

Records of the Zoological Survey of India

**LIMNOLOGICAL INVESTIGATION ON WARD'S LAKE —
A WETLAND IN SHILLONG, MEGHALAYA, N.E. INDIA**

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Page 1-125

CONTENTS

General Introduction	1
Background of the region	2
Study site	4
Review of Literature	
Physico-chemical factors	7
Phytoplankton, Zooplankton, Bacteria	8
Primary Production	9
Material and Methods	
Physico-chemical factors	12
Phytoplankton, Zooplankton, Bacteria	13
Primary Production	14
Results	
Physico-chemical factors	15
Phytoplankton	25
Zooplankton	57
Bacteria	75
Primary Production	78
Discussion	
Physico-chemical factors	86
Phytoplankton, Zooplankton, Bacteria	90
Primary Production	94
General Discussion	96
References	104

FIGURES

1.	Map of Meghalaya	2
2.	Bathymetric Map of Ward's Lake	6
3.	Metereological data.	16
4.	Air temperature and secchi disc at all Stations.	17
5.	Conductivity, pH, water temperature and Magnesium for Stations A, B and D.	19
6.	Conductivity, pH, water temperature and Magnesium for Station C.	20
7.	Conductivity, pH, water temperature and Magnesium for Station E.	21
8.	Oxygen, Carbon dioxide, Alkalinity, Phosphate, Silicate, Nitrate and Calcium for Stations A, B and D.	22
9.	Oxygen, Carbon dioxide, Alkalinity, Phosphate, Silicate, Nitrate and Calcium for Station C.	23
10.	Oxygen, Carbon dioxide, Alkalinity, Phosphate, Silicate, Nitrate and Calcium for Station E.	24
11.	Relative percent abundance of phytoplankton, class-wise.	45
12.	Relative percent abundance of zooplankton, group-wise.	64
13.	Seasonal abundance of bacteria at Station A, B and D.	76
14.	Seasonal abundance of bacteria at Stations C and E.	77
15.	Gross and Net Primary Productivity at Stations A, B and D.	82
16.	Gross and Net Primary Productivity at Station C.	83
17.	Gross and Net Primary Productivity at Station E.	84

TABLES

I	: List of vegetation	11
IIa,b	: Genera and total phytoplankton, seasonally at Station A.	29, 30
IIIa,b	: Families and class of phytoplankton seasonally at Station A.	31, 32
IVa,b	: General and total phytoplankton, seasonally at Station B.	36, 37
Va,b	: Families and class of phytoplankton seasonally at Station B.	38, 39
VIa,b	: Genera and total phytoplankton, seasonally at Station C.	42, 43
VIIa,b	: Families and class of phytoplankton sessionally at Station C.	46, 47
VIIIa,b	: Genera and total phytoplankton, seasonally at Station D.	50, 51
IXa,b	: Families and class of phytoplankton seasonally at Station D.	52, 53
Xa,b	: Genera and total phytoplankton, seasonally at Station E.	55, 56
XIa,b	: Families and class of phytoplankton seasonally at Station E.	58, 59
XIIa,b	: Zooplankton, seasonally at Station A.	61, 62
XIIIa,b	: Zooplankton, seasonally at Station B.	65, 66
XIVa,b	: Zooplankton, seasonally at Station C.	68, 69
XVa,b	: Zooplankton, seasonally at Station D.	71, 72
XVIa,b	: Zooplankton, seasonally at Station E.	73, 74
XVII	: Co-efficient correlation between biota, physico-chemical factors and primary productivity, for Stations A, B, D.	97-98
XVIII	: Co-efficient correlation between biota, physico-chemical factors and primary productivity, for Station C	99
XIX	: Co-efficient correlation between biota, physico-chemical factors and primary productivity, for Station E.	100-101

SUMMARY

Lakes are usually considered as part of a larger system which in turn contains three sub-systems. The first involves the physical sub-system and is defined primarily on a regional basis. The second sub-system includes all the biota and judgements are made on the long term effects of specific interactions based on the best information available at any given time. The third depending upon the productivity is a social subsystem and determines what the problems are, what has caused them and what their solutions ultimately will be.

It was with these ideas that the present work was initiated. The study site chosen was the Ward's Lake — a lake situated in the heart of Shillong (Meghalaya, North East India) at an altitude of 1460 m (Lat. 25° 34'N and Long. 91° 52'E). The lake has a maximum length of 333 m and a maximum breadth of 75 m with a shore line of 1284 m. The total area of the lake is 23800 sq m enclosing 80920 cu m of water. The maximum depth is 6 m with a mean depth of 3.4 m.

A number of physico-chemical variables were undertaken to understand the oscillating rhythmic phenomena of the system. This was supplemented by detailed analysis of the biota at the phytoplankton, zooplankton and bacterial levels to enable judgement of their resiliency and capacity for change in response to the abiotic factors over the season. Finally the productivity of the system was analysed to enable identify expenditure of energy directly related to the utility operation at the various levels.

Hence an attempt into the limnological investigation of the lake, the study of the functional relationships and productivity of biotic communities as affected by the dynamics of the physical, chemical and biotic environmental parameters were undertaken in detail during the present investigation, for a period of two years. A total of 15 physicochemical factors were analysed, to enable identify one or more factor/s as limiting or responsible for the biotic oscillations in the system. The physico-chemical aspects revealed a circulation phenomenon more than once, some revealing a dimictic while others a monomictic nature. This was attributed to the residence time of elements being greater or lesser than the water itself. The interplay of the physico-chemical factors depended largely on the geographical location of the lake. The lake was therefore polymictic and though sufficiently deep to stratify, yet not deep enough to support a thermocline. Among the phytoplankton, Chlorophyceae dominated with Chrysophyceae and Euglenophyceae as the next abundant, while Bacillariophyceae and Dinophyceae were the least recorded. The lake generally harboured an oligotrophic assemblage of phytoplankton — though seasonally with the presence of *Scenedesmus* it shifted to the eutrophic nature for a brief period during winter. The lake was probably establishing an equilibrium of total oligotrophy, that even with the incorporation of the eutrophic species for a brief period of time, the lake is capable of regaining its original condition every annual cycle. Hence it behaved as a system becoming mature and at present in a transitional stage. Among the zooplankton, Rotifera was the dominant followed by Copepoda and Cladocera. Protozoa could not establish itself very well while Ostracoda was the least recorded. All this was further indicative of the oligotrophic nature of the system. Most of them revealed a bimodal peak and since the generation time was synchronous with the phytoplankton — the trend of the seasonal variation of both the phyto and zooplankton was similar. Total bacteria counts also ranged from levels of oligotrophy to eutrophy. However, it was seen that an equilibrium was set in the limnetic waters. A definite relationship was seen to be established between the bacteria and the phytoplankton. Unfortunately very little was known about the rate of supply of organic nutrients

especially those coming from the living organisms excretion, leached materials of plants and hydrolysis of older detritus. The primary productivity values recorded from this lake system was indicative of oligotrophy. It seems that small lakes in the tropics situated at higher altitudes and latitudes behave like their temperate deep lake counterparts. Therefore, though comparative basis are ideal, regional limnology gets intimately associated with the trophic concepts — which has to be looked into first, since primary production within the sub-surface layers of optimal light exhibit such a great regional variation, its determination becomes all the more valuable for any biological characterisation of wetlands in an area or region.

Finally, it was seen that it is not any one factor which was limiting but a rather a combination of variables which helped in the total understanding of the system. We realized that the entire watershed and not just the lake, or the lake or its shoreline was the total ecosystem as the gravitational movements of minerals in drainage waters from land to water, establishing the major terrestrial-aquatic linkage would give a holistic approach to the entire study.

GENERAL INTRODUCTION

Aquatic ecosystems are essential segments of the environment of man. The study of lake ecosystem-limnology involves, basically, the casual relationships of biotic communities to their environment including the inter-associations of organisms or, in essence, aquatic ecology.

The major lacustrine system available in the region which was primarily utilised for recreational purposes was taken up for detailed investigation. A number of physico-chemical variables were undertaken to get an adequate knowledge of their oscillating rhythmic phenomena, and to throw a greater insight into the nature of the system. This was corroborated by the analysis of biota at the phytoplankton, zooplankton and bacterial levels to judge their resiliency and capacity for change in response to the abiotic factors seasonally. This was followed by the study of production levels in the system to identify the turnover in the system.

Finally, it was with the idea that studies of the general rules of biotic transformations of matter and energy in aquatic ecosystems are necessary for they may stimulate the biological analysis of the ecosystem components. Hence, the comparison of the final data would probably reveal some general qualities of freshwater ecosystem of this region and thereby initiate more studies helping us to discover the characteristic distinctions of the various types of aquatic ecosystems in these hilly regions of North-Eastern India.

LOCATION

Meghalaya as the twenty first State of the Union of India comprising of three major hills-the Garo, the Khasi and the Jaintia is today divided into seven major districts, the Jaintia, the East and West Khasi, Rhibhoi and the Santh East and West Garo hills districts. The whole state of Meghalaya lies as a land-locked territory, sandwiched between the Assam plains on the north and the Surma plains (Bangladesh) on the south, in North-East India.

The state lies between latitudes $25^{\circ}47'N$ and $26^{\circ}10'N$ and $89^{\circ}45'E$ and $92^{\circ}47'E$ longitudes. Meghalaya has a total area of nearly 22,500 sq. km. The whole territory is interspersed with high and low rolling hills and is a plateau with a geomorphological landscape of streams, brooks, rivulets, waterfalls and small ponds or lakes. The altitude varies between 600 and 1950 m., the highest peak-the Shillong peak situated in the East Khasi Hills district, Shillong, the capital of Meghalaya, is situated at an elevation of 1496m. (Fig.1).

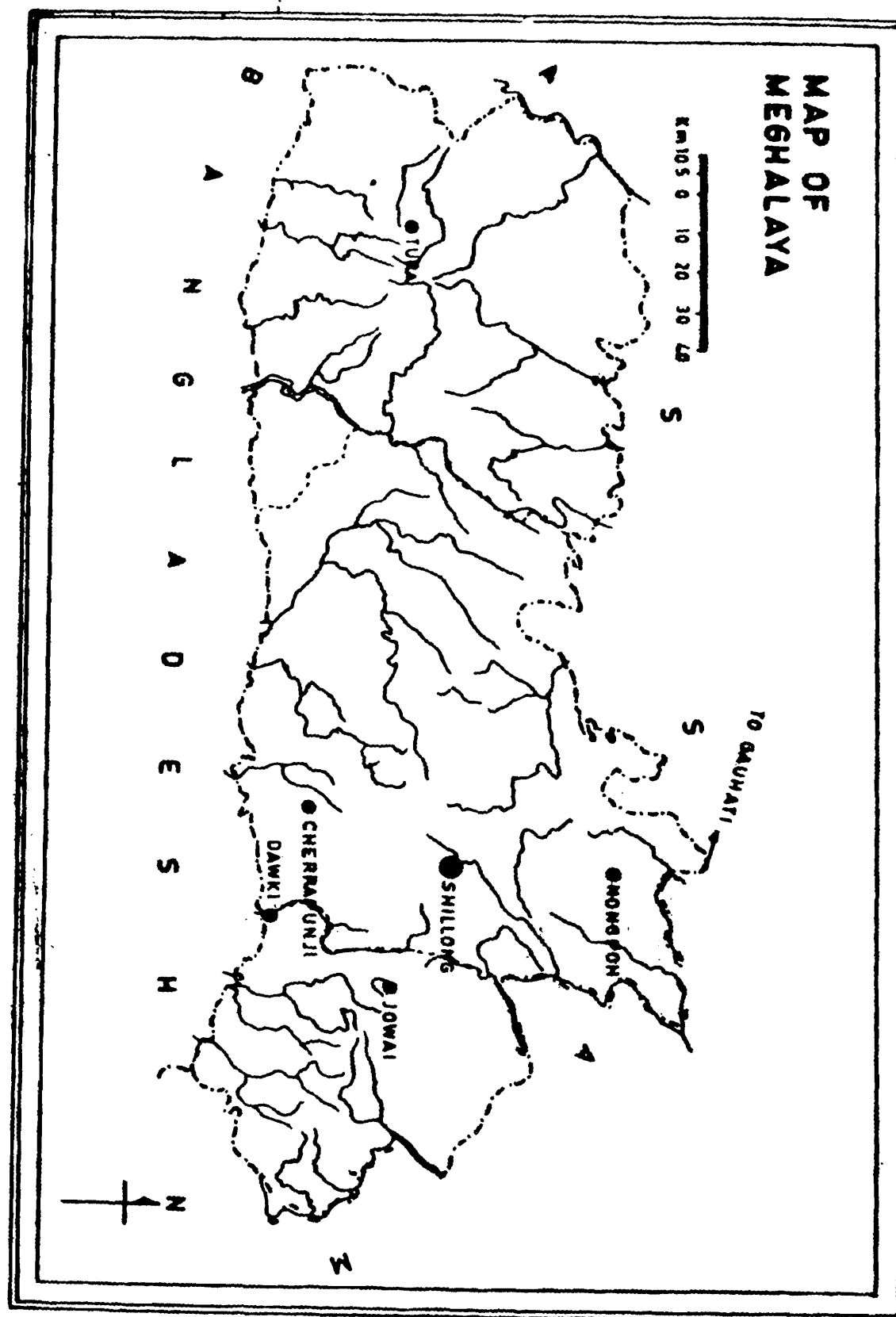


Fig 1. Map of Meghalaya

PHYSIOGRAPHY

Physiographically Meghalaya represents a remnant of ancient plateau of Pre-Cambrian peninsular shield uplifted to its present height. It comprises of exposed Archaean gneiss and schists covered in the central and eastern parts. The region was formed when the great Himalayan chain were uplifted from the Tethys Sea', during Mesozoic and early Tertiary Times. The hills are nearly 135 million years old. The Shillong plateau is therefore best regarded as a part of Indian Peninsula cut off therefrom by the intervening spread of the Ganges and Brahmaputra alluvium. The rocks have more in common with the gneissic and Dharwar rocks of Bengal and Bihar than those of the more neighbouring Himalayan sequence.

The drainage pattern of the region has a feature revealing straight course of rivers, rivulets and streams evidently along joints and faults. The magnificent gorges in the Southern Khasi and Jaintia Hills are the result of massive headward erosion by antecedent streams along joints and sedimentary rocks. The northern part of the plateau is marked by long incisive valleys due to headward erosion along joints in the gneissic rock and granities. The limestone covered areas of southern Garo, Khasi and Jaintia Hills reveal a typical kurst topography. The present physiographic events from Mesozoic to Present, are indicative of the Polycyclic erosional surface at various levels.

CLIMATE

The climate of the region is generally tropical monsoon. The central and eastern parts due to higher elevations has very little temperature fluctuations while the western parts except during winter records quite high temperature. The range of temperature is usually from as low as 0°C in Shillong to about 35°C in Garo Hills. The winter months are usually from December to February and the ground is covered by hoar frost every morning but there is no record of snowfall at all.

The important climatic characteristic of these regions is very high rainfall averaging annually 7200 mm. In fact Mawsynram, situated about 16 km west of Cherapunji which itself is nearly 50 km from Shillong records the world's heaviest rainfall, of nearly 14,000 mm. This is due to the fact that the South-West monsoon from the Bay of Bengal blowing over Bangladesh gets suddenly cut off by the cliffs with an average elevation of about 1,200 m and resulting in very heavy rainfall which after reaching the heads of the gorges ascends vertically upwards.

One can divide Meghalaya into four distinct seasons, Spring (March to May), Summer or rainy season (June to September), Autumn (October and November) and winter (December to February). Usually strong winds blow from South-west towards North-east from about the middle of February to about middle of May each year. An interesting feature of the State is that it lies in a highly seismic axis and tremors of small magnitudes are very frequent.

SOILS

The soil varies all over the Meghalaya plateau both in physical characters and fertility conditions. They are mostly lateritic in origin and vary from sandy loam, red loam to clay loam. The soils in the

basins are more fertile than the upland soils since much of the bases and organic matter from the top soil of the latter gets washed away due to high rainfall.

The sediments are mainly sandstones and shales (mud stone), and well defined fossiliferous limestone. The percentage of organic carbon is nearly 5 to 10 and the pH between 4.5 to 6.5.

VEGETATION

The state of Meghalaya is endowed with a rich natural vegetation ranging from Sub-Temperate to Tropical. In the upper hill regions and specially the plateau of Khasi hills coniferous pine (*Pinus kesiya* Royle) dominates. They extend to the Jaintia Hills but in the comparatively dried places are stunted. On the slopes of Shillong peak specially the northern slopes Rhododendrons exist along with *Cryptomaria japonica*, resin and *Cinnamomum species*. The trees on the upper reaches are stag-headed and covered with moss and lichens. Canes and bamboos are rich growths and undergrowths of the lower hills. There are nearly 150 species of grass. The lower elevations are also occupied by deciduous forest. The common under growth which runs like belts on all the hills whatever the altitude is *Eupatorium sp.* and *Lantana camera*.

STUDY SITE

The study site chosen was the Ward's Lake. This is an artificial lake situated in the heart of Shillong (Meghalaya, North-East India) at an altitude of 1,460 meters above sea level and latitude 25°34'N and longitude 91°32'E (Plate 1)

The lake has had many names like Hopkinson's Tank, Elliot's Lake, Ward's Lake, Nan Palok (in Khasi) and Laath Saab ko Talao (In Nepal). The origin of the lake though the date is not known was the initiation of digging by a convict, when water was struck that the district authorities took over and extended the digging to the present lake. The idea of using this lake for recreation with a small park all around it goes to the credit of the then Chief Commissioner, William E. Ward 1893 after whom the lake is presently known.

The source of the lake which are undulating risings from the water levels towards the main road is covered with grass and forms a meadow with pine trees (*Pinus kesiya* Royle) scattered all along. The vegetation along the shore line, free floating and submerged in the water of the lake is depicted in Table-I

The lake receives water through two inlets, both perennial, one from the South end of the lake and the other from the west. There is only one outlet at the North end. This outlet is controlled by sluice gates for allowing excess water to flow away during peak monsoon. It is therefore that the water level does not change appreciably throughout the year. The inlet from the south end is primarily water from of the hill streams which traverses from the upper hills to reach Ward's Lake and then flow away as hill streams. The inlet at the west end of the lake is water of the drains and canals of Shillong. The latter therefore is allowed to flow first into the isolated pond which serves as a sedimentation tank from where the decanted water flows into the major lake. In addition, the lake receives surface run-off waters from the adjoining slopes of the hills.

TABLE-I

A list of Marginal, floating and submerged vegetation of Ward's Lake.

1. <i>Hydrilla verticillata</i> (L.f.) Royle	28. <i>Hydrocotyle javanica</i> Thunb.
2. <i>Anthoxanthum odoratum</i> L.	29. <i>Lindernia cordata</i>
3. <i>Axonopus compressus</i> (Sw) P. Beauv.	30. <i>Richardsonia</i> sp.
4. <i>Cynodon dactylon</i> (L.) Pers.	31. <i>Utricularia bifida</i> L.
5. <i>Eragrostris gangetica</i> (Roxb.) Steud.	32. <i>Utricularia caerulea</i> L.
6. <i>Eragrostris nigra</i> Nees ex-Steud.	33. <i>Utricularia</i> sp.
7. <i>Imperata cylindrica</i> (Linn.) P. Beauv.	34. <i>Emilia sonchifolia</i> (L.). DC
8. <i>Paspalum dilatatum</i> Pair.	35. <i>Erigeron karvinskianus</i> DC.
9. <i>Poa annua</i> L.	36. <i>Erigeron</i> sp.
10. <i>Pogonatherum crinatum</i> (Thunb.)	37. <i>Galinsoga parviflora</i> Cav.
11. <i>Sphaerocarpon</i> sp	38. <i>Gnaphalium luteoalbum</i> L.
12. <i>Eleocharis congesta</i> D. Don.	39. <i>Hypochaeris radicata</i> Linn.
13. <i>Kyllinga brevifolia</i> Rattb.	40. <i>Sonchus asper</i> (L.) Hill.
14. <i>Lipocarpus chinensis</i> (Osbeck) Kern.	41. <i>Sonchus</i> sp.
15. <i>Hedychium caronarium</i> Koen. ex Ritz.	42. <i>Juncus prismatocarpus</i> R. Br.
16. <i>Polygonum hydropiper</i> L.	43. <i>Eurya acuminata</i> D.C.
17. <i>Polygonum orientale</i> L.	44. <i>Plantago major</i> L.
18. <i>Polygonum punctatum</i> Ham.	45. <i>Denothera rosea</i> W. Ait.
19. <i>Nymphaea nauchali</i> Burm. f.	46. <i>Centella asiatica</i> Urb.
20. <i>Ranunculus contoniensis</i> DC.	47. <i>Davallia imersa</i>
21. <i>Cardamine hirsuta</i> L.	48. <i>Osmunda regalis</i> L.
22. <i>Nasturtium indicum</i> Hook. F & Anders, non DC.	49. <i>Pteris vittata</i> L.
23. <i>Potentilla mooniana</i> Wt.	50. <i>Selaginella</i> L.
24. <i>Trifolium repens</i> L.	51. <i>Thuja orientalis</i>
25. <i>Oxalis corniculata</i> L.	52. Ground pine
26. <i>Oxalis corymbosa</i> . DC	53. <i>Pinus kesiya</i> Roye
27. <i>Rotala rotundifolia</i> (D. Don) Koehme	

MORPHOMETRY

The lake has a maximum length of 333 meters and maximum breadth of 75 metres with a shore line of 1,284 metres. The total area of the lake is 23,800 square metres which encloses 80, 920 cubic metres volume of water. The maximum depth is 6 metres with a mean depth of 3.4 metres (Fig.2).

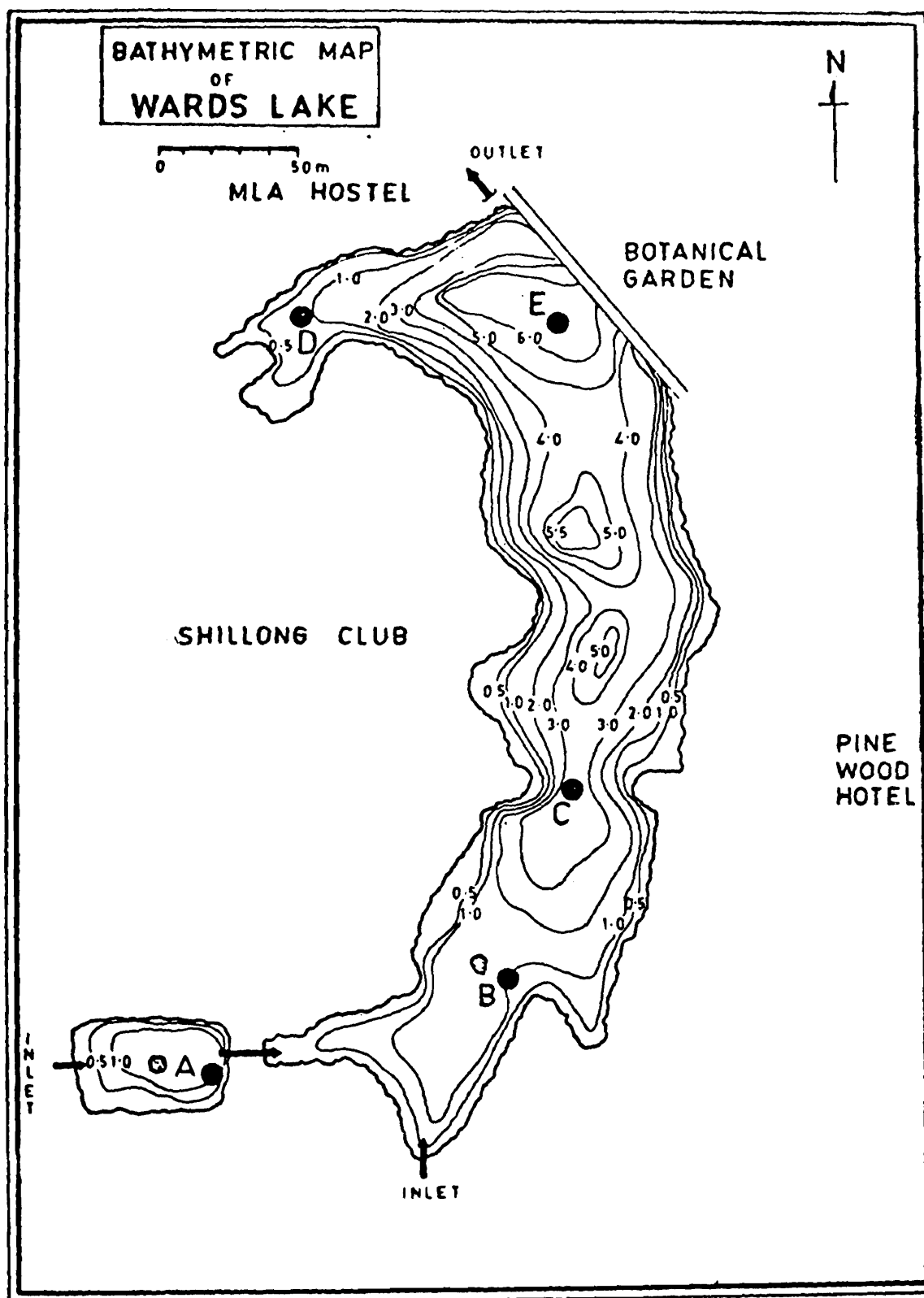


Fig. 2 : Map showing the bathymetric features of Ward's Lake along with the location of the regular sampling Stations A, B, C, D and E.

REVIEW OF LITERATURE

Physico-chemical factors

Detailed limnological studies are available for lower latitudes and there is nothing available to the extent one would like to have in not only higher latitudes but simultaneously higher altitudes. Shillong occupies an enviable position in this respect in that it lies in an ecotone, where both tropical and sub-tropical, temperate and sub-temperate elements interplay.

Since the time of Forel (1892-1895) when original limnological observations were made there is nothing worth the mention till Caspari (1910) and Muttkowski (1918) who formulated a set of criteria or categorization either for the bottom deposits or for the thermal stratification of water respectively. Kemmerer *et al*, (1923) probably were the first to identify a thermal stratification with depth.

The interplay of factors was probably first reported by Więbe (1930) who revealed pH and carbonates directly proportional to each other. Ruttner (1931) has been one of the earliest workers on the tropics where he did identify a thermal stratification in places like Java and Sumatra. In India the work of Pruthy (1933) could be the earliest though other than the monthly observations no intricate relationships were discussed. Hutchinson (1938) attributed a hypolimnetic oxygen deficit as an indicator of the trophic status of the lake.

Phosphorus as an important limiting factor was revealed as early as 1940 by Deevey and simultaneous in India on other hydrological factors by Ganapati (1940, 1941 and 1943). It was only from 1942 when the causative factors for the nutrient complexes and release from the sediments, their interplay with oxygen concentration level, identification of spring turnover and summer stratification accompanied by an increased level of CO₂ and related substances, with a decrease in pH were identified (Aberg and Rodhe, 1942; Mortimer, 1942). Since then relationship between two factors or more either directly or indirectly proving to be indices of lake productivity was reported (Edmondson, 1948; Ohle, 1952; and Ganapati, 1955 and 1959).

It was in the late fifties that the importance of one or more nutrients being responsible for the biotic rise and fall was elucidated (Hutchinson, 1957 and Vallentyne, 1957). The fluctuations of nutrients being affected by rainfall was revealed by Tucker (1958). Goldman (1960) attributed the importance of minor nutrients responsible for the different rates of carbon fixation while Sharp (1960) attributed rapid eutrophication due only to metalimnetic depletion of dissolved oxygen. Wetzel (1966) attributed differential patterns of thermal stratification while Hussainy (1967) revealed turbid waters being warmer than clear ones. The sediment water interface affecting the whole column of water has been well documented by Golterman (1969). Vijayaraghavan *et al*, (1969), Kalff (1970) and King (1970) attributed carbon as the ultimate limiting nutrient. This was supported by Kerr *et al*, (1970) and Lange (1970) who identified carbon rather than nitrogen and phosphorus to limit production. Sreenivasan (1970), Timms (1970) and Vijayaraghavan (1971) considered oxygen deficit as a factor to be reckoned with in production. The concepts of nitrification and denitrification in lake sediments affecting the total biota was shown by Chen *et al*, (1972), Keenay (1973), Tan and Overbeck (1973). Lasenby (1975) and Wetzel (1975) attributed turbulence pattern of waters to be related to oxygen and correlated with average secchi disc depth. The late seventies has been a period of

utilising the factors identified, their permutations and combinations in the manipulation of the experiments either at microcosm or macrocosm levels (Cheng and Tyler, 1976; Alfred and Chellappa, 1978; Allen and Ocevski, 1977; Schindler, 1977; Alfred *et al*, 1978; Dillon *et. al.*, 1978).

A review on the present status on Limnology in India based primarily on publications in Hydrobiologia is excellently given by Gulati and Wurtz (1980). They have identified 325 papers of Indian work upto 1979 and have revealed that two-thirds appeared in the last one decade alone. Simultaneously, Michael (1980) has reviewed as far as possible all Indian freshwater investigations published till that date.

Phytoplankton, Zooplankton and Bacteria

It was not till the middle of the last century that the existence of plankton in aquatic system was known. The usage of the term plankton has come down over the century since the time of Hensen (1887, 1895) who was an oceanographer, attributing all heterogenous assemblage of minute organisms under this term. The earliest Indian work was on rotifers by Anderson (1889). Apstein (1896) was probably the first to study the plankton in freshwaters and particularly the inland lakes. Schrater and Kirchner (1896) introduced the term *pleuston* to designate the whole biological communities associated with air-water interface. Daday (1898) described many new species of Cladocera and reviewed the previous works on Cladocera, Copepoda and Rotifera of oriental region.

Naumann (1917) introduced the term *neuston* to designate the assembly of microorganisms associated with the surface film of water.

The geographical distribution, diurnal movements, the effect of light, the seasonal variations and organic matter as a factor, all responsible for either the growth, the reproduction and distribution of plankton was initiated in the early part of this century (West and West, 1912; Dice, 1914; Ruttner, 1914; Prasad, 1916; Jennings, 1918).

It was only Hutchinson in the year 1941 who first revealed the concept of an ecosystem based on all these studies that physical, chemical and biological processes have an interrelationship both temporally and spatially.

It was then that subsequent works were aimed at finding out the causative factor or factors responsible for the growth and sustainance of groups of phytoplankton or zooplankton, their interpretation for the rise and fall of population, in particular the algal blooms and the intricate relationship between species of phytoplankton and zooplankton with the idea and rate of both colonization and succession (Edmondson, 1944, 1945 and 1946; Hutchinson, 1944; Pennak, 1944; Brooks, 1947; Nygaard, 1949 and 1955; Plew and Pennak, 1949; Gerloff *et al*, 1950, 1952; Gossler, 1950; Moore, 1950; Smith, 1950).

The decade beginning 1970 though has been a period of intensive limnological work all over the globe, yet it was primarily directed towards the understanding of pollution in aquatic systems. In this respect work on plankton done in oligotrophic systems in contrast to eutrophic ones, the identification of indicator species, the effect of manipulation in terms of addition of nutrients and in particular fertilizers in fish ponds, the life history patterns and the developmental stages in relation to abiotic

factors, the effect of acidification and most of all the influence on the biota particularly phytoplankton and zooplankton in relation to the nature of effluents from the establishment of industries, the accumulation and biological magnification in groups of plankton by pesticides were all part of the general limnological studies. (Fitzgerald, 1971; Fogg, 1971; Fott, 1971; Hagedorn, 1971; Kristiansen, 1971; Navaneethakrishnan and Michael, 1971; Reynolds, 1971; Abeliovich and Shilo, 1972; Green, 1972; Kryuchkova, 1972; Saunders, 1972; Soarokin and Paveljeva, 1972; Burgis, 1973; Fogg *et al*, 1973; Pennak, 1973; Shapiro, 1973; Tilzer, 1973; Wolk, 1973; Droop, 1974; Hutchinson, 1975; Lewkowicz and Lewkowicz, 1975; Reynolds and Walsby, 1975; Wetzel, 1975; Begg, 1976; Burns, 1976; Ferrante, 1976; Green, 1976; Jacobson and Comita, 1976; Munawar and Munawar, 1976; Zaret, 1976; Brown and Sibert, 1977; Hbracek, 1977; Alfred *et al*, 1978; Boers and Carter, 1978; Vincent, 1978; Yan and Stokes, 1978; Venkataraman and Job, 1979; Zagorodnyaya, 1979; Cooney and Gehrs, 1980; Fallon and Brock, 1980; Fernando, 1980; Gilbert, 1980; Lei and Armitage, 1980; McCracken *et al*, 1980; Pourriot *et al*, 1980; Swar and Fernando, 1980; Venkataraman and Job, 1980).

Though work on freshwater systems in India are mentioned in the foregoing literature, the reviews of Gulati and Wurtz (1980) and Michael (1980) cover a detailed account of the Indian work in this field.

Heterotrophic planktonic bacteria are the most numerous groups of organisms participating in the decaying processes of organic matter in fresh water ecosystems (Kutznitsov, 1970; Parson and Strickland, 1962). The assimilation of organic compounds by uni-and multi-species of bacterial groups, their investigations by normal substrate as well as those marked with radioactive C_{14} show uptake in varying intensities of organic matter (Hobbie and Wright, 1965; Wright and Hobbie, 1965, 1966; Baccaro and Jonness, 1967; Hobbie and Crawford, 1969).

Though Jones (1971) showed a relationship between bacteria and physico-chemical criteria yet the relationship between phytoplankton and bacterial population had been established in the late sixties, (Sorokin, 1968; Smidth, 1969; Overbeck and Babenzien, 1964 and Overbeck, 1965, 1967 and 1968). It was however, in the late seventies that bacteria, its species and population was used to determine the classifying characteristics of a lake. Godlewska-Lipowa (1976a) reviewed literature till that date pertaining to bacterial population and biomass related to eutrophication. Neissen, 1977; Akagi *et al*, 1977; Takahashi and Norton, 1977; Kaneko *et al*, 1977 and Hickman Penn, 1977 thereafter studied the population dynamics of bacteria, the diversity index and both seasonal and vertical distribution of heterotrophic bacteria in freshwaters. Work done till date has been reviewed with new ideas for the further understanding of bacteria in freshwaters by Saunders *et al*, (1980).

Primary Production

It is the rate of production or the primary productivity which establishes the total life in an aquatic system. These are only possible depending on the algae or the total phytoplankton in waters. However in any phytoplanktonic community varying fractions are distributed in sub-optimum or optimum light conditions. At any given time regardless of the taxonomic positions of the phytoplankton of a population they belong to three overlapping groups of metabolic activities: (a) Active organisms – where cell number increases, (b) Neutral organisms – where cell numbers are more or less constant, and (c) Inactive organisms – where cell numbers mostly decreasing – degenerating or decaying. Therefore primary production will be affected by the respective proportion of these three groups.

Though Johnson (1903) pioneered the light and dark bottle method it was Osterhout and Hass

(1977) and later Warburgh (1919) who used phytoplankton and the Winkler's method for an indirect estimation of primary production.

It was thereafter that work on aquatic macrophytes and phytoplankton in relation to various factors and in particular nutrients and their effects on the producer organisms were undertaken (Ruttner, 1921; Briggs, 1922; Blackman, 1923; Putter, 1924; Gaarder and Gram, 1927; Thienemann, 1927; Marshal and Orr, 1928; Strom, 1928; Rawson, 1930; Emerson and Arnold, 1932; Fritsch, 1931; Birge and Juday, 1934; Harvey *et al*, 1935; Gaffron and Wohl, 1936; Jenkin, 1937 and Mortimer, 1950 and 1955).

The C_{14} method was discovered by Steemann Nielsen (1952) for regular analysis of the photosynthetic rate of planktonic algae. The oxygen deficit as an index of aquatic productivity was shown by Hutchinson (1938) which was opposed by Rawson (1939) who attributed other morphological, adaphic and climatic factor responsible for primary production. Riley (1940) was the first to identify reciprocal relationship between chlorophyll and productivity and Ruben *et al*, (1941) revealed that oxygen evolved from water and not carbon dioxide during the process of photosynthesis. Work in isolated chloroplasts and algae to identify the causative factor for increase or decrease in phytoplankton rate of production was carried at. (Arnon *et al*, 1954; Fogg and Wolf, 1954; Dysens, 1955; Fogg and Westlake, 1955; Kratz and Myers, 1955; Rodhe, 1955 and 1962; Northcote and Larkin, 1956; Steemann Nielsen and Al Kholy, 1956; Hutchinson, 1957; Arnon, 1958; Ryther and Yentsch, 1958).

The concept of nutrient limiting production and the experiments directed towards understanding of both the quality and quantity responsible both under field and laboratory conditions were initiated in the sixties of the present century. Some of these were the identification of molybdenum, phosphorus or nitrogen and chelated iron all directly or indirectly affecting carbon fixation (Goldman, 1960; Steele and Yentsch, 1960; Evans, 1961; Rodhe, 1962 and 1963; Schelske *et al*, 1962; Talling, 1962; Yentsch, 1962; Rodhe *et al*, 1966).

Talling (1965) identified a population density less pronounced in equatorial lakes, while Fogg *et al*, (1965) attributed extracellular release to be a significant portion for the total carbon fixed (Wetzel, 1966 a, b, 1967 and 1968; Dumont, 1968; Hamilton, 1969; Qasim *et al*, 1969; Vijayaraghavan *et al*, 1969; Adams, 1970; King, 1970; Golterman, 1971; Hickman, 1977; Sakamoto, 1971; Schindler and Holmgran, 1971).

In the early part of the last two decades after such identification of causative factors, experiments both at micro and macro levels were conducted. This was done in terms of permutation and combinations of varying amounts of nutrients and the manipulation of water bodies to see the increase or decrease of the standing crop directly related to the carbon fixed. (Fee, 1973; Schindler and Fee, 1973; Stross *et al*, 1973; Schindler, 1974; Goldman and Amezaga, 1975; Saunders *et al*, 1975; Allen and Ocevski, 1976; Berman, 1976; Sreenivasan, 1976; Tilzer, 1976; Alfred and Chellappa, 1978).

The above work revealed the causative factors in the eutrophication process classifying the water bodies as highly productive and therefore with not only the effect of additive phenomena of allochthonous material but also the recycling nature within the system was understood. It was with this idea that the late seventies work were initiated on the relationship of production efficiencies to that of bacteria-plankton. (Berman, 1976; Haniffa, 1978; Matsuyama and Shirouzu, 1978; Jana, 1979; Khan and Zutshi, 1980; Rishi and Kachroo, 1981).

As mentioned in the earlier chapters in addition to the Indian works, the reviews of Gulati and Wurtz-Schulz (1980) and Michael (1980) reveal either one or more of the above mentioned phenomena studied elsewhere available for Indian latitudes too. Further a total analysis of primary production with importance and relevance at the different latitudes and altitudes of the globe has been brought in a concise form by Westlake *et al*, (1980) and Brylynsky (1980).

MATERIAL AND METHODS

Five different sampling stations were chosen in the lake based mainly on the direction of inflow of water and depth distribution. In this respect stations A, B and D are the shallowest stations, having depth of less than 1m. Station A was chosen because it represented the isolated part of the lake and served as a sedimentation tank from where the overlying waters flowed into the major lake. The actual depth at this station was 0.69 m. Station B though shallow (0.7 m deep) was chosen as it represented the incoming water first into the major lake. Station D which was 0.5 m deep was situated exactly at the other end and arm of the lake directly opposite to Station A. Stations C and E were the deep portions of the lake, the former being 3 m deep and the latter 6 m. Station E was that portion of the lake which was deepest (Plate 2).

Station A was the most turbid and a totally undisturbed station by human activity except for the regular inflow of drainage water. Station B had macrophytic vegetation predominantly occupied by *Nymphaea nonchali*, while Station C was the open waters. Station D had *Nymphaea nonchali* and in addition *Microcystis* formed a scum at the station due to the effect of wind. Station E like Station C was a totally exposed open water and had the outlet near it. Except for Stations A and D, all other stations were disturbed due to the recreational activities, boating being one major criteria.

The lake was also stocked annually with fish like the Golden carp (*Cyprinus carpio communis*), Chocolate Mahaseer (*Acrossocheilus hexagonolepis*), Silver carp (*Hypothalamichthys molitrix*), and Scale carp (*Cyprinus carpio specularis*).

BATHYMETRY

The lake was initially measured in all aspects to arrive at a map and the contour depicting depths. The procedure followed was based on the shore line survey after Welch (1948) with a slight modification. The whole area of the lake instead of enclosing by a complete rectangle, a multi-sided polygonal structure was set up with well defined and measured lines along with the angles which formed as the base reference lines. From these, vertical distances between the shore and these reference lines was measured with a tape at an interval of 1 metre. In this way each side of the lake all along its shore, lines was drawn and plotted on a graph paper. The 1 metre intervals of the shore line distances automatically when plotted brought out the shore line of the lake.

For the depth measurements stakes were placed across the width of the lake and rope tied touching the surface of the water. At intervals of 0.25 m all along the rope from one end to the other a graduated rope with a sinker attached to it was let down till it hit the bottom and the reading recorded. This process was throughout the length of the lake all along its breadths. The depths so obtained was drawn and the contour lines were joined for similar depths (Fig.2).

Stations A, B and D had only two depths, the surface and the bottom while Stations C and E were divided into 6 and 12 depths respectively based on the column of water from top to bottom being divided at every 0.5 m depth till the bottom. The sampling was confined to 0.5 m above the bottom as a heavy accumulation of slush had accumulated, at these two stations.

Physico-chemical factors

Thirteen physico-chemical parameters were undertaken for the detailed investigation. The period of study was for two years. Water samples were collected at the different depths weekly. The time of collection was always confined to the morning hours just after sunrise (0500 hrs to 0800 hrs). All weekly triplicate samples were brought together as monthly averages for sake of convenience and brevity and the figures represent the seasonal variations monthwise.

All water samples were collected in triplicate from each depth at each station by a PVC Van Dorn bottle of 3 litres capacity and let down except for the surface at 0.5 m intervals with the help of a graduated rope. Immediately the water sample was transferred into 125 ml ground glass stoppered bottles again in triplicate and fixed for oxygen analysis. Further, water was taken from the Van Dorn bottle into polythene bottles of 500 ml and closed tightly with the help of the stopper for nutrient and gas analysis.

Air temperature was measured with the help of an ordinary mercury thermometer at about 1 m above the surface of water at the different stations. The water temperature was taken with a similar thermometer by placing it inside the Van Dorn bottle securely and the readings taken immediately after the samples were brought up which indicated the temperature of the water enclosed, as obtained from that depth of the station. Transparency was determined by the use of a Secchi Disc.

All other factors were analysed in the laboratory within one hour of collection. pH and Conductivity were read off from a Toshniwal pH Meter (Model No. Cat. CI-43) and Elico Conductivity Bridge (Model No. Type CM-82) respectively. For oxygen, the samples which were fixed in the field was further reacted as per Azide (Asterberg) method and was estimated with the help of the unmodified Winkler's Technique (American Public Health Association, 1965). Carbon dioxide and alkalinity were determined in the usual way after Welch (1958).

Nitrate was estimated by phenol-di-sulphonic acid method while phosphate was by the stannous chloride and molybdate method both after American Public Health Association (1965). Silicate was estimated after Mackereth (1963) though the standards were prepared after Golterman and Clymo (1968). Similarly, Calcium and Magnesium were analysed as outlined by Mackereth (1963) and Golterman and Clymo (1969).

Meteorological factors like relative humidity, rainfall and wind velocity for the area under consideration was collected regularly from the local Meteorological station.

Phytoplankton, Zooplankton, and Bacteria

Water samples for phyto – and zooplankton were collected only from the surface at the five sample stations, A-E. Collection was weekly and carried out always in the morning hours (0500-0800 hrs.). The depthwise collection were not done due to the lack of apparatus for obtaining large quantities of water to be drawn from different depths. At each station, triplicate samples were collected by filtering a volume of 50 litres of water through a bolting silk net of mesh size 25 μ . This was made to 50 ml and preserved in formalin and Lugol's iodine.

All triplicate weekly sample from all the five stations were collected for two annual cycles.

A well shaken samples from the 50 ml preserved collection was drawn with the help of a wide mouthed pipette and poured into a counting cell (Sedgwick Rafter Plankton Counting Cell) of 1 ml capacity marked with 1000 squares. Counts were made after Utermohl (1958) of all organisms present at random in 100 squares. Individuals and colonies were counted as such, while filamentous algae were counted by their approximate lengths being kept uniform. All these were presented numerically upto the genus level and placed under the appropriate family and class. Such counts were done in triplicate for each replicate weekly sample and an average count evolved. Such weekly samples were brought together as monthly averages along with their standard deviation. The generic identification of phyto- and zooplankton were done with the help of Smith (1950), Pennak (1953), Edmondson (1959), Needham and Needham (1962).

The computation for the numbers of phyto – and zooplankton per litre at different stations of the lake was done by the formula –

$$n = (a \cdot 1000) C \div l$$

where n = number of plankton per litre of original water.

a = average number of plankton in all counts in Sedgwick Rafter Cell.

C = volume of original concentration in ml.

l = volume of original water expressed in litres.

Water samples for bacterial analysis were collected by autoclaved JZ bacteriological sampler (Zobell, 1941). The surface film was disturbed and care was taken to avoid contamination. Such samples were taken in triplicate for the surface and bottom for all the stations and in addition the mid-depths for the two deepest stations. Immediately after collection, the bottles were kept in a dark chamber to be transported to the laboratory as such. Within three hours of collection the samples were inoculated for viable bacteria by the spread plate method using Casein peptone starch agar (CPS) (Collins and Willoughby, 1962). Aliquots of 0.5 ml serial dilutions were inoculated on the surface of this freshly poured medium in 100 mm diameter petriplates. Three replicates were maintained for every dilution. They were then kept at 10°C for 12 hours for absorption of the aliquot and further incubated at 25°C for 7 days. A total count of the colonies were then estimated.

In addition, a direct microscopic count of the total bacteria was done, after the method of Sorokin and Kadota (1972). For this 25 ml of the collected water samples was filtered through a 0.22 μ millipore filter. The filters and the residue on them were fixed under formaldehyde vapours. They were

then stained with erythrosin solution (0.5 g of erythrosin in 96% of ethyl alcohol). The stained filters were then decolorised to a weak pink colour by placing them on moistened filter paper. The filters were placed on a slide where a drop of immersion oil was previously kept and another drop of the oil was slowly spread on the surface of the filter. When the filter became transparent it was covered with a large cover glass. Microscopic examination of 100 X was used and ocular grid of 25 squares for counting a minimum of 10 microscopic fields were chosen at random at different parts of the filter and the bacteria counted. Clumps and aggregates were counted separately. The number of bacteria per ml. of water sample was calculated using the formula –

$$N = s. n. 10^6 \div SV \text{ Cells/ml.}$$

where N = Number of bacteria.

a = area of the working surface of filter in mm²

S = area of one section in the ocular grid

n = average number of bacteria per ocular grid

V = volume of water filtered

An average of the above two counts helped in the near approximation of absolute values of total bacteria encountered at the different stations throughout the study period.

Primary Production

The situation of our laboratory, and due to the remoteness of the region the new Department, the technique followed in the present investigation was confined only to the light and dark bottle after Goarder and Gran (1927). The usual unmodified Winkler's method for the estimation of oxygen with the incorporation of Azide modification was used (APHA, 1975).

Water samples were collected by Van Dorn bottles of 3 litres capacity from all depths at all stations. All collections were done in the morning hours between 0500 to 0800 hrs. The water from each Van Dorn bottle collected at different depths was used to fill sets of 2 light bottles and one dark bottle in replicates for the different depths. The water from the Van Dorn bottle was however first passed through a bolting silk net of mesh size 100 μ before filling the light and dark bottles of 125 ml capacity. Hence 6 light bottles and 3 dark bottles were used for each depth. These were then incubated at precisely each located depth from where the water was collected. This was so done for all the depths and all the stations. These bottles were incubated *in situ* for 24 hours. Simultaneously replicates of water samples were taken from the same depths and stations where the bottles were left for incubation at the same time for estimation of the initial oxygen values. A total of 72 initial oxygen bottles were fixed at the lake with manganous sulphate and alkaline iodide solutions for the different depths in all the stations before returning to the laboratory for oxygen estimation. Similarly a total of 144 light bottles and 72 dark bottles were placed *in situ* in the lake at the different depths in all the five stations. These were collected the next day and immediately fixed at the lake and then returned to the laboratory for final oxygen estimations.

The results were converted to gross oxygen production (light bottle – dark bottle), net oxygen production (light bottle – initial bottle) and respiratory oxygen uptake (initial bottle – dark bottle). the oxygen values in mg/litre were converted to mg C/M³ by multiplying it with a factor of 375.36 (Vollenweider, 1971).

RESULTS

Physico-chemical factors

From the general meteorological data the average maximum temperature at the study site ranged between 13.4°C and 25.0°C during the period of investigation. The minimum was recorded in January while the maximum in August.

The average minimum temperature ranged from 4.5°C to 18.1°C the minimum again in January though the maximum in July (Fig.3).

The average rainfall during the period of investigation recorded a maximum of 460.1 mm in the month of June while the same was nil in the months of January and December. Relative humidity was maximum in July as 87% and the minimum as 40% in the month of December (Fig.3).

The air temperature taken at 1 metre above the surface of waters at the various stations of the lake revealed a consistency of the lowest air temperature being recorded in the winter months and especially in January during both the annual cycles, However, the maximum air temperature recorded was seen to be in the month of July for Stations A, B and C and in the month of February D and E for the first annual cycle and the months of June and July for the second annual cycle in all the stations. Thus the range of air temperature over the lake irrespective of stations ranged between 8.3° Celsius and 25° Celsius. The minimum was recorded in Station A and the maximum at Stations D and E (Fig. 4).

The water temperature was recorded not only for the surface but also for the various depths at the different stations of the lake. There seemed to be a clear consistency at all the depths in that the winter months of January and February recorded the least while the summer months of June-July recorded the maximum. The range of water temperature was between 10.9°C to around 23.6° celsius, the former being recorded at the bottom depth of Station A and the latter at the surface of Stations B, C and D (Fig.5,6 and 7).

The Secchi disc readings taken at the different stations was seen to be minimum in Station A and the maximum at Station E, the former being 30 cms and the latter 144 cms. However, the range between the minimum and maximum was seen to be the least in Stations A and B, 30 cms to 66.7 cms and 60 cms to 78 cms. respectively. Station D was unique in that throughout the period of investigation the bottom was always seen (Fig. 4).

The pH of the water at the different depths at the different stations revealed an acidic nature throughout the year. The range between the minimum and maximum pH recorded was very less, being nearly 1 unit. The minimum occurrences were seen at the bottom stations of Station A as 5.7 units in the month of February while the maximum was 6.9 recorded in the month of July for the Station D at both the depths. However, all the minimum records of pH in all stations was around 6 ± 0.2 occurred in the winter months of November, December and February. A similar analysis for the maximum pH was seen to be 6.7 ± 0.2 during the summer months and in particular the months of May and June (Fig. 5, 6 and 7).

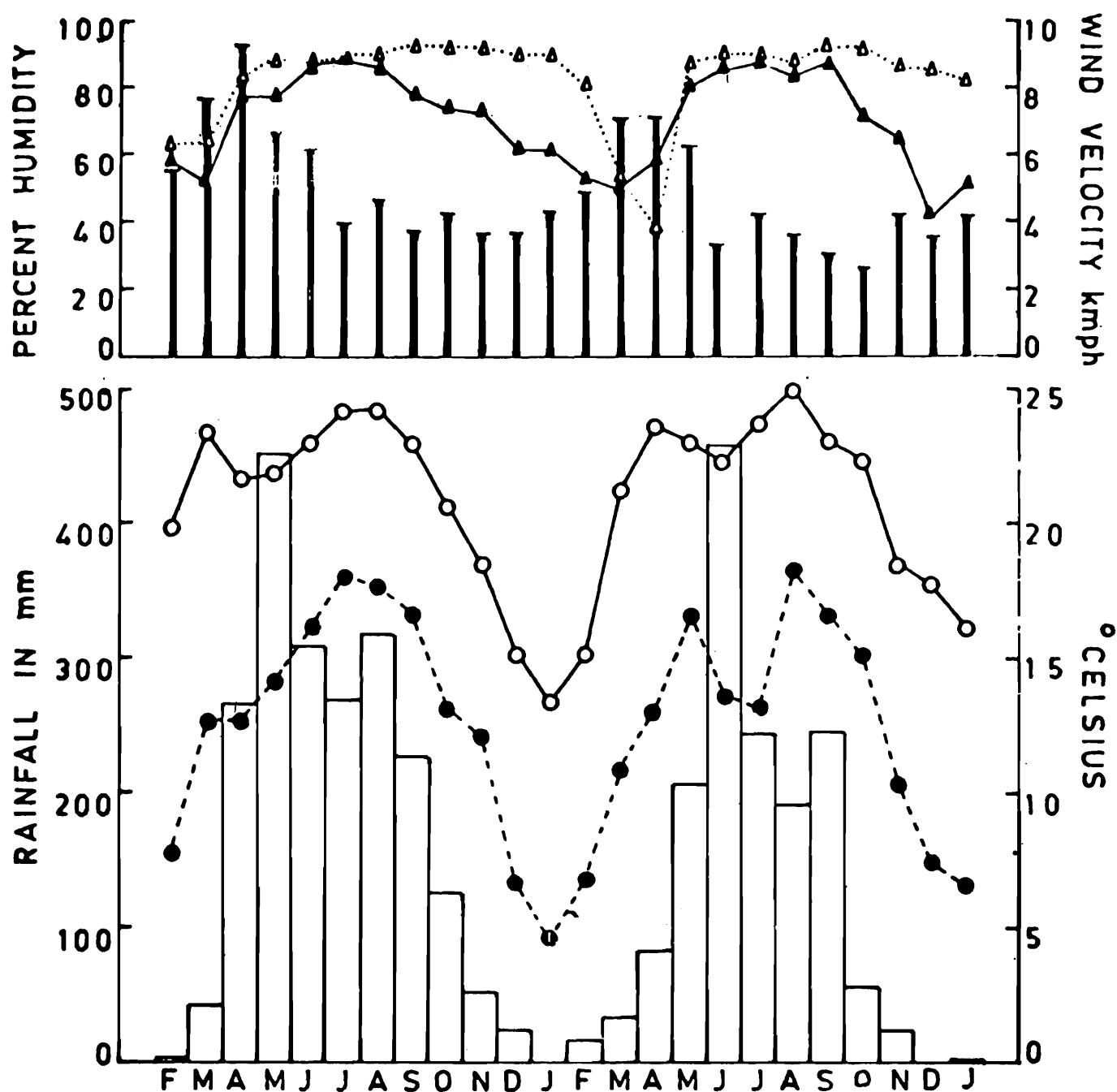


Fig. 3 : Figure showing the meterological aspects of Shillong during the period of investigation

- : Maximum Temperature
- : Minimum Temperature
- : Relative Humidity at 0830 Hrs.
- : Relative Humidity at 1730 Hrs.
- : Rainfall
- : Wind Velocity

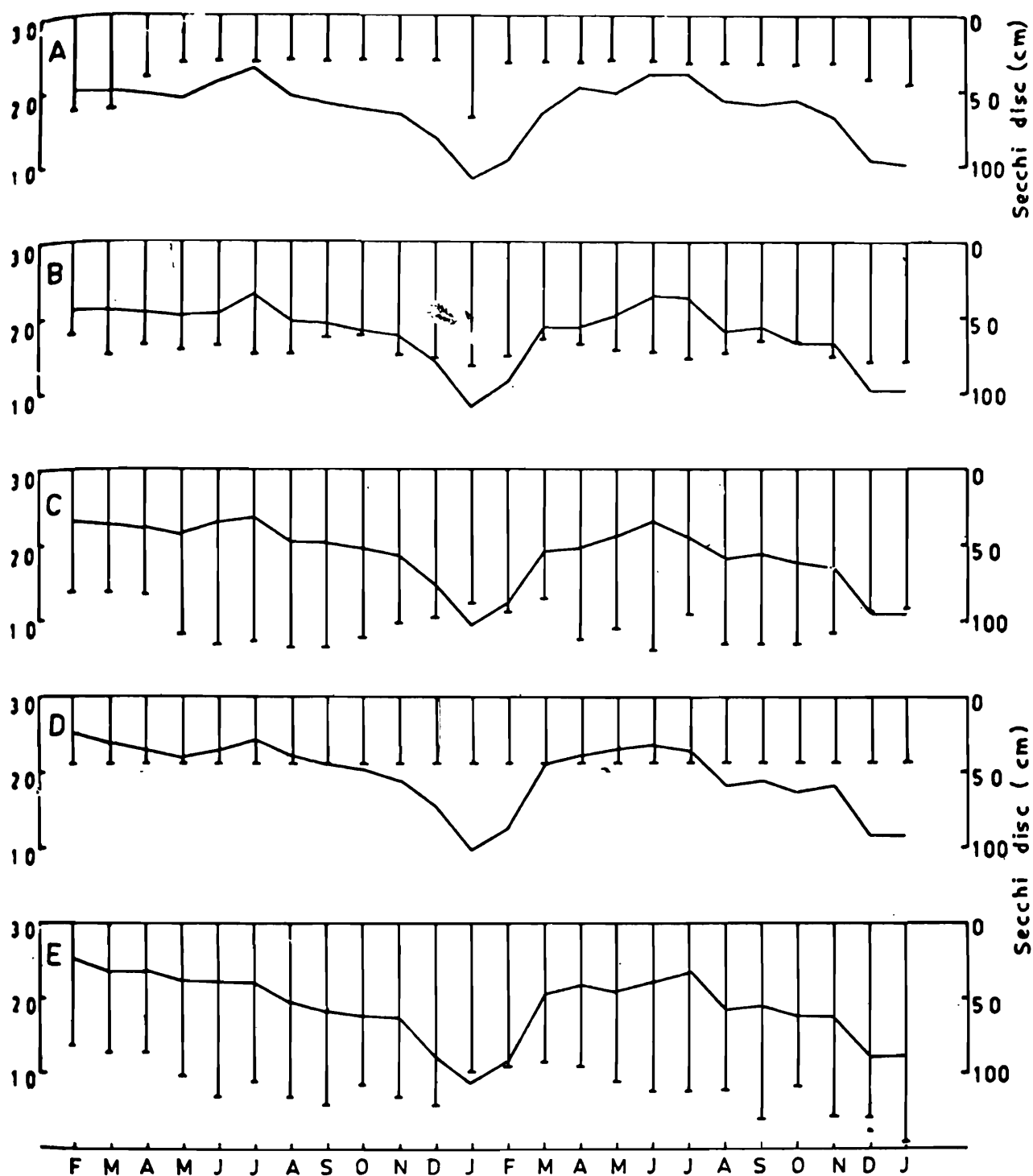


Fig. 4 : Seasonal Oscillations of the Secchi disc values (1) and Air Temperature at the Stations A, B, C, D, and E.

Conductivity or specific conductance expressed in $\mu\text{mhos/cm}$ was seen to be maximum in the month of April in both the annual cycles and recording more in the first annual cycle of the study period. The maximum, however, was recorded at Station A at both the depths recording nearly 235 to 240 $\mu\text{mhos/cm}$. In all the others however, the maximum though never less than 100 $\mu\text{mhos/cm}$ very rarely reached 150 $\mu\text{mhos/cm}$. The minimum record was seen to be during the winter months and especially after October till January the values recorded being around 50 $\mu\text{mhos/cm}$. The minimum of course was 49.4 $\mu\text{mhos/cm}$ as recorded for the surface waters of Station C in the month of October and not very different from 51.1 $\mu\text{mhos/cm}$ in the same station in January (Fig. 5.6 and 7).

Dissolved oxygen revealed the phenomena of clinograde as observed at least in the two deepest stations undertaken viz. Stations C and E. There is definitely a marked reduction at levels at all stations as one goes from top to the bottom. The maximum values recorded were always seen to be in the winter months of January and February and this was true irrespective of the stations and the depths. 9.8, 9.6 and 9.5 mg/l were the maximum records of dissolved oxygen as observed in the month of February during the first annual cycle at the fifth depth of Station E, the second depth of Station E and surface of Station C respectively. The minimum records of dissolved oxygen were again seen to be consistent in some months in two annual cycles in all the stations and for all depths. This minimum was usually recorded in the months of September, October, November during the first annual cycle and during July-August during the next annual cycle. Nil values were recorded at the deepest portions at Station E while values ranging between 4 to 5 mg/l of dissolved oxygen were observed to be in most of other stations and also at different depths (Figs. 8.9 and 10).

Carbon dioxide revealed a negative relationship, in that with the increase in depth the values of free carbon dioxide also increased. The maximum values in the two annual cycles occurred in summer months of June and July. The maximum was 39.9 mg/l in the deepest station of the lake at the twelfth depth of Station E even though the maximum oscillated around the values of 10 mg/l in all cases except for Station C. The minimum was in the winter months of January and February in both the annual cycles. The minimum though was around 8 mg/l again for Station E but the real minimum values which oscillated between 2 and 3 mg/l was observed in all the other stations. The least record of 2.2 mg/l was seen in the surface waters of Stations C and D (Figs. 8.9 and 10).

Alkalinity values increased with depth at different stations. The maximum was in the summer month of July and the autumn month of September. The maximum was in the deepest portion (the twelfth depth) of the lake recording 66 mg/l. The maximum values at the other stations however, oscillated around 45 mg/l, for both annual cycles. Minimum values occurred in the winter months of January and February and in most cases were between 25 to 28 mg/l. 25mg/l in the month of January for the second depth at Station E was the least record: (Figs. 8.9 and 10).

Phosphate was seen to increase with depth in the early spring months and showed a reverse trend during the winter months. However, the maximum value of 14 mg/C was seen to be always in the months of May to June in both the annual cycles in the deepest portion of the lake, twelfth depth of Station E. The maximum values recorded in all the other stations and depths were around 10 ± 2 mg/l. The minimum was in the winter months of November and December at Station E, (deepest portion 2.2mg/l), Station C (deepest portion 1.9mg/C) and the bottom of Station A. The minimum in all the other stations did not go beyond 4 mg/l. (Figs. 8.9 and 10).

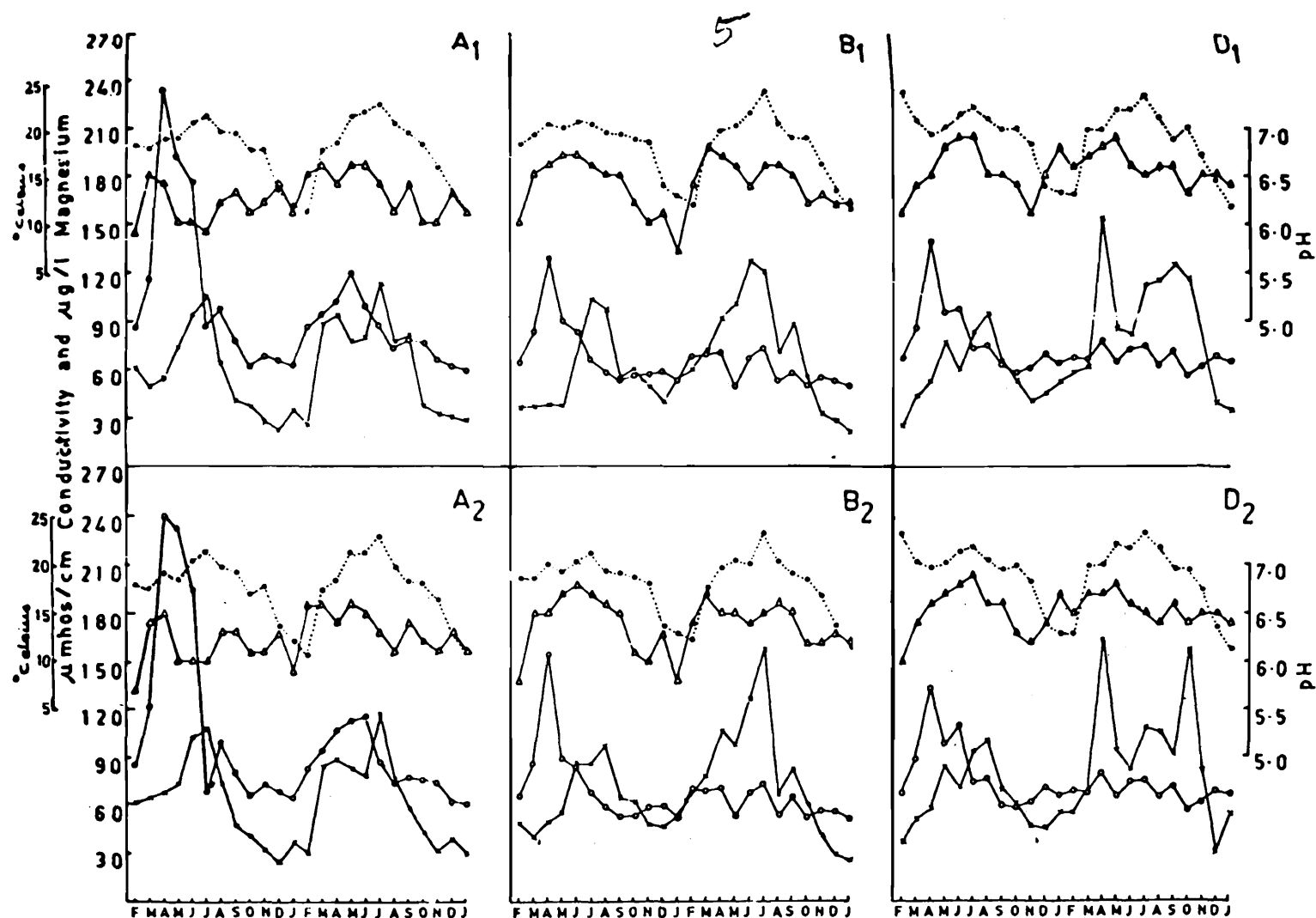


Fig 5. Conductivity, pH, water temperature and Magnesium for Stations A, B and D.

• — • Water Temperature
 ○ — ○ Conductivity

Δ — Δ pH
 × — × Magnesium

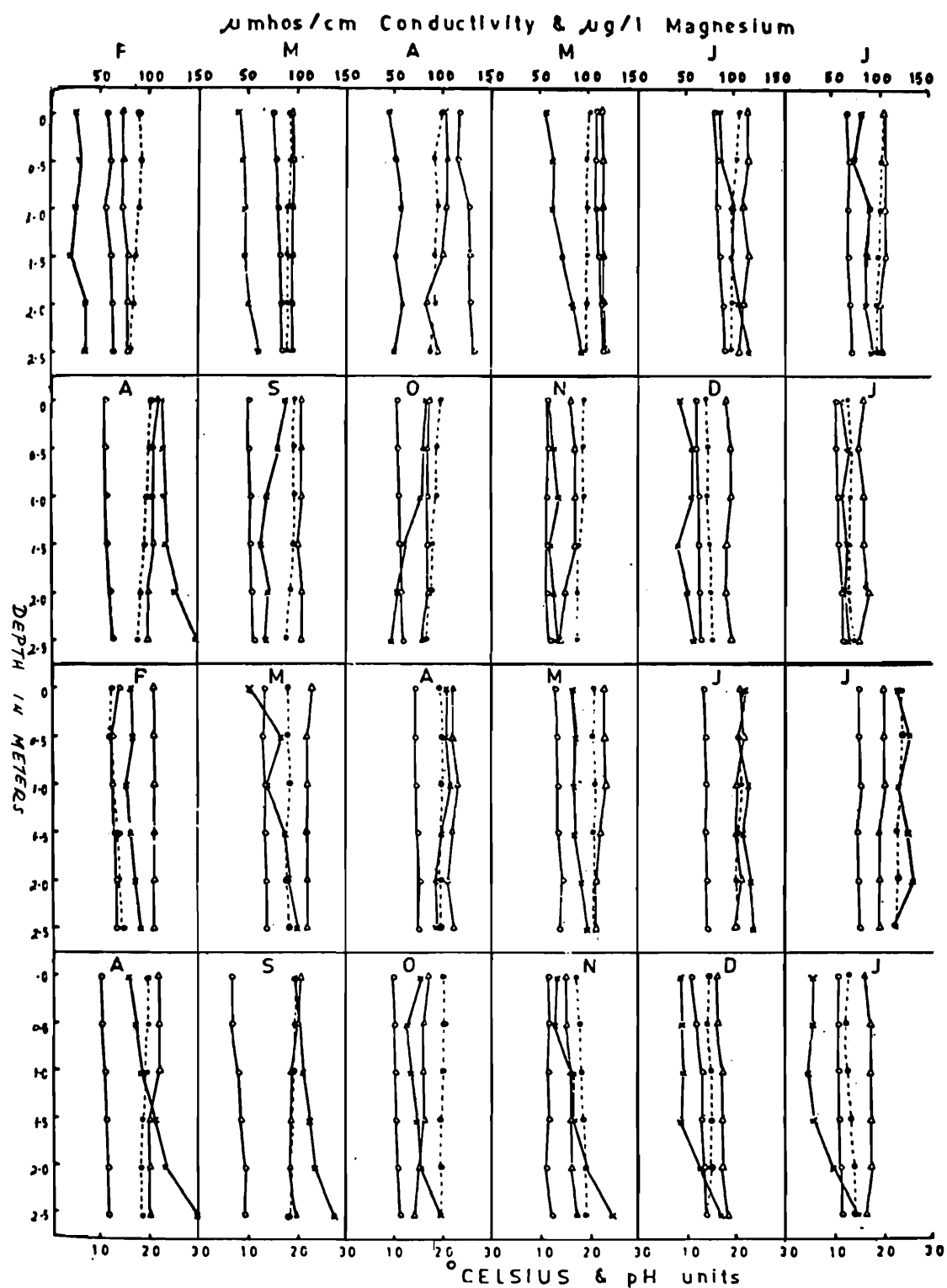


Fig 6. Conductivity, pH, water temperature and Magnesium for Station C.

●.....● Water Temperature
 ○.....○ Conductivity
 Δ.....Δ pH
 ×.....× Magnesium

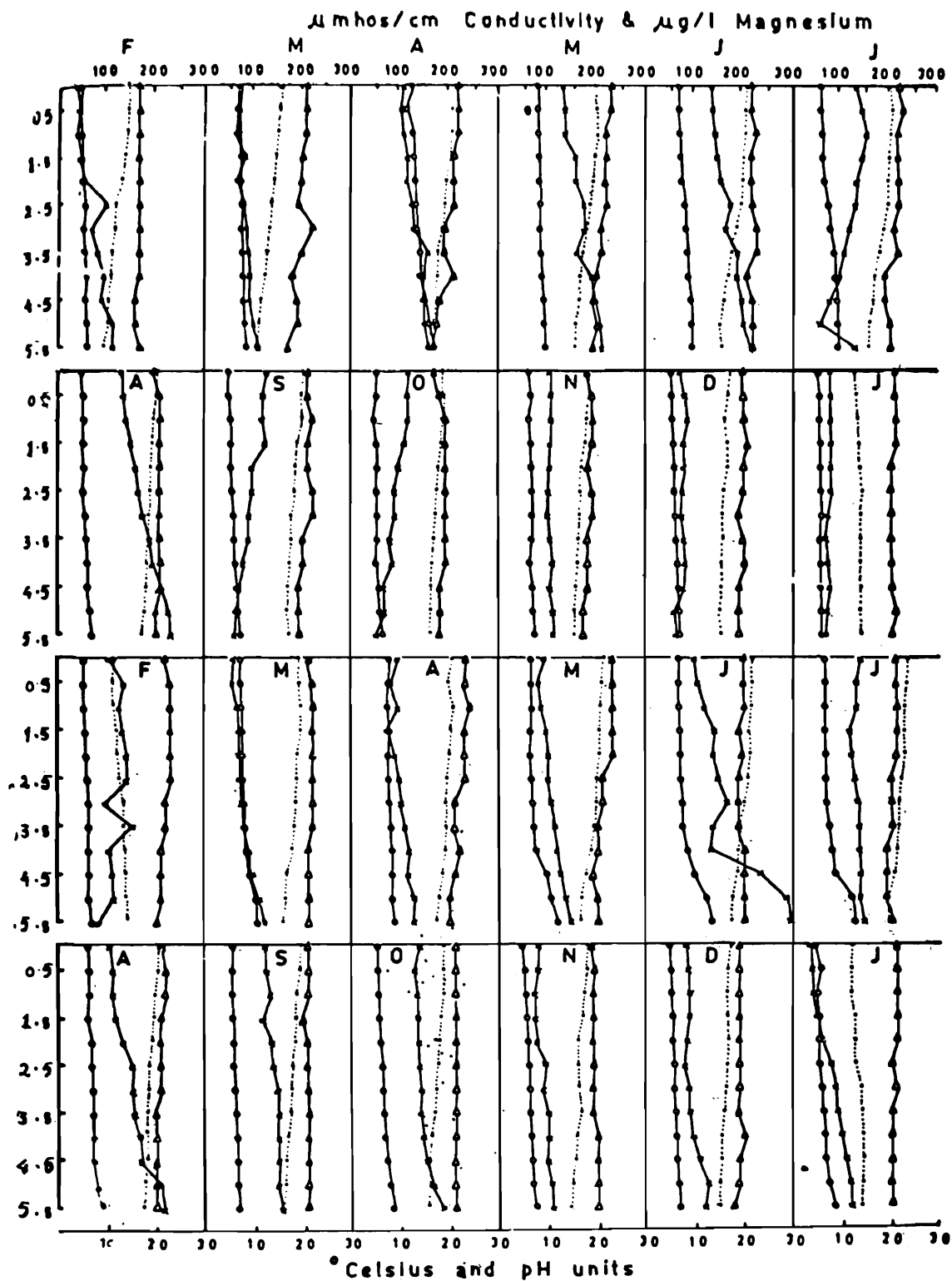


Fig 7. Conductivity, pH, water temperature and Magnesium for Station E.

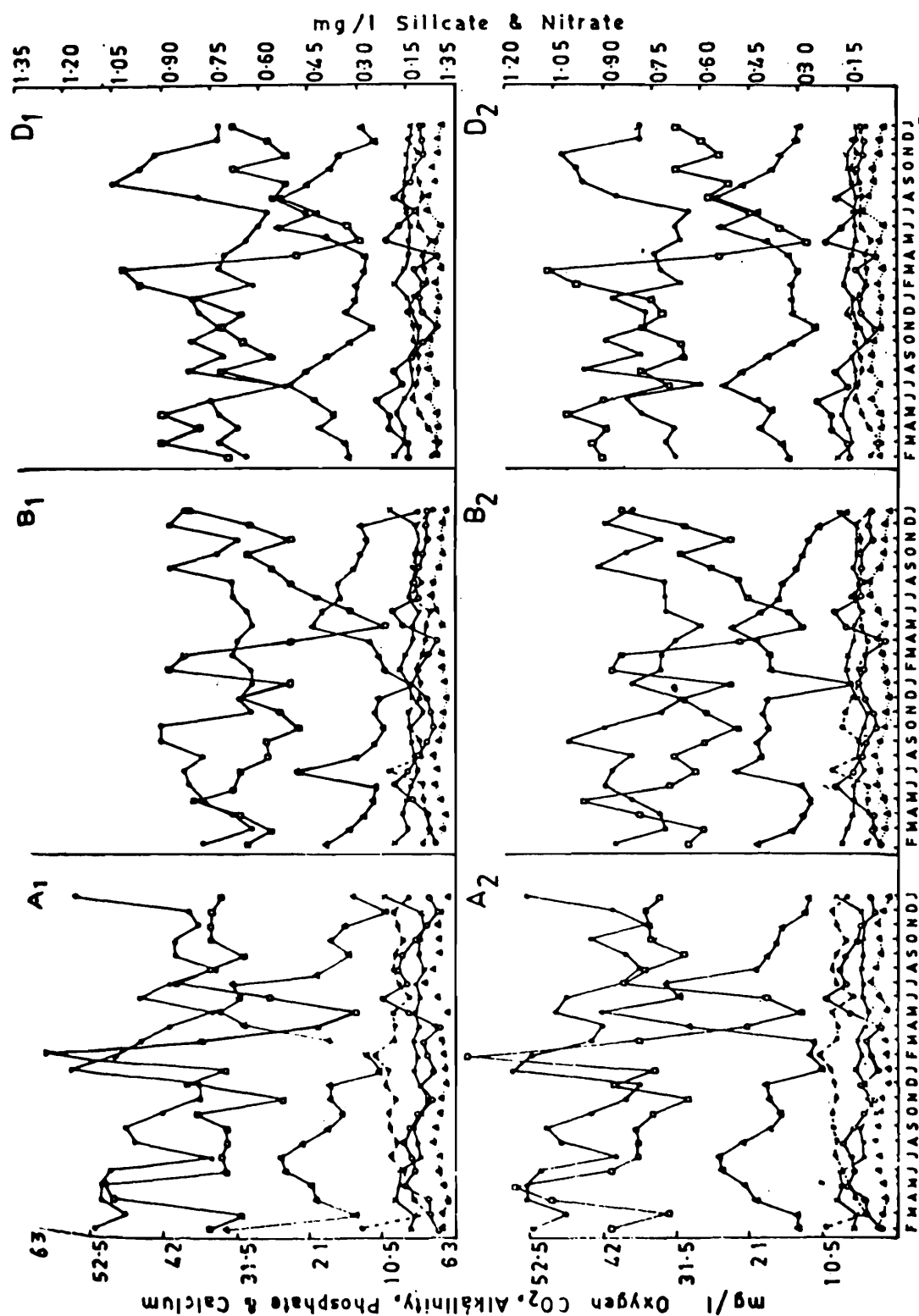


Fig 8. Oxygen, Carbondioxide, Alkalinity, Phosphate, Silicate, Nitrate and Calcium for Stations A, B and D.

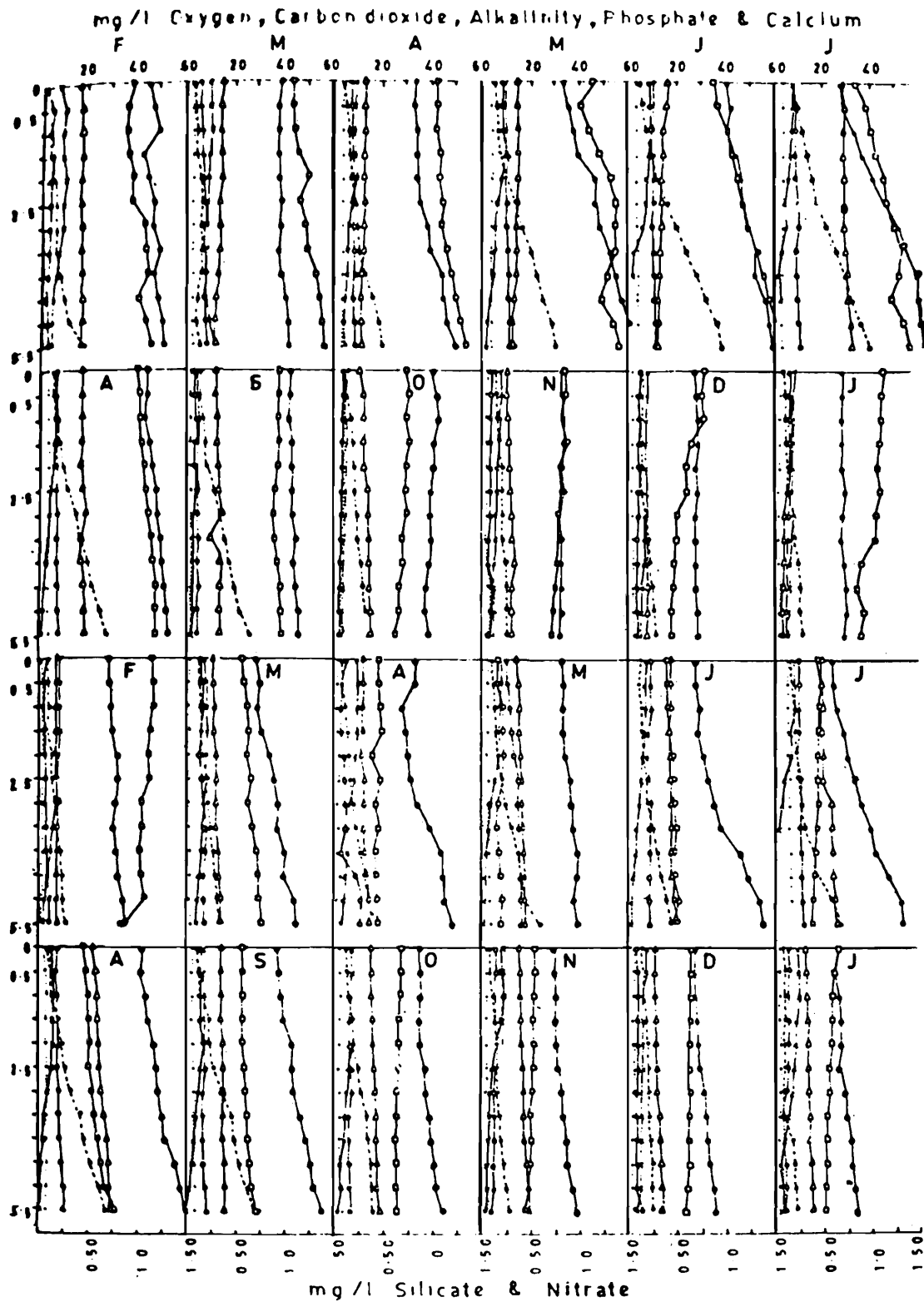


Fig 9. Oxygen, Carbondioxide, Alkalinity, Phosphate, Silicate, Nitrate and Calcium for Station C.

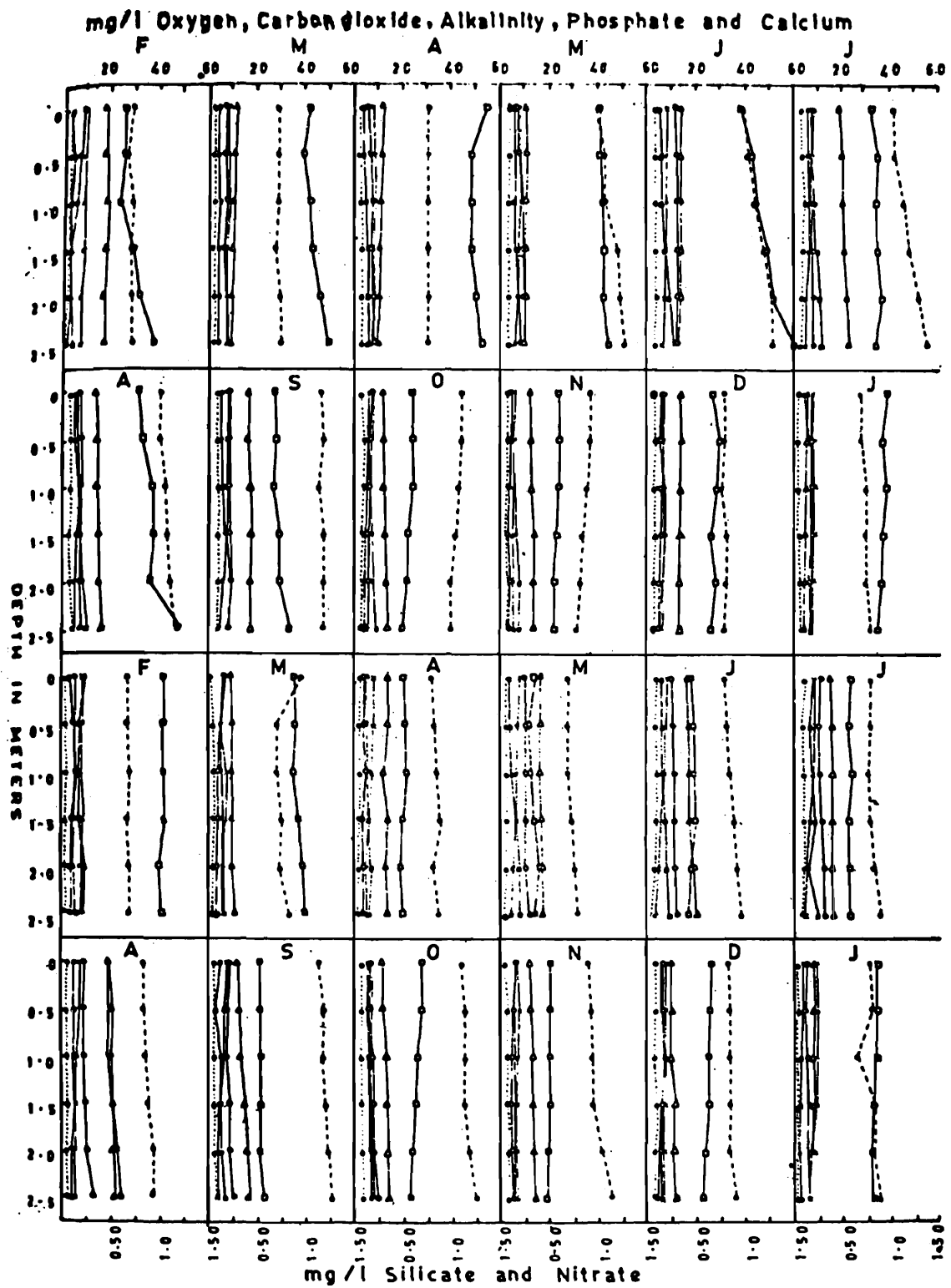


Fig 10. Oxygen, Carbon dioxide, Alkalinity, Phosphate, Silicate, Nitrate and Calcium for Station E.

Nitrate, in certain months revealed a definite increase in their depth distribution but was not consistent. Consistent maximum values were recorded in the months of May and June during the first annual cycle in all stations, but during the second annual cycle maximum was during the months of February and March. In most cases the values were 1.1 mg/l with the maximum record of 1.6 at the deepest portion of Station C. The minimum value 0.2 mg/l was seen in all stations and depths in the month of May during the second annual cycle. (Figs. 8,9 and 10).

Silicate showed a more or less uniform distribution depthwise. The maximum values were in the months of July and August at all the stations, for all the depths and in both the annual cycles. The maximum values were between 0.5 and 0.9 mg/l with the maximum record being for the bottom of Station A. January recorded the least at all the stations and depths and for both the annual cycles. The minimum values were between 0.1 and 0.2 mg/l. (Figs. 8,9 and 10).

Calcium though increased from top to the bottom in the various stations, it was not very significant. The maximum values which never went beyond 5.0 mg/l in all the stations and all depths were in the months of July and August in both the annual cycles. A maximum of 4.9 mg/l was seen during the second annual cycle in three bottom most layers of Station E. The minimum record of this nutrient was seen to occur in winter months of January and February and in all the cases it ranged between 1.0 and 1.5 mg/l. The minimum was seen in the surface waters of Station E (Figs. 8, 9 and 10).

Magnesium also revealed in certain months an increase from the top to the bottom but in certain months a reverse. The earlier phenomena was however true for all the months in Stations E and C except in the summer month of June where there was no real trend. The maximum value of 293 µg/l was in the summer months of June, July and August in the deepest portion of the lake. The minimum values always occurred in the winter months of January and February in all the Stations in all the depths during the annual cycles. These ranged between 22 to 50 µg/l. The least was recorded in the surface waters of Station B and the mid-depths of Station C (Figs. 5, 6, and 7).

Phytoplankton :

Phytoplankton was analysed and counted upto the generic levels. They were brought first under the different families and these were ultimately grouped under the seven major classes of phytoplankton – Chlorophyceae, Euglenophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Dinophyceae and Myxophyceae. Chlorophyceae comprised of the families Chlamydomonadaceae with one genus *Chlamydomonas*, Volvocaceae comprising of *Eudorina*, *Pandorina* and *Gonium*, Palmellaceae again with one genus *Gloeocystis* and Dictyosphaeriaceae, Hydrodictyaceae, Coelastraceae and Zygnemataceae all with one genus, *Dictyosphaerium*, *Pediastrum*, *Coelastrum* and *Spirogyra* respectively. Ulotrichaceae and Scenedesmaceae had two genera, the former comprising of *Hormidium* and *Ulothrix* while the latter *Actinastrum* and *Scenedesmus*. Oocystaceae was made up of six different genera *Ankistrodesmus*, *Closteriopsis*, *Kirchneriella*, *Oocystis*, *Selenastrum* and *Westella*. Desmidiaceae also had six genera comprising of *Closterium*, *Cosmarium*, *Desmidium*, *Gymnozyga*, *Micrasterias* and *Staurastrum*.

Euglenophyceae comprised of only one family Euglenaceae with two genera *Euglena* and *Phacus*. Xanthophyceae comprised of two families Gleobotrydiaceae and Xanthophyceae with one genus each *Gleobotrys* and *Botryococcus* respectively. Chrysophyceae comprised of four families Chromulinaceae, Synuraceae, Tribonemataceae and Ochromonadaceae. Each of these contained only one genus – *Chrysococcus*, *Synura*, *Tribonema* and *Dinobryon* in that order respectively.

Bacillariophyceae like Chlorophyceae also dominated the phytoplankton of the lake. They comprised of the families Coscinodiscaceae, Tabellariaceae, Meridionaceae, Diatomaceae, Fragillariaceae, Nitzschiaceae and Cymbellaceae all having only one genus. These were *Melosira*, *Tabellaria*, *Meridion*, *Diatoma*, *Synedra*, *Nitzschia* and *Cymbella* respectively. In addition, this class also had the family Naviculaceae comprising of three genera, *Amphipleura*, *Navicula* and *Pinnularia*.

Dinophyceae was represented by the families Gymnodiniaceae, Peridiniaceae and Ceratiaceae. Each of these comprised of only one genus, *Gymnodinium*, *Peridinium* and *Ceratium* respectively.

Myxophyceae had only two families Chroococcaceae and Oscillatoriaceae. The former was made up of seven genera, *Coelosphaerium*, *Microcystis*, *Gloecapsa*, *Merismopedia*, *Chroococcus*, *Aphanocapsa* and *Anacystis*, while the latter had only two genera *Oscillatoria* and *Spirulina*.

In Station A, the Class Xanthophyceae was totally absent. Chlorophyceae had Chlamydomonaceae with a single genus *Chlamydomonas*, which revealed peaks of abundance during the month of August and May in the first annual cycle with 260 units/litre and 133 units/litre respectively. They were totally absent during the winter months. Volvocaceae, had only one genus *Eudorina* while the other two *Pandorina* and *Gonium* being totally absent. This genus *Eudorina* had a peak of abundance in May (108 units/litre) and March (105 units/litre) in the two annual cycles and absent in both the autumn and winter months beginning September to February. Palmellaceae with its single genus *Gloeocystis* had a peak in the month of July (15 units/litre) in the first annual cycle and was nearly seven times that in the month of September (100 units/litre) during the second annual cycle and absent in the months of February, March, September to December in the first and May to July in the second annual cycles. Hydrodictyaceae with the single genus *Pediastrum* was present throughout the study period, in both the annual cycles. Peaks of abundance were recorded in the months of June (525 units/litre and 397 units/litre). The minimum recorded for both the annual cycles was seen in the month of February with 10 units/litre and 40 units/litre. Oocystaceae was made up of *Ankistrodesmus* and *Westella* genera. In both the annual cycles the peaks of abundance were in the summer months though *Westella* in the second annual cycle had a fall in the month of June. *Ankistrodesmus* showed maximum abundances in the months of June in both the annual cycles with 523 and 397 units/litre. In the first annual cycle *Westella* reached a maximum of 50 units/litre in the month of July and 33 units/litre in April in the next annual cycle. *Scenedesmus* was the only genus recorded from the family Scenedesmaceae, and was found to be one of the dominant groups of phytoplankton. In both the annual cycles the seasonal fluctuations were similar in that a steady increase till June when a peak (3577 units/litre) was formed and thereafter a subsequent steady decline. The peak however shifted to May (3193 units/litre) in second annual cycle. The last family under the class Chlorophyceae was Desmidiaceae and the genera *Desmidium*, *Gymnozyga* and *Staurostrum* were recorded at this station. *Desmidium* was absent during the winter months and recorded a peak in July during the first annual

cycle (755 units/litre) and in September (1560 units/litre) in the second annual cycle. *Gymnozyga* was similarly absent during the winter months. The month of May recorded the maximum (130 units/litre) during the first annual cycle, while July during the second (127 units/litre). The genus *Staurastrum* was recorded throughout the study period at this station with peak values in July (1625 units/litre) and August (1727 units/litre) for the first and second annual cycles respectively.

Euglenophyceae was recorded at this Station by the presence of both the genera, *Euglena* and *Phacus* of the family Euglenaceae. *Euglena* disappeared during the winter months, the maximum abundance being in the months of May and April during the first and second annual cycle recording 718 units/litre and 408 units/litre respectively. *Phacus* also revealed nil during winter months with July and August showing peaks of abundance for the two annual cycles recording 2915 and 5220 units/litre respectively.

Chrysophyceae was represented by only one family Ochromonadaceae and one genus *Dinobryon* in this station which was totally absent during the winter months and recorded peaks of abundance in the months of June, July and August during the two annual cycles recording 123 units, 128 units and 187 units/litre respectively.

Bacillariophyceae was represented with only four families. The family Coscinodiscaceae with its single genus *Melosira* revealed irregular seasonal fluctuation, in that during the first annual cycle it was present only in the months of April, May, June and August with August showing the maximum (8 units/litre) while in the second annual cycle it was present in February, August to January with the month of November recording maximum (30 units/litre). The family Meridionaceae with only one genus *Meridion* also had an irregular fluctuation. It was absent during the first annual cycle except during the months of March, April and January. In the second annual cycle it was present except during the months of July, October and December. April recorded the maximum (55 units/litre) in the first annual cycle while February (82 units/litre) in the second annual cycle. Naviculaceae at this station was represented by all the genera *Amphipleura*, *Navicula* and *Pinnularia*. *Amphipleura* was also irregular in its seasonal fluctuation with a peak in April (35 units/litre) during the first annual cycle and in November (20 units/litre) in the second annual cycle and a total absence in February, June and January of first annual cycle, and March to October in the second annual cycle. *Navicula* tended to show an increase in autumn and winter months They had small peaks of abundances in September (47 units and 85 units/litre respectively) during both the annual cycles and a larger peak in January (133 units/litre) and November (200 units/litre) in the second annual cycle. *Pinnularia* revealed an increase in the winter months. However, it also had small peaks of abundance in the spring months of April and May and a maximum abundance peak in December (60 units and 75 units/litre) during both the annual cycles. The family Nitzschiaceae had *Nitzschia* which was present at this station except during the months of June to October in the first annual cycle and March to August in the second annual cycle. There were two peaks a large one in the month of April (100 units/litre) and small one in February of abundance in the first annual cycle while November showed a peak of maximum abundance (145 units/litre) not only in the first annual cycle but also in the entire study period.

Dinophyceae was represented by the family *Peridiniaceae* and genus *Peridinium*. During both the annual cycles the peak abundance was seen to be in the months of June-July with total disappearance

in the winter months. The maximum was in the month of July (50 units/litre and 187 units/litre) in both the annual cycles.

Myxophyceae was represented by families Chroococcaceae and Oscillatoriaceae. The former family was represented by three genera *Coelosphaerium*, *Microcystis* and *Gloeocapsa*. *Coelosphaerium* disappeared during the winter months and recorded peaks of abundance in the months of May (200 units/litre) and June (293 units/litre) during both the annual cycles. *Microcystis* was very peculiar in that it was totally absent in the first annual cycle and present only during the months of March, April, August and October in the second annual cycle with a peak in April (48 units/litre). *Gloeocapsa* was totally absent during the winter months and showed a single peak in the month of July (100 units/litre) in the first annual cycle and April (110 units/litre) in the second. *Oscillatoria* was the only one represented under Oscillatoriaceae showing fluctuations of absence and presence consistent only for maximum abundance peak being recorded for both the annual cycles in the month of August (130 units/litre) (Table-II a,b).

The seasonal fluctuation under Chlorophyceae at this Station at family level viz Chlamydomonadaceae, Volvocaceae, Palmellaceae, Hydrodictyaceae, Oocystaceae, Scenedesmaceae and Desmidiaceae revealed peaks of abundance in the summer months of May, June and July for both the annual cycles. There was tendency of decrease and sometimes a total absence during the winter months. The family Scenedesmaceae recorded maximum numbers and was at least seven to eight times more than that recorded for the other families.

The class Chlorophyceae in its seasonal fluctuation followed a similar pattern to all the families and in particular to that of *Scenedesmus*, with a maximum of 6390 units/litre in the first annual cycle in the month of June and 5493 units/litre in the month of May for the second annual cycle. However, when this class was seen as percentage of total phytoplankton the peak shifted from June to October during the first annual cycle as Chlorophyceae represented only 64% in the former month while nearly 93% in the latter. In the winter months the percentages of this class of the total phytoplankton was always lower.

Euglenaceae was the only one under the class Euglenophyceae. The seasonal fluctuation was similar to that of the families of Chlorophyceae and the months of July (3065 units/litre) and August (5320 units/litre) recorded peaks for the two annual cycles. Further, a decline was seen during the winter months. When the percentage of Euglenophyceae was seen as that of total phytoplankton, the trend was similar to their actual numbers with slight variations.

Ochromonadaceae was the only one family under the class Chrysophyceae at this station. Its seasonal fluctuation was similar to that of Euglenophyceae. The class Chrysophyceae as the percentage of total phytoplankton followed the same trend as that of its numbers.

Bacillariophyceae at this station had four families, Coscinodiscaceae, Meridionaceae, Naviculaceae and Nitzschiaceae. These families recorded peaks in winter and early spring while a fall was seen in the summer months. As a percentage of the total phytoplankton it formed 40%.

Peridiniaceae was a single family under the class Dinophyceae. It followed a trend of a summer maxima and a winter minima for both the annual cycles. This was true even when the class Dinophyceae was seen as a percentage of total phytoplankton.

Myxophyceae had two families viz. Chroococcaceae and Oscillatoriaceae. The spring, summer and autumn months seemed to be peaks with a decline and sometimes a total absence during winter.

Total phytoplankton formed a maximum in the month of June (9965 units/litre) and August (9392 units/litre) during the first and second annual cycles respectively.

Table-IIa : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the first annual cycle at Station A.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlamydomonas</i>	0	0	0	66	87	70	260	183	28	0	0	0
2 <i>Eudorina</i>	0	5	50	108	57	0	8	0	0	0	0	0
3 <i>Gloeocystis</i>	0	0	10	4	0	15	6	0	0	0	0	7
4 <i>Pediastrum</i>	10	33	95	320	523	165	464	143	168	140	132	67
5 <i>Ankistrodesmus</i>	0	0	0	2	20	40	2	7	0	0	0	0
6 <i>Westella</i>	0	0	0	28	39	50	12	0	0	0	0	0
7 <i>Scenedesmus</i>	40	33	143	624	3577	2250	2888	987	1153	880	220	80
8 <i>Desmidium</i>	0	0	13	214	527	755	486	77	33	3	0	0
9 <i>Gymnozyoa</i>	0	0	25	130	7	0	0	0	0	0	0	0
10 <i>Staurostrum</i>	40	73	635	1417	1553	1625	956	87	140	90	98	60
11 <i>Euglena</i>	20	58	185	718	700	150	230	47	0	0	8	47
12 <i>Phacus</i>	0	40	40	902	2343	2915	566	150	43	53	14	0
13 <i>Dinobryon</i>	0	0	0	52	123	60	128	13	0	0	0	0
14 <i>Melosira</i>	0	0	3	4	3	0	8	0	0	0	0	0
15 <i>Meridion</i>	0	28	55	0	0	0	0	0	0	0	0	20
16 <i>Amphipleura</i>	0	8	35	12	0	5	4	3	20	3	4	0
17 <i>Navicula</i>	60	3	0	10	13	10	20	47	33	48	62	133
18 <i>Pinnularia</i>	0	28	50	82	27	0	0	0	0	0	60	7
19 <i>Nitzschia</i>	20	88	100	66	0	0	0	0	0	33	52	53
20 <i>Peridinium</i>	0	0	0	24	27	50	46	0	0	0	0	0
21 <i>Coelosphaerium</i>	0	0	18	112	293	235	258	80	0	0	0	10
22 <i>Microcystis</i>	0	0	0	0	0	0	0	0	0	0	0	0
23 <i>Gloeocystis</i>	0	33	70	52	3	100	94	17	23	0	0	0
24 <i>Oscillatoria</i>	0	0	8	10	33	5	128	0	3	10	0	0
Total	190	430	1535	4958	9965	8500	6564	1841	1644	1260	650	484

Table IIa

Table-IIb : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the second annual cycle at Station A.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlamydomonas</i>	0	25	45	133	117	47	15	20	0	0	0	00
2 <i>Eudorina</i>	16	105	58	3	7	27	60	0	0	0	0	0
3 <i>Gloeaocystis</i>	20	23	5	0	0	0	35	100	80	65	5	30
4 <i>Pediastrum</i>	40	73	118	210	397	287	185	175	70	85	85	45
5 <i>Ankistrodesmus</i>	0	0	0	30	50	23	5	0	0	0	0	0
6 <i>Westella</i>	18	5	33	17	7	30	10	0	0	5	0	0
7 <i>Scenedesmus</i>	180	850	1888	3193	1010	1037	990	775	915	130	100	85
8 <i>Desmidium</i>	54	133	125	167	174	140	415	1560	330	120	20	0
9 <i>Gymnozyoa</i>	0	3	5	20	87	127	40	0	0	0	0	0
10 <i>Staurastrum</i>	162	855	1358	1720	1303	1723	1727	1135	360	75	5	60
11 <i>Euglena</i>	130	220	408	107	87	127	100	60	0	0	0	5
12 <i>Phacus</i>	10	10	80	523	2367	3433	5220	2735	530	100	0	0
13 <i>Dinobryon</i>	0	40	80	77	187	163	30	110	45	0	0	0
14 <i>Melosira</i>	2	0	0	0	0	0	5	5	10	30	20	0
15 <i>Meridion</i>	82	70	70	33	17	0	50	30	0	40	0	10
16 <i>Amphipleura</i>	6	0	0	0	0	0	0	0	0	20	5	0
17 <i>Navicula</i>	112	73	68	80	7	53	0	85	60	200	70	100
18 <i>Pinnularia</i>	18	3	53	40	53	13	40	30	10	30	75	0
19 <i>Nitzschia</i>	6	0	0	0	0	0	0	50	5	145	55	50
20 <i>Peridinium</i>	2	18	63	157	187	127	100	20	0	20	5	0
21 <i>Celosphaerium</i>	46	85	95	200	140	153	170	90	15	0	65	5
22 <i>Microcystis</i>	0	15	48	0	0	0	40	0	30	0	0	0
23 <i>Gloeocystis</i>	54	68	110	73	23	3	25	0	0	0	0	0
24 <i>Oscillatoria</i>	24	23	40	20	7	0	130	30	40	5	30	50
Total	982	2697	4750	6803	6227	7513	9392	7010	2500	1070	540	440

Table - IIb

Table-IIIa : Seasonal abundance of the classes and the families of phytoplankton at Station A.*First annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i> (Cl.)	90	144	971	2914	6390	4970	5082	1484	1522	1113	450	214
2 <i>Chlamydomonadaceae</i>	0	0	0	66	87	70	260	183	28	0	0	0
3 <i>Volvocaceae</i>	0	5	50	108	57	0	8	0	0	0	0	0
4 <i>Palmellaceae</i>	0	0	10	4	0	15	6	0	0	0	0	7
5 <i>Hydrodictyaceae</i>	10	33	95	320	523	165	464	143	168	140	132	67
6 <i>Oocystaceae</i>	0	0	0	30	59	90	14	7	0	0	0	0
7 <i>Scenedesmaceae</i>	40	33	143	625	3577	2250	2888	987	1153	880	220	80
8 <i>Desmidiaceae</i>	40	73	673	1761	2087	2380	1442	164	173	93	98	60
9 <i>Euglenophyceae</i> (Cl.) (<i>Euglenaceae</i>)	20	98	225	1620	3043	3065	796	197	43	53	22	47
10 <i>Chrysophyceae</i> (Cl.) (<i>Ochromonadaceae</i>)	0	0	0	52	123	60	128	13	0	0	0	0
11 <i>Bacillariophyceae</i> (Cl.)	80	155	243	174	53	15	32	50	53	84	178	213
12 <i>Coscinodiscaceae</i>	0	0	3	4	3	0	8	0	0	0	0	0
13 <i>Meridionaceae</i>	0	28	55	0	0	0	0	0	0	0	0	20
14 <i>Naviculaceae</i>	60	39	85	104	50	15	24	50	53	51	126	140
15 <i>Nitzschiaceae</i>	20	88	100	66	0	0	0	0	0	33	52	53
16 <i>Dinophyceae</i> (Cl.) (<i>Peridiniaceae</i>)	0	0	0	24	27	50	46	0	0	0	0	0
17 <i>Myxophyceae</i> (Cl.)	0	33	96	174	329	340	480	97	26	10	0	10
18 <i>Chroococcaceae</i>	0	33	88	164	296	335	352	97	23	0	0	10
19 <i>Oscillatoriaceae</i>	0	0	8	10	33	5	128	0	3	10	0	0

Table - IIIa
(First annual cycle)

Table-IIIb : Seasonal abundance of the classes and the families of phytoplankton at Station A.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i> (Cl.)	490	2072	3635	5493	3152	3441	3482	3765	1755	480	215	220
2 Chlamydomonadaceae	0	25	45	133	117	47	15	20	0	0	0	0
3 Volvocaceae	16	105	58	3	7	27	60	0	0	0	0	0
4 Palmellaceae	20	23	5	0	0	0	35	100	80	65	5	30
5 Hydrodictyaceae	40	73	118	210	397	287	185	175	70	85	85	45
6 Oocystaceae	18	5	33	47	57	53	15	0	0	5	0	0
7 Scenedesmaceae	180	850	1888	3193	1010	1037	990	775	915	130	100	85
8 Desmidiaceae	216	991	1488	1907	1564	1990	2182	2695	690	195	25	60
9 <i>Euglenophyceae</i> (Cl.) (Euglenaceae)	140	230	488	630	2454	3560	5320	2795	530	100	0	5
10 <i>Chrysophyceae</i> (Cl.) (Ochromonadaceae)	0	40	80	77	187	163	30	110	45	0	0	0
11 <i>Bacillariophyceae</i> (Cl)	226	146	191	153	77	66	95	200	85	465	225	160
12 Coscinodiscaceae	2	0	0	0	0	0	5	5	10	30	20	0
13 Meridionaceae	82	70	70	33	17	0	50	30	0	40	0	10
14 Naviculaceae	136	76	121	120	60	66	40	115	70	250	150	100
15 Nitzschiaceae	6	0	0	0	0	0	0	50	5	145	55	50
16 <i>Dinophyceae</i> (Cl.) (Peridiniaceae)	2	18	63	157	187	127	100	20	0	20	5	0
17 <i>Myxophyceae</i> (Cl.)	124	191	293	292	170	156	365	120	85	5	95	55
18 Chroococcaceae	100	168	253	273	163	156	235	90	45	0	65	5
19 Oscillatoriaceae	24	23	40	20	7	0	130	30	40	5	30	50

Table IIIb
(Second annual cycle)

Station B was similar to that of Station A. However, in this station there were some genera of phytoplankton which were absent and some present not found in the earlier station. *Chlamydomonas* was totally absent at this station, Volvocaceae had two genera *Eudorina* and *Pandorina*. Both these genera had their peaks of abundance in the summer and early autumn months, with a decline in winter. *Pandorina* in the first annual cycle had a peak in the month of April (140 units/litre) which fell thereafter to peak in the month of July (100 units/litre) in the first annual cycle and August recorded the maximum (210 units/litre) in the second annual cycle. *Gloeocystis* of the family Palmellaceae recorded nil values during the winter months while the months of June showed a peak (27 units/litre) in the first annual cycle and September (85 units/litre) during the second. Ulotrichaceae had both the genera *Hormidium* and *Ulothrix*. Maximum abundance was in July during both the annual cycles and total absence during the winter months. *Hormidium* was maximum in the months of June and July (43 units/litre) and in July (447 units/litre) during the first and second annual cycles respectively, while *Ulothrix* peaked in the month of July (60 units/litre and 27 units/litre) during both the annual cycles. *Dictyosphaerium*, *Pediastrum* and *Coelastrum* of the family Dictyosphaeriaceae, Hydrodictyaceae and Coelastraceae respectively had a more or less seasonal trend of fluctuation to that of the earlier genera. All these three recorded nil during the winter months and a peak in the summer months of June and July. *Dictyosphaerium* showed a maximum abundance in July (623 units/litre and 490 units/litre) during both the annual cycles. *Pediastrum* had a spurt in April (150 units/litre) which fell substantially in the next month to reach a peak in July (170 units/litre) during the first annual cycle. In the second annual cycle *Pediastrum* followed the same trend as the other two except that the peaks shifted to August (190 units/litre). Oocystaceae recorded only three genera, *Ankistrodesmus*, *Kirchneriella* and *Westella*. *Kirchneriella* and *Westella* had the usual pattern of seasonal fluctuation with a summer maxima and winter minima during both the annual cycles. However, *Ankistrodesmus* seemed to occur only during the spring and early summer months. *Ankistrodesmus* showed peaks in the month of June (30 units/litre) and April (40 units/litre) in the first and second annual cycles respectively. *Kirchneriella* was maximum in the month of July (53 units/litre and 193 units/litre) during both the annual cycles. *Westella* had its peaks in the month of July (413 units/litre and 343 units/litre) in both the annual cycles. *Scenedesmus* was the only one under the family Scenedesmaceae, recorded quite high numbers in February which fell in the subsequent months in April recording maximum abundance (228 units/litre). It thereafter fell steadily till September. The second annual cycle had a drastic increase in December and January (370 units/litre and 350 units/litre). The last two families under the class Chlorophyceae were Zygnemataceae and Desmidiaceae. The former had *Spirogyra* while the latter comprised *Cosmarium*, *Desmidium*, *Micrasterias* and *Staurastrum*. One common feature in all these genera irrespective of the two families was that their seasonal trend of fluctuation revealed the usual pattern of summer maxima in June and July and winter minima in November, December, January and February. *Spirogyra* had its peaks in July (47 units/litre) and June (80 units/litre) corresponding to the first and second annual cycles respectively. *Cosmarium* was most abundant in August (52 units/litre) of the first annual cycle and June (87 units/litre) in the second annual cycle. *Micrasterias* was maximum in July (310 units/litre) in the first and second annual cycles and September (310 units/litre) respectively. *Staurastrum* had its peak of 1413 units/litre in June of the first annual cycle and July with 1373 units/litre in the second annual cycle.

Euglenophyceae, Xanthophyceae and Chrysophyceae all were represented by only one family and only one genus each, Euglenaceae *Phacus*, Xanthophyceae *Botryococcus* and Ochromonadaceae *Dinobryon* respectively. All these three had the same trend of seasonal fluctuation. *Botryococcus* and

Dinobryon peaks were in July in both the annual cycles representing 857 units and 570 units/litre and 1490 units and 3653 units/litre respectively. *Phacus* had a peak in July (93 units/litre) in the first annual cycle but the peak shifted to September (70 units/litre) in the next annual cycle.

Bacillariophyceae was represented by five families with again one genus each. These were Coscinodiscaceae, Tabellariaceae, Diatomaceae, Fragilariaceae and Navicuaceae representing *Cyclotella*, *Tabellaria*, *Diatoma*, *Synedra* and *Navicula* respectively. These followed a trend in the reverse in that all of them recorded either nil or low values during the summer and autumn months and a peak in winter. *Cyclotella* was most abundant in the month of December with 50 units/litre and January with 50 units/litre in the first and second annual cycle respectively. *Tabellaria* was maximum in February (100 units/litre) in the first and in December (65 units/litre) in the second annual cycles. *Diatoma*, in February showed 80 units/litre and November with 63 units/litre indicated peaks in the first annual cycle but were absent during the second annual cycle. *Synedra* recorded maximum in January (150 units/litre), of first annual cycle and 45 units/litre in November in the second annual cycle. The genus *Navicula* had shown its peak in January (130 units/litre) and December (200 units/litre) in the first and second annual cycles respectively.

Peridiniacea and Ceratiaceae and their genera *Peridinium* and *Ceratium* respectively represented class Dinophyceae. *Peridium* recorded a spring maxima and an autumn and winter minima, while *Ceratium* followed a summer maxima and winter minima in both the annual cycles. *Peridinium* was observed to have its peaks in May (704 units/litre) in the first and in April (1058 units/litre) in the second annual cycle. *Ceratium* peak was in June (347 units/litre) and July (893 units/litre) during the first and second annual cycles respectively.

Myxophyceae was represented by the families Chroococcaceae and Oscillatoriaceae. The latter had only one genus *Oscillatoria* while the former comprised of 5 genera-*Coelosphaerium*, *Microcystis*, *Gloeocapsa*, *Merismopedia* and *Anacystis*. *Coelosphaerium* peak was in May (240 units/litre) and in February (64 units/litre) in the first and second annual cycles. In the second annual cycle it disappeared from April and was nil in February, March, September, October and November of the first annual cycle. *Microcystis* was present except in the months of February, December and January in the first and February and March in the second annual cycle. The peaks in the first annual cycle was seen in the month of June (13363 units/litre) and July 73093 units/litre) in the second. *Gloeocapsa* was maximum in July (457 units/litre) and June (423 units/litre) in the first and second annual cycles respectively. The peak, for *Merismopedia* was in May (82 units and 167 units/litre) in both the annual cycles and nil in February, August, September, October, November, December and January of the first annual cycle and August onwards in the second annual cycle. *Oscillatoria* was encountered from April to September in the first annual cycle and from May to November in the second annual cycle with peaks in the months of July (157 units/litre) and August (100 units/litre) in the first and second annual cycles respectively (Table-IV a, b).

Chlorophyceae was represented by ten families Volvocaceae, Palmellaceae, Ulotricaceae, Dictyosphaeriaceae, Hydrodictyaceae, Coelastraceae, Oocystaceae, Scenedesmaceae, Zygnemataceae and Desmidiaceae. In all these families except the family Scenedesmaceae a clear rise in population forming a peak in summer and a decline in winter was observed during both the annual cycles. The single peak was in June-July in all these families while Volvocaceae during the first annual cycle revealed a peak during the month of April before the second peak in July. Desmidiaceae had a spring maxima in March-April during the two annual cycles and a peak during the second annual cycle in December and January. As a class Chlorophyceae had the usual summer maxima and winter minima. Yet this class as a percentage of total phytoplankton represented the lowest percentages but in September and October of the first annual cycle and December and January during the second annual cycle formed the largest percentage. Euglenophyceae, Xanthophyceae and Chrysophyceae all had only one family each, Euglenaceae, Xanthophyceae and Ochromonadaceae respectively. All these had the usual summer maxima and winter minima. However, there was a shift in Euglenophyceae which recorded maximum in November during second annual cycle when the actual counts were less. Xanthophyceae similarly recorded a maximum percentage in October during the first annual cycle and March during the second when the actual numbers were far less. A very significant trend was seen in Chrysophyceae in that the peak numbers actually were the lowest percentages of total phytoplankton while the lowest numbers in February in the first annual cycle and December in the second annual cycle recorded maximum percentages of the total phytoplankton to 55% in the former and 37% in the latter.

Bacillariophyceae represented by five families, Coscinodiscaceae, Tabellariaceae, Diatomaceae, Fragillariaceae and Naviculaceae, which had winter maxima and summer minima. Bacillariophyceae as a percentage of phytoplankton, was similar to that of their actual numbers.

Dinophyceae with families Peridiniaceae and Ceratiaceae had the usual summer maxima and winter minima except that Peridiniaceae in the second annual cycle revealed a spring maxima. This trend was also seen in Dinophyceae for the actual numbers. As percentage of the total phytoplankton Dinophyceae more or less followed the actual numbers except that the peaks started one month earlier than for the actual numbers.

Myxophyceae was represented by families Chroococcaceae and Oscillatoriaceae. The trend for both the families and the class was the usual summer maxima and winter minima. The percentages of Myxophyceae as of total phytoplankton also followed a similar trend of that of seasonal fluctuation (Table-Va,b Fig. 11)

The total phytoplankton was not affected by Bacillariophyceae or Scenedesmaceae and followed the majority in having a summer maxima and winter minima during both the annual cycles at this station (Table-IVa,b).

Table-IV a: The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the first annual cycle in Station B.

Table IVa

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Eudorina</i>	0	0	0	0	3	37	34	0	0	0	0	0
2 <i>Pandorina</i>	0	15	145	36	27	100	28	0	3	50	8	0
3 <i>Gloeocystis</i>	0	0	0	0	37	27	24	0	0	0	0	0
4 <i>Hormidium</i>	0	0	0	8	43	43	18	0	7	0	0	0
5 <i>Ulothrix</i>	0	0	0	0	0	60	20	0	0	0	0	0
6 <i>dictyosphaerium</i>	0	0	0	0	4	53	70	0	0	0	0	0
7 <i>Pediastrum</i>	0	0	150	128	67	170	46	40	3	0	0	0
8 <i>Coelastrum</i>	0	0	48	284	560	623	318	205	153	23	0	0
9 <i>ankistrodesmus</i>	0	0	23	12	30	10	0	0	0	0	0	0
10 <i>Kirchneriella</i>	0	0	0	50	83	53	36	0	0	0	0	0
11 <i>Westella</i>	50	25	75	34	220	413	188	0	7	0	0	0
12 <i>Scenedesmus</i>	160	148	228	128	23	10	18	0	30	53	20	77
13 <i>Spirogyra</i>	0	0	8	36	13	47	10	0	0	0	0	0
14 <i>Cosmarium</i>	0	0	8	54	40	30	52	15	3	0	0	0
15 <i>Desmidium</i>	0	8	13	15	187	47	12	0	0	0	0	0
16 <i>Micrasterias</i>	40	8	8	26	73	310	228	0	3	3	8	7
17 <i>Staurastrum</i>	0	193	320	748	1413	1220	1150	700	323	60	33	0
18 <i>Phacus</i>	0	0	0	0	80	93	34	0	0	0	0	0
19 <i>Botryococcus</i>	0	45	75	186	470	857	384	190	123	23	0	0
20 <i>Dinobryon</i>	780	803	1105	1472	1420	1490	1090	950	530	253	165	147
21 <i>Cyclotella</i>	10	38	25	2	0	0	0	5	23	30	50	3
22 <i>Tabellaria</i>	100	40	30	0	0	0	0	0	0	0	0	0
23 <i>Diatoma</i>	80	48	15	0	0	0	8	0	10	63	3	3
24 <i>Synedra</i>	10	15	10	0	0	0	0	0	30	90	55	150
25 <i>Navicula</i>	60	110	30	86	70	70	22	35	63	83	125	130
26 <i>Peridinium</i>	140	133	535	704	427	27	48	0	40	17	15	7
27 <i>Ceratium</i>	0	68	105	294	347	97	8	5	60	40	15	63
28 <i>Coelosphaerium</i>	0	0	58	240	47	70	4	0	0	0	18	40
29 <i>Microcystis</i>	0	130	530	4688	13363	11178	2316	120	7	17	0	0
30 <i>Gloeocapsa</i>	0	0	5	50	223	457	392	120	17	13	58	13
31 <i>Merismopedia</i>	0	25	25	82	33	13	0	0	0	0	0	0
32 <i>Anacystis</i>	0	13	58	78	37	13	0	0	0	0	0	0
33 <i>Oscillatoria</i>	0	0	8	56	93	157	14	15	0	0	0	0
Total	1430	1865	3640	9497	19433	17775	6572	2400	1435	818	573	640

Table IVb

Table-IVb : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the second annual cycle in Station B.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Eudorina</i>	0	0	10	23	40	7	0	0	0	0	0	0
2 <i>Pandorina</i>	0	10	35	67	63	127	210	40	10	25	0	5
3 <i>Gloeocystis</i>	0	0	0	0	53	47	15	85	10	35	0	0
4 <i>Hormidium</i>	0	0	0	20	107	447	200	75	30	20	0	0
5 <i>Ulothrix</i>	0	0	0	3	13	27	0	0	0	0	0	0
6 <i>dictyosphaerium</i>	0	0	25	3	47	23	0	0	0	0	0	0
7 <i>Pediastrum</i>	0	0	10	23	107	143	180	80	15	5	0	0
8 <i>Coelastrum</i>	0	18	60	220	480	490	415	220	60	35	0	0
9 <i>ankistrodesmus</i>	0	0	40	33	0	0	0	0	0	0	0	0
10 <i>Kirchneriella</i>	0	0	0	7	143	193	75	5	0	0	0	0
11 <i>Westella</i>	0	10	65	57	277	343	215	70	5	0	0	0
12 <i>Scenedesmus</i>	140	320	165	50	23	0	5	5	10	100	370	350
13 <i>Spirogyra</i>	0	0	0	3	80	53	50	10	5	40	0	0
14 <i>Cosmarium</i>	0	0	23	7	87	83	30	70	55	25	0	0
15 <i>Desmidium</i>	0	0	0	13	160	123	30	40	0	0	0	0
16 <i>Micrasterias</i>	8	63	53	43	53	70	300	310	110	0	0	0
17 <i>Staurastrum</i>	0	0	55	317	1283	1373	1175	810	480	445	115	0
18 <i>Phacus</i>	0	0	0	0	0	17	15	70	5	50	5	0
19 <i>Botryococcus</i>	0	125	145	107	430	570	375	225	185	40	0	0
20 <i>Dinobryon</i>	102	310	403	907	1080	3653	1095	870	1155	510	510	160
21 <i>Cyclotella</i>	0	5	0	0	0	0	0	0	5	10	30	50
22 <i>Tabellaria</i>	32	48	15	0	0	0	0	0	35	30	65	30
23 <i>Diatoma</i>	10	0	0	0	0	0	0	0	0	0	0	0
24 <i>Synedra</i>	10	0	0	0	0	0	0	0	35	45	10	0
25 <i>Navicula</i>	112	48	70	50	20	0	75	100	160	135	200	140
26 <i>Peridinium</i>	100	638	1058	623	130	80	0	0	5	0	10	0
27 <i>Ceratium</i>	26	18	208	260	600	893	16	50	0	0	0	0
28 <i>Coelosphaerium</i>	64	0	10	0	0	0	0	0	0	0	0	0
29 <i>Microcystis</i>	0	0	40	903	8643	73093	31950	17930	5120	930	70	40
30 <i>Gloeocapsa</i>	8	18	55	247	423	377	270	40	15	30	0	0
31 <i>Merismopedia</i>	4	35	83	167	83	7	0	0	0	0	0	0
32 <i>Anacystis</i>	0	3	5	13	43	103	130	110	10	20	0	0
33 <i>Oscillatoria</i>	0	0	0	17	23	87	100	40	40	25	0	0
Total	612	1669	2643	4183	14491	82429	37026	21255	7560	2555	1385	775

Table-Va : Seasonal abundance of the classes and the families of phytoplankton at Station B.*first annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i> (Cl.)	250	397	1026	1563	2872	3270	2182	960	530	189	69	84
2 <i>Volvocaceae</i>	0	15	145	36	30	137	62	0	3	50	8	0
3 <i>Palmellaceae</i>	0	0	0	0	37	27	24	0	0	0	0	0
4 <i>Ulotricaceae</i>	0	0	0	8	43	103	38	0	7	0	0	0
5 <i>Dictyosphaeriaceae</i>	0	0	0	4	53	70	0	0	0	0	0	0
6 <i>Hydrodictyaceae</i>	0	0	150	128	67	170	46	40	3	0	0	0
7 <i>Coelasteraceae</i>	0	0	48	284	560	623	318	205	153	23	0	0
8 <i>Oocystraceae</i>	50	25	98	96	333	476	224	0	7	0	0	0
9 <i>Scenedesmaceae</i>	160	148	228	128	23	10	18	0	30	53	20	77
10 <i>Zygnemataceae</i>	0	0	8	36	13	47	10	0	0	0	0	0
11 <i>Desmidiaceae</i>	40	209	349	843	1713	1607	1442	715	329	63	41	7
12 <i>Euglenophyceae</i> (Cl.)	0	0	0	0	80	93	34	0	0	0	0	0
<i>Euglenaceae</i>												
13 <i>Xanthophyceae</i> (Cl.)	0	45	75	186	470	857	384	190	123	23	0	0
14 <i>Chrysophyceae</i> (Cl.)	780	803	1105	1472	1420	1490	1090	950	530	253	165	147
<i>(Ochromonadaceae)</i>												
15 <i>Bacillariophyceae</i> (Cl.)	260	251	110	88	70	70	30	40	126	266	233	286
16 <i>Coscinodiscaceae</i>	10	38	25	2	0	0	0	5	23	30	50	3
17 <i>Tabellariaceae</i>	100	40	30	0	0	0	0	0	0	0	0	0
18 <i>Diatomaceae</i>	80	48	15	0	0	0	8	0	10	63	3	3
19 <i>Fragillariaceae</i>	10	15	10	0	0	0	0	0	30	90	55	150
20 <i>Naviculaceae</i>	60	110	30	86	70	70	22	35	63	83	125	130
21 <i>Dinophyceae</i> (Cl.)	140	201	640	998	774	124	56	5	100	57	30	70
22 <i>Peridiniaceae</i>	140	133	535	704	427	27	48	0	40	17	15	7
23 <i>Ceratiaceae</i>	0	68	105	294	347	97	8	5	60	40	15	63
24 <i>Myxophyceae</i> (Cl.)	0	168	684	5194	13796	11888	2726	255	24	30	76	53
25 <i>Chroococcaceae</i>	0	168	676	5138	13703	11731	2712	240	24	30	76	53
26 <i>Oscillatoriaceae</i>	0	0	8	56	93	157	14	15	0	0	0	0

Table Va
First annual cycle

Table-Vb: Seasonal abundance of the classes and the families of phytoplankton at Station B.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i> (Cl.)	148	421	551	889	3016	3549	2900	1820	790	730	485	355
2 <i>Volvocaceae</i>	0	10	45	90	103	134	210	40	10	25	0	5
3 <i>Palmellaceae</i>	0	0	0	0	53	47	15	85	10	35	0	0
4 <i>Ulotricaceae</i>	0	0	0	23	120	474	200	75	30	20	0	0
5 <i>Dictyosphaeriaceae</i>	0	0	35	3	47	23	0	0	0	0	0	0
6 <i>Hydrodictyaceae</i>	0	0	10	23	107	143	180	80	15	5	0	0
7 <i>Coelasteraceae</i>	0	18	60	220	480	490	415	220	60	35	0	0
8 <i>Oocystaceae</i>	0	10	105	97	420	536	290	75	5	0	0	0
9 <i>Scenedesmaceae</i>	140	320	165	50	23	0	5	5	10	100	370	350
10 <i>Zygnemataceae</i>	0	0	0	3	80	53	50	10	5	40	0	0
11 <i>Desmidiaceae</i>	8	63	131	380	1583	1649	1535	1230	645	470	115	0
12 <i>Euglenophyceae</i> (Cl.)	0	0	0	0	0	17	15	70	5	50	5	0
<i>Euglenaceae</i>												
13 <i>Xanthophyceae</i> (Cl.)	0	125	145	107	430	570	375	225	185	40	0	0
14 <i>Chrysophyceae</i> (Cl.)	102	310	403	907	1080	3653	1095	870	1155	510	510	160
<i>(Ochromonadaceae)</i>												
15 <i>Bacillariophyceae</i> (Cl.)	164	101	85	50	20	0	75	100	235	220	305	220
16 <i>Coscinodiscaceae</i>	0	5	0	0	0	0	0	0	5	10	30	50
17 <i>Tabellariaceae</i>	32	48	15	0	0	0	0	0	35	30	65	30
18 <i>Diatomaceae</i>	10	0	0	0	0	0	0	0	0	0	0	0
19 <i>Fragillariaceae</i>	10	0	0	0	0	0	0	0	35	45	10	0
20 <i>Naviculaceae</i>	112	48	70	50	20	0	75	100	160	135	200	140
21 <i>Dinophyceae</i> (Cl.)	126	656	1266	883	730	973	16	50	5	0	10	0
22 <i>Peridiniaceae</i>	100	638	1058	623	130	80	0	0	5	0	10	0
23 <i>Ceratiaceae</i>	26	18	208	260	600	893	16	50	0	0	0	0
24 <i>Myxophyceae</i> (Cl.)	72	56	193	1347	9215	73667	32550	18120	5185	1005	70	40
25 <i>Chroococcaceae</i>	72	56	193	1330	9192	73580	32450	18080	5145	980	70	40
26 <i>Oscillatoriaceae</i>	0	0	0	17	23	87	100	40	40	25	0	0

Table Vb
Second annual cycle

The third station C was represented of all the classes except Euglenophyceae. The major groups however were found under the Class Chlorophyceae. The genera *Eudorina*, *Pandorina* and *Gonium* under Volvocaceae revealed the usual summer peaks and a disappearance in winter during both the annual cycles. This phenomena was also seen for *Hormidium* and *Ulothrix* of the family Ulotricaceae. The genus *Eudorina* showed peaks in July (80 units/Litre) and in April (38 units/litre) in the first and second annual cycles respectively. *Pandorina* was maximum in June (133 units/litre) and in July (113 units/litre) during the first and second annual cycles. *Gonium* revealed its first peak in May (24 units/litre) during first annual cycle and in July (37 units/litre) in the second annual cycle. The maximum number of *Hormidium* was in June and July (40 units/litre) in the first annual cycle and in July (157 units/litre) during the second annual cycle. *Ulothrix* had its peak in July (63 units/litre) of the first and May (57 units/litre) during the second annual cycle. *Dictyosphaerium* of the family Dictyosphaeriaceae though disappeared totally in winter, showed summer maxima in July (73 units/litre) for the second annual cycle and peak in August (26 units/litre) and September (20 units/litre) during the first annual cycle. *Pediastrum* and *Coelastrum* of the families Hydrodictyaceae and Coelastraceae respectively revealed the usual summer maxima in the former during the month of June and autumn maxima in the latter in the month of September during both the annual cycles. However, both recorded nil during winter. *Pediastrum* had its peak in the month of June in both the annual cycles revealing 37 units/litre and 113 units/litre respectively, while *Coelastrum* was most abundant in June (107 units/litre) and July (117 units/litre) during the first and second annual cycles respectively.

Oocystaceae was represented by *Ankistrodesmus*, *Kirchneriella*, *Selenastrum* and *Westella*. All had peaks in summer and a total disappearance in the winter. *Ankistrodesmus* had its peaks in June (37 units/litre) in the first annual cycle and April and July (23 units/litre) in the next annual cycle. The maximum for *Kirchneriella* was recorded in July (247 units/litre) and June (233 units/litre) in the first and second annual cycles while *Selenastrum* showed its peak in the month of July (90 units/litre and 50 units/litre) in the both annual cycles. *Westella* was most abundant in the month of June (1220 units/litre and 1217 units/litre) during both the annual cycles. *Scenedesmus* was the only representative of the family Scenedesmaceae and revealed a winter maxima and a summer minima as usual. February and December had maximum counts (100 units and 142 units/litre) in the first annual cycle and February (208 units/litre) and December and January (180 units/litre) in the second annual cycle. Class Chlorophyceae had the family Desmidiaceae and the genera *Cosmarium*, *Gymnozyga*, *Micrasterias* and *Staurastrum* represented. All of them revealed the usual summer maxima and winter minima with the peaks slightly shifted in the second annual cycle. The peak in the first annual cycle in the above order of sequence were in the months of July (53 units/litre), July (33 units/litre), July (117 units/litre) and July (1013 units/litre) while in the next annual cycle the month of September (40 units/litre), May (20 units/litre), June (330 units/litre) and August (1345 units/litre) respectively.

Xanthophyceae was represented by its families Gleobotrydiaceae and Xanthophyceae with a single genus each *Gleobotrys* and *Botryococcus* respectively. The usual summer maxima and winter minima was observed with peaks either in July or August during both the annual cycles. However, both these genera recorded nil in winter. In the first annual cycle *Gleobotrys* and *Botryococcus* had a peak in August and July amounting to 2086 units/litre and 187 units/litre respectively while peaks were observed July with their corresponding counts amounting to 4247 units/litre and 310 units/litre respectively in the second annual cycle.

Chrysophyceae had two representatives *Synura* and *Dinobryon* of the family Synuraceae and Ochromonadaceae respectively. *Synura* had a peak as soon as it was recorded in the early month of May and fell considerably in the next month to again rise in July though not to original levels. These were the only three months that they were recorded during both the annual cycles and absent during the rest of the investigation period. *Dinobryon* followed a usual pattern of summer peak and disappearance in winter. *Synura* showed a maximum record of 36 units/litre and 30 units/litre in the first and second annual cycles in May. *Dinobryon* had a peak in June (980 units/litre) during the first and in July (810 units/litre) in the second annual cycle.

Bacillariophyceae was represented by *Tabellaria*, *Meridion*, *Navicula*, *Nitzschi* and *Cymbella* of the families Tabellariaceae, Maridionaceae, Naviculaceae, Nitzschiaceae and Cykbellaceae respectively. Except for *Meridion* which occurred only during four months of first annual cycle throughout the study period and recorded a July peak, all the others had a winter maxima with a total disappearance in summer. *Cymbella* during the second annual cycle was recorded only twice during February and March and thereafter disappeared completely. *Tabellaria* had its peak in March (33 units/litre) and December (35 units/litre); *Navicula* in February (160 units/litre) and January (150 units/litre); *Nitzschia* in October (58 units/litre) and November (65 units/litre) during the first and second annual cycles respectively. *Meridion* and *Cymbella* was found maximum in July (37 units/litre) and February (40 units/litre) of the first annual cycle only and were absent in the second annual cycle.

Peridinium and *Ceratium* of the families Peridiniaceae and Ceratiaceae respectively were the ones recorded under the class Dinophyceae at this station. Both these genera during the two annual cycles revealed the spring/summer maxima and winter minima. The month of May with 142 units/litre and June with 380 units/litre have the peak for *Peridinium* and *Ceratium* respectively in the first annual cycle and both of them had peaks in the month of May (187 units/litre and 390 units/litre) in the second annual cycle.

Myxophyceae was represented by two families Chroococcaceae and Oscillatoriaceae, the former with genera *Coelosphaerium*, *Microscystis* and *Merismopedia* while the latter with *Oscillatoria* and *Spirulina*. All the genera under the family Chroococaceae revealed peaks in summer and a total disappearance in winter which was also true for the genus *Spirulina*. However, *Oscillatoria* was recorded twice during the entire study period during March and April of the second annual cycle with the latter month recording the highest. *Coelosphaerium*, *Microscystis*, *Merismopedia* and *Spirulina* had their peaks in the July, June, and September with 127 units/litre, 6107 units/litre, 83 units/litre and 63 units/litre respectively. *Oscillatoria* was maximum in April of the second annual cycle with 50 units/litre (Table-VIa, b).

Chlorophyceae as usual dominated with eight families- Volvocaceae, Ulotricaceae, Dictyosphaeriaceae, Hydrodictyaceae, Coelasteraceae, Oocystaceae, Scenedesmaceae and Desmidiaceae. All these families except Scenedesmaceae revealed the usual seasonal trend of a summer maxima and winter minima. In contrast Scenedesmaceae had winter maxima and a summer minima. As a class Chlorophyceae however was not affected by Scenedesmaceae and revealed the steady increase till the summer peak and a slow steady decrease subsequently, true for both the annual cycles. When Chlorophyceae was seen as a percentage of the total phytoplankton, maximal percentage was during the winter months when the actual numbers were less.

Table-VIa : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the first annual cycle in Station C.

Table VIa

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Eudorina</i>	0	0	3	24	77	80	16	0	0	0	0	0
2 <i>Pandorina</i>	0	3	4	62	133	87	48	47	3	8	10	0
3 <i>Gonium</i>	0	0	0	24	23	3	4	0	0	0	0	0
4 <i>Hormidium</i>	0	0	0	22	40	40	18	0	0	0	0	0
5 <i>Ulothrix</i>	0	0	0	44	63	0	0	0	0	0	0	0
6 <i>Dictyosphaerium</i>	0	0	0	0	7	7	26	20	0	0	0	0
7 <i>Pediastrum</i>	0	0	0	4	37	33	30	0	0	0	0	0
8 <i>Coelastrum</i>	0	0	3	22	107	40	18	113	63	0	0	0
9 <i>Ankistrodesmus</i>	0	0	0	6	37	20	6	0	0	0	0	0
10 <i>Kirchneriella</i>	0	0	0	6	60	247	74	3	0	0	0	0
11 <i>Selenastrum</i>	0	0	0	16	17	90	26	0	0	0	0	0
12 <i>Westella</i>	0	0	0	248	1220	673	86	0	0	0	0	0
13 <i>Scenedesmus</i>	100	128	43	36	30	63	22	20	20	43	142	177
14 <i>Cosmarium</i>	0	0	0	12	30	53	6	13	0	0	0	0
15 <i>Gymnozyga</i>	0	0	0	0	10	33	28	0	0	0	0	0
16 <i>Micrasterias</i>	10	3	13	42	67	117	92	103	83	20	2	7
17 <i>Staurastrum</i>	0	128	255	298	560	1013	490	343	178	90	22	0
18 <i>Gloeobatrachys</i>	0	0	0	0	40	750	2086	193	15	0	0	0
19 <i>Botryococcus</i>	0	35	50	78	77	187	166	73	0	0	0	7
20 <i>Synura</i>	0	0	0	36	10	20	0	0	0	0	0	0
21 <i>Dinobryon</i>	230	338	635	870	980	730	420	87	10	0	0	13
22 <i>Tabellaria</i>	10	33	15	0	0	0	0	0	0	20	20	0
23 <i>Meridion</i>	0	0	0	16	27	37	12	0	0	0	0	0
24 <i>Navicula</i>	160	110	15	8	0	0	2	0	18	30	100	47
25 <i>Nitzschia</i>	10	25	0	0	0	0	8	3	58	10	26	46
26 <i>Cymbella</i>	40	23	0	0	0	0	0	0	0	8	28	13
27 <i>Peridinium</i>	0	88	108	142	20	13	20	0	13	0	0	0
28 <i>Ceratium</i>	0	35	65	188	380	167	56	0	0	0	0	0
29 <i>Coelosphaerium</i>	0	0	15	42	107	127	44	0	0	0	0	0
30 <i>Microcystis</i>	0	10	595	1150	6107	3730	1364	653	55	0	0	0
31 <i>Merismopedia</i>	0	0	0	12	83	13	54	70	43	0	0	0
32 <i>Oscillatoria</i>	0	0	0	0	0	0	0	0	0	0	0	0
33 <i>Spirulina</i>	0	0	0	0	20	30	16	63	30	3	4	0
Total	560	959	1816	3408	10369	8456	5232	1804	589	232	354	310

Table - VIb

Table-VIb : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the second annual cycle in Station C.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Eudorina</i>	0	3	38	17	20	30	25	0	0	0	0	0
2 <i>Pandorina</i>	0	5	33	77	80	113	60	30	0	35	15	0
3 <i>Gonium</i>	0	0	0	0	33	37	5	0	0	0	0	0
4 <i>Hormidium</i>	0	0	0	30	110	157	75	0	0	0	0	0
5 <i>Ulothrix</i>	0	0	15	57	10	27	5	0	0	0	0	0
6 <i>Dictyosphaerium</i>	0	0	0	3	7	73	30	0	0	0	0	0
7 <i>Pediastrum</i>	0	0	15	63	113	60	0	0	0	0	0	0
8 <i>Coelastrum</i>	0	0	0	3	27	117	150	40	20	0	0	0
9 <i>Ankistrodesmus</i>	8	0	23	3	10	23	10	0	0	0	0	0
10 <i>Kirchneriella</i>	0	0	0	17	233	173	115	40	0	0	0	0
11 <i>Selenastrum</i>	0	0	3	13	50	30	5	0	0	0	0	0
12 <i>Westella</i>	0	15	185	630	1217	857	765	100	0	0	0	0
13 <i>Scenedesmus</i>	208	90	40	17	0	20	0	70	45	160	180	180
14 <i>Cosmarium</i>	0	23	28	30	0	20	35	40	0	0	0	0
15 <i>Gymnozyga</i>	0	0	0	20	3	0	0	0	0	0	0	0
16 <i>Micrasterias</i>	0	23	98	23	330	310	185	10	0	0	0	0
17 <i>Staurastrum</i>	0	0	43	147	390	1253	1345	550	365	175	30	0
18 <i>Gloeobatrax</i>	10	15	23	187	1077	4247	335	10	0	0	0	0
19 <i>Botryococcus</i>	22	90	105	160	170	310	175	85	90	0	0	0
20 <i>Synura</i>	0	0	30	7	17	0	0	0	0	0	0	0
21 <i>Dinobryon</i>	34	298	245	263	703	810	640	435	165	0	0	0
22 <i>Tabellaria</i>	0	0	0	0	0	0	0	0	5	10	35	5
23 <i>Meridion</i>	0	0	0	0	0	0	0	0	0	0	0	0
24 <i>Navicula</i>	96	23	30	3	0	3	0	0	90	120	90	150
25 <i>Nitzschia</i>	0	0	0	0	0	0	45	15	0	65	70	20
26 <i>Cymbella</i>	8	20	0	0	0	0	0	0	0	0	0	0
27 <i>Peridinium</i>	12	63	183	187	37	3	0	0	0	0	0	0
28 <i>Ceratium</i>	0	65	178	390	100	17	0	0	0	0	0	0
29 <i>Coelosphaerium</i>	0	28	60	63	83	257	100	0	0	0	0	0
30 <i>Microcystis</i>	0	213	195	283	793	3520	1020	335	130	40	0	0
31 <i>Merismopedia</i>	0	0	0	0	97	97	50	60	20	20	0	0
32 <i>Oscillatoria</i>	0	8	15	0	0	0	0	0	0	0	0	0
33 <i>Spirulina</i>	8	3	0	0	0	7	50	15	40	5	0	0
Total	406	985	1570	2693	5620	12571	5225	1835	950	630	420	355

Xanthophyceae was represented by Gloeobotrydiaceae and Xanthophyceae. Both families and class showed the usual summer maxima and winter minima and this was also similar for the percentages.

Synuraceae and Ochromonadaceae came under the class Chrysophyceae. Again the families and the class revealed the usual summer maxima and winter minima but when the percentages of Chrysophyceae of the total phytoplankton was seen, the values of minimal numbers showed maximum percentages.

Bacillariophyceae had families Tabellariaceae, Naviculaceae, Nitzschiaceae, Cymbellaceae and Meridionaceae as its representatives. In all except the family Meridionaceae, the peaks were during winter months and an absence in the summer months. This was also true for the percentages of Bacillariophyceae of the total phytoplankton. Meridionaceae however was recorded only four times during the months of May to August with a peak in July and totally absent during the remaining study period.

Dinophyceae was represented by families Peridiniaceae and Ceratiaceae. The usual summer peak and disappearance in winter was the seasonal trend of fluctuation for both the families and class. However, Dinophyceae and its percentage peak as that of the total phytoplankton was shifted to one month earlier.

Myxophyceae was represented by families Chroococcaceae and Oscillatoriaceae. Chroococcaceae and the class Myxophyceae revealed the trend of summer maxima and winter minima, while the family Oscillatoriaceae though possessed the usual winter minima yet its peak was in the early autumn month of August. The percentage of Myxophyceae followed a trend to that of its actual numbers (Table-VIIa,b: Fig. 11).

When the total phytoplankton was computed for its seasonal abundance, it was in concordance with the majority of the remaining groups with summer maxima and winter minima (Table-VI a, b).

The next station was Station D. Under Chlorophyceae the genera were *Pandorina* of the family Volvocaceae, *Gloeocystis* of the family Palmellaceae, *Dictyosphaerium* of the family Dictyosphaeriaceae, *Pediastrum* of the family Hydrodictyaceae, *Coelastrum* of the family Coelastraceae, *Ankistrodesmus*, *Closteriopsis*, *Kirchneriella* and *Oocystis* – all of the family Oocystaceae, *Scenedesmus* of Scenedesmaceae and *Cosmarium*, *Gymnozyga*, *Micrasterias* and *Staurastrum*, all under the family Desmidiaceae. All these genera, except *Scenedesmus* revealed the usual trend of summer maxima and winter minima. *Scenedesmus* however showed peaks in the winter months with very low numbers of disappearance in summer. *Pandorina*, *Closteriopsis* and *Micrasterias* had peaks in May in the first annual cycle when their corresponding counts were 48 units/litre, 22 units/litre and 78 units/litre respectively. The genera with peaks in June of the first annual cycle were *Gloeocystis* (80 units/litre), *Dictyosphaerium* (20 units/litre), *Coelastrum* (410 units/litre), *Ankistrodesmus* (47 units/litre) and *Cosmarium* (77 units/litre). The genera which had peaks in the month of July of the first annual cycle were *Pediastrum* (127 units/litre), *Kirchneriella* (180 units/litre), *Oocystis* (40 units/litre), *Gymnozyga* (77 units/litre) and *Staurastrum* (9863 units/litre). In the second annual cycle, the genera showing maximum peaks of abundance in the month of April were *Cosmarium* (180 units/litre) and *Gymnozyga* (18 units/litre). In the month of May, *Pandorina* (70 units/litre), *Coelastrum* (230 units/litre) and *Closteriopsis* (50 units/litre) showed their peaks. *Gloeocystis* and *Pediastrum* had peaks in the month June with their respective counts of 180 units/litre and 303 units/litre. *Kirchneriella*, *Oocystis*, *Micrasterias* and *Staurastrum* had their peaks in July amounting to 223 units/litre, 50 units/litre, 47 units/litre and 11667 units/litre respectively. *Dictyosphaerium* and *Ankistrodesmus* were absent during most of the second annual cycle. *Scenedesmus* had peaks in February (440 units/litre) and in April (200 units/litre) during the first and second annual cycle respectively.

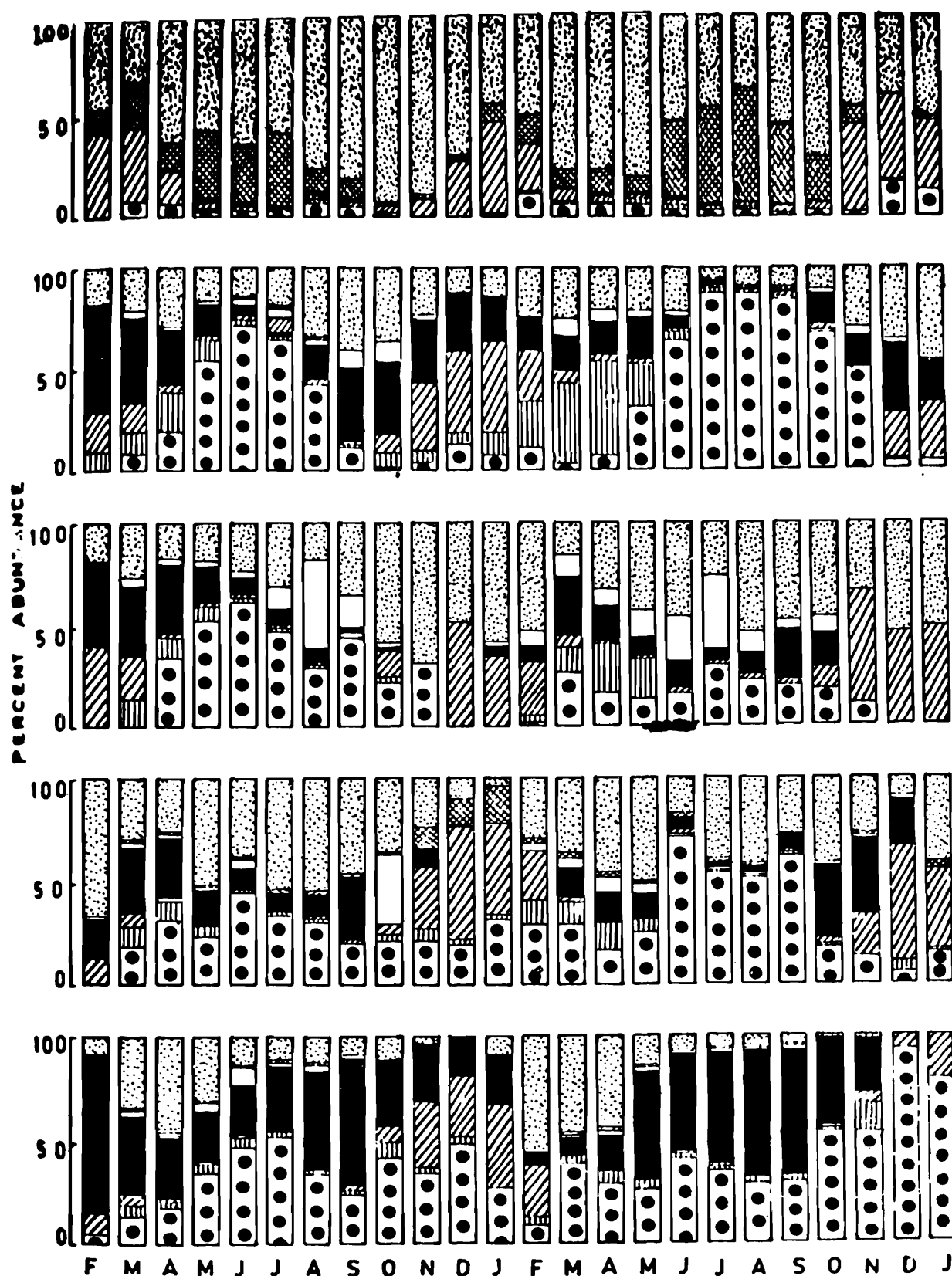


Fig. 11 : Showing histograms representing the seasonality of the relative of the relative percent abundance of the major phytoplanktonic groups at the surface waters of the Stations A, B, C, D and E

Chlorophyceae; Euglenophyceae; Xanthophyceae; Chrysophyceae;
 Bacillariophyceae; Dinophyceae; Myxophyceae.

Table-VIIa : Seasonal abundance of the classes and the families of phytoplankton at Station C.

First annual cycle

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Déc	Jan
1 <i>Chlorophyceae</i>	110	262	318	866	2518	2652	964	662	347	161	176	184
2 <i>Volvocaceae</i>	0	3	7	110	233	170	68	47	3	8	10	0
3 <i>Ulotricaceae</i>	0	0	0	66	103	40	18	0	0	0	0	0
4 <i>Dictyosphaeriaceae</i>	0	0	0	0	7	7	26	20	0	0	0	0
5 <i>Hydrodictyceae</i>	0	0	0	4	37	33	30	0	0	0	0	0
6 <i>Coelastraceae</i>	0	0	3	22	107	40	18	113	63	0	0	0
7 <i>Oocystaceae</i>	0	0	0	275	1334	1030	192	3	0	0	0	0
8 <i>Scenadesmaceae</i>	100	128	43	36	30	63	22	20	20	43	142	177
9 <i>Desmidiaceae</i>	10	131	268	352	667	1269	590	459	261	110	24	7
10 <i>Xanthophyceae</i>	0	35	50	78	117	937	2262	266	15	0	0	7
11 <i>Gloeobotrydiaceae</i>	0	0	0	0	40	750	2086	193	15	0	0	0
12 <i>Xanthophyceae</i>	0	35	50	78	77	187	166	73	0	0	0	7
13 <i>Chrysophyceae</i>	230	338	635	906	990	750	420	87	10	0	0	13
14 <i>Synuraceae</i>	0	0	0	36	10	20	0	0	0	0	0	0
15 <i>Ochromonadaceae</i>	230	338	635	870	980	730	420	87	10	0	0	3
16 <i>Bacillariophyceae</i>	220	191	30	24	27	37	22	3	76	68	174	106
17 <i>Tabellariaceae</i>	10	33	15	0	0	0	0	0	0	20	20	0
18 <i>Naviculaceae</i>	160	110	15	8	0	0	2	0	18	30	100	47
19 <i>Nitzschiaceae</i>	10	25	0	0	0	0	8	3	58	10	26	46
20 <i>Cymbellaceae</i>	40	23	0	0	0	0	0	0	0	8	28	13
21 <i>Meridionaceae</i>	0	0	0	16	27	37	12	0	0	0	0	0
22 <i>Dinophyceae</i>	0	123	173	330	400	180	86	0	13	0	0	0
23 <i>Peridiniaceae</i>	0	88	108	142	20	13	30	0	13	0	0	0
24 <i>Ceratiaceae</i>	0	35	65	188	380	167	56	0	0	0	0	0
25 <i>Myxophyceae</i>	0	10	610	1204	6317	3900	1478	786	128	3	4	0
26 <i>Chroococcaceae</i>	0	10	610	1204	6297	3870	1462	723	98	0	0	0
27 <i>Oscillatoriaceae</i>	0	0	0	0	20	30	16	63	30	3	4	0

Table VIIa
First annual cycle

Table-VIIb : Seasonal abundance of the classes and the families of phytoplankton at Station C.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i>	216	159	523	1150	2633	3300	2810	880	430	370	225	180
2 <i>Volvocaceae</i>	0	8	71	94	133	180	90	30	0	35	15	0
3 <i>Ulotricaceae</i>	0	0	15	87	120	184	80	0	0	0	0	0
4 <i>Dictyosphaeriaceae</i>	0	0	0	3	7	73	30	0	0	0	0	0
5 <i>Hydrodictyaceae</i>	0	0	15	63	113	60	0	0	0	0	0	0
6 <i>Coelastraceae</i>	0	0	0	3	27	117	150	40	20	0	0	0
7 <i>Oocystaceae</i>	8	15	213	663	1510	1083	895	140	0	0	0	0
8 <i>Scenadesmaceae</i>	208	90	40	17	0	20	0	70	45	160	180	180
9 <i>Desmidiaceae</i>	0	46	169	220	729	1583	1565	600	365	175	30	0
10 <i>Xanthophyceae</i>	32	105	128	347	1247	4557	510	95	90	0	0	0
11 <i>Gloeobotrydiaceae</i>	10	15	23	187	1077	4247	335	10	0	0	0	0
12 <i>Xanthophyceae</i>	22	90	105	160	170	310	175	85	90	0	0	0
13 <i>Chrysophyceae</i>	34	298	275	270	720	810	640	435	165	0	0	0
14 <i>Synuraceae</i>	0	0	30	7	17	0	0	0	0	0	0	0
15 <i>Ochromonadaceae</i>	34	298	245	263	703	810	640	435	165	0	0	0
16 <i>Bacillariophyceae</i>	104	43	13	3	0	3	45	15	95	195	195	175
17 <i>Tabellariaceae</i>	0	0	0	0	0	0	0	0	5	10	35	5
18 <i>Naviculaceae</i>	96	23	13	3	0	3	0	0	90	120	90	150
19 <i>Nitzschiaceae</i>	0	0	0	0	0	0	45	15	0	65	70	20
20 <i>Cymbellaceae</i>	8	20	0	0	0	0	0	0	0	0	0	0
21 <i>Meridionaceae</i>	0	0	0	0	0	0	0	0	0	0	0	0
22 <i>Dinophyceae</i>	12	128	361	577	137	20	0	0	0	0	0	0
23 <i>Peridiniaceae</i>	12	63	183	187	37	3	0	0	0	0	0	0
24 <i>Ceratiaceae</i>	0	65	178	390	100	17	0	0	0	0	0	0
25 <i>Myxophyceae</i>	8	251	270	346	883	3881	1220	410	170	65	0	0
26 <i>Chroococcaceae</i>	0	240	255	346	883	3874	1170	395	130	60	0	0
27 <i>Oscillatoriaceae</i>	8	11	15	0	0	7	50	15	40	5	0	0

Table VIIb
Second annual cycle

Euglenophyceae was represented by family Euglenaceae and genus *Phacus* which followed the usual summer maxima and winter minima trend of seasonal fluctuation. It recorded nil in February and September, but maximum in January (30 units/litre) and May (60 units/litre) in the first and second annual cycles respectively.

A single peak in summer with very low numbers in winter with total disappearance was also seen in Xanthophyceae and Chrysophyceae. The former was represented by *Gloeobotrys* of the family Gloeobotrydiaceae and *Botryococcus* of the family Xanthophyceae while the latter represented by *Synura*, *Tribonema* and *Dinobryon* of the families Synuraceae, Tribonemataceae and Ochromonadaceae respectively. *Gloeobotrys* had its peak in May (48 units/litre) and July (47 units/litre) during the first and second annual cycles respectively. The genera having their summer peaks in the month of June in the first annual cycle were *Botryococcus* (1367 units/litre), *Synura* (80 units/litre), *Tribonema* (43 units/litre) and *Dinobryon* (2450 units/litre) while in the second annual cycle *Botryococcus* in May (270 units/litre), *Gloeobotrys* and *Synura* in July (47 units/litre) and 33 units/litre respectively). *Dinobryon* had a peak in August (1295 units/litre) while *Tribonema* occurred only from April to August of the first annual cycle.

Bacillariophyceae was represented by two families, Tabellariaceae with the genus *Tabellaria* and Naviculaceae with the genus *Navicula*. As usual for this class the winter peaks of abundance and with low or disappearance in summer was also observed seasonally at this station. *Tabellaria* was maximum in January (73 units/litre) and November (115 units/litre) in the first and second annual cycles. *Navicula*'s peak was in December (98 units/litre) in the first annual cycle and in December and January (100 units/litre) of the second annual cycle.

The last two classes were Dinophyceae and Myxophyceae with the genera *Peridinium* and *Ceratium* of the families Peridiniaceae and Ceratiaceae and the family Chroococcaceae with the genera *Coelosphaerium*, *Microcystis*, *Merismopedia* and *Aphanocapsa*. *Peridinium* and *Ceratium* revealing spring peaks of abundance with the usual winter minima whereas *Coelosphaerium*, *Microcystis* and *Aphanocapsa* showed the usual trend of fluctuation with the summer maxima and winter minima while *Merismopedia* had an autumn maxima during the first annual cycle and a winter minima during the second. *Peridinium* was maximum in April (223 units/litre) of the first and April and May (23 units/litre) of the second annual cycle. *Ceratium* had peaks in April and May (180 units/litre) and July (130 units/litre) in the first and second annual cycles respectively. In both the annual cycles *Coelosphaerium* showed its peaks in July (953 units/litre and 14190 units/litre). Similarly *Microcystis* had its peaks in June in both the annual cycles amounting to 11293 units/litre and 10903 units/litre respectively. *Merismopedia* was most abundant in October (100 units/litre) and January (35 units/litre) in the first and second annual cycles respectively. *Aphanocapsa* showed its peaks in June (77 units/litre) and April (120 units/litre) in the first and second annual cycles respectively (Table-VIII a, b).

When the percentage of abundance of the different classes of the total phytoplankton was observed, except for the classes Bacillariophyceae and Myxophyceae which had the same peak values coinciding with their actual numbers, in all the others there was a slight shift. Chlorophyceae and Chrysophyceae

maximal percentages were seen in the autumn months, Euglenophyceae and Xanthophyceae in the winter months and Dinophyceae in the spring months (Table-IXa,b Fig. 11).

The total phytoplankton at this Station D however, followed the usual trend of summer maxima and winter minima throughout the study period true for both the annual cycles (Table-VIIIa, b)

The last station E was also represented by all the major classes as present in the other stations with however different genera and families. Chlorophyceae at this station also was the dominant group of phytoplankton and was represented by *Pandorina*, *Gloeocystis*, *Dictyosphaerium*, *Pediastrum*, *Coelastrum* and *Scenedesmus* of the families Volvocaceae, Palmellaceae, Dictyosphaeriaceae, Hydrodictyaceae, Coelastraceae and Scenedesmaceae respectively. *Ankistrodesmus*, *Kirchneriella*, *Selenastrum* of the family Oocystaceae and *Closterium*, *Cosmarium*, *Micrasterias* and *Staurastrum* of the family Desmidiaceae were also present. All these except *Pandorina*, *Coelastrum* and *Closterium* revealed the usual summer maxima and winter minima in their seasonal trend of fluctuation during both the annual cycles. *Pandorina*, *Coelastrum* and *Closterium* revealed a spring maxima with the winter minima. *Pandorina* and *Staurastrum* showed their peaks simultaneously in the months of May in the first and during April in the second annual cycle respectively recording 50 units/litre and 1310 units/litre respectively for the former months and 73 units/litre and 1835 units/litre respectively for the latter month. *Coelastrum*, *Selenastrum* and *Closterium* had peaks in April recording 263 units/litre, 28 units/litre and 105 units/litre respectively in the first annual cycle. These genera had in May (437 units/litre), August (50 units/litre) and March (63 units/litre) their respective peaks in the second annual cycle. *Pediastrum*, *Scenedesmus*, *Ankistrodesmus* and *Micrasterias* had their peaks in June in the first annual cycle recording 60 units/litre, 183 units/litre, 20 units/litre and 63 units/litre respectively, while in the second annual cycle the peaks were observed in July (173 units/litre), May (383 units/litre), June (20 units/litre) and July (90 units/litre) respectively. In the month of July during the first annual cycle, *Gloeocystis*, *Dictyosphaerium*, *Kirchneriella* and *Cosmarium* showed their peaks of abundance simultaneously amounting to 100 units/litre, 70 units/litre, 90 units/litre and 47 units/litre respectively, but the second annual cycle were peaks in July (127 units/litre), August (95 units/litre), August (90 units/litre) and June (30 units/litre) respectively.

Euglenophyceae and Xanthophyceae were represented by *Phacus* under Euglenaceae in the former and *Gloeobotrys* of the family Gloeobotrydiaceae and *Botryococcus* of Xanthophyceae in the latter. All the genera followed the usual pattern of a summer maxima and winter minima. Chrysophyceae had *Chrysococcus* of the family Chromulinaceae and *Dinobryon* of the family Ochromonadaceae recorded at this station. *Chrysococcus* revealed winter peaks of abundance with summer minima while *Dinobryon* had the usual trend of maximal abundance in summer and minimal or total disappearance in winter. Peaks were in April and July (40 units/litre) of the first annual cycle and May (43 units/litre) in the second. In the first annual cycle *Gloeobotrys* and *Dinobryon* had their peaks in July with 107 units/litre and 3200 units/litre respectively and the former peak in May and July (67 units/litre) while the latter in July (12543 units/litre) of the second annual cycle. *Botryococcus* was most abundant in June (877 units/litre) and in July (750 units/litre) of the first and second annual cycles. The months of November (58 units/litre) and August (30 units/litre) showed the peaks of abundance of *Chrysococcus* in the first and second annual cycles respectively.

Table-VIIIa : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the first annual cycle in Station D.

Table VIIIa

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Eudorina</i>	0	0	5	48	17	0	4	3	5	0	0	0
2 <i>Gloeocystis</i>	0	0	5	40	80	63	14	10	0	0	0	0
3 <i>Dictyosphaerium</i>	0	0	0	4	20	0	0	0	0	0	0	0
4 <i>Pediastrum</i>	0	0	0	6	117	127	68	0	0	0	0	0
5 <i>Coelastrum</i>	0	5	70	404	410	150	22	0	0	0	0	0
6 <i>Ankistrodesmus</i>	0	0	0	8	47	20	0	0	0	0	0	0
7 <i>Closteriopsis</i>	0	0	5	22	13	3	0	0	0	0	0	0
8 <i>Kirchneriella</i>	0	0	55	70	160	180	44	0	3	0	0	0
9 <i>Oocystis</i>	0	0	0	34	30	40	2	0	0	3	0	0
10 <i>Scenedesmus</i>	440	180	78	280	67	3	0	0	0	0	4	0
11 <i>Cosmarium</i>	0	0	8	38	77	67	6	20	10	15	0	7
12 <i>Gymnozyga</i>	0	0	0	8	10	77	4	0	0	0	24	0
13 <i>Micrasterias</i>	0	0	13	78	97	73	20	0	0	0	0	0
14 <i>Staurastrum</i>	80	213	800	3770	8570	9863	4354	1053	368	73	0	0
15 <i>Phacus</i>	0	18	5	16	20	20	4	27	8	28	22	30
16 <i>Gloeobotrys</i>	0	5	10	48	23	10	24	3	0	0	0	0
17 <i>Botryococcus</i>	10	33	138	228	1367	670	150	17	0	13	16	0
18 <i>Synura</i>	0	0	0	6	80	60	16	0	0	0	0	0
19 <i>Tribonema</i>	0	0	20	42	43	13	4	0	0	0	0	0
20 <i>Dinobryon</i>	150	445	1113	1618	2450	1657	886	743	370	35	0	0
21 <i>Tabellaria</i>	50	35	40	4	0	0	0	3	25	70	62	73
22 <i>Navicula</i>	50	30	8	4	0	0	6	33	35	43	98	0
23 <i>Peridinium</i>	0	120	223	178	180	70	2	23	20	25	8	3
24 <i>Ceratium</i>	0	10	180	180	117	40	32	0	0	0	0	0
25 <i>Coelosphaerium</i>	0	15	433	482	260	953	744	33	0	0	0	0
26 <i>Microcystis</i>	0	238	780	1684	11293	5880	1974	390	135	0	0	0
27 <i>Merismopedia</i>	0	0	3	4	7	27	14	30	100	80	52	53
28 <i>Aphanocapsa</i>	0	0	15	22	77	10	0	0	3	0	0	0
Total	780	1347	4007	9326	25632	20076	8392	2388	1082	385	286	166

Table VIIIb

Table-VIIIb : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the second annual cycle in Station D.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Eudorina</i>	0	43	13	70	53	7	5	0	0	0	0	0
2 <i>Gloeocystis</i>	0	3	5	70	180	100	80	0	5	0	0	0
3 <i>Dictyosphaerium</i>	0	0	0	0	0	0	0	0	0	5	5	15
4 <i>Pediastrum</i>	10	78	113	160	303	258	85	0	0	0	0	0
5 <i>Coelastrum</i>	0	0	75	230	157	57	80	65	5	0	0	10
6 <i>Ankistrodesmus</i>	0	0	0	0	0	0	0	0	0	0	0	0
7 <i>Closteriopsis</i>	0	0	28	50	3	0	0	0	0	0	0	0
8 <i>Kirchneriella</i>	0	10	38	43	103	223	130	100	20	0	0	20
9 <i>Oocystis</i>	2	5	20	23	20	50	0	0	0	0	5	10
10 <i>Scenedesmus</i>	26	155	200	183	83	27	25	0	0	0	0	0
11 <i>Cosmarium</i>	2	78	180	157	23	13	0	5	0	20	10	10
12 <i>Gymnozyga</i>	0	3	18	13	0	0	0	0	0	0	0	0
13 <i>Micrasterias</i>	0	3	10	13	40	47	0	0	0	0	0	0
14 <i>Staurastrum</i>	0	40	560	1613	2080	11667	8560	6675	778	175	0	70
15 <i>Phacus</i>	2	15	65	60	13	10	40	0	15	20	5	10
16 <i>Gloeobotrys</i>	0	28	20	40	23	47	0	0	0	10	0	0
17 <i>Botryococcus</i>	6	45	193	270	143	83	15	0	10	0	0	0
18 <i>Synura</i>	0	0	28	23	10	33	0	0	0	0	0	0
19 <i>Tribonema</i>	0	0	0	0	0	0	0	0	0	0	0	0
20 <i>Dinobryon</i>	10	163	365	630	197	1217	1295	1165	730	280	55	0
21 <i>Tabellaria</i>	32	28	0	0	3	0	0	0	10	115	25	25
22 <i>Navicula</i>	0	0	0	0	7	3	30	30	45	40	100	100
23 <i>Peridinium</i>	14	120	223	223	117	20	15	10	5	0	10	5
24 <i>Ceratium</i>	2	68	120	77	73	130	15	0	0	0	0	0
25 <i>Coelosphaerium</i>	2	10	23	503	1897	14190	9435	4135	105	0	0	0
26 <i>Microcystis</i>	0	230	325	703	10903	3123	1730	815	250	75	0	0
27 <i>Merismopedia</i>	34	3	3	0	0	0	0	10	0	20	10	35
28 <i>Aphanocapsa</i>	2	10	120	70	40	3	0	0	0	0	5	15
Total	134	1138	2745	5224	17471	31308	21540	13010	1978	760	230	325

Table-IXa : Seasonal abundance of the classes and the families of phytoplankton at Station D.*First annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i>	520	398	1039	4810	9715	10666	4538	1086	386	91	28	7
2 <i>Volvocaceae</i>	0	0	5	48	17	0	4	3	5	0	0	0
3 <i>Palmellaceae</i>	0	0	5	40	80	63	14	10	0	0	0	0
4 <i>Dictyosphaeriaceae</i>	0	0	0	4	20	0	0	0	0	0	0	0
5 <i>Hydrodictyaceae</i>	0	0	0	6	117	127	68	0	0	0	0	0
6 <i>Coelastraceae</i>	0	5	70	404	410	150	22	0	0	0	0	0
7 <i>Oocystaceae</i>	0	0	60	134	250	243	46	0	3	3	4	0
8 <i>Scenedesmaceae</i>	440	180	78	280	67	3	0	0	0	0	0	0
9 <i>Desmidiaceae</i>	80	213	821	3894	8754	10080	4384	1073	378	88	24	7
10 <i>Euglenophyceae</i> (<i>Euglenaceae</i>)	0	18	5	16	20	20	4	27	8	28	22	30
11 <i>Xanthophyceae</i>	10	38	148	276	1390	680	174	20	0	13	16	0
12 <i>Gloeobotrydiaceae</i>	0	5	10	48	23	10	24	3	0	0	0	0
13 <i>Xanthophyceae</i>	10	33	138	228	1367	670	150	17	0	13	16	0
14 <i>Chrysophyceae</i>	150	445	1133	1666	2573	1730	906	743	370	35	0	0
15 <i>Synuraceae</i>	0	0	0	6	80	60	16	0	0	0	0	0
16 <i>Tribonemataceae</i>	0	0	20	42	43	13	4	0	0	0	0	0
17 <i>Ochromonadaceae</i>	150	445	1113	1618	2450	1657	886	743	370	35	0	0
18 <i>Bacillariophyceae</i>	100	65	48	8	0	0	6	36	60	113	160	73
19 <i>Tabellariaceae</i>	50	35	40	4	0	0	0	3	25	70	62	73
20 <i>Naviculaceae</i>	50	30	8	4	0	0	6	33	35	43	98	0
21 <i>Dinophyceae</i>	0	130	403	358	297	110	32	23	20	25	9	3
22 <i>Peridiniaceae</i>	0	120	223	178	180	70	2	23	20	25	8	3
23 <i>Ceratiaceae</i>	0	10	180	180	117	40	30	0	0	0	0	0
24 <i>Myxophyceae</i> (<i>Chroococcaceae</i>)	0	253	1231	2192	11637	6870	2732	453	238	80	52	53

Table IXa

First annual cycle

Table-IXb : Seasonal abundance of the classes and the families of phytoplankton at Station D.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i>	40	418	1260	2625	3045	12449	8965	6845	808	200	20	135
2 <i>Volvocaceae</i>	0	43	13	70	53	7	5	0	0	0	0	0
3 <i>Palmellaceae</i>	0	3	5	70	180	100	80	0	5	0	0	0
4 <i>Dictyosphaeriaceae</i>	0	0	0	0	0	0	0	0	0	5	5	15
5 <i>Hydrodictyaceae</i>	10	78	113	160	303	258	85	0	0	0	0	0
6 <i>Coelastraceae</i>	0	0	75	230	157	57	80	65	5	0	0	10
7 <i>Oocystaceae</i>	2	15	86	116	126	273	130	100	20	0	5	30
8 <i>Scenedesmaceae</i>	26	155	200	183	83	27	25	0	0	0	0	0
9 <i>Desmidiaceae</i>	2	124	768	1796	2143	11727	8560	6680	778	195	10	80
10 <i>Euglenophyceae</i> (<i>Euglenaceae</i>)	2	15	65	60	13	10	40	0	15	20	5	10
11 <i>Xanthophyceae</i>	6	73	213	310	166	130	15	0	10	10	0	0
12 <i>Gloeobotrydiaceae</i>	0	28	20	40	23	47	0	0	0	10	0	0
13 <i>Xanthophyceae</i>	6	45	193	270	143	83	15	0	10	0	0	0
14 <i>Chrysophyceae</i>	0	163	393	653	1207	1250	1295	1165	730	280	55	0
15 <i>Synuraceae</i>	0	0	28	23	10	33	0	0	0	0	0	0
16 <i>Tribonemataceae</i>	0	0	0	0	0	0	0	0	0	0	0	0
17 <i>Ochromonadaceae</i>	0	163	365	630	1197	1217	1295	1165	730	280	55	0
18 <i>Bacillariophyceae</i>	32	28	0	0	10	3	30	30	55	155	125	125
19 <i>Tabellariaceae</i>	32	28	0	0	3	0	0	0	10	115	25	25
20 <i>Naviculaceae</i>	0	0	0	0	7	3	30	30	45	40	100	100
21 <i>Dinophyceae</i>	16	188	343	300	190	150	30	10	5	0	10	5
22 <i>Peridiniaceae</i>	14	120	223	223	117	20	15	10	5	0	10	5
23 <i>Ceratiaceae</i>	2	68	120	77	73	130	15	0	0	0	0	0
24 <i>Myxophyceae</i> (<i>Chroococcaceae</i>)	38	253	471	1276	12840	17316	11165	4960	355	95	15	50

Table IXb

Second annual cycle

Tabellaria of the family Tabellariaceae was the only representative of class Bacillariophyceae at this station. Like others it showed a winter abundance and a total disappearance in summer. It showed peaks in March (48 units/litre) and January (80 units/litre) in the first and October (25 units/litre) in the second annual cycles.

The last two classes recorded at this station were Dinophyceae and Myxophyceae. The former was represented by *Peridinium* and *Ceratium* of the family Peridiniaceae and Ceratiaceae while the latter had only one family Chroococcaceae but represented by seven genera *Coelosphaerium*, *Microcystis*, *Gloeocapsa*, *Merismopedia*, *Chroococcus*, *Aphanocapsa* and *Anacystis*. All except *Merismopedia*, *Aphanocapsa* and *Anacystis* had the usual seasonal trend of a summer maxima and a winter minima. *Merismopedia* revealed a winter peak during the first annual cycle and an early autumn peak during the second, while *Aphanocapsa* had peaks of winter abundance with summer minima while *Anacystis* recorded late spring or early summer peaks but with the usual winter minima. Maximum abundance in case of *Peridinium* and *Ceratium* was observed in June (197 units/litre and 237 units/litre) for the first annual cycle and in July (190 units/litre) for the former and May (380 units/litre) for the latter genus during the second annual cycle. *Coelosphaerium* had peaks in May and July with 160 units/litre and July with 203 units/litre in the first and second annual cycles respectively. *Microcystis* and *Gloeocapsa* recorded abundance in July recording 4778 units/litre and 147 units/litre respectively in the first annual cycle and corresponding peaks shifted to June (8093 units/litre) and May (127 units/litre) respectively in the second annual cycle. *Chroococcus* and *Anacystis* were abundant in May in both the annual cycles with the former recording 28 units/litre and 80 units/litre in the first and second annual cycles respectively and the latter 20 units/litre and 20 units/litre. *Merismopedia* had a peak in December (55 units/litre) and in July (147 units/litre) and *Aphanocapsa* in October (90 units/litre) and December (205 units/litre) in the first and second annual cycles respectively (Table-X a,b).

At this Station E when the phytoplankton was grouped under the families and classes, the general trend of seasonal fluctuation was seen to follow a pattern similar to their representative genus or genera. However, on a detailed analysis the dominant group was the class Chlorophyceae with eight families. These eight families all showed a summer maxima and a winter minima at least during the first annual cycle as well as the families Palmellaceae, Dictyosphaeriaceae, Hydrodictyaceae and Oocystaceae for the second annual cycle. A late spring or early summer maxima (April and May) but with the usual winter minima was seen in the families Volvocaceae, Coelastraceae, Scenedesmaceae and Desmidiaceae. The class Chlorophyceae also followed a pattern similar to the last four families. However, when the percentage of this class as of total phytoplankton was seen, the peak shifted to at least two months before the actual numbers peak for both the annual cycles. Euglenophyceae and Xanthophyceae represented by the families Euglenaceae of the former and Gloeobortrydiaceae and Xanthophyceae of the latter followed the usual trend of summer maxima and winter minima. The percentages when computed for class as of total phytoplankton, the class Euglenophyceae showed a shift towards the earlier two months as seen for the class Chlorophyceae while Xanthophyceae's percentage of total plankton followed a pattern similar to their actual numbers.

Chromoliniaceae and Ochromonadaceae of the class Chrysophyceae, with the family Ochromonadaceae having the usual summer maxima and winter minima and with very high numbers in contrast to Chromoliniaceae which had a trend in opposite in that there were winter peaks with summer minima. Chrysophyceae as such being reflective of large numbers of Ochromonadaceae followed a pattern similar to it. However, when the percentage of abundance was seen maximum was in winter during the first annual cycle and in early autumn for the second annual cycle.

Table Xa

Table-Xa : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the first annual cycle in Station E.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Pandorina</i>	0	3	43	50	7	3	4	0	0	0	0	0
2 <i>Gloeocystis</i>	0	0	3	54	110	93	22	0	0	0	0	0
3 <i>Dictyosphaerium</i>	0	0	3	58	70	33	28	0	0	0	0	0
4 <i>Pediastrum</i>	0	0	25	20	60	23	12	0	0	0	0	0
5 <i>Coelastrum</i>	10	13	263	126	10	33	2	0	0	0	0	0
6 <i>Ankistrodesmus</i>	0	0	0	12	20	3	3	0	0	0	0	0
7 <i>Kirchneriella</i>	0	0	0	16	63	90	46	20	0	0	0	0
8 <i>Selenastrum</i>	0	0	28	20	13	0	0	0	0	0	0	0
9 <i>Scenedesmus</i>	0	20	75	176	183	180	26	13	13	0	0	3
10 <i>Closterium</i>	10	25	105	56	40	10	6	0	3	0	0	3
11 <i>Cosmarium</i>	0	0	13	30	23	47	14	7	0	0	0	0
12 <i>Micrasterias</i>	0	0	25	30	63	17	0	0	0	0	0	0
13 <i>Staurastrum</i>	0	220	773	1310	940	570	238	87	28	8	0	13
14 <i>Phacus</i>	0	10	40	14	20	40	22	3	0	0	0	0
15 <i>Gleobotrys</i>	0	0	15	48	100	107	20	0	0	0	0	0
16 <i>Botryococcus</i>	0	30	17	362	877	151	96	0	0	0	0	0
17 <i>Chrysococcus</i>	50	18	15	22	0	7	8	3	5	58	38	50
18 <i>Dinobryon</i>	120	295	876	1508	2803	3200	1516	863	123	10	0	0
19 <i>Tabellaria</i>	20	48	8	0	0	0	0	17	33	75	60	80
20 <i>Peridinium</i>	0	35	88	196	197	137	44	27	30	5	3	0
21 <i>Ceratium</i>	0	0	8	168	237	143	8	0	0	0	0	0
22 <i>Coelosphaerium</i>	0	0	25	106	120	160	84	27	0	0	0	0
23 <i>Microcystis</i>	0	65	380	1802	4703	4778	882	227	55	0	0	0
24 <i>Gloeocapsa</i>	0	0	68	126	130	147	48	7	0	0	0	0
25 <i>Merismopedia</i>	0	35	8	10	23	27	30	27	20	30	55	43
26 <i>Chroococcus</i>	0	0	23	28	17	10	4	0	0	0	0	0
27 <i>Aphanocapsa</i>	10	8	0	0	0	0	4	30	90	50	44	13
28 <i>Anacystis</i>	0	0	13	26	3	3	4	0	0	0	0	0
Total	220	825	2940	6374	10832	10012	3171	1358	400	236	200	205

Table-Xb : The seasonal variations of individual phytoplanktonic genera and the total phytoplankton (units/litre) for the second annual cycle in Station E.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Pandorina</i>	0	15	73	20	30	0	0	0	0	0	0	0
2 <i>Gloeocystis</i>	0	0	20	60	87	127	50	0	0	0	0	0
3 <i>Dictyosphaerium</i>	0	5	20	30	53	87	95	60	10	5	0	0
4 <i>Pediastrum</i>	0	5	38	27	133	173	95	35	0	0	0	0
5 <i>Coelastrum</i>	8	43	153	437	350	240	75	5	0	0	0	0
6 <i>Ankistrodesmus</i>	0	0	0	0	20	3	0	0	0	0	0	0
7 <i>Kirchneriella</i>	0	0	18	47	77	77	90	0	0	0	0	0
8 <i>Selenastrum</i>	0	0	20	27	40	40	50	0	0	0	0	0
9 <i>Scenedesmus</i>	34	160	220	383	150	157	40	10	5	0	0	0
10 <i>Closterium</i>	10	63	35	17	3	3	0	0	0	0	0	0
11 <i>Cosmarium</i>	0	0	18	17	30	20	20	5	20	0	0	0
12 <i>Micrasterias</i>	0	0	0	7	60	90	25	25	0	0	0	0
13 <i>Staurastrum</i>	30	478	1835	1150	457	153	170	35	0	0	0	0
14 <i>Phacus</i>	0	25	25	43	3	7	20	5	0	0	0	0
15 <i>Gleobotrys</i>	0	3	23	67	63	67	20	30	0	0	0	0
16 <i>Botryococcus</i>	0	10	113	533	517	750	380	35	20	5	0	0
17 <i>Chrysococcus</i>	10	70	35	20	0	7	30	10	10	0	0	0
18 <i>Dinobryon</i>	0	90	933	7957	9850	12543	7025	3590	595	80	0	0
19 <i>Tabellaria</i>	34	0	0	0	0	0	0	0	25	20	15	20
20 <i>Peridinium</i>	3	30	153	160	97	190	90	40	20	30	0	0
21 <i>Ceratium</i>	0	15	120	380	290	90	0	0	0	0	0	0
22 <i>Coelosphaerium</i>	0	18	43	110	123	203	50	5	0	0	0	0
23 <i>Microcystis</i>	0	540	1425	3637	8093	7447	3280	1565	755	55	0	0
24 <i>Gloeocapsa</i>	0	38	80	127	140	107	15	30	0	0	0	0
25 <i>Merismopedia</i>	6	30	3	43	33	147	45	55	25	0	0	0
26 <i>Chroococcus</i>	8	8	55	80	70	70	30	5	0	0	0	0
27 <i>Aphanocapsa</i>	0	0	0	0	3	10	15	60	35	100	205	70
28 <i>Anacystis</i>	0	0	8	30	3	10	0	0	0	0	0	0
Total	143	1646	5466	15409	20775	22818	11710	5605	1520	290	220	90

Table Xb

Bacillariophyceae was represented by only one family **Tabellariaceae**. It recorded winter maxima with total disappearance in summer and the percentage of abundance followed a similar pattern.

Peridiniaceae and **Ceratiaceae** under the class **Dinophyceae** and the family **Chroococcaceae** under **Myxophyceae**, all followed the usual summer maxima and winter minima. The percentage abundance for **Dinophyceae** shifted one month earlier as maxima while for **Myxophyceae** it coincided for the first annual cycle with the actual numbers, but peak values of percentages were recorded during the last two winter months of the annual cycle (Table-XIa,b; Fig. 11).

The total phytoplankton at this station irrespective of the variations followed a pattern similar to the majority of the groups with a summer maxima and winter minima in both the annual cycles (Table-X a, b).

Zooplankton

Zooplankton recorded in the present study was represented by five major groups Protozoa, Rotifera, Cyclopoda, Cladocera and Ostracoda. Protozoa was represented by *Centropyxis* and *Diffugia*, Rotifera by *Keratella*, *Brachionus*, *Lecne*, *Epiphanes*, *Asplanchna*, *Trichocerca*, *Testudinella*, *Proales*, *Cephalodella*, *Polyarthra* and *Lepadella*, while *Cyclops* and *Diaptomus* were the only two genera under Cyclopoda. Cladocera was represented by the *Diaphanosoma*, *Chydorus*, *Daphnia* and *Bosmina*. *Cypris* was the only genus under Ostracoda.

At Station A *Centropyxis* was the only genus of Protozoa showing an autumn peak in both the annual cycles though a trend towards its increase was seen during the winter month. The maximum was recorded in December (72 units/litre) and September (105 units/litre) during the first and second annual cycles respectively while July in the second annual recorded nil.

Only six genera of Rotifera were recorded at this station, *Keratella* showed a bimodal peak of abundance in spring and autumn in the first annual cycle, while the second peak moved earlier to summer in the second annual cycle. *Asplanchna*, *Polyarthra* and *Lepadella* revealed a summer maxima and winter minima during both the annual cycles. *Trichocerca* and *Testudinella* had bimodal peaks of abundance in winter with very low numbers in summer or total disappearance at least during the first annual cycle, and though similar for the second annual cycle the peak was in the summer months for *Trichocerca* which needs further clarification. *Keratella* had maximum numbers in September (597 units/litre) and April (125 units/litre) in the first and second annual cycles respectively. *Asplanchna* and *Polyarthra* was most abundant in July (70 units/litre and 130 units/litre respectively) in the first cycle but the former showed a peak in August (100 units/litre) and the latter in June (127 units/litre) during the second annual cycle. *Lepadella* and *Trichocerca* had their peaks in June recording 203 units/litre and 93 units/litre respectively in the first but during the second annual cycle the former revealed a peak in August (125 units/litre) and the latter in July (130 units/litre). *Testudinella* was most abundant in January (113 units/litre) and in November (145 units/litre) in the first and second annual cycles respectively.

Cyclops was the only genus recorded at this station under Cyclopoda and it revealed bimodal peak in spring and summer and minimum in winter. Maximum occurrence was seen in April and July of the first annual cycle recording 338 units/litre and 330 units/litre respectively whereas May recorded a peak (294 units/litre) in the second annual cycle. February recorded the least (10 units/litre) in the first annual cycle.

Table-XIa : Seasonal abundance of the classes and the families of phytoplankton at Station E.*First annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i>	20	281	1356	1958	1602	1102	401	127	44	8	0	19
2 <i>Volvocaceae</i>	0	3	43	50	7	3	4	0	0	0	0	0
3 <i>Palmellaceae</i>	0	0	3	54	110	93	22	0	0	0	0	0
4 <i>Dictyosphaeriaceae</i>	0	0	3	58	70	33	28	0	0	0	0	0
5 <i>Hydrodictyaceae</i>	0	0	25	20	60	23	12	0	0	0	0	0
6 <i>Coelastraceae</i>	10	13	263	1263	10	33	20	0	0	0	0	0
7 <i>Oocystaceae</i>	0	0	28	48	93	93	49	20	0	0	0	0
8 <i>Scenedesmaceae</i>	0	20	75	176	183	180	26	13	13	0	0	3
9 <i>Desmidiaceae</i>	10	245	916	1426	1076	644	258	94	31	8	0	16
10 <i>Euglenophyceae</i>	0	10	40	14	20	40	22	3	0	0	0	0
11 <i>Euglenaceae</i>	0	10	40	14	20	40	22	3	0	0	0	0
12 <i>Xanthophyceae</i>	0	30	32	410	977	258	116	0	0	0	0	0
13 <i>Gloeobotrydiaceae</i>	0	0	15	48	100	107	20	0	0	0	0	0
14 <i>Xanthophyceae</i>	0	30	17	362	877	151	96	0	0	0	0	0
15 <i>Chrysophyceae</i>	170	313	891	1530	2803	3207	1524	866	128	68	38	50
16 <i>Chromoliniaceae</i>	50	18	15	22	0	7	8	3	5	58	20	50
17 <i>Ochromoliniaceae</i>	120	295	876	1508	2803	3200	1516	863	124	10	10	0
18 <i>Bacillariophyceae</i>	20	48	8	0	0	0	0	17	33	75	60	80
19 <i>Tabellariaceae</i>	20	48	8	0	0	0	0	17	33	75	60	80
20 <i>Dinophyceae</i>	0	35	96	364	434	280	52	27	30	5	3	0
21 <i>Peridiniaceae</i>	0	35	88	196	197	137	44	27	30	5	3	0
22 <i>Ceratiaceae</i>	0	0	8	168	237	143	8	0	0	0	0	0
23 <i>Myxophyceae</i>	10	108	517	2098	4996	5125	1056	318	165	80	99	56
24 <i>Chroococcaceae</i>	10	108	517	2098	4996	5125	1056	315	165	80	99	56

Table-XIa (First annual cycle)

Table-XIb : Seasonal abundance of the classes and the families of phytoplankton at Station E.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 <i>Chlorophyceae</i>	82	769	2450	2222	1490	1170	710	265	30	0	0	0
2 <i>Volvocaceae</i>	0	15	73	20	30	0	0	0	0	0	0	0
3 <i>Palmellaceae</i>	0	0	20	60	87	127	50	0	0	0	0	0
4 <i>Dictyosphaeriaceae</i>	0	5	20	30	53	87	95	60	10	5	0	0
5 <i>Hydrodictyaceae</i>	0	5	38	27	133	173	95	35	0	0	0	0
6 <i>Coelastraceae</i>	8	43	153	437	350	240	75	5	0	0	0	0
7 <i>Oocystaceae</i>	0	0	38	74	137	120	140	0	0	0	0	0
8 <i>Scenedesmaceae</i>	34	160	220	383	150	157	40	10	5	0	0	0
9 <i>Desmidiaceae</i>	40	541	1888	1191	550	246	215	65	20	0	0	0
10 <i>Euglenophyceae</i>	0	25	25	43	3	7	20	5	0	0	0	0
11 <i>Euglenaceae</i>	0	25	25	43	3	7	20	5	0	0	0	0
12 <i>Xanthophyceae</i>	0	13	136	600	580	817	400	65	20	5	0	0
13 <i>Gloeobotrydiaceae</i>	0	3	23	67	63	67	20	30	0	0	0	0
14 <i>Xanthophyceae</i>	0	10	113	533	517	750	380	35	20	5	0	0
15 <i>Chrysophyceae</i>	10	160	968	7977	9850	12550	7055	3600	605	80	0	0
16 <i>Chromoliniaceae</i>	10	70	35	20	0	7	30	10	10	0	0	0
17 <i>Ochromoliniaceae</i>	0	90	935	7957	9850	12543	7025	3590	595	80	0	0
18 <i>Bacillariophyceae</i>	34	0	0	0	0	0	0	0	25	20	15	20
19 <i>Tabellariaceae</i>	34	0	0	0	0	0	0	0	25	20	15	20
20 <i>Dinophyceae</i>	3	45	273	540	387	280	90	40	20	30	0	0
21 <i>Peridiniaceae</i>	3	30	153	160	97	190	90	40	20	30	0	0
22 <i>Ceratiaceae</i>	0	15	120	380	290	90	0	0	0	0	0	0
23 <i>Myxophyceae</i>	14	634	1614	4027	8465	7994	3435	1720	815	155	205	70
24 <i>Chroococcaceae</i>	14	634	1614	4027	8465	7994	3435	1720	815	155	205	70

Table-XIb (Second annual cycle)

Cladocera was represented by *Bosmina* at this station, and had a spring peak with summer and winter minima but in the second annual cycle a rise was seen in the summer month of June. This genus formed a peak in April during both the annual cycles recording 135 and 195 units/litre while the lowest of 13 units/litre was observed in the month of October in the first annual cycle.

Cypris under Ostracoda had a winter maxima and summer minima. It was abundant in February (100 units/litre) and January (90 units/litre) in the first annual cycle and in December with 165 units/litre during the second. During summer this genus recorded nil. (Table-XIIa,b).

When the groups of zooplankton were seen for their seasonal fluctuations irrespective of the genera present under them – Protozoa, Copepoda, Cladocera and Ostracoda represented by one genus each therefore showed the same picture of seasonal fluctuation. The group Rotifera, however, showed a summer maxima and the winter minima (Table-XIIa,b).

When the percentage of abundance of these groups of the total zooplankton and their seasonal abundances were computed they followed a trend similar to their actual numbers (Fig. 12)

When the total zooplankton and its seasonal abundance was seen they showed a bimodal peak of abundance one during spring and the other in autumn for the first annual cycle and one peak during early autumn for the second annual cycle (Table-XIIa,b).

The next Station B represented maximum genera with the total absence of *Cypris* under Ostracoda.

Centropyxis and *Diffugia* recorded under Protozoa, had a spring maxima and total absence during summer and winter months for the former while the latter had a winter maxima and summer minima. The former was maximum in April in the first and in March during the second annual cycles recording 23 units/litre and 35 units/litre respectively and the latter was found to be most dominant in November (157 units/litre) and December (170 units/litre) in the first and second annual cycles respectively.

Rotifera was represented by eight genera with only *Testudinella* and *Cephalodella* being absent. *Keratella* had the usual summer peak and winter minima. *Brachionus* and *Proales* revealed a spring peak with summer and winter minima during the first annual cycle while though the trend was same for *Proales* in the second annual cycle, the peak shifted to summer for *Brachionus*. *Lecane* and *Epiphanes* revealed an autumn peak with winter and summer minima while *Trichocerca* though had an autumn and a spring peak during the first annual cycle revealed only a spring peak during the second annual cycle. *Asplanchna* had a winter peak with summer minima as also seen for *Polyarthra* though a peak of smaller magnitude was seen during late spring in both the annual cycles. *Lecane*, *Epiphanes* and *Trichocerca* had peaks in October representing 77 units/litre, 53 units/litre and 193 units/litre respectively in the first annual cycle, but during the second annual cycle, *Lecane* recorded maximum in September and December having 45 units/litre and *Trichocerca* in May (193 units/litre). *Epiphanes* had a peak in the month of October (25 units/litre) of the second annual cycle. *Keratella* had a peak in June in both the annual cycles recording 617 units/litre and 430 units/litre respectively. *Brachionus* was found to be most dominant during April (68 units/litre) and June (70 units/litre) of the first and second annual cycles respectively. *Proales* and *Polyarthra* had peaks of abundance in May (38 units/litre) and November (223 units/litre) respectively during the first but their peaks were seen in April (28 units/litre) and in October (190 units/litre) respectively during the second annual cycle. *Asplanchna* was the most dominant in December (90 units/litre) and in November (160 units/litre) during the first and second annual cycles respectively.

Table-XIIa : Seasonal abundance of the major groups and genera of zooplankton at Station A.

		<i>First annual cycle</i>											
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1	PROTOZOA <i>Centropyxis</i>	10	45	20	14	20	40	54	60	60	25	72	27
2	ROTIFERA	280	265	344	450	449	445	294	757	332	119	162	243
3	<i>Keratella</i>	40	65	210	180	77	90	170	597	284	28	70	3
4	<i>Asplanchna</i>	0	0	0	46	43	70	6	20	0	23	0	0
5	<i>Trichocerca</i>	80	65	43	72	93	75	18	3	5	18	50	107
6	<i>Testudinella</i>	60	75	58	14	0	0	0	0	0	0	10	113
7	<i>Polyarthra</i>	80	40	38	66	33	130	38	17	8	0	4	7
8	<i>Lepadella</i>	20	20	30	72	203	80	62	120	35	50	28	13
9	COPEPODA <i>Cyclops</i>	10	143	338	86	67	330	132	93	68	65	60	70
10	CLADOCERA <i>Bosmina</i>	80	65	135	124	47	25	38	33	13	50	60	23
11	OSTRACODA <i>Cypris</i>	100	25	0	2	0	0	0	0	0	25	56	90
Total		480	543	837	676	583	840	518	943	473	284	410	453

Table XIIa
First annual cycle

Table-XIIb : Seasonal abundance of the major groups and genera of zooplankton at Station A.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA <i>Centropyxis</i>	10	23	33	53	20	0	65	105	25	45	40	50
2 ROTIFERA	268	249	254	377	467	413	510	325	380	365	260	110
3 <i>Keratella</i>	28	83	125	73	110	60	25	45	35	55	40	15
4 <i>Asplanchna</i>	12	3	63	70	27	33	100	35	0	0	0	0
5 <i>Trichocerca</i>	64	33	18	67	93	130	75	70	105	100	115	15
6 <i>Testudinella</i>	102	60	3	7	0	10	100	65	120	145	10	50
7 <i>Polyarthra</i>	62	70	30	77	127	67	85	45	45	0	0	0
8 <i>Lepadella</i>	0	0	15	83	110	113	125	65	75	65	95	30
9 COPEPODA <i>Cyclops</i>	246	283	265	294	243	140	140	105	45	40	45	40
10 CLADOCERA <i>Bosmina</i>	92	142	195	67	177	23	105	45	30	20	15	95
11 OSTRACODA <i>Cypris</i>	32	3	5	0	0	0	120	30	145	120	165	135
Total	648	700	752	791	907	576	940	610	625	590	525	430

Table XIIb

Copepoda was represented by *Cyclops* and *Diaptomus*. Both possessed an autumnal peak with winter minima. The former genus was seen to form a peak of abundance in September (250 units/litre) and November (210 units/litre) while the latter had maximal occurrence in October (497 units/litre) and August (280 units/litre) during first and second annual cycles respectively.

Cladocera was represented by *Diaphanosoma*, *Daphnia* and *Bosmina*. The former had an autumn peak and present only in these months with total absence during the remaining period of investigation while the latter two had winter maxima and summer minima. The first genus had its abundance in of October (63 units/litre), the second in January (66 units/litre) and the third in November (450 units/litre) during the first annual cycle, while their corresponding peaks in the second annual cycle were observed in September (75 units/litre), January (135 units/litre) and December (375 units/litre) respectively (Table-XIIIa,b).

When the major groups of zooplankton and their seasonal trends of fluctuation were observed, Protozoa and Cladocera recorded winter maxima and summer minima while Rotifera had a summer maxima and winter minima and Copepoda with autumn peaks of abundance during both the annual cycles (Table-XIIIa,b).

The percentage of abundance of these major groups of zooplankton as that of total zooplankton a trend similar to their actual numbers was observed (Fig. 12).

When the total zooplankton and its trend of fluctuation was observed it was very irregular in that with minor rises and falls during both the annual cycles, peaks were observed in summer and autumn (Table-XIIIa,b).

In the next Station C as for the previous Station all the major groups of zooplankton were represented except Ostracoda and its genus *Cypris*.

Protozoa was represented by both *Centropyxis* and *Diffugia* which had spring peaks during both the annual cycles. *Diffugia* had an autumnal peak also. The former genus had its peak in May recording 32 units/litre and 50 units/litre during the two annual cycles respectively while the latter was most abundant in the month of April (60 units/litre) and March and April 970 units/litre) during the first and second annual cycles respectively.

Rotifera was represented by eight genera with the absence of *Testudinella* and *Cephalodella*. *Keratella*, *Brachionus* and *Proales* had an early summer peak during both the annual cycles with a total absence during winter. *Asplanchna* and *Polyarthra* had a winter maxima and summer minima. *Lecane* and *Epiphanes* had an autumn peak with summer minima, while *Trichocerca* had a summer maxima and winter minima during both the annual cycles. *Keratella* and *Brachionus* had their peak in May with their respective counts of 178 units/litre and 60 units/litre in the first annual cycle while the former had a peak in May (950 units/litre) and March and April (70 units/litre) during the second annual cycle. *Proales*, *Asplanchna*, *Polyarthra*, *Trichocerca*, *Epiphanes* and *Lecane* had their respective peaks of abundance in June (50 units/litre), February (40 units/litre), November (63 units/litre), July (107 units/litre), September (47 units/litre) and October (85 units/litre) in the first annual cycle respectively while during the second annual cycle in the same sequence were observed to reveal their peaks in June (83 units/litre), December (25 units/litre), July (120 units/litre), September (75 units/litre) and November (175 units/litre) respectively.

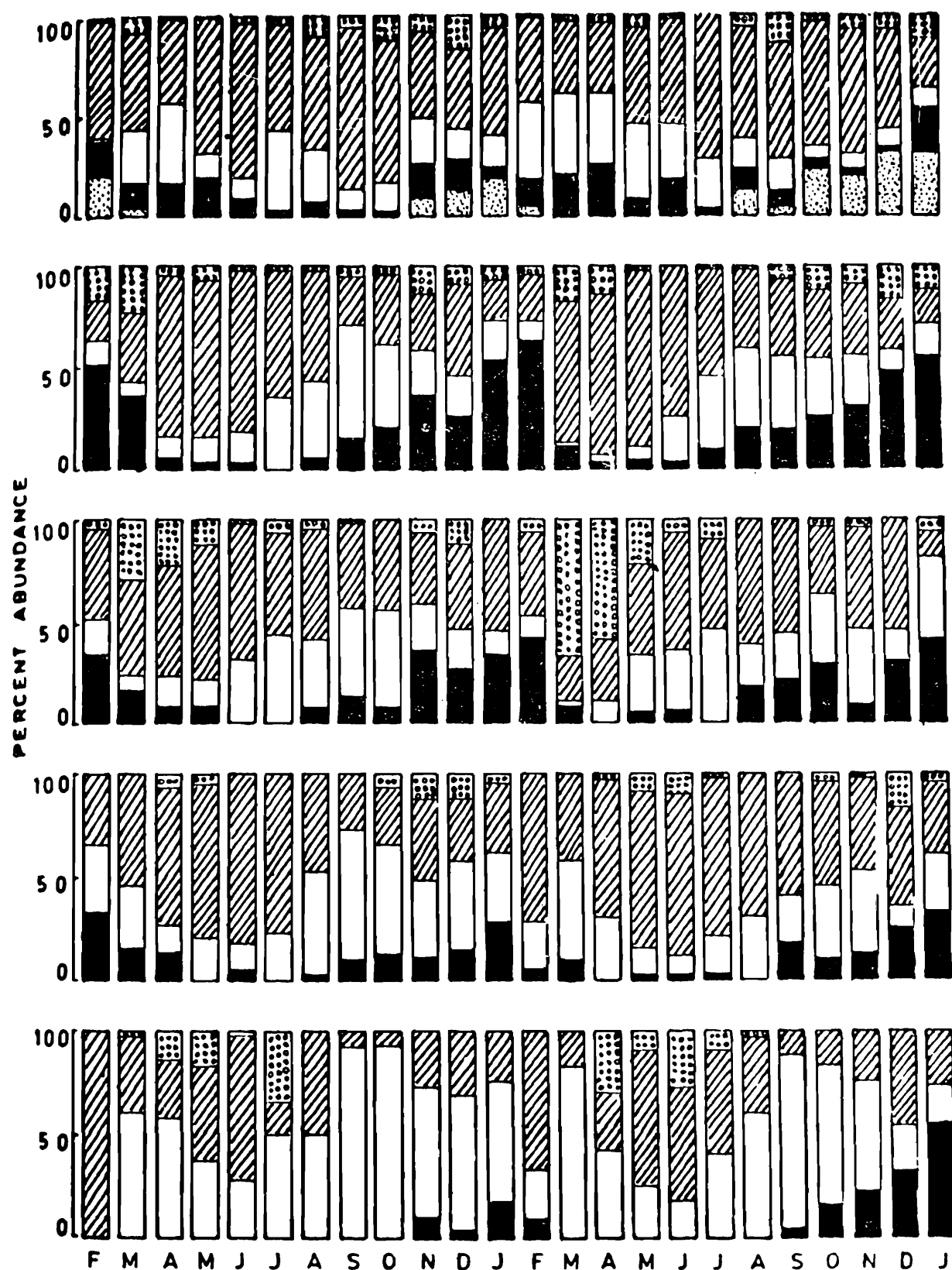


Fig. 12 Showing histograms representing the seasonality of the relative percent abundance of the major zooplanktonic groups at the surface waters of the Stations A, B, C, D and E.

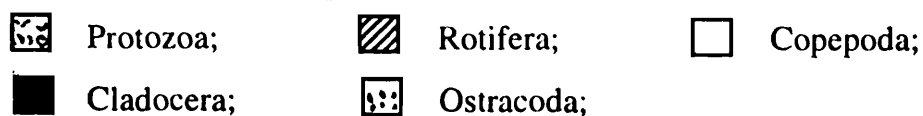


Table-XIIIa : Seasonal abundance of the major groups and genera of zooplankton at Station B.*First annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA	80	53	26	40	3	3	12	60	70	157	43	23
2 <i>Centropyxis</i>	0	0	23	8	0	0	0	0	0	0	0	0
3 <i>Diffugia</i>	80	53	3	32	3	3	12	60	70	157	43	23
4 ROTIFERA	100	81	409	535	728	509	450	295	614	352	253	70
5 <i>Keratella</i>	20	25	160	364	617	403	346	100	97	0	13	27
6 <i>Brachionus</i>	0	10	68	22	7	7	0	15	0	0	0	0
7 <i>Lecane</i>	0	0	0	0	0	0	14	20	77	73	40	0
8 <i>Epiphanes</i>	0	0	0	0	0	0	6	50	53	13	15	0
9 <i>Asplanchna</i>	80	20	13	0	7	3	0	15	17	13	90	33
10 <i>Trichocerca</i>	0	18	133	52	30	70	10	60	193	30	0	0
11 <i>Proales</i>	0	0	0	38	20	13	0	0	0	0	0	0
12 <i>Polyarthra</i>	0	8	35	58	47	13	74	35	177	223	95	10
13 COPEPODA	60	16	61	86	137	286	312	725	737	261	110	66
14 <i>Cyclops</i>	60	13	23	32	110	213	136	250	240	114	70	63
15 <i>Diaptomus</i>	0	3	38	54	27	73	176	475	497	147	40	3
16 CLADOCERA	260	85	28	26	30	0	42	200	390	453	143	183
17 <i>Diaphanosoma</i>	0	0	0	0	0	0	8	40	63	27	0	0
18 <i>Daphnia</i>	0	0	0	0	0	0	0	0	0	6	0	66
19 <i>Bosmina</i>	260	85	28	26	30	0	34	160	251	420	143	117
Total	500	235	524	687	898	798	816	1280	1811	1223	549	345

Table-XIIIa

First annual cycle

Table-XIIIb : Seasonal abundance of the major groups and genera of zooplankton at Station B.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA	12	73	61	20	0	3	15	65	135	100	170	70
2 <i>Centropyxis</i>	2	35	28	17	0	0	0	0	0	0	0	0
3 <i>Diffugia</i>	10	38	33	3	0	3	15	65	135	100	170	70
4 ROTIFERA	58	296	377	790	587	432	425	350	360	380	250	115
5 <i>Keratella</i>	6	213	245	453	430	330	345	170	30	10	0	0
6 <i>Brachionus</i>	10	10	0	17	70	23	0	0	0	0	0	0
7 <i>Lecane</i>	0	0	0	0	0	0	0	45	30	25	45	0
8 <i>Epiphanes</i>	0	0	0	0	0	0	0	10	25	0	0	0
9 <i>Asplanchna</i>	40	23	28	0	0	13	0	0	55	160	100	115
10 <i>Trichocerca</i>	2	45	48	193	57	50	35	45	30	10	20	0
11 <i>Proales</i>	0	0	28	27	20	3	0	0	0	0	0	0
12 <i>Polyarthra</i>	0	5	28	100	10	13	45	80	190	175	85	0
13 COPEPODA	24	8	16	60	164	283	435	324	315	290	110	105
14 <i>Cyclops</i>	24	5	11	33	84	156	155	50	170	210	110	105
15 <i>Diaptomus</i>	0	3	5	27	80	127	280	275	145	80	0	0
16 CLADOCERA	161	48	18	47	37	80	220	195	285	350	495	370
17 <i>Diaphanosoma</i>	8	0	0	0	0	0	40	75	35	10	0	0
18 <i>Daphnia</i>	5	28	0	0	0	0	0	20	40	95	120	135
19 <i>Bosmina</i>	145	20	18	47	37	80	180	120	210	245	375	235
Total	255	425	472	917	788	798	1095	935	1095	1120	1025	660

Table-XIIIb

Second annual cycle

Copepoda was represented by both *Cyclops* and *Diaptomus* at this Station. *C. Cyclops* possessed an autumn peak while *Diaptomus* a summer peak and both showed a winter minima during both the annual cycles. *Cyclops* showed maximum abundance in September and July recording 210 units/litre and 187 units/ litre respectively while *Diaptomus* had its peak in July and June amounting to 53 units/litre and 60 units/litre respectively in the first and second annual cycles.

Cladocera was represented by *Bosmina*. It possessed winter maxima in November (145 units/litre) and December (135 units/litre) and summer minima recording even nil in July and April during the first and second annual cycles respectively (Table-XIVa,b).

When the major groups of zooplankton were observed for their seasonal trend of fluctuation, Protozoa showed a spring peak with autumn minima, Rotifera with summer and autumn maxima and Cladocera with the winter maxima and summer minima (Table-XIVa,b).

These groups when seen as percentages of abundances of the total zooplankton, had a pattern similar to their actual numbers (Fig. 12).

The seasonal trend of fluctuation for the total zooplankton had an early summer and middle autumn peaks with winter minima for the both the annual cycles (Table-XIVa,b).

Zooplankton at the next Station D was represented by most of the genera of the major groups except Ostracoda.

Protozoa was represented by both *Centropyxis* and *Diffugia*, the former present only during the winter months with their peak in November (60 units/litre) and December (100 units/litre) and totally absent during the remaining period of investigation. The latter was present only during the late spring and early summer months with peaks in May (24 units/litre) and June (30 units/litre) during both the annual cycles and a total absence for the remaining period.

Rotifera was represented by seven genera of which *Keratella*, *Trichocerca* and *Testudinella* recorded peaks of abundance during spring months with a winter and summer minima. *Lecane* and *Asplanchna* had winter peaks of abundance with a total absence in summer months during both annual cycles. *Cephalodella* and *Polyarthra* also had winter peaks of abundance with a total absence in summer, though the former was recorded at two times in spring during the first annual cycle. *Keratella* was most abundant in May (258 units/litre) and June (9247 units/litre) during the first and second annual cycles respectively. *Trichocerca* and *Testudinella* had their peaks of abundance in April in the first annual cycle recording 163 units/litre and 20 units/litre in that order but peaked in February (144 units/litre) and January (30 units/litre) respectively during the second annual cycle. During the first annual cycle, *Lecane*, *Asplanchna* and *Cephalodella* had their maximum number in November recording 38 units/litre, 100 units/litre and 28 units/litre respectively while *Lecane* and *Asplanchna* in the second annual peak was in November (75 units/litre) and December (150 units/litre) with *Cephalodella* disappearing in the second annual cycle. *Polyarthra* was maximum in December (42 units/ litre and 100 units/litre) during both the annual cycles.

Copepoda was represented by *Cyclops* and *Diaptomus*. *Cyclops* had a bimodal peak one in autumn and the other in winter, while *Diaptomus* had a late spring peak with a total absence in summer during both the annual cycles. The former was maximum in December (194 units/litre) and November (180 units/litre) in the first and second annual cycles respectively and recorded least in May (3 units/litre). *Diaptomus* had its peak in May (44 units/litre) and March (75 units/ litre) in the first and second annual cycles respectively.

Table-XIVa: Seasonal abundance of the major groups and genera of zooplankton at Station C.*First annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA	10	40	60	54	6	23	10	3	0	25	40	0
2 <i>Centropyxis</i>	0	0	0	32	3	3	4	0	0	0	0	0
3 <i>Diffugia</i>	10	40	60	22	3	20	6	3	0	25	40	0
4 ROTIFERA	100	66	146	298	229	190	156	201	139	144	136	89
5 <i>Keratella</i>	0	13	125	178	90	60	64	53	5	0	0	0
6 <i>Brachionus</i>	0	0	5	60	23	0	0	0	0	0	0	0
7 <i>Lecane</i>	40	18	0	0	0	7	24	57	85	53	70	53
8 <i>Epiphanes</i>	0	0	0	0	0	3	8	47	18	0	0	0
9 <i>Asplanchna</i>	40	15	0	0	0	0	0	0	0	28	22	20
10 <i>Trichocerca</i>	10	5	13	26	63	107	42	37	3	0	4	3
11 <i>Proales</i>	0	0	0	34	40	10	0	0	0	0	0	0
12 <i>Polyarthra</i>	10	15	3	0	13	3	18	7	28	63	40	13
13 COPEPODA	40	10	40	58	103	167	96	210	148	95	66	20
14 <i>Cyclops</i>	40	10	17	28	73	114	76	210	148	95	66	20
15 <i>Diaptomus</i>	0	0	23	30	30	53	20	0	0	0	0	0
16 CLADOCERA <i>Bosmina</i>	80	23	23	42	3	0	22	63	28	145	90	53
Total	230	139	269	452	341	380	284	477	315	409	332	162

Table XIVa

First annual cycle

Table-XIVa : Seasonal abundance of the major groups and genera of zooplankton at Station C.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA	21	75	103	73	33	54	0	0	20	15	0	10
2 <i>Centropyxis</i>	0	5	33	50	30	37	0	0	0	0	0	0
3 <i>Diffugia</i>	2	70	70	23	3	17	0	0	20	15	0	10
4 ROTIFERA	16	25	54	151	337	240	240	195	145	200	240	25
5 <i>Keratella</i>	16	25	33	90	144	43	95	30	5	0	0	0
6 <i>Brachionus</i>	0	0	3	7	47	0	0	0	0	0	0	0
7 <i>Lecane</i>	0	0	0	0	0	20	20	70	100	175	170	25
8 <i>Epiphanes</i>	0	0	10	17	3	13	35	75	20	0	0	0
9 <i>Asplanchna</i>	0	0	0	0	0	0	0	0	5	10	25	0
10 <i>Trichocerca</i>	0	0	8	23	60	120	55	5	0	0	20	0
11 <i>Proales</i>	0	0	0	7	83	37	35	0	0	0	0	0
12 <i>Polyarthra</i>	0	0	0	7	0	7	0	15	15	15	25	0
13 COPEPODA	4	3	19	93	167	240	85	80	165	150	70	70
14 <i>Cyclops</i>	4	3	11	43	107	187	80	75	165	150	70	70
15 <i>Diaptomus</i>	0	0	8	50	60	53	5	5	0	0	0	0
16 CLADOCERA <i>Bosmina</i>	16	10	0	17	40	7	70	75	130	40	135	75
Total	38	113	176	334	577	541	395	350	460	405	445	180

Table XIVb
Second annual cycle

Cladocera was represented by *Chydorus*, *Daphnia*, *Bosmina* and *Simocephalus*. *Chydorus*, *Chydorus* had an autumn peak with a total absence in spring and summer while *Daphnia* a winter peak with total absence during the remaining period of both the annual cycles. *Bosmina* had two peaks one in spring and one in late autumn with low abundances in summer during the entire period of investigation. *Simocephalus* was recorded only during the four months of March, April, May and June only during the first annual cycle with May and June showing the peaks recording 10 units/litre. *Chydorus*, *Daphnia* and *Bosmina* had their peaks in September (13 units/litre), December (46 units/litre) and November (50 units/litre) respectively during the first annual cycle while it was in October (30 units/litre), December (120 units/litre) and November (40 units/litre) respectively during the second annual cycle (Table-XVa,b).

When the major groups Protozoa, Rotifera, Copepoda and Cladocera and their seasonal trend of fluctuation was seen all had two peaks of abundance during each annual cycle-one in spring and the other in winter, with only Copepoda showing a tendency of increase also during the autumnal months (Table-XVa,b).

The above phenomena for the major groups was more or less consistent with their percentages of abundance among total zooplankton. This becomes obvious when the total zooplankton with spring and winter maxima for both the annual cycles was observed (Table-XVa,b; Fig. 12).

The last Station E was seen to possess qualitatively fewer representative genera of zooplankton in contrast to the other station. Though all the major groups were represented, yet Ostracoda was again seen to be absent.

Diffugia was the only genus recorded from Protozoa and occurred only in the spring and summer months with peaks in June (23 units/litre and 50 units/litre) during both the annual cycles.

Rotifera was represented by only five genera at this station. *Brachionus* and *Trichocerca* had summer peaks of abundances with winter minima. *Lecane*, *Epiphanes* and *Asplanchna* had winter peaks and summer minima during both the annual cycles. *Brachionus* and *Trichocerca* had their respective peaks in May (12 units/litre and 47 units/litre) and June (97 units/litre and 70 units/litre) respectively during both the annual cycles. *Lecane* had its peak in February during both the annual cycles with 20 units/litre and 80 units/litre respectively. *Epiphanes* and *Asplanchna* was the most abundant in the month of December during the first annual cycle recording 40 units/litre and 118 units/litre respectively while both the species showed their peaks simultaneously in the month of November with 35 units/litre and 100 units/litre respectively during the second annual cycle.

Copepoda was represented by *Cyclops* and *Diaptomus*. Both these had a bimodal peak in late spring or summer and late autumn or winter months during both the annual cycles. *Cyclops* was most abundant in December (293 units/litre) and November (320 units/litre) and *Diaptomus* was maximum in January (150 units/litre) and September (175 units/litre) in the first and second annual cycles respectively.

Cladocera represented by *Daphnia* at this station was recorded only during the winter months with peaks in January (987 units/litre) and November (9145 units/litre) during the first and second annual cycles respectively (Table-XVIa,b).

Table-XVa : Seasonal abundance of the major groups and genera of zooplankton at Station D.

First annual cycle

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA	0	0	18	24	0	0	0	0	20	60	52	10
2 <i>Centropyxis</i>	0	0	0	0	0	0	0	0	20	60	52	10
3 <i>Diffugia</i>	0	0	18	24	0	0	0	0	0	0	0	0
4 ROTIFERA	40	71	214	376	287	177	64	77	86	186	136	76
5 <i>Keratella</i>	0	0	28	258	160	147	40	67	0	0	0	0
6 <i>Lecane</i>	10	3	0	0	0	0	0	0	28	38	16	20
7 <i>Asplanchna</i>	20	20	3	0	0	0	0	7	40	100	78	20
8 <i>Trichocerca</i>	10	43	163	114	127	30	24	0	0	0	0	23
9 <i>Testudinella</i>	0	5	20	4	0	0	0	0	0	0	0	0
10 <i>Cephalodella</i>	0	0	0	0	0	0	0	3	0	28	0	0
11 <i>Polyarthra</i>	0	0	0	0	0	0	0	0	18	20	42	13
12 COPEPODA	40	41	41	94	43	50	72	190	176	186	199	80
13 <i>Cyclops</i>	30	31	28	59	30	50	70	190	171	186	194	73
14 <i>Diaptomus</i>	10	10	13	44	13	0	2	0	5	0	5	7
15 CLADOCERA	40	21	46	12	20	3	4	30	43	58	73	63
16 <i>Chydorus</i>	0	0	0	0	0	0	0	13	3	5	15	20
17 <i>Daphnia</i>	0	0	0	0	0	0	0	0	0	3	46	30
18 <i>Bosmina</i>	40	18	38	2	10	3	4	17	40	50	12	13
19 <i>Simocephalus</i>	0	3	8	10	10	0	0	0	0	0	0	0
Total	120	133	319	506	350	230	140	297	325	490	460	229

Table XVa

First annual cycle

Table-XVb: Seasonal abundance of the major groups and genera of zooplankton at Station D.*Second annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA	0	0	8	17	30	3	0	0	10	5	100	15
2 <i>Centropyxis</i>	0	0	0	0	0	0	0	0	10	5	100	15
3 <i>Diffugia</i>	0	0	8	17	30	3	0	0	0	0	0	0
4 ROTIFERA	184	131	226	173	273	126	85	105	185	215	315	130
5 <i>Keratella</i>	0	0	100	130	247	60	25	15	0	0	0	0
6 <i>Lecane</i>	0	0	0	0	0	0	0	5	40	75	55	30
7 <i>Asplanchna</i>	16	0	0	0	0	13	35	40	65	70	150	55
8 <i>Trichocerca</i>	144	100	118	43	23	50	25	0	0	0	0	0
9 <i>Testudinella</i>	24	23	0	0	3	0	0	0	0	0	0	30
10 <i>Cephalodella</i>	0	8	8	0	0	3	0	0	0	0	0	0
11 <i>Polyarthra</i>	0	0	0	0	0	0	0	45	80	70	110	15
12 COPEPODA	62	153	101	30	26	30	40	40	125	185	65	95
13 <i>Cyclops</i>	60	78	83	3	23	30	40	125	125	150	50	85
14 <i>Diaptomus</i>	2	75	18	27	3	0	0	0	0	5	15	10
15 CLADOCERA	15	35	3	7	13	7	0	35	40	65	170	125
16 <i>Chydorus</i>	0	0	0	0	0	0	0	0	30	15	15	0
17 <i>Daphnia</i>	3	0	0	0	0	0	0	0	0	10	120	105
18 <i>Bosmina</i>	12	35	3	7	13	7	0	35	10	40	35	25
19 <i>Simocephalus</i>	0	0	0	0	0	0	0	0	0	0	0	0
Total	261	319	338	227	342	166	125	180	360	470	650	365

Table XVb

Second annual cycle

Table-XVIa : Seasonal abundance of the major groups and genera of zooplankton at Station E.*First annual cycle*

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1 PROTOZOA Diffugia	0	3	15	22	3	23	0	0	0	0	0	0
2 ROTIFERA	50	43	33	62	107	10	38	10	8	86	166	110
3 <i>Brachionus</i>	0	0	0	12	10	0	0	0	0	0	0	0
4 <i>Lecane</i>	20	10	13	0	0	0	0	0	0	5	8	17
5 <i>Epiphanes</i>	20	3	0	0	0	0	0	0	0	8	40	24
6 <i>Asplanchna</i>	10	20	5	2	7	0	0	3	8	73	118	70
7 <i>Trichocerca</i>	0	10	15	48	97	10	38	7	0	0	0	0
8 COPEPODA	0	74	68	54	44	36	40	127	114	203	356	257
9 <i>Cyclops</i>	0	66	33	20	37	33	36	74	81	188	293	107
10 <i>Diaptomus</i>	0	8	35	34	7	3	4	53	53	15	63	150
11 CLADOCERA <i>Daphnia</i>	0	0	0	0	0	0	0	0	0	40	30	87
Total	50	120	116	138	154	69	78	137	122	329	552	454

Table XVIa
First annual cycle

Table-XVIIb : Seasonal abundance of the major groups and genera of zooplankton at Station E.

		<i>Second annual cycle</i>											
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1	PROTOZOA <i>Diffugia</i>	0	0	30	10	50	20	5	0	0	0	0	0
2	ROTIFERA	149	11	28	77	103	123	80	40	90	155	165	45
3	<i>Brachionus</i>	0	0	5	47	20	40	20	0	0	0	0	0
4	<i>Lecane</i>	80	3	0	0	0	7	0	10	0	20	70	20
5	<i>Epiphanes</i>	0	0	0	0	0	0	5	10	20	35	0	0
6	<i>Asplanchna</i>	66	3	3	27	13	13	5	10	70	100	95	25
7	<i>Trichocerca</i>	3	5	20	3	70	63	50	10	0	0	0	0
8	COPEPODA	52	58	46	30	34	100	130	310	385	325	80	30
9	<i>Cyclops</i>	28	40	46	27	17	90	60	135	300	320	80	30
10	<i>Diaptomus</i>	24	18	0	3	17	10	70	175	85	5	0	0
11	CLADOCERA <i>Daphnia</i>	24	0	0	0	0	0	0	25	100	145	120	100
Total		225	69	104	117	187	243	215	375	575	625	365	175

Table XVIIb

Second annual cycle

While dealing with the major groups of zooplankton and their seasonal fluctuation it was the same for Protozoa and Cladocera which had only one genus each. Rotifera and Copepoda had two peaks of abundance one in early summer and the other in winter with the latter showing an increase in the autumn month during the second annual cycle. The percentage of abundance of these major groups of the total zooplankton and their seasonal trend of fluctuation were more or less similar to that of their actual numbers (Table-XVIa,b; Fig. 12).

When the dynamics of the total plankton in this system was observed there was always a summer maxima confined to June and July and winter minima in January and February throughout the lake irrespective of the five stations undertaken (Table-XVIa,b).

Bacteria

Bacteria was recorded during the present investigation for the surface and bottom of all the stations and for the middle depths at the two deepest portions of the lake. A perusal of Figures 13 and 14 show some very obvious similar phenomena at all the stations. One of these is that the lower (middle and bottom) layers invariably recorded a maximum count and was so throughout the study period. The other was a clear rise of population during the spring months of April and May during both the annual cycles which was true not only at the different stations but also at the different depths throughout the study period and winter always recorded minimum.

In all the stations and at all depths, the total bacterial counts were found to reveal peaks in May during both the annual cycles except the middle layer of Station C, bottom layer of Station D, middle and bottom layers of Station E. The first of these revealed its peak in February and the rest of them in April during the first annual cycle. In the second annual cycle only the middle layer of Station E had its maximum in March (Fig. 13 and 14).

The surface waters of Station A had maximum values of total bacterial counts in May (363.1×10^5 and 130.0×10^5 counts) and minimum counts in December (1.1×10^5 and 4.5×10^5 counts) during the first and second annual cycles respectively. This condition coincided with the seasonal fluctuation of bacteria in the bottom layers of water at this station, where 943×10^5 and 167.2×10^5 counts were in May in the first and second annual cycles respectively with 3.88×10^5 and 4.8×10^5 as the minimum counts in December of both the annual cycles (Fig. 13).

Station B also had maxima in May for both the annual cycles at the surface and bottom layers. The surface recorded 38.4×10^5 and 103.5×10^5 counts, while the bottom had 40.3×10^5 and 119.8×10^5 counts respectively in the first and second annual cycles respectively. In the surface waters, the least counts was observed in November and December (1.8×10^5 counts) and November (1.8×10^5 counts) during the two annual cycles respectively. The bottom had a minima of 1.7×10^5 count in January and 4.0×10^5 counts in November respectively during the first and second annual cycles (Fig. 13).

At station C, the surface waters revealed a peak of abundance in May in both the annual cycles representing 34.8×10^5 and 62.3×10^5 counts and recorded minimal counts of 2.0×10^5 in January and 2.3×10^5 in November during the first and second annual cycles respectively. May recorded the

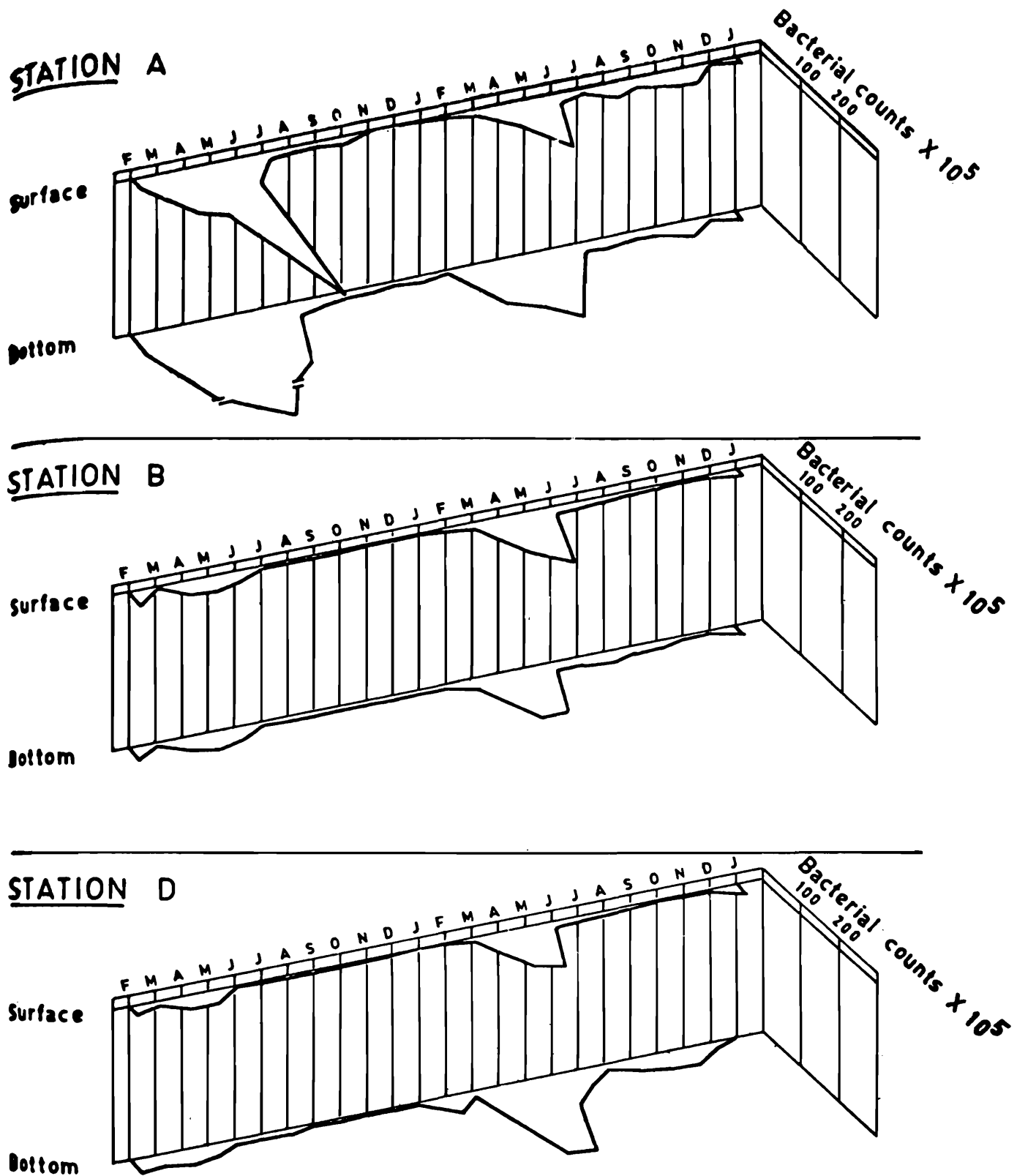
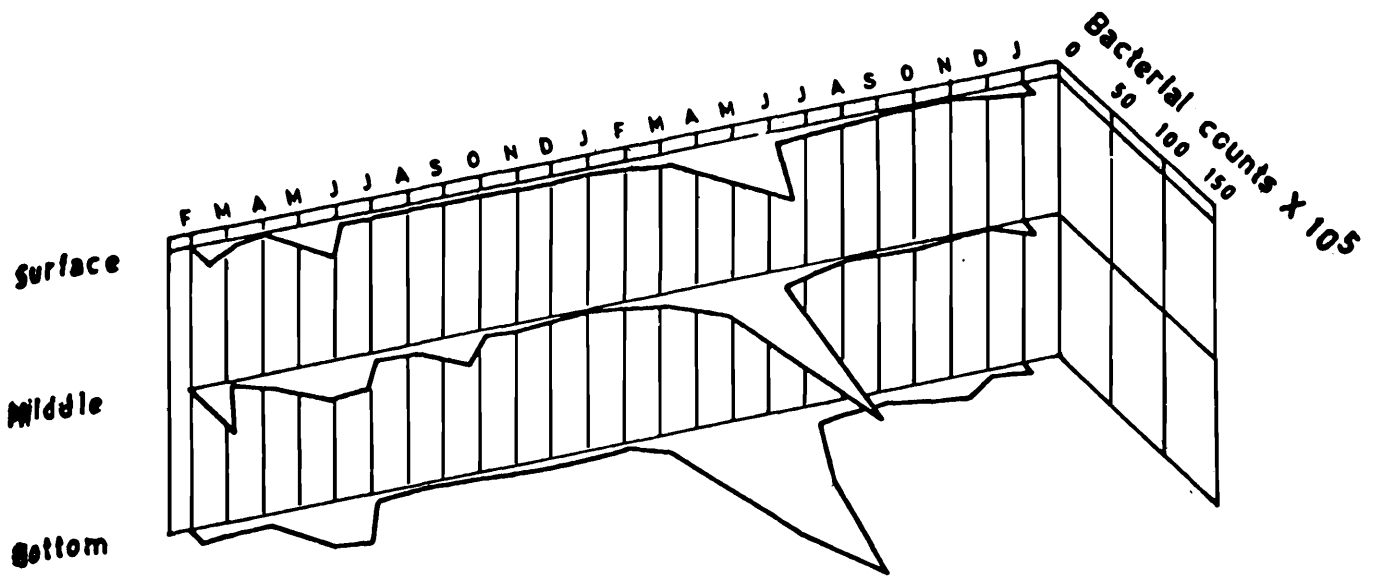


Fig. 13 : Showing the seasonal fluctuations of the heterotrophic bacterial counts (units/m³) at the surface and bottom layers of water at Stations A, B and D.

STATION C



STATION E

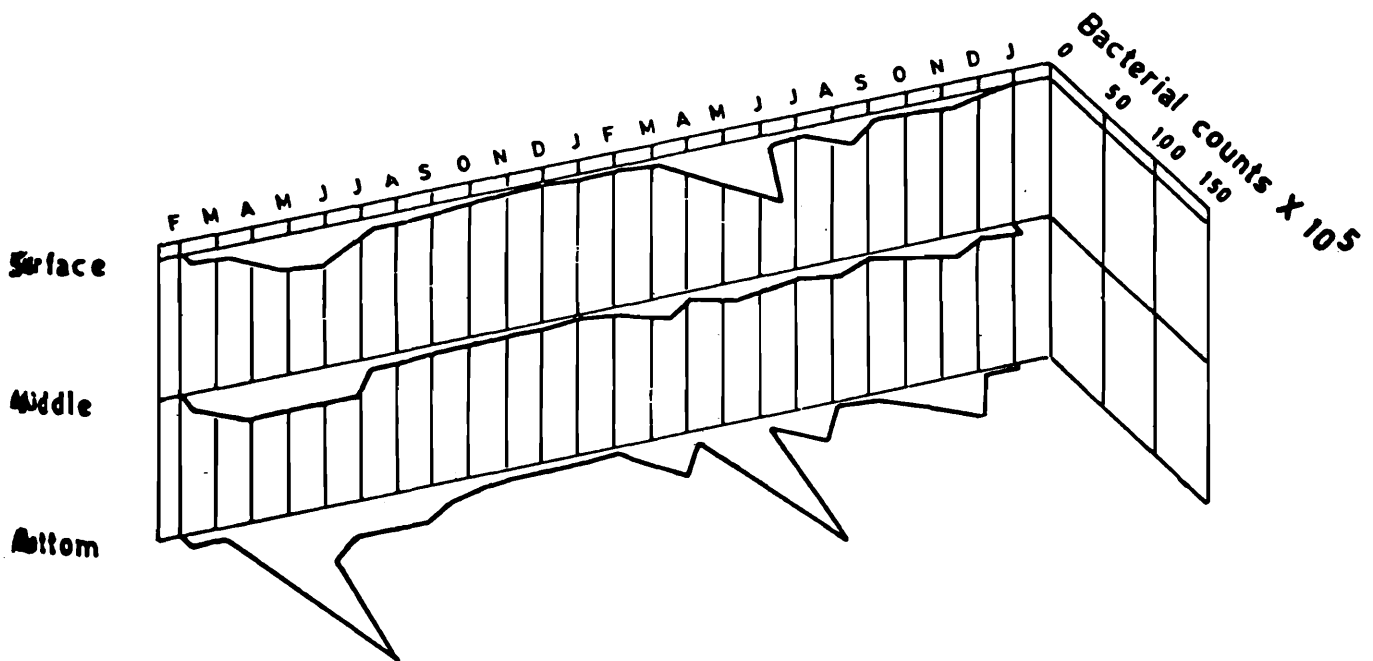


Fig. 14. : Showing the seasonal fluctuations of the heterotrophic bacterial counts (units/ml) at the surface, middle and bottom layers of water at Stations C and E.

maximum for the bottom layer with 35.0×10^5 and 153.4×10^5 counts during the first and second annual cycles respectively, while the minimum was observed in October (3.5×10^5 counts) and September (2.2×10^5 counts) during the first and second annual cycles respectively. The middle layer, however, had the maximal counts of bacteria in February (44.3×10^5) during the first and in May (145.6×10^5) during the second annual cycles with the least recorded in December of both the annual cycles representing 2.9×10^5 and 0.4×10^5 counts respectively (Fig. 14).

Station D also revealed maximum in its surface and bottom samples, in May in both the annual cycles except the bottom layer in the first annual cycle where the peak was in April. The counts of total bacteria at the surface, during both the annual cycles were 36.28×10^5 and 101.61×10^5 counts respectively with the peak value of the bottom layer recording 194.98×10^4 counts for the second annual cycle. In the first, the bottom had a maximum of 40.62×10^5 counts in the month of April. The minimum, for surface waters was recorded in January (1.68×10^5 counts) and February (2.90×10^5 counts) while the bottom layers had a minimum in November (8.64×10^5 counts) and in January (0.54×10^5 counts) during the first and second annual cycles respectively (Fig. 13).

At Station E, the surface waters revealed a peak for total bacteria in May recording 34.9×10^5 and 53.0×10^5 counts and minimum was in November (3.8×10^5 counts) and January (0.54×10^5 counts) during the first and second annual cycles respectively. The middle layer, however, had maximum in March (33.4×10^5 counts and 19.5×10^5 counts) of the first and second annual cycles, whereas, their respective minima was in January (2.9×10^5 counts) and September (2.2×10^5 counts) respectively. April and May had maximum for the bottom layers at this station revealing 140.1×10^5 and 120.0×10^5 counts respectively during the first and second annual cycles with corresponding minimum values in January recording 4.4×10^5 and 3.0×10^5 counts for both the annual cycles (Fig. 14).

Primary Production

On an overall observation it was seen that with increase in depth the values of Gross primary productivity and Net primary productivity decreased. This was quite obvious at the two deepest portions of the lake at stations C and E. At the other stations, A, B and D where only the surface and bottom were analysed, a decrease though seen for the bottom layers was not as significant as in other two deep stations.

Station A revealed peak values of Net primary productivity during March, August and October for both the layers (Surface and bottom) during the first annual cycle while during the second annual cycle, the surface waters revealed peaks in March, May and July ($876 \text{ mg C/M}^3/\text{day}$) while the bottom showed in May ($500 \text{ mg C/M}^3/\text{day}$), November and December. However, the peak values were seen in October ($497 \text{ mg C/M}^3/\text{day}$) and August ($390 \text{ mg C/M}^3/\text{day}$) in the first annual cycle for the surface and bottom layers respectively while it was July and May during the second annual cycle. The minimum value at this station was in May ($90 \text{ mg C/M}^3/\text{day}$) and August ($75 \text{ mg C/M}^3/\text{day}$) for the surface during the first and second annual cycles respectively while it was in February, June and September for the first annual cycle and September again during the second annual cycle for the bottom.

At Station B, November had the peak value in the first annual cycle at both the layers though May and June also revealed a rise for the surface waters and May and September for the bottom. July recorded the highest peak at both the layers during second annual cycle. The minimum recorded at this station was in February during the first annual cycle for both the layers recording nil values while December, January for the upper layer and October and December for the lower layer revealed values of a fall during the first annual cycle. The second annual cycle for the surface waters showed January as the minimum with nil value and similarly in December for the bottom. In addition the month of April during the second annual cycle dropped to low levels for the bottom layer. The surface layer of the Station showed its peaks of Net primary productivity in the months of November ($347 \text{ mg C/M}^3/\text{day}$) and July ($275 \text{ mg C/M}^3/\text{day}$) and its minimum was observed in February and January, both recording nil values during the first and second annual cycles respectively. The bottom layer had its maxima in November ($310 \text{ mg C/M}^3/\text{day}$) and July ($626 \text{ mg C/M}^3/\text{day}$) and minima during the months of February and December recording nil both during the first and second annual cycles respectively.

At Station C the peak values of Net primary productivity during the first annual cycle was seen to be in November for surface, 1.0 m and 1.5 m depth, while it was August for 0.5 m depth, February for 2.0 m depth and September for 2.5 m depth. Further the seasonal trend of fluctuation during the first annual cycle also revealed peaks of lower magnitude in December for 0.5 m depth, September for 1.0 m depth, May, August and January for 1.5 m depth, April, August and November for 2.0 m depth and February and June for 2.5m depth. The second annual cycle revealed July as peak values only for surface and 0.5 m depth, while it was November for 1.0 m and 1.5 m depth, June for 2.0 m depth and January for 2.5 m depth. In addition, a trend towards the increase was also seen in the months of April and January for surface, April and November for 0.5 m depth, January for 1.0 m depth, April and January for 1.5 m depth, January for 2.0 m depth and June for 2.5 m depth. During the first annual cycle at this Station C, the minimum values recorded for Net primary productivity were January, October and February for surface 0.5 m, 1.0 m and 1.5 m depths respectively, while June, December and January was for 2.0 m depth and August, December and January for 2.5 m depth at this depth recording nil values. During the same first annual cycle in addition to these lowest values July and October for 0.5 m depth and 1.0 m depth and fluctuated downwards and June, September and December for 2.0 m depth and March for 2.5 m depth. During the second annual cycle at this Station C, March and May for surface, 0.5 m depth and 1.0 m depth respectively, while July and December for 1.5 m depth and 1.0 m depth September to December for 2.0 m depth, February, July, September to December for 2.5 m depths during these months recorded nil values. The month of November during the first annual cycle revealed maxima for surface, 1.0 m and 1.5 m depth recording $300 \text{ mg C/M}^3/\text{day}$, $235 \text{ mg C/M}^3/\text{day}$ and $141 \text{ mg C/M}^3/\text{day}$), April ($244 \text{ mg C/M}^3/\text{day}$) and April ($272 \text{ mg C/M}^3/\text{day}$), respectively during the second annual cycle. August, February and September were the months revealing the peak values for surface, 2.0 m and 2.5 m depths recording 255, 225 and $275 \text{ mg C/M}^3/\text{day}$ respectively during the first annual cycle. During the second annual cycle, the months of July ($250 \text{ mg C/M}^3/\text{day}$), June ($275 \text{ mg C/M}^3/\text{day}$) and June ($150 \text{ mg C/M}^3/\text{day}$) respectively had their peaks. The minimum values of Net primary productivity for surface and 0.5 m depth were observed in October in the first annual cycle recording 113 and $19 \text{ mg C/M}^3/\text{day}$ respectively while March ($38 \text{ mg C/M}^3/\text{day}$) and February ($0 \text{ mg C/M}^3/\text{day}$) recorded minima for 1.0 m and 1.5 m depth

respectively. July, December and January recorded the same minimal value of 25 mg C/M³/day for 2.0 m depth while January recorded nil for 2.5 m depth during the first annual cycle. March, September and May represented the minimal Net primary production for surface, 0.5 m and 1.0 m depth with values of 75, 113 and 25 mg C/M³/day respectively during the second annual cycle. July and December had nil Net primary productivity at 1.5 m depth. Similarly March, July, September, October, November, December and January recorded nil for 2.0 m depth while February, July, September, October, November and December recorded nil for 2.5 m depth during the second annual cycle.

The next Station D where only the surface and bottom was analysed, revealed November as peak of Net primary productivity recording 300 mg C/M³/day in the first annual cycle with smaller peaks rising in March and August for the surface and it was October (432 mg C/M³/day) for the bottom layers with May and August similarly revealing smaller peaks. During the second annual cycle July with 400 mg C/M³/day and January with 525 mg C/M³/day showed the maximum peaks for the surface and bottom layers respectively. The months of March, September, November, and January had small increases for the surface while February, July and October were the months for the bottom. The minimum Net primary productivity for this station was in December recording nil during the first annual cycle for both surface and bottom layers while it was May (75 mg C/M³/day) during the second annual cycle for surface layers, while the bottom layers recorded nil during June and December.

The last Station E during the first annual cycle recorded maximum values of Net primary productivity in July at 0.5m, 1.0 m, 1.5 m, 2.0 m, 2.5 m, 3.5 m, 4.0 m and 4.5 m depths recording 450 mg C/M³/day, 507 mg C/M³/day, 770 mg C/M³/day, 488 mg C/M³/day, 657 mg C/M³/day, 319 mg C/M³/day, 188 mg C/M³/day respectively, while it was February (450 mg C/M³/day) for surface, June (375 mg C/M³/day) for 3.0 m depth, April (262 mg C/M³/day) for 5.0 m depth and December (200 mg C/M³/day) for 5.5 m depth. In addition smaller peaks were seen in June and October for surface, October for 0.5 m depth, February for 1.0 m depth, July for 3.0 m depth, March for 4.0 m, 4.5 m, 5.5 m depths and October for 5.0 m depth. During the second annual cycle, the peaks of maximum record was in the month of November as seen at surface, 0.5 m and 1.0 m depth recording 488, 563 and 488 mg C/M³/day respectively while it was January for 1.5 m, 2.0 m and 2.5 m depths with the values of 413, 263 and 169 mg C/M³/day respectively. The month of April showed the peak values for 4.0 m, 5.0 m and 5.5 m depths recording 244, 150 and 263 mg C/M³/day respectively. The months of May, June and March showed the maxima for 3.0 m, 3.5 m and 4.5 m depths recording the values of 375, 325 and 225 mg C/M³/day respectively. Further, smaller peaks of abundance was seen during March and July at surface, March, July and January for 0.5 m depth, March and July for 1.0 m depth, April, June and September and November at 1.5 m depth, April, June and September at 2.0 m depth. Similarly September, June and April were seen at 2.5 m, 4.0 m and 4.5 m depths respectively during the second annual cycle. The minimal values at this Station E was seen to record nil values below the 2.0 m depths. This was seen during both the annual cycles especially in the month of February during the first annual cycle and June to September and in the winter months. However, the month of April recorded minimum for surface (38 mg C/M³/day) and 1.5 m depth (75 mg C/M³/day), while it was September for 0.5 m depth (50 mg C/M³/day). The months of February for 2.0 m and 3.0 m depths, February, June, November and January for 2.5 m depth, February, June,

September to November for 3.5 m depth, February, June, September to December and January for 4.0 m depth, February, June, September to December for 4.5 m depth, February to September, November and December for 5.0 m depth and February to October for 5.5 m depth recorded nil values of Net primary productivity which also indicated the minimum values for the second annual cycle. Similarly August recorded minimum for surface, 0.5 m and 1.5 m depth during the second annual cycle recording 113, 113 and 38 mg C/M³/day respectively, while it was February for 1.0 m depth (90 mg C/M³/day). The second annual cycle also recorded nil for depths below 2.0 m depth and this was seen to be mostly in the winter months and with increase in depth, the nil values were recorded starting from July and even from May for the bottom most layer. The months which recorded the nil values that also represented the minima for the whole annual cycle simultaneously with their depths are May and October for 2.0 m depth, May and December for 2.5 m depth, October-December for 3.0 m depth, February, August and January for 3.5 m depth, February and July-January for 4.0 m depth, February, May and July-January for 4.5 m depth, February and July- January for 5.0 m depth and May-January for 5.5 m depth.

It was felt that the Gross primary productivity and their values over the season would help in a better understanding of the biota in this system. Irrespective of the stations and depths, it was seen that higher values were recorded mostly during the spring and summer months while it was autumn and winter months that recorded minimum. A trend in the reverse was seen in the second annual cycle in the deeper portions of the lake.

Station A recorded June peaks for both the surface (1326 mg C/M³/day) and bottom waters (1176 mg C/M³/day) during the first annual cycle though it was July (2252 mg C/M³/day) for the surface and March (1201 mg C/M³/day) for the bottom during the second annual cycle. February, April and October in addition showed an increasing trend for the surface waters while it was February and March for the bottom waters at this Station. Similarly, March and May for surface, May and November for the bottom where increase in values though of lower magnitude during the second annual cycle was observed. The minimum however was observed in the months of January and April for surface and bottom recording 249 and 178 mg C/M³/day respectively during the first and August (225 mg C/M³/day) and February (275 mg C/M³/day) respectively during the second annual cycle. (Fig. 15).

Station B, the maximum values of Gross primary productivity occurred more or less during the same seasons with slight variations in the months. It was February (1051 mg C/M³/day), June, August and November for the surface and April, June (775 mg C/M³/day), August and November (750 mg C/M³/day) for the bottom that was maximum during the first annual cycle at this station. July recorded peaks at both the layers during both the annual cycles recording 1201 and 1351 mg C/M³/day respectively. However March, May and November for the surface and March for the bottom also recorded higher values though not as in July during the second annual cycle. The minimum recorded for the surface layer was again seen to be the winter months of December and January (300 mg C/M³/day) and January (37 mg C/M³/day) during the first and second annual cycles respectively. The bottom layer recorded the least in the month of October (206 mg C/M³/day) during the first annual cycle and January (37 mg C/M³/day) in the second annual cycle. (Fig. 15)

Station C with its six depths was seen to have a regular pattern at least for the first annual cycle for maximal peaks. At the various depths one common factor was that the months of February, June

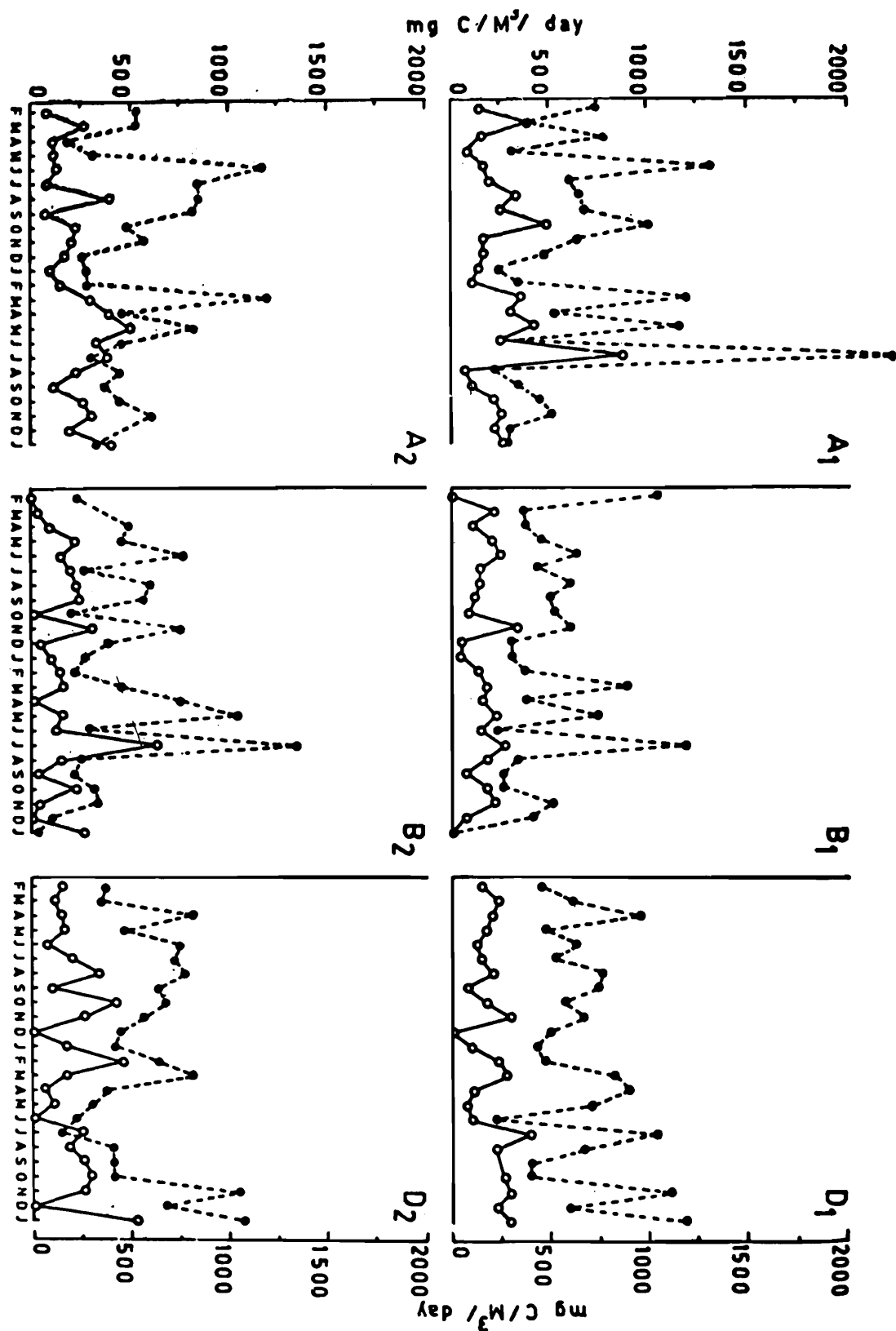


Fig. 15 : Showing the magnitude of fluctuations seasonally of Gross primary productivity (● - - ●) and Net primary productivity (O — O) at the surface and bottom water layers in the three shallow stations A, B and D.

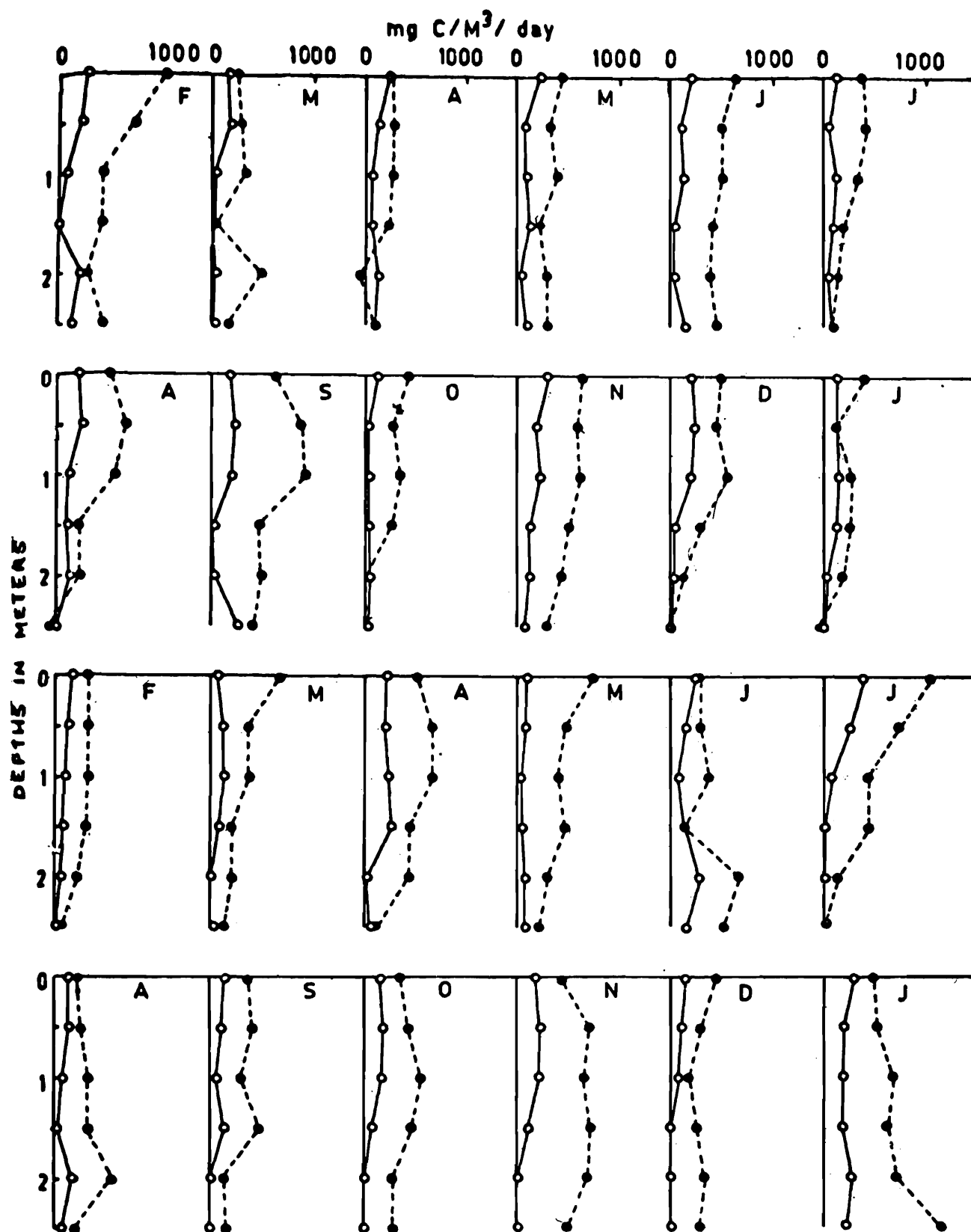


Fig. 16 : Showing the magnitude of fluctuations seasonally of Gross primary productivity (● - - - ●) and Net primary productivity (O—O) along with their vertical profile at Station C.

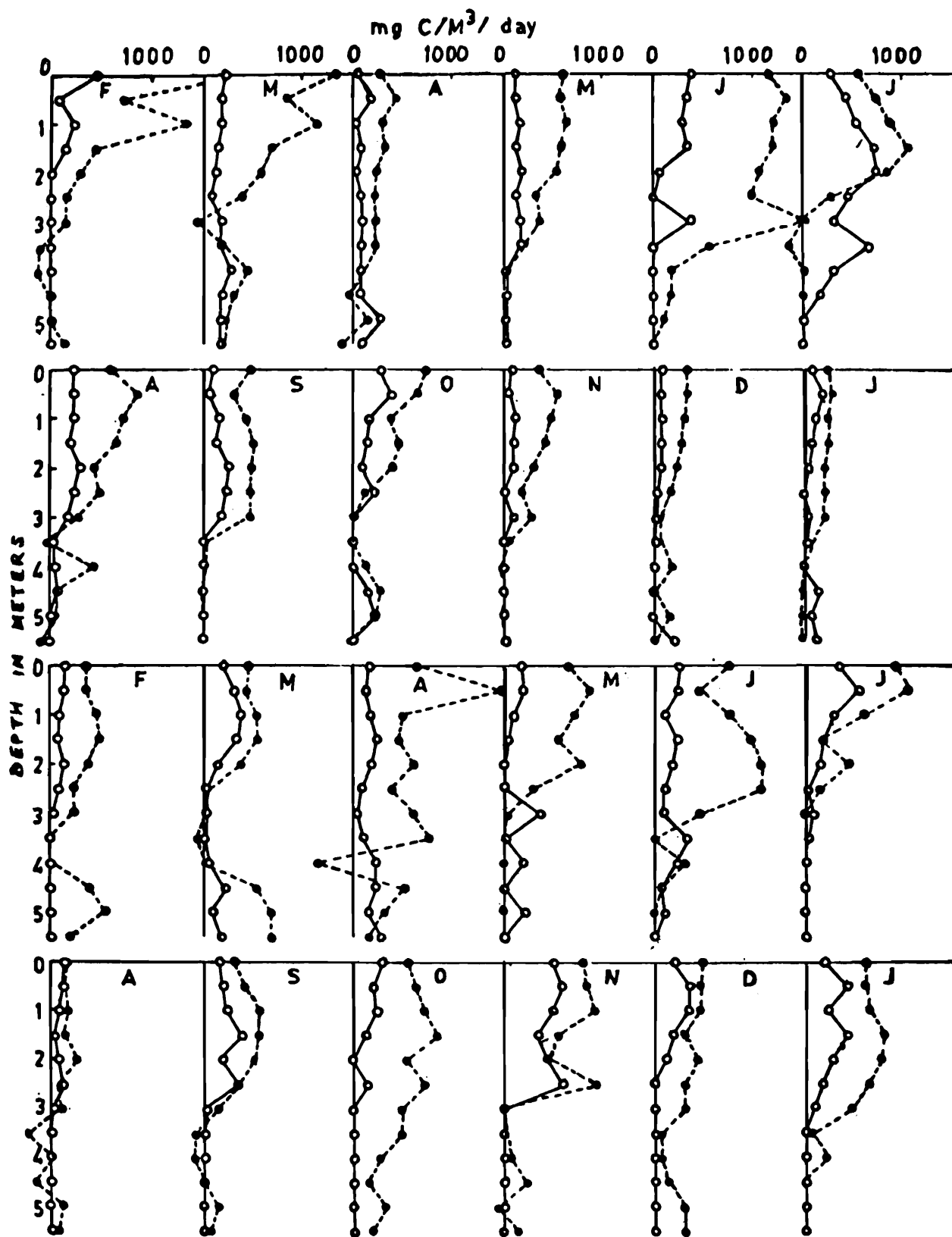


Fig. 17 : Showing the magnitude of fluctuation of Gross primary productivity (● - - - ●) and Net primary productivity (O — O) along with their vertical profile at Station E.

and November had peaks and in September for most depths. However, the peaks were in February for surface, September for 0.5 m depth, September for 1.0 m depth, November for 1.5 m depth, September for 2.0 m depth and February and June for 2.5 m depth recording 1051, 875, 923, 516, 499 and 450 mg C/M³/day respectively during the first annual cycle. Similarly during the second annual cycle the peaks were during the spring, summer and winter months like July (1051 mg C/M³/day) for surface, July (750 mg C/M³/day) for 0.5 m depth, April, November and January (675 mg C/M³/day) for 1.0m depth, January (600 mg C/M³/day) for 1.5 m depth, January (713 mg C/M³/day) for 2.0 m depth and January (1126 mg C/M³/day) for 2.5 m depth during the second annual cycle. The minimum recorded were during the spring for the first annual cycle for the various depths at this Station. The months of March, January, March, October and December showed minimal values of Gross primary productivity for surface, 0.5 m, 1.0 m, 1.5 m, 2.0 m, 2.5 m depths recording 243, 124, 275, 56, 0 and 0 mg C/M³/day respectively during the first annual cycle. In the next annual cycle, the month of August showed peaks for surface and 0.5 m depth recording 225 and 262 mg C/M³/day respectively while the months of December, June, September, July for 1.0 m, 1.5 m, 2.0 m, 2.5 m depths with the values of 187, 150 and 0 mg C/M³/day respectively. The two bottom-most layers recorded minus values during April for 2.0 m depth and August January for 2.5 m depth for the first annual cycle, while such negative quantities were not revealed during the second annual cycle for these two layers.(Fig. 16.)

At Station D the maxima occurred during April at both surface and bottom layers during the first annual cycle recording 957 and 844 mg C/M³/day respectively, while it was in January with 1201 and 1088 mg C/M³/day respectively during the second annual cycle. The minimum recorded at this station was January (425 mg C/M³/day) and March 356 mg C/M³/day for surface and bottom respectively during the first annual cycle while it was June (225 mg C/M³/day) and July (150 mg C/M³/day) respectively during the second annual cycle.(Fig. 15).

The last station E with its twelve depths revealed more or less constant phenomena of a spring and summer peak at all the depths during both the annual cycles. this was very true beyond the depth of 1.5 m depth as their surface layers in addition recorded peaks in late winter (February) or early winter (November) for surface and 1.0 m depth respectively recording 1876 and 900 mg C/M³/day during the first and second annual cycles respectively. June revealed peaks for 0.5 m, 1.5 m, 2.0 m, 2.5 m, 2.0 m and 3.5 m depths recording 1326, 1201, 1076, 975, 1551 and 575 mg C/M³/day respectively during the first annual cycle. April had peak values for 0.5 m, 3.0 m and 3.5 m depths recording 1501, 600 and 750 mg C/M³/day respectively while it was June for 1.5 m, 2.0 m, 2.5 m and 4.0 m depths with 960, 1051, 1051 and 300 mg C/M³/day respectively for the second annual cycle. During both the annual cycles March revealed peak for 4.0 m, 4.5 m, 5.0 m and 5.5 m depths except for 4.0 m depth which showed June as its peak during the second annual cycle. The values of Gross primary productivity in the first annual cycle, in the same sequence was 450, 300, 243 and 225 mg C/M³/day respectively and 4.5 m, 5.0 m and 5.5 m depths had their respective values as 525, 675 and 675 mg C/M³/day respectively during the second annual cycle. The minimum values at this station at all the depths during the first annual cycle occurred during the winter months while it was late summer or early autumn during the first and second annual cycles at the various depths. Gross primary productivity was minimum in the month of January for surface, 0.5 m, 1.0 m, 1.5 m and 2.0 m

depths with their values of 249, 275, 249, 249 and 200 mg C/M³/day respectively during the first annual cycle while August for the second recording 187, 150, 187, 150 and 262 mg C/M³/day respectively during the second annual cycle. 2.5 m depth had a minima in October (112 mg C/M³/day) and March and August (75 mg C/M³/day) for the first and second annual cycles respectively. The depth beyond 3.0 m showed not only nil values but also negative values of Gross primary production for most parts of the year during both the annual cycles. (Fig. 17).

DISCUSSION

Physico-chemical factors

Under the physical and chemical aspects of this lacustrine system a total of fifteen parameters were undertaken for seasonal studies for two annual cycles. Of these rainfall, maximum-minimum temperature were seen as general meteorological phenomena affecting the system either directly or indirectly. Broadly, temperature of the air and water, transparency were the physical factors with pH and specific conductivity to see to the buffering capability and the ionic mobilities respectively in these waters while oxygen and carbon dioxide were the gases undertaken, the latter reflecting on the carbonate molecules in terms of alkalinity and finally Phosphate, Nitrate, Silicate, Calcium and Magnesium were the nutrients undertaken.

Irrespective of the different stations at the lake and also the depths, all the factors except one had a summer maxima and a winter minima. Oxygen was that which possessed a trend in the reverse exhibiting a winter maxima and either an early autumn or late summer minima.

Atmospheric temperature was seen to play a direct effect on the water temperature and in part the temperature of the water at various depths. This effect on the water temperature did seem to affect the mixing of lake where stratifications clearly developed during summer and winter with a spring and autumn overturn. The system therefore could be dimictic, though the major overturn is during spring.

A clear thermal stratification was established and obvious in the deepest portion of the lake. This was unique inspite of the relatively shallow basin as has been presented by Welch (1952) and Yaron (1964) who have shown a clear thermal stratification even in ponds of one-tenth the depth of the present system. Ganapati (1960) while reviewing the thermal stratification of tropical waters of South India has observed that this phenomena was more stable in tropics as its co-ordinated with changes in density of waters. Ruttner (1953) has however observed that tropical waters were not characterized by the large differences between surface and bottom temperatures but by the high temperatures. This will therefore apply in the present study indicating a warm dimictic or unstable thermal stratification. The presence of a definite thermocline, however, is not clear cut. Hence, for all practical purposes it does not reveal a stratification during certain parts of the year and being homothermal during other months yet the intricate relationship would have been better understood only if observed with diurnal periodicity. Moreover the relationship of the morphometry of the lake to its water temperature as in the present study, of a large area with relatively shallow depth, being affected by strong wind disturbing the whole water column does not help in true thermal stratification. It was therefore, the uptake of heat per unit area entering the lake which got immediately disrupted by the structure of the basin and the overlying effect of wind.

Transparency in these waters during June-July and January was maximum while the spring months of March-April being the minimum. This revealed more or less a warm monomictic system with a spring overturn though the clear dimictic picture did not evolve by this factor alone. It is known that low values were primarily due to turbidity during monsoon and in lakes as the present one due to suspended particles carried by the inflow from the catchment area especially at higher altitudes. The values, however, are indicative of eutrophication irrespective of the stations or depths. These have been very well documented by Löffler (1969) ; Rodhe *et al*, (1966) in mountain and valley lakes, respectively, while Kant and Anand (1968) attributed monsoon rains to lower secchi disc values.

Rainfall as the chief source of turbidity in waters affecting various phenomena is of overriding importance. Not only does it help in the enrichment of an aquatic system after it reached the earth but now it is recognised that the direct atmospheric loading may provide a significant proportion of total inputs of major ions and nutrients (Likens *et al*, 1977). The most important variable in the climate within the tropics is rainfall, and the nutrient status is reflected by the seasonal flush of rains. Hence not only is precipitation important but could affect and have detrimental effects on poorly buffered lake systems (Dillon *et al*, 1978)

Specific conductivity has usually been taken up as an indicator for assessing the trophic status of lakes. In the present investigation the values were indicative of meso-eutrophic situation (Vollenweider and Frei, 1953). Further, the increase from top to bottom layers with maximum showing in the spring months indicated its direct relationship to the different nutrients with a fall during winter.

The importance of pH is useful for determining the hardness and softness of the water. However, the most important aspect of pH is that it varies with the concentration of carbon dioxide. The changes in one reflecting the other is a non-linearity in the relationships between the two parameters (Verduin, 1956; Beyers and Odum, 1959 and 1960; Lyman, 1961). The present study revealed the usual summer maxima and winter minima and the values decreased with depth. This is understandable as not only pH and carbon dioxide are interrelated but a more or less a direct relationship exists between pH and oxygen. The values of pH in the present study was towards the acidic range preventing thereby a total buffering in the system. The characteristic eutrophic natural system revealing higher pH values was not seen in the present study and the acidic nature of the lake may be attributed to inflow, of surface runoff from the pine litter which is highly acidic.

Dissolved oxygen showed a very clear picture of Clinograde. This pronounced difference in the oxygen content of surface and bottom layers is lent support because of the demand of oxygen in the process of decomposition and respiration at the bottom than at the surface. The oxygen deficit at the bottom is a characteristic feature of a productive lake (Sreenivasan, 1970; Timms, 1970). The increase in oxygen during the winter months could be attributed to low temperature, while the drop during the summer months or early autumn may be due to the lack of prolific growth of phytoplankton (Sreenivasan, 1966; Sahai and Sinha, 1969). It is assumed that the amount of seston sinking into the hypolimnion is proportional to that in the epilimnion. This decrease in eutrophic lakes falls in its rate of depletion during the later stages of summer stagnation (Hutchinson, 1938 and Hargave, 1972). If this relation exists then perhaps in future a series of models could be constructed that would relate hypolimnetic deficit of oxygen to other parameters. This was seen to be feasible from the present investigation.

The free carbon dioxide in waters form carbonic acid (H_2CO_3) resulting a change in pH (Gonzalves and Joshi, 1946). In the present study this factor having a summer maxima and winter minima throughout the lake irrespective of the stations and depths reveals a clear increase in its value as one goes from surface waters to bottom layers. The increase in the summer months could be attributed to the growth rate of phytoplankton as far as the surface waters are concerned. The bottom layers increase, probably reflects the respiration at the decomposition levels. These criteria relating to its depletion in the epilimnion and build up in the hypolimnion was in concordance with oxygen values as mentioned earlier, both revealing a mirror image of the other.

The importance of calcium carbonate precipitation in any lake metabolism has been elaborated by several workers (Ohle, 1952; Hutchinson, 1957; Wetzel and Allen, 1972). As alkalinity recorded in the present investigation it was seen to have maximum peaks in summer and late autumn and minimum in winter. This accumulation of larger quantities of bicarbonates during summer may be due to the liberation of carbon dioxide in the process of decomposition of bottom deposits, which possibly resulted in the conversion of insoluble carbonates of calcium into soluble bicarbonates. This was seen in the present study, where alkalinity also increased with depth and maximum values were recorded in the deepest portion of the lake (Ruttner, 1953). The dilution of alkalinity with the advent of rains (Chakraborty *et al*, 1959; Goldman and Wetzel, 1963; Sreenivasan, 1966) and its increase with decrease in water levels (Subba Rao and Govind, 1964) is a feature displayed in the present investigation also. Moreover, it is possible that the present lake water having moderate alkalinity indicated a chemical thermodynamic approach for the description of a solution-phase composition (Davies, 1962; Nancollas, 1966).

Among the major nutrients the importance of phosphates in lakes is well documented (Stewart and Rohlich, 1967; Vollenweider, 1968; Shanon and Brezonick, 1972; Golterman, 1975). In lake waters the dissolved inorganic phosphorus is the form available for algal growth. In addition the net amount in the sediments would include allochthonous material in the lake water. In the present investigation phosphates were seen to increase during the early summer months and decreased during winter. They also increased from the surface to the bottom layers and very significant in the deepest portion of the lake. In the present system therefore the concentration of this nutrient was controlled by the properties of sediments. Movement to and from the sediments occurred only after the sediment has been sufficiently reduced through energy input of sedimenting organic material. In the present investigation these occurred in the summer period, while in winter the net amount of movement was towards the sediments (Golterman, *et al*, 1969; Fitzgerald, 1970). The values of phosphates though comparatively less as one would expect in productive waters could be attributed to the seston releasing not only an element considered as a limiting nutrient but also an organic phosphorus compound (Rigler, 1972). This quixotic behaviour is unprofitable for the organisms and perhaps is a stress response to high biomass and/or low phosphate concentrations. This phenomena gets clarified when it is understood that the dissolved concentrations of nutrients is not a measure of metabolic activity but rather a representation of an equilibrium with the reserve in the sediments.

Nitrate is indicative of nitrogen richness in an aquatic system primarily attributed to animal origin (Thresh *et al*, 1944). The phenomena is emphasized by the fact that dead organic matter decomposes in

water to form complex proteins, that get converted to nitrogenous organic matter and finally into nitrates by bacterial activity (Zafar, 1964). Inputs into a lake system in the biologically usable form could possibly occur through influents, from precipitation, as groundwater or through biological nitrogen-fixation. Whatever the case may be the importance lies in the fact of regeneration particularly in the epilimnion for sustained algal growth (Kleerckoper, 1953; Lawacz, 1969). In the present investigation nitrate like phosphate showed early summer maxima with winter minima and certainly an increase in its values in the bottom layers as compared to the surface of the water column. Therefore, in such stratified systems the internal nutrient load due to bottom regeneration competes with that brought in from the drainage areas, though the qualitative composition of the internal load plays a major role (Bachofen, 1960; Burns and Ross, 1971). In the present investigation the low average values of nitrates could be attributable to the insufficiency in the system to oxidise biologically the ammonia to increase the nitrate levels. Usually low nitrate levels is recorded in oxygen deficit tropical waters (Butcher *et al*, 1927 and 1928; Berg, 1943; Ganapati, 1943 and Zafar, 1964). Further, increased nitrate metabolism due to seasonal increase in standing crops of autotrophic organisms has been determined to cause a decreased nitrogen (Taylor and Welch, 1970).

Silicon is usually present as a form of hydrated amorphous silicon or polymerised silicic acid, but once it is solidified and deposited, the amorphous silicon does not act as a source supply during deficiency (Lewin, 1961). However, as soon as the cells particularly of diatoms, die, silicic acid begins to leach out. In the present investigation silicate had a late summer peak of maximum values with winter minima. Its values increased from top to the bottom. This vertical distribution with steady increase in its concentration below the trophogenic zone and strong gradient near the sediment water interphase was observed at all the stations. This has been reported earlier even in temperate lakes (Mortonson and Brooks, 1976). Zafar (1967) and Singh (1960) reported that silica did not become a limiting factor in their studies. However, some measure of silica demand could be used as an index of increasing environmental enrichment on eutrophication. From the present study it was very clear that the rate of dissolved silica released from the bottom muds was much greater during the warmer temperature (Tessenow, 1966), though dissolution of this nutrient was greatly accelerated by the disruption of diatom frustules by zooplankton (Beklemishev, 1961 and Tessenow, 1966). Such differences could possibly be explained by the assumption of a "functional" and "stored" silicon having different mineralization times (Golterman, 1960).

Calcium and Magnesium which constitute the most abundant ions in freshwaters, of which calcium is more abundant. Calcium is required usually as a micronutrient for algae though it is also known to be a nutrient essential for the metabolism of higher plants. Magnesium is very important as it forms a major component of the chlorophyll molecule. In the present study the values of Calcium and Magnesium were seen to be low. Both these factors did reveal a summer maxima and winter minima with an increase with depth. Low concentration of Calcium could be attributed to its being taken up by the sediments. This ion has earlier been shown to possess the greatest absorbed concentrations in the sediments (Hongve, 1978). This uptake is known to take place as exchange with hydrogen ion revealing an acidifying effect on the lake. The process depends upon the concentration of Calcium ion and Hydrogen ion both in the adsorbed and dissolved state with the probability of a reversal with increase in acidity (Hongve, 1978). This aspect was very clearly seen in the present

investigation where acidity increased with depth and so did Calcium. Magnesium values obtained in the present study was very low, which could be termed poor (Ohle, 1934) yet a true soft water terminology could not be attributed to the present system as Calcium increases moderately in the hypolimnion during the usual stratification process. A similar effect was seen for Magnesium. These two ions is an index playing an important role in antagonising the toxic effects of various ions and in neutralising excess acid produced (Munawar, 1970).

On general analysis of these physico-chemical factors one could attribute that a number of limiting factors can operate in rapid sequence but their effects need not be synchronous with the sequence of oscillations of the organisms growth response times. This aspect could be attributed to the present system where increased Hydrogen ion concentration during the warmer months along with spring blooms would increase the carbon dioxide concentration incident to bacterial metabolism. Further, the shallowness of the basin though indicative of higher production yet has its contradictions when the values of carbonate system was seen. This was further elaborated by the presence of the clinograde curve of oxygen which should normally follow the biomass of autotrophic organisms. Though tropical limnology has massive survey date, there are numerous gaps in our knowledge of tropical lakes since the exploratory ventures of Juday (1915) and Ruttner (1931). A high rate of density change at higher temperatures makes tropical thermocline possible though the upper limit is substantially lower than in the temperate zone (Talling, 1966). In the present study based on physico-chemical aspects there seems to be a circulation phenomena more than once though some factors reveal a dimictic and others monomictic in nature. The overall lake, could probably be attributed to be polymictic in nature. This was partly due to the fact that the residence time of the elements may be greater or lesser than the water (Stumm and Morgan, 1970; Megard, 1971). The net result of stratification as seen in the present study since the larger concentration of nutrients often was in the lower waters may possibly increase the time when a new equilibrium could be established (Vollenweider, 1969). Moreover, lakes as the present one with high watershed to volume may have pelagic metabolism strongly influenced by the terrestrial metabolic activities and edaphic factors (Ross, 1963; Hynes, 1963). Finally, the interacting rhythmic phenomena affecting the factors depends upon the geographical location of the system including its latitude and longitude, which indicated that the present investigation revealed that the lake was polymictic though sufficiently deep to stratify and yet not deep enough to support a thermocline (Hutchinson and Loffler, 1956; Hutchinson, 1957).

Phytoplankton, Zooplankton, Bacteria

During the present investigation the biota was broadly categorized into three major groups - the phytoplankton, the zooplankton and the bacteria., The analysis of the former two was confined only to the surface waters of the system while the latter was analysed at both the middle and bottom layers of the water columns.

Among phytoplankton at different stations the group Chlorophyceae dominated in all. Chrysophyceae and Euglenophyceae came next in importance with Bacillariophyceae and Dinophyceae being the lowest (recorded). However, when seen as families and genera it revealed a picture of aggregation at certain stations under Chlorophyceae, where *Scenedesmus* was dominant. In Stations D

and E, Desmidiaceae dominated. Moreover the dominant associations of algal groups was found to differ at different stations. Chrysophyceae and Dinophyceae were seen to occur more together at Stations B and C, while Dinophyceae and Bacillariophyceae at D and E. The importance of such associations is very well documented to be indicative of the general lake trophic status. Moreover, each species or group gets aggregated due to its own physiological requirements permitting it to exist in a habitat depending upon the multidimensional space or hyper-space corresponding to the values of variables (Hutchinson, 1967). Under these conditions of contemporaneous disequilibrium at any given time many patches of water exist in which one group has a competitive advantage relative to the other but the masses are obliterated frequently enough to prevent exclusive occupation by a single species or group.

The present investigation indicated that generally an oligotrophic assemblage of plankton was prevalent in the system. However, with *Scenedesmus* occupying a dominant role was indicative of a eutrophic chlorococcal plankton. However, this is understandable only when a seasonal phenomena and the succession of these major groups are seen. In the present investigation it was seen that all the groups of phytoplankton either at family or at generic levels except for Bacillariophyceae had a summer maxima and winter minima. Scenedesmaceae revealed a winter minima in all the stations except in Station E. The family Chromuliniaceae which was absent in all the stations except in E revealed a summer minima and winter maxima. Though numerically the seasonal trend revealed a build up in summer yet when the relative percentages of abundance of the major groups of phytoplankton when seen as that of total phytoplankton was mostly in the reverse. This is indicative of the fact that even though the numbers were high for the dominant groups during the maximal peaks yet they did not go down to levels of minimum affecting the total phytoplankton.

The seasonal succession is indicative of those present in temperate situations where a rise starts in spring builds in early summer to maximise during mid summer and then fall. It is also true of a system of a predominantly oligotrophic type. The replacement of *Scenedesmus* during winter is attributed to the fact that the seston is capable of releasing more nutrients for the faster intrinsic growth rate of this group. The lake therefore indicated a general oligotrophic situation establishing an equilibrium of a total recycling that with the incorporation of eutrophic species it regains its original condition at every annual cycle. It therefore behaved as a system directed towards maturation process usually indicative of greater varieties and oligotrophic in nature.

Aside from its basic importance of the understanding of phytoplanktonic community structure it is always relevant to indicate blooms developed from directional changes in nutrients. It is therefore possible that the presence or absence of particular species of phytoplankton in a habitat could be predicted from the fluctuation of abundance frequency than from the relative abundance (Margalef, 1958 and 1968). The green to blue-green algae has not been clearly established though there was definitely an existence of a trend in the reverse between these two throughout the period of investigation. However, the minor shifts in succession was seen when the relative abundances of Chlorophyceae and Myxophyceae have different peaks and could be attributed to mixing of the lake just before winter (Symons *et al*, 1967). The increase in amplitude of the turnover rates during the seasons could be explained by the altered diversity of phytoplankton population and by decrease of total biomass (Javarnicky and Komarkava, 1978). The aspect of a productive system could possibly

be extended to the present lake as it is very well documented that green algae and diatoms are more efficient producers than blue-greens and dinoflagellates (Findenegg, 1965 and Pyrina, 1966). The present study indicated that there existed an analogy between the changes of phytoplankton structure along the succession and the changes from oligotrophy to eutrophy. Summer is indicative of an oligotrophic situation while in winter a typical eutrophic situation was encountered (Gliwicz, 1975). The critical environmental factors precipitating species specific period of maximum growth and reproduction are important to a total understanding of phytoplankton succession (Dozier and Beauchamp, 1978). It is felt that it was sufficient to understand that the field rhythms as in the present study could probably be a compromise between forced oscillations in the environment and an inherent rhythmicity in the potential of the organisms (Enright, 1970).

As is usual in any lake system in the present investigation also it was seen that zooplankton comprised of Rotifers, Copepods, Cladocerans, Ostracods and Protozoa. Among these Rotifera seemed to dominate at all the stations followed closely by Copepoda and Cladocera. Protozoa was not very well established and Ostracoda was the least. From this it was understandable that the system is definitely an oligotrophic type. The cleanliness of water is known to depend directly on the quantity of Rotifers. This was further documented by the fact that the group Rotifera over the seasons possessed a bimodal peak of maximal occurrence, one during summer and the other in winter with autumn recording the least. Copepoda however has a definite autumn maxima and winter minima while Cladocera revealed an autumn maxima and summer minima. The usual summer and winter minima was seen only in Protozoa.

Rotifers are known to feed largely by sedimenting seston particles into their mouth orifice by means of the pulsating action of their coronal cilia (Pourriot, 1965; Hutchinson, 1967). Moreover, the reproductive rate of Rotifers is related strongly to the quality and abundance of food as well as temperature (Edmondson, 1946 and 1965; King, 1967; Halbach and Halbach-Keup, 1974). In all probability the bimodal phenomena of abundance could be attributed to a summer species feeding primarily on green algae and a winter species on either *Scenedesmus* or diatoms as in the present investigation. Copepoda and Cladocera, are more or less selective feeders and probably depend upon the complete turnover for their sustenance (Richman, 1958). These definitely exhibit an over-wintering population with high summer mortality and small peak preceeding a winter fall (Keen, 1973). The magnitude of the rate of multiplication which is the productive basis of this periodicity phenomena was influenced by the seasonal variations in environmental factors. Hence a temporal succession of environmental differences occurred (Fry, 1947; McCombie, 1953).

As phytoplankton and zooplankton are dependent on each other, zooplankton grazing and in particular fracturing the frustules could strongly enhance the dissolution process (Ferrante and Parker, 1976). It was only when the water temperatures fall that the grazing pressure of zooplankton gets lowered and therefore with the generation rates of phyto- and zooplankton having more or less the same time scale, the zooplankton suppress the algae to low levels if not itself being grazed upon by small fish (Steel, 1975). Moreover, the aggregation of zooplankton especially adults in the narrow zones of light intensity and or at the surface may be involved in the narrow zones of light intensity and or at the surface may be involved in this population regulation. Wynne-Edwards (1962) suggests

that the social display could be the test for population density and stimulate responses which will hold it or restore it to the optimum. This in turn effects the filtration rate. Therefore a significant inverse relationship not only between the quantities of phyto- and zooplankton but also in their horizontal distribution is due to the grazing effect (Riley and Bumpus, 1948; Bainbridge, 1953 and Prasad, 1956).

The dominant group seemed to follow a pattern of rhythmicity parallel to total phytoplankton over the seasons. This phenomenon of the regulation of fecundity by food intake may not be instantaneous and in it may underlie the oscillatory zooplankton dynamics. This is more so because at any given time the brood size may be appropriate not to the actual trophic potential but to some hours earlier during which time the population had increased. It therefore leads to the production of population of more than the equilibrium size even if the constant rate of the supply of food is maintained. Finally among zooplankton populations there is considerable genetic control of longevity and fecundity and considerable heterozygosity with respect to the genus involved in the population.

Total phytoplankton and zooplankton, where the different forms had been discussed revealed a summer maxima and winter minima in the present investigation revealing the same functional properties as discussed above.

Among the biota the last major group undertaken for detailed study was the analysis of total bacteria. This revealed the usual summer maxima and winter minima, dominant in the bottom layers of the water column in contrast to the surface. This revealed the high activity of the bacteria on the sinking seston, the detritus and the organic ooze in the sediments. In the present investigation the actual counts ranged between 1.1 to 943.8×10^5 numbers per ml. This range as shown by Godlewska-Lipowa (1976a), was that both the oligotrophic and eutrophic nature was operating in the present system. However, on a detailed analysis it was seen that the maximum density of occurrence of bacteria was at Station A-which primarily served as a sedimentation tank where the overlying water flows into the main lake. It was understandable that an equilibrium was set up in the main system with the fall in the bacterial counts revealing a more or less oligotrophic nature.

The phenomena of maximal occurrence in hypolimnion has also been observed by Cappenberg (1972) who attributed seasons to play a major role which has the support of Andranikova and Drabkova (1972) with their detailed meteorological factors. In the present study though the phytoplankton was not analysed for the same regions in the lakes as for bacteria yet it was clearly seen that a definite inverse relationship existed between plankton and bacteria at least in the surface waters. There are contradictory reports in that some authors attribute a positive correlation while the others do not. Silvey and Roach (1964), Schegg (1968) and Fonden (1969) were of the former opinion while Potaenko and Mikhewa (1969), Gerletti and Melchiorri-Santolini (1968) and Goldman *et al*, (1968) to the latter.

The summer maxima may be attributed to the increased availability of food source favouring multiplication of bacterial population and enhanced substantially by the rise in temperature (Jannasch, 1955; Potter, 1964 and Andronikova and Drabkova, 1972). Further the presence of these in the hypolimnion in abundance may be due to sedimentation through the thermocline or by transportation

by migratory zooplankton. However, the fluctuations appear to represent the damp oscillations during winter of a perturbed steady state system. In the present system since green algae dominated it was an established fact that high density of bacteria coincide with periods of highest occurrence of phytoplankton other than blue-green algae (Overbeck, 1975). Moreover, since a differentiation between autotrophic and heterotrophic bacteria has not been done, one would tend to believe that it was the heterotrophic bacteria in the present system which was far more abundant than the autotrophic one, even though understandably no essential difference exists in the biochemical activities of bacterial plankton in freshwaters (Antipchuk and Jana, 1977a, b). In addition to the above criteria as pointed out by Brook and Brock (1966) that in each geographical locality, mutation, recombination and selection would act to create a group of local strains which are best adapted to that particular geographical locality. Further depending upon the agitation and bacterial biomass, the dissolved organic matter coalesces to produce organic aggregates in that area affecting bacterial populations. Moreover, the importance of bacteria for the releasing of nutrients to enable a sustained growth in particular for the majority of suspension feeders is very well documented (Freedman, 1960 and Jorgensen, 1966). Though this is controlled in part by temperature the effect was seen only in winter when the death of bacteria reduces the planktonic organisms in the overlying water and the sediment bacteria in hypolimnion to very low levels as seen in the present investigation. Unfortunately very little is known about the rate of supply of organic nutrients especially those coming from the living organisms excretion, leached materials of plants and hydrolysis of older detritus. The present investigation does imply the existence of an intrinsic relationship between bacteria and zooplankton, bacteria and phytoplankton and phytoplankton and zooplankton.

Primary Production

In the present investigation the Net primary productivity and Gross primary productivity values were calculated based on the classical light and dark bottle method. The values at the different stations were seen to be higher in the euphotic zone with a reduction in their levels as one goes from the top to the bottom column layers of the water. At all the shallow Stations A, B and D a definite decrease was observed which became very significant at the two deepest portions of the lake namely Stations C and E where the values not only touched nil, but in some cases Gross primary productivity indicated negative values.

Though the depthwise lessening of primary productivity was understandable it was felt that during a seasonal analysis, the values of productivity depend not only on the autotrophic organisms but also on the light energy, which gives an idea on the turnover of nutrients in the system. The maximum peaks of occurrence not only varied among the different Stations but also during the two annual cycles. This was true also for the minimal values. On a detailed observation Stations A, B and D revealed more or less a late autumn or early winter maxima during the first annual cycle while Station E showed mid-summer peak during the same period. This however reversed during the second annual cycle in that Station E revealed either a late winter or early spring maxima while for the other stations it was in summer. This was true for both the Net primary productivity and Gross primary productivity values. The actual values recorded were nearly 900 mg C/M³/day for Net primary

productivity and nearly 2000 mg C/M³/day for Gross primary productivity. These values definitely reveal the oligotrophic nature of the system where even the annual primary production comparatively would be indicative of a moderately productive lake but with an assemblage of autotrophic organisms where production values does not reach eutrophic levels (Vollenweider, 1971). This further documented by the fact that succession in algal species into various assemblages in different seasons would be indicative of maximal peak at different times of the year within the same system (Schelske and Stoermer, 1971).

In limnological investigations it is usually the deep lakes that are less productive than shallow ones but the present investigation reveals a situation like that of a deep lake and could be attributed to its location and primarily its altitude (Rawson, 1955). This suggests that multiple layering and the incorporation of atelomixis takes place which frequently follows the break down of complex stratification. It is, therefore, that small lakes in the tropics and especially those at high altitudes and latitudes may be superficial lakes or temperate counterparts. Therefore, the epilimnion will be thinner due to reduced effects of wind and vertical zonation would therefore be less likely to survive ordinary diurnal convective mixing (Lewis, 1973).

The present investigation revealed increases in primary productivity values subsequent to rain in many occasions suggesting stimulation of algal production by rainfall. This was due partly to the nitrogen fixing algae present in those stations which aids in supporting primary production in summer (Brakke, 1977). The typical seasonal cycle of primary productivity with low production either in summer and winter (Raymont, 1963) could probably be the result of a stabilized water column which slows the resupply of nutrients to surface waters not being utilised in summer added to decreased solar radiation creating increased depths of the non-euphotic zone. Further, the aspects of light availability due to the self-shading effects is a complex feed-back problem common to all photosynthetic systems (Talling, 1970), which is a factor to be reckoned with in the present study.

Usually in tropical waters production is moderate throughout the year with very little oscillations but the present investigation revealed a situation similar to temperate waters where summer or spring and sometimes even winter recorded high values, (Raymont, 1966). At the same time temperature controlled photosynthetic rates require very high turnover rates of these elements which being low could be undetectable (Ganf and Viner, 1973).

The continuous circulation in the present system could therefore be the result of rapid mineralization of zooplankton and phytoplankton decaying process which are immediately taken up by the succession of algal community and to the translocation of photosynthetic algae to levels below the euphotic zone. In the present investigation it was therefore very likely that these translocated communities while not actively photosynthesising do not die and pass once again into the photosynthetic zone within a reasonable time (Lewis, 1974 and Allanson and Hart, 1975). One complicating factor to be considered in the present aquatic system was the sporadic and interrupted nature of primary production even though the phytoplanktonic production occurred in periodic pulses. Such a phenomena has been studied under laboratory conditions and has been identified as "Adoptive" (Jorgensen, and Steemann Nielsen, 1965; Yentsch and Lee, 1966; Steemann Nielsen and Jorgensen,

1968 a, b; Javornicky, 1970). These adoptive changes could be achieved either by altering pigment content or the amounts of enzymes involved in photosynthetic dark reaction. Algal population can therefore adjust their photosynthetic metabolism to changing light intensity (Vollenweider, 1970) even though algae respond to momentary stress conditions (Yentsch and Lee, 1966). It is therefore that the volume based photosynthesis was enhanced in surface populations exposed throughout the profile, since light inhibition becomes a minor effect and their utilization at low relatively small water volumes compared with the entire area, the photosynthetic rates are low (Tilzer and Schwarz, 1976).

Though comparative studies are ideal, regional limnology gets intimately associated with the trophic concepts. This is all the more, since primary production within the sub-surface layers of optimal light exhibit such a great regional variation, its determination is valuable for the biological characterization of different waters in that area or region (Rodhe, 1958). The present aquatic system behaved in a well established equilibrium. This was probably indicative that the actual or potential productivity of the newly formed lake could have been greater during the first few years and subsequently a balance struck between the subsequent store or release by the lake (Round, 1957; Mackereth, 1966 and Macan, 1970). The only (aspect) was the rate of sediment accumulation which from the present study though revealing severity of deoxygenation in the hypolimnion returns to stabilization by bacterial consumption processes needs further study.

GENERAL DISCUSSION

The present investigation reveals that there exists a cyclic development of the pulses of the various factors undertaken. However, the time in which the annual pulses were initiated or terminated get displaced somewhat. In addition the magnitude of a pulse also vary considerably from one year to the other. It was, therefore, felt to incorporate the statistical analysis of correlation coefficient between the major physico-chemical factors and the biota along with the production levels. This was done to indicate whether there existed intricate relationships between them. Tables-XVII, XVIII and XIX present the correlation coefficients for the factors and biota and primary productivity, a perusal of which reveals no regular relationships either at the stations undertaken or at the different depths. At the surface waters of Station A, primary production was correlated only with Calcium while for the bottom waters of the same station it was correlated with pH, Silicate and Nitrate concentrations. The last two were highly significant. All were positive, while with Nitrate it was negatively significant. Phytoplankton for the surface waters at the Station A was correlated with air temperature, water temperature, Silicate, Calcium and Magnesium at $P < 0.01$ level, while with secchi it was negatively significant at $P < 0.05$. Similarly zooplankton was positively significant only for water temperature at $P < 0.01$ level. Bacteria in the same surface waters was significant with conductivity and oxygen both positively at $P < 0.01$ level and similarly so, for the bottom nutrients. With carbon dioxide, bacteria was negatively significant both at the surface and bottom in the former at $P < 0.05$ level and in the latter at $P < 0.01$ level. In addition bacteria and alkalinity in the bottom waters were significant at the lower level of significance.

Table XVII

Table-XVII : Correlation Table showing the Correlation coefficient among the physical, chemical and biological parameters undertaken at Station A, B and D.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	I	(+)	(+)	(+)	(-)	(-)	(-)	(-)	(+)	(+)	(-)	(+)*	(+)	(-)	(+)	(-)	(-)
		0.301	0.330	0.303	0.135	0.149	0.081	0.108	0.117	0.355	0.183	0.462	0.370	0.107	0.117	0.089	0.128
		(+)**	(+)**	(-)	(+)	(-)	(-)	(-)	(+)**	(+)**	(-)	(+)**	(+)**	(-)*		(+)*	
		(b)	0.625	0.730	0.038	0.238	0.138	0.268	0.020	0.721	0.526	0.251	0.530	0.784	0.498		0.470
		(+)*	(+)**	(+)	(+)	(-)	(-)	(+)	(+)*	(+)	(-)	(+)	(+)*	(-)			
	(c)	0.469	0.517	0.241	0.345	0.345	0.058	0.043	0.491	0.353	0.052	0.200	0.487	0.327			
		(+)	(-)	(-)	(+)**	(-)*	(+)	(+)**	(+)	(+)	(+)	(-)	(+)	(-)	(+)	(+)	
		(d)	0.263	0.063	0.070	0.732	0.467	0.310	0.515	0.141	0.175	0.207	0.214	0.218	0.282	0.141	0.220
		(+)	(+)	(+)*	(-)	(-)	(-)	(-)	(+)	(+)**	(-)**	(+)	(+)	(-)			(-)
	(a)	0.165	0.209	0.477	0.148	0.128	0.186	0.306	0.202	0.549	0.613	0.162	0.166	0.292			0.207
		(+)	(+)	(+)	(+)**	(-)*	(+)	(+)**	(+)	(+)	(+)	(-)	(+)	(+)			
B	I	(d)	0.294	0.229	0.042	0.923	0.685	0.419	0.578	0.050	0.096	0.357	0.242	0.272	0.066		
		(+)*	(+)**	(+)*	(+)	(+)	(-)	(-)	(+)	(+)	(-)	(+)	(+)	(+)	(+)	(+)	(+)
		(a)	0.446	0.546	0.412	0.154	0.139	0.401	0.209	0.226	0.241	0.265	0.305	0.305	0.088	0.354	0.186
		(+)	(+)**	(+)	(+)	(+)	(-)	(-)	(+)	(+)	(-)	(+)**	(+)**	(+)		(+)	0.110
		(b)	0.395	0.558	0.340	0.082	0.296	0.006	0.145	0.285	0.344	0.271	0.671	0.554	0.128		0.102
	(c)	(+)	(+)	(-)	(-)*	(+)	(+)*	(-)	(-)	(+)	(-)	(+)		(-)			
		0.114	0.253	0.086	0.410	0.343	0.514	0.363	0.018	0.078	0.358	0.205	0.049	0.264			
		(+)	(+)	(+)	(+)	(-)	(-)	(+)	(+)	(+)	(-)	(+)	(+)	(-)	(-)	(-)	
		(d)	0.296	0.299	0.395	0.158	0.300	0.234	0.050	0.073	0.271	0.328	0.145	0.284	0.272	0.068	0.210
	(a)	(+)	(+)	(+)	(-)	(+)	(-)	(-)	(+)	(+)	(+)	(+)	(+)*	(+)			(-)
		0.215	0.326	0.221	0.025	0.211	0.062	0.007	0.216	0.063	0.068	0.306	0.484	0.282			0.101
		(+)	(+)	(+)	(+)	(-)	(-)	(+)**	(+)	(+)	(-)	(+)	(+)	(-)			
	(d)	0.276	0.326	0.262	0.140	0.283	0.306	0.659	0.025	0.369	0.270	0.130	0.329	0.101			

(Continued on next page)

Table-XVII : Correlation Table showing the Correlation coefficient among the physical, chemical and biological parameters undertaken at Station A, B and D.

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
D	I	(a)	(-)	(-)	(-)	(-)	(-)	(+)	(+)	(-)	(-)	(+)	(+)	(+)		(+)	(-)=	(-)
			0.102	0.008	0.354	0.062	0.127	0.280	0.037	0.245	0.084	0.136	0.091	0.123		0.155	0.077	0.291
			(+)*	(+)**	(+)	(+)	(+)	(-)	(-)	(+)*	(+)**	(-)	(+)*	(+)*			(-)	
		(b)	0.404	0.546	0.387	0.137	0.106	0.241	0.008	0.495	0.737	0.293	0.443	0.435			0.336	
			(-)	(-)	(-)	(-)	(+)	(+)	(-)	(-)	(-)	(+)	(+)	(+)				
	(c)	0.376	0.031	0.247	0.207	0.291	0.398	0.012	0.117	0.076	0.031	0.110	0.170					
		(+)	(+)	(+)	(+)	(-)*	(-)	(+)	(+)	(-)	(-)	(-)	(+)		(-)	(-)		
	(d)	0.314	0.242	0.364	0.198	0.421	0.276	0.111	0.125	0.115	0.354	0.066	0.384		0.076	0.060		
	II		(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)	(-)	(+)	(+)	(+)				(-)
		(a)	0.301	0.283	0.270	0.269	0.035	0.258	0.240	0.026	0.184	0.161	0.200	0.026				
		(+)	(+)	(+)	(+)	(-)	(-)	(+)	(+)	(-)	(-)*	(-)	(+)**					
	(d)	0.313	0.295	0.288	0.024	0.365	0.243	0.030	0.071	0.126	0.507	0.065	0.523					

Legends :

I : Surface

a) : Primary productivity

c) : Total zooplankton

1) Air temperature

2) Water temperature

3) pH

4) Conductivity

5) Carbondioxide

6) Alkalinity

7) Oxygen

8) Phosphate

II : Bottom

b) : Total phytoplankton

d) : Bacterial counts.

9) Silicate

10) Nitrate

11) Calcium

12) Magnesium

13) Secchi disc

14) Total phytoplankton

15) Total zooplankton

16) Bacterial counts

Table XVII

Table-XVIII : Correlation Table showing the Correlation coefficient among the physical, chemical and biological parameters undertaken at Station C.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		(+)	(+)	(-)	(+)	(+)	(-)	(+)	(-)	(+)	(+)	(+)	(+)	(-)	(+)	(+)	(-)
I	(a)	0.129	0.155	0.195	0.217	0.124	0.244	0.076	0.057	0.079	0.027	0.352	0.001	0.107	0.287	0.289	0.094
		(+)*	(+)**	(+)**	(+)	(+)*	(+)	(-)	(+)**	(+)**	(-)	(+)**	(+)**	(+)		(+)*	
	(b)	0.503	0.673	0.517	0.244	0.512	0.088	0.164	0.664	0.558	0.005	0.646	0.593	0.345		0.453	
		(+)	(+)**	(-)	(-)	(+)**	(+)	(-)*	(+)*	(+)*	(+)	(+)*	(+)	(+)**			
	(c)	0.316	0.533	0.010	0.132	0.531	0.399	0.506	0.416	0.446	0.362	0.447	0.357	0.561			
		(+)	(+)	(+)	(+)	(-)	(-)	(+)	(+)	(+)	(-)	(-)	(+)	(+)	(+)	(-)	
	(d)	0.254	0.219	0.391	0.140	0.324	0.282	0.266	0.107	0.921	0.206	0.131	0.181	0.029	0.075	0.089	
			(+)	(-)	(-)	(-)	(-)	(+)	(-)	(+)	(-)	(+)	(-)				
0.5m	(a)		0.026	0.227	0.216	0.131	0.126	0.080	0.230	0.161	0.204	0.204	0.001				
		(-)	(-)	(-)	(-)	(+)	(+)	(-)	(-)*	(-)	(-)	(-)	(-)	(+)			(-)
1.0m	(a)	0.314	0.248	0.162	0.350	0.118	0.137	0.226	0.481	0.173	0.067	0.096	0.101	0.211			0.251
		(+)	(+)	(+)	(+)	(-)	(-)	(+)	(+)	(+)	(-)	(-)	(+)	(-)			
	(d)	0.285	0.260	0.371	0.074	0.297	0.241	0.174	0.331	0.166	0.236	0.097	0.185	0.251			
			(-)	(+)	(-)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(+)				
1.5m	(a)		0.104	0.114	0.067	0.145	0.012	0.140	0.294	0.257	0.119	0.035	0.247				
			(-)	(-)	(-)	(-)	(-)	(-)	(+)	(+)	(-)	(+)	(-)				
2.0m	(a)		0.120	0.039	0.036	-0.260	0.230	0.073	0.035	0.160	0.070	0.109	0.073				
		(+)	(-)	(+)	(+)	(-)	(+)	(-)	(-)	(+)	(+)	(+)	(-)	(+)			(+)
II	(a)	0.260	0.052	0.134	0.092	0.030	0.147	0.149	0.122	0.133	0.192	0.080	0.207	0.109			0.211
		(+)	(+)*	(+)*	(+)	(-)	(-)	(-)	(-)	(+)	(-)	(-)	(+)	(+)			
	(d)	0.285	0.453	0.428	0.157	0.013	0.177	0.365	0.189	0.133	0.267	0.219	0.211	0.166			

Legends :**I : Surface****II : Bottom****a) Primary productivity****b) Total phytoplankton****c) Total zooplankton****d) Bacterial counts**

1) Air Temperature

2) Water temperature

3) pH

4) Conductivity

5) Carbondioxide

6) Alkalinity

7) Oxygen

8) Phosphate

9) Silicate

10) Nitrate

11) Calcium

12) Magnesium

13) Secchi disc

14) Total phytoplankton

15) Total zooplankton

16) Bacterial counts

Table XVIII

Table-XIX : Correlation Table showing the Correlation coefficient among the physical, chemical and biological parameters undertaken at Station E.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		(+)	(+)	(-)	(-)	(-)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(+)	(+)	(-)
	(a)	0.217	0.100	0.344	0.361	0.020	0.030	0.108	0.099	0.365	0.234	0.129	0.170	0.221	0.124	0.081	0.178
		(+)*	(+)**	(+)	(+)	(+)	(-)	(-)	(+)**	(+)**	(-)**	(+)**	(+)	(-)		(-)	(+)
	(b)	0.472	0.568	0.325	0.194	0.211	0.215	0.015	0.555	0.578	0.644	0.523	0.357	0.016		0.238	0.366
I		(-)**	(-)	(-)	(-)*	(+)	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(+)*			(-)
	(c)	0.578	0.383	0.319	0.404	0.040	0.323	0.080	0.179	0.243	0.142	0.100	0.051	0.445			0.388
		(+)*	(+)*	(+)**	(+)*	(-)	(+)	(+)	(+)**	(+)	(-)	(-)	(+)	(-)			
	(d)	0.499	0.444	0.550	0.484	0.282	0.172	0.304	0.594	0.147	0.262	0.006	0.174	0.371			
			(+)	(-)	(-)	(+)	(-)	(-)	(+)	(+)	(-)	(+)	(+)				
0.5m	(a)		0.075	0.031	0.059	0.363	0.366	0.085	0.071	0.304	0.251	0.192	0.039				
			(+)	(-)	(-)	(+)*	(-)	(+)	(+)	(+)	(-)	(+)	(+)				
1.0m	(a)		0.118	0.089	0.230	0.442	0.171	0.028	0.051	0.383	0.102	0.006	0.037				
			(+)	(+)	(-)	(+)**	(-)	(-)	(-)	(+)*	(-)	(-)	(+)				
1.5m	(a)		0.071	0.135	0.064	0.525	0.055	0.099	0.190	0.439	0.084	0.084	0.038				
			(+)	(+)	(-)	(+)*	(+)	(-)*	(+)	(+)*	(-)	(-)	(+)				
2.0m	(a)		0.009	0.204	0.124	0.504	0.068	0.418	0.023	0.467	0.040	0.026	0.134				
		(+)	(-)	(+)	(-)	(+)	(+)	(-)*	(+)	(+)*	(-)	(+)	(+)	(+)			(-)
2.5m	(a)	0.051	0.051	0.076	0.148	0.346	0.204	0.420	0.056	0.467	0.129	0.143	0.139	0.352			0.076
		(+)**	(+)	(+)	(+)**	(+)	(+)	(+)	(+)*	(+)	(+)*	(-)	(+)	(-)			
	(d)	0.549	0.314	0.109	0.726	0.140	0.272	0.230	0.409	0.003	0.466	0.019	0.269	0.381			
			(-)	(+)*	(+)	(+)**	(+)*	(-)	(+)**	(+)	(+)	(+)	(+)				
3.0m	(a)		0.105	0.469	0.275	0.594	0.484	0.395	0.667	0.213	0.132	0.104	0.312				
			(+)	(+)	(+)	(+)	(+)	(-)	(+)	(+)*	(-)	(-)	(-)				
3.5m	(a)		0.233	0.188	0.279	0.040	0.349	0.315	0.291	0.427	0.031	0.018	0.004				
			(+)	(-)	(+)	(+)	(+)	(-)	(+)	(+)	(-)	(-)	(-)				
4.0m	(a)		0.352	0.059	0.360	0.143	0.319	0.202	0.219	0.256	0.111	0.137	0.113				

(Continued on next page)

Table XIX

Table-XIX : Correlation Table showing the Correlation coefficient among the physical, chemical and biological parameters undertaken at Station E.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		(+)	(+)	(+)	(-)	(+)	(+)	(+)	(-)	(+)	(-)	(-)				
4.5m (a)		0.113	0.072	0.181	0.087	0.080	0.227	0.092	0.081	0.108	0.391	0.234				
		(+)	(-)	(+)*	(-)	(-)	(+)	(+)	(-)	(+)	(-)	(-)				
5.0m (a)		0.159	0.282	0.436	0.265	0.139	0.226	0.184	0.286	0.060	0.219	0.065				
	(-)	(-)	(-)	(+)	(-)	(-)	(+)**	(+)	(-)*	(+)	(-)	(-)	(-)*			(-)
(a)	0.006	0.111	0.113	0.041	0.379	0.263	0.579	0.009	0.486	0.122	0.394	0.283	0.428			0.010
II	(+)*	(+)	(-)	(+)**	(+)	(+)	(+)	(+)*	(-)	(+)**	(+)	(+)	(-)			
(d)	0.412	0.080	0.173	0.742	0.215	0.148	0.261	0.477	0.006	0.699	0.117	0.073	0.289			

Legends :

I : Surface

a) : Primary productivity

c) : Total zooplankton

II : Bottom

b) : Total phytoplankton

d) : Bacterial counts.

1) Air temperature

2) Water temperature

3) pH

4) Conductivity

5) Carbondioxide

6) Alkalinity

7) Oxygen

8) Phosphate

9) Silicate

10) Nitrate

11) Calcium

12) Magnesium

13) Secchi disc

14) Total phytoplankton

15) Total zooplankton

16) Bacterial counts

Table XIX

At Station B primary productivity was correlated with water temperature at $P < 0.01$ level while with air temperature and pH at $P < 0.05$ level while bacteria and oxygen were correlated at highly significant levels.

At Station C primary productivity was seen to be only correlated with phosphate, that too negatively only at the mid depth while phytoplankton and zooplankton were correlated with various physico-chemical factors for the surface waters all positively except zooplankton and oxygen which showed negative correlation. Bacteria was correlated at the bottom of this station with water temperature and pH both positively at : < 0.05 levels.

At Station D only phytoplankton seem to be correlated with air temperature, Phosphate, Calcium and Magnesium at $P < 0.05$ levels and with water temperature and Silicate at $P < 0.01$ level while the bottom layers at this station revealed a significance with bacteria and carbon dioxide only which was negative. No other correlations existed at this station.

At the last Station E, the primary production was correlated with either carbon dioxide and oxygen at 1.0 m, 1.5 m, 2.0 m and 3.0 m depths with the former while at 2.0 m, 2.5 depth and bottom with the latter. All these were positively significant except with oxygen at 2.0 m and 2.5 m, depths which revealed a negative correlation. In addition primary productivity was significant with silicate at 1.5 m, 2.0 m, 2.5 m depths and bottom, the last negative and all the others positive. At 3.5 m primary productivity was correlated with alkalinity and phosphate while in 5.0 m depth with conductivity and a negative correlation with secchi disc with bottom. There was no correlation at all between primary productivity and any factor for the surface was of this station. However phytoplankton was positively correlated with air temperature, water temperature, phosphate, silicate and calcium positively while with nitrate a negative correlation existed for the surface waters at the station. Similarly, zooplankton was correlated with air temperature, conductivity and secchi disc, the former two negatively related while the latter positively at the same surface waters for the station. Correlations with bacteria was seen only with the mid-depth and bottom which in the former had high correlations with air temperature and conductivity and at lower levels with nitrate and phosphate and in the latter a similar effect except that conductivity and nitrate showed much higher levels of correlations.

From the above it was clear that primary production was seldom being affected at the different stations of the lake except in the deepest portion. The major physico-chemical factors seem to effect phytoplankton more and to some extent zooplankton in particular for the surface waters at all the stations. The correlation between bacteria and physical factors was seen to dominate primarily in the bottom layers.

From the above it seemed that water temperature and oxidisable organic matter go hand in hand and related inversely to the dissolved oxygen. However, it was not comparable to some of the highly productive tropical ponds (Pennak, 1950 and 1955). The correlation with phytoplankton may be due to various phenomena like that of a favourable desmid growth in waters poor in Calcium and Magnesium and that the dominance of Chlorococcales at comparatively higher pH. The present investigation also revealed such a phenomena and the algal growth seemed to be in agreement with observations of earlier workers (Rao, 1955; Zafar, 1964 and 1967; Munawar, 1970). The significance of dissolved silica

which though agrees to earlier findings of an inverse relationship with diatoms yet it seemed not to be a limiting factor in the present study (Singh, 1960; Zafar, 1967).

The rapid and often extreme availability in the underwater light climate may be short term depending upon the local weather conditions which is characteristic as the present one, located at the cool high altitudes, where intense thunderstorm occurred periodically. These intermittent changes in concert with the influx of inorganic and organic substances play a significant role in regulating the phytoplankton assemblages. The green algae and the diatoms in the present system may suggest that the pigment system of these representatives were capable of adaptation to rapid light conditions in combination to the heterotrophic active capacity (Stewart *et al*, 1974). Also of interest is the loading of acid (Hydrogen ion) by precipitation which enhances the detrimental effects on a poorly buffered lake ecosystem as the present one (Dillon *et al*, 1978).

The negative correlation of nitrate could be attributed to the process of nitrification which modified the environment by increasing the oxygen demand and by supplying an adequate substrate to denitrifiers. The composition of the algal population would therefore be changed by the elimination of those groups which are unable to compete with bacterial nutrient uptake. The sediments would then produce a rapid nitrification when suitable conditions are supplied (Serruya *et al*, 1974). Moreover, with waters of low alkalinity as the present one indicated that carbon dioxide from bacterial activity can stimulate algal growth. Respiratory carbon dioxide was therefore important in replenishing carbon dioxide in the carbonate bicarbonate equilibrium system in waters where carbon dioxide from inorganic sources was in short supply. It was, therefore, the interactions of dissolved organic matter in heterotrophic metabolism, as growth factor in auxotrophy, as antibiotic and growth substances, in provision of macro- and micro-elements and the many ways in which chelation and complexing can modify, controlling the nutritional factors, all integrate into a complex of a function which control algal metabolism or influence it indirectly through inorganic nutrition. This has, there, led to the realization that nutrient concentrations at half-uptake maximal rate do not necessarily reflect growth capabilities of phytoplankton species (Caperon, 1972; Fuhs *et al*, 1972; Rhee, 1973; Chisholm, 1974; Eppley and Renger, 1974). This was very obvious in the present investigation where the correlation between the different stations revealed a positive relationship when, one would tend to believe lowering levels of nutrients with higher biomass of autotrophs. The aspect was further enhanced by the lack of precipitation of phosphates which require higher pH and therefore levels tend to be higher, as in the present system when the pH was always in acidic range.

Production levels especially at Station E showing positive relationship with carbon dioxide and negative relationship with oxygen could again be attributed to an artifact due to the depletion of carbon dioxide or some limiting nutrient, inside the confined volumes of water in the bottles used for measurements. Though the same process should have taken place in free waters it was probably weakened by the mixing of the water levels, where contact with the atmosphere, hypolimnion or bottom sediments and by the passive and active vertical migration of phytoplankton. Therefore the photosynthetic activity could possibly decrease with increased biomass of phytoplankton (Verduin, 1959 and 1960; Pyrina, 1961; Vollenweider and Nauwerck, 1961; Findenegg, 1965; Goldman *et al*, 1968). All these could be further enhanced or slowed down by temperature and though primary

production had very little significant correlation with either air or water temperatures yet phytoplankton revealed higher levels of significance at the different stations and especially for the surface waters.

It was therefore understandable to identify the causative factor determining a stable coexistence in a limnetic community. Passive concentration in vortices and active searching for clumped food by consumers results in spatial horizontal positioning. This commonly observed phenomena has also been seen in the present investigation which resulted in a patchy distribution of consumers along with that of the producers. Moreover, significant correlations between phyto- and zooplankton were seen at the surface waters only at some stations and not in the others. It therefore confirms that spatial heterogeneity is more important than selective feeding in establishing natural population.

The present ecosystem with its highly erratic phenomena could probably be attributed to polymictic nature revealing for most parts an oligotrophic nature while certain factor which seemed to be limiting but rather a combination of variables which determined the total understanding in the present investigation. It was important to realize that the entire watershed and not just the lake, or the lake and its shore line as the basic ecosystem unit. The terrestrial and the aquatic portion of any watershed is inherently linked with the gravitational movements of minerals in drainage waters flowing from land to water, attributed as the major terrestrial-aquatic linkage (Likens and Bormann, 1974). The implication of this in terms of the lake capacity for the development is that any alterations in water shed ultimately affects the lake.

The present investigation though revealing the fundamental aspects of ecosystems under study lacks informations on the balance between inputs and outputs and therefore a basic detriment to the adequate elucidation of structure and function in the present lake ecosystem. Much of the problems identified as an outcome of present investigation, which needs to be tackled in the future, is related to the difficulty of measuring all parameters, quantities of water and dissolved matter lost or added, such as the seepage losses and ground water inputs to the basin. The further insight from the present work had also led us to believe that the significance of autotrophs in relation to the growth and production could better be understood at their specific levels rather than as dealt with in the present investigation. The study does give results where it could form a pioneer in that considerable variables along with primary productivity rhythms have been undertaken for the first time in wetlands from their region.

REFERENCES

- Abeliovich, A. and Shilo, M. 1972. Photooxidative death in blue green algae. *J. Bacteriol.*, 111 : 682-689.
- Aberg, B. and Rodhe, W. 1942. Über die Milieufactoren in einigen Sudschwedischen Seen. *Symbolae Botanicae Upsalienses*, 5 : 1-256.
- Adams, G. F. 1970. Soluble carbohydrates as a factor influencing gross primary productivity and bacterial population in lakes. *Journal of the Arizona Academy of Science*, 6 (1) : 5-7.
- Akagi, Y., Taga, N. and Simidu U. 1977. Isolation and distribution of oligotrophic marine bacteria. *Can. J. Microbiol.*, 23 : 981-987.

- Alfred, J. R. B. and Chellappa, N. T. 1978. Absence of primary production in a shallow Oligotrophic pond. *Verh. Internat. Verein. Limnol.* 20 : 2737-2742.
- Alfred, J. R. B., Kaur, S. and Thapa M. P. 1978. The role of nutrients and their effects on the biota in freshwater lentic systems. *Int. Confr. of Water Poll. Res. Bangkok, Water. Poll. Res.*, 1 : 133-139.
- Allanson, B. R. and Hart, R. C. 1975. The primary production of Lake Sibaya, Kwa-Zulu, South Africa. *Verh. Internat. Verein. Limnol.*, 19 : 1426-1433.
- Allen, H. and Ocvski, B. T. 1976. Limnological studies in a large deep, oligotrophic lake (Lake Ohrid, Yugoslavia). *Arch. Hydrobiol.* 77 (1) : 1-21.
- Allen, H. L. and Ocvski, B. T. 1977. Limnological studies in a large, deep, Oligotrophic lake (Lake Ohrid, Yugoslavia). A summary of nutritional radiobioassay responses of the pelagial phytoplankton. *Hydrobiologia*, 53 : 49-54.
- Anderson, H. H. 1889. Notes on Indian Rotifers. *J. Asiatic Soc. Bengal*, 58 : 345-358.
- Andronikova, I. N. and Drabkova, V. G. 1972. Specificity of annual limnological cycles in Lake Krasnoe versus climatic factors. *Verh. Internat. Verein. Limnol.*, 18 : 522-527.
- Antipchuk, A. F. and Jana, B. B. 1977a. Some microbiological indices in ponds with mono and polyculture (in Russian). *Fisheries Science* (Kiev).
- A. P. H. A. 1965. *Standard methods for the examination of water and wastewater*. 12th ed.
- Apstein, C. 1896. *Das Susswasserplankton*, Lipsius & Tischer, Kiel and Leipzig, 206 pp.
- Arnon, D. I.. 1958. The role of micronutrients in plant nutrition with special reference to photosynthesis and nitrogen assimilation. *Proc. Conf. Ohio. agric. Exp. Sta.*, (1957) : 1-33.
- Arnon, D. I., Allen, M. B. and Whatley, F. R. 1954. "Photosynthesis by isolated chloroplasts" *Nature*. 174 : 394
- Bachofen, R. 1960. Stoffhaushalt und sedimentation im Baldegger und Hallwibersee. *Diss. Juris. Verlag, Zurich*. 118 pp.
- Bainbridge, R. 1953. Studies on the Inter-relationship on zoo-plankton and phytoplankton. *J. Mar. Biol. Ass. U. K.*, 32 : 385-447.
- Begg, G. W. 1976. The relationship between the diurnal movements of some of the zooplankton and the sardine *Limnothrissa miodon* in Lake Kariba, Rhodesia. *Limnol. Oceanogr.*, 21 : 529-539.
- Beklemishev, C. W. 1961. Superfluous feeding of the marine herbivores zooplankton. *Rapp. P.-V. Reun., Cons. Int. Explor. Mer.*, 153 : 108-113.

- Berg, K. 1943. Physiographical studies on the Ruver Susaa. *Folia limnol. Scand.*, 1 : 1-174.
- Berman, T. 1976. Release of dissolved organic matter by photosynthesizing algae in Lake Kinneret, Israel. *Freshwat. Biol.* 6 : 13-18 (1976).
- Beyers, R. J. and Odum, H. T. 1959. The use of carbon dioxide to construct pH curves for the measurement of productivity. *Limnol. Oceanogr.*, 4 : 499-502.
- Birge, E. A. and Juday, C. 1934. "Particulate and dissolved organic matter in Wisconsin lakes" *Ecol. Monogr.* 4 : 440-474.
- Blackman, F. F. 1923. The Biochemical Problems of Chloroplastic Photosynthesis. *Brit. Ass. Adv. Sci., Rep. 90th Meeting, Hull, 1922.* Publ. London, 1923.
- Boers, J. J. and Carter, J. C. H. 1978. Instar development rates of *Diaptomus minutus* (Copepoda : Calanoida) in a small lake in Quebec. *Can. J. Zool.*, 56 : 1710-1714.
- Brakke, D. F. 1977. Rainwater : Nutrient additions to hypereutrophic lake. *Hydrobiologia*, 52 : 159-163.
- Briggs, G. E. 1922. Experimental Researches on Vegetable Assimilation and Respiration. XVI. The characteristic of Subnormal Photosynthetic Activity Resulting from Deficiency of Nutrient Salts. *Proc. Roy. Soc., B*, 94 : 20-35.
- Brock, T. D. and Brock, M. L. 1966. Temperate optima for algal development in Yellowstone and Iceland hot springs. *Nature*, 209 : 733-734.
- Brooks, J. L. 1947. Turbulence as an environmental determinant of relative growth in *Daphnia*. *Proc. Nat. Acad. Sci.*, 33 : 141-148.
- Brown, T. J. and Sibert, J. R. 1977. Food of some benthic harpacticoid copepods. *J. Fish. Res. Board Can.*, 34 : 1028-1031.
- Burgis, M. J. 1973. Observations of the Cladocera of Lake George, Uganda. *Journal of Zoology, London*, 170 : 3399-349.
- Burns, N. M. 1976. Temperature, Oxygen and nutrient distribution patterns in Lake Erie, 1970. *J. Fish. Res. Board Can.*, 33 : 458-511.
- Burns, N. M. and Ross, C. 1971. Nutrient relationships in a stratified eutrophic lake. *proc. 14th Conf. Great Lakes Res. (Int. Assoc. Great Lakes Res.) 1971* : 749-760.
- Butcher, R. W., Pentelow, F. T. K. and Woodley, J. W. L. 1927. The diurnal variation of the gaseous constituents of river waters. *Biochem. J.*, 21 : 945-957.
- Butcher, R. W., Pentelow, F. T. K. and Woodley, J. W. L. 1928, The diurnal variation of the gaseous constituents of river waters. Part III. *Biochem. J.*, 22 : 1035-1047.

- Cappenberg, T.E. 1972. Ecological observations on heterotrophic, methane oxidising and sulphate reducing bacteria in a pond. *Hydrobiologia*, 40 : 471-485.
- Caperon, J.C. 1972. Nitrogen limited growth of marine phytoplankton. I. Changes in population characteristics with steady state growth rate. *Deep-Sea Res.*, 19 : 601-618.
- Casperi, W.A. 1910. Deposits of the Scottish freshwater lochs. In Murray and Pullar's Bathymetrical Survey of the Scottish Freshwater Lochs, 1: 261-274.
- Chakrabarty, R.D., Ray, P. and Singh, S.B. 1959. A quantitative study of the plankton and the physico-chemical conditions of the river Yamuna at Allahabad in 1954-55. *Indian J. Fish.*, 6 : 186-203.
- Chen, R.L., Keeney, D.R. and Konrad, J.C. 1972. Nitrification in sediments of selected Wisconsin lakes. *J. Environ. Qual.*, 1 : 151-154.
- Cheng, D.M.H. and Tyler, P.A. 1976. Nutrient economics and trophic status of Lakes Sorell and Crescent, Tasmania. *Aust. J. Mar. Freshwater Res.*, 27: 151-163.
- Chisholm, S.W. 1974. Studies on daily rhythms of phosphate uptake in *Euglena* and their potential ecological significance. Ph. D. Thesis, State University of New York at Albany, 106 pp.
- Collins, V.G. and Willoughby, L.G. 1962. The distribution of bacteria and fungal spores in Blelhan Tarn with particular reference to an experimental overturn. *Arch. Microbiol.* 43 : 294-307.
- Cooney, J.D. and Gehrs, C.W. 1980. The relationship between egg size and naupliar size in calanoid copepod *Diaptomus claviceps*. Schacht. *Limnol. Oceanogr.*, 25 : 549-552.
- Daday, E. 1898. Microscopische Süsswasserthiere aus Ceylon. *Termeszetr. Fuz. (Budapest)* 21 : 1-23.
- Davies, C.W. 1962. *Ion Association*. Butterworth and Co., Washington. 190 pp.
- Deevey, E.S. 1940. Limnological Studies in Connecticut. V Contribution to Regional Limnology. *Am. Jour. Sci.*, 238: 717-741.
- Dice, L.R. 1914. The factors determining the Vertical Movements of *Daphnia*. *Jour. Animal Behavior*, 4 : 229-265.
- Dillon, P. J., Jeffries, D.S. Snyder, W., Reid, R., Yan, N. D., Evans, D., Moss, J. and Scheider, W.A. 1978. Acidic precipitation in South central Ontario : recent observations. *J. Fish. Res. Bd. Can.*, 35 : 809-815.
- Dozier, B.J. and Beauchamp, J. J. 1978. An autoradiographic investigation of the seasonal photosynthetic activity of three diatom species in Lake Tahoe, California Nevada. *Verh. Internat. Verein. Limnol.*, 20 : 414-418.

- Droop, M.R. 1974. Heterotrophy of carbon. *In*. W.D.P. Stewart, ed. *Algal Physiology and Biochemistry*. Berkeley, Univ. of California Press, pp. 530-559.
- Dumont, H.J. 1968. Een limnologische studie van het Donk-meer (Oost-Vlaanderen). -Doctor's Thesis, Gent, 222 pp. (Unpublished).
- Edmondson, W.T. 1944. Ecological studies of sessile rotatoria. Part I. Factors affecting distribution. *Ecol. Monogr.*, 14 : 31-56.
- Edmondson, W.T. 1945. Ecological studies of sessile Rotatoria. Part II. Dynamics of Population and social structures. *Ecol. Monogr.*, 15 : 141-172.
- Edmondson, W.T. 1946. Factors in the dynamics of rotifer populations. *Ecol. Monogr.*, 16 : 357-372.
- Edmondson, W. T. 1948. Ecological applications of Lensing's physiological work on longevity in *Rotatoria*. *Science*, 108 : 123-126.
- Emerson, R. and Arnold, W. 1932. "A separation of the reactions in photosynthesis by means of intermittent light" *J. Gen. Physiol.* 15 : 391.
- Enright, J. T. 1970. Ecological aspects of endogenous rhythmicity. *In*: R.F. Johnston, Ed., *Annual Review of Ecology and Systematics*, 1970. annual Reviews, Palo Alto, California.
- Eppley, R. W. and Renger, E. H. 1974. Nitrogen assimilation of an oceanic diatom in nitrogen-limited continuous culture. *J. Phycol.*, 10 : 15-23.
- Evans, J. H. 1961. "Growth of Lake Victoria phytoplankton in enriched culture" *Nature* 189 : 417.
- Fallon, R. D. and Brack 1980. Planktonic blue-green algae : Production, sedimentation and decomposition in Lake Mendota, Wisconsin. *Limnol. Oceanogr.*, 25 : 72-88.
- Fee, E.J. 1973. A numerical model for determining integral primary production and its application to Lake Michigan. *J. Fish. Res. Board Can.* 30 : 1447-1468.
- Fernando, C.H. 1980. The species and size composition of Tropical freshwater zooplankton with special reference to the Oriental Region (South East Asia). *Int. Revue. Ges. Hydrobiol.*, 65(3) : 411-426.
- Ferrante, J.G. 1976. The characterization of phosphorus excretion products of a natural population of limnetic zooplankton. *Hydrobiologia*, 50 : 11-15.
- Ferrante, J.G. and Parker, J.I. 1977. Transport of diatom frustules by copepod fecal pellets to the sediments of Lake Michigan. *J. Fish. Res. Bd. Can.*, 34 : 545-551.

- Findenegg, I. 1965. "Relationship between standing crop and primary productivity" P. 271-289. In : C. R. Goldman(ed.), *Primary Productivity in Aquatic Environments*. Mem. Ist. Ital. Idrobiol., 18 suppl., pp. 271-289. University of California Press, Berkeley.
- Fitzgerald, G.P. 1970. Aerobic Lake Mud for the removal of phosphorus from Lake waters. *Limnol. Oceanogr.*, 15 : 550-555.
- Fitzgerald, G.P. 1971. The biotic relationships within water blooms pp. 26-32, University of Nebraska Press, Lincoln, p. 876. In : Rosowski, J. R. and B. C. Parker (eds.) *Selected Papers in Phycology*.
- Fogg, G. E. 1971. Extracellular products of algae in freshwater. *Archiv fur Hydrobiologie, Beihefte, Ergebnisse der Limnologie*, 5 : 1-25.
- Fogg, E. E. and Wolf, M. 1954. Nitrogen metabolism of blue-green algae. *Symposium Soc. Gen. Microbiol.* 4 : 99-125.
- Fogg, G. E. and Westlake, D. F. 1955. The importance of extracellular products of algae in freshwater. *Verh. internat. Verein. Limnol.* 12 : 219-323.
- Fogg, G. E., Nalewajko, C. and Watt, W. D. 1965. Extracellular products of photosynthesis. *Proc. R. Soc. Lond.* (9). 162 : 517-534.
- Fogg, G. E., Stewart, W. D. P. Ray, P. and Walsby, A. E. 1973. *The Blue-green algae*. New York, Academic Press, 459 pp.
- Fonden, R. 1969. Heterotrophic bacteria in Lake Malaren and Lake Hjalmararen. *Oikos*, 20 : 344-372.
- Forel, F. A. 1892. *Le Lemane : Monographie Limnologique. Tome I. Geographie, Hydrographie, Geologie, Climatologie, Hydrologie*. Lausanne, F. Rouge, 543 pp.
- Forel, F. A. 1895. *Le Lemane : Monographie Limnologique. Tome II. Mecanique, Hydraulique, Thermique, Optique, Acoustique, Chemie*. Lausanne, F. Rouge, 651 pp.
- Fott, B. 1971. *Algenkunde*. 2 Auflage. Gustav Fischer.
- Freden, F. J. H. 1960. Bacteria as a source of food for black fly larvae. *Nature*, London, 187 : 963.
- Fritsch, F. E. 1931. Some aspects of the ecology of fresh-water elgae. *Jour. Ecology*, 19 : 233-272.
- Fry, F. E. J. 1947. Effects of the environment on animal activity. *Univ. Toronto Studies, Biol. Ser.* 55.
- Fuhs, G. W., Demmerle, S. D., anelli, E. and .Ten, M. 1972. Characterization of phosphorus limited plankton algae (with) reflections on the limiting nutrient concept). *Limnol. Oceanogr., Spec. Sumpos.*, 1 : 113-32.

- Gaarder, T. and Gran, H. H. 1927. Production of plankton in the Oslo Fjord. *Rapp. Cons. Explor. Mer.* 42 : 1-48.
- Gaffron, H. and Wohl, K. 1936. Zur theorie der assimilation. *Naturwissen schaften*, 24 : 81.
- Ganapati, S. V. 1940. The ecology of a temple tank containing a permanent bloom of *Microcystis aeruginosa* (Kutz.), Honfr. *J. Bombay natl. Hist. Soc.*, 42(1) : 65-77..
- Ganapati, S. V. 1941. Seasonal changes in the physical and chemical conditions of a garden pond containing abundant aquatic vegetation. *J. Mad. Univ.*, 13 : 55-69.
- Ganapati, S. V. 1943. An ecological study of a garden pond containing abundant zooplankton. *Proc. Acad. Sci.*, 17 : 41-58.
- Ganapati, S. V. 1955. Diurnal variations in dissolved gases, hydrogen ion concentration and some of the important dissolved substances of biological significance in three temporary rock ponds in stream bed at Mettur Dam. *Hydrobiologia*, 7 : 285-303.
- Ganapati, S. V. 1959. Ecology of tropical waters. *Proc. Symp. on Algology, New Delhi (ICAR)* 200-218.
- Ganapati, S. V. 1960. Ecology of tropical waters. *Proc. Symp. on Algology. ICAR* : 204-218.
- Ganf, G. G. and Viner, A. B. 1973. Ecological stability in a shallow equatorial lake (Lake George, Ugande). *Proc. R. Soc. Lond. B.*, 184 : 321-346.
- Gerletti, M. and Melchiorri-Santolini, U. 1968. A comparative study on primary productivity, bacterial microflora and ecological factors in lakes : bolsena, Maggiore, Mergozzo and Monate. *Mem. Inst. Ital. Idrobiol.*, 24 : 161-195.
- Gerloff, G. C., Fitzgerald, G. P. and Skoog, F. 1950. The mineral nutrition of *Coccochloris peniocyctis*. *Am. J. Biol.*, 37 : 835-840.
- Gerloff, G. C., Fitzgerald, G. P. and Skoog, F. 1952. Theminal nutrition of *Microcystis aeruginosa*. *Am. J. Bot.*, 39 : 26-32.
- Gilbert, J. J. 1980. Observations on the susceptibility of some protists and Rotifers to predation by *Asplanchna girodi*. *Hydrobiologia*, 73 : 87-91.
- Gliwicz, Z. M. 1975. Effect of zooplankton grazing on photosynthetic activity and composition of phytoplankton. *Verh. Internat. Verin. Limnol.*, 19 : 1490-1497.
- Godlewska-Lipowa, W. A. 1976a. Bacteria as indicators of the degree of eutrophication and degradation of lakes. *pol Arch. Hydrobiol.*, 23 : 341356.
- Goldman, C. R. 1960. Molybednum as a factor limiting primary productivity in Castle Lake, California. *Science* 132 : 1016-1017.

- Goldmen, C. R. and De Amezaga, E. 1975. Spatial and temporal changes in the primary productivity of Lake Tahoe, California-Nevada between 1959 and 1971. *Verh. Internat. Verein. Limnol.* 19 : 812-825.
- Goldmen, C. R. and Wetzel., R. G. 1963. A study of the primary productivity of Clear Lake, Lake County, California. *Ecology*, 44 : 283-294.
- Goldman, C. R., Gerletti, M., Javornicky, P. U., Melchiorri-Santo-lini , U. and Amenzaga., E. 1968. Primary productivity, bacteria, phyto-and zooplankton in Lake Maggiore correlations and relationships with ecological factors. *Mem. Inst. Ital. Idrobiol.*, 23 : 49-127.
- Gossler, O. 1950. Funktionsanalysen am Raderorgan von Rotatorien durch optische Verlangsamung. *Oesterr. zool. Zschr.* 2.
- Golterman, H. L. 1960. Studies of the cycle of elements in freshwater. *Acts. Bot. Nearl.*, 9 : 1-58.
- Golterman, H. L. ed. 1969. *Methods for Chemical Analysis of Fresh Waters*. Int. Biol. Program Handbook 8. Oxford, Blackwell Scientific publications, 172 pp.
- Golterman, H. L. 1971. The determination of mineralization losses in correlation with the estimation of net primary production with the oxygen method and chemical inhibitors. *Freshwat. biol.* 1 : 249-256.
- Golterman, H. L. 1975. *Physiological Limnology, An approach to the Physiulogy of Lake Ecosystems*. Elsevier, Amsterdam. 489 pp.
- Golterman, H. L. and Clymo, R. S. 1969. *Methods for Chemical Analysis of Freshwaters*. IBP Handbook No. B. Blackwall scientific Publications, Oxford.
- Golterman, H. L., Bakels, G. C. and Jacobs-Mogelon, J. J 1969. Availability of mud phosphates for the growth of algae. *Verhn Internat. Verein, Limbol.*, 17 who 174 : 467-479.
- Gonzalves, E. A. and Joshi, D. S. 1946. Fresh water algae near Bombay8. I. the seasonal succession of the algae in a tank at Bandra. *J. Bombay nat. Hist. Goc.*, 46(1) : 154-176.
- Green, J. 1972. Latitudinal variation oin associations of planktonic Rotifera. *J. Zool. Lond.*, 167 : 31-34
- Green, J. D. 1976. Population dynamics and production of calanoid copepod *Calamoecia lucasi* in a northern New Zealand lake. *Arch. Hydrobiol. Supplement*, 50 : 313-400.
- Gulati, R. D. and Wurtz-Schulz, G. 1980. Remarks on the present status of limnology in India based mainly on the Indian publications in Hydrobiologia and suggestions for future approach. *Hydrobiologia*, 72 : 211-222.
- Hagedorn, H. 1971. Experimentelle Untersuchungen uber den Einfluss der Thiamins auf die naturliche Algen population des Pelacials. *Arch. Hydro-biol.*, 68 : 382-399.

- Halbach, U. and G. Halbach-Keup. 1974. Quantitative Beziehungen zwischen Phytoplankton und der Populationsdynamik des Rotators *Brachionus calyciflorus* Pallas. Befunde aus Laboratoriumsexperimenten and Freilanduntersuchungen. *Arch. Hydrobiol.*, 73 : 273-309.
- Hamilton, D. H. 1969. "Nutrition limitations of a summer phytoplankton growth in Cayuga Lake". *Limnol. Oceanogr.* 14 : 579-590.
- Hargrave, B. T. 1972. A comparison of sediment oxygen uptake, hypolimnetic oxygen deficit and primary production Lake Esrom, Denmark. *Verh. Int. Ver. Limnol.*, 18 : 134-139.
- Harvey, W. H., Cooper, L. H. N., Lebour, M. V. and Russell., F. S. 1935. Plankton production and its Control. *J. mar. biol. Ass. U. K.* 20, 407-441.
- Hensen, V. 1887. Über die Bestimmung des Planktons oder des in Meere treibenden Materials on Pflanzen und Tieren, 5. *Ber. Kommiss. wiss. Unters. Dt. Mere* 12-16, 1-108.
- Hensen, V. 1895. *Ergebnisse der Planktonexpedition der Humboldtstiftung, Lipsius & tiecher*, Kiel and Leipzig.
- Hickman, M. 1971. Standing crop and primary productivity of the epipelon of two small pond in north Somerset, U.K. *Oecologia* (6(3)) : 238-253.
- Hickman, M. and penn, I. D. 1977. The relationship between planktonic algae and bacteria in a small lake. *Hydrobiologie*, 52 : 213-219.
- Hobbie, J. E. and Wright, R. T. 1965. Bioassay with bacterial uptake kinetics; glucose in freshwater. *Limnol. Oceanogr.*, 10 : 471-474.
- Hobbie, J. E and Crawford, C. C. 1969. Respiration corrections for bacterial uptake of dissolved organic compounds in natural water. *Limnol. Oceanogr.*, 14 : 528-532.
- Hongve, D. 1978. Buffering of acid lakes by sediments. *Verh. Internat. Verein. Limnol.* 20 : 743-748.
- Hussiny, S. V. 1967. Studies on the Limnology and primary production of a tropical Lake. *Hydrobiologia*. 30(3-4) : 335-352.
- Hutchinson, G. E. 1938. On the relation between oxygen deficit and the productivity and typology of lakes. *Int. Rev. Gesamten Hydrobiol. Hydrogr.*, 36 : 336-335.
- Hutchinson, G. E. 1941. Limnological studies in connecticut. *Ecol. Monogr.*, 11 : 21-60.
- Hutchinson, G. E. 1944. Limnological studies in connecticut. VII. A critical examination of the supposed relationship between phytoplankton periodicity and chemical changes in lake waters. *Ecology*, 25 : 3-26.
- Hutchinson, G. E. 1957. "A treatise on Limnology. Vol. I. Geography, physics and chemistry" John Wiley and Sons, Inc., New York, N. Y 1015 p.

- Hutchinson, G. E. 1967. *A treatise on Limnology. II. Introduction to lake Biology and Limnoplankton*. New York, John Wiley and Sons, Inc., 1115 pp.
- Hutchinson, G. E. 1975. *A treatise on Limnology. III. Aquatic Macrophytes and Attached Algae*. New York, John Wiley & Sons, Inc.
- Hutchinson, G. E. and Löffler, H. 1957. The thermal classification of lakes. *Proc. Nat. Acad. Sci. U. S.*, 42 : 84-86.
- Hynes, H. B. N. 1963. Imported organic matter and secondary productivity in streams. *Proc. 16th Int. Congr. Entomol.*, 4 : 324-329.
- Jacobson, T. R. and Comita, G. W. 1976. Ammonia-Nitrogen excretion in *Daphnia pulex*. *Hydrobiologia*, 51 : 195-200.
- Jannasch, H. W. 1955. Zur ökologie der zymogenen planktischen Bakterienflora natürlicher Gewässer. *Arch. Mikrobiol.*, 23 : 147-180.
- Javornicky, P. 1970. On the utilization of light by freshwater phytoplankton. *Arch. Hydrobiol. Suppl.*, 39, Algological studies, 2/3, : 68-85.
- Javornicky, P. and J. Komarkova., 1978. The changes in several parameters of plankton primary productivity in Slapy Reservoir 1960-1967, their mutual correlations and correlations with the main ecological factors. *Hydrobiological studies*, 2 : 155-211.
- Jennings, H. S. 1918. *The wheel animalcules (Rotatoria)*. Chap. XVII In: Ward and Whipple's Fresh-water Bio-logy, pp. 553-620.
- Jones, J. G. 1971. Studies on freshwater bacteria: factors which influence the population and its activity. *J. Ecol.*, 59 : 593-613.
- Jonsson, B. 1903. Assimilationsversuche bei verschiedener Meerestiefe. *Nyt. Mag. Nat.* 41 : 1-22.
- Jorgensen, C. B. 1966. *Biology of Suspension Feeding*. Pergamon Press, New York. 357 pp.
- Juday, C. 1915. Limnological studies on some lakes in Central America. *Trans. Wis. Acad. Sci.*, 18 : 214-250.
- Kalff, J. 1970. "Nutrient limiting factors in an arctic tundra pond" *Ecology* 52 : 655-659.
- Kaneko, T., Atlas, R. M. and Krichevsky, M. 1977. Diversity of bacteria populations in the Beaufort sea. *Nature*, 270 : 596-599.
- Kant, S. and Anand, V. K. 1968. Interrelationships of phytoplankton and physical factors in Mansar lake, Jammu. *Indian J. Ecol.*, 5 : 134-140.
- Keen, R. 1973. A probabilistic approach to the dynamics of natural populations of the Chydoridae (Cladocera, Crustacea). *Ecology*, 54 : 524-534.

- Keeney, D. R. 1973. The nitrogen cycle in sediment water systems. *J. Environ. Quality*, 2 : 15-29.
- Kemmerer, G., Bovard J. F. and Boorman, W. R. 1923. Northwestern Lakes of the United States : Biological and Chemical Studies with Reference to Possibilities in Production of Fish. *Bull. U. S. Bur. Fish.*, 39 : 51-140.
- Kerr, P. C. Paris, D. F. and Brockway, D. L. 1970. *The interrelationship of Carbon and phosphorus in regulating heterotrophic and autotrophic populations in aquatic ecosystems*. U. S. Gov. Print. Off., Washington, D. C. 53 p.
- Khan, M. A. & Zutshi, D. P. 1980. Primary productivity and trophic status of a Kashmir Himalayan lake. *Hydrobiologia*, 68 : 3-8.
- King, C. E. 1967. Food, age and dynamics of a laboratory population of rotifers. *Ecology*, 48 : 111-128.
- King, D. L. 1970. The role of carbon in eutrophication. *J. Water Pollut. Contr. Fed.*, 42 : 2035-2051.
- Kleerekoper, H. 1953. The mineralization of plankton. *J. Fish. Res. Bd. Can.*, 10 : 283-291.
- Kratz, W. A. and Myers, J. 1955. "Photosynthesis and respiration of three blue-green algae" *Pl. Physio., Lancaster*, 30 : 275-280.
- Kristiansen, J. 1971. Phytoplankton of two Danish lakes with special reference to seasonal cycles of the nanoplankton. *mitt. Internat. Verein. Limnol.*, 19 : 253-265.
- Kryuchkova, N. M. 1972. Role of phyto- and zppplankton i the selfpurification processes (on) the example of biological purifying ponds *Gidrobiol. Zh.*, 8(5), 106-111.
- Lange, W. 1970. Cyanophyta Bacteria systems: Effects of added carbon compounds or phosphate on algal growth at low nutrient concentrations. *jJ. Phycol.*, 6 : 230-234.
- Lasenby, D. C. 1975. Development of oxygen deficits in 14 southern Ontario lakes. *Limnol. Oceanogr.*, 20 (6) : 993-999.
- Lawacz, W. 1969. The characteristics of sinking material and the formation of bottom deposits in a eutrophic lake. *Mitl. Int. Ver. Theor. Angew. Limnol.*, 17 : 319-331.
- Lei, C. and Armitage, K. S. 1980. Growth, development and body size of field and laboratory population of *Daphnia ambigue Oikos*, 35 : 31-48.
- Lewin, J. C. 1961. The dissolution of silica from diatorm walls. *Geochim. Cosmochim. Acta*, 21 : 182-195.
- Lewis, W. M. Jr. 1973. A ther regime of lake Lanao (Philippines) and its theoritical implications for tropicallakes. *Limol. Oceanogr.*, 18 : 200-217.

- Lewis, W. M. Jr. 1974. Primary production in the plankton community of a tropical lake. *Ecol. Monogr.*, 44 : 377-409.
- Lewkowicz, M. and Lewkowicz, S. 1975. The role of zooplankton in self-purification of the pond after five years of fertilization with sugar wastes. *Pol. Arch. Hydrobiol.*, 22 : 311-326.
- Likens, G. E. and Bormann, F. H. 1974. Linkages between terrestrial and aquatic ecosystems. *Bioscience*, 24 : 447-457.
- Likens, G. E., Bormann, F. H., Pierce, R. S., Eaton, J. S. and Johnson, N. M. 1977. *Biogeochemistry of a forested ecosystem*. Springer-Verlag. 146 pp.
- Löffler, H. 1969. High altitude lakes in Mount Everest region. *Verh. Internat. Verein. Limnol.*, 17 : 373-385.
- Lyman, J. 1961. Changes in pH and total CO₂ in natural waters. *Limnol. Oceanogr.*, 6 : 80-82.
- Macan, T. T. 1970. *Biological Studies of the English Lakes*. Longmans, London. 260 pp.
- Mackereth, F. J. H. 1963. *Some methods of water analysis for Limnologists*. Scientific Publication No. 21, Fresh water Biol. Assoc., Ambleside. 70 pp.
- Mackereth, F. H. J. 1966. Some chemical observations on post-glacial lake sediment. *Phil. Trans. B.*, 250 : 165-213.
- Margalef, R. 1958. Temporal succession and spatial heterogeneity in phytoplankton, p. 323-349. In A. Buzzati-Traverso (ed.) *Perspectives in marine biology*. Univ. Calif. Press.
- Marshall, S. M. and A. P. Orr. 1928. The photosynthesis of diatom cultures in the sea. *Jour. Mar. Biol. Assoc. U. K.* 16 : 321-364.
- McCombie, A. M. 1953. Factors influencing the growth of phytoplankton. *J. Fish. Res. Bd. Can.*, 10.
- McCracken, M. D., Middaugh, R. and Middaugh, R. S. 1980. A chemical characterisation of an algal inhibitor obtained from *Chlamydomonas*. *Hydrobiologia*, 70 : 271-276.
- Megard, R. O. 1971. *Phosphorus and eutrophication : The potential response of an urban lake to pollution abatement*. Paper presented at 34th annual meeting of ASLO in Winnipeg, Canada on 14th June 1971.
- Michael, R. G., 1980. A historical resume of Indian limnology. *Hydrobiologia*, 72 : 15-20.
- Moore, W. G., 1950. Limnological studies of Louisiana Lakes. I. Lake Providence. *Ecology*, 31 : 86-99.
- Mortimer, C. H. 1942. The exchange of dissolved substances between mud and water in lakes. *J. Ecol.*, 29 : 280-329.

- Mortimer, C. H. 1950. "The use of models in the study of wate movement in stratified lakes" *Verh. int. Ver. Limnol.* 11 : 254-260.
- Mortimer, C. H. 1955. "Some effects of the earth's rotation on water movements in stratified lakes" *Verh. int. Ver. Limnol.* 12 : 66-77.
- Mortonson, J. A. and A. S. Brooks. 1976. *The vertical distribution of Chlorophyll and nutrients at a deep station in Lake Michigan*. Presented at 39th Annu. Meet., Am. Soc. of Limnol. Oceanogr., Savannah, Ga., June 21-24, 1976.
- Munawar, M. and Munawar, I. F. 1975. The abundance and significance of phytoflagellates and nannoplankton in the St. Lawrence Great Lakes. 1. Phytoflagellates. *Verh. Internat. Verein. Limnol.*, 19 : 705-725 (1975).
- Munawar, M. and Munawar, I. F. 1976. A lakewide study of phytoplankton biomass and its species composition in Lake Erie, April-December 1970. *J. Fish. Res. Board. Can.*, 33 : 581-600.
- Muttkowski, R. A. 1918. The Fauna of Lake Mendota-A qualitative and quantitative Survey with Special Reference to the Insects. *Trans. Wis. Acad. Sci., Arts, Let.*, 19 : 374-482.
- Nancollas, G. H. 1966. *Interactions in Electrolyte Solutions*. Elsevier Publishing Co., Amsterdam. 214 pp.
- Naumann, E. 1917. Beitrage zur kenntnis das Teichnanoplanktons II. Uber des Neuston^odes Susswassers. *Biol. Zbl.*, 37 : 98-106.
- Navaneethakrishnan, P. and Michael, R. G. 1971. Egg production and growth in *Daphnia Carinate* King. *Proc. Ind. Acad. Sci.*, LXXIII (3) B : 117-123.
- Northcote, T. G. and Larkin, P. A. 1956. Indices of lake productivity in British Columbia lakes. *J. Fish. Res. Board Can.* 13 : 515-540.
- Nygaard, G. 1949. *Hydrobiological studies on some Danish ponds and lakes. Part II. The quotient hypothesis and some new or little known phytoplankton organisms*. Kongel. Danske Vidensk. Selskab. Biol. Skrift., &(1), 293 pp.
- Nygaard, G. 1955. On the productivity of five Danish waters. *Verh. Int. Ver. Limnol.*, 12 : 123-133.
- Ohle, W. 1934. Chemische und physikalische Untersuchunge noddeutscher Seen. *Arc Hydrobiol.*, 26 : 386-464.
- Ohle, W. 1952. Die hypolimnische kohlendioxy drakkumulation als produktions biologischer Indikator. *Arch. Hydrobiol.*, 46 : 153-285.
- Overbeck, J. 1965. Primarproduktion und Gewasserbakterien. *Naturwissenschaften*, 6 : 145-146.
- Overbeck, J. 1967. Zur Bakteriologie der Susswassersees Ergebnisse und Probleme. *Gasu Wasserfach.*, 108 : 44, 1258-1260.

- Overbeck, J. 1968. Prinzipielles zum vorkommen der Bakterien im see. *Mitt. int. Verein. theor. angew. Limnol.*, 14 : 134-144.
- Overbeck, J. 1975. Ecology of Aquatic Organisms. I. Bacteria. Distribution pattern of uptake kinetic responses in a stratified eutrophic lake (Plubsee ecosystem study IV). *Verh. Internat. Verein. Limnol.*, 19 : 2600-2615.
- Overbeck, J. and Babenzien, H. D., 1964. Ueber den Nachweis von freien Enzymen im Gewässer. *Arch. Hydrobiol.*, 60 : 107-114.
- Parsons, T. R. and Strickland, J. D. 1962. On the production of particulate organic carbon by heterotrophic processes in sea water. *Deep Sea Res.*, 18 : 211-222.
- Pennak, R. W. 1944. Diurnal movement of Zooplankton Organisms in some Colorado Mountain Lakes. *Ecology*, 25 : 387-423.
- Pennak, R. W. 1955. Comparative Limnology of eight Colorado Mountain Lakes. *Univ. Colorado Studies, Ser. Biol.*, 2 : 1-75.
- Pennak, R. W. 1973. Some evidence for aquatic macrophytes as repellents for a limnetic species of *Daphnia*. *Int. Rev. ges. Hydrobiol.*, 58 : 569-576.
- Plew, W. F. and Pennak, R. W. 1949. A Seasonal Investigation of the Vertical Movements of Zooplankters in an Indiana Lake. *Ecology*, 30 : 93-100.
- Potaenko, Y. S. and Mikhewa, T. M. 1969. Relationships between bacteria and phytoplankton. *Mikrobiologiya*, 37 : 603-607.
- Potter, L. F. 1964. Plankton and benthic bacteria of lakes and ponds. In : *Principles and Applications in Aquatic Microbiology*. Eds. H. Heukelekian and N. C. Dondero. John Wiley and Sons Inc., New York.
- Pourriot, R. 1965. Recherches sur l'ecologie des rotiferes. *Vie et Milieu, Suppl.*, 21 : 224 pp.
- Pourriot, R., Rougier, C. and Benest, D. 1980. Hatching of *Brachionus rubens* O. F. Muller resting eggs (Rotifers). *Hydrobiologia*, 73 : 51-54.
- Prasad, B. 1916. *J. Asiatic Soc. Bengal.*, 12 : 142-145.
- Prasad, R. R. 1956. Further studies on the plankton of the in shore waters of Mandapam. *Indian J. fish.*, 3 : 1-41.
- Pruthi, H. S. 1933. Studies on the bionomics of freshwaters in India. I. Seasonal changes in the physical and chemical condition of the waters of the tank in the Indian Museum Compound. *Int. Rev. ges. Hydrobiol. Hydrogr.* 28 : 46-47.
- Putter, A. 1924. Der Umfang der Kohlensäurereduktion durch die Plankton algen. *Pflug. Arch. Ges. Physiol.* 205: 293-312.

- Pyrina, I. L. 1961. (*Dependence of primary production on phytoplankton composition*). In : Perv. prod. Mar. vnutr. vod., : 308-313, Minsk. (In Russian).
- Pyrina, I. L. 1966. Pervicnaja produkcija fitoplanktoma Ivanskogo, Rybinskogo i Kulbysevskogo vodochranilisca v zavisimosti ot mekotrych factorov. In : *Produktivnost i krugovaroť organiceskogo vescestva ve vnutrennyh vodoemach*. Moskva, pp. 249-270.
- Qasim, S. Z., Wellershaus, S. Bhattathiri, P. M. A. and Abidi, S. A. M. 1969. Organic production in a tropical estuary. *Proc. Ind. Acad. Sci.*, 69B(2) : 51-94.
- Rao, C. B. 1955. On the distribution of algae in a group of six small ponds. II. Algal periodicity. *J. Ecol.*, 43 : 291-308.
- Raymont, J. E. G. 1963. *Plankton and productivity in the oceans*. Vol. 1-*Phytoplankton*. Pergamon Press, Oxford. 489 pp.
- Raymont, J. E. G. 1966. The production of marine plankton. *Advances in Ecol. Res.*, 3 : 117-205.
- Rawson, D. S. 1930. The bottom fauna of Lake Simcoe and its role in the Ecology of the lake. *Univ. Toronto Studies, Publ. Ont. Fish. Res. Lab.*, No. 40; 1-183.
- Rawson, D. S. 1939. Some physical and chemical factors in the metabolism of lakes. In Problems of Lake Biology, *Publ. Am. Assoc. Adv. Sci.*, No. 10, pp. 9-26.
- Rawson, D. S. 1955. Morphometry as a dominal factors in the productivity of large lakes. *Proc. Internat. Assoc. theor. appl. Limnol.*, 12 : 164-175.
- Reynolds, C. S. 1971. The ecology of planktonic blue-green algae in the north Shropshire meres. *Fld. Stud.*, 3 : 409-432.
- Reynolds, C. S. and Walsby, A. E. 1975. Water blooms. *Biol. Rev.* 50 : 437-481.
- Rhee, G-Yull. 1973. A continuous culture study of phosphate uptake, growth rate and polyphosphate in *Scenedesmus sp.* *J. Phycol.*, 9 : 495-506.
- Richman, S. 1958. The tansformation of energy by *Daphnia pulex*. *Ecol. Monogr.*, 28 : 273-291.
- Rigler, F. H. 1972. A dynamic view of the phosphorus cycle in lakes, P. 539-568. In E. J. Griffith *et al* (ed.). *The Environmental phosphorus handbook*.
- Riley, G. A. 1940. Limnological studies in connecticut. Part III. The plankton of Linsley Pond. *Ecol. Monogr.* 10 : 279-306.
- Riley, G. A. and Bumpus, D. F. 1948. Phytoplankton-Zooplankton relationship on Georges bank. *J. Mar. Res.* VI; 33-46.
- Rishi, V. and Kachroo, P. 1981. Effect of Sewage and fertilizers on phytoplankton of Doodhghanga. *Geobios*, 8 : 160-162.

- Rodhe, W. 1955. Can plankton production proceed during winter darkness in subarctic lakes ? *Verh. internat. Verein. Limnol.* 12 : 117-112.
- Rodhe, W. 1958. The primary production in Lakes: some results and restrictions of the ^{14}C Method. *Rapp. et. Proc.-Verb.*, 144 : 122-128.
- Rodhe, W. 1962. Sulla produzione di fitoplancton in laghi trasparenti di alta montagna. *Mem. Ist. Ital. Idrobiol.* 15 : 21-28.
- Rodhe, W., Hobbie, J. E. and Wright, R. T. 1966. Phototrophy and Heterotrophy in high mountain lakes. *Verh. Internat. Verein. Limnol.* 16 : 302-313.
- Ross, H. H. 1963. Stream communities and terrestrial biomes *Arch. Hydrobiol.*, 59 : 235-242.
- Round, F. E. 1957. The late-glacial and post-glacial diatom succession in Kentmere Valley deposit. *New Phytol.*, 56 : 98-126.
- Ruben, S., Randall, M, Kamen, M. and Hyde, J. L. 1941. Photosynthesis with radioactive Carbon. *V. J. Am. Chem. Soc.* 63 : 877.
- Ruttner, F. 1921. Das elektroytische Leitvermogen verdunnter Losungen unter dem Einfluss submerser Gewachse. I., Sitzungsber. *Akad. Wiss. Wien, Math.-nat. Kl., Abt. 1*, 130 : 71-108.
- Ruttner, F. 1931. Hydrographische und hydrochemische Beobachtungen auf Java, Sumatra und Bali. *Arch. Hydrobiol. Suppl.* 8 : 197-454.
- Ruttner, F. 1953. *Fundamentals of Limnology*. 1st ed. (Transl. by D. G. Frey and F. E. J. Fry). Univ. Toronto Press, Toronto. 295 pp.
- Ryther, J. H. and Yentsch, C. S. 1958. Primary production of continental shelf waters off New York. *Limnol. and Oceanogr.* 3 : 327-335.
- Sahai, R. and Sinha, A. B. 1968. Investigations on bio-ecology of inland waters of Gorakhpur (U.P.), India. I. Limnology of Ramgarh Lake. *Hydrobiologia*, 34 : 433-447.
- Sakamoto, M. 1971. Chemical factors involved in the control of phytoplankton production in Experimental Lakes Area, northwestern Ontario. *J. Fish. Res. Board. Can.*, 28 : 203-213.
- Saunders, G. W. 1972. The transformation of artificial detritus in Lake water. *Mam. Ist. Ital. Idrobiol.*, 29 (Suppl.) : 261-288.
- Saunders, G. W. Jr, Cofman, W. P., Michael, R. G. and Krishnaswamy, S. 1975. Photosynthesis and extracellular release in ponds of South India. *Verh. Internat. Varein. Limnol.* 19 : 2309-2314.
- Saunders, G. W. Jr, Cummins, K. W., Gak, D. Z. Pieczynska, E., Straskrabova, V. and Wetzzel, R. G. 1980. Organic matter and decomposers. In : Le Gren E. D. and R. H. Lowe-McConnel (eds.). *The functioning of freshwater ecosystems*, Cambridge University Press, 588 pp.

- Schegg, E. 1968. Relation between plankton development and bacteria in Lake Lucerne and Rotsee. *Schweiz. Z. Hydrol.*, 30 : 289-296.
- Schelske, C. L., Hooper, F. F. and Haertl, E. J. 1962. Responses of a marl lake to chelated iron and fertilizer. *Ecology* 43 : 646-653.
- Schelske, C. L. and Stoermer, E. F. 1971. Eutrophication, silica and predicted changes in algal quality in Lake Michigan. *Science*, 173 : 423-424.
- Schindler, D. W. 1974. "Eutrophication and recovery in experimental lakes. Implications for lake management" *Science* 184 : 897-899.
- Schindler, R. W. 1977. Evolution of phosphorus limitation in lakes. *Science*. 195 : 260-262.
- Schindler, R. W. and Holmgren, S. K. 1971. Primary Production and phytoplankton in the experimental Lakes Area, northwestern Ontario and other low-carbonate waters and a liquid scintillation method for determining ^{14}C activity in photosynthesis. *J. Fish. Res. Bd. Canada*. 28 : 189-201.
- Schindler, R. W. and Fee, E. J. 1973. Diurnal variation of dissolved inorganic carbon and its use in estimating primary production and CO_2 invasion in lake 227. *J. Fish. Res. Board, Can.* 30 : 1501-1510.
- Schrater, C. and Kirchner, D. 1896. Die Vegetation der Bodensees. *Lindau, Bodensee Forsch.*, 9, T1. 1 : 1-122, T1. II : 1-86.
- Serruya, C., Jelstein, M., Bilingher, U and Serruya, S. 1974. Lake Kinneret sediments : Nutrient composition of the pore water and mud water exchanges. *Limnol. Oceanogr.*, 19 : 489-508.
- Shanon, E. E. and Brezonik, P. L. 1972. Relationships between Lake Trophic State and Nitrogen and Phosphorus Loading Rates. *Environm. Sci. Technol.*, 6 : 719-725.
- Shapiro, J. 1960. The cause of a metalimnetic minimum of dissolved oxygen. *Limnol. Oceanogr.*, 5 : 216-227.
- Shapiro, J. 1973. Blue-green algae : Why they become dominant. *Science*, 179 : 382-384.
- Silvey, J. R. G. and Roach, A. W. 1964. Investigation of the microbiological cycle in surface waters. *J. Am. Wat. Wks. Ass.*, 56 : 60-71.
- Singh, V. P. 1960. Phytoplankton ecology of the inland waters of Uttar Pradesh. *Proc. Symp. Algology, ICAR*. New Delhi, 243-271.
- Smith, G. M. 1950. *The fresh-water algae of the United States*, 2nd. ed. New York, McGraw-Hill Book Co., vii, 719 pp.
- Sorokin, Y. I. 1968. Primary production and microbiological process in Lake Gek-Gell. *Mikrobiologiya*, 37 : 289-296.

- Sorokin, Y. I. and Kadota (eds.), H. 1972. *Techniques for the assessment of microbial production and decomposition in freshwaters*. IBP Handbook No. 23. Blackwell Sci. Publ. Oxford. 112 pp.
- Sreenivasan, A. 1966. Fish production in some rural demonstration Ponds in Madras (India) with an account of the chemistry of water and soil. *FAO Fish. Rep.*, (44). Vol. 3 : 179-197.
- Sreenivasan, A. 1970. Limnology of tropical impoundments : A comparative study of the major reservoirs in Madras State (India). *Hydrobiologia*, 36(3-4) : 443-469.
- Sreenivasan, A. 1976. Limnological studies of and primary production in temple pond ecosystems. *Hydrobiol.* 48(2) : 117-123.
- Steel, J. A. 1975. The management of Thames Valley reservoirs. Water research Centre Symposium : *The effects of storage on water quality*. Medmenham.
- Steele, J. H. and Yentsch, C. S. 1960. The vertical distribution of Chlorophyll. *J. Mar. Biol. Ass. U. K.*, 39 : 217-226.
- Steemann-Nielsen, E. and Jorgensen, E.G. 1968a. The adaptation of plankton algae. I. General Part. *-Phycol. Plant.*, 21 : 401-413.
- Steemann-Nielsen, E. and Al Kholy, A. A. 1956. Use of C14 technique in measuring photosynthesis of phosphorus or nitrogen deficient algae. *Physiol. Plant.* 9 : 114-153.
- Stewart, K. M. and Rohlich, S. A. 1967. Eutrophication A Review A Report to the State Water Quality control Board, California, No. 34, 188 pp.
- Stewart, A. J., Blinn, D. W., Tompkins, T. & Wilkes, S. 1974. Phytoplankton population dynamics in warm Creek Bay, Lake Powell. In : *environmental impact studies of Navajo and Kaiparawits power plants*. Third annual report. Northern Arizona university. 149pp.
- Strom, K. M. 1928. Recent Advances in Limnology. *Proc. Linn. Soc. London*, pp 96-110.
- Stross, R. G., Chisholm, S. W. and Downing, T. A. 1973. Causes of daily rhythms in photosynthetic rates of phytoplankton. *Biol. Bull.* 145 : 200-209.
- Stumm, W. and Morgan, J. J. 1970. *Aquatic Chemistry* Wiley, Interscience. 583 p.
- Subba Rao, D. and Govind, B. V. 1964. Hydrology of tungabhadra reservoir, *Indian J. Fish.*, 11 : 321-344.
- Swar, D. B. and Fernando, C. H. 1980. Some studies on the ecology of Limnetic crustacean zooplankton in Lakes Begnas and Rupa, Pokhara Valley, Nepal. *Hydrobiologia*, 70 : 235-245.
- Symons, J. M., Irwin, W. H., Demarco J. and Robeck, G. G. 1967. Effects of impoundments on water quality : a research summary. The Transactions of the Seventeenth Annual conf. on Sanitary Engineering, *The Bull of Engin. and Arch.* No. 57 : 28-36.

- Takahashi, M. and Norton, A. B. 1977. Seasonal changes in microbial biomass in the Fraser River estuary, British Columbia. *Arch. Hydrobiol.*, 79 : 133-143.
- Talling, J. F. 1962. Freshwater algae. In: *Physiology and Biochemistry of Algae*. R. A. Lewin (ed.), pp. 743-753. Academic Press, New York.
- Talling, J. F. 1965. The photosynthetic activity of phytoplankton in east African Lakes. *Int. Rev. ges. Hydrobiol.*, 50 : 1-32.
- Talling, J. F. 1966. The annual cycle of stratification and phytoplankton growth in Lake Victoria (East Africa). *Int. Rev. Gesamten Hydrobiol.*, 51 : 545-621.
- Talling, J. F. 1970. Generalized and specialized features of phytoplankton as a form of photosynthetic cover. In: *Prediction and measurement of photosynthetic productivity*. Proc. IBP/PP Technical Meeting, Trebon.
- Tan, J. L. and Overbeck, J. 1973. Okologische Untersuchungen uber nitratreduzierende Bakterien im Wasser des Pluss sees (Schleswig-Holstein). *Z. Allg. Mikrobiol.*, 13 : 83-94.
- Taylor, M. P. and Welch, E. B. 1970. *Morris Reservoir Study: Part II, Effects of thermal stratification and nutrient availability on the production of reservoir phytoplankton*. 34 p.
- Teasenow, U. 1966. Untersuchungen uber den kieselsaurehaushalt der Binnengewasser. *Arch. Hydrobiol. Suppl.*, 32 : 1-136.
- Thienemann, A. 1927. Der Bau des Seebeckens in seiner Bedeutung fur das Leben im See. *Verh. Zool. Bot. Ges.* 77 : 87-91.
- Thresh, J. C., Suckling, E. V. and Beale, J. F. 1944. *The examination of water supplies*. Ed. Taylor, E. W., 1949.
- Tilzer, M. M. 1973. Diurnal periodicity in the phytoplankton assemblage of a high mount in lake. *Limnol. Oceanogr.*, 18 : 15-30.
- Timms, B. V. 1970. Chemical and zooplankton studies of lentic habitats in north eastern New South Wales. *Aust. J. Mar. Fresh Wat. Res.*, 21 : 11-33.
- Utermohl, H. 1958. Zur Vervollkommung der quantitativen Phytoplankton Methodik. *Mitt. Int. Ver. Limnol.*, 9 : 1-58.
- Vallentyne, J. R. 1957. Principles of Modern Limnology. *Amer. Scientist*, 45 : 218-244.
- Venkataraman, K. and Job, S. V. 1979. The influence of temperature of oxygen consumption of *Daphnia carinata* King (Cladocera : Daphnidae). *Curr. Sci.*, 48 (1) : 24-25.
- Venkataraman, K. and Job, S. V. 1980. Effect of temperature on the development, growth and egg production in *Daphnia carinata* King (Cladocera : Daphnidae). *Hydrobiologia*, 68 : 217-224.

- Verduin, J. 1956. Energy fixation and utilization by natural communities in Western Lake Erie. *Ecology*, 37 : 40-50.
- Verduin, J. 1959. Photosynthesis by aquatic communities in northwestern Ohio. *Ecology*, 40 : 377-383.
- Vijayaraghavan, S. 1971. Studies on the diurnal variations in physico-chemical and biological factors in Teppakulam Tank. *Proc. Ind. Acad. Sci.*, 44B : 63-73.
- Vijayaraghavan, S. 1969., Navaneethakrishnan, P. and Michael, R. G. 1969. Diel cycle of dissolved carbohydrates in two freshwater pond. *Proceeding of Ind. Acad. Sci. LXX* (4) : 157-168.
- Vincent, W. F. 1978. Survival of aphotic phytoplankton in Lake Tahoe throughout prolonged stratification. *Verh. Internat. Verein. Limnol.*, 20 : 401-406.
- Volenweider, R. P. and Nauwerdck, A. 1961. Some observations on the ^{14}C method for measuring primary production. *Verh. int. Verein. Limnol.*, 14 : 134-139.
- Vollenweider, R. A. 1968. *Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in Eutrophication*. Organization for economic cooperation and development publication: DAS/CSI/68 : 27 Paris, France. 182 pp.
- Vollenweider, R. A. 1969. Moglichkeiten und Grenzen elementarer Modelle der Stoffbilanz von Seen. *Arch. Hydrobiol.*, 66 : 1-36.
- Vollenweider, R. A. 1970. *Models for calculating integral photosynthesis and some simplifications regarding structural properties of the community metabolism of aquatic systems*, p 455-472.-In : prediction and measurement of photosynthetic productivity. Proc. IBP/PEEe Tech. Meeting Trebon, CSSR, Centre Agr. Publ. Doc. Wageningen.
- Vollenweider, R. A. 1971. *A manual on methods for measuring primary production in aquatic environment*. IBP Handbook No. 12. Blackwell Scientific Publications, Oxford. 213 pp.
- Vollenweider, R. A. and Frei, M. 1953. Vertikale und zeitliche Verteilung der Leitfähigkeit in einem eutrophen Gewässer während der Sommerstagnation. *Schweiz. A. Hydrol.*, 15 : 158-167.
- Warburgh, O. 1919. Über die Geschwindigkeit der photochemischen Kohlensäurezersetzung in lebenden Zellen. I., *Biochem. Zeitschr.*, 100 : 230-270.
- Welch, P. S. 1948. *Limnological Methods*. Philadelphia, 381 pp.
- Welch, P. S. 1952. *Limnology*. McGraw-Hill Book Co., New York, 538 pp.
- West, W. and West, G. S. 1912. On the periodicity of the phytoplankton of some British Lakes. *J. Linn. Soc. Botany*, 40 : 395-432.

- Westlake, D. F., Adams, M. S., Bindloss, M. E., Ganf, G. G., Gerloff, G. C., Hammer, U. T., Javornicky, P., Koonce, J. F., Marker, A. F. H., McCracken, M. D., Moss, B. Nauwerck, A. Pyrina, I. L., Steel, J. A. P., Tilzer, M. and Walters, C. J., 1980. Primary production. In. Le cren, E. D. and R. H. Lowe-Mc Connell (eds.). *The functioning of freshwater ecosystems*, Cambridge University Press, 588 pp.
- Wetzel, R. G. 1966. Variations in productivity of Goose and hypereutrophic sylvan Lakes, *Indiana. Invest. Indiana Lake streams* 7.
- Wetzel, R. G. 1966a. Nutritional aspects of algal productivity in marl lakes with special reference to enrichment bioassays and their interpretation, p. 139-157. In. *Primary productivity in aquatic environments*. Univ. of California Press, Berkeley, Calif.
- Wetzel, R. G. 1966b. Productivity and nutrient relationships in marl lakes of northern Indiana. *Verh. Int. ver. Limnol.* 16 : 321-332.
- Wetzel, R. G. 1967. Variations in productivity in Goose and hypereutrophic Sylvan lakes, Indiana. *Invest. Ind. Lakes Streams* 7 : 147-184.
- Wetzel, R. G. 1968. Dissolved organic matter and phytoplanktonic productivity in marl lakes. *Mitt. Int. Verh. Limnol.*, 17 : 72-85.
- Wetzel, R. G. 1975. *Limnology* W. B. Saunders Co., Philadelphia. 743 pp.
- Wetzel, R. G. and Allen, H. L. 1972. Functions and interactions of dissolved organic matter and the littoral zone in lake metabolism and eutrophication.- In. *"Productivity problems of freshwaters"* Z. Kajak and a. Hillbricht Ilkowska, Eds. pp. 333-347.
- Weibe, A. H. 1930. Investigations on plankton production in fish ponds. *Bull. U. s. Bur. Fish.*, 46 : 137-176.
- Wolk, C. P. 1973. Physiology and Cytological chemistry of blue-green algae. *Bacteriol. Rev.*, 37 : 32-101.
- Wynne-Edwards, V. C. 1962. *Animal dispersion in relation to social behaviour*. Oliver and Boyd, Edinburgh. 653 pp.
- Yan, W. D. and Stokes, P. 1978. Phytoplankton of an acidic lake and its responses to experimental alterations of pH. *Environ. Conser.*, 5 : 93-100.
- Yaron, Z. 1964. Notes on the ecology of Entomostracan Fauna of temporary rainpools in Israel. *Hydrobiologia*, 24 : 489-513.
- Yentsch, C. S. and Lee, R. W. 1966. A study of photosynthetic light reactions and a new interpretation of sun and shade type phytoplankton. *J. Mar. Res.*, 24 : 319-337.
- Zafar, A. R. 1964. On the ecology of algae in certain fish ponos of Hyderabad-India. I. Physico-chemical complexes. *Hydrobiologia*, 23 : 179-195.

- Zafar, A. R. 1964. On the ecology of algae in certain fish ponds of Hyderabad, India. II. Distribution of unicellular and colonial forms. *Hydrobiologia*, 24 : 556-566.
- Zafar, A. R. 1967. On the ecology of algae in certain fish ponds of Hyderabad, India. III. The periodicity. *Hydrobiologia*, 30 : 96-112.
- Zagorodnyaya, Yu. A. 1979. The dynamics of glycogen content in the copepod *Pseudocalanus elongatus*. Biol. Morya (Vladivost.) (1) : 79-82.
- Zaret, T. M. and Suffern, S. 1976. Vertical migration in zooplankton as a predator avoidance mechanism. *Limnol. Oceanogr.*, 21 : 804-813.
- Zobell, C. E. 1941. Apparatus for collecting water samples from different depths for bacteriological analysis. *J. Mar. Res.*, 4 : 173-188.