

STUDIES ON MICROFLORA OF A FRESHWATER LAKE : AN ECOLOGICAL APPROACH

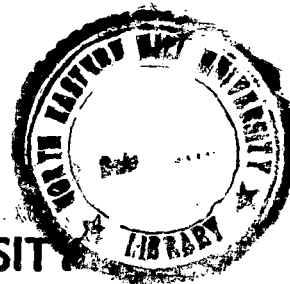
BRAJESH KUMAR TIWARI

**DEPARTMENT OF BOTANY
SCHOOL OF LIFE SCIENCES**

**SUBMITTED IN FULFILMENT OF THE REQUIREMENT OF
THE DEGREE OF**

DOCTOR OF PHILOSOPHY

To



**NORTH-EASTERN HILL UNIVERSITY
SHILLONG, INDIA**

DECEMBER, 1980

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I certify that the thesis entitled "STUDIES ON MICROFLORA OF A FRESHWATER LAKE: AN ECOLOGICAL APPROACH" submitted by Shri Brajesh Kumar Tiwari, M.Sc. for the degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any degree of any other University.

Date: December 29, 1980
Place: Shillong.

R.R. Mishra
Signature of the
Supervisor.

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Brajesh Kumar Tiwari
(BRAJESH KUMAR TIWARI)

Date 28.12.1980
Shillong

Appendix-3

List of Fungi

Achlya americana HumphreyA. diffusa Harvey ex Johnson.A. flagellata Coker.A. prolifera Nees von Esenbeck.Aphanomyces laevis de BaryDictyuchus monosporus LeitgebPythium debaryanum HesseP. monospermum PringsheimP. undulatum WaterhouseSaprolegnia dichina HumphreyS. ferax (Gruithuysen) ThuretS. parasitica CokerAbsidia cylindrospora HageniMucor circinelloides van TieghemM. hiemalis WehmerM. plumbeus BonordenM. racemosus FreseniusRhizopus nigricans EhrenbergPhoma humicola Gilman & Abbott.Aureobasidium pullulans (de Bary) Arnaud.Aegerita candida Pers. ex Fries.Alternaria alternata (Fries) KeisslerAspergillus candidus Link ex Thom et ChurchA. nidulans (Eidam) Winter.A. niger van TieghemA. sydowii Thom et Church.

IV

A. versicolor Tiroboschi

Cladosporium cladosporioides (Fresenius) Fries.

C. herbarum (Persoon) Link.

Curvularia lunata (Wakker) Boedijn.

Fusarium oxysporum Schlechtendahl.

F. roseum Link ex Fries.

Geotrichum candidum Link ex Persoon

Gliocladium penicilloides Corda.

Penicillium brefeldianum Dodge

P. chrysogenum Thom

P. javanicum Beyma.

P. nigricans (Sainier) Thom

P. oxalicum Currie et Thom

Pseudotorula heterospora Subram.

Trichoderma harzianum Rifai

T. koningii Oudemans

T. viride. Persoon ex S.F. Gray.

Trichothecium roseum (Pers.) Link ex Fries

Verticillium tenerum (Nees ex Pers) Link

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GENERAL INTRODUCTION

GENERAL INTRODUCTION

One of the most ubiquitous problems of freshwater bodies is their present rate of change in response to man made perturbations. Any management strategy to exploit these resources requires fundamental knowledge of the freshwater ecosystem structure and function. Achlorophyllous microorganisms play basic role in the transformation and cycling of various materials in a given ecosystem. Many of the trophic relations outlined in various models lay considerable emphasis on these tiny organisms as they play an important part in the ecosystem function. But very little information is available so far regarding the quantification of these organisms and their taxonomic composition is further less known.

Freshwater ecosystems comprise about 0.5% of the earth's surface having a volume of $2.84 \times 10^5 \text{ km}^3$. Although their areal and volumetric extent is relatively small, freshwater bodies are some of the most productive systems on earth. Freshwater resources are least utilized for their productive capacities. Primary productivity estimations based on phytoplankton photosynthesis have received ample attention of limnologists throughout the world (Munawar et al 1972; Kalff, 1967; Vijayraghavan, 1971). The contribution of saprobes towards the productivity of aquatic ecosystems has received little attention (Sorokin and Kadota, 1972). Hynes (1972) emphasized that a major part of carbon in the aquatic ecosystems does not enter the

photosynthetic fixation by phytoplankton. This external source of carbon is available for the organisms of higher trophic levels. The allochthonous carbon passes through the same pathways as carbon fixed by the green cells and, therefore, should be considered as a part of the total production in understanding the metabolisms of aquatic ecosystems. The extraneous input of carbon is relatively more significant in the freshwater lakes surrounded by terrestrial vegetation and receiving litter and surface run-off waters from neighbouring areas. Further, saprobes are more important in the shallow and small water bodies where the allochthonous organic material remains in the direct contact of the epilimnion water where the liberation of nutrients is faster due to constant availability of oxygen and is instantaneously available for the utilization by the primary producers. The importance of heterotrophic microbial populations in the functioning of lake ecosystems has been clearly demonstrated by Anderson and Dokulil (1977). They found that biological activity (production/biomass) in the bacteria is ten times higher than that of phytoplankton.

The primary production by bacteria is not much important in natural ecosystems because of the nonavailability of light and anaerobic conditions which are the prerequisites. The secondary production by C-heterotrophic bacteria and fungi is quite significant as 20-40 percent of the total organic nutrients are used by these organisms

(Rheinheimer, 1974). Apart from the above, these bacteria can also fix atmospheric CO_2 to the extent of 6 percent of their biomass production (Sorokin and Romanenko, 1966) and may thus contribute even more than the autotrophic production in many lakes receiving extraneous organic materials (Kusnetsov and Romanenko, 1966; Overbeck, 1971; 1972).

Besides being important decomposers and producers in aquatic habitats, many of the microbes are parasites of phytoplanktons zooplanktons and fishes (Masters, 1976; Green, 1974; Scott and O'Bier, 1962). Many zoosporic Phycomycetes are known to regulate the population and activity of the planktonic communities by causing serious diseases (Redfield and Vincent, 1979). Bacteria and fungi also play important role in the sedimentation. Fungi with the help of their mycelia and many bacteria through slime production can bring about some degree of aggregation of the particles. Also they transform many organic and inorganic dissolved substances into particulate aggregates through their various metabolics activities.

The limnological studies have mainly emphasized the zoological and production biology aspects. The microbiology and biochemistry of natural waters have received little attention. Further, most of the studies on the microbiological aspects deal with the comparison of various water bodies differing in trophic status. Only a

few freshwater lakes such as Windermere and Esthwaite Waters (Jones 1971, 1972a, 1977) in England, Mazurian and Mikolajskie lakes in Poland (Godlewska-Lipowa, 1974a, b, 1976a, b and Mirror Lake in USA (Jordon and Likens, 1975) have been studied in detail for the structural and functional role of the heterotrophic microbial populations.

Data on the role of aquatic bacteria and fungi on the functioning of aquatic ecosystems in India are still virtually non-existent.

Present study deals with the structural and functional aspects of heterotrophic bacteria and fungi in a freshwater lake (Wards Lake) located in Shillong. This lake has been worked out for various microbiological characters with a view to understand the seasonal and spatial distribution of the microbes in the lake water and functions which they perform in the water body under study. To understand the structural aspect of the heterotrophic microbial community the population dynamics of heterotrophic bacteria and fungi has been studied for a period of two years. In order to access the role of these organisms in the lake ecosystem two major approaches have been adopted. First estimation of the biological activity of these organisms using enzymatic and substrate utilization rate measurements and second the process of decomposition of extraneous plant litters in the lake to know the role of these organisms in decomposition.

Various parts of the investigation have been dealt-

in separate chapters each having its own introduction, materials and methods, results and discussions. The relevant literature has also been reviewed in the introduction parts of the different chapters.

DESCRIPTION OF THE LAKE

The study was conducted in Wards Lake situated in Shillong (India) at an altitude of 1460 m (m.s.l.), latitude 25.34°N and Longitude 91.52°E. The lake is a man made reservoir built in late nineteenth century. The adjoining slopes of the valley are covered with dense managed grasses and scattered trees, predominantly composed of pine (Pinus kesiya Royle). The lake receives water inflow throughout the year and had a controlled surface outlet which allows the excess water to flow out during rainy months. Throughout the year the water level does not change appreciably except during January-February when the level drops approx. 30 cm. The bathymetric map and general morphometry of the lake is given in Fig. 1.

The sampling stations are shown by bold numbers 1 to 5. Station 1 is situated in the isolated part of the lake. The average depth of this portion of the lake is 0.80 m. This station is comparatively richer in the nutrient content. The water input in the isolated portion flows out to the main lake through a surface out flow. The portion of the lake between station 1 and 2 is shallow and covered with water lilly (Nelumbo nucifera Gaertn.). The water at station 2 is comparatively clear and the depth of the lake is 0.50 m. Station 3 is situated in the main body of the lake where

**Fig.1. Bathymetric map of Ward's Lake,
Shillong. Values given in the map
represent the depth at each contour
(stations are shown by bold numbers,
1-5).**

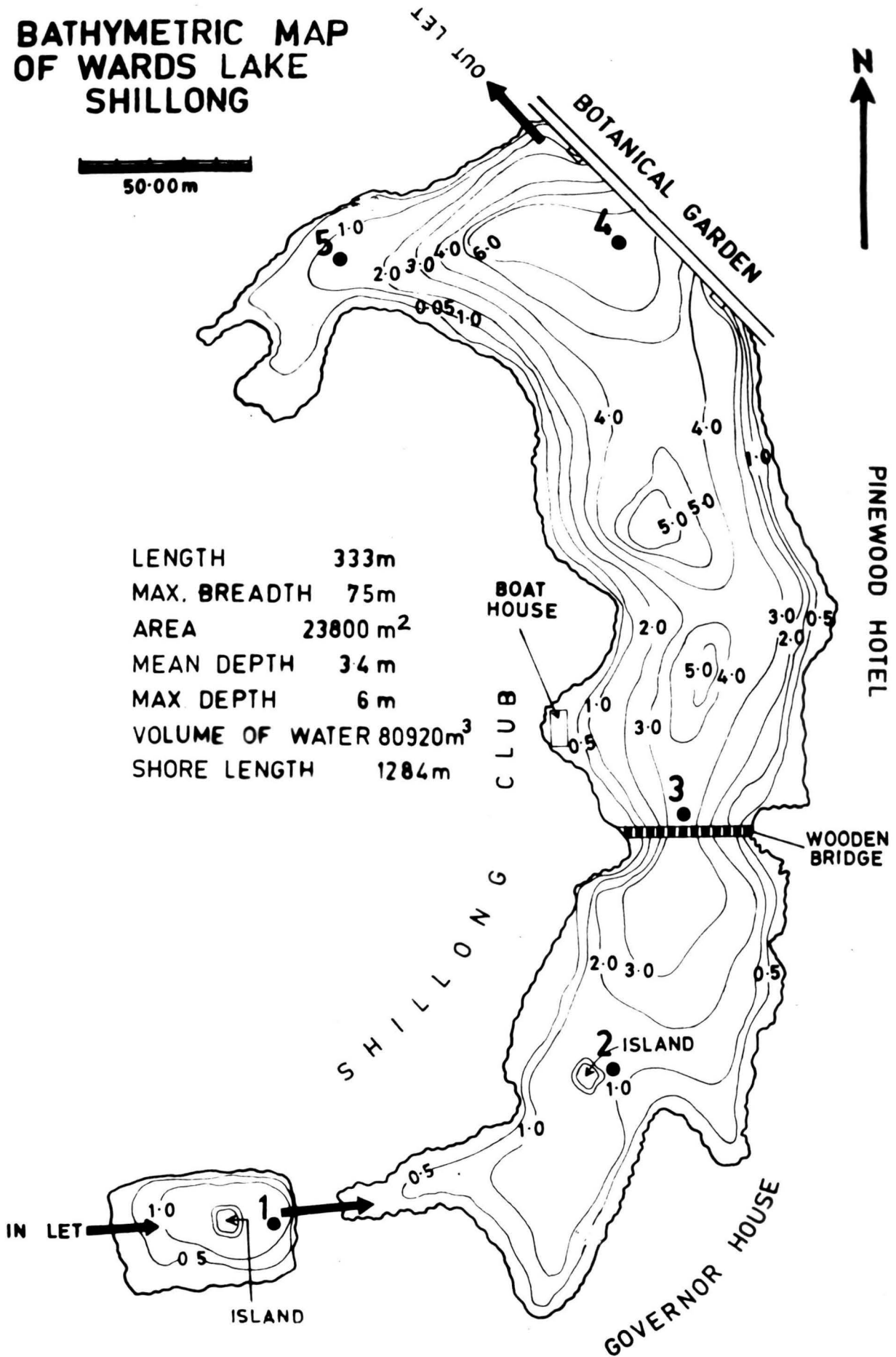
Fig. 1

BATHYMETRIC MAP OF WARDS LAKE SHILLONG

50.00m



LENGTH 333m
MAX. BREADTH 75m
AREA 23800 m²
MEAN DEPTH 3.4 m
MAX DEPTH 6 m
VOLUME OF WATER 80920m³
SHORE LENGTH 1284m



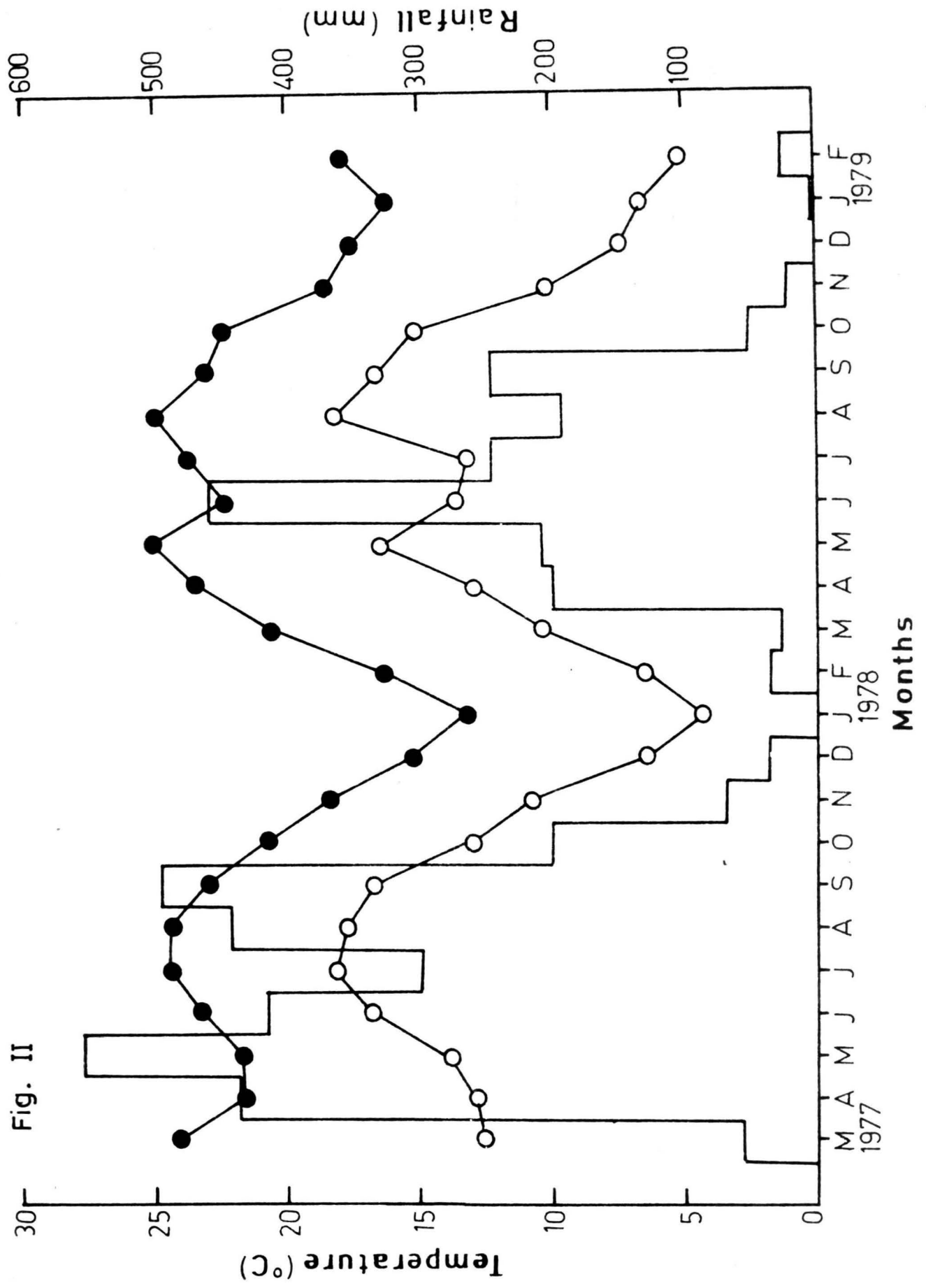
depth is 3 m. This station is characterized by the rocky bottom covered with gravels. The space between the gravels is occupied by a thin layer of coarse sand particles. Station 4 is situated in the deepest part of the lake and nearest to the outlet. The lake bottom at this station is silt with a cover of semi-decomposed plant litter composed mainly of pine needles. The water depth at this station is 6 m. Station 5 is situated at the next corner of the lake where depth was 0.5 m. The observations of this station were deleted as they did not differ appreciably when compared with the station 2. The informations collected on station 5 were, however, used when the data were compiled for the whole lake.

Chlorella sp. and Microcystis spp. dominate the phytoplankton community. The lake also harbours a sizeable community of zooplankters and fishes. The main body of the lake is free from macrophyte vegetation. Areas between station 1 and 2 and the extension beyond station 5 are covered by water lily. The isolated portion of the lake (station 1) harbours submerged growth of Hydrilla verticillata (Linn.F.) Royle. and Utricularia spp. The lake receives nutrients in the form of leaf and needle litter of the adjoining vegetation during fall.

The lake falls in the category 72 of classification of Hutchinson (1957). The lake is also used for recreational purposes and regular boating is a prominent feature.

Fig. II. Rainfall and temperature of the study area (March 1977-February 1979). Histograms: rainfall, Maximum temperature: closed circles, minimum temperature: open circles.

Fig. II



CLIMATE AND SEASONS OF SHILLONG

The climate of Shillong is temperate due to its altitude. The monsoon from the Bay of Bengal together with the thick vegetational cover of the region keeps the area humid and cool. For major part of the year sky remains cloudy which also helps in keeping the temperature down. Rains are distributed throughout the year except a short period during winter (December-January). Most of the rains, however, occur between April and September. Shillong has four distinct seasons:

Spring	March to May
Summer	June to September
Autumn	October and November
Winter	December to February.

The rainfall and temperature at Shillong during the course of study is shown in Fig.II. These data were obtained from the Central Seismological Observatory at Meath Home, Shillong-5.

Apart from the seasonal variations, the climate of Shillong is unique in the diurnal variations of light and temperature conditions. Sudden changes in temperature due to cloud cover in the after-noons is a common feature.

CHAPTER I

PHYSICO-CHEMICAL CHARACTERS OF THE LAKE

INTRODUCTION

To understand the population dynamics and ecosystem function of any biotope the most important aspect to be worked out is the physico-chemical characters of the system. The productivity of any ecosystem is strictly connected with the available nutritional compounds. Physico-chemical characters directly regulate the structure and function of the biological community of the natural water bodies. Of many physico-chemical factors that regulate the population and activity of the organisms, temperature, pH, dissolved oxygen concentration, dissolved organic carbon, dissolved carbon di-oxide, conductivity, phosphates, nitrate, alkalinity, silicate, calcium and magnesium are the most important ones. These characters control and also reflect various biological processes in natural waters. Temperature, pH, dissolved oxygen and dissolved organic carbon values are of particular significance for the heterotrophic microbial populations. Present chapter deals with the seasonal and spatial variations of various physico-chemical characters of the lake water during the course of investigation.

MATERIALS AND METHODS

The methods adopted for the estimation of various parameters are as outlined in Standard Methods (APHA, 1971). Water temperature was measured using a mercury thermometer

of 0.01°C accuracy. The water temperature of surface water was measured directly by immersing the thermometer knob. The temperature of deeper waters was estimated after bringing up the water sample in Van Dorn sampler (Van Dorn, 1956). pH was estimated using Systronics digital pH meter. Conductivity was measured using Elico conductivity bridge. Ortho-phosphate values are the soluble reactive phosphate. The estimations have been done on every 50 cm depth of the water column. Data of station 1 and 2 represent the arithmetic mean values of all the depths. This was done because depth-wise variation in the values was not remarkable. Values of surface water, mid-depth water and bottom waters are plotted for stations 3 and 4. All the values were recorded on weekly intervals, the data included, however, are averaged for the months. Dissolved organic carbon could not be estimated during first year of study because the method could not be standardized at appropriate time. Later it was estimated following the method described by Gocke and Hoppe (1977). The value of oxygen consumed for the oxidation of organic carbon was estimated by permanganate oxidation method and it was then converted to equivalent amount of carbon by multiplying the value by 0.375. It has been noted during the course of study that this method underestimated the total value as compared to other advanced methods based on gas analyser techniques (Mezel and Vaccaro, 1964). The method adopted, however, is quite useful to get comparable results with the available laboratory facilities.

RESULTS

Temperature

As evident from the Fig. 1.1 the water temperature varied between 10 and 24°C. Thermal stratification was observed at stations 3 and 4. The opposite trend of stratification was noted during January-February which results into mixing of the water column during this period of the year. This phenomenon is particularly clear at the station 4 (Fig. 1.1).

pH

The pH of water did not vary appreciably and remained fairly constant, near neutrality, at all the stations as well as at different depths. In general, it varied between 6 and 7 (Fig. 1.2).

Dissolved Oxygen

Throughout the study period the dissolved oxygen values remained fairly constant at the stations 1 and 2 and at the surface of the stations 3 and 4 except a tendency of increment during the spring months. Distinct depth-wise gradient was recorded at station 4. The oxygen level at the bottom of this station showed an interesting pattern of seasonal variation. It was fairly high in the month of March and decreased steadily upto July. In the months of July and August the bottom water was completely devoid of

**Fig.1.1. Monthly variation in temperature (°C)
of lake water at various stations from
March 1977 to February 1979. Circles:
surface waters, triangles mid-depth
waters, squares :bottom waters.**

Fig. 1.1

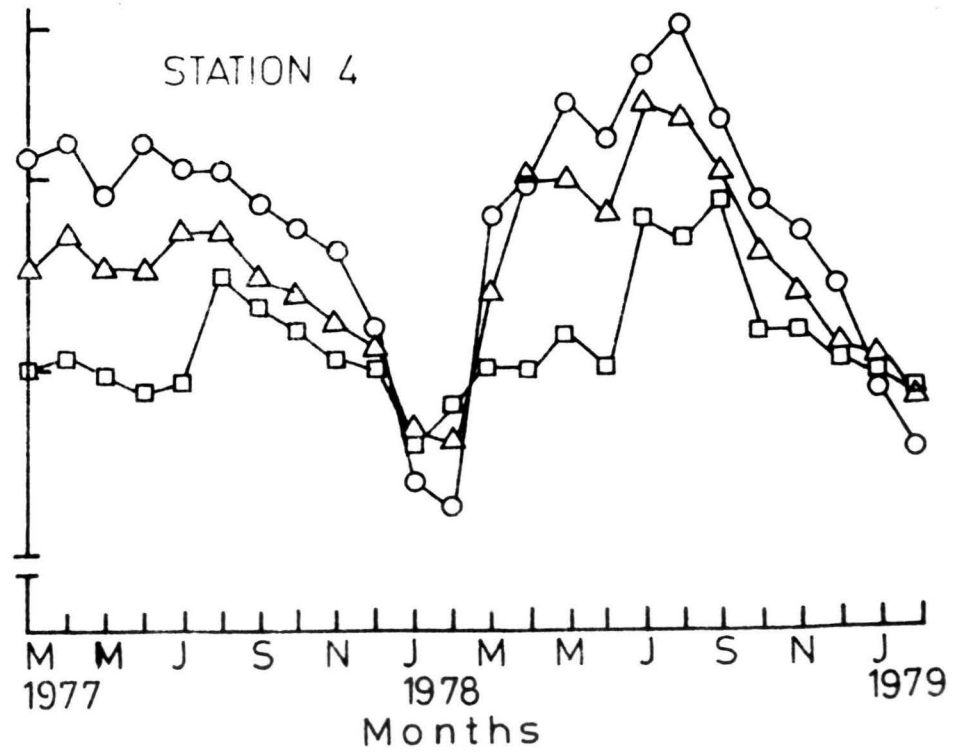
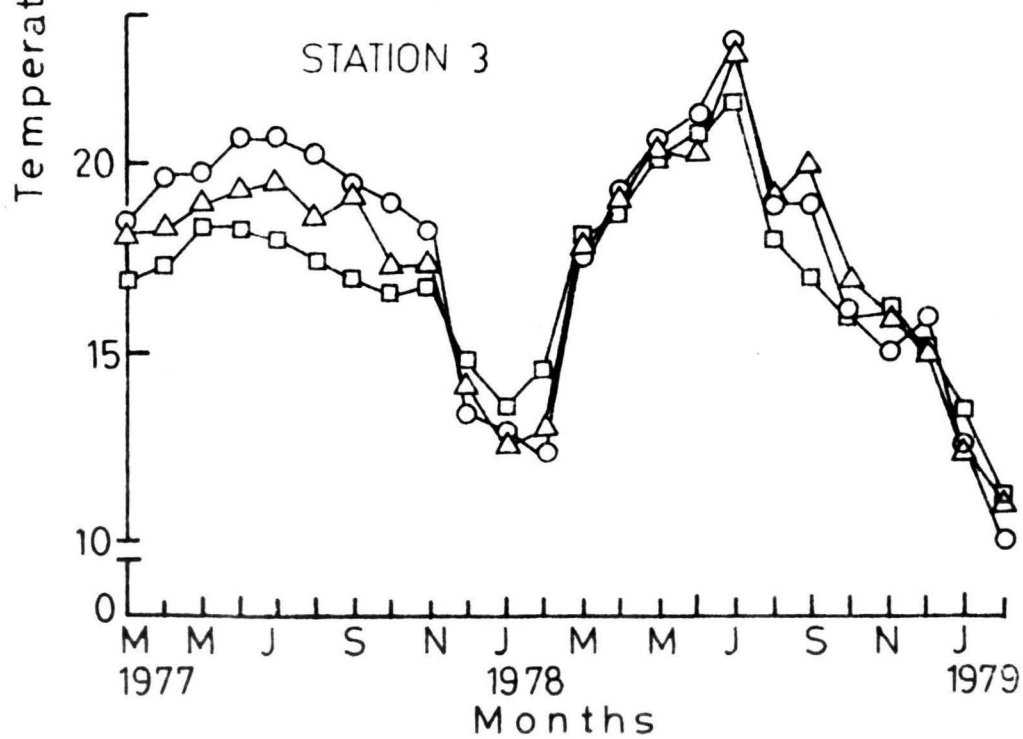
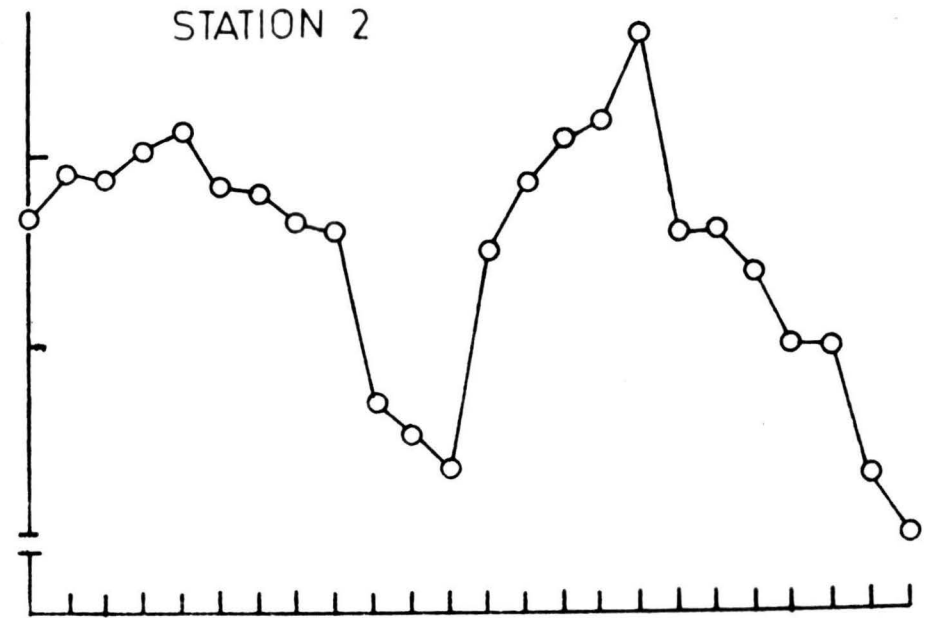
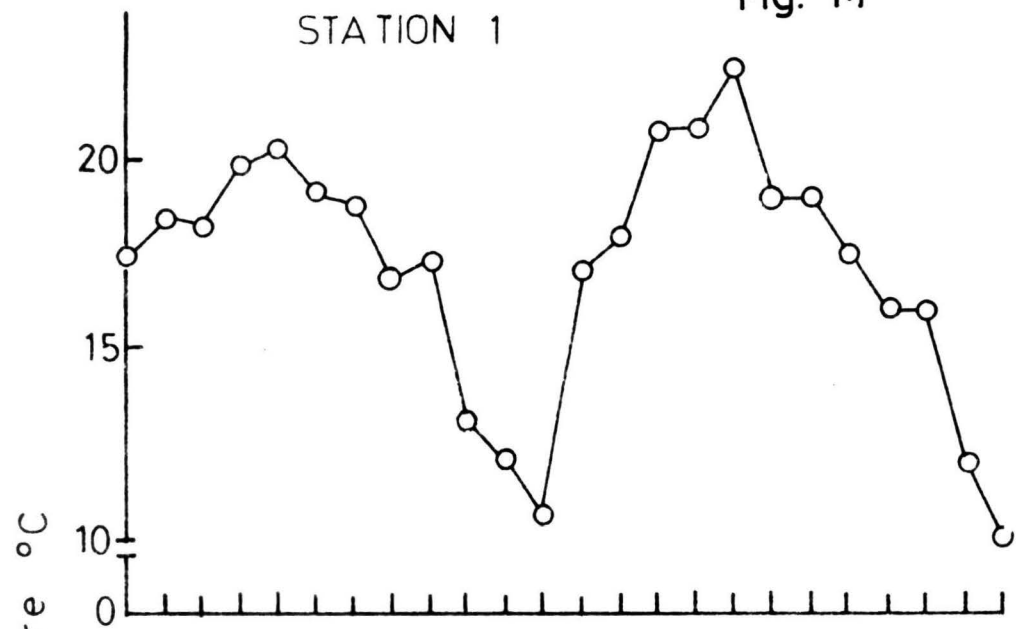


Fig.1.2. Monthly variation in pH values in the lake water at various stations from March 1977 to February 1979. Squares: surface waters, triangles: mid-depth waters, and squares: bottom waters.

Fig. 1.2

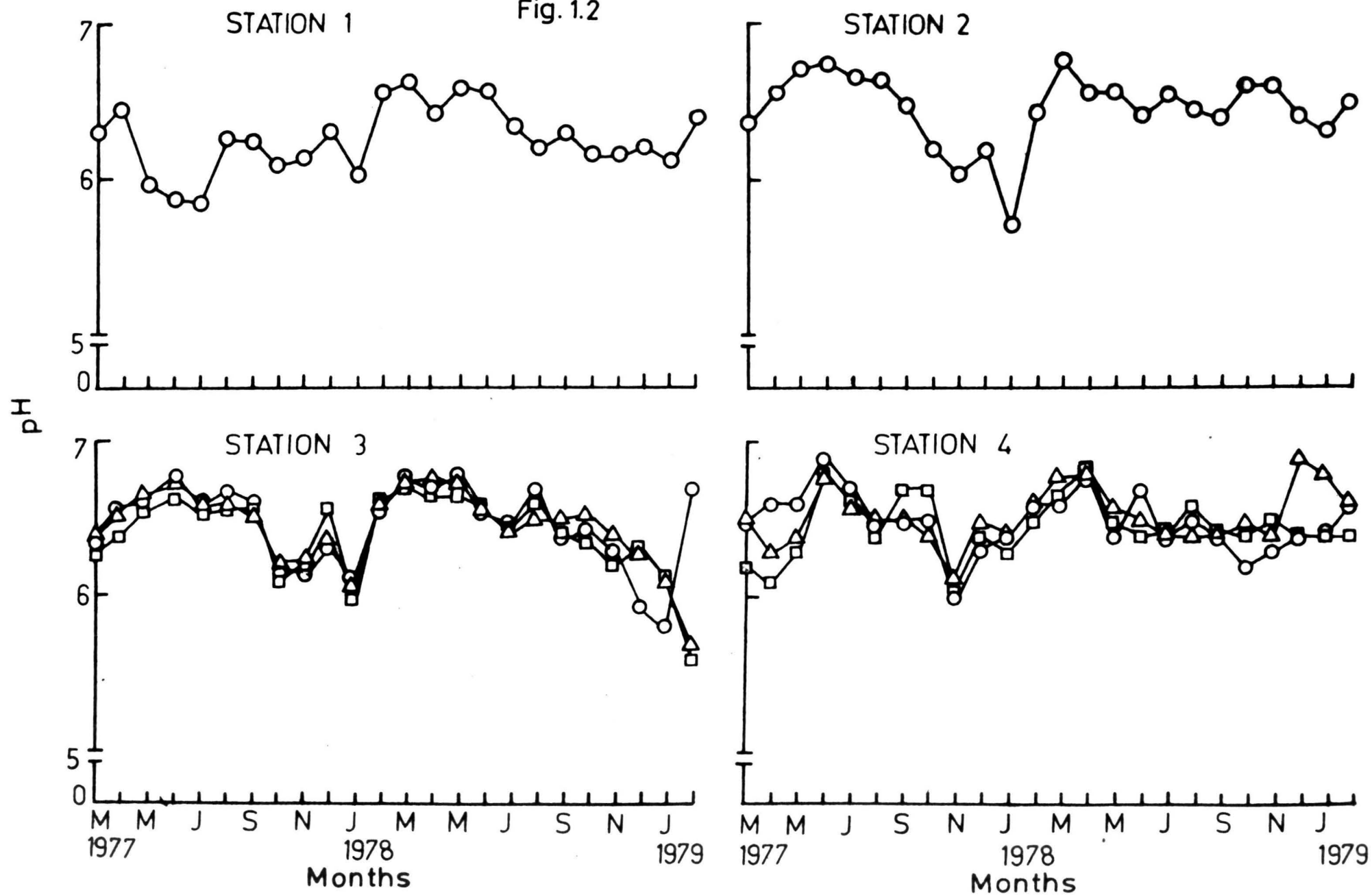


Fig.1.3. Monthly variation in dissolved oxygen concentration (mg/l) in the lake water at various stations from March 1977 to February 1979. Squares surface waters, triangles: mid-depth waters, and squares bottom waters.

Fig. 1.3

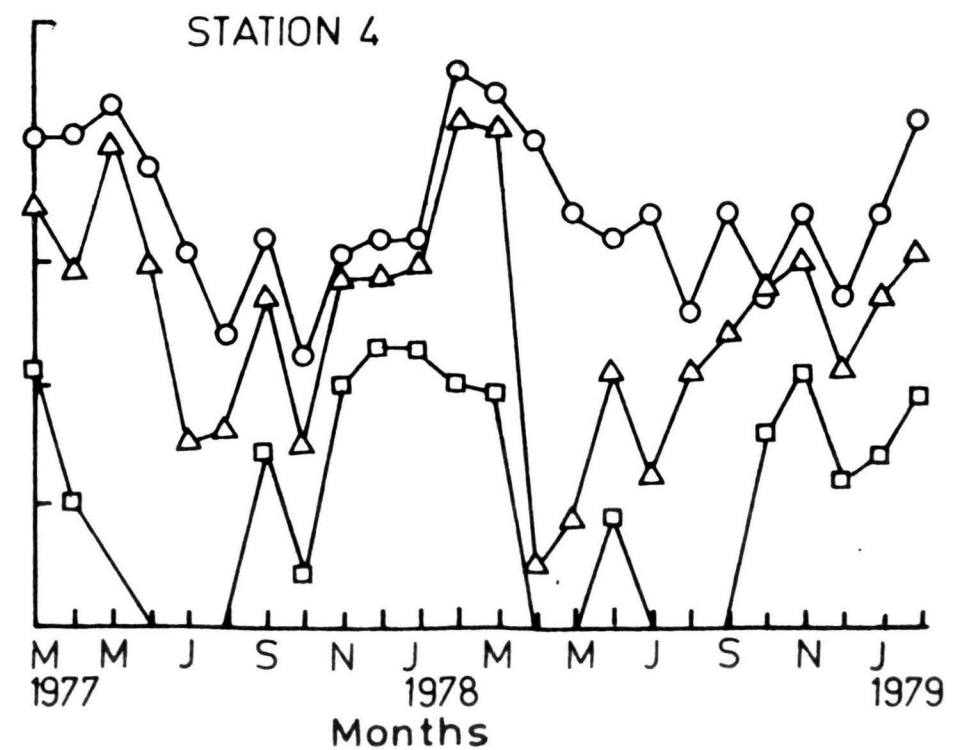
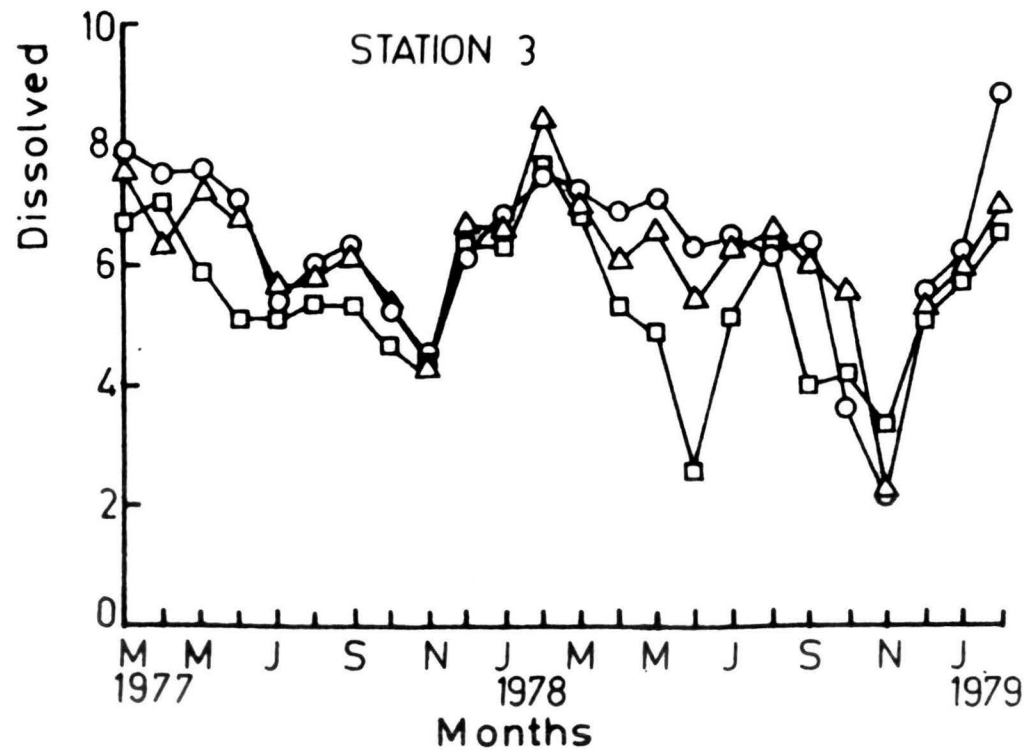
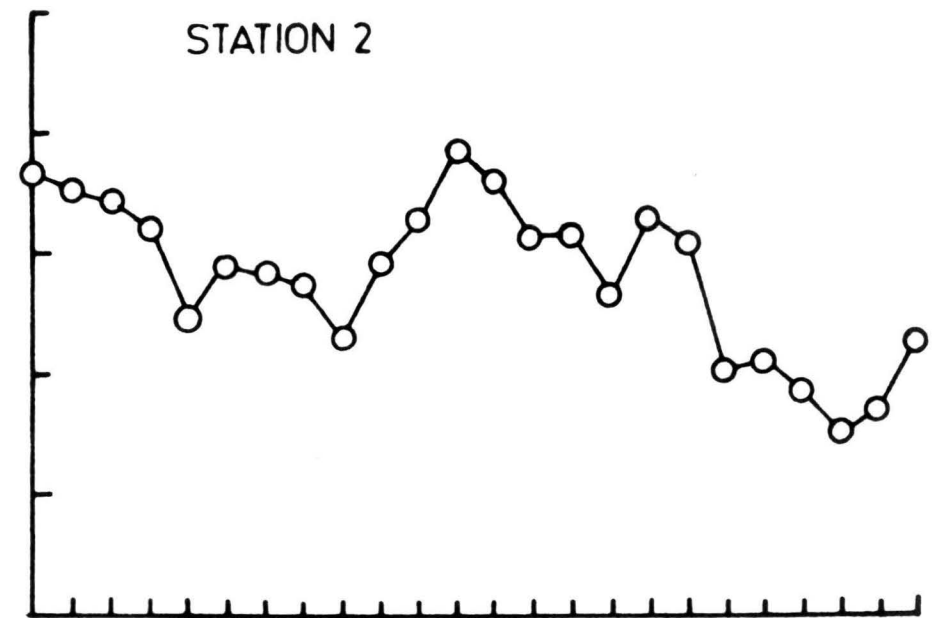
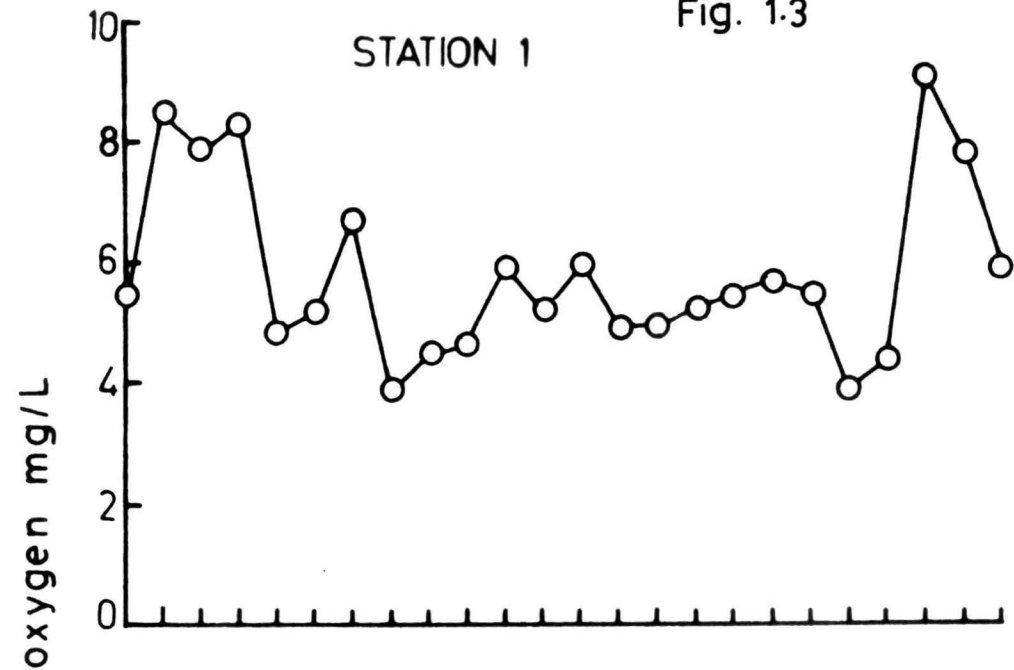
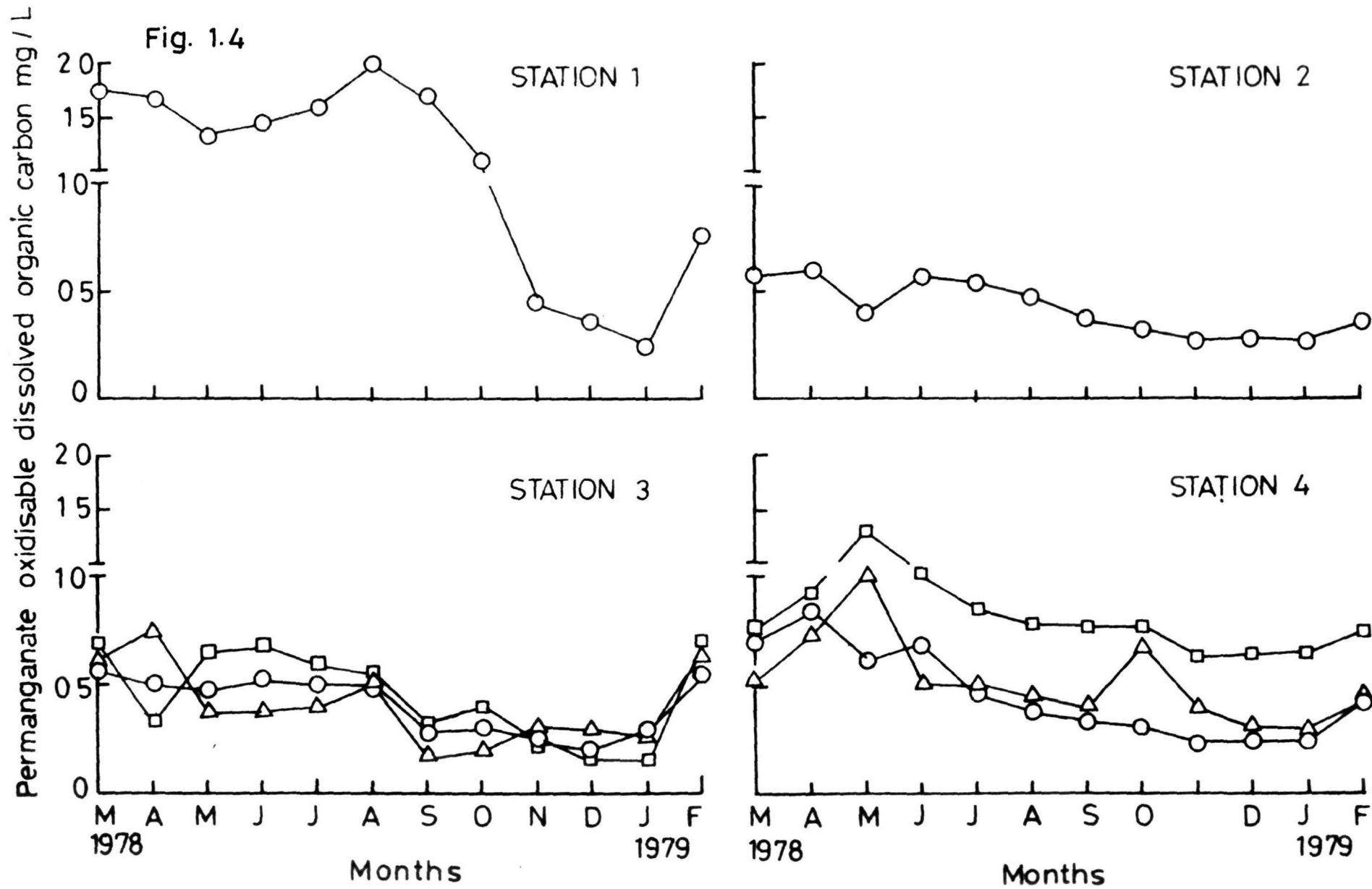


Fig.1.4. Monthly variation in permanganate oxidisable dissolved organic carbon concentration (mg/l) in the lake water at various stations from March 1977 to February 1979. Circles:surface waters, triangles:mid-depth waters and squares: bottom waters.



**Fig.1.5. Monthly variation in conductivity
(u mho/cm) in the lake water at
various stations from March 1977
to February 1979. Circles:surface
waters, triangles:mid-depth waters
and squares:bottom waters.**

APPENDIX

Appendix table - 1. Percentage occurrence of various fungi in the lake water at different stations.

Number of months of occurrence x 100

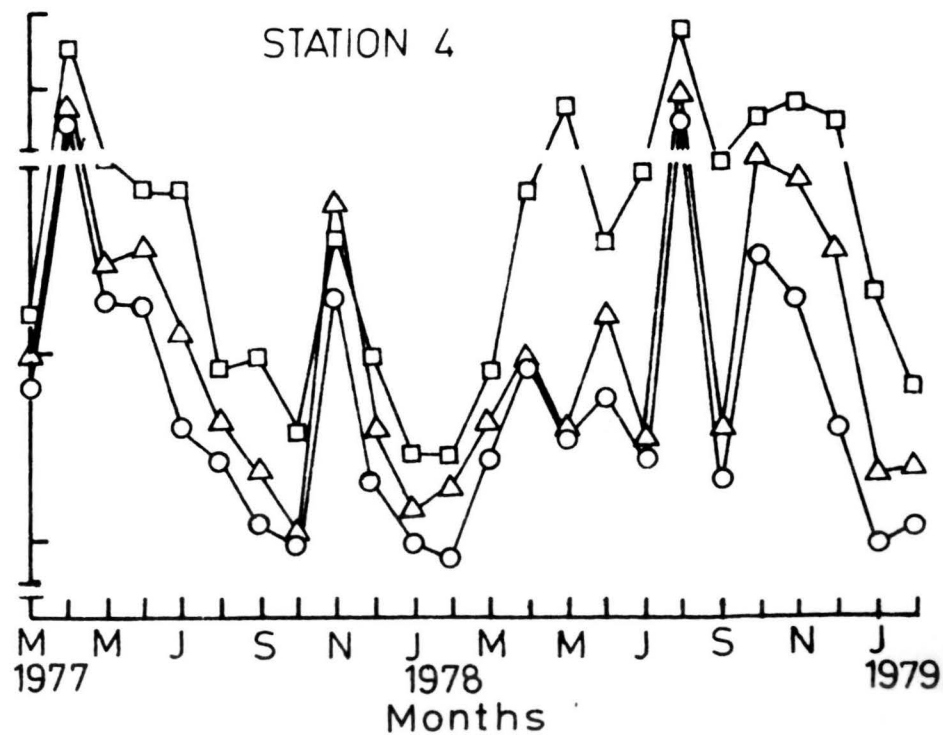
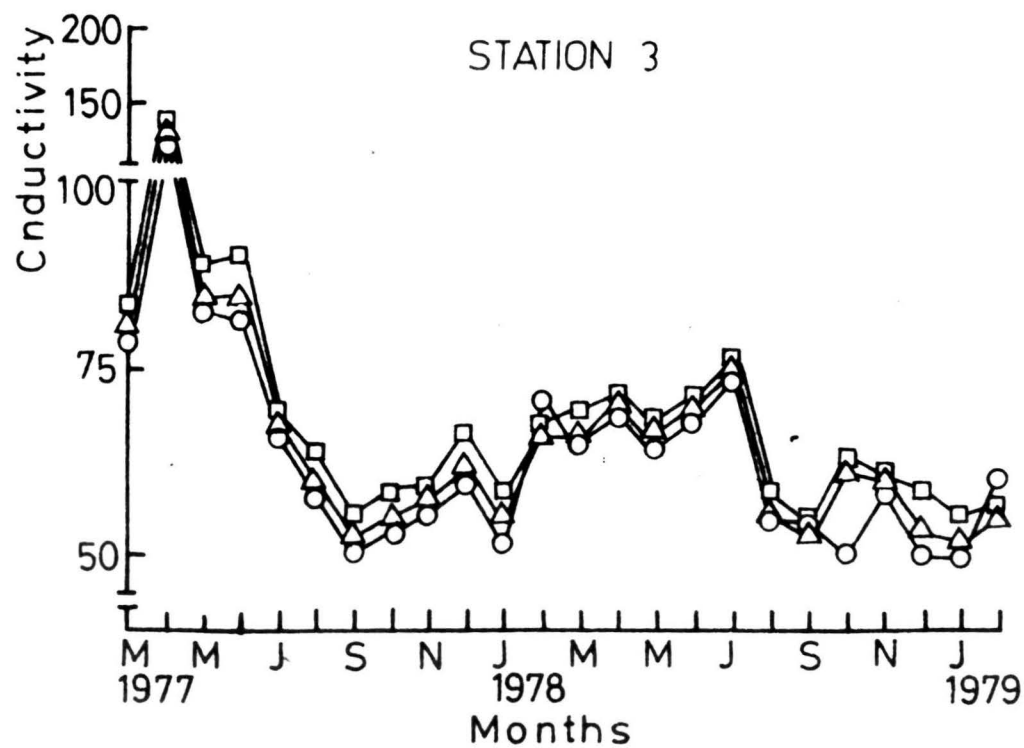
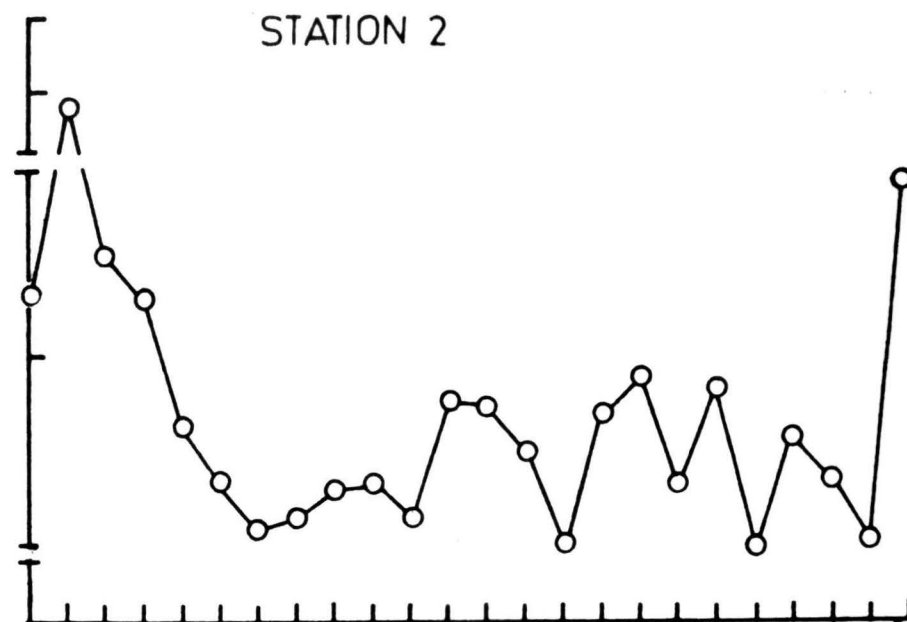
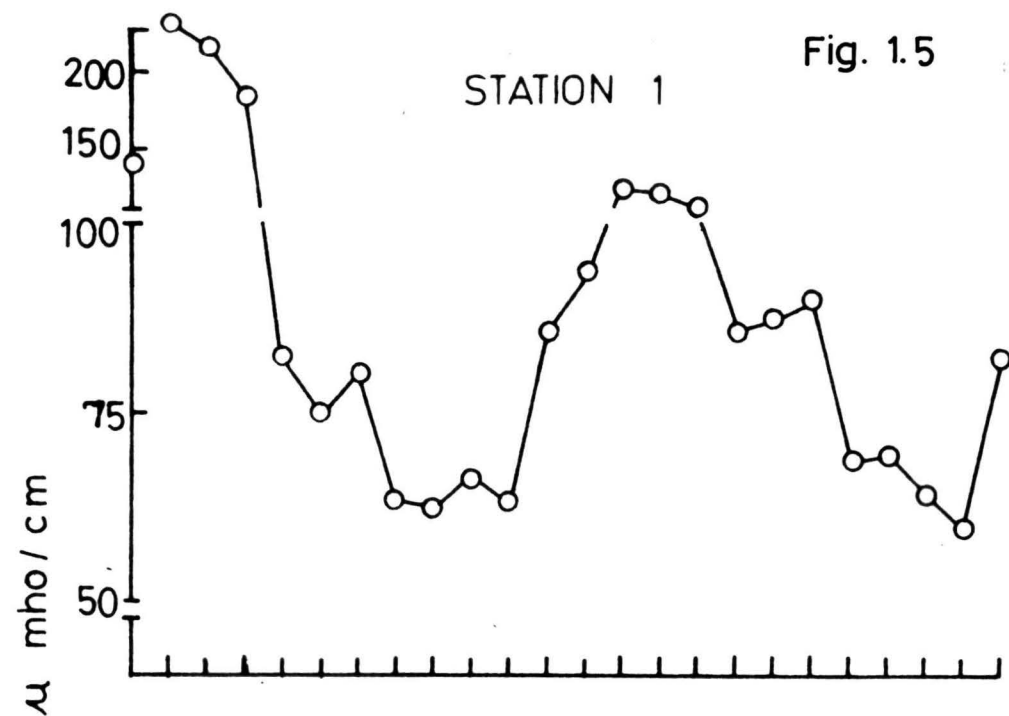
Number of months sampled

Name of fungi	Station 1			Station 2			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B	S	M	B
<u>OOMYCETES</u>												
<u>Achlya</u> sp.	4.16	4.16	4.16	-	-	-	4.16	4.16	-	-	-	-
<u>Pythium debaryanum</u>	20.83	8.33	12.50	-	4.16	16.66	16.66	4.16	12.50	4.16	4.16	8.33
<u>P. monospermum</u>	37.50	54.16	41.66	41.66	50.00	50.00	58.33	37.50	45.83	66.66	29.17	37.50
<u>P. ultimum</u>	12.50	12.50	4.16	4.16	-	-	-	4.16	-	4.16	-	-
<u>Saprolegnia</u> sp.	-	4.16	-	-	-	-	4.16	-	-	-	8.33	4.16
<u>ZYGOMYCETES</u>												
<u>Absidia cylindrospora</u>	-	-	-	-	-	-	-	-	-	-	12.50	-
<u>Cunninghamella</u> sp.	4.16	-	-	-	-	-	-	-	-	-	-	-
<u>Nucor circinelloides</u>	-	-	-	-	4.16	4.16	-	8.33	4.16	-	4.16	-
<u>N. hiemalis</u>	12.50	-	16.66	16.66	-	4.16	-	8.33	4.16	12.50	4.16	16.66
<u>N. plumbeus</u>	4.16	4.16	4.16	-	-	-	-	4.16	4.16	-	-	-
<u>N. racemosus</u>	-	12.50	4.16	-	12.50	8.33	-	-	4.16	4.16	4.16	4.16
<u>Mortierella</u> sp.	-	-	-	-	-	8.33	-	-	-	-	-	-
<u>Rhizopus</u> sp.	-	-	-	4.16	-	-	-	-	-	-	-	4.16
<u>Zygorhynchus</u> sp.	-	-	-	4.16	-	-	-	-	-	-	-	-
<u>ASCOMYCETES</u>												
<u>Cheetomium</u> sp.	-	-	-	-	-	-	-	-	-	-	-	8.33
<u>DEUTEROMYCETES</u>												
<u>Sphaeropsidales</u>												
<u>Phoma humicola</u>	4.16	29.16	20.83	16.16	4.16	-	4.16	16.66	-	16.66	-	4.16
<u>Phoma</u> sp.	16.66	8.33	8.33	-	4.16	16.66	16.66	16.66	12.50	-	8.33	20.83
<u>Phoma</u> sp.	4.16	4.16	4.16	4.16	12.50	8.33	12.50	-	8.33	8.33	20.83	16.66

<u>Gliocladium penicilloides</u>	-	-	-	8.33	-	-	-	-	-	-	-	-	-
<u>Graphium</u> sp.	-	-	4.16	4.16	-	-	-	-	-	4.16	-	-	-
<u>Humicola</u> sp.	-	-	-	4.16	-	-	-	-	-	-	-	-	-
<u>Monilia</u> sp.	8.33	-	-	20.83	4.16	-	-	-	-	12.50	-	-	-
<u>Paecilomyces</u> sp.	-	-	-	-	-	-	-	4.16	-	-	-	-	-
<u>Papularia</u> sp.	4.16	-	4.16	12.50	12.50	-	-	-	-	-	-	4.16	-
<u>Penicillium brefeldianum</u>	12.50	4.16	8.33	8.33	-	4.16	-	4.16	12.50	4.16	-	8.33	-
<u>P. chrysogenum</u>	75.00	66.66	62.50	87.50	41.66	45.83	75.00	54.16	62.50	50.00	37.50	25.00	-
<u>P. javanicum</u>	8.33	-	8.33	4.16	-	-	-	-	4.16	-	-	-	-
<u>P. oxalicum</u>	20.83	25.00	8.33	16.66	4.16	4.16	-	8.33	-	-	8.33	16.66	-
<u>P. nigricans</u>	4.16	4.16	4.16	-	-	4.16	4.16	-	-	-	-	12.50	-
<u>Phialophora</u> sp.	70.83	54.16	54.16	58.33	58.33	62.50	58.33	58.33	58.33	58.33	70.83	54.16	-
<u>Pseudotorula heterospora</u>	4.16	-	-	-	-	-	-	-	-	8.33	-	-	-
<u>Scopulariopsis</u> sp.	4.16	-	-	4.16	-	8.33	4.16	4.16	-	-	-	-	-
<u>Stilbella</u> sp.	8.33	-	4.16	-	-	-	-	-	-	8.33	-	-	-
<u>Torula</u> sp.	-	-	-	-	-	-	8.33	8.33	-	4.16	-	-	-
<u>Trichoderma harzianum</u>	20.83	20.83	16.66	8.33	20.83	4.16	12.50	-	8.33	-	16.66	8.33	-
<u>T. koningi</u>	12.50	4.16	-	-	4.16	-	-	-	-	4.16	-	-	-
<u>T. viride</u>	12.50	12.50	33.33	16.66	37.50	37.50	20.83	33.33	29.14	12.50	16.66	33.33	-
<u>Trichothecium roseum</u>	-	4.16	-	-	-	4.16	-	-	-	-	-	-	-
<u>Verticillium tenerum</u>	4.16	-	-	8.33	-	-	4.16	-	-	-	-	4.16	-
<u>Verticillium</u> sp.	-	-	-	8.33	-	4.16	4.16	4.16	4.16	-	-	4.16	-
White sterile septate	4.16	-	8.33	4.16	12.50	4.16	-	12.50	4.16	16.66	16.66	12.50	-

S = Surface, M=Middle, B = Bottom.

Fig. 1.5



oxygen. Thereafter, oxygenation of bottom water was noted and the value increased steadily until November with a drop during December (Fig. 1.3).

Permanganate Oxidisable Dissolved Organic Carbon (PODOC)

The PODOC values were quite high at station 1 as compared to the other stations. The seasonal fluctuation was also quite steep in the station 1. Almost similar general trend of seasonality was noted in all the stations except that the values were quite low. Depth-wise variation at station 4 was quite distinct and it was observed that the PODOC was always highest at bottom of this station. At station 3 also a trend of higher values in the bottom water was noted but it was not true for all the months (Fig.1.4).

Conductivity

A perusal to Fig. 1.5 shows that the conductivity of water shows a distinct seasonality. During first year of study the maximum values were observed in the spring months which declined later and touched to the lowest value in the months of September-October. Thereafter, it remained at a fairly constant level upto winter in the stations 1,2 and 3 but the station 4 showed a peak value in the month of November also. During second year of study station 1 showed general pattern of seasonal variation similar to the preceding year but stations 2,3 and 4 exhibited a rhythmic behaviour during spring and summer, however, pre-winter decreasing

Fig.1.6. Monthly variation in dissolved carbon dioxide concentration (mg/l) in the lake water at various stations from March 1977 to February 1979. Circles: surface waters, triangles; mid-depth waters and squares bottom waters.

Fig. 1.6

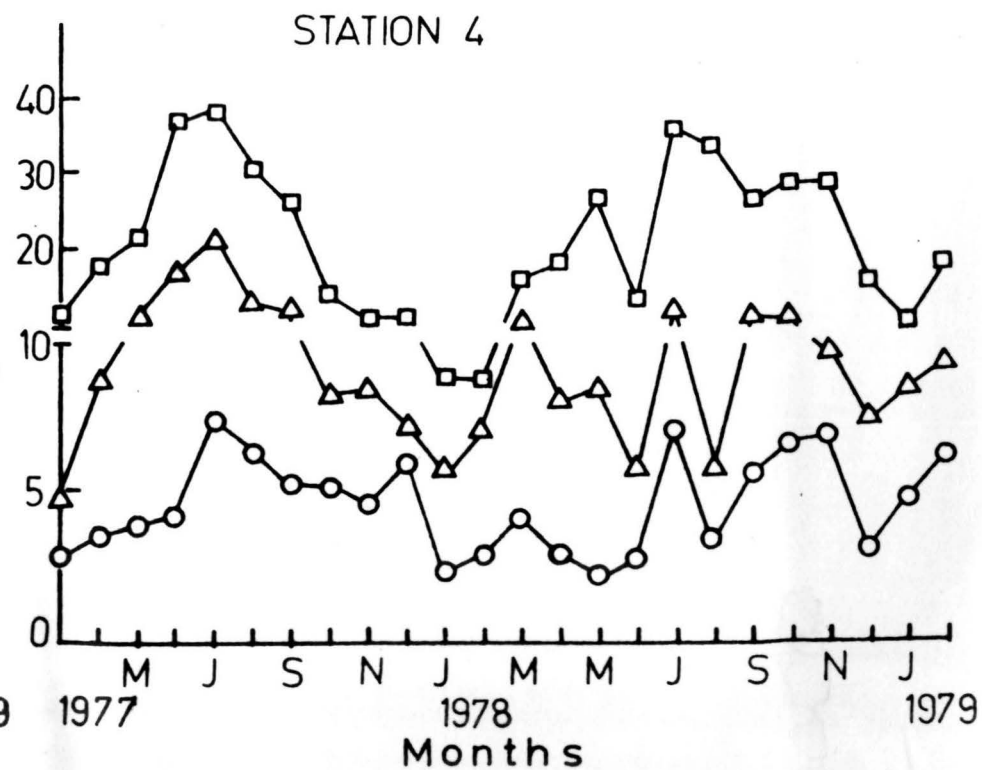
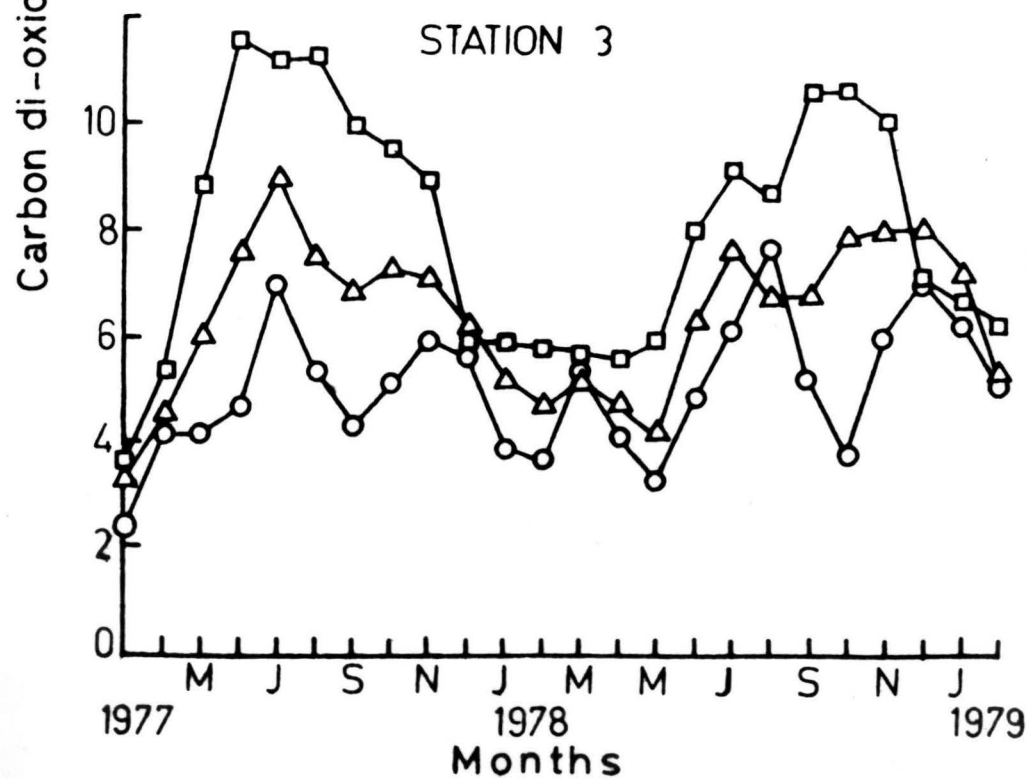
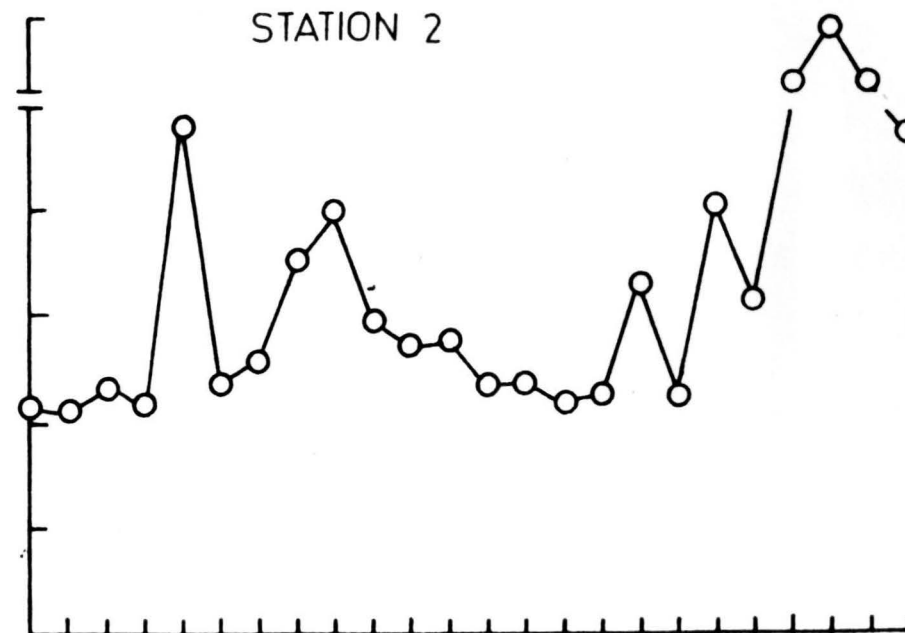
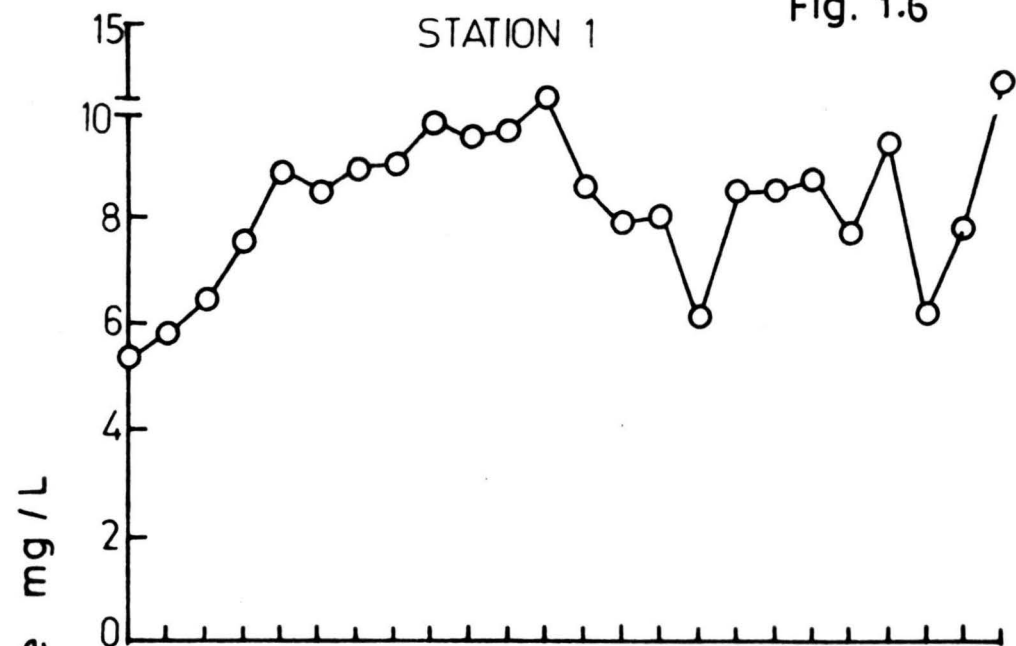
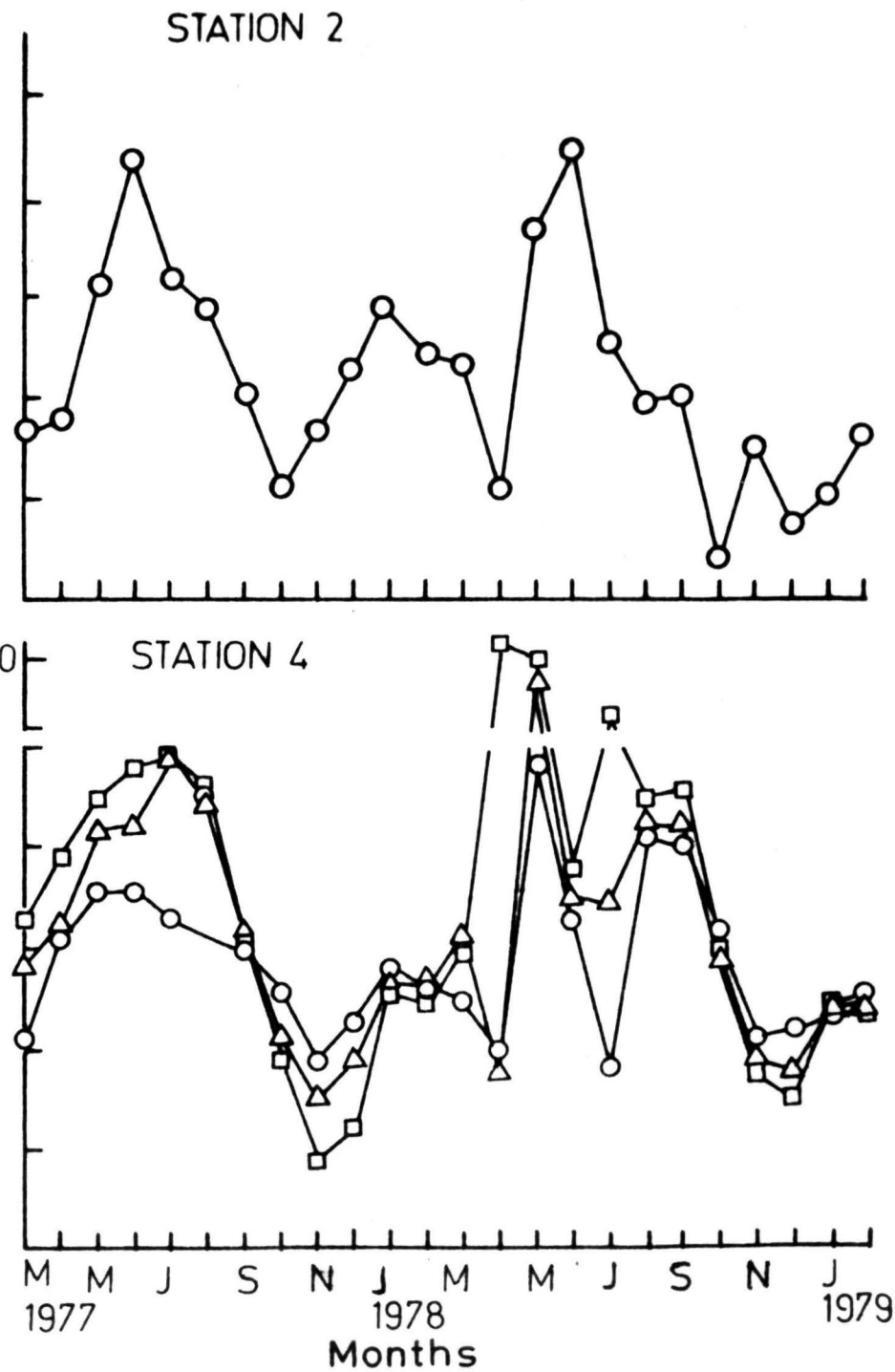
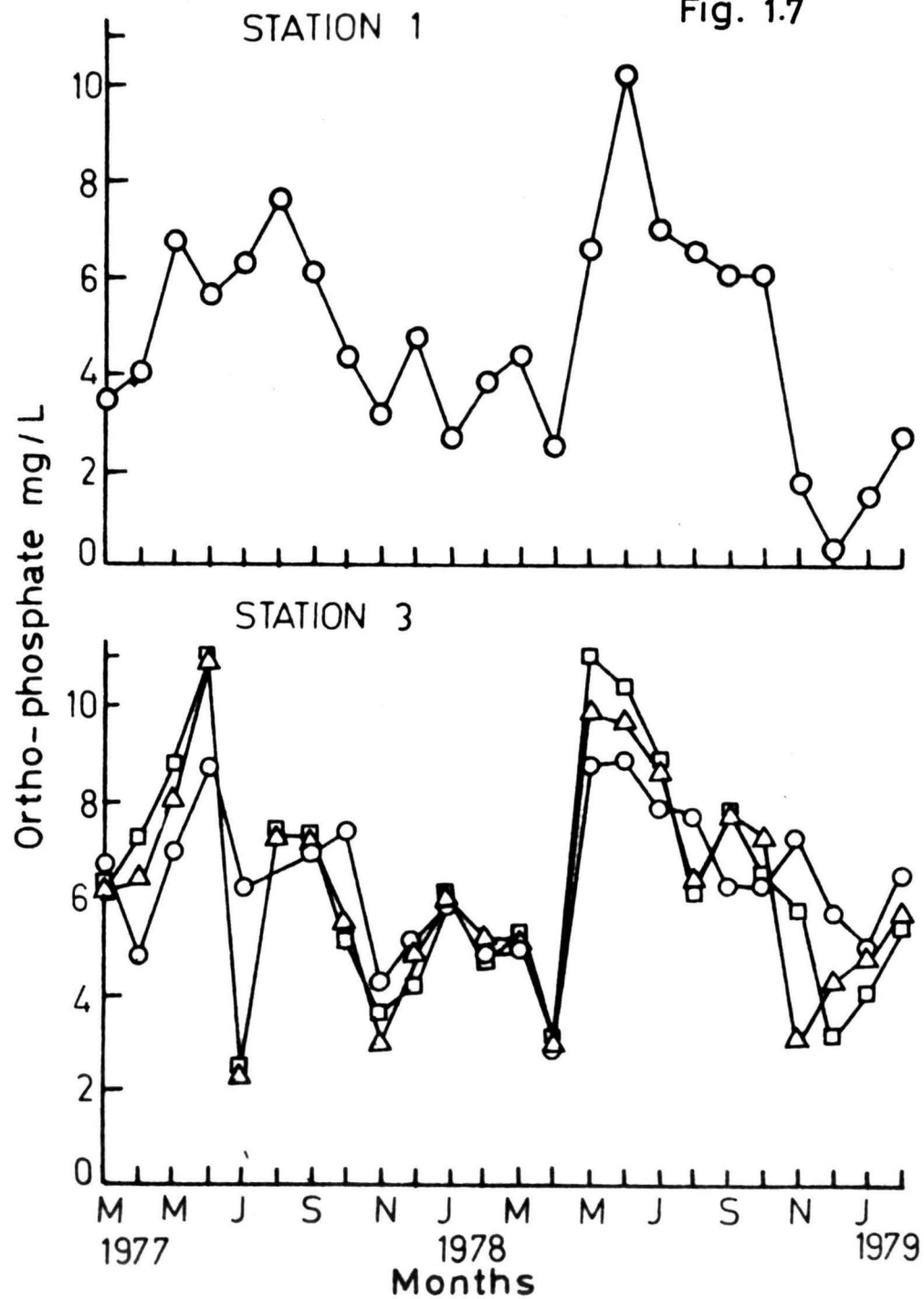


Fig.1.7. Monthly variation in soluble ortho-phosphate concentration (mg/l) in the lake water at various stations from March 1977 to February 1979. Circles:surface waters, triangles: mid-depth waters and squares:bottom waters.

Fig. 1.7



trend was quite similar to the preceding year's observations.

Dissolved Carbon Di-oxide

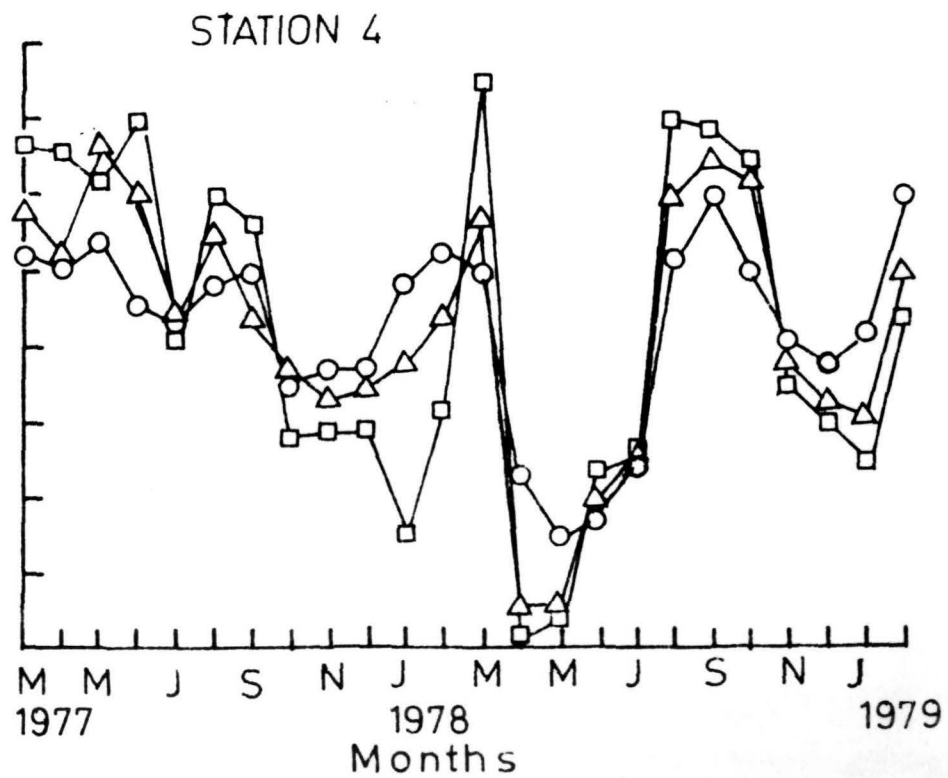
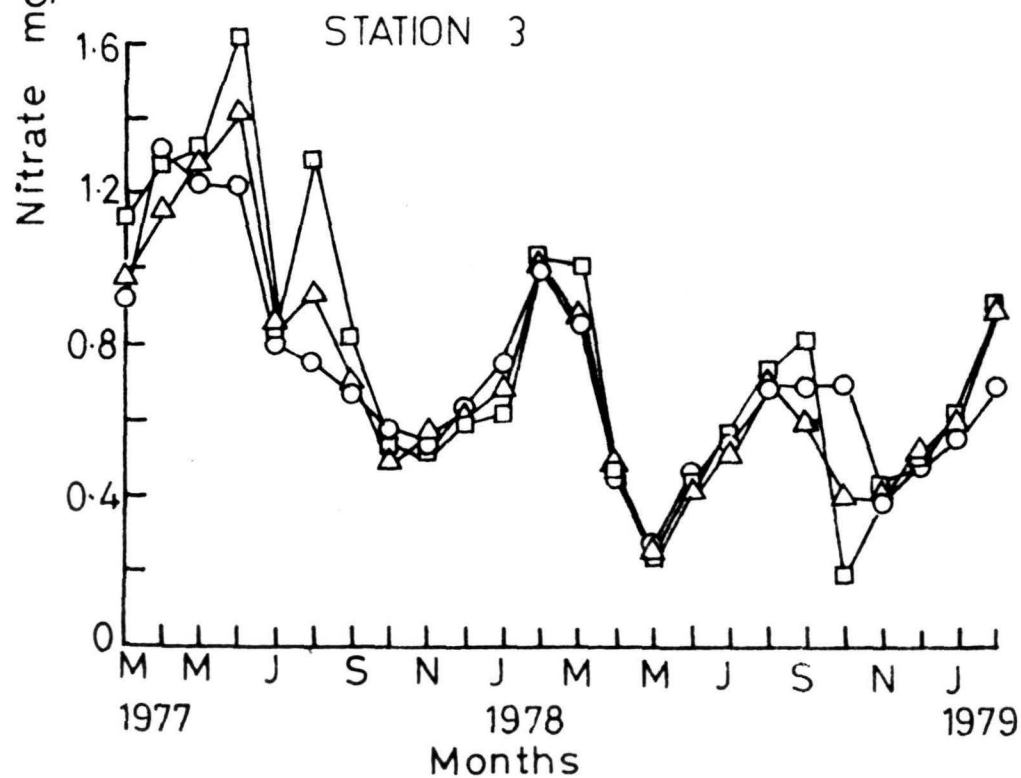
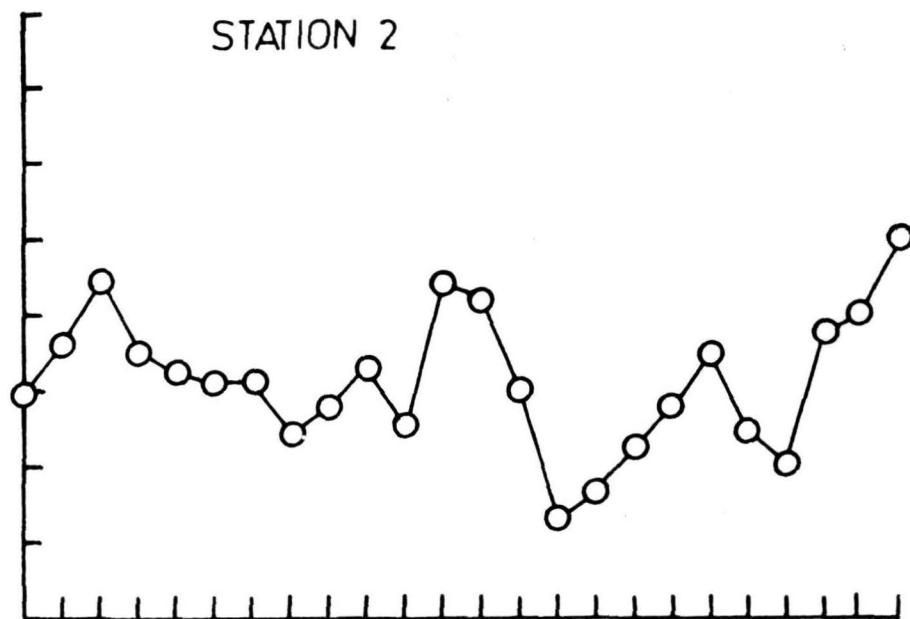
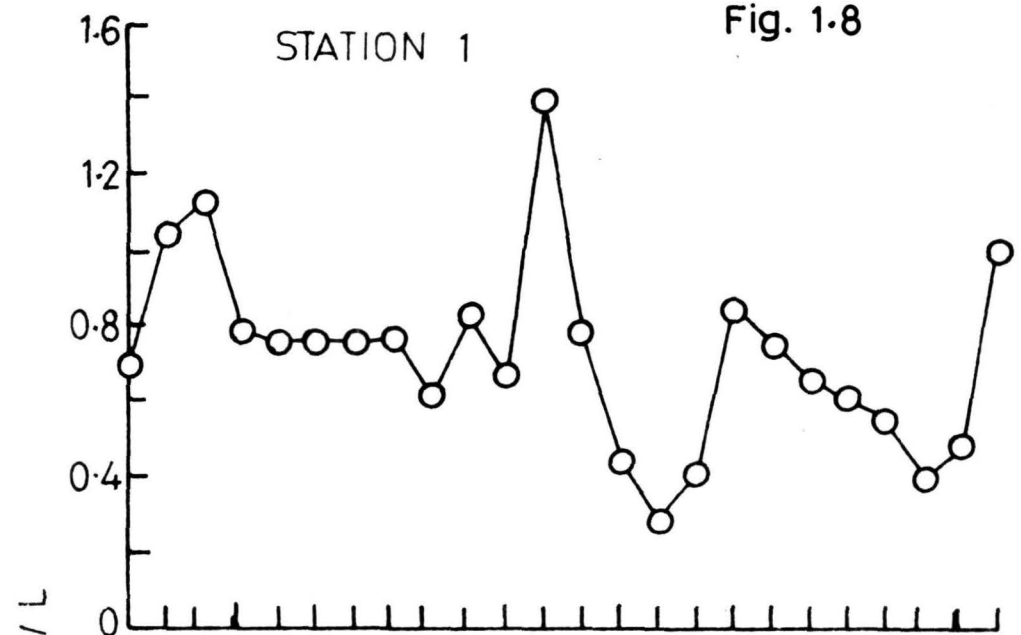
Distinct monthly variation in the dissolved carbon di-oxide values has been observed at station 3 and 4 where low values were observed during winters and high values during summers. Interestingly enough, the deeper waters contained higher carbon di-oxide and showed quite distinct seasonality as compared to the surface waters. The values were many fold higher at the bottom waters of station 4 when compared with the surface waters. Almost similar general trend of variation was observed at the stations 1 and 2 (Fig. 1.6).

Ortho-phosphate

Ortho-phosphate values correspond to the total soluble reactive phosphates. The maximum values of ortho-phosphates in the lake water was recorded during post spring months. The seasonality was more distinct at the deeper stations as compared to the shallow stations. Almost similar general pattern of variation was observed at all the stations. In general, higher values were recorded during spring and summer when it also showed a definite increase along depth. During winter, however, the pattern was either opposite or did not vary significantly. Throughout the year ortho-phosphate remained at fairly high level (Fig. 1.7).

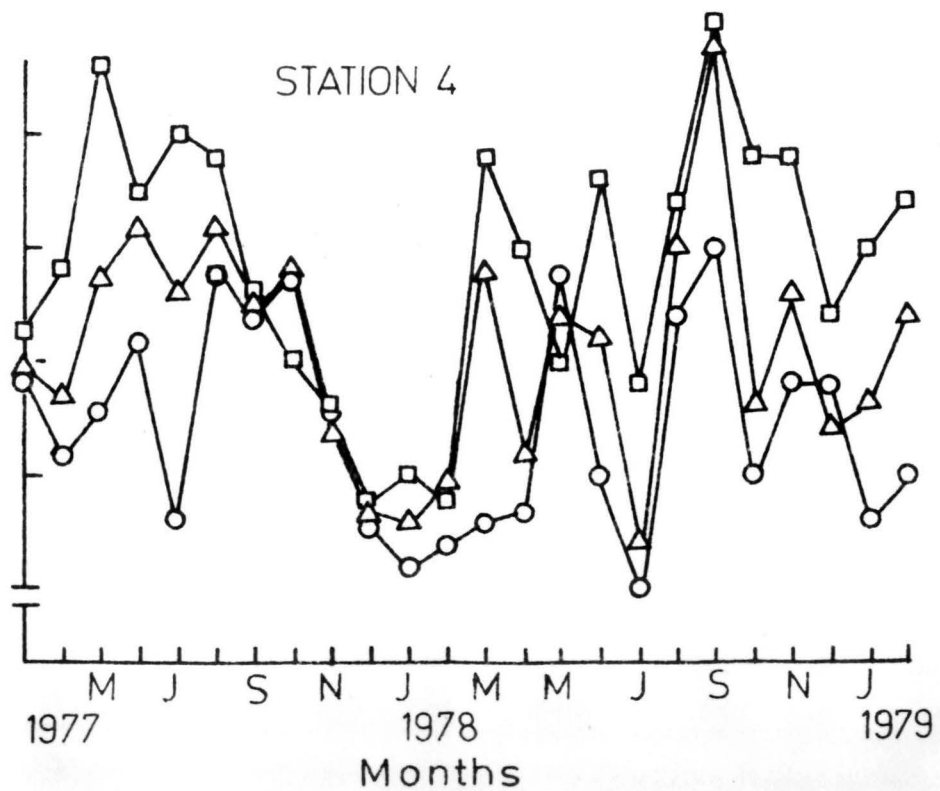
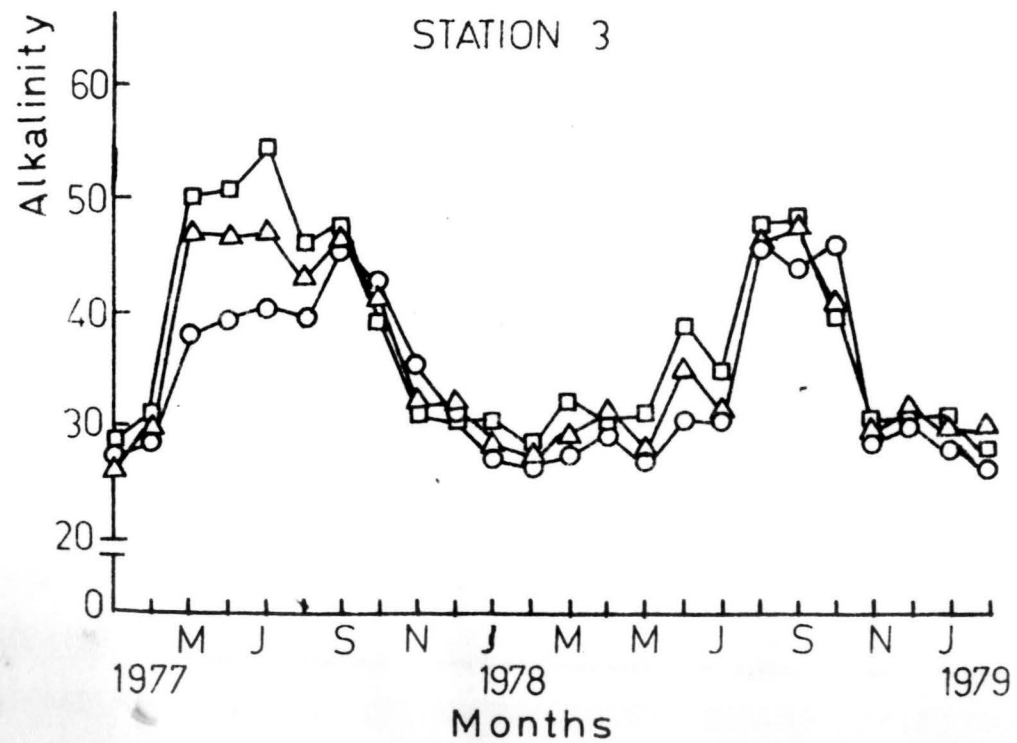
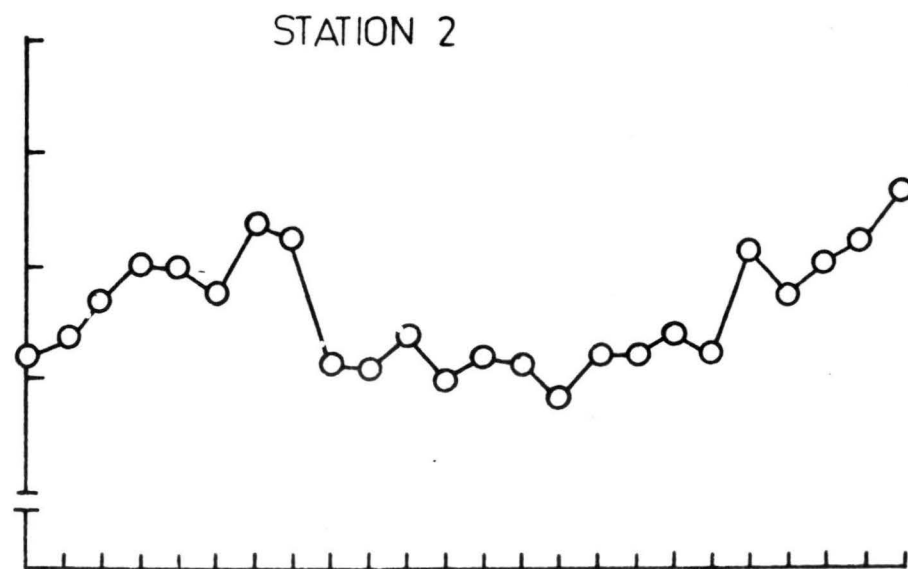
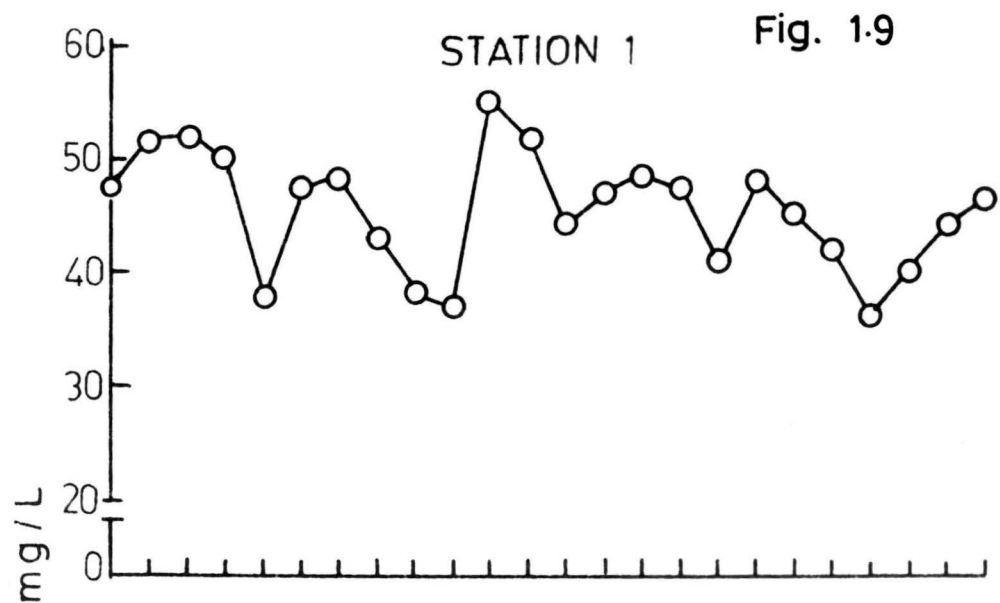
Fig.1.8. Monthly variation in soluble nitrate concentration (mg/l) in the lake water at various stations from March 1977 to February 1979. Circles surface waters, triangles:mid-depth waters and squares bottom waters.

Fig. 1.8



**Fig.1.9. Monthly variation in alkalinity (mg/l)
in the lake water at various stations
from March 1977 to February 1979. Circles:
surface waters, triangles:mid-depth waters
squares:bottom waters.**

Fig. 1.9



Nitrate

The general pattern of seasonal variation of nitrate concentration in the lake water differed during the two years of the study. During first year higher values were recorded during spring months which peaked in the month of May. Thereafter, the values declined and increased only in the next spring. During second year just after the March peak the values dropped suddenly and touched to minimum in the late spring months. Higher values of nitrate were again recorded during August-October which declined in the winters followed by an increment with the onset of next spring (Fig. 1.8).

Alkalinity

The alkalinity values showed monthly variation which was more distinct at the stations 3 and 4. The lowest values were generally recorded during winter months and highest during July to September. The pattern of seasonality was not so marked at the stations 1 and 2. The depth-wise variation of alkalinity was quite distinct and higher values were recorded in the deeper waters (Fig. 1.9).

Silicate

Silicate concentration in the lake water varied between 0.10 and 1.65 mg/L. The general pattern of seasonal variation was such that higher values were noted during summer months and lower values during winters. Station 1,2 and 3 exhibited almost similar pattern of oscillation. But the station 4 differed

Fig.1.10. Monthly variation in silicate concentration (mg/l) in the lake water at various station from March 1977 to February 1979. Circles: surface waters, triangles:mid-depth waters and squares:bottom waters.

Fig. 1.10

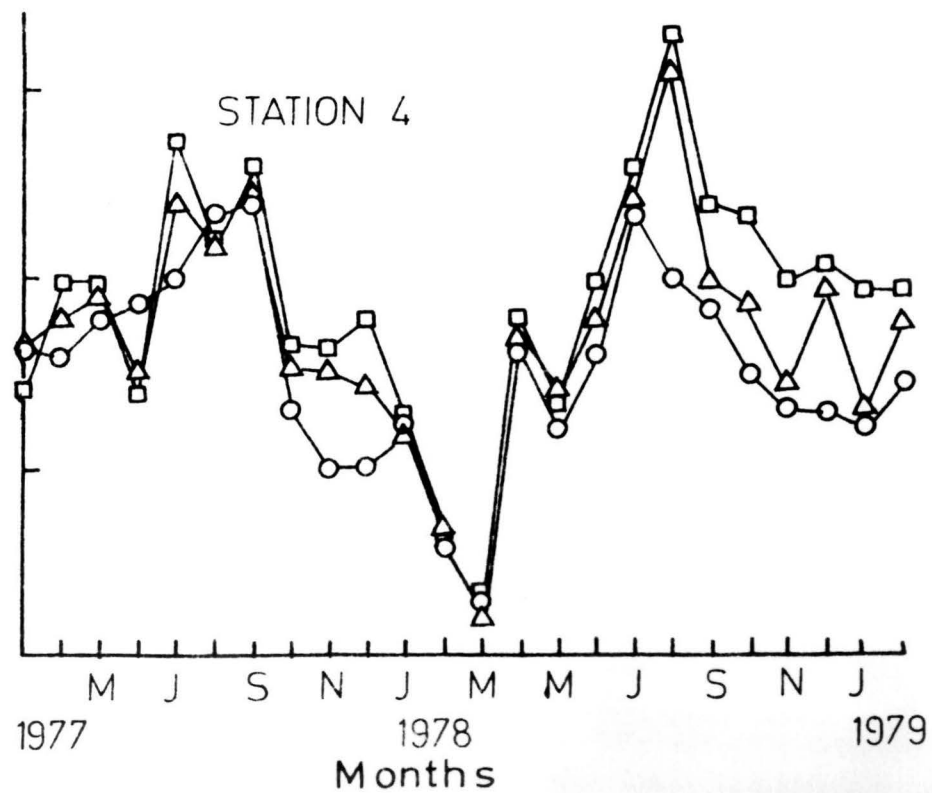
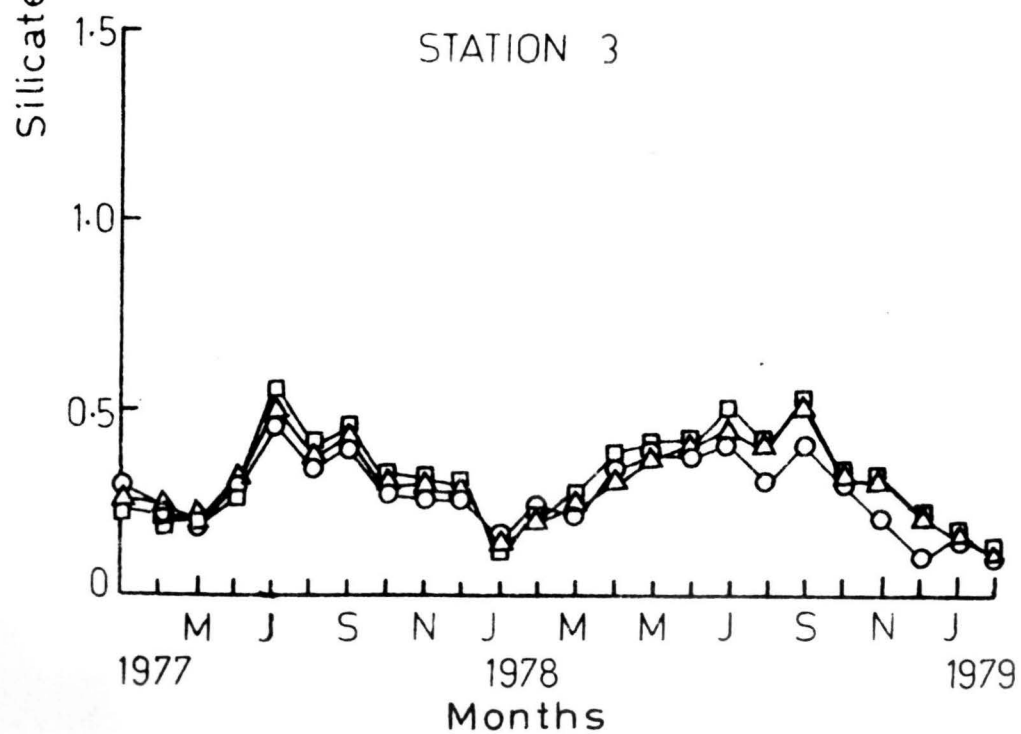
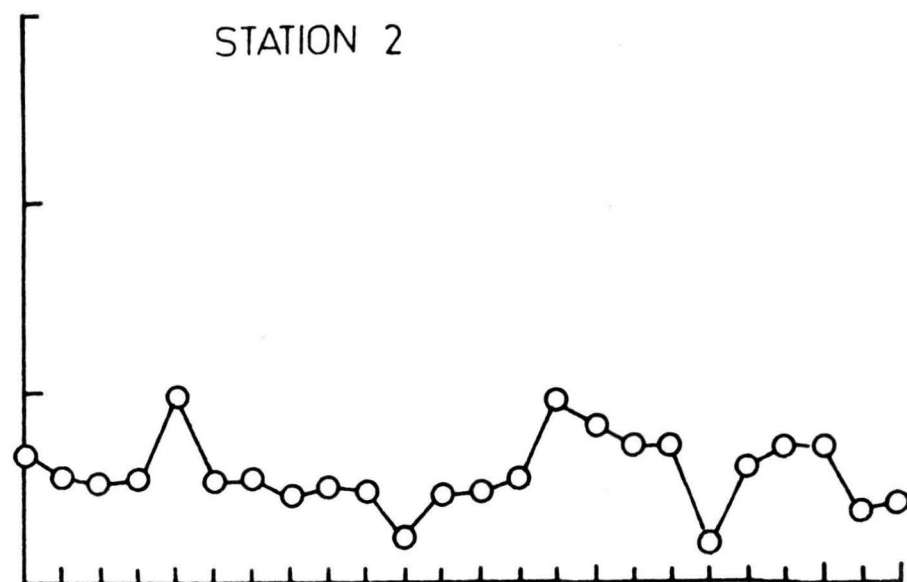
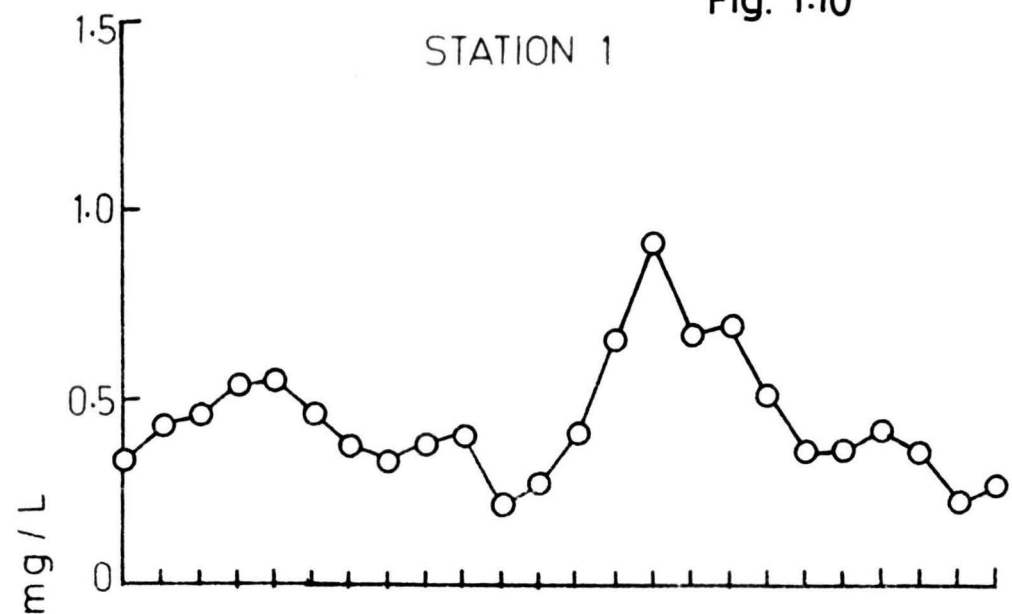


Fig.1.11. Monthly variation in soluble calcium concentration (mg/l) in the lake water at various stations from March 1977 to February 1979. Circles:surface waters, triangles:mid-depth waters and squares:bottom waters.

Fig. 1.11

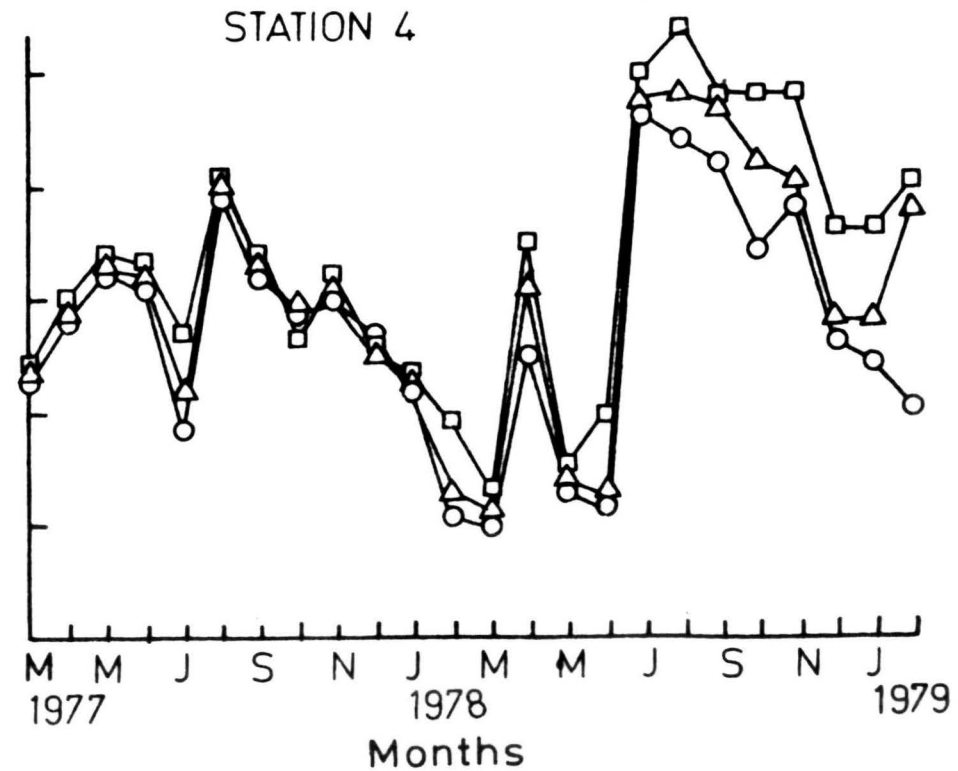
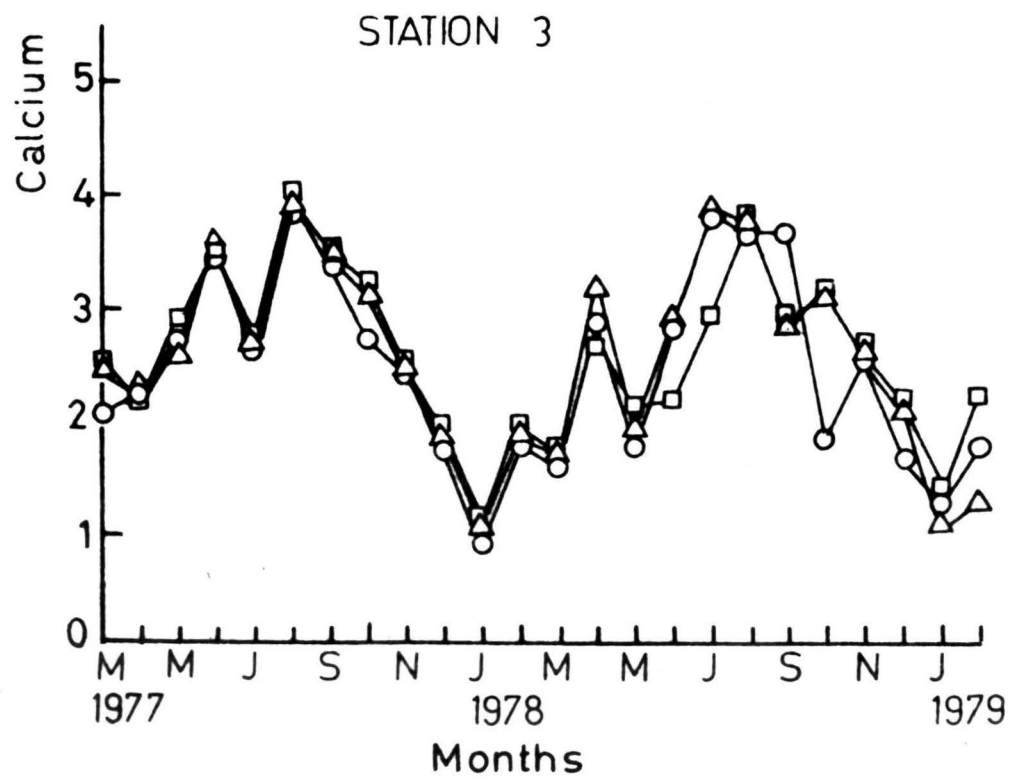
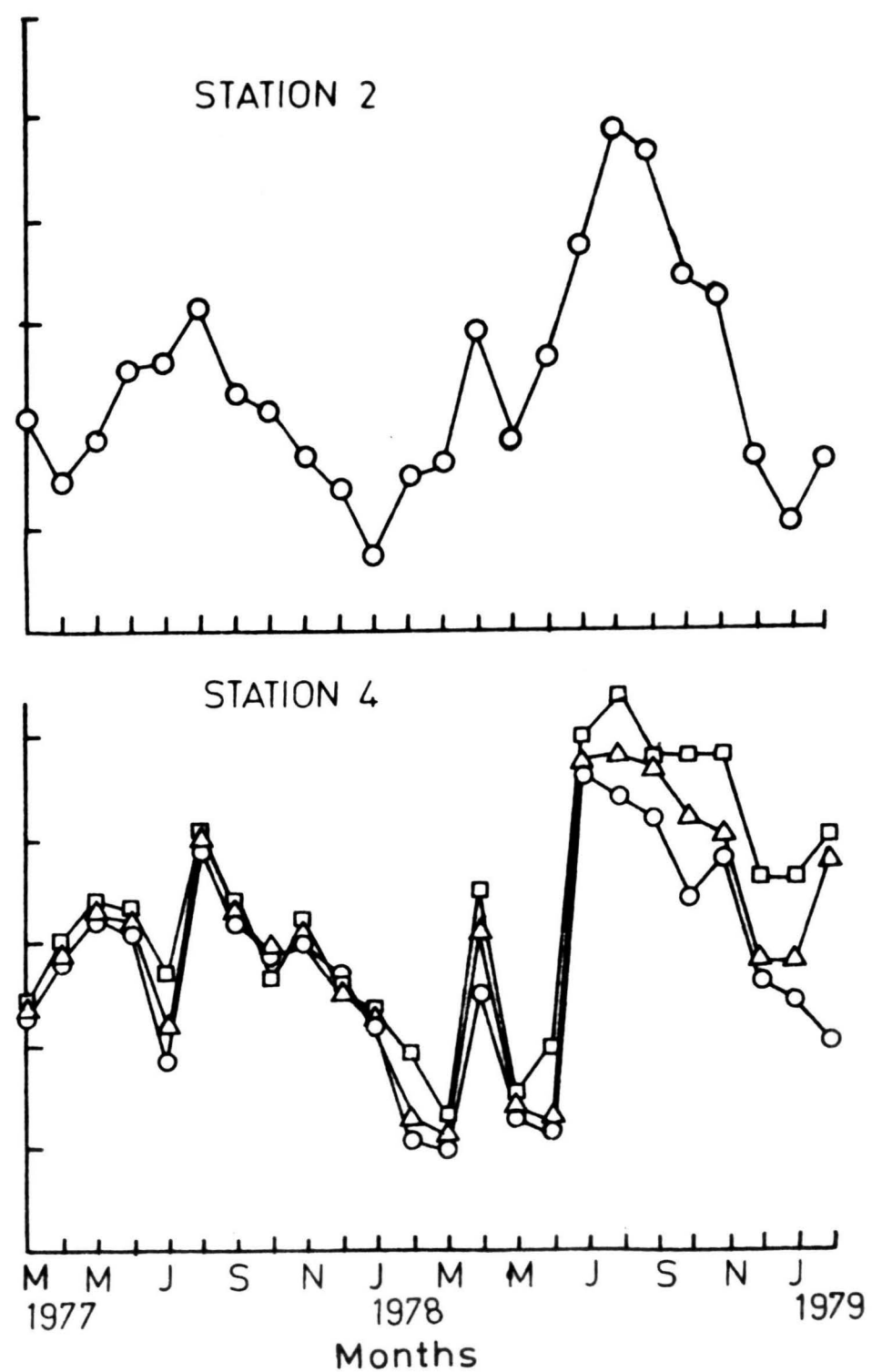
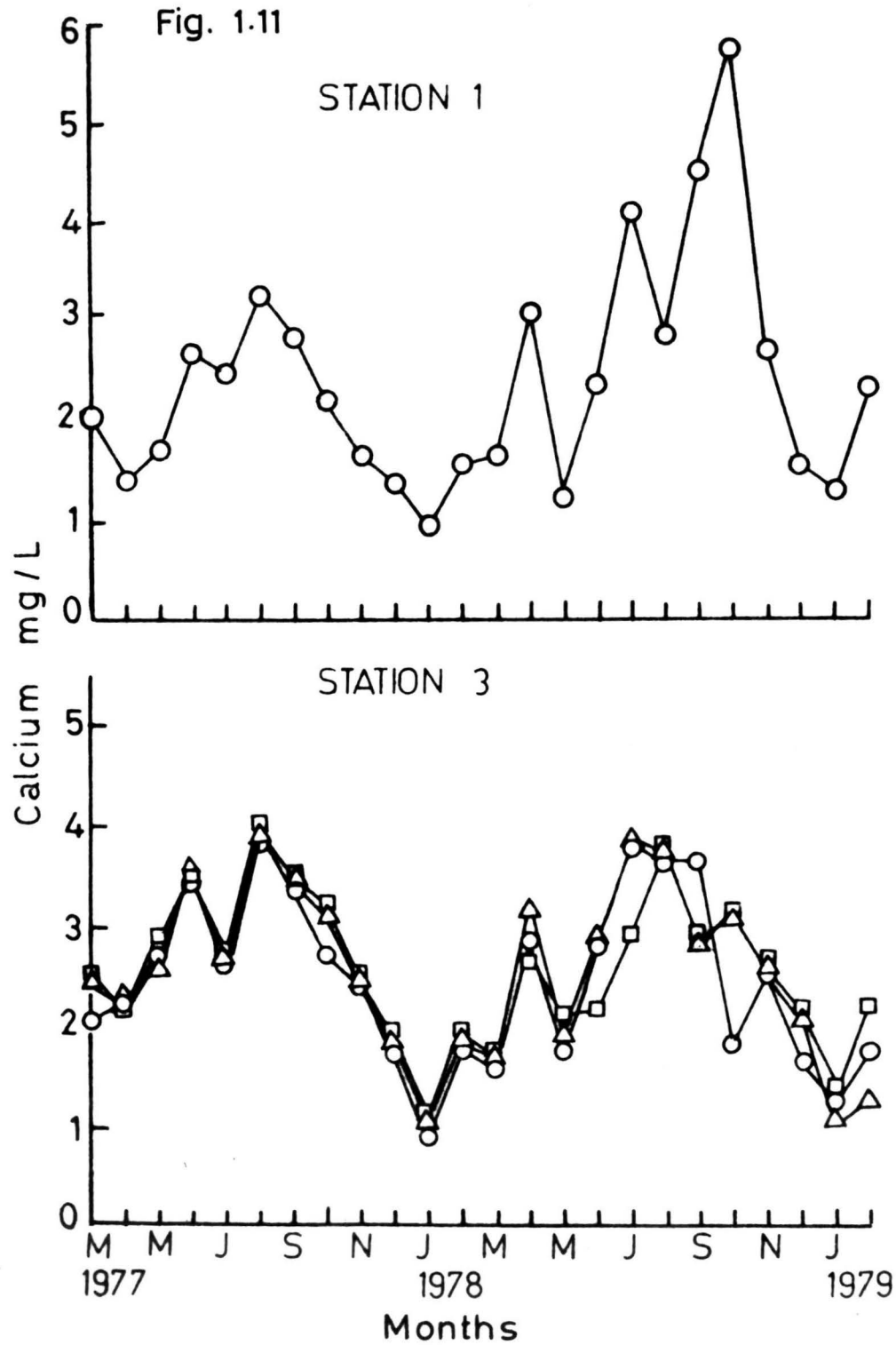
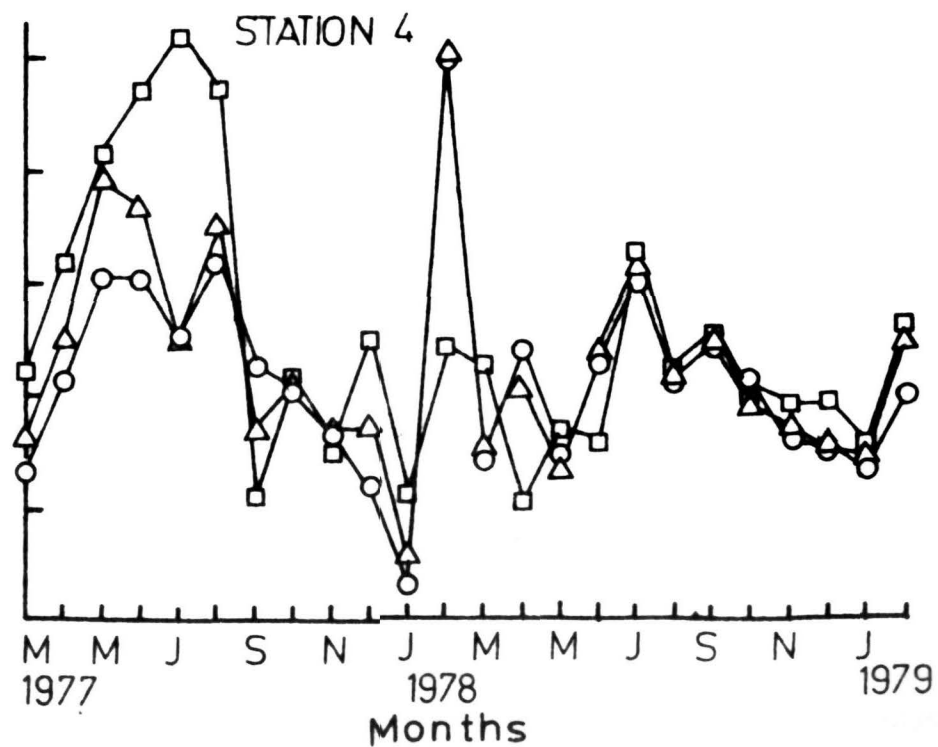
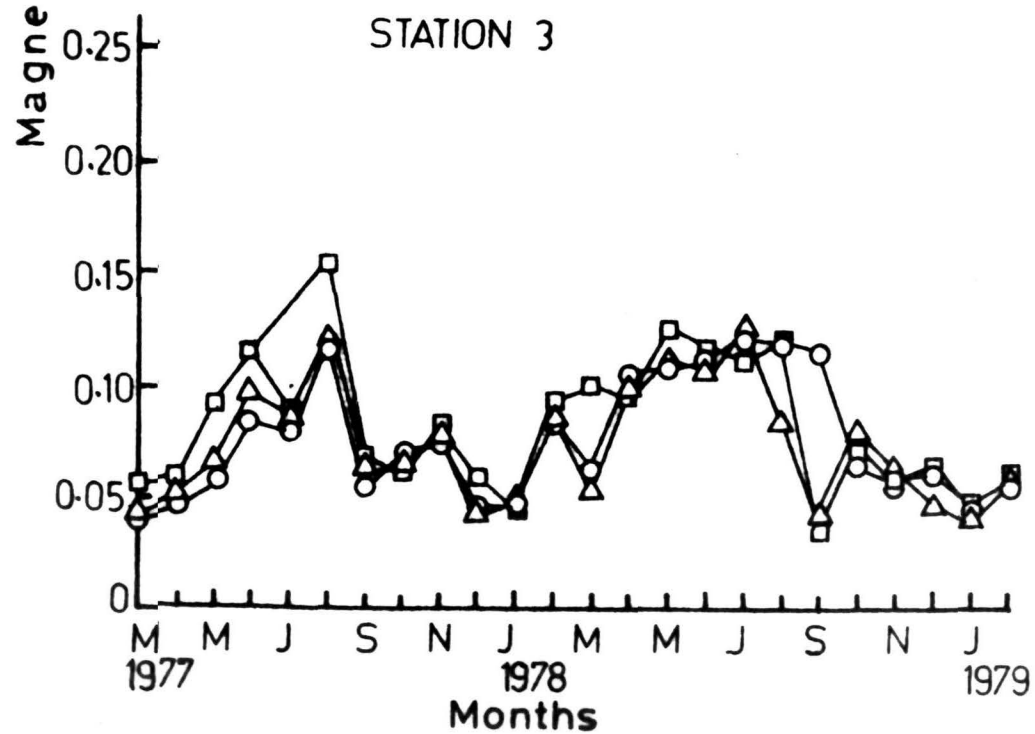
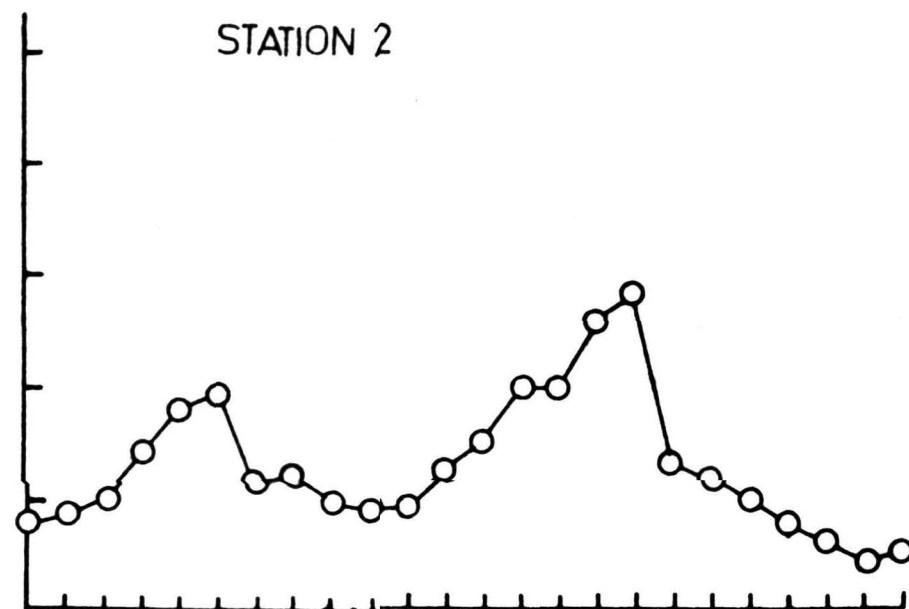
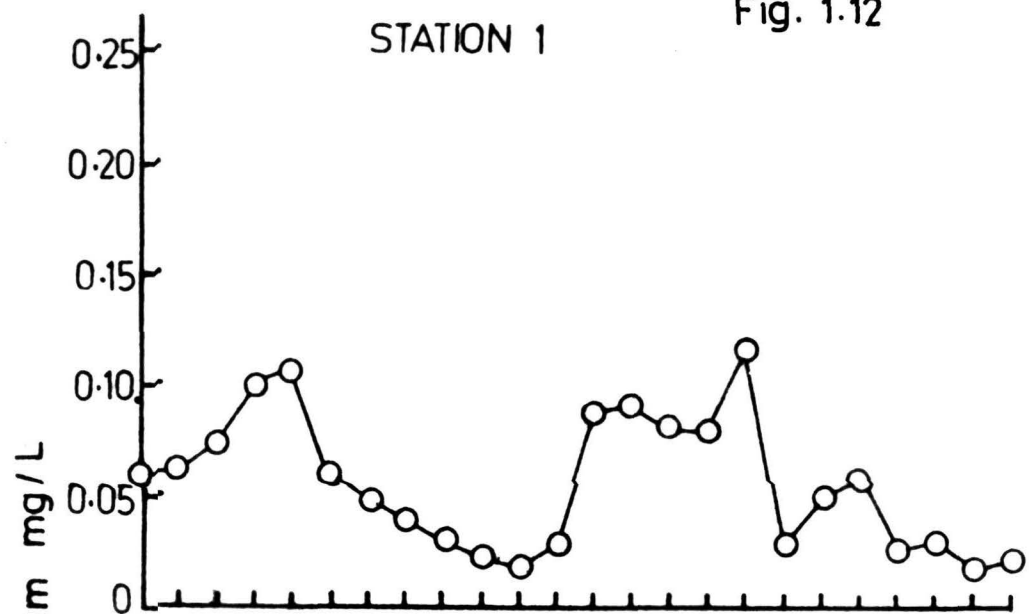


Fig.1.12. Monthly variation in soluble magnesium concentration (mg/l) in the lake water at various stations from March 1977 to February 1979. Circles:surface waters, triangles:mid-depth waters and squares:bottom waters.

Fig. 1.12



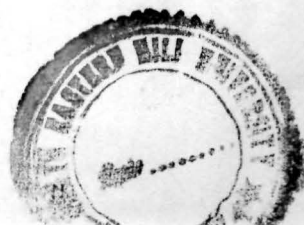
both in the concentration and magnitude of variations. In general, bottom waters harboured higher silicate concentration than the upper water column (Fig. 1.10).

Calcium

Soluble calcium in the lake water varied with seasons. Although estimates for the two years did not show similar variation pattern in general, a tendency of increment in the values from March to August (Except July) followed by consistent decrease upto January was observed during the year 1977-1978. During second year also the peak values were observed in the months of July-August (except station 1). The only marked departure was the small peak in the month of April and a drop in May-June. Not much difference was noted in the calcium concentrations along depth at stations 1,2 and 3. But quite significantly the deeper waters at station 4 contained higher concentrations of calcium (Fig. 1.11).

Magnesium

The general trend of variation of magnesium in the lake water was almost similar to the calcium values. Higher values were observed during summers and lowest during the winters. Almost similar general pattern of seasonality was observed at all the stations. Depth-wise distribution at deeper stations was such that quite often the bottom water contained higher concentrations of magnesium (Fig. 1.12).



DISCUSSION

Most of the physico-chemical characters reveal that the lake is mesotrophic having moderate concentrations of the nutrients. Station 1 is more enriched in nutrients particularly in dissolved organic carbon, phosphates and dissolved ions (conductivity). The results of the limnological characters are quite comparable with other studies (Munawar, 1970). Of particular significance is high values of dissolved soluble ortho-phosphates. This may be ascribed to the relatively small size of the system receiving high amount of drainage in the form of surface run-off and through the inlet, the molybdate method of estimation of phosphates generally overestimates the soluble phosphate concentration (J.G. Jones, personal communication). Further, high concentration of dissolved organic carbon in the isolated system (Station 1) is probably because of its nearness to the inlet and luxuriant growth of macrophytes. Here, probably the incoming waters get comparatively rid of excess organic load due to their microbial degradation and settlement. Thus, the waters of the large system contain lesser amount of dissolved organic matter. It appears that probably this unit of the lake acts as a sort of settlement reservoir and, therefore, saves the main body from eutrophication.

The high values of dissolved organic carbon and conductivity at the bottom of station 4 clearly depict that

soluble nutrients are released from the decomposition of bottom deposits of organic detritus, mainly extraneous litter, which due to the stratification of the system remains localized to the deeper layers of water column.

The seasonality of carbon-di-oxide values seems to be resultant of the microbial activity which becomes more pronounced in the deeper waters. Comparatively less values obtained at the shallow stations were most probably because of the mixing of the water column. Dissolved carbon di-oxide values also demonstrate the pronounced stratification of the lake at the station 4.

Nitrate values were also quite comparable to the nitrate concentrations observed in similar systems elsewhere (Munawar, 1970). The steep decline of the spring maxima may be ascribed to the organismal biomass. The bound nitrate is probably again released to the soluble form on the onset of springs when increased microbial activities help the cause. Similar results were obtained by Rheinheimer (1977a). In additions to this there may be other causes responsible for the dynamics of nitrate such as input from the adjoining areas and biological nitrogen fixation which are not accounted in the present study. The values of alkalinity, silicate, calcium, and magnesium showed a seasonal and depth-wise variation typical to the natural lakes (Hutchinson, 1957; Munawar, 1970). The water temperature values were well in

correspondance with the seasonal fluctuations of ambient temperature. The temperature gradient was observed throughout the study period at the deeper stations except during January-February which also corresponds to the mixing times of the lake. The mixing of the lake water at station 4 in the month of January and February is also demonstrated by the depth-wise distribution of dissolved oxygen at this station.

The inter-relationship among various physico-chemical characters have not been tried as they were beyond the scope of the present work. The relationships of these characters with the biological characters are discussed in detail while dealing with the populations and activity measurements.

CHAPTER 2

SEASONAL VARIATION IN PLANKTONIC POPULATION OF HETEROTROPHIC BACTERIA

INTRODUCTION

The heterotrophic bacterial population constitutes an important part of the freshwater community. It is responsible for nutrient release in the ecosystem enabling optimum utilization of available energy resources for proper functioning of the ecosystem. Their activity and quantitative enumeration reflect the hydrologic structure and nutrient levels in fresh-water lakes (Godlewska-Lipowa, 1978). It is often difficult to interpret the relationship between bacterial populations and other environmental factors. This is due to fluctuations in physico-chemical characters in time and space which may very often mask the effects due to biological changes (Jones, 1971). Earlier observations (Collins, 1963) have added considerably to the ecology of freshwater bacteria. Since then, a large amount of data has accumulated which relates the effect of environmental factors on the bacterial population in natural waters. Such findings are in many cases inconsistent (Olah, 1971).

Chen (1968) and Fonden (1969) observed a relationship between bacterial populations and concentrations of phosphate and nitrate, but this was not noted in the study of Woodbridge and Garret (1969). A relationship between weather conditions and bacterial populations was established by Collins (1960, 1970) and Chen (1968). Taylor (1940), Melchiorri-Santolini (1966) and Guthrie (1968), however, did not observe the same.

Depth (Olah, 1969; Melchiorri⁰-Santolini, 1966) temperature (Allen, 1969) and dissolved oxygen concentration (Goldman et al., 1968) have been found to affect the bacterial population. Jones (1972) states that the decrease in temperature, dissolved oxygen, pH and algal density with increasing depth may be responsible for the apparent correlation of bacterial numbers with these factors.

The relationship between phytoplankton and bacterial populations is complex. Sorokin (1968), Schmidt (1969), Overbeck and Babenzien (1964), and Overbeck (1965, 1967, 1968) while studying the vertical distribution; and Silvey and Roach (1964), Schegg (1968) and Fonden (1969) while studying seasonal distribution found positive correlations between phytoplankton and bacterial populations. On the contrary Potanenko and Mikheeva (1969), Gerletti and Melchiorri Santolini (1968), Goldman et al. (1968) could not find any direct relationship. Gunkel (1968) and Jones (1971, 1972a) have reported that maximum densities of phyto-plankton preceded those of bacteria.

Jones (1970) studied the effect of various inorganic and organic components used in media for estimating population of freshwater bacteria and concluded that casein-peptone starch medium (Collins and Willoughby, 1962) was the best among all. He further noted that spread plate method was superior to pour plate method.

Jones (1971) found that temperature, dissolved oxygen concentration and pH control the bacterial population in nutrient rich Esthwaite waters and in Windermere, temperature, pH, particulate matter and rainfall were positively correlated with the bacterial population.

Jones (1973) found a relatively stable mixture of several species of bacteria in Blelham Tarn. The population of heterotrophic bacteria was maximum during April and May which declined later.

Jones (1977) has critically appraised the methodology adopted for the water bacteriology and with the help of data collected at six different sites for five years representing bacterial population and a total of eighteen variables concluded that the same amount of information could have been obtained from five of the regressor variables. He further emphasized the need of horizontal samplings for examining the temporal variation in detail.

Uwagi-Wstepne (1971) pointed out that heterotrophic microbes regulate the dissolved organic matter either through breaking down it to inorganic form or through transforming them into particulate state. He opined that it was because of the microbial activity that in spite of constant influx of dissolved organic matter to the water bodies, the level of dissolved organic matter concentration in natural waters is not subjected to any great fluctuation.

Strickland (1971) reviewed various methods of estimation of microbial activity in aquatic environments and concluded that there is no really reliable routine technique available so far which can be used for a large number of samples within a reasonable period of time.

Strzelczyk et al (1971) reported that heterotrophic bacteria isolated from different ecological zones namely planktonic bacteria, epiphytic bacteria and benthic bacteria showed distinct differences in morphology, nutritional requirements, biochemical activity and antibiotic resistance.

Andronikova and Drabkova (1972) studied the effect of climatic factors on the annual limnological cycles in Lake Krasnoe and based on sufficient data concluded that annual pattern of most of the processes are largely determined by the meteorological factors and, therefore, may significantly vary from year to year.

Cappenberg (1972) observed that the heterotrophic bacterial population was maximum in the hypolimnion in the spring while in the summer it was in the metalimnion and after the autumn turnover the distribution of bacteria was somewhat uniform till the next spring sets in.

Melchiorri Santolini et al (1975) measured temporal and depth-wise distribution of a large number of variables with an aim to select those microbiological variables which

were most useful to the understanding of the role of bacteria in freshwater ecosystems. They identified direct microscopic count, cultural estimates, primary productivity and particulate and dissolved organic carbon as variables closely related with bacterial dynamics.

Berland et al (1975) estimated bacterial population which ranged from 5×10^3 to 1.7×10^6 cells per ml.

Berland et al (1976a) opined that bacteria play an important role in maintaining the growth factors above the limiting concentrations required for a normal level of primary production. In a separate study these workers (Berland et al 1976 b) found that fatty acids and nitrogenous organic substances were most frequently attacked by heterotrophic bacteria as compared to other organic substances.

Mikulski et al (1975) estimated biomass of bacteria in Goplo lake, Poland which varied between the range of 1.01 to 7.82 mg. per litre of water.

Overbeck (1975) put forth the supposition that the lake ecosystem could be subdivided into biochemical compartments marked by different physiological responses of the bacterial microflora.

Monheimer (1975) while emphasizing the need of the development of adequate methods for measurements of heterotrophic production estimated total heterotrophic production higher than the autotrophic production.

Chan and Kueh (1976) observed marked variation in environmental parameters but the heterotrophic population remained relatively constant. They noticed summer stratification of temperature, pH, salinity and dissolved oxygen but no stratification of bacterial distribution in water column was noted.

Godlewska-lipowa (1976) reviewed literature pertaining to the relation of bacterial population and biomass with the degree of eutrophy of the lakes. He arranged the lakes in trophic gradation and classified oligotrophic lakes with the density of bacteria in the order of 1×10^6 per ml of water; mesotrophic lakes with the number of bacteria in the range of about $2-3 \times 10^6$ per ml of water and eutrophic lakes with the number of bacteria in the range of $4-50 \times 10^6$ per ml of water depending on the degree of eutrophication and water pollution. Lakes with total number of bacteria higher than 50×10^6 per ml of water were included among saprotrophic lakes. Similar to bacterial population level, bacterial biomass was also taken into consideration. In oligotrophic lakes it ranges from 0.098 to 0.4 mg. per litre of water; mesotrophic lakes from 0.5 - 3 mg per litre of water. In polytrophic lakes and in fish breeding ponds the bacterial biomass values may be quite high ranging from 30 to 50 mg per litre of water.

Mason (1977) noted peaks of bacterial population in Spring and in Autumn. The bacterial population ranged

between 0.4×10^6 to 6.8×10^6 cells per litre. Donderski (1977) estimated the bacterial biomass between the range of 0.005 mg and 7.82 mg per litre in lake Goplo, Poland.

Akagi et al (1977) classified aquatic bacteria into two classes. Oligotrophic bacteria which require extremely low concentrations of substrate and are generally free living and heterotrophic bacteria which can survive only either in high concentration of dissolved organic matter or attached to the detritus.

Takahashi and Norton (1977) noted heterotroph bloom in the month of May which was just after the phytoplankton maxima during March and April.

Kaneko et al (1977) first of all applied the diversity index to bacterial population and observed that bacterial populations upto a threshold population size showed an inverse relation between diversity and population size. Beyond the threshold size, the diversity index did not correlate with population size.

Hickman and Penn (1977) studied the seasonal and vertical distribution of planktonic bacteria in a 3.5 m deep lake and noted extremely irregular vertical distribution of aerobic bacteria and any pattern could be noted only when the lake was stratified. He further noted a large population of facultative anaerobic bacteria.

Coveney et al (1977) while investigating the relationship among phytoplankton, zooplankton and bacteria observed spring maxima in bacterial population immediately following the algal blooms, indicating algal autolysis and decomposition products as important substrate for bacterial growth.

Donderski and Strzelczyk (1977) reported that the bacterial population was more numerous in spring and autumn and the littoral water harboured higher population as compared to the pelagial.

Kaper et al (1978) strongly recommended rapid sample handling to minimize variations in the microbial populations of aquatic environments.

Dutka and Kwan (1978) observed maximum bacterial and fungal populations in surface microlayer and pointed out that the traditional bacteriological sample collections at one meter below the surface invariably underestimates the population densities.

Schroeder (1978) found more than double increase in the fish production by using organic manure. The increment in the fish production could not be attributed to any of the conventional fish food. Through a series of experiments he proved that the additional fish production comes from the consumption of the microorganisms that thrive on the manure in the pond and rapidly convert it into a high quality food.

Jana (1979) found highly significant effect of season on the bacterioplankton population. Primary productivity and biological oxygen demand, however, did not show any definite relationship with the bacterioplankton population.

Further studies are needed to evaluate the effect of environmental factors on bacterial population particularly in the hill lakes of India where environmental factors are often far from the optimum and where such studies are lacking. Present chapter takes into account the bacterial population estimates using plate count method and microscopic count method and relates them to various physico-chemical characters of the water taking into consideration both temporal and depth-wise variations.

MATERIALS AND METHODS

Collection of water samples

The subsurface water samples for microbiological analyses were collected by autoclaved JZ bacteriological sampler (Zobell, 1941). The bottom samples were collected from approximately 10 cm above the lake bed. The middle samples were collected from the mid-depth of each sampling station. The surface samples were collected in sterile glass bottles from 1-2 cm below the surface. Before collection the surface film was disturbed and care was taken as to avoid the contamination of the film. All the samplings were

done between 900-1100 hours. For other analyses the subsurface water samples were collected by a 5 litre polyethylene Van Dorn bottle (Van Dorn, 1956), while the surface water samples were collected directly as above in polyethylene bottles of 2 litres capacity. Bottles were maintained in a dark chamber and transported to the laboratory within half an hour of sampling.

Viable count of bacteria

Within three hours of collection the samples were inoculated for the estimation of viable bacteria by spread plate method. Casein peptone starch agar (CPS, Collins and Willoughby, 1962) was used for the plate count ^{of} bacteria.

Aliquot of 0.5 ml in serial dilutions were inoculated on the surface of freshly poured medium in 100 mm dia. Petri-plates. Three replicates were maintained for every dilutions. The plates were kept at 10°C for 12 hours for absorption of the aliquot and incubated at 25°C for 7 days. The plates having 30 to 300 visible colonies were counted. The composition of medium was: soluble casein (BDH) 0.5g, Bacto-peptone (BDH) 0.5g, soluble starch 0.5g, K₂HPO₄ 0.2g, MgSO₄ 0.05g, FeCl₃ trace (4 drops of a 0.01% solution). Agar 15.00g in 1000 ^{ml} distilled water. In all the cases, medium was autoclaved at 15 pounds pressure for 20 minutes. Petriplates were sterilized in hot air oven at 175°C for 12 hours and 20 ml of medium was poured in the Petriplates.

Microscopic count of bacteria

Direct microscopic count of bacteria was done following the method described by Sorokin and Kadota (1972). 25 ml of lake water was filtered through a 0.22 μ m pore size millipore filter using Millipore filtration unit (Millipore Corporation Massachusetts, USA). The water samples were fixed in formaldehyde (2% final concentration). The bacteria on filters (millipore filters) were fixed in formaldehyde vapour. The filters were put in Petriplates on the upper lid of which was put a filter paper soaked in formalin. The filters were stained with erythrosin solution prepared by dissolving 0.5 g of the dye in 96% of ethyl alcohol. For staining, the filters were put on a filter paper moistened with stain for 2 minutes. The stained filters were then decolourized by placing them on the surface of a moistened filter paper. The filters were transferred to fresh moistened filter papers until the filter was decolourized to a weak pink colour. For the microscopic examination the filters were placed on a drop of immersion oil placed on the surface of a new slide. A further drop of oil was put on the surface of the filter. The filter, thus made clear and transparent, was covered with a cover glass. Microscopic examination of the preparation was done with an immersion objective (x100) and ocular(x15) in a binocular microscope. A 25 section ocular grid was used for the counting and 9 sections were counted for each microscopic field. A minimum of 10 microscopic fields,

chosen at random at different parts of the filter, were counted. The water samples were hand shaken before filtration. The clumps and aggregates of cells were counted separately. The volume of water filtered was adjusted so as to get an average of more than 5 cells per sections of the ocular grid. The number of bacteria per ml of water sample was calculated using formula:

$$N = \frac{S \cdot n \cdot 10^6}{SV} \text{ cells/ml.}$$

where N = number of bacteria, s = area of the working surface of filter (mm^2), S = area of 1 section in the ocular counting net measured with the objective micrometer under the same magnification of the microscope (μ^2), n = average number of bacteria per section of the ocular net and V = volume of water filtered.

RESULTS

The population estimates of total (microscopic count) and viable bacteria (plate count) in the lake water is given in the fig 2.1-2.4 and Tables 2.1-2.4. A general perusal of the data shows that the total population of bacteria was 10 to 50 times more than the viable population suggesting that only a fraction of total bacteria could be estimated by the cultural method. The trend of variation in total population and viable population was almost similar which is evident from highly significant correlation between

Fig.2.1. Seasonal variation in population of planktonic bacteria in the lake water at station 1. Broken lines: viable population, unbroken lines: total population, circles: surface waters, triangles: mid-depth waters, squares: bottom waters.

Fig. 2.1

STATION 1

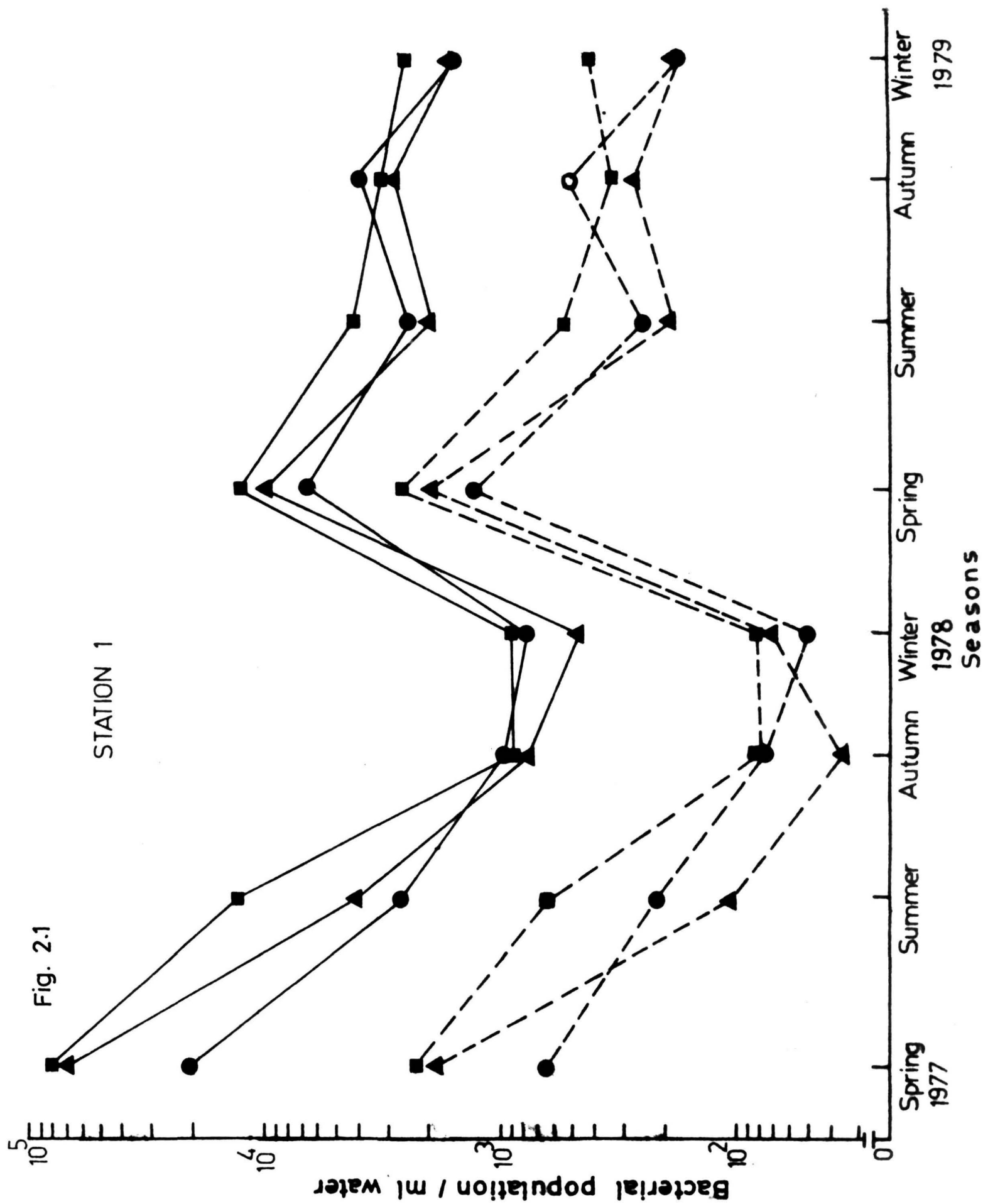


Fig.2.2. Seasonal variation in population of planktonic bacteria in the lake water at station 2. Broken lines; viable population, unbroken lines; total population, circles: surface waters, triangles: mid-depth waters, squares: bottom waters.

Fig. 2.2

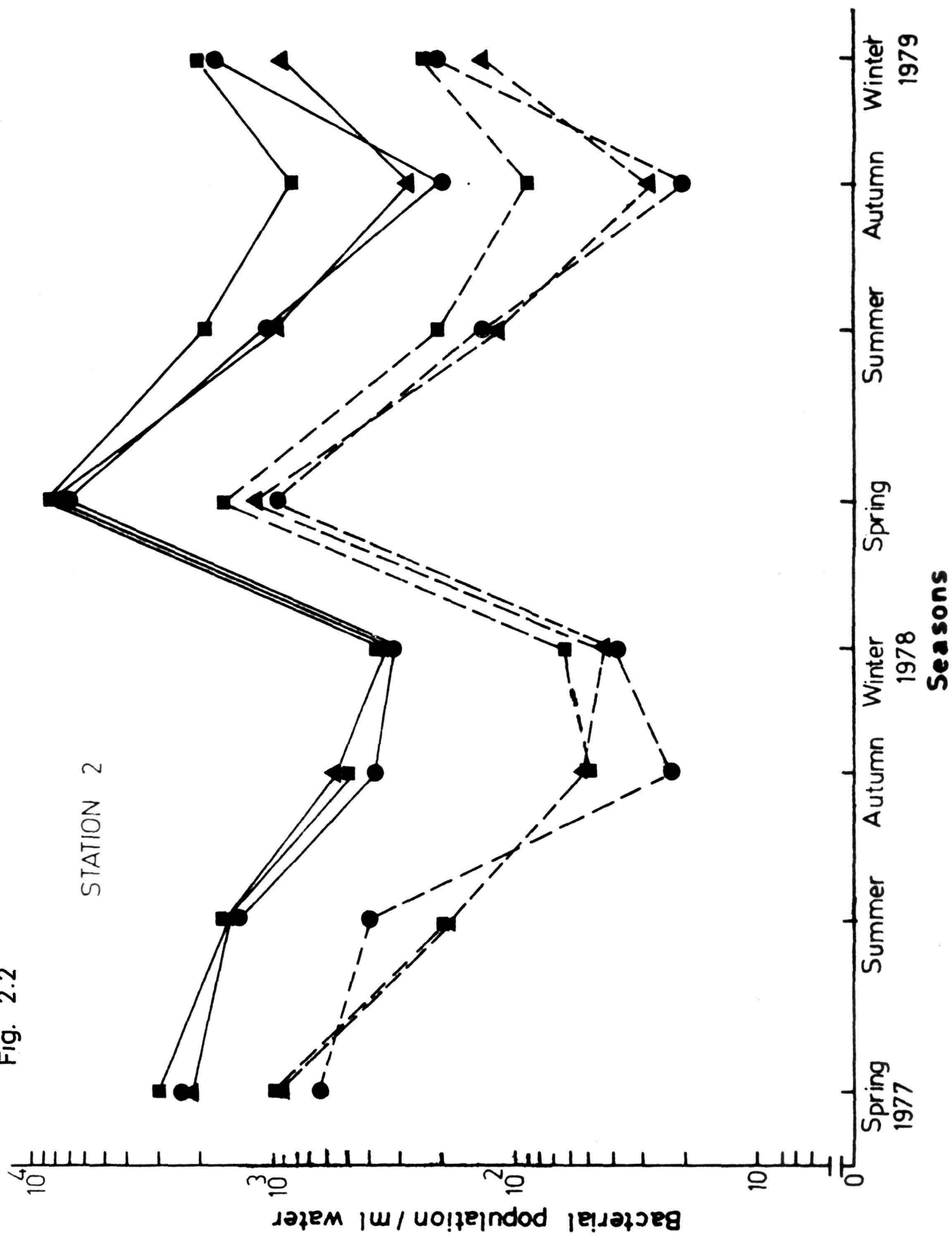


Fig.2.3. Seasonal variation in population of planktonic bacteria in the lake water at station 3. Broken lines:viable population, unbroken lines:total population, circles: surface waters, triangles:mid-depth waters squares: bottom waters.

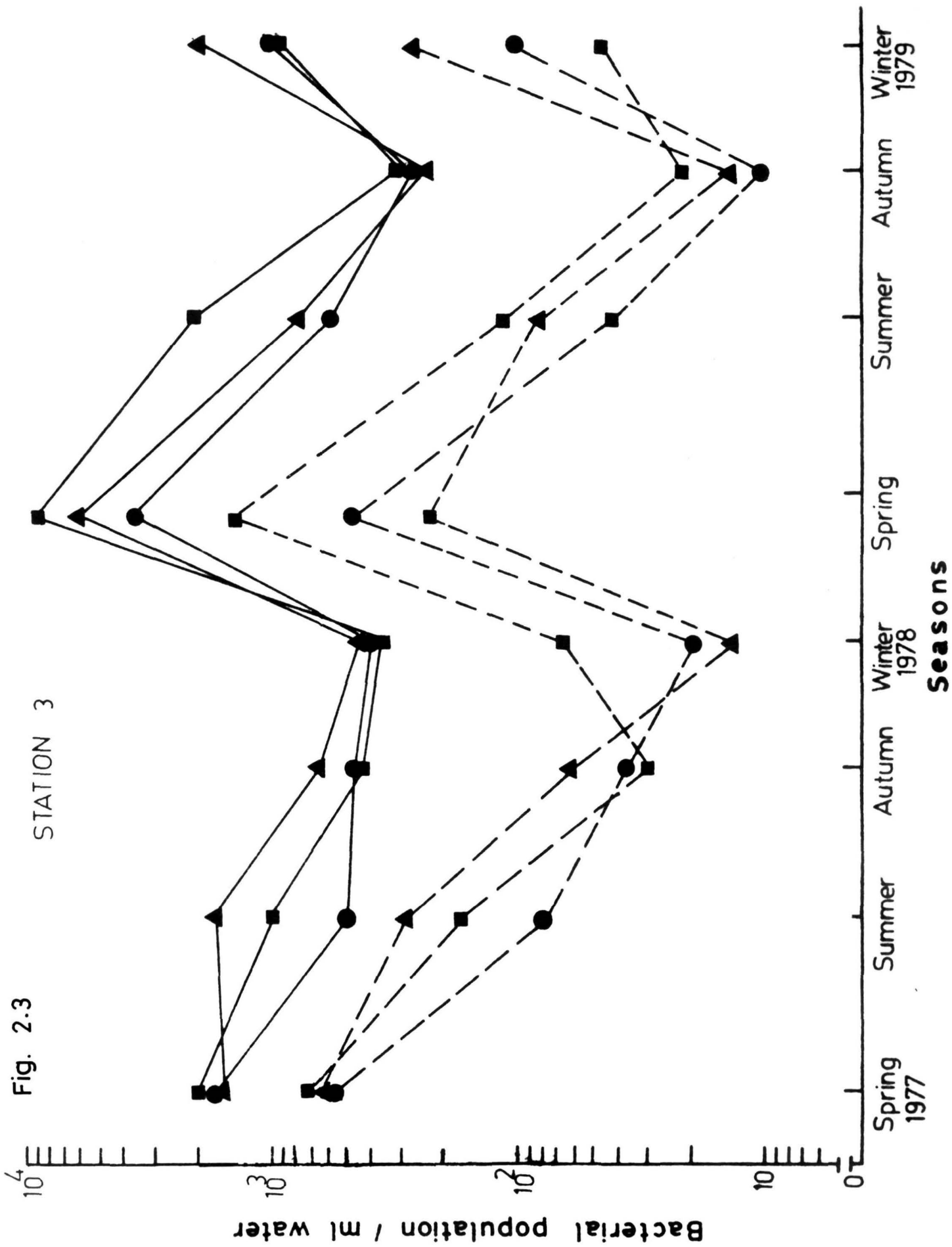


Fig.2.4. Seasonal variation in population of planktonic bacteria in the lake water at station 4. Broken lines: viable population, unbroken lines: total population, circle: surface water, triangles: mid-depth waters Squares: bottom waters.

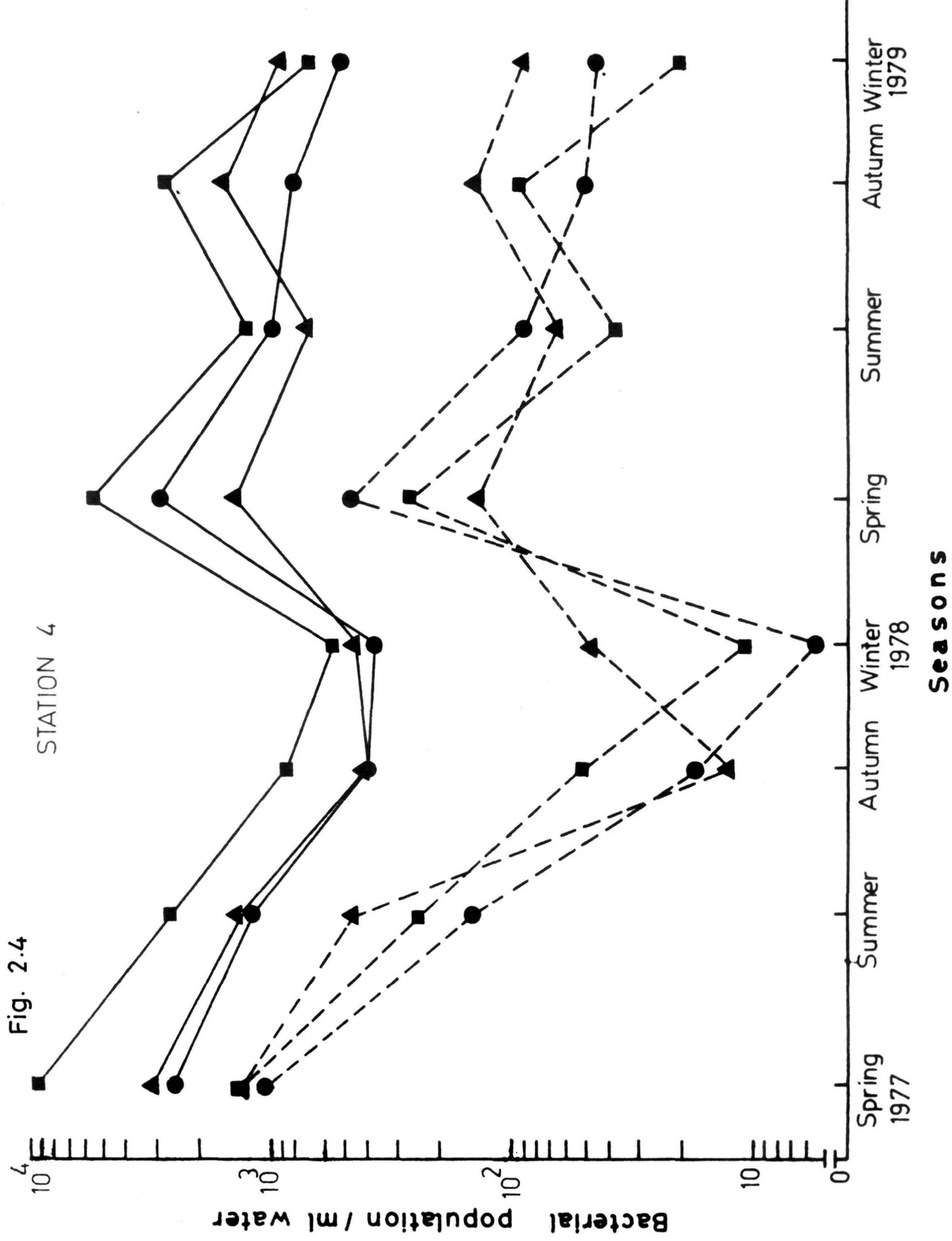


Table 2.1.: Monthly variation in viable population of planktonic bacteria (C.P.S. plate count) $\times 10^4$, 1977-1978.

Station	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
S	21.86	54.00	116.2	5.2	35.2	26.0	19.8	14.4	0.86	2.9	3.2	9.3
1 M	62.14	266.0	253.2	11.9	12.8	998	8.6	5.3	1.9	4.2	3.2	13.7
B	169.16	210.0	277.2	58.6	64.0	51.0	42.6	12.8	1.9	4.6	3.9	17.6
S	8.73	44.0	142.9	140.2	9.4	7.8	6.3	4.0	0.6	3.3	2.0	6.5
2 M	15.72	20.0	240.0	46.5	10.1	9.1	8.9	9.1	1.17	3.8	1.8	7.8
B	20.7	148.0	245.1	33.9	16.6	12.6	12.2	8.8	17.98	3.5	2.1	13.6
S	16.66	49.0	107.7	13.5	7.3	6.2	4.4	3.1	4.6	2.8	0.8	2.1
3 M	6.5	16.3	165.1	62.1	1.5	18.0	34.6	5.6	7.3	5.3	5.2	2.9
B	20.1	26.0	166.5	60.2	4.7	3.2	2.6	1.2	4.6	9.0	9.1	2.2
S	10.01	82.8	219.2	22.7	12.9	11.5	10.5	3.3	0.2	0.5	1.02	1.3
4 M	64.4	174.8	166.8	168.8	8.4	6.2	4.2	2.4	3.9	12.5	0.13	1.80
B	101.6	188.6	117.9	40.0	28.6	19.6	11.2	8.9	1.3	2.9	0.30	0.38

S = Surface, M = Middle, B = Bottom.

Table 2.2.: Monthly variation in viable population of planktonic bacteria (C.P.S. plate count) $\times 10^4$. 1978-1979.

Station	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
1	S	46.8	115.6	248.7	36.2	16.0	50.4	35.9	46.1	59.6	4.0	18.4	30.8
	M	64.5	276.0	278.6	12.7	15.6	24.9	24.1	26.0	29.6	3.8	18.7	30.7
	B	224.6	248.5	328.8	111.0	32.8	47.6	26.6	31.3	36.9	4.6	27.6	91.3
2	S	24.4	123.1	153.0	24.6	18.6	9.4	3.2	2.3	1.9	3.0	17.6	45.6
	M	29.0	136.8	196.4	24.7	19.4	3.9	1.35	2.0	3.5	4.0	14.6	23.5
	B	32.4	231.7	238.8	31.4	26.0	2.3	27.9	14.5	3.9	4.4	31.2	38.8
3	S	13.7	40.4	94.8	5.6	5.1	4.5	1.8	1.4	0.7	2.2	11.2	19.1
	M	12.0	305.6	142.8	17.4	15.3	1.6	0.8	1.1	1.8	3.1	2.3	6.0
	B	15.9	205.2	236.4	28.7	15.5	2.5	0.7	1.8	2.8	3.2	3.2	8.1
4	S	4.8	39.7	68.0	6.1	6.7	18.4	2.2	3.5	6.8	4.9	2.0	11.2
	M	17.6	5.3	19.6	9.9	6.1	10.6	0.9	9.0	2.2	6.4	8.5	12.4
	B	12.5	24.8	43.2	2.5	8.9	1.5	2.2	6.5	13.2	16.4	4.16	4.08

S = Surface, M = Middle, B = Bottom.

S = Surface, M = Middle, B = Bottom.

Table 2.3.: Monthly variation in total population of planktonic bacteria (Microscopic count) $\times 10^5$. 1977-78.

Station	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
1	S	113.2	132.3	363.1	64.1	18.6	14.3	10.8	17.7	1.5	1.1	1.6	5.0
	M	342.4	943.6	850.8	63.2	69.2	15.4	14.9	14.3	1.6	3.7	3.5	7.3
	B	546.7	853.3	943.8	350.8	138.6	31.2	28.6	16.8	16.1	3.88	13.6	9.8
2	S	5.6	28.9	38.4	36.4	8.4	6.19	5.8	4.0	1.8	2.2	1.8	5.4
	M	6.3	21.0	39.4	34.2	9.6	8.3	8.4	8.9	2.1	2.3	1.6	6.4
	B	11.4	38.5	40.3	32.4	10.2	8.6	8.4	7.8	2.2	2.2	1.7	6.9
3	S	7.8	2.9	34.8	7.0	5.2	5.1	4.8	4.6	4.8	4.7	2.0	5.4
	M	4.8	10.9	34.9	31.6	4.0	10.9	24.2	5.6	7.4	2.9	3.0	7.2
	BB	12.2	12.8	35.0	31.5	4.4	4.2	3.9	3.5	4.8	3.9	3.9	3.3
4	S	11.9	30.2	34.9	21.4	9.8	8.8	7.9	4.2	3.8	3.9	4.1	2.9
	M	28.6	33.4	31.4	31.9	8.9	7.8	6.8	4.2	3.8	4.6	2.9	4.9
	B	9.6	149.1	45.6	32.4	30.1	28.6	18.4	10.4	7.1	7.8	4.4	4.4

S = Surface, M = Middle, B = Bottom.

Table 2.4.: Monthly variation in total population of planktonic bacteria (Microscopic count) $\times 10^5$. 1978-1979.

Station	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
1	S	20.8	55.6	130.0	22.5	17.9	35.9	26.3	34.3	45.2	4.5	18.2	26.9
	M	26.9	135.5	137.0	152.4	16.3	24.3	24.4	25.6	34.3	38.8	18.4	26.8
	B	100.8	125.3	167.2	87.8	24.3	30.6	25.6	26.6	35.8	4.8	19.3	53.3
2	S	18.2	96.3	103.5	19.4	14.4	8.1	3.3	2.2	1.8	2.8	15.3	36.4
	M	21.4	117.4	116.8	18.3	17.3	3.6	1.4	2.2	3.5	3.8	12.0	12.8
	B	24.4	118.5	119.8	19.3	18.6	28.0	18.8	13.3	4.0	4.1	25.9	31.8
3	S	14.2	36.4	62.3	7.5	6.8	5.8	4.0	3.4	2.3	3.6	10.2	18.6
	M	13.3	32.6	145.6	115.4	12.6	2.4	2.3	2.3	2.8	0.4	18.5	44.3
	B	14.3	106.3	153.4	64.8	13.4	2.8	2.2	2.9	3.4	4.3	10.0	12.8
4	S	4.4	32.5	53.0	8.5	7.4	20.6	4.2	6.3	7.8	2.3	0.54	12.6
	M	19.5	7.3	16.6	9.8	6.3	10.1	2.2	11.2	18.5	6.5	8.8	12.9
	B	36.8	13.2	120.0	7.5	32.8	6.0	7.2	18.5	40.6	6.2	3.0	12.1

S = Surface, M = Middle, B = Bottom.

Table 2.5.: Monthly variation in viable population of planktonic bacteria (C.P.S. Plate count) $\times 10^4$. Figures are average of the three depths.

Station	Year	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1	1977-78	91.0	176.6	215.5	25.2	37.3	28.9	23.6	10.8	1.5	3.9	3.4	13.5
	1978-79	111.9	213.3	285.1	49.9	21.4	40.9	28.8	34.4	42.0	4.1	21.5	50.8
2	1977-78	15.0	70.6	209.3	73.5	12.0	9.8	9.1	7.3	1.2	3.5	1.9	9.3
	1978-79	28.6	163.8	196.0	26.9	21.3	5.2	10.8	6.2	3.1	3.8	21.1	36.0
3	1977-78	14.7	30.4	146.3	45.2	4.5	9.1	13.8	3.3	5.5	4.1	3.5	2.4
	1978-79	13.8	92.0	115.1	17.2	11.9	2.8	1.1	1.4	1.7	2.8	12.5	29.1
4	1977-78	58.7	148.7	167.9	77.1	16.6	12.4	8.6	4.8	0.6	5.2	0.4	0.6
	1978-79	13.3	23.2	43.6	6.8	7.2	10.1	1.7	6.3	14.0	2.8	3.6	9.2

the two parameters ($r = 0.99$). In general, the bacterial population was high during the spring months (March-May) which declined to minimum during winter (December-January). During remaining part of the years population remained almost within a stable range.

The population estimates varied along depth. For most of the seasons the bottom waters contained highest populations. This generalization was more correct for the total counts. The viable bacteria also follow same pattern of distribution but at some samplings it varied deferently. Almost similar pattern of seasonality was noted both the years. A few departures to the previous year's observations were that station 2 and 3 showed an increment in the population in the winters. The seasonality pattern was quite clear in the total population estimates but the viable count showed a rhythmic pattern during the periods of low populations. The pattern of seasonality is more clear in the table 2.5 where the values have been averaged for the stations. A comparison of the values recorded at various stations reveals that station 1 harboured highest bacterial population for most of the periods. Other stations did not vary significantly with each other.

Pseudomonas, Flavobacterium, Bacillus and Achromobacter were identified from the water samples. The surface samples were always dominated by light yellow to light red coloured

colonies. The bottom samples contained violet colonies of Chromobacterium which were usually absent from other depths.

DISCUSSION

On comparison of bacterioplankton population estimates by two methods it appears that both the methods depicted similar general trend of population variation with depth and time. However, the depth-wise distribution of bacterial population estimated by one method did not always correspond with the population estimation by the other method. This phenomenon was quite marked at the station 4 where the bottom waters always harboured maximum bacterial population by microscopic methods (except in December 1978 and January, 1979) but the same was not true with plate count method. This may probably be due to difference in physiological state of bacteria in the bottom water which for most part of the year remains comparatively anoxic and rich in dissolved inorganic and organic nutrients (chapter 1) and therefore, bacteria living in bottom waters probably do not grow that well on the culture medium when incubated aerobically. Thus, it may be concluded that the viable count is definitely an underestimation of the total population and probably this becomes more pronounced in the extremity of the environmental conditions. Jones (1977) also observed similar results.

The seasonal variation in the bacterial population is

marked by the spring maximum and winter minimum. The high bacterial population during spring also coincides with the higher values of various inorganic and organic nutrients (chapter 1) as well as the biological activity measurements (chapter 4). This may very conveniently be ascribed to the phytoplankton maxima which occurs during March-April and followed by the peak of bacterial populations. Similar results have been reported by Jones (1971, 1972), Takahashi and Norton (1977) and Gunkel (1968). The first post winter rains may also contribute to the cause by bringing in the allochthonous bacteria and dissolved and particulate organic matter such as pine needles and pollens from the adjoining areas. The higher values of dissolved organic carbon during this period proves this. The increased availability of food source favours microbial multiplication which may be further promoted due to rise in temperature during this period. Similar results have been reported by Andronikova and Drabkova (1971), Jannasch (1955) and Potter (1964).

The period that follows i.e. June-September is characterized by heavy rainfall (Fig. II) and shows a decline in bacterial populations which results from an excessive dilution of the lake water. Similar influence of water influx on the bacterial population was observed by Zimmermann (1977). There is further increase in temperature during this period which favours rapid multiplication, however, this

was not observed. It was probably masked by the other factors. The other probable reason for the sudden decline of population during post spring periods may be exhaustion of the available organic and inorganic nutrients by the phytoplankton and bacterial blooms.

Spring depletion of oxygen in the lake bottom at station 4 (chapter 1) may be a result of the microbial utilization. The bacterial activity is also reflected in the higher conductivity values during warm periods and low values in the winter which may be ascribed to the mineralization. The higher values for the nutrients at the bottom waters coupled with the higher bacterial population estimates confirm the association between the two (chapter 1). The bacteria are probably responsible for the release of nutrients from the sediments. No significant correlation was observed with most of the measured environmental factors. This may be ascribed to a wide range of population structure of heterotrophic bacteria present at different depths and time. Owing to low level of organisation, fast growth rate and adaptations to stand unfavourable circumstances, the overall population of bacteria may not show a response to varying conditions. This results from their fast homeostatic regulation mechanisms allowing them to reach the 'maximum persistent biomass' within a short span of time. The tendency to 'persist and grow' in fluctuating environments may result in the replacement of populations, change in community structure or even the mode of nutrition. All this may help them in adjusting

to change in the environmental factor within a very short span of time. The comparison of bacterial population with dissolved organic carbon estimates shows clear positive relationship between the two variables although the correlation coefficient values ($r = 0.55$; $p = 0.05$) was not statistically significant.

The absence of correlation of bacterial population with most of the factors may also be due to the fact that these organisms are not dependant upon a single factors all the year round. Also the factors may not act in isolation at a given time.

At station 4 three sampling depths may harbour different physiological groups of bacteria belonging to the same or different taxonomic groups (Strzelczyk et al 1971). It is assumed that the bottom bacteria are facultative anaerobes which produce sizeable number of colonies when incubated aerobically.

The taxonomic composition of the bacterial population is typical to the freshwater lakes. The dominance of coloured form in the surface samples is probably an adaptation to the light intensity.

It may be concluded that the effect of environmental changes on the populations of planktonic bacteria would be significantly evident only if the changes were well

beyond their tolerance range. The coincidence of the spring blooms with the maxima of most of the biological activity measurements such as BOD, alkaline phosphatase activity, coefficient of heterotropic activity and rate of bacterial production (chapter 4) shows that the bacterial populations have positive relationship with the activity measurements.

CHAPTER 3

SEASONAL VARIATION IN PLANKTONIC POPULATION OF VIABLE FUNGAL PROPAGULES

INTRODUCTION

Fungal populations in natural waters represent such a heterogeneous array of microorganisms that it is difficult to group them according to the habitat. The term aquatic fungi has generally been used for the "fungi living in water" (Ainsworth and Bisby, 1963). Representatives of almost all subdivisions of fungi are found in natural waters (Sparrow, 1968; Johnson, 1968). The motile zoospore producing Phycomycetes are generally included in aquatic fungi (Sparrow, 1960). Another important group of aquatic fungi produces non-motile spores characterized by tetra-radiate arms (Ingold, 1942, 1959, 1976; Nilson, 1964). This group forms a great bulk of fungus life in well aerated waters of streams and rivers where they are dominant saprophytes on extraneous plant litters. They are not so common in lakes and ponds. Most of the dominant soil fungi have been isolated from the natural waters (Cooke, 1976; Park, 1972). These so called "geofungi" have been reported to be actively involved in the leaf litter decomposition in natural waters (Kaushik and Hyne, 1971; Padgett, 1976).

It is an established fact that fungi as a group have definite edge over bacteria in the process of decomposition of plant materials (Harley, 1971; Saito, 1965; Kaushik and Hyne, 1968). They are involved in making it suitable for bacterial attack and bacteria and fungi together attract

animals whose feeding breaks down the substrate into smaller particles, thereby increasing surface area and stimulating bacterial growth (Parr et al., 1967).

Fungi constitute quality food for the aquatic invertebrates. The aquatic invertebrates have a preference for the leaf area of highest fungal concentration (Barlocher and Kendrick, 1973 a,b). Studies of Willoughby and Sutcliffe (1976), Marcus and Willoughby (1978) and Rossi and Fan (1979) have clearly demonstrated that it is fungi associated with detritus particles that constitute the bulk of energy source for detritivorous aquatic invertebrates and not the organic part of it.

Besides being active decomposer of plant litter and quality food for the aquatic invertebrates many aquatic fungi are known to be dominant parasites of phytoplanktons, zooplanktons and fishes. It has been conclusively shown that fungal parasites quite often regulate the population of other aquatic organisms (Masters, 1976; Redfield and Vincent, 1979; Scott and Obier, 1962).

Coker (1923) reviewed the literature on taxonomy and seasonal periodicity of aquatic Saprolegniaceae. Based on his observations and literature he concluded that spring was the most favourable season for the organisms. He observed maximum occurrence of Saprolegniaceae during spring and very few species could be collected during winter and summer. The

seasonal periodicity of species was regarded to be associated with environmental factors among which temperature has a profound effect.

Forbes (1935 a,b) studied the seasonality of aquatic Phycomycetes in several ponds and reported winter maxima which declined later and totally disappeared during summer. Salvin (1941) studied the effect of temperature on the activity of primary and secondary zoospores. He found that at temperatures below 10°C and above 30°C the zoospore activity was abnormal.

Harvey (1942) reported that the small population and great species diversity were associated with nutrient deficiency. The nutrient rich area was often poor in water-molds because the zoospores of Saprolegniaceae may be easily injured when subjected to high osmotic concentration. He also suggested that the altitude has a pronounced effect on the distribution of the fungi.

Harvey (1952) reported that species of Saprolegnia and Achlya were absent from the polluted waters whereas Aphanomyces showed some affinity for polluted waters.

Waterhouse (1942) noted that most of the fungi appear in September or October, reach to a maximum in December to February and disappear in summer.

Chaudhuri et al (1947) studied the seasonal periodicity of Saprolegniaceae in tropical waters and found that favourable growth periods are October to December and February to May.

Studies on the oxygen utilization by aquatic fungi have shown that they have great capacity to utilize oxygen which may even exceed those of bacteria. They can successfully compete with other microorganisms for organic matter in solution and oxygen available in dissolved state (Cooke et. al., 1956).

Through a series of papers Suzuki (in Sparrow, 1968) has proved that temperature plays the most important part in the growth and reproduction of Saprolegniaceae which it exercises through governing the zoospore production which are the most important reproductive units for the distribution of the organisms of this family.

Dayal and Tandon (1962) found a marked seasonal occurrence of Saprolegniaceae. They observed that species collected during October and November grew vigourously and produced sex organs whereas those collected in March and April undergo a period of dormancy. Most of the species remain dormant during summer and, therefore, their occurrence was restricted to winter months.

Dayal and J1 (1965) listed twenty three species of aquatic fungi from various ponds of Varanasi (India).

Hughes(1962) proposed that Saprolegniaceae could be divided into two groups with respect to seasonal periodicity, one, with centric and subcentric oospores which showed marked seasonal periodicity with temperature change, and the other with ecentric oospores does not show any definite pattern

and also to these the effect of temperature was negligible. He found that Saprolegnia spp. were dominant in spring and Achlya spp. in autumn.

Roberts (1963) studied the distribution of Saprolegniales in relation to pH and temperature. She grouped her isolates into three categories: winter species, summer species and constant species based on the period of isolation. She further observed that typically more species were isolated from the bottom than from surface waters.

Cooke (1966) isolated species of fungi from acid streams and suggested that many of these fungi were performing a useful function by removing waste organic matter from the waters.

Cooke (1967) isolated hundred twenty eight species of fungi from various aquatic habitats most of which were 'so called' terrestrial fungi. He opined that these fungi use organic wastes as food and their populations increase in such habitats.

Srivastava (1967) studied the seasonal variation of aquatic Phycomycetes and grouped them with respect to temperature and pH preference. He observed maximum number of species in the winter and minimum during spring.

Sparrow (1968) reviewed literature pertaining to the ecology of freshwater fungi and concluded that seasonal occurrence of the fungi seem to be certainly associated with

temperature and its effects. He pointed out that temperature may also act indirectly to restrict competition for substratum by other fungi or even by algae. He suggested that for temperate regions spring is the best time for the collection of unusual and rare fungi.

Howard et al (1970) described the taxonomic characters of the members of Saprolegniaceae isolated from Iceland. Ji and Dayal (1971) described the life cycle of Allomyces javanicus Kniep. Johnson (1971) described the taxonomic characters of sixteen species of Pythium isolated from Iceland.

Ristonovic (1973a) quantified the fungal propagules in Skadar Lake and found that it varies between 20-730 propagules per ml of water. In another study (1973b) he isolated twenty three species of aquatic Phycomycetes and discussed the possibilities of their use as indicator of water pollution.

Clausz (1974) observed that spring and fall were the seasons for maximum activity of Saprolegniaceae. He further observed that the viability of zoospores is only few hours which increases at low temperatures and less aerations.

Querehi and Dutka (1974) described various roles of fungi in the lake ecosystem and they pointed out possibilities of the use of terrestrial fungi as a potential indicator of water pollution and the degree of eutrophication. They concluded that more qualitative and quantitative information on the population of terrestrial fungi in lake waters are required for the better understanding of their specific ecological roles within the lake ecosystems.

Ho (1975a) observed the behaviour of zoospores of Saprolegnia towards its baits and reported that a large number of zoospores encyst around the baits. Subsequently they germinate towards the bait and colonize it. In another study (1975b) he proposed a new medium selective for the growth of Saprolegnia sp. While studying the seasonality of aquatic fungi Ho (1975c) observed peaks in spring and fall and low values in summer and winter. Liu and Volz (1976) extensively reviewed the literature on the ecology of the Saprolegniaceae. They considered various physico-chemical factors and described the effect of the factors on distribution and activity of the organisms.

Fox and Wolf (1977) found that the fungal population did not vary along depth and in their later studies they collected only surface waters from the edge of the lake. Results of their seasonality studies were similar to that of Hughes (1962).

Khulbe and Bhargava (1977) found that the periodicity of aquatic fungi is governed by temperature and not by the seasons. They observed maximum occurrence of water molds during summer and autumn in temperate lakes and during spring and autumn in subtropical lakes.

Chrzanowski and Stevenson (1979) found significant positive association between fungi and particulate organic carbon. Based on sufficient data they concluded that fungi are attached to particulate organic materials. Rossi and Fan (1979) studied the role of fungi as food for aquatic inverte-

brates and noted that the fungi growing on the detritus constitute the food of the invertebrate studied not the detritus proper.

However a paucity of informations on occurrence, distribution and relative abundance of fungi in freshwater lakes exists. In particular, the Indian hill lakes have not been surveyed for the fungi. The only study of this nature was carried out by Khulbe and Bhargava (1977). They primarily examined the zoosporic Phycomycetes and did not study geofungi. It is thought that informations concerned with the distribution and seasonal variation of geofungi within the aquatic environment is necessary. As they constitute an important part of the planktonic saprophyte community their population estimates and relationship with other microorganisms would be necessary to understand the role of fungi in the lake ecosystem.

Present chapter takes into account the quantitative and qualitative distribution of fungi in lake water.

MATERIALS AND METHODS

Viable count of fungal propagules.

Viable fungal propagules were estimated by spread plate count method. 0.5 ml of the lakewater was inoculated on the surface of freshly poured Rose Bengal Streptomycin Agar (Martin, 1950). The inoculum was uniformly spread on the Agar and the Petriplates were incubated at $25^{\circ} \pm 1^{\circ}\text{C}$ for 7 days. The total number of fungal colonies was counted

to calculate the number of fungal propagules per ml of water. The composition of medium was: Dextrose (BDH) 10g; Bacteriological Peptone (BDH), 5 g; KH_2PO_4 , 1 g; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.5 g; Agar (BDH), 20 g; Distilled water, 1000 ml; Rose Bengal 0.033 mg. 0.100 g of Streptomycin (IDPL) was added to the autoclaved medium when the latter was cooled to 45°C. The pH of the medium was adjusted to 5.4. Medium was autoclaved at 15 pounds pressure for 20 minutes. Petriplates were sterilized in hot air oven at 175°C for 12 hours and 20 ml of medium was poured in 100mm dia. Petriplates.

Baiting for zoosporic Phycomycetes

For the isolation of aquatic Phycomycetes baiting technique was used. To begin with, a number of materials were used as baits viz., hemp seeds (Cannabis sativa L.), cabbage seeds (Brassica oleracea Var. capitata L.) popped rice, pieces of leaves, grasses, bird feathers, termite wings, beetle wings and pine pollens. After working out quite a few samples the hemp and cabbage seeds were found to be the best baits because they trapped a board spectrum of fungi; were easy to handle for a number of samples at a time; gave reproducible results and above all the baits of almost same chemical and morphological nature could be used for all the samples. Throughout the course of study two baits were used for isolations. For primary isolation from the samples both type of baits were used, Subculture, purification, and reisolation were done either on hemp seeds or on corn meal agar (Johnson and Curl, 1972).

Seeds with approximately 150 ml of distilled water in separate 250 ml conical flasks were autoclaved at 20 pounds pressure for 15 minutes. The seeds were then dissected out to get the cotyledons separated. These cotyledons were used as baits. Baits were put in the field and in the laboratory. In the former, the baits were placed in the lake water for 24 hours and were then withdrawn and brought back to the laboratory. In the latter the water samples were brought to the laboratory and baiting was done by setting up trap cultures in Petriplates(100 mm dia) in the laboratory.

Laboratory Methods.

20 ml of lake water was transferred to previously autoclaved Petriplates. 10 ml of 1% NaCl solution and 1 ml of membrane filter (0.22 μ m) sterilized Streptomycin solution (1 g per 100 ml) was added to it. 10 sterilized baits were aseptically transferred to the solution with the help of a flattened sterile needle so that they float on the surface and precautions were taken to avoid clumping together of the baits. The Petriplates were incubated at room temperature (20-26°C) for three days. Later on the baits were transferred to 20 ml sterilized distilled water in separate plates. The Petriplates were again incubated at room temperature till a visible fungal mycelium around the baits was seen. As soon as a bait was noted positive for fungus

it was transferred to 50 mm dia Petriplates containing sterilized distilled water. 2-3 sterilized cotyledons of hemp seeds were transferred to this. The fresh cotyledons were used for the identification, subculture and preservation purposes. To get the sexual organs the hemp seed cultures were incubated at 10-15°C for 15 days. A few cultures were identified by Commonwealth Mycological Institute, Kew, Surrey, England.

Field Methods

Approximately 50 sterilized baits of each kind were tied separately in a nylon net (1 mm pore size) along with a sterile glass piece (generally a bottle stopper) heavy enough to hold it below the water surface. These pockets were tied at the sampling stations with the help of a nylon cord. The baits were brought back to the laboratory after an exposure of 24 hours. 10 randomly selected baits of each type was transferred to the Petriplates and further processing was done as in the case of laboratory method except in the place of lake water 20 ml of sterilized distilled water was used in this case.

The procedure followed in the present study is a modification of the method described by Dutka (1978). This method has an advantage over the simple baiting procedures, as the bacterial and the protozoan infestation of the seeds could be avoided to a minimum.

Only filamentous aquatic Phycomycetes were taken into account and the afilamentous forms were not considered. The

Fig. 3.1. Seasonal variation in viable population
of planktonic fungi in the lake water
at station 1. Circles: surface waters,
triangles: mid-depth waters, squares:
bottom waters.

Fig. 3.1

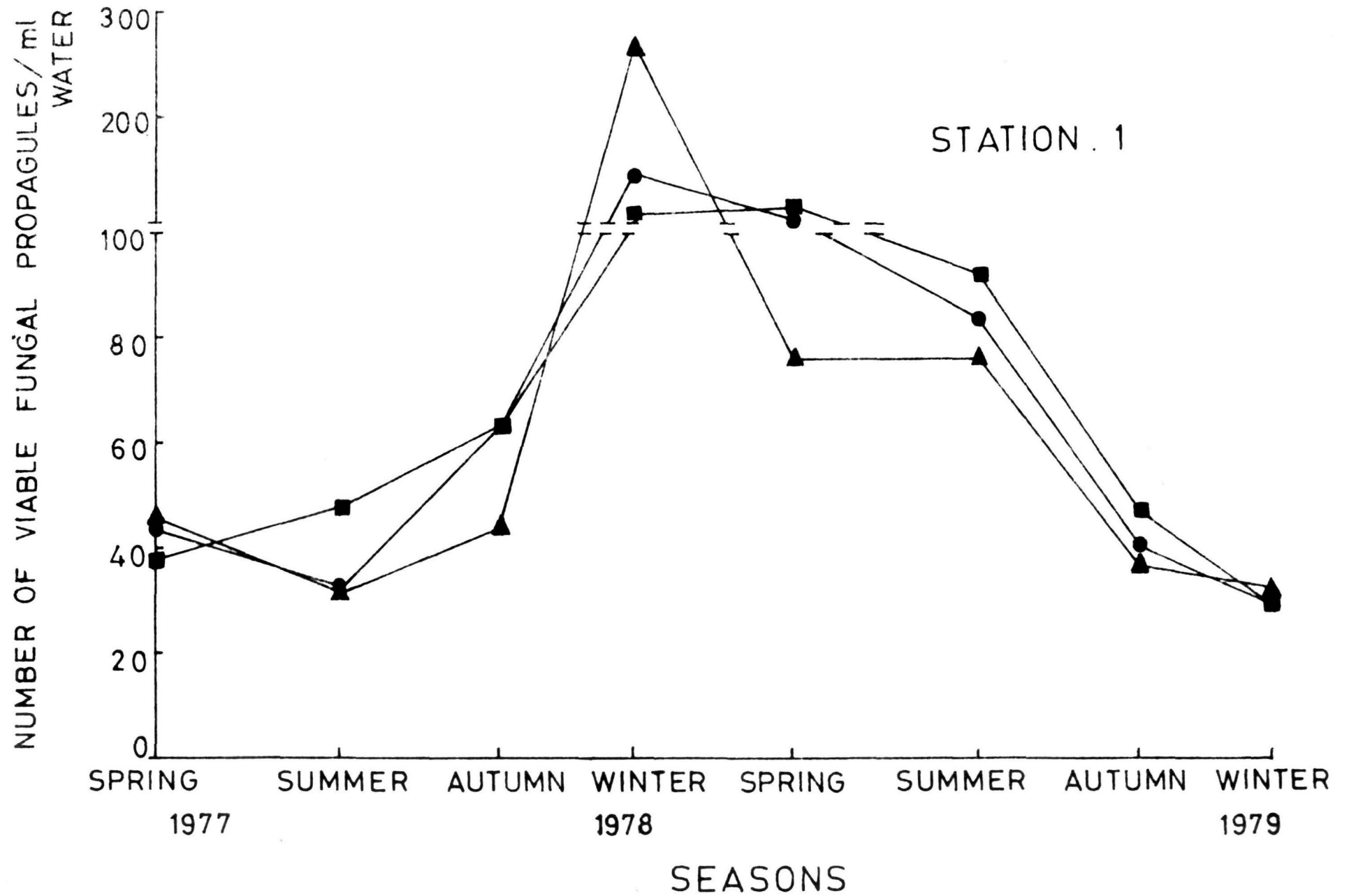


Fig.3.2. Seasonal variation in the viable population of planktonic fungi in the lake water at station 2. Circles: surface waters, triangles: mid-depth waters, squares: bottom waters.

Fig. 3.2

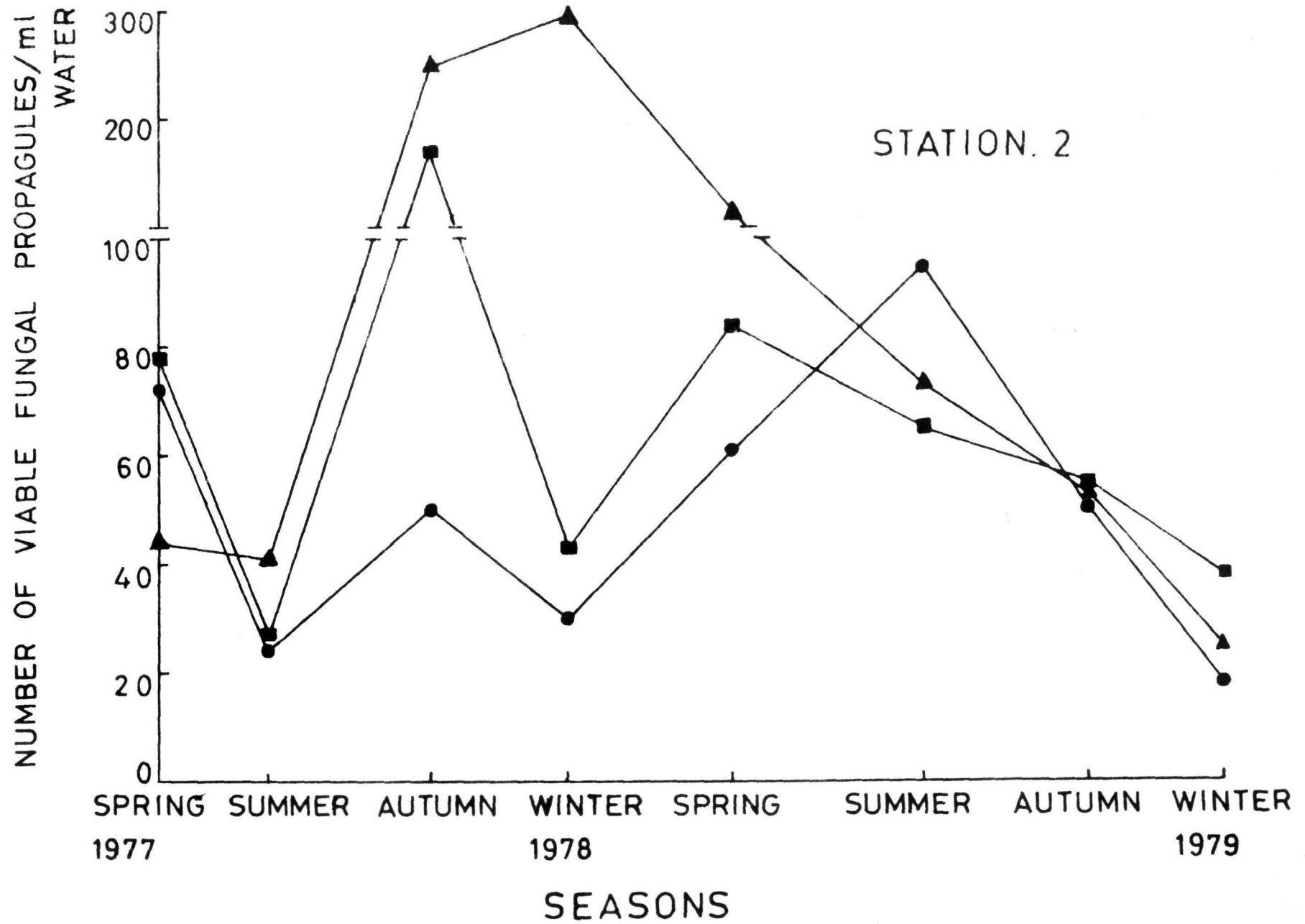


Fig.3.3. Seasonal variation in the viable population of planktonic fungi in the lake water at station 3. Circles:surface waters, triangles:mid-depth waters, squares:bottom waters.

Fig. 3.3

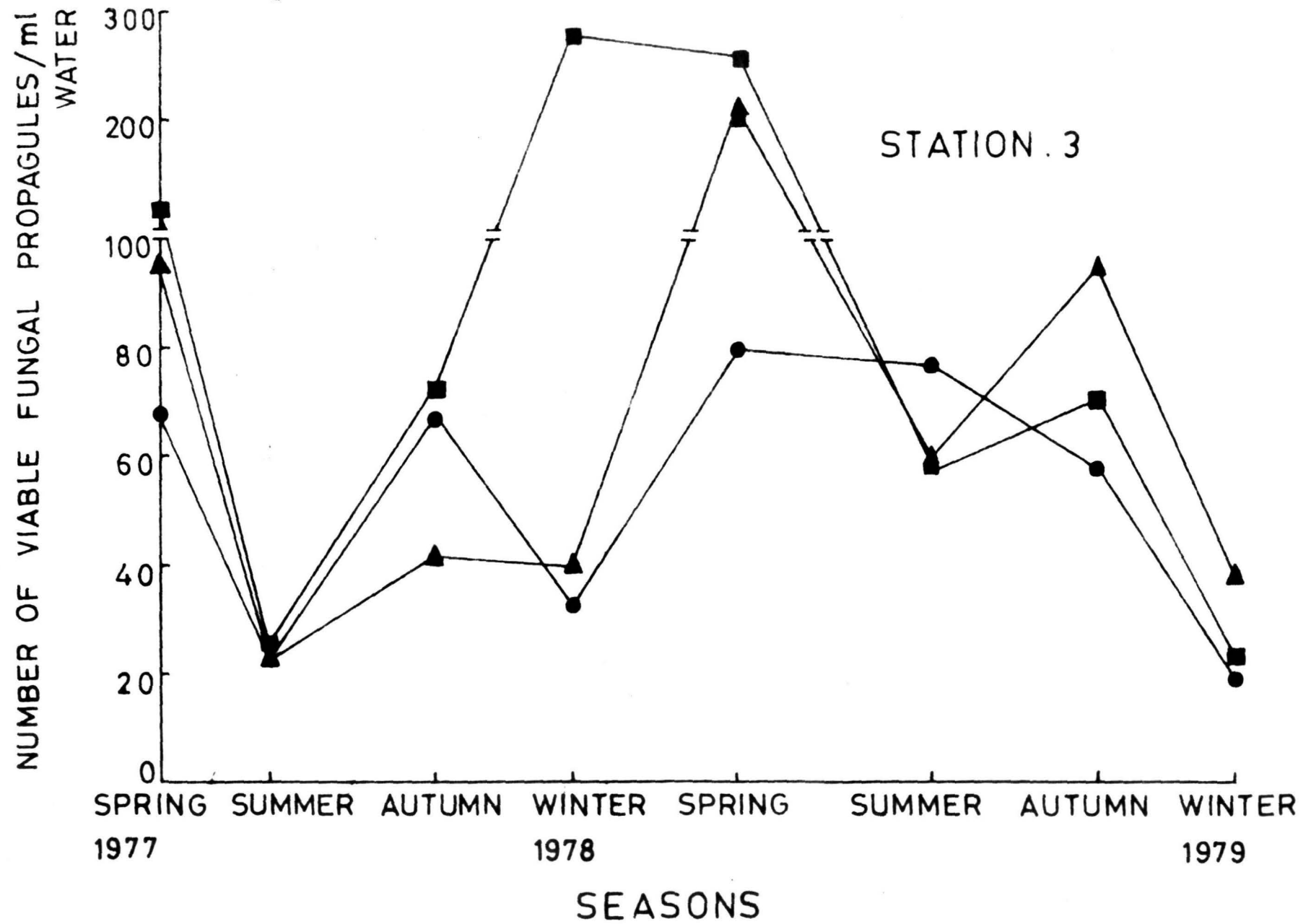
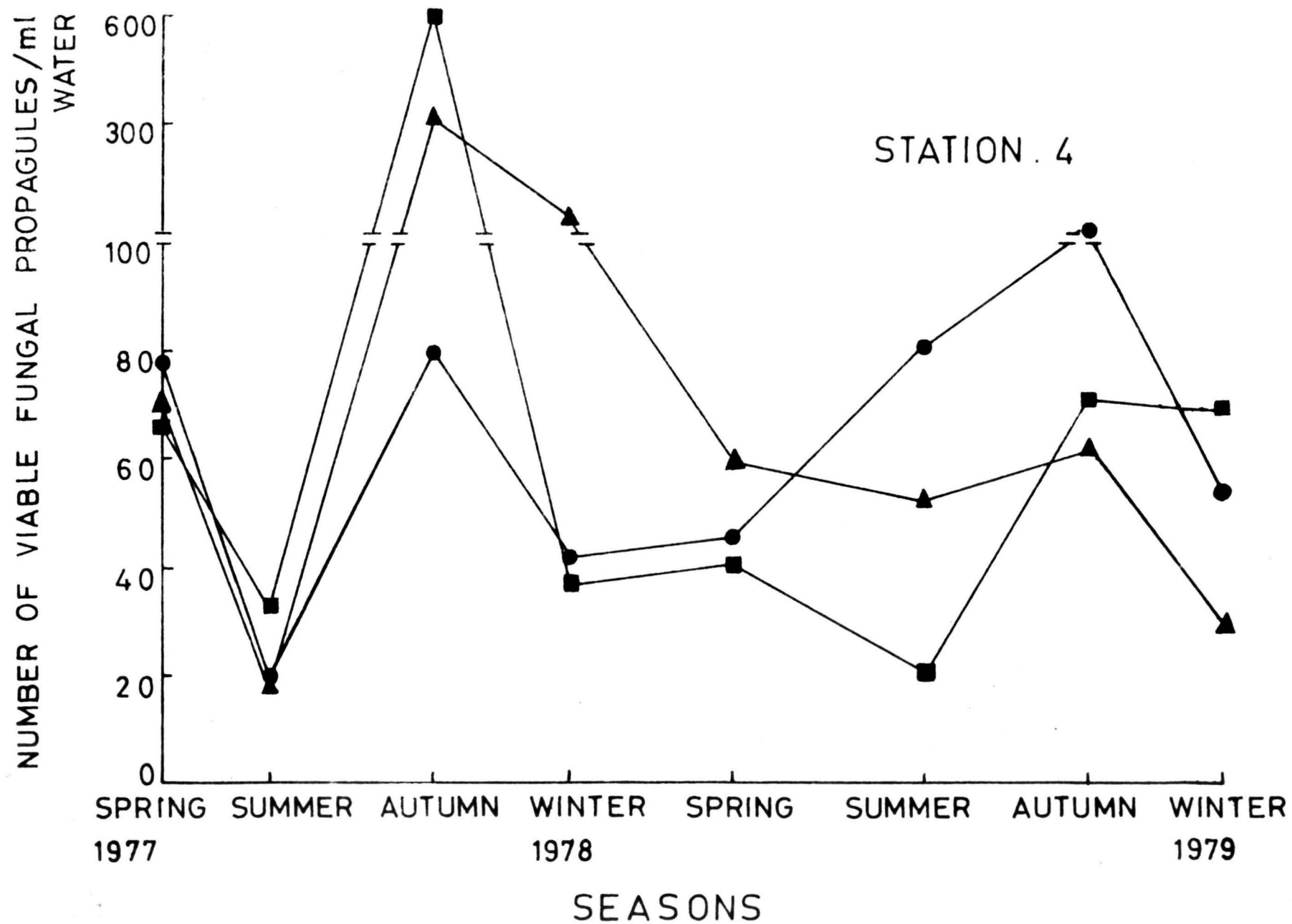


Fig.3.4. Seasonal variation in viable population of planktonic fungi in the lake water at station 4. Circles:surface waters, triangles:mid-depth waters, squares bottom waters.

Fig. 3.4



preservation of aquatic Phycomycetes was done in 20 ml culture tubes on corn meal agar. A fully grown colony on corn meal agar was flooded with sterilized mineral oil and stored at 5°C in a freeze. For short time preservations and day to day study the fungi were maintained on hemp seeds in sterilized distilled water stored in a freeze at 5°C.

RESULTS

Viable Fungal Propagules (Plate count method)

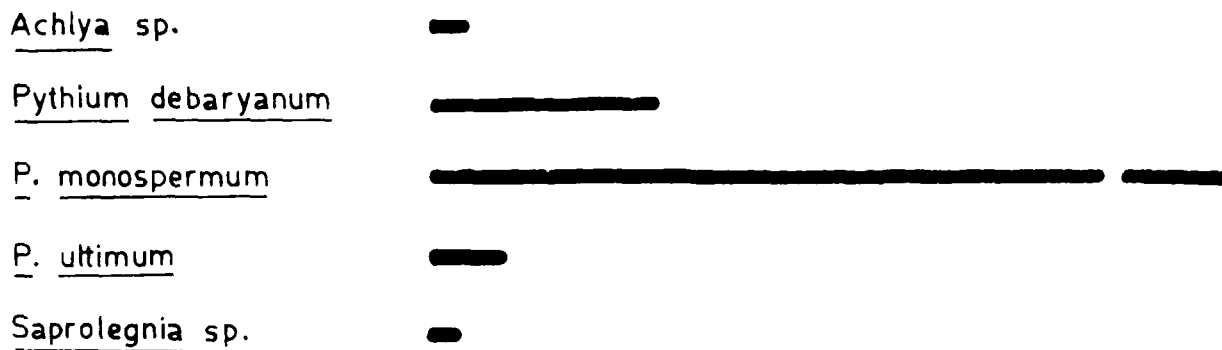
A perusal of the data presented in Fig. 3.1-3.4 suggest that the planktonic fungal population showed a marked seasonal variation. However, all the stations did not show the same pattern of seasonality. The stations 2,3 and 4 showed almost similar trend of population variation while station 1 showed altogether different trend. Station 2,3 and 4 showed a spring and autumn peaks during first year of study but this trend was not repeated in subsequent year. The station 1 showed increase in fungal population from spring to winter during the first year while in the second year of study a constant decrease in population was observed. The depth-wise distribution of fungal population did not vary significantly although qualitative as well as quantitative differences in the population were observed.

The fungal forms isolated from the lake waters by plate culture method mostly belong to the terrestrial group of fungi. Pythium monospermum, Aureobasidium pullulans,

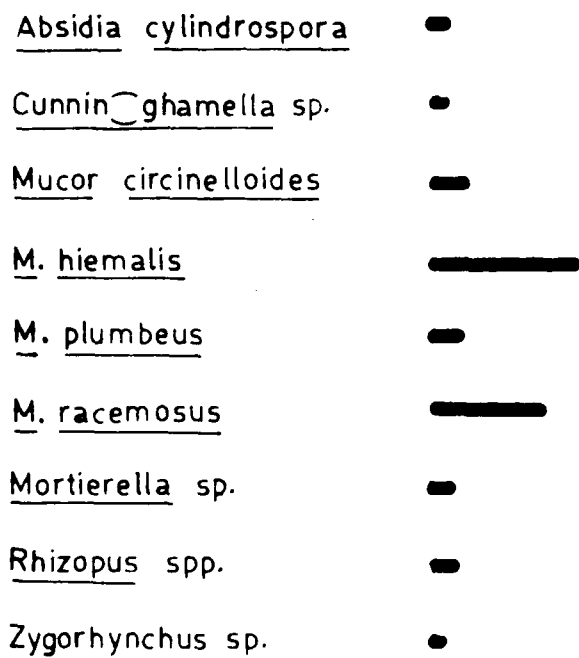
**Fig.3.5. Percentage occurrence of various
fungi in the lake water calculated
with the data (360 samples) collected
at all the stations and depths
(March 1977 - February 1979).**

OOMYCETES

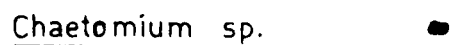
Fig. 3-5



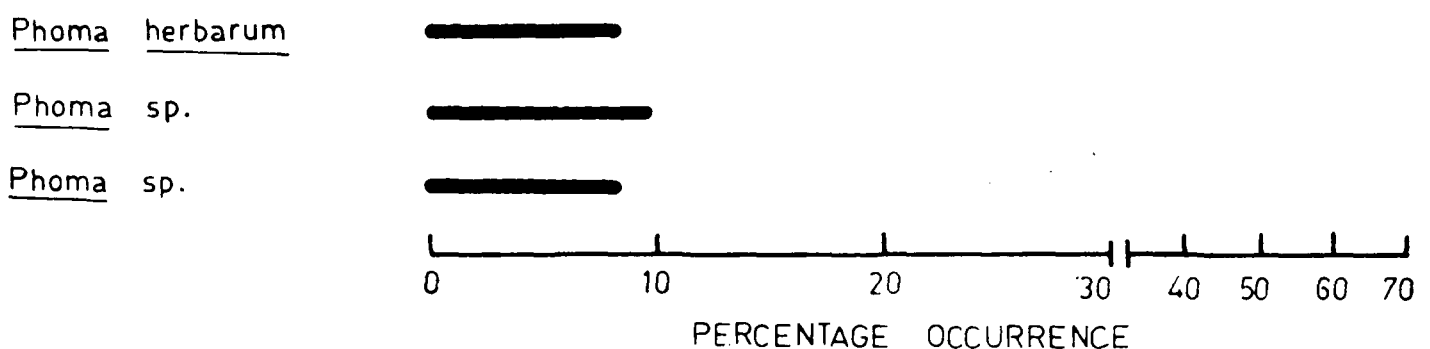
ZYGOMYCETES



ASCOMYCETES



FUNGI IMPERFECTI (Sphaeropsidales)



MONILIALES (yeasts)

Fig. 3.5 contd.

Aureobasidium pullulans



Candida spp.



Cryptococcus spp.



Rhodotorula sp.



Sporobolomyces spp.



Trichosporon sp.



MONILIALES (filamentous)

Acremonium sp.



Aegerita candida



Alternaria alternata



Aspergillus candidus



A. clavatus



A. flavus



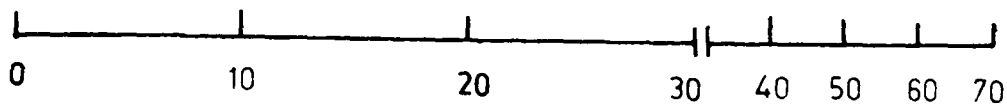
A. fumigatus



A. nidulans



A. niger



PERCENTAGE OCCURRENCE

Fig. 3.5 contd.

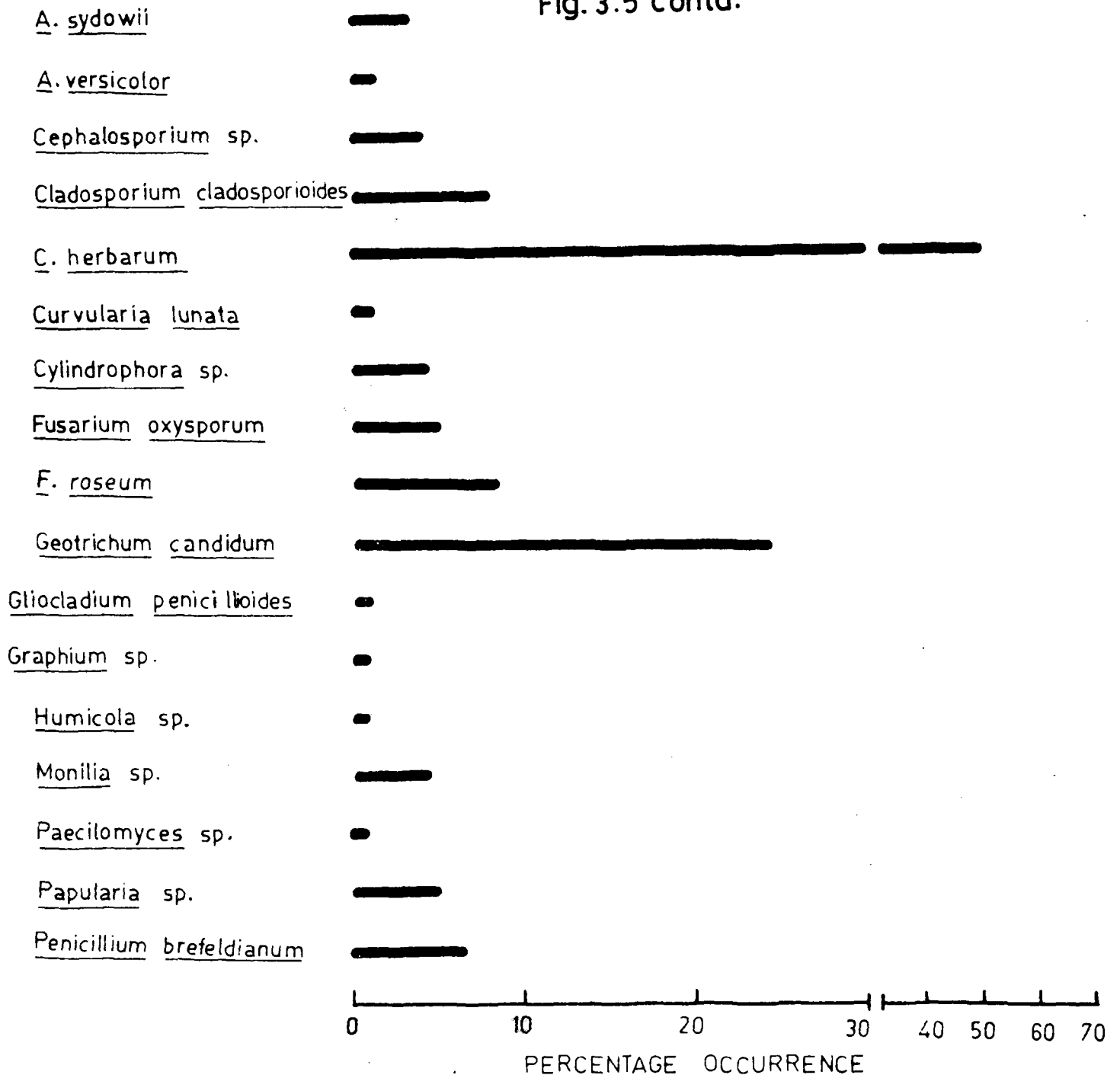


Fig. 3.5 contd.

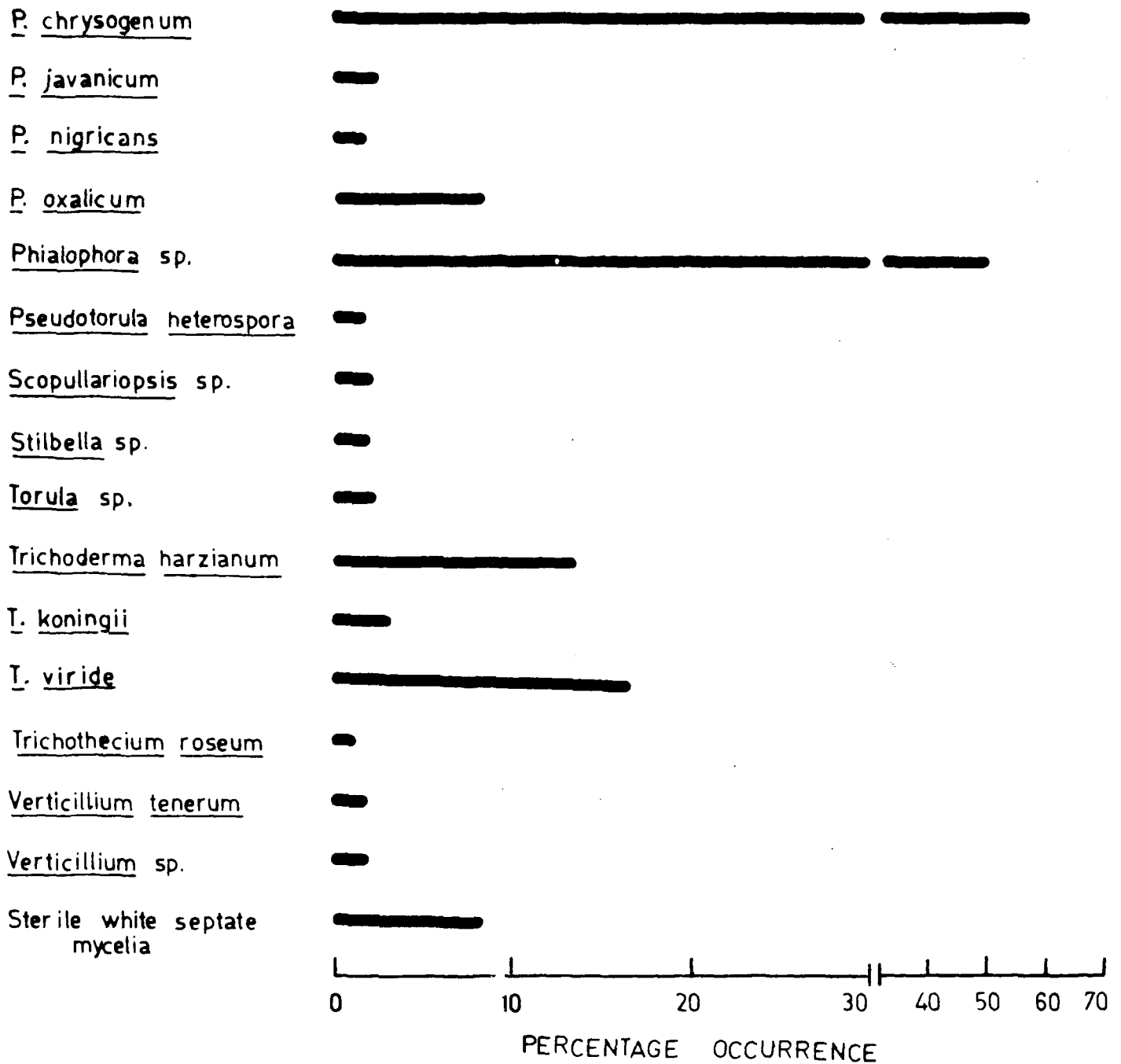


Fig.3.6. Seasonal variation in relative density (%) of certain dominant fungi in the lake water at station 1 (spring 1977 to winter 1979).

Fig. 3.6

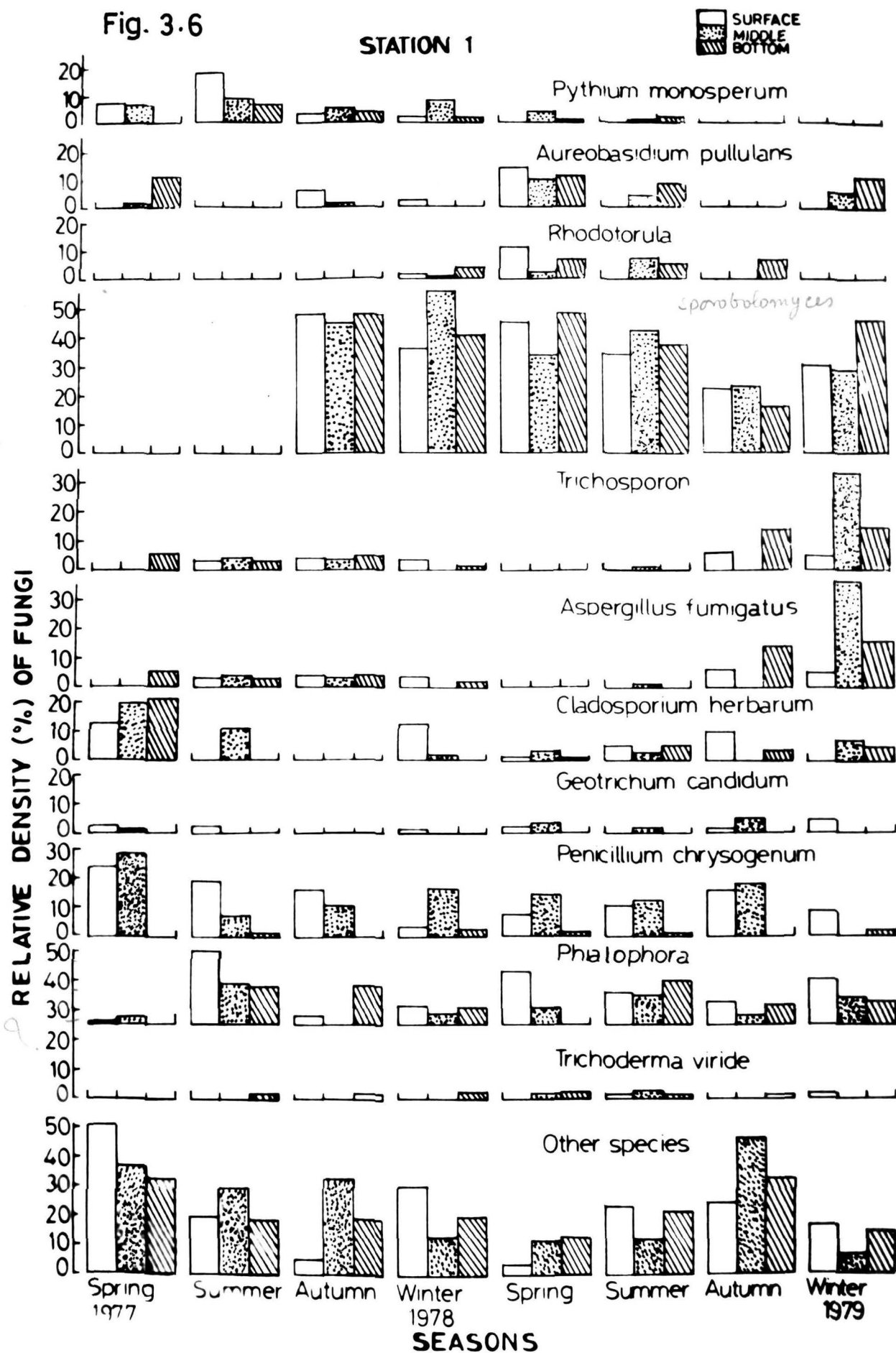
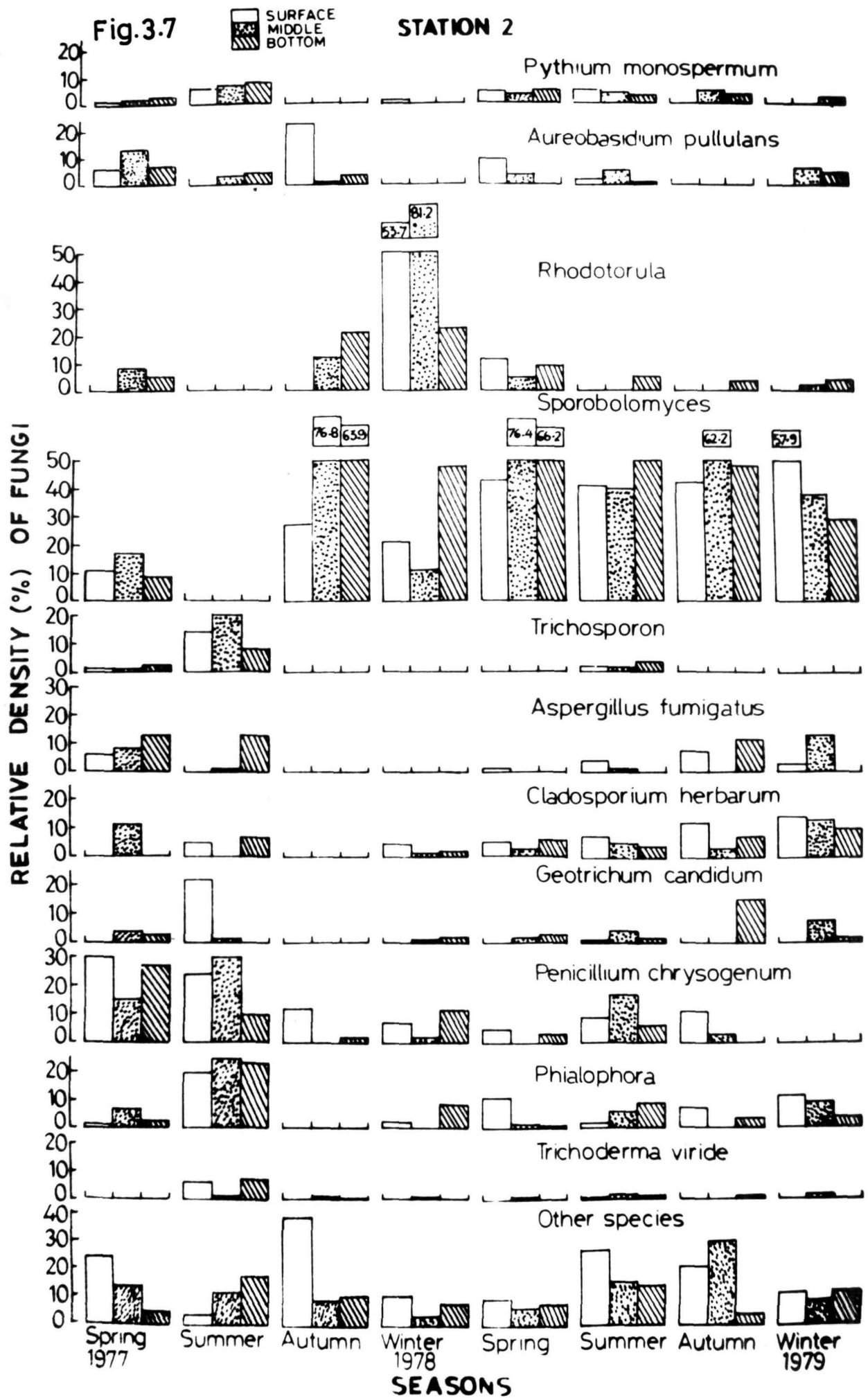


Fig.3.7. Seasonal variation in relative density (%) of certain dominant fungi in the lake water at station 2. (spring 1977 to winter 1979).



**Fig.3.8. Seasonal variation in relative
density (%) of certain dominant fungi
in the lake water at station 3
(spring 1977 to winter 1979).**

Fig. 3.8

STATION 3

SURFACE
 MIDDLE
 BOTTOM

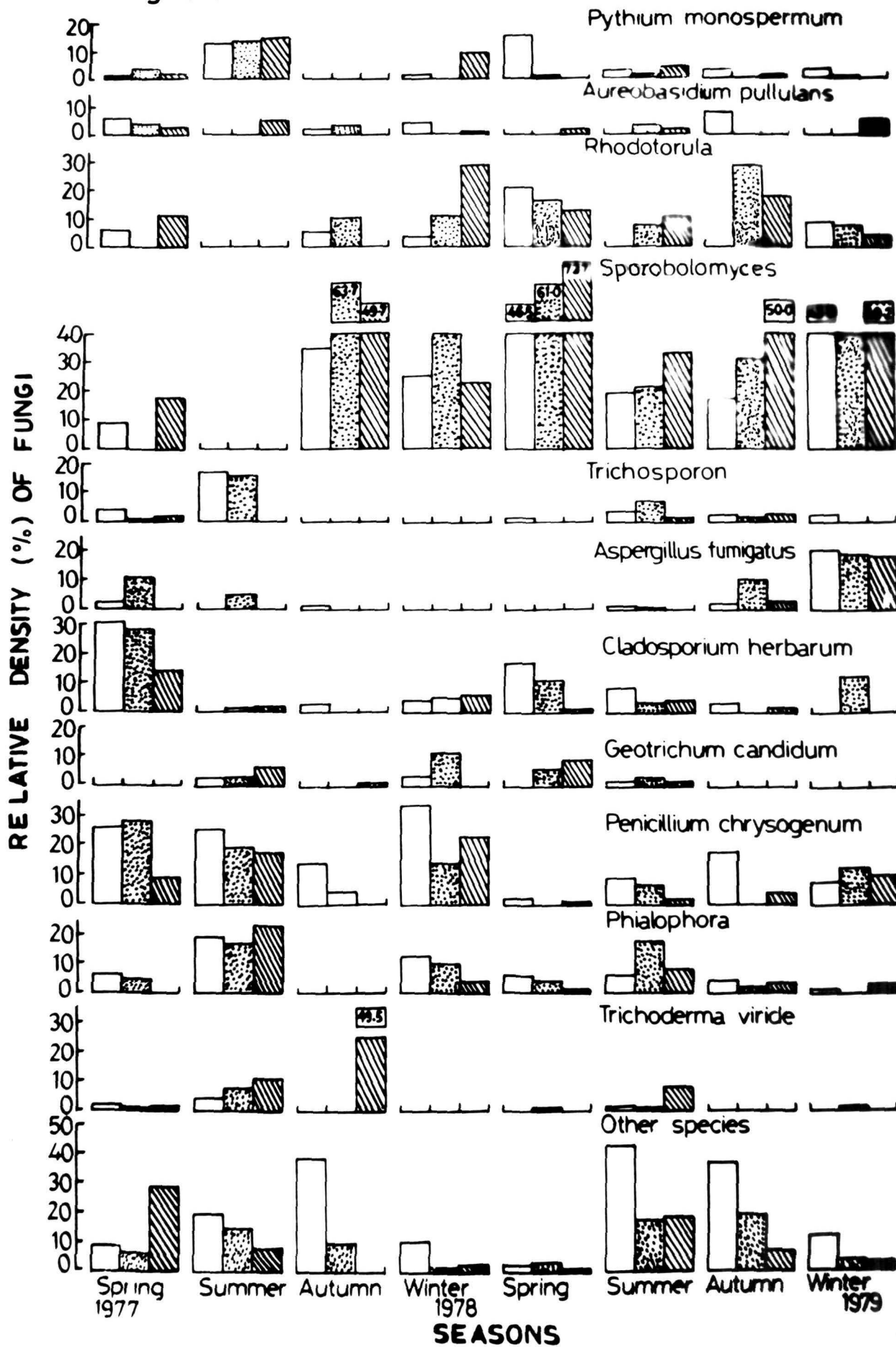
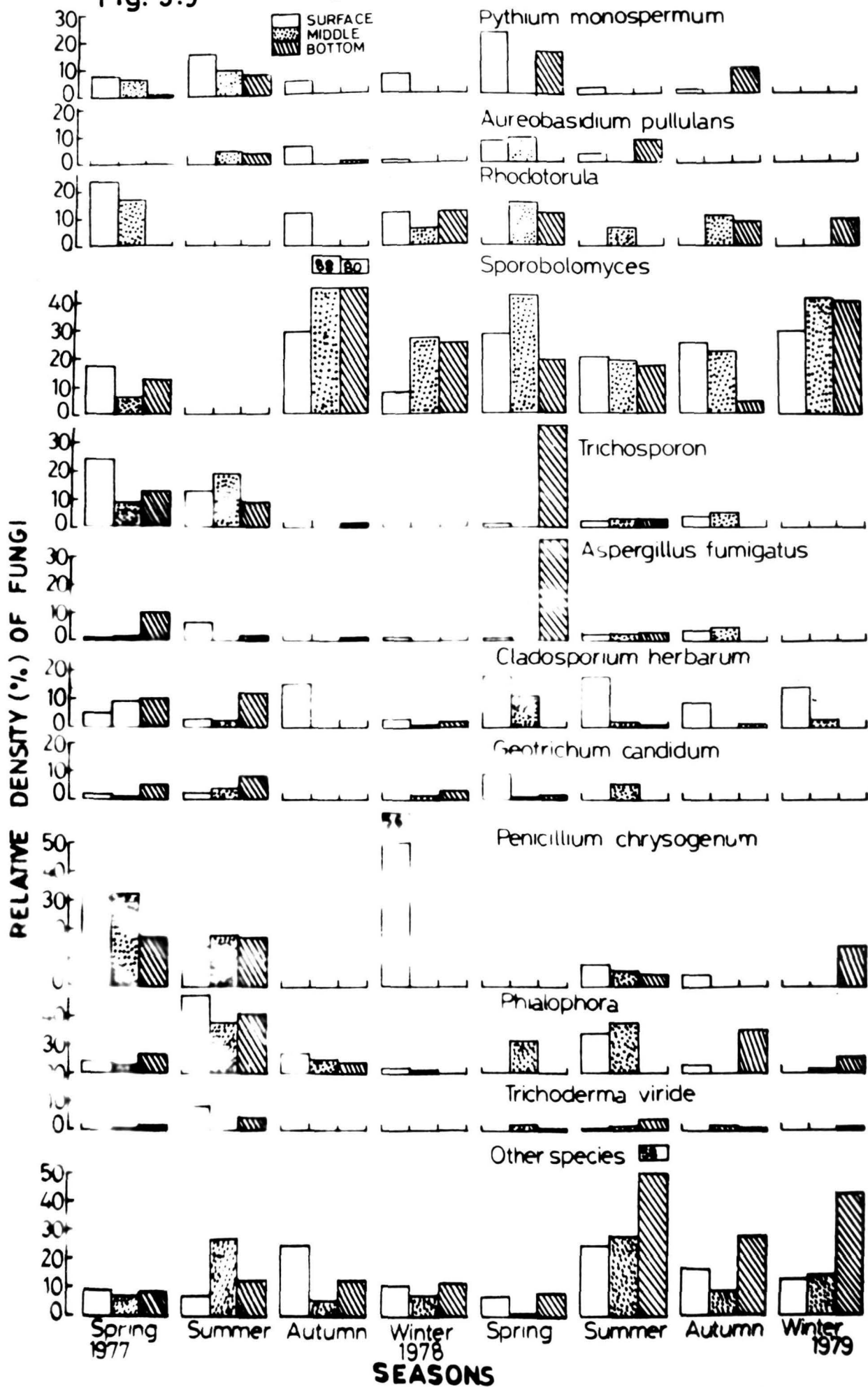


Fig.3.9. Seasonal variation in relative density (%) of certain dominant fungi in the lake water at station 4 (spring 1977 to winter 1979).

Fig. 3.9

STATION 4



Rhodotorula sp., Sporobolomyces sp., Trichosporon sp., Aspergillus fumigatus, Cladosporium herbarum, Geotrichum candidum, Penicillium chrysogenum, Phialophora sp. and Trichoderma sp. were the most commonly isolated forms. The percentage occurrence of various fungi throughout the study is given in Fig. 3.5. In general, the isolates belong to the forms which produce large number of spores. Fig. 3.6 - 3.9 depict the relative density of dominant forms. It is evident that the unicellular yeasts and/or the filamentous fungi producing small unicellular spores such as Cladosporium herbarum mostly dominate the fungal flora.

A general look at the representation of various groups of fungi reveals that majority of the fungi belong to the class Deuteromycetes. Other classes are represented by very few species. Quite significantly class Ascomycetes is represented by only one genus. The monthly variation in species composition of fungi isolated by plate culture method did not show any marked variation. To some extent, however, it appears that a few species of yeasts were more in number during winter months. Most of the filamentous forms were isolated throughout the year, however, the site of occurrence varied. The percentage occurrence different fungal species and number of species isolated at various samplings are given in appendix tables 1 and 2. The differences in the number of propagules of different species did not show any pattern of seasonality. However, the number of fungal propagules per ml of water ranged from 0 to 100.

Fig.3.10. Monthly occurrence of various
zoosporic Phycomycetes (baiting
method) in the lake water at
station 1 (March 1977 to February
1979).

Fig. 3.10

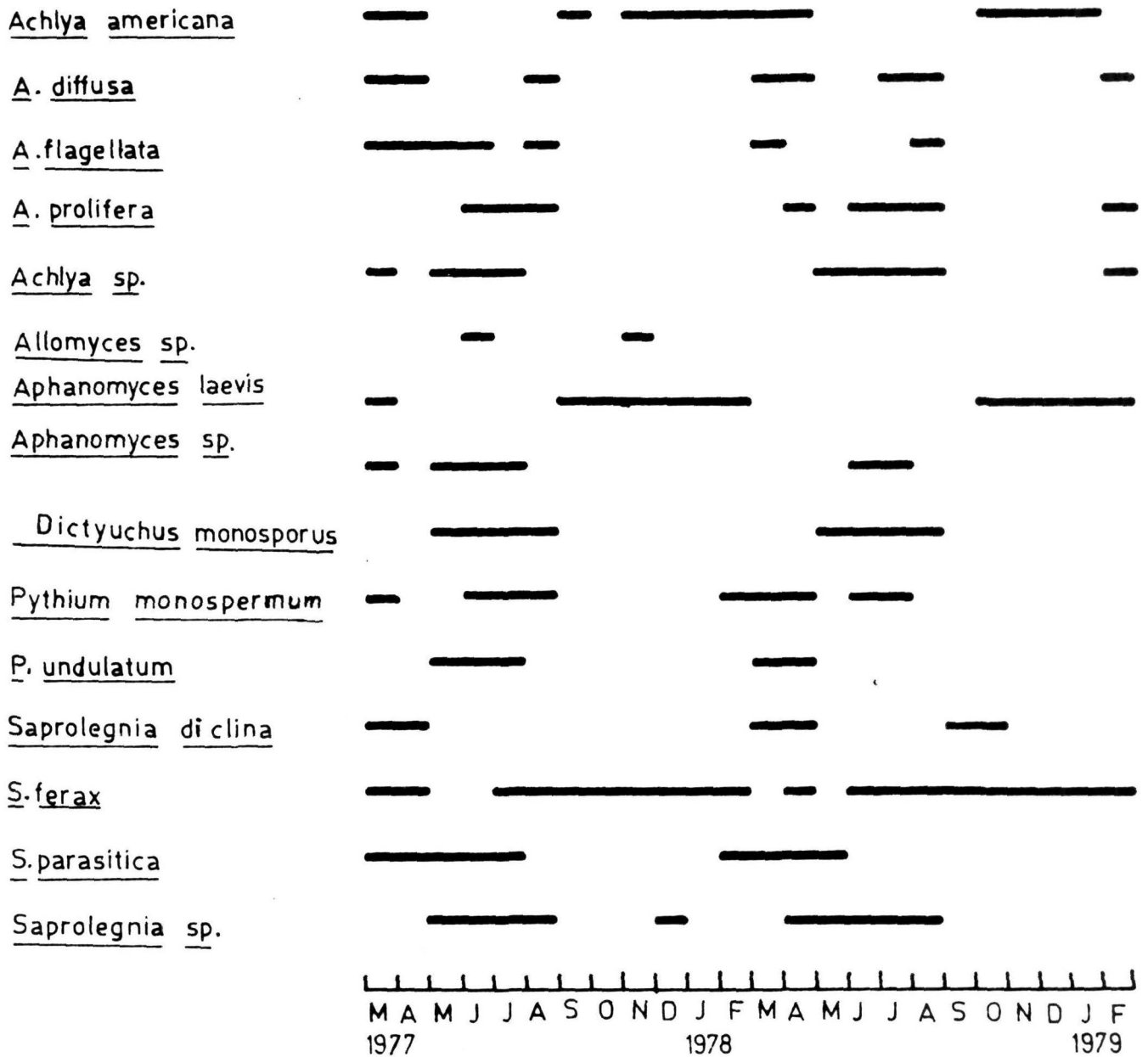


Fig. 3.11. Monthly occurrence of various
zoosporeic Phycomycetes (baiting
method) in the lake water at
station 2 (March 1977 to February
1979).

Fig. 3.11

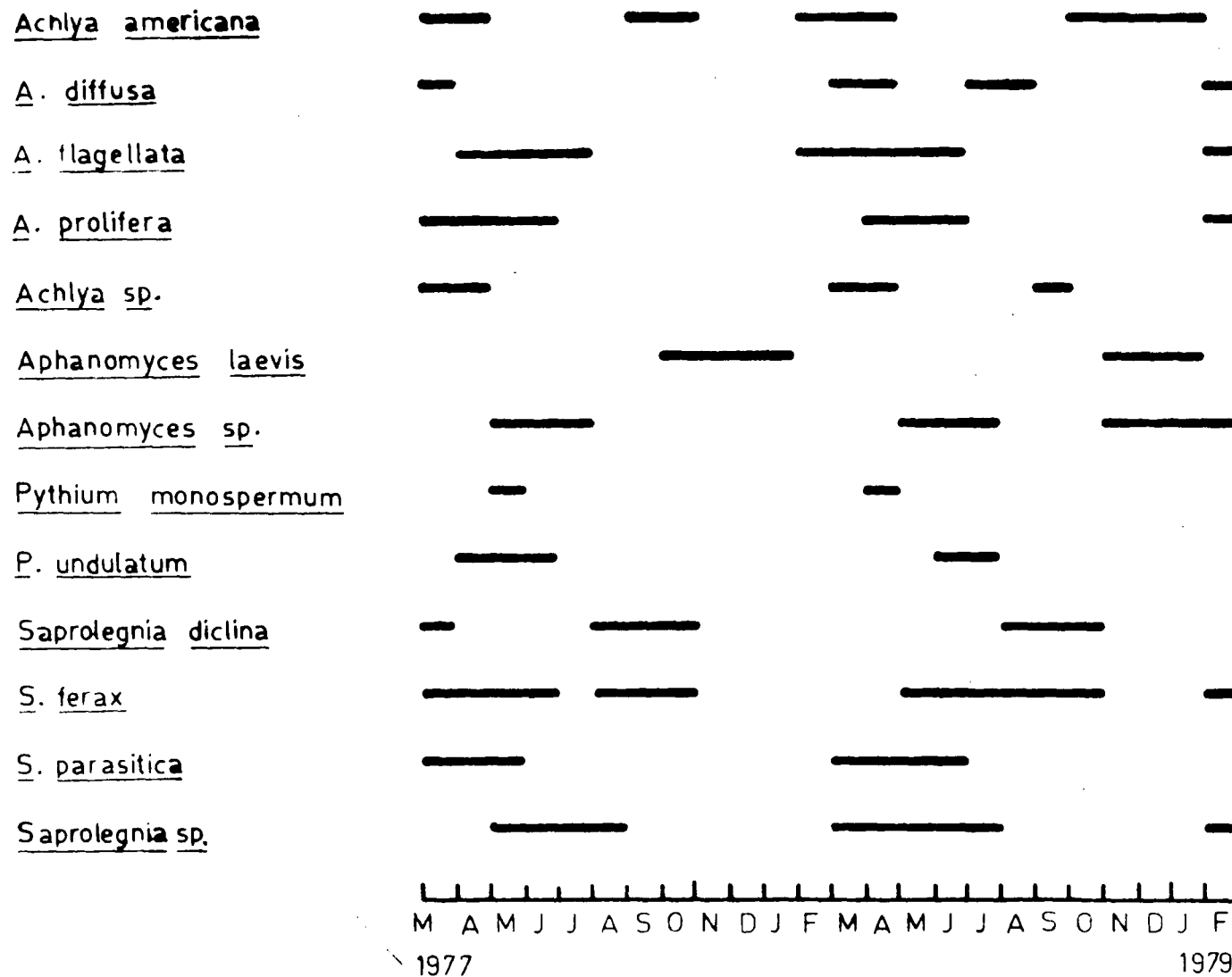
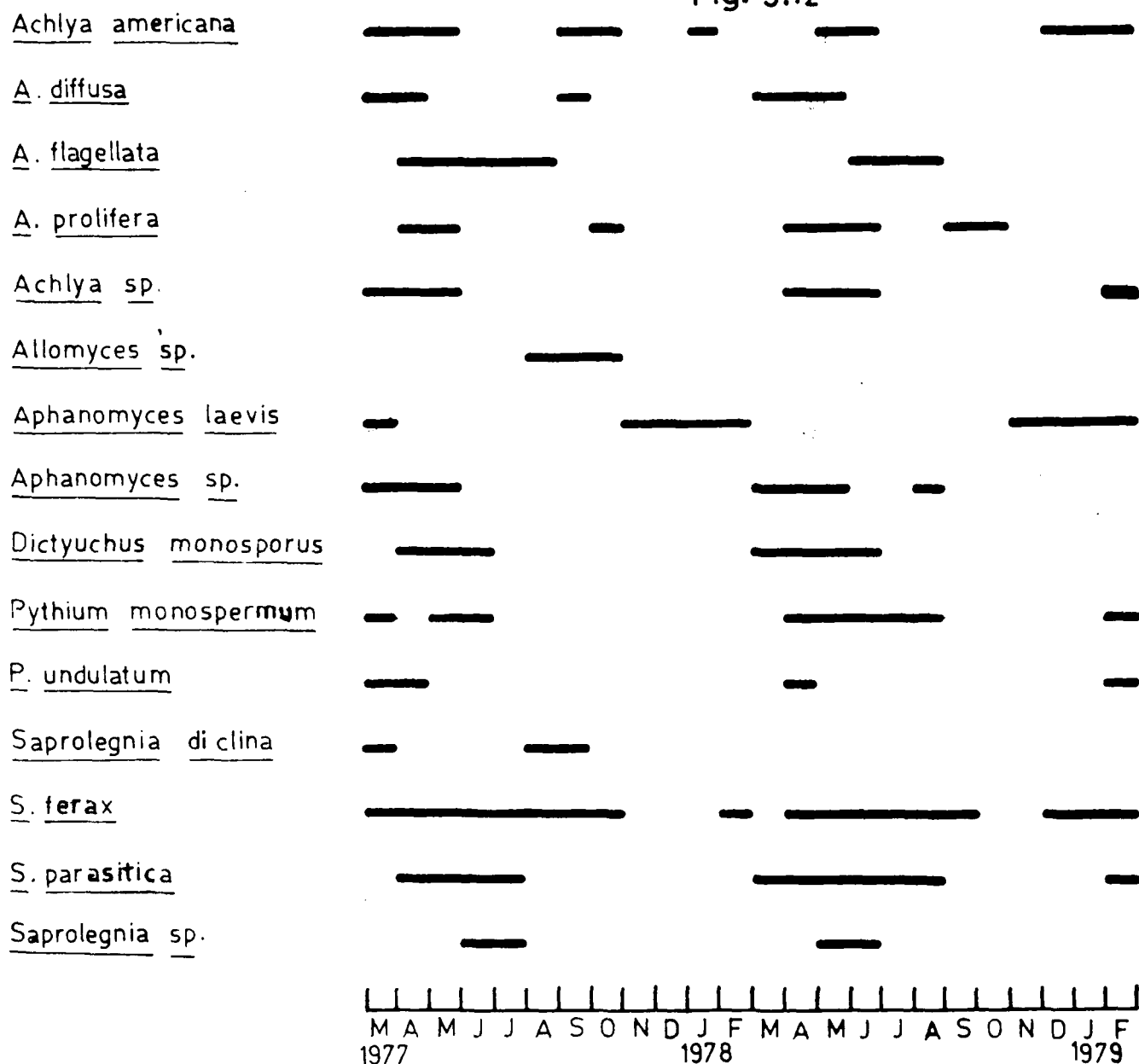


Fig.3.12. Monthly occurrence of various
zoosporic Phycomycetes (baiting
method) in the lake water at
station 3 (March 1977 to February
1979).

Fig. 3.12



**Fig.3.13. Monthly occurrence of various zoosporic
Phycomycetes (baiting method) in the
lake water at the surface of station 4
(March 1977 to February 1979).**

Fig. 3.13

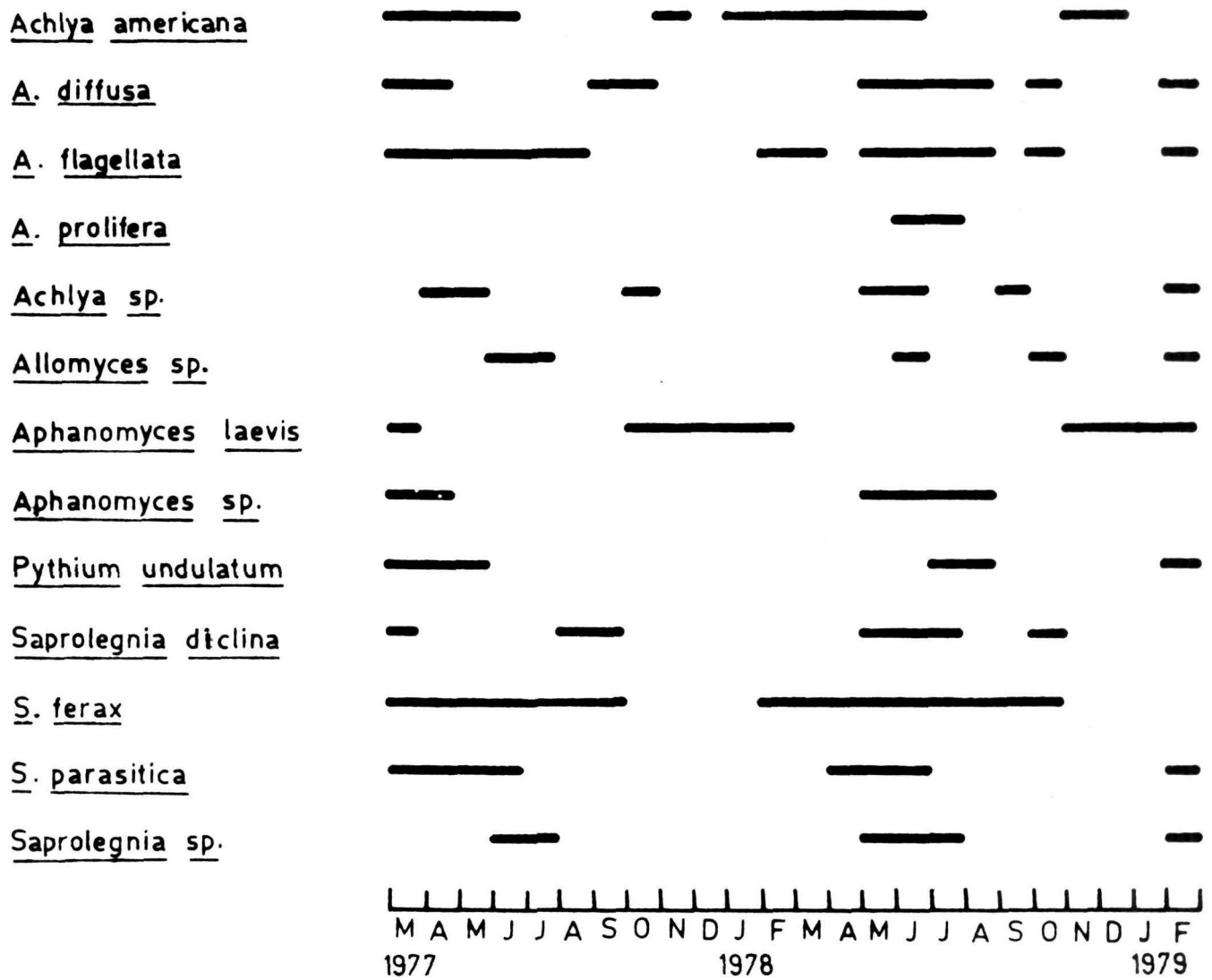


Fig. 3.14. Monthly occurrence of various zoosporic Phycomycetes (baiting method) in the lake water at the mid-depth of station 4 (March 1977 to February 1979).

Fig. 3.15. Monthly occurrence of various zoosporic Phycomycetes (baiting method) in the lake water at the bottom of station 4 (March 1977 to February 1979).

Fig. 3.14

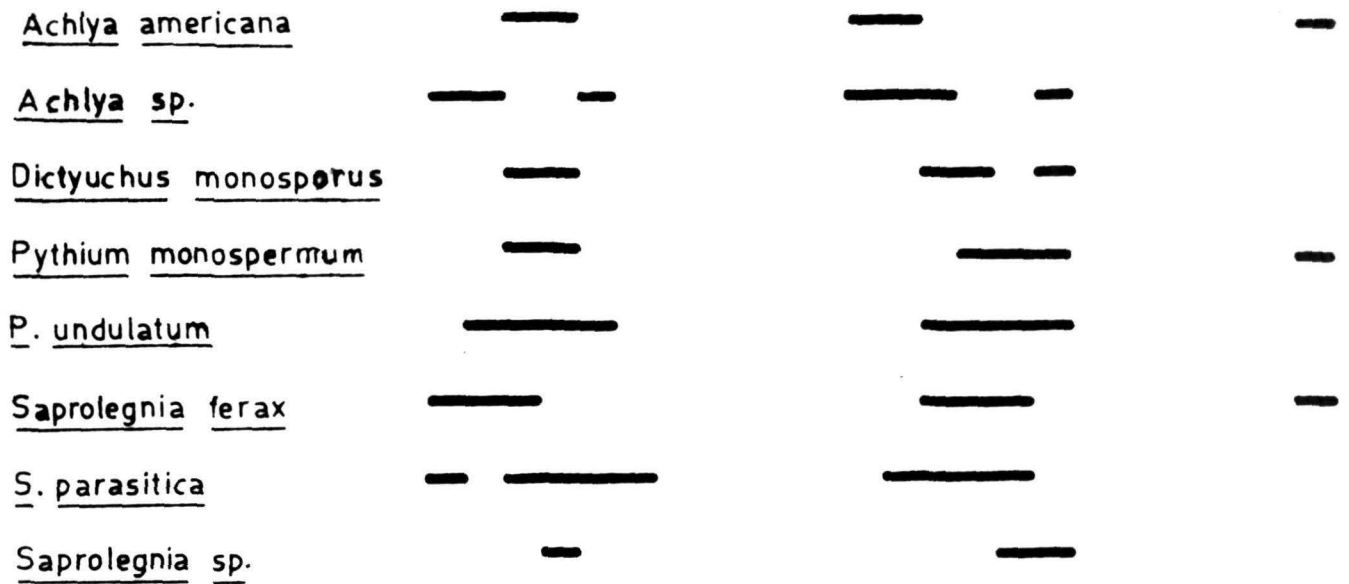
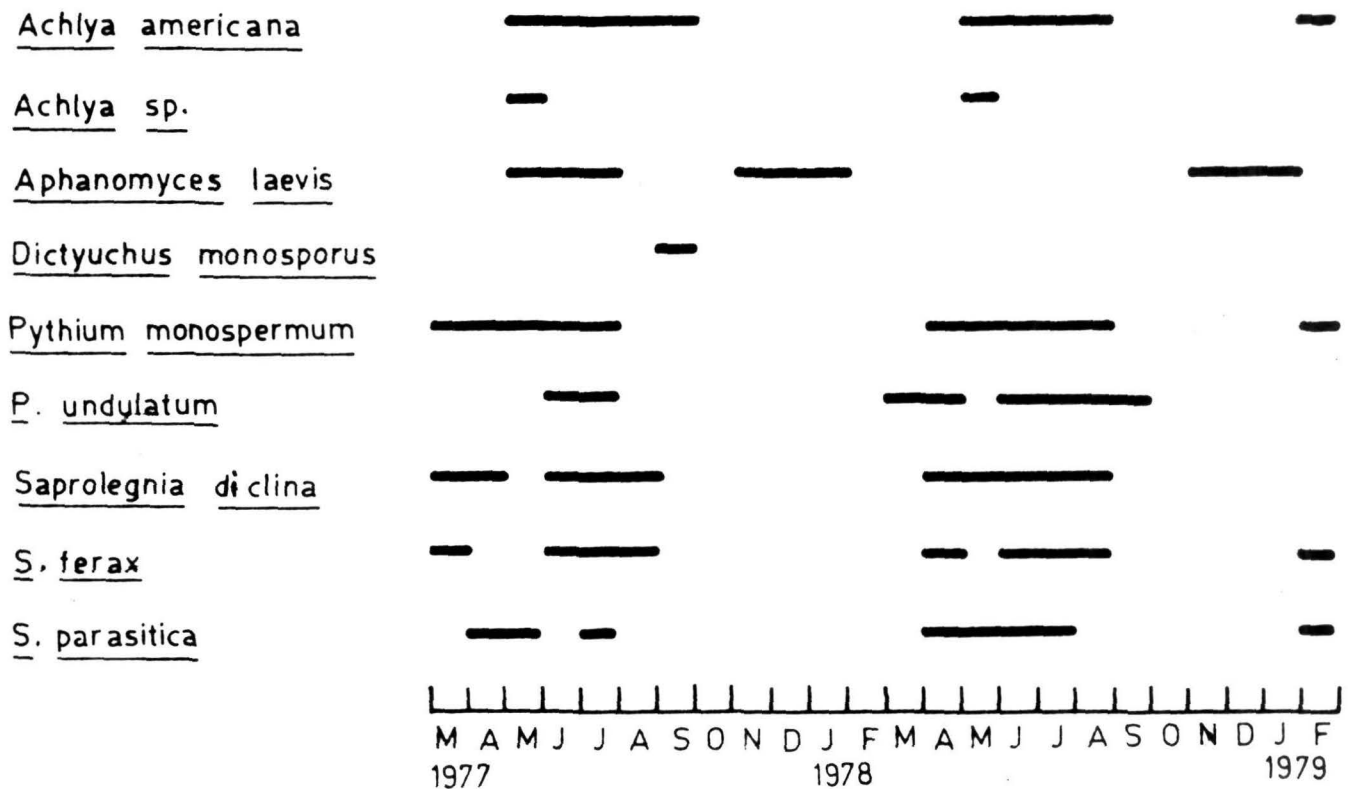


Fig. 3.15



**Fig.3.16. Monthly occurrence of various zoosporic
Phycomycetes (baiting method) in the
lake water considering all stations
together (March 1977 to February 1979).**

Fig. 3.16

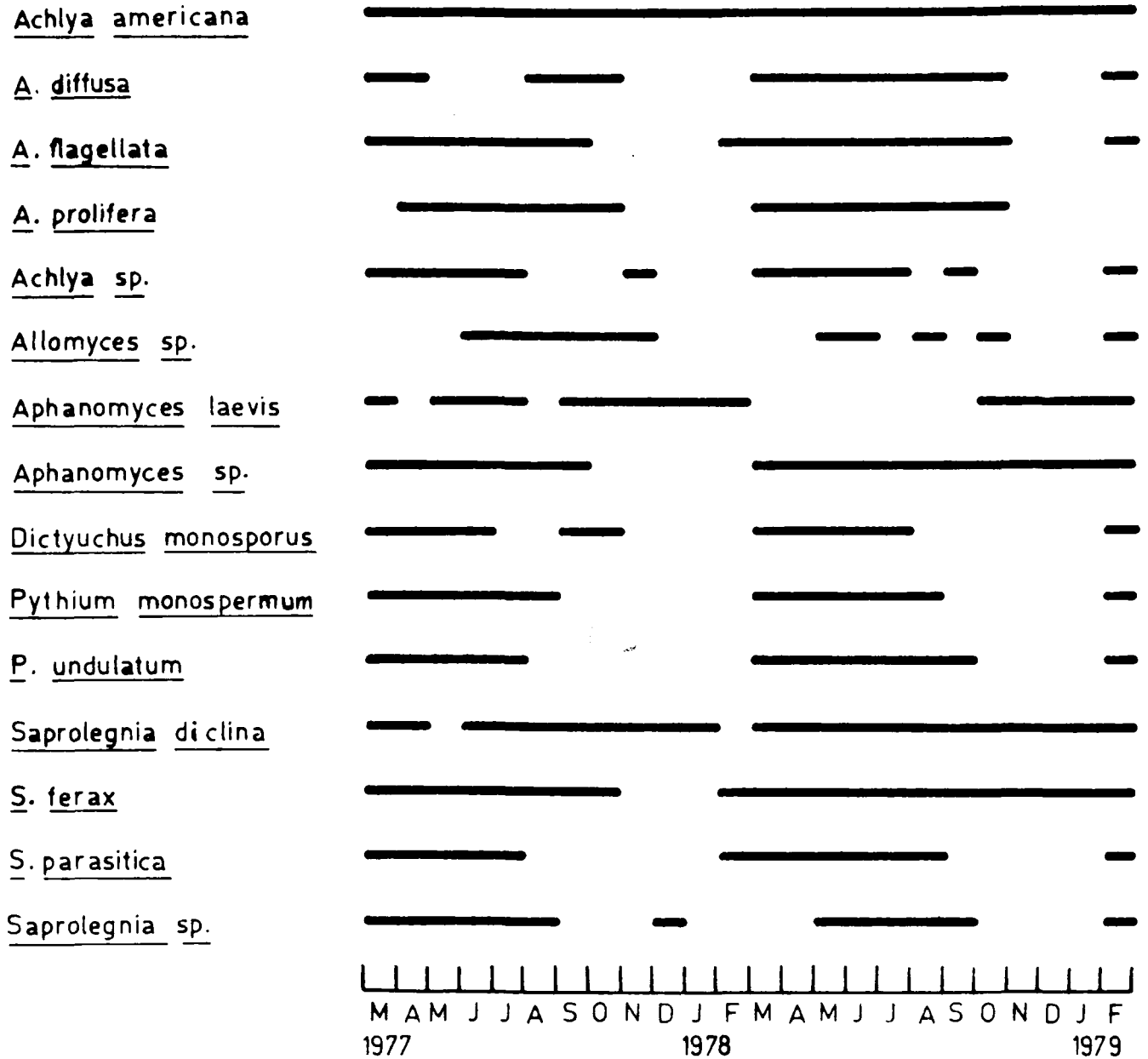
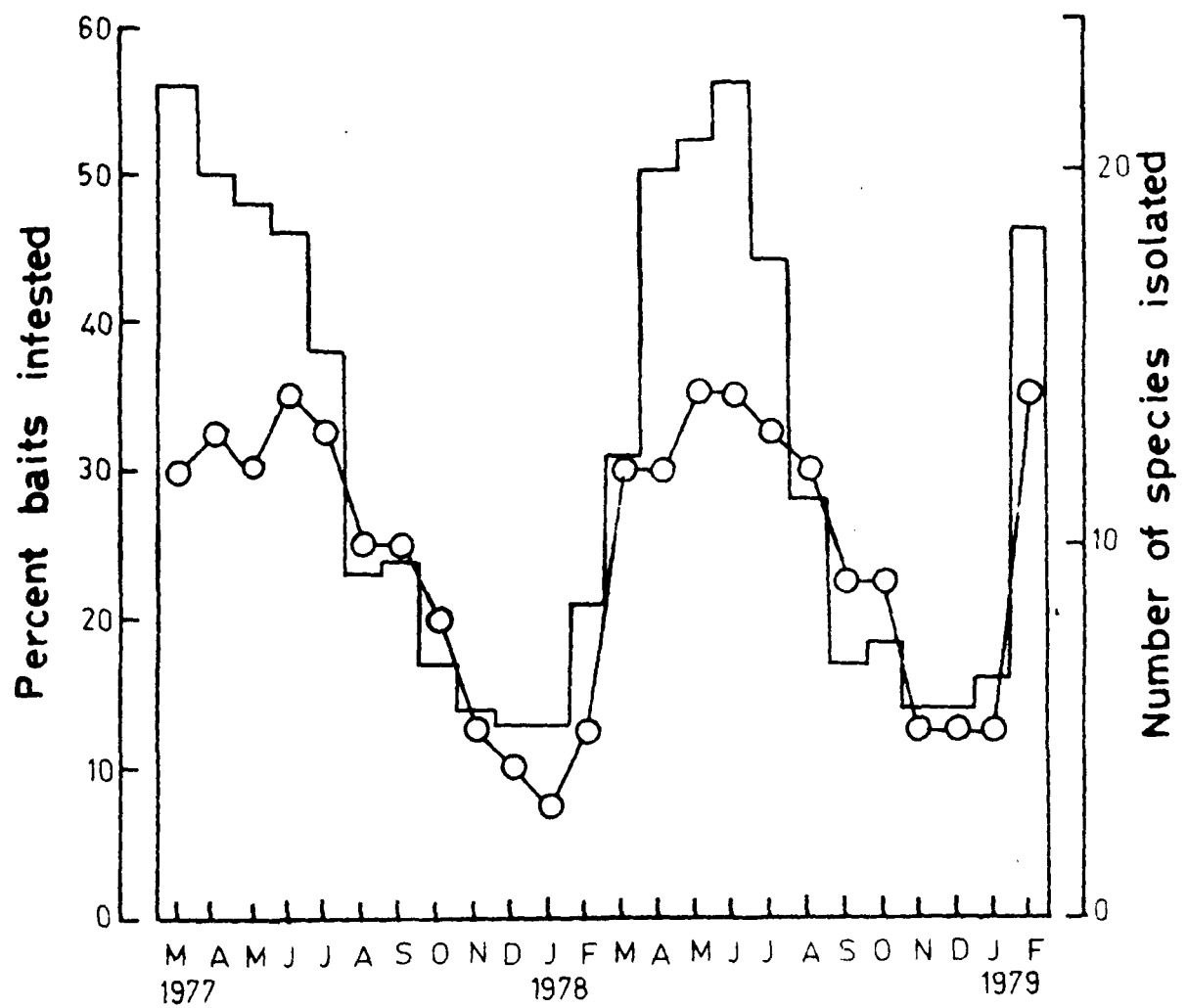


Fig.3.17. Monthly variation in number of species of zoosporic Phycomycetes (baiting method) and percentage baits infested in the lake water considering all the stations together (March 1977 to February 1979).

Fig. 3.17



Zoosporic Phycomycetes (Baiting method)

The number of species isolated during spring and summer was much higher as compared to winter months (Fig. 3.10-3.15). Seventeen species were isolated throughout the study period. The maximum in any month was 13 while the minimum was 2. The surface waters were comparatively rich in species composition and as the depth increased the population decreased (Fig. 3.13-3.15). Fig. 3.16 summarizes the data considering all the stations together which clearly depicts the seasonality of various fungi isolated from the lakewater. The number of baits infested was also maximum during spring and summer months indicating the possibility of more fungal propagules being present in the water samples during the period.

The depth-wise distribution of the fungi at stations 1, 2 and 3 was not significantly different and, therefore, the values were pooled together. No marked variation was observed when the various stations were compared with each other except that the station 1 was quite often rich in number of species. An over-all picture of the seasonality of the fungi in the lake would emerge only when the data collected at all the stations and depths were combined together to give the general pattern of seasonality of each fungi during the course of study (Fig. 3.17).

The fungal species showed a definite seasonal periodicity. According to their preference for the seasons

they could be grouped into 3 major categories (Table 3.1).

Table 3.1. Seasonal occurrence of zoosporic Phycomycetes in the lake.

Spring and summer species	Winter species	All Season species
<u>Achlya diffusa</u>	<u>Aphanomyces laevis</u>	<u>Achlya americana</u>
<u>A.prolifera</u>		<u>Aphanomyces sp.</u>
<u>Achlya sp.</u>		<u>Saprolegnia diclina</u>
<u>Dictyuchus monosporus</u>		<u>S.ferax</u>
<u>Pythium monospermum</u>		<u>Saprolegnia sp.</u>
<u>P.undulatum</u>		
<u>Saprolegnia parasitica</u>		

Achlya diffusa, A.prolifera, Achlya sp., Allomyces sp., Dictyuchus monosporus, Pythium monospermum, P.undulatum and Saprolegnia parasitica were isolated during warm periods of the year (Spring-Summer). Aphanomyces laevis was consistently isolated during winters. However, on one occasion (from the bottom of station 4) it was isolated during summer also. A.americana, Aphanomyces sp., S.declina S.ferax and Saprolegnia sp. were isolated in all the seasons. S.ferax and A.americana were the most dominant fungi and they did not show any seasonal preference. S.parasitica was always isolated during spring and early summer. S.parasitica was also observed to infest the fish eggs and occasionally the adult fishes were also attacked.

DISCUSSION

Viable Fungal Propagules

The results on seasonality and occurrence of fungi collected by the plate count method suggest that fungi constitute an important component of the planktonic community and the lake harbours a sizeable population of fungi throughout the year. As evident from the studies of Kaushik and Hyne (1968, 1971), Jones (1974), and Suberkropp and Klug (1976) fungi are the dominant decomposers of extraneous plant litters in the aquatic systems. Thus, it appears, that a good inoculum of fungi is always available in the lake waters to colonize the incoming extraneous substrates. Studies on decomposition (Chapter 5) clearly demonstrate that these fungi colonize the extraneous plant litters and take active part in their decomposition. Most of the forms isolated are dominant saprophytes usually found in both terrestrial as well as aquatic habitats (Cooke, 1976). In general, the fungal flora isolated by this method is dominated by the terrestrial forms (Das, 1980).

The dominance of fungal flora by the yeasts and yeast like forms suggests that probably they can remain free floating in the lake waters and their sedimentation rate is slower as compared to the forms producing large sized spores. Secondly such forms are probably better adapted to reproduce and multiply in the aquatic habitats and, therefore, they may be

regarded as the resident populations of the habitats.

It may be speculated that among planktonic fungi the unicellular forms are more important and the mycelial forms probably grow only when they get suitable organic substrates. The occurrence of most of the species throughout the year may be because of the longevity of the fungal propagules (spores and conidia) which once produced may remain suspended in viable state for longer periods (Sussman, 1968). This is *in* contrast to the Saprolegniaceous zoospores whose active phase of life is often limited to less than 24 hours (Clausz, 1974).

Most of the fungi isolated during the course of present study have been found in other aquatic habitats too (Cooke, 1963, 1970, 1976; Quereshi and Dutka, 1976). Fungi isolated by plate culture technique are generally regarded as aliens and depending on their activity and role in the ecosystem processes they have been variously classified (Dick, 1971, 1976). Whether the terrestrial fungi have any worth while role in aquatic environments has often been a point of controversy. Cooke (1962, 1963, 1976) has emphasized that such fungi do play an important role in aquatic environments and they remain active and perform similar functions there as in the terrestrial habitats. Park (1972, 1974a), however, differs from Cooke and the former believes that these fungi are passively accumulated on the substrates exposed to the natural waters and play little role

in the microbiology of extraneous plant litter decomposition (Chapter 5) suggests that these fungi have some role to play in aquatic environments. The degree to which they are responsible for the degradation of plant litter in aquatic habitats can be ascertained only after a thorough investigations based on the advanced ecological methodology.

Further, it would be important to note that most of the fungal colonies on plate cultures come from the spores and conidia (Warcup, 1955; Harley, 1971) and plate cultures technique, therefore, tells little about the real activity of the organisms. However, this technique is quite useful for the studies on the fungal flora and population estimates.

Zoosporic Phycomycetes

Unlike plate count method the fungi isolated by baiting technique exhibited a definite seasonality. The seasonality pattern is similar to the studies in temperate regions (Coker, 1923; Hughes, 1962; Roberts, 1963). The spring maxima and winter minima as found in the present investigation is typical to the temperate waters. In tropical regions Dayal and Tandon (1962) and Srivastava (1967) noted maximum activity of aquatic Phycomycetes during winter when the temperature was almost similar to the spring of this region. Liu and Volz (1977), Sparrow (1968) and Hughes (1962) pointed out that temperature is the most

important single factor which regulates the activity of water molds. The positive relationship with temperature noted during the present study also depicts that the seasonality of these fungi is probably governed by the temperature. It appears that during cold months most of the species remain dormant and they become active when the temperature increases. However, Dayal and Tandon (1962) reported the dormancy period during summer months. Sussman (1968) has emphasized the role of temperature in the breaking of dormancy of the fungal propagules. Temperature sensitivity and spring maxima have also been reported by Clausz (1974) who points out: "Whether the periodicity of a species is controlled directly by climate acting on the fungus or indirectly by regulating abundance of food is a problem requiring more study".

The maximum activity of aquatic Phycomycetes also coincides with the maximum bacterial population (Chapter 2) and maximum biological activity estimates (Chapter 4). Also the organic carbon values as well as other nutrient concentrations peaked during these months (Chapter 1). It appears that the activity of these forms is also regulated by the same set of physico-chemical and biological factors which govern the bacterial populations and microbial activity.

The depth-wise distribution of fungi reveals that surface waters are comparatively rich in the fungal flora

and deeper water harbour less number of fungal propagules (Fig. 3.13-3.15). As evident from the methodology, most of the isolations by baiting method come from zoosporic propagules. Thus, the fungal populations estimated by this method is often a reflection of the activity of zoospores. It may therefore, be inferred that the zoospore population is more in the surface waters. It may not, however, be said with certainty whether the zoospores are produced in surface waters. Less number of species in deeper waters may be attributed to the anoxic conditions and higher concentrations of dissolved substances in deeper waters (Chapter 1) which may be detrimental for the growth and activity of these fungi (Liu and Volz 1977; Harvey, 1942).

The seasonal periodicity of various fungi observed in the present study is similar to the works of other investigators (Alabi, 1971). It appears that Aphanomyces laevis probably grows better at low temperatures. The "all season species" may have a wide ecological amplitude and can survive and/or grow in a wide range of seasonal conditions. The spring and summer species may require higher temperatures for their growth. Possibility of extraneous fungal propagules coming during the spring and summer months (which also coincides with the high rain fall) through runoff and stream inlet may also contribute to greater fungal population during the period.

A comparison of the two methods used for study of the fungal populations in the lake water reveals that while plate count gives quantitative information it tells little about the activity of fungi. However, it gives information on occurrence and distribution of viable fungal propagules in the natural waters. The baiting method is quite suitable for the study of zoosporic Phycomycetes. It reveals their activity as well as responses to the temporal and depth-wise variations. It appears that planktonic fungi isolated by plate culture method remain suspended in lakewaters for quite some time and they become active only when they get suitable substratum. The actual origin of the terrestrial fungi in lakewaters has not been fully worked out (Clausz, 1974) but their population variation shows that probably they enter the lake through run-off, rain water, streams and air and they become active aliens in these environments (Dick, 1976).

The Ascomycetes were isolated from the lake in very low number which may be attributed to the unsuitability of the methodology adopted for their isolation and culture. Many Ascomycetes do not grow on the routine plate culture media and we do not have suitable baits to trap them like aquatic Phycomycetes. Thus, it appears that the methods employed in the present study are not suitable for this group of fungi. Similar may be the case with the Basidiomycetes, which are very rarely found in aquatic habitats (Ingold, 1976). The

groups of fungi presently considered to be rare in aquatic habitats may be isolated in relatively larger numbers if the methodology for their isolation and quantification is perfected.

CHAPTER 4

BIOLOGICAL ACTIVITY IN THE LAKEWATER

INTRODUCTION

Population estimates have been most widely used as a measure of activity of microorganisms. However, many times they do not necessarily reflect the actual activity of the group of microbes (Strickland, 1971). Populations of bacteria have been measured by direct microscopic counts and by plate count. While the former does not reflect whether these cells are active or dead the latter always underestimates the population, and the counts reflect certain ecophysiological groups which can grow on the medium used for the culture. General awareness of this problem has increased and during the last two decades attempts have been made to measure the biological activity in various environments using enzymatic methods (Hoffmann and Hoffmann, 1966; Lenhard, 1967; Reichardt, 1971; Jones, 1972 a,b) and utilization of substrates (Azam and Holm Hansen, 1973; Godlewska-Lipowa, 1974a,b, 1976a; Vaccaro and Jannasch, 1966; Wright and Hobbie, 1965; 1966). These methods have been most widely used to understand the involvement of microbial communities in the functioning of various ecosystems. Studies on heterotrophic activity measurements of bacterial microflora (Wright and Hobbie, 1965; Vaccaro and Jannasch, 1966) have shown that bacteria assimilate organic substrates in relation to their concentration. Godlewska-Lipowa (1974a) measured coefficient of heterotrophic activity by estimating the quantity of oxygen utilized by bacteria. He reported

that the coefficient of heterotrophic activity is a direct measure of degree of eutrophy and process of destruction of organic matter in the aquatic ecosystems.

Phosphatases are responsible for phosphate regeneration in aquatic environments. In such environments phosphatases, first demonstrated by Steiner (1938), are produced by bacteria (Jones, 1972 a,b) algae (Brandes and Eston, 1956) and zooplankters (Jansson, 1976). Phosphatases may be associated with seston and as free dissolved enzymes (Berman, 1970; Jones, 1972a; Overbeck and Babenzien, 1964; Reichardt et al 1967). The release of enzymes in soluble form has been often attributed to mineralization of planktonic organisms (Reichardt et al, 1967). Phosphatase activity has been proved to be good indicator of degree of eutrophication (Jones, 1972 a).

Several studies have proved that synthesis and secretion of phosphatases are regulated by the ortho-phosphate concentration in the water. Some algal species when grown in phosphorus limited conditions produce alkaline phosphatase, which are capable of releasing ortho-phosphates from phosphomonoesters (Fitzerald and Nelson, 1966). Heath and Cooke (1975) reported that low Ortho-phosphates concentrations in lake water were associated with higher alkaline phosphatase activity indicating an adaptation to release ortho-phosphate from phosphomonoesters. They further observed that appearance of alkaline phosphatase was related to the increase in the size of the

algal populations and emphasized that this recycling process might be an additional and significant source of ortho-phosphate levels and the enzyme synthesis is largely controlled by the end product repression. The repression of synthesis of phosphatases by ortho-phosphates has also been reported by Reichardt et al (1967). In most of the microbial systems phosphate starvation has been reported to cause increase in the synthesis of phosphatases namely bacteria (Dobozy et al, 1968); Friedberg and Avigad, 1967; Moses, 1970; Shah and Blobel, 1967; Torriani, 1960) fungi (Kadner and Nye, 1969; Schurr and Yagel, 1971) and algae (Knutsen, 1965; Kuenzler and Perrans, 1965; Liedtka and Ohmann, 1969 a,b). Patni et al (1977) reported that phosphate starvation led to an increased activity of phosphatase over a broad pH range from 4 to 10 with a maximum activity in the alkaline range at pH 9.20 in Chlamydomonas reinhardtii. It has been assumed that phosphatase may serve as the trigger for algal blooms in phosphorus deficient natural waters.

Reichardt (1971) while studying the influence of various environmental conditions on phosphatase activity in lake water noted that pH, substrate concentration, inorganic ortho-phosphate concentration, depth and seasons have pronounced effect on the phosphatase activity. Apart from above he observed diurnal variation in the phosphatase activity which followed the trend similar to that of

the saprophytic bacteria. The alkaline phosphatase activity in lake waters has been shown to be directly related to the degree of eutrophication and microbial biomass. (Reichardt et al., 1967; Jones, 1972a; Jansson, 1977) showed that phosphate was enzymatically released from particulate matter. He further observed that particulate matters are important source of phosphorus for planktons and the phosphatases directly degrade the organic phosphates from particulate matter to available form.

Healey (1973) has found that phosphatase activity may be conveniently used as an ideal indicator of nutrient deficiency.

Heath and Cooke (1975) observed direct correlation between alkaline phosphatase activity and potential productivity. They observed a rise in potential productivity with increase in phosphatase activity.

Verstraete et al. (1976) found that phosphatase may be useful to characterize the bioactivity in aquatic environments and they reported strong seasonal fluctuations in the enzyme activity. They observed maximum activity in spring and a secondary peak in the autumn. They further observed a strong relation between the microbial numbers and the enzymatic activities and reported that phosphatase activity is a linear function of the viable microorganisms.

It is an established fact that heterotrophic microbes play a fundamental role in the energy transfer through the food chain. The transformation of dissolved organic matter into the microbial biomass is one of the basic metabolic pathways in the lake ecosystem function. Thus in order to understand the functional aspects of lake ecosystem an estimate of microbial production is of fundamental importance. Microbial production in present context implies for the dark assimilation of carbon dioxide by heterotrophic microbial population. Microbial production in natural waters has gathered attention of a large number of aquatic microbiologists in the recent past. Studies of Romanenko (1964), Sorokin (1965), Overbeck (1974), Overbeck and Daley (1973), Kusnetsov and Romanenko (1966) have proved that the average value of CO_2 incorporation for the biosynthesis of bacterial cells was of the order of 6% of the bacterial biomass. Microbial production is always coupled with the microbial decomposition of organic compounds as the energy for the process comes from the breakdown of autochthonous or allochthonous organic materials. Thus the microbial production estimates give a relative picture of microbial activity of these environments.

The importance of bacterial production in natural waters has been well understood during last two decades. Various studies on subject have revealed that the biomass

production by heterotrophic bacteria may be of the same magnitude as the autotrophic primary production. Kusnetsov and ^{na}Ronenko (1966) reported a relation of 01.1 between primary production and bacterial production. Sorokin (1965) while emphasizing the importance of bacterial production pointed out: "Dark bacterial production is in principle secondary production because it derives its energy from organic matter built during photosynthesis. It is, however, in some respects more nearly primary than secondary production because it proceeds mostly by the utilization of organic matter which would otherwise be practically lost for the direct feeding of animals. This is particularly true in the case of some inland waters and certain oligotrophic ocean waters where bacterial biosynthesis through the oxidation of allochthonous materials is more important than photosynthesis".

Bacterial biomass and generation time are other two most important characters of aquatic ecosystems which directly quantify the dynamics of bacterial activity and growth in these systems. While bacterial biomass largely shows the net stock of heterotrophic biomass at any time the generation time of the bacteria in natural waters is an expression of close correlation between the environment and the microorganism (Donderski, 1977; Hagstrom et al., 1979).

Present chapter takes into consideration the biological activity of the lakewater measured by various methods

with particular reference to heterotrophic microbial populations in the lake ecosystem and relates them to the bacterial population and biomass and the related physico-chemical characters of the water taking into consideration both temporal and depth variations.

MATERIALS AND METHODS

General methods of sample collection and processing are described in Chapter 2. The estimation of alkaline phosphatase activity was done following the method described by Verstraete et al (1976). The only modification was that the reagents and distilled water were filter sterilized and aseptic precautions were observed. Soluble alkaline phosphatase was measured in the lake water filtered through 0.22 μ pore size millipore filter. Co-efficient of heterotrophic activity was determined following the method of Godlewska-Lipowa (1974a). Lake water was filtered through a 40 μ m pore size sieve to remove phyto and zooplanktons. After measuring the initial dissolved oxygen concentration the water was transferred to six BOD bottles. Bacteriological peptone (BDH) was added to three bottles to the concentration of 10 mg/L. All the bottles were incubated at $20 \pm 1^\circ\text{C}$ in a BOD incubator for 24 hours and dissolved oxygen concentration was measured. Coefficient of heterotrophic activity was calculated by dividing the oxygen consumption in lakewater with peptone by the oxygen consumption in the lakewater without peptone.

Estimation of microbial production was done following the method described by Romanenko and Sorokin (1972). The rate of oxygen consumption was measured in situ by oxygen bottles method in the water filtered through 40 μm pore size filters to remove phyto and zooplanktons. Approximate values of rate of microbial production was calculated from the rate of the oxygen consumption by use of the equation: $P=0.08 D$ mg C/L/day where P =rate of microbial production and D =rate of the oxygen consumption in mg O_2 /L/day. Bacterial biomass was calculated from the data on microscopic count using standard factors such as mean cell volume = $0.06 \mu\text{m}^3$ (Salonen, 1977; Watson, et al., 1977; Zimmerman, 1977; Hagstrom et al., 1979), bacterial cell density = $1.1\text{g}/\text{cm}^3$ (Lamanna et al., 1973) coefficient for weight in terms of carbon = 0.10 (Straskrbova and Sorokin, 1972). The estimation of generation time was done by assuming that the microbial production is the result of bacterial multiplication. Based on this the generation time was calculated by dividing the microbial production (mg C/ M^3 /day) values by the bacterial biomass (mg C/ M^3). Biological oxygen demand (BOD) was estimated by the method described in Standard Methods (APHA, 1971). The water samples were incubated at $20 \pm 1^\circ \text{C}$ in BOD incubator for 5 days and BOD values thus represent the value of oxygen consumption in 5 days at 20°C . Due to certain practical difficulties estimates of enzyme activity and

Fig. 4.1. Monthly variation in alkaline
phosphatase activity ($\mu\text{mole/l/hour}$)
in the lake water at station 4 from
March 1978 to February 1979. First
part of each histogram: surface waters,
second: mid-depth waters, third: bottom
waters. Partition at the base represents
the soluble component of the alkaline
phosphatase activity.

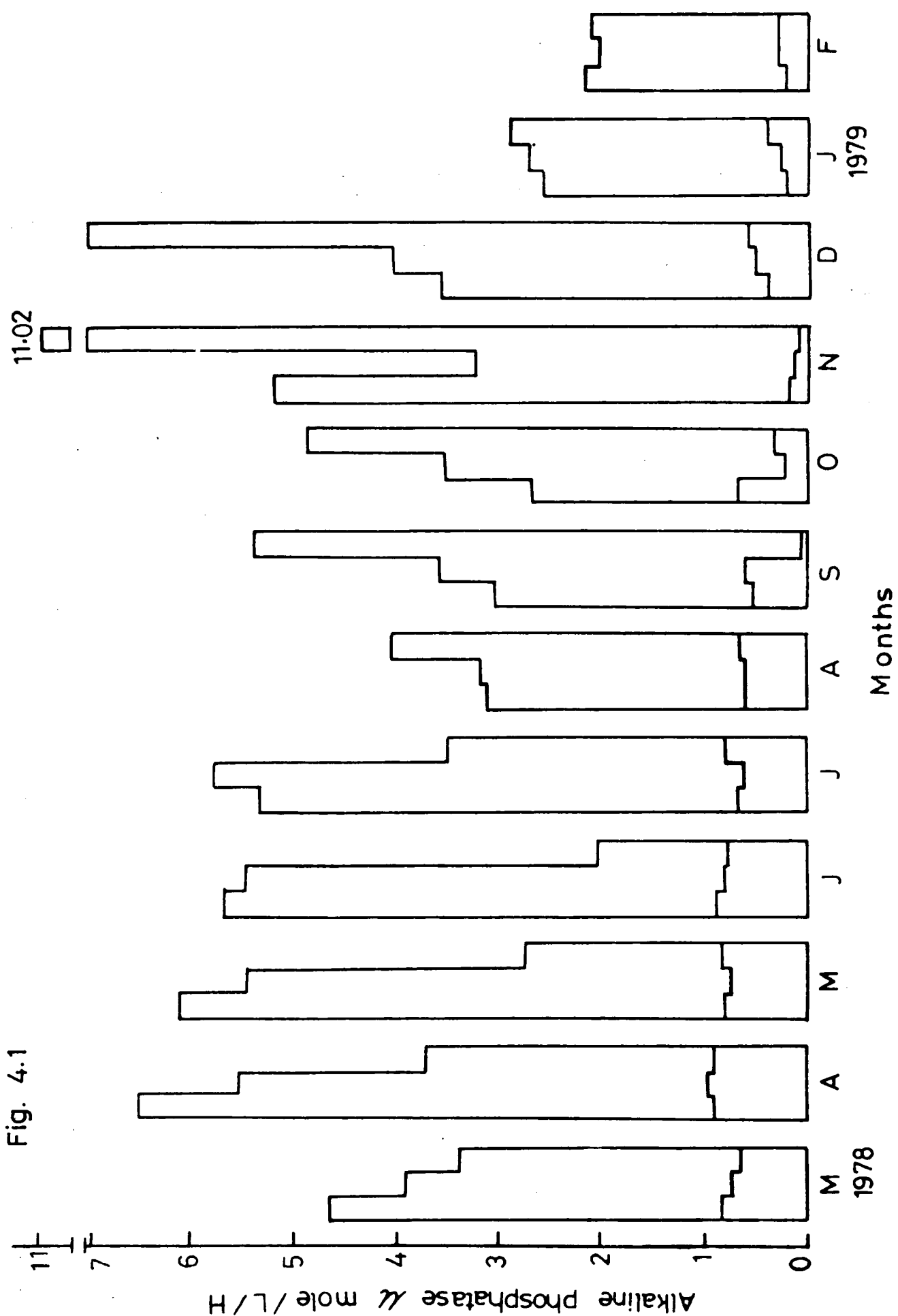


Fig. 4.1

coefficient of heterotrophic activity were done only at station 4.

RESULTS

Alkaline Phosphatase Activity

The alkaline phosphatase activity showed distinct seasonality. The trend of variation at the three depths, however, did not follow the same pattern. While surface water showed maximum activity during late spring months (March-June), bottom waters exhibited maximum in the early winter (November). Depth-wise, the activity decreased during March-June after which the maxima tend to shift to bottom waters and from the month of August to January maximum activity was recorded at the bottom. Minimum activity was recorded in the months of January and February. The soluble enzyme remained at fairly constant level throughout the most part of the year except during winter when the values were comparatively low (Fig.4.1).

Coefficient of Heterotrophic Activity

The coefficient of heterotrophic activity was highest during late spring and summer (April-June) and lowest during winter (November-January). During the remaining part of the year the coefficient of heterotrophic activity was consistently higher in the bottom waters as compared to surface and middle waters except in the months of August and September when it touched the lowest

Fig.4.2. Monthly variation in coefficient of heterotrophic activity in the lake water at station 4 from March 1978 to February 1979. First histogram: surface waters, second histogram: mid-depth waters, third histogram: bottom waters.

Fig. 4.2

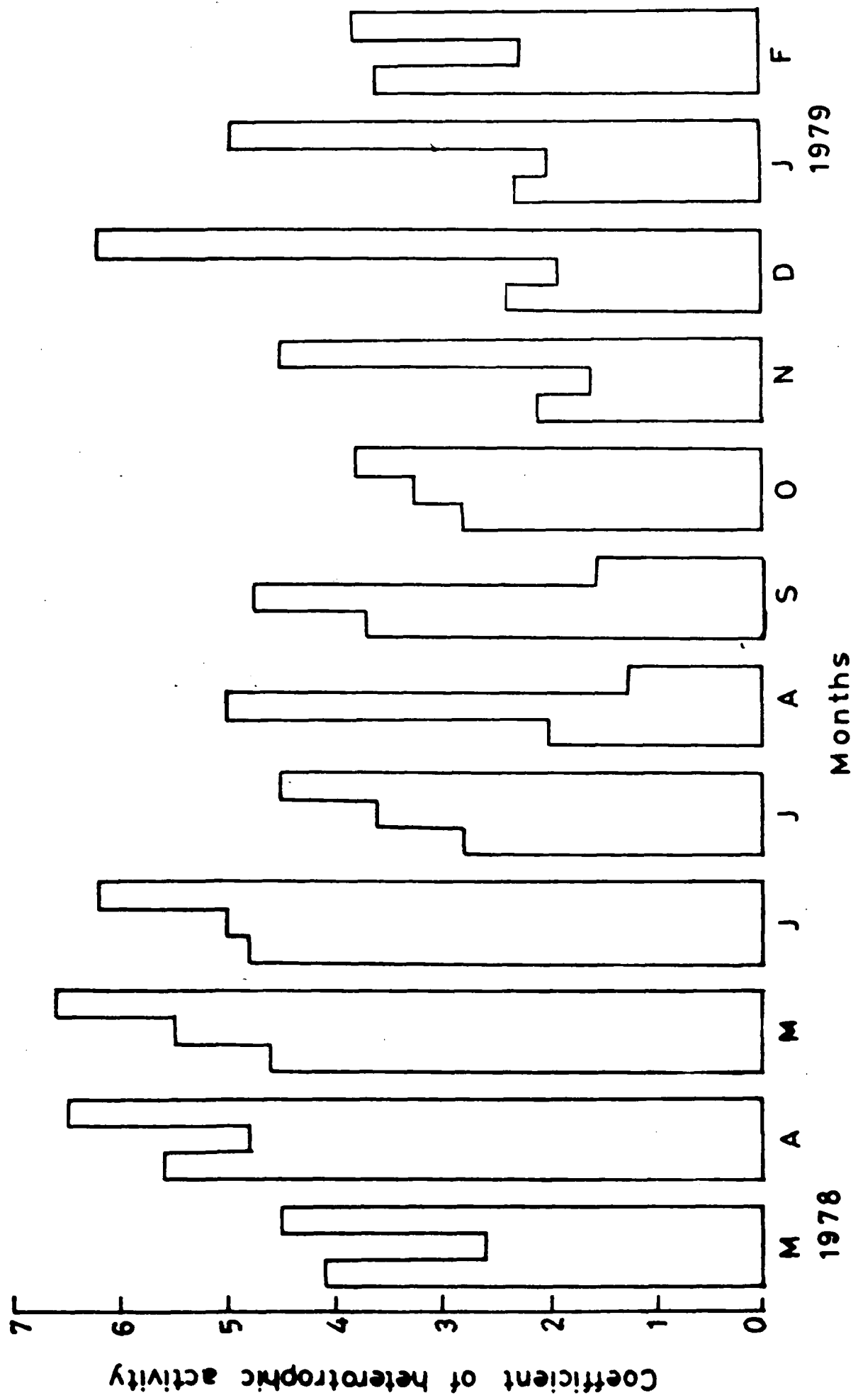


Fig. 4.3. Monthly variation in biological
oxygen demand ($\text{mg O}_2/\text{l}$) values
in the lake water at various stations
(March 1978 to February 1979). Values
for station 1, 2 and 3 are mean of
the three depths. For station 4,
circles: surface waters, triangles:
mid-depth waters and squares: bottom
waters.

Biological oxygen demand mg O₂/L

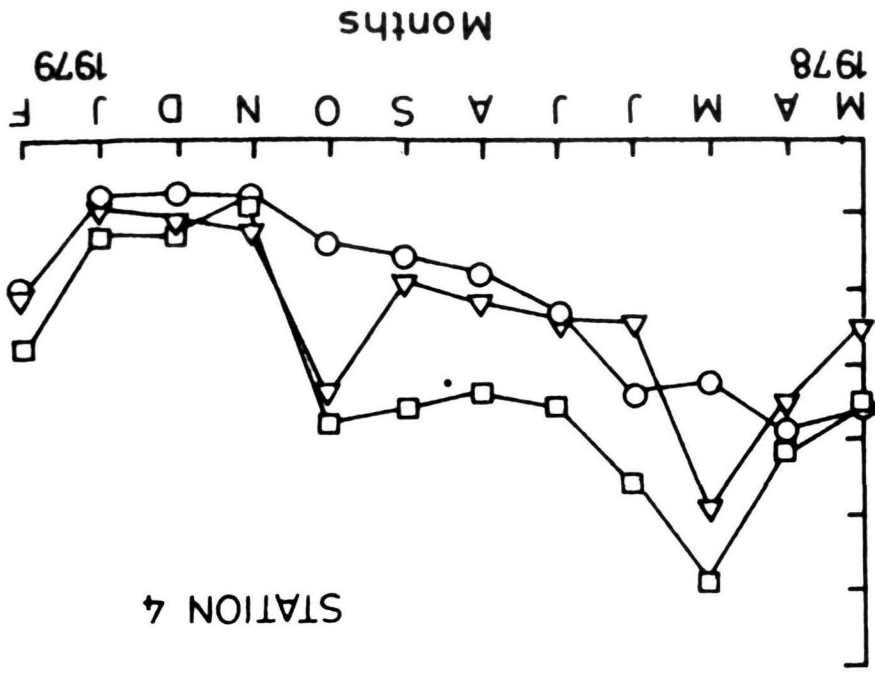
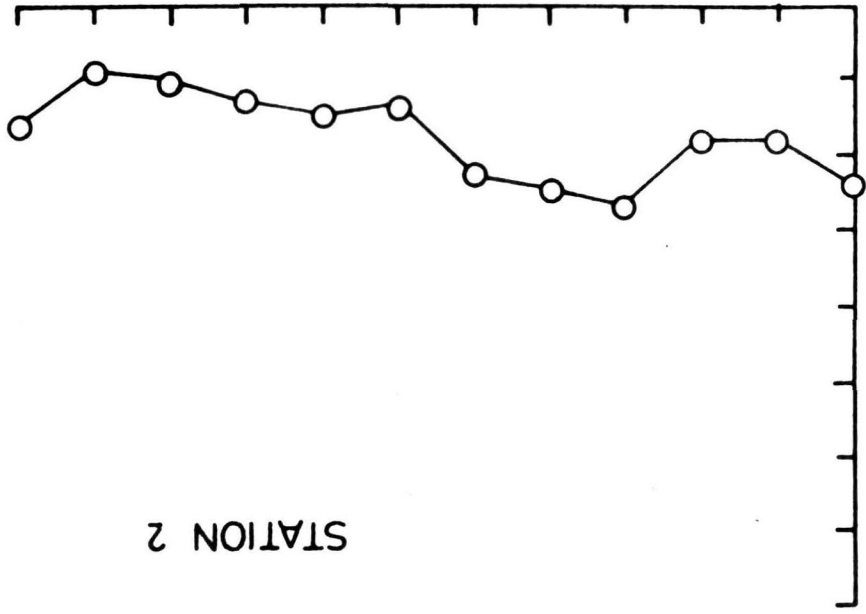
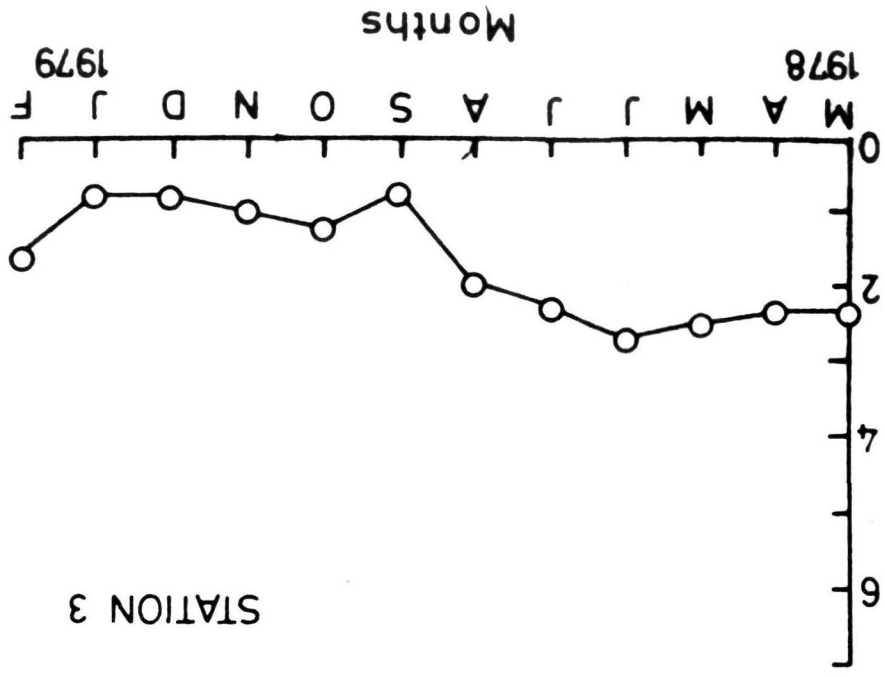
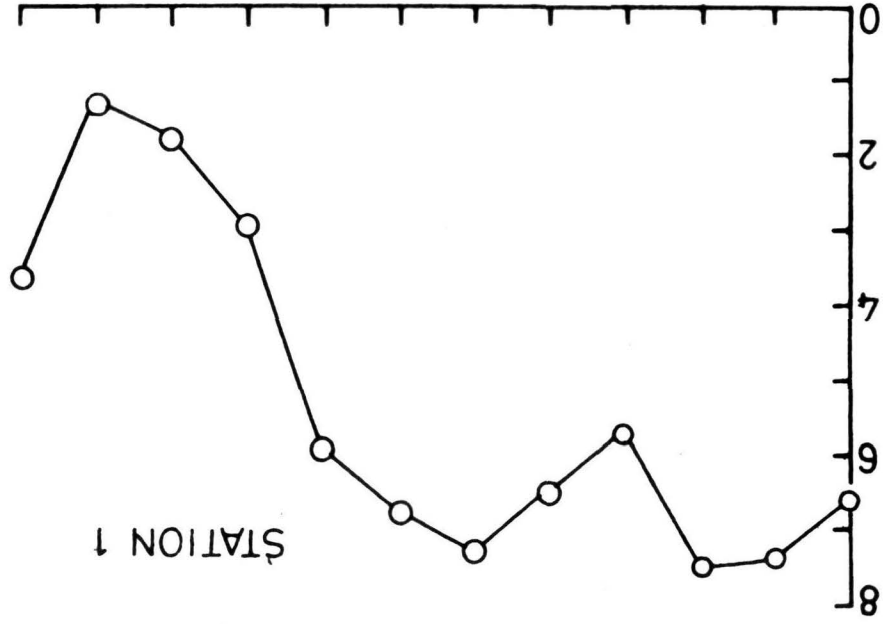
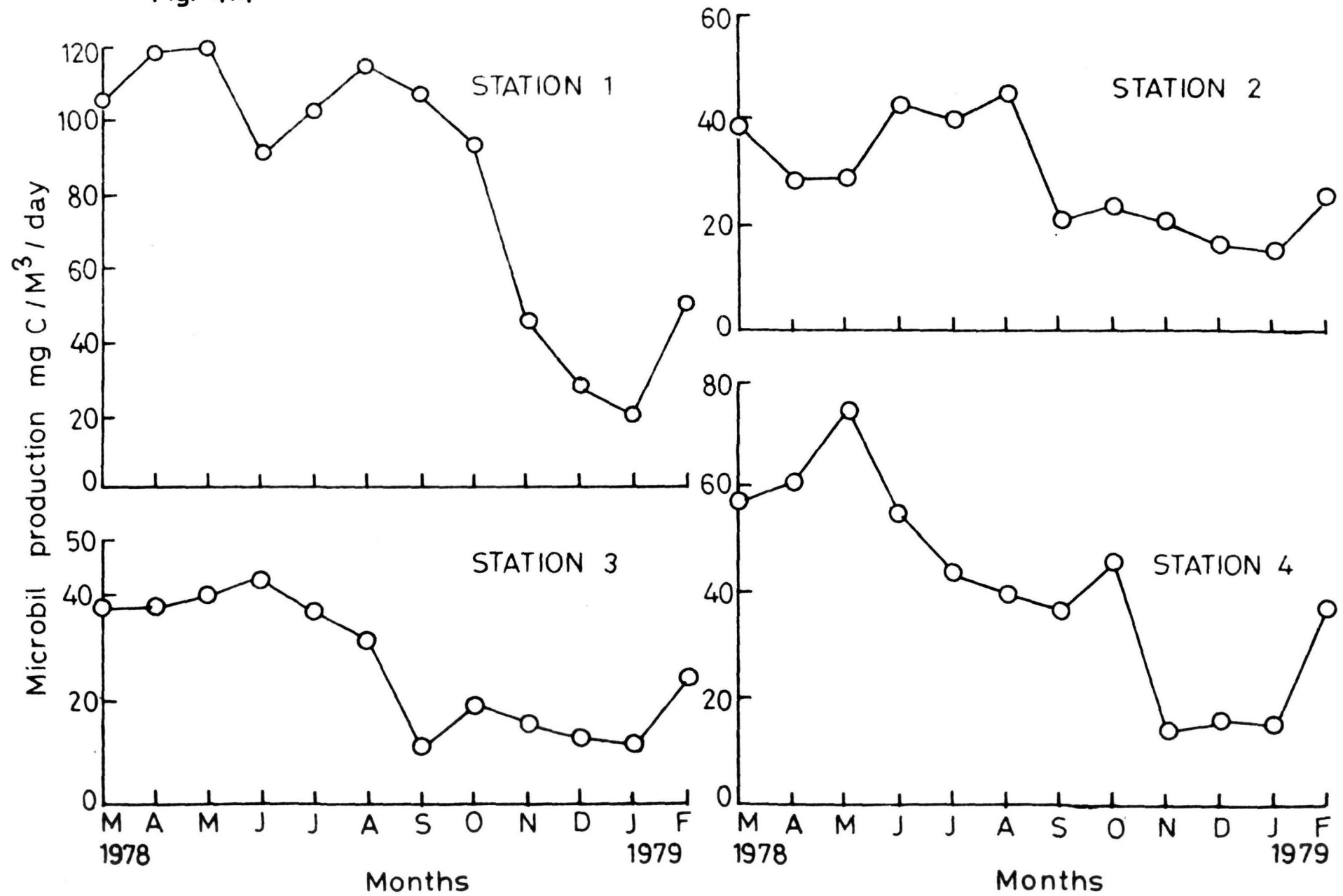


Fig. 4.3

Fig.4.4. Monthly variation in microbial production ($\text{mg C/M}^3/\text{day}$) in the lake water at various stations. Values are mean of the estimations at three depths (surface, middle and bottom) from March 1978 to February 1979).

Fig. 4.4



value. Besides distinct seasonality, marked variation was also observed at different depths. During winter months the mid-depth water consistently harboured less heterotrophic activity as compared to surface and bottom water (Fig.4.2).

Biological Oxygen Demand (BOD)

Biological oxygen demand showed distinct seasonal variation. It was maximum during spring and decreased with the onset of summer. The lower values were recorded during winter (November-January) followed by slight increase in February. In general, the highest BOD values were associated with bottom waters in the station 4 samples. The depth-wise variations at the station 1,2 and 3 was not statistically significant and, therefore, the values shown are the mean of the three depths sampled. BOD values were quite high at station 1 as compared to the other stations, clearly depicting organic loading of the station (Fig.4.3).

Microbial Production

Microbial production values are shown in Fig.4.4. Data are the arithmetic mean of the depth-wise estimate as not much variation could be noted at different depths. The values differed considerably in different months with a general tendency of higher values during the warm months and steep decrease during winters. Another important feature was that the values were always highest in the station 1.

Fig.4.5. Monthly variation in biomass of bacteria (mg C/M³) in the lake water at various stations. Values are mean of the estimations at three depths (surface, middle, bottom) from March 1978 to February 1979.

Fig. 4.5

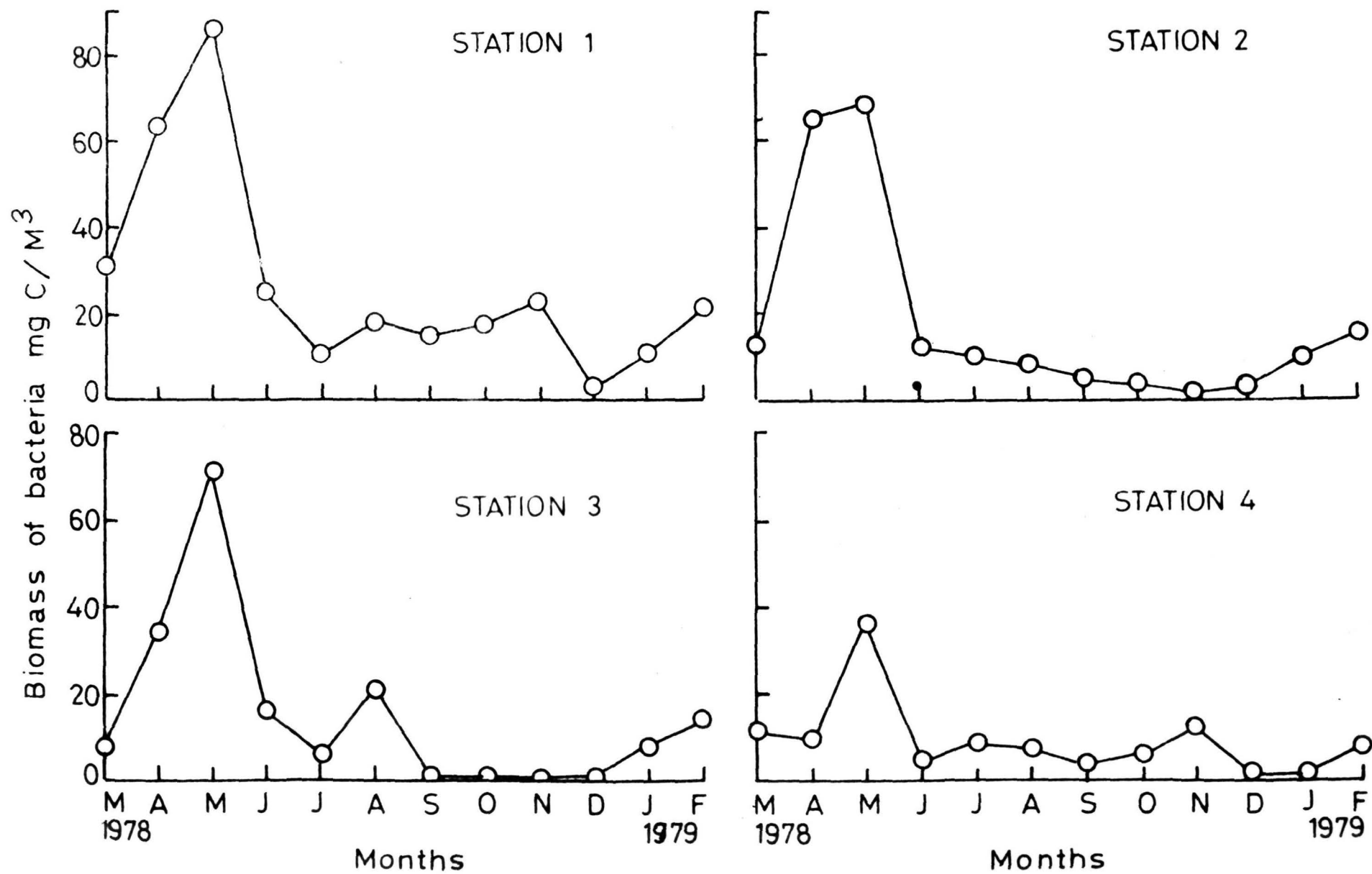


Fig.4.6. Monthly variation in generation time of bacteria (hours) in the lake water at various stations. Values are mean of the estimations at three depths (surface, middle, bottom) from March 1978 to February 1979.

Fig. 4.6

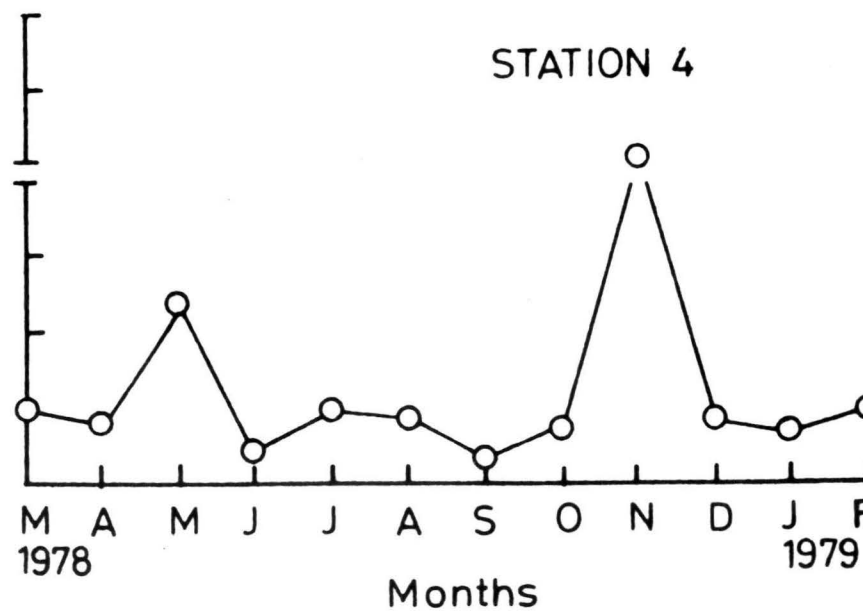
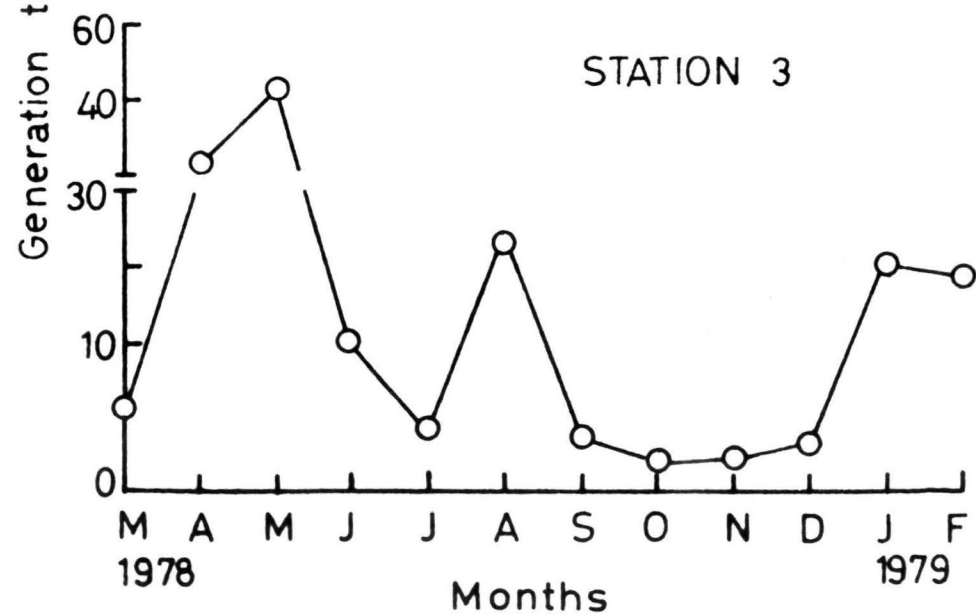
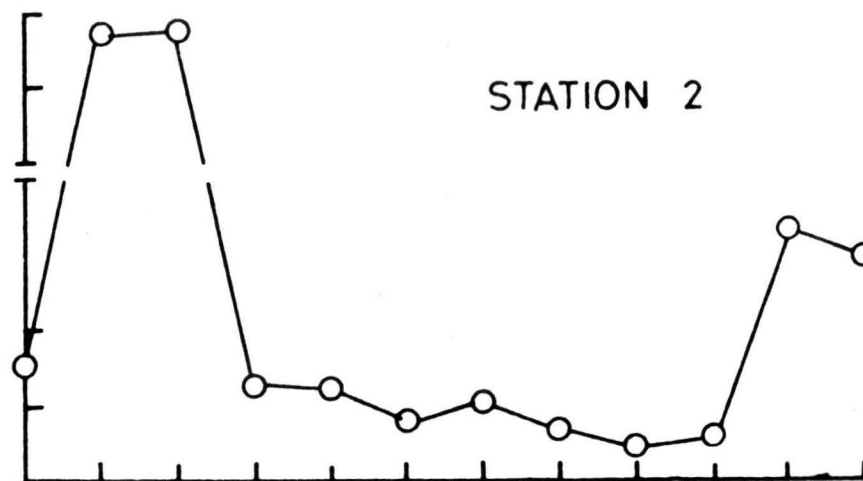
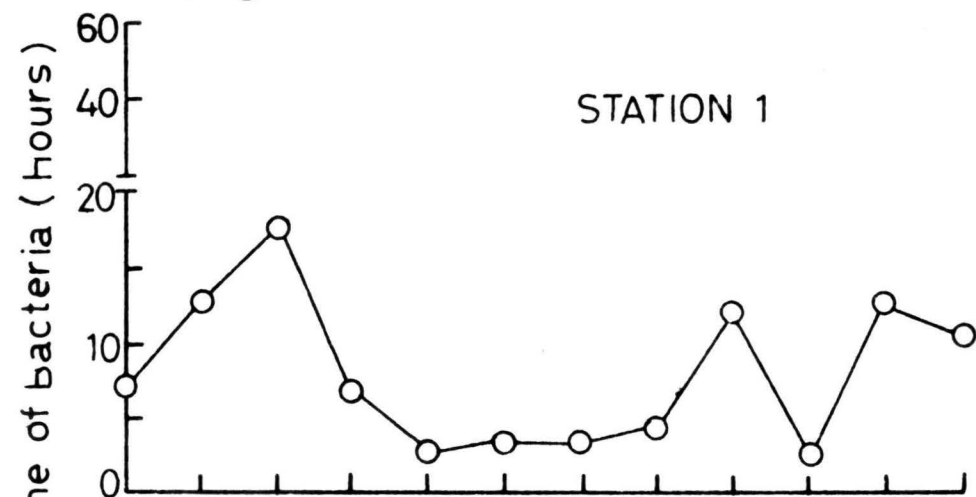


Table 4.1. Simple correlation coefficient (r) values among various parameters.

	Microscopic count of Bacteria	Viability count of Bacteria	Biological Oxygen Demand	Coefficient of Heterotrophic activity	Total alkaline Phosphatase activity	Soluble alkaline phosphatase activity	Total Alkaline Phosphate activity	Alkaline oxidase activity	Phosphate activity	Permanganate activity
Microscopic count of Bacteria	-	0.9926**	0.5404	0.5201	0.5430	0.4500	0.5324			
Viability count of Bacteria		-	0.5503	0.5497	0.5754	0.4523	0.5173			
Biological Oxygen Demand			-	0.8631**	0.6519*	0.6359**	0.9932**			
Coefficient of Heterotrophic activity				-	0.6015*	0.7072**	0.89501**			
Total alkaline Phosphatase activity					-	0.6157*	0.6903*			
Soluble alkaline phosphatase activity						-	0.8344**			

*, ** significant at 0.05 and 0.01 P respectively.

Bacterial Biomass

Biomass of bacteria showed marked variation with seasons. Most significant observation was that the biomass of bacteria peaked once in the month of May which was many fold higher than the values observed during rest of the year. The values shown in the Fig.4.5 are arithmetic means of the three values recorded at three different depths.

Generation Time of Bacteria

The generation time of bacteria showed distinct variation at different period of samplings. During spring in general and particularly in the month of May the generation time was consistently higher at all the sampling stations which coincides with the peak period of biomass also. Except a single departure at station 3 in the month of August the generation time was quite low during summer months. If generation time is considered as a measure of growth it appears that growth rate slows down during the periods of maximum population and biomass. (Fig.4.6).

DISCUSSION

Earlier studies on alkaline phosphatases have well established their role in phosphate regeneration (Jansson, 1977) and as an indicator of eutrophication and microbial biomass (Reichardt et al., 1967; Jones, 1972 a). These and most of the other attempts to relate phosphatase activity

with microbial biomass and other limnological characters have been based on short term studies except those of Stevens and Parr (1977) and Heath and Cooke (1975). During this study higher values of alkaline phosphatase activity were coupled with higher bacterial populations and other biological activity measurements during the months of April-July which was consistent with the observations of Jones (1972a). The second maximum in phosphatase activity was observed in the bottom waters during November-December which was associated with the lowest values of Ortho-phosphate concentration. It may, therefore, be inferred that during the period of high microbial activity (March-June) the phosphatase activity was not repressed by higher ortho-phosphate values as observed by Heath and Cooke (1975). But low values of ortho-phosphates could probably trigger the enzymatic activity (November-December) in order to release the ortho-phosphates from the organic phosphate compounds. During the period of higher phosphatase activity the depth-wise distribution of ortho-phosphates showed a trend opposite to phosphatase activity clearly depicting negative relation between the two. The relationship between ortho-phosphate and phosphatase activity observed during present study is very much in conformity with those of Stevens and Parr (1977). It may, therefore, be inferred that in natural waters phosphorous limitations may enhance the phosphatase activity but the repression of phosphatase activity by ortho-phosphate may not occur if it also coincides with the high microbial

activity as noted in the present study. The absolute values of phosphatase activity often cannot be compared with other reports because of differences in units as well as methods employed. Data of the present study are within the range as reported by Heath and Cooke (1975). The depth-wise distribution of phosphatase activity suggests that probably during spring and warm periods of the year the phosphatases were produced more in the surface waters than the bottom waters largely by the phytoplanktons which peaked during this period (Thapa, unpublished). The November-December maximum of phosphatase activity in the bottom waters may be due to the bottom organisms or particulate sources. Jones (1972a) also observed some increase in phosphatase activity in deeper water in late summer. Berman (1970) did not find any induction repression and/or activation of phosphatases in Lake Kinneret with ortho-phosphates. Similarly Jones (1972b) also did not find a relationship and suggested that without a detailed survey of water bodies the control mechanism of enzymes could not be determined satisfactorily. Results also clearly depict that major portion of the alkaline phosphatase activity remain associated with the particulate matter and only a small fraction of it was present in the soluble form.

Coefficient of heterotrophic activity has been used as a measure of biological activity (Godlewska-Lipowa; 1973;1974b). The present study revealed that although it

could be correlated with the microbial population estimates it was more directly related to the dissolved organic carbon concentrations. BOD measurements have been the most widely used single parameter as an estimate of biologically utilizable organic matter in the natural waters. BOD values in this study were significantly related with the dissolved organic carbon (Table-4.1). Although maximum and minimum values also corresponded with the bacterial population maximum and minimum, a general relationship was not observed.

Microbial production estimates were higher during the warm periods of the year. The relationship between the bacterial biomass and microbial production was such that both peaked during spring months but while former dropped abruptly the latter maintained a plateau throughout the warm periods of the year. Thus, it appears that there is no direct relationship between the biomass and production values. Even quite low biomass values observed during late summers may contribute to the same level of production. On comparison of the dissolved organic concentration with microbial production it is evident that microbial production has positive relationship with the dissolved organic carbon concentrations. The comparison of the data with similar studies (Overbeck, 1979) shows that the values are quite high. Higher values of microbial production at station 1 can be clearly explained with the higher values of organic carbon concentration at this station.

The microbial production estimates are of quite high order when compared with Pechlaner (1970) whose estimates of primary productivity were either less or equal to the microbial productivity estimates of the present study. The microbial production estimates clearly demonstrate that quite high amount of biomass is synthesized by heterotrophic microbial communities. It may, therefore, be pointed out that studies concerned with the productivity estimates should also consider the microbial production failing which there is likelihood of ignoring a most important facete of the production biology. The biomass of bacteria has been quite low when compared with the observations of Godlewska-Lipowa (1947b) in the Mazurian lakes. Godlewska-Lipowa estimated it to be between 200 and 700 mg C/M³. Donderski (1977) estimated bacterial biomass in two lakes in Poland. In the eutrophic lake the biomass estimates were as high as 782 mg C/M³ while in the mesotrophic lake the highest value was 75.6 mg C/M³. On comparison with the estimates of the present study it is evident that the values were comparable to the mesotrophic lake estimates. It may, therefore, be inferred that on the basis of the bacterial biomass the lake may be classified as mesotrophic. The generation time of bacteria oscillated between 1.8 to 58 hours, which was comparable with the observations of Donderski (1977). Hagstrom et al (1979) calculated generation time of bacteria and found it within the range of 10 and 100 hrs. Although

seasonal fluctuations of generation time of bacteria cannot be discussed with quite precision, the higher values observed during spring shows that during high biomass values probably the rate of multiplication slows down. This may be probably because of the increased longevity of the cells in the favourable conditions of growth. Not much could be concluded from these data because of the scarcity of similar data from other systems. Before we can generalize the findings of our study more studies are required on the biomass and generation time of bacteria in different natural water bodies on periodic sampling basis.

The maximum biological activity, microbial population, and biomass were noted during spring which may be ascribed to the mixing of the water column in the month of February (clearly evident from the bottom oxygen level in the month of March) resulting into March phytoplankton bloom followed by bacterioplankton bloom. The fresh input of extraneous nutrients in the form of plant litter during late February and early March from the adjoining vegetation may also contribute to this.

From the present study it may be concluded that in shallow stratified lakes, distinct seasonal variation in the biological activity measurements and the microbial population estimates takes place. The mixing of lake water occurs during the end of winter resulting in a bloom of

phytoplankton in the month of March-April followed by a bacterioplankton bloom in the month of May. The spring blooms also coincide with the maxima of most of the biological activity measurements such as alkaline phosphatase activity, coefficient of heterotrophic activity BOD and the rate of microbial production. These values were positively correlated (Table 4.1). Results obtained on the phosphatase activity suggested that caution should be exercised in the use of phosphatase activity as a measure of biological activity (Verstraete et al., 1976) although further investigations are needed on periodic sampling basis before we can generalize the same for other systems, also. There appears to be sufficient information to suggest, however, that the phosphatase activity is affected by the microbial population and ortho-phosphate levels.

CHAPTER 5

DECOMPOSITION OF ALLOCHTHONOUS PLANT LITTER

INTRODUCTION

Dictionary meaning of decomposition is the act of separation of anything into its constituent elements. Biological usage of the term has been in the sense to describe the process by which the dead organic materials decay and resolve into simpler compounds and ultimately result into the simple inorganic compounds. During the process chemical bond energy of the organic materials is utilized by various microorganisms whose qualitative and quantitative composition may vary as the materials decay.

The process of decomposition is extremely complex and is controlled by the multitude of organisms, the chemical and physical properties of litter and by the abiotic environment. The quantity, quality and activity of the decomposer organisms are determined largely by the chemistry of the material and the abiotic environment. All these are manifested in the period of time required for the breakdown of the litter. The average rate of decomposition is, therefore, measured as fractional loss rate with the formula

$$W_t = W_o e^{-kt}$$

where W_o is the initial weight, W_t is the weight at time t and k is the rate constant per day (Olson, 1963).

Decomposition is of fundamental importance for the proper functioning of any ecosystem. It helps in unlocking and regeneration of nutrients which are made available for

the synthesis of fresh biomass by the green plants. Understanding of the decomposition process becomes of added importance in the aquatic ecosystems receiving allochthonous organic matter which serves as an additional source of energy for the system. Besides primary production, microbial production at the expense of energy of the allochthonous organic matter, contributes significantly towards the total production of organic matter in such ecosystems. Streams, soil below litter layer, lake and marine benthos and estuaries which are primarily heterotrophic depend considerably for their energy requirements on the allochthonous organic matter.

The importance of organic matter in aquatic ecosystems was first of all pointed out by Thienemann (1912) Since then several workers have added considerably towards the understanding of the subject.

Levanidov (1949) reported that the littoral zone of wooded lakes receives 200-500 gram per meter² of leaves per year. Nelson and Scott (1962) noted that in spite of a high primary production of Piedmont stream 66% of the net production of primary consumers was derived from allochthonous organic matter.

Hyne (1963) showed that the terrestrial organic matter is the major source of energy for the microbial and animal community metabolism of unpolluted streams. He further concluded that a large part of the productivity of

running waters is based on the allochthonous organic matter without which these habitats would turn to be almost a desert.

Egglishaw (1964) concluded that the distribution of streams bottom fauna is associated with the distribution of plant detrites. Szczepanski (1965) reported an annual transport of 500 gram of dry leaves per meter of shoreline of the lake Mikolazki, Poland.

Minshall (1967) found that allochthonous leaf materials were the most important invertebrate food and constituted well over 90% of their diet. Mean standing crop of allochthonous leaf materials was estimated to be 4.7 - 13 k cal per meter². The energy flow studies reveal that the allochthonous leaf materials are the main source of energy for the primary consumers.

Kaushik and Hyne (1968) concluded that fungi were responsible for the increase in protein content of the decomposing leaves. They reported that fungi and bacteria showed some sort of antagonism for each other; when former increase the latter decreases and vice versa. All the fourteen genera of fungi recorded were the common soil fungi. They confirmed the view of Cooke (1962) that these fungi are definite members of the population of aquatic systems and their role is of fundamental importance. They opined that the study of microbial population of the decomposing leaves deserve more consideration than it has received. Extending the same study, Kaushik and Hyne (1971)

emphasized the importance of allochthonous leaf litter in the aquatic systems as source of energy for secondary and tertiary production and noted that absolute quantity of nitrogen increases as the leaf decomposition proceeds. They observed that initially fungi were more important than bacteria for the breakdown the leaves.

Seki et al (1969) reported that the terrestrial organic material contribute appreciably towards the annual primary production of the sea understudy.

Fisher and Likens (1973) estimated that air borne inputs of plant organic matter constitute more than 40% of total input of organic matter in the stream ecosystem.

Peterson and Cummins (1974) reviewed the literature on decomposition of plant litter in stream habitats and compared the decay coefficients of various plant litter in different habitats. They further proved the earlier observations that the differential invertebrate colonization of leaf packs is a function of microbial colonization and conditioning.

Iversen (1973) reported that autumn shed beech leaves placed in net bags lost 90% of their weight during one year. Initial rapid increase of nitrogen percentage in the first month of processing made the leaves palatable for invertebrates. He further concluded that most of the organic nitrogen released by the microbes are redeposited on the leaves.

Park (1974) used the litter bag method for the

decomposition studies in running waters and observed that litter bag method do not permit full analysis of the range of processes occurring during breakdown.

Willoughby (1974) extensively reviewed the various aspects of decomposition of plant litter in freshwaters. Based on literature he concluded that the decomposition in freshwater is regulated by the physico-chemical status of the environment, chemical composition of the litter, and the biological community involved in the process.

Sedell et al (1975) emphasized the role of invertebrates in the decomposition of conifer needles and confirmed that the leaf litter fed upon by invertebrates must be microbially colonized. The rate of decomposition was slow for the first 100 days which increased drastically afterwards. While the former was attributed to the microbial decomposition the speeding up of the rate was due to the invertebrate feeding.

Triska et al (1975) reported increase of percentage nitrogen following initial leaching and continuous decrease in lignin content of the decomposing plant materials.

In laboratory experiments Harrison (1977) found that amphipods feed selectively on the detritus colonized by epibionts and the presence of amphipods increased the rate of decomposition.

Barlocher et al (1978b) for the first time reported that Pinus resinosa needles are naturally colonized by

aquatic hyphomycetes in streams. The maximum fungal activity was coupled with the maximum invertebrate feeding. The treatments of the needles with HCL, H_2O , C_3H_5OH or NaOH increased the palatability of the needles for the invertebrates and the fungal colonization was also increased. Experimental findings proved that the cuticle was inhibitory for the fungal colonization.

Barlocher and Oertli (1978) extending their studies on the colonization of aquatic hyphomycetes on conifer needles reported that dead needles of several other conifer species namely; Abies alba, Pinus sylvestris, P. lucodermis and Sequoia gigantea were also colonized by aquatic hyphomycetes in streams. In a separate experiment they reported that while low doses of needle powders allowed the growth of fungi the higher doses were always inhibitory.

Using large-mesh bags Danell and Sjöberg (1979) studied the decomposition of Carex and Equisetum litter in northern Swedish lake. They reported that Equisetum litter decomposed faster than Carex. They were of the view that animals do not themselves consume litter but their presence leads to an increase in the rate of microbial decomposition.

Ingold (1979) reviewed literature on the study of aquatic Hyphomycetes on the decaying dicotyledonous plant litter and suggested the term amphibious Hyphomycetes in place of aquatic Hyphomycetes for the latter has become

obsolete in the light of recent researches on the terrestrial occurrence of many of the so-called aquatic Hyphomycetes.

The subject of litter decomposition on terrestrial habitats has reached to an advanced stage of perfection and sophistication (Dickinson and Pugh, 1974). A perusal to the informations given above in the field of decomposition of allochthonous plant litter in aquatic habitats on the other hand shows that the subject is as yet at its starting point and still there is scarcity of data. Further, most of the studies are done in temperatre streams with a primary aim to investigate the relationship of allochthonous leaf litter either with the invertebrate fauna or with a small group of fungi namely; so-called 'aquatic' Hyphomycetes.

So far, we know very little about the general microbiological aspects of plant litter decomposition in lakes. The quantification of bacterial and fungal populations associated with the decomposing plant litter in natural waters has not received sufficient attention.

Investigations on the litter decomposition in standing waters are very few particularly pine needles litter decomposition in standing waters has been studied rarely (Hedkinson, 1975). It would be worth mentioning that no work has been done on the subject in India so far.

Pine (Pinus kesiya Royle) needles constitute the most important component of the forest vegetation of the higher elevations of north eastern India and a sizable

amount of needles litter enters the various aquatic ecosystems of the region. The lake under study do receives pine needles as the most important component of the allochthonous organic litter input. Keeping in view, the above points it was thought that there was an urgent need to study the problem of extraneous plant litter decomposition in lakes.

Present study deals with the estimates of decomposition rate on weight loss basis, quantification of microbial (bacteria and fungi) populations associated with the litter and the chemical changes of the processing litter. The process of decomposition of two types of plant litters (pine needles, teak leaves) have been studied for a period of 18 months.

MATERIALS AND METHODS

Bulk samples of the main litter input pine (Pinus kesiya Royle) needles were collected from an area adjacent to the lake in the months of March-April, 1977. Senescent teak (Tectona grandis L.) leaves were collected from a twenty year old forest plantation situated in Umling 70 km away from Shillong. All samples were air dried for three weeks and an oven dry (80°C for 48 hours) weight correction factor was determined. Five grams of air dried litter was exposed in nylon bags 20 x 20 cm of 1 mm of mesh size which permitted entry of most of the invertebrate decomposers and simultaneously reducing losses of small fragments of the litters. Thus the dry weight losses

subsequently recorded are composite figures representing both microbial decomposition and invertebrate consumption.

Prior to introduction into the lake, weighed litter bags were placed in a moist atmosphere for two days to take up the moisture; this prevented the fragmentation observed when air dried needles were put directly into water. Litter bags were placed in the pond on August 8, 1977. A fraction of the needles was separated for the microbial and chemical analysis prior to their processing in water.

First two collections were done at 15 days intervals, after that four collections were done at monthly intervals and subsequent collections were done at an interval of two to three months. After collection, the bags were gently agitated in distilled water to remove any visible covering of sediments or algal filaments and then oven dried (55°C for 5 days) to determine dry weight loss. The replicates were then mixed to form composite samples which were used for chemical analyses.

The litter bags were put at three different sites viz., station 1, 3 and 4. The bags were tied to nylon cord. To each cord 5 litter bags were tied from the same point. A stone of sufficient weight was also tied to the same point to keep the cord stationary on the bottom. Litter at each station was placed at the bottom middle and the surface of the lake (5 cm below the surface) each sample to be collected were put in a separate cord. Samples were

brought to the laboratory in sterile polythene bags within an hour of collection.

Microbiological analysis

One bag from all the samples was washed gently in sterile water to remove the surface contaminants. The litters were cut into small pieces of 10 mm with the help of a sterile scissors in a sterile Petridish. 2 grams wet weight was put in 100 ml of sterile distilled water and the dilution was made after a thorough shaking of the water in a 250 ml conical flask. A minimum of 50,000 dilution was used for bacteria and 500 for the fungi. 0.5 ml of suitable dilution was inoculated on the surface of the bacterial and fungal media (chapter 2,3). The media used were the same which have been used in the case of water samples. The plates were incubated for 7 days at 25°C in a BOD incubator. Yeast colonies were counted on the fungal medium. Simultaneously with the weighing of litter for microbiological analysis three 2 grams of the litter samples were weighed in the separate Petridish and dried in hot air oven at 80°C for 48 hours to determine the moisture content of the litter. The numerical estimation of microbes were computed on the basis of per gram dry weight of the litter.

The initial microbial population associated with the litters was estimated before putting the bags in the lake using same method as described above.

Estimation of cellulose, hemicellulose and lignin of the decomposing litters.

Cellulose, hemicellulose and lignin content of litters were estimated by the method described by Peach and Tracey (1955). The samples were ground to fine powder by electric grinder and processed for estimation of the three compounds. 0.5 g of powder was treated with 20 ml of 25% aqueous KOH (W/V) for twelve hours at room temperature. The samples were then centrifuged at 3000 rpm for 10 minutes. The decant obtained was used for hemicellulose. The residue left was washed several times with distilled water to remove the last trace of KOH. It was dried at 80° for 48 hours in a hot air oven, cooled to room temperature in a desiccator^c and weighed. The amount obtained was designated as total cellulose. The decant was neutralized with an equal amount of glacial acetic acid and ethanol. The precipitate was filtered, washed, dried and weighed as above and this was accounted for hemicellulose. Three replicate samples were considered in each case.

For estimation of lignin 0.5 of dried samples were treated with 72% of sulphuric acid (AR) and kept in a deep freeze for 24 hours. After this, the content of the test tube was centrifuged at 6000 rpm for 20 minutes. The clear supernatant was discarded. The residue was washed many times to remove the last trace of sulphuric

acid. It was finally washed in a watch glass, dried and weighed as above. The amount so obtained was recorded as total lignin. Three replicates were considered in each case.

Estimation of total sugar and total aminoacid in the decomposing litters.

Total sugars and aminoacids were estimated by the method described by Peach and Tracey (1955). 100 mg of the sample was crushed with a mortar and pestle in 80% ethanol and filtered through a Whatman No.1 filter paper. The filtrate was treated with activated charcoal and centrifused at 6000 rpm to get a clear supernatant. Ethanol was boiled off in a hot water bath and the volume was made up to 5 ml with the addition of double glass distilled water. 3 ml of this solution was taken in a test tube and 6 ml of Anthrone reagent (0.4% in H_2SO_4 w/v) was added gently to it from the side while the test tube was kept in ice. Then the test tube was gently shaken and warmed in a hot water bath for 3 minutes. A green colour was obtained. The transmittance of this coloured solution was observed in spectrophotometer (Systronics 103) at 610 nm. Standard curve was obtained from the transmittance of varying concentration of glucose solution treated with anthrone reagent as described above. The values of the total sugars were expressed in $\mu g/100$ mg by weight of samples.

To rest of the 2 ml extract, 2.5 ml of acetate buffer (40 g NaOH dissolved in distilled water in 1000 ml volumetric flask, 100 ml of glacial acetic acid was added to it and the volume made upto 1000 ml with distilled water) and 2.5 ml of ninhydrin solution (1% in isopropyl alcohol) were added simultaneously. The test tube containing the solution was kept in hot water bath for half an hour, a light purple colour was obtained. The transmittance of this coloured solution was measured in a spectrophotometer (Systronics 103) at 540 nm.

Standard curve was obtained from the transmittance of the varying concentration of leucine solution treated with acetate buffer and ninhydrin solution as described above. From the standard curve the values of the total amino acids of the samples were expressed in $\mu\text{g}/100\text{ mg}$ dry weight of samples. The estimations in each case were done in triplicates. The nitrogen estimations were done by Kjeldahl method as outlined by Allen (1974).

RESULTS

Rate of Decomposition

Fig.5.1 to 5.3 depict the rate of decomposition of pine needles and teak leaves studied on weight loss basis at the three stations, viz; station 1, station 3 and station 4. The two types of extraneous litters put for the decomposition lost their weights with different

Fig.5.1. Changes in dry weight of pine needles and teak leaves processing in the lake at station 1 (August 1977 to February 1979) circles:surface, triangles:mid-depth and squares:bottom.

Fig. 5.1 STATION 1

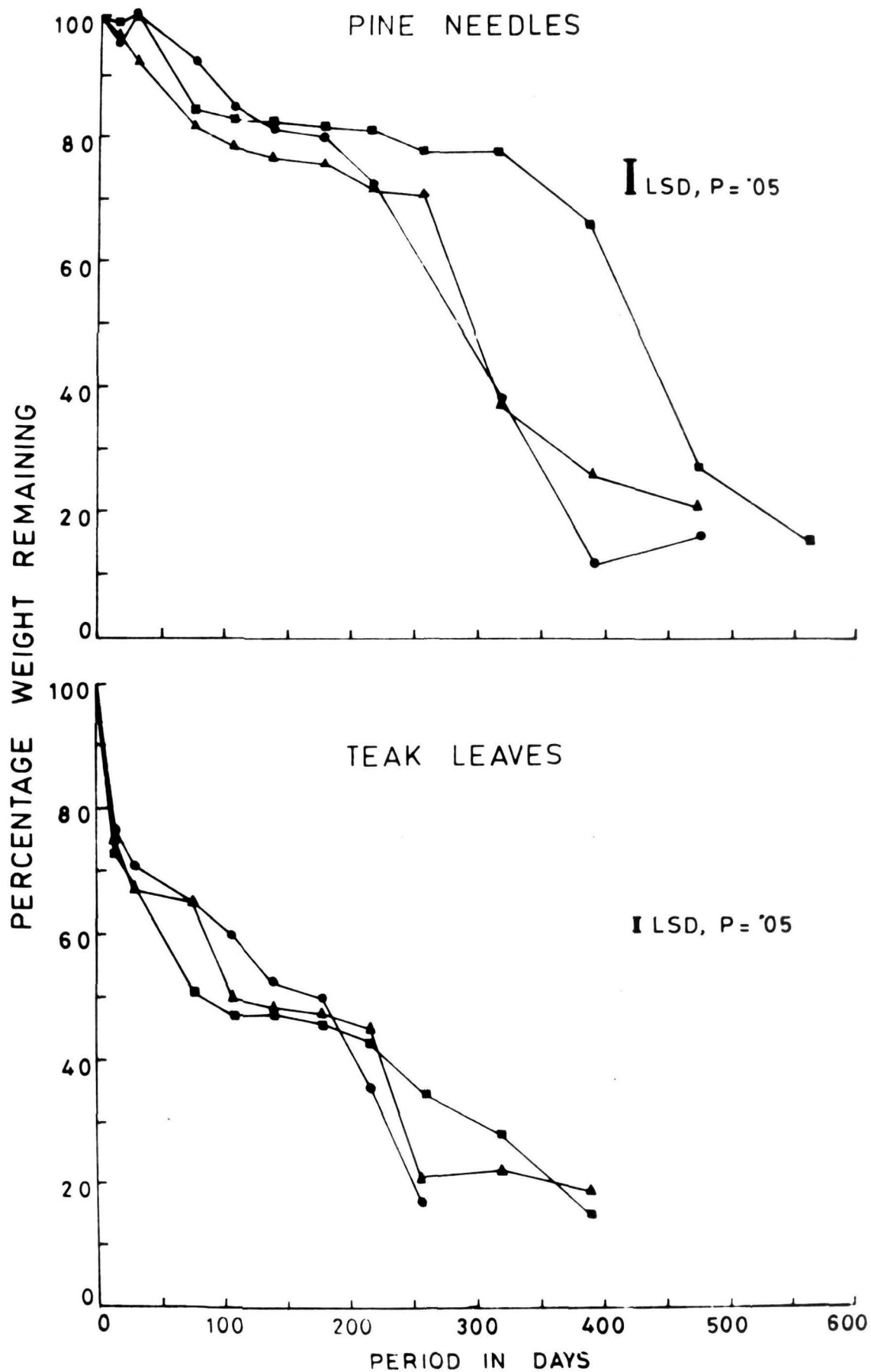


Fig.3.2. Changes in dry weight of pine needles and teak leaves processing in the lake at station 3 (August 1977 to February 1979). Circles: surface, triangles:mid-depth and squares:bottom.

Fig. 5.2

STATION 3

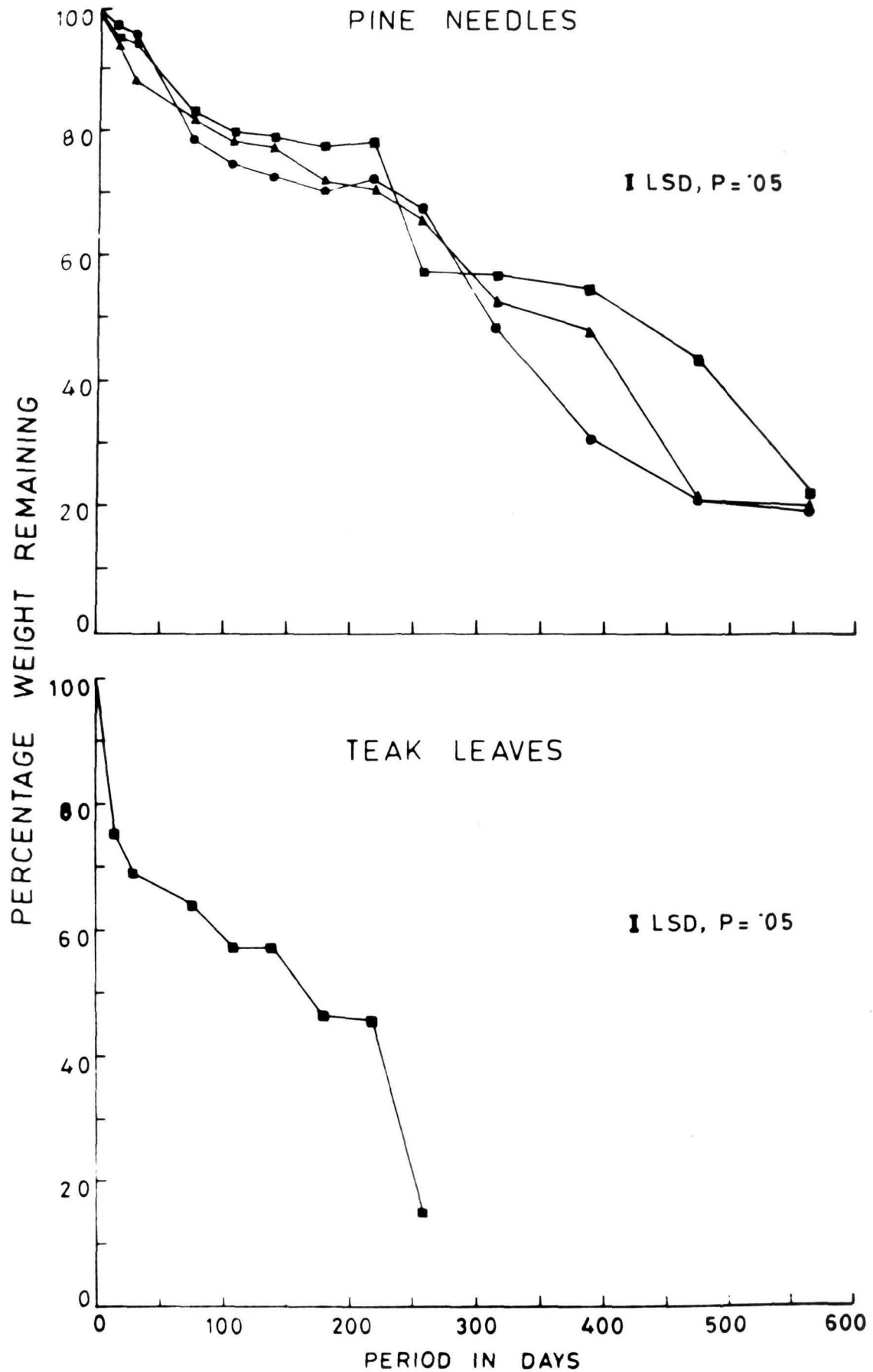
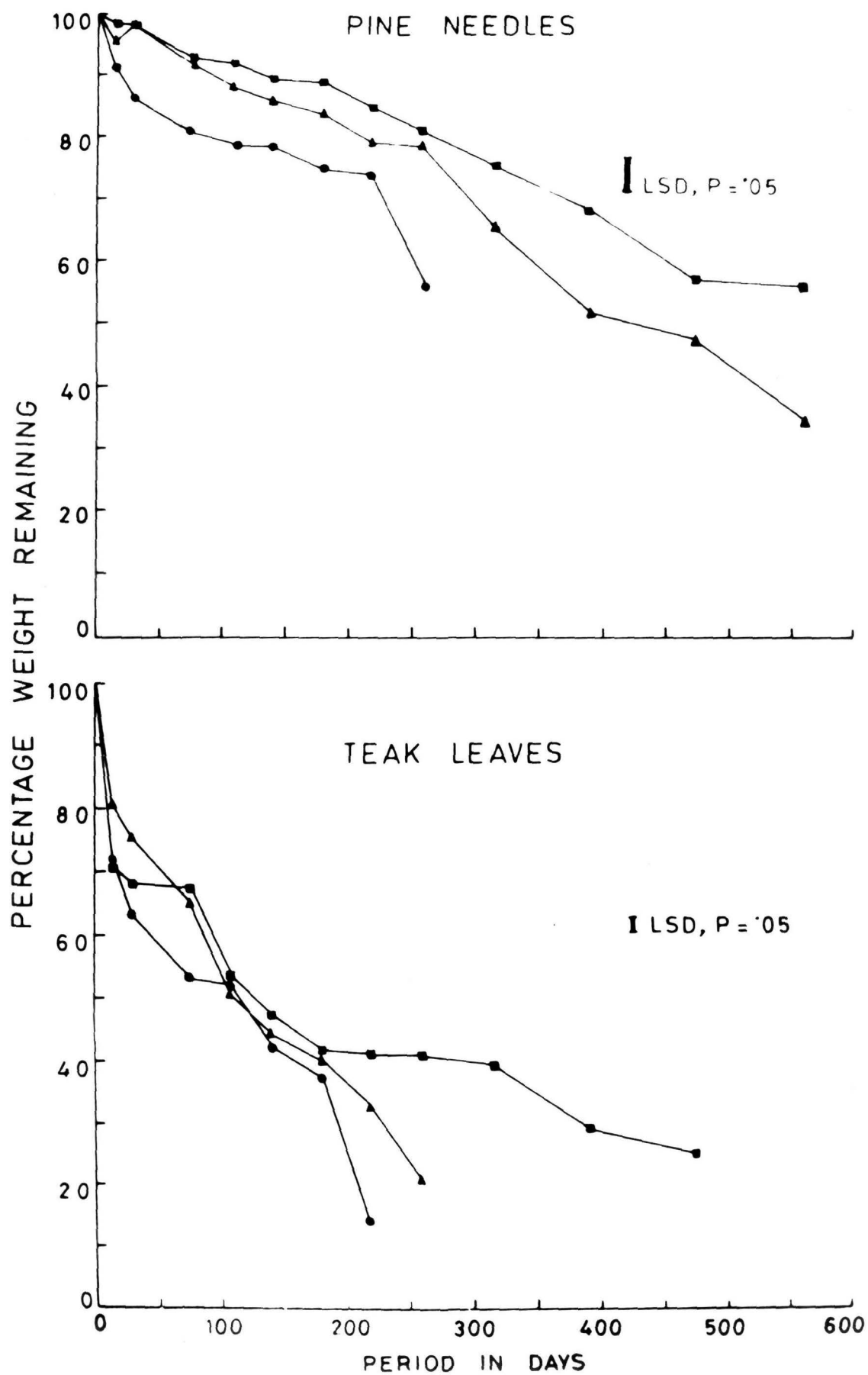


Fig.5.3. Changes in dry weight of pine needles and teak leaves processing in the lake at station 4 (August 1977 to February 1979).Circles: surface, triangles:mid-depth and squares:bottom.

Fig. 5.3

STATION 4



rates. The rate of decomposition of pine needles was very slow as compared to the teak leaves. The initial decomposition of teak leaves was very fast and bags lost twenty to thirty percent of their weight within first thirty days. In general, the rate of weight loss was fast during first sixty to hundred days which slowed down for next hundred to two hundred days and after three to four hundred days the rate was again quite fast. The pattern of initial fast-slow-fast rates of decomposition was more clearly depicted in the teak leaf litter weight loss than in the pine needles. However, this general pattern of weight loss was not followed by the pine needle litters put at the mid-depth and bottom of station 4 where the rate of weight loss was almost constant throughout the study period. In all the cases it was observed that after attaining approximately twenty percent of original weight the rate of weight loss slowed down to minimum and sometimes there was no loss at all. During later periods of the study the litters were changed into an unidentifiable detritus which was as much as ten percent of the original weight but these collections were not considered.

The rate of decomposition at various depths did not differ significantly during early periods of processing but as the time elapsed marked differences were observed. However, at station 4 (where depth is more) the differences were quite evident from very start of the study (Fig.3.3).

Fig.5.4. Number of bacteria per gram dry weight of pine needle and teak leaf litter processing in the lake at station 1 (August 1977 to February 1979). Circles: surface, triangles:mid-depth and squares: bottom.

Fig. 5.4

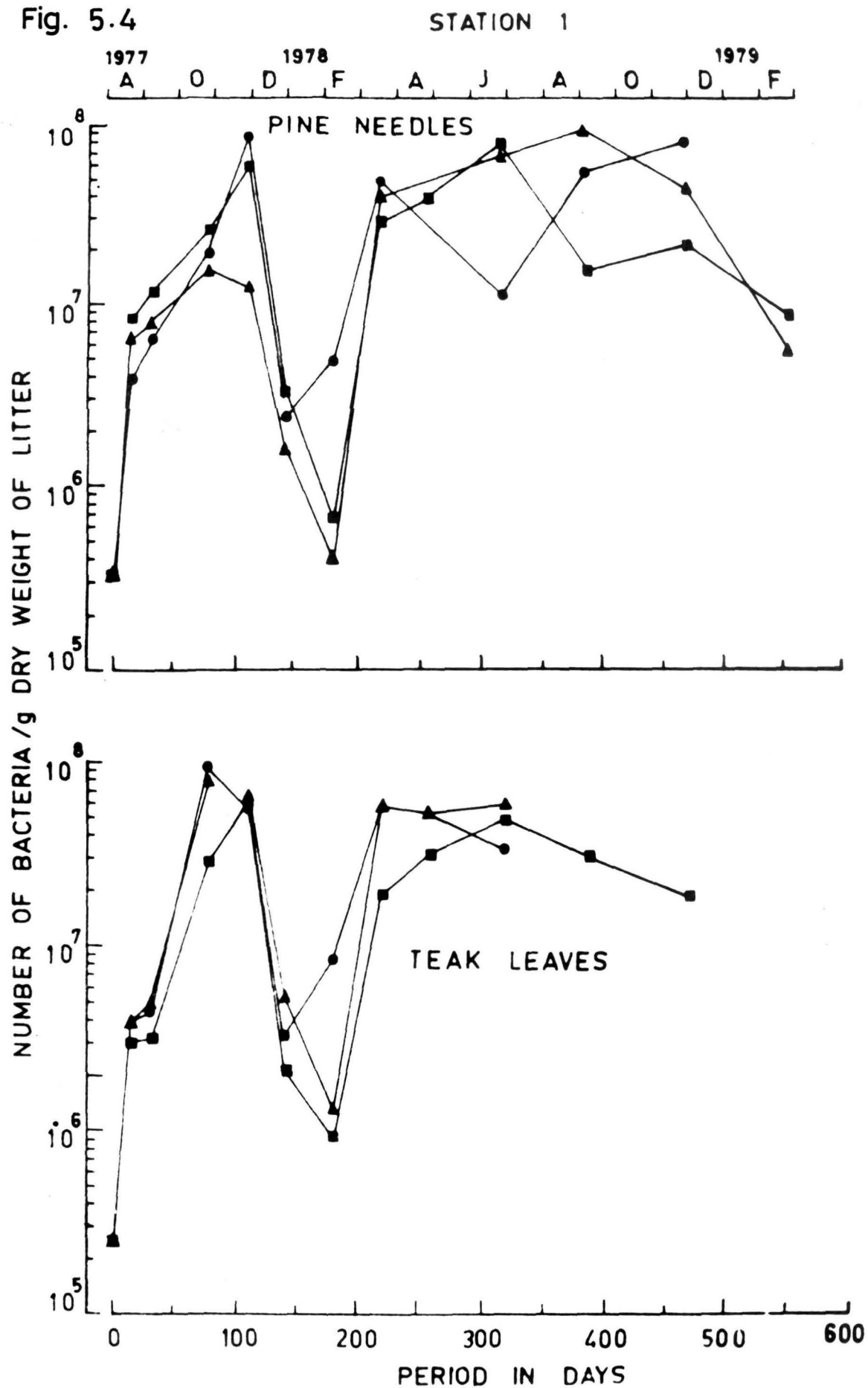


Fig.5.5. Number of bacteria per gram dry weight of pine needle and teak leaf litter processing in the lake at station 3 (August 1977 to February 1979). Circles:surface, triangles: mid-depth, squares:bottom.

Fig. 5.5

STATION 3

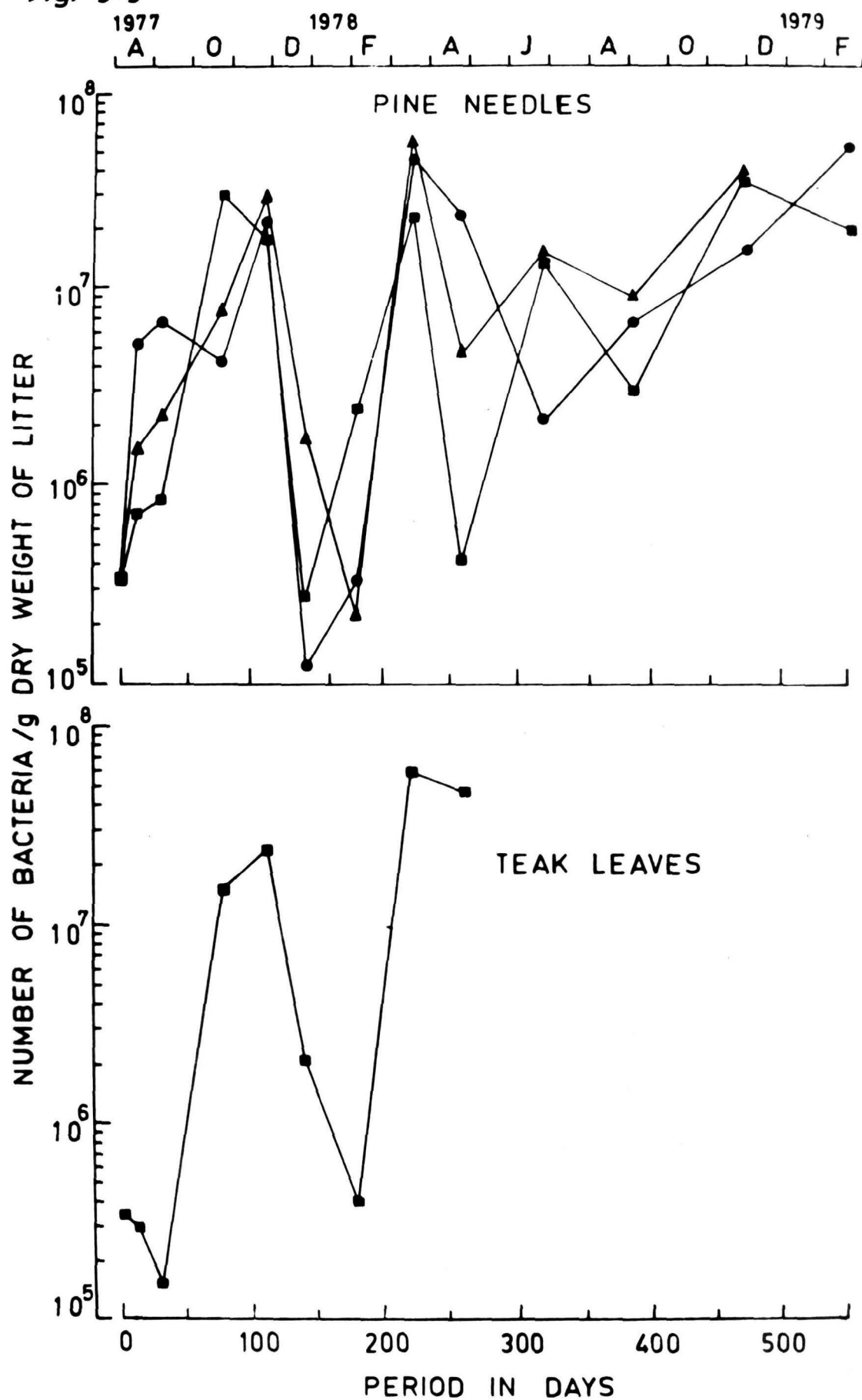


Fig.3.6. Number of bacteria per gram dry weight of pine needle and teak leaf litter processing in the lake at station 4 (August 1977 to February 1979). Circles: surface, triangles: mid-depth and squares:bottom.

Fig. 5.6

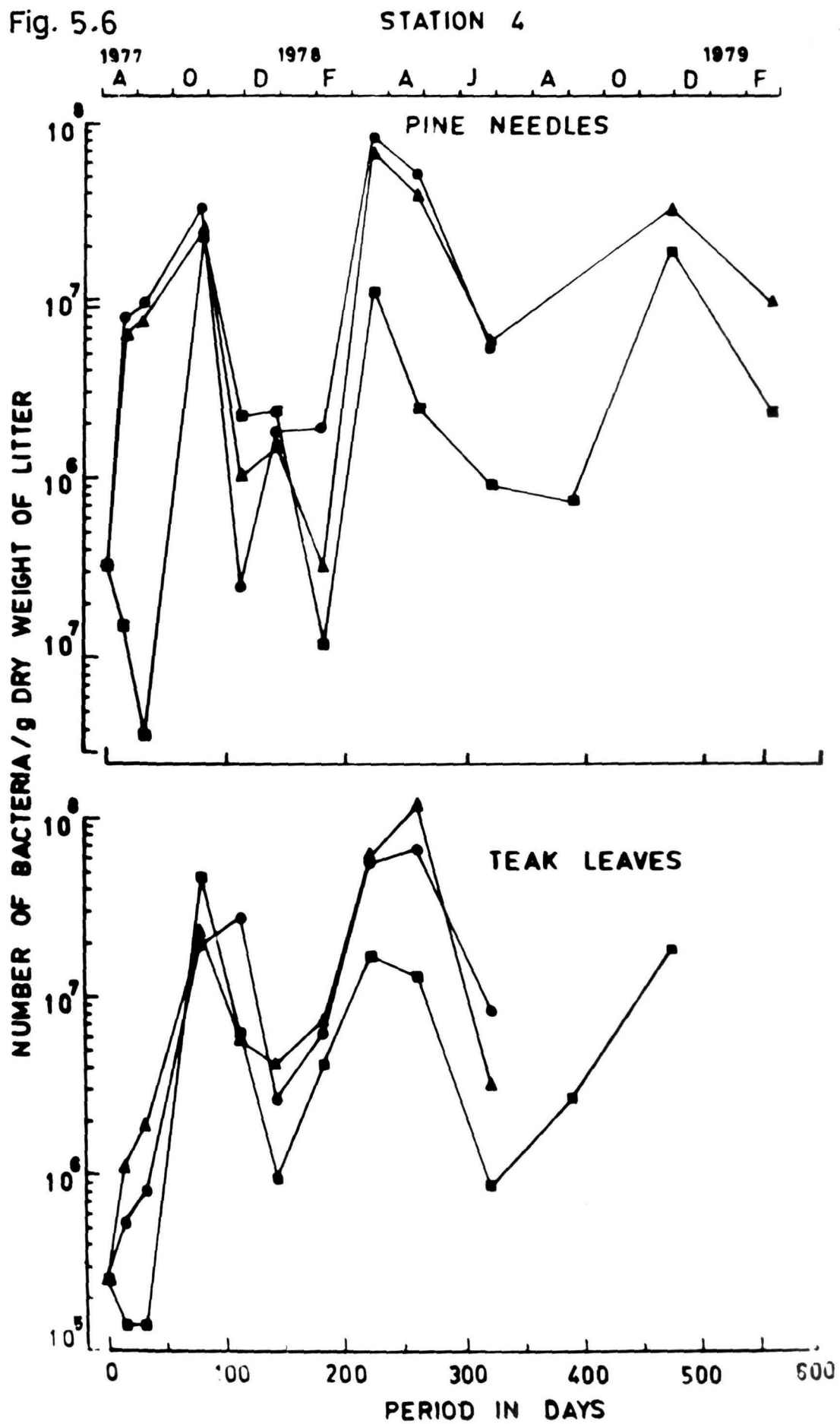


Fig.5.7. Number of viable fungal propagules per gram dry weight of pine needle and teak leaf litter processing in the lake at station 1 (August 1977 to February 1979). Circles:surface, triangles:mid-depth and squares:bottom.

Fig. 5.7

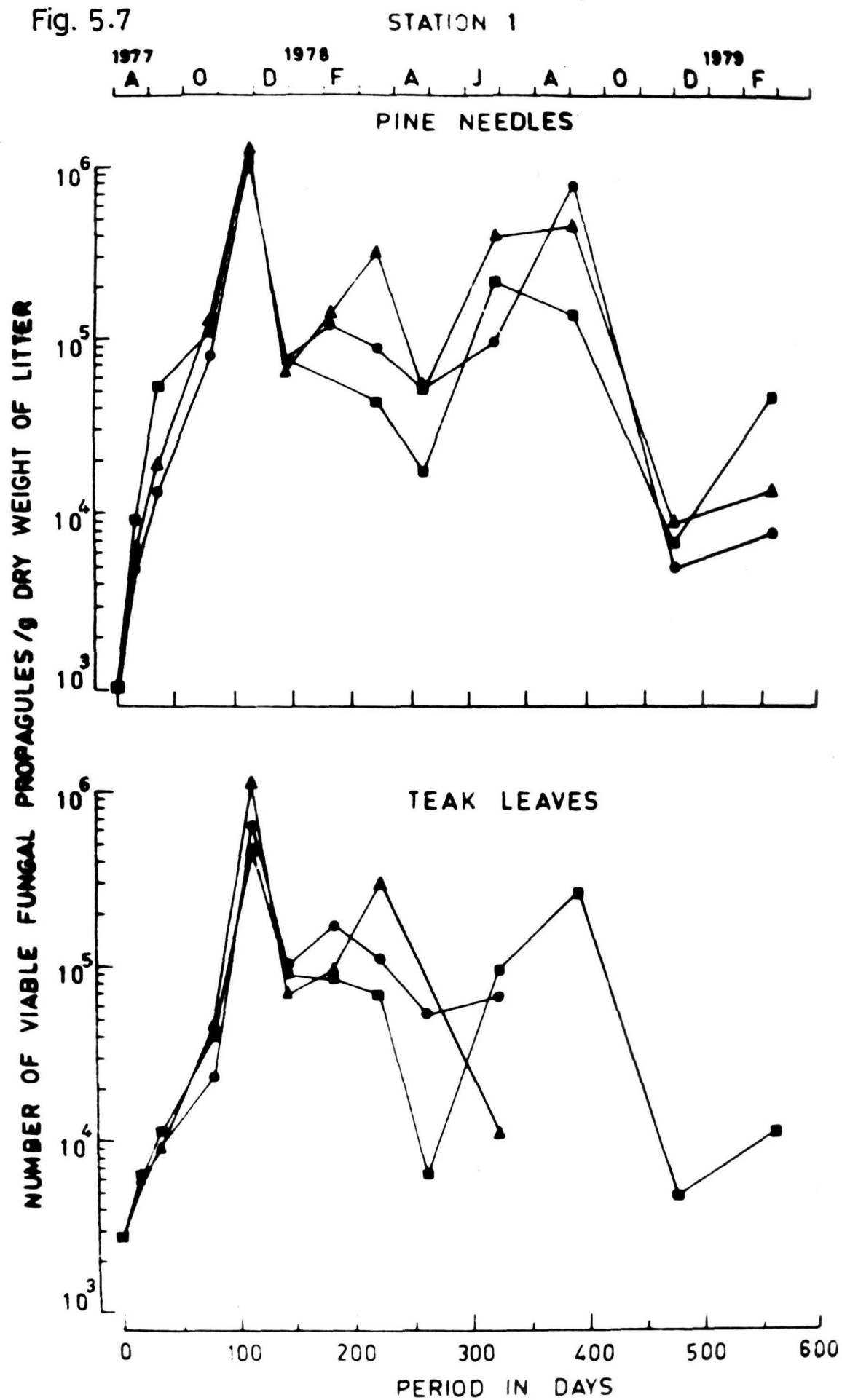


Fig.5.6. Number of viable fungal propagules per gram dry weight of pine needles and teak leaf litter processing in the lake at station 3 (August 1977 to February 1979). Circles:surface, triangles:mid-depth and squares:bottom.

Fig. 5.8

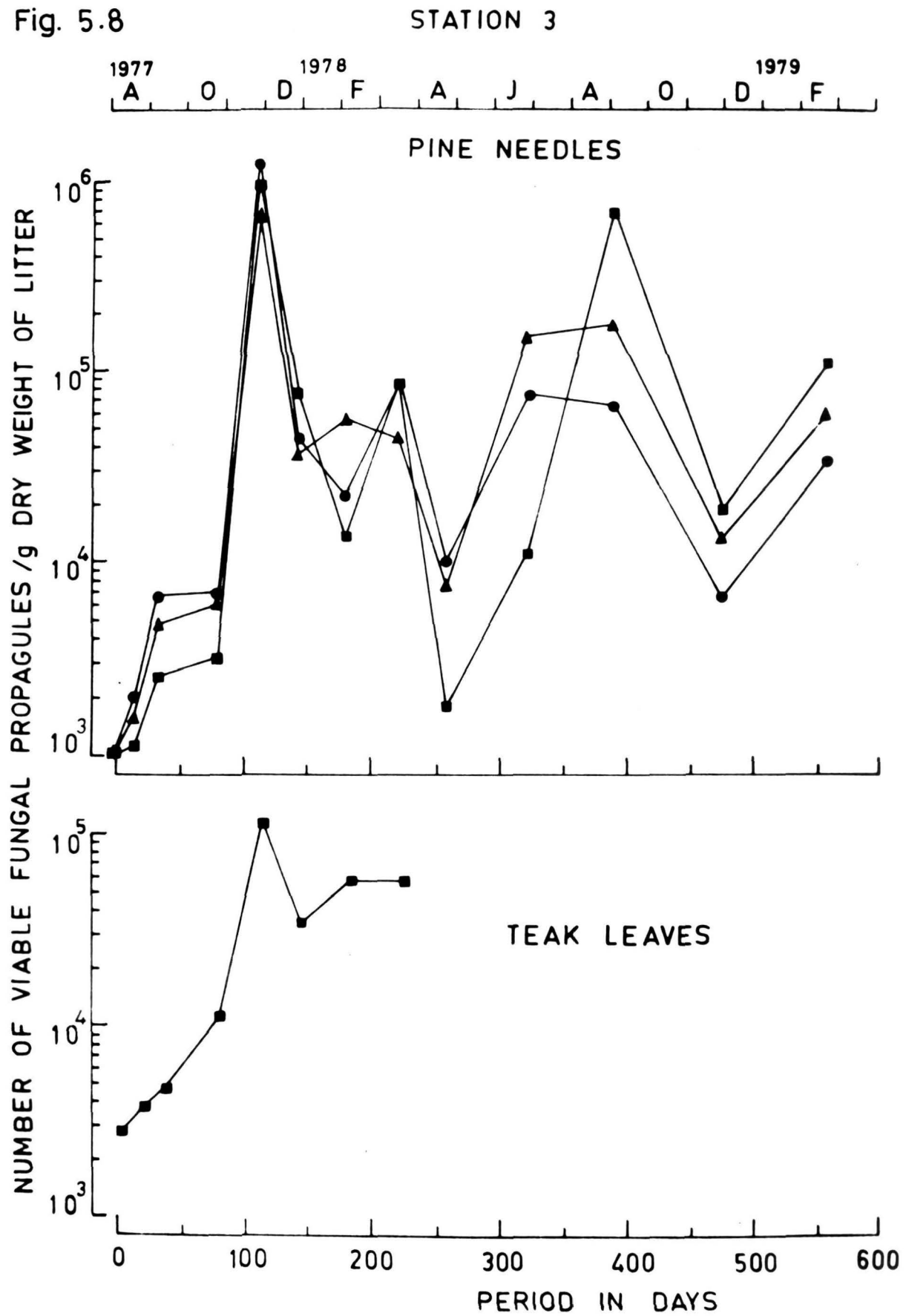


Fig.5.9. Number of viable fungal propagules per gram dry weight of pine needles and teak leaf litter processing in the lake at station 4 (August 1977 to February 1979). Circles:surface, triangles:mid-depth and squares: bottom.

Fig. 5.9

STATION 4

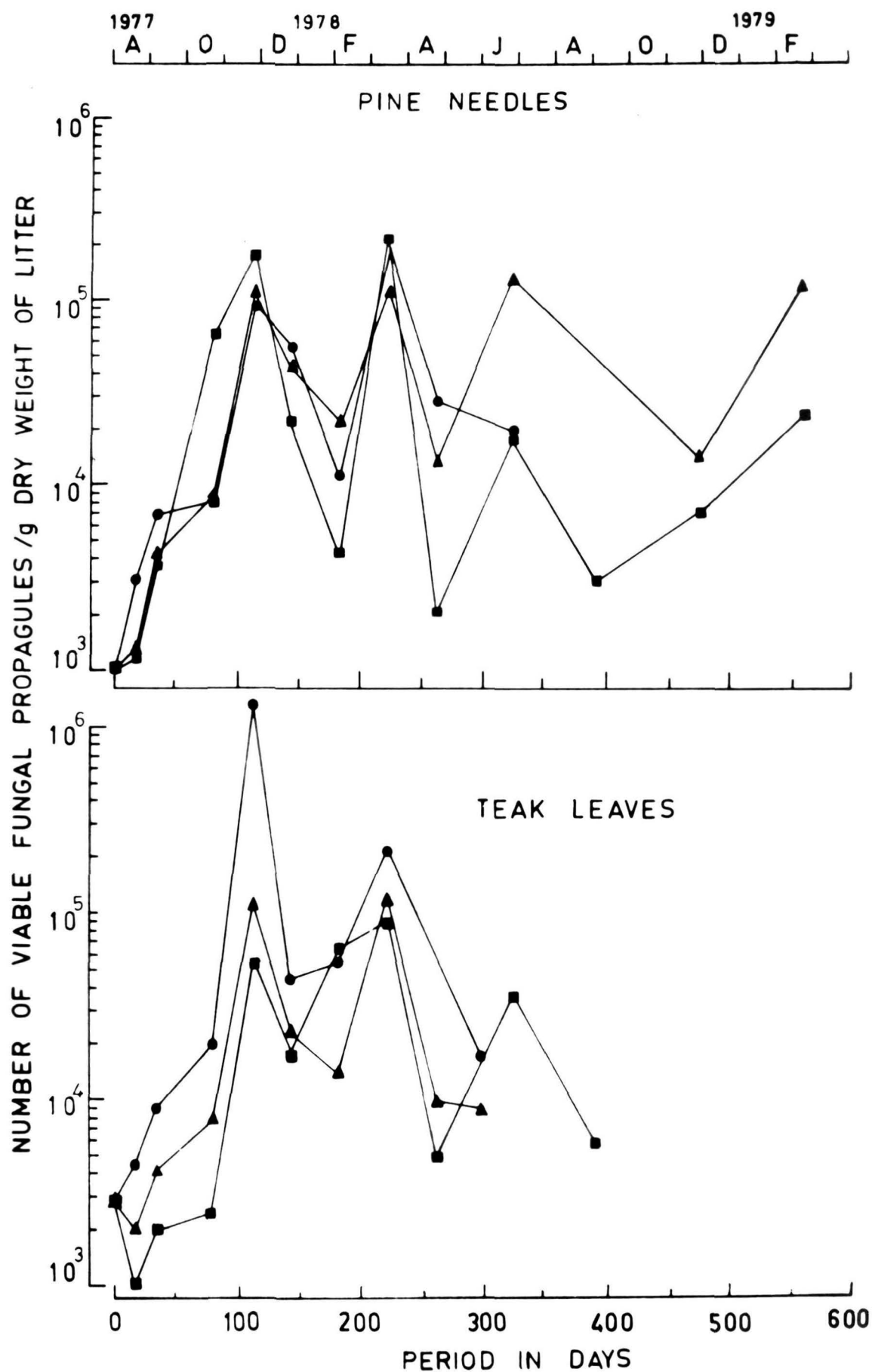


Table 5.1.: A, B and r values for regression analysis of Pine needle decomposition weight loss data (Percentage weight remaining vs. time in days).

Stations	A	B $\times 10^{-3}$	r	k/day	Half Life (days)	95% Life (days)
Station 1						
S	4.846	4.422	-0.919	.0037	167.30	810.81
M	4.726	3.252	-0.970	.0033	210.00	909.10
B	4.951	2.999	-0.929	.0026	247.50	1071.43
Station 3						
S	4.668	2.786	-0.985	.0032	216.56	937.50
M	4.967	3.001	-0.977	.0032	216.56	937.50
B	4.647	2.138	-0.977	.0032	216.56	937.50
Station 4						
S	4.553	1.627	-0.933	.0023	301.30	1304.35
M	4.680	1.772	-0.990	.0016	433.12	1875.00
B	4.602	0.836	-0.983	.0009	770.00	3333.33

S = Surface, M = Middle, B = Bottom.

Table 5.2.: A, B and r values for regression analysis of Teak Leaf decomposition weight loss data (Percentage weight remaining vs. time in days).

Stations	A	B $\times 10^{-3}$	r	k/day	Half Life (days)	95 % Life (days)
Station 1						
S	4.562	5.139	0.956	.0068	101.91	441.17
M	4.475	4.308	0.941	.0061	113.61	491.80
B	4.410	3.722	0.910	.0041	169.02	731.70
Station 2						
B	4.493	5.574	0.927	.0074	93.64	405.40
Station 3						
S	4.446	6.194	0.933	.0089	77.86	337.08
M	4.546	5.491	0.969	.0061	113.61	491.80
B	4.334	2.451	0.881	.0029	238.96	1034.48

S = Surface, M = Middle, B = Bottom.

The station and depth-wise variations in decomposition rate is given in tables 5.1 and 5.2. The data computed from the exponential decay model suggest that fastest decomposition was observed at the surface waters which slowed down as the depth increased. A comparison of table 5.1 and 5.2 shows that the rate of decomposition of teak leaves was two to four times faster than the pine needles. High values of correlation coefficient (r) between exposure time and percentage weight remaining clearly demonstrate that weight loss was a function of exposure time.

Microbiology of litter decomposition

The most conspicuous observation of the microbiology of extraneous plant litter decomposition in the lake was the initial fast colonization of the litters by various microbes which was true for both fungi and bacteria. However, a departure to this general pattern was observed at the bottom of station 4 where either a initial decrease was observed or the rate of initial colonization was very slow. Other important general pattern was a sudden fall in the microbial population after the first peak followed by a further increment. In general, three peaks of microbial populations were observed; one after hundred days, second after two hundred to two hundred fifty days and third approximately after four to five hundred days (Fig.5.4 - 5.9).

No marked difference in the microbial population

of the litters at various depths was observed at the station 1 and 3 (Fig.5.4, 5.5, 5.7, 5.8). Station 4, however, showed a clear difference in the microbial population associated with the litters at various depths which was marked by less populations of bacteria and fungi in the litters put in the deeper waters (Fig.5.6,5.9).

A comparison of microbial populations associated with decomposing plant materials at various stations showed that the populations did not vary significantly. The station to station difference were very less except at station 1 where the values were quite often higher than other two stations. The microbial populations did not vary with respect to type of litter also. The microbial population associated with the two types of litter did not show much difference and it varied within a narrow range. Also, the type of litter probably did not have much influence over the dynamics of microbial population. Because almost the same general pattern of population variation with time was observed in both the litters.

The taxonomic composition of fungal population associated with decomposing plant litters changed successively. Most of the fungi present initially were replaced by new comers within thirty days of processing in the lake. The fungal population constantly changed

for first six months. Afterwards, the population did not show any definite succession pattern. However, a few new colonizers were found during later periods of decomposition. Initially fungal population associated with the two litters were quite different but later the species composition did not differ significantly and almost same set of fungi were isolated from both the litters. The maximum number of fungal species were isolated in December, 1977 (or February, 1978 collection). Yeast populations also showed a trend almost similar to the filamentous forms. However, for most of the period yeasts were more in numbers as compared to the filamentous forms. Most of the forms belong to the class Deuteromycetes and other classes are represented by very few number of species. Also, a general perusal of the species composition depicts that majority of fungal species are terrestrial forms (Table 5.3-5.18).

Nitrogen

The concentration of nitrogen in the decomposing pine needles dropped to a quite low value after thirty days of processing in the lake water, but it was followed by a rapid increase in the nitrogen concentration reaching upto the double of the initial values at station 1. Later on again the nitrogen concentration dropped to almost the initial concentration level and then throughout the course of study it did not change appreciably. This general pattern of change in nitrogen content was, however,

Table 5.3 Fungi associated with decomposing pine needles at the surface of station 1. Upper figures are number of fungal propagules/gram dry weight of litter ($\times 10^3$). Figures in brackets are relative density (%).

Name of fungi	Initial	Aug., 22 1977	Sept., 25 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 26 1978	June, 26 1978	Sept., 2 1978	Nov., 28 1978	Feb., 22 1979
<i>Ascar racemosus</i>	-	-	-	5.47 (32.62)	102.36 (7.35)	-	-	-	-	-	3.70 (0.47)	0.75 (1.53)	17.88 (25.40)
<i>Ascar gercinelloides</i>	-	-	-	-	44.61 (3.20)	5.45 (5.12)	3.60 (3.44)	-	-	0.97 (1.17)	5.56 (0.71)	-	-
<i>Ascar hiemalis</i>	-	-	-	-	2.62 (0.19)	5.45 (5.12)	-	-	-	-	-	-	-
<i>Aspergillus niger</i>	2.27 (47.39)	1.33 (9.08)	0.66 (3.55)	0.94 (3.84)	31.00 (1.51)	1.31 (1.70)	10.80 (10.34)	-	-	0.98 (1.17)	-	-	-
<i>Penicillium chrysogenum</i>	-	4.33 (20.09)	2.60 (14.00)	-	-	-	21.60 (20.68)	40.46 (15.32)	-	-	35.15 (4.47)	-	-
<i>P. oxalicum</i>	-	-	-	-	25.87 (2.07)	34.55 (32.48)	-	-	-	-	-	-	-
<i>Nisopora monacera</i>	0.20 (4.17)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Penicillium</i> sp.	-	-	-	-	-	-	-	-	-	39.88 (40.25)	50.00 (6.35)	-	-
<i>Trichoderma koningi</i>	-	-	1.66 (5.94)	2.82 (11.53)	-	-	-	-	-	-	-	-	-
<i>T. viride</i>	-	-	-	-	-	-	19.25 (7.30)	-	-	15.56 (18.82)	3.70 (0.47)	10.37 (21.22)	1.63 (2.13)
<i>Cladosporium herbarum</i>	1.90 (39.68)	1.20 (8.19)	3.20 (17.25)	-	-	-	2.29 (0.68)	25.90 (10.94)	-	-	-	-	9.75 (12.76)
<i>Acremonium</i> sp.	-	-	-	-	-	10.91 (10.25)	-	1.91 (0.72)	-	-	-	-	-
<i>Gentriconum</i> sp.	-	-	-	-	107.61 (7.73)	0.91 (0.55)	-	-	-	-	685.88 (87.53)	-	-
<i>Fusarium</i> sp.	0.41 (8.56)	4.20 (26.66)	3.60 (19.35)	-	-	-	-	-	-	-	-	-	-
<i>Chiropus</i> sp.	-	-	-	-	-	-	-	-	-	-	-	0.73 (1.50)	-
<i>Pseudotorella</i> sp.	-	-	-	-	-	-	-	-	-	-	-	0.73 (1.50)	-
<i>Ascomycete-2</i>	-	-	-	-	-	25.46 (23.93)	68.40 (65.51)	77.03 (29.20)	-	12.64 (15.29)	-	-	-
White sterile septate	-	5.54 (24.16)	6.85 (36.29)	6.58 (26.90)	-	-	3.84 (1.45)	-	-	-	-	-	17.88 (23.40)
White sterile septate	-	-	-	-	-	21.82 (20.31)	-	42.37 (16.06)	-	12.64 (15.29)	-	-	-
Synonematales	-	-	-	-	31.00 (1.30)	-	-	1.91 (0.72)	-	-	-	-	-
<i>Pirium</i> sp.	-	-	-	-	1063.00 (76.41)	-	-	1.91 (0.73)	-	-	-	36.30 (74.26)	29.27 (38.31)
<i>Illeceporium hibisci</i>	-	-	-	5.65 (23.18)	-	-	-	-	-	-	-	-	-
Red yeast	5.04	-	-	555.53	8561.67	582.88	679.56	475.89	-	3.88	7029.63	-	-
Black yeast	-	-	-	185.48	165.35	210.94	392.29	46.26	-	-	-	-	-
White yeast	-	-	-	-	771.65	11.83	-	7.68	-	-	-	-	-
Orange yeast	-	-	-	-	-	34.55	104.40	-	-	-	-	-	-
Total filamentous fungi	4.79	14.65	15.57	24.46	1391.07	106.36	104.40	217.60	-	59.65	787.04	40.88	76.41
Total yeasts	5.04	34.60	114.43	741.01	9498.67	640.19	1078.65	662.74	-	3.89	7029.62	-	-
Total fungi	9.83	49.25	133.00	765.47	10868.74	746.47	1176.05	880.34	-	66.54	7816.66	40.88	76.41

Sample of April, 1978 was spoiled due to human interference.

Table 5.4 Fungi associated with decomposing leaf litter at the surface of station 1. Upper figures are number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density (%).

Name of Fungi	Initial	August, 22 1977	Sept., 8 1977	October, 25, 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 24 1978	June, 26 1978
<u>Neor girardinelloides</u>	6.90 (26.55)	4.33 (27.09)	2.33 (8.74)	1.94 (5.22)	1.53 (0.26)	3.25 (0.49)	2.29 (0.66)	-	-	-
<u>M. racemosus</u>	8.66 (35.37)	2.20 (14.17)	14.66 (53.01)	12.73 (34.23)	1.53 (0.26)	12.21 (1.91)	16.05 (4.74)	-	-	-
White sterile septate	4.33 (17.68)	6.00 (38.65)	6.00 (23.51)	5.88 (15.81)	-	-	-	26.78 (8.96)	-	-
<u>Trichoderma koningii</u>	1.33 (5.43)	1.33 (8.57)	2.33 (8.74)	12.73 (34.23)	-	-	-	-	-	-
<u>Phoma</u> sp	-	-	1.33 (5.00)	3.91 (10.51)	1.53 (0.26)	-	-	-	4.33 (30.15)	-
<u>M. hiemalis</u>	-	-	-	-	4.65 (8.75)	-	-	-	-	-
<u>Pythium</u> sp	-	-	-	-	519.05 (56.03)	-	-	-	-	-
<u>Aspergillus niger</u>	2.33 (9.51)	1.66 (10.69)	-	-	3.97 (8251)	1.62 (0.24)	12.61 (3.73)	-	-	-
<u>Penicillium</u> sp	1.33 (5.42)	-	-	-	12.37 (2.66)	11.39 (1.72)	9.17 (2.71)	-	-	-
Synonematales	-	-	-	-	65.12 (10.88)	0.81 (0.12)	1.15 (0.34)	-	-	-
<u>T. viride</u>	-	-	-	-	-	6.51 (0.98)	-	34.98 (11.72)	-	-
<u>Geotrichum</u> sp	-	-	-	-	-	5.69 (0.86)	-	-	-	39.58 (50.68)
<u>Ascomycete-2</u>	-	-	-	-	-	608.72 (91.66)	281.25 (56.18)	-	-	-
White sterile septate	-	-	-	-	-	13.82 (2.68)	-	-	-	-
<u>Cladosporium herbarum</u>	-	-	-	-	-	-	2.29 (0.68)	-	-	-
<u>Fusarium</u> sp	-	-	-	-	-	-	3.44 (1.02)	-	-	-
<u>Penicillium chrysogenum</u>	-	-	-	-	-	-	-	236.63 (79.31)	-	-
<u>Acromonium</u> sp	-	-	-	-	-	-	-	-	1.08 (12.44)	-
<u>Verticillium tenebrum</u>	-	-	-	-	-	-	-	-	1.08 (12.44)	-
<u>Phoma hunicola</u>	-	-	-	-	-	-	-	-	2.17 (25.08)	-
<u>Aspergillus fumigatus</u>	-	-	-	-	-	-	-	-	-	38.52 (49.32)
Red yeast	3.20	21.14	30.33	128.88	5308.51	61.01	802.23	746.91	103.32	408.76
Black yeast	-	20.00	39.68	72.51	65.12	1066.90	907.23	34.98	62.00	32.10
Cream yeast	-	-	-	-	421.67	-	-	-	-	-
White yeast	-	-	-	-	93.02	-	-	-	-	66.32
Wrinkled yeast	-	-	-	-	-	-	3.44	-	-	-
Total filamentous fungi	24.48	15.52	26.65	37.19	599.85	663.07	338.25	298.36	8.68	78.10
Total yeasts	3.20	41.14	70.01	197.01	5888.32	1126.51	1412.67	751.89	165.32	507.18
Total fungi	27.68	56.66	96.66	234.20	6488.18	1790.58	1750.92	1050.25	174.00	585.28

Table - 5.5. Fungi associated with decomposing pine needles at the middle of station 1. Upper figures are number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density (%).

Name of fungi	Initial	Aug., 22 1977	Sept., 2 1977	Oct., 26 1977	Nov., 27 1977	Dec., 27 1977	Feb., 4 1978	March, 16 1978	April, 26 1978	June, 26 1978	Sept., 2 1978	Nov., 28 1978	Feb., 22 1979
<i>Aspergillus niger</i> - 1	3.27 (47.39)	-	-	-	-	-	-	1.54 (0.94)	-	-	-	0.81 (1.01)	-
<i>Cladosporium herbarum</i>	1.96 (39.68)	6.40 (39.32)	2.33 (15.56)	-	-	-	-	-	-	-	-	-	-
<i>Fusarium oxysporum</i>	0.41 (8.56)	-	1.67 (11.15)	-	-	-	-	-	-	-	-	-	-
<i>Bispora monacera</i>	0.20 (4.17)	4.20 (25.14)	-	-	-	-	-	-	-	-	-	-	-
<i>Aspergillus fumigatus</i>	-	6.10 (36.84)	9.20 (62.12)	11.76 (16.21)	-	-	-	-	-	-	-	-	14.82 (11.43)
<i>Aspergillus</i> sp.	-	-	1.67 (11.15)	2.94 (4.08)	-	-	-	-	-	-	-	-	-
<i>Penicillium chrysogenum</i>	-	-	-	37.82 (79.72)	-	-	-	38.38 (23.68)	-	-	106.66 (21.62)	-	(11.11)
<i>Urocladus gerdinellae</i>	-	-	-	-	5.33 (0.43)	1.14 (0.84)	4.30 (3.85)	-	-	-	-	-	-
<i>U. hiemalis</i>	-	-	-	-	55.23 (2.89)	1.72 (0.82)	-	64.82 (39.62)	-	-	-	-	-
<i>Penicillium</i> sp.	-	-	-	-	749.97 (38.40)	6.07 (3.29)	17.20 (15.39)	-	-	34.37 (9.09)	56.66 (11.49)	17.07 (21.21)	-
Synanthales	-	-	-	-	1136.07 (38.18)	3.44 (1.65)	4.36 (3.65)	-	-	-	-	-	-
<i>Aspergillus</i> sp.	-	-	-	-	-	2.80 (1.34)	-	-	-	-	-	-	-
<i>Trichoderma viride</i>	-	-	-	-	-	3.44 (1.65)	-	10.52 (11.32)	-	-	-	-	1.85 (1.43)
<i>Geotrichum candidum</i>	-	-	-	-	-	4.58 (2.29)	12.90 (11.54)	-	-	343.82 (90.91)	326.66 (66.22)	-	-
<i>Cladosporium cladosporioides</i>	-	-	-	-	-	5.73 (2.75)	21.50 (19.24)	-	0.09 (0.18)	-	-	10.57 (13.13)	-
<i>Phialophora</i> sp.	-	-	-	-	-	146.84 (70.86)	51.60 (46.18)	-	458.04 (97.12)	-	-	11.36 (14.14)	-
White sterile septate	-	-	-	-	-	30.96 (14.85)	-	26.23 (16.07)	11.78 (2.50)	-	-	-	-
<i>Phoma</i> sp.	-	-	-	-	-	0.86 (0.41)	-	-	-	-	-	-	-
<i>Urocladus ramosus</i>	-	-	-	-	-	-	-	-	-	-	3.33 (0.67)	-	-
<i>Aspergillus niger</i> - 2	-	-	-	-	-	-	-	1.54 (0.94)	-	-	-	0.81 (1.01)	-
White sterile septate	-	-	-	-	-	-	-	13.09 (8.50)	-	-	-	-	25.93 (20.00)
<i>Fusarium</i> sp.	-	-	-	-	-	-	-	-	0.89 (0.18)	-	-	-	-
<i>Pythium</i> sp.	-	-	-	-	-	-	-	-	-	-	-	21.14 (26.27)	35.93 (20.00)
<i>Bispora</i> sp.	-	-	-	-	-	-	-	-	-	-	-	0.81 (1.01)	4.85 (3.76)
<i>Saprolegnia</i> sp.	-	-	-	-	-	-	-	-	-	-	-	0.94 (11.11)	0.74 (00.57)
<i>Acremonium</i> sp.	-	-	-	-	-	-	-	-	-	-	-	3.25 (4.04)	-
<i>Pseudocercaria</i> sp.	-	-	-	-	-	-	-	-	-	-	-	6.80 (8.08)	-
Red yeast	5.04	27.00	132.50	1288.23	9388.23	398.72	968.90	297.84	-	2941.35	3960.00	-	-
Black yeast	-	20.96	42.19	-	86.10	40.02	292.30	2654.32	27.21	-	-	-	-
White yeast	-	-	-	-	822.19	-	-	-	-	603.18	-	-	-
Wrinkled yeast	-	-	-	-	-	-	-	-	-	-	-	5.70	-
Orange yeast	-	-	-	-	-	-	-	47.84	-	-	-	-	-
Total filamentous fungi	4.79	16.70	14.97	72.52	1980.70	208.38	111.73	163.58	471.60	378.19	493.31	80.48	129.60
Total yeasts	5.04	47.96	174.69	1288.23	10276.91	436.74	1361.10	3000.00	27.21	3544.83	3960.00	5.70	-
Total fungi	9.83	64.66	189.66	1360.75	12247.61	645.12	1372.83	3163.58	498.81	3922.72	4553.31	86.18	129.60

Table 3.6 Fungi associated with decomposing leaf leaves at the middle of the Station 1. Upper figures are number of fungal propagules/gram dry weight of litter, Figures in brackets are relative density (%).

Name of Fungi	Initial	Aug., 22 1977	Sept., 8 1977	Oct., 23 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 24 1978	June, 26 1978
White sterile septate	4.33 (17.68)	4.66 (13.84)	6.39 (17.46)	8.32 (10.34)	-	-	-	14.52 (8.47)	-	-
<i>Penicillium chrysogenum</i>	-	6.80 (20.19)	2.33 (6.43)	11.40 (14.44)	-	-	-	55.23 (32.20)	-	-
<i>Penicillium</i> sp.	-	-	10.66 (29.41)	33.24 (42.12)	-	-	-	-	-	-
<i>Penicillium</i> sp.	1.33 (19.61)	13.33 (39.37)	12.33 (34.01)	25.93 (32.88)	54.43 (6.00)	18.27 (5.04)	15.62 (10.46)	-	-	27.24 (45.93)
<i>Uroc hiansalis</i>	-	-	-	-	2.98 (0.21)	-	-	-	-	-
<i>Geotrichum</i> sp.	-	-	-	-	57.28 (4.97)	-	7.01 (5.23)	8.72 (5.08)	-	-
<i>Synonectasis</i>	-	-	-	-	1262.44 (89.71)	7.53 (2.42)	0.78 (0.52)	-	-	-
<i>Uroc ramosus</i>	8.66 (35.37)	6.23 (18.49)	4.66 (12.60)	-	-	3.22 (1.03)	7.03 (4.71)	-	-	-
<i>Uroc circinelloides</i>	6.50 (26.35)	1.33 (3.95)	-	-	-	2.15 (0.69)	4.65 (3.13)	-	-	-
<i>Trichoderma</i> sp.	1.33 (5.43)	1.33 (3.94)	-	-	-	4.30 (1.38)	0.78 (0.52)	11.63 (7.78)	-	5.84 (9.85)
<i>Aspergillus niger</i>	2.33 (9.31)	-	-	-	-	3.22 (1.03)	-	-	-	-
<i>Aspergillus</i> sp.	-	-	-	-	-	1.07 (0.34)	-	-	-	-
<i>Ancoarcta-2</i>	-	-	-	-	-	200.00 (65.15)	97.65 (65.45)	29.06 (16.94)	-	10.69 (18.03)
White sterile septate	-	-	-	-	-	26.87 (8.61)	-	37.50 (22.04)	-	-
<i>Mitobella</i> sp.	-	-	-	-	-	35.47 (11.37)	-	-	-	-
<i>Glaesporium herbarum</i>	-	-	-	-	-	9.67 (3.10)	14.84 (9.94)	-	-	4.54 (8.16)
<i>Phoma</i> sp.	-	-	-	-	-	-	-	5.81 (3.31)	-	-
Black sterile septate	-	-	-	-	-	-	-	-	-	10.69 (18.03)
Red yeasts	3.20	27.20	54.08	92.40	9182.48	232.20	526.90	337.21	-	45.72
Black yeast	-	-	-	209.71	35.79	122.53	279.10	2415.69	-	-
Cream yeast	-	-	-	-	591.28	-	-	-	-	-
White yeast	-	-	-	-	-	17.20	-	-	-	-
Trinkled yeast	-	-	-	-	-	4.30	0.78	11.63	-	-
Orange yeast	-	-	-	-	-	-	-	69.76	-	-
Total filamentous fungi	24.46	33.60	36.25	78.91	1407.13	311.77	149.19	171.90	-	59.30
Total yeasts	3.20	27.20	54.08	382.11	9820.49	376.75	806.10	2834.29	-	45.72
Total fungi	27.66	60.80	90.33	461.02	11236.62	688.02	955.37	3005.79	-	105.02

Sample of April, 1978 was spoiled.

Table 5.7. Fungi associated with decomposing pine needles at the bottom of station 1. Upper figures are number of fungal propagules/gram dry weight of litter; figures in brackets are relative density (%).

Name of fungi	Initial	Aug., 22 1977	Sept., 25 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 26 1978	June, 26 1978	Sept., 2 1978	Nov., 28 1978	Feb., 22 1979
<i>Elepora monoceras</i>	0.20 (4.17)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Fusarium oxysporum</i>	0.41 (8.56)	4.26 (15.24)	-	-	-	-	-	-	-	-	-	-	-
<i>Aspergillus niger</i>	2.27 (47.39)	3.20 (11.44)	6.20 (17.45)	1.03 (9.28)	-	-	1.12 (1.49)	1.59 (1.58)	-	-	-	-	3.42 (0.74)
White sterile asseptate	-	13.26 (47.42)	13.80 (38.90)	4.03 (36.34)	-	-	-	-	-	-	-	-	218.00 (47.40)
<i>Aspergillus fumigatus</i>	-	4.44 (15.87)	4.60 (12.97)	3.03 (27.32)	-	-	-	-	-	-	-	-	-
<i>Aspergillus</i> sp.	-	-	8.64 (24.42)	1.00 (9.02)	-	-	-	-	-	-	-	-	-
<i>Cladogonium herbarum</i>	1.90 (39.68)	2.80 (10.01)	2.20 (6.20)	2.00 (18.04)	-	27.48 (15.71)	28.33 (37.63)	-	-	14.13 (7.00)	-	1288 (3.15)	-
<i>Necor hiemale</i>	-	-	-	-	5.23 (3.00)	8.04 (4.34)	6.80 (9.04)	-	-	8.24 (4.07)	-	-	-
<i>Geotrichum candidum</i>	-	-	-	-	10.97 (2.66)	2.01 (1.15)	9.88 (13.14)	12.84 (12.70)	-	179.77 (85.93)	111.11 (45.47)	-	-
White sterile asseptate	-	-	-	-	76.80 (18.66)	26.80 (15.32)	16.66 (22.18)	20.87 (20.63)	15.10 (42.13)	-	27.77 (1.36)	52.53 (88.45)	-
<i>Penicillium</i> sp.	-	-	-	-	27.43 (6.66)	32.84 (18.77)	12.40 (18.30)	4.82 (4.76)	-	-	-	3.14 (5.26)	-
Synonematales	-	-	-	-	289.01 (70.00)	12.06 (6.89)	-	1.59 (1.58)	-	-	2.77 (1.13)	-	-
<i>Trichoderma viride</i>	-	-	-	-	-	6.70 (3.83)	-	24.09 (23.81)	-	-	5.50 (2.25)	1.26 (2.11)	6.84 (1.40)
White sterile asseptate	-	-	-	-	-	58.98 (33.72)	-	-	6.66 (18.41)	-	-	-	-
<i>Necor racemosus</i>	-	-	-	-	-	-	-	-	-	-	-	-	16.80 (4.07)
<i>Penicillium chrysogenum</i>	-	-	-	-	-	-	-	24.09 (23.81)	5.66 (15.88)	-	25.00 (10.23)	-	205.13 (44.44)
<i>Phoma</i> sp.	-	-	-	-	-	-	-	11.23 (11.11)	-	-	-	-	-
<i>Verticillium leucon</i>	-	-	-	-	-	-	-	-	1.88 (5.24)	-	-	-	-
<i>Acremonium</i> sp.	-	-	-	-	-	-	-	-	6.66 (18.41)	-	-	-	-
<i>Fusarium</i> sp.	-	-	-	-	-	-	-	-	-	-	72.22 (29.53)	-	-
<i>Abidia</i> sp.	-	-	-	-	-	-	-	-	-	-	-	0.63 (1.05)	-
<i>Whiteopus nigricans</i>	-	-	-	-	-	-	-	-	-	-	-	-	8.55 (1.85)
Red yeast	5.04	61.24	498.25	962.60	10941.82	510.72	94.50	271.47	15.85	1634.61	2355.55	9.43	-
Black yeast	-	-	-	145.49	-	64.34	46.60	25.68	9.44	284.64	-	-	-
Wrinkled yeast	-	-	-	-	-	-	10.14	-	-	-	-	-	-
Orange yeast	-	-	-	-	-	-	-	30.50	-	-	-	-	-
Total filamentous fungi	4.79	27.96	35.46	11.09	411.44	174.94	75.19	101.12	135.84	202.14	244.37	99.73	461.53
Total yeasts	5.04	61.24	498.25	1108.09	10941.82	575.06	141.10	327.65	28.32	1919.25	2355.55	9.43	-
Total fungi	9.83	89.20	533.66	1119.18	11353.26	749.97	216.29	428.77	164.16	2121.49	2999.92	69.16	461.53

Table 5.6 Fungi associated with decomposing test leaves at the bottom of the station 1. Upper figures are number of fungal propagules/gram dry weight of litter; figures in brackets are relative density (%).

Name of Fungi	Initial 1977	Aug., 22 1977	Sept., 8 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 15 1978	April, 26 1978	June, 26 1978	Sept., 2 1978	Nov., 28 1978
<u>Mucor racemosus</u>	8.66 (35.37)	6.66 (15.45)	4.84 (9.85)	10.25 (35.61)	-	1.73 (5.71)	7.88 (4.04)	-	1.69 (5.64)	-	3.51 (2.29)	-
<u>Trichoderma koningi</u>	1.33 (5.42)	2.33 (5.40)	5.66 (11.51)	13.58 (49.87)	-	-	-	-	-	-	-	1.23 (3.06)
<u>Penicillium</u> sp	1.33 (19.61)	12.66 (29.38)	15.33 (31.19)	3.41 (12.51)	20.33 (5.75)	20.90 (8.57)	12.40 (6.36)	-	-	-	-	-
<u>Mucor hiemalis</u>	-	-	-	-	14.77 (4.18)	-	-	-	-	-	-	-
<u>Geotrichum</u> sp	-	-	-	-	18.30 (5.23)	1.74 (0.71)	15.77 (8.09)	6.13 (3.06)	1.69 (5.64)	68.00 (95.60)	128.07 (83.91)	-
Symmetrales	-	-	-	-	281.44 (79.66)	-	1.12 (0.57)	4.60 (3.86)	-	-	-	-
White sterile septate	4.33 (17.68)	11.45 (26.57)	11.66 (23.72)	-	18.30 (5.23)	10.45 (4.29)	-	22.99 (19.00)	-	-	-	7.40 (18.48)
<u>Mucor circinellides</u>	6.30 (26.55)	6466 (15.45)	-	-	-	12.18 (5.00)	-	1.83 (1.26)	-	-	-	-
<u>Trichoderma viride</u>	-	-	-	-	-	34.83 (14.29)	7.88 (4.04)	29.11 (24.05)	2.56 (13.08)	3.15 (4.43)	5.26 (3.45)	-
<u>Aspergillus niger</u>	2.33 (9.51)	3.33 (7.73)	11.66 (23.72)	-	-	62.68 (25.72)	1.12 (0.57)	3.06 (2.53)	-	-	-	-
Ascomycete 2	-	-	-	-	-	85.32 (35.00)	135.10 (69.38)	-	5.13 (26.21)	-	-	11.11 (27.70)
White sterile septate	-	-	-	-	-	-	-	-	-	-	-	-
<u>Stilbella</u> sp	-	-	-	-	-	6.96 (2.85)	-	-	-	-	-	-
<u>Cladoperium herbarum</u>	-	-	-	-	-	6.96 (2.85)	13.51 (6.93)	22.99 (19.00)	-	-	-	-
<u>Mucor hiemalis</u> -	-	-	-	-	-	-	-	4.60 (3.86)	-	-	-	-
White sterile septate	-	-	-	-	-	-	-	3.06 (2.53)	-	-	-	-
<u>Penicillium chrysogenum</u>	-	-	-	-	-	-	-	21.45 (17.72)	1.69 (8.64)	15.79 (10.34)	-	-
<u>Penicillium</u> sp	-	-	-	-	-	-	-	1.53 (1.26)	-	-	-	-
<u>Verticillium tenerum</u>	-	-	-	-	-	-	-	-	1.69 (8.64)	-	-	-
<u>Phoma humicola</u>	-	-	-	-	-	-	-	-	2.56 (13.08)	-	-	-
<u>Phoma</u> sp.	-	-	-	-	-	-	-	-	-	-	-	10.51 (46.15)
<u>Aspergillus</u> sp.	-	-	-	-	-	-	-	-	-	-	-	1.88 (3.06)
Red yeast	3.20	15.11	61.51	-	3711.11	625.14	592.34	398.46	30.77	612.10	2526.30	4.94
Black yeast	-	-	-	-	-	26.12	23.65	45.97	11.10	49.01	-	-
Orange yeast	-	-	-	-	-	-	-	124.15	-	-	-	-
Cream yeast	-	-	-	-	486.88	-	-	-	-	-	-	-
Wrinkled yeast	-	-	-	-	68.30	24.37	10.14	7.66	-	257.79	-	1.83
Total filamentous fungi	24.48	43.09	41.15	27.25	353.54	245.78	194.86	121.04	19.57	71.15	152.63	40.11
Total yeasts	3.20	15.11	61.51	0.00	4266.49	675.63	626.33	576.24	41.87	918.90	2526.31	6.77
Total fungi	27.68	58.20	110.66	27.25	4622.03	919.42	821.19	697.28	61.44	990.05	2679.94	46.88

Table-5.9 Fungi associated with decomposing pine needles at the surface of station 5. Upper figures are number of fungal propagules/gram dry weight of litter (x10³). Figures in brackets are relative density (%).

Name of fungi	Initial	Aug., 22 1977	Sept., 22 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 26 1978	June, 26 1978	Sept., 2 1978	Nov., 20 1978	Feb., 22 1979
<i>Aspergillus niger</i>	0.20 (4.17)	1.33 (5.36)	-	-	-	-	-	-	-	-	-	-	-
<i>Fusarium oxysporum</i>	0.41 (3.36)	0.66 (7.62)	-	-	-	-	-	-	-	-	-	-	-
<i>Cladosporium herbarum</i>	1.90 (39.60)	2.00 (23.10)	6.00 (16.66)	-	-	-	-	-	-	-	-	-	-
<i>Aspergillus niger</i>	2.27 (47.39)	2.00 (23.10)	9.00 (25.00)	2.44 (11.13)	-	1.26 (6.75)	-	-	-	-	-	-	-
<i>Aspergillus fumigatus</i>	-	2.66 (30.70)	15.00 (41.66)	4.68 (22.26)	-	-	0.91 (0.80)	-	-	-	-	-	12.12 (3.95)
<i>Penicillium chrysogenum</i>	-	-	6.00 (16.66)	10.56 (48.17)	-	-	-	-	5.84 (12.11)	10.85 (58.84)	-	-	-
<i>Pythium</i> sp.	-	-	-	4.05 (10.47)	-	-	94.96 (51.90)	-	-	-	-	-	-
<i>Mucor circinelloides</i>	-	-	-	-	582.97 (100.00)	5.83 (3.30)	-	-	-	-	-	-	-
<i>M. bisporus</i>	-	-	-	-	-	-	-	-	1.46 (3.02)	-	-	-	-
<i>Aspergillus</i> sp.	-	-	-	-	-	3.16 (1.88)	-	-	-	-	-	-	-
<i>Penicillium</i> sp.	-	-	-	-	-	13.79 (9.44)	23.05 (12.49)	-	-	-	-	-	-
<i>Trichoderma viride</i>	-	-	-	-	-	5.83 (3.30)	5.83 (3.00)	13.14 (9.41)	-	-	4.45 (1.31)	0.83 (0.30)	-
<i>Geotrichum candidum</i>	-	-	-	-	-	3.95 (2.36)	-	-	11.69 (24.24)	-	202.20 (59.47)	-	-
<i>Cladosporium herbarum</i>	-	-	-	-	-	11.85 (7.04)	6.44 (3.50)	33.69 (36.46)	-	-	-	-	80.50 (23.63)
<i>Sarvalaria</i> sp.	-	-	-	-	-	1.26 (0.75)	2.76 (1.80)	-	-	-	-	-	-
Synneutales	-	-	-	-	-	2.37 (1.41)	0.91 (0.51)	-	-	-	-	-	-
<i>Phialophora</i> sp.	-	-	-	-	-	58.45 (32.88)	49.80 (27.00)	47.33 (29.40)	30.46 (42.43)	-	-	4.17 (41.70)	6.06 (1.77)
White sterile septate	-	-	-	-	-	36.85 (16.03)	-	39.77 (24.71)	5.77 (9.19)	7.61 (41.16)	48.89 (14.38)	-	-
<i>Phoma</i> sp.	-	-	-	-	-	1.26 (0.75)	-	-	-	-	-	-	-
<i>Acromonium</i> sp.	-	-	-	-	-	-	-	-	-	-	84.46 (24.84)	-	-
<i>Rhizopus</i> sp.	-	-	-	-	-	-	-	-	-	-	-	0.83 (0.30)	-
<i>Aspergillus</i> sp.	-	-	-	-	-	-	-	-	-	-	-	0.83 (0.30)	-
<i>Pseudotorula</i> sp.	-	-	-	-	-	-	-	-	-	-	-	3.34 (33.40)	-
<i>Mucor racemosus</i>	-	-	-	-	-	-	-	-	-	-	-	-	26.26 (7.69)
White sterile septate	-	-	-	-	-	-	-	-	-	-	-	-	216.16 (63.32)
Red yeast	5.04	11.94	-	39.83	11503.60	105.04	13.83	45.45	23.39	454.24	300.00	-	-
Black yeast	-	-	-	9.76	334.77	147.69	22.13	623.16	23.39	5.44	-	-	-
Orange yeast	-	-	-	-	-	-	-	26.50	5.77	-	-	32.50	-
White yeast	-	-	-	-	-	-	-	-	-	249.44	-	23.32	-
Total filamentous fungi	4.79	8.66	36.00	21.93	582.97	167.26	184.39	160.91	48.22	18.49	340.00	10.00	341.40
Total yeasts	5.04	11.94	30.66	89.59	11638.37	252.73	34.96	685.11	55.35	709.12	300.00	55.82	-
Total fungi	9.83	20.60	66.66	71.52	12421.34	419.99	220.35	856.02	103.77	727.61	640.00	65.82	341.40

Table. 5.10 Fungi associated with decomposing pine needles at the middle of station 3. Upper figures are number of fungal propagules/gram dry weight of litter; figures in brackets are relative density (%).

Name of Fungi	Initial 1977	Aug., 22 1977	Sept., 25 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 26 1978	June, 26 1978	Sept., 2 1978	Nov., 28 1978
<i>Biscora monocera</i>	0.20 (4.17)	-	-	-	-	-	-	-	-	-	-	-
<i>Fusarium oxysporum</i>	0.41 (8.56)	3.66	12.18 (37.49)	-	-	-	-	-	-	-	-	-
<i>Urocybe hiemalis</i>	-	6.10	16.25 (50.01)	0.96 (4.27)	-	5.45 (4.57)	-	1.70 (1.90)	1.14 (2.14)	-	-	-
<i>Trichoderma konigii</i>	-	-	4.06 (12.30)	2.94 (13.98)	-	-	-	-	-	-	-	-
Sterile white septate	-	3.44	-	10.76 (47.88)	-	-	-	-	-	-	-	-
<i>Gestrichum</i>	-	-	-	7.01 (35.07)	277.08 (75.72)	-	2.42 (0.45)	9.39 (9.61)	1.14 (2.14)	130.74 (82.05)	270.37 (72.64)	-
<i>Urocybe ramosa</i>	-	-	-	-	7.84 (2.14)	-	0.81 (0.15)	-	-	-	1.85 (0.30)	-
<i>Cladoperium</i>	1.90 (39.65)	-	-	-	81.03 (22.14)	-	8.10 (1.51)	51.87 (51.94)	11.55 (21.78)	5.14 (2.79)	7.41 (2.00)	-
<i>Urocybe sarcinilloides</i>	-	-	-	-	-	1.37 (1.14)	0.81 (0.15)	-	1.14 (3.14)	-	3.70 (1.00)	-
<i>Aspergillus niger</i>	2.27 (47.39)	-	-	-	-	1.37 (1.14)	-	-	-	-	-	-
<i>Penicillium</i> sp.	-	-	-	-	-	13.70 (11.42)	18.60 (3.47)	-	-	25.00 (14.04)	-	-
Synonatales-1	-	-	-	-	-	3.42 (2.85)	1.61 (0.30)	-	-	-	-	-
<i>Phialophora</i> sp.	-	-	-	-	-	85.20 (46.29)	45.30 (8.47)	-	23.16 (43.56)	-	-	1.95 (5.69)
White sterile septate	-	-	-	-	-	32.90 (27.44)	403.62 (75.50)	23.05 (23.10)	11.58 (21.78)	-	18.51 (4.97)	-
<i>Phoma</i> sp.	-	-	-	-	-	3.42 (2.85)	-	-	-	2.04 (1.11)	-	24.80 (71.45)
Synonatales-2	-	-	-	-	-	2.74 (2.28)	-	-	-	-	-	-
<i>Erythium</i> sp.	-	-	-	-	-	-	10.51 (1.96)	-	-	-	-	-
<i>Aspergillus fumigatus</i>	-	-	-	-	-	-	39.63 (7.41)	-	-	-	-	-
<i>Aspergillus</i> sp.	-	-	-	-	-	-	1.61 (0.30)	-	-	-	-	-
<i>Trichoderma viride</i>	-	-	-	-	-	-	1.61 (0.30)	-	-	-	1.05 (0.50)	6.88 (20.06)
<i>Penicillium chrysogenum</i>	-	-	-	-	-	-	-	13.43 (13.43)	1.14 (2.14)	-	22.20 (5.96)	-
<i>Pepparia</i> sp.	-	-	-	-	-	-	-	-	2.29 (4.30)	-	-	-
<i>Equarium</i> sp.	-	-	-	-	-	-	-	-	-	-	46.30 (12.84)	-
<i>Curvularia lunata</i>	-	-	-	-	-	-	-	-	-	-	-	0.96 (2.89)
Red yeast	5.04	-	-	19.60	2850.62	146.65	12.13	144.10	3.46	877.72	1322.22	53.92
Black yeast	-	-	-	18.63	-	92.51	-	170.97	17.39	-	-	-
White yeast	-	-	-	-	3063.60	-	-	11.52	1.14	421.31	-	-
Orange yeast	-	-	-	-	-	-	-	-	-	-	-	43.13
Total filamentous fungi	4.79	12.20	32.49	22.47	365.95	119.90	534.65	99.88	53.17	183.72	372.19	34.19
Total yeasts	5.04	3.46	16.17	38.23	5944.22	239.16	12.13	326.59	22.01	1299.03	1322.22	97.05
Total fungi	9.83	15.66	48.66	60.70	6310.17	359.06	546.78	426.43	75.18	1482.77	1694.41	131.34

Table 5.11 - Fungi associated with decomposing pine needles at the bottom of station 3. Upper figures are number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density (%).

Name of fungi	Initial	Aug. 22 1977	Sept. 25 1977	Oct. 25 1977	Nov. 27 1977	Dec. 27 1977	Feb. 6 1978	March 16 1978	April 26 1978	June 26 1978	Sept. 2 1978	Nov. 28 1978	Feb. 22 1979
<i>Aspergillus niger</i>	0.20 (4817)	-	-	-	-	-	-	-	-	-	-	-	-
<i>Pythium</i> sp.	-	-	-	-	-	-	-	-	-	-	-	26.83 (50.00)	-
<i>Trichoderma konigii</i>	-	1.33 (12.48)	2.66 (22.22)	7.69 (23.71)	-	-	-	-	-	-	-	-	-
<i>Geotrichum candidum</i>	-	4.00 (37.56)	2.66 (22.22)	15.38 (47.42)	230.08 (89.46)	4.42 (1.29)	1.23 (1.60)	6.56 (13.65)	-	-	1042.22 (95.32)	7.32 (13.64)	-
White sterile septate	-	-	1.33 (11.11)	0.85 (2.62)	-	-	-	9.98 (15.90)	-	-	-	-	195.95 (56.72)
<i>Penicillium chrysogenum</i>	-	-	5.32 (44.44)	1.69 (5.21)	-	-	-	2.85 (4.54)	-	-	-	-	62.62 (18.12)
<i>Fusarium</i> sp.	0.41 (0.56)	2.66 (24.97)	-	6.82 (21.02)	-	-	-	2.85 (4.54)	-	5.85 (6.46)	-	-	-
<i>Urocybe circinelloides</i>	-	-	-	-	16.60 (6.45)	-	-	-	-	-	22.22 (2.03)	-	-
White sterile septate	-	-	-	-	2.37 (0.92)	28.06 (3.19)	28.25 (26.40)	-	-	4.66 (5.14)	-	-	-
<i>Phialophora</i> sp.	-	-	-	-	7.12 (2.76)	236.68 (75.00)	36.21 (47.21)	18.54 (39.55)	5.23 (30.00)	40.93 (45.18)	-	19.51 (36.56)	-
<i>Urocybe hiemalis</i>	-	-	-	-	-	1.47 (0.43)	1.23 (1.60)	5.69 (9.05)	-	-	-	-	-
<i>Aspergillus niger</i>	2.27 (47.39)	1.33 (12.48)	-	-	-	1.47 (0.43)	-	-	-	-	-	-	-
<i>Aspergillus</i> sp.	-	-	-	-	-	1.47 (0.43)	0.61 (0.80)	-	1.74 (10.00)	19.47 (21.49)	-	-	-
<i>Penicillium</i> sp.	-	-	-	-	-	26.55 (7.75)	6.75 (8.80)	4.74 (10.00)	1.74 (10.00)	-	6.67 (0.61)	-	-
<i>Trichoderma viride</i>	-	-	-	-	-	1.47 (0.43)	-	9.98 (15.90)	-	-	-	-	8.09 (2.34)
<i>Gladosporium herbarum</i>	1.90 (39.66)	1.33 (12.48)	-	-	-	11.00 (3.45)	6.14 (8.00)	-	-	-	8.89 (0.81)	-	50.50 (14.62)
Synonymatales-1	-	-	-	-	-	5.90 (1.72)	0.61 (0.80)	2.85 (4.54)	-	-	-	-	-
Synonymatales-2	-	-	-	-	-	2.96 (0.86)	-	-	-	-	-	-	-
<i>Aspergillus fumigatus</i>	-	-	-	-	-	-	0.61 (0.80)	-	-	-	-	-	-
<i>Aspergillus niger</i>	-	-	-	-	-	-	0.61 (0.80)	-	-	-	-	-	-
<i>Penicillium</i> sp.	-	-	-	-	-	-	8.23 (1.60)	-	-	-	-	-	-
<i>Curvularia</i>	-	-	-	-	-	-	1.23 (1.60)	-	-	-	-	-	-
<i>Colletotrichum</i> sp.	-	-	-	-	-	-	-	1.41 (2.25)	-	-	-	-	-
<i>Hyphomycetes</i> sp.	-	-	-	-	-	-	-	-	6.97 (40.00)	-	-	-	-
<i>Verticillium tomentosum</i>	-	-	-	-	-	-	-	-	1.74 (10.00)	-	-	-	-
<i>Phoma huicicola</i>	-	-	-	-	-	-	-	-	-	9.74 (10.75)	-	-	-
<i>Phoma</i> sp.	-	-	-	-	-	-	-	-	-	0.96 (1.06)	-	-	-
<i>Urocybe racemosa</i>	-	-	-	-	-	-	-	-	-	-	13.33 (2.22)	-	28.28 (9.19)
Red yeast	5.04	0.33	-	-	6091.50	147.50	41.12	219.55	-	-	299.11	90.23	749.49
Black yeast	-	-	-	-	-	272.67	14.73	578.16	-	-	-	-	-
White yeast	-	-	-	-	3104.94	2.95	-	-	-	-	-	-	-
Orange yeast	-	-	-	-	-	-	-	5.56	-	-	-	37.40	-
Total filamentous fungi	4.79	10.65	11.97	32.43	287.17	342.19	76.70	62.71	17.42	90.58	1080.04	53.66	345.45
Total yeasts	5.04	0.33	14.69	-	9196.24	423.32	55.85	806.55	-	16.55	4071.15	127.63	749.48
Total fungi	9.83	10.98	26.66	32.43	9453.41	765.41	132.55	869.26	17.42	107.13	7071.15	181.29	1094.93

Table 5.12. Fungi associated with decomposing beak leaves at the bottom of the station 3. Upper figures number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density(%).

Name of fungi	Initial	Aug., 22 1977	Sept., 8 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978
White sterile asenate	4.33 (17.66)	12.04 (50.40)	4.00 (16.69)	9.37 (38.25)	-	-	-	-
White sterile asenate	-	-	10.64 (44.41)	91.67 (36.93)	-	-	32.74 (19.17)	35.08 (25.45)
<u>Penicillium</u> sp	1.33 (5.43)	7.68 (31.12)	6.66 (27.60)	12.50 (11.01)	-	-	-	-
<u>Mucor racemosus</u>	8.66 (35.37)	-	-	-	27.08 (2.27)	-	22.22 (13.01)	-
<u>Geotrichum</u> sp	-	-	-	-	200.95 (16.91)	-	1.16 (0.68)	-
<u>Cladosporium</u> sp	-	-	-	-	202.93 (17.04)	-	-	40.10 (29.10)
<u>Cylindrophora</u> sp	-	-	-	-	757.56 (63.76)	-	-	-
<u>Mucor circinellides</u>	6.30 (26.85)	4.02 (16.80)	2.66 (11.10)	-	-	1.08 (0.85)	-	-
<u>Trichoderma koningi</u>	1.33 (5.43)	0.67 (3.14)	-	-	-	6.50 (3.35)	-	-
<u>Asergillus niger</u>	2.33 (9.51)	2.01 (9.40)	-	-	-	1.08 (0.85)	101.74 (59.59)	-
<u>Asergillus</u> sp	-	-	-	-	-	3.25 (1.67)	-	-
Ascomycete-2	-	-	-	-	-	187.33 (61.01)	-	-
White sterile asenate	-	-	-	-	-	21.7 (11.11)	-	-
<u>Stilbella</u> sp	-	-	-	-	-	2.17 (1.11)	-	-
<u>Curvularia</u> sp	-	-	-	-	-	1.08 (0.85)	-	5.01 (3.64)
<u>Trichoderma viride</u>	-	-	-	-	-	-	12.86 (7.53)	20.08 (14.85)
<u>Penicillium chrysogenum</u>	-	-	-	-	-	-	-	30.08 (21.81)
Syncomatales	-	-	-	-	-	-	-	5.01 (3.64)
<u>Papularia</u> sp	-	-	-	-	-	-	-	2.51 (1.82)
Red yeast	3.20	16.61	24.34	-	-	44.24	108.71	192.98
Black yeast	-	-	-	-	-	114.28	301.72	220.85
Orange yeast	-	-	-	-	-	-	-	25.06
Winkled yeast	-	-	-	-	-	1.08	-	-
Total filamentous fungi	24.48	21.39	23.96	113.52	1186.13	194.19	170.72	137.84
Total yeasts	3.20	16.61	24.34	-	-	159.60	410.48	438.59
Total fungi	27.68	38.00	48.00	113.52	1186.13	353.79	581.20	576.43

Table 5.13. Fungi associated with decomposing pine needles at the surface of the station 4. Upper figures are number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density (%).

Name of Fungi	Initial	Aug., 22 1977	Sept., 25 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 26 1978	June, 26 1978
<u>Fusarium oxysporum</u>	0.41 (8.56)	0.66 (9.49)	1.00 (5.13)	-	-	-	-	-	-	-
<u>Bispora monacensis</u>	0.20 (4.17)	0.66 (9.49)	-	-	-	-	-	-	-	-
<u>Trichoderma koningii</u>	-	-	1.30 (7.70)	5.49 (30.00)	-	-	-	-	-	-
<u>Penicillium</u> sp	-	-	3.00 (15.50)	5.49 (30.00)	-	20.51 (4.25)	4.77 (6.40)	-	-	-
<u>Cladosporium herbarum</u>	1.90 (38.56)	2.66 (30.27)	6.00 (30.77)	-	127.33 (28.11)	36.92 (7.66)	6.60 (8.96)	44.16 (28.20)	-	-
<u>Phoma</u> sp	-	-	8.00 (41.02)	-	33.70 (7.44)	-	-	-	-	-
<u>Aspergillus</u> sp	-	-	-	-	11.23 (2.48)	-	-	-	-	20.82 (10.50)
White sterile septate	-	-	-	-	44.94 (9.95)	24.61 (5.10)	15.15 (24.36)	80.30 (51.26)	15.33 (7.28)	-
<u>Phialophora</u> sp	-	-	-	-	183.50 (40.50)	378.48 (78.77)	44.90 (60.25)	-	197.44 (92.23)	14.95 (7.72)
<u>Penicillium</u> sp	-	-	-	-	44.94 (9.93)	-	-	-	-	-
Sphaeropsidales	-	-	-	-	7.49 (1.17)	-	-	-	-	-
<u>Usher hiemalis</u>	-	-	-	-	-	2.05 (0.42)	-	-	-	-
<u>Aspergillus</u> (yellow)	-	-	-	-	-	4210 (0.88)	-	-	-	-
<u>Trichoderma viride</u>	-	-	-	-	-	2.05 (0.42)	-	-	-	-
<u>Geotrichum</u> sp.	-	-	-	-	-	8.20 (1.70)	-	30.12 (19.33)	-	1.06 (0.55)
<u>Curvularia</u> sp	-	-	-	-	-	4.10 (0.88)	-	-	-	-
<u>Aspergillus niger</u>	2.27 (47.39)	2.97 (42.73)	-	-	-	-	-	1.98 (1.27)	-	-
<u>Verticillium tomentosum</u>	-	-	-	-	-	-	-	-	1.09 (0.51)	-
<u>Acromonium</u> sp	-	-	-	-	-	-	-	-	-	13.90 (7.10)
<u>Alternaria</u> sp	-	-	-	-	-	-	-	-	-	2.12 (1.09)
<u>Fusarium</u> sp	-	-	-	-	-	-	-	-	-	2.12 (1.09)
<u>Phoma humicola</u>	-	-	-	-	-	-	-	-	-	139.10 (71.86)
Red yeast	5.04	-	-	65.68	310.83	14.36	35.35	1170.66	58.80	4.27
White yeast	-	-	-	-	157.83	8.20	-	-	-	-
Orange yeast	-	-	-	-	32.82	32.82	178.68	176.88	-	-
Black yeast	-	-	-	-	-	10.24	-	367.47	-	-
Uninked yeast	-	-	-	-	-	-	-	1.95	-	-
Total filamentous fungi	4.79	8.95	19.50	10.98	453.13	482.13	184.68	156.56	214.06	193.50
Total yeasts	5.04	23.38	50.16	65.68	868.13	65.62	35.35	1714.81	58.80	4.27
Total fungi	9.83	30.33	69.66	79.66	921.26	547.64	109.85	1871.37	272.86	197.85

Table 5.14. Fungi associated with decomposing tank leaves at the surface of station 4. Upper figures are number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density (%).

Name of Fungi	Initial 1977	Aug., 22 1977	Sept., 6 1977	Oct., 23 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 24 1978	June, 26 1978
<i>Mucor circinelloides</i>	6.50 (26.55)	6.28 (23.53)	3.33 (12.52)	3.95 (37.49)	17.26 (1.40)	-	-	-	-	-
White sterile asseptate	4.33 (17.68)	-	-	14.92 (62.50)	-	17.19 (4.20)	338.75 (74.06)	117.12 (56.52)	-	10.00 (7.10)
<i>Mucor racemosus</i>	8.66 (33.37)	7.88 (29.41)	5.90 (16.80)	-	109.69 (9.82)	2.63 (0.66)	2.71 (0.59)	3.00 (1.45)	-	-
<i>Penicillium</i> sp	1.33 (5.43)	4.71 (17.64)	6.64 (24.97)	-	56.74 (4.61)	7.90 (1.97)	10.26 (2.24)	-	-	113.10 (80.18)
<i>Geotrichum</i> sp	-	-	-	-	834.07 (67.75)	2.36 (0.56)	1.35 (0.30)	-	-	-
<i>Cladosporium</i> sp	-	-	-	-	214.81 (17.43)	10.32 (2.63)	28.74 (5.63)	72.10 (34.80)	-	4.00 (2.84)
<i>Trichoderma</i> sp	1.33 (5.43)	1.57 (5.98)	1.66 (6.24)	-	-	5.26 (1.31)	-	-	-	-
Ascomycete	-	-	-	-	-	331.10 (87.60)	46.07 (10.07)	-	-	-
<i>Synnematale</i> sp	-	-	-	-	-	2.63 (0.66)	-	-	-	1.98 (1.40)
<i>Curvularia</i> sp	-	-	-	-	-	10.31 (0.33)	-	-	-	-
<i>Aspergillus niger</i>	2.33 (9.31)	6.28 (23.53)	9.96 (37.45)	-	-	-	4.06 (0.88)	-	-	1.98 (1.40)
<i>Fusarium</i> sp	-	-	-	-	-	-	25.48 (2.89)	-	-	-
<i>Trichoderma viride</i>	-	-	-	-	-	-	-	6.00 (2.89)	-	-
<i>Penicillium chrysogenum</i>	-	-	-	-	-	-	-	9.01 (4.35)	-	-
<i>Acronosium</i> sp	-	-	-	-	-	-	-	-	-	10.00 (7.10)
Red yeast	3.20	17.97	63.07	-	-	39.24	24.40	1288.30	-	32.01
Black yeast	-	-	-	174.62	11745.63	22.35	69.10	585.58	-	-
White yeast	-	-	-	-	-	1.31	-	-	-	-
Orange yeast	-	-	-	-	-	-	-	117.120	-	-
Total filamentous fungi	24.46	26.69	26.59	23.87	1231.92	400.81	437.40	207.23	-	141.05
Total yeasts	3.20	17.97	63.07	174.62	11745.63	53.90	93.50	1991.00	-	32.01
Total fungi	27.66	44.66	89.66	198.49	12977.55	454.70	530.90	2198.23	-	173.06

Sample of April, 1978 was spoiled.

Table 5.15. Fungi associated with decomposing pine needles at the middle of the station 4. Upper figures are number of fungal propagules/per gram dry weight of litter. Figures in brackets are relative density (%).

Name of Fungi	Initial	Aug., 22 1977	Sept., 25 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 26 1978	June, 26 1978	Nov., 28 1978	Feb., 22 1979
<i>Aspergillus niger</i>	2.27 (47.35)	1.98 (15.79)	-	-	-	-	-	-	-	-	-	-
<i>Fusarium oxysporum</i>	0.41 (8.56)	3.96 (31.35)	-	-	-	-	-	-	-	-	-	-
<i>Dicella monoceros</i>	0.20 (4.17)	-	-	-	-	-	-	-	-	-	-	-
White sterile aseptate	-	3.30 (26.55)	1.65 (8.19)	6.57 (11.61)	-	-	-	-	-	-	-	111.11 (22.73)
<i>Pythium</i> sp.	-	-	1.98 (9.54)	10.53 (18.61)	-	-	-	-	-	-	-	-
<i>Fusarium</i> sp.	-	-	11.22 (55.74)	23.68 (41.86)	-	-	6.32 (5.79)	58.69 (25.00)	-	-	-	-
Black sterile septate	-	-	5.28 (26.23)	15.79 (27.91)	-	-	-	-	-	-	8.77 (35.72)	-
<i>Trichoderma</i> sp.	-	-	-	-	8.67 (1.37)	10.06 (6.95)	3.93 (3.62)	-	-	-	-	8.09 (1.82)
<i>Cladosporium herbarum</i>	1.90 (39.65)	3.30 (26.55)	103.05 (16.16)	2.52 (1.71)	7.11 (6.52)	-	-	-	-	-	-	177.78 (36.36)
<i>Aspergillus</i> sp.	NRs	10.06	-	-	55.6 (9.06)	10.06 (6.05)	-	-	-	-	-	-
<i>Penicillium</i>	-	-	-	-	254.32 (39.58)	59.76 (61.16)	11.85 (10.57)	-	1.01 (3.21)	13.08 (38.39)	1.75 (7.13)	-
Ascomycete-2	-	-	-	-	118.49 (18.59)	30.20 (30.57)	37.16 (34.06)	-	30.44 (96.78)	-	-	-
White sterile septate	-	-	-	-	95.37 (15.00)	1.67 (1.13)	34.00 (31.16)	-	-	-	-	-
<i>Geotrichum</i> sp.	-	-	-	-	-	0.54 (0.57)	4.74 (4.34)	173.30 (73.40)	-	25.28 (58.74)	-	-
Synonemates	-	-	-	-	-	1.67 (1.13)	0.80 (0.73)	-	-	-	-	-
<i>Hecov circinaloides</i>	-	-	-	-	-	-	3.16 (2.09)	-	-	-	-	-
<i>Hecov biobliis</i>	-	-	-	-	-	-	-	3.79 (1.61)	-	-	-	-
<i>Phoma hamicola</i>	-	-	-	-	-	-	-	-	-	3.74 (8.69)	-	-
<i>Abeidia</i> sp.	-	-	-	-	-	-	-	-	-	0.93 (2.16)	-	-
<i>Aspergillus sydowii</i>	-	-	-	-	-	-	-	-	-	-	1.75 (7.13)	-
<i>Phoma</i> sp.	-	-	-	-	-	-	-	-	-	-	10.28 (50.02)	-
<i>Penicillium chrysogenum</i>	-	-	-	-	-	-	-	-	-	-	-	191.11 (39.10)
Red yeast	5.04	-	-	19.74	297.67	50.33	59.30	215.84	-	1277.13	64.02	688.09
Black yeast	-	-	-	-	86.70	220.64	49.01	836.16	94.37	-	-	-
White yeast	-	-	-	-	-	-	-	-	2.02	-	-	-
Strinkled yeast	-	-	-	7.59	-	-	-	-	-	-	-	-
Orange yeast	-	-	-	-	-	-	-	-	-	-	5.00	-
Total Filamentous Fungi	4.79	12.54	20.13	56.57	637.70	146.76	109.10	234.78	31.45	43.03	24.55	488.90
Total Yeasts	5.04	1.12	22.53	27.63	384.37	270.97	109.11	852.00	96.39	1277.03	114.02	688.09
Total Fungi	9.83	13.66	42.66	84.20	1022.07	417.73	218.21	1086.78	129.84	1320.16	138.57	1177.76

Sample of September, 2 1978 was spoiled due to human interference.

Table 5.16. Fungi associated with decomposing teak leaves at the middle of station 4. Upper figures are number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density(%).

Name of Fungi	Initial	Aug., 22 1977	Sept., 6 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 24 1978	June, 26 1978
<u>Aspergillus niger</u>	2.33 (9.51)	5.36 (30.78)	0.67 (3.06)	-	-	-	-	-	-	-
<u>Mucor racemosus</u>	0.66 (38.37)	5.36 (30.78)	-	2.94 (3.88)	-	4.18 (2.91)	-	-	-	0.88 (1.07)
<u>Phoma</u> sp	-	-	1.98 (9.04)	2.94 (8.88)	-	-	-	-	-	7.95 (9.79)
Ascomycete-2	-	-	10.66 (48.69)	32.35 (64.70)	41.33 (73.28)	94.80 (66.03)	35.43 (41.42)	-	31.94 (84.10)	8.82 (10.86)
<u>Penicillium</u> sp	-	-	1.65 (7.54)	11.76 (23.92)	-	-	-	-	-	-
<u>Trichoderma</u> sp.	1.33 (5.43)	2.01 (11.94)	1.98 (9.04)	1.00 (1.82)	1.00 (1.82)	8.36 (5.83)	1.73 (2.02)	10.81 (28.00)	-	-
<u>Penicillium</u> sp	1.33 (5.43)	1.34 (7.69)	-	2.00 (3.64)	2.00 (3.64)	13.94 (9.70)	10.37 (12.12)	-	-	-
Synonatales	-	-	-	1.33 (2.42)	1.33 (2.42)	-	-	-	-	-
White sterile asenate	4.33 (17.68)	2.01 (11.94)	4.95 (22.61)	6.66 (12.13)	6.66 (12.13)	13.84 (8.73)	15.55 (18.18)	28.22 (88.84)	-	-
<u>Cladosporium herbarum</u>	-	-	-	2.66 (4.88)	2.66 (4.88)	-	19.67 (23.23)	3.60 (8.33)	2.95 (7.91)	7.94 (9.78)
<u>Aspergillus</u> sp	-	-	-	-	-	2.78 (1.93)	-	-	-	-
<u>Geotrichum</u> sp	-	-	-	-	-	4.18 (2.91)	0.86 (1.00)	-	-	22.06 (22.17)
<u>Curvularia</u> sp	-	-	-	-	-	2.78 (1.93)	-	-	-	-
<u>Mucor circinelloides</u>	6.30 (26.85)	1.33 (7.69)	-	-	-	-	0.86 (1.00)	-	-	-
<u>Mucor hiemalis</u>	-	-	-	-	-	-	0.86 (1.00)	-	-	-
<u>Penicillium chrysogenum</u>	-	-	-	-	-	-	-	3.60 (8.33)	-	-
<u>Aspergillus fumigatus</u>	-	-	-	-	-	-	-	-	2.99 (8.02)	-
<u>Aspergillus</u> sp	-	-	-	-	-	-	-	-	-	32.26 (40.33)
<u>Verticillium lanorum</u>	-	-	-	-	-	-	-	-	-	0.88 (1.07)
Red yeast	3.20	2.92	-	-	80.66	55.76	55.31	50.45	26.05	10.59
Black yeast	-	-	-	26.47	66.00	27.00	-	1091.81	32.81	-
White yeast	-	-	-	-	-	4.18	-	-	-	-
Total filamentous fungi	34.48	17.41	21.69	50.00	54.98	143.56	85.33	43.23	37.28	81.19
Total yeasts	3.20	2.98	18.99	26.47	146.66	87.74	55.31	1142.26	59.66	10.59
Total fungi	27.68	20.33	40.68	76.47	201.64	231.30	140.64	1185.49	96.94	91.78

Table 3.17 Fungi associated with decomposing pine needles at the bottom of station 4. Upper figures are number of fungal propagules/gram dry weight of litter. Figures in brackets are relative density (%).

Name of Fungi	Initial	Aug., 22 1977	Sept., 25 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 9 1978	March, 16 1978	April, 26 1978	June, 26 1978	Sept., 28 1978	Nov., 28 1978	Feb., 22 1979
<i>Aspergillus</i> sp.	-	-	8.55 (32.50)	82.58 (90.33)	-	-	-	-	-	-	-	-	-
Synematales-1	-	-	0.66 (2.50)	8.82 (9.67)	14.68 (7.03)	-	-	-	-	-	-	-	-
<i>Trichoderma</i> sp.	-	-	-	-	20.52 (9.84)	-	-	-	-	-	-	-	-
<i>Cladosporium herbarum</i>	1.90 (39.68)	1.00 (25.12)	7.92 (30.00)	-	30.78 (14.75)	-	-	-	-	-	-	-	-
<i>Aspergillus moniliformis</i>	0.20 (4.17)	1.65 (41.45)	9.24 (35.00)	-	-	-	-	-	-	-	-	-	-
<i>Aspergillus</i> sp.	-	-	-	82.35 (90.88)	-	-	10.05 (24.56)	-	-	2.65 (8.12)	-	-	-
Synematales-2	-	-	-	8.82 (9.67)	14.68 (7.03)	-	-	-	-	-	-	-	-
<i>Trichoderma viride</i>	-	1.00 (25.12)	-	-	20.52 (9.84)	9.87 (11.74)	-	-	1.35 (5.63)	-	2.02 (33.33)	1.90 (3.22)	-
<i>Cladosporium cladosporioides</i>	-	-	-	-	30.78 (14.75)	-	-	-	-	-	4.04 (66.67)	9.52 (16.13)	109.10 (47.37)
<i>Penicillium</i> sp.	-	-	-	-	34.20 (16.39)	26.32 (31.26)	11.45 (26.04)	-	-	-	-	-	-
Ascomycetes-2	-	-	-	-	109.44 (52.46)	34.83 (41.37)	-	-	18.66 (53.36)	-	-	-	-
<i>Mucor hiemalis</i>	-	-	-	-	-	1.64 (1.95)	-	-	5.43 (26.65)	-	-	-	-
<i>Aspergillus fumigatus</i>	-	-	-	-	-	6.55 (7.81)	-	-	-	-	-	-	-
<i>Aspergillus niger</i>	2.27 (47.39)	0.33 (8.29)	-	-	-	1.64 (1.95)	-	1.66 (9.04)	-	-	-	-	-
<i>Cervularia</i> sp.	-	-	-	-	-	3.29 (3.91)	-	-	-	-	-	-	-
<i>Gephyrospora</i> sp.	-	-	-	-	-	-	10.05 (24.56)	-	-	-	-	-	-
White sterile septate	-	-	-	-	-	-	9.33 (25.80)	16.03 (34.80)	-	-	-	21.90 (37.10)	-
<i>Alternaria alternata</i>	-	-	-	-	-	-	-	3.35 (18.22)	-	-	-	-	-
<i>Verticillium tenuum</i>	-	-	-	-	-	-	-	1.66 (9.04)	-	-	-	-	-
<i>Trichoderma koningii</i>	-	-	-	-	-	-	-	1.66 (9.04)	2.71 (13.31)	-	-	-	-
<i>Geotrichum candidum</i>	-	-	-	-	-	-	-	-	-	4.39 (13.46)	-	-	-
<i>Fusarium oxysporum</i>	0.41 (8.56)	-	-	-	-	-	-	-	-	7.94 (24.34)	-	-	-
<i>Phoma humicola</i>	-	-	-	-	-	-	-	-	-	4.39 (13.46)	-	-	-
Black sterile septate	-	-	-	-	-	-	-	-	-	-	-	23.81 (40.33)	-
<i>Mucor racemosus</i>	-	-	-	-	-	-	-	-	-	-	-	1.90 (3.22)	26.28 (12.50)
<i>Penicillium chrysogenum</i>	-	-	-	-	-	-	-	-	-	-	-	-	74.24 (32.24)
White sterile septate	-	-	-	-	-	-	-	-	-	-	-	-	18.18 (7.90)
Red yeast	5.04	-	-	-	995.22	19.74	0.72	191.43	-	20.29	24.24	-	-
Black yeast	-	-	-	547.05	232.56	111.86	-	1813.61	-	133.32	-	-	-
White yeast	-	-	-	-	359.10	-	-	-	-	-	-	-	-
Total filamentous fungi	4.79	3.98	26.40	91.17	203.62	84.18	40.91	18.35	20.35	19.37	6.06	59.03	230.30
Total yeasts	5.04	7.68	10.26	547.05	1586.85	131.60	0.72	2005.03	-	153.61	24.24	-	-
Total fungi	9.83	11.66	36.66	636.22	1795.50	215.78	41.63	2023.41	20.35	172.98	30.30	59.03	230.30

Table 5.18 Fungi associated with decomposing teak leaves at the bottom of the Station 4. Upper figures are number of fungal propagules/gram dry weight of litter^(100%). Figures in brackets are relative density (%).

Name of Fungi	Initial 1977	Aug., 22 1977	Sept., 5 1977	Oct., 25 1977	Nov., 27 1977	Dec., 27 1977	Feb., 6 1978	March, 16 1978	April, 26 1978	June, 26 1978	Sept., 2 1978	Nov., 26 1978
<i>Phoma</i> sp.	-	-	1.32 (11.73)	3.66 (18.75)	-	-	-	3.85 (8.33)	-	-	-	-
<i>Maras</i> sp.	39.36 (35.26)	3.66 (16.75)	-	-	-	-	-	-	-	-	-	-
<i>Aspergillus candidus</i>	-	-	3.96 (35.20)	4.87 (25.00)	-	-	-	-	-	-	-	-
<i>Ascomycota-2</i>	-	1.32 (19.94)	0.67 (5.95)	7.32 (37.30)	-	66.66 (55.06)	45.64 (47.65)	-	12.93 (27.20)	-	-	-
<i>Aspergillus niger</i>	2.33 (9.51)	0.67 (10.12)	0.67 (5.95)	-	0.33 (4.51)	-	1.98 (2.93)	-	-	-	-	-
<i>Aspergillus</i> sp.	-	-	-	-	0.33 (4.51)	3.33 (2.75)	-	-	-	-	-	-
<i>Penicillium</i> sp.	1.33 (8.43)	-	-	-	4.33 (39.15)	22.22 (18.35)	9.92 (14.71)	-	-	-	-	10.40 (26.58)
<i>Cladonoporus herbarum</i>	-	-	-	-	2.33 (31.03)	7.77 (6.42)	-	-	-	-	-	-
<i>Urocybe racemosa</i>	8.66 (38.37)	1.98 (29.91)	-	-	-	2.22 (1.83)	-	-	-	-	-	-
<i>Hirsutiella</i>	6.30 (26.35)	1.98 (29.91)	-	-	-	2.22 (1.83)	-	-	-	-	-	-
<i>Trichoderma</i> sp.	-	-	-	-	-	4.44 (3.66)	4.96 (7.35)	3.85 (8.33)	-	-	2.90 (4.35)	-
<i>Geotrichum</i>	-	-	-	-	-	11.11 (9.17)	4.96 (7.35)	9.63 (20.33)	-	-	14.30 (21.75)	-
<i>Synneurospora</i>	-	-	-	-	-	1.11 (0.92)	-	-	-	-	-	-
White septate sterile	4.33 (17.68)	0.67 (10.12)	0.67 (5.95)	-	-	-	-	28.90 (62.51)	-	-	20.30 (30.44)	-
<i>Aspergillus candidus</i>	-	-	-	-	-	-	-	2.98 (16.64)	-	28.98 (43.47)	-	-
<i>Verticillium tomentosum</i>	-	-	-	-	-	-	-	-	2.00 (11.17)	-	-	-
<i>Trichoderma koningii</i>	1.33 (5.34)	-	-	-	-	-	-	-	-	-	-	5.21 (14.30)
<i>Alternaria alternata</i>	-	-	-	-	-	-	-	-	-	-	-	1.03 (3.53)
Black sterile septate	-	-	-	-	-	-	-	-	-	-	-	19.79 (55.32)
Red yeast	3.20	2.71	9.41	-	26.00	34.44	587.47	514.42	20.85	-	318.84	7.29
Black yeast	-	-	-	4.87	63.00	-	-	321.25	9.95	-	-	-
White yeast	-	-	-	-	-	12.10	-	3.85	-	-	-	5.18
Orange yeast	-	-	-	-	-	-	-	-	-	-	-	8.33
Total filamentous fungi	24.48	6.62	11.25	19.52	7.32	121.08	67.46	46.23	17.91	-	66.68	36.43
Total yeasts	3.20	2.71	9.41	4.87	69.00	46.54	587.47	540.02	30.83	-	318.84	20.50
Total fungi	27.68	9.33	20.66	24.39	96.32	167.62	654.93	886.25	48.74	-	385.53	57.23

Sample of June, 1978 was spoiled.

not followed by the pine needles put at the bottom of station 4 (anaerobic site) where the initial drop was steep followed by steady build up of the nitrogen concentration. The differences in the change in the nitrogen content at three stations were not much pronounced except that at the station 1 the increment in the nitrogen concentration was high as compared to the station 3 and station 4. Another marked feature was very high nitrogen content at mid-depth of station 4 at 257 days and 317 days samplings. The nitrogen content of teak leaves also followed somewhat similar trend of variation except here the initial drop in the nitrogen content was not observed. The increment in the nitrogen concentration was highest at the mid-depth of station 4. Throughout the study period percentage nitrogen content was higher in the teak leaves than pine needles (Table 5.19,5.20).

Cellulose

The cellulose content in the pine needles changed very slowly. After a slight increment the values decreased steadily. The variations between station 1 and station 3 were not significant, however, at the mid-depth and bottom of station 4 the loss of cellulose content was appreciably slow. The teak leaves also followed almost similar general trend but in this case the initial increment was more pronounced. The total loss of percentage cellulose at the end of the study period was very less as

compared to the pine needles (Table 5.21, 5.22).

Hemicellulose

The hemicellulose content of the pine needles did not change appreciably and remained within a narrow range of the initial concentration. In general, the hemicellulose concentration decreased during the processing period but slight increment in the values were also observed towards the end of the study period. The initial concentration of hemicellulose in the teak leaves was quite less as compared to the pine needles. The pattern of change was almost similar in both the litters but in the case of teak leaves the increments were not observed (Table 5.23,5.24).

Lignin

The lignin content of pine needles increased steadily at all the stations and depths, the total increment at the end of the study period, however, varied at various stations. The increment at the station 1 was as high as 14 percent but at the bottom of station 4 the increment was only 3 percent. Almost similar general trend was observed for teak leaves also except that the values were quite low (Table 5.25,5.26).

Sugars

The sugars content of the pine needles changed steadily with time. The most conspicuous drop in the value was observed after 30 days of processing when the percentage values dropped upto as much as fifty percent

Table 5.19 : Percentage Nitrogen concentration in decomposing pine needles at various stations.

Exposure Period(Days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
30	0.66	0.69	0.73	0.63	0.50	0.80	0.66	0.76	0.37
108	2.05	1.89	2.14	1.01	1.01	1.00	1.06	1.11	0.60
160	1.10	1.09	0.90	1.09	1.04	0.87	1.00	1.08	0.79
257	0.99	1.15	0.90	1.09	1.15	1.33	1.08	1.72	0.93
317	1.08	1.16	0.816	1.11	0.95	0.90	0.98	1.96	1.05
367	1.05	1.19	0.82	1.20	1.05	1.08	1.00	1.36	0.83
476	1.10	1.33	1.06	1.06	0.88	1.08	1.08	1.03	1.00

S = Surface, M = Middle, B = Bottom.

Table 5.20: Percentages nitrogen concentration in decomposing teak leaves
at various stations.

Exposure Period (days)	Station 1			Station 3		Station 4		
	4	M	B	B		S	M	B
Initial	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87
30	2.12	2.42	1.99	1.71	2.25	2.69	2.69	1.36
108	1.76	2.06	2.00	1.25	2.51	2.51	2.51	1.44
180	2.71	1.70	2.61	1.15	1.77	3.02	3.02	0.90
257	1.47	1.70	1.90	1.90	1.77	2.05	2.05	0.95
317	-	-	1.72	-	-	1.69	1.69	0.90
387	-	-	-	-	-	-	-	0.86
476	-	-	-	-	-	-	-	-

S = Surface, M = Middle, B = Bottom.

- Materials insufficient for analysis.

Table 5.21: Percentage cellulose concentration in decomposing pine needles at various stations.

Exposure Period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	58.33	58.33	58.33	58.33	58.33	58.33	58.33	58.33	58.33
30	59.66	58.30	60.20	59.45	59.22	58.33	59.33	58.00	58.20
108	55.40	56.20	57.20	55.20	56.33	55.20	55.40	57.80	58.20
180	56.20	54.60	55.20	54.60	53.90	56.20	56.30	56.20	57.60
257	54.00	53.60	54.20	53.66	52.20	54.20	53.60	53.80	57.20
317	46.36	45.80	48.80	47.60	50.80	53.60	46.80	53.88	57.33
387	48.40	45.20	46.00	44.20	48.30	52.80	45.20	54.00	56.80
476	44.00	44.80	42.80	40.38	48.20	51.60	40.00	53.80	56.33

S = Surface, M = Middle, B = Bottom.

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Table 5.22: Percentage cellulose concentration in decomposing teak leaves at various stations.

Exposure period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	46.66	46.66	46.66	46.66	46.66	46.66	46.66	46.66	46.66
30	56.50	54.48	55.55	60.20	62.33	62.33	48.42	49.33	49.33
108	44.80	48.66	50.33	55.33	54.30	48.00	47.33	47.33	47.33
180	44.66	44.50	46.66	51.33	53.40	46.66	43.33	43.33	43.33
257	45.00	44.66	45.20	44.48	46.66	44.25	43.33	43.33	43.33
317	-	-	42.20	-	-	-	42.66	42.66	42.66
387	-	-	40.33	-	-	-	42.66	42.66	42.66
476	-	-	-	-	-	-	43.33	43.33	43.33

S = Surface, M = Middle, B = Bottom.

- Materials insufficient for analysis.

Table 5-23.: Percentage hemicellulose concentration in decomposing pine needles
at various stations.

Exposure Period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	16.75	16.75	16.75	16.75	16.75	16.75	16.75	16.75	16.75
30	15.66	15.66	16.33	15.88	17.55	17.50	18.47	16.88	16.80
108	15.88	15.90	16.22	14.90	15.80	16.60	15.66	17.45	17.90
180	14.33	15.40	15.40	14.67	14.40	15.80	14.66	15.45	17.25
257	14.13	14.80	12.60	14.67	12.80	16.60	12.80	14.33	16.20
317	14.50	14.33	13.44	14.33	13.80	-	-	14.38	16.33
387	14.50	-	-	-	-	-	-	-	15.45
476	-	-	-	-	-	-	-	-	-

S = Surface, M = Middle, B = Bottom.
- materials insufficient for analysis.

Table 5-24.: Percentage hemicellulose concentration in decomposing teak leaves
at various stations.

Exposure Period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	11.33	11.33	11.33	11.33	11.33	11.33	11.33	11.33	11.33
30	11.33	12.25	12.25	13.45	11.33	11.33	13.45	11.33	11.66
106	10.60	11.50	12.00	12.66	11.66	11.33	11.66	12.62	11.33
180	8.68	11.22	11.62	11.33	10.25	10.66	13.20	10.25	10.66
257	7.80	12.33	11.45	10.45	9.75	10.50	10.34	9.75	10.50
317	6.33	11.45	11.66	9.62	9.75	10.50	9.68	9.75	10.50
367	-	-	10.75	-	-	9.66	-	-	9.66
476	-	-	-	-	-	9.66	-	-	9.66

S = Surface, M = Middle, B = Bottom.
- Materials insufficient for analysis.

Table 5.25: Percentage lignin concentration in decomposing pine needles
at various stations.

Exposure Period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	28.34	28.34	28.34	28.34	28.34	28.34	28.34	28.34	28.34
30	28.50	30.20	30.16	28.80	30.00	28.34	28.50	28.60	28.60
106	33.67	31.26	30.66	29.80	29.20	30.30	29.20	28.90	29.00
257	36.67	34.66	33.20	35.20	30.60	33.33	36.20	29.33	30.20
317	40.00	38.66	36.67	39.80	31.00	33.66	37.00	30.33	30.33
367	40.32	38.96	38.00	38.20	32.00	33.66	39.40	30.33	30.33
476	43.60	39.20	39.20	41.30	34.00	34.00	39.60	31.20	31.33

S = Surface, M = Middle, B = Bottom.

Table 5.26: Percentage lignin concentration in decomposing teak leaves at various stations.

Exposure Period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	19.60	19.60	19.60	19.60	19.60	19.60	19.60	19.60	19.60
30	22.20	20.66	21.33	20.00	20.00	20.00	22.60	20.00	19.66
106	23.60	24.00	25.20	20.60	20.60	20.60	23.60	20.20	20.20
180	24.20	23.86	24.60	21.80	21.80	21.80	24.33	21.00	21.20
275	26.60	24.20	24.66	22.00	22.00	22.00	26.32	20.89	21.20
317	30.00	29.23	26.80	23.00	23.00	23.00	31.20	20.96	21.20
387	30.30	29.89	29.66	23.60	23.60	23.60	32.20	31.33	31.50
476	30.30	-	-	-	-	-	-	-	-

S = surface, M = Middle, B = Bottom

- Materials insufficient for analysis.

Table 5.27.: Sugar concentration in decomposing pine needles at various stations.
(ug/100 mg).

Exposure Period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	98	98	98	98	98	98	98	98	98
30	46	49	58	38	48	59	42	60	76
108	44	36	38	33	39	43	34	49	65
180	48	34	44	34	38	38	32	44	61
257	30	28	35	19	36	38	24	44	54
317	21	30	26	21	29	34	-	35	54
387	24	36	26	26	32	39	-	36	58
476	36	42	46	29	32	41	-	36	58

S = Surface, M = Middle, B = Bottom.

- Materials insufficient for analysis.

Table 5.28.: Sugar concentration in decomposing teak leaves at various stations.
(ug/100 mg).

Exposure period (days)	Station 1			Station 3			Station 4		
	S	M	B	B			S	M	B
Initial	156	156	156	156			156	156	156
30	96	112	126	106			98	124	133
108	68	92	88	82			72	98	126
180	54	72	74	84			58	86	116
257	56	58	67	58			54	86	110
317	-	-	66	-			-	-	92
387	-	-	69	-			-	-	78
476	-	-	-	-			-	-	75

S = Surface, M = Middle, B = Bottom.
- Materials insufficient for analysis.

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Table 3.29.: Amino acid concentration in decomposing pine needles at various stations (ug/100 mg).

Exposure Period (days)	Station 1			Station 3			Station 4		
	S	M	B	S	M	B	S	M	B
Initial	123	123	123	123	123	123	123	123	123
30	96	99	99	86	90	94	80	110	112
108	96	98	103	86	92	96	82	96	96
180	94	98	92	84	92	96	82	91	94
257	84	84	88	76	78	72	84	80	96
317	88	92	90	82	92	82	80	76	82
387	82	98	86	94	92	84	92	82	78
476	98	112	126	94	98	91	96	82	74

S = Surface, M = Middle, B = Bottom.

Table 5.30.: Amino acid concentration in decomposing teak leaves at various
(ug/100 mg).

Exposure Period (Days)	Station 1			Station 3		Station 4		
	S	M	B	B	S	M	B	B
Initial	146	146	146	146	146	146	146	146
30	96	112	118	92	88	124	133	
108	72	79	98	78	68	114	126	
180	92	72	88	82	88	82	94	
257	94	72	84	84	72	74	98	
317	-	-	94	-	-	-	89	
387	-	-	98	-	-	-	77	
476	-	-	-	-	-	-	72	

S = Surface, M = Middle, B = Bottom.
- Materials insufficient for analysis.

of the original concentration. Later on the sugar content decreased slowly. The samples collected at the end of the study, sometimes, showed slight increment in the values. Almost similar trend was observed in the case of teak leaves also except that the initial drop was more pronounced in this case. In general, the change in the sugar content was slow in the litters placed in deeper waters (Table 5.27, 5.28).

Amino acids

Like sugars the amino acids content of the pine needles decreased steadily. The initial decrease was quite pronounced and later for a period of nearly two hundred days the values oscillated within a narrow range. A marked increment in the values was observed towards the end of the study period. Teak leaves also showed almost similar general pattern of change in the amino acids content (Table 5.29, 5.30).

DISCUSSION

The litter bag method has been quite often used for the study of plant litter decomposition in the aquatic environments (Park 1974b; Hadkinson, 1975). 1 mm pore size of the nets have been found to be most appropriate which permits the microbial as well as invertebrate activity in the litter bags and at the same time reduces the mechanical loss to a minimum. During the course of present study also the litter bag method using 1mm pore size net has been

found quite appropriate.

The rate of decomposition was found to be directly governed by the litter chemistry and depth of water (Fig. 5.1, 5.2). Hodgkinson (1975) while reviewing the results of several studies on decomposition of terrestrial litters in aquatic environments has clearly demonstrated that the chemical composition (type of litter) has the most pronounced effect on the rate of decomposition. This observation has been further strengthened by the results of this study. The decomposition of teak leaves have been found to be more than three times faster than the pine needles (Table 5.1-5-2). The lignin content (Table 5.25, 5.26), wax deposition (Millar, 1974) and less surface area of the pine needles were positive factors for its slow rate of decomposition. When compared with the similar studies conducted in Europe, the rate of decomposition is faster in the lake under study (Hodgkinson, 1975). The steep loss in the weight during initial phase of processing might be due to the loss of soluble compounds from the materials. Gilbert and Bocoek (1960) estimated the water soluble fraction of freshly fallen litters of oak and ash leaves and found that it may amount as high as 32% of the dry weight. Similar results were reported by Nykvist (1963) who found that angiospermic leaves contain as higher as 16.5% of the dry weight while pine needles contain only 0.9% soluble component. From the comparison of the initial weight loss in the two types of litters it appears that the teak leaves contain more soluble component than the pine needles (Fig. 3.1-3.3). The period of

rapid loss also coincides with the microbial colonization. The two phenomenon may be related and microbes might also be responsible for the rapid loss in the weight during this period, however, the former cause seems to be more important. The rate of loss in the weight slows down after two to four months which is more clear in the case of pine needles. This period of slow weight loss coincides with low microbial population (Fig. 5.4-5.9) and low water temperature (November-January). It seems, therefore, that the season has also got pronounced effect on the rate of decomposition probably through regulating the microbial activity. Besides above factors the accumulation of refractory materials (e.g. lignin fraction Table 5.25, 5.26). and the subsequent slower breakdown of this material might be one of the important cause for the slow rate of weight loss during this period. The rapid loss in weight during spring and summer (second year) coincides with the high population of bacteria and fungi clearly demonstrating the relationship between the two. The effect of this maximum of bacterial and fungal population has more effect on the weight loss of the teak leaves as compared to the pine needles and during this period, the teak leaves, at most of the stations disappear completely.

The data on decay parameters (Table 5.1, 5.2) clearly demonstrate that the weight loss for both the litter types and at all the stations showed a very close fit to Olson's

(1963) negative exponential decay model. The comparison of the k values with other similar studies poses problem due to the differences in the litter type, locality, type of habitat, duration of experiment and litter bag mesh size. However, the range of k values for both the litter types in the lake are of a comparable order of magnitude to those of Kaushik and Hyne (1971), Thomas (1970), Mathews and Kowalczewski (1969) and Hodgkinson (1975). The k values are lower when compared with the studies conducted in streams and rivers (Kaushik and Hyne, 1971; Thomas, 1970) and higher when compared with the studies conducted in pond (Hodgkinson, 1975). Most of the studies on decomposition of allochthonous plant litter in aquatic ecosystems have been conducted in running waters (see introduction). The current action and invertebrate have been found to be the cause of higher rate of decomposition in rivers and streams (Hodgkinson, 1975). In general, the rate of decomposition of extra-neous litters in the present system is higher in comparison to similar systems of temperate climatic zones.

Microbiology

The initial rapid increment in the population of bacteria associated with both the litter types may be attributed to the colonization of new substrate. The population after reaching a threshold level suddenly drops to quite low level. This drop may be due to

exhaustion of soluble nutrients (eg. sugars and amino acids Table 5.27-5.30). and simultaneously the population may also be regulated by the seasonal changes as during the said period (winter) the population of heterotrophic bacteria in the lakewater also drops ^{to} a quite low level (chapter 2). The second maximum of the bacterial populations also coincides with the maximum of the lakewater bacteria (chapter 2). It appears that to some extent the population of bacteria associated with decomposing litters was governed by the season. During later periods of study the population remained quite high and even during winters (when the water bacterial population was quite low) the population did not decrease clearly demonstrating its association with the litter. During later stages of processing more surface area of the litter is exposed due to the fungal and invertebrate activity. The increase in the microbial metabolism at later stages of decomposition has been demonstrated by Finchel (1970) and Hargrave (1972). Suberkropp and Klug (1976) noted continuous increase in the bacterial population associated with decomposing litter plant litters in stream. The data on bacterial population is quite comparable with the findings of Suberkropp and Klug (1976).

The variation in population of bacteria was almost similar at all the depths as well as stations. The slight less population in the bottom sites may be due the same set of factors which are responsible for the water bacteria (chapter 2). The population at station 1 was slightly

higher than the other two stations which may be attributed to the higher dissolved nutrient concentration at this station (chapter 1).

In general, fungi also exhibited the pattern of population variation similar to that of bacteria. In contrast to bacteria the active involvement of terrestrial fungi in the leaf litter decomposition have been quite often criticised (Park, 1972; 1974). However, there consistent isolation (Suberkropp and Klug, 1976; Padgett, 1976) have provided ample evidence that these fungi grow in this environment, and therefore, are active in the processing of extraneous litters in the aquatic environments. The definite succession (Table 5.3-5.18) clearly demonstrates the involvement of these fungi in the processing of litter. However, it is important to note that the methodology has a serious drawback as it is a bit selective for the heavily sporulating forms (Warcup, 1955). The population variation, its association with weight loss and chemistry change also suggest the active involvement of these fungi in the processing of litters.

Very little difference in the species composition of fungal population associated with the two types of litters understudy suggests that most of the fungi are non-selective and they can utilize a wide variety of substrates. Suberkropp and Klug (1976), while studying the decomposition of oak and hickory leaves, also did not find much difference in the fungal populations associated with the two litter types.

Plate count of fungal population tells little about their real activity (Harley, 1971). However, it has been quite often used as a measure of fungal activity (Park, 1972). The conspicuous absence of aquatic Hyphomycetes (Ingold, 1942) might also be attributed to the unsuitability of the plate culture technique for this group of fungi. Although it may be recorded that this group is rarely found in lakes and ponds. Further, they are generally absent from the Gymnospermic needles (Ingold, 1976). Only recently Barlocher et al (1978) reported that needles of Pinus resinosa can be naturally colonized by this group of fungi.

Chemistry

The increment in the nitrogen content of litter during the process of decomposition has been observed by a number of workers (Suberkropp et al, 1976) and this has been attributed the immobilization of N to the microbial biomass (Kaushik and Hyne, 1968; Anderson, 1973; Iversen, 1973; Triska et al, 1975). The present study also confirms the findings of these workers. Hodgkinson (1975) also observed results comparable to this study. He also observed differences in the nitrogen enrichment depending on the litter types. The enrichment of nitrogen in the dicot litters was more than the Gymnosperms which was similar to the findings of this study.

The loss in the cellulose and hemicellulose content of the litters was very slow but steady throughout the study period. It appears that the decomposition of these components is continuous and it is only slightly higher than the other

components (Table 5.21-5.24). The rate of disappearance of these components is slightly faster in the case of teak leaves than the pine needles which may be accounted to the differences in the fine chemistry of the two litter types. These observations are comparable with the findings of Handey (1954) and Suberkropp et al (1976).

Like cellulose and hemicellulose, the initial content of lignin fraction was also higher in pine needles than teak leaves. The rate of disappearance of lignin was the slowest and an increase in the percentage lignin content was noted throughout the course of study in both the litter types clearly indicating slow rate of decay of this material and/preferential utilization of other less refractile components. The accumulation and slow rate of lignin decomposition has been accounted to the complex chemistry of this component (Alexander, 1961) Suberkropp et al (1976) found a positive relation between the accumulation lignin and nitrogen and they observed formation of a 'lignin-nitrogen compound' which makes a high percentage of nitrogen unavailable to the microbes. Similar increase in the lignin fraction has been reported by other workers (Waksman and Tenney, 1927; King, 1967; Triska et al, 1975).

The disappearance of soluble sugars and amino acids followed almost similar trend which is initially very rapid and gradually slows down (Table 5.27-5.30). The initial rapid loss may be accounted to the soluble nature of these components which after the immersion of the litters into

the lakewater leaches out. The findings are comparable to those of Krumholz (1972) who observed 55% - 80% loss soluble carbohydrates in the initial 2 weeks. Suberkropp et al (1976) found that 70% - 80% of reducing sugars were lost during the first two weeks of processing of the litter. A very low concentration of these components observed during the later periods of the study may be due to instantaneous loss of these materials to the lakewater. The relationship between microbial population and the disappearance of sugars and amino acids probably does not exist as the values of these component does not vary with the variations in the microbial population.

GENERAL DISCUSSION

GENERAL DISCUSSION

In contrast to most of the ecosystem investigations carried out upto date in freshwater lakes, this study is concerned with the heterotrophic microbial community. Data on physico-chemical characters of the lakewater (chapter 1) suggest that the lake is mesotrophic having moderate concentration of dissolved nutrients. However, the concentration of soluble ortho-phosphates was exceptionally high (Fig. 1.7) which can be attributed to extraneous loading through run-off and stream inlet. This may have greater effect particularly in view of the shallowness and small size of the system under study (Fig. 1). The high values of dissolved organic carbon were obtained at station 1 and at the bottom of station 4. The increased release from the decomposing litters in the lake bed contributes to the high concentration of dissolved organic carbon at station 1 while the localized release of organic carbon in the deeper waters due to the stratification of the lake may be the cause at station 4 (Fig. 1.4). Similar results have been reported by Strazelsky *et al* (1971). The exceptionally high depletion of oxygen in the bottom of the station 4 is due to its utilization by the heterotrophs associated with the decomposing litters in the lake bed (Fig. 1.3). The seasonality pattern and stratification is similar to other temperate lakes (Hutchinson, 1957). The mixing pattern of the lake is of monomictic type.

The seasonality pattern of the bacterial population is marked by spring maximum and winter minimum (Fig.2.1-2.4) which is typical to temperate climatic zones (Hickman and Penn, 1977; Jones,1977). It may thus be assumed that bacterial population dynamics in relatively shallow and small water bodies such as the present one is basically similar to the temperate lakes in Europe but the populations show larger fluctuations, especially in the summer and autumn. The spring maximum can be attributed to increase in temperature, dissolved organic carbon, phytoplankton exudates and/or release of organic and inorganic nutrients from the dying algal cells (which peaked in the month of March; Thapa, unpublished data). The association of bacterial population maxima with the collapse of phytoplankton population has also been reported by Jones (1972a). The total bacterial population, their biomass, and population of viable bacteria, phosphatase activity, coefficient of heterotrophic activity and microbial production values are higher in spring and summer and significantly lower during winter. The seasonality of bacterial population and their activity seems to be largely dependent on water temperature. These observations are similar to those of Rheinheimer (1977b). Chan and Kueh (1976) found that temperature has little effect on the horizontal and vertical distribution of heterotrophic bacteria in Tolo Harbour. But their

conclusions were based on a short term study and, therefore, are open to criticism. It appears that during summer and autumn the bacterial population is influenced by hydrographic and other non-periodic changes in the environmental factors which can mask the effects of seasonal changes resulting into wide fluctuations in the population. Another problem is presented by the differences in the meteorological conditions in the two years of study (Fig.11) which may be accounted for the differences in the bacterial population of the two years (Fig.2.1-2.4). The bacterial population is also affected by the local and short term changes in the environmental factors (Tiwari and Mishra,1980) which are not accounted in periodic samplings. It may be suggested that samplings within shorter intervals can reveal added information to the seasonality pattern.

From the results on the population dynamics of fungi in the lakewater (Fig.3.1-3.4) it could be noted that the lakewater contains a high population of fungi throughout the year. However, the number of viable fungal propagules did not show any definite seasonality which can be generalized for all the stations and both the years. The dominant fungi isolated by plate culture procedure are quite similar to the fungal flora of soils of the region (Das,1980). The dominance of yeasts and yeast like fungi suggests that either they are better adapted to the aquatic mode of life or they can survive longer in plank-

tonic state. The occurrence of high number of terrestrial forms in aquatic habitats has been reported by Cooke (1976); Quereshi and Dutka (1974). Although high number of viable propagules of these fungi have been isolated throughout the course of investigation, their population regulation and activity could not be ascertained. Very low number of isolations of Ascomycetes can be attributed to the unsuitability of methodology for this group.

The distinct seasonality pattern of zoosporic Phycomycetes (baiting method) is typical to temperate waters (Coker, 1923). The depth-wise distribution of the fungi suggests that the surface waters are more conducive for the growth and/or survival of the fungal propagules. Spring is the most favourable season for most of the species (Fig. 3.17) and the seasonal periodicity of a number of species is similar to the findings of Alabi (1971).

Results on the activity measurements (Fig. 4.1-4.4) indicate that like bacterial population estimates, the activity parameters are also governed by the season. Most of the activity parameters peak during spring and touch lowest values during winter clearly demonstrating some relation with water temperature. Phosphatase activity is affected by phytoplankton, bacteria, and soluble ortho-phosphate concentration which is in conformity with the findings of Jones (1972a). Low values of ortho-phosphate can trigger the enzyme activity while high values of

ortho-phosphates have been reported to repress the activity (Heath and Cooke, 1975). On the contrary, in the present study high values of ortho-phosphates during spring season did not have repressive effect on the enzymes. This observation is similar to the findings of Ichikawa and Freese (1974), and Carillo Castaneda and Ortega (1967) as reviewed by Patni and Aaronson (1977). The high phosphatase activity during winters was not accompanied with high biological activity which suggests that the phosphatase activity cannot always be taken as a measure of biological activity as has been the earlier contention (Verstraete et al., 1976).

The results on coefficient of heterotrophic activity suggested that a sizeable population of heterotrophic microbes is always available in the lakewater which can utilize the organic substrates added in low concentrations. It is concluded that the coefficient of heterotrophic activity is directly related to the dissolved organic carbon concentration (Fig.1.4,4.2). The BOD estimates also show a seasonality pattern similar to the coefficient of heterotrophic activity values. Although the maxima of these two parameters coincide with the maximum of bacterial population their relation with dissolved organic carbon concentration is rather more close (Fig.1.4, 4.2, 4.3).

The bacterial biomass estimates suggest that quite high amount of organismal biomass is contained in this

form (Fig.4.5) which is similar to other mesotrophic lakes (Donderski, 1977). The results are comparable with the similar studies conducted by Ferguson and Rublee (1976) and Tilzer (1972). The microbial production estimates are quite high and it appears that lake utilizes extraneous organic matters for its metabolism. The microbial production, therefore, appears to play a significant role in the total productivity of the lake (Fig.4.4). The estimation of bacterial production by oxygen consumption method (Sorokin and Kadota, 1972) overpredicts the values especially in lakes receiving high input of allochthonous litters. However, the method gives comparable results and has been widely used (Anderson and Dokulil, 1977). The results of present investigation are comparable to the findings of Anderson and Dokulil (1977) and Takahashi et al (1970).

Results on the process of decomposition in the lake suggest that it is governed largely by the chemical composition of the substrate and depth of the water column (Fig.5.1-5.3; Table 5.1,5.2). In the deeper waters the rate of decomposition is extremely slow as compared to surface and shallow waters presumable due to low oxygen concentration and low microbial activity. The decomposition of teak leaves is more than three times faster than pine needles (Table 5.1-5.2). These differences are attributed to the differences in the

chemistry and physical structure of the two litter-types. The fungal inhibitors (Barlocher and Oertli, 1978) and fungistatic substances (Tiwari et al, 1980) present in the pine needles may also be responsible for their slow decomposition. It is inferred that the rate of decomposition of litters is faster when compared with the similar studies conducted in temperate climatic zones (Hodkinson, 1975). When viewed as a whole, it appears that the process of decomposition can conveniently be divided into three distinct phases :

Leaching phase : This is characterized by fast microbial colonization attaining peak values within a short span of time, rapid loss of soluble components, rapid weight loss and little change in the composition of organic compounds but significant loss in the percentage nitrogen content. This period is 2-4 months depending upon the site characters and type of litter.

Processing phase : This is characterized by low microbial activity, low content of soluble compounds, slow weight loss and slow change in composition of organic compounds and often an increase in percentage nitrogen. This phase continues for a long period of time unless the material is quite softened and becomes palatable for invertebrate fauna.

Dispersal phase : This is characterized by high microbial activity, rapid loss in weight, colonization

by detritivorous invertebrates, high lignin content and sometimes loss in percentage nitrogen. During this phase the animal population has the most important role to play by cutting the litter into smaller pieces. This phase continues until the litter is changed into an unrecognizable detritus heavily loaded with various extraneous objects which are mainly composed of exuvae of various insects and chironomids and shells of molluscs.

From the results of this study, it is possible to relate a given microbial parameters with the other(s) and the various microbial parameters could be shown to depend on different physico-chemical parameters. Yet these represent only a small part of the various relations which exist in a given system. The relationship may exist between parameters for which no correlations can be found as there may be a time lag (as observed in phytoplankton and bacteria) which might mask the relationship between any two parameters. Besides direct relationship, quite often an indirect relationship may also be found which could not be explored during the present investigation.

In addition to the parameters measured in the present study, phytoplankton production, organic input to the system, role of zooplanktons and concentration of dissolved organic compounds such as amino acids, sugars etc. could also be determined to find the relations, if any, of these parameters with microbial activity. Besides, frequent

samplings at short intervals might also be desirable. During the course of study more than one methods were employed for measuring some of the parameters but for a better insight into the microbial ecology of the lake waters certain other methods may also be tried. However, these additional works can hardly be undertaken in a time-bound programme like this. Although some useful conclusions can be drawn from the observations contained in the thesis in respect of microbiology of the lakewater study. The role of terrestrial fungi in aquatic environments, relationship between primary and microbial production the importance of allochthonous litter in the lake metabolism and role of zooplanktons in the regulation of bacterial populations remain yet to be investigated.

SUMMARY

The population dynamics and activity of heterotrophic microbes in a small freshwater lake, situated in Shillong (India) at an altitude of 1460 m (25.34°N, 91.52°E) has been investigated for a period of two years. Data collected on spatial and temporal distribution of bacteria and fungi, using various methods, from four stations show that the population of the microbes is governed by the season. Among various physico-chemical and biological parameters investigated, temperature, dissolved organic carbon depth and phytoplanktons were found to be directly related to the bacterial population. The bacterial population was maximum during spring and minimum during winters. The total bacterial population ranged between 0.11×10^6 and 19.5×10^6 cells per ml of water and the viable bacterial population ranged between 0.007×10^6 and 3.4×10^6 cells per ml of water. The biomass of bacteria ranged from 85 mg to less than one mg per M^3 . The total population of bacteria was 10-50 times more than the viable population. Data on vertical distribution of bacteria (station 4) show that quite often higher populations were estimated in deeper waters. The bacterial population was dominated by gram negative rods with polar flagella. The major representative genera were Pseudomonas, Flavobacterium, Bacillus and Achromobacter.

Data on physico-chemical characters of the lake

water exhibited that the lake remains stratified for most period of the year and mixing occurs once in the month of February. The measurements of dissolved nutrients show that the lake has a moderate concentration of nutrients and may be classified as a mesotrophic system.

The population of viable fungal propagules was also found to be related to season but the seasonality pattern could not be established as the oscillation pattern of fungal population varied from year to year as well as among the stations. Spring was most favourable season for the zoosporic Phycomycetes (baiting method) and winter was the period of least activity. Seventeen species of zoosporic Phycomycetes were isolated from the lake during the course of investigation. The population of fungi is dominated by the terrestrial forms which ranged between 10-100 propagules per ml of water. Cladosporium herbarum, Penicillium chrysogenum, Sporobolomyces sp., Rhodotorula sp., Aureobasidium pullulans, Trichosporon sp., Aspergillus fumigatus, Geotrichum candidum, Pythium monospermum and Phialophora were the dominant terrestrial fungi isolated from the lake water.

The microbial production ranged between 10 and 120 mg C per M³ which was highest during spring months. The generation time of bacteria ranged between 2 and 60 hours which also peaked during spring months. The biological activity of lake water was measured by estimating

alkaline phosphatase activity, coefficient of heterotrophic activity, and BOD values. These observations suggest that the biological activity was also influenced by the seasons. The activity parameters were found to be related to the bacterial population and concentrations of dissolved organic carbon. Phosphatase activity was also related to the soluble ortho-phosphate concentrations. The coefficient of heterotrophic activity and BOD values varied hand in hand and they were found to have strong relation with the dissolved organic carbon concentration. Depth has got profound effect on the biological activity of lakewater.

The process of decomposition of terrestrial litters in the lake was studied using litter bag method for a period of eighteen months. It was found that the rate of decomposition was largely influenced by the water depth and type of the litter. The rate of decomposition of teak leaves was more than three times faster than the pine needles. The weight loss for both the litter types and for all stations showed a very close fit to Olson's (1963) negative exponential model. The rate of decomposition was faster in comparison to those recorded in other aquatic systems in temperate climatic zones. Microbiological estimations of the litters during the decomposition process exhibited two

peaks, one at the time of colonization, generally after six months, and the other after sixteen months towards the end of the study period. Significant change in the species composition of fungal population with time was observed. The increment in the percentage nitrogen was noted which declined towards the end of the study period. The constant increase in the percentage Lignin content was noted. Rate of change in the percentage cellulose and hemicellulose contents was slow. Based on the observations on weight loss, microbiology, and chemistry change of the decomposing litters it is suggested that the whole process may be divided into three distinct periods, namely leaching phase, processing phase and dispersal phase.

The results presented in the thesis emphasize the importance of the heterotrophic microbes in the lake ecosystem. It has been suggested that the microbial ecology of freshwater warrants more attention of limnologists. Various avenues in field have been suggested.

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