total solids	580	602.66	591.33

Table 3

Averages of the physico-chemical parameters of Shantisagar lake
STATION II (1995-1997)

Sl.No.	Parameters	Averages for first year 1995-96	Averages for second year 1996-97	Total Averages
1.	Air Temperature	33.24	33.25	33.24
2.	Water Temperature	28.75	29.18	28.97
3.	pH	7.14	7.1	7.12
4.	Turbidity	27.93	28.97	28.36
5.	Electrical Conductivity	161	152.75	158.37
6.	Dissolved oxygen	6.76	6.71	6.73
7.	Free Carbondioxide	39.22	39.30	39.26
8.	Biological oxygen demand	1.76	1.60	1.68
9.	Chemical oxygen demand	7.78	8.45	8.11
10.	Calcium	35.8	37.01	36.40
11.	Magnesium	26.8	27.09	36.94
12.	Sodium	10.41	10.91	10.66
13.	Potassium	1.7	1.75	1.72
14.	Carbonates	2.6	2.5	2.55
15.	Bicarbonates	9.21	10.80	10.00
16.	Sulphates	18.16	107.16	107.66
17.	Chlorides	36.51	36.8	36.66
18.	Dissolved organic matter	1.29	1.29	1.29
19.	Nitrates	3.13	3.15	3.14
20.	Nitrites	0.0014	0.0017	0.015
21.	Organic nitrogen	0.80	0.80	0.80
22.	Ammonia nitrogen	1.75	1.52	1.63
23.	Total kjeldahl nitrogen	6.50	6.7	0.0155
24.	Phosphates	1.05	1.06	1.055
25.	Silica	0.124	0.11	0.117
26.	Iron	0.02	0.024	0.023
27.	Total hardness	138.83	140.41	199.62
28.	Total solids	632.25	633.5	139.62

Table 4**Averages of the physico-chemical parameters of Shantisagar lake
STATION III (1995-1997)**

Sl.No.	Parameters	Averages for first year 1995-96	Averages for second year 1996-97	Total Averages
1.	Air Temperature	33.40	33.65	33.52
2.	Water Temperature	29.30	29.49	29.39
3.	pH	7.15	7.15	7.15
4.	Turbidity	29.38	29.62	29.50
5.	Electrical Conductivity	164.91	165.00	164.95
6.	Dissolved oxygen	6.79	6.92	6.85
7.	Free Carbondioxide	39.61	40.51	40.06
8.	Biological oxygen demand	2.04	1.84	1.94
9.	Chemical oxygen demand	7.37	7.65	7.51
10.	Calcium	30.78	36.57	33.67
11.	Magnesium	29.07	29.93	29.5
12.	Sodium	11.33	11.41	11.37
13.	Potassium	1.85	1.83	1.84
14.	Carbonates	2.5	2.65	2.57
15.	Bicarbonates	10.17	10.09	10.13
16.	Sulphates	1119.4	113.58	116.49
17.	Chlorides	39.27	42.49	40.88
18.	Dissolved organic matter	1.40	1.46	1.43
19.	Nitrates	2.87	3.22	3.04
20.	Nitrites	0.0016	0.0015	0.00156
21.	Organic nitrogen	0.82	0.80	0.81
22.	Ammonia nitrogen	1.38	1.35	1.36
23.	Total kjeldahl nitrogen	5.94	6.83	6.38
24.	Phos pates	1.15	1.14	1.145
25.	Silica	0.125	0.12	0.122
26.	Iron	0.017	0.0176	0.0173
27.	Total hardness	151.16	157.66	154.41
28.	Total solids	660.66	662.5	661.55

Table 5

Averages of the physico-chemical parameters of Shantisagar lake
STATION IV (1995-1997)

Sl.No.	Parameters	Averages for first year 1995-96	Averages for second year 1996-97	Total Averages
1.	Air Temperature	33.53	33.60	33.56
2.	Water Temperature	29.30	29.27	29.28
3.	pH	7.15	7.15	7.15
4.	Turbidity	28.78	29.81	29.29
5.	Electrical Conductivity	169	174.25	171.62
6.	Dissolved oxygen	7.16	7.19	7.17
7.	Free Carbondioxide	46.82	44.31	45.56
8.	Biological oxygen demand	1.65	1.86	1.75
9.	Chemical oxygen demand	7.85	8.12	7.98
10.	Calcium	36.94	38.35	37.62
11.	Magnesium	26.30	27.17	26.73
12.	Sodium	11.75	11.33	11.54
13.	Potassium	2.45	2.55	2.5
14.	Carbonates	3.9	4	3.95
15.	Bicarbonates	10.4	10.36	10.38
16.	Sulphates	120	121.16	120.58
17.	Chlorides	43.84	46.67	45.25
18.	Dissolved organic matter	1.64	1.54	1.59
19.	Nitrates	2.98	3.08	3.03
20.	Nitrites	0.0016	0.0016	0.0016
21.	Organic nitrogen	0.79	0.77	0.78
22.	Ammonia nitrogen	1.58	1.67	1.62
23.	Total kjeldahl nitrogen	7.36	7.59	7.47
24.	Phos pates	1.33	1.29	1.31
25.	Silica	0.12	0.134	0.127
26.	Iron	0.023	0.024	0.023
27.	Total hardness	158.08	163.41	160.74
28.	Total solids	635.33	649.50	642.41

Table 6

Seasonal averages of physico-chemical parameters for the year 1995-96 in Shantisagar lake.

Seasons	Air temperature	Water temperature	pH	Turbidity	Electrical Conductivity	Dissolved Oxygen	Free carbon dioxide
Station I							
Rainy	31.25	28.25	7.15	27.98	198.75	6.53	48.3
Winter	31.05	27.75	7.25	16.28	273.75	6.72	42.33
Summer	37.32	30.25	7.27	29.96	105.25	5.89	30.23
Station II							
Rainy	32.53	28.35	7.12	29.21	140.25	6.76	43.75
Winter	30.85	27.35	7.17	20.3	248.5	7.06	49.93
Summer	37.42	30.57	7.12	34.27	94.25	6.46	28.36
Station III							
Rainy	31.75	29.05	7.17	29.52	148.00	6.97	47.83
Winter	30.92	27.8	7.1	22.53	259.00	6.21	39.64
Summer	37.55	31.00	7.17	36.07	85.2	5.81	28.63
Station IV							
Rainy	31.9	29.22	7.2	22.17	162.00	7.05	52.84
Winter	31.1	27.85	7.07	30.15	256.25	7.15	50.82
Summer	37.6	30.85	7.17	33.95	88.75	6.21	33.48

Table 6.1

Seasonal averages of physico-chemical parameters for the year 1996-97 in Shantisagar lake.

Seasons	Air temperature	Water temperature	pH	Turbidity	Electric al Conductivity	Dissolved Oxygen	Free carbon dioxide
Station I							
Rainy	32.4	29.05	7.15	34.74	180.0	6.43	43.15
Winter	29.72	27.22	7.0	16.85	297.00	6.86	50.83
Summer	36.57	32.27	7.2	21.16	102.75	5.85	45.5
Station II							
Rainy	31.52	28.8	7.12	34.94	140.50	6.96	43.89
Winter	31.2	27.95	7.07	18.31	231.00	7.12	43.58
Summer	37.05	30.82	7.1	33.12	95.75	6.05	28.93
Station III							
Rainy	32.02	29.30	7.2	29.81	146.00	6.89	49.49
Winter	31.17	28.00	7.07	22.91	262.50	6.41	41.95
Summer	37.77	31.15	7.17	36.22	86.5	5.92	28.78
Station IV							
Rainy	31.72	29.27	7.12	22.32	166.25	7.31	52.16
Winter	31.12	27.52	7.15	30.28	265.00	7.12	46.76
Summer	37.9	31.02	7.17	36.85	91.50	5.82	30.65

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Table 6.2**Seasonal averages of physico-chemical parameters for the year 1995-97 in Shantisagar lake**

Seasons	Air temperature	Water temperature	pH	Turbidity	Electrical Conductivity	Dissolved Oxygen	Free carbon dioxide
Station I							
Rainy	31.82	28.65	7.15	31.35	189.37	6.48	45.72
Winter	30.38	27.48	7.12	16.56	285.37	6.79	46.58
Summer	36.94	31.26	7.23	25.56	104.00	5.87	37.86
Station II							
Rainy	32.03	28.57	7.12	32.07	140.37	6.86	43.82
Winter	31.02	27.65	7.12	19.30	239.75	7.09	43.75
Summer	37.23	30.69	7.11	33.69	95.00	6.25	28.64
Station III							
Rainy	31.88	29.18	7.18	29.66	147.0	6.93	48.66
Winter	31.04	27.90	7.08	22.72	260.75	6.31	40.79
Summer	37.66	31.07	7.17	36.14	85.85	5.86	28.70
Station IV							
Rainy	31.81	29.24	7.16	22.24	162.12	7.18	52.80
31.15	31.15	27.68	7.11	30.21	260.25	7.13	48.79
Summer	37.75	30.93	7.17	35.40	90.12	60.01	32.06

Table 6.3

Seasonal averages of physico-chemical parameters for the year 1995-96 in Shantisagar lake.

Seasons	Bio-chemical oxygen demand	Chemical oxygen demand	Calcium	Magnesium	Sodium	Potassium	Carbonates
Station I							
Rainy	1.51	8.22	37.85	32.17	11.00	1.41	---
Winter	1.64	4.85	44.05	27.02	13.75	2.47	1.4
Summer	2.42	9.12	26.20	20.75	8.5	1.55	4.0
Station II							
Rainy	1.85	8.27	38.52	30.57	10.25	1.5	---
Winter	1.40	4.72	43.37	28.30	13.75	2.25	1.2
Summer	2.05	9.07	25.50	21.52	7.25	1.35	4.0
Station III							
Rainy	1.97	8.3	41.75	34.65	12.25	1.55	---
Winter	1.43	4.7	41.13	28.57	14.25	2.55	1.0
Summer	2.02	8.97	26.89	23.99	7.5	1.45	4.0
Station IV							
Rainy	2.0	8.57	43.52	34.67	11.00	2.47	---
Winter	1.82	5.8	40.30	20.92	15.25	3.00	---
Summer	1.6	9.17	27.02	23.31	9.0	1.9	3.9

Table 6.4**Seasonal averages of physico-chemical parameters for the year 1996-97 in Shantisagar lake.**

Seasons	Bio-chemical oxygen demand	Chemical oxygen demand	Calcium	Magnesium	Sodium	Potassium	Carbonates
Station I							
Rainy	1.87	8.15	38.50	29.97	15.75	1.42	—
Winter	1.53	5.1	43.1	31.07	17.75	2.75	1.6
Summer	2.18	9.00	25.87	21.62	9.25	1.4	3.9
Station II							
Rainy	1.7	8.85	38.92	30.37	9.75	1.5	—
Winter	1.27	6.97	43.88	28.91	15.00	2.42	1.4
Summer	1.85	9.55	28.23	21.98	8.00	1.35	3.6
Station III							
Rainy	1.99	8.57	42.41	35.68	11.75	1.45	—
Winter	1.51	5.55	40.43	29.18	15.00	2.45	1.2
Summer	2.014	8.85	26.87	27.94	7.50	1.6	4.1
Station IV							
Rainy	2.02	8.52	42.57	35.11	9.0	2.57	—
Winter	1.87	6.05	42.97	22.95	15.75	3.1	—
Summer	1.7	8.3	29.51	23.44	9.25	2.0	4.0

Table 6.5

Seasonal averages of physico-chemical parameters for the year 1995-97 in Shantisagar lake.

Seasons	Bio-chemical oxygen demand	Chemical oxygen demand	Calcium	Magnesium	Sodium	Potassium	Carbonates
Station I							
Rainy	1.69	.18	38.17	31.07	13.37	1.44	--
Winter	1.58	4.97	43.57	29.04	15.75	2.59	1.5
Summer	2.3	9.06	26.03	21.18	8.87	1.47	3.95
Station II							
Rainy	1.77	8.56	38.72	30.47	10.00	1.50	--
Winter	1.33	5.84	43.62	28.60	14.37	2.36	1.3
Summer	1.95	9.31	26.86	21.75	7.62	1.35	3.8
Station III							
Rainy	1.98	8.43	42.11	35.16	14.25	1.5	--
Winter	1.47	5.12	40.78	28.87	14.62	2.50	1.1
Summer	2.01	8.91	26.88	24.46	7.5	1.52	4.05
Station IV							
Rainy	2.01	8.54	43.04	34.89	10.00	2.52	--
Winter	1.84	5.92	41.63	21.93	15.50	3.05	--
Summer	1.65	8.73	28.26	23.37	9.12	1.95	3.95

Table 6.6

Seasonal averages of physico-chemical parameters for the year 1995-96 in Shantisagar lake.

Seasons	Bicarbonate	Sulphate	Chloride	Dissolved organic matter	Nitrate	Nitrite	Organic nitrogen
Station I							
Rainy	7.14	96.74	31.10	0.45	3.67	0.001	0.85
Winter	3.2	88.5	18.02	1.73	3.32	0.001	0.68
Summer	7.95	128.75	49.98	0.74	2.25	0.0017	0.80
Station II							
Rainy	9.0	106.75	34.78	0.947	3.65	0.001	0.88
Winter	10.37	85.75	23.46	2.03	3.2	0.001	0.77
Summer	10.77	132.00	51.29	0.907	2.52	0.001	0.75
Station III							
Rainy	9.1	75.5	39.47	1.03	3.65	0.002	0.89
Winter	10.45	88.25	23.92	2.16	3.3	0.001	0.82
Summer	10.97	137.75	54.41	1.01	2.42	0.002	0.76
Station IV							
Rainy	9.7	131.00	47.55	1.23	3.45	0.003	0.92
Winter	10.72	92.25	27.49	2.76	3.07	0.001	0.68
Summer	10.77	136.75	77.95	0.92	2.42	0.002	0.77

Table 6.7

Seasonal averages of physico-chemical parameters for the year 1996-97 in Shantisagar lake.

Seasons	Bicarbonate	Sulphate	Chloride	Dissolved organic matter	Nitrate	Nitrite	Organic nitrogen
Station I							
Rainy	7.75	110.25	30.79	0.53	3.72	0.002	0.80
Winter	3.52	90.25	20.19	1.69	3.35	0.001	0.86
Summer	79.42	130.00	49.64	0.84	2.67	0.002	0.77
Station II							
Rainy	8.87	106.25	36.40	0.935	3.55	0.001	0.92
Winter	10.47	84.75	22.39	2.04	3.4	0.001	0.78
Summer	10.37	130.50	51.66	0.89	2.5	0.002	0.60
Station III							
Rainy	9.1	109.00	41.53	1.05	3.80	0.001	0.932
Winter	10.52	91.25	24.73	2.34	3.4	0.001	0.73
Summer	10.65	140.5	61.19	0.98	2.45	0.002	0.74
Station IV							
Rainy	9.85	124.00	47.56	1.04	3.32	0.003	0.90
Winter	10.62	95.50	26.13	2.67	3.45	0.001	0.67
Summer	10.70	144.00	66.34	0.92	2.52	0.001	0.75

Table 6.8

Seasonal averages of physico-chemical parameters for the year 1995-97 in Shantisagar lake.

Seasons	Bicarbonate	Sulphate	Chloride	Dissolved organic matter	Nitrate	Nitrite	Organic nitrogen
Station I							
Rainy	7.44	103.50	30.94	0.49	3.69	0.001	0.82
Winter	3.36	89.37	19.10	1.71	3.33	0.001	0.77
Summer	8.68	129.37	49.81	0.79	2.64	0.001	0.78
Station II							
Rainy	8.93	106.50	35.59	0.94	3.61	0.001	0.90
Winter	10.42	85.25	22.92	2.03	3.3	0.001	0.77
Summer	10.57	131.25	51.47	0.89	2.41	0.001	0.67
Station III							
Rainy	9.1	92.25	40.5	1.04	3.72	0.001	0.91
Winter	10.48	89.75	24.32	2.25	3.35	0.001	0.77
Summer	10.81	139.12	57.8	0.99	2.43	0.002	0.75
Station IV							
Rainy	9.75	127.5	47.55	1.13	3.38	0.003	0.91
Winter	10.67	93.87	26.81	2.71	3.26	0.001	0.675
Summer	10.73	140.37	72.14	0.92	2.47	0.001	0.78

Table 6.9

Seasonal averages of physico-chemical parameters for the year 1995-96 in Shantisagar lake.

Seasons	Ammonia nitrogen	Total kjedahl nitrogen	Phosphate	Silica	Iron	Total hardness	Total solids
Station I							
Rainy	1.42	6.4	1.08	0.08	0.014	165.75	538.5
Winter	1.95	8.32	0.90	0.06	0.021	160.00	655.00
Summer	0.77	5.12	1.44	0.15	0.018	84.75	546.5
Station II							
Rainy	1.66	7.92	0.98	0.12	0.023	165.75	577.00
Winter	2.34	6.82	0.89	0.107	0.025	162.00	750.25
Summer	0.815	4.77	1.27	0.145	0.019	88.75	569.5
Station III							
Rainy	1.60	7.1	1.04	0.12	0.0155	189.00	599.5
Winter	1.75	6.2	0.967	0.105	0.0215	168.00	784.00
Summer	0.78	4.52	1.45	0.14	0.015	96.5	598.5
Station IV							
Rainy	1.87	8.27	1.42	0.13	0.021	204.25	608.25
Winter	1.99	7.87	0.995	0.09	0.025	173.5	719.5
Summer	0.87	5.95	1.57	0.165	0.023	96.5	578.25

Table 7

Seasonal averages of physico-chemical parameters for the year 1996-97 in Shantisagar lake.

Seasons	Ammonia nitrogen	Total Kjeldahl nitrogen	Phosphate	Silica	Iron	Total hardness	Total solids
Station I							
Rainy	1.33	5.97	1.08	0.08	0.014	165.75	538.5
Winter	2.07	8.37	0.90	0.06	0.021	160.00	655.00
Summer	0.96	5.1	1.44	0.15	0.018	84.75	546.5
Station II							
Rainy	1.41	8.05	0.97	0.107	0.024	166.00	582.00
Winter	2.28	7.12	0.86	0.102	0.027	159.75	757.5
Summer	0.867	4.95	1.37	0.147	0.02	95.5	561.00
Station III							
Rainy	1.58	8.1	1.1	0.135	0.02	196.75	615.25
Winter	1.64	7.35	0.99	0.10	0.019	175.5	774.5
Summer	0.845	5.05	1.42	0.14	0.015	100.75	597.75
Station IV							
Rainy	1.78	8.0	1.45	0.14	0.026	213.25	612.75
Winter	2.27	8.67	1.01	0.09	0.023	181.5	754.75
Summer	0.96	6.1	1.29	0.16	0.25	95.5	580.00

Table 7.1

Seasonal averages of physico-chemical parameters for the year 1995-97 in Shantisagar lake.

Seasons	Ammonia nitrogen	Total kjedahl nitrogen	Phosphate	Silica	Iron	Total hardness	Total solids
Station I							
Rainy	1.37	6.18	1.10	0.09	0.015	162.12	544.87
Winter	2.01	8.34	0.93	0.06	0.022	162.5	642.87
Summer	0.86	5.11	1.49	0.145	0.0175	83.12	586.25
Station II							
Rainy	1.53	7.98	0.975	0.11	0.0235	165.87	579.00
Winter	2.31	6.97	0.875	0.103	0.026	160.87	753.87
Summer	0.841	4.86	1.32	0.104	0.0195	92.12	565.25
Station III							
Rainy	1.59	7.6	1.07	0.125	0.017	192.87	607.37
Winter	1.69	6.77	0.978	0.10	0.02	171.75	779.25
Summer	0.81	4.78	1.43	0.14	0.015	98.62	598.12
Station IV							
Rainy	1.82	8.27	1.43	0.135	0.023	208.75	610.5
Winter	2.13	8.13	1.002	0.09	0.024	177.5	737.12
Summer	0.91	6.02	1.43	0.162	0.024	96.0	579.62

BIOLOGICAL ANALYSIS

Society's basic interest in pollution is owing to its effects on living organisms; hence the assessment of pollution is basically a biological problem. Yet the assessment of pollution has traditionally been chemically oriented and biological aspects have been either omitted or put in a subsidiary position. The reason for doing so have been (i) Physico-chemical data are amenable to numerical descriptions but much of the biological information has been non-quantitative in nature.

(ii) Biological data collection has been tedious and expensive, especially in developing countries. However, the biological information entails a number of advantages:

1. The damage to an aquatic ecosystem is caused by different kinds of pollutants. The estimation of all of them is extremely difficult at one time. The organisms through their presence, number and behaviour can integrate the whole effect.
2. Many chemical pollutants produce adverse biological reactions at concentrations below the present analytical capabilities.
3. Organisms tend to preserve the past effect of a waste discharge or any other ecological perturbation, even if the source of pollution is removed.

However, the need for Physico-chemical data is important. Infact, the chemical data measures the concentration of pollutants but the degree of ecosystem imbalance is measured by biological information. It must be borne in mind that the biological and chemical data cannot replace each other. The biological analysis is used mainly in finding out:

(i) Bio-indicators of water pollution.

(ii) To measure the efficiency of water and waste water treatment plants.

(iii) To understand the biological disturbance caused by water pollution. This in widest sense has been referred as bio-monitoring.

Identification of organisms in various types of water indicates degree of pollution. For e.g. presence of species such as Oscillatoria agardhii, Nitzschia palea and Chironomid larvae indicate organic pollution.

Algae such as Spirogyra, Pithophora and Cladophora lead to loss of recreational value of fresh water.

Species such as Microcystis, Oscillatoria, Aphanizomenon, Spirulina, Arthrospira, Lyngbya, Phormidium, Chlorella, Gomphonema, Scenedesmus, Spirogyra, Chlamydomonas, Pandorina, Nitzschia, Euglena and Phacus indicate organic pollution.

Cyclotella ocellata and Melosira islandica and many desmids indicate purity of water.

BIOLOGICAL CHARACTERISTICS

Distribution and periodicity of phytoplankton:

The phytoplankton form the basic bulk of food material for all the aquatic organisms including zoo-plankton. Many a times, the periodicity and distribution of phytoplankton goes a long way in identifying rich fish yield in the given waterbody. Infact, some of the fish species are very specific in their feeding habit in the sense that they feed exclusively on one particular group of phytoplankton.

It is rather very difficult to study the periodicity and distribution of all the phytoplankton occurring in a given ecosystem together. Hence, it is always convenient to study them individually for their behaviour and occurrence. It is with this background that the phytoplankton recorded are discussed individually.

The phytoplankton recorded during the period of study are classified into five i.e., Chlorococcales, Desmids, Diatoms, Euglenoids and Blue greens.

Chlorococcales: (Figs. 29, 29.1, 29.2 and 29.3) (Table 8).

Chlorococcales, one of the orders of chlorophycean group includes unicellular and colonial forms. The ecology of chlorococcales has been studied by many researchers of which the contributions of Singh (1960); Zafar (1967); Munawar (1974) and Singh and Swarup (1979) are very important with regard to Indian fresh water bodies.

Singh (1960) and Munawar (1974) are of the opinion that high temperature favours the abundance of chlorococcales. Jyothi *et al.*, (1990) have also concluded that high temperature with bright sunshine triggers the abundance of these organisms.

In the present investigation the water and air temperature was found to be more than 30° C at all the stations. With regard to the abundance of Chlorococcales, it was noted that they reached their peak during summer (Table 8.1) with an appreciable rise in temperature indicating the fact that the higher range of temperature favours the abundance of chlorococcales as has been concluded by the above researchers. On the contrary, Zafar (1967) is of the opinion that lower temperature during winter supports the luxuriant growth of chlorococcales. When this is applied to the present study it is found that winter relatively shows chlorococcales in lesser numbers as compared to summer indicating that our observations are at variance with that of Zafar (1967). (Table 8.1).

Gonzalves and Joshi (1946), Zafar (1964) and Munawar (1974) are of the opinion that alkaline pH and low concentration of calcium favour the abundance of chlorococcales. In the present study also these factors have a great bearing on the regulation of chlorococcales population wherein their number reached its peak of 6488 o/l. during summer at station II with alkaline pH and low calcium concentration (Table 8).

Singh and Swarup (1979) and Nandan and Patel (1985) have stated that the chlorococcales are favoured by high concentration of dissolved oxygen and low concentration of organic matter. However, in the present study no such correlation could be established as the density of chlorococcales was more during summer when the dissolved oxygen concentration was low (Figs. 29, 29.1, 29.2 and 29.3). Zafar (1967) opined that magnesium exhibits an inverse relationship with chlorococcales. However, Munawar (1974) is of the opinion that there is no such relationship. It is quite interesting to note that the concentration of magnesium was relatively low during summer when the

population of chlorococcales was at its peak. Hence, the present observations go hand in hand with the findings of Munawar (1974).

Venkateswarlu (1981); Hegde and Bharathi (1983) and Singh (1985) are of the opinion that phosphates and chlorococcales show a positive correlation which is also true in the present investigations.

Munawar (1974) has stated that the low nitrate concentration favours the luxuriant growth of chlorococcales in summer. In the present investigation also a similar relationship has been noted.

The statistical correlation has revealed that the chlorococcales have a positive correlation with temperature, sulphate, phosphates and silica and negative correlation with dissolved oxygen, carbon dioxide, calcium, magnesium and nitrates. However, factors such as carbonates, bicarbonates and iron do not have any bearing on the chlorococcalean population (Correlation matrix II).

Periodicity: (Tables 8.1, 8.2 and 8.3)

In all, 11 genera and 28 species of chlorococcales have been recorded during the entire period of investigation. Of the 11 genera, Scenedesmus, Pediastrum and Tetraedon were found to be more dominant at all the stations (Table 8.3). With regard to their number they reached their maximum of 5998 o/l during May 1995 and their number reduced to 2189 o/l in the month of September 1996 at Station I. A peak of 7125 o/l was recorded in the month of May 1995 at Station II while their lowest population was observed during Sept 1996 i.e., 3296 o/l. Interestingly, in the other two stations too, a similar situation was observed with May recording the highest number of organisms.

Seasonally, chlorococcales were found to be dominant during summer and their population declined towards winter (Table 8.1).

To conclude high temperature, phosphate, alkaline pH coupled with low dissolved oxygen, calcium, magnesium, nitrate and low organic matter favour the abundance of chlorococcales. Also, carbonates, bicarbonates and iron have no significant bearing on the chlorococcales. Seasonwise, chlorococcales occurred abundantly during summer.

Table - 8

**Two yearly averages of certain related physico-chemical parameters to
Chlorococcales (mg/l) 1995-97 in Shantisagar lake.**

Parameters	Station I	Station II	Station III	Station IV
Water temperature	29.12	28.97	29.30	29.28
pH	7.15	7.12	7.15	7.15
Dissolved oxygen	6.38	6.73	6.79	7.17
Calcium	35.93	36.40	30.78	37.62
Magnesium	27.10	26.94	29.07	26.73
Nitrate	3.21	3.14	2.87	3.03
Dissolved organic matter	0.999	1.29	1.40	1.59

Fig. 29 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND CHLOROCOCCALES AT STATION - I

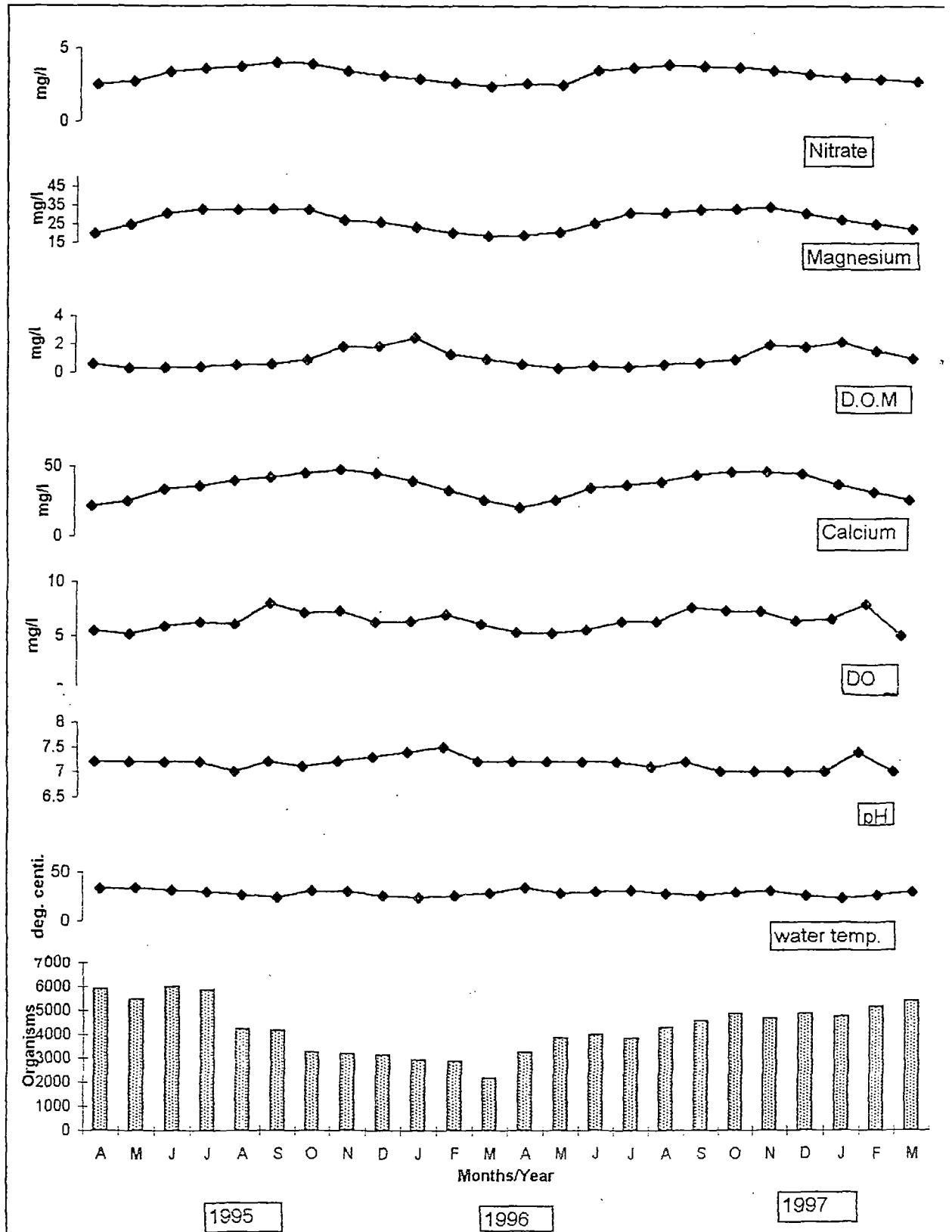


Fig. 29.1 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND CHLOROCOCCALES AT STATION - II

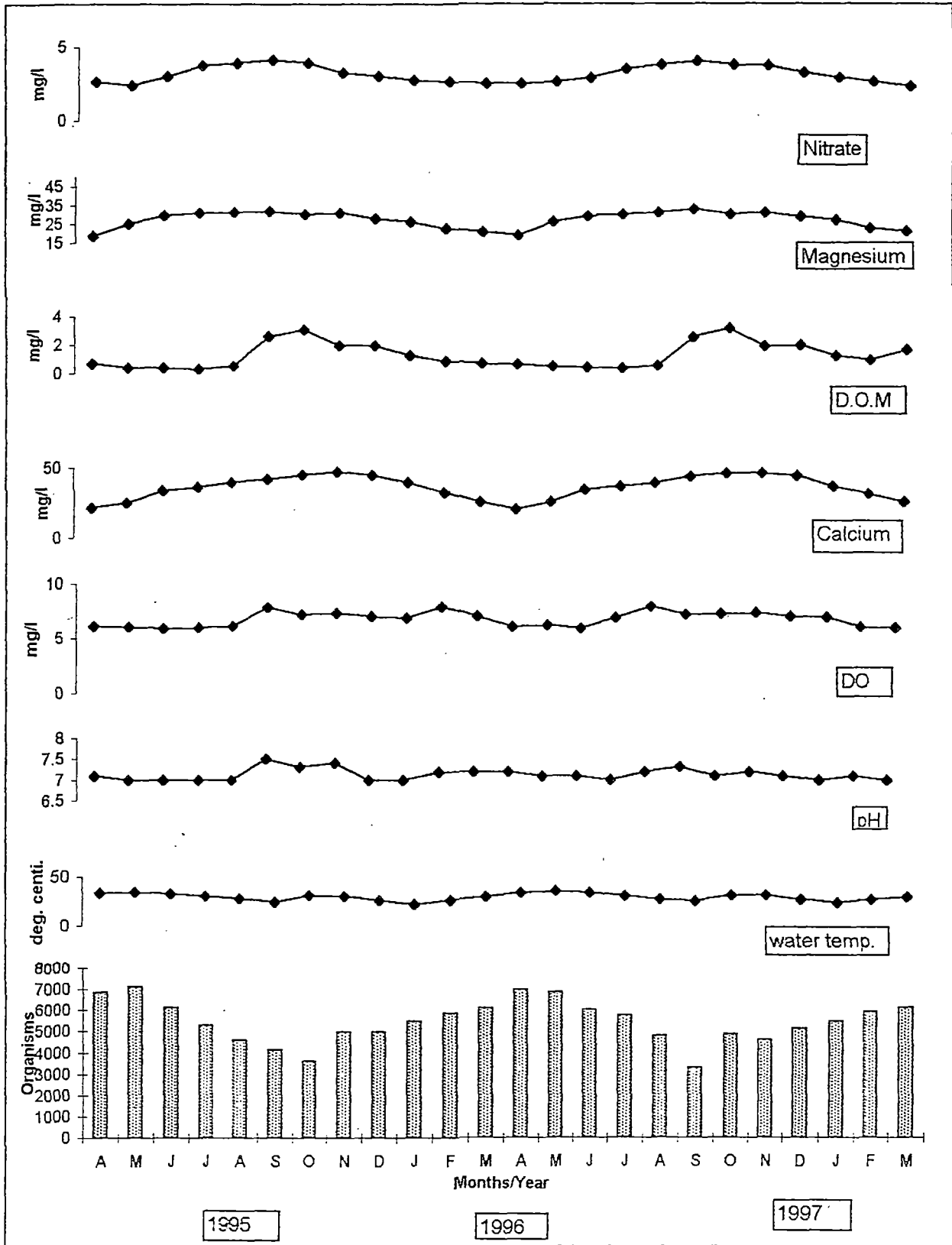


Fig. 29.2 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND CHLOROCOCCALES AT STATION - III

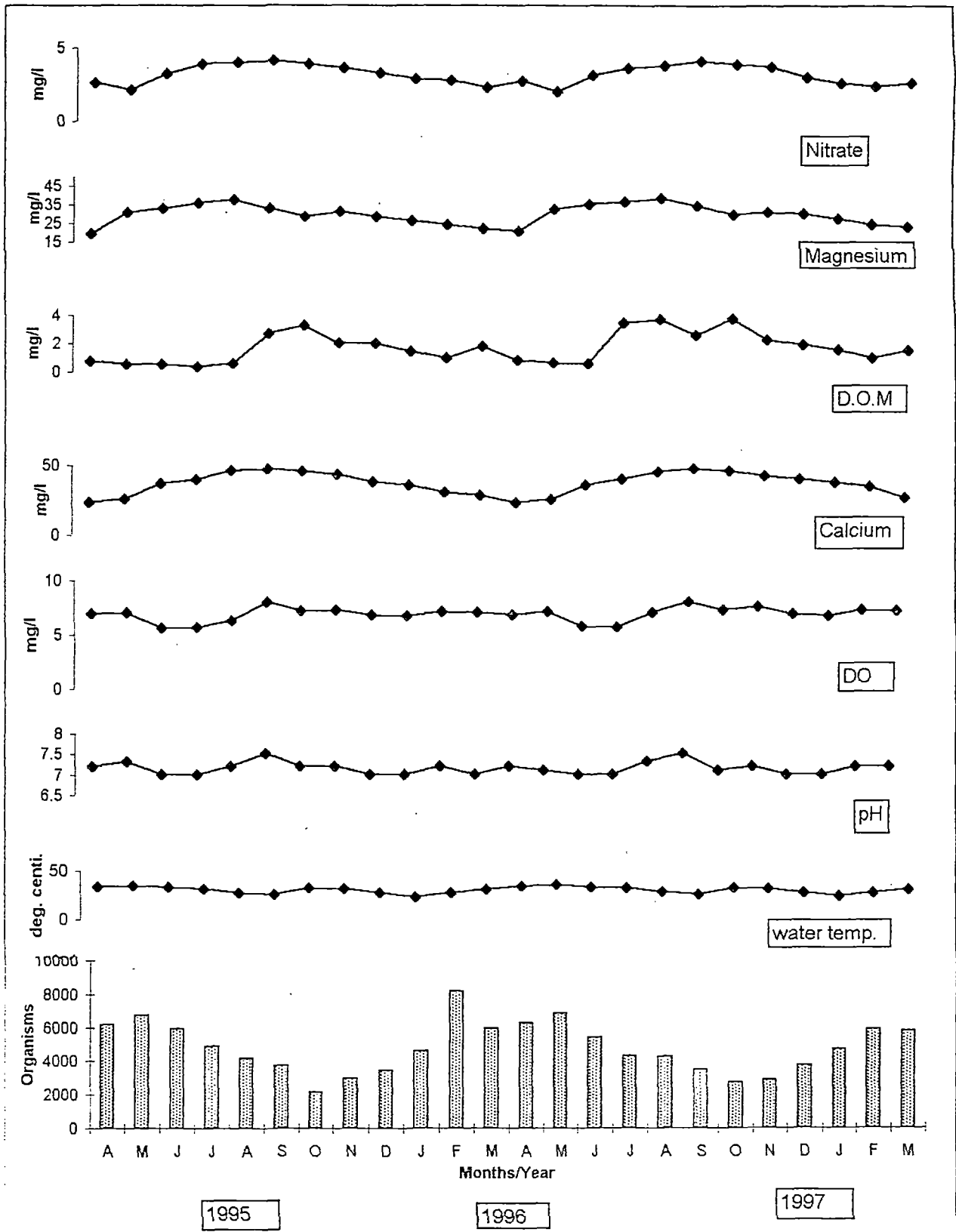


Fig. 29.3 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND CHLOROCOCCALES AT STATION - IV

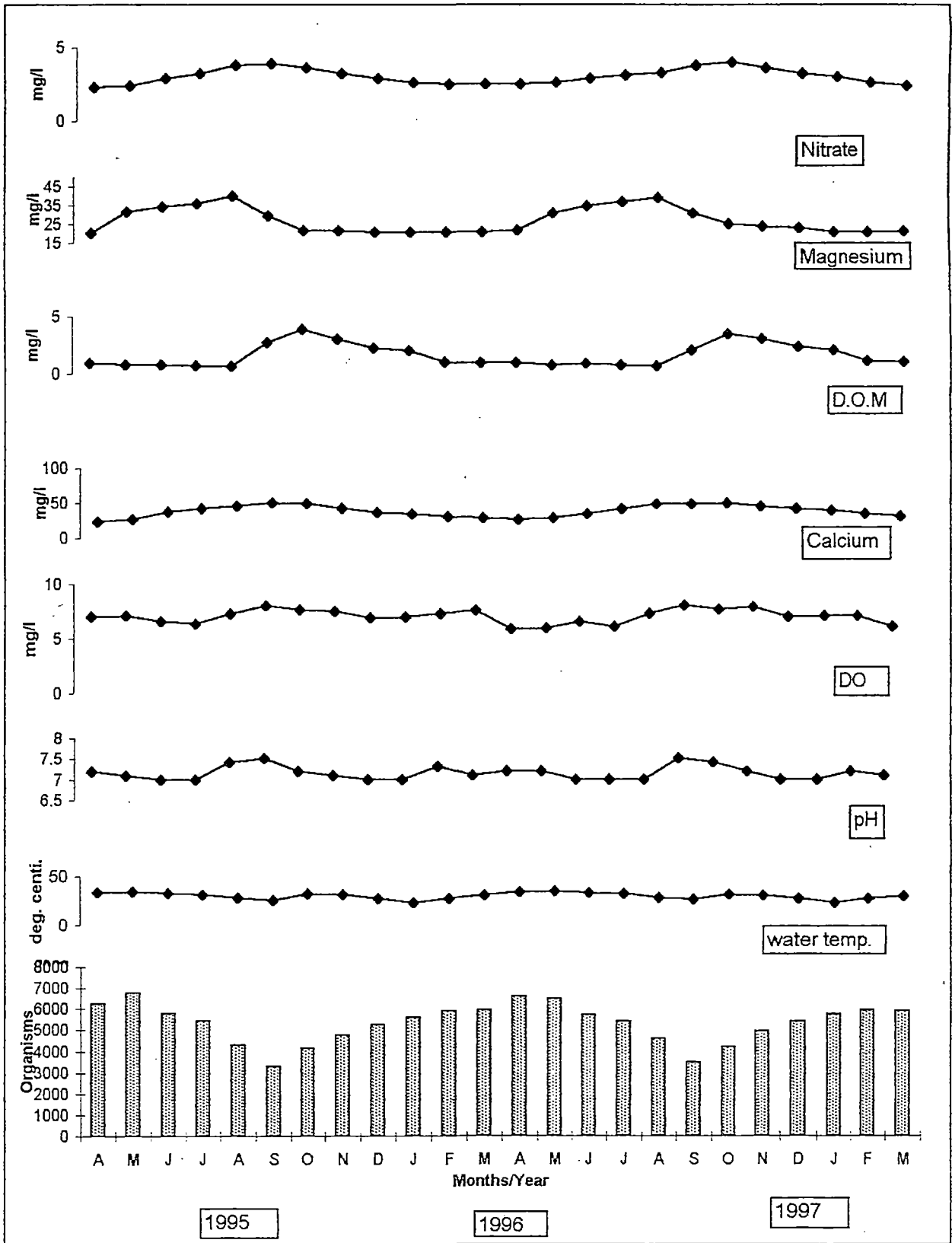


Table 8.1**Seasonal averages of Chlorococcales in Shantisagar lake (1995-97)**

Seasons	Station I			Station II		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	3370.5	3119.75	3245.125	5.36	4964.75	5000.37
Winter	4100.25	4234.75	4167.5	4763.75	5016	4889.87
Summer	5476.25	5364.5	5420.375	6488.75	6478.75	6483.75

Seasons	Station III			Station IV		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	4672.75	3119.75	3896.25	4691.75	4781.75	4736.75
Winter	3282.5	4234.75	3758.62	4932.25	5076	5004.12
Summer	6017.25	5364.5	5690.87	6218.25	6213	6215.62

Table - 8.2

**Yearly and two yearly occurrence of chlorococcales in
Shantisagar lake.**

Stations	1995-96	1996-97	1995-97
Station I	51767	50876	102644
Station II	65152	65838	130990
Station III	55890	56314	112204
Station IV	63372	64283	127655

Table 8.3

Occurrence of Chlorococcales at four stations in Shantisagar lake during April 1995 to March 1997.

Group	Stations			
	I	II	III	IV
Chlorococcales				
1. <u>Scenedesmus quadricauda</u> var. <u>maxima</u>	CC	CCC	CCC	C
2. <u>Ankistrodesmus falcatus</u> (Corda) Ralfs	C	CC	-	-
3. <u>Ankistrodesmus spiralis</u> (Turner) Lemm. V fasciculatus	CC	r	C	-
4. <u>Closteriopsis longissima</u> Lemm	C	CC	C	-
5. <u>Scenedesmus platidiscus</u>	CC	CCC	r	C
6. <u>S. dimorphous</u>	C	CC	CC	-
7. <u>S. protuberans</u>	C	CCC	-	CC
8. <u>S. quadricauda</u> (Turpin) Bre' b var. <u>quadrispina</u>	CC	r	CC	C
9. <u>S. arcuatus</u>	CCC	CC	-	-
10. <u>S. accuminatus</u>	CC	C	r	r
11. <u>S. bijugatus</u> var. <u>bicellularis</u>	C	CC	C	r
12. <u>Selenastrum gracile</u>	CC	CCC	CC	-
13. <u>S. westlii</u>	CC	CC	r	-
14. <u>Tetraedon caudatum</u>	C	CC	r	r
15. <u>Pediastrum simplex</u>	CC	CCC	C	C

Group	Stations			
	I	II	III	IV
16. <u>P. duplex</u> var. <u>clathratum</u>	CC	C	CC	-
17. <u>P. duplex</u> var. <u>reticulatum</u>	C	CC	C	C
18. <u>Gonatozygon kinahanii</u>	r	C	C	-
19. <u>Tetraedon muticon</u>	CC	C	CC	C
20. <u>T. minimum</u>	C	CC	C	r
21. <u>Microactinium pussillum</u>	r	C	r	-
22. <u>Coelastrum microporum</u>	CC	C	C	C
23. <u>Tetrastrum heterocanthum</u>	C	r	-	-
24. <u>Crucigenia crucifera</u>	C	CCC	CC	C
25. <u>Pediastrum tetras</u> var. <u>tetraedon</u>	CC	CCC	C	-
26. <u>P. duplex</u> var. <u>coronatum</u>	CC	CC	r	-

CCC = 500 (above)

CC = 100 - 500

C = 50 - 100

r = rare

- = absent.

Desmids: (Figs. 30, 30.1, 30.2 and 30.3) (Table 9)

The occurrence of desmids in an aquatic ecosystem is of prime importance as they are the organisms which act as indicators of water quality. They are very sensitive organisms which upon a slight change in water quality due to input of pollutants perish. Since the time of West and West (1909) it has become clear that water supporting desmids are chemically distinct from those harbouring Myxophyceae and Diatoms.

Extensive studies on Indian desmids have been carried out by Iyengar and Nirmalabai (1941); Gonzalves and Joshi (1946); Suxena and Venkateswarlu (1966 and 1970); Philipose (1960); Munawar (1970); Hedge and Bharathi (1983); Hedge (1986); Hedge and Karanth (1987) and Pisolkar *et al.*, (1992).

Several factors govern the occurrence and distribution of desmids in lakes. Zafar (1967) is of the opinion that pH around neutrality coupled with low concentration of calcium and magnesium favour the growth of desmids while Rao (1975) has reported that dissolved organic matter and desmid population have an inverse relationship. Hedge and Bharathi (1985) have observed that higher concentration of calcium, bicarbonates, dissolved organic matter and low concentration of dissolved oxygen have deleterious effect on the desmid population.

In the present study the pH was found to be alkaline (Tables 2, 3, 4 and 5), supporting a desmid population of 287 o/l. Zafar (1967) and Pandey and Pandey (1980) have observed that water temperature in the range of 20-30 ° C promotes the growth of desmids. However, in the present study the water temperature was invariably greater than 34 °C thus harbouring a lesser number of desmids. Therefore, the present findings

are in agreement with Seenayya (1971 b) who pointed out that temperature of a waterbody is not a critical factor for the growth of desmid population.

The concentration of calcium in the present study ranged between 20.4 to 49.78 mg/l which is considerably high. Hence, the desmid population is quite poor. Nevertheless, Munawar (1970) has pointed out that the desmids respond quite irregularly towards calcium mainly because he studied the waterbodies that contained high as well as low concentration of calcium favouring a dense population of desmids. Hence, in the present study a higher concentration of calcium had a negative effect on the desmid population.

Hedge and Bharathi (1985), Bowling and Tyler (1988); Pisolkar *et al.*, (1992) and Vaishya and Adoni (1992) have concluded that total solids play a vital role in promoting desmid population and the two exhibit a positive relationship. In the present study, the concentration of total solids varied from 486 - 857 mg/l inspite of which the desmid population was less.

If the nitrates and phosphates as factors are taken into account, it is found that the concentration of phosphate is relatively high whereas nitrate concentration is rather low. Hence, these two factors cannot be correlated with the distribution and abundance of desmids. This is in conformity with the observations of Venkateswarlu (1986).

If the seasonal averages are taken into consideration it is found that desmid population is more during summer.(Table 9.1).

The statistical analysis reveals that desmids have a positive significant correlation with sulphates, chlorides, nitrates and silica and a significant negative correlation with electrical conductivity, dissolved oxygen, free carbondioxide, calcium, magnesium,

potassium, dissolved organic matter, ammonia-nitrogen, total hardness and total solids. However, it is independent of water temperature, carbonates, bicarbonates and iron. (correlation matrix II).

In the present study it has been noted that myxophycean population inhibited the abundance of desmids. Such an antagonistic behavior between the two groups was observed by Seenayya (1971), Hedge and Bharathi (1981) and Vaishya and Adoni (1992).

Periodicity: (Tables 9.1, 9.2 and 9.3)

The lake under study was represented by a total of 7 genera and 31 species of desmids of which Closterium and Cosmarium species were dominant. The Closterium species were represented by Closterium gracile, C. acutum, C. parvulum, C. asciculariae and the Cosmarium species by Cosmarium protuberans, C. depressum, C. granatum, Euastrum serratum, Pleurotaenium eugineum, Penium cucurbitinum, Staurastrum sebaldi, Desmidium bailey occurred as rare forms.

The desmids reached their peak during summer with 242 o/l at station I during April 1995, 287 o/l at station II during May 1995, 219 o/l during March 1997 at Station III and 242 o/l at station IV during May 1995. Their least population was recorded during October at all the stations.

Hence, from the foregoing observations it can be concluded that high calcium concentration, high concentration of phosphates and alkaline pH coupled with low concentration of nitrates are responsible for the low desmid population. Moreover, the desmids were found in abundance during summer with high species diversity.

Table - 9

Two yearly averages of certain related physico-chemical parameters to Desmids

(mg/l) 1995-97 in Shantisagar lake.

Parameters	Station I	Station II	Station III	Station IV
Water temperature	29.12	28.97	29.30	29.28
pH	7.15	7.12	7.15	7.15
Calcium	35.93	36.40	30.78	37.62
Phosphate	1.17	1.055	1.145	1.31
Nitrates	3.21	3.14	2.87	3.03

Fig. 30 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND DESMIDS AT STATION - I

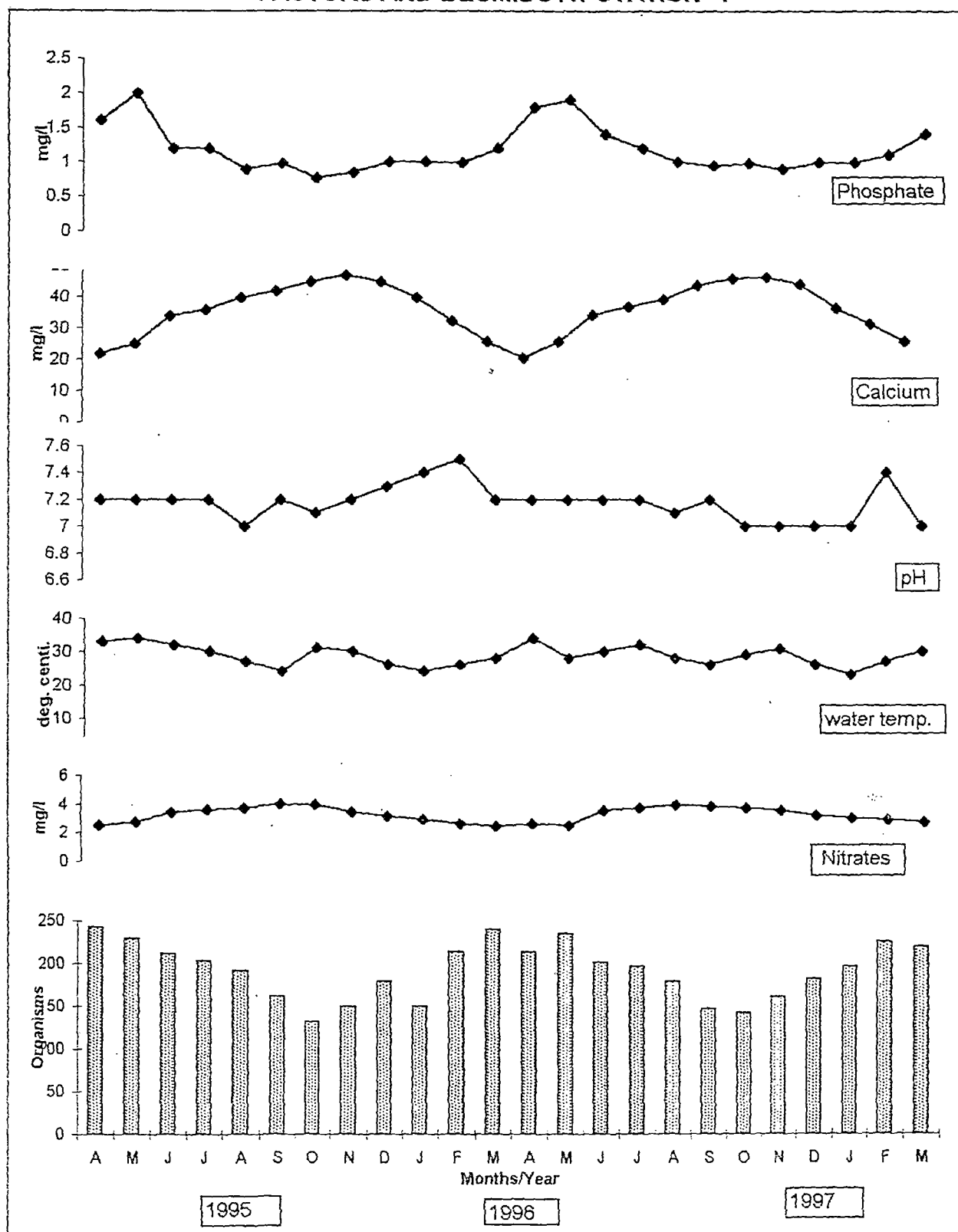


Fig. 30.1 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND DESMIDS AT STATION - II

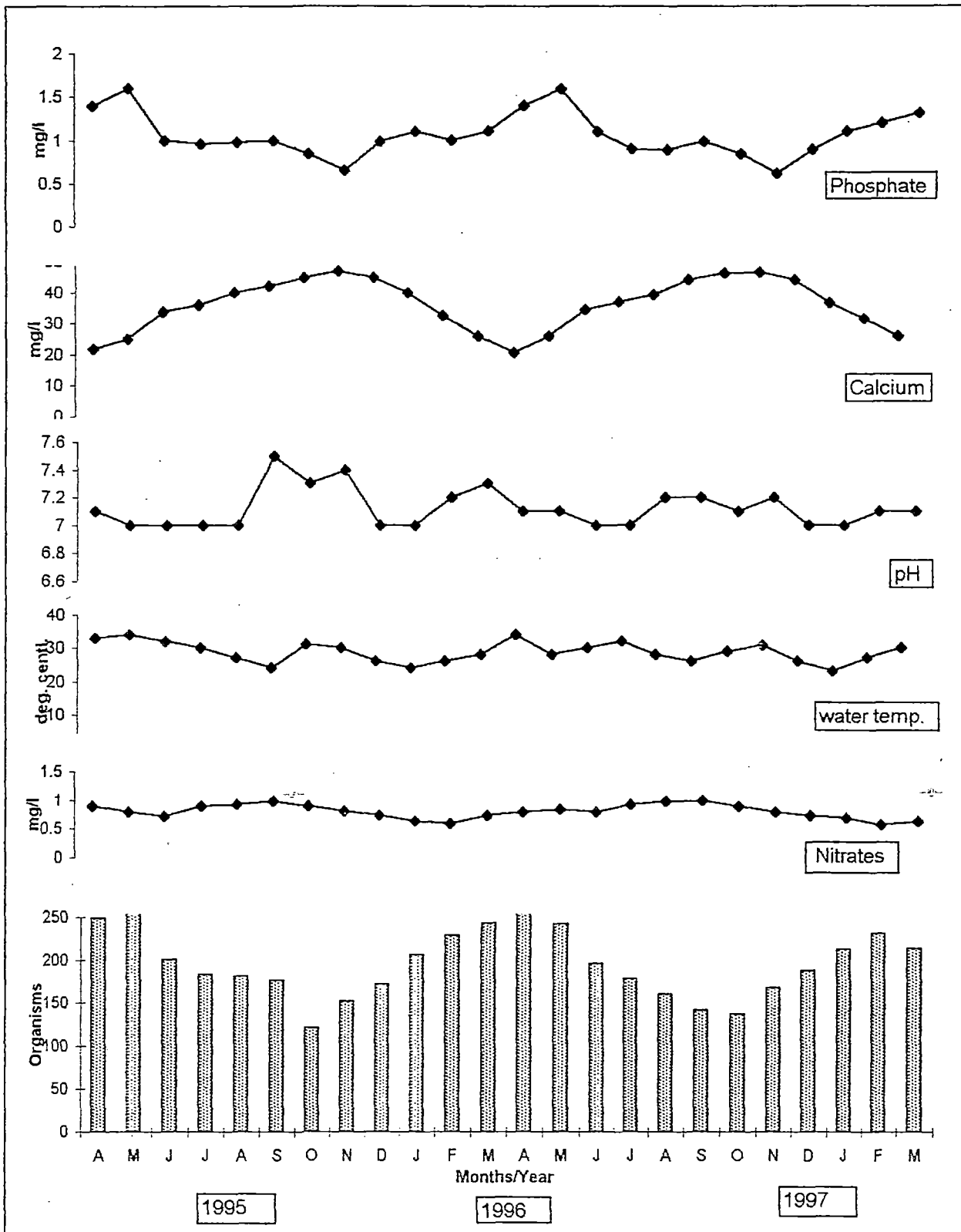


Fig. 30.2 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND DESMIDS AT STATION - III

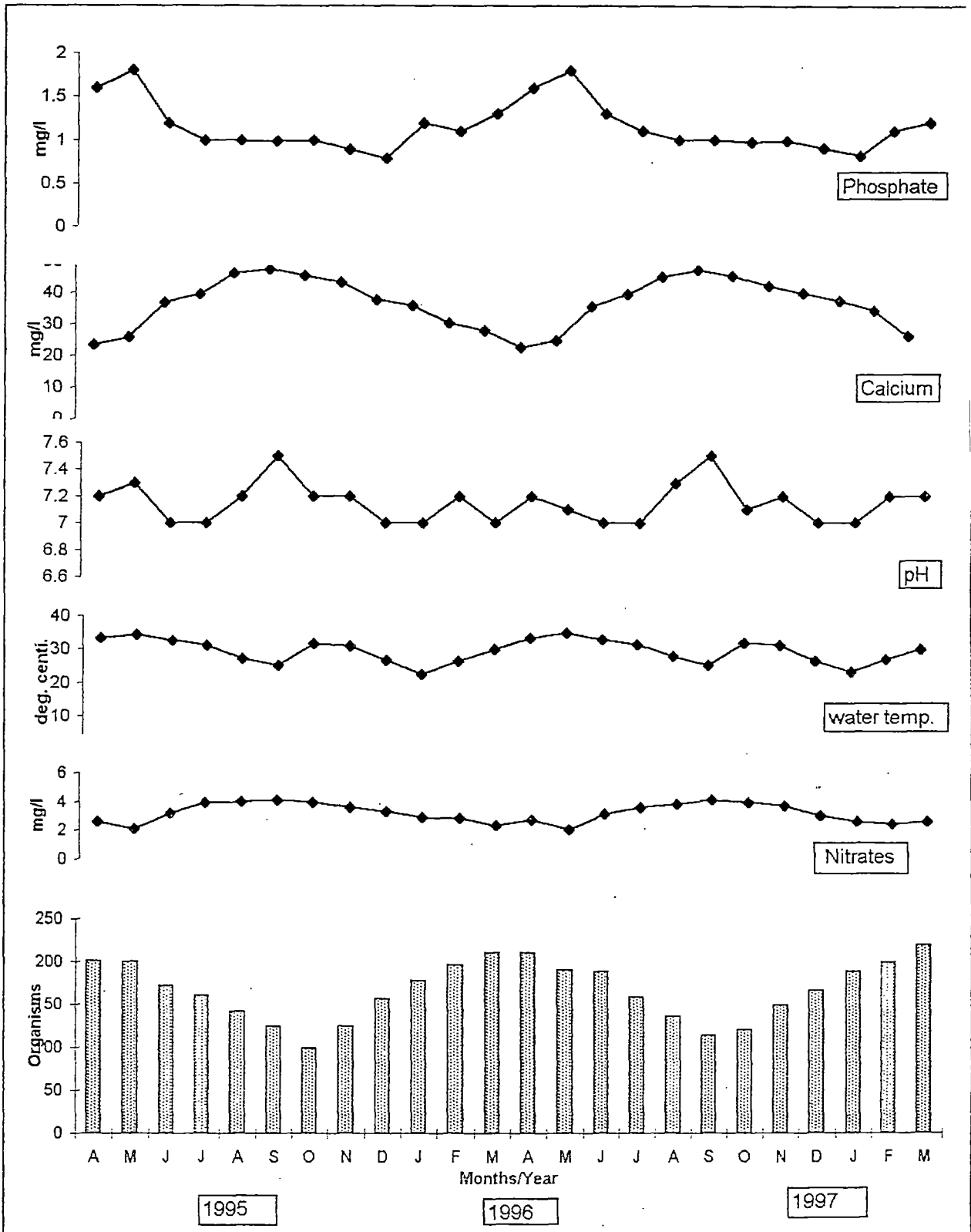


Fig. 30.3 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND DESMIDS AT STATION - IV

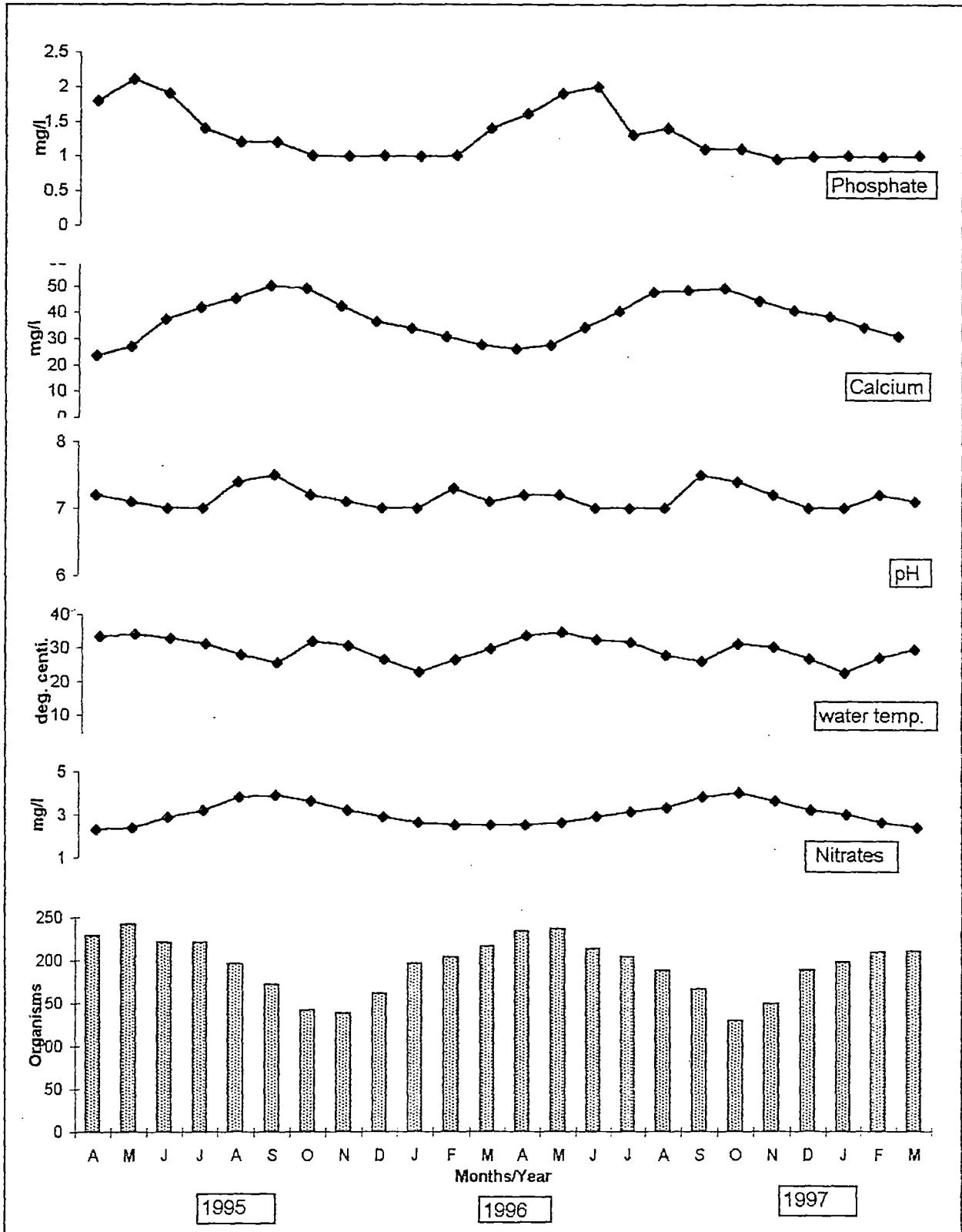


Table 9.1

Seasonal averages of Desmids in Shantisagar lake (1995-97)

Seasons	Station I			Station II		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	192.25	180.75	186.5	186	169.5	177.75
Winter	152	170.25	161.125	163	108.75	135.87
Summer	231	223.25	227.125	252	238.25	245.12

Seasons	Station III			Station IV		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	150	180.75	165.37	202.5	193.5	198
Winter	139.75	170.25	155	159.5	166.25	162.87
Summer	202	223.25	212.62	222.75	223	222.87

Table 9.2

**Yearly and two yearly occurrence of Desmids in
Shantisagar lake.**

Stations	1995-96	1996-97	1995-97
Station I	2301	2297	4598
Station II	2404	2340	4744
Station III	1967	2044	4011
Station IV	2339	2331	4670

Table 9.3

Occurrence of Desmids at four stations in Shantisagar lake during April 1995 to March 1997

Group	Stations			
	I	II	III	IV
1. <u>Closterium acutum</u> (Lyngb) Breb	r	C	r	-
2. <u>C. gracile</u>	-	C	-	-
3. <u>C. ehrenbergii</u> Menegh	r	C	r	r
4. <u>C. parvulum</u> nag	r	C	-	r
5. <u>Euastrum serratum</u>	r	r	r	-
6. <u>Cosmarium protuberans</u>	C	C	r	r
7. <u>C. portianum</u> var. <u>nephroroideum</u> witt	r	C	C	r
8. <u>C. blyttii</u> wille. v. <u>novae silvae</u> w. et G.S. West	r	C	r	r
9. <u>Closterium acerosum</u> (schrank) Ehreno	C	c	r	r
10. <u>C. lunula</u> (Mull.) Nitzsch	r	C	r	-
11. <u>C. remarginatum</u>	r	C	r	-
12. <u>C. subtrigosum</u>	r	r	r	r
13. <u>Cosmarium quadrum</u> Lund. v. minus Nordst	r	C	C	r
14. <u>Euastrum pseudospinolasum</u> Hegde et Malamnavar	r	r	-	-
15. <u>Cosmarium depressum</u> Nag. f. <u>minor</u> .f. <u>nova</u>	r	C	-	-
16. <u>Pleurotaenium euginium</u>	r	r	r	r

Group	Stations			
	I	II	III	IV
17. <u>Penium cucurbitinum</u> Birs	r	r	-	-
18. <u>Staurostrum sebaldi</u> Reinsch	r	C	r	r
19. <u>S. cuspidatum</u> Breb	r	C	r	r
20. <u>Euastrum sublobatum</u> Breb.	r	r	r	-
21. <u>Closterium lineatum</u> Breb	C	C	r	r
22. <u>C. arcuatum</u> Breb	C	C	C	C
23. <u>C. asciculariae</u>	r	C	r	r
24. <u>Cosmarium corda</u>	C	C	r	-
25. <u>C. contractum</u> var. <u>ellipsoideum</u> f. <u>minor</u> .f. <u>nova</u>	C	C	r	-
26. <u>C. granatum</u>	r	C	-	r
27. <u>C. pseudoconatum</u> Nordst	C	r	-	-
28. <u>C. regnelli</u> wille	r	r	r	r
29. <u>Desmidiium baileyi</u> (Ralfs) Nordestii f. tetragonum west	r	r	r	r
30. <u>Cosmarium retusiformae</u> (wille) Gutn.	C	C	r	-
31. <u>C. lundellii</u> Delp	C	C	r	r

CCC = 500 (above)
 CC = 100 - 500
 C = 50 - 100

r = rare
 - = absent.

Diatoms: (Figs. 31, 31.1, 31.2 and 31.3) (Table 10)

Diatoms (Bacillariophyceae) are unicellular algae characterised by a siliceous cell wall [Round *et al.*, (1990)]. They comprise one of the most abundant algal groups globally and are important in benthic and planktonic algal communities in freshwater, marine and terrestrial habitats. The extent of global biodiversity in diatoms is still being debated. Although there are something in the order of 10,000-12,000 described taxa (Andersen, 1992)), there may be as many as 2,00,000 actual species (Man and Droope in press (1996)).

The ecology of fresh water diatoms has been studied by West and West (1911); Fritsch (1907); Bowling and Tyler (1988); Pisolkar *et al.*, (1992) and Agbeti and Smol (1995). Recently the ecology, distribution and diversity of diatoms of Antarctic inland waters has been discussed by Jones (1996). In the Indian subcontinent, the ecological studies on diatoms have been made by Philipose (1960); Singh (1960); Zafar (1967); Munawar (1970); Rao (1977) and Venkateswarlu (1976).

Diatoms are ubiquitous organisms that form the basic bulk of planktonic population in fresh waters. The photosynthetic importance of diatoms in aquatic systems is unparalleled by any other single group of organisms.

Patrick (1948) opined that distribution of diatoms is determined by their internal physiology rather than the external factors. However, a large number of investigators have stressed the role of many chemical factors such as silicates, phosphate, calcium, sodium, dissolved organic matter and pH in the distribution of diatoms (Rao (1953); Singh (1960); Zafar (1967) and Srivastava (1980)).

The value of physico-chemical factors and the relative density of diatoms population in the waterbody is appended in Figs. 31,31.1, 31.2 and 31.3.

The pH of water remained slightly alkaline at all the stations which by and large, lodged a similar density of phytoplankton. Patrick (1948); Singh and Swarup (1979) and Vaishya and Adoni (1992) are of the opinion that alkaline pH favour the diatomic population in natural waters which is also partially true in the present study. Venkateswarlu (1970) is of the opinion that higher values of dissolved oxygen favour the abundance of diatoms. However, in the present investigation the average dissolved oxygen concentration was found to be relatively low, yet the diatomic population was comparatively more indicating the fact that the lower concentration of dissolved oxygen favour the abundance of diatoms.

Sheavly and Marshal (1989) however, have recorded that aerated waters that are rich in dissolved oxygen favour the abundance of diatoms which is at variance with the present investigation. Seenayya (1972) states that diatom growth is favoured by lower concentration of dissolved organic matter. In the present investigation also a similar situation has been observed.

The iron concentration in water appears to have a direct influence on diatoms. In the present study the concentration of iron was found to be extremely low (Table 10) inspite of which the diatomic population always remained high indicating that iron and diatoms have an inverse relationship. A similar observation has been made by Zafar (1967) and Munawar (1970).

Pearsall (1932); Zafar (1967); Munawar (1970); Hegde and Bharathi (1985) and Vaishya and Adoni (1992) noted dense diatomic population in waters that are rich in

phosphates. In the present investigation, the phosphate concentration ranged from a minimum of 1 mg/l to 2.1 mg/l which is relatively high and that supported a luxuriant growth of diatoms. Hence, the present observations coincide with the above researchers.

The role of silica in regulating the diatomic population appears to be rather very interesting wherein its concentration being less than 0.5 mg/l and supported a luxuriant growth of diatoms at all the stations indicating that silica at lower concentration favours their abundance. Nevertheless, Venkateswarlu (1969) is of the opinion that silica between 2.0 - 4.0 mg/l supports luxuriant growth of diatoms in fresh water. Hence, our observations do not conform with the conclusion of Venkateswarlu (1969). Potter et al., (1975) and Pandey and Pandey (1980) concluded that the concentration of silicates in natural water depends on the sandy nature of the lake bed. In the present investigation too, the lake does not contain sandy bed and hence it shows low concentration of silicates.

Further, Venkateswarlu (1969) suggested that dissolved oxygen and free carbon dioxide play a prominent role in governing the distribution of diatoms. In the present investigation these two parameters at relatively low concentration promoted the luxuriant growth of diatoms.

Pahwa and Mehrotra (1966) and Singh and Swarup (1979) opined that higher temperature promotes the growth of diatoms while lower temperature retards their growth. In the present study too a similar observation has been made. For instance, during winter the average temperature recorded was around 27 °C with a diatomic population of 65884 o/l as compared to summer when the temperature was around 32 °C

with the diatomic population of 77383 o/l. An inverse relationship appears to exist between sodium and diatomic population in the present study.

Zafar (1964); Munawar (1970); Rao (1977) and Hedge and Bharathi (1985) stressed the importance of Pearsall's basic ratio as the possible factor regulating the diatomic population. According to them, higher the value, lower the abundance of diatoms. In the present study Pearsall's basic ratio was calculated to be 0.213 which is very low. Hence, the diatomic population was found to be very high.

Periodicity: (Tables 10.1, 10.2 and 10.3)

A total of 17 genera and 61 species of diatoms have been observed of which Pinnularia microstauron, Navicula purpula, Cymbella cuspidata, Gomphonema accuminatus, Stauronies phoenicenteron, Nitzschia palea, and Synedra ulna appeared as dominant forms whereas Gomphonema longiceps, and Gyrosigma kutzingii appeared as rare forms.

Stationwise, diatoms reached their peak in the month of April 1996 at station I and April 1995 at station IV with 10,472 and 9,942 o/l respectively. On the other hand, stations I and III recorded a high diatomic population during April 1996 and April 1995 with 10,472 and 9942 o/l respectively. Their lowest density was almost uniform of around 5000 o/l at all stations during October save station I where the number declined during September for both the years.

Seasonally, summer experienced higher density of diatoms at all the stations and their number reduced towards rainy season (Table 10.1).

The statistical data indicates that diatoms have a significant positive correlation with temperature, sulphates, phosphates and nitrites and a significant negative correlation

with dissolved oxygen, magnesium, sodium, potassium, dissolved organic matter and total hardness. However, their population is independent of factors such as carbonates, bicarbonates and organic nitrogen (correlation matrix I).

Hence, it can be concluded that an average low concentration of dissolved oxygen, high concentration of phosphates and high temperature coupled with low concentrations of dissolved organic matter, iron and silica favour the abundance of diatoms. Summer recorded their peak population. Also, carbonates and bicarbonates do not have any influence on their growth.

Table - 10

**Two yearly averages of certain related physico-chemical parameters to Diatoms
(mg/l) 1995-97 in Shantisagar lake.**

Parameters	Station I	Station II	Station III	Station IV
Dissolved oxygen	6.38	6.73	6.79	7.17
Water Temperature	29.12	28.97	29.30	29.28
Phosphate	1.17	1.055	1.145	1.31
Dissolved organic matter	0.999	1.29	1.40	1.59
Iron	0.0185	0.023	0.0173	0.023
Silica	0.10	0.117	0.122	0.127

Fig. 31. RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND DIATOMS AT STATION - I

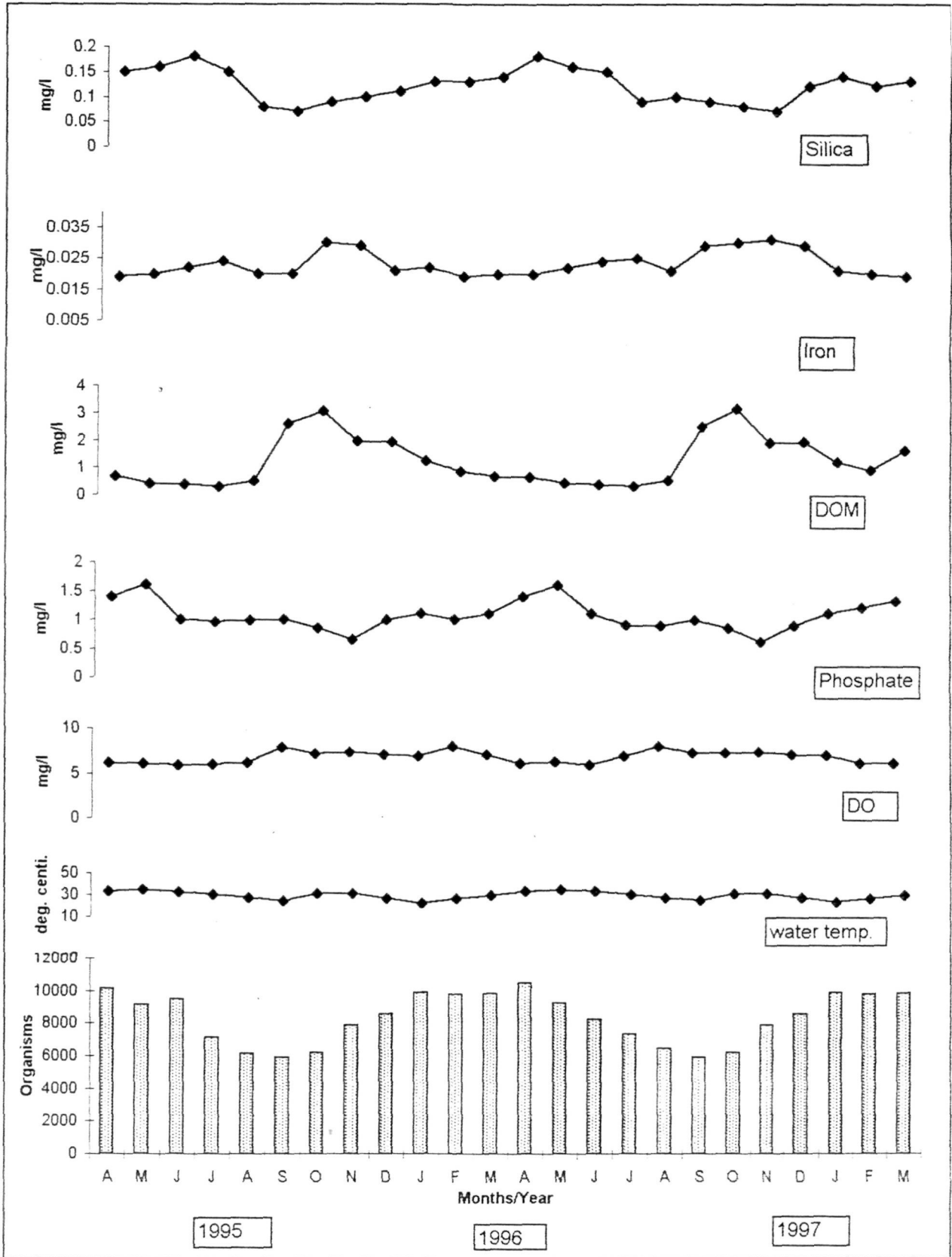


Fig. 31.1 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND DIATOMS AT STATION - II

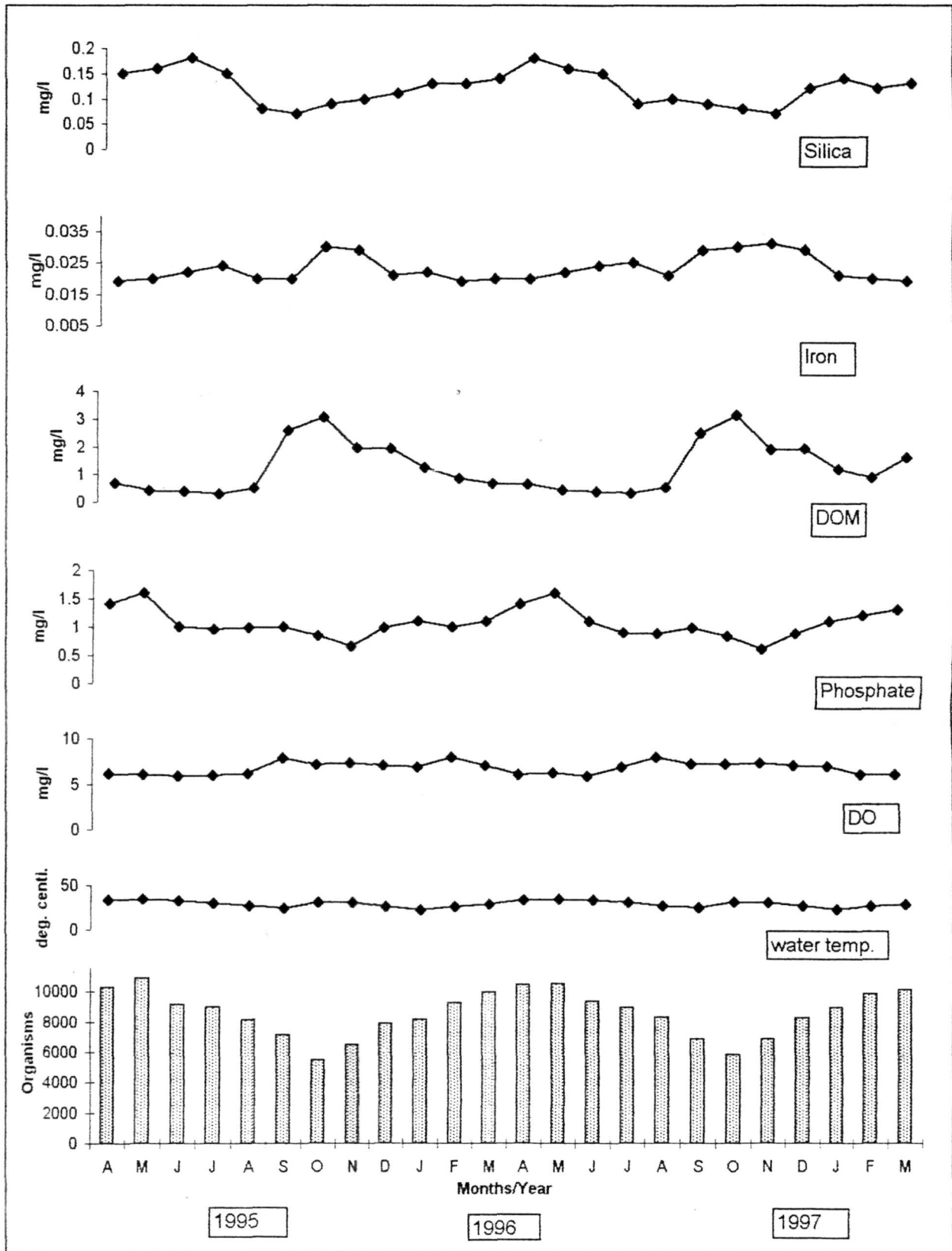


Fig. 31.2 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND DIATOMS AT STATION - III

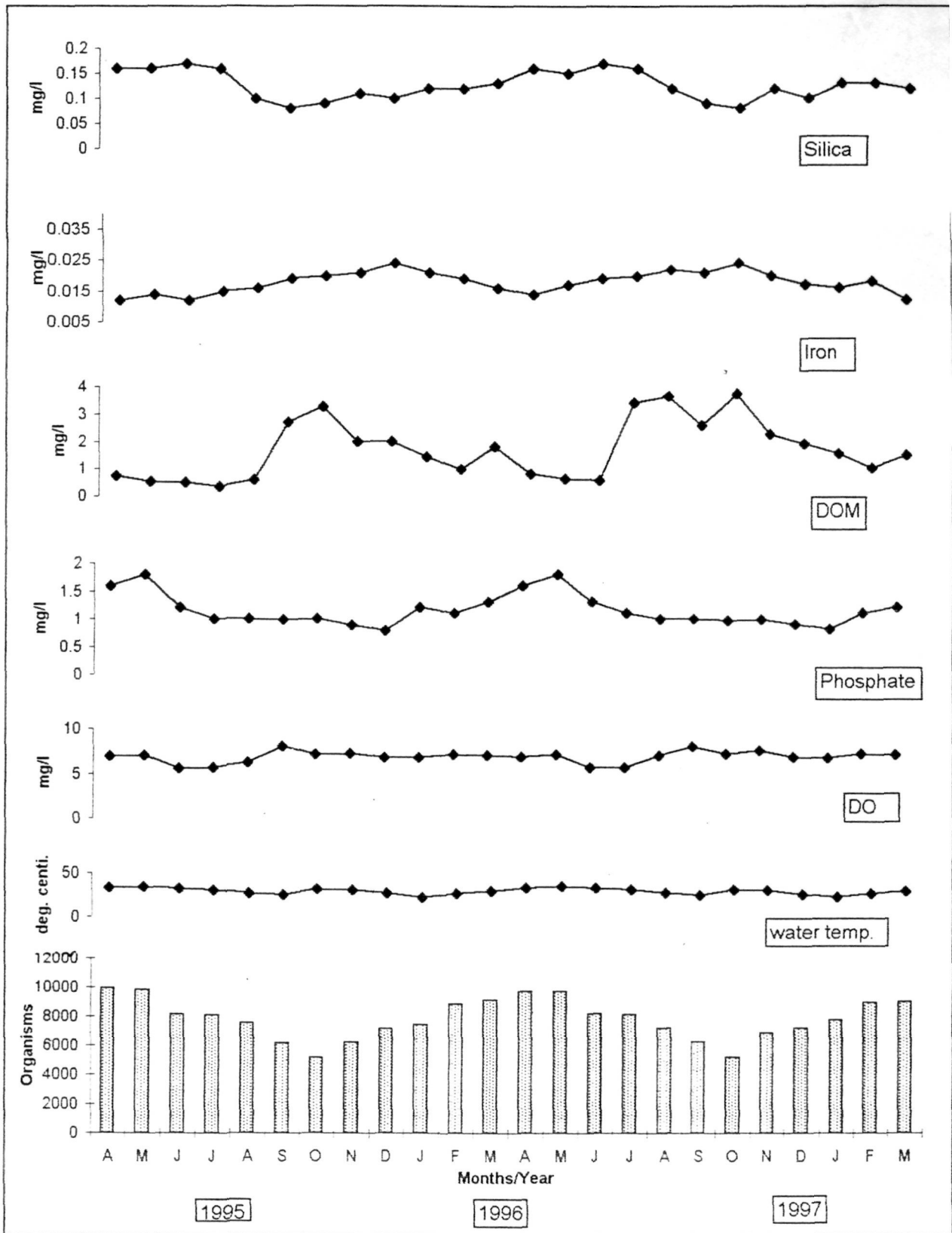


Fig. 31.3 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND DIATOMS AT STATION - IV

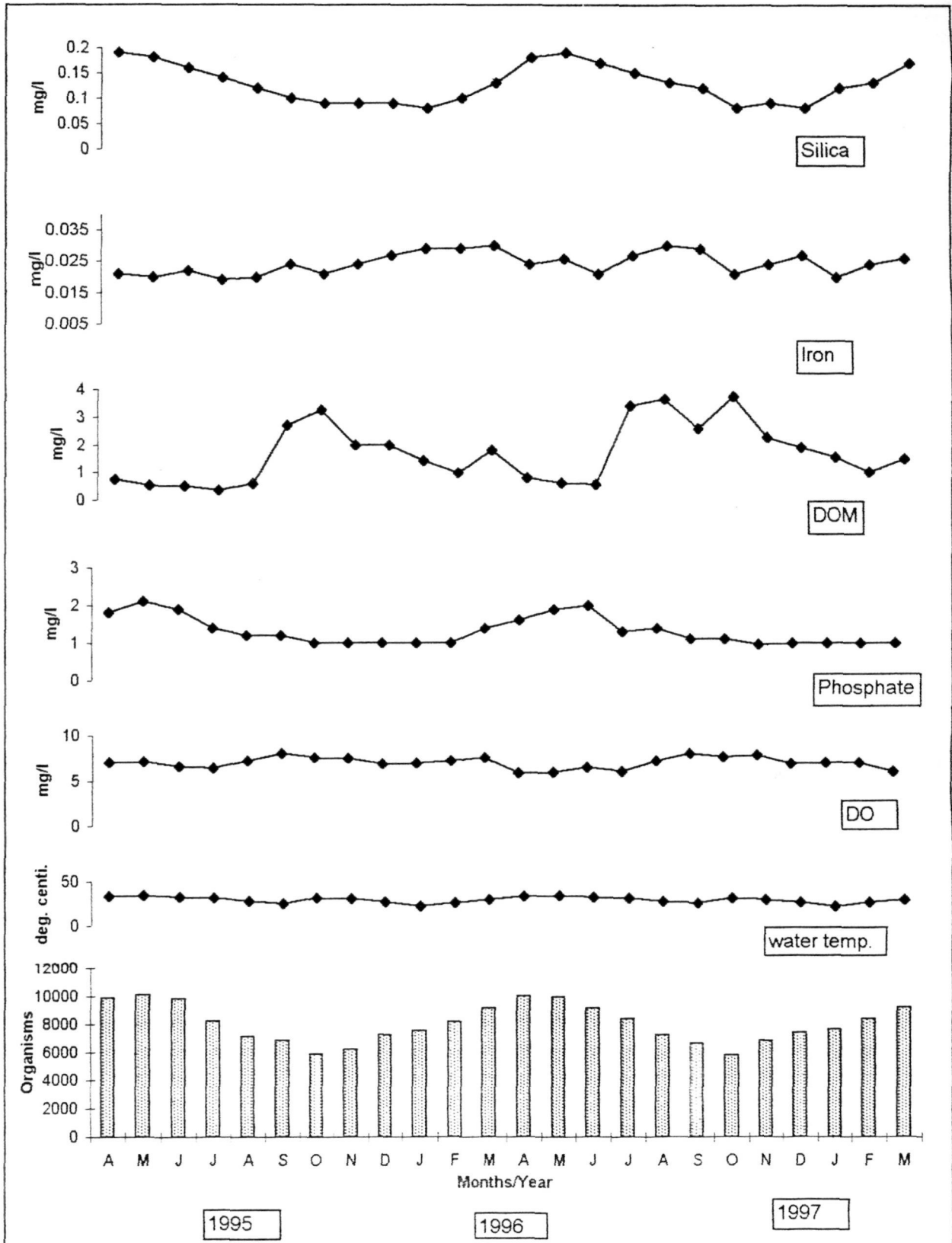


Table 10.1

Seasonal averages of Diatoms in Shantisagar lake (1995-97)

Seasons	Station I			Station II		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	6910.5	6787	6848.5	8366	8373.25	8366.62
Winter	8114.75	7974	8044	6995	7471.75	7233.37
Summer	9722.25	9588.5	9655.37	10117.25	10232.25	10174.75

Seasons	Station III			Station IV		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	7484	6787	7164	8007.5	7835	7921.25
Winter	6505.5	7974	7240.25	6706.5	6911.75	6809.12
Summer	9441.25	9588.5	9514.87	9317	9378.75	9347.87

Table 10.2

**Yearly and two yearly occurrence of diatoms in
Shantisagar lake**

Stations	1995-96	1996-97	1995-97
Station I	98990	97397	196387
Station II	101913	104309	206222
Station III	93685	94387	188072
Station IV	96124	96502	192626

Table 10.3
Occurrence of Diatoms at four stations in Shantisagar lake during April 1995 to March 1997

Group	Stations			
	I	II	III	IV
1. <u>Synedra ulna</u> (Nitzsch) ehr	CC	CCC	C	C
2. <u>S. acus</u> Kutz	CC	CCC	CC	r
3. <u>Gomphonema lacus-rankala</u> Gandhii	C	CC	C	r
4. <u>G. longiceps</u> Ehr. V. graciels Hust.	C	CC	CC	r
5. <u>Surirella robusta</u> Ehr. V. splendida (ehr)	CC	C	r	-
6. <u>Cocconeis placentula</u> (ehr) v. euglyphyta (ehr). cleve	CC	CC	C	C
7. <u>Cymbella lanceolata</u> Kutz.	CC	C	r	-
8. <u>Surirella subsalsa</u> . w. smith	C	CC	r	-
9. <u>Anomoeoneis sphaerophora</u> (Kutz). pffzer	CC	CCC	CC	C
10. <u>Navicula crucicula</u> . v. obtusata Grun	CC	CCC	C	C
11. <u>Stauroneis anceps</u> (Ehr).	C	Cc	r	C
12. <u>Navicula cuspidata</u> Kutz. v. conspicua	CC	CCC	CC	r
13. <u>N. crucicula</u>	CC	CC	C	CC
14. <u>N. scoliopleuroides</u> Quint	CC	CCC	C	c
15. <u>N. ridiosa</u> Kutz	CCC	CCC	C	C

Stations

Group	I	II	III	IV
16. <u>Pinnularia microstauron</u>	CC	CCC	CC	c
17. <u>P. acrosphaeria</u> . v. <u>minor cleve</u>	C	CC	C	C
18. <u>P. acrosphaeria</u> (Bre'b) w. <u>smith</u> . v. <u>asiatica</u>	CC	CC	r	r
19. <u>P. gibba</u> (Ehr)	r	C	C	-
20. <u>P. microstauron</u> (Ehr). <u>cleve</u>	CC	CCC	C	C
21. <u>P. conica</u> <u>gandhi</u>	C	CC	C	r
22. <u>P. brevicostata</u> <u>cleve</u>	r	C	CC	r
23. <u>Nitzschia acuta</u> <u>Hantz</u>	CC	CCC	C	C
24. <u>N. obtusa</u>	C	CC	C	C
25. <u>N. closterium</u>	CC	CC	C	C
26. <u>N. angustata</u>	CC	C	C	C
27. <u>N. palea</u>	CC	CCC	C	C
28. <u>Hantzschia amphioxys</u> (Ehr). <u>Grun</u>	C	C	r	r
29. <u>H. amphioxys</u> . v. <u>vivax</u> (Hantz). <u>Grun</u>	C	r	r	r
30. <u>Nitzschia linearis</u> <u>Smith</u>	CC	CCC	CC	C
31. <u>N. microcephala</u> <u>Grun</u>	CC	CC	C	C
32. <u>N. fonticola</u> <u>Grun</u>	CCC	CC	C	C

Stations

Group	I	II	III	IV
33. <u>N. acularis</u>	CC	CC	C	r
34. <u>Cyclofella compla</u> Kutzing	C	CC	C	r
35. <u>Pinnularia viridis</u> Smith	C	CC	C	C
36. <u>P. borealis</u> Ehr.	C	C	C	-
37. <u>P. braunii</u> (Grun). cl	C	C	CC	-
38. <u>P. major</u>	r	C	CC	-
39. <u>P. microstauron</u>	C	C	r	-
40. <u>Navicula cuspidata</u> Kutz. v. <u>Ambigud</u> (Ehr) cleve	CC	CC	C	C
41. <u>N. bacillum</u> Ehrif genuina Hust.	CC	CC	C	C
42. <u>N. rostellata</u> Kutz	C	CCC	C	r
43. <u>N. pupula</u> . F. <u>vestangularis</u> (Greg). Grun	CC	C	r	-
44. <u>N. pygmaea</u> Kutz	CC	CCC	C	C
45. <u>N. wardensis</u> sp. Nor	C	CC	-	r
46. <u>N. mutica</u> Kutz, v. <u>productra</u> Grun	CC	C	r	r
47. <u>N. purpula</u> Kutz, v. <u>Captina</u> Hustedt	CC	CCC	CC	C
48. <u>Cymbella cuspidata</u> Kutzing	CCC	CC	C	r
49. <u>Gomphonema accuminatus</u>	CC	CC	C	C

Group	Stations			
	I	II	III	IV
50. <u>G. parvulum</u>	CC	C	r	r
51. <u>G. gracile</u> Ehr	r	C	r	-
52. <u>Cocconeis pediculus</u> Ehrberg	C	CC	C	C
53. <u>Achanathes affinis</u>	CC	CCC	C	C
54. <u>A. minutissima</u>	C	C	C	r
55. <u>Synedra tabulata</u>	CC	CC	C	C
56. <u>Fragillaria vacuheriae</u> (Kutz.) Buye Pec var. genuina (VH).A.cl	CC	CC	C	C
57. <u>Melosira granulata</u>	C	CCC	C	r
58. <u>Anomooneis brachysira</u> car.thermalis	C	CC	C	r
59. <u>Gyrosigma kutzingii</u>	C	C	C	r
60. <u>Tabellaria flocculosa</u>	C	C	C	C
61. <u>Stauroneis phoenicenteron</u> Ehr. f. producta Gandhi	C	CC	C	C

CCC = 500 (above)

CC = 100 - 500

C = 50 - 100

r = rare

- = absent.

Euglenoids:(Figs. 32, 32.1, 32.2 and 32.3) (Table 11)

The ecology of Euglenineae has been investigated thoroughly by several researchers and the discussions have centered mainly on the physico-chemical factors and their influence on the distribution. [Prescott (1951); Davis (1956); Seenayya (1971);]. Almost everyone has reached a common consensus that carbon dioxide and dissolved oxygen play a pivotal role in the occurrence and distribution of euglenineae. Munawar (1972) and Hedge and Bharathi (1985) have observed that a high concentration of carbon dioxide coupled with a low concentration of dissolved oxygen enhance the population of euglenineae. However, in the present study inspite of the low concentration of dissolved oxygen, which ranged from 5.02 to 8.01 mg/l and relatively high concentration of carbon dioxide ranging from 23.4 to 61.96 mg/l the population of euglenineae was found to be low compared to diatoms and chlorococcales. Hence, the present observations tend to vary with those of the above mentioned researchers.

Davis (1956); Seenayya (1971) and Munawar (1972) observed that water temperature regulates the multiplication of euglenoids and that a temperature below 25 ° C is congenial for their growth. However, in the present study the water temperature exceeded 34 °C and the low density of euglenoids could be attributed to this.

It has been observed that carbon dioxide has an intimate relationship with iron, oxygen and phosphates and these form an ecological complex with water. Whenever there is an oxygen deficiency, iron is reduced from ferric to ferrous form and phosphorous is released into water. It appears that deficiency of oxygen promotes the development of euglenoids, possibly in the presence of iron and phosphates. Forsyth and Mccol (1975) reported the presence of euglenoids in water that have nitrogen rich

organic matter. Rao (1953), opined that euglenoids require a high concentration of iron for their better growth and development. In the present investigation, the concentration of iron was low and hence at variance with the observations of Rao (1953). The concentration of dissolved organic matter was also found to be quite low. However, Hedge and Bharathi(1985) concluded that there is no clear cut correlation between iron, dissolved organic matter and the occurrence of euglenoids.

Munawar (1972) observed that euglenoids occur abundantly when the concentration of albuminoid ammonia is high. In the present study, the concentration of ammonia nitrogen was very low thus supporting a very meagre population of euglenoids. Further, he also pointed out that a high concentration of nitrates promotes the euglenoid population. In the present observation the nitrate concentration too was very low thus retarding the growth of euglenoids.

The concentration of chlorides was found to be relatively high (89.14 mg/l). Hegde and Bharathi (1985) have opined that a high chloride concentration supports a luxuriant growth of euglenoids. Hence, the present observations tend to differ from them.

The statistical treatment to the data reveals that euglenoids have a significant positive correlation with temperature, turbidity, sulphates, chlorides, phosphates and silica and a significant negative correlation with dissolved oxygen, carbon dioxide, calcium, magnesium, total solids and total hardness. (correlation matrix II).

Seasonally, the euglenoids reached their peak in the months of April-May during the course of study and thier population declined during September – October (Table 11.1).

Periodicity: (Tables 11.1, 11.2 and 11.3)

In the present study, 3 genera and 39 species of euglenoids were noticed. Phacus, Euglena and Trachelomonas were the predominant genera observed. Stationwise, their maximum abundance was recorded at station II with 3899 o/l followed by 3527 o/l, 3256 o/l and 3214 o/l at stations I, III and IV respectively while their population declined to a lowest of 1749 o/l at station III followed by 1842 o/l, 1851 o/l and 1891 o/l at stations II, I and IV respectively. The predominant species were Phacus pleuronectes, P. curvicauda, P. anomalus, P. anacoelus, Euglena limnophila, E. minuta, Trachelomonas bulla, T. volvocina and T. neotropica.

Euglena tripteris, E. spirogyra, E. oxyuris, E. desis and Trachelomonas zorensis were the rare forms observed.

On a seasonwise average basis, their population always enhanced during summer followed by monsoon (Table 11.1).

Hence, it can be concluded that a low concentration of dissolved oxygen, nitrates, ammonia-nitrogen, dissolved organic matter and iron added with high water temperature, high concentration of carbondioxide and chlorides was responsible for the dwindling population of euglenineae.

Table - 11

**Two yearly averages of certain related physico-chemical parameters to Euglenoids
(mg/l) 1995-97 in Shantisagar lake.**

Parameters	Station I	Station II	Station III	Station IV
Water temperature	29.12	28.97	29.30	29.28
Dissolved oxygen	6.38	6.73	6.79	7.17
Nitrates	3.21	3.14	2.87	3.03
Dissolved organic matter	0.999	1.29	1.40	1.59
Iron	0.0185	0.023	0.0173	0.023
Carbondioxide	38.18	39.26	39.61	45.56
Chlorides	33.28	36.66	39.27	45.25

Fig. 32.1 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND EUGLENOIDS AT STATION - II

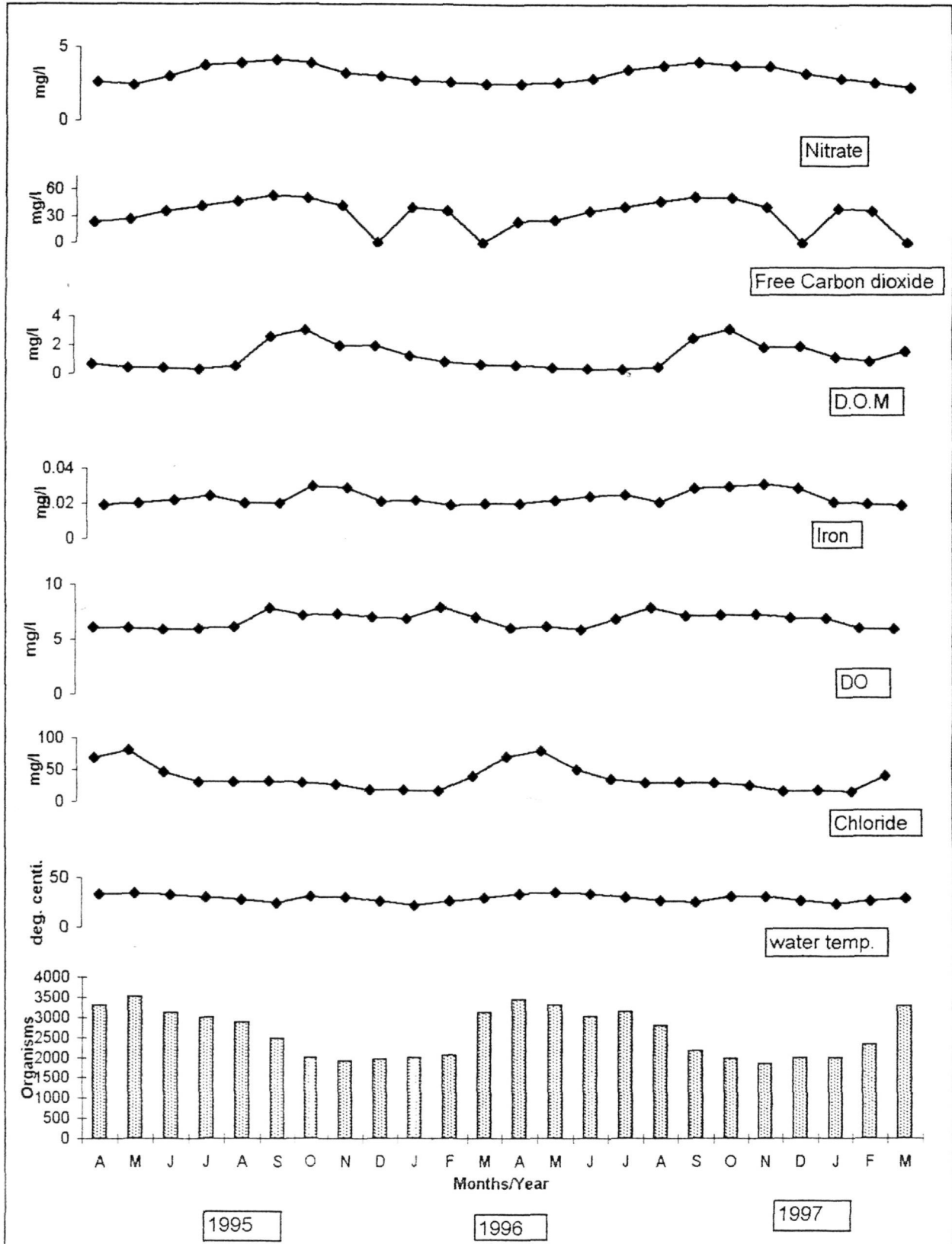


Fig. 321 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL

FACTORS AND EUGLENOIDS AT STATION - II

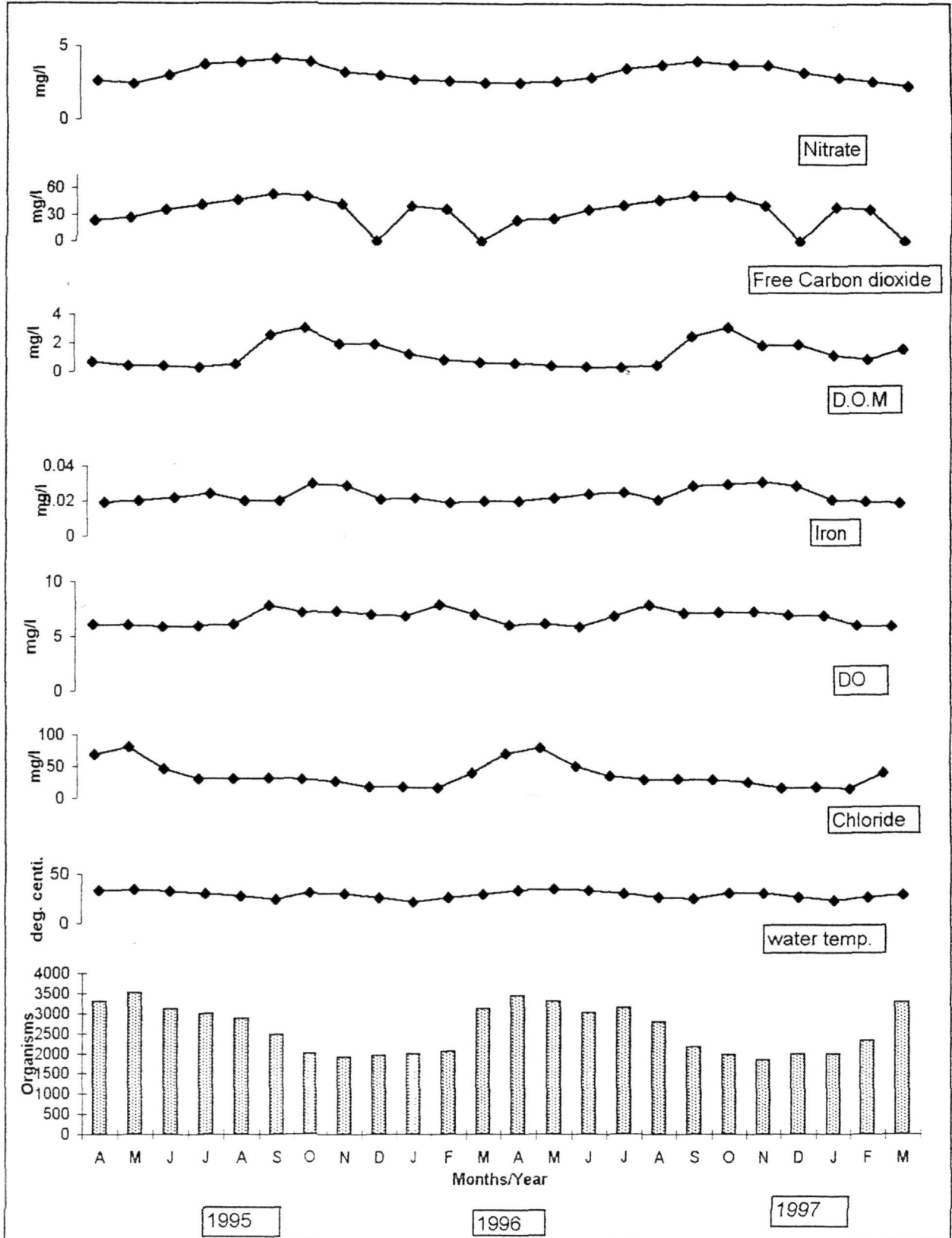


Fig. 32.2 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND EUGLENOIDS AT STATION - III

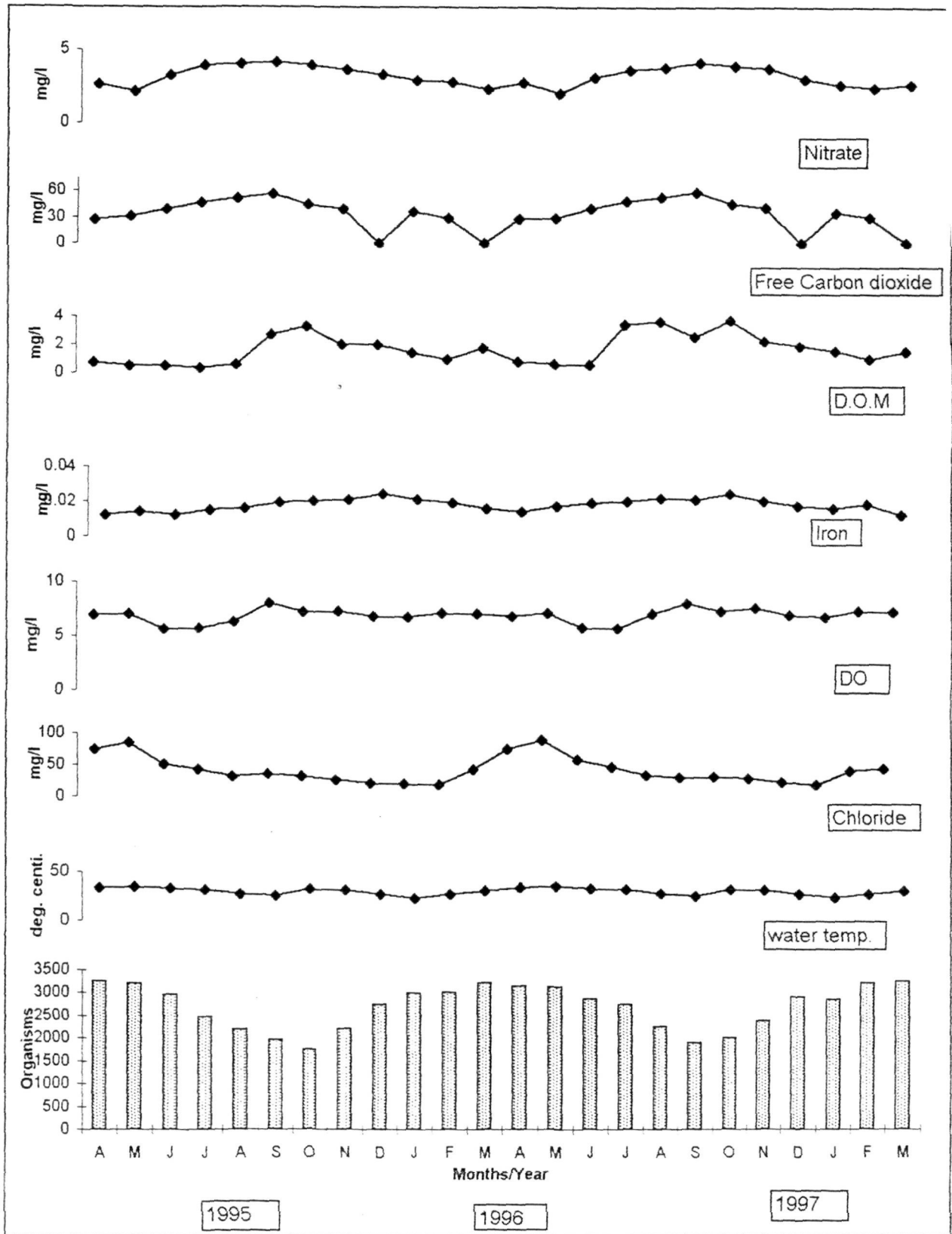


Fig. 32.3 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND EUGLENIDS AT STATION - IV

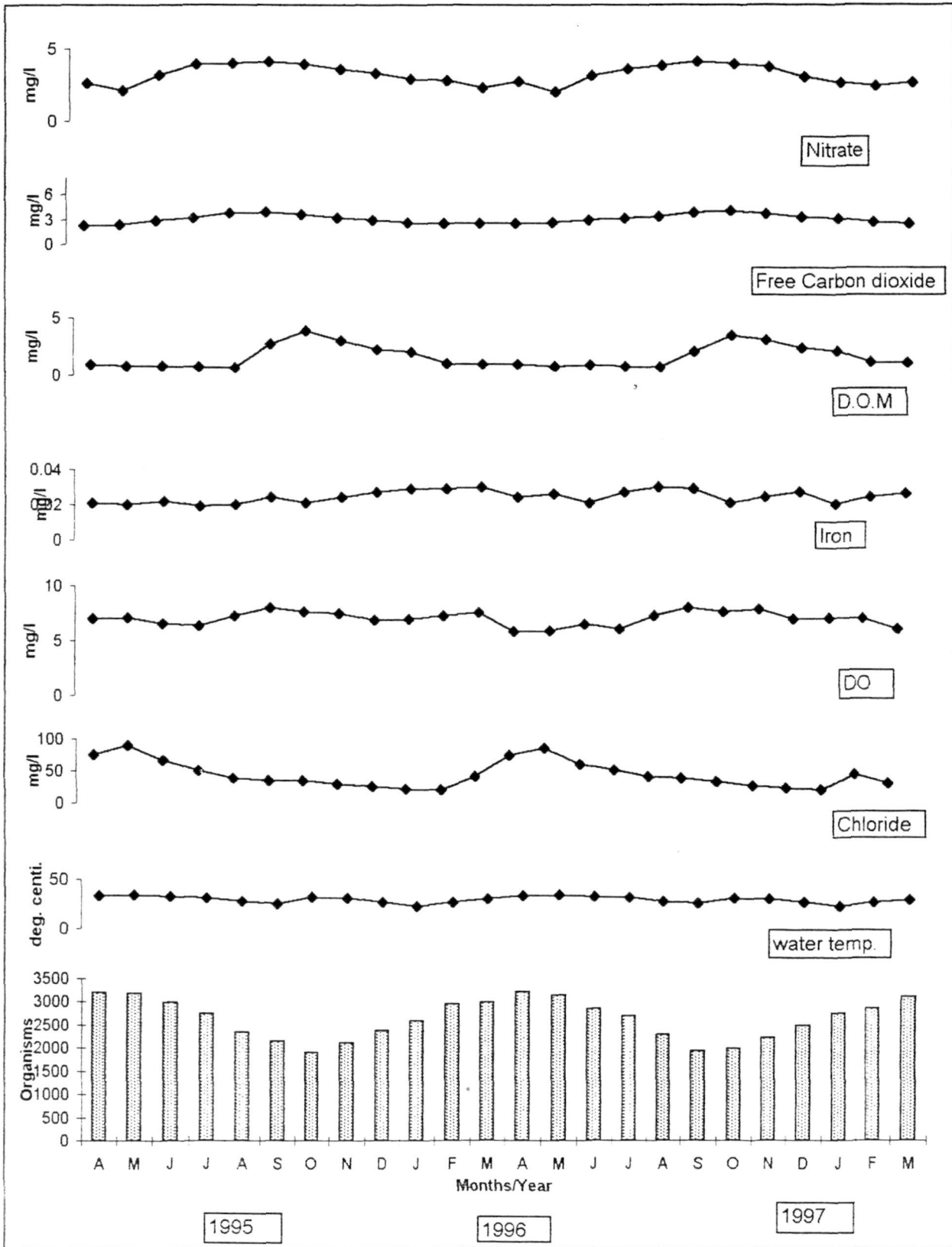


Table 11.1

Seasonal averages of Euglenoids in Shantisagar lake (1995-97)

Seasons	Station I			Station II		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	2867.25	2776	2821.62	2707.25	2564.25	2635.75
Winter	1959.5	1955	1957.25	2293.75	2260.5	2277.12
Summer	2993	3084.5	3038.75	3003.75	3425.5	3214.62

Seasons	Station III			Station IV		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	2383.75	2776	2579.387	2555.5	2440.5	2498
Winter	2423.5	1955	2189.25	22.43	2359.75	2301.37
Summer	3174.25	3084.5	3129.37	3079.25	3080.5	3079.62

Table 11.2
Yearly and two yearly occurrence of Euglenoids in
Shantisagar lake.

Stations	1995-96	1996-97	1995-97
Station I	31279	31262	62541
Station II	32574	33001	65575
Station III	31926	32613	64539
Station IV	31511	31519	63030

Table 11.3

Occurrence of Euglenoids at four stations in Shantisagar lake during April 1995 to March 1997

Group	Stations			
	I	II	III	IV
1. <u>Phacus pleuronectes</u>	C	CC	C	C
2. <u>P. atrakoides</u>	CC	C	r	r
3. <u>P. curvicauda</u>	C	CC	C	C
4. <u>P. anomalus</u>	C	CC	C	C
5. <u>P. undulatus</u>	C	C	r	r
6. <u>P. tortus</u>	r	C	C	-
7. <u>P. ranula</u>	C	C	r	r
8. <u>P. ankylonoton</u>	C	C	C	C
9. <u>P. caudatus</u>	C	CC	C	r
10. <u>P. indicus</u>	C	C	C	C
11. <u>P. anacoelus</u>	C	CC	r	r
12. <u>Euglena limnophila</u> Lemm. var. minor drez	C	C	C	c
13. <u>E. acus</u>	C	CC	C	C
14. <u>E. polymorpha</u>	C	C	C	r
15. <u>E. elastica</u>	C	C	r	r

Stations

Group	I	II	III	IV
16. <u>E. spirogyra</u>	r	C	r	r
17. <u>E. tripteris</u>	r	r	r	-
18. <u>E. desis</u>	r	r	r	r
19. <u>E. proxima</u>	r	C	C	r
20. <u>E. oxyuris schmarda</u>	r	r	-	-
21. <u>E. gracilis</u>	r	C	C	C
22. <u>E. fusca</u>	CC	CC	C	C
23. <u>E. minuta</u>	CC	CCC	C	C
24. <u>Trachelomonas bulla stein emend Defl.</u>	CC	CCC	C	C
25. <u>T. hispida</u>	C	CC	C	-
26. <u>T. robusta</u>	C	CC	CC	C
27. <u>T. volvocina</u>	CC	CC	C	C
28. <u>T. volvocinopsis</u>	C	CC	C	C
29. <u>T. superba swir, emend, Defl.</u>	C	C	C	r
30. <u>T. curata Dacunha emend Defl.</u>	C	C	r	r
31. <u>T. lismorensis</u>	C	C	C	C
32. <u>T. armata (Ehr.) stein</u>	C	C	r	-

Group	Stations			
	I	II	III	IV
33. <i>T. mucosa</i> swir var. <i>Sphaerica philet</i>	C	CC	C	C
34. <i>T. neotropica</i> Batech	CC	CC	C	C
35. <i>T. bacillifera</i>	C	C	C	C
36. <i>T. lacusteris</i>	C	C	C	C
37. <i>T. abrupta</i>	Cc	CCC	CC	C
38. <i>T. armata</i>	C	C	C	-
39. <i>T. zorensis</i>	C	C	r	-

CCC = 500 (above)

CC = 100 - 500

C = 50 - 100

r = rare

- = absent.

Cyanophyceae: (Figs. 33, 33.1, 33.2 and 33.3) (Table 12)

The cyanobacteria or blue-green algae are minute organisms morphologically simple in their organization with complicated internal physiological, biological, biochemical and genetic systems. They are ubiquitous forms frequently forming dense plankton populations or water blooms in fresh water ecosystems. In tropical lakes, their growth may be continuous throughout the year but in temperate lakes, there is a characteristic seasonal succession of the bloom forming species.

Pearsall (1932); Prescott (1938); Singh (1960); Munawar (1970); Philipose (1972); Smith (1983) and Zutshi and Wanganeo (1984) have emphasized the role of temperature, pH, dissolved oxygen, carbondioxide, nitrate, phosphates, dissolved organic matter and total nitrogen as factors regulating the presence or absence of cyanophyceae in fresh waterbodies.

In the present study, it was noticed that the population of blue green algae reached its maximum during summer (Table 12.1). Gonzalves and Joshi (1946); Zafar (1967); Hegde and Bharathi (1985); Bilgrami *et al.*, (1985) and Swarnalatha and Narasingarao (1993) have observed that high temperature favours a luxuriant growth of blue-greens, which is also true in the present investigation.

Zafar (1967); Hedge and Bharathi (1985) and Swarnalatha and Narasingarao (1993) have recorded that alkaline pH coupled with low dissolved oxygen favour the abundance of blue-greens. In the present investigation the pH was alkaline and the dissolved oxygen ranged from 5.02-8.01 mg/l. However, the cyanophycean population was low compared to diatoms, chlorococcales and euglenoids.

The concentration of dissolved organic matter in the present study ranged from 0.29 - 3.89 mg/l which is relatively high. Zafar (1967); Sreenivasan (1970) and Munawar (1970) have opined that high concentration of dissolved organic matter triggers the cyanophycean population. In the present investigation, even though the dissolved organic matter concentration was high, the population of blue-greens was low. Hence, our observations are at variance with the above researchers.

The concentration of calcium as a factor is correlated with periodicity and distribution of cyanophyceae. Swarnalatha and Narasingrao(1993) while investigating on Banjara lake have observed that high concentration of calcium and magnesium promotes the maximum growth of myxophycean population. In the present study also the concentration of calcium and magnesium was high. However, the cyanophycean population was low thus disagreeing with the conclusions of the above researchers that high calcium concentration favours a high population of blue greens.

Singh (1960); Zafar (1967) and Sreenivasan (1969) have attributed the abundance of blue greens to a minimum concentration of phosphates. In the present study, the concentration of phosphates was quite high reaching a maximum of 2.1 mg/l. However, the cyanophycean population was found to be low. Hence, our observations are in accordance with the above researchers. Nonetheless, Zutshi and Khan (1988) have recorded phosphate concentration as high as 26.19 mg/l in Dal lake that supported a high population of blue- greens.

If the concentration of total kjeldahl nitrogen is taken into consideration it ranged from a minimum of 4.3 mg/l to a maximum of 9.6 mg/l. Marshal and Falcones (1973); Rao (1977) and Hegde and Bharathi (1985) have concluded that a high concentration of

nitrogen favours the blue-greens. Hence, the present observations do not go hand in hand with the conclusions of the above researchers.

Smith (1983); Hegde and Bharathi (1985) and Zutshi and Khan (1988) have opined that a high carbondioxide concentration enhances the growth of blue-greens. However, in the present context the concentration of carbondioxide was relatively high (61.96 mg/l.) which did not support a luxuriant growth of blue-greens. Therefore, the present study does not support the above view.

The statistical analysis indicates that blue-greens have a significant positive correlation with turbidity, sulphates, chlorides, nitrites and silica and a negative significant correlation with dissolved oxygen, calcium, sodium, dissolved organic matter, nitrates, organic nitrogen, ammonia-nitrogen and total kjeldahl nitrogen (matrix.II).

Periodicity: (Tables 12.1, 12.2 and 12.3)

A total of 11 genera and 23 species of cyanophyceae were observed and recorded in the present investigation. Oscillatoria earlei, Spirulina princeps, Microcystis aeruginosa, Oscillatoria princeps, Anabaena naviculoides, Gloeocapsa minuta were the dominant species found. Cylindrospermum muscicola, Aphanothecae nidulans and Arthrospira tenuis occurred rarely.

Stationwise, their population reached the peak of 2005 o/l at station II followed by 1995 o/l, 1991 o/l and 1989 o/l at stations I, IV and III respectively. Their number reduced during September-October at all the stations during the entire course of investigation.

If the seasonal averages are taken into account, the lake experienced the *highest* number of organisms during summer and their population dwindled and was lowest during rainy season at stations I and III and during winter at stations II and IV (Table 12.1).

Hence, to conclude alkaline pH, high concentrations of dissolved organic matter, carbon dioxide, phosphates and calcium associated with low concentration of total kjeldahl nitrogen are responsible for the low abundance of blue-greens. Summer recorded their highest population.

Table - 12

**Two yearly averages of certain related physico-chemical parameters to
Cyanophyceae (mg/l) 1995-97 in Shantisagar lake.**

Parameters	Station I	Station II	Station III	Station IV
pH	7.15	7.12	7.15	7.15
Dissolved organic matter	0.999	1.29	1.40	1.59
Carbondioxide	38.18	39.26	39.61	45.56
Total kjeldahl nitrogen	6.54	6.6	6.38	7.47
Phosphates	1.17	1.055	1.145	1.31
Calcium	35.93	36.40	30.78	37.62

Fig. 33 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND MYXOPHYCEAE AT STATION - I

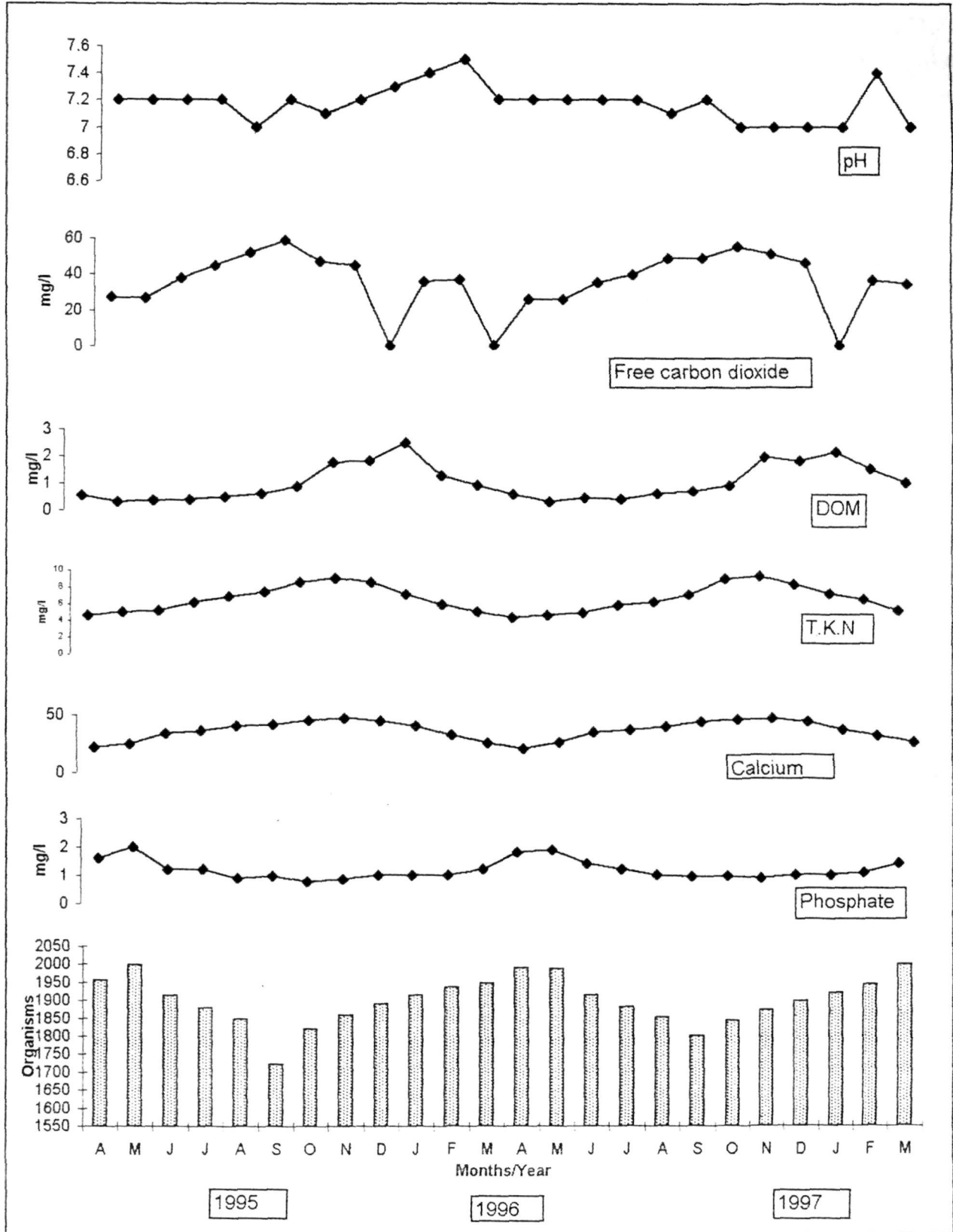


Fig. 33.1 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND MYXOPHYCEAE AT STATION - II

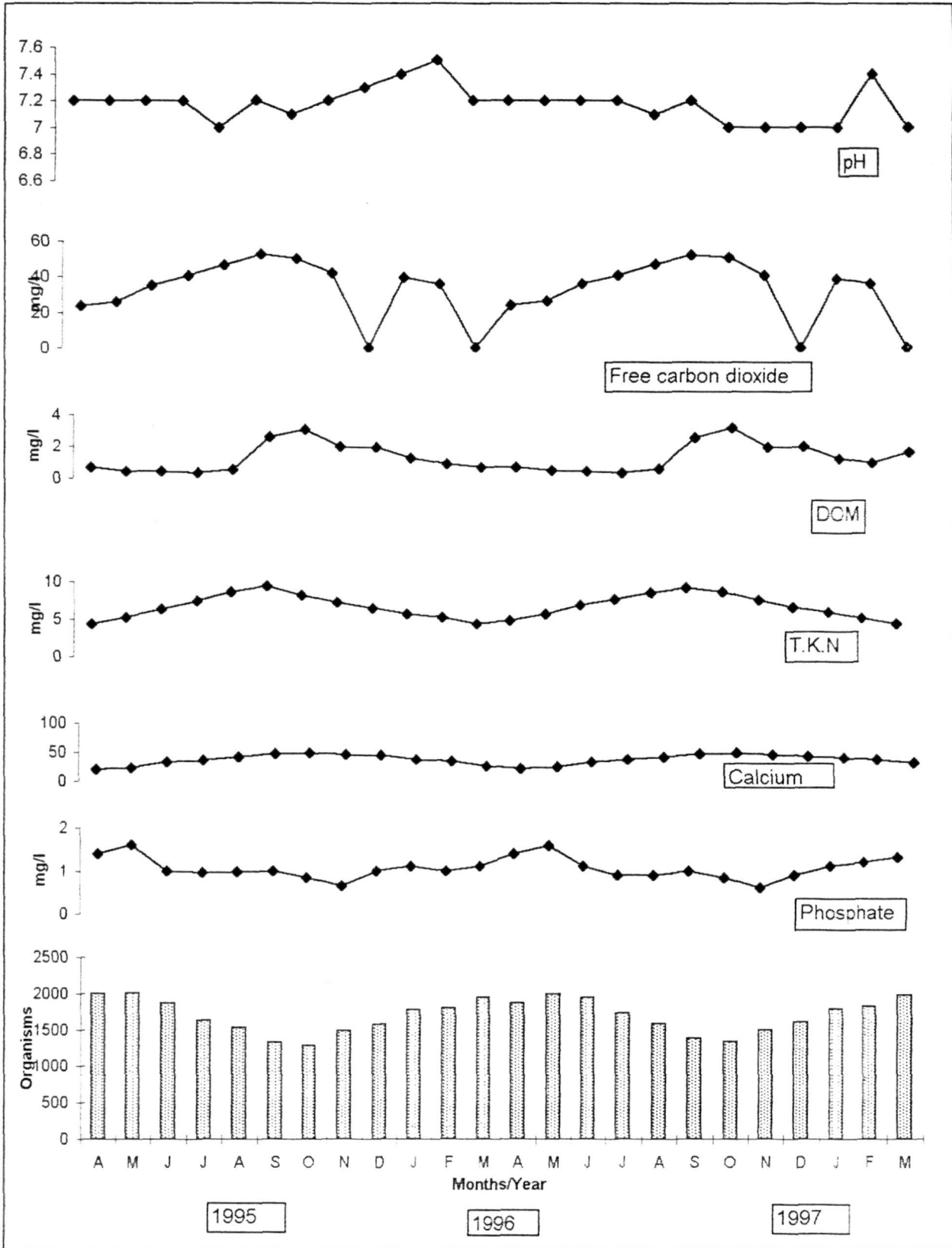


Fig. 33.2 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND MYXOPHYCEAE AT STATION - III

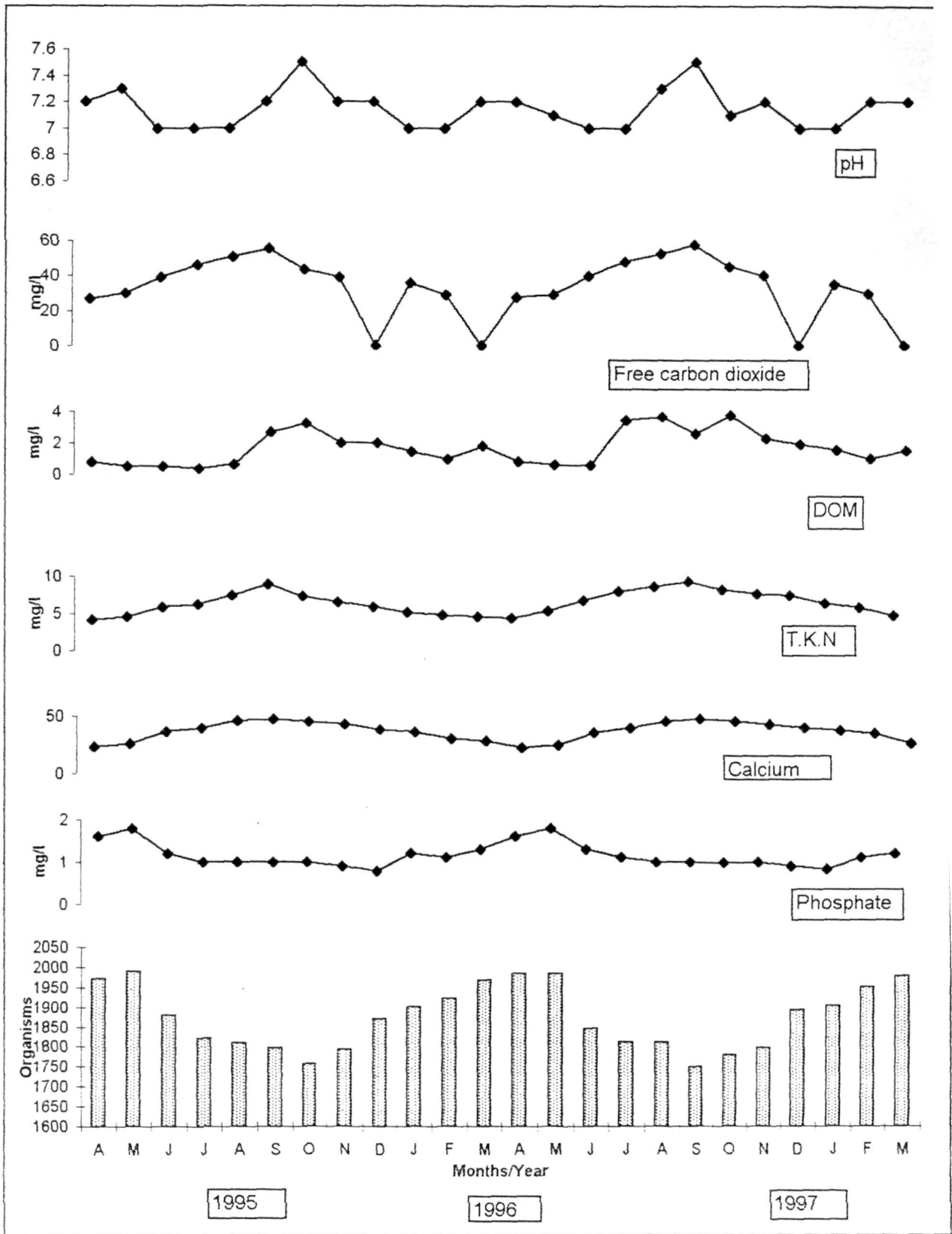


Fig. 33.3 RELATIONSHIP BETWEEN CERTAIN PHYSICO-CHEMICAL FACTORS AND MYXOPHYCEAE AT STATION - IV

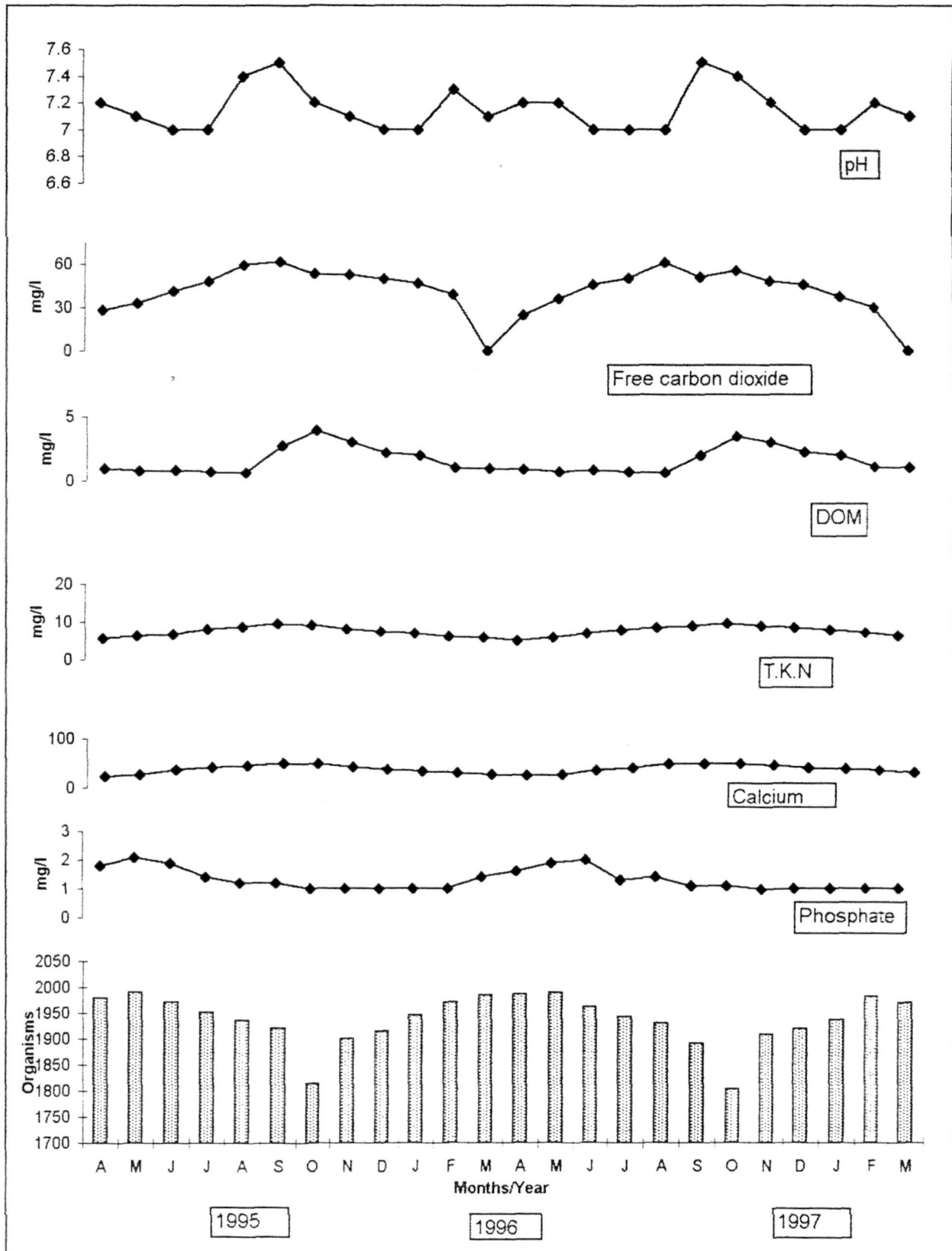


Table 12.1

Seasonal averages of Cyanophyceae in Shantisagar lake (1995-97)

Seasons	Station I			Station II		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	1840	1861	1850.5	1585	1663.25	1624.12
Winter	1870.25	1882	1876.125	1529	1558.5	1543.75
Summer	1959.5	1979.25	1969.37	1935.5	1910.25	1922.87

Seasons	Station III			Station IV		
	1995-96	1996-97	1995-97	1995-96	1996-97	1995-97
Rainy	1826.25	1861	1843.62	1945	1930.75	1937.87
Winter	1829	1882	1855.5	1893.25	1891.25	1892.25
Summer	1962.5	1979.25	1970.87	1981.25	1981.5	1981.37

Table 12.2

**Yearly and two yearly occurrence of Cyanophyceae in
Shantisagar lake.**

Station	1995-96	1996-97	1995-97
Station I	22679	22889	45568
Station II	20198	20526	40724
Station III	22471	22478	44949
Station IV	23278	23214	46492

Table 12.3
Occurrence of Cyanophyceae at four stations in Shantisagar lake during April 1995 to March 1997

Group	Stations			
	I	II	III	IV
1. <u>Merismopedia glauca</u>	C	CC	C	r
2. <u>M. tenuissima</u>	C	C	C	r
3. <u>Microcystis aeruginosa</u>	CC	CCC	CC	CC
4. <u>M. viridis</u>	Cc	CC	C	C
5. <u>Aphanothecae nidulans</u>	C	C	C	r
6. <u>Chroococcus turgidus</u>	C	CC	r	-
7. <u>Spirulina princeps</u>	CC	CCC	C	C
8. <u>Arthrospira tenuis</u>	Cc	C	C	r
9. <u>Oscillatoria earlei</u>	CC	CCC	C	-
10. <u>Q. pseudogeminata</u>	CC	CCC	C	C
11. <u>Q. terebriformes</u>	CC	CC	C	-
12. <u>Q. curviceps</u>	C	CC	C	C
13. <u>Q. princeps</u>	CC	CCC	C	r
14. <u>Q. acuta</u>	C	CC	C	C

Group	Stations			
	I	II	III	IV
15. <u>Cylindrospermum muscicola</u>	C	C	r	r
16. <u>Anabaena naviculooides</u>	CC	CCC	CC	C
17. <u>A. cylindria</u>	C	CC	C	C
18. <u>A. spiroides</u>	CC	CCC	CC	C
19. <u>Gloeocapsa minuta</u>	C	CC	C	C
20. <u>Oscillatoria ornata</u>	C	CC	C	C
21. <u>Spirulina nordstedtii</u>	C	CC	C	C
22. <u>S. spiroides</u>	C	CC	C	C
23. <u>Phormidium molle</u>	CC	CCC	CC	CC

CCC = 500 (above)

CC = 100 - 500

C = 50 - 100

r = rare

- = absent.

STATISTICAL SYNOPSIS

To find out the inter-relation between the physico-chemical complexes and biological parameters, the data obtained in the present study has been analysed statistically.

Materials and methods:

Correlation analysis was employed to study the relationship between different variables. The variables identified for the study have been detailed. Three different correlation matrices were worked out;

- (1) Correlation between different physico-chemical parameters.
- (2) Correlation between physico-chemical and biological parameters
- (3) Correlation between different biological parameters.

The formulae employed for Carl Pearson's correlation coefficient were as follows.

Carl Pearson's correlation coefficient

$$r = \frac{\text{COV}(x,y)}{x \cdot y}$$

$$\text{Cov}(x,y) = \left[\frac{1}{(n-1)} \sum x_i y_i - \frac{(\sum x_i)(\sum y_i)}{n} \right]$$

$$x = \sqrt{\frac{1}{n-1} \sum x_i^2 - \frac{(\sum x_i)^2}{n}}$$

$$y = \sqrt{\frac{1}{n-1} y_i^2 - \frac{(y_i^2)}{n}}$$

The resultant correlation coefficients were tested for their significance, using students 't' test.

$$t = \frac{r \sqrt{(n-2)}}{\sqrt{1-r^2}}$$

at (n-2) degree of freedom.

The statistical result (correlation matrix – 1, 2 and 3) obtained has been discussed along with the physico-chemical and biological characteristics.

RESULTS

I Correlation between physico-chemical parameters.

The table correlation matrix I shows that the 28 physico-chemical parameters are inter-correlated with one another. Some of the variables that form a group are air temperature which shows the inter-correlation with water temperature, dissolved oxygen, chlorides and sulphates. Other few variables which form a group include dissolved oxygen with pH, electrical conductivity, calcium, potassium, sodium, nitrates, ammonia nitrogen, iron, total hardness and electrical conductivity with free carbon dioxide,

Turbidity is negatively correlated with dissolved oxygen, calcium, magnesium, potassium, total solids and total hardness whereas chlorides are negatively correlated with electrical conductivity, dissolved oxygen, nitrates, ammonia nitrogen, total solids and total hardness, Sulphate is negatively correlated with dissolved oxygen, free carbon dioxide, calcium, magnesium, potassium, total kjeldahl nitrogen, total solids and total hardness.

II Correlation between physico-chemical and biological parameters

The table correlation matrix II shows sulphates and chlorides are positively correlated with chlorococcales. Phosphate also shows significant correlation with chlorococcales but from table II it can be found that there is not much inter-correlation between other physico-chemical parameters and biological groups.

III Correlation between different biological parameters

The table correlation matrix III shows the inter-correlation between the different groups of phytoplankton indicating that the five groups namely chlorococcales, desmids, diatoms, euglenineae and myxophyceae are significantly correlated with each other which can be ascertained from the high correlation values obtained.

Variables identified for the study

Physico-chemical parameters

X1	Air Temperature °C
X2	Water Temperature °C
X3	pH
X4	Turbidity
X5	Electrical Conductivity
X6	Dissolved oxygen
X7	Free carbon dioxide
X8	Biochemical oxygen demand
X9	Chemical oxygen demand
X10	Calcium
X11	Magnesium
X12	Sodium
X13	Potassium
X14	Carbonates
X15	Bicarbonates
X16	Sulphates
X17	Chlorides

X18	Dissolved organic matter
X19	Nitrates
X20	Nitrites
X21	Organic nitrogen
X22	Ammonia nitrogen
X23	Total kjeldahl nitrogen
X24	Phosphate
X25	Silica
X26	Iron
X27	Total hardness
X28	Total solids

Biological parameters (organisms per litre)

Y1	Chlorococcales
Y2	Desmids
Y3	Diatoms
Y4	Myxophyceae
Y5	Euglenoids

CORRELATION MATRIX - I

Correlation between different physico-chemical parameters

X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	
X1	1.00	0.80	-0.04	0.63	-0.57	-0.49	-0.34	0.49	0.65	-0.76	-0.31	-0.72	-0.44	0.12	0.25	0.78	0.75	-0.44	-0.65	0.67	-0.07	-0.68	-0.67	0.70	0.75	-0.20	-0.66	-0.47
X2	0.80	1.00	-0.04	0.41	-0.30	-0.43	-0.04	0.39	0.58	-0.44	0.02	-0.52	-0.27	-0.05	0.21	0.55	0.76	-0.31	-0.20	0.37	0.35	-0.33	-0.31	0.59	0.54	-0.21	-0.39	-0.32
X3	-0.04	-0.04	1.00	-0.12	0.12	0.44	0.12	-0.15	-0.01	-0.01	-0.09	0.18	0.09	0.04	0.35	-0.06	0.07	0.23	0.11	-0.08	0.10	0.08	0.02	0.06	-0.18	0.11	0.09	0.12
X4	0.63	0.41	-0.12	1.00	-0.71	-0.43	-0.22	0.51	0.67	-0.71	-0.36	-0.59	-0.63	0.07	0.32	0.68	0.58	-0.53	-0.48	0.51	-0.14	-0.72	-0.59	0.50	0.64	-0.33	-0.59	-0.59
X5	-0.57	-0.30	0.12	-0.71	1.00	0.52	0.34	-0.55	-0.76	0.78	0.29	0.74	0.78	-0.11	-0.18	-0.83	-0.67	0.65	0.59	-0.47	0.03	0.84	0.67	-0.67	-0.75	0.24	0.66	0.75
X6	-0.49	-0.43	0.44	-0.43	0.52	1.00	0.28	-0.48	-0.52	0.51	0.13	0.55	0.55	-0.09	0.18	-0.51	-0.40	0.56	0.36	-0.30	0.03	0.54	0.51	-0.42	-0.53	0.32	0.51	0.57
X7	-0.34	-0.04	0.12	-0.22	0.34	0.28	1.00	-0.09	-0.08	0.46	0.30	0.28	0.24	-0.64	0.01	-0.31	-0.10	0.10	0.60	-0.45	0.40	0.45	0.55	-0.15	-0.29	0.09	0.34	0.11
X8	0.49	0.39	-0.15	0.51	-0.55	-0.48	-0.09	1.00	0.63	-0.47	-0.22	-0.56	-0.43	-0.01	0.06	0.64	0.49	-0.41	-0.34	0.30	-0.07	-0.51	-0.37	0.51	0.58	-0.20	-0.40	-0.51
X9	0.65	0.58	-0.01	0.67	-0.76	-0.52	-0.08	0.63	1.00	-0.63	-0.11	-0.71	-0.71	0.01	0.21	0.78	0.69	-0.62	-0.35	0.33	0.17	-0.66	-0.51	0.68	0.72	-0.25	-0.59	-0.74
X10	-0.76	-0.44	-0.01	-0.71	0.78	0.51	0.46	-0.47	-0.63	1.00	0.48	0.69	0.65	-0.23	-0.16	-0.77	-0.65	0.56	0.80	-0.66	0.19	0.89	0.86	-0.67	-0.96	0.19	0.79	0.60
X11	-0.31	0.02	-0.09	-0.36	0.29	0.13	0.30	-0.22	-0.11	0.48	1.00	0.20	0.13	-0.60	-0.11	-0.30	-0.12	0.11	0.55	-0.35	0.41	0.38	0.42	-0.18	-0.27	0.02	0.36	0.14
X12	-0.72	-0.52	0.18	-0.59	0.74	0.55	0.28	-0.56	-0.71	0.69	0.20	1.00	0.61	0.04	-0.20	-0.79	-0.70	0.54	0.56	-0.54	0.04	0.71	0.59	-0.68	-0.76	0.22	0.63	0.61
X13	-0.44	-0.27	0.09	-0.63	0.78	0.55	0.24	-0.43	-0.71	0.65	0.13	0.61	1.00	-0.06	0.00	-0.57	-0.43	0.71	0.33	-0.28	-0.06	0.75	0.65	-0.42	-0.54	0.29	0.57	0.76
X14	0.12	-0.05	0.04	0.07	-0.11	-0.09	-0.64	-0.01	0.01	-0.23	-0.26	0.04	-0.06	1.00	-0.10	0.18	-0.07	0.05	-0.35	0.15	-0.21	-0.18	-0.26	-0.00	0.05	-0.02	-0.18	-0.06
X15	0.25	0.21	0.35	0.32	-0.18	0.18	0.01	0.06	0.21	-0.16	-0.11	-0.20	0.00	-0.10	1.00	0.22	0.31	0.20	-0.13	0.20	-0.05	-0.06	-0.18	0.24	0.35	-0.05	-0.10	0.21
X16	0.78	0.55	-0.06	0.68	-0.83	-0.51	-0.31	0.64	0.78	-0.77	-0.30	-0.79	-0.57	0.18	0.22	1.00	0.79	-0.54	-0.68	0.56	-0.03	-0.79	-0.64	0.83	0.84	-0.25	-0.70	-0.67
X17	0.75	0.76	0.07	0.58	-0.67	-0.40	-0.10	0.49	0.69	-0.65	-0.12	-0.70	-0.43	-0.07	0.31	0.79	1.00	-0.44	-0.43	0.51	0.31	-0.59	-0.44	0.85	0.73	-0.28	-0.53	-0.51
X18	-0.44	-0.31	0.23	-0.53	0.65	0.56	0.10	-0.41	-0.62	0.56	0.11	0.54	0.71	0.05	0.20	-0.54	-0.44	1.00	0.33	-0.24	-0.12	0.66	0.52	-0.45	-0.53	0.27	0.56	0.76
X19	-0.65	-0.20	0.11	-0.48	0.59	0.36	0.60	-0.34	-0.35	0.80	0.55	0.56	0.33	-0.35	-0.13	-0.68	-0.43	0.33	1.00	-0.69	0.50	0.73	0.76	-0.55	-0.61	0.05	0.69	0.33
X20	0.67	0.37	-0.08	0.51	-0.47	-0.30	-0.45	0.30	0.33	-0.66	-0.35	-0.54	-0.28	0.15	0.20	0.56	0.51	-0.24	-0.69	1.00	-0.30	-0.59	-0.63	0.62	0.55	-0.08	-0.57	-0.24
X21	-0.07	0.35	0.10	-0.14	0.03	0.03	0.40	-0.07	0.17	0.19	0.41	0.04	-0.06	-0.21	-0.05	-0.03	0.31	-0.12	0.50	-0.30	1.00	0.18	0.32	0.14	-0.03	-0.12	0.14	-0.12
X22	-0.68	-0.33	0.08	-0.72	0.84	0.54	0.45	-0.51	-0.66	0.89	0.38	0.71	0.75	-0.18	-0.06	-0.79	-0.59	0.66	0.73	-0.59	0.18	1.00	0.82	-0.65	-0.72	0.28	0.70	0.70
X23	-0.67	-0.31	0.02	-0.59	0.67	0.51	0.55	-0.37	-0.51	0.86	0.42	0.59	0.65	-0.26	-0.18	-0.64	-0.44	0.52	0.76	-0.63	0.32	0.82	1.00	-0.52	-0.63	0.28	0.75	0.44
X24	0.70	0.59	0.08	0.50	-0.67	-0.42	-0.15	0.51	0.68	-0.67	-0.18	-0.68	-0.42	0.00	0.24	0.83	0.85	-0.45	-0.55	0.62	0.14	-0.65	-0.52	1.00	0.73	-0.23	-0.57	-0.56
X25	0.75	0.64	-0.16	0.64	-0.75	-0.53	-0.29	0.58	0.72	-0.69	-0.27	-0.76	-0.54	0.05	0.35	0.84	0.73	-0.53	-0.61	0.55	-0.03	-0.72	-0.63	0.73	1.00	-0.25	-0.64	-0.50
X26	-0.20	-0.21	0.11	-0.33	0.24	0.32	0.09	-0.20	-0.25	0.19	0.02	0.22	0.29	-0.02	-0.05	-0.25	-0.28	0.27	0.05	-0.08	-0.12	0.28	0.28	-0.23	-0.25	1.00	0.08	0.31
X27	-0.66	-0.39	0.09	-0.59	0.66	0.51	0.34	-0.40	-0.59	0.79	0.36	0.63	0.57	-0.18	-0.10	-0.70	-0.53	0.56	0.69	-0.57	0.14	0.70	0.75	-0.57	-0.64	0.08	1.00	0.55

CORRELATION MATRIX – II

Correlation between physico-chemical and biological parameters

	Y1	Y2	Y3	Y4	Y5
X1	0.68	0.60	0.70	0.50	0.70
X2	0.36	0.30	0.30	0.20	0.40
X3	-0.20	-0.00	-0.20	-0.00	-0.20
X4	0.60	0.50	0.50	0.40	0.80
X5	-0.70	-0.80	-0.80	-0.40	-0.80
X6	-0.40	-0.50	-0.50	-0.30	-0.60
X7	-0.40	-0.50	-0.50	-0.30	-0.40
X8	0.44	0.40	0.50	0.50	0.50
X9	0.55	0.60	0.60	0.40	0.70
X10	-0.70	-0.80	-0.80	-0.60	-0.90
X11	-0.50	-0.40	-0.50	-0.30	-0.40
X12	-0.70	-0.70	-0.70	-0.40	-0.70
X13	-0.40	-0.50	-0.60	-0.20	-0.70
X14	0.16	0.20	0.20	0.20	0.20
X15	0.24	0.10	0.00	-0.10	0.20
X16	0.74	0.80	0.80	0.60	0.80
X17	0.61	0.50	0.60	0.40	0.60
X18	-0.40	-0.60	-0.60	-0.40	-0.70
X19	-0.80	-0.80	-0.80	-0.60	-0.70
X20	0.64	0.60	0.60	0.50	0.60
X21	-0.30	-0.30	-0.20	-0.30	-0.20
X22	-0.70	-0.80	-0.80	-0.60	-0.90
X23	-0.60	-0.70	-0.70	-0.50	-0.80
X24	0.58	0.60	0.60	0.60	0.60
X25	0.70	0.60	0.70	0.50	0.70
X26	-0.60	-0.10	-0.10	-0.20	-0.30
X27	-0.70	-0.70	-0.80	-0.40	-0.70
X28	-0.40	-0.60	-0.60	-0.40	-0.60

CORRELATION MATRIX – III

Correlation between different biological parameters

	Y1	Y2	Y3	Y4	Y5
Y1	1.00	0.75	0.84	0.42	0.68
Y2	0.75	1.00	0.84	0.54	0.79
Y3	0.84	0.84	1.00	0.52	0.72
Y4	0.42	0.54	0.52	1.00	0.53
Y5	0.68	0.79	0.72	0.53	1.00

CHAPTER IV

SUMMARY AND CONCLUSION

Water is one of the most important commodities which man has exploited than any other resource for the sustenance of his life. Pinder has rightly said "Best of all things is water". The quantity of utilizable water is quite limited on the earth. Though water is continuously purified by evaporation and precipitation, pollution of water has emerged as one of the most significant environmental problems of recent times. There is an increasing concern for the fast depleting quantity of utilizable water. The causes of such a situation are aplenty, but gross pollution of water has its origin mainly in urbanization, industrialization and increasing human population during the past one and a half century.

Water being the internal medium of all organisms holds a unique place. Almost 70% of the body weight of most organisms including man is constituted of water. In fact, life on this planet has been possible only because of the presence of abundant water. All organisms use water for their metabolic processes, and all the biochemical reactions in the body occur only in the presence of water. It consists of an exceptional quality of dissolving a number of substances without changing their chemical nature and therefore plays an important role in transporting materials in the body. Waste products from the body are removed in the dissolved state with water.

Water is the substance which is present in all the three states of matter. i.e. gaseous, liquid and solid within the ranges of temperature and pressure common to the earth. Approximately 97 % of the total water exists in gigantic oceans but this water is of little importance in our daily requirement. Remaining 3% of water is distributed in the form of ice sheets, underground, atmosphere, lakes, rivers and biological water contained

in the living organisms. The surface fresh water in the form of lakes and rivers is hardly 0.01 % of total water supply on the earth. Since our demand for water is mostly for fresh water, we have to depend mainly on the tiny fraction of the total water present on this planet. Further, the uneven distribution of water on the surface of the earth, makes it a scarce commodity at several places. Any kind of pollution of water will further add to the difficulty of procuring this precious resource.

Lakes, reservoirs and ponds represent the lentic waters. They serve multifarious purposes like domestic water supply, industrial processes, irrigation, navigation, flood protection and recreation and generation of hydroelectricity. In rural areas or small communities, lakes and ponds may become important source of water for drinking, washing clothes, bathing and become lung space for urban sectors.

The unique properties of water which make it an universal solvent and a renewable resource also make it a substance which by virtue of these properties has got a much greater tendency to get polluted. Water pollution is a serious problem faced by all countries and it is true with surface waterbodies of Indian sub-continent too. Water quality deterioration precedes environmental degradation. Everybody has an inherent right to use pure and clean water. Therefore, a prior knowledge on the physico-chemical and biological characteristics of the waterbodies is a pre-requisite before it is exploited for the benefit of human welfare.

A critical review of the available literature reveals that absolutely no work has been carried out on Shantisagar lake with reference to physico-chemical and biological aspects.

With this background Shantisagar lake has been chosen for the present investigation in order to understand the physico-chemical complexes and biological characteristics of the lake.

The study involved the collection of water samples at four identified stations of Shantisagar lake for the analysis of physico-chemical and biological components. Established techniques were employed for the analysis of various physico-chemical parameters and biological components. Some of the factors such as temperature, pH, turbidity and color were noted down at the spot of collection. Dissolved oxygen was fixed on the spot using Winkler's method while other parameters were studied immediately after returning to the laboratory. Simultaneously, water samples were collected for biological parameters and were preserved by adding 4% formalin for further investigation.

In general, APHA methods were adopted for analysis of chemical parameters and all the values except few are expressed in mg/l. The frequency of phytoplankton population was calculated by using standard procedure and the plankton were identified with the help of related literature. The population density of phytoplankton was counted as o/l. Further, interrelationship between the various physico-chemical parameters have been studied and are correlated with the frequency and occurrence of phytoplankton composition. The following observations have been recorded.

PHYSICO-CHEMICAL CHARACTERISTICS

Temperature: Air temperature is found to be minimum at station I during January and it is recorded to be 26 °C while it reached its maximum of 39.8 °C at stations III and IV during May.

On the contrary, the ranges for water temperature vary from a minimum of 22°C at station II to a maximum of 38 °C at station I. Also, it is observed that air and water temperature vary with each other by 5 °C. Moreover, the data recorded reveals that temperature and dissolved oxygen are inversely related, and it is inferred that the water temperature always remains lower than air temperature and exhibit a wide range of variation.

pH: The pH of water at all the stations was found to vary from a minimum of 7.0 at stations I and II to a maximum of 7.5 at all stations. During a number of collections, pH remained exactly neutral at all the stations. Nevertheless, it is noted that pH and bicarbonates are positively correlated. Moreover, pH is subjected to variation depending on the seasons and the yearly averages indicate that the water is slightly alkaline.

Turbidity: Turbidity values ranged from a minimum of 13.14 NTU at station II to a maximum of 40.21 NTU at station I. It was highest during rainy season when seasonal averages are considered, while monthly collections reveal maximum turbidity during summer. Moreover, it has a positive correlation with temperature and negative correlation with dissolved oxygen.

Color: The color of the water remained clear and colorless except in rainy season when it turned muddy.

Electrical Conductivity: The values of electrical conductivity in the present study fluctuated between a minimum of 43 μ mhos at station II to a maximum of 397 μ mhos at station I. In general, values of conductance were high during winter and low during summer.

Total solids: The quantity of total solids in general are proportional to the degree of pollution. In the present investigation, the concentration of total solids ranged from a minimum of 486 mg/l at station I during July 1996 to a maximum of 857 mg/l at station III during November 1995. Moreover, the concentration of total solids was always more during winter at all the stations.

Dissolved Oxygen: The concentration of dissolved oxygen varied from a minimum of 5.02 mg/l at station I to a maximum of 8.01 mg/l at station III and it was low during summer at all the stations. Dissolved oxygen shows a negative correlation with temperature, pH and chloride and it is observed that it does not exhibit any relationship with free carbon dioxide.

Free carbondioxide: The range of values for free carbondioxide vary from 23.4 mg/l at station II to a maximum of 61.96 mg/l at station IV and it was found to be absent during certain months of collection. The free carbondioxide and dissolved oxygen are found to behave rather independent of each other.

Carbonates: The carbonate concentration was high at station III with a value of 4.1 mg/l during the month of March and it was found to be absent in the other months. A similar situation was recorded at all the other stations too. It is found that carbonate is negatively correlated with free carbondioxide and nitrates and behaves independently with respect to other parameters.

Bicarbonate: Bicarbonate varied between 1.6 mg/l to 12 mg/l during the entire period of investigation. Its concentration was maximum during summer. It exhibited a positive correlation with pH, turbidity and chlorides.

Calcium: Calcium concentration ranged from a minimum of 20.4 mg/l at station II during April 1995 to a maximum of 49.78 mg/l at station IV during Sep. 1995. Stations III and IV registered its high concentration during monsoon and low during summer while the other stations showed a high concentration during winter.

Magnesium: Magnesium concentration varied between 18.4 mg/l at station I and II to 39.6 mg/l at station IV. It was found to be high during rainy season. Moreover, calcium and magnesium exhibit a positive correlation.

Sulphate: The sulphate concentration varied from 65 mg/l at station I during Oct'1995 to 162 mg/l at station IV during April 1996. Its concentration was high during summer and low during winter at all the stations.

Chloride: In the present study the concentration of chloride ranged from 14.85 mg/l at station I to 89.14 mg/l at station IV. Seasonally, summer recorded highest concentration of chlorides.

Dissolved organic matter: Dissolved organic matter concentration fluctuated from a minimum of 0.29 mg/l at station I during May 1995 to a maximum of 3.89 mg/l at station IV during Oct 1995. On a general consideration, dissolved organic matter was found to be low at all the stations. Statistical analysis reveals that dissolved organic matter and nitrates are positively correlated whereas no relationship exists between dissolved organic matter and free carbondioxide.

Chemical oxygen demand: The chemical oxygen demand ranged from a minimum of 4.0 mg/l at station II during November 1995 to a maximum of 10.9 mg/l at stations I and II during May and June respectively. However, its negative correlation with dissolved oxygen has been observed.

Biochemical oxygen demand: The concentration of biochemical oxygen demand ranged from 1.2 mg/l at station II during November, December 1996 to a maximum of 2.9 mg/l at station I during May 1995. Interestingly, summer recorded high biochemical oxygen demand concentration at all the stations except at station IV where it was high during rainy season. Moreover, it is positively correlated with temperature and negatively correlated with dissolved oxygen.

Ammonia nitrogen: The concentration of ammonia-nitrogen recorded was a minimum of 0.52 mg/l at station I and a maximum of 2.96 mg/l at station II. Its peak was during winter and lowest during summer at all the stations.

Total kjeldahl nitrogen: In the present study, the concentration of total kjeldahl nitrogen varied from a minimum of 4.3 mg/l at station I and II to a maximum of 9.6 mg/l at station IV. Its highest concentration was recorded during monsoon at all the stations except in station I where it was high during winter.

Organic nitrogen: Organic nitrogen concentration fluctuated from a minimum of 0.52 mg/l at stations I and IV to a maximum of 0.99 mg/l at all the stations. Its concentration was maximum during rainy season.

Phosphates: Phosphate registered a minimum concentration of 0.61 mg/l at station II and a maximum concentration of 2.1 mg/l at station IV. The seasonal averages indicate that the phosphate concentration was high during summer and least in winter.

Nitrate: The concentration of nitrate varied from a minimum of 2.0 mg/l to a maximum of 4.1 mg/l at station III during May 95 and September 1995 respectively.

Nitrite: In the present study nitrite appeared in minute concentration ranging from 0.001 mg/l to 0.003 mg/l at all the stations.

Iron: A minimum of 0.01 mg/l was recorded at station I during April 1995 and a maximum of 0.031 mg/l during November 1996 at station II. Seasonwise, its concentration was invariably more during winter. Also, it is positively correlated with dissolved oxygen and total solids and negatively correlated with turbidity.

Silica: It is an important parameter regulating the diatomic population in fresh water ecosystems. In the present investigation, the concentration of silica ranged from a minimum of 0.04 mg/l at station I during September and October 1995 to a maximum of 0.19 mg/l at station I and IV during May 95 and May 96 respectively. Its concentration increases towards summer.

Sodium and potassium: In the present investigation, sodium was found to be more than potassium. Both the cations were recorded during the entire period of study. The concentration of sodium varied from 3.0 mg/l to 26.0 mg/l at station I itself.

Whereas, the concentration of potassium fluctuated between 1.0 mg/l to 3.3 mg/l.

Both sodium and potassium are represented by higher concentration during winter.

Total hardness: The concentration of total hardness varied from a minimum of 64 mg/l at station I during April 1995 to a maximum of 290 mg/l at station IV during October 1996. Rainy season recorded high hardness.

BIOLOGICAL CHARACTERISTICS

PHYTOPLANKTON

A total of 49 genera and 182 species of phytoplankton have been collected and identified:

Chlorococcales: They react with changing physico-chemical characteristics showing their plasticity. A total of 11 genera and 28 species of chlorococcales have been recorded during the present investigation.

The genus Scenedesmus was found to occur as dominant form at all the stations. Genera Ankistrodesmus, Crucigenia and Closteriopsis occurred as rare forms.

Seasonally, chlorococcales were dominant during summer and their population declined towards winter.

High temperature, phosphate, alkaline pH, coupled with low concentrations of dissolved oxygen, calcium, magnesium, nitrate and organic matter favour the abundance of chlorococcales. Also, carbonates, bicarbonates and iron have no significant bearing on chlorococcales.

Desmids: In the present investigation 7 genera and 31 species of desmids have been identified. Genus Cosmarium and Closterium were found to be dominant. Genera Penium, Desmidium and Euastrum occurred as rare forms.

It is observed that high concentrations of calcium, phosphate and alkaline pH associated with low concentration of nitrates are responsible for the low desmid population. Water temperature, carbonates, bicarbonates and iron do not have any marked influence on the desmid population.

Desmids occurred abundantly during summer.

Diatoms: In the present investigation diatoms occurred abundantly at all the stations.

It is observed that an average low concentration of dissolved oxygen, high concentration of phosphates and high temperature along with low concentrations of dissolved organic matter, iron and silica trigger the diatomic population. Moreover, carbonates and bicarbonates do not have any influence on their growth.

In all, a total of 17 genera and 61 species of diatoms have been observed of which genera Navicula, Pinnularia and Nitzschia appeared predominantly. Cocconeis, Gyrosigma, Hantzschia and genus Melosira appeared as rare forms.

Summer recorded peak of diatomic population.

Euglenoids: It is found that a low concentration of dissolved oxygen, nitrates, ammonia-nitrogen, dissolved organic matter and iron added with high water temperature, high concentration of carbon dioxide and a high concentration of chlorides are responsible for the low population of euglenoids.

A total of 3 genera and 39 species of euglenoids were identified. Phacus, Euglena and Trachelomonas were the genera observed.

Seasonwise, their population always enhanced during summer followed by monsoon.

Cyanophyceae: The present investigation reveals low population of blue-green algae compared to chlorococcales, diatoms and euglenoids.

A total of 11 genera and 23 species of blue-greens were observed. Genera Oscillatoria, Spirulina, Microcystis and Anabaena occurred abundantly. Arthrospira, Cylindrospermum and Aphanothecae occurred as rare forms.

Alkaline pH, high concentration of dissolved organic matter, carbon dioxide, phosphates and calcium coupled with low concentration of total kjeldahl nitrogen is responsible for the low abundance of blue-green algae. However, summer recorded their highest population.

In general, the lake is oligotrophic but occasionally tends to show the characters of eutrophication. The lake is rich in plankton population with the species diversity. The data generated clearly reveals that the lake under study is oligotrophic. Hence, it is suggested to maintain the status quo of the lake by enforcing the necessary mitigative environmental protection acts. Also, it is imperative to protect the lake from the adverse effects of human activities.

To avoid pollution stress, the following mitigative steps have to be undertaken on a war footing:

Unplanned growth of human habitation in the vicinity of the lake has to be checked.

An awareness among public and farmers regarding the impact of pollution and conserving the quality of water should be created through mass media programmes.

The farmers of the adjoining area should be educated for judicious utilisation of chemical fertilisers to prevent the enrichment of water through nitrogenous and phosphate derivatives.

The use of pesticides should be avoided to the maximum extent possible. However, if necessary, the required dose of pesticides should be used against the target organism. This helps to reduce the pesticide load in the lake.

The people residing in the neighbouring villages should be advised strictly against washing clothes and animals in the lake. They are to be informed about the impact of environmental degradation and sustainable conservation of this lake.

The practice of encroaching the area by farmers of nearby villages adjoining the lake for irrigation during summer should be curbed.

The surrounding hillocks offer an excellent panoramic view of the lake. Moreover, the clear water of the lake could give immense pleasure and joy while on a boating trip. But sadly, the government has not evinced any interest to develop this lake as a tourist spot. Hence, nature clubs and non-government organisations should come forward and pave way to give the lake the status of being one of the most popular tourist resort of our state.

BIBLIOGRAPHY

- Adamczak, Bonena, Marta Luscinska, Andezej's Oleksowicz and Marian Rejewski, 1979. The preliminary production of lake Tynwald, Poland. ACTA UNI UNI COLAI COPERNICI PRLIMON,0(11): 3-10
- Adikary, S.P and Jayanti Sahu .1988. Limnology of the thermal springs of Orissa (India). J. Bombay Nat. Hist. Soc. 84 (2): 497 -503.
- Adikary, S.P. and J. Sahu. 1992. Trichodesmium bloom of Chilka lake, East coast of India. Phykos. Delhi, 30(1 and 2), 101-7.
- Adoni, A.D. 1975. Studies on micro-biology of Sagar lake; Ph.D. Thesis (Sagar; Saugar University), 254 p.
- Agbeti, M.D and John. P. Smol.1995. Winter limnology: A comparison of physical, chemical and biological characteristics in two temperate lakes during icecover. Hydrobiologia,304: 221-23
- Agbeti. M.D; Smol J.P. 1995. Winter limnology: A comparison of physical, chemical and biological characteristics in two temperate lakes during ice cover. Hydrobiologia,304(3): 221-234.
- Ahluwalia, A.S., M. Kaur and S.Dua. 1989. Physio-chemical characteristics and effect of some industrial effluents on the growth of a Green Alga Scenedesmus Sp. Indian J. Environ. Hlth; 31 :112-119.
- Akhmetova, N.I. 1986. Seasonal change in the composition of diatom in Eastern lake Balchash (Kazakh SSR, USSR). Bot Zh(Leningr), 71(5): 631-634.

- Ambasht, R.S. 1971. Ecosystem study of a tropical pond in relation to primary production of different vegetation zones, Hydrobiologia, 12:57-61.
- Anand, V.K. 1988. Limnology of fresh water algae of the Gadigarh stream, Jammu. J. Curr. Bio. Sci. 5(1): 11-16.
- Andersen, R.A. (1992). Diversity of eukaryotic algae. Biodiv. Conserv. 1, 267-92.
- Adhikary S.P.; Sahu. J.K. 1992. Distribution and seasonal abundance of algal forms in Chilka Lake, east coast of India. Japanese Journal of Limnology 53(3): 197-205.
- Anon. 1968. Eutrophication of inland waters. Notes on water pollution No. 1.41.1 (HMSO, London).
- APHA; 1975. Standard methods for the examination of water and waste water. 14 Edition. American Public Health Association (NEW YORK).
- APHA. 1976. AMPHA, Standard methods for the examination of water and waste water, 15th Ed. Washington.
- APHA; 1985. AMPHA Standard methods for the examination of water and waste water, 16th Ed. Washington.
- Alvarej; Cobelas. M; Velasco J.L; Rubio. A; Rojo C. 1994. The time course of phytoplankton biomass and related limnological factors in shallow and deep lakes: A multivariate approach. Hydrobiologia 275-276(0): 139-151.
- Basterrechea, Manuel. 1986. Limnological characteristics of lake Amatitlan. Guatemala. Rev. Bras. Biol. 46(2): 461-468.

- Beaver, R., John, L. Thomas, Cristman and James. S. Bays; 1981. Thermal regimes of Florida (USA) lakes. Hydrobiologia, 83(2); 267-274.
- Berbert Romeufontes and P. Fernando Nunesdacruz. 1987. Residue levels of BHC (HCH) in the main rivers and lakes of the Cacao region of southern Bhuia, Brazil. Rev. Theobroma. 16(2); 89-96.
- Bhattacharya, T., R.K. Saha and T. Chakrabarti. 1988. Diet Variation in the water quality, plankton population and primary production in a fresh water pond in Tripura. Environ. Ecol., 6(4); 928-32.
- Belsare, D.K; Gautam A; Prasad.D.Y; Gupta. S.N. 1992. Limnological studies on Bhopal lakes; Numerical and volumetric variation in plankton population of a polymictic tropical lake. Proceedings of the Natn. Acad of Sciences India section B (Biological Sciences) 62(4): 521-533.
- Bhunya, S.P. and B.S.Mohanty. 1990. Hydrobiological status of NandanKanan lake - A preliminary report. Proc. Indian Sci. Congr. Ass., Indore 78 pt. 111, Sect. 1x, 92-3.
- Bilgrami, K.S., J.S. Datta Munshi, R.N. Yadava and B.N. Bhowmick. 1985. Limnological studies of thermal springs of Bihar, India. Proc. Indian. Natn. Sci. Acad B51 No. 1: 70-77.
- Bajpai A.K; Verma. S. S.S; Agarker M.S. 1994. Ecological study on a fresh water pond in Gwalior, M.P. Bionature 14(2): 123-129.
- Birge, EA and C. Juday. 1911. The inland lakes of Wisconsin. The dissolved gases of the water and their biological significance. Wisconsin Geol. Nat. Hist. Surv Bull., 22; 7-259.

- Begum Z.N.T; Hadi A.A. 1994. Comparative abundance of phytoplankton, periphyton, pelagic algae and some related physico-chemical parameters in two shrimp culture ponds. Bangladesh Journal of Botany,23(1): 93-98.
- Brett M.T. Wiackowski K; Lubnow F.S; Mueller Solger A; Elser J.J. 1994. Species dependent effects of zooplankton on planktonic ecosystem processes in Castle lake, California. Ecology (Tempe) 75(8): 2243-2254.
- Bodre, R.M., K.P.N. Kumaran, and C. Rajshekar. 1993. Eutrophication of Lonar lake. Maharashtra. Current Science,65: 347-351.
- Borker, M.R., K. Saraswat, S. V. Quadros and D. Fernandes. 1992. Diecycle of some abiotic and microbial quality of a fresh water reservoir during monsoon at Mormugao, Gao, Bioved, 3(2): 133-136.
- Burr, G.O. 1941. Photosynthesis of algae and other aquatic plants. A symp. Hydrobiology Univ, Wisconsin Press, pp. 163-181.
- Bowling, R.C. and P.A. Tyler. 1988. Lake Chisholm, a polyhumic forest lake in Tasmania. Hydrobiologia,161: 55-67.
- Campos, Hugo, Wladimir Steffen Cartosroman, Luiszuniga and Gloria Aguero. 1983. Limnological studies in lake, Villarrica (Chile); Morphometric, Physical, Chemical, planktonic factors and primary productivity. Arch. Hydroboil Suppl., 65(4): 371-406.
- Chandan Bohra (1990). Limnological survey of an ancient pond at Barharwa (Bihar). J. Fresh water Bio., 2(4): 361-364.
- Chandra prakash. 1983. water quality of Keetham lake (Soor Sarovar). J. Envir. Biol., Muzaffarnagar. 4(4): 193-200.

- Charlton M.N. 1980. Hypolimnion Oxygen Consumption in lakes; Discussion of productivity and morphometry effects. Can. J. Fish Aquat Sci., 37(1); 1531- 1539.
- Chitranshi, V.R., R.S. Bilgrami. 1986. Comparative ecological studies on two-ox-bow lakes of river Burhi Gandak I report on macrophytes. Proc. Natn. Acad. Sci., India Sec. B 56(3): 247-253.
- Chatterjee, A.A.K. 1992. Water quality of Nandankanan lake. Indian J. Environ. Hlth., 34(4): 329-333.
- Chavez, F.P., K.R. Buck, K.H. Coale, J.H. Martin, G.R. Dijullio, N.A. Wellschmeyer, and A.C. Barber. 1991. Growth rate, grazing, sinking, and iron limitation of equatorial pacific phytoplankton. Limnol. Oceanogr, 36: 1816-1833.
- Clarke G.L. 1954 Elements of ecology. John wiley and sons, Inc. New York.
- Clarke, 1965. Elements of ecology, John Wiley and sons Inc., New York (First Edition), 549.
- Cole. G.A 1983. Textbook of limnology (3rd ed). C.V. Mosby Co. St. Louis. 401 pp.
- Cahoon, L.B.; Kucklick J.K; Kiefer R.H; Willey J.D. 1993. Effects of chemical weathering on limestone distrubution and phosphate release into lake Waccamaw, North Carolina. Journal of the Elisha Mitchell scientific society 109(3)123-134.
- Conway, C.J. 1982. Vertical and seasonal distribution of organic and inorganic nutrients at a deep station in lake Michigan. Diss Abst. Int pt B. Sci and Eng., 43(6): 242.

- Croome, R.L. and P.A. Tyler. 1988. Phytoflagellates and their ecology in Tasmanian polyhumic lakes. Hydrobiologia 161: 254-253.
- Dakshini, K.M. M and S.K. Gupta. 1984. Physiography and limnology of three lakes in the environs of the Union territory of Delhi, India. Proc. Indian Natn. Sci. Acad 4: 417-430.
- Davis, C.C. 1956. Notes on the bloom of Euglena haematodes in Ohio, Ecology, 37: 192-193
- Deshmukh, S.B., N.S. Phadke and V. Kothandaraman. 1964. physico-chemical characteristics of Ambazari lake water. Environmental Health 6: 186-188.
- Divakaran, O., M. Aruna Chaiam, N.B. Nair and N.K. Balasubramaniam. 1982. Seasonal variation of zooplankton of the Ashtamudi lake, South West Coast of India. Mahasagar, Indian J. Ecol., 15(1): 43-50.
- Druvietis, I. 1995. Phytoplankton periodicity in different trophic state lakes in Latvia. Proceedings of the Latvian Natural sciences 0(3-4): 98-100.
- Duce, R.A. and N.W. Tindale. 1991. Atmospheric transport of iron and its deposition in the oceans. Limnol. Oceanogr. 36: 1715-1726.
- Fogg, G.E. 1960. The extracellular products of algae. Proc. Symposium on Algology, New Delhi, 138-143.
- Eckartz Nolden G. 1992. The phytoplankton of lake Laacher See: Species composition and seasonal periodicity. Ergebnisse der Limnologie 0(38): 143-160.

- Frenette J.J., Vincent W.F; Legendre L; Nagata T. 1996. Size dependent changes in phytoplankton C and N uptake in the dynamic mixed layer of lake Biwa. Fresh water Biology., 36(2): 221-236.
- Forbes, S.A. 1887. The Lake as Microcosm. Bull Peoria (111) Science Association. Reprinted 1925 in Illinois Natural History Survey. Bull., 15: 537-550
- Forel, F.A 1901, Hand Buch der Seckunde, Allgemeine Limnologie. Stuttgart., 3: 249.
- Forsyth, D.J., M.T. Downes, M.M. Gibbs, L. Kemp, I. Mccallum, L. Mackenzie, and G. Payni. 1983. Aspects of the limnology of lake Rotongaio (Newzealand). Nz. J. Mar Fresh Water Res., 17(4): 423-436
- Fritsch, F.E. 1907. The subaerial and fresh water algal flora of the tropics. Ann. Bot., 21: 235-275.
- Gandhi, H.P. 1955. A contribution to our knowledge of the fresh water diatoms of Pratabgarh, Rajasthan. J. Indian bot. Soc., 34, 307-337.
- Guiral. D; Arfi. R; Bouvy. M; Pagano. M; Saint Jean L. 1994. Ecological organisation and succession during natural recolonisation of a tropical pond. Hydrobiologia., 294(3): 229-242.
- Green, J. and Holden, M.J. 1960. The hydrology and plankton of the river Sokoto, J. Anim. Ecol., 29: 65-84.
- Ghosh, A. and J.P. George. 1989. Studies on the abiotic factors and zoo plankton in a polluted urban reservoir: Hussain Sagar, Hyderabad: Impact on water quality and embryonic development of fishes. Indian J. Environ Hlth; 31(1) : 49-59.

- Gibson, C.E., Y. Wu, S.J. Smith and S.A. Wolfe-Murphy. 1995. Synoptic limnology of a diverse geological region: Catchment and water chemistry. Hydrobiologia, 306: 213-224.
- Gajewski A.J. 1993. Phytoplankton production and bacterial activity in decomposition of organic matter in an eutrophic lake: The case of amino peptidase activity. Acta Microbiologica Polonica, 42(3-4) 291-302.
- Goeltenboth, F. 1982. Ecology of a seminatural lake, Rawapening (Central Jawa). Int.J. Ecol. Environ Sci., 8(3): 179-186.
- Gonzalves, E.A. and D.B. Joshi. 1946. Fresh water algae near Bombay. The seasonal succession of the algae in a tank at Bandra. J. Bomb. Nat. Hist. Soc., 46: 154-176.
- Gorham, Eville, Walter E. Dean and Jon E. Sanger 1983. The chemical composition of lakes in north central USA. Limnol. Oceanogr., 28(2): 287-301.
- Gojdic, M. 1939. Some observations of Euglena sanguinea Ehrd. Trans. Amer. Micr. Soc., 58: 241-248.
- Grygiere, K., Eugenia, Maria Januszka, Danuta Kruger and Blandyna Ewawasilewska. 1979. The influence of ammonia water on bacteria, plankton and bottom fauna of Ponds. Rocz Nauk Roln. Ser H. Ry – bactwo., 99(1): 121-140.
- Gunnerson, C.G. and T.E. Bailey. 1963. Oxygen relationship in the Sacramento river. J. Saint. Eng. Div. Am. Soc. Civ. Engrs., 89: 59-124.
- Ggdward, M.B.E., 1934, An investigation of the causal distribution of algal epiphytes. Bot, Zbl. Band., 3506-539.

- Heath Cote, W. Isobel, R. Weiler and James. W.Tanner. 1982. Lake Erie near shore water chemistry at Nanticoke, Ontario, Canada, 1961 - 78, J.Great Lakes Res; 7 (2): 120-125.
- Hegde, G.R. and S.G. Bharati. 1983. Fresh water algae of Bijapur district , Karnataka State, India. Phykos, 22 : 167-170.
- Hegde, G.R. and S.G. Bharati. 1985. Comparative phytoplankton ecology of fresh water ponds and lakes of Dharwad, Karnataka State, India. Proc. Nat. symp. pure and Appl. limnology, (ed. o. Adoni, A.D. Bull. Bot. Soc. Sagar 32: 24-29)
- Hehmann A; Krienitz L. 1996. The succession and vertical distribution of the experimentally divided naturally acidic Lake Grosse Fuchskuhle (Brandenburg, Germany). Limnologica;26(3): 301-309.
- Holopainen A.L; Huttunen P; Letanskaya G.I; Protopopora E.V. 1996. The trophic state of Lake Ladoga as indicated by late summer phytoplankton. Hydrobiologia;322 (1-3): 9-16.
- Howland, L and Lucy, J, 1931. A four year investigation of the Hertford Shire Pond New Phytol, 30:211-265.
- Happey; Wood.; C.M; Lund A.H. 1994. Production of new organic carbon and its distribution between autotrophic picoplankton, bacteria, extracellular organic carbon and phytoplankton in an upland lake. Fresh water. biology;31(1): 1-18.
- Hamid, A. 1942. Indian water moulds III Proc. Indian Acad. Sci. B. 15: 206-215.

- Hegde, G.R. and L.V. Karanth. 1987. New records of fresh water algae from Karnataka State (India). Journal Bombay Nat. Hist. Society, vol. 84(2) : 493-497
- Hickel, B. 1973. Limnological investigation in lakes of the Pokara valley, Nepal. Int. Revuees Hydrobiol., 58: 659-672.
- Hindak, Fretisek and Andrejholod. 1983. Some planktonic coccoid green algae (Chlorococcales, Chlorophyceae) from the gravel pit lake near Kosice (Czechoslovakia). Biologia (BRATISL), 38 (5) : 427-444
- Hodgetts, W.J. 1922. Periodicity of fresh water algae in nature. New phytol., 21:15-33
- Hoskin, C.M. 1959. Studies of oxygen metabolism of streams in North Carolina. Publ. Inst. Mar. Sci. Univ. Texas 6: 186-192
- Hurghisu and Ileana. 1988. The dynamics of the most important nutrients (nitrogen and phosphorus) in some lakes of the Danube Delta that are regarded as trophic status indicators. Revroum. Biol. Ser. Biol. Anim., 33(2): 149-157.
- Hutchinson, G.E. 1957. A Treatise on Limnology. New York, John wiley and sons. 1:1015-1016.
- Hutchinson. G.E. and Pickford, G.E. 1932 Limnological observations on Mountain lake, Virginia. Int. Revue. Geo. Hydrobiol. Hydrogr., 1932, 27, 25-64.
- Imhoff, Johannes, F., Hans, G. Sahl, Gaber, S.H. Soliman and Hans. G. Trueper. 1980. The wadi naturn. Egypt. Chemical composition and microbial mass developments in alkaline brines of eutrophobic desert lakes. Geomicrobiol J. 1(3): 219-234.

- Ilmavirta V., Huttunen. P. 1990. Characterisation of 151 small lakes in Eastern Finland based on their water chemistry, land use on catchment and phytoplankton communities. Limnologica, 20(2): 229-242.
- ISI (Indian standard Institution), 1982, Indian standard tolerance limits for inland surface water subject to pollution. Second revision, IS: 2296.
- Iyengar, M.O.P and B. Nirmala Bai. 1941. Desmids from Kodaikanal, South India. J. Indian Bot. Soc., 20: 73-103.
- Jindal R; Ghezta R.K. 1991. Diel Variations in an eutrophic pond. Geobios, 18(1): 25-28
- Jana, B.B. and H.L. Sarkar 1971. The limnology of Swetganga, the thermal spring of Bakreswar, West Bengal, India. Acta Hydrobiol., 10: 101-108.
- Jensen, Henning Skovgaard and Frede Ostergaard Anderson. 1987. Sulphate reduction in a coastal lake during summer stratification. Arch. Hydrobiol. 108(4): 465-482.
- Jones, V.J. 1996. The diversity, distribution and ecology of diatoms from Antarctic inland waters, Biodiversity and conservation 5, 1433-1449.
- June and Fred, C. 1987. Physical, chemical and biological characteristics of lake sharpe, South Dakota (USA) 1966-1975. US Fish Wild. serv. Fish Wild. L. Tech. Rep., 0(8): 1-20.
- Jyothi. B. 1990. Ecology and biochemical aspects of Algal blooms. Ph. D. Thesis. Osmania University.

- Kaushik S.; Agarkar M.S; Saksena D.N. 1991. Water quality and periodicity of phytoplankton algae in Chamban Tal, Gwalior, M.P. Bionature., 11(2): 87-94.
- Kanungo, V.K., M.L. Naik and Y.K. Jain 1985. Physico-chemical characteristics of sullage and some ponds of Raipur City Geobios., 12(3-4): 154-156.
- Karydis, Michael and Nikoletta Mos-Chopoulou. 1982. Vertical nutrient and phytoplankton distribution in relation to physical stability. Hydrobiologia., 94(1): 97- 102.
- Kaul, V., J.K. Handoo and R. Raina 1980. Physico-chemical characteristics of Nilnag-A high altitude forest lake in Kashmir-and its comparison with the valley lakes. Proc. Indian Natn. Sci. Acad., 46(4): 528-541.
- Khan M.A. 1996. The phytoplankton periodicities of two warm climate lakes subject to marked seasonal variability. Journal of Tropical ecology., 12(4): 461-474.
- Kamala, A and Kanth Rao, D.L., 1990. Environmental Engineering, Tata McGraw-Hill Publishing Company Ltd., p.p. 57.
- Kaul, V. and Nirmala Saraf. 1985. Gross composition of two weeds in the Dal lake. Proc. Indian Natn. Sci., Acad., 51 (1-3): 240-247.
- Kaul, Siddarth, 1983. Limnological studies of an aquatic body; Lalpari Talab, Rajkot (India). Indian J. Ecol., 10(1): 124-128.
- King, R.D. and P.A. Tyler. 1981. Limnology of Perched lake, South-west Tasmania, Australia, Aust. Mar. Fresh water Res., 32(4): 501-515.77,
- Koschel and Rainer. 1980. Phosphate affinity of plankton in the euphotic zone of lakes. Limnologica., 12(1) : 141-146.

- Koschel, Rainer, Juergen Benndorf, Gottfried Proft and Frieder Recknaget. 1983. Calcite precipitations as a natural control mechanism of eutrophication. Arch Hydrobiol.(3): 380.
- Kratz, Timothy, K., Robert. B. Cook, Carl. j. Bowser and Patrick L. Brezonik. 1987. Winter and spring pH depressions in northern Wisconsin (USA) lakes caused by increase in carbon dioxide partial pressure. Can J. Fish Aquat Sci., 44(5): 1082-1088.
- Krishna Rao, D.S. 1990 - Periphyton producers in peninsular tank-Env. Eco. 5(1): 184-188.
- Kumagi, Michio, Hiroto maeda and Yukio Oonishi. 1986. Vertical circulation and formation of anoxic layer. Case study at dredged area in southern basin of lake Biwa (Japan). Jpn. J. Limnol.,47(1): 27-36.
- Lalman and Dixith, A.M. 1989. Changes in water quality by industrial waste disposal. Indian J. Environ. Hlth., 31, 1: 73-78.
- Leach, J.H. 1982. Limnological sampling intensity in lake St. Clair, Canada, in relation to distribution of water masses. J. Great lakes Res. 6(2): 141-145.
- Lerman, Abraham and Werner Stumm. 1989. Carbon dioxide storage and alkalinity trends in lakes. Water Res., 23(2): 139-146.
- Larson G.L.; Mc Intire. C.D, Karmangh - Thomas E; Hawkins Hoffman. C. 1995. Limnology of isolated and connected high-mountain lakes in olympic NationalPark; Washington State, USA. Archiv fuer Hydrobiologie ., 134(1): 75-92.

- Lindpear and Aini. 1981. Major components of bottom sediments of Estonian lakes, USSR. Eesti Nsvtead. Akad Toimbol.,30(4): 322-326.
- Lyubezhov, Yu, E. and M.E. Kravchenko. 1986. Phytoplankton of Kopet-Dag storage lake (Turkmen SSR, USSR) in 1980-82. IZV Akad Nauk Turkm SSR SER Biolnauk,0(1): 1-25
- Lindgaard C. 1994. The role of zoobenthos in energy flow in two shallow lakes. Hydrobiologia;275-276(0): 313-322.
- Lehr, J.H., Tyler, E.G., Wayne. A.P. and Jack, D.,1980, Domestic water treatment. McGraw Hill Book company, New York.
- Lund, A. 1934. Studies on Danish fresh water Phycomycetes and notes on their occurrence particularly relative to the hydrogen ion concentration of water. Mem. Acad. Roy. Sci. Denmark 6: 1-97.
- Madhusudanan, M., B.P. Shukla and S. Sharma. 1989. Water quality management of fresh water lakes - A case study of Mayem lake in Goa. J. Instn. Public Hlth. Engrs. India. 3: 26-30.
- Maes, L. 1983. Diatoms and water quality in a polluted low land brook pond system at bloom (Antwerp, Belgium) during an aeration experiment. Biol. Jaarb.,51(0): 79- 103.
- Manikya Reddy, P. 1984. *Ecological studies in the river Tungabhadra (A.P) with special reference to the effect of paper mill effluents on the river.* Ph. D. thesis. Osmania University, Hyderabad.

- Mansoor Ali and J.N. Tiwari. 1989. Monitoring the pollution of lake Hussain Sagar through correlations among its water quality parameters. Proc. Nath. Acad Sci Letters., 12(7): 301-303.
- Macintyre S; Melack J.M 1995. Vertical and horizontal transport in lakes linking littoral, benthic and pelagic habitats. Journal of the North American Benthological Society.,14(4): 599-616.
- Mahamood, S; Sheni A.N. 1993. Regression studies on the Physico-chemical characteristics and plankton life of fish pond. Pakistan Journal of Zoology., 25(1): 19-21.
- Mann, D.G. and Droope, S.J.M (in press) Biodiversity, biogeography and conservation of diatoms. Hydrobiol.
- Mansoor H.A; Tiwari J.P.; Gurudev A.S. 1993. Limnological study of Lakshmital lake, Jhansi, India during rainy season. Geobios (Jodhpur),20(3): 120-122.
- Marshall, B.E. and Falcones, A.C. 1973. Eutrophication of tropical impoundment lake Mclwaine, Rhodesia. Hydrobiologia, 43(1-2): 109-123.
- Muukankameje R; Plisnier P.D; Descy J.P; Massant L. 1993. Lake Muzahi, Rwanda: Limnological features and phytoplankton production. Hydrobiologia., 257(2): 107-120.
- Munawar. M. 1970. Limnological studies on fresh water ponds of Hyderabad, India-II. The Biotype. Hydrobiologia,35: 127-162.
- Molot, L.A. and P.J. Dillon. 1991. Nitrogen/Phosphorus ratios and the prediction of chlorophyll in phosphorus limited lakes in Central Ontario Can. J. Fish Aquat. Sci., 48:140-145.

- Morgan, J.A.J., and Roger, N. Pickup. 1993. Activity of microbial peptidases, oxidases and esterases in lake waters of varying trophic status. Canadian Journal of Microbiology, 39(8): 795-803.
- Munawar. M. 1974. Limnological studies of fresh water ponds of Hyderabad, India IV. The Biocenose. Periodicity and species composition of unicellular and colonial phytoplankton in polluted environments. Hydrobiologia,45: 1-32.
- Nandan, S.N. and Patel. R.J. 1985. Study of phytoplankton and Physico-chemical parameters as indicators of eutrophication Res. J. Pt. Environ,2(1): 23-27.
- Nygaard. G. 1991. Seasonal periodicity of plankton i.e., desmids in oligotrophic lake Grane Langso, Denmark. Hydrobiologia;211(3): 195-226.
- Narendrababu, G.C., Manohara Chary and N.S. Shyamasunder rao.1993. Physico-chemical complexes of two polluted pond waters. Indian J. Microbial. Ecol., 3: 131-136
- Nayak, T.R. 1993. Phytoplankton and certain Physico-chemical conditions in fresh water lake "Matyatal" panna (M.P.) India. Proc. Acad. Environ. Biol., 2(2) :179-85.
- Olila, O.G., K.R. Reddy and W.G. Harris. 1995. Forms and distribution of inorganic phosphours in sediments of two shallow eutrophic lakes in Florida Hydrobiologia; 302 :147-161.
- Ouellet, M.M. Dickman, M. Bisson and P. Page. 1989. Physico-chemical characteristics and origin of hyper saline meromictic lake Garrow in the Canadian high arctic. Hydrobiologia, 172: 215-234

- Pahwa, D.V. and Mehrotra, S.N. 1966. Observation of the fluctuations in abundance of plankton in relation to certain hydrobiological conditions of River Ganga. Proc. Nat. Acad. Sci., India XXXVI Section B., part II. 157-190.
- Pande, V.C. and D.C. Pandey. 1980. Diatom flora of Allahabad (India) - I. Proc. Indian Natn. Sci. Acad., B: 46 3: 350-355.
- Panda, D. Tripathy, S.K., Patrick, D.K., Choudhury, S.B. Gouda, R. and R.C. Panigrahy. 1989. Distribution of nutrients in Chilka lake, east coast of India. Indian J. Marine Sci. 18(4): 286-288.
- Pant, M.C. and A.P. Sharma. 1983. Nano plankton chief primary producers in lake Nainital. Current Science, 50(15) : 739-41.
- Parimala Varadaraj and S. Ayyappan. 1989. Population and distribution of heterotrophic bacterial flora in fresh waterbodies in Bangalore. Indian J. Environ. Hlth., 31(2) : 162-170.
- Parra, Oscar, O., Eduardo Ugarte and Vicotrdellarossa. 1981. Seasonal succession and hydro phytoplankton association of three lentic fresh waterbodies in the region of Concepcion, Chile. Gayana Bot ., 0 (36): 1-35.
- Parvateesam, M., M. Mathur and N. Sharma. 1991. Influence of Physico-chemical characteristics on the periodicity of algal flora in a fresh water lake J. Photol. Res); 4(1) 33-40.
- Parvateesam, M. and M. Mishra. 1993. Algae of Pushkar lake including pollution indicating forms. phykos., Delhi. 32 (1 and 2): 27-39.

- Patil, M.K., Usha Namboodiri and K.S. Unni. 1986. Changes after sediment removal in a sewage pond-physical-chemical characteristics. All India sem: on water quality around urban ecosystem (Ed.) K.S. Unni, 222 pp.
- Patrick, R. 1948. Factors affecting the distribution of diatoms .Bot. Rev., 14 (8): 473-524
- Perrow .M.R; Moss B; Stansfield. J. 1994. Trophic interactions in a shallow lake following a reduction in nutrient loading: A long term study. Hydrobiologia , 275-276(0): 43-52.
- Pearsall, W.H. 1930. Phytoplankton in the English lakes - I. The proportion in the water of some dissolved substances of biological importance. J. Ecol. , 18: 306-320.
- Pearsall, W.H. 1932. Phytoplankton in the English lakes - II. The composition of the phytoplankton in relation to dissolved substances J. Ecol. , 29: 241-262.
- Petre, T. 1975. Limnology and fisheries of Nyumba Yamung, a man-made lake in Tanzania. Afr. J. Trop. Hydrobiol Fish., 4: 39-50.
- Pearsall, W.H. 1921. The Development of vegetation of English lake considered in relation to general evolution of glacial and rock basins. Proc. Roy. Soc. London, 13: 259-284.
- Philipose, M.T. 1960. Fresh water phytoplankton of inland fisheries. Proc. Symp Algal., ICAR, New Delhi. 272-291.
- Philipose, M.T. 1972. Notes on the ecology , role and possible control of some common blue-green algal blooms in Indian fresh water ponds in T.V. Desikachary (ed.). Taxonomy and biology of the Blue-green algae, 455-60, Madras Univ.

- Pisolkar, M.D., Rao., P.L.N., Singh, B.K. and B.L. Pandey. 1992. A note on periphytic communities of Bhatghar reservoir, Pune, Maharashtra. Sci. and Cult.,58(11 and 12): 239
- Philipose, M.T. 1959. Freshwater Phytoplankton of Inland fisheries, Proc. Symp. Algol. ICAR, New Delhi, pp. 272-291.
- Potter, I.C., Cannan, D. and J.W. Moore. 1975. The ecology of algae in the Moruya river, Australia. Hydrobiologia Res., 47: 415-430.
- Prasad, D.Y. 1990. Primary productivity and energy flow in upper lake, Bhopal, Indian J. Environ. Halt.,32(2): 132-139.
- Prescott, G.W. 1938. Objectionable algae and their control in lakes and reservoirs Louisiana Municipal;Rev. 1: 2-3
- Prescott, G.W. 1951. Algae of the Western Grate lakes area. Exclusive of desmids and diatoms. Trans. Amer. Micro Soc., 70: 946 pp.
- Price, N.M., L. F. Anderson, and F.M.M. Morel 1991. Iron and nitrogen nutrition of equatorial pacific plankton. Deep sea Res. 38: 1361-1678.
- Puttaiah, E.T. and R.K. Somashekhar. 1985. Limnological studies on certain fresh waterbodies of Mysore district, Karnataka I. Ionic composition.Proc. sym. Recent advances in plant sciences.,381-386.
- Puttaiah. E.T. and R.K. Somashekar. 1987. Distribution of euglenoids in lakes of Mysore city. phykos.,26: 39.46.

- Rai Hakumat and Gary Hill. 1980. Classification of Central Amazon lakes (South America) on the basis of their microbiological and Physico-chemical characteristics Hydrobiologia., (1/2) : 85-100.
- Rai, H. and G. Hill. 1982. On the nature of ecological cycle of Lago January: A Central Amazonian Ria - Varzea Lake Trop. Ecol., 23: 1-49.
- Rai, H. and G. Hill 1984. Microbiology of Amazonian waters. pp. 413-441. In: Sioli (ed). The Amazon. Dr. W. Zunk publishers, Netherlands.
- Rosas. I; Velasco A; Belmont R; Baez A; Martinez A. 1993. The algal community as an indicator of the trophic status of lake Ratzcuaro, Mexico Environmental pollution., 80(3): 255-264.
- Rao, C.B. 1953. On distribution of algae in a group of six small ponds J. ecol., 41: 62-17.
- Rask, M; Arvola. L; Salonen. K, Ruuhijar. J. 1992. Limnological studies on the lakes in Evo forest area: A historical perspective. Aqua Fennica., 22(2): 185-192.
- Rao V.N.R; Mohan R; Hariprasad V, Ramasubramaniam R. 1993. Seasonal dynamics of Physico-chemical factors in a tropical high altitude lake; An assessment in relation to phytoplankton. Journal of Environmental Biology., 14(1): 63-75.
- Rao, V.S. 1977. An ecological study of three fresh water ponds of Hyderabad. India IV. The phytoplankton. Hydrobiologia., 53: 13-22.
- Rao, N. G.S., S.L. Ragavan and A. David . 1982. Limnology of selected village ponds in Bangalore district of Karnataka. Mysore J. Agri., Sci., 16: 183-200.

- Rao, P.B., Sharma A.P. and J.S. Singh. 1992. Limnology and phytoplankton production of high altitude lake. Int. J. Ecol. Envir Sci., 8(1): 31-50.
- Ramakrishna Rao, S. 1990. Bioenergetics and methodology of energy flow in important wet lands and lake systems of Eastern Ghats. Environmental Research., 1: 42, Pub. by Ministry of Environ. and Forest, New Delhi, India.
- Rautray, B.K., P.K., Bailar Singh, S. Padhi and R.C. Choudhury. 1991. Biological monitoring of fresh water ponds of Berhampur near Behrampur, Orissa. Proc. Indian Sci. Congr Asc Indian. 78 Pt. 111, SE ct. VIII: 107.
- Reddy, K.R., P.D. Sacco, D.A. Graetz. K.L, Campbekl and L.R Sinclair. Water treatment by aquatic ecosystem: Nutrient removal by reservoirs and flooded fields. Environmental management; 6(3): 261-271.
- Rome S; Miracle. R. 1995. Diversity of the phytoplankton assemblages of a polymictic hypertrophic lake. Archiv fuer Hydrobiologic, 132(3): 363-384.
- Rekha Purohit and S.P. Singh. 1981. Seasonal variation in Physico-chemical limnology of shallow zones of Nainital lake, Western Himalaya India. Proc. Indian Natn. Sci. Acad., B 47(2): 194-203.
- Rhode, W. 1949. The ionic composition of lake waters. Proc. Int. Ass. Limnol., 10: 377-386.
- Round, F.E. 1953. An investigation of two benthic algal communities in Mahan Tarn, Yorkshire J. Ecol. 41: 174 -197.
- Round, F.E., Crawford, R.M. and Mann, D.G. (1990). The diatoms. P. 747. Cambridge: Cambridge University press.

- Roy, T.K. and P.K. Verma. 1984. Biological studies of Sitakund - A thermal spring of Munger (Bihar) in relation to Physico-chemical parameters. Proc. Indian Sci. Congr. Ass. Ranchi Zool. Ent. Fish Sect. 715.
- Romo S., Miracle M.R. 1994. Population dynamics and ecology of subdominant phytoplankton species in a shallow hypertrophic lake (Albufera of Valencia, Spain). Hydrobiologie 273(1): 37-56.
- Saha, T.K. 1990. Volumetric estimation of planktonic biomass in relation to limnological conditions of the Hazaribag lake. Geobios. 17(1): 33-35.
- Saifullah, S.M., A.S. Mandura and A.K. Khafaji. 1988. A platy monas bloom in coastal waters of Jeddah, Saudi Arabia. Pak. J. Bot., 20(2): 285-290.
- Sakharov. V.B. 1982. Evaluating the state of lake Baikal phytoplankton by the method of desirability function Biol Navki. (Mosc). 0(5): 64-68.
- Sankaran Unni, K. 1985. Comparative limnology of several reservoirs in Central India. Int. Revue Ges. Hydrobiol. 70(6): 845-856.
- Santisi, Salvatore. 1979. A preliminary account on some mountain lakes of the Southern Appennines: phytoplankton investigation on three ponds of the Montesirino (Basilicata, Italy) G. Bot. Ital., 113(4): 275-286.
- Sarwar, S.G. and Zutshi, D.P. 1987. Studies on periphyton population of Himalayan lakes. I species composition and community structure on natural and artificial substrates. Proc. Indian Natn. Sci. Acad., B 53(3): 239-242.
- Sarwar, S.G. and M.A. Wazir. 1991. Physico-chemical characteristics of a fresh water pond of Srinagar (Kashmir): pollution Res. 10(4): 233-7.

- Sathyakala, G., Sayeeda Begum and Ahwarul Hasan. 1986. Effect of aquatic pollution on the mineral accumulation in water hyacinth. Proc. Indian Acad Sci. (Plant Sci), 96(1): 37-40.
- Schelske, Claire, L., Hans Zullig and Mary Boucherle. 1987. Limnological investigation and biogenic silica sedimentation and silica biogeochemistry in lake St. Moritz and lake Zurich (Switzerland). Sch Weiz Zhydrol., 49(1): 42-50.
- Schroeder, H.G., H. Windolph and J.Schneider. 1983. Balance of the biogenic calcium carbonate production in an oligotrophic lake Attersee (Salzkammergut, Austria). Arch. Hydrobiol., 97 (3): 356-372.
- Singh. R. 1990. Correlation between certain Physico-chemical parameters and primary production of phytoplankton at Jamalpur, Munger, India. Geobios (Jodhpur), 17(5-6): 229-234.
- Schulz, Liselotte. 1981. Nutrient input in lakes by bathers. Zentralbl bakteriol mikrobiol hygablorigb. hygumwelthyg Karankenhaushyg Arbeitshyg Praevmed., 173(6): 528-548.
- Sarkka J. 1996. Meiofauna ratios as environmental indicators in the profundal depths of large lakes. Environmental monitoring and Assessment, 42(3): 229-240.
- Seenayya, G. 1971. b. Ecological studies on the phytoplankton of certain fresh water ponds of Hyderabad, India II. The phytoplankton I, Ibid. 37: 55-88
- Seenayya, G. 1972. Ecological studies on the plankton of certain fresh water ponds of India II. Phytoplankton Hydrobiol., 39: 247-271

- Shardendu and R.S. Ambasht. 1988. Limnological studies of a rural pond and an urban tropical aquatic ecosystem: Oxygen enforms and ionic strength. Tropical Ecology,29(2): 98-109.
- Sharma, U.P. and D.N. Rai. 1989. Biomass of hydrophytes in an eutrophic pond of Bhagalpur, Bihar J. Fresh Water Bio., 1(2): 173-176.
- Sharma, J.P., Gupta, V.K. and J.B. Srivastava. 1986. Seasonal variations in the primary production and Physico-chemical properties of a eutrophic pond Bull. Environ. Sci., 3(3): 3-33.
- Shapiro, Joseph and Edward. B. Swain. 1983. Lessons from the silica decline in lake Michigan (USA). Science (Wash DC) 221(4609): 457-459.
- Shastry, C.A., K.M. Aboo, H.L. Bhatia and A.V. Rao. 1970. Pollution of upper lake and its effect on Bhopal water supply. Environmental Health,12: 218-238.
- Singh, V.P. 1960. Phytoplankton ecology of the inland waters of Uttar Pradesh. Proc. Sym. Algal. ICAR. New Delhi., 220-222.
- Singh, P. 1985. Environmental pollution and Management . Chungh. Pub., Allahabad.
- Singh, S.R. 1987. Observation on the phytoplankton primary production in an oxbow lake. Proc. Natn. Acad Sci., India Sec. B. 57(4): 328-36
- Singh and R. Mahajani. 1987. Phytoplankton and water chemistry of Rewalsar and Renuka lakes, Himachal Pradesh - Indian J. Ecol.,14(2): 273-277.
- Singh, D.K. and C.P. Singh. 1990. Pollution studies on river Suvernakha around industrial belt of Ranchi (Bihar). Ind. J. Envrion. Hlth; 32: 26-83.

- Sinha, S.K. 1995. Potability of some rural pond's water at Muzaffarpur (Bihar)
A note on water quality index poll Res,14(1): 135-140.
- Sinha Minakumari, K.P. Singh and T.R.C. Sinha. 1987. Plankton population of
 Saryamon lake, Bull Environ Sci., 4(4): 11-12.
- Singh, D.F. and M.K. Rai. 1984. Ecology of engineering college of Jabalpur (M.P.)
 Muzaffarnagar 5(3): 165-168.
- Singh, S.R. and K. Swarup. 1979. Limnological studies of Suraha lake (Ballia) II.
 Periodicity of phytoplankton. J. Indian Bot. Soc., 58: 319-329.
- Smith, Val H. 1982. The nitrogen and phosphorus dependence of algal biomass in
 lakes. An emperical and theoretical analysis. Limnol Oceanogr.,
 27(6): 1101-1112.
- Smith, V.H. 1983. Low nitrogen to phosphorus ratios favour dominance by blue-green
 algae in lake phytoplankton . Science Vol. 221, 669-671.
- Storm, K.M. 1924. Studies on the ecology and geographical distribution of fresh
 water algae and plankton. Rev. Algol., 1924, 43, 127-155.
- Smolander, V. and L. Arvola. 1988. Seasonal variation in the diel vertical distribution
 of the migratory alga Cryptomonas marssonii (cryptophyceae) in a small,
 highly humic lake. Hydrobiologia,161: 89-98.
- Sreenivasan, A. 1969. Eutrophication trends in a chain of artificial lakes in Madras
 (India). Environmental Health,11:392-401.
- Sreenivasan, A. 1970. Limnology of tropical impoundments. A comparative study of
 the major reservoirs in Madras state, India. Arch. Hydrobiol,36: 443-469.

- Srivastava, V.S. A.K. Rai and R.C. Mehrotra. 1989. Pollution status of soil beneath sewage disposal pond. Indian J. Environ. Hlth.,31(4): 314-320.
- Surendra Kumar and L. Sharma.1991. Comparative Physico-chemical limnology of lakes Pichhola and Fatehsagar, Udaipur (Rajasthan). Pollution Res., 10(3): 173-8.
- Subramanyan, R. and Sahay M.N. Observation on nitrogen fixation by some blue-green algae and remarks on its potentialities in rice culture. Proc. Indian Acad. Sci., 60 B, 145-154, 1964.
- Suxena M.R. and V. Venkateswarlu. 1966. Desmids of Andhra pradesh I from Pakhal lake, Warangal. Hydrobiologia,28: 49-65.
- Suxena M.R. and V. Venkateswarlu. 1970. Desmids of Andhra pradesh V from Warangal and its environs. phykos, 9: 17-28.
- Swarnalatha, N. and A. Narasing rao. 1991. Investigation of lake Saroor Nagar with reference to water pollution J. Phyto Res. 4(2): 121-9
- Swarnalatha, N. and A. Narasingrao. 1992. Ecological evaluation of cyanobacterial blooms. Advpi.Sci. 5(sp issue): 326-40.
- Swarnalatha, N. and A. Narasingrao. 1993. Ecological investigation of two lentic environments with reference to cyanobacteria and water pollution Indian J. Microbial Ecol.3: 41- 48.
- Swarnalatha, N and A. Narasingrao, 1997. Ecological studies of two lentic water bodies with reference to cyanobacteria. Indian J., microbial. Ecol.3:41-48.

- Takahashi and Eiji. 1981. Floristic study of ice algae in the sea ice of a lagoon, lake Saroma, Hokkaido, Japan. Mem Natl. Inst. polar Res. Ser., E. Biol Med. Sci., 0(34): 49-56.
- Talling, J.F. and Talling, I.B. 1965. The chemical composition of African lake water. Int. Rev. Gesamten Hydrobiol., 1965, 50, 421-463.
- Tugrul S.M, Morkoc. E.1991. Determination of limnological characteristics of Sapanca Lake. Doga Turk muhendislikve cerge Bilimleri Dergisi., 15(3): 265-282.
- Thomas, W.H. 1966, "Surface nitrogenous nutrients and plankton in north -eastern tropical pacific ocean." Limnol. and Oceanogr,11(3): 393.
- Tripathi, A.K., S.N. Pandey and R.K. Tiwari. 1987. Eutrophication study of Kalyanpur pond, Kanpur (India). Proc. Natn Acad. Sci. India. Sect B.,57 (3): 279-83.
- Tripathi A.K. and S.N. Pandey. 1989. Algae of polluted ponds of Kanpur, India. III. Eutrophication in Chandari pond. Polluted res,8(1): 7and10.
- Tryfon E; Moustaka Goni M; Nikolaidis. G. Tsekos I. 1994. Phytoplankton and physical-chemical features of the shallow lake Mikri Prespa, Macedonia, Greece. Archiv fuer Hydrobiologie,131(4): 477-494.
- Tripathy, P.K. and S.P. Adhikary.,1990. Preliminary studies on the water pollution of river Nandira. Indian J. Environ. Hlth.,32 : 363-368.
- Unni, K.S. 1985. Comparative limnology of several reservoirs in Central India. Int. Rev. Gensanteh. Hydrobiol., 70: 845-856.

Unni, K.S. and M.N. Naugoriya. 1989. Effect of thermal effluents on the stand structure and production of Typha angustata; Int. J. Ecol. Environ. Sci. 15:125-133.

Uspenskle. E. 1927. Iron as a factor in the distribution of lower aquatic plants. Plafanzenforschung, 9:66-75.

Ushakumari, Singh, S.K. and U.N. Singh. 1991. Biological parameters of Basman lake of Motihari, Bihar. J. Ecobiol.: 56-63.

Van Der Brink F.W.B.; De Leeuw. J. P.H.M; Van Der Velde. G; Verheggen. G.M.
1992. Impact of hydrology on the chemistry and phytoplankton development in flood plain lakes along the lower Rhine and Meuse. Biogeochemistry. (Dordrecht) 19(2): 103-128.

Vaishya, A.K. and A.D. Adoni. 1992. Phytoplankton seasonality and their relationships with Physico-chemical properties in a hypereutrophic Central Indian lake. Proc. Indian Sci. Acad., B 59: 153-160.

Van Den Brink. R.W.B., 1993. Impact of hydrology on the chemistry and phytoplankton development in flood plain lakes along the lower Rhine and Meuse; Biogeochemistry (Dordrecht)., 19(2): 103-128.

Venkateswarlu, V. 1969 b. An ecological study of the algae of the river Moosi, Hyderabad (India) with special reference to water pollution II. Factors influencing the distribution of algae. Hydrobiol. , 33 (3-4): 352-363.

Venkateswarlu, B. 1976. Taxonomy and ecology of algae in the river Moosi, Hyderabad, India-1 chlorophyceae, cyanophyceae and euglenophyceae. Nova. Hedwigia., 27: 661-688.

- Venkateswarlu, B. 1981. Algae as indicators of river water quality and pollution in : WHO workshop on biological indicators and indices of environmental pollution. Central Bd. Prev. cont. wat. pollution and Osmania university, Hyderabad. 93-100 pp.
- Vaquer. A.; El Hafa. M. 1991. Primary production of phytoplankton in an oligomestrophic lake. Archiv Fuer Hydrobiologie 121(2): 203-218.
- Venkateswarlu, V. 1996. Ecological studies on the river of Andhra pradesh with special reference to water quality and pollution. Proc. Indian. Acad Sci (plant-Sci) 96: 495-508.
- Venkateswaran, K., A. Shimada, H. Sakou and T. Maruyama. 1993. Microbial characteristics of Palau jelly fish lake. Canadian J. of microbiology. 39(5): 506-512.
- Verduin, J. 1954. Phytoplankton and turbidity in western lake Erie. Ecology 35: 550-556. 193.
- Verma, S.R. and (Miss) C.R. Shukla. 1968. Hydrobiological studies of a temple tank "Devikund" in Deoband (U.P), India. Environmental Health 10: 177-188.
- Vyas, L..N (1968). Studies in phytoplankton ecology of Pichhola lake, Udaipur, Proc. Symprecent Adv. Trop. Ecol 334-347.
- Welch, P.S. 1952. Limnology Mc, Graw- Hill Book company, USA. 3-443.
- West, W and West G.S 1912. On the periodicity of Phytoplankton of some British lakes. J. Linm. Soc. Bat. 40: 395-432.
- West, W. and G.S. West. 1911. The British fresh water plankton and the distribution of desmids. Proc. Roy Soc. 81. 165-206.

- Welch, P.S. 1958. Limnological methods, Balakristan, Philadelphia. U.S.A, PP. 281-381.
- Whitton, B.A., 1976. Algae, Vol. 2. River ecology. Edtd. by Whitton, PP. 81-105.
- Yamamoto, Ken, Ichi and O. Samu Hirano. 1980. The plankton of Ono Dammed lake, Japan. Shimonoseki Univ. Fish. 28(1): 33-46.
- Zafar, A.K. 1964. On the ecology of algae in certain fish ponds of Hyderabad, India, I, Physico-chemical complexes. Hydrobiologia,23: 179-195.
- Zafar, A.R. 1967. On the ecology of algae in certain fresh water ponds of Hyderabad. India 111. The periodicity. Hydrobiologia,30(1): 96-112.
- Zutshi, D.P. and A. Wanganeo. 1984. The phytoplankton and primary productivity of a high altitude subtropical lake. Verh. Internat. verein. Limnol.,22: 1168-1172.
- Zutshi, D.P. and A.U. Khan. 1988. Eutrophic gradient in the Dal lake, Kashmir. Indian J. Environ Hlth.,30(4): 348-354.