A DESCRIPTION OF THE EPIPHYTIC, EPIPELIC AND PLANKTONIC ALGAL COMMUNITIES IN TWO SHALLOW EUTROPHIC LAKES IN SOUTHWESTERN MANITOBA

A Thesis

Submitted to

The Faculty of Graduate Studies

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Jennifer Joyce Shamess

March, 1980

A DESCRIPTION OF THE EPIPHYTIC, EPIPELIC AND PLANKTONIC ALGAL COMMUNITIES IN TWO SHALLOW EUTROPHIC LAKES IN SOUTHWESTERN MANITOBA

BY

JENNIFER JOYCE SHAMESS

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

ABSTRACT

Species composition and biomass (expressed as cell volume and chlorophyll *a*) of the epiphytic, epipelic and planktonic algal communities of the littoral zones in two shallow prairie lakes were examined and the periphytic communities on *Typha latifolia* and cellulose acetate were compared.

Species diversity was considerably lower in all communities studied than previously reported values. The Bacillariophyceae contributed large volumes, often 90-100% of the total community in the epiphytic communities on *Typha* and in the epipelon in both Lakes 255 and 623. The epiphyton on the artificial substrates (smooth and roughened) in L255 was dominated by the Cyanophyta which often contributed more than 45% of the total community. In L623 the communities on the smooth and roughened acetate were almost completely dominated by the green alga *Stigeoclonium nanum* which frequently comprised 90-100% of the total community. Seasonal mean biomass estimates expressed as cell volume and chlorophyll *a* in both lakes were lowest among the epiphyton and highest in the epipelon. Generally the epiphytic and epipelic biomass estimates were lower in L255 than in L623 but the phytoplankton biomass expressed as cell volume and chlorophyll *a* was much higher in L255 than L623. However in only 3 of the 10 communities investigated during 1979 did the seasonal cell volume and

chlorophyll *a* biomass estimates correlate significantly. Cell volume was considered to be a much better method of biomass determination than chlorophyll *a* when comparisons were made with the actual species present. The epiphytic algal communities on smooth and roughened cellulose acetate compared to those on *Typha* displayed comparable seasonal mean cell volume estimates only. Community composition differed significantly and in all cases the values obtained as either species composition or biomass demonstrated great similarity between the populations on the two artificial substrates but never between the artificial and natural substrate.

ACKNOWLEDGEMENTS

The author deeply appreciates the constant support and encouragement throughout this investigation by Dr. G.G.C. Robinson.

Assistance in the field by W. Linnebach is gratefully acknowledged as is the unfailing friendship and encouragement of A. Coulombe.

TABLE OF CONTENTS

LIST OF FIGURES

Figure Page

Figure

Page

LIST OF TABLES

LIST OF APPENDICES

.....continued

Appendix Page

INTRODUCTION

Purposes of this study were firstly to describe the seasonal succession of the epiphytic, epipelic and littoral planktonic algal communities within two shallow prairie lakes; to quantify successional events by the use of cell volume and chlorophyll *a* biomass estimates; to assess the validity of these estimations; and to evaluate the use of smooth and roughened cellulose acetate artificial substrates as a means of studying epiphytic communities.

Examination of these three algal communities was undertaken in the littoral zones of Lakes 255 and 623 of an aquaculture project in the Erickson-Elphinstone area of Southwestern Manitoba from May to October of 1978 and 1979. In 1978 the epiphyton attached to smooth cellulose acetate artificial substrates was investigated. In 1979 the study was extended to the epiphyton attached to smooth and roughened acetate artificial substrates and to the emergent macrophyte *Typha latifolia* (L.). The algae of the epipelon and phytoplankton were also examined during the 1979 season.

LITERATURE REVIEW

Terminology

There is much confusion and disagreement as to the definitions of three widely used terms pertaining to the algal communities attached to substrates or 'free-living' in aquatic sediments. They are 'benthos','Aufwuchs' and 'periphyton'.

The definition of the 'benthos' or 'benthic organisms' should by the very nature of the word, indicate bottom-dwelling organisms but very few, Sládečková(1962) perhaps being the only notable exception, have recognized the benthos as only those organisms 'free-living' in the sediment.

Most others (Cooke 1956, Hutchinson 1967 and Woerkerling 1976), have defined the benthos broadly as those organisms attached to substrates or living freely within the sediment.

Moss(1968) and Moore(1974c) in the original terminology of Round(1964) referred to the benthic algae as those algae associated with either the sediment-water or attachment surface-water interface. Round(1964) defined three benthic algal communities: epipelic(on sediments), epilithic(on rocks and stones) and epiphytic (on plant surfaces). Moss(1968) recognized the benthic algae as consisting of epipelic, attached (epiphytic,epilithic,epipsammic) and mat-forming groups.

The truly benthic component has been labelled through the years by such terms as 'ooze'(Cooke 1956), 'herpobenthos'(Hutchinson 1967) and 'pelos'(Woerkerling 1976). Most workers now refer to it as the'epipelon' regardless of their definition of the benthos.

The adnate portion of the benthos as defined by Cooke(1956), Hutchinson(1967) and Woerkerling(1976) is often confused by other terms such as 'Aufwuchs' and 'periphyton'.

The European term Aufwuchs, reported by Cooke(1956) and others is synonomous with the periphyton of Young(1945) in Sládečková(1962), Sládečková(1962), Hutchinson(1967) and 'haptobenthos introduced by Warming(1923) in Hutchinson (1967) and revised by Hutchinson(1967).

Whichever term is used (Aufwuchs, periphyton,haptobenthos) the community is limited to all those organisms, except macrophytes, that are attached to but do not penetrate the substratum. Subsequently, modifiers have been used to more thoroughly describe the association with the host(eg. epiphyton, epilithon, epizoon, epixylon etc.). Stockner and Armstrong(1971) described the epilithon as the 'epilithophyton'. Foerster and Schlichting(1965) used the term 'phyco-periphyton' to desribe the epiphytic algae on both natural and artificial substrates. Neither of these latter terms has been used extensively by others.

Woerkerling(1976) more specifically restricted that component of the benthos attached to solid substrata

as Aufwuchs if the organisms were attached to biological substrates and 'lithos'(=Bewuchs,lasion) for those organisms associated with non-biological substrata.

Hutchinson(1967) and Woerkerling(1976) limited their definition of Aufwuchs to include only those organisms associated with biological substrates. Hutchinson(1967) equated this definition of Aufwuchs to the epiphyton which is confusing since 'biological substrate' does not necessarily imply a plant host.

Wetzel(1964) and Tai and Hodgkiss(1975)(using a previous definition of Wetzel's) expanded the definition of periphyton to include those organisms attached to solid surfaces, including the epipsammon and epipelon.

Sládečková's(1962) definition of Aufwuchs(=periphyton) and benthos appear the most logical to date. She subdivided the Aufwuchs, that group of organisms attached to any kind of substrate into: a)true-periphyton— attached organisms that are immobile and adjusted to the sessile life by gelatinous stalks, pads etc. and b)pseudo-periphyton— free-living, creeping and grazing organisms among the former group. The benthos remains restricted to a particular group of organisms living freely in the upper layer of sediments.

An association that is intermediate between the periphyton and the phytoplankton is the 'metaphyton' described by Wetzel(1975) as a group of algae "aggregated in the littoral zone which are neither strictly attached

nor strictly planktonic".

The planktonic matter in a body of water is referred to as the seston. The seston consists of the bioseston (plankton) and the abioseston (particles of allochthonous and autochthonous nature). The plankton consists of the net plankton and the nannoplankton, depending upon the size of the organism. The nannoplankton was originally defined to include everything not enclosed by a tow net and remains approximated as such.

There are several groups of planktonic communities: euplankton(permanent plankton community), meroplankton (organisms with temporary planktonic stages), pseudoplankton (accidental plankters=tychoplankton), limnoplankton(plankton of large lakes) and heleoplankton(plankton of ponds) (Hutchinson 1967). The tychoplankton and heleoplankton are frequently equated but are not synonyms and therefore cannot be used interchangeably.

Methodology

The collection of aquatics for analysis of their attached epiphyton has been reported by many. Godward(1937) collected macrophytes in shallow water from a boat while aquatics of deeper water were obtained with the help of a line bearing a weight with three hooks on the end. Siver(1977) harvested *Potamogeton* from 0.5-1.0m depths with a garden hoe. These methods were not satisfactory because many loosely attached forms were undoubtedly lost

in the rather rough retrieval process. Moore(1974c) collected samples of *Mougeotia* underwater in a plastic container and immediately preserved in 4% formalin. Sheldon and Boylen(1975) collected *Potamogeton* at 3m depths. Leaves were placed in empty, inverted Erlenmeyer flasks allowing for minimal loss of epiphytes underwater.

The use of artificial substrates to sample the epiphytic algal community has been employed since the turn of the century. Hentschel(1916) in Cooke(1956) was among the first to use glass slides as an artificial substrate. He exposed known surface areas of glass mounted vertically on pontoons. Glass remains the most popular artificial substrate(Godward 1937, Castenholz 1960, Sládečková 1962, Hansmann and Phinney 1973, Brettum 1974, Hooper and Robinson 1976, Siver 1977, Rosemarin and Gelin 1978). Numerous other artificial substrates have been tried with varying results (such as wood, slate,clay,concrete,asbestos, sheet metals,celluloid,plastics,styrofoam,gelatine,paraffin, plexiglass,cellulose acetate)(Sládečková 1962,Flint *et al* 1977). Various mechanisms for suspending the substrates has been used but they have generally involved a frame connected to the bottom by weighted ropes and to the surface by a flotation device.

The orientation of the artificial substrates was shown to be important. Three positions are possible: vertical, inclined and horizontal. Sládečková(1962) found that comparative analysis of the epiphytes attached to

horizontal and vertically situated slides produced differences dependant upon the environment. Generally results showed that horizontal substrata collected true periphyton but also a large amount of settling seston. The upper and lower surfaces of the slide differed in composition, possibly because of the light regime difference. The periphyton on vertical slides developed more slowly and generally less luxuriantly than on those positioned horizontally. The vertical orientation is most used in comparative studies with macrophyte hosts and horizontal orientation is used in studies of the epilithon.

Inherent problems exist in the use of artificial substrates (Hansmann and Phinney 1973, Brown 1976, Hooper and Robinson 1976, Siver 1977) several of which were pointed out by Wetzel(1964). The spatial orientation of the substrate has been mentioned. The influence of water movement and substrate retrieval may cause loss of materials. Cooke(1956) and Hansmann and Phinney(1973) greatly reduced this loss by orienting the glass slide substrate with the edge facing the current. The loss of material upon retrieval has been studied more intensively in examinations of macrophytes and their epiphytic populations.

The problem of exposure time for natural and artificial substrates has received little attention. Brown(1976) attempted to partially correct this problem by exposing clean *Eleocharis* plants and vertically positioned glass slides for the same time interval. Hooper and Robinson(1976,

1978a,b) eliminated the exposure period problem by inserting artificial substrates within stands of natural macrophyte populations at spring emergence times.

Limitations to the comparative analysis of the communities found upon natural and artificial substrates have been noted often. Results of such comparisons seem to depend upon whether or not the natural substrate was biological(Castenholz 1960), exposure times(Brown 1976, Hooper and Robinson 1976) and artificial substrate composition(Foerster and Schlichting 1965, Tippett 1970). Tippett(1970) stated that ' at its best the method (of artificial substrate use) can only be comparative, showing relative changes in the flora'. Foerster and Schlichting (1965) determined 'that an artificial barren surface gives a false indication of the true productivity trends and indicated only some of the significant genera present'.

There are basically three accepted methods of sampling the epipelic community in shallow water: aspiration alone, corer and aspiration and corer alone.

The aspirator was developed by Round(1953) and used by others(Round and Eaton 1966, Brown *et al* 1972). Round (1953) studied two sites in Malham Tarn, Yorkshire with calcareous and silt sediments. One end of a glass tube (0.5cm internal bore x 1m long) was lowered into the sediment while the upper end was held above the water surface and closed by the thumb. The tube was then opened and slowly drawn across the sediment and allowed to fill

with a mixture of mud and water which was then run into a bottle. This was repeated until sufficient quantities of the sediment were collected.

A modification of the method was developed when it was decided that quantitative results could only be obtained if a known depth and surface area of sediment were sampled.

Eaton and Moss(1966) modified Round's(1953) procedure to solve this problem. An acrylic plastic cylinder (9cm diameter x 35cm length) was pushed into the sediment to delimit an area. A glass tube of 0.4-0.5cm bore was connected by polyethylene tubing to a stoppered bottle. The bottle was squeezed to expel the air and the glass tube was moved over the surface within the cylinder such that it picked up surface material. Only the upper 2cm was retained for analysis. This modified aspiration technique has been used by Hickman and Round(1970), Moore(1974a,b), Tai and Hodgkiss(1975) and Hickman(1978).

The third general method employed in sampling the epipelon is to obtain a sediment core(Hunding 1971, Gruendling 1971, Sullivan 1975, Stanley 1976). The core sampler may consist of a plexiglass tube either conically pointed(Hunding 1971) or not(Gruendling 1971). Small slits are often calibrated up the corer so that distinct depth zones of the sediment may be delimited for various analyses.

The study of the phytoplankton is perhaps the oldest in Limnology. Sampling techniques have varied little from

the initial experiments on the community. The Van Dorn sampler is widely used in freshwater systems(e.g.Wetzel 1964, Kowalczewski and Lack 1971, Hickman and Jenkerson 1978, Schwartzkopf and Hergenrader 1978, Rosemarin and Gelin 1978, Hickman 1979 etc.).

Plankton tow nets have also been used when the desire is either to concentrate the sample or to restrict the study to a specific size range of organisms e.g. 20μm (Rosemarin and Hart 1978). A combination of net and water sampler has been devised by Schindler (1969).

One of the earlier methods of studying periphyton was by direct examination of the community. This was conducted on very thin-leaved plants like *Elodea*. By observing the leaf through a ruled slide, quantitative estimates of each population could be made (Cooke 1956, Sládečková 1962). Where chloroplast interference occurred bleaching in chloral hydrate was utilized. Glass slides have been examined directly by removing the periphyton from one side of the slide and viewing of the other.

Quantitative analysis of the epiphytic community most often, however, involves removal of the community from the host. The most common method has been to scrape the epiphyton from the macrophyte(Godward 1937, Siver 1977, Hooper-Reid and Robinson 1978a). Others though have used swirling or agitation(Knudson 1957, Sheldon and Boylen 1975).

Methodology in estimation of epipelon biomass is limited and therefore quite universal although the initial

procedures may affect the outcome of the estimates. Wetzel(1964), Gruendling(1971), Moore(1974a,b), Tett *et al* (1975) and Stanley(1976) did not attempt to separate the epipelic floral community from the sediment itself before conducting their analyses. Attempts at separating the epipelic organisms from the sediment were initiated by Round(1953) who took advantage of the natural diurnal vertical migration patterns in most epipelic algae. By placing a coverslip on top of a shallow dish containing sediment for 24h he was able to capture a large proportion of the eipelic flora. The coverslips could then be removed and observed microscopically. Errors in this procedure occurred when the population contained blue-green filaments or large numbers of desmids and flagellates. Eaton and Moss (1966) utilized 2x2cm tissues instead of coverslips and found the accuracy of the retrieval of all phototactic members of the epipelon increased.

The tissue-trapping method has also been used in the estimation of chlorophyll content(Eaton and Moss 1966, Brown *et al* 1972, Tai and Hodgkiss 1975, Sullivan 1975, Hickman 1978). The procedures for chlorophyll determination follow those outlined by Strickland and Parsons (1968) with the acidification procedures of either Lorenzen(1967) or Moss(1967).

The most common parameters of the biomass of algal populations are cell numbers, cell volume and chlorophyll *a* content.

Lund *et al* (1958) presented a method for estimating algal numbers on a statistical basis. The method is widely accepted today as the principal counting procedure. Olsen (1950) devised a procedure to quantitatively evaluate filamentous forms whether they were staight, curved or spiral. Unfortunately this author's work remains little used today for community studies.

Cell volume determinations have generally been made on the major species in a community study. Castenholz (1960) compared volumes on a per unit basis assigning a value of one to organisms with approximate volumes of $30\mu m^3$. Evans and Stockner (1972) used the same procedure in their study on Lake Winnipeg. Cell volumes of most recorded species differed between authors. For example, Castenholz (1960) gave *Cocconeis placentula* and *Synedra acus* comparative values of 8 and *Cymbella cistula* 79. In Evans and Stockner's (1972) study comparative volumes of C.*placentula* and S.*acus* were 12 and 118 for C.*cistula*.This is an apparent difference of about 120 $m\mu^3$ for C.*placentula* and S.*acus* and 1170 $m\mu^3$ for C.*cistula*. The value of calculating cell volumes in each separate study is noted since the same species may differ considerably in size from one environment to another.

Chlorophyll *a* determinations appear to be the most widespread biomass index because of their simplicity and speed of accomplishment. There has been much work in the past 15 years on improvements in methodology related to chlorophyll analysis. It was first realized that there must

be some means of accounting for the degradation products formed as a result of chlorophyll breakdown. Moss (1967) and Lorenzen (1967) developed methods based on the principle that upon acidification a molecule of chlorophyll *a* loses a Mg atom and is converted to pheophytin *a*. In 90% acetone this change is accompanied by a shift in the absorption maximum of 430 nm, characteristic of chlorophyll *a* to one at 410 nm, characteristic of pheophytin *a*. They separately developed methods that discriminated between the chlorophyllous compounds containing Mg atoms (chlorophyll *a* and chlorophyllide *a*) and those which were Mg free (pheophytin and pheophorbide). The extracting medium has been given considerable attention. Ninety per cent acetone has been routinely used in the spectrophotometric method in the determination of chlorophyll. The alcohols, primarily methanol, have been suggested as alternates for acetone (Johnson and Watson 1956, Wintermans and DeMots 1965, Sestak *et al* 1971, Marker 1972, Daley *et al* 1973, Tett *et al* 1975, Holm-Hansen and Riemann 1978). Although methanol is a more powerful extracting agent, it has not replaced acetone primarily because the spectral characteristics of the photosynthetic pigments in methanol are not as well known. While allomerization of chlorophyll may occur with considerable changes in the spectral characteristics of chlorophyll *a* and *b* in methanol, it does not affect the absorption spectra of these chlorophylls in acetone (Johnson and Watson 1956, Marker 1972). On the other hand acetone's extraction

efficiency is much less than that of methanol when algal populations consist of Cyanophyta and some Chlorophyceae. Holm-Hansen and Riemann (1978) have recommended that methanol be used because of the advantages of shorter extraction time and the elimination of the homogenization step necessary particularily when certain thick-celled filaments are being extracted in acetone.

The fluorometric technique may be used as an alternative to spectrophotometric determinations. It has several advantages over light absorption methods. The first is that it is more sensitive. Secondly it is quicker than determining extinction values at several wavelengths. The third advantage is that the instrument measuring fluorescence does not depend upon critical wavelength alignment as does the spectrophotometer (Holm-Hansen *et al* 1965). The method may result however in variations of chlorophyll *a* being ±20% of the value determined spectrophotometrically.

Community successional studies have been hindered by the lack of consistency in biomass estimate methodology. In two investigations by Hobro and Willen (1975,1977) cell numbers, cell volume and community composition distribution of a single sample was conducted in five separate laboratories. It was found that the largest errors resulted in counting the Chrysophyta and Pyrrophyta. They found that the lowest variation between maximum and minimum values of the total number of all counted species was over 500%. Chlorophyll *a* correlates well with cell volume or

cell numbers in some instances (Hickman and Round 1970, Hickman and Jenkerson 1978, Tolstoy 1979) but in others may not (Jones 1977a, Rott 1978, Hooper-Reid and Robinson 1978a, Tolstoy 1979).

There are inherent disadvantages to all three methods. Biomass as cell numbers tends to overestimate the significance of small species and underestimate the larger ones while cell volume does the opposite. Chlorophyll *a* is a mass method that does not lend itself to the identification of the algal population. In chlorophyll analysis an initial assumption that the concentration of chlorophyll per cell is constant is required. Of course this is not so. Different groups of algae and indeed cells of the same species may contain varying amounts of chlorophyll which could result in either overestimation or underestimation of total biomass.

Community Composition

Almost all truly epiphytic organisms possess some positive means of attachment. Several common mechanisms are mucilagenous pads (*Cocconeis*) or stalks (*Gomphonema*, *Cymbella*) and terminal holdfast cells (*Ulothrix*). Many others possess mucilagenous sheaths that aid in the initial colonization of a host plant (eg. *Gloeotrichia*, *Aphanocapsa*, *Lyngbya*).

Allen (1971) found that the attachment of epiphytes was greatly facilitated by calcium carbonate crystals and chlorotic diatoms interwoven in a mucilagenous matrix on

the plant surface. Allanson (1975) confirmed Allan's (1971) findings using SEM. He found that the epiphytic diatoms on *Chara* were held in place by a matrix formed largely of gelatinous stalks above calcareous deposits on the host cell wall.

There is some evidence that epiphytes display substrate specificity (Harlin 1973, Sieburth *et al* 1974, Brown 1976, Siver 1977, Mason and Bryant 1975). Harlin (1973) stated that'many epiphytic algae are restricted in their habitat to surfaces of one or a few organisms'. The highly specific association of *Gonimophyllum skottsbergii* on the red alga *Botryoglossum ruprechtiana* was compared with the free associations of the brown alga *Sargassum muticum* and numerous epiphytes. Harlin (1973) proposed that few algae would grow upon any host that secretes growth inhibitors. The growth rate of the host, physical means of attachment and the surface tension of the host were all considered to be valid considerations in epiphyte-macrophyte specificity relationships.

The composition of the epiphytic community on natural and artificial hosts generally shows a rather characteristic pattern of biomass succession in shallow, temperate lakes (Godward 1937, Castenholz 1960, Stockner and Armstrong 1971, Klarer and Hickman 1975, Siver 1977). Hutchinson (1967) reported similar successional patterns in the phytoplankton of temperate lakes. The scheme is generally one of spring and autumn biomass maxima and summer minimum.

In the spring diatoms generally predominate due to their adaptation to low light and temperature regimes. The green algae may increase to domination in the early summer followed by predominance of blue-greens in the mid-late summer. This is followed by an autumnal biomass maximum by diatoms. The epilithic community is very similar to the epiphyton in species composition and successional pattern (Godward 1937).

Although *Cocconeis placentula* was originally defined as a winter species it occurs in large numbers either intermittently throughout the season (Hickman and Klarer 1973, Hooper-Reid and Robinson 1978a) or in large blooms in the summer (Hansmann and Phinney 1973, Klarer and Hickman 1975). Several other species of diatoms appear to be practically ubiquitous in temperate, shallow water systems. These are *Gomphonema parvulum* and *G.olivaceum* (Allen 1971, Mason and Bryant 1975, Flint *et al* 1977, Eminson 1978) and *Achnanthes minutissima* and *A.microcephela* (Godward 1937, Klarer and Hickman 1975, Mason and Bryant 1975, Siver 1977, Moore 1972, Eminson 1978). Species of *Eunotia* (Hansmann and Phinney 1973), *Epithemia* (Godward 1937) and *Fragilaria* and *Tabellaria* (Allen 1971) are also common.

Comparison of the three major groups of epiphytic algae, the Bacillariophyceae, Chlorophyta and Cyanophyta; generally results in the Bacillariophyceae exhibiting the greatest species diversity and contribution to the total biomass. The Chlorophyta is generally second showing more

distinct seasonal patterns and the Cyanophyta most often display the lowest diversity although their biomass may be quite high at certain times of the year. Stockner and Armstrong (1971) in an epilithic study noted that diatoms consistently composed more that 60-70% of the total algal volume. Evans and Stockner (1972) reported similar results on their study of the periphyton on navigational buoys. Klarer and Hickman (1975) related this lack of seasonal change in domination to 'nutrient' effects in their study of the effect of thermal effluent on the epiphytic community on *Scirpus*. They equated the effect of heat to nutrient excess. In the non-heated sites studied there was no species that ever constituted more that 50% of the population. At the heated stations diatoms especially often accounted for more than 50% of the total population volume. They concluded that an increase in nutrient concentration resulted in a decrease in species diversity and an increase in the importance of a few species. The studies involving the epipelic flora of shallow water systems are mainly restricted to temperate and arctic conditions.

It has generally been assumed that diatoms predominate in the temperate epipelic environment (Gruendling 1971, Hickman 1978) and that members of the Chlorophyta dominate in arctic epipelic communities. Moore (1974a,b) determined, in a study involving nine rivers and ten temporary ponds on Baffin Island, that diatoms constituted 63-83% of the total species diversity and were the most

prevalent group. *Mougeotia* did however become dominant in the few rivers where it occurred.

In temperate ponds and lakes few exceptions can be found. Wright and Pfiester (1978), in a comparative study of the epipelon in ponds with clay and sandstone bottoms found a higher diversity of taxa on the sandstone. Round (1953) found a greater diversity on calcareous sediments than on peat. In temperate waters, while Chlorophyta do contribute a great deal to the total community, they do not generally dominate the population for the entire season.

The phytoplankton of small temperate lakes and ponds generally display distinct seasonal pulses (Hutchinson 1967). The domination by Cyanophyta in the mid-late summer, particularily by bloom-forming algae like *Microcystis* and *Aphanizomenon* has been noted previously (Kling 1975, Jones 1977a, Coveney *et al* 1977, Hickman and Jenkerson 1978, Hickman 1979). The spring and fall domination of diatoms and the early and late summer prevalence of the Chlorophyta has often been observed.

In his study of the tributary streams of Lake Ontario, Moore (1972) determined that the phytoplankton had been derived from the epipelon and that Chlorophyta, Euglenophyta and Chrysophyta reached their maximum relative abundance during the summer while the Cyanophyta population peaked in the fall and winter.

Hickman (1978) in an investigation of five prairie-

parkland lakes observed that four of them exhibited large mixed summer populations of Chlorophyta and Cyanophyceae. Stanley (1976) found the phytoplankton of a tundra pond to consist of the Chrysophyceae and Cryptophyta, especially *Rhodomonas* and *Cryptomonas*. Diatoms and green algae were much less important.

MATERIALS AND METHODS

Study Site

Lakes 255 and 623, the two lakes under consideration are part of an aquaculture experimental lakes project in Southwestern Manitoba, approximately 16km south of Riding Mountain National Park at 50°30'N and 100°10'W. The entire study area is approximately 800km^2.

The study area lies near the edge of the Manitoba Escarpment on the second prairie steppe. The elevation ranges from 500 to 650m above sea level and generally slopes to the south. It is situated on undulating glacial till plain of the Riding Mountain Formation. In and between numerous hummocks exist many marshes, sloughs and pothole lakes, many of which originated as kettle lakes. The area is drained mostly by the Minnedosa and Rolling Rivers. There are very few other permanent streams.

The lakes are generally saucer-shaped with approximately flat bottoms. Shoreline development indices of lakes less than 40ha are usually less than 1.2. Bottoms and shorelines are composed of soft organic muck. L255 is typical of most of the lakes in the region in that it is landlocked. L623 has a rather intermittent surface outflow. This discharge may not occur annually (Sunde and Barica 1975).

According to the data accumulated by these workers the mean July temperature is 18°C and the mean January temperature is -18°C. Mean annual precipitation as rain is 450-

480mm and as snow 1140-1270mm. Ice thickness in late winter averages 70cm. Snow cover averages 15-30cm. The snow remains quite soft and evenly distributed over the lakes due to their relatively small size and protection provided them by the hills and trees.

Figure 1a illustrates L255. This lake has a mean depth of 1.7m, maximum depth of 2.7m and an area of 3.2ha. L623 (Fig.1b) has a mean depth of 0.7m, maximum depth of 1.5m and an area of 2.4ha.

Submergent and emergent vegetation of the two lakes as found by Sunde and Barica(1975) is presented in Table 1. *Myriophyllum.Ceratophyllum, Chara, Lemna trisulcus, Scirpus validus, Typha latifolia,Carex* and filamentous algae are found in both lakes. *Potamogeton pectinatus* is specific to L255.

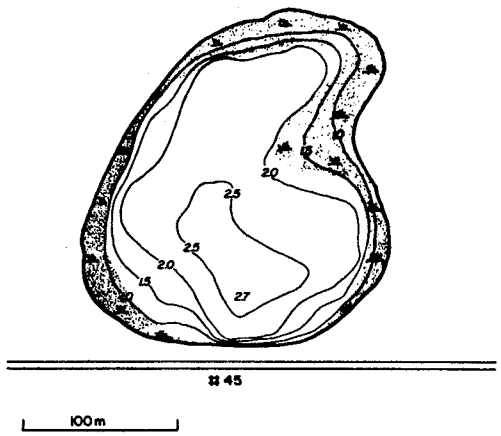
Sampling Procedures

a) Epiphyton

Cellulose acetate artificial substrates were utilized in part of the study to simulate natural emergent macrophytic host plants. Forty x 1.5" strips of 0.005" cellulose acetate were cut with a razor blade. Half of the strips were roughened in a longitudinal fashion by running coarse alumide sandpaper over the surface of the acetate three to five times on both sides to make the striations approximate those natural ridges of a T. *latifolia* reed stem. One hundred strips were inserted in each lake (50 smooth and

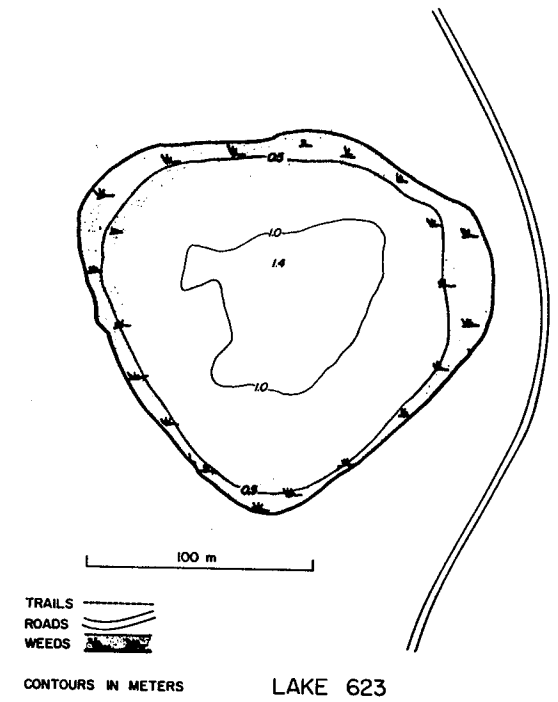
Figure 1: Bathymetric maps of a) Lake 255 and b) Lake 623

(a)



LAKE 255

(b)



LAKE 623

(from Sunde and Barica, 1975)

Table 1: Emergent and submergent vegetation of Lakes 255 and 623 recorded as % of the shoreline occupied by 3 of the most common emergents, P(present), C(common) and A(abundant). (From Sunde and Barica 1975)

VEGETATION	L255	L623
Myriophyllum	C	P
Ceratophyllum	C	A
Lemna trisulca	C	A
Potamogeton pectinatus	P	--
Chara sp.	P	C
Filamentous algae	A	A
Scirpus validus	20%	10%
Carex sp.	100%	100%
*Typha latifolia**	10%*	100%

* Observations in the 1978 and 1979 growing seasons indicate this value is underestimated.

50 roughened) as soon as the sediment was sufficiently free of ice to permit placement.

The frames were 2' square by 5' in length. Two frames were inserted in each lake in the event of breakage of a frame. The frames were installed May 16/1978 and May 24/1979. Each frame was constructed of 1"x4" boards for the horizontals and 2"x2" posts for the verticals.

The ends of the acetate strips were bound by electrician's tape to prevent tearing when stapled to the frame and also to prevent the chance of mineral elements (Fe,Al) in the staples affecting the natural assemblage of species on the acetate. The strips were attached vertically to the frames as illustrated (Fig.2).

Each frame with strips was placed in the *Typha* bed in both lakes to approximate the natural physico-chemical environment of the emergent zone. The frames were also inserted within one to two days of the emergence of the macrophytes.

At weekly intervals thereafter a strip each of smooth and roughened cellulose acetate and a *Typha* reed stem (submergent portion) was removed and taken back to the laboratory for the removal of the epiphytic populations in the 1979 season. In 1978 smooth acetate only was sampled.

To sample the *Typha*, the stem was pulled gently and smoothly out of the sediment and cut with a sharp knife at the water-sediment and water-air interfaces.

Samples were generally taken between 0900 and 1100h

Figure 2: The positioning of the cellulose acetate substrates on the frames in the littoral zone.

as recommended by Round and Eaton(1966) and Brown *et al*(1972) to maintain a consistency in the sampling procedure of algae with diurnal vertical migration patterns.

Upon return to the laboratory, the cellulose acetate strips and the *Typha* reed stems were gently scraped with a razor blade to remove epiphytes. The scraped substrates were blotted dry and the colonizable surface area was calculated by tracing them onto graph paper.

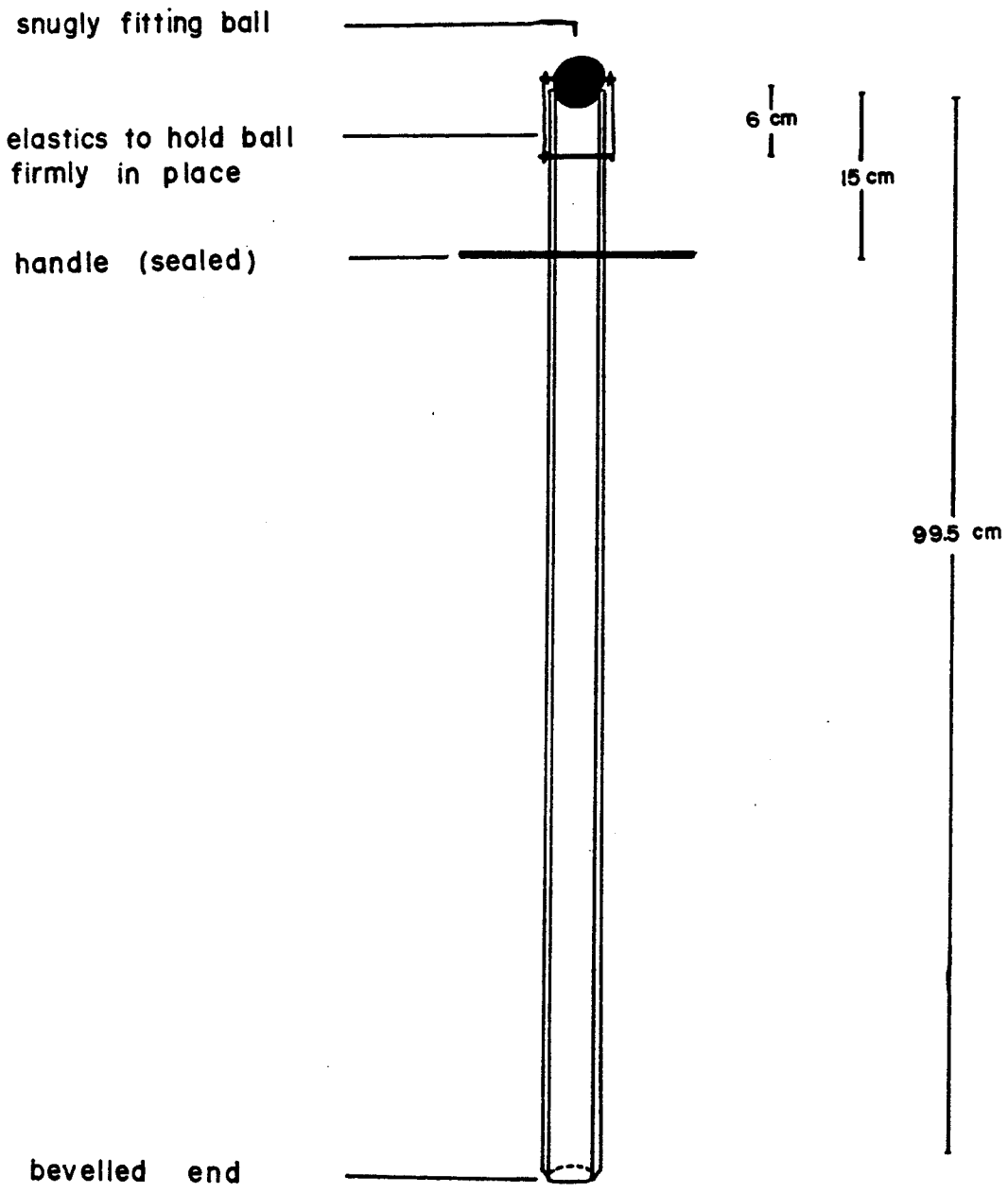
The epiphytes were suspended in bidistilled water and made to exactly 1ℓ. A small vial was filled with some of the epiphytic suspension and 5% Lugol's iodide was added for sample preservation. The remainder was used for chlorophyll determinations.

b) Epipelon

A modification of sampling devices previously used (Round 1953,Eaton and Moss 1966) was successfully employed. The sampler consisted of a clear plexiglass tube (Fig.3) with one end bevelled and the other sealed with a removable, snugly fitting rubber ball.

The rubber ball was removed and the sediment sampler was slowly lowered into the sediment of the emergent macrophyte zone, great care being taken to avoid disturbance of the sediment. The tube was pushed in as far as possible and then the ball was replaced on the top to create a vacuum. With a slow and smooth twisting motion the sampler was raised containing its core until the bottom of the tube was just below the surface of the water. A smooth plate was then

Figure 3: Scale diagram of the device used in sampling the epipelic community.



EPIPELIC SAMPLER

quickly placed over the bottom of the tube to prevent sudden release of the vacuum upon release into the atmosphere.

Once the sediment had settled and the surface line was clearly evident, the muck was very carefully eluted through the bottom of the tube by brief removal of the plate. When the upper 2cm of sediment remained a collecting bottle retreived this and the sample was returned to the laboratory.

Each sediment core was made to exactly 1ℓ with bidistilled water and, after vigorous shaking to homogenize the sample, a small amount was taken for algal identification and enumeration and the remainder used for chlorophyll analysis.

c) Phytoplankton

The epipelic sampler was utilized for phytoplankton sampling as a column of water from surface to sediment could be easily and quickly obtained. The water sample was poured into a sampling bottle and immediately returned to the laboratory. A small portion was preserved for enumeration and the remainder used for chlorophyll determinations.

Chlorophyll Analysis

a) Epiphyton and Phytoplankton

The procedure for chlorophyll analysis as outlined by Strickland and Parsons (1968), with some modifications, was utilized on the epiphytic and phytoplanktonic populations.

Known volumes of the samples were filtered using 4.5cm Whatman GF/C filters. Extractions were triplicated.

Approximately 1ml of 1% magnesium carbonate was added to the suspension as it filtered through the apparatus. The filters were drained thoroughly under gentle suction and the peripheral excess of unstained filter was cut away.

The pigments were immediately extracted by adding approximately 5ml of 90% acetone to a tissue grinder in which the filter had been placed. The filter was completely macerated and the chlorophyll extract was placed in complete darkness for 20h at 4°C. Extracts were refiltered through paper filters and the filtrate made to exactly 10ml with 90% acetone. The extinction values were determined at 750, 665, 645, 630 and 480nm in an SP6-500 UV Pye Unicam Ltd. spectrophotometer. The samples were acidified with 2-3 drops of 6M HCl and reread at 750 and 665nm for pheophytin determinations (Strickland and Parsons 1968).

Phytoplankton samples were treated in the same way as the epiphytes and in both pigment concentrations were determined using the equations of Strickland and Parsons(1968). For epiphytes these concentrations were expressed as μg pigment/cm^2 of substrate surface and for phytoplankton as μg pigment/ℓ.

b) Epipelon

The method of chlorophyll determination was essentially that of Stanley(1976) with some modifications. Known volumes (in triplicate) were poured into 500ml centrifuge tubes and centrifuged at 10°C for 20 minutes at 7000rpm. The supernatant was decanted off and the pellet was suspended in 90%

acetone (30-40ml) and then stored in complete darkness for 20 hours at 4°C.

Extracted samples were then filtered through paper filters and the clear chlorophyll extracts made to known volumes with 90% acetone. Extinction values and pigment concentrations were determined as above.

Cell Counts

Since most benthic samples contained dense algal populations a Palmer cell (0.1ml capacity) in conjunction with a Nikon phase contrast microscope was employed. For sparser populations such as phytoplankton and some epiphytes, a sedimentation chamber and a Wild Leitz inverted microscope was utilized. Identification was made at 400-1000x with the phase contrast microscope and 200-400x with the inverted microscope.

Standard techniques were adopted to assure compatability and consistency. They differ from those used by most other workers who predetermine the number of organisms they will count to represent a population(Lund *et al* 1958;Hobro and Willen 1975,1977). Preset statistics were utilized to more efficiently count the algae and calculate their volumes. An acceptable standard error of the mean was set at 20% for the number of microscope fields and 5% for the cell volumes it was necessary to record.

A sample size of twenty was initially evaluated to obtain the population estimates of standard deviation (σ),

mean ($\bar{x}$) and standard error ($\hat{s}$). Due to the small sample size the Students 't' representation of the normal population was used. The $t_{\alpha/2,n-1}$ value was left as 1.0 indicating a precision at the 85% level of confidence.

A summary of the general procedure for counting accuracy and cell volume determinations is as follows:

1. Pretest: 20 fields (or organisms), n_1, were evaluated to determine sample size. The following values can be approximated:
   - i) sample mean ($\bar{x}$)
   - ii) standard deviation (σ)
   - iii) variance (σ^2)
   - iv) standard error of the mean at $t_{\alpha/2,n-1=1.00}$ ($\hat{s}$)
   - v) n_1=number of fields necessary to count for population representation
   - vi) n_2=number of cell volumes to calculate for population representation
2. From the pretest s is evalulated at either 0.20 or 0.05 level of confidence from the formula $\hat{s}=(\bar{x})$(% deviation).
3. n_1 or n_2 determined from $n=\sigma^2/\hat{s}^2$

The confidence limits could be adjusted to suit the purposes of the experimenter. Lund *et al*(1958) have stated that a total standard deviation of $\pm$50% is quite accurate for most studies.

The time spent increasing the level of significance is largely wasted in such a heterogeneous system. These workers also stated: "As the accuracy of a count varies

indirectly as the square root of the number counted, to obtain any degree of increase in accuracy it is necessary to make very much larger counts. Thus to obtain twice the accuracy four times the number of organisms must be counted. For example, a count of 100 has an accuracy of 20%, and a count of 400 an accuracy of 10%, for the same confidence coefficient. It is thus rarely worth while counting more than the minimum number necessary to provide the required degree of accuracy."

Cell Volume Estimates

The cell volumes were calculated by approximating the shape of the algae to a geometric shape or a combination of geometric shapes. All volumes were calculated during the study and no values from the literature were employed due to variation that might exist due to: 1. lack of statistical comparisons to assess accuracies of methodology; 2. differences in the approximation of geometric shapes among workers; 3. uniqueness of each environment may alter the morphological shape and size of many algae.

A list of the most common species ancountered and their volume estimates, calculated at 95% confidence limits is found in Appendix 1.

Algal Taxonomy and Diatom Preparation

Algal taxa were identified with the aid of the keys of Prescott (1962,1970), U.S. Dept. of the Interior (1966), Thienemann (1962), Tilden (1910) and Patrick and Reimer (1966, 1975).

In order to identify diatoms it was necessary to remove their organic contents so that the silica frustules

could be observed clearly. In order to accomplish this, the following procedure of 'acid-cleaning' was adopted.

An appropriate aliquot (30-100 ml) of each sample was centrifuged into a pellet. The supernatant was decanted off and 15-20 ml of concentrated sulfuric acid was carefully added. Tubes containing the pellet and sulfuric acid were loosely covered and placed in an oven (100°C) overnight. The tubes were removed from the oven and the acid diluted. Samples were serially centrifuged with increasing amounts of water until the cleaned frustules were suspended in water alone. To dehydrate the samples for semi-permanent mounting, each was suspended serially in 50,70,90% alcohol, centrifuging between each change. Following two changes in absolute alcohol, samples were cleared in xylene overnight. The xylene was decanted off and more added. The frusules were mounted on slides with a mounting medium such as "Pro-texx" (Lerner Laboratories) (r=1.496) and sealed when dry with nailpolish.

RESULTS

The community composition and biomass as cell volume and chlorophyll *a* were determined for the epiphytic, epipelic and planktonic algal populations of the littoral zones of Lakes 255 and 623. Species lists are found in Appendix 2. All standard error values for biomass estimates are calculated at the 95% level of significance.

1. COMMUNITY COMPOSITION

A. Lake 255

i) Epiphyton

The diversity of the epiphyton within each of the seven major groups (Cyanophyta, Chlorophyta, Euglenophyta, Pyrrophyta, Cryptophyta, Chrysophyceae and Bacillariophyceae) found on *Typha latifolia* and the cellulose acetate substrates were similar (Tab.2) (Wilcoxon Rank Sum $P<0.05$) although their contributions to the cell volumes differed greatly. The Cyanophyta was a minor contributor on *Typha* becomong significant sporadically in July, August and September. However, this group was important throughout much of the season on the artificial substrates (Fig.4a). The Chlorophyceae sometimes comprised 100% of the cell volume in June and July on all substrates but were generally larger on the artificial substrates (Fig.4b). *Typha* supported the greatest populations of diatoms of all substrates (Fig.4c).

Algal taxa that accounted for more than 10% of the total cell volume were similar among the three substrates. *Aphanocapsa delicatissima*, *Stigeoclonium nanum* and

Table 2: The species distribution of algae contributing to the epiphytic, epipelic and phytoplanktonic communities of the littoral zone in L255.

HABITAT	TOTAL	CYANO-PHYTA	CHLORO-PHYTA	EUGLENO-PHYTA	PYRRO-PHYTA	CRYPTO-PHYTA	CHRYSO-PHYCEAE	BACILLARIO-PHYCEAE
Typha stem	44	12	7	4	1	0	7	13
Smooth acetate (1979)	37	14	8	3	1	0	3	8
Smooth acetate (1978)	31	7	9	2	1	0	3	9
Roughened acetate	43	15	9	3	1	0	5	10
Epipelon	49	5	9	5	1	1	3	25
Phytoplankton	38	8	7	3	1	1	5	13

Cocconeis placentula var. *lineata* were the most predominant. *Typha* also supported significant populations of *Ankistrodesmus falcatus* and *Trachelomonas robusta*. The seasonal occurrence of these algae is illustrated in Fig.5a-c. Complete domination of a single taxon did not occur on *Typha* but was the norm on the artificial substrates.

ii) Epipelon

The epipelic algal community of L255 supported the greatest species diversity in that lake's littoral zone. A total of 49 taxa were identified of which more than 50% were members of the Bacillariophyceae (Tab.2). Diatoms often represented 90-100% of the total community although the Cyanophyta and Euglenophyta were periodically evident in the latter half of the season (Fig.6).

Species constituting more than 10% of the total volume were *Aphanizomenon flos-aquae*, *Trachelomonas robusta*, *Gomphonema parvulum* var. *parvulum*, *Cocconeis placentula* var. *lineata*, *Synedra ulna* var. *ulna* and *Surirella ovalis* (Fig.7).

C. placentula var. *lineata* was consistent throughout the season from early June to the end of the study period. *S. ovalis* contributed enormous volumes sporadically from June to August.

iii) Phytoplankton

The phytoplankton of the littoral zone in L255 consisted of the Cyanophyta, Pyrrophyta and Cryptophyta. The Cryptophyta dominated from late May to mid-June. Members of the Pyrrophyta appeared briefly in July after

Figure 4: Per cent contribution on a cell volume basis of the epiphytic algae on *Typha*, smooth and roughened acetate by the a) Cyanophyta b) Chlorophyta and c) Bacillariophyceae in L255.

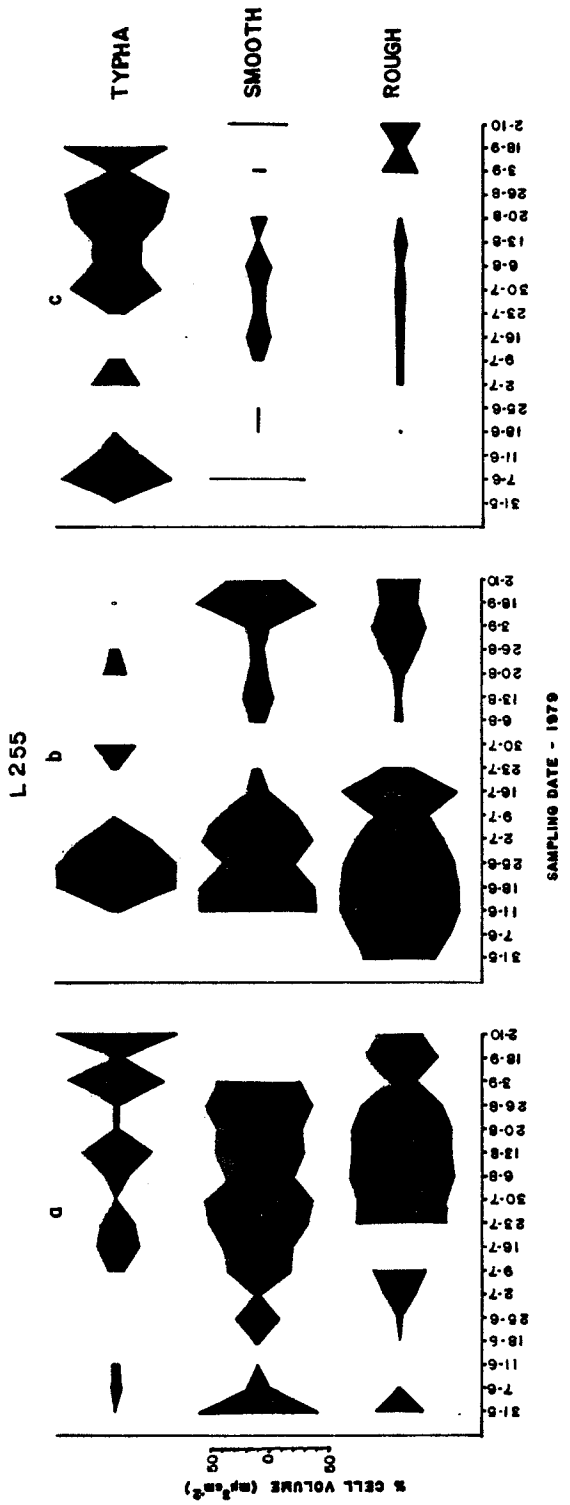


Figure 5: Contribution by the epiphytic flora of L255 that represented more than 10% of the total population volume on a) *Typha*, b) smooth acetate and c) roughened acetate.

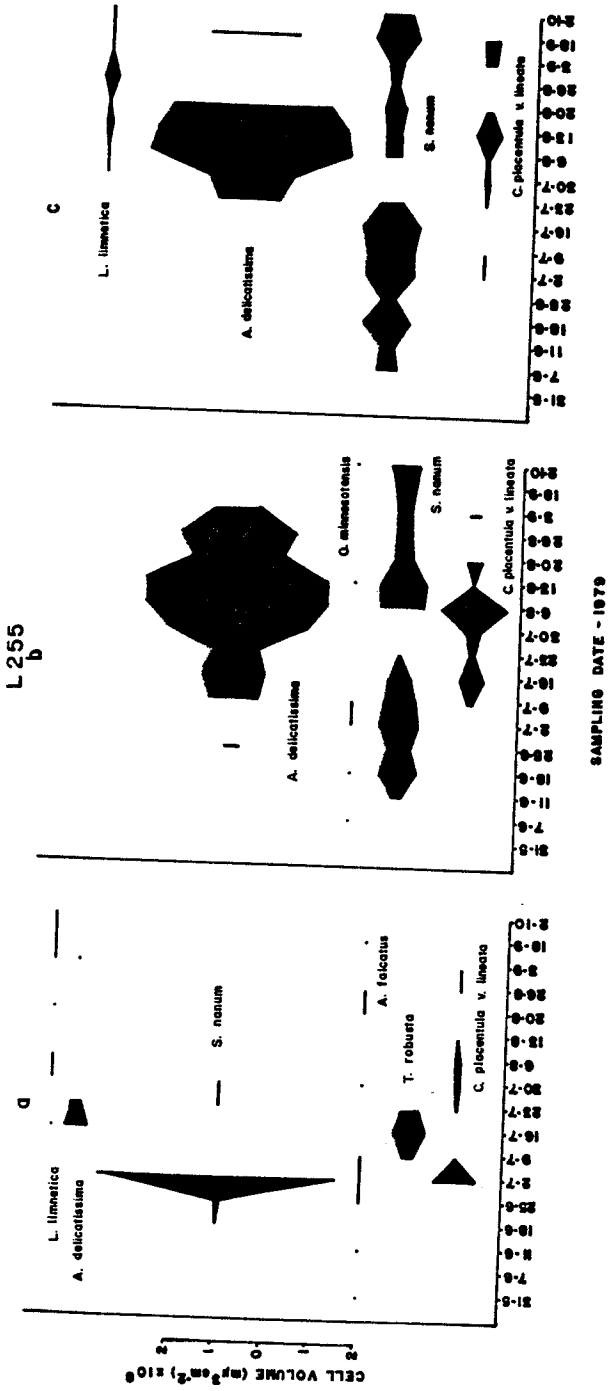

L 255
a
b
c
L. limnetica
A. delicatissima
S. nanum
A. falcatus
T. robusta
C. placentula v. lineata
O. mikesaetensis
CELL VOLUME (mμ³cm⁻³) x10⁸
SAMPLING DATE - 1979

Figure 6: Per cent contribution on a cell volume basis of the Cyanophyta, Euglenophyta and Bacillariophyceae in the epipelon in L255.

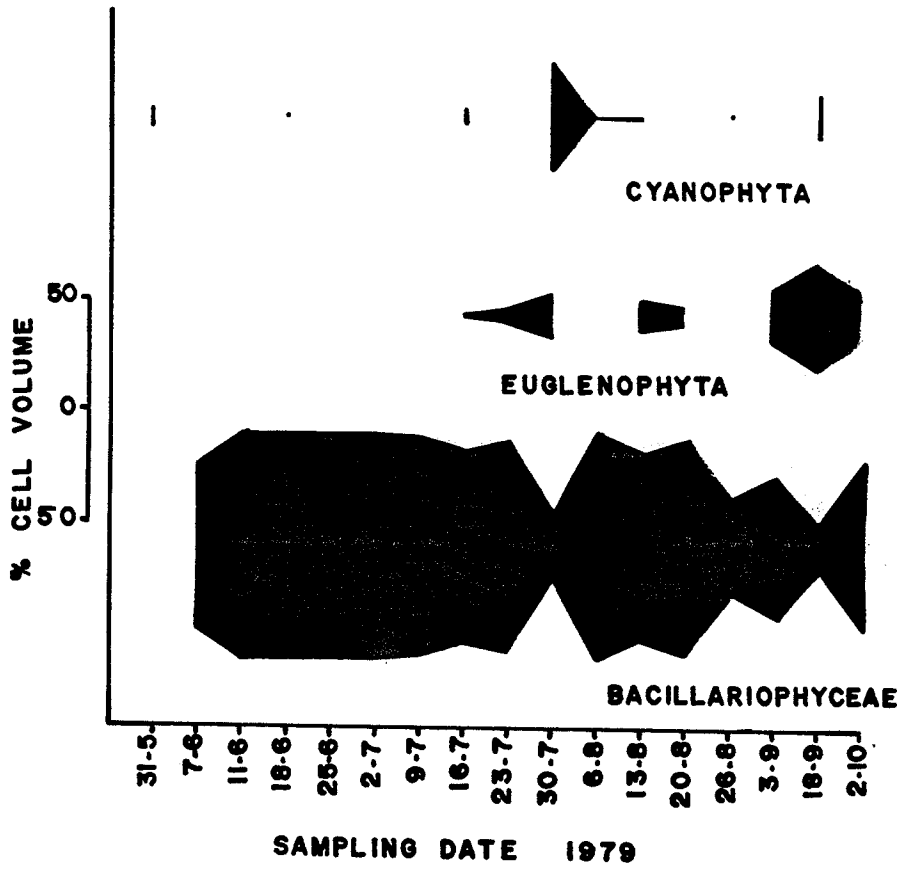
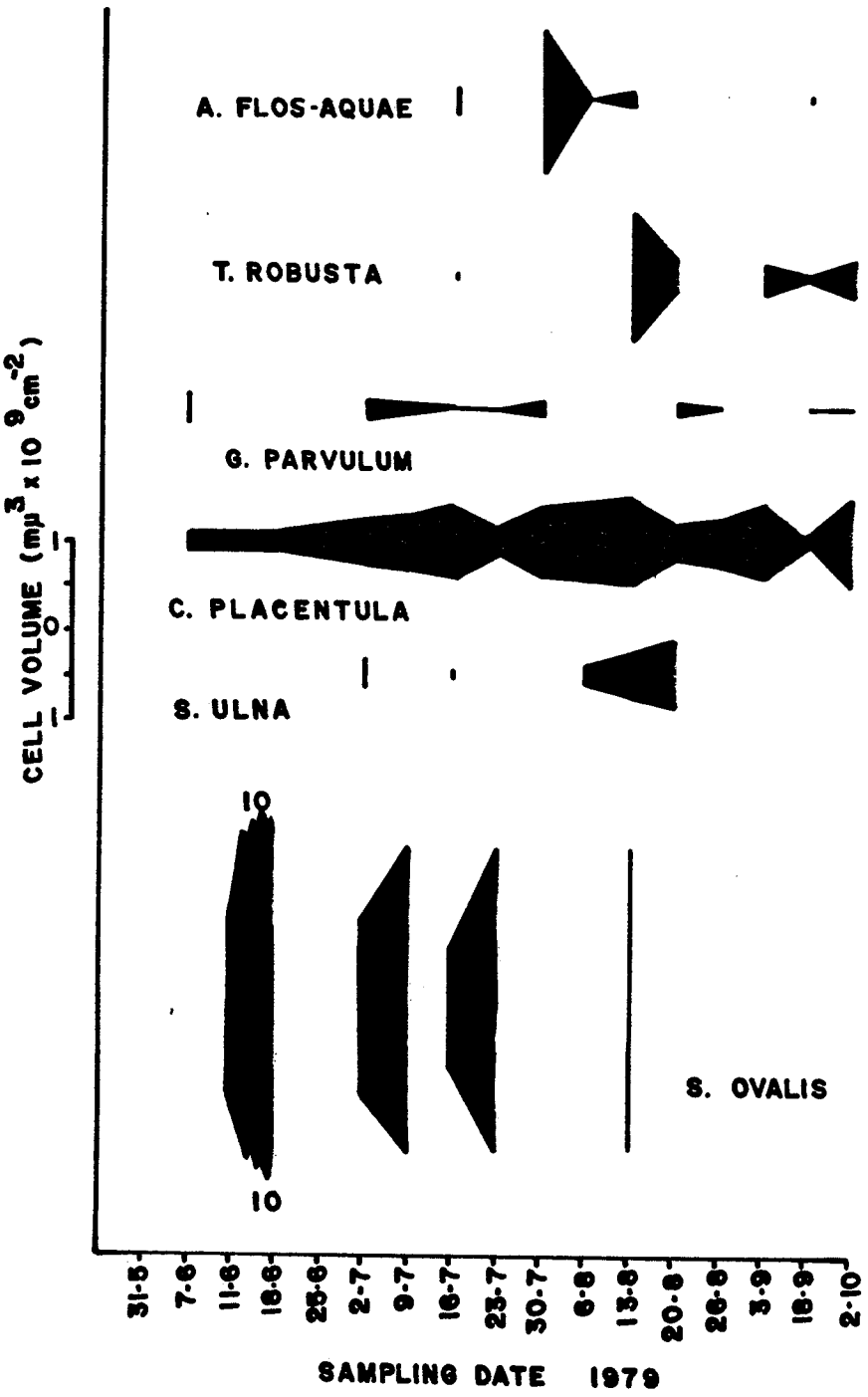

CYANOPHYTA
EUGLENOPHYTA
BACILLARIOPHYCEAE
% CELL VOLUME
50
0
50
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

Figure 7: Contribution by the epipelic taxa of L255 that represented more than 10% of the total population volume.


A. FLOS-AQUAE
T. ROBUSTA
G. PARVULUM
C. PLACENTULA
S. ULNA
S. OVALIS
10
0
10
CELL VOLUME (mμ³ x 10⁹ cm⁻²)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

which time the Cyanophyta completely dominated to the end of the season (Fig.8).

Species constituting more than 10% of the phytoplankton were A. *flos-aquae*, *Microcystis aeruginosa*, *Schroederia Judayi*, *Chromulina obconica*, *Ceratium hirundinella* and *Cryptomonas erosa* (Fig.9). A. *flos-aquae* and C. *hirundinella* were by far the greatest community contributors due to their large sizes.

B. Lake 623

i) Epiphyton

The species diversity of the three substrates was found to be similar (P 0.05) as shown in Table 3. Their contribution to the total biomass differed however as in L255.

The Cyanophyta remained relatively insignificant on all three substrates (Fig.10a), rarely contributing more than 25% of the population volume. While the artificial substrates supported the largest proportion of their blue-green populations in June and July, this group only became apparent on *Typha* briefly in August.

The Chlorophyceae were the major contributors to the epiphyton of the artificial substrates through most of the growing season (Fig.10b). The green algae became important on *Typha* in the late summer-early autumn.

The epiphyton on *Typha* was dominated by diatoms from early June to the onset of the Chlorophyceae in late August (Fig.10c). Diatoms could not outcompete the green

Table 3: The species distribution of algae contributing to the epiphytic, epipelic and phytoplanktonic communities of the littoral zone in L623.

HABITAT	TOTAL	CYANO-PHYTA	CHLORO-PHYTA	EUGLENO-PHYTA	PYRRO-PHYTA	CRYPTO-PHYTA	CHRYSO-PHYCEAE	BACILLARIO-PHYCEAE
Typha stem	43	9	13	1	0	0	6	14
Smooth acetate (1979)	55	15	9	5	0	0	9	17
Smooth acetate (1978)	36	10	12	3	1	0	4	6
Roughened acetate	45	11	10	3	1	0	7	13
Epipelon	67	11	13	9	0	0	7	27
Phytoplankton	47	15	7	2	1	1	5	16

Figure 8: Per cent contribution on a cell volume basis of the phytoplankton in L255 represented by the Cyanophyta, Pyrrophyta and Cryptophyta.

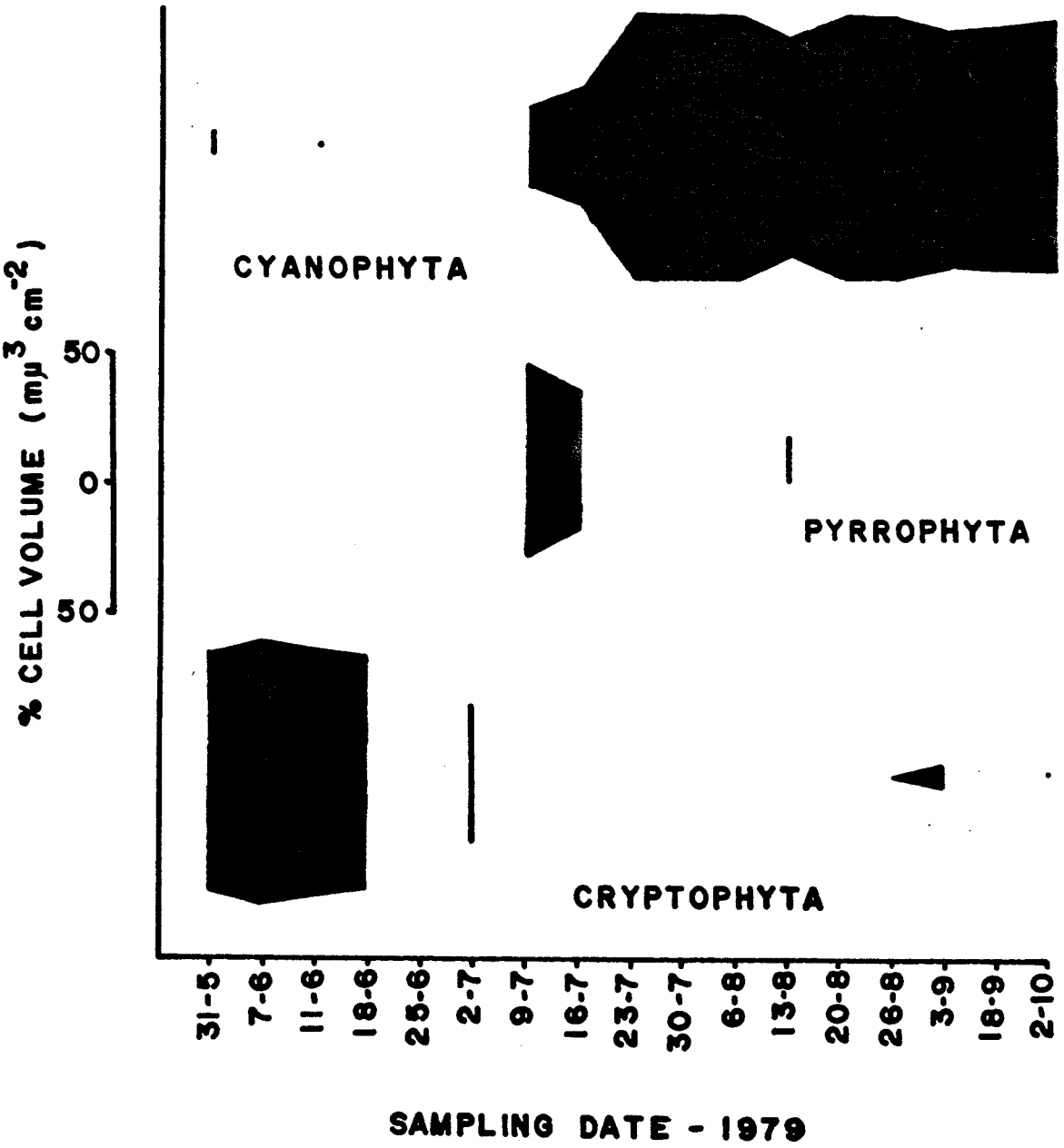

CYANOPHYTA
PYRROPHYTA
CRYPTOPHYTA
% CELL VOLUME ($m\mu^3 cm^{-2}$)
50
0
50
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 9: Contribution by the phytoplankton species constituting more than 10% of the total population volume in L255.

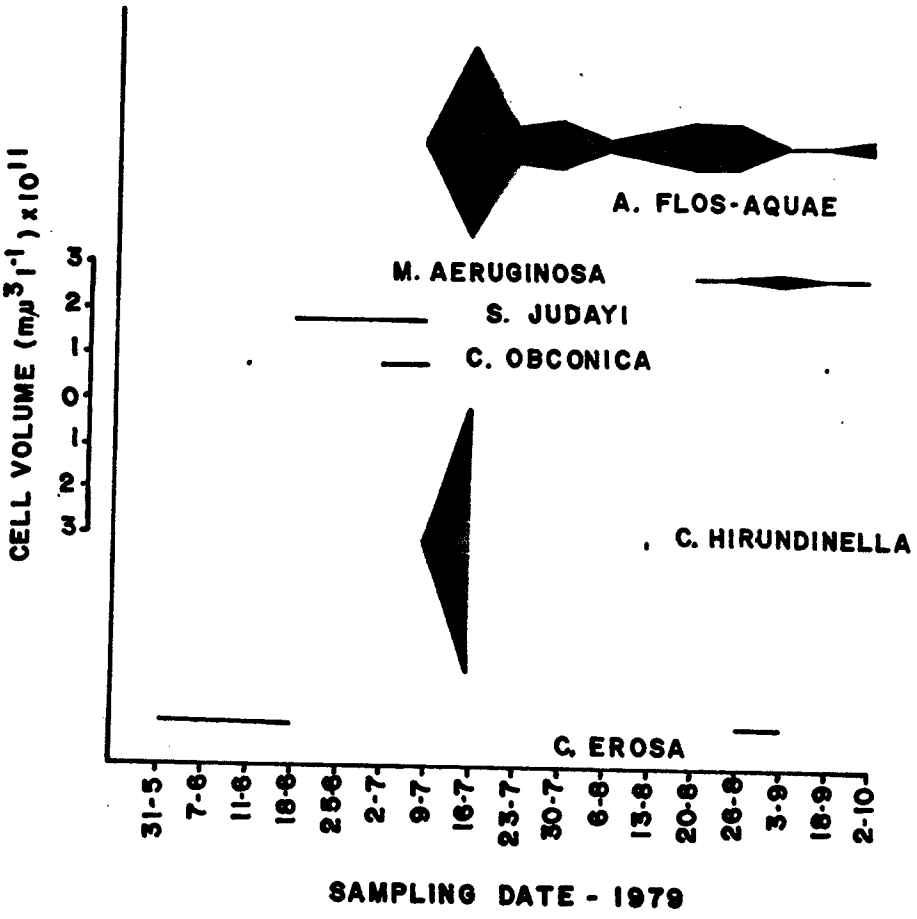
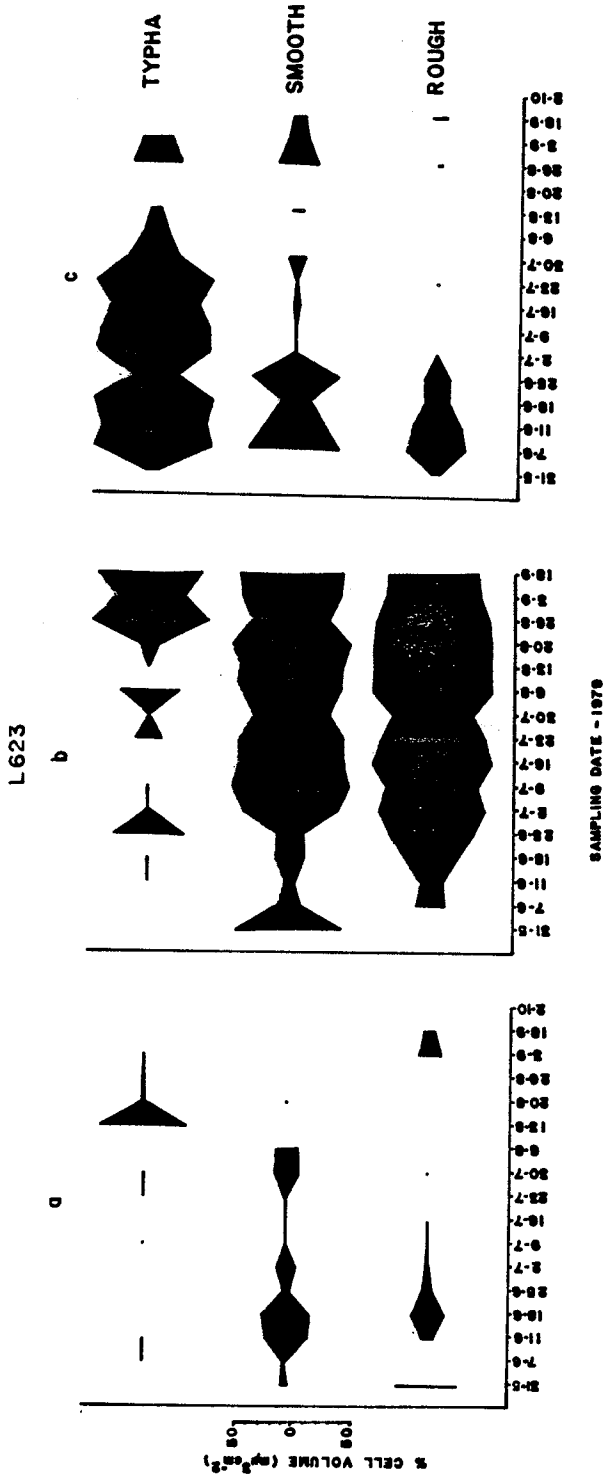

CELL VOLUME ($m\mu^3 l^{-1}$) x 10^{11}
3
2
1
0
1
2
3
A. FLOS-AQUAE
M. AERUGINOSA
S. JUDAYI
C. OBCONICA
C. HIRUNDINELLA
C. EROSA
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
28-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 10: Per cent contribution on a cell volume basis of the epiphytic algae on *Typha*, smooth acetate and roughened acetate by the a) Cyanophyta, b) Chlorophyta and c) Bacillariophyceae in L623.


TYPHA
SMOOTH
ROUGH
L623
c
b
a
SAMPLING DATE - 1978
% CELL VOLUME (mm³ cm⁻³)

algae on the artificial substrates after their initial spring growth period. The occurrence of major taxa is illustrated in Figures 11a-c. *Nitzschia holsatica* and *Gomphonema parvulum* var. *parvulum* represented large June populations. *Stigeoclonium nanum* was present briefly in August. On the artificial substrates *S. nanum* had little competition from other epiphytes although small populations of *N. holsatica* and *Synedra ulna* var. *ulna* contributed to the biomass on the smooth acetate while the roughened substrate supported isolated occurrences of *Oscillatoria minnesotensis* and *Trachelomonas robusta*.

ii) Epipelon

The epipelon of L623's littoral zone supported 67 species, the greatest diversity found in either lake. By far the largest contribution was by the Bacillariophyceae with lesser participation from the Cyanophyta, Chlorophyta, Euglenophyta and Chrysophyceae (Fig.12). Diatoms frequently accounted for 90-100% of the total community volume.

Species considered major were *O. minnesotensis*, *Ankistrodesmus convolutus*, *Ophiocytium capitatum* var. *irregulare*, *T. robusta*, *Gomphonema parvulum* var. *parvulum*, *Nitzschia palea*, *Cocconeis placentula* var. *lineata* and *Amphora ovalis* var. *affinis* (Fig.13).

iii) Phytoplankton

The littoral phytoplankton was represented by members of the Cyanophyta, Chlorophyta, Chrysophyceae and Bacillario-

Figure 11: Contribution by the epiphytic flora of L623 that represented more than 10% of the total population volume on a) *Typha* b) smooth acetate and c) roughened acetate.

L 623

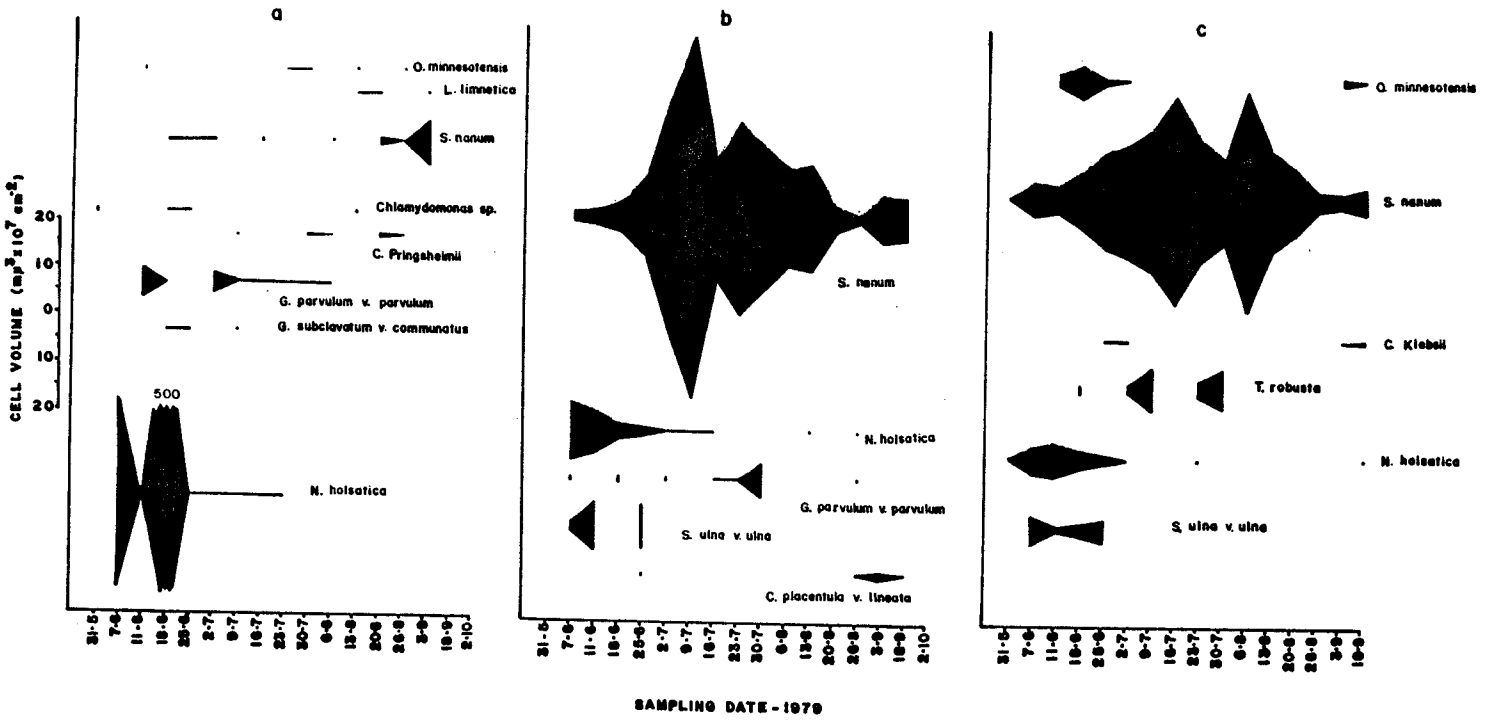

a
b
c
O. minnesotensis
L. limnetica
S. nanum
Chlamydomonas sp.
C. Pringsheimii
G. parvulum v. parvulum
G. subclavatum v. communatus
500
N. holsatica
CELL VOLUME (mm³ x 10⁷ cm⁻²)
20
10
0
10
20
S. nanum
N. holsatica
G. parvulum v. parvulum
S. ulna v. ulna
C. placentula v. lineata
O. minnesotensis
S. nanum
C. Kiebeli
T. robusta
N. holsatica
S. ulna v. ulna
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
27-8
3-9
10-9
2-10
SAMPLING DATE - 1979

Figure 12: Contribution on a per cent volume basis of the Cyanophyta, Chlorophyta, Euglenophyta, Chrysophyceae and Bacillariophyceae in the epipelic community of L623.

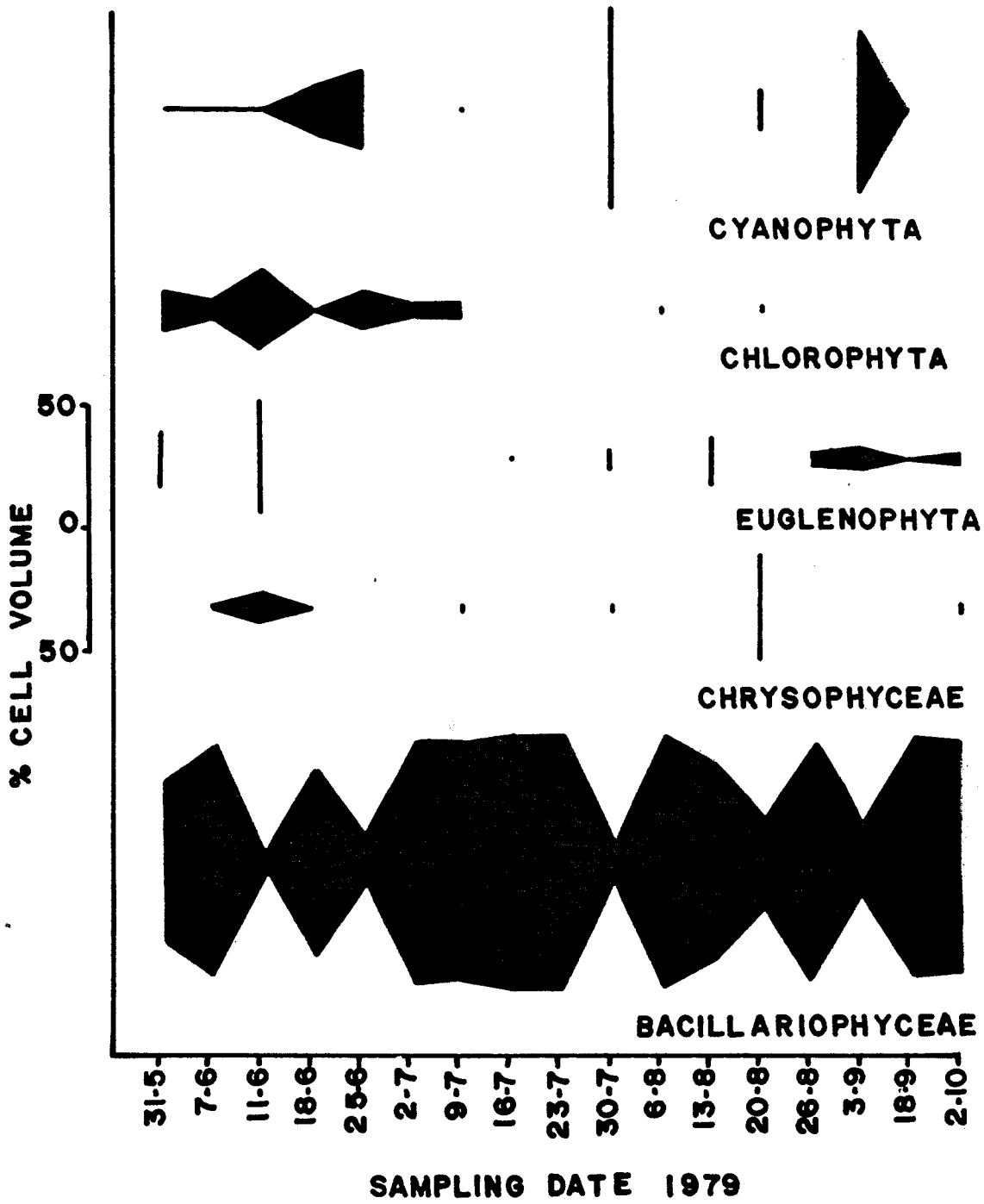
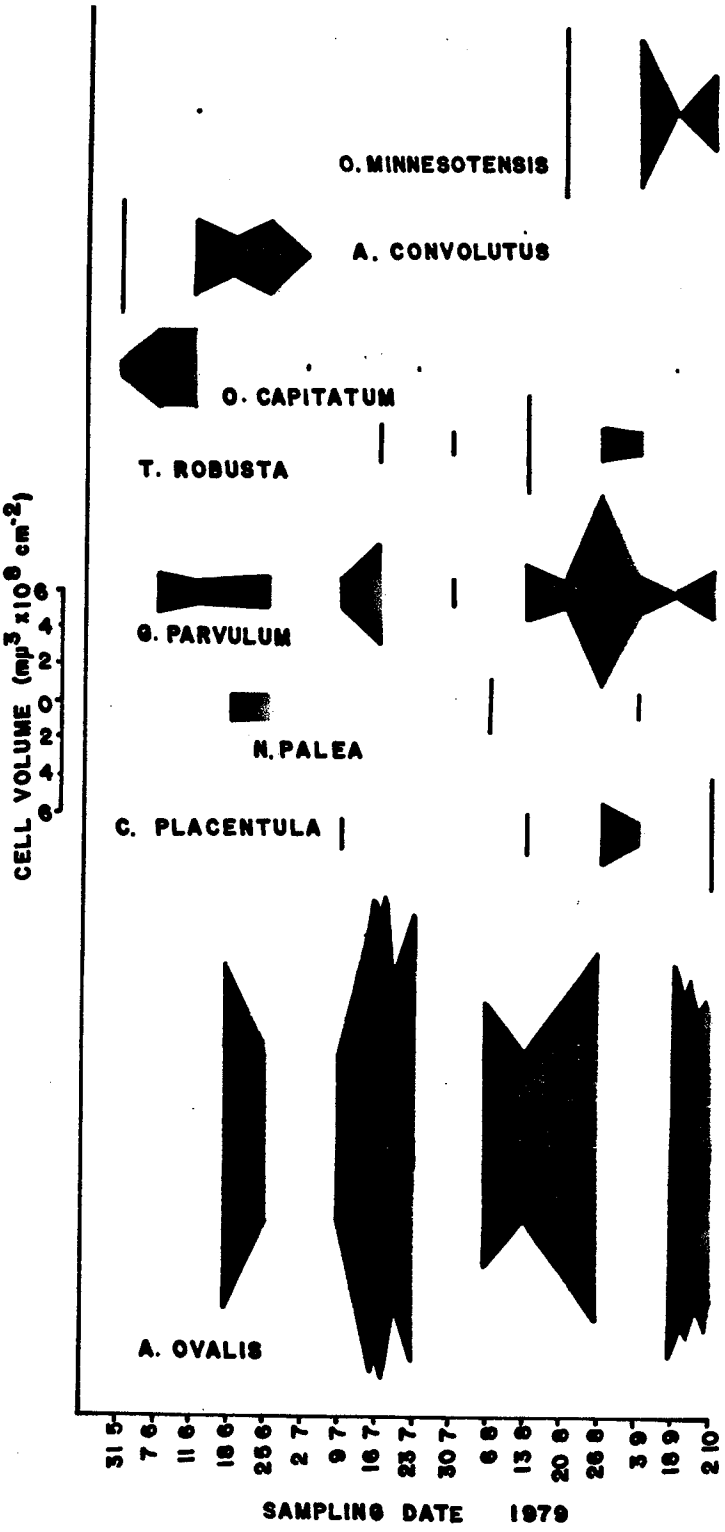

CYANOPHYTA
CHLOROPHYTA
EUGLENOPHYTA
CHRYSOPHYCEAE
BACILLARIOPHYCEAE
50
0
50
% CELL VOLUME
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

Figure 13: Contribution by the epipelic taxa of L623 that represented more than 10% of the total population volume.


O. MINNESOTENSIS
A. CONVOLUTUS
O. CAPITATUM
T. ROBUSTA
G. PARVULUM
N. PALEA
C. PLACENTULA
A. OVALIS
CELL VOLUME (mμ3 x10^6 cm-2)
0 4 2 0 2 4 6
31 5 7 6 11 6 18 6 25 6 2 7 9 7 16 7 23 7 30 7 6 8 13 8 20 8 28 8 3 9 10 9 2 10
SAMPLING DATE 1979

phyceae. Diatoms predominated throughout the season except for a brief period in June when the Chlorophyceae attained dominance (Fig.14). The Cyanophyta, Chlorophyta and Chrysophyceae occurred intermittently throughout the study period.

The major taxa were *Oscillatoria* sp., *Schroederia Judayi*, *Chromulina obconica*, *Cocconeis placentula* var. *lineata*, *Amphora ovalis* var. *affinis* and *Gomphonema parvulum* var. *parvulum* (Fig.15).

It was noted that in the epiphytic and epipelic communities, *Nitzschia holsatica* appeared in the spring while in the phytoplankton it became a major contributor in late summer and autumn. *A. ovalis* var. *affinis* was the only diatom that predominated in the early part of the season, its first bloom ceasing at the same time it became evident in the epipelic community.

2. BIOMASS-CELL VOLUME

A. Lake 255

i) Epiphyton

The seasonal biomass estimates expressed as cell volume differed greatly between the epiphyton on *Typha* and the artificial substrates. This was verified by the Wilcoxon Rank Sum Test. Cell volume estimates on the two cellulose acetate substrates were similar at $P < 0.01$ (Fig.16). Despite this discrepancy, seasonal means of the three communities were very similar. These were 1.04×10^8 ($\pm 1.06 \times 10^8$), 1.88×10^8 ($\pm 9.10 \times 10^7$) and 1.84×10^7 ($\pm 7.87 \times 10^7$) $m\mu^3$ cm^{-2} on *Typha*,

Figure 14: Contribution on a per cent volume basis of the Cyanophyta, Chlorophyta, Chrysophyceae and Bacillariophyceae of the phytoplankton in L623.

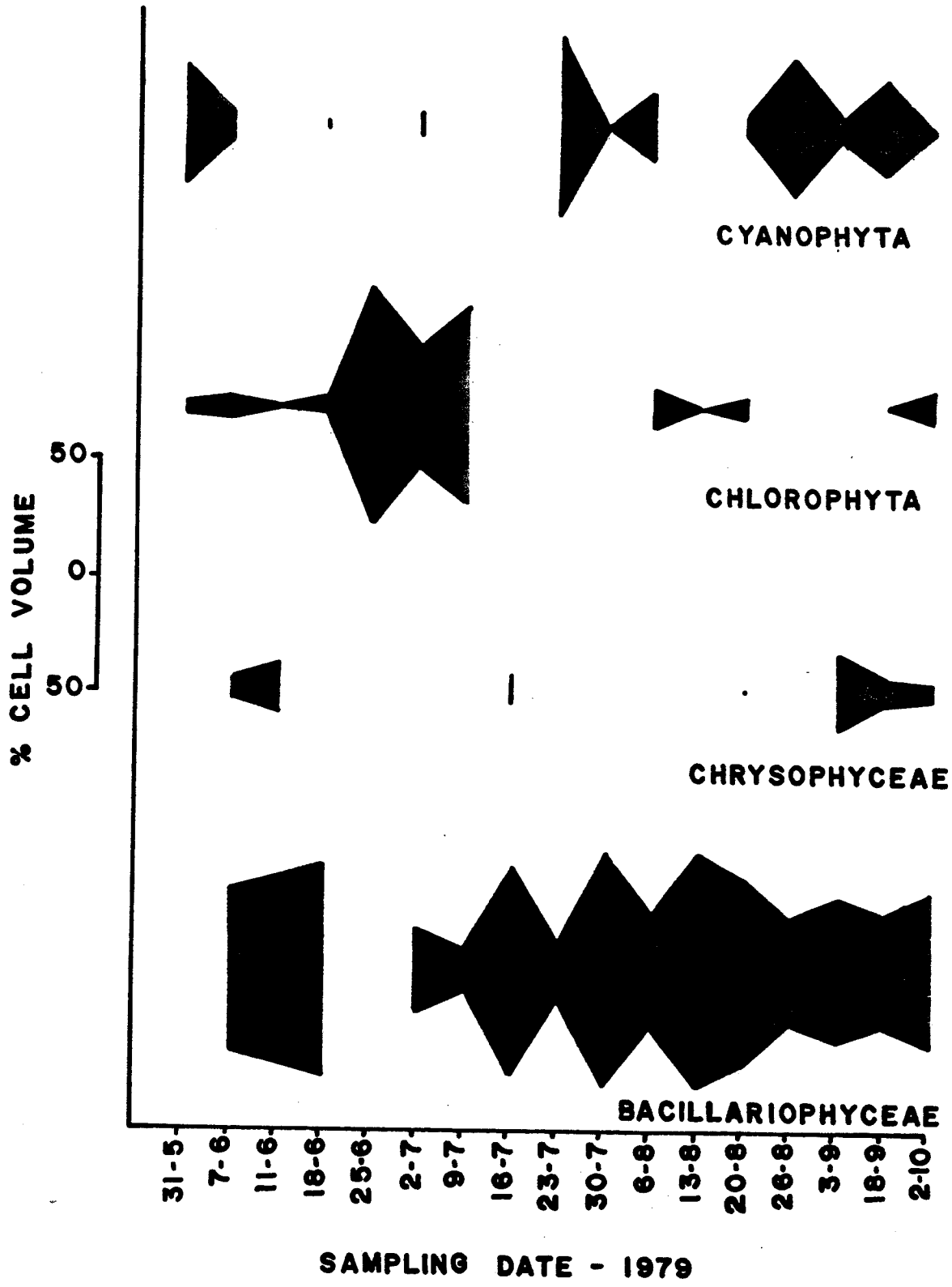

CYANOPHYTA
CHLOROPHYTA
CHRYSOPHYCEAE
BACILLARIOPHYCEAE
% CELL VOLUME
50
0
50
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 15: Contribution by the phytoplankton species constituting more than 10% of the total population volume in L623.

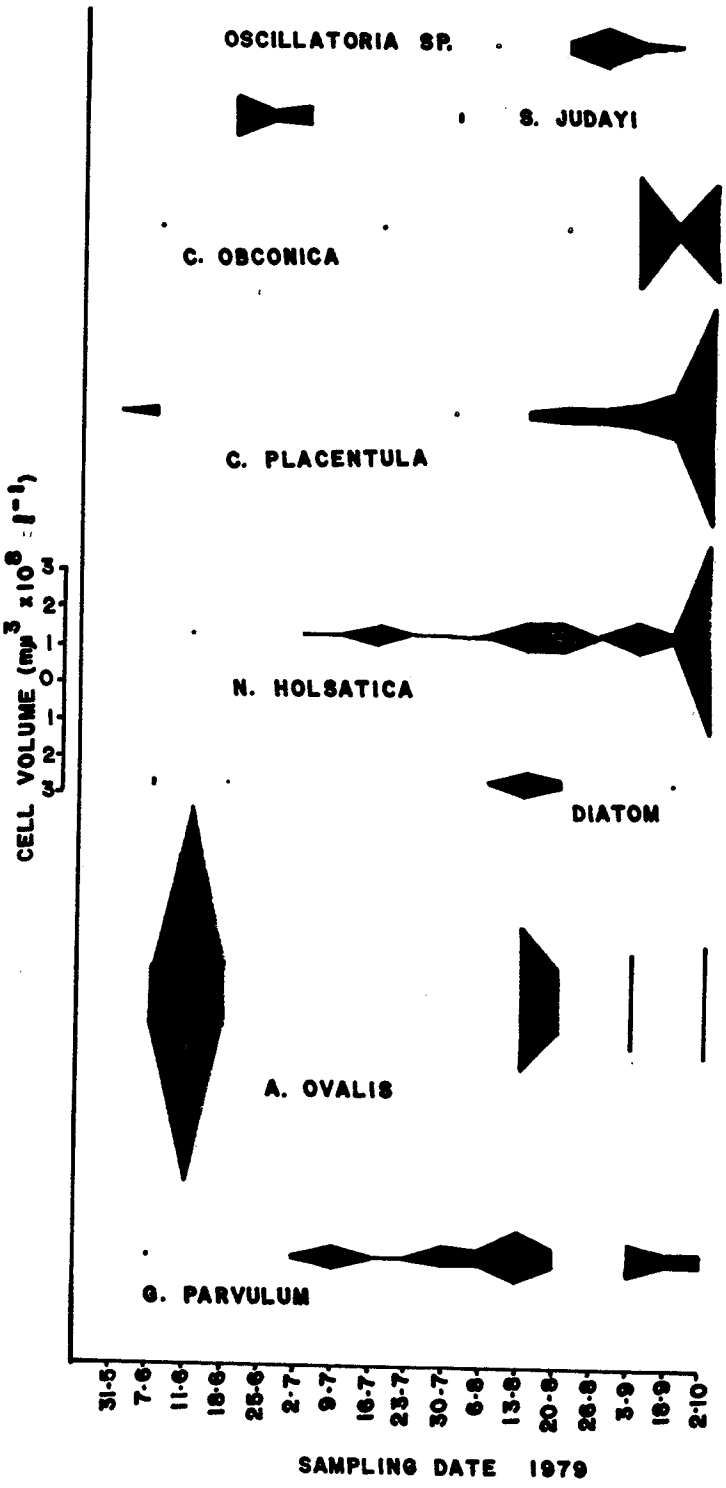
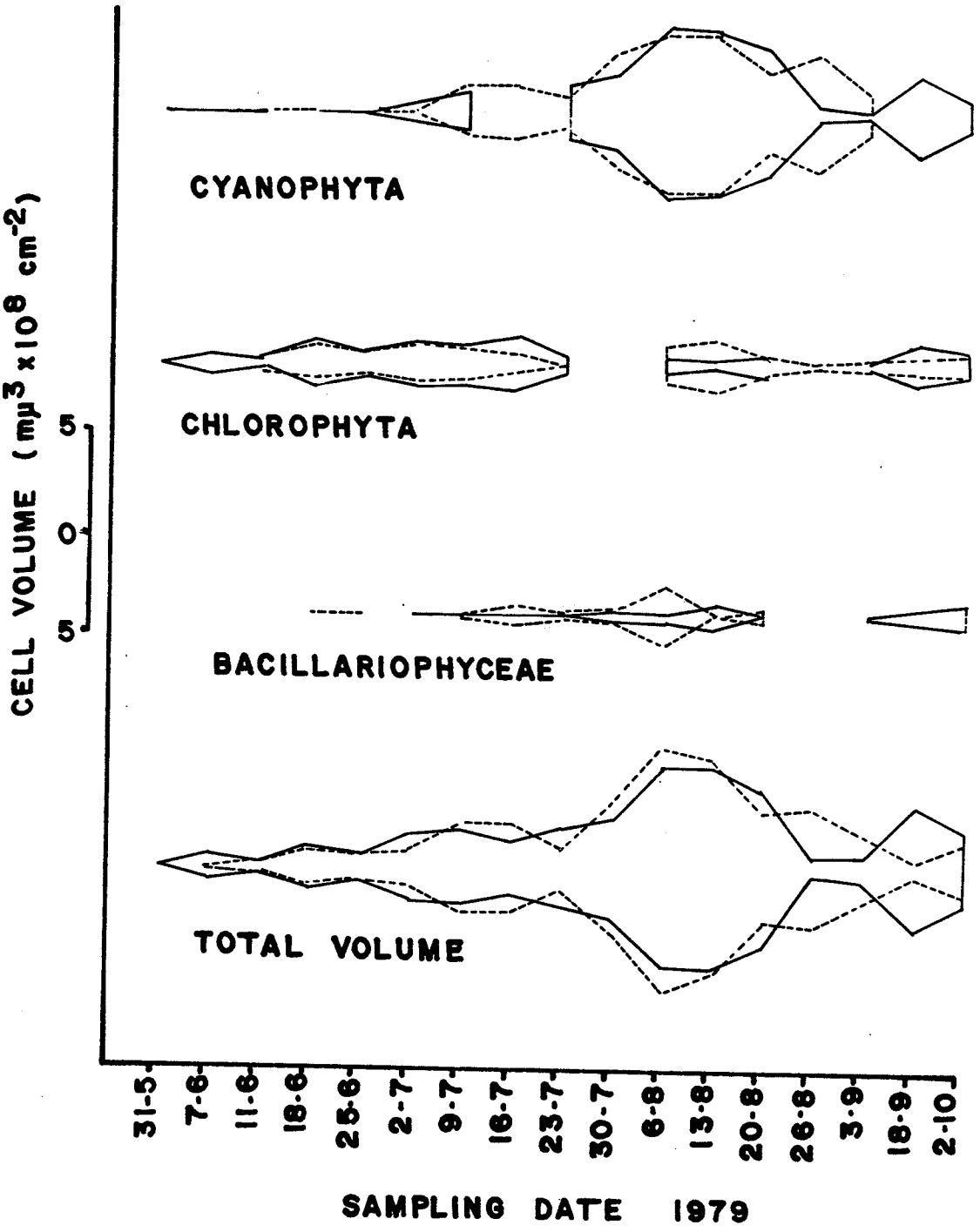

OSCILLATORIA SP.
S. JUDAYI
C. OBCONICA
C. PLACENTULA
N. HOLSATICA
DIATOM
A. OVALIS
G. PARVULUM
CELL VOLUME (mμ³ x10⁸ l⁻¹)
3
2
1
0
1
2
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
10-9
2-10
SAMPLING DATE 1979

Figure 16: Comparison of cell volume biomass estimates (r=0.640) of the epiphyton on the smooth (-----) and roughened (——) acetate in L255.


CELL VOLUME (mμ3 x 10^8 cm^-2)
5
0
5
CYANOPHYTA
CHLOROPHYTA
BACILLARIOPHYCEAE
TOTAL VOLUME
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

and the smooth and roughened acetate respectively. The epiphytic cell volume on *Typha* peaked one month in advance of the populations on the artificial substrates(Fig.17). The maximum cell volumes on *Typha*, smooth and roughened acetate were 8.52×10^8, 6.27×10^8 and 4.92×10^8 $m\mu^3 cm^{-2}$ respectively.

ii)Epipelon

Cell volume biomass estimates for the epipelic community exhibited four maxima; mid-June, two in July and the fourth in mid-August. All maxima were followed by sharp declines in volume. The maxima were always a consequence of very large populations of *Surirella ovalis* (Fig.18). The seasonal maximum occurring in June was 1.08×10^{10} $m\mu^3 cm^{-2}$. The seasonal mean was 3.89×10^9 $m\mu^3 cm^{-2}$ ($\pm 1.69 \times 10^9$).

iii)Phytoplankton

The phytoplankton was characterized by a mid-July maximum volume of 1.03×10^{12} $m\mu^3 \ell^{-1}$. A mixed *Ceratium hirundinella-Aphanizomenon flos-aquae* bloom existed at this time. A lesser peak occurred in the latter part of August with complete domination of the blue-green, *A. flos-aquae* (Fig. 19). Although *Cryptomonas erosa* was the major plankter in June its relatively small size prevented it from attaining significant population volumes. The seasonal mean biomass as cell volume was 9.47×10^{10} $m\mu^3 \ell^{-1}$ ($\pm 1.26 \times 10^{11}$).

Figure 17: Cell volume estimates of the epiphyton on *Typha* (■——■), smooth (▲——▲) and roughened (○——○) acetate substrates in L255.

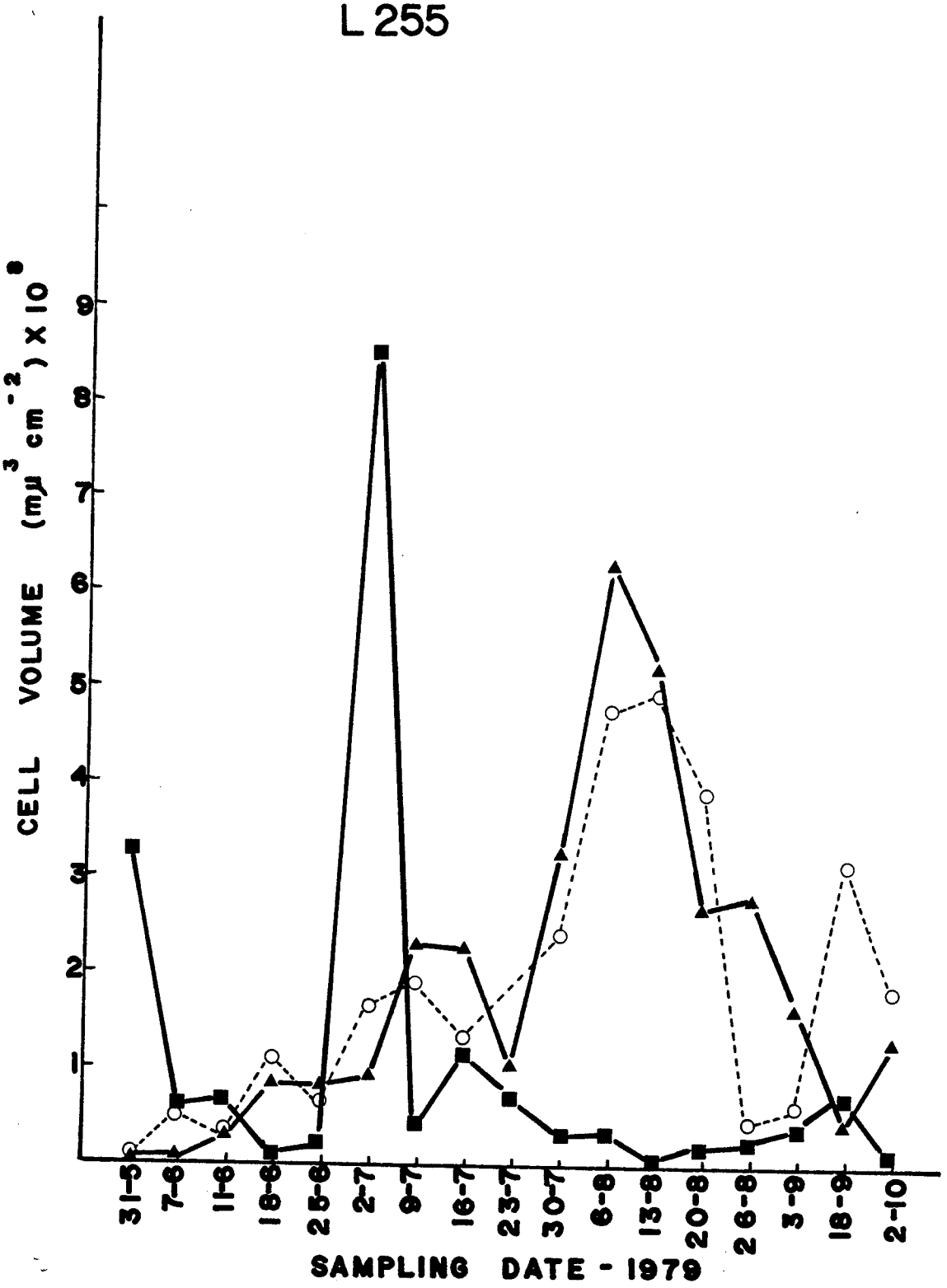

L 255
CELL VOLUME (mμ³ cm⁻²) X 10⁸
0
1
2
3
4
5
6
7
8
9
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
28-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 18: Cell volume estimates (□——□) of the epipelic flora in L255.

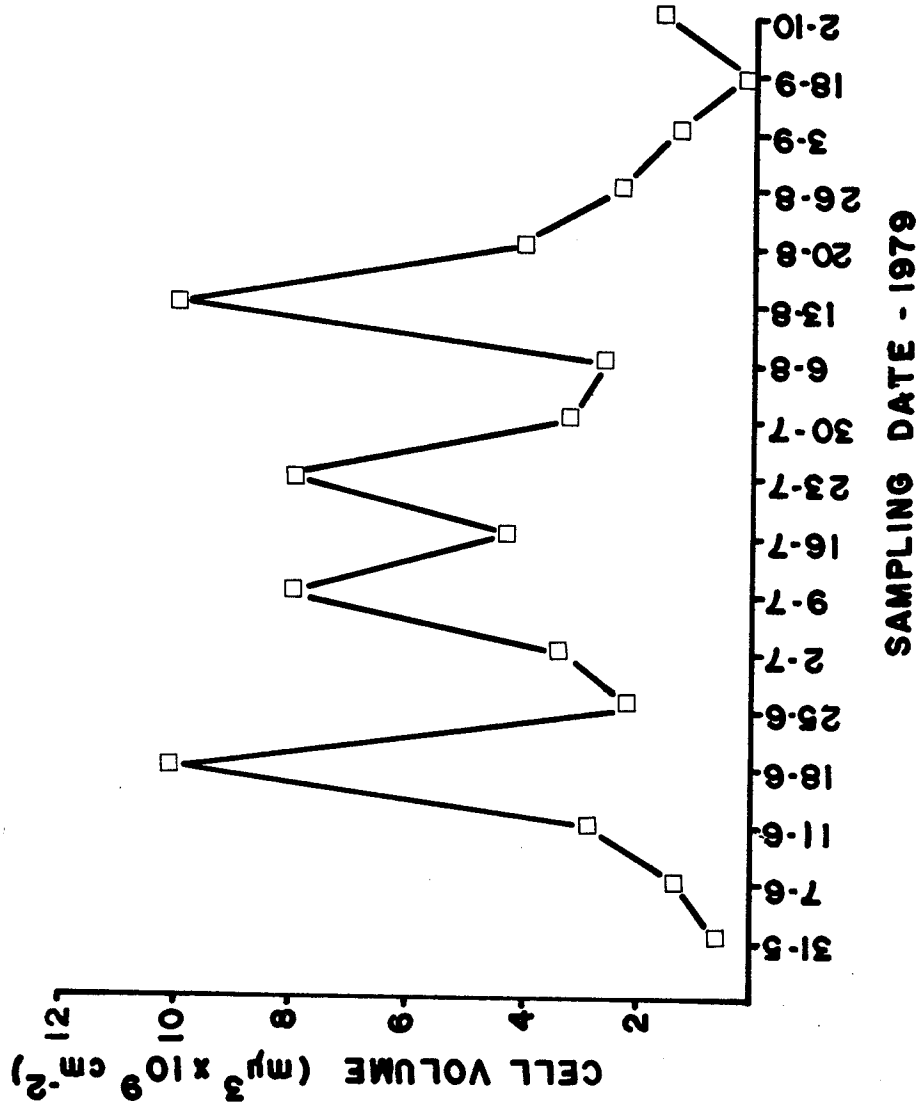
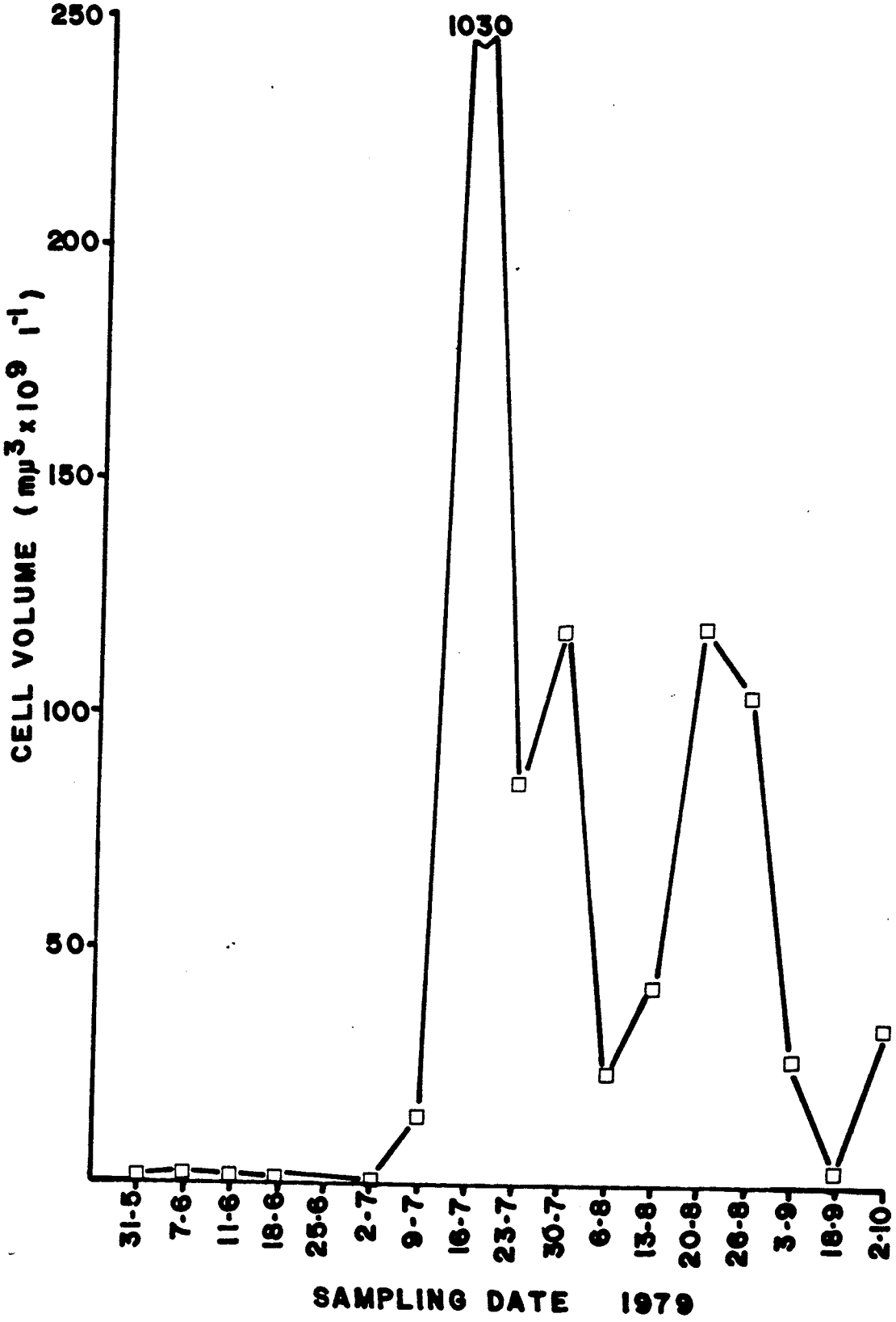

CELL VOLUME ($mm^3 \times 10^9$ cm^{-2})
12
10
8
6
4
2
SAMPLING DATE - 1979
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10

Figure 19: Cell volume biomass estimates (□——□) of the phytoplankton in L255.


250
200
150
100
50
1030
CELL VOLUME (mμ3 x 10^9 l-1)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

B.Lake 623

i)Epiphyton

Linear regression analysis of cell volumes on the three substrates resulted in excellent correlation between the two artificial substrates($P<0.01$)(Fig.20). Neither artificial substrate compared well to the natural host.

Cell volume attained a maximum on *Typha* in mid-June. The epiphytes on the artificial substrates reached their maxima about a month later(Fig.21). Seasonal mean cell volumes on *Typha*, smooth and roughened acetate were $7.35\times10^{8}(\pm1.43\times10^{9})$, $3.03\times10^{8}(\pm1.27\times10^{8})$, and 2.56×10^{8} $(\pm7.51\times 10^{7})$ $m\mu^{3}cm^{-2}$ and maxima were 1.01×10^{10}, 7.68×10^{8} and 4.58×10^{8} $m\mu^{3}cm^{-2}$ respectively.

ii)Epipelon

The cell volumes in the epipelon displayed three distinct maxima; mid-June,mid-July and mid-September(Fig.22). *Amphora ovalis* var.*affinis* was the predominant alga in all cases.

The mid-July peak resulted in a seasonal maximum of $1.42\times10^{11}m\mu^{3}cm^{-2}$. The seasonal mean was $1.28\times10^{10}m\mu^{3}cm^{-2}$ $(\pm1.73\times10^{10})$. This mean volume was two orders of magnitude greater than that of any of the epiphytic populations in L623.

iii)Phytoplankton

The phytoplankton of L623 exhibited a bimodal volume distribution. Cell volume maxima occurred at the end of May and the beginning of October(Fig.23). Mid-summer values were comparatively low. The spring peak was made of

Figure 20: Comparison of cell volume biomass estimates ($r=0.634$) of the epiphyton on the smooth (----) and roughened (———) acetate in L623.

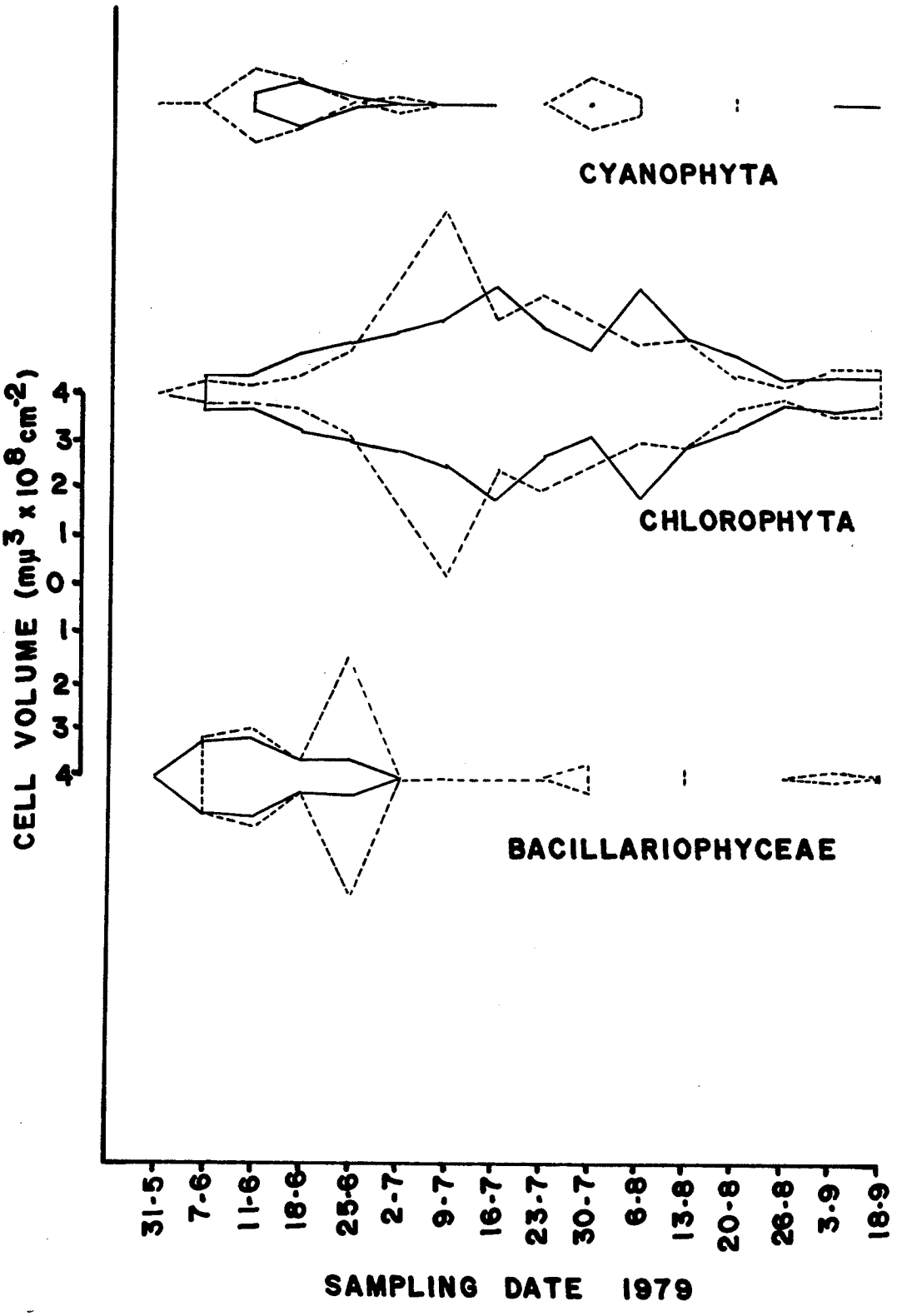

CYANOPHYTA
CHLOROPHYTA
BACILLARIOPHYCEAE
CELL VOLUME (mμ3 x 10^8 cm^-2)
4 3 2 1 0 1 2 3 4
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
SAMPLING DATE 1979

Figure 21: Cell volume biomass estimates of the epiphyton on *Typha* (●——●), smooth (▲——▲) and roughened (△——△) substrates in L623.

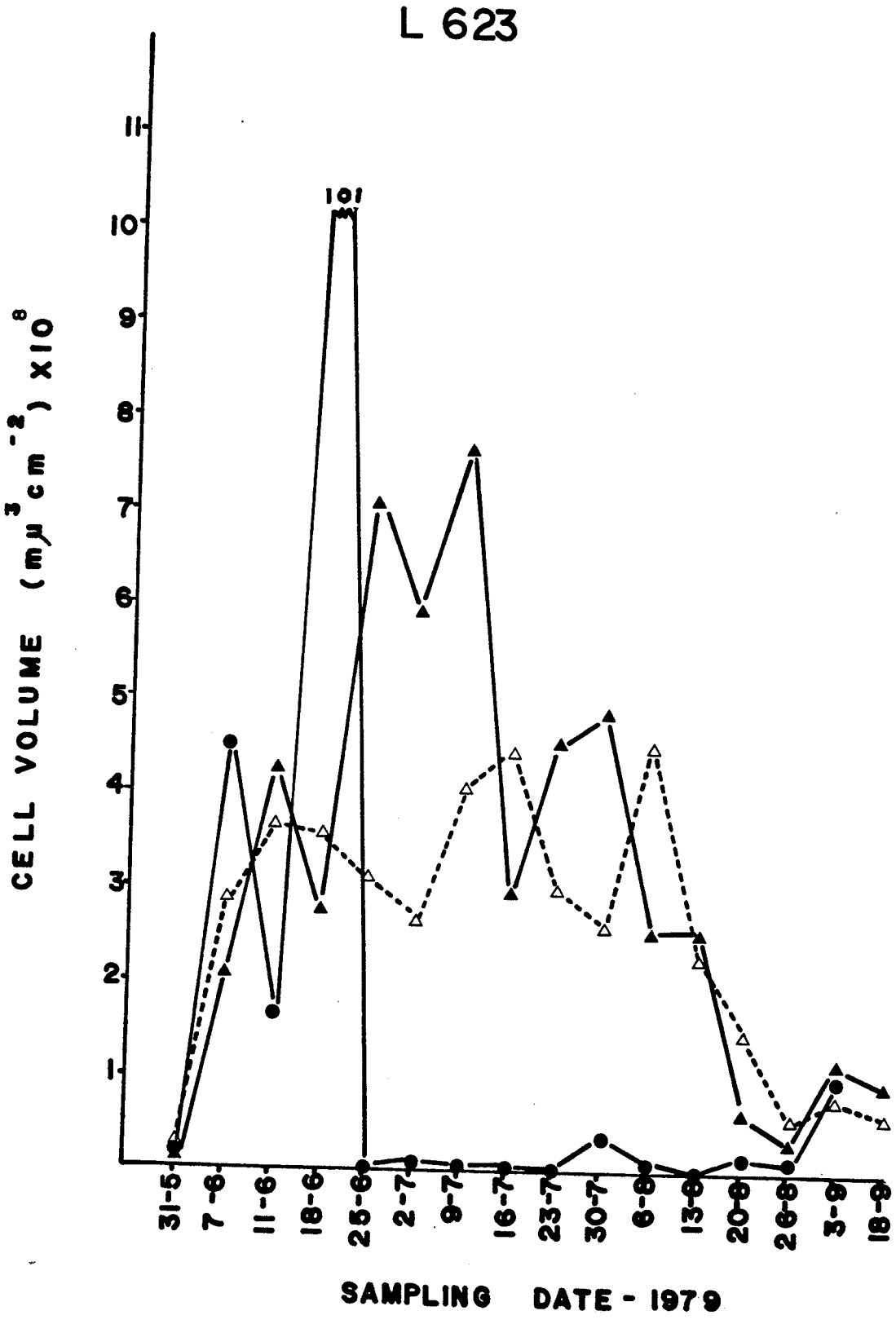

L 623
CELL VOLUME (mμ³cm⁻²) X10⁸
101
11
10
9
8
7
6
5
4
3
2
1
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
SAMPLING DATE - 1979

Figure 22: Cell volume biomass estimates (● —— ●) of the epipelic flora in L623.

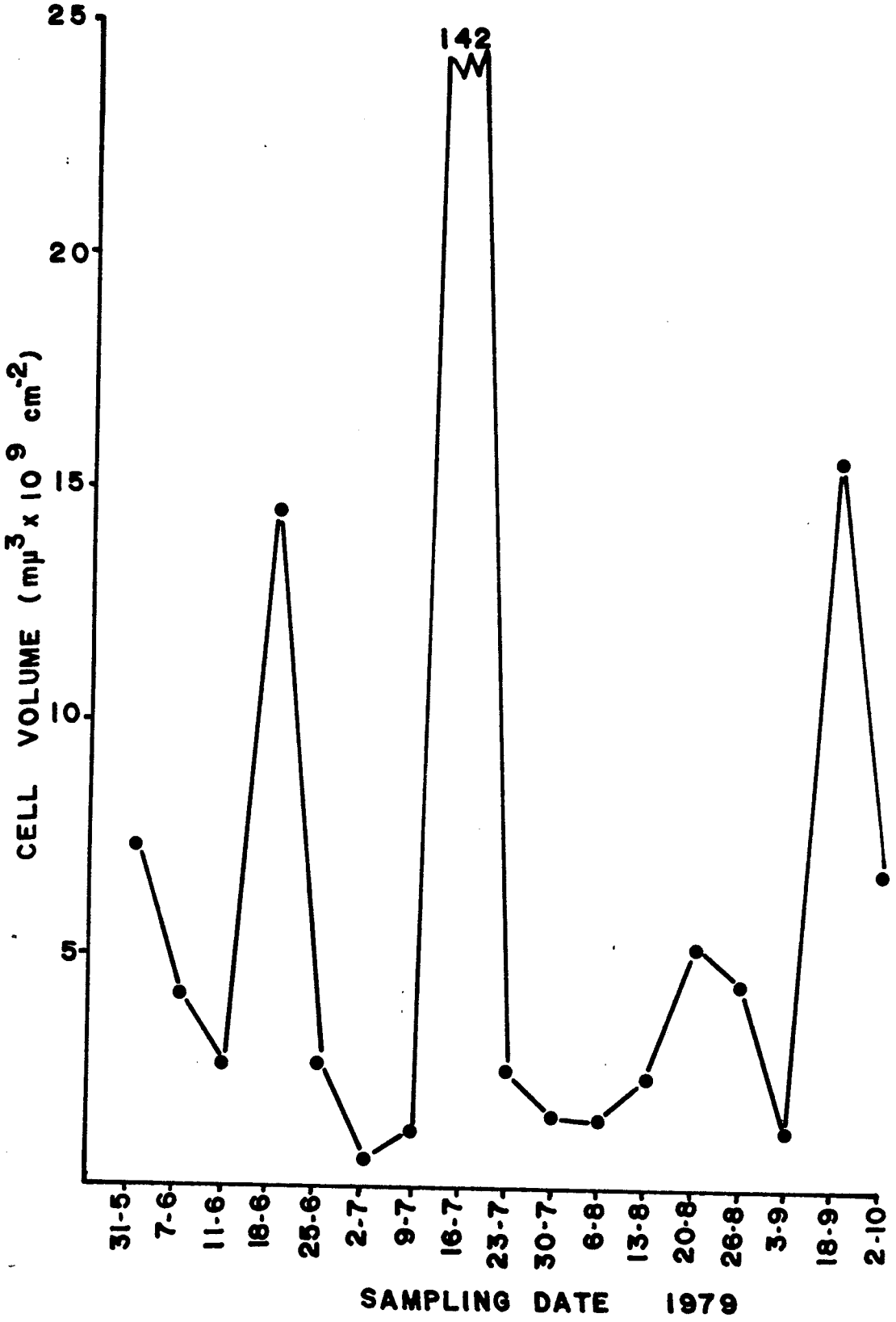
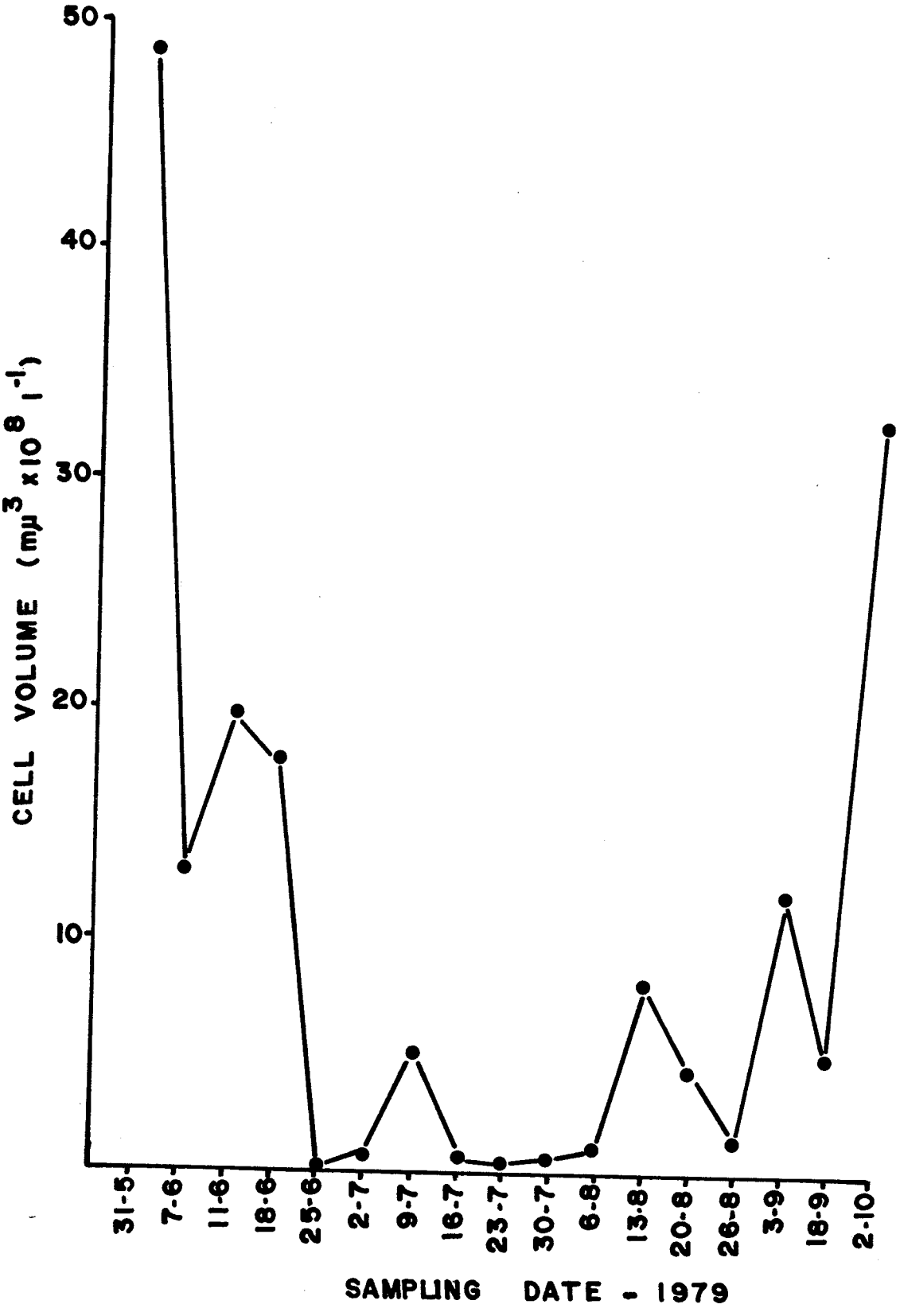

25
20
15
10
5
142
CELL VOLUME (mμ3 x 10 9 cm-2)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

Figure 23: Cell volume biomass estimates (●——●) of the phytoplankton in L623.


50
40
30
20
10
CELL VOLUME (mμ³ x10⁸ l⁻¹)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
18-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Cryptomonas erosa and various Cyanophyta while the autumnal maximum consisted of a mixed diatom population of C.*placentula* var.*lineata*,*Nizschia holsatica* and A.*ovalis* var.*affinis*. The maximum cell volume of $4.91 \times 10^9 m\mu^3 \ell^{-1}$ occurred in the spring bloom. The seasonal mean was $1.02 \times 10^9 m\mu^3 \ell^{-1} (\pm 6.89 \times 10^8)$.

BIOMASS- CHLOROPHYLL *a*

A.Lake 255

i)Epiphyton

Biomass, estimated by µg chlorophyll *a* (pheophytin corrected) per cm^2 substrate increased erratically throughout the season in all three epiphytic communities(Fig.24). Linear regression analysis revealed that seasonal chlorophyll *a* values were very similar for the two artificial substrates ($P < 0.01$) but neither related well to chlorophyll *a* estimates on the natural host. Mean seasonal biomass values of the epiphyton on *Typha*, smooth and roughened acetate were $0.239 (\pm 0.065)$, $0.780 (\pm 0.205)$ and $1.074 (\pm 0.303)$ $\mu g cm^{-2}$ respectively.

Chlorophyll *a* and the corresponding cell volume measures of biomass were compared. R values for the epiphyton of *Typha*, smooth and roughened acetate were 0.252, 0.414 and 0.291 $\mu g cm^{-2}$ respectively. This lack of a linear relationship is illustated in Fig.25,26 and 27.

ii)Epipelon

Biomass as chlorophyll *a* was generally very high ($x = 28.90 \mu g cm^{-2} \pm 6.536$) but erratic throughout the season (Fig.28).

Figure 24: Chlorophyll *a* biomass estimates of the epiphyton on *Typha* (●——●), smooth (■——■) and roughened (□——□) acetate in L255.

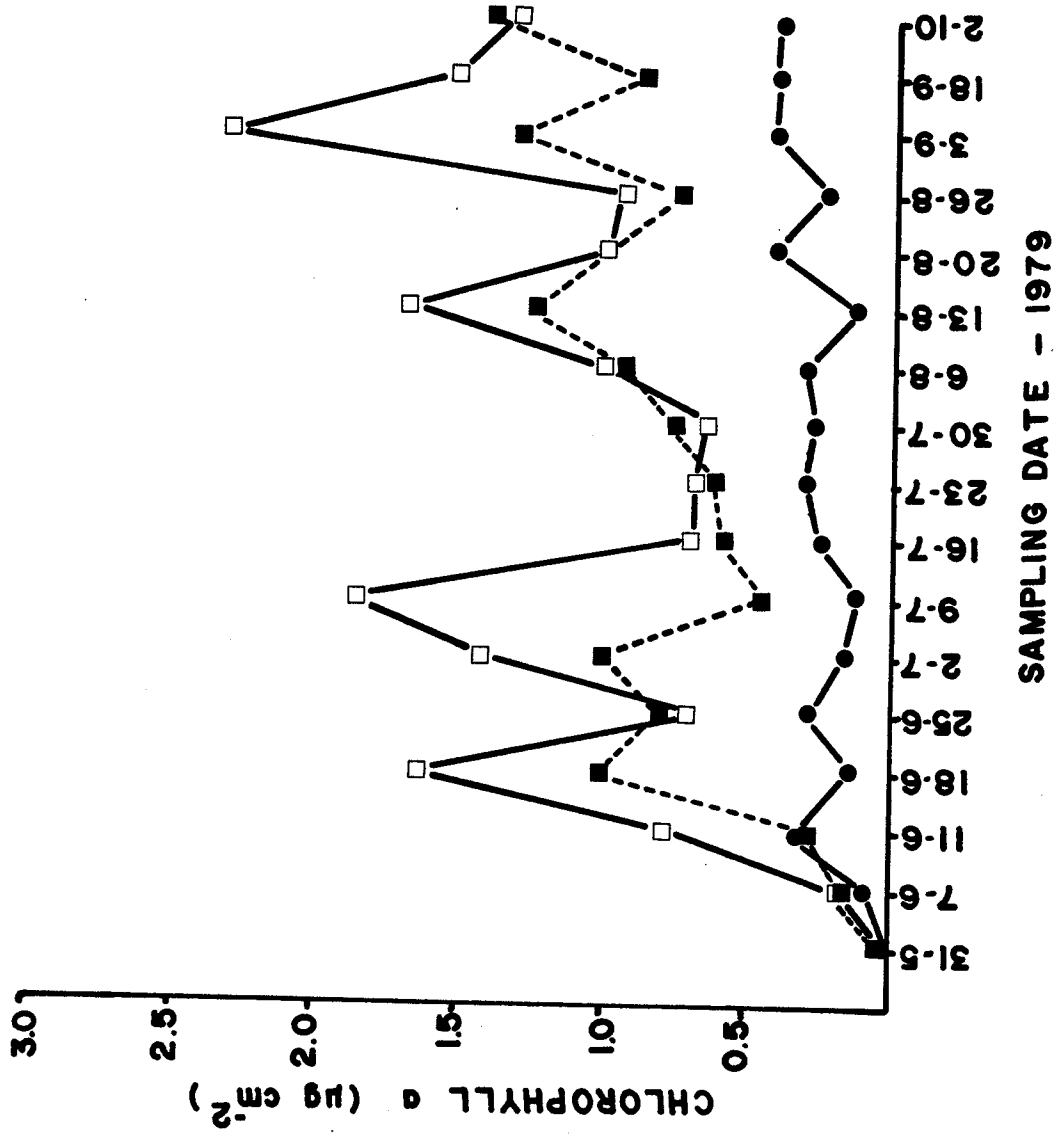

CHLOROPHYLL a (µg cm⁻²)
3.0
2.5
2.0
1.5
1.0
0.5
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 25: Comparison of cell volume (▲——▲) and chlorophyll *a* (◆ ---- ◆) biomass estimates (r=0.252) of the epiphyton on *Typha* in L255.

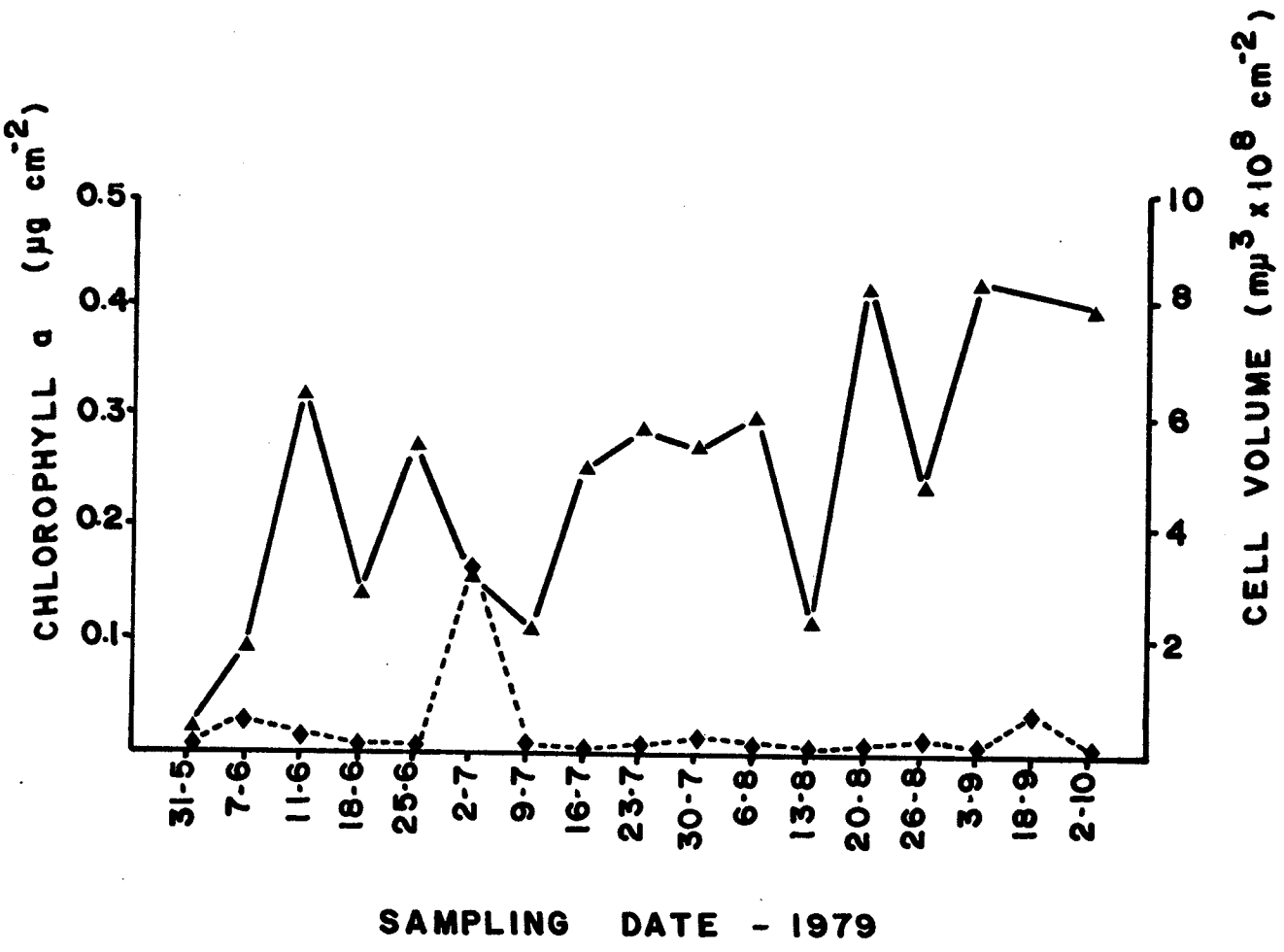

CHLOROPHYLL a (µg cm-2)
0.5
0.4
0.3
0.2
0.1
CELL VOLUME (mµ3 x 10^8 cm-2)
10
8
6
4
2
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 26: Comparison of cell volume (● —— ●) and chlorophyll *a* (◆ ---- ◆) biomass estimates of the epiphyton on the smooth cellulose acetate in L255. The r value was 0.291.

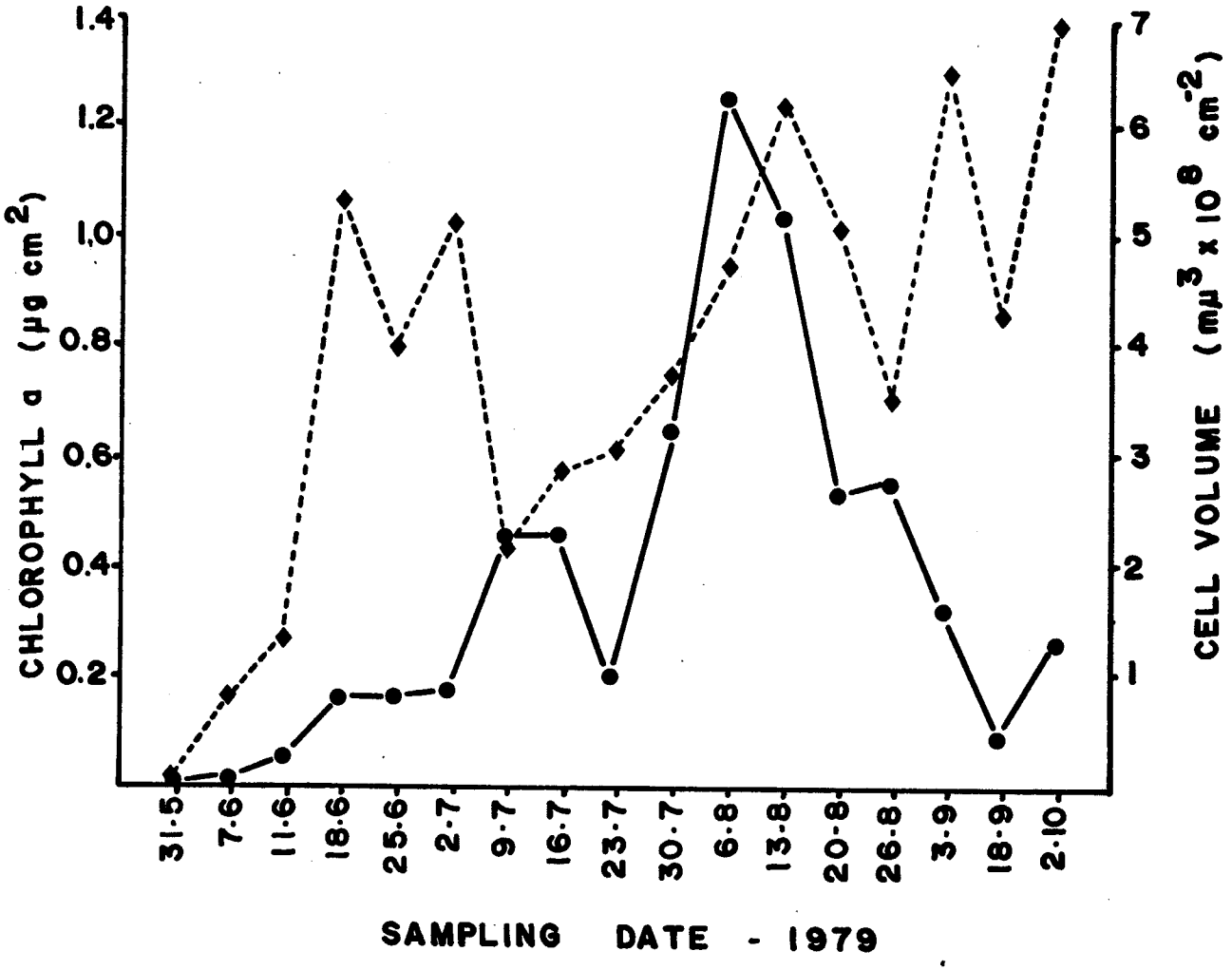

CHLOROPHYLL a (µg cm^{-2})
CELL VOLUME (mµ^3 x 10^8 cm^{-2})
1.4
1.2
1.0
0.8
0.6
0.4
0.2
7
6
5
4
3
2
1
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 27: Comparison of cell volume (○——○) and chlorophyll *a* (▲——▲) biomass estimates of the epiphyton on roughened cellulose acetate in L255. The r value was 0.291.

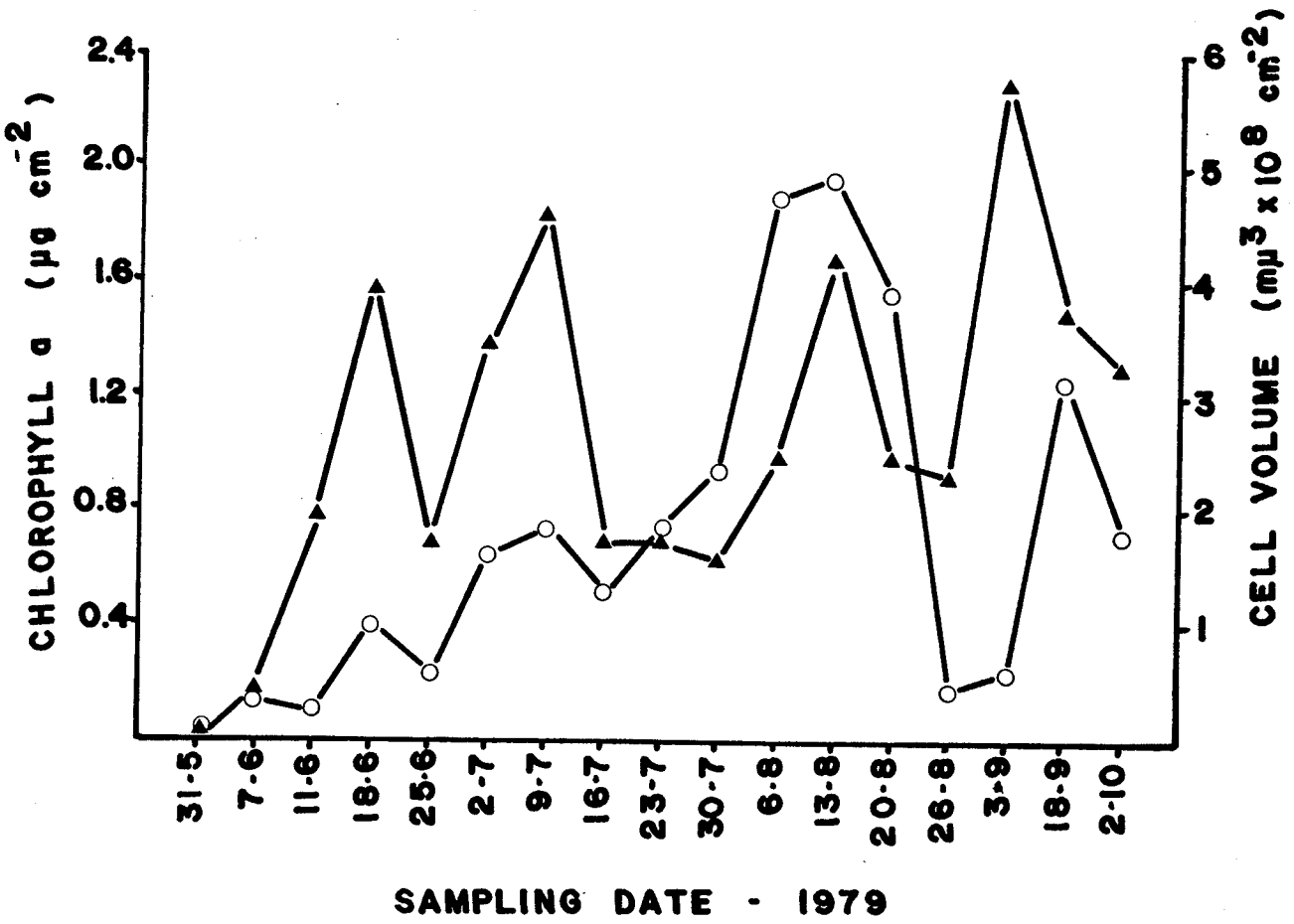
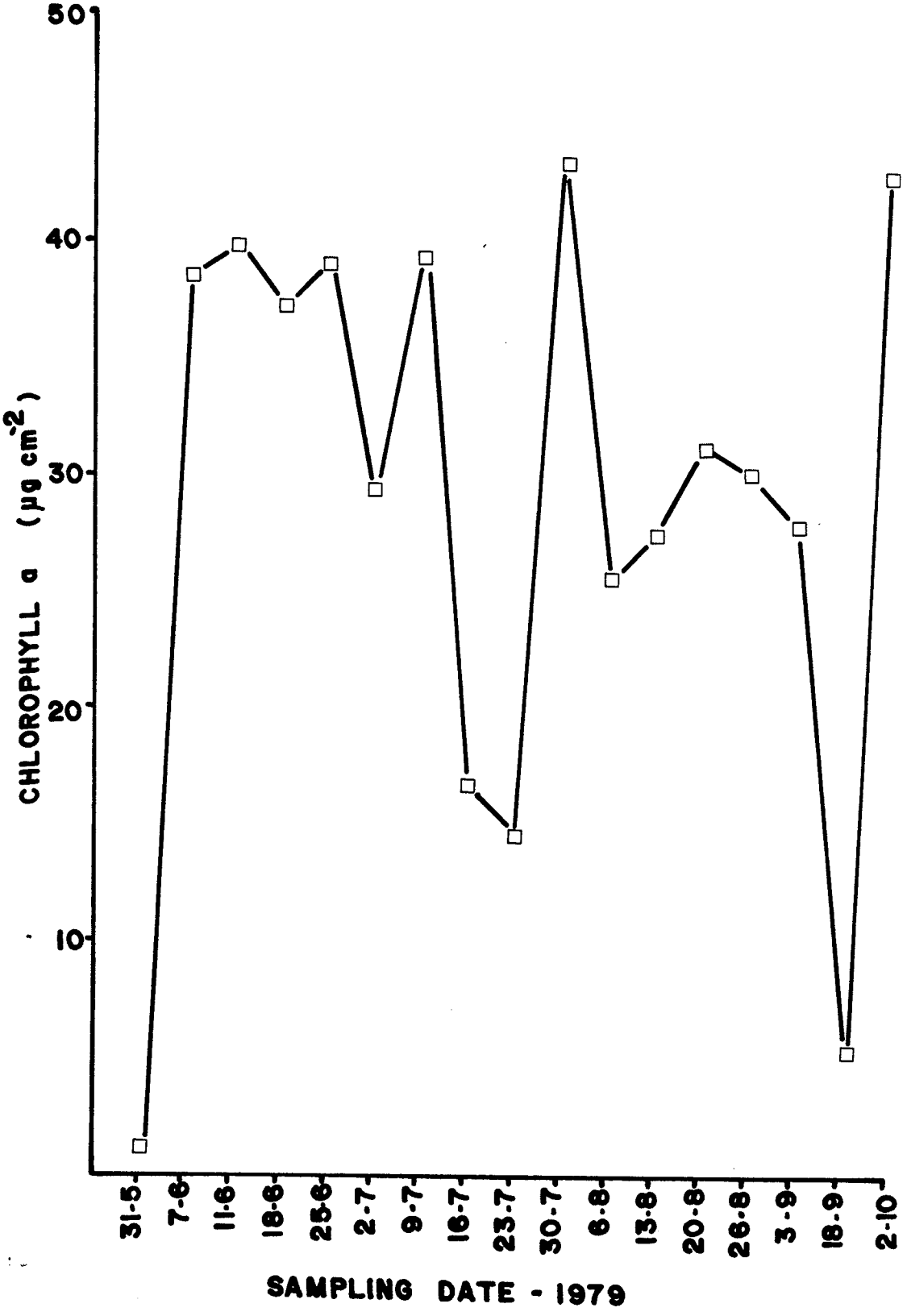

CHLOROPHYLL a (µg cm⁻²)
2.4
2.0
1.6
1.2
0.8
0.4
CELL VOLUME (mµ³ x 10⁸ cm⁻²)
6
5
4
3
2
1
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 28: Chlorophyll *a* (□——□) biomass estimates of the epipelic algae in L255.


50
40
30
20
10
CHLOROPHYLL a (µg cm⁻²)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

The highest chlorophyll *a* value was 43.53µgcm^{-2} at the end of July. High chlorophyll and cell volume estimates coincided very infrequently, regardless of the composition of the population(Fig.29). The correlation coefficient r relating the two measures was only 0.175 indicating a lack of a linear relationship.

iii)Phytoplankton

Chlorophyll *a* values were comparatively low until mid-July when they increased dramatically to the end of the season(Fig.30). The subsequent peaks coincided with large blue-green populations, primarily *A. flos-aquae* and *Microcystis aeruginosa*. The seasonal mean was 71.62µgℓ^{-1} (±37.078) and the highest value, 234µgℓ^{-1} occurred in the early part of September when a large amount of *M.aeruginosa* predominated.

Biomass as cell volume and chlorophyll *a* displayed a total lack of correlation(r=0.070),surmisable from Fig.31.

B.Lake 623

i)Epiphyton

Chlorophyll *a* estimates of biomass correlated highly between the two artificial substrates (r=0.920)(Fig.32). Neither artificial substrate supported biomass values approximating those on the natural surface.

The seasonal mean chlorophyll *a* for the epiphyton on *Typha*, smooth and roughened acetate were 0.238(±0.135), 2.028(±0.935) and 1.956(±1.005) µg cm^{-2} with maxima of 0.542, 5.50 and 4.91 µg cm^{-2} respectively.

The relationship between cell volume and chlorophyll

Figure 29: Comparison of cell volume (▲——▲) and chlorophyll *a* (△---△) biomass estimates (r=0.175) in the epipelic algal community of L255.

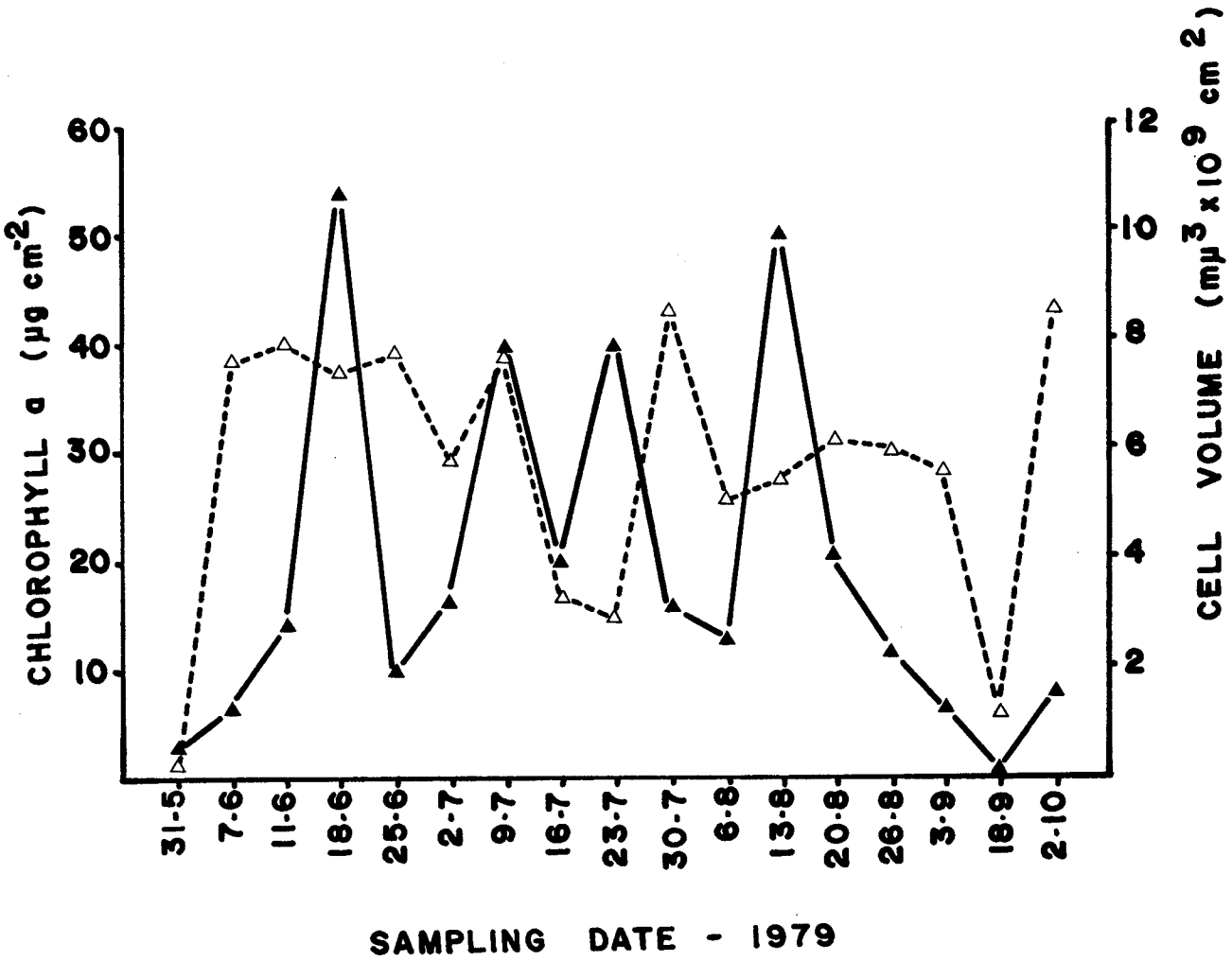

CHLOROPHYLL a (µg cm⁻²)
CELL VOLUME (mµ³ x 10⁹ cm⁻²)
60
50
40
30
20
10
12
10
8
6
4
2
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 30: Chlorophyll *a* (□——□) biomass estimates of the phytoplankton in L255.

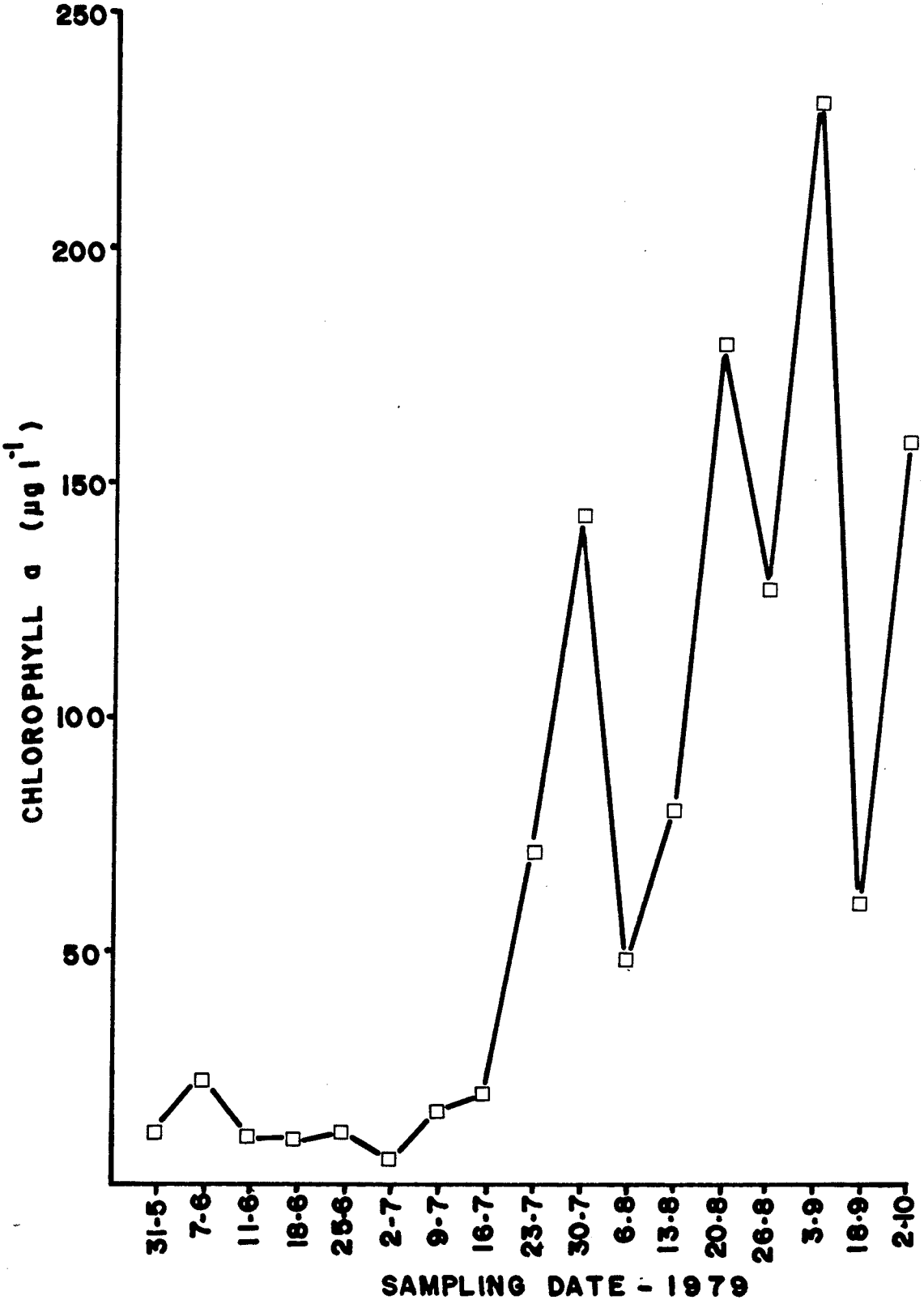

250
200
150
100
50
CHLOROPHYLL a (µg l⁻¹)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE - 1979

Figure 31: Comparison of cell volume (○---○) and chlorophyll *a* (■——■) biomass estimates (r=0.070) of the phytoplankton in L255.

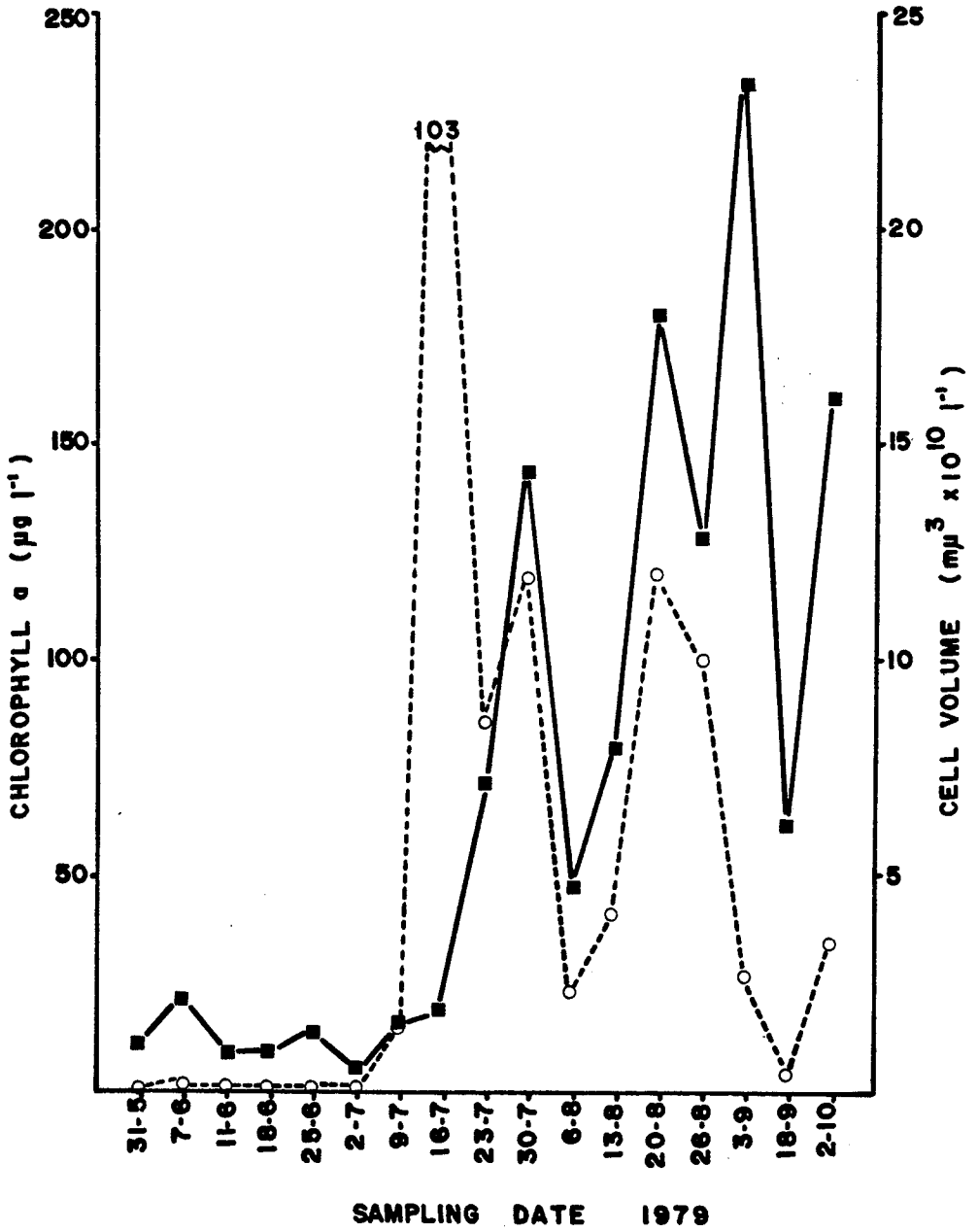
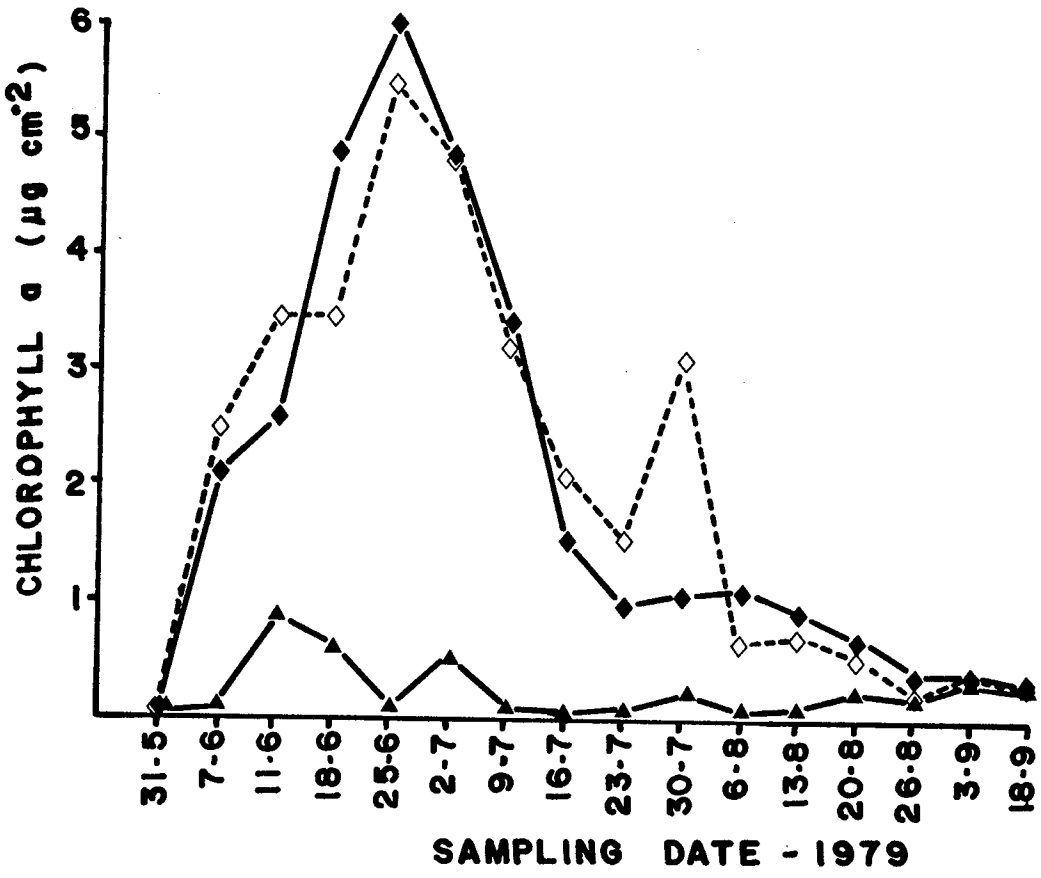

250
200
150
100
50
25
20
15
10
5
103
CHLOROPHYLL a (µg l⁻¹)
CELL VOLUME (mµ³ x10¹⁰ l⁻¹)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

Figure 32: Chlorophyll *a* biomass estimates of the epiphyton on *Typha* (▲——▲), smooth (◇ ---- ◇) and roughened (◆ ——◆) acetate in L623.


CHLOROPHYLL a (µg cm-2)
0
1
2
3
4
5
6
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
SAMPLING DATE - 1979

a was tested by linear regression analysis. Correlations were significant ($P<0.05$) for the communities on the artificial substrates but not on *Typha* (Fig.33, 34, 35).

ii) Epipelon

Biomass estimates as chlorophyll *a* were erratic throughout the season (Fig.36). The seasonal average was 22.35 $\mu g\ cm^{-2}$ (±6.570) and the July maximum was 43.24 $\mu g\ cm^{-2}$.

Linear regression analysis of cell volume versus chlorophyll *a* resulted in an r value of only 0.249. This lack of a linear relationship is evident in Figure 37.

iii) Phytoplankton

Chlorophyll *a* estimates were characterized by early and late summer maxima and a mid-summer minimum (Fig.38). The seasonal mean was 30.52 $\mu g\ \ell^{-1}$ (±33.802) while the October maximum was 280 $\mu g\ \ell^{-1}$. The maximum at the season's end coincided with increasingly larger populations of *Amphora ovalis* var. *affinis*, *Cocconeis placentula* var. *lineata* and *Nitzschia holsatica*.

Linear regression analysis revealed that cell volume and chlorophyll *a* correlate well with $r=0.676$ ($P<0.01$). They are illustrated in Figure 39.

Figure 33: Comparison of cell volume (◇——◇) and chlorophyll *a* (▲---▲) biomass estimates (r=0.414) of the epiphyton on *Typha* in L623.

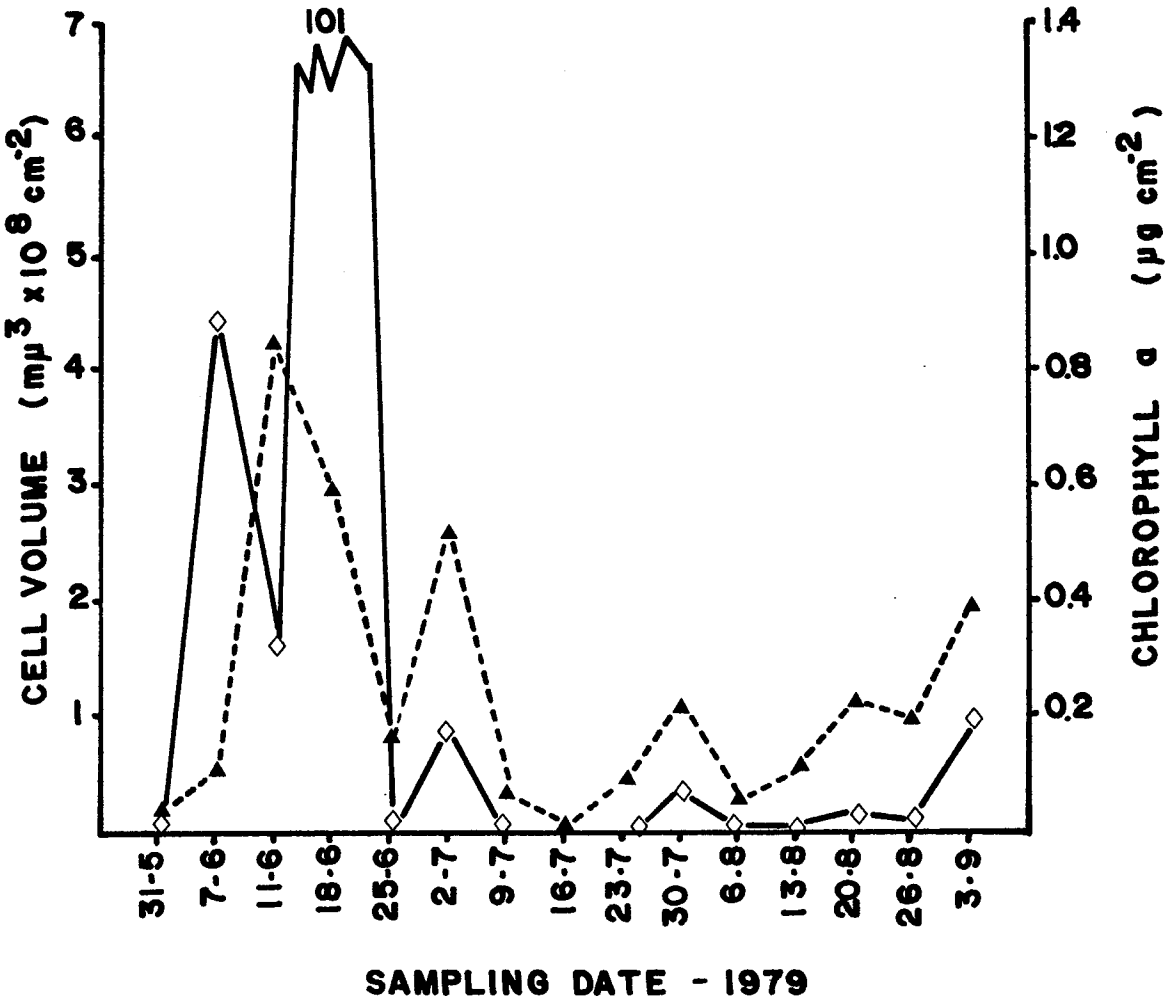

101
CELL VOLUME (mμ3 x10^8 cm^-2)
CHLOROPHYLL a (μg cm^-2)
SAMPLING DATE - 1979
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9

Figure 34: Comparison of cell volume (◆ —— ◆) and chlorophyll *a* (◇---- ◇) biomass estimates (r=0.842) of the epiphyton on the smooth acetate in L623.

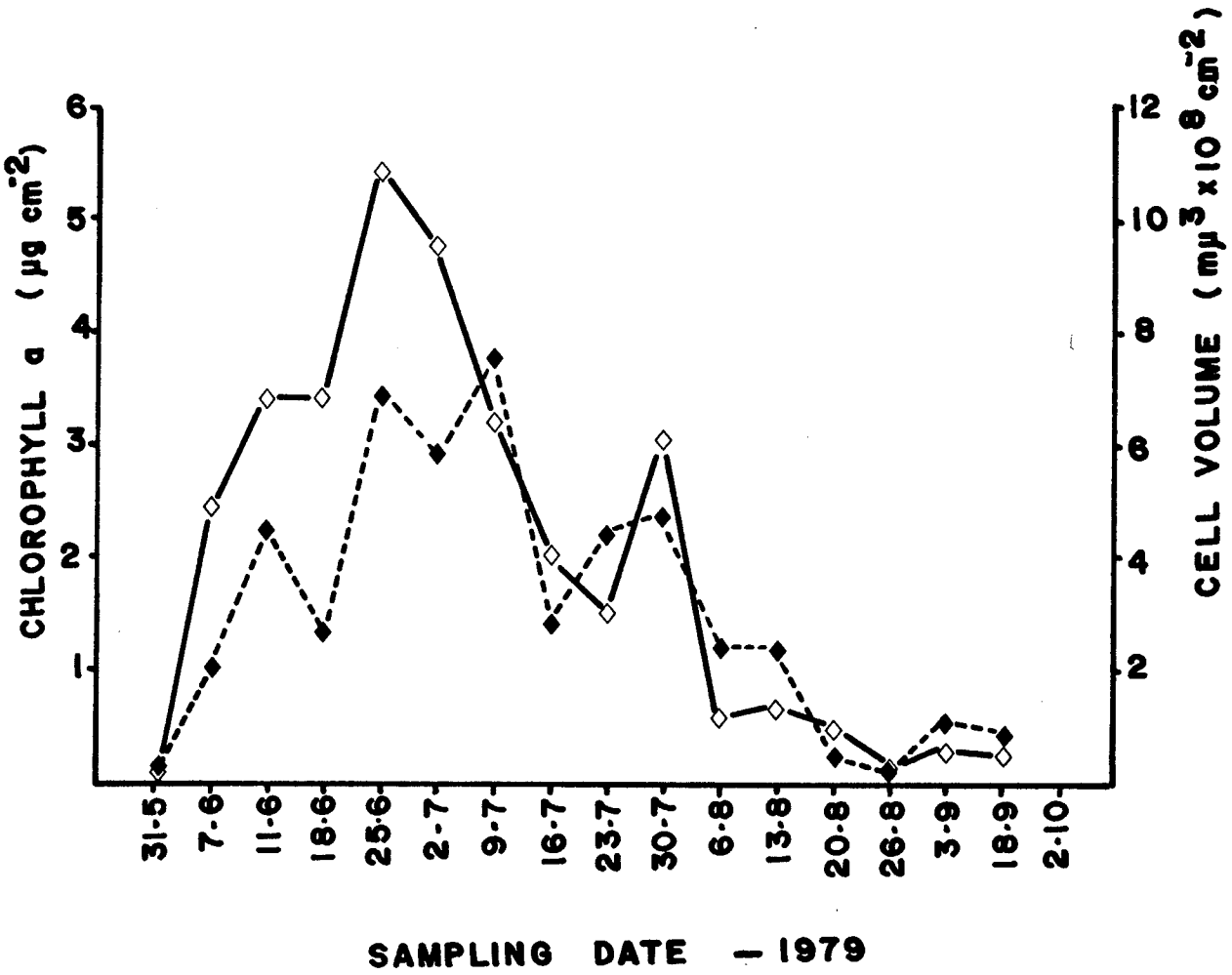

CHLOROPHYLL a (µg cm⁻²)
CELL VOLUME (mµ³ x 10⁸ cm⁻²)
SAMPLING DATE — 1979
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10

Figure 35: Comparison of cell volume (○——○) and chlorophyll *a* (■---■) biomass estimates (r=0.518) of the epiphyton on the roughened cellulose acetate in L623.

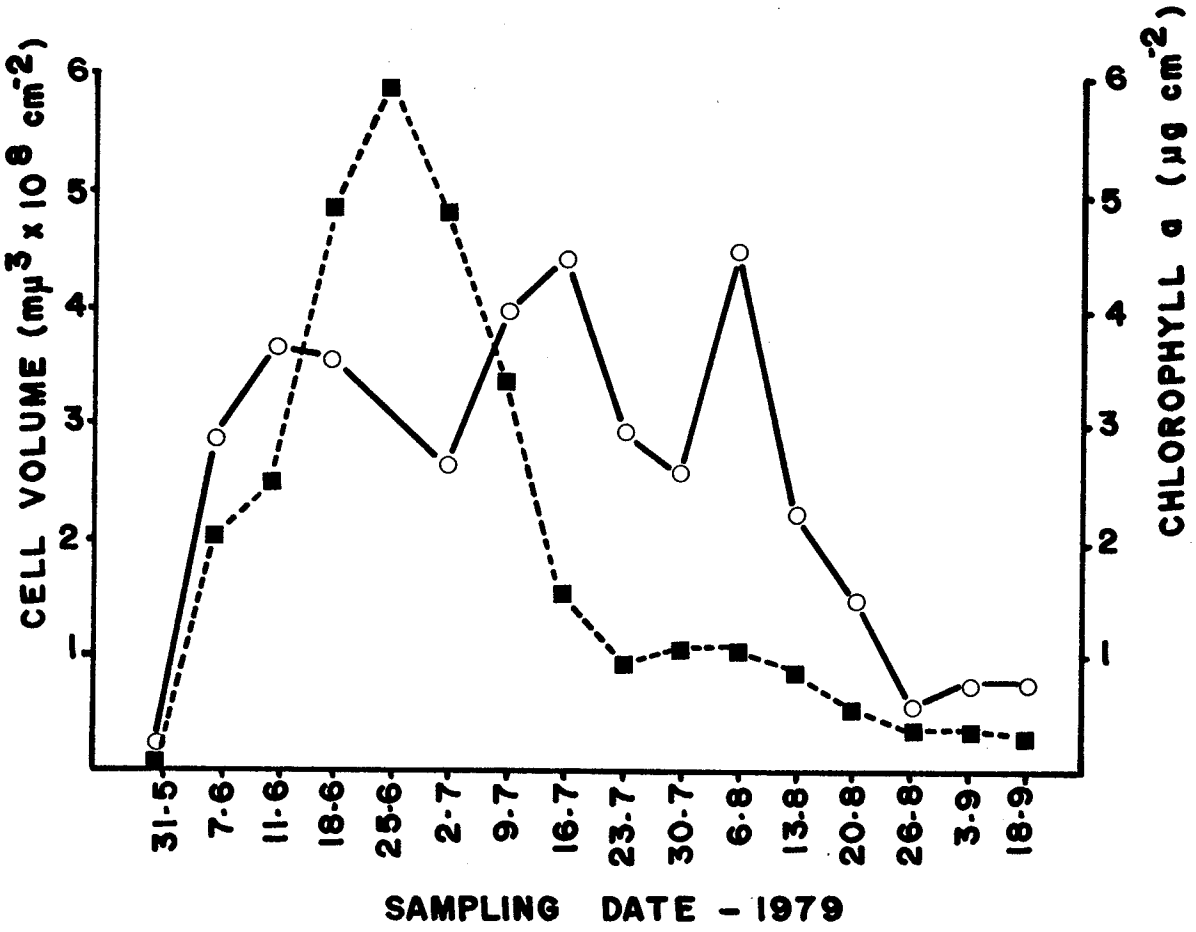

CELL VOLUME (mμ³ x 10⁸ cm⁻²)
CHLOROPHYLL a (μg cm⁻²)
1
2
3
4
5
6
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
SAMPLING DATE - 1979

Figure 36: Chlorophyll *a* (◇——◇) biomass estimates of the epipelic algal community in L623.

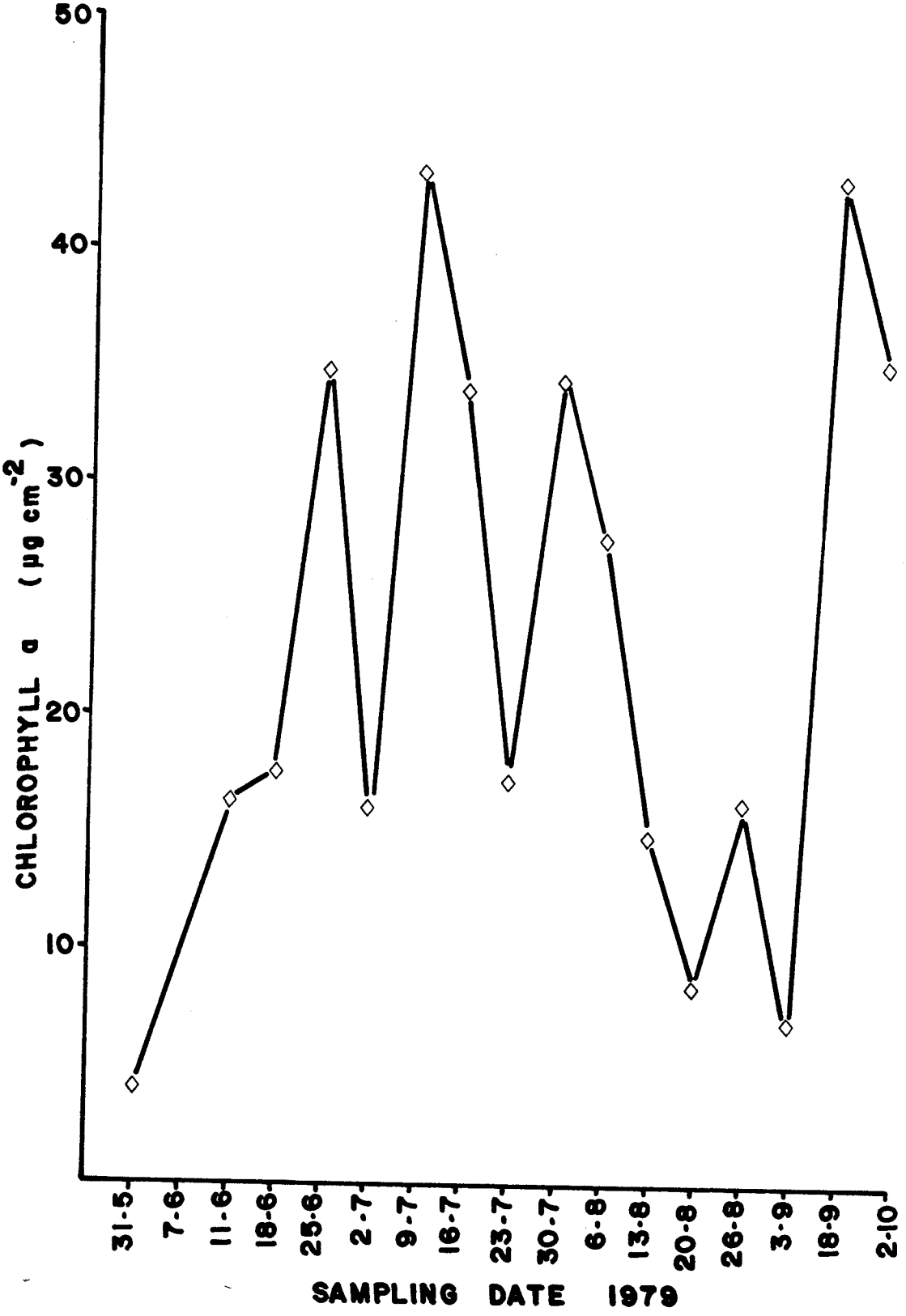

50
40
30
20
10
CHLOROPHYLL a (µg cm-2)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

Figure 37: Comparison of cell volume (◇——◇) and chlorophyll *a* (▲----▲) biomass estimates (r=0.249) of the epipelon in L623.

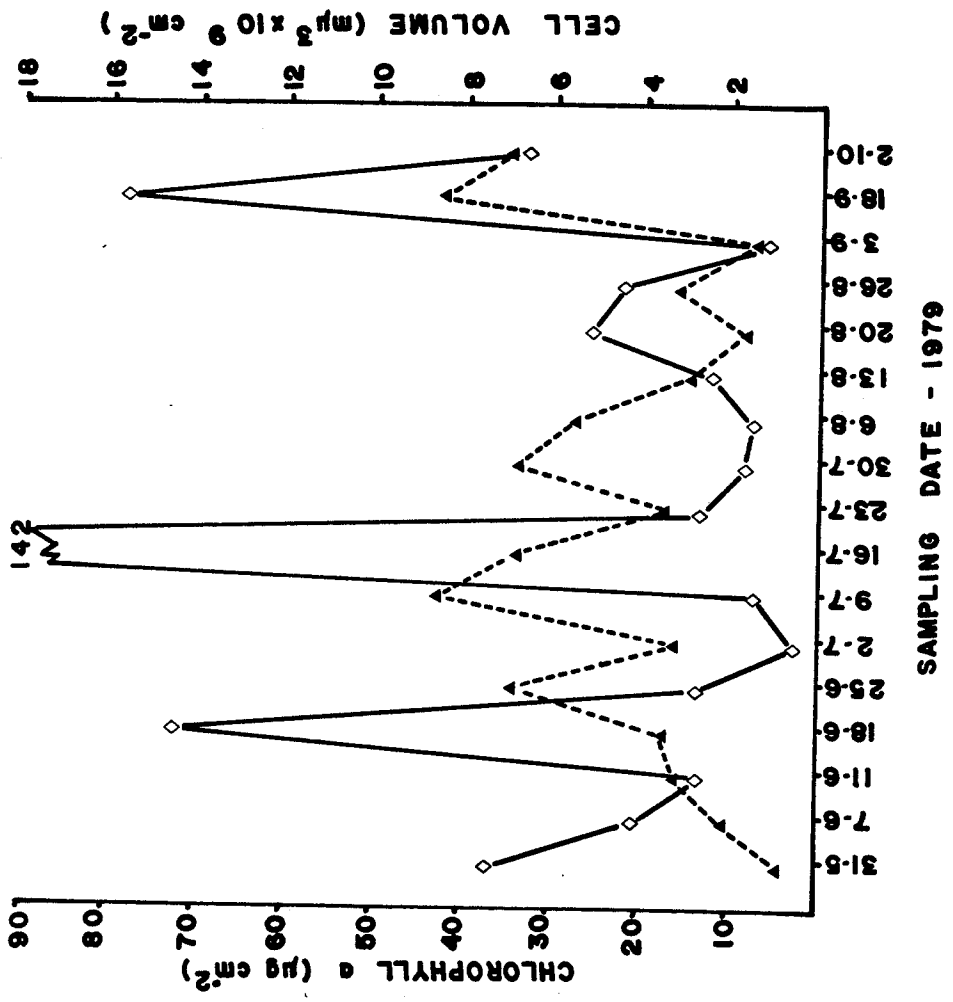

CELL VOLUME ($mu^3 \times 10^9$ cm^{-2})
2
4
6
8
10
12
14
16
18
CHLOROPHYLL a (μg cm^{-2})
10
20
30
40
50
60
70
80
90
142
SAMPLING DATE - 1979
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10

Figure 38: Chlorophyll *a* (□——□) biomass estimates of the phytoplankton in L623.

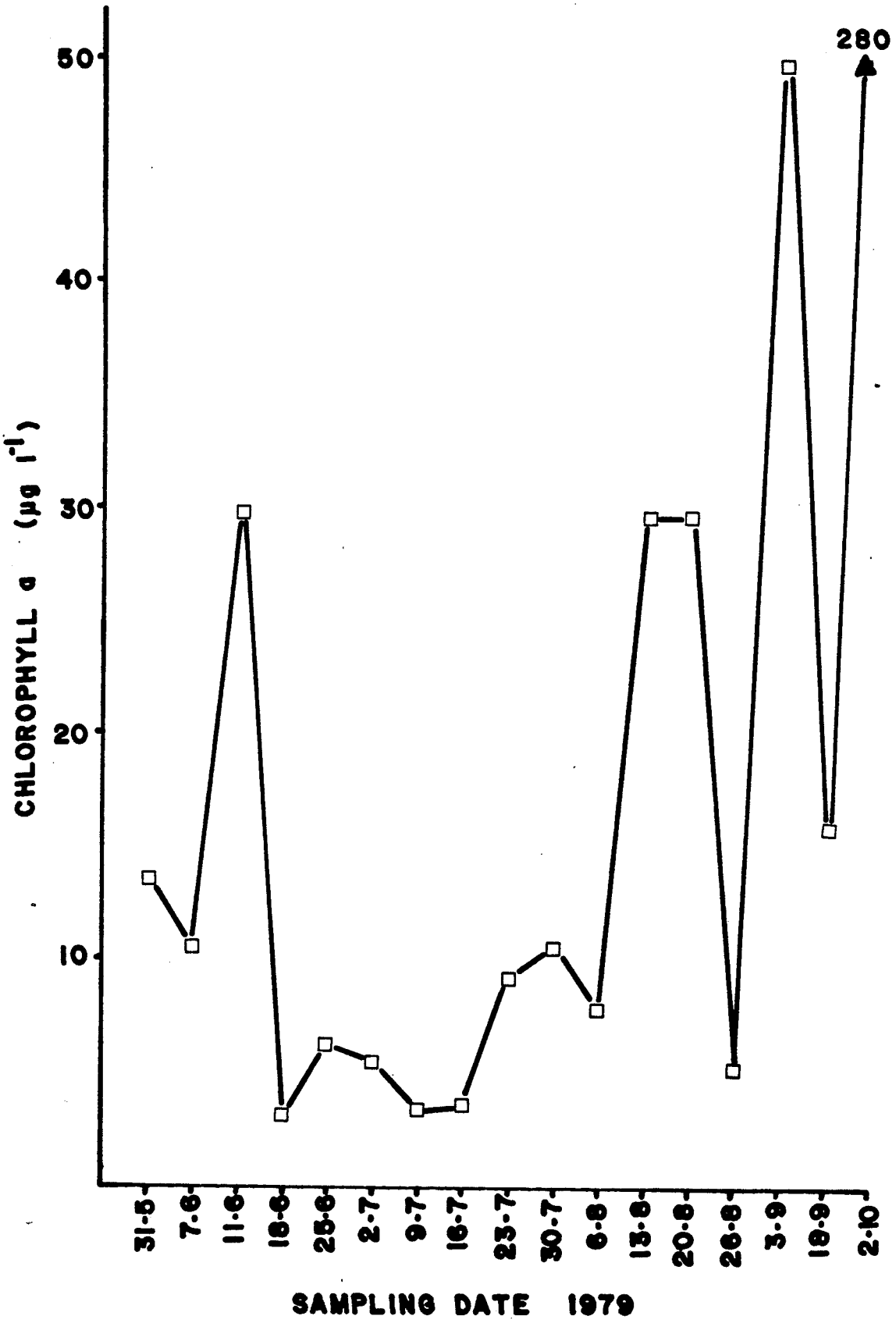
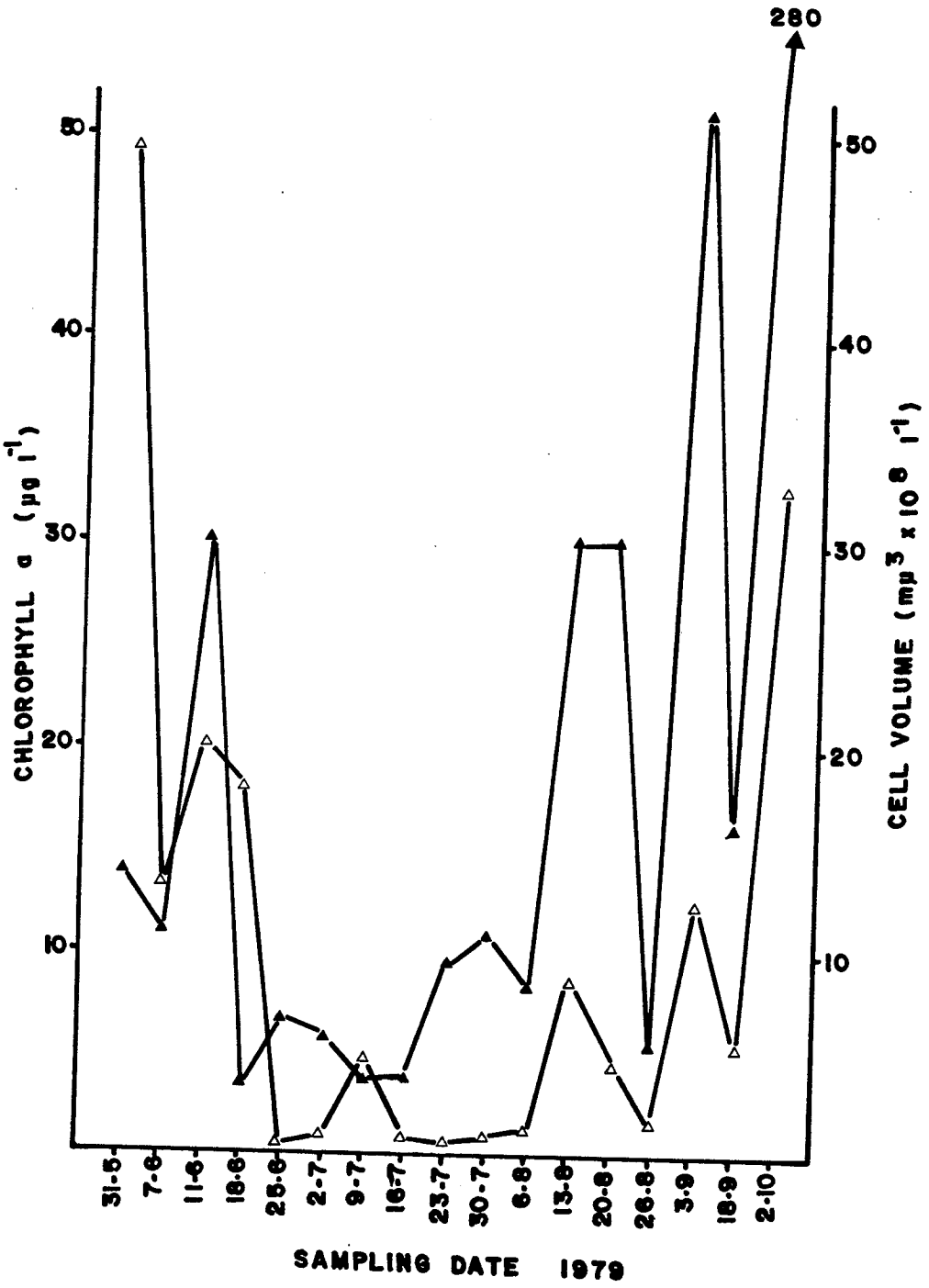

280
50
40
30
20
10
CHLOROPHYLL a (µg l⁻¹)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
10-9
2-10
SAMPLING DATE 1979

Figure 39: Comparison of cell volume (△——△) and chlorophyll *a* (▲——▲) biomass estimates (r=0.676) of the phytoplankton in L623.


280
50
40
30
20
10
CHLOROPHYLL a (µg l⁻¹)
CELL VOLUME (mµ³ x 10⁸ l⁻¹)
31-5
7-6
11-6
18-6
25-6
2-7
9-7
16-7
23-7
30-7
6-8
13-8
20-8
26-8
3-9
18-9
2-10
SAMPLING DATE 1979

3. SEASONAL SUCCESSION

A.Lake 255

In L255 there appeared to be three distinct communities with little overlap in species(Fig.40). The epiphytic communities on the natural and artificial substrates had the majority of their taxa in common. The epipelon had only two major species in common with the epiphyton; *Cocconeis placentula* which was ubiquitous on the epiphytes and *Trachelomonas robusta* which was common only on *Typha*. The phytoplankton community was the most isolated. *A. flos-aquae* was present on the sediment as well as in the plankton but it has not been decided yet whether or not this blue-green germinates from overwintering akinetes on the sediment or is an artifact on the bottom settling from the plankton.

In the epiphytic communities seasonal mean cell volumes were very similar(Tab.4) but neither the maxima, peak date nor dominant species coincided. The epiphyton on *Typha* attained a maximum cell volume of $8.52 \times 10^{8} m\mu^{3} cm^{-2}$ on July 2 when *Stigeoclonium nanum* predominated. The cell volume did not reach maximum levels until August 6-13 on the artificial substrates. Here *Aphanocapsa delicatissima* predominated.

On September 3, chlorophyll *a* concentrations on *Typha* and the roughened acetate were at a maximum. *A. delicatissima* dominated the population on *Typha* and *S. nanum* and *placentula* var.*lineata* composed much of the

Figure 40: A composite illustration of all taxa found on *Typha* (T), Smooth acetate (S), Roughened acetate (R), the Epipelon (E) and the Phytoplankton (P) diagramming their similarity of habitats in L255.

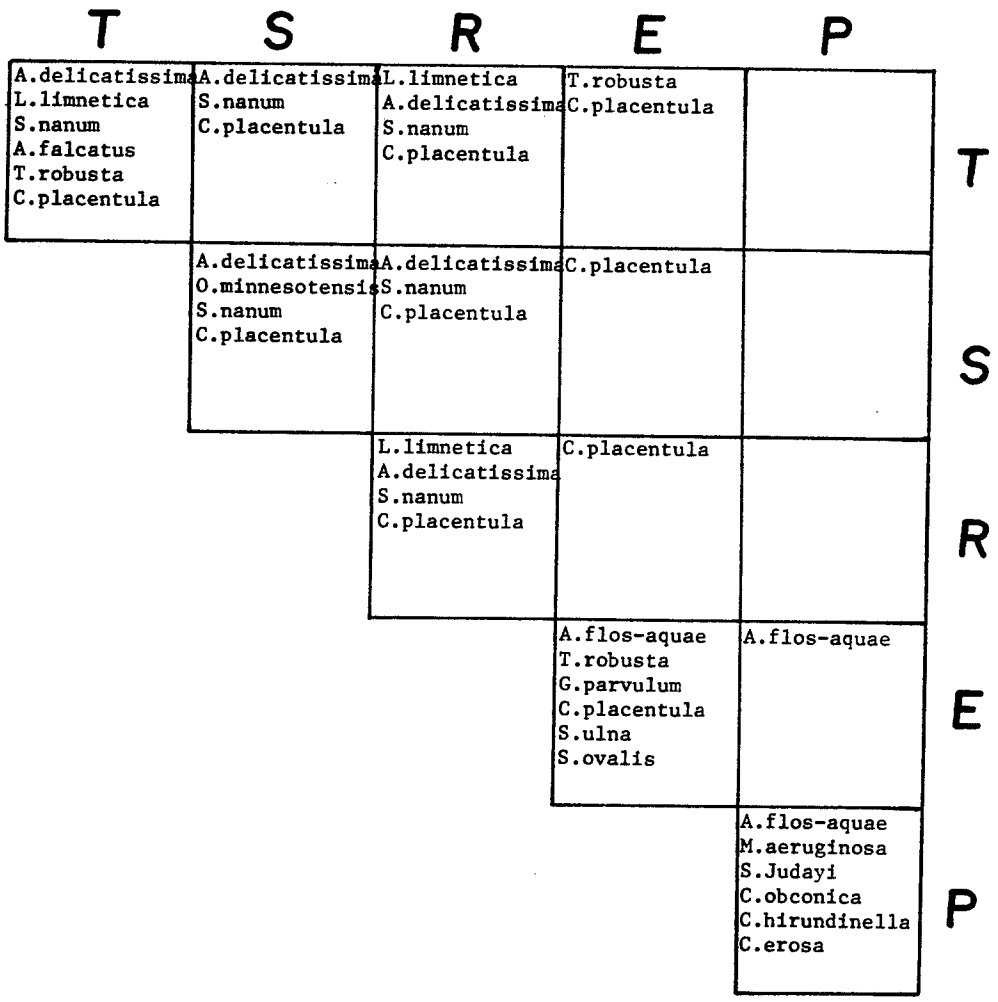

T
S
R
E
P
A.delicatissima
L.limnetica
S.nanum
A.falcatus
T.robusta
C.placentula
A.delicatissima
S.nanum
C.placentula
L.limnetica
A.delicatissima
S.nanum
C.placentula
T.robusta
C.placentula
A.delicatissima
O.minnesotensis
S.nanum
C.placentula
A.delicatissima
S.nanum
C.placentula
C.placentula
L.limnetica
A.delicatissima
S.nanum
C.placentula
C.placentula
A.flos-aquae
T.robusta
G.parvulum
C.placentula
S.ulna
S.ovalis
A.flos-aquae
A.flos-aquae
M.aeruginosa
S.Judayi
C.obconica
C.hirundinella
C.erosa
T
S
R
E
P

Table 4: A summary of the biomass and community composition findings of the five communities in Lake 255

	TYPHA	SMOOTH	ROUGH	EPIPELON	PHYTOPLANKTON
Mean cell volume ($m\mu^3 cm^{-2}$; $m\mu^3 \ell^{-1}$)	1.04×10^8	1.88×10^8	1.84×10^8	3.89×10^9	9.47×10^{10}
Peak cell volume ($m\mu^3 cm^{-2}$; $m\mu^3 \ell^{-1}$)	8.52×10^8	6.27×10^8	4.92×10^8	1.08×10^{10}	1.03×10^{12}
Date of Peak volume	July 2	August 6	August 13	June 18	July 16
Peak dominated by—	Stigeoclonium nanum	Aphanocapsa delicatissima	Aphanocapsa delicatissima	Surirella ovalis	A. flos-aquae C. hirundinella
Mean chlorophyll *a* (µg)	0.239	0.780	1.074	28.90	71.62
Peak chlorophyll *a* (µg)	0.442	1.409	2.313	43.53	234.96
Date of Peak	September 3	October 10	September 3	July 30	September 3
Peak dominated by—	Aphanocapsa delicatissima	Stigeoclonium nanum	S. nanum C. placentula	A. flos-aquae C. placentula	M. aeruginosa A. flos-aquae
Correlation coefficient Chl. *a* vs. cell volume	0.252	0.414	0.291	0.175	0.070
Most predominant group	Bacillariophyceae	Cyanophyta	Cyanophyta	Bacillariophyceae	Cyanophyta
Major species	A. delicatissima L. limnetica S. nanum T. robusta C. placentula A. falcatus	A. delicatissima O. minnesotensis S. nanum C. placentula	A. delicatissima L. limnetica S. nanum C. placentula	A. flos-aquae T. robusta G. parvulum C. placentula S. ulna S. ovalis	A. flos-aquae M. aeruginosa S. Judayi C. obconica C. hirundinella C. erosa

population on the roughened cellulose acetate. The chlorophyll *a* maximum on the smooth acetate occurred on October 10 coinciding with a large *S. nanum* population. On the artificial substrates the Cyanophyta were the seasonal dominants while on *Typha* the Bacillariophyceae predominated.

The epipelic community showed a cell volume maximum on June 18 and a chlorophyll *a* peak at the end of July. The large cell volume was a direct result of a population of *Surirella ovalis*. The chlorophyll *a* maximum coincided with large populations of *A. flos-aquae* and *C. placentula* var.*lineata*. The most significant group overall was the Bacillariophyceae however.

In the phytoplankton the seasonal maximum as cell volume on July 16 was a result of large populations of *A. flos-aquae* and *Ceratium hirundinella*. The biomass as chlorophyll *a* peaked at the beginning of September when *A. flos-aquae* and *Microcystis aeruginosa* predominated. The Cyanophyta was the most influential group in the phytoplankton.

B.Lake 623

The littoral communities of L623 were not as well defined as those in L255(Fig.41). *N. holsatica* and *S. nanum* were common to all three epiphytic communities. There was also overlap of *G.parvulum* var.*parvulum* and *C. placentula* var.*lineata* from the epiphyton to the epipelon and phytoplankton.

The seasonal peak in volume biomass of the epiphyton

Figure 41: A composite illustration of the taxa found on *Typha* (T), Smooth acetate (S), Roughened acetate (R), the Epipelon (E) and the Phytoplankton (P) diagramming their similarity of habitats in L623.

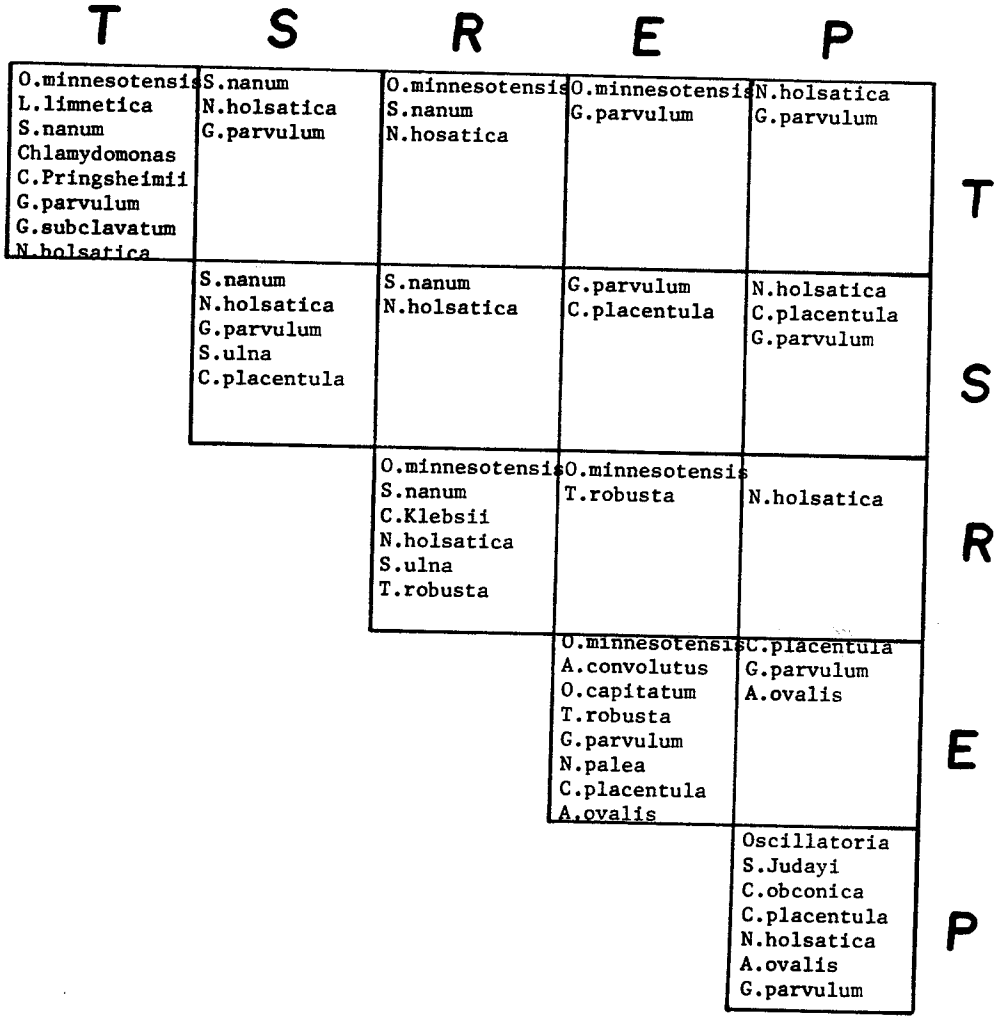

T S R E P
O.minnesotensis
L.limnetica
S.nanum
Chlamydomonas
C.Pringsheimii
G.parvulum
G.subclavatum
N.holsatica
S.nanum
N.holsatica
G.parvulum
O.minnesotensis
S.nanum
N.hosatica
O.minnesotensis
G.parvulum
N.holsatica
G.parvulum
T
S.nanum
N.holsatica
G.parvulum
S.ulna
C.placentula
S.nanum
N.holsatica
G.parvulum
C.placentula
N.holsatica
C.placentula
G.parvulum
S
O.minnesotensis
S.nanum
C.Klebsii
N.holsatica
S.ulna
T.robusta
O.minnesotensis
T.robusta
N.holsatica
R
O.minnesotensis
A.convolutus
O.capitatum
T.robusta
G.parvulum
N.palea
C.placentula
A.ovalis
C.placentula
G.parvulum
A.ovalis
E
Oscillatoria
S.Judayi
C.obconica
C.placentula
N.holsatica
A.ovalis
G.parvulum
P

Table 5: A summary of the biomass and community composition findings of the five communities in Lake 623

	TYPHA	SMOOTH	ROUGH	EPIPELON	PHYTOPLANKTON
Mean cell volume ($m\mu^3 cm^{-2}$; $m\mu^3 \ell^{-1}$)	1.04×10^8	3.16×10^8	2.56×10^8	1.28×10^{10}	1.02×10^9
Peak cell volume ($m\mu^3 cm^{-2}$; $m\mu^3 \ell^{-1}$)	1.01×10^{10}	7.68×10^8	4.58×10^8	1.42×10^{11}	4.91×10^9
Date of Peak	June 18	July 9	August 6	July 16	May 31
Peak dominated by—	Nitzschia holsatica	Stigeoclonium nanum	Stigeoclonium nanum	Amphora ovalis	Cryptomonas erosa
Mean chlorophyll *a* (µg)	0.238	2.028	1.956	22.35	30.52
Peak chlorophyll *a* (µg)	0.865	5.495	6.015	43.24	280.35
Date of Peak	June 11	June 25	June 25	July 9	October 2
Peak dominated by—	G. parvulum	Mixed diatoms S. nanum	S. nanum S. ulna	G. parvulum A. ovalis	N. holsatica C. placentula A. ovalis C. obconica
Correlation coefficient Chl *a* vs cell volume	0.414	0.842	0.518	0.249	0.676
Most predominant group	Bacillariophyceae	Chlorophyta	Chlorophyta	Bacillariophyceae	Bacillariophyceae
Major species	O. minnesotensis L. limnetica S. nanum Chlamydomonas sp. C. Pringsheimii G. parvulum G. subclavatum N. holsatica	S. nanum N. holsatica G. parvulum S. ulna C. placentula	O. minnesotensis S. nanum C. Klebsii T. robusta N. holsatica S. ulna	O. minnesotensis A. convolutus O. capitatum T. robusta G. parvulum N. palea C. placentula A. ovalis	Oscillatoria sp. S. Judayi C. obconica C. placentula N. holsatica A. ovalis G. parvulum Unknown diatom

occurred at three different times:mid-June(on *Typha*),early July(smooth acetate) and early August(roughened acetate) (Tab.5). The peak on *Typha* was two orders of magnitude greater than on the artificial substrates. *N. holsatica* caused the volume maximum on *Typha*. *S.nanum* predominated on artificial substrates.

The maximum chlorophyll *a* values were over six times greater on the artificial than natural substrates. Chlorophyll *a* peaks coincided on June 25 with a mixed diatom- *S. nanum* population on the cellulose acetate. On June 11 a large population of *G. parvulum* var.*parvulum* on *Typha* resulted in the chlorophyll *a* maximum. Chlorophyll *a* and cell volume biomass correlated well on the artificial substrates but not on the natural host. The dominant group on the cellulose acetate was the Chlorophyta and *Typha* supported considerable populations of diatoms.

The cell volumes in the epipelic community were the highest of all communities studied. The peak on July 16 by *A. ovalis* var.*affinis* was preceded by a chlorophyll *a* peak on July 9 when *A. ovalis* var.*affinis* and *G. parvulum* var.*parvulum* predominated. There was no linear relationship between chlorophyll and cell volume.

The phytoplankton community displayed a *Cryptomonas erosa* dominated cell volume maximum on May 31 and a chlorophyll *a* maximum on October 2 consisting of mixed diatoms. Chlorophyll and cell volume biomass estimates were linearly related to $P<0.01$.

In no community in either lake where the blue-greens were the predominant group did cell volume and chlorophyll *a* biomass estimates correlate linearly. The same phenomenon occurred when communities were completely diatom-dominated.

4. EPIPHYTON ON SMOOTH CELLULOSE ACETATE IN THE 1978 AND 1979 SEASONS

A.Lake 255

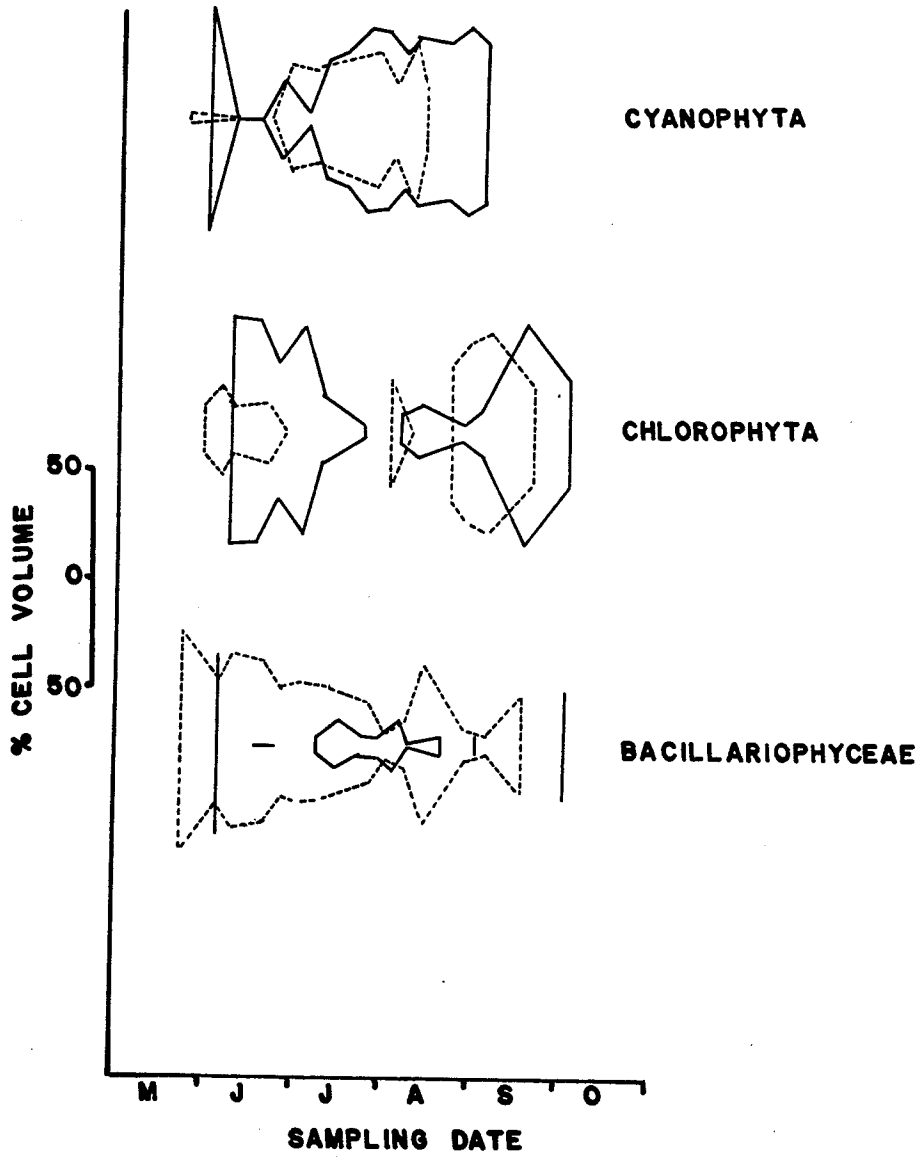
The 1978 epiphytic communities revealed a successional pattern involving the Cyanophyta, Chlorophyta and Bacillariophyceae. Diatoms prevailed in the spring, blue-greens in mid-summer and green algae in the fall. The diatoms did maintain reasonable populations throughout the season however.

In 1979 the Cyanophyta were major contributors from mid-July to the end of the season. Chlorophyta were evident in the early and late summer. Diatoms were generally insignificant(Fig.42).

In 1978 taxa constituting more than 10% of the population volume were *Lyngbya Lagerheimii* (Moebius) Gomont, *Aphanocapsa delicatissima*, *Coleochaete irregularis* Pringsheim, *Stigeoclonium nanum* and *C.placentula* var.*lineata*. In 1979 the only change was that *Lyngbya* and *Coleochaete* were minor contributors and *Oscillatoria minnesotensis* became significant.

Seasonal cell volume comparisons in the two years resulted in r=0.204. The average cell volumes were however very close; $2.07 \times 10^8 (\pm 7.59 \times 10^7)$ and $1.88 \times 10^8 (\pm 9.10 \times 10^7)$

Figure 42: Comparison of the per cent cell volume distribution patterns among the Cyanophyta, Chlorophyta and the Bacillariophyceae of the epiphyton on the smooth cellulose acetate in L255 during the 1978 (----) and 1979 (——) study seasons.


CYANOPHYTA
CHLOROPHYTA
BACILLARIOPHYCEAE
% CELL VOLUME
50
0
50
M
J
J
A
S
O
SAMPLING DATE

$m\mu^3$ cm^{-2} respectively. In both seasons the mid-summer bloom was the result of large populations of *Aphanocapsa delicatissima* .

Chlorophyll *a* concentrations in the two seasons were linearly related at $P<0.01$ ($r=0.707$). The average seasonal values were 0.371 µg cm^{-2} (±0.161) in 1978 and 0.780 µg cm^{-2} (±0.205) in 1979.

In neither season did cell volume correlate well with chlorophyll *a* biomass estimates (Fig.43). R values for 1978 and 1979 were 0.119 and 0.414 respectively.

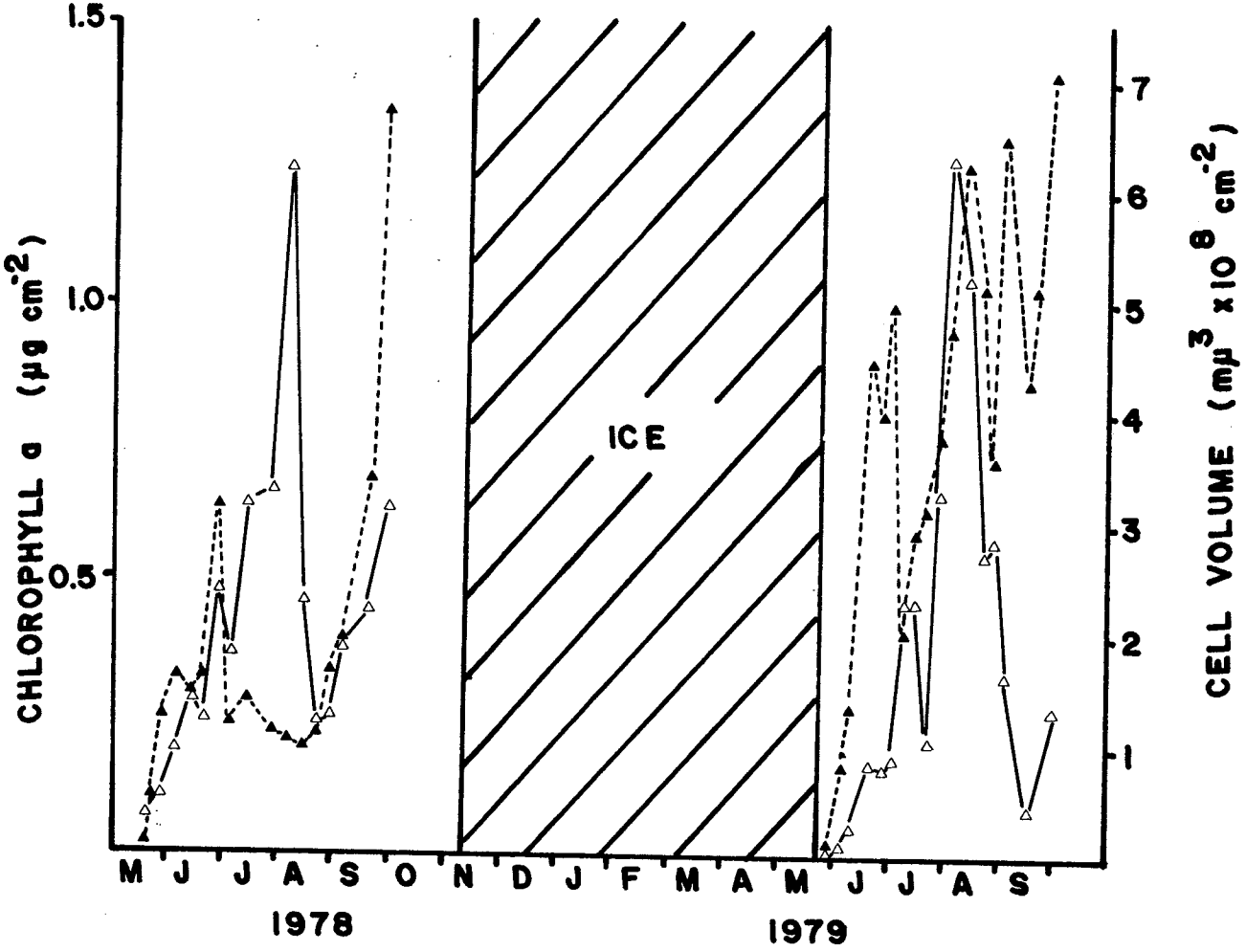
B. Lake 623

In 1978 the community was generally dominated by the Chlorophyta although diatoms became intermittently significant during the course of the summer. The Cyanophyta contributed between 1 and 10% of the total community.

In the 1979 season the Chlorophyta remained predominant and the total diversity of major diatoms increased (Tab.2). It was determined statistically that the communities were of the same species diversity duing the two seasons ($P<0.05$).

Dominant taxa in 1978 on the smooth acetate were *Chlamydomonas* sp., *Coleochaete irregularis*, *Stigeoclonium nanum* and *Cocconeis placentula* var. *lineata*. In the 1979 study season the dominant species revealed an increase in the diatoms. *S. nanum*, *Nitschia holsatica*, *Synedra ulna* var. *ulna*, *C. placentula* var. *lineata* and *G. parvulum* var.

Figure 43: Comparison of cell volume (△——△) and chlorophyll *a* (▲----▲) of the epiphyton on the smooth cellulose acetate substrates demonstrating seasonal patterns in L255 during the 1978 and 1979 study seasons.


1.5
1.0
0.5
CHLOROPHYLL a (µg cm-2)
ICE
7
6
5
4
3
2
1
CELL VOLUME (mµ3 x 10-8 cm-2)
M J J A S O N D J F M A M J J A S
1978
1979

parvulum predominated here.

Biomass as cell volume had seasonal means of 2.3×10^8 $m\mu^3 cm^{-2}$ ($\pm 6.64 \times 10^7$) in 1978 and 3.16×10^8 $m\mu^3 cm^{-2}$ ($\pm 1.27 \times 10^8$) in 1979. The seasonal patterns were very different however with an r value of only 0.110 correlating the two seasons(Fig.44).

Chlorophyll *a* concentrations coincided well with the corresponding cell volume estimates in both seasons ($P<0.05$). Successional patterns varied considerably from 1978 to 1979(Fig.45). The seasonal mean chlorophyll *a* concentrations correlated well with one another in both years. The 1978 correlation coefficient was $r=0.717$ and in 1979 $r=0.842$.

Figure 44: Comparison of the per cent total volume distribution patterns among the Cyanophyta, Chlorophyta and the Bacillariophyceae of the epiphyton on the smooth cellulose acetate in L623 during the 1978 (——) and 1979 (----) study seasons.

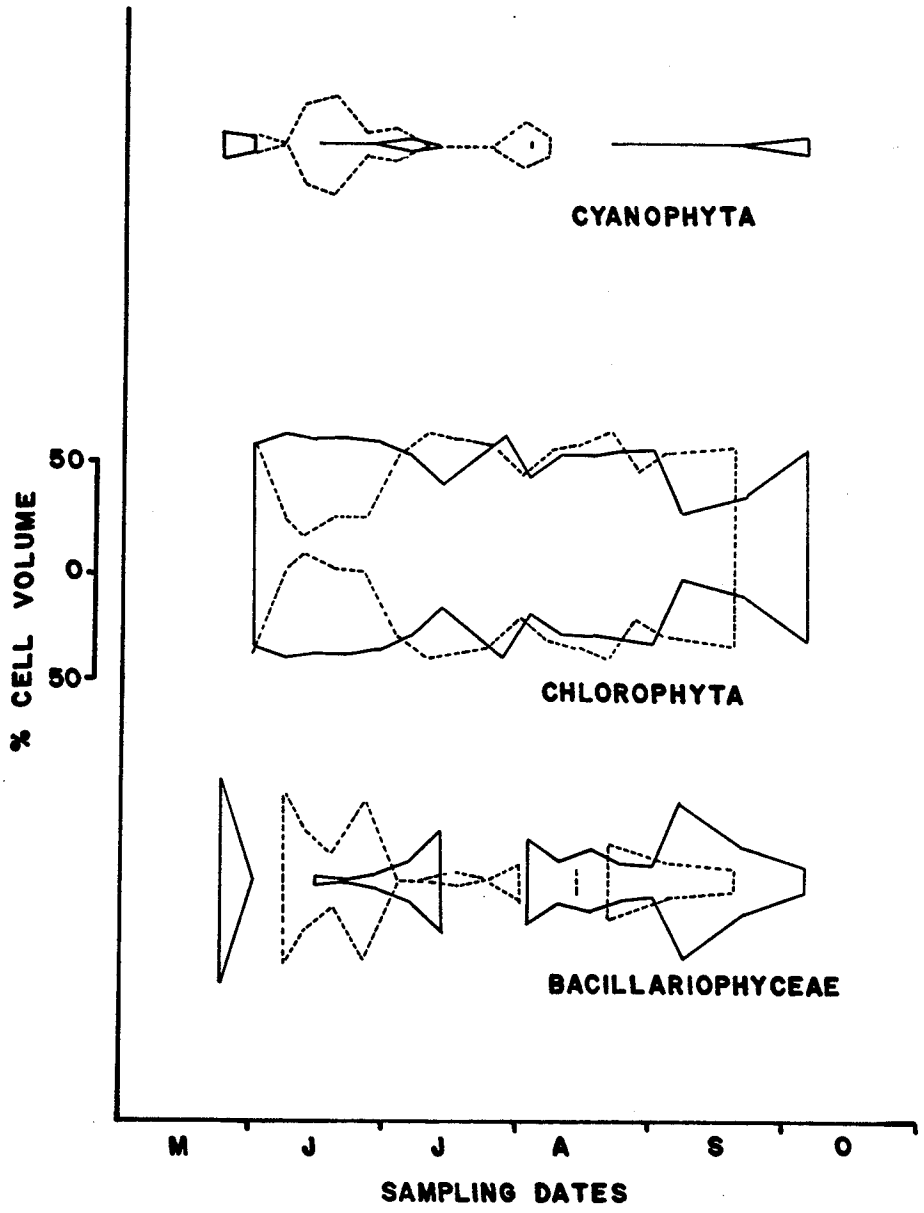
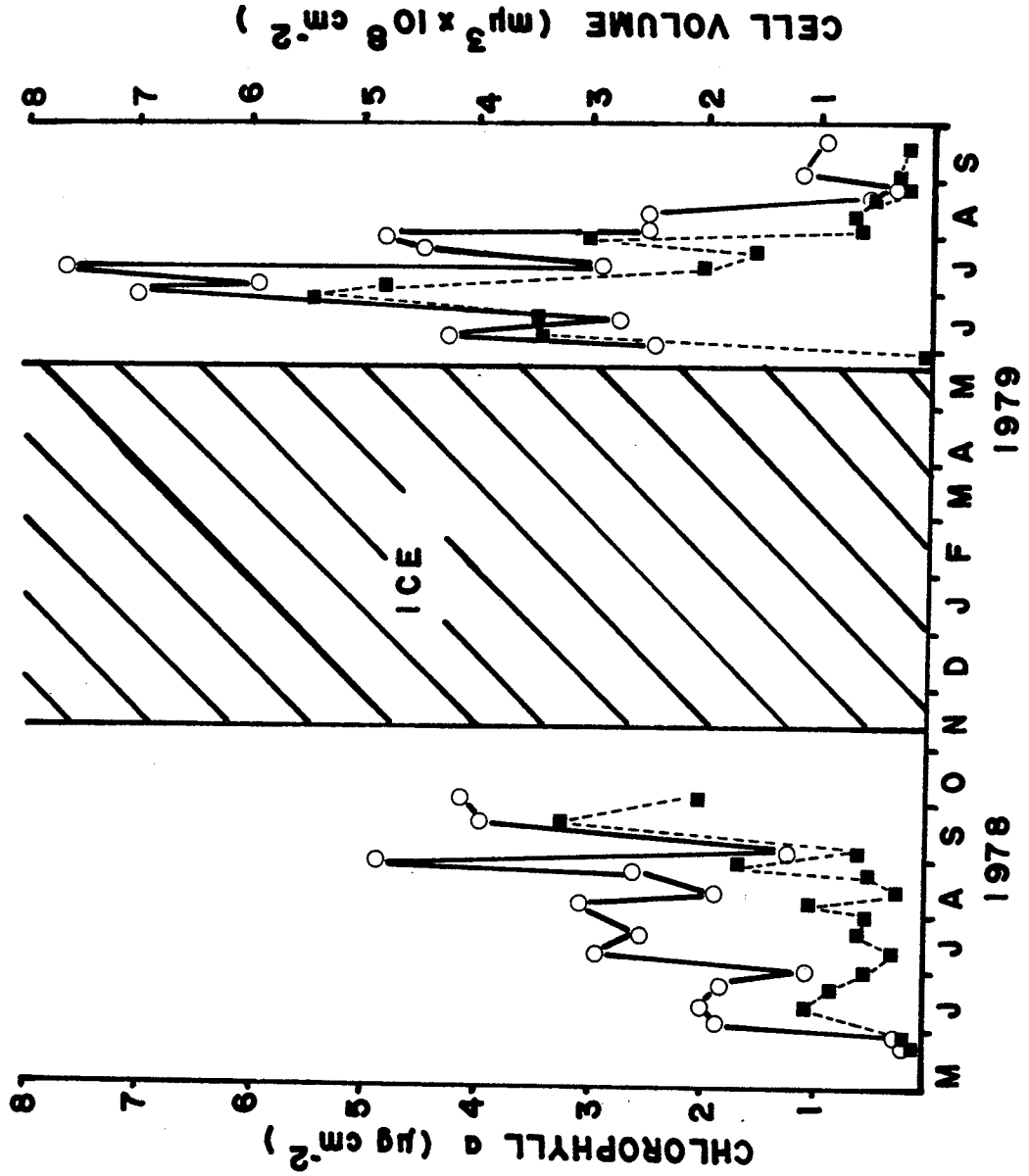

CYANOPHYTA
CHLOROPHYTA
BACILLARIOPHYCEAE
% CELL VOLUME
50
0
50
M
J
J
A
S
O
SAMPLING DATES

Figure 45: Comparison of cell volume (○——○) and chlorophyll *a* (■----■) of the epiphyton on smooth cellulose acetate demonstrating seasonal patterns in L623 during the 1978 and 1979 study seasons.


CELL VOLUME (mμ³ x 10⁸ cm⁻²)
CHLOROPHYLL a (μg cm⁻²)
ICE
1978
1979
M J J A S O N D J F M A M J J A S
1 2 3 4 5 6 7 8

DISCUSSION

Methodology

The reliability of results of any successional study is a direct function of the methods employed. For this reason the majority of this discussion will involve an analysis of the methodologies of sampling with artificial substrates; biomass estimation; and the statistical evaluation of samples.

Artificial substrates for the evaluation of periphyton has been routinely used since at least 1916 (Cooke 1956). Many materials have been used but glass has remained the most popular (Sládečková 1962). Although there have been some comparable results between epiphytic communities on glass and aquatic plants, evidence suggests that a positive correlation far more often exists if the natural substrate is non-biological (Castenholz 1960, Stockner and Armstrong 1971, Evans and Stockner 1972).

Hooper-Reid and Robinson (1976,1978a,b) introduced cellulose acetate as an appropriate artificial substrate for epiphytic algal communities. This material provided a chemically inert surface. One of the major problems of glass has been that it provides a source of silica to epiphytic flora which might favour diatom colonization.

While the procedures undertaken for insertion and positioning of the artificial substrates followed closely those of Hooper-Reid and Robinson (1978a) conclusions as

to the validity of artificial substrate use differed significantly. In their study no significant difference was detected among epiphytic communities on natural and cellulose acetate substrates. In the present investigation the Bacillariophyceae contributed more than any other group to the epiphyton on *Typha* in both lakes while on the average the cellulose acetate substrates rarely supported significant populations of diatoms. On the acetate in L255 the Cyanophyta dominated while in L623 the Chlorophyta formed the major fraction.

Further comparison of the foregoing results with others is limited due to the frequent improper use of artificial substrates with regards to exposure time. Most investigations have involved the insertion of the artificial substrates into a system for several weeks or a month and the results obtained are then directly compared to a natural community that had been developing for an extended period of time.

In Lakes 255 and 623 the communities on cellulose acetate demonstrated a decrease in the number of important species in comparison to those on *Typha*. The acetate appeared to have the effect of decreasing the relative importance of the diatoms and conversely increasing the significance of the green and blue-green algae. Prescott (1962) has noted an increase of Chlorophycean and Cyanophycean flora in hard-water seepage lakes. Kling (1975) reported a shift to predominance by the Cyanophyta or Chlorophyta with

increased eutrophication in her study of the lakes in the Erickson-Elphinstone region.

The differences between *Typha* and the artificial substrates were significant. One reason for such differences may lie in the physiological state of the host plant. Artificial substrates can generally be expected to change little chemically from the time of initial insertion to sampling time while a macrophyte may constantly be undergoing physiological change.

Dissolved nutrients in the water flowing past a substrate are likely sources for the epiphyton. Cellulose acetate strips provide little resistance to current and so nutrients may be assumed to be in constant supply. The ridged epidermis of a *Typha* stem and its protected location within a macrophyte stand could contribute to a decrease in water flow and nutrient supply. Competition for nutrients might therefore be more intense on the *Typha* and the establishment of microniches could occur.

It is evident that there is a complex biochemical relationship that exists between host and epiphyte. Harlin (1973) determined that a penetrating rhizoid is not required for exchange of products. By their proximity alone, epiphytic flora are capable of exchanging products before these are diluted by the surrounding water.

Physical factors such as light and temperature have been found to be more significantly linked to algal community structure than nutrients in several investigations (Haertel

1976, Jones 1977a,c, Rosemarin and Hart 1978, Schwartzkopf and Hergenrader 1978). It is possible that the water surrounding the macrophyte stands is somewhat cooler and the light intensity lower than the environment of the artificial substrates due to shading effects of the emergent portions of *Typha*. For obvious reasons artificial substrates must be inserted at the edge of the macrophyte stands and not within. Thus the cellulose acetate strips may have been exposed to higher light intensities, incident heat radiation and wind-induced currents than the *Typha* in its protective stand.

The paucity of diatoms may have been a direct consequence of these higher light and temperature regimes. Further controlled studies would be necessary to confirm such speculation.

Biomass estimates made using cell volumes are one of three widely used methods. Comparisons with other literature is difficult when studies have been conducted with varying degrees of accuracy and methodological parameters. Reported volume estimates for a single species appear to vary from one author to another (Castenholz 1960, Evans and Stockner 1972). Such variation may be genetic, it may be the result of seasonal variation or it may have resulted from the use of different stereometrical formulae. Cell volumes accurate to the 95% confidence level were calculated during this study, although it must be stressed that such estimates are not necessarily applicable to

other investigations.

The seasonal mean cell volumes on cellulose acetate were about twice as high in L623 as in L255 although seasonal maxima were similar. The mean cell volume estimate on *Typha* in L623 was seven times greater than in L255 and the peak was almost two orders of magnitude greater.

The *Typha* host consistently supported a maximum population that differed entirely from the epiphytic communities on cellulose acetate substrates in the same lake although communities of the two types of artificial substrates in both were always similar.

Peak values were higher than those found by Moore (1974a) and Hooper-Reid and Robinson (1978a) in epiplithic and epiphytic studies respectively. The maxima were within the mid-range of the results of Evans and Stockner (1972) who studied the epilithon of navigational buoys in Lake Winnipeg.

The seasonal mean cell volumes of the epipelon in both Lakes 255 and 623 were in the range determined by Moore (1974a). The value found in Moore's (1974a) arctic river investigation was 1.85×10^{10} $m\mu^3 cm^{-2}$ which was midway between the 1×10^{10} and 1.42×10^{11} $m\mu^3 cm^{-2}$ maxima of L255 and L623 respectively. Peaks occurred in mid-June (L255) and mid-July (L623). Moore (1974a) and Gruendling (1971) both found a significant relationship to exist between high cell volume and high temperature although the epipelic crop does fluctuate considerably, both seasonally and from year to

year (Hickman and Round 1970).

Cell volume estimates obtained from the littoral phytoplankton communities were generally higher than recorded values of pelagial phytoplankton and fit closely into the range determined by Moore (1974a) in his study of arctic river epipelon. Peak cell volume estimates determined by Jones (1977a) were intermediate between those found for the two lakes in this study.

The major advantages of the use of cell volume as an algal community biomass estimator are that it provides both an indication of population size and a common comparable volume base. On the other hand, cell volume does tend to overestimate the significance of larger taxa and underestimate the importance of smaller ones. When large numbers of large or small taxa contribute to the total community the problem of the use of cell volume can present itself. For this reason possibly, but more likely because it is quicker, most determine populations on a cell number basis. Cell numbers provide an indication of the absolute number of cells in a particular volume of water or on a substrate surface area. The base value of '1 cell' has little association with community biomass. For example, a sample containing 1000 cells/ml of *Nitzschia holsatica* (vol.= $43 m\mu^3$) and 1000 cells/ml of *Cymbella cistula* var *cistula* (volume= $4514\ m\mu^3$) may not demonstrate differences as clearly as when expressed as $4.3 \times 10^4\ m\mu^3 ml^{-1}$ *N. holsatica* and $4.514 \times 10^6\ m\mu^3 ml^{-1}$ *C. cistula* var *cistula*. The reader

unfamiliar with the taxonomy of such populations can thus assess possible physiological and ecological differences more effectively. Cell numbers should however be used in community studies to assure that small, abundant algae are considered as significant members of the community.

Paasche (1960), Hooper-Reid and Robinson (1978a) proposed that cell surface area be used instead of either cell numbers or cell volume since it was found that a better relationship existed between surface area and production.

Chlorophyll *a* as a biomass estimator of algal communities is perhaps more widely used than any other method despite the fact that seasonal chlorophyll trends rarely coincide with cell volume or cell number estimates (Kowalczewski and Lack 1971, Haertel 1976, Jones 1977a, Rott 1978, Tolstoy 1979). The results of this study supported such findings. Only three communities in L623 exhibited linear correlation between cell volume and chlorophyll *a* concentration. These were the epiphytic communities on the smooth and roughened cellulose acetate and the phytoplanktonic community. The relationships did not reveal any common factor. In fact Rott (1978) has suggested that the relationship between cell volume and chlorophyll *a* is not linear at all but a complex asymmetric one.

The inherent problems of the spectrophotometric method are important if one is to fairly assess the method's validity. The obvious advantage is that the method is

simple, fast and relatively inexpensive. Problems lie not only in the procedural analysis but also in the assumptions necessary to accept the method at all. The most crucial of these is that all algal cells regardless of volume, size or group association contain the same concentration of chlorophyll *a* whereas, in fact, the chlorophyll *a* content of a single species may fluctuate quite noticeably depending upon physiological status and the environment.

The commonly used method of Strickland and Parsons (1968) including the acidification modifications of Lorenzen (1967) was employed in this study and results compared to the literature. While the chlorophyll *a* estimates of the epiphyton on *Typha* in L255 and L623 were very low generally they did fall into the upper range of those in Allen's (1971) investigation of glass slides in a *Scirpus* bed. However the chlorophyll *a* maximum on the artificial substrates in L623 were similar to those maxima found by Hooper-Reid and Robinson (1978a) and by Allen (1971).

The seasonal means and peaks of the epipelon in both lakes were very similar. The means corrosponded well to values obtained by Hickman and Round (1970) and by Moss (1968). Maxima were much lower than almost all other reported literature.

The seasonal mean chlorophyll *a* estimates of the phytoplankton values were higher than those determined in Gelin's (1975) investigation but considerably lower than those in Cooking Lake (Hickman 1979). Peak values were higher

than those of both Gelin (1975) and Kling (1975) on a previous study of the pelagial phytoplankton of L255. Values for both lakes were in the same range as the chlorophyll *a* estimates determined by Kowalczewski and Lack (1971), Jones (1977a), Hickman and Jenkerson (1978), Schwartzkopf and Hergenrader (1978). While the average chlorophyll values for the phytoplankton of L255 was twice that in L623, peaks were similar in magnitude. This was undoubtedly a consequence of the different community compositions in the two lakes.

Methods used in chlorophyll analysis of the epipelic community differed from the most commonly used technique of Eaton and Moss (1966), in which the algae exhibiting diurnal vertical migration rhythms were separated from the mud and water before acetone extraction. In the present study the technique was a modification of Tett *et al* (1975) and Stanley (1976). While the epipelon in the sediment was separated from the water before extraction, no attempt was made to separate the algal community from the sediment itself. It was assumed that degradation products in the sediment did not interfere extensively in the analysis but as no comparisons were made between the methods the accuracy of such an assumption is unknown. Extreme seasonal fluctuations of epipelon chlorophyll *a* has also been observed by Hickman and Round (1970) who used the method outlined by Eaton and Moss (1966).

The determination of the number of organisms that it

was necessary to count to achieve a given level of statistical confidence was initially proposed by such workers as Lund *et al* (1958), who stated that since studies generally involve changes in generations these are, in fact changes of 100%. Therefore one need only ensure that the probable range within which the true number lies is within ±50%. In this investigation the total standard error acceptable, including that of the cell volume calculation was set at 35%. It was then possible to calculate the number of microscope fields necessary for the enumeration of a statistically accurate representation of sample. The species recorded on any one sampling day depended upon their observed diversity in the first 20 sample fields. This set an arbitrary limit on the diversity. It has been shown by Hobro and Willen (1975) that variability is reduced significantly once some limits are set on the number of species to be evaluated. The method was consistent and it is believed to have been much more efficient than pre-determining the number of algae that it would be necessary to count (Castenholz 1960, Brown 1976, Siver 1977) which does not take into account the population size or structure.

Seasonal Succession

The relatively low species diversity determined for all communities could be the result of any of a number of factors.The sampling method may have affected the retrieval of organisms. Due to the heterogeneity of the community

structure it is possible that some taxa were overlooked in random sampling. The increase in efficiency of identifying species depended to a large extent on the time spent looking for them. Lund *et al* (1958) have discussed the disadvantages of spending disproportionately large periods of time in an effort to increase accuracy. The time spent on the system greatly affects the number of species found (Kling 1975). A study of 5 months cannot be considered equivalent to one of several years as far as characterization of the community. The time of year can affect the number of taxa found. Kling (1975) has remarked that spring and fall samples generally contain more species than summer and winter samples.

When it was originally proposed that artificial substrates be employed a hypothesis was formulated that a roughened surface would simulate a plant stem more closely than a smooth one. For this reason both smooth and roughened cellulose acetate (vertically striated) were used. The use of roughened substrates has been attempted previously (Flint *et al* 1977, Sládečková 1962) with varying results.

The biomass estimate as either cell volume or chlorophyll *a* and community composition correlated closely ($P<0.05$) between smooth and roughened acetate substrates in both lakes. In neither lake however, did the community structure on the natural substrate correlate with the populations on the artificial hosts. Although almost without exception major species found on the artificial

substrates were present on *Typha*, never did a species or group completely dominate the natural host's community as occurred on the acetate substrates.

The communities on *Typha* stems in L255 and L623 had few major species in common but in both cases diatoms were the predominant group accounting for mean per cent volumes of 37% and 56% in Lakes 255 and 623 respectively. In both lakes the epiphytic flora of the natural substrates appeared to show more distinct seasonal changes in community structure than the algae attached to the artificial substrates. The effect of the natural substrate on the epiphytic communities appeared to be one of retarding the trends that might be expected to accompany eutrophication; such as a decrease in the number of important species. Klarer and Hickman (1975) studied the effects of heat on the epiphyton attached to *Scirpus*. They found that during the mid-summer in unheated stations no one species accounted for more than 50% of the total population. The present study supported these findings when the *Typha* stem is likened to the unheated stations and cellulose acetate substrates considered representative of heated stations. The *Typha* plant perhaps provided exudates or as previously mentioned provided more favourable light and temperature regimes to allow for increased competition among the epiphytic flora and fauna. Evans and Stockner (1972) determined that where the water was more oligotrophic in their Lake Winnipeg study the epilithon was dominated by diatoms (as on *Typha*)

but in the more eutrophic areas the community was predominated by Chlorophyceae and Cyanophyceae.

Lake 623 is less deep than L255; is smaller and possibly receives greater agricultural run-off. Chemical data (Barica 1978) suggests that L623 is more eutrophic than L255. The influence of eutrophication is not particularily obvious in the epiphytic community on *Typha* but was reflected in the epiphytic populations on the artificial substrates where *Stigeoclonium nanum* comprised an average of 64% of the total population during the course of the season. Domination by S.*nanum* has been noted on numerous occasions and has generally been regarded as an indicator of organic pollution (McLean and Benson-Evans 1974).

Increased eutrophication may lead to increased algal biomass. The cell volume biomass of L623 was always greater than in L255. One would expect the biomass on the artificial substrates to exceed that on *Typha* in both lakes if indeed eutrophication effects are more advanced on the former. However cell volume peaks of the epiphyton on the artificial substrates never exceeded that on *Typha*.

The epipelic community was characteristically dominated by diatoms and diversity values were considerably lower than reported in the literature (Moore 1972,1974a,b).

The two lakes supported quite different communities despite the fact that the Bacillariophyceae predominated. The contributions of the Bacillariophyceae, Euglenophyta and Cyanophyta in L255 were 75%, 8% and 5% respectively.

In L623 the Bacillariophyceae contributed 70%, the Cyanophyta 13%; Euglenophyta, 7%; Chlorophyta, 5% and the Chrysophyceae 4%. Such contributions are of the range reported by Moore (1974a,b).

Despite the fact that L623 is more eutrophic than L255 the epipelic community was generally much smaller. Increased grazing effects and decreased light intensities due to constant deposition of organic matter are possible causal agents.

The littoral phytoplankton communities of the two lakes were quite different, being composed of different algal species and groups. The community in L255 consisted of Cyanophyta, Pyrrophyta and Cryptophyta with mean seasonal contributions of 56%, 9% and 26% respectively. L623 was dominated by the Cyanophyta, Chlorophyta, Chrysophyceae and Bacillariophyceae with respective seasonal mean contributions of 18%, 18%, 5% and 56%.

The much lower phytoplankton biomass in L623 may be a result of more dense macrophytic growth. Macrophytes may produce substances capable of suppressing the phytoplankton but the absence of phytoplankton could be a direct result of competition by epiphytic and filamentous algae for nutrients (Eminson and Phillips 1978).

The seasonal succession of littoral phytoplankton in L255 was very similar to that found by Kling (1975) in her examination of the pelagial plankton. Maxima of *Aphanizomenon flos-aquae* and *Ceratium hirundinella*

were evident and are characteristic of mildly eutrophic lakes. Domination by A. *flos-aquae* and *Microcystis* in the mid-late summer has been found frequently (Kling 1975, Haertel 1976, Coveney *et al* 1977, Hickman 1979).

The domination by the Bacillariophyceae in the littoral phytoplankton of L623 was unusual as this group is not generally abundant in such systems (Hickman 1979). Upon closer examination of the phytoplanktonic community it appeared that the majority of major species were not true plankters at all but 'metaphyton' represented by such attached forms as *Cocconeis placentula*, *Gomphonema parvulum*, *Amphora ovalis* and *Oscillatoria*. The larger diversity in L623 may indeed be more of a reflection of attached forms in suspension rather than an indication of trophic status.

SUMMARY

The epiphytic, epipelic and planktonic algal communities of the littoral zone in Lakes 255 and 623 of an aquaculture project in Southwestern Manitoba were investigated from May to October in 1978 and 1979. In 1978 the epiphyton adnate to smooth cellulose acetate artificial substrates only was examined. In 1979 the epiphytic communities studied were those attached to smooth and roughened cellulose acetate and *Typha latifolia*. Examination of the epipelic and planktonic algal communities was included during the 1979 study.

Species composition and proportional group representation of epiphyton on *Typha* and the cellulose acetate differed. Smooth and roughened cellulose acetate supported very similar communities in all respects in both lakes and no significant difference was detected between the use of textured or smooth artificial substrate surfaces. The community structure of epiphytes on *Typha* in both lakes was more defined than on the artificial substrates and individual taxa did not dominate the community for long periods of time as was the case on the cellulose acetate.

The epipelon in both lakes was dominated by raphidinate diatoms for much of the season, this group often accounting for over 70% of the population volume. While the phytoplankton in L255 demonstrated typical seasonal succession patterns for a mildly eutrophic lake this

community in L623 did not and was derived for the most part from the epipelon.

Biomass estimates of the communities were made using cell volume and chlorophyll *a* analysis. Generally the seasonal mean values of both cell volume and chlorophyll *a* biomass estimates were of the order of recorded estimates for similar studies. Peak cell volumes for individual communities occurred at different times during the season, even when the epiphytic communities were compared with one another. Chlorophyll *a* displayed more consistency as far as peak periods but these maxima did not reflect the actual magnitude of the community. Comparative results of species composition suggested that cell volume was a much better indicator of the community structure than chlorophyll.

CONCLUSIONS

1. Artificial substrates such as cellulose acetate should not be used for the evaluation of the structure of epiphytic communities.
2. The use of the artificial substrates in this study appeared to have the same effect as increased eutrophication: the number of predominant taxa decreased with a relative increase in the importance of a few species.
3. The relationship between epiphyte and host appeared to be more than physical as no qualitative or quantitative difference was noted between the epiphyton on the smooth and roughened acetate substrates.
4. Cell volume determination as a biomass estimation method was superior to that of chlorophyll *a* analysis but corrections must be made for the overemphasis of larger taxa in relation to numerous small ones. The additional determination of cell numbers seemed advantageous.
5. The use of a statistical basis for the evaluation of the communities by volume and numbers is necessary to maintain consistency and accuracy in seasonal measurements.
6. Species diversity was much lower than previous reports for similar communities. The epipelic communities in both lakes had the greatest species diversity.

7. Both published nutrient data and the composition of the communities examined suggest L623 to be at a more advanced trophic status than L255.
8. Physical factors such as light and temperature may have differentially affected the immediate environments of the artificial substrates and the *Typha* stands.

LITERATURE CITED

Allanson, B. 1975. The fine structure of the periphyton of *Chara* sp. and *Potamogeton natans* from Wytham Pond, Oxford, and its significance to the macrophyte-periphyton metabolic model of R.G. Wetzel and H.L. Allen. Freshwat. Biol. 3: 535-541.

Allen, H.L. 1971. Primary production, chemo-organotrophy, and nutrient interactions of epiphytic algae and bacteria on macrophytes in the littoral of a lake. Ecol. Monogr. 41: 97-127.

Barica, J. 1978. Variability in ionic composition and phytoplankton biomass in saline eutrophic prairie lakes within a small geographic area. Arch. Hydobiol. 81: 304-326.

Brettum, P. 1974. The relation between the new colonization and drift of periphytic diatoms in a small stream in Oslo, Norway. Norw. J. Bot. 21: 277-284.

Brown, D.H., C.E. Gibby and M. Hickman. 1972. Photosynthetic rhythms in epipelic algal populations. Br. phycol. J. 7: 37-44.

Brown, H.D. 1976. A comparison of the attached algal communities of a natural and artificial substrate. J. Phycol. 12: 301-306.

Castenholz, R.W. 1960. Seasonal changes in the attached algae of freshwater and saline lakes in the Lower Grand Coulee, Washington. Limnol. Oceanogr. 5: 1-28.

Cooke, W. 1956. Colonization of artificial bare areas by microorganisms. Bot. Rev. 22: 613-638.

Coveney, M.F., G. Cronberg, M. Enell, K. Larsson and L. Olofsson. 1977. Phytoplankton, zooplankton and bacteria- Standing crop and production relationships in a eutrophic lake. Oikos 29: 5-21.

Daley, R.J., C.B.J. Gray and S.R. Brown. 1973. A quantitative, semi-routine method for determining algal and sedimentary chlorophyll derivatives. J. Fish. Res. Bd. Can. 30: 345-356.

Eaton, J.W. and B. Moss. 1966. The estimation of numbers and pigment content in epipelic algal populations. Limnol. Oceanogr. 11: 584-595.

Eminson, D. 1978. A comparison of diatom epiphytes, their diversity and density, attached to *Myriophyllum spicatum* L. in Norfolk Dykes and Broads. Br. phycol. J. 13: 57-64.

Eminson, D. and G. Phillips. 1978. A laboratory experiment to examine the effects of nutrient enrichment on macrophyte and epiphyte growth. Verh. Internat. Verein. Limnol. 20: 82-87.

Evans, D. and J. Stockner. 1972. Attached algae on artificial and natural substrates in Lake Winnipeg, Manitoba. J. Fish. Res. Bd. Can. 29: 31-44.

Flint, R.W., R. Richards and C. Goldman. 1977. Adaptation of styrofoam substrates to benthic algal productivity studies in Lake Tahoe, California, Nevada. J. Phycol. 13: 407-409.

Foerster, J. and H. Schlichting. 1965. Phycoperiphyton in an oligotrophic lake. Amer. Micro. Soc. Trans. 84:485-502.

Gelin, C. 1975. Nutrients, biomass and primary productivity of nannoplankton in eutrophic Lake Vombsjon, Sweden. Oikos 26: 121-139.

Godward, M. 1937. An ecological and taxonomic investigation of the littoral algal flora of Lake Windermere. J. Ecol. 25: 496-568.

Gruendling, G.K. 1971. Ecology of the epipelic algal communities in Marion Lake, British Columbia. J. Phycol. 7: 239-249.

Haertel, L. 1976. Nutrient limitation of algal standing crops in shallow prairie lakes. Ecology 57: 664-678.

Hansmann, E.W. and H.K. Phinney. 1973. Effects of logging on periphyton in coastal streams of Oregon. Ecology 54: 194-199.

Harlin, M. 1973. Transfer of products between epiphytic marine algae and host plants. J. Phycol. 9: 243-248.

Hickman, M. 1978. Ecological studies on the epipelic algal community in five prairie-parkland lakes in central Alberta. Can. J. Bot. 56: 991-1009.

Hickman, M. 1979. Phytoplankton of shallow lakes: Seasonal succession, standing crop and the chief determinants of primary productivity 1. Cooking Lake, Alberta, Canada. Holarctic Ecology 1: 337-350.

Hickman, M. and C.G. Jenkerson. 1978. Phytoplankton primary productivity and population efficiency studies in a prairie-parkland lake near Edmonton, Alberta, Canada. Int. Revue ges. Hydobiol. 63: 1-24.

Hickman, M. and D.M. Klarer. 1973. Methods for measuring the primary productivity and standing crops of an epiphytic algal community attached to *Scirpus validus* Vahl. Int. Revue ges. Hydrobiol. 58: 893-901.

Hickman, M. and F.E. Round. 1970. Primary production and standing crops of epipsammic and epipelic algae. Br. phycol. J. 5: 247-255.

Hobro, R. and E. Willen. 1975. Phytoplankton countings and volume calculations from the Baltic - A method comparison. Vatten 31: 317-326.

Hobro, R. and E. Willen. 1977. Phytoplankton countings. Intercalibration results and recommendations for routine work. Int. Revue ges. Hydobiol. 62: 805-811.

Holm-Hansen, O., C. Lorenzen, R. Holmes and J. Strickland. 1965. Fluorometric determination of chlorophyll. J. Cons. perm. int. Explor. Mer. 30: 3-15.

Holm-Hansen, O. and B. Riemann. 1978. Chlorophyll *a* determination: Improvements in methodology. Oikos 30: 438-447.

Hooper, N.M. and G.G.C. Robinson. 1976. Primary production of epiphytic algae in a marsh pond. Can. J. Bot. 54: 2810-2815.

Hooper-Reid, N.M. and G.G.C. Robinson. 1978a. Seasonal dynamics of epiphytic algal growth in a marsh pond: productivity, standing crop and community composition. Can. J. Bot. 56: 2434-2448.

Hooper-Reid, N.M. and G.G.C. Robinson. 1978b. Seasonal dynamics of epiphytic algal growth in a marsh pond: composition, metabolism and nutrient availability. Ca. J. Bot. 56: 2441-2448.

Hunding, C. 1971. Production of benthic microalgae in the littoral zone of a eutrophic lake. Oikos 22: 389-397.

Hutchinson, G. 1967. A Treatise on Limnology Vol 3. John Wiley and Sons Inc., New York. 1115 pp.

Johnson, L. and W. Watson. 1956. The allomerization of chlorophyll. J. Chem. Soc. 1203-1212.

Jones, J.G. 1974. A method for observation and enumeration of epilithic algae directly on the surface of stones. Oecologia 16: 1-8.

Jones, R.I. 1977a. Factors controlling phytoplankton production and succession in a highly eutrophic lake (Kinnego Bay, Lough Neagh) I. The phytoplankton community and its environment. J. Ecol. 65: 547-559.

Jones,R.I. 1977b. Factors controlling phytoplankton production and succession in a highly eutrophic lake (Kinnego Bay, Lough Neagh) II. Phytoplankton production and its chief determinants. J. Ecol. 65: 561-577.

Jones, R.I. 1977c. Factors controlling phytoplankton production and succession in a highly eutrophic lake (Kinnego Bay, Lough Neagh) III. Interspecific competition in relation to irradiance and temperature. J. Ecol. 65: 579-586.

Klarer, D.M. and M. Hickman. 1975. The effect of thermal effluent upon standing crop of an epiphytic community. Int. Revue ges. Hydrobiol. 60: 17-62.

Kling, H. 1975. Phytoplankton successions and species distribution in prairie ponds of the Erickson-Elphinstone District, Southwestern Manitoba. Fish. Mar. Serv. Res. Dev. Tech. Rep. No. 512: 31 pp.

Knudson, B.M. 1957. Ecology of the epiphytic diatom *Tabellaria flocculosa* (Roth) Kutz var. *flocculosa* in three English lakes. J. Ecol. 45: 93-112.

Kowalczewski, A. and T.J. Lack. 1971. Primary production and respiration of the phytoplankton of the River Thames and Kennet at Reading. Freshwat. Biol. 1: 197-212.

Lorenzen, C.J. 1967. Determination on chlorophyll and phaeopigments: Spectrophotometric equations. Limnol. Oceanogr. 12: 343-346.

Lund, J.W.G., C. Kipling and E.D. LeCren. 1958. The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. Hydobiologia 11: 143-170.

Märker, A.F.H. 1972. The use of acetone and methanol in the estimation of chlorophyll in the prescence of pheophytin. Freshwat. Biol. 2: 361-385.

Mason, C. and R.J. Bryant. 1975. Periphyton production and grazing by chironomids in Alderfen Broad, Norfolk. Freshwat. Biol. 5: 271-277.

McLean, R.O. and K. Benson-Evans. 1974. The distribution of *Stigeoclonium tenue* Kutz in South Wales in relation to its use as an indicator of organic pollution. Br. phycol. J. 9: 83-89.

Moore, J.W. 1972. Composition and structure of algal communities in a tributary stream of Lake Ontario. Can J. Bot. 50: 1663-1674.

Moore, J.W. 1974a. The benthic algae of Southern Baffin Island I. Epipelic communities in rivers. J. Phycol. 10: 50-57.

Moore, J.W. 1974b. Benthic algae of Southern Baffin Island II. The epipelic communities in temporary ponds. J. Ecol. 62: 809-819.

Moore, J.W. 1974c. Benthic algae of Southern Baffin Island III. Epilithic and epiphytic communities . J. Phycol. 10: 456-462.

Moss, B. 1967. A spectrophotometric method for the estimation of percentage degradation of chlorophylls to phaeopigments in extracts of algae. Limnol. Oceanogr. 12: 335-340.

Moss, B. 1968. The chlorophyll *a* content of some benthic algal communities. Arch. Hydrbiol. 65: 51-62.

Olsen, F. 1950. Quantitative estimates of filamentous algae. Trans. Amer. Micros. Soc. 69: 272-279.

Paasche, E. 1960. On the relationship between primary production and standing stock of phytoplankton. J. Cons. Int. Explor. Mer. 26: 33-48.

Patrick, R. and C. Reimer. 1966. The Diatoms of the United States Vol. 1 Monograph 13. Academy of Natural Sciences of Philadelphia. 213 pp.

Patrick, R. and C. Reimer. 1975. The Diatoms of the United States Vol. 2 Monograph 13. Academy of Natural Sciences of Philadelphia. 213 pp.

Prescott, G. 1962. Algae of the Western Great Lakes Area. W.M. Brown Co. Publishers. Dubuque, Iowa. 977 pp.

Prescott, G. 1970. The Freshwater Algae. W.M. Brown Co. Publishers. 348 pp.

Rosemarin, A.S. and C. Gelin. 1978. Epilithic algal prescence and pigment composition on naturally occurring and artificial substrates in Lake Trummen and Fiolen, Sweden. Verh. Internat. Verein. Limnol. 20: 808-813.

Rosemarin, A.S. and J.S. Hart. 1978. Annual seasonal variation of phytoplankton primary productivity and biomass, correlated with physical parameters in the Ottawa River, Canada. Verh. Internat. Verein. Limnol. 20: 1299-1306.

Rott, E. 1978. Chlorophyll *a* concentration and cell volume as measures of phytoplankton biomass.(summary in English). Ber. nat. med. Ver. Innsbruck 65: 11-21.

Round, F.E. 1953. An investigation of two benthic algal communities in Malham Tarn, Yorkshire. J. Ecol. 41: 174-197.

Round, F.E. 1964. The ecology of benthic algae. In D.F. Jackson (ed.), Algae and Man. Plenum Press, New York. pp. 138-184.

Round, F.E. and J.W. Eaton. 1966. Persistent vertical-migration rhythms in benthic microflora III. The rhythm of epipelic algae in a freshwater pond. J. Ecol. 54: 609-615.

Schindler, D.W. 1969. Two useful devices for vertical plankton and water sampling. J. Fish. Res. Bd. Can. 26: 1948-1955.

Schwartzkopf, H. and G.L. Hergenrader. 1978. Comparative analysis of the relationship between phytoplankton standing crops and environmental parameters in four eutrophic prairie reservoirs. Hydrobiologia 59: 261-273.

Sestak, Z., J. Catsky and P. Jarvis.(ed. by). 1971. Plant photosynthetic production manual of methods. Dr. W. Junk publ., The Hague. pp. 672-701.

Sheldon, R.B. and C.W. Boylen. 1975. Factors affecting the contribution by epiphytic algae to the primary productivity of an oligotrophic freshwater lake. Appl. Micro. 30: 657-667.

Sherman, B. and H. Phinney. 1971. Benthic algal communities of the Metolius River. J. Phycol. 7: 269-273.

Sieburth, J., R. Brooks, R. Gessner, C. Thomas and J. Tootle. 1974. Microbial colonization of marine plant surfaces as observed by Scanning Electron Microscopy. In R. Colwell and R. Morita (ed.), Effect of Ocean environment and microbial activities. Univ. Park Press. pp. 418-432.

Siver, P. 1977. Comparison of attached diatom communities on natural and artificial substrates. J. Phycol. 13: 401-406.

Sládečková, A. 1962. Limnological investigation methods for the periphyton ("Aufwuchs") community. Bot. Rev. 28: 286-350.

Stanley, D. 1976. Productivity of epipelic algae in tundra ponds and a lake near Barrow, Alaska. Ecology 57: 1015-1024.

Stockner, J.G. and F.A.J. Armstrong. 1971. Periphyton of the Experimental Lakes Area, Northwestern Ontario. J. Fish. Res. Bd. Can. 28: 215-229.

Strickland, J.D. and T.R. Parsons. 1968. A Practical handbook of seawater analysis. Fish. Res. Bd. Can. 311 pp.

Sullivan, M.J. 1975. Diatom communities from a Delaware salt marsh. J. Phycol. 11: 384-390.

Sunde, L.A. and J. Barica. 1975. Geography and lake morphometry of the Aquaculture Study Area in the Erickson-Elphinstone District of Southwestern Manitoba. Fish. Mar. Serv. Res. Dev. Tech. Rep. No. 510: 35pp.

Tai, Y.C. and I.J. Hodgkiss. 1975. Studies on Plover Cove Reservoir, Hong Kong. Freshwat. Biol. 5: 85-103.

Tett, P., M. Kelly and G. Hornberger. 1975. A method for the spectrophotometric measurement of chlorophyll *a* and phaeophytin *a* in benthic microalgae. Limnol. Oceanogr. 20: 887-896.

Thienemann, A. 1962. Die Binnengewasser, Das Phytoplankton Des Susswassers Vol. 16, Part 2. E. Schweizerbart'sche Verlagsbuchhandlung (Erwin Nagele). 365 pp.

Tilden, J. 1910. Minnesota Algae, Vol. 1. Minneapolis, Minnesota. 328 pp.

Tippett, R. 1970. Artificial substrates as a method of studying populations of benthic micro-algae in freshwater. Br. phycol. J. 5: 187-199.

Tolstoy, A. 1979. Chlorophyll *a* in relation to phytoplankton volume in some Swedish Lakes. Arch. Hydrobiol. 85: 133-151.

United States Department of the Interior, Federal Water Pollution Control Administration. 1966. A guide to the common diatoms at water pollution surveillance system stations. U.S. Dept. of the Interior. 98 pp.

Wetzel, R.G. 1964. A comparative study of the primary productivity of higher aquatic plants, periphyton, and the phytoplankton in a large, shallow lake. Int. Revue ges. Hydrobiol. 49: 1-61.

Wetzel, R.G. 1975. Limnology. W.B. Saunders and Co., Toronto. 743 pp.

Wintermans, F. and A. DeMots. 1965. Spectrophotometric characteristics of chlorophylls *a* and *b* and their pheophytins in ethanol. Biochim. Biophys. Acta 109: 448-453.

Woerkerling, W.J. 1976. Wisconsin Desmids. I. Aufwuchs and plankton communities of selected acid bogs, alkaline bogs, and closed bogs. Hydrobiologia 48: 209-232.

Wright, T.L. and L.A. Pfiester. 1978. A comparison of algal composition and seasonal succession between farm ponds with sandstone and clay substrates. Southwestern Naturalist 23: 431-456.

Appendix 1: List of algal species encountered during the course of the study period with calculations of cell volume estimates.

Species List and calculated cell volumes resulting from the study in Lakes 255 and 623.

TAXA	CELL VOLUME ($m\mu^3$)
Anabaena circinalis Rabenhorst	192
A. spiroides Lemmerman	180
A. torulosa (Carmichael) Lagerheim	72
Aphanizomenon flos-aquae L. Ralfs (/ cell)	136
Aphanocapsa delicatissima West and West (colony)	6505
Calothrix epiphytica West and West	38
C. fusca (Kuetz) Born and Flah.	32
Chroococcus minutus (Kuetz) Naegeli	9
Lyngbya aerugineo-caerulea (Kuetz) Gomont	21
L. Diguetti Gomont	5
L. ferruginea G.S. West	3
L. Lagerheimii (Moebius) Gomont	4
L. limnetica Lemmermann	4
Merismopedia elegans v. *major* G.M. Smith	6
M. tenuissima Lemmermann	2
Microcycstis aeruginosa Kuetz emend Elenkin (/ cell)	48
Oscillatoria amphibia C.A. Agardh	19
O. angustissima West and West	1
O. limnetica Lemmermann	10
O. minnesotensis Tilden (Original)	8
O. tenuis C.A. Agardh	55
Pseudoanabaena sp.	34
Spirulina major Kuetzing	77
Ankistrodesmus convolutus Corda	94
A. falcatus (Corda) Ralfs	62
Carteria Klebsii (Dang) Dill	248
Characium Pringsheimii A. Braun	97
Chlamydomonas globosa Snow	248
Coleochaete irregularis Pringsheim	725
Oedogonium sp.	255
Oocystis solitaria Wittrock	248
Schroederia Judayi G.M. Smith	71
Scenedesmus quadricauda (Chod) G.M. Smith (/ cell)	30
Selenastrum minutum (Naeg) Collins	56
Stigeolconium nanum Kuetzing	258
Ulothrix variabilis Kuetzing	295
Chlamydomonas sphagnicola Fritsch and Takeda	1767
Euglena gracilis Klebs	736
Phacus acuminatus Stokes	432
Trachelomonas robusta Swirenko	600
T. volvocina Ehrenberg	1767
Chromulina freiburgensis	1150
C. obconica Scherff	165
C. Woroniniana Fisch	248

....continued

Botrydiopsis arrhiza Borzi (/ cell)	8
Dinobryon sociale (Imh) Bachm.	944
Ceratium hirundinella (O.F. Muell) Dujardin	111213
Cryptomonas erosa Ehrenberg	1999
Achnanthes minutissima v. *minutissima* Kütz	58
Amphora ovalis v. *affinis* (Kütz) Kütz	2338
Cocconeis placentula v. *lineata* (Ehr.)	570
Cymbella cistula v. *cistula* (Ehr.) Kirchn.	4514
Epithemia argus v. *protracta* A. Mayer	889
Epithemia turgida v. *turgida* (Ehr.) Kütz	5746
Fragilaria construens (Ehr.) Grun	275
F. crotonensis v. *crotonsis* Kitton	316
Gomphonema angustatum v. *intermedia* Grun	247
G. intricatum v. *intricatum* Kütz	981
G. olivaceum v. *olivaceum* (Lyngb.) Kütz	478
G. parvulum v. *parvulum* (Kütz)	247
G. subclavatum v. *commutatum* (Grun.) A. Mayer	204
T. truncatum v. *capitatum*	640
Navicula cuspidata v. *cuspidata* (Kütz) Kütz	22864
Nitzschia denticula	331
N. holsatica	43
Pleurosigma delicatulum v. *delicatulum* W. Smith	5309
Rhopolodia gibba v. *gibba* (Ehr.) O. Mull.	1786
Surirella ovalis	13047
Synedra ulna v. *ulna* (Nitz) Ehr.	1751

Appendix 2. Species lists for the communities encountered in the 1978 and 1979 study seasons.

Epiphytic species present on *Typha latifolia* in Lake 255.

CYANOPHYTA

Aphanizomenon flos-aquae (L.) Ralfs
Aphanocapsa delicatissima West and West
Chamaesiphon sp.
Chroococcus minutus (Kuetz) Naegeli
Gloeocapsa punctata Naegeli
Lyngbya Lagerheimii (Moebius) Gomont
L. limnetica Lemmermann
Merismopedia tenuissima Lemmermann
Oscillatoria amoena (Kuetz) Gomont
O. limnetica Lemmermann
O. minnesotensis Tilden (Original)
O. tenuis C.A. Agardh

CHLOROPHYTA

Ankistrodesmus falcatus (Corda) Ralfs
Chaetosphaeridium
Characium Pringsheimii A. Braun
Chlamydomonas epiphytica G.M. Smith
C. sp.
Oedogonium sp.
Stigeoclonium nanum Kuetzing

EUGLENOPHYTA

Ascoglena sp.
Trachelomonas charkowiensis Swirenko ex Deflandre
T. robusta Swirenko
T. volvocina Ehrenberg

PYRROPHYTA

Peridiniun inconspicuum Lemmermann

CHRYSOPHYCEAE

Botrydiopsis arrhiza Borzi
Chromulina freiburgensis Dofl.
C. obconica Scherff
C. Woroniniana Fisch
Chrysochromulina parva Lackey
Dinobryon divergens Imhof
Ophiocytium capitatum Wolle

....continued

BACILLARIOPHYCEAE

Achnanthes minutissima v. *minutissima* Kütz
Cocconeis placentula v. *lineata* (Ehr.)
Cyclotella Meneghiniana
Gomphonema angustatum v. *intermedia* (Grun.)
G. intricatum v. *intricatum* Kütz
G. olivaceum v. *olivaceum* (Lyngb.) Kütz
G. parvulum v. *parvulum* (Kütz)
G. subclavatum v. *communatatum* (Grun) A. Mayer
G. sp.
Nitzschia denticula
N. holsatica
Surirella ovalis
Synedra acus v. *acus* Kütz

Epiphytic species present on the smooth cellulose acetate substrates in L255 during the 1978 study season.

CYANOPHYTA

Aphanocapsa delicatissima West and West
Chamaesiphon sp.
Lyngbya Lagerheimii (Moebius) Gomont
Oscillatoria limnetica Lemmermann
O. minnesotensis Tilden (Original)
Pseudoanabaena sp.

CHLOROPHYTA

Chlamydomonas epiphytica G.M. Smith
C. sphagnicola Fritsch and Takeda
C. sp.
Chlorophysema sp.
Coleochaete irregularis Pringsheim
Monoraphidium sp.
Oocystis Borgei Snow
Stigeoclonium nanum Kuetzing
Tetrastrum sp.
Ulothrix variabilis Kuetzing

EUGLENOPHYTA

Ascoglena sp.
Trachelomonas robusta Swirenko
T. sp.

PYRROPHYTA

Gymnodinium sp.

CHRYSOPHYCEAE

Chysochromulina sp.
Hemidinium sp.

BACILLARIOPHYCEAE

Achnanthes minutissima v. *minutissima* (Kütz)
Cocconeis placentula v. *lineata* (Ehr.)
Cymbella sp.
Epithemia sorex v. *sorex* Kütz
Gomphonema olivaceum v. *olivaceum* (Lyngb.) Kütz
Navicula confervaceae (Kütz)
N. sp.
Nitzschia sp.
Synedra ulna v. *ulna* (Nitz.) Ehr.

Epiphytic species present on the smooth cellulose acetate substrates in L255 during the 1979 study season.

CYANOPHYTA

Aphanocapsa delicatissima West and West
Calothrix epiphytica West and West
C. fusca (Kuetz) Born. and Flah. (After Teodoresco)
Chamaesiphon sp.
Chroococcus minutus (Kuetz) Naegeli
Lyngbya Diguetii Gomont
L. Lagerheimii (Moebius) Gomont
L. limnetica Lemmermann
Merismopedia aerugineum Breb
M. elegans v. *major* G.M. Smith
M. tenuissima Lemmermann
Oscillatoria angustissima West and West
O. geminata Meneghini
O. limnetica Lemmermann
O. minnesotensis Tilden (Original)

CHLOROPHYTA

Carteria Klebsii (Dang) Dill
Characium Pringsheimii A. Braun
Chlamydomonas angulosa Dill
C. sp.
Gloeocystis gigas (Kuetz) Lagerheim
Stigeoclonium nanum Kuetzing
Ulothrix subtilissima Rabenhorst
Scenedesmus quadricauda (Chod.) G.M. Smith

EUGLENOPHYTA

Ascoglena sp.
Trachelomonas pulchella Drezepolski
T. volvocina Ehrenberg

PYRROPHYTA

Peridinium inconspicuum Lemmermann

CHRYSOPHYCEAE

Botrydiopsis arrhiza Borzi
Chromulina obconica Scherff
C. Woroniniana Fisch

...continued

BACILLARIOPHYCEAE

Achnanthes minutissima v. *minutissima* Kütz
Cocconeis placentula v. *lineata* (Ehr.)
Cymbella sp.
Gomphonema olivaceum v. *olivaceum* (Lyngb.) Kütz
G. parvulum v. *parvulum* (Kütz)
G. sp.
Nitzschia denticula
N. sp.

Epiphytic species present on the roughened cellulose acetate substrate in L255 during the 1979 study season.

CYANOPHYTA

Aphanizomenon flos-aquae (L.) Ralfs
Aphanocapsa delicatissima West and West
Calothrix epiphytica West and West
C. fusca (Kuetz) Born. and Flah. (After Teodoresco)
Chamaesiphon sp.
Chroococcus minutus (Kuetz) Naegeli
Gloeocapsa punctata Naegeli
Lyngbya aeruginosa-caerulea (Kuetz) Gomont
L. Diguetti Gomont
L. ferruginea G.S. West
L. Lagerheimii (Moebius) Gomont
L. limnetica Lemmermann
Oscillatoria limnetica Lemmermann
O. minnesotensis Tilden (Original)
Spirulina major Kuetzing

CHLOROPHYTA

Carteria Klebsii (Dang.) Dill.
Chlamydomonas epiphytica G.M. Smith
C. Snowii Printz
C. sp.
Crucigenia quadrata Morren
Oocystis solitaria Wittrock
Merotrichia sp.
Selanastrum minutum (Naeg.) Collins
Stigeoclonium nanum Kuetzing

EUGLENOPHYTA

Trachelomonas pulchella Drezepolski
T. pulcherrima Playfair
T. sp.

PYRROPHYTA

Peridinium inconspicuum Lemmermann

CHRYSOPHYCEAE

Botrydiopsis arrhiza Borzi
Chromulina mikroplankton Pasch
C. obconica Scherff
C. sp.
Chrysococcus punctiformis Pasch

....continued

BACILLARIOPHYCEAE

Achnanthes minutissima v. *minutissima* (Kütz)
Cocconeis placentual v. *lineata* (Ehr.)
Epithemia adnata v. *adnata* (Kütz) Breb
E. argus v. *protracta* A.Mayer
Gomphonema angustatum v. *intermedia* Grun
G. olivaceum v. *olivaceum* (Lyngb.) Kütz
G. parvulum v. *parvulum* (Kütz)
G. sp.
Nitzchia holsatica
Rhopolodia gibba v. *gibba* (Ehr.) O. Mull.

Epipelic species present in the upper 2 cm of the sediment in L255 during the 1979 study season.

CYANOPHYTA

Aphanizomenon flos-aquae (L.) Ralfs
Chroococcus minutus (Kuetz) Naegeli
Oscillatoria amphibia C.A. Agardh
O. limnetica Lemmermann
O. minnesotensis Tilden (Original)

CHLOROPHYTA

Ankistrodesmus falcatus (Corda) Ralfs
Characium Pringsheimii A. Braun
Chlamydomonas globosa Snow
C. sp.
Coleochaete irregularis Pringsheim
Haematococcus sp.
Oocystis Borgei Snow
O. solitaria Wittrock
Stigeoclonium nanum Kuetzing

EUGLENOPHYTA

Ascoglena sp.
Trachelomonas hispida (Perty) Stein
T. robusta Swirenko
T. scabra v.*longicollis* Playfair
T. volvocina Ehrberg

PYRROPHYTA

Peridinium inconspicuum Lemmermann

CHRYSOPHYCEAE

Botrydiopsis arrhiza Borzi
Chromulina freiburgensis Dofl.
Ochromonas (*Chlorochromonas*) *minuta* (Lewis)

BACILLARIOPHYCEAE

Achnanthes minutissima v. *minutissima* Kütz
Amphora ovalis v. *ovalis* (Kütz) Kütz
Cocconeis placentula v. *lineata* (Ehr.)
Cyclotella Meneghiniana
C. sp.
Cymbella sp.
Epithemia turgida (Ehr.) Kütz
E. sp.
Fragilaria construens (Ehr.) Grun.

....continued

F. crotensis v. *crotensis* Kitton
Gomphonema acuminatum Ehr.
G. angustatum v. *intermedia* Grun
G. intricatum v. *intricatum* Kütz
G. parvulum v. *parvulum* (Kütz)
G. truncatum v. *capitatum* (Ehr.) Patr. nom. nov.
G. sp.
Nitzschia denticula
N. holsatica
N. lacunarum
N. palea
N. sp.
Pleurosigma delicatulum v. *delicatulum* W.Sm.
Rhopolodia gibba v. *gibba* (Ehr.) O. Mull
S urirella ovalis
Synedra ulna v. *ulna* (Nitz.) Ehr.

CRYPTOPHYCEAE

Cryptomonas erosa Ehrenberg

The phytoplankton species present in the littoral zone of L255 during the 1979 study season.

CYANOPHYTA

Anabaena affinis Lemmerman
Anabaena circinalis Rabenhorst
Aphanizomenon flos-aquae (L.) Ralfs
Chroococcus minutus (Kuetz.) Naegeli
Dichothrix meneghiniana (Kuetz.) De Toni (after Wolle)
Microcystis aeruginosa Kuetz. emend Elenkin
Oscillatoria amphibia C.A. Agardh
O. minnesotensis Tilden (Original)

CHLOROPHYTA

Ankistrodesmus falcatus (Corda) Ralfs
Characium Pringsheimii A. Braun
Chlamydomonas sphagnicola Fritsch and Takeda
C. sp.
Oocystis lacustris Chodat
Scenedesmus quadricauda (Chod.) G.M. Smith
Schroederia Judayi G.M. Smith

EUGLENOPHYTA

Phacus acuminatus Stokes
Trachelomonas robusta Swirenko
T. scabra v. *longicollis* Playfair

PYRROPHYTA

Ceratium hirudinella (O.F. Muell.) Dujardin

CRYPTOPHYTA

Cryptomonas erosa Ehrenberg

CHRYSOPHYCEAE

Chromulina mikoplankton Pasch
C. *minima* Dofl.
C. *obconica* Scherff
C. *Woroniniana* Fisch
Chrysochromulina parva Lackey

BACILLARIOPHYCEAE

Amphora ovalis v. *ovalis* (Kütz) Kütz
Cocconeis placentula v. *lineata* (Ehr.)
Cymbella sp.
Eunotia sp.

.....continued

Fragilaria construens (Ehr.) Grun
F. crotensis v. *crotensis* Kitton
Gomphonema parvulum v.*parvulum* (Kütz)
Gomphonema sp.
Melosira distans
Navicula sp.
Nitzchia holsatica
N. palea
Synedra acus v. *acus* Kütz

Epiphytic species present on *Typha latifolia* in L623 during the 1979 study season.

CYANOPHYTA

Anabaena sp.
Aphanocapsa delicatissima West and West
Calothrix epiphytica West and West
Chamaesiphon sp.
Chroococcus minutus (Kuetz.) Naegeli
Lyngbya limnetica Lemmermann
Merismopedia tenuissima Lemmermann
Oscillatoria angustissima West and West
O. minnesotensis Tilden (Original)

CHLOROPHYTA

Ankistrodesmus convolutus Corda
A. falcatus (Corda) Ralfs
Carteria Klebsii (Dang) Dill
Characium Pringsheimii A. Braun
Chlamydomonas angulosa Dill
C. epiphytica G.M. Smith
C. Snowii Printz
C. sp.
Scenedesmus quadricauda (Chod.) G.M. Smith
Selenastrum minutum (Naeg.) Collins
Staurastrum sp.
Stigeoclonium nanum Kuetzing
Ulothrix variabilis Kuetzing

EUGLENOPHYTA

Ascoglena sp.

CHRYSOPHYCEAE

Botrydiopsis arrhiza Borzi
Chromulina obconica Scherff
C. Woroniniana Fisch.
Chrysococcus punctiformis Pasch.
Dinobryon sociale (Imh.) Bachm.
Synura sp.

BACILLARIOPHYCEAE

Achnanthes minutissima v. *minutissima* Kütz
Amphora ovalis v. *ovalis* (Kütz) Kütz
Cymbella sp.
Eunotia pectinatis v. *minor* (Kütz) Rabh.
Gomphonema intricatum v. *intricatum* Kutz
G. olivaceum v.*olivaceum* (Lyngb.) Kütz

...continued

Gomphonema parvulum v. *parvulum* (Kütz)
G. subclavatum v. *communatatum* (Grun.) A. Mayer
G. sp.
Nitzschia holsatica
N. palea
Surirella ovalis
Synedra acus v. *acus* Kütz
S. ulna v. *ulna* (Nitz.) Ehr.

Epiphytic species present on the smooth cellulose acetate substrates in L623 during the 1978 study season.

CYANOPHYTA

Lyngbya Lagerheimii (Moebius) Gomont
Merismopedia tenuissima Lemmermann
Oscillatoria angustissima West and West
O. limnetica Lemmermann
O. minnesotensis Tilden (Original)
O. tenuis C.A. Agardh
O. sp.
Pseudoanabaena sp.
Spirulina laxa G.M. Smith
S. major Kuetzing

CHLOROPHYTA

Ankistodesmus falcatus (Corda) Ralfs
Carteria Klebsii (Dang) Dill
Characium Pringsheimii A. Braun
Chlamydomonas epiphytica G.M. Smith
C. globosa Snow
C. polyprenoideum Prescott
C. Snowii Printz
Coleochaete irregularis Pringsheim
Mougeotia nummuloides (Hass.) DeToni
Scenedesmus quadricauda (Chod.) G.M. Smith
Sphaerocystis sp.
Stigeoclonium nanum Kuetzing

EUGLENOPHYTA

Ascoglena sp.
Trachelomonas robusta Swirenko
T. sp.

PYRROPHYTA

Peridinium sp.

CHRYSOPHYCEAE

Chrysochromulina sp.
Chrytochrysis sp.
Hemidinium sp.
Synura sp.

....continued

BACILLARIOPHYCEAE

Achnanthes minutissima v. *minutissima* (Kütz) Kütz
Cocconeis placentula v. *lineata* (Ehr.)
Cymbella affinis v. *affinis* Kütz
Navicula canalis v. *canalis* Patr.
N. cryptocephala Kütz
Synedra acus v. *acus* Kütz

Epiphytic species present on smooth cellulose acetate substrates in L623 during the 1979 study season.

CYANOPHYTA

Anabaena spiroides Lemmermann
A. *torulosa* (Carmichael) Lagerheim
Aphanocapsa delicatissima West and West
Chamaesiphon sp.
Chroococcus minutus (Kuetz) Naegeli
Lyngbya aerugineo-caerulea (Kuetz) Gomont
L. *Lagerheimii* (Moebius) Gomont
Oscillatoria angustissima West and West
O. *lacustris* (Kleb) Geitler
O. *limnetica* Lemmermann
O. *minnesotensis* Tilden (Original)
O. *tenuis* C.A. Agardh
Phormidium fragile (Menegh.) Gom. (after Gomont)
Spirulina laxa G.M. Smith

CHLOROPHYTA

Carteria Klebsii (Dang) Dill
Characium Pringsheimii A. Braun
Chlamydomonas globosa Snow
C. *Snowii* Printz
Scenedesmus quadricauda (Chod.) G.M. Smith
Selenastrum minutum (Naeg.) Collins
Stigeoclonium nanum Kuetzing
Ulothrix subtilissima Rabenhorst
U. *variabilis* Kuetzing

EUGLENOPHYTA

Ascoglena sp.
Trachelomonas granulosa Playfair
T. *pulchella* Drezepolski
T. *robusta* Swirenko
T. *volvocina* Ehrenberg

CHRYSOPHYCEAE

Botrydiosis arrhiza Borzi
Chromulina obconica Scherff
C. *parvula* Conr.
C. *pseudonebulosa* Pasch.
C. sp.
Chrysochromulina parva Lackey
Dinobryon sociale (Imh.) Bachm.
Ochromonas sociata Pasch.
Ophiocytium capitatum v. *irregulare* Heering

...continued

BACILLARIOPHYCEAE

Amphora ovalis v. *ovalis* (Kütz) Kütz
Cocconeis placentula v. *lineata* (Ehr.)
Cyclotella Meneghiniana
Cymbella cistula v. *cistula* (Ehr.) Kirchn.
C. diluviana v. *diluviana* (Krasske) Florin
Fragilaria crotonensis v. *crotonensis* Kitton
Gomphonema angustatum v. *intermedia* Grun.
G. gracile v. *gracile* Ehr. emend V.H.
G. parvulum v. *parvulum* (Kutz)
G. subclavatum v. *communatatum* (Grun) A. Mayer
G. truncatum (Ehr.)
G. sp.
Nitzschia acicularis
N. denticula
N. holsatica
N. palea
Synedra ulna v. *ulna* (Nitz) Ehr.

Epiphytic species present on the roughened cellulose acetate substrate in L623 during the 1979 study season.

CYANOPHYTA

Aphanocapsa delicatissima West and West
Calothrix epiphytica West and West
Chamaesiphon sp.
Lyngbya Lagerheimii (Moebius) Gomont
L. limnetica Lemmermann
Merismopedia tenuissima Lemmermann
Oscillatoria lacustris (Kleb.) Geitler
O. limnetica Lemmermann
O. minnesotensis Tilden (Original)
O. tenuis C.A. Agardh
Spirulina major Kuetzing

CHLOROPHYTA

Ankistrodesmus convolutus Corda
Carteria Klebsii (Dang.) Dill
Chlamydomonas epiphytica G.M. Smith
C. Snowii Printz
C. sp.
Coleochaete irregularis Pringsheim
Oocystis solitaria Wittrock
Scenedesmus quadricauda (Chod.) G.M. Smith
Stigeoclonium nanum Kuetzing
Ulothrix subtilissima Rabenhorst

EUGLENOPHYTA

Trachelomonas mammillosa Prescott
T. robusta Swirenko
T. volvocina Ehrenberg

PYRROPHYTA

Peridinium sp.

CHRYSOPHYCEAE

Chromulina obconica Scherff
C. parvula Conr.
Chrysocapsa fenestrata Pasch
Chrysochromulina parva Lackey
Chrysococcus punctiformis Pasch
Dinobryon sociale (Imh.) Bachm.
Ophiocytium sp.

...continued

BACILLARIOPHYCEAE

Cocconeis placentula v. *lineata* (Ehr.)
Cymbella cistula v. *cistula* (Ehr.) Kirchn.
C.diluviana v. *diluviana* (Krasske) Florin
C. sp.
Fragilaria crotonensis v. *crotonensis* Kitton
Gomphonema angustatum v. *intermedia* Grun.
G.gracile v. *gracile* Ehr. emend V.H.
G.parvulum v.*parvulum* (Kütz)
G. sp.
Nitzschia denticula
N.holsatica
Synedra acus v. *acus* Kütz
S. ulna v. *ulna* (Nitz) Ehr.

Epipelic algal species present in the upper 2 cm of sediment in L623 during the 1979 study season.

CYANOPHYTA

Aphanocapsa delicatissima West and West
Chamaesiphon sp.
Cyanarcus sp.
Lyngbya limnetica Lemmermann
Oscillatoria amphibia C.A. Agardh
O. lacustris (Kleb.) Geittler
O. limnetica Lemmermann
O. minnestotensis Tilden (Original)
O. tenuis C.A. Agardh
Pseudoanabaena sp.
Spirulina princeps (West and West) G.S. West

CHLOROPHYTA

Ankistrodesmus convolutus Corda
A. falcatus (Corda) Ralfs
Carteria Klebsii (Dang.) Dill
Characium Pringsheimii A. Braun
Chlamydomonas globosa Snow
C. Snowii Printz
C. sp.
Microspora tumidula Hazen
Oocystis solitaria Wittrock
Selenastrum gracile Reinsch
S. minutum (Naeg.) Collins
Scenedesmus quadricauda (Chod.) G.M. Smith
Ulothrix subtilissima Rabenhorst

EUGLENOPHYTA

Ascoglena sp.
Euglena polymorpha Dangeard
E. sp.
Trachelomonas mammillosa Prescott
T. pulcherrima v. *minor* Playfair
T. pulchella Drezepolski
T. robusta Swirenko
T. scabra v. *longicollis* Playfair
T. volvocina Ehrenberg

.....continued

CHRYSOPHYCEAE

Botrydiopsis arrhiza Borzi
Chromulina freiburgensis Dofl.
Chrysacapsis sp.
Chrysococcus punctiformis Paasch
C. rufescens Klebs
Epichrysis Melosirae K.J. Meyer
Ophiocytium capitatum v. *irregulare* Heering

BACILLARIOPHYCEAE

Acnanthes minutissima v. *minutissima* Kütz
Amphora ovalis v. *affinis* (Kütz) V.H. ex DeT.
Cocconeis placentula v. *lineata* (Ehr.)
Cyclotella Meneghiniana
Cymbella cistula v. *cistula* (Ehr.) Kirchn.
C. cymbiformis v. *nonpunctata* Font.
C. sp.
Epithemia argus v. *protracta* A. Mayer
E. turgida (Ehr.) Kütz
E. sp.
Eunotia pectinalis v. *minor* (Kütz) Rabh.
E. sp.
Fragilaria construens (Ehr.) Grun.
Gomphonema angustatum v. *intermedia* (Grun.)
G. parvulum v. *parvulum* (Kütz)
G. subclavatum v. *communatatum* (Grun.) A. Mayer
G. truncatum v. *capitatum* (Ehr.) Patr. nom nov
G. sp.
Navicula aurora v. *aurora* Sov.
N. cuspidata v. *cuspidata* (Kütz) Kütz
N. maculata (J.W. Bail)
N. sp.
Nitzschia holsatica
N. palea
Surirella angustata
Synedra rumpens Grun.
S. ulna v. *ulna* (Nitz) Ehr.

Phytoplankton species present in the littoral zone of L623 during the 1979 study season.

CYANOPHYTA

Anabeana affinis Lemmermann
A. circinalis Rabenhorst
Aphanizomenon flos-aquae (L.) Ralfs
Aphanocapsa delicatissima West and West
Chroococcus minutus (Kuetz) Naegeli
Cyanarcus hamiformis Pascher
Lyngbya limnetica Lemmermann
Merismopedia elegans v. *major* G.M. Smith
Oscillatoria limnetica Lemmermann
O. minnesotensis Tilden (Original)
O. tenuis C.A. Agardh
O. sp.
Spirulina laxa G.M. Smith
S. major Kuetzing

CHLOROPHYTA

Ankistrodesmus convolutus Corda
A. falcatus (Corda) Ralfs
Characium Pringsheimii A. Braun
Chlamydomonas sphagnicola Fritsch and Takeda
Schroederia Judayi G.M. Smith
Scenedesmus quadricauda (Chod.) G.M. Smith
Selenastrum minutum (Naeg.) Collins

EUGLENOPHYTA

Euglena gracilis Klebs
Trachelomonas scabra v. *longicollis* Playfair

PYRROPHYTA

Peridinium pusillum (Penard) Lemmermann

CRYPTOPHYTA

Cryptomonas erosa Ehrenberg

CHRYSOPHYCEAE

Botrydiopsis arrhiza Borzi
Chromulina freiburgensis Dofl.
C. obconica Scherff
Chrysococcus minutus (Fritsch) Nyg.
C. punctiformis Paasch

....continued

BACILLARIOPHYCEAE

Amphora ovalis v. *affinis* (Kütz) V.H. ex Det.
Cocconeis placentula v.*lineata* (Ehr.)
Cymbella sp.
Epithemia sp.
Gomphonema angustatum v. *intermedia* (Grun)
G. gracile v.*gracile* Ehr. emend V.H.
G. olivaceum v.*olivaceum* (Lyngb.) Kütz
G. parvulum v.*parvulum* (Kütz)
G. sp.
Navicula cuspida v.*cuspida* (Kütz) Kütz
N. elegans v.*elegans* W.Sm.
Nitzschiz denticula
N. holsatica
N. palea
Synedra acus v.*acus* Kütz
Synedra sp.