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LONG-TERM WHOLE-LAKE STUDIES AND FOOD-WEB EXPERIMENTS

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INTRODUCTION

Many lakes throughout the world have been polluted through man's activities. Especially in urbanized areas lakes have become sinks for sewage and industrial waste water. Sometimes the polluted lakes become rich in decaying and foul-smelling algae, causing great inconvenience for people in the surroundings.

Beside the surface scum of dense blue-green algae blooms and the nasty odour from decaying algae, excessive macrophyte growth and fish kills caused by oxygen deficiency are typical manifestations of eutrophication caused by pollution. Shallow and small lakes are, of course, more sensitive to an excess of nutrients and are disturbed more easily than large deep lakes.

Several lakes have become irreversibly damaged through the deposition of nutrients to the sediments. Once present, nutrients will then be released from the sediments to the water and circulate within the ecosystem year after year. If such polluted lakes with special morphologic and hydrologic characteristics should have a chance to recover, they must be appropriately treated.

Various attempts to cure damaged lakes have been performed. One of the first successful efforts to improve a polluted lake was done by Kolkwitz with Lake Lietzensee in Berlin, Germany. In this case the lake was diluted with water of good quality (Kolkwitz 1915).

However, in most cases such a dilution is insufficient and true restoration measures must be carried out in the lake itself (Björk 1966, 1968, 1978). These must result in a nutrient reduction in the lake which gives a long lasting effect, i.e. the internal loading must be minimized. To build new effective sewage treatment plants or to divert sewage water from a lake are of course necessary prerequisites, but are not always enough. Even though the external loading is reduced, the measures do not imply a reduction of the stores of nutrients in the lake ecosystem itself.

During the last decades different methods for restoration have been introduced. According to Ripl (1978) three main groups of methods can be distinguished, viz. mechanical, chemical and biological (Dunst et al. 1974).

As lake ecosystems are very different in structure and function , taylor-made restoration methods must often be designed in the individual case. It is seldom possible to get the original, e.g. oligotrophic, conditions back again, but the conditions can be greatly improved. The lakes can thus be restored to serve for recreational purposes such as swimming, boating, fishing or bird watching.

Several polluted lakes have recovered after diversion of sewage or building of efficient treatment plants. These are mostly large and deep lakes which were not irreversibly damaged. Typical examples of this kind are Lake Washington, USA (Edmondson 1979) and Lake Vättern, Sweden (Olsén & Willén 1980) . Lake Mjösa, Norway (Holtan 1979), can without doubt be saved in the same way. Lake Washington and Lake Vättern have not completely returned to their original state but they have improved considerably. In Sweden the external loading of a great number of lakes have been lowered by diversion of sewage or the construction of efficient treatment plants. The response of the ecosystem to these measures is especially well documented for Lake Norrviken by Ahlgren (1978) and studied in a long series of lakes by Forsberg (e.g. 1979) and Ryding (e.g. 1978).

The originally oligotrophic Lake Trummen, situated in the city of Växjö in central south Sweden was used as a recipient for sewage and industrial waste water during the period 1936 to 1958. It became heavily polluted and constituted a serious environmental problem for the city. Although the sewage and waste water was diverted in 1958, the lake did not recover during the following decade. Lake Trummen was apparently irreversibly damaged. At the end of the 1960s the city authorities of Växjö planned to build a university on the shore of Lake Trummen, which, therefore, had to be saved. It was then decided to restore Lake Trummen according to the principles presented by Sven Björk (1966), i.e. through suction dredging of the nutrient-rich sediments (mechanical method) deposited during the pollution period. The restoration, made in 1970-1971, resulted in a drastic decrease in phosphorus, nitrogen and phytoplankton concentrations. Afterwards there has been, year by year, a continued small nutrient reduction, but in 1975 a sudden, significant increase occurred in phosphorus and nitrogen concentrations and biomass of phytoplankton. During the spring of that year masses of small fish immigrated to the lake from the downstream situated Lake Växsjösjön. It is supposed that the fish fed on herbivorous zooplankton which resulted in reduced grazing on phytoplankton.

In summary, the diversion of sewage from Lake Trummen abolished the main part of the external, unnatural nutrient loading. The removal of the nutrient-rich sediment deposited during the pollution period normalized the internal loading and restored the lake.

During the post-restoration period it was obvious that the response of the ecosystem was a complicated interaction between nutrients, phytoplankton, zooplankton and fish. The ecosystem was further governed by climatic, physical and chemical factors.

With the initiative from Dr. Gunnar Andersson, Institute of Limnology, Lund, large-scale reduction of coarse fish (roach, bream) started 1976 in Lake Trummen. In 1975 the first food-web experiment with fish in plastic enclosures was carried out *in situ* in the lake (Andersson *et al.* 1978, Andersson 1979 a and b). The food-web experiments were performed during the summers 1975 to 1978, but the reduction of coarse fish is still going on and will not be finished before 1980.

The main purpose of the present investigation was to study changes in the phytoplankton community due to the restoration. On the basis of results from such studies more detailed predictions could be made on the development of phytoplankton concerning future lake restoration projects. The second part of this paper deals with changes in the phytoplankton community in the plastic enclosures - limnocorrals - stocked with different species of fish.

The restoration research project was carried out by scientists from the Institutes of Limnology, Microbiology, Plant Ecology and Quarternary Geology at the University of Lund in cooperation with the Växjö city authorities. The Swedish company Skånska Cementgjuteriet was responsible for suction-dredging of the sediments. The effects of restoration have been followed closely and will be under observation until 1983.

LAKE TRUMMEN

Lake Trummen ($55^{o}52'$N, $14^{o}50'$E, altitude 161 m a.s.l.) is situated in the city of Växjö in the south Swedish uplands. It is in the drainage area of River Mörrumsån (Fig 1), where the archaean bedrock consists of granites and the till is poor in lime and basic minerals. The drainage area is 13 km^2 and the lake area 1 km^2.

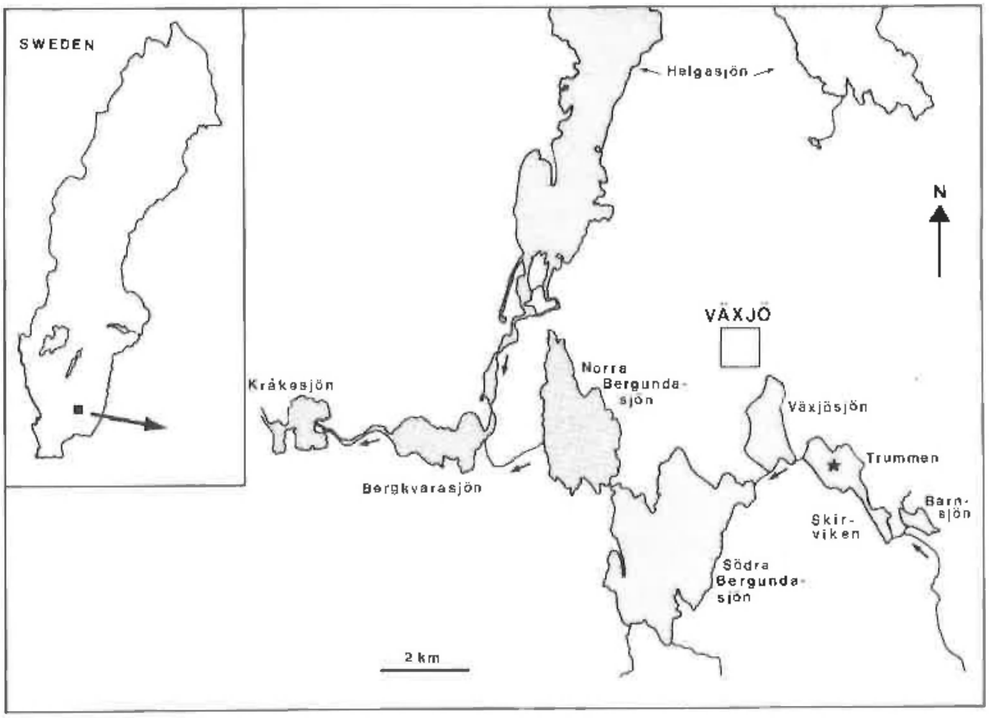


Fig 1. The investigation area.

Originally Lake Trummen was an oligotrophic lake typical for the region (Digerfeldt 1972), but during this century it received sewage from part of the city and industrial waste water from a flax factory. The worst pollution period was 1936-1958, and although the sewage and waste water was diverted from the lake in 1958, the lake did not recover.

During the 1960s Lake Trummen showed all signs of an overexploited recipient with dense water-blooms during summer, steadily expanding reeds of *Phragmites* and *Typha* and plaur formations along the shores, and sometimes fish kills occurred during the winter. There was no submerged vegetation.

According to Digerfeldt (*op. cit.*) the annual sediment growth rate in the oligotrophic Lake Trummen was 0.4 mm, but this increased during the pollution period to 8 mm. Finally, about 0.5 m FeS-coloured black, nutrient-rich sediment had been deposited on top of the brown, nutrient-poor layers.

The macrophyte vegetation was investigated by Thunmark (1945 a), Björk (1967) and Persson (1969) and showed increasing growth of reeds and plaur formations.

Lang (1928) studied rotifers in Lake Trummen (April 16, 1927) and mentioned rich development of phytoplankton. Gessner (1934) measured nitrogen and phosphorus concentrations in humic lakes in the Aneboda region and made comparisons with the Växjö lakes. He writes that the water of these lakes (September 10, 1933) "bietet ... das Bild eines dicken grünen Cyanophyceenbreies". Thunmark (1945 a and b) described dense blooms of *Anabaena* spp., *Microcystis* spp. and chlorococcal green algae in his regional investigation of Växjö lakes. The first whole-year study of Lake Trummen was performed by Björk & Digerfeldt (1965) in 1960-1961, several years after diversion of sewage from the lake, and they found the blue-green algal blooms to be even worse than described by Thunmark (*op. cit.*).

Restoration of Lake Trummen

At the end of the 1960s the city authorities of Växjö planned to build a new university on the south-west shore of Lake Trummen, and something had to be done to improve conditions in and around the lake.

Björk (1966) designed a plan to restore Lake Trummen, and an ecosystem-oriented teamwork started in 1968 as a whole-lake study of Trummen before and after restoration (cf. Björk *et al.* 1972). The following time table was applied.

1968-1969	Pre-investigation
1970-1971	Restoration
1972-1973	Post-investigation
1974-1980	Follow-up investigations and food-web experiments.

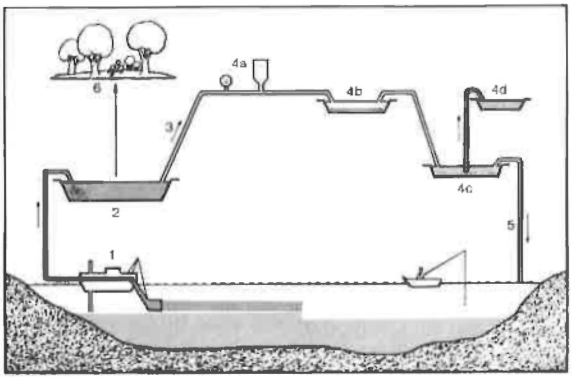


Fig 2. Lake Trummen's tailor-made treatment: (1) suction dredger designed to operate with minimal turbidity and mixing; (2) settling pond; (3) runoff water; (4) precipitation of phosphorus and suspended matter with aluminium sulphate; /(4a) automatic dosage, (4b) aeration, (4c) sedimentation, (4d) sludge pond/, and (5) clarified run-off water. (6) The dried sediment is used as fertilizer for parks and lawns. - From Björk 1973.

The pre-investigation of conditions in Lake Trummen (1968-69) included field investigations and laboratory experiments made with sediment (Bengtsson & Fleischer 1971) to test the restoration method and predict the response of the lake ecosystem to sediment removal by suction-dredging.

Restoration was carried out during the summer 1970 and 1971. About 0.5 m of FeS-enriched, black sediment was removed through suction-dredging, and the sediments were deposited in settling ponds beside the lake (Fig 2). Run-off water from the ponds was treated with aluminium sulphate in order to reduce the phosphorus concentration before it was returned to the lake.

In 1971 the shores were cleaned, and the main part of the macrophyte vegetation was taken away. Some completely overgrown bays were diked and used for sediment deposition. Skirviken, the southernmost narrow and unpolluted bay of Lake Trummen was not treated but left untouched as a bird preserve. The changes in lake morphology due to restoration are described in Table 1.

Table 1. Lake Trummen, morphometrical data. (From Andersson 1975.)

	Lake Trummen		Skirviken
Morphometrical data	Before restoration	After restoration	
Surface, km^2	0.81	0.65	0.19
Volume, Mm^3	0.89	1.14	0.12
Mean depth, m	1.10	1.75	0.62
Max. depth, m	2.1	2.5	1.3
Shoreline, km	5.3	4.4	2.2
Retention time, month	4	5	-

The Lake Trummen ecosystem changed drastically after restoration. Concentrations of phosphorus and nitrogen were reduced by 90 % and 70 %, respectively (Bengtsson *et al.* 1975). As a result of this reduction, phytoplankton biomass declined 85-90 % (Cronberg *et al.* 1975). The light climate in the lake improved (Gelin & Ripl 1978), and submerged vegetation started colonization of the lake bottom. Continued investigations show that conditions in the restored lake are still (1982) improving.

WHOLE LAKE STUDY

I. MATERIAL AND METHODS

1. Sampling

Samples for phytoplankton and chemical analyses since January 1968 were taken monthly in the middle of the lake (indicated in Fig 1) at 0.2 m depth. For quantitative phytoplankton analyses samples were taken with a Ruttner sampler and immediately fixed with Lugol's solution (T. Willén 1962). Net samples (45 µm) were fixed with formalin to 4 % solution.

2. Quantitative analyses of phytoplankton with light microscopy (LM)

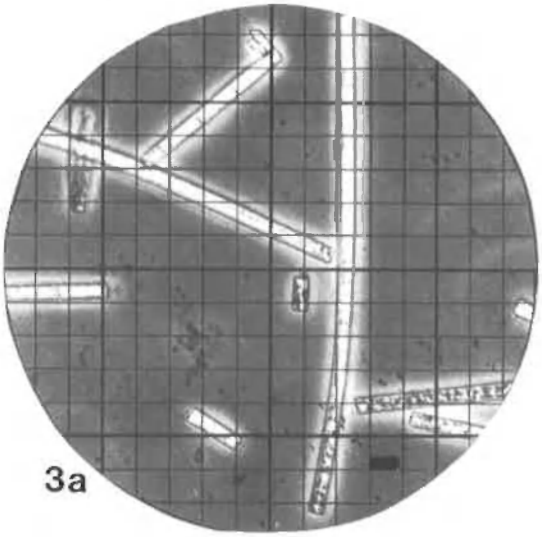
A. The Utermöhl method

Phytoplankton was counted in sedimentation chambers (0.3, 2 and 5 ml) with an inverted microscope according to Utermöhl (1958). Sedimentation time was 4 to 12 hours. Single cells were counted and all filamentous algae measured with a special graticule placed in the eyepiece with a grid covering the whole field of sight (Fig 3). Magnifications: 100, 200 and 400 x.

To get an acceptable reliability in the estimations, 60-100 cells of each species or group (e.g. cryptomonads) were counted. This gives 95 % confidence intervals of ± 26 % for 60 individuals and ± 20 % for 100 individuals (Lund *et al.* 1958, E. Willén 1976).

At least 20 cells of each species or group (e.g. cryptomonads) were measured for calculation of mean volume on every sampling occasion. Phytoplankton specific weight was taken as 1.0 for calculating fresh weight biomass. The number of species counted varied from 2 to 18 (Fig 4).

During the period 1968 to 1978 168 phytoplankton samples were



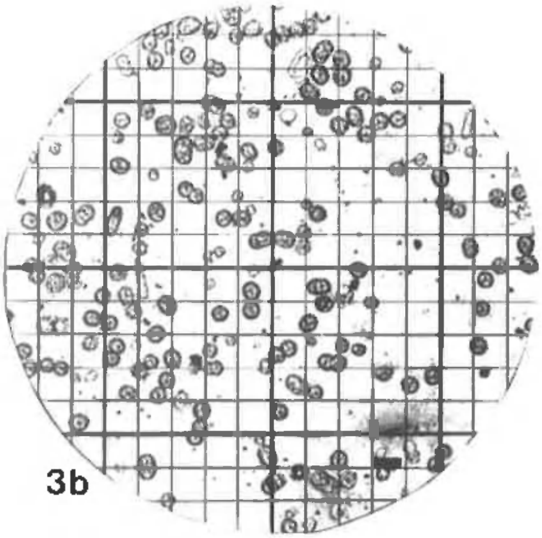


Fig. 3. a) Sonicated *Aphanizomenon flos-aquae* as seen through eyepiece with counting grid. The length of the trichome can be measured on the grid. Scale = 10 µm.

b) Sonicated *Anabaena spiroides* as seen through eyepiece with counting grid. Scale = 10 µm.

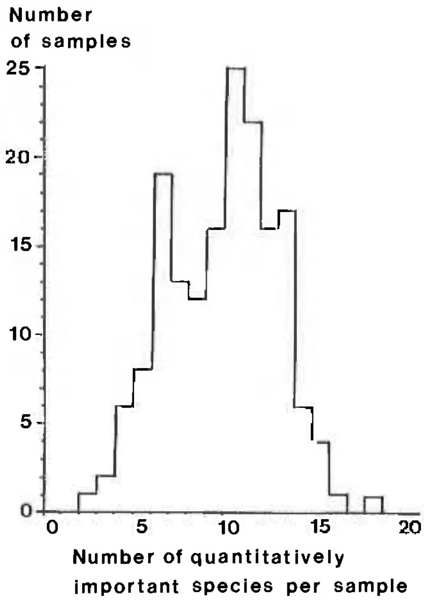


Fig. 4. Number of important species per sample in phytoplankton samples counted 1968-1978.

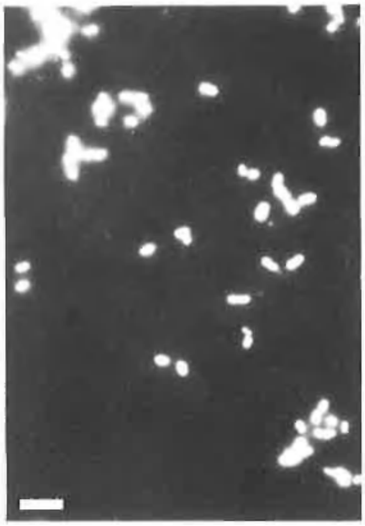


Fig. 5. Epifluorescence micrograph of *Cyanodictyon imperfectum*, acridine orange stained on Nuclepore filter. Scale = 5 µm.

collected. All samples were analysed by the author in order to exclude personal discrepancies with respect to biomass, etc.

During the summers 1968 and 1969 samples were so rich in phytoplankton that special types of chambers were required, viz. the Sedgewich Rafter Cell and the Howard Cell (from Graticules, Tonbridge, Kent, England). Heusden (1972) pointed out the usefulness of the Sedgewich Rafter Cell. These chambers have a depth of 1 mm and 0.1 mm, respectively, and can be used with a normal microscope. They have the advantage of short sedimentation time (1-5 minutes). As defined volumes can be counted, counting can be stopped when enough cells have been included. However, these chambers can be used only at low magnification (100 - 200 x). Especially blue-greens and *Melosira* spp. were counted and measured in these chambers when the algae were found in large numbers.

B. Sonication of blue-green algae

Before restoration of Lake Trummen dense blooms of *Aphanizomenon flos-aquae*, *Anabaena* spp. and *Microcystis* spp. appeared during the whole summer. Quantitative analyses were impossible using standard Utermöhl techniques. Biometric determinations of colony volume were attempted, but the results did not seem reliable.

Therefore, samples rich in blue-greens were first sonicated with a Rapidis 50 Ultrasonic Disintegrator at 20 kHz for 15-60 seconds to split the bundles of *Aphanizomenon* into filaments, *Anabaena* into small chains and *Microcystis* into cells (Fig 6 a-f). The exact time needed for sonication had to be determined, since too long treatment could destroy the cells. Newly developed colonies of *Microcystis* and bundles of *Aphanizomenon* needed longer sonication times than older, due to the fact that young colonies had more resistant mucilage.

Gas vacuoles were also disrupted by sonication, which simpli-

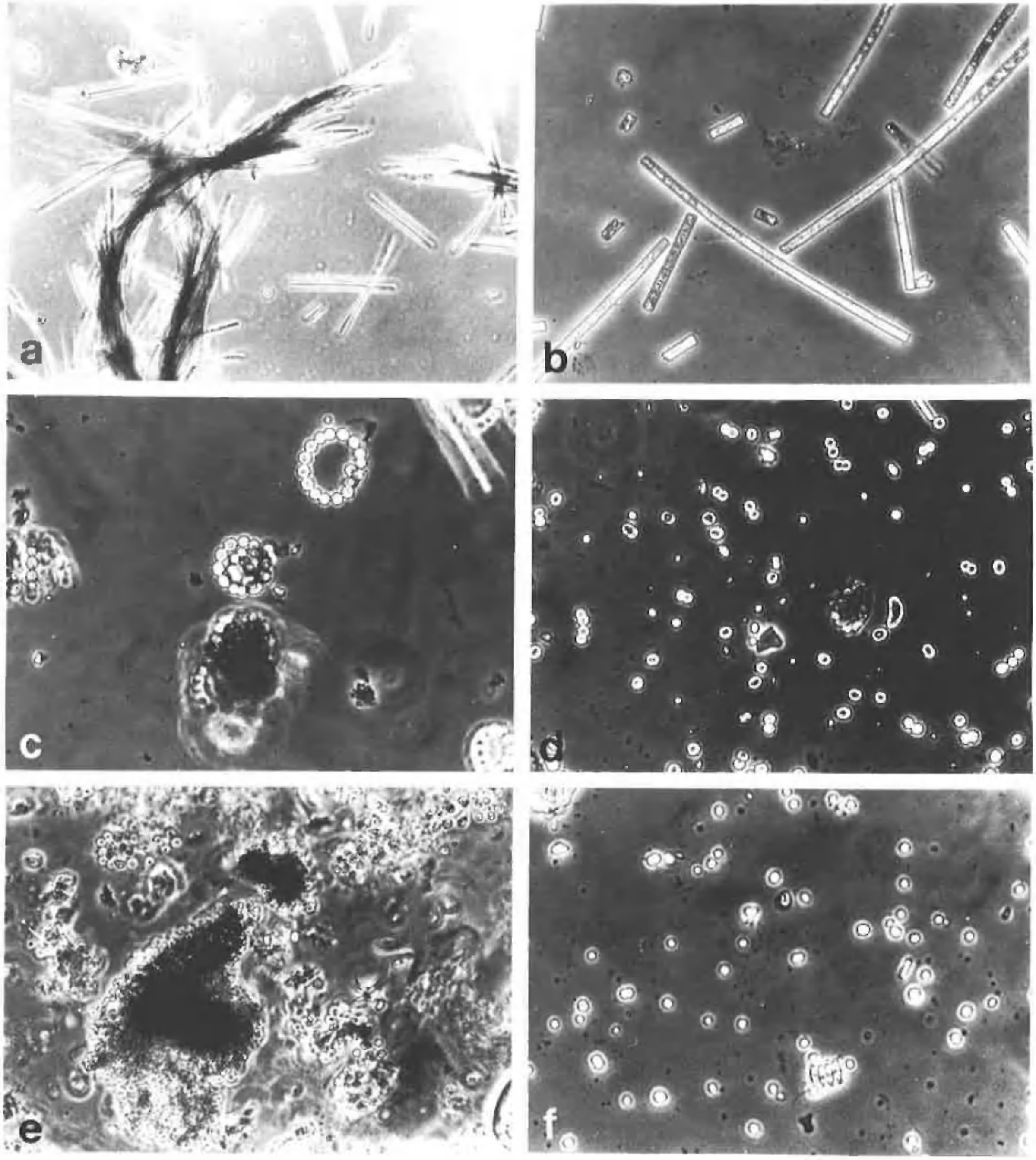


Fig 6. a) *Aphanizomenon flos-aquae* before sonication.
b) " " " after "

c) *Anabaena spiroides* f. *spiroides* before sonication.
d) " " " after "

e) *Microcystis aeruginosa* before sonication.
f) " " after "

fied sedimentation. Fig 7 shows differences in biomass calculations before and after sonication. It was clear that the biometric method resulted in much lower biomass values from bloom periods due to difficulties in estimating the thickness of the colonies.

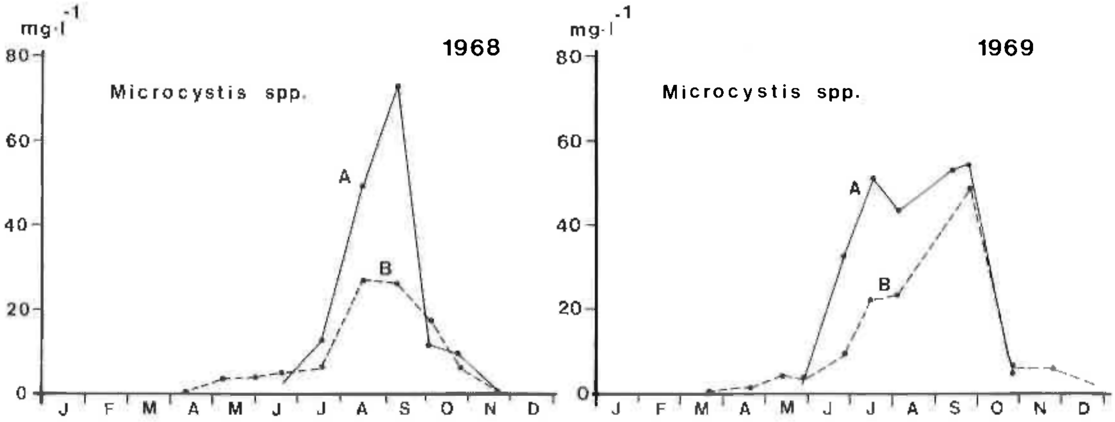


Fig 7. Biomass of *Microcystis* spp. determined with (A) and without (B) sonication. Lake Trummen 1968 and 1969.

C. The epifluorescence method (Larsson *et al*. 1977)

After restoration of Lake Trummen the *Microcystis* population diminished and was replaced by small blue-green algae, e.g. *Aphanothece clathrata* and *Cyanodictyon imperfectum*. These small blue-green algae created another problem in counting since they never settled completely in sedimentation chambers. In particular, it was necessary to change counting technique in 1975 when a bloom of *C. imperfectum* appeared. Subsamples were first sonicated about 15 seconds to disintegrate the aggregations into cells. 1-2 ml of the sonicated sample was then stained with an equal volume of 0.1 % acridine orange solution and filtered through a 0.2 µm Nuclepore filter. At least 400 cells were counted at 1250 x magnification with a Zeiss standard RA microscope equipped with epifluorescence (Fig 5). Cf. Larsson *et al*. 1978.

3. Qualitative analyses with LM

Net samples were studied primarily by LM. Drawings were made with a camera lucida, and micrographs were taken with Zeiss standard or universal microscopes. The species were identified with the help of taxonomic literature recorded in the list of references in the present paper. The taxonomic scheme follows Bourrelly (1966, 1968, 1970).

Special preparations were made when large numbers of diatoms appeared in the lake. The subsamples were then cleaned with distilled water, treated with 10 % HCl and heated gently for one hour. They were then rinsed with distilled water, heated with 30 % H_2O_2 in a water bath (1/2 - 1 hour at 60°C), and again rinsed with distilled water. A drop of the diatom suspension was placed on a coverslip, air dried for 24 hours and embedded with Clophenharz (Clophen W + Clophen A 60-5:1), which has refraction index 1.66.

The terminology proposed at the Third Symposium on Recent and Fossil Diatoms in Kiel (Anonymous 1975) has been followed. Identification of taxonomic troublesome diatoms has been discussed with Mrs. Hannelore Håkansson at the Department of Quaternary Geology, University of Lund.

4. Qualitative analyses with EM

Many groups of algae, e.g. the Synuraceae, *Scenedesmus* and many diatoms, can be identified to genus or species only with electron microscopy (EM). For investigation of species belonging to these groups both scanning electron microscopy (SEM) and transmission electron microscopy (TEM) have been applied.

A. Preparation for SEM

Fixed samples were first cleaned with distilled water. A drop of the suspension was placed on a round coverslip which was glued onto a specimen stub. After the drop had dried, the stub was coated with a layer of gold (60 %) and palladium (40 %) under vacuum. The sample was studied in a Cambridge Stereoscan II A microscope (Institute of Zoology, University of Lund) at 30 kV for optimal resolution.

Diatoms and Chrysophyceae with silica frustules or scales could be prepared in this direct way, but algae with soft cell walls (e.g. *Pediastrum* and *Scenedesmus*) were dehydrated and dried in a critical point apparatus (CPM). The samples were filtered on Nuclepore filters (0.2 µm), rinsed with distilled water, dehydrated with alcohol over to Freon and at last treated in the CPM (Polaron). The filter was glued onto the specimen stub and coated with gold and palladium as described above. CPM treatment prevented shrinkage of the soft-walled cells.

B. Preparation for TEM

a. Drop-preparation for scale and cell wall studies

Subsamples of fixed material were rinsed with distilled water, and a drop of the sample was placed on formvar-coated grids and dried. This method was used when studying the ultrastructure of scaled Chrysophyceae and the cell wall structure of *Scenedesmus* (Komárek & Ludvig 1972).

b. TEM preparation for ultrastructural studies of cell organelles

The method used follows Larsson *et al.* (1978) in essential parts. The formalin-fixed sample was washed three times by centrifugation in 0.2 M Michaelis buffer (pH 6.1) at 0-2 ^{o}C. The pellet was mixed with an equal volume of 3 % melted agar (50 ^{o}C) which was stirred carefully. The solidified agar pellet was cut into 1 mm^3 cubes and treated with osmium tetroxide and uranyl acetate, dehydrated with alcohol and embedded in Epon. Sections were cut with a LKB Ultratome III microtome. The micrographs were taken with a Philips EM 300 electron microscope at the Institute of Microbiology, University of Lund.

C. Preparation for EDS analysis

Scanning electron microscopy (Cambridge Stereoscan II A at the Institute of Zoology, University of Lund) was used in connection with an energy dispersive X-ray analyzer EDS (Kevecs X-ray analyzer) for identification of the inorganic elements precipitated in the colonies of *Cyanodictyon* (Hayat 1978).

Formalin-fixed samples were rinsed with distilled water on 0.2 µm Nuclepore filters and dehydrated with alcohol. The dried filters were glued onto specimen stubs and carbon-coated under vacuum. Several rings of inorganic material were analyzed with EDS at 20 kV and SEM micrographs taken.

5. Calculation of species diversity

For calculating species diversity, Brillouin's (1956) formula was used.

$$H = (1/N)\ \log_2 N! - \sum_{i=1}^{s} \log_2 Ni!$$

H = bits/cell, s = number of species, N = number of individuals in s species, Ni = number of individuals in the ith species.

Subsamples were settled for at least 6 hours in sedimentation chambers of the same size (4 mm deep) and counted with the Utermöhl technique (Utermöhl 1958). Samples very rich in blue-green algae were first sonicated to split colonies of *Microcystis*, etc., and then sedimented. About 1500 cells were counted on every occasion, and samples from June to October were investigated. This period was selected as the most interesting time for judging the effects of restoration.

In 1975, during the dense bloom of *Cyanodictyon*, a Bürker chamber was used instead of the ordinary sedimentation chambers where small cells never settled completely.

Diversity was calculated on a cellular basis. The diversity indices were calculated by means of a Hewlett-Packard computer (Model 9830A).

6. Appendices

In Appendix I a list of the species found 1968-1978 in Lake Trummen is given together with the authors' names. In the text, however, these names are omitted.

In Appendix II the dimensions of cells are given together with all plankton volumes used for calculating biomass. Furthermore the total biomasses per year for different species during the whole investigation period are included. All data concerning biomass are expressed in mg/l fresh weight in this publication.

Appendix III includes micrographs (LM, EM) of algal species in Lake Trummen.

II. RESULTS

1. Phytoplankton from 1943-1967

The Lund Institute of Limnology has a large collection of formalin-fixed phytoplankton samples from the beginning of this century. All samples in this planktotek from Lake Trummen have been investigated. The oldest sample is from 1943 and is well preserved. Altogether about 20 samples from 1943-1967 (May-September) have been analysed by the present author. Most of the samples were collected by Prof. Sven Thunmark and his students during summer courses in limnology. They used a coarse plankton net (mesh-size 55 µm, Müller-Gaze 25), and therefore only large algae were caught.

Old phytoplankton samples showed dense blooms of blue-green algae (Table 2). Seasonal changes in phytoplankton development were evident. At the beginning of the summer the plankton consisted of mainly *Aphanizomenon flos-aquae*, *Anabaena* spp. and chlorococcal green algae (Table 3). During this period *Golenkinia radiata*, *Micractinium pusillum* and *Scenedesmus* spp. were also frequent. Later during the summer *Microcystis aeruginosa*, *M. wesenbergii* and *M. viridis* developed and could dominate until late autumn. Other common green algae during July-September were *Pediastrum boryanum*, *P. duplex*, *Coelastrum sphaericum* and *Scenedesmus* spp. (Table 3). Only few desmids, Chrysophyceae and diatoms were found (Table 4).

It is obvious from Table 5 that blue-green algae and chlorococcal green algae were represented by most species, and that few species of the other groups were present. Probably this was due to the predominance of summer samples, especially regarding the Chrysophyceae and the diatoms which belong to the early spring flora of Lake Trummen. Only large forms of algae are present which depends on the sampling with a coarse plankton net.

From this investigation it is clear that eutrophication conditions in Lake Trummen were getting worse as a result of sewage

Table 2. LAKE TRUMMEN, PHYTOPLANKTON 1943 -1967 (JUNE - SEPTEMBER)

CYANOPHYTA	1943	1944	1946	1947	1949	1950	1952	1953	1954	1956	1957	1959	1960	1961	1962	1963	1965	1967
Anabaena lemmermannii	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+	-
A. spiroides var. crassa	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-
A. spiroides var. spiroides	-	-	-	-	-	-	+	-	+	-	-	-	-	D	-	-	+	+
A. solitaria f. smithii	-	-	+	-	-	-	+	-	+	-	-	D	-	+	D	-	+	+
Aphanizomenon flos-aquae	-	-	++	-	-	-	-	-	-	-	-	+	+	+	+	-	+	D
A. gracile	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Aphanocapsa delicatissima	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
Aphanothece clathrata	-	-	-	-	-	-	-	+	+	-	-	-	+	+	-	-	-	-
A. pulverulenta	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Chroococcus limneticus	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	+	+	-
Gomphosphaeria naegeliana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Lyngbya limnetica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Merismopedia tenuissima	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
Microcystis aeruginosa	D	++	+	++	++	++	++	++	D	D	D	++	D	D	++	++	++	++
M. incerta	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	+	-
M. viridis	++	+	-	-	++	++	-	+	-	D	-	-	-	-	-	++	++	-
M. wesenbergii	++	+	+	-	++	D	D	D	+	D	-	D	-	++	-	++	D	++
Oscillatoria agardhii	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	-	+	-
O. tenuis	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-
Pseudanabaena mucicola	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Raphidiopsis mediterranea	-	-	-	-	-	-	+	-	-	-	-	-	+	+	+	-	-	+

D = dominant ++ = common
\+ = single - = not recorded

Table 3. LAKE TRUMMEN, PHYTOPLANKTON 1943 - 1967 (JUNE - SEPTEMBER)

CHLOROPHYTA	1943	1944	1946	1947	1949	1950	1952	1953	1954	1956	1957	1959	1960	1961	1962	1963	1965	1967
Chlorococcales																		
Actinastrum hantzschii	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	-	-	-
Ankistrodesmus bribraianum	+	-	+	-	-	-	-	-	+	-	-	-	-	-		-	+	-
A. gracilis	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	-	-	-
A. nannoselene	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
Botryococcus braunii	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chodatella citriformis	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coelastrum sphaericum	+	-	+	-	-	-	-	+	++	+	-	-	++	+	+	-	+	-
Crucigeniella rectangularis	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Dictyosphaerium pulchellum	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Golenkinia radiata	-	-	-	-	++	-	+	+	+	+	+	-	++	+	-	-	-	-
Kirchneriella lunaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Micractinium pusillum	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-
Pediastrum angulosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
P. biradiatum	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
P. boryanum	+	+	-	-	+	++	-	-	-	+	+	+	+	+	+	+	+	+
P. duplex	+	-	-	+	+	-	+	-	+	-	-	-	-	+	+	+	+	-
P. gracillimum	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-
P. tetras	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scenedesmus abundans	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+
S. arcuatus	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
S. armatus	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
S. denticulatus	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
S. opoliensis	-	+	-	-	-	-	+	+	+	+	-	-	+	+	+	-	+	+
S. quadricauda	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-
Tetraedron caudatum	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-

Table 4. LAKE TRUMMEN, PHYTOPLANKTON 1943 - 1967 (JUNE - SEPTEMBER)

CHLOROPHYTA	1943	1944	1946	1947	1949	1950	1952	1953	1954	1956	1957	1959	1960	1961	1962	1963	1965	1967
Zygnematales																		
Closterium limneticum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Staurastrum paradoxum v. parvum	+	-	-	+	-	+	-	-	-	-	-	-	+	+	-	-	+	-
S. tetras	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-
S. uplandicum	+	-	-	+	-	+	+	+	+	+	-	-	-	+	+	-	-	-
CHROMOPHYTA																		
Chrysophyceae																		
Dinobryon divergens	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Synura petersenii	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Diatomophyceae																		
Asterionella formosa	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Fragilaria crotonensis	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Melosira granulata	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Melosira spp.	+	-	++	-	+	-	-	-	++	-	+	-	+	D	+	+	+	-
Stephanodiscus hantzschii	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-
Synedra acus	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
S. berolinensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Tabellaria fenestrata	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Xanthophyceae																		
Pseudostaurastrum limneticum ...	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-
EUGLENOPHYTA																		
Phacus suecicus	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Trachelomonas verrucosa	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-

discharge. In spite of the fact that sewage was diverted in 1957-1958, no improvement was observed. The heavy plankton blooms continued.

Thunmark investigated one sample from July and one from September, 1944. He found 76 species, mainly blue-green and chlorococcal green algae. From the planktotek of the Institute of Limnology I studied 20 samples from 1943 to 1967, but found only 63 species, more blue-green and fewer green algae than Thunmark (1945a). This could not be interpreted as a real change in the phytoplankton community, but might be dependent on a better preservation of blue-greens than green-algae in samples fixed with formalin.

Table 5. Number of species in the different groups of algae listed by Thunmark (1945 a) and Cronberg (present paper).

	Thunmark 2 samples 1944	Cronberg 20 samples 1943-1967	Cronberg 170 samples 1968-1978
CYANOPHYTA			
Chroococcales	11	10	22
Nostocales	6	11	14
CHLOROPHYTA			
Volvocales	-	-	17
Tetrasporales	-	-	3
Chlorococcales	39	25	75
Zygnematales	3	4	16
CHROMOPHYTA			
Chrysophyceae	2	2	50
Diatomophyceae	8	8	86
Xanthophyceae	-	1	4
EUGLENOPHYTA	6	2	21
PYRRHOPHYTA			
Dinophyceae	1	-	4
Cryptophyceae	-	-	7
RAPHIDOPHYTA	-	-	1
TOTAL	76	63	320

In my study 1968-1978 the number of species was more than Thunmark had recorded. This must to a certain degree depend on the whole-year and long-term investigation together with better sampling and microscopic technique. However, the phytoplankton community changed much in connection with the restoration. The species composition before and after restoration was quite different. When comparing my species list (Tables 2-4) from the years 1943-1967 with Thunmark's list, I found my list very meager. This indicates that the old samples were not representative anymore. It is, therefore, better to rely on the species list made by Thunmark. However, it is very difficult to interprete changes when only using the species list. This ought to be accompanied with drawings or micrographs. Thunmark published some micrographs, but very few from Lake Trummen.

Many algae have changed names since Thunmark published his book in 1945 about the polluted lakes of the Växjö region. He also used another taxonomy for *Microcystis* than we use today, but this gave no misunderstanding, since he published micrographs of the *Microcystis* community. Thunmark recorded only few small chroococcal blue-green algae, but these have increased much in Lake Trummen after restoration. They can have been lost when sampling with coarse nets in the 1940's. Most probably, however, the representation of these algae was weak in Lake Trummen at that time.

2. Phytoplankton from 1968-1978

A. General seasonal changes

During the period 1968-1978 the phytoplankton was investigated monthly both qualitatively and quantitatively. Seasonal changes were similar year to year with few exceptions. In winter very few algae were found in the lake (see page 28), mainly Chrysophyceae, Cryptophyceae and small green algae, but later in spring diatoms and/or Chrysophyceae developed, sometimes forming blooms for short periods. Blue-green algae started to develop in the beginning of June. Mostly filamentous blue-greens dominated initially, but in July-August they were succeeded by *Microcystis* spp. In autumn a new maximum of diatoms appeared, consisting of *Melosira* and/or *Synedra*. Most algae disappeared when ice cover developed. The quantitative maximum of phytoplankton was most often observed in July-September and the minimum in January-March.

B. Qualitative and quantitative changes within the taxonomic groups

In the summers 1968 and 1969, i.e. before restoration, the total biomass of phytoplankton was high (see Fig 8). However, there was a drastic decrease from the start of restoration in 1970 and onwards. A decreasing trend in phytoplankton biomass has been observed after 1970 (Fig 8), with exception for 1975.

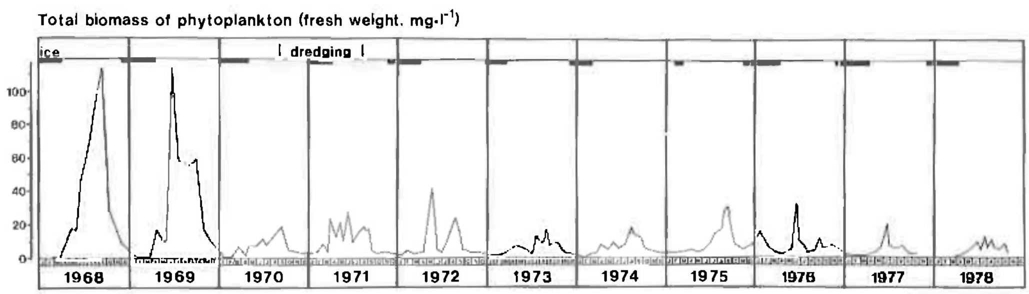


Fig 8. Total phytoplankton biomass in Lake Trummen 1968-1978.

In the following chapters the quantitative development of phytoplankton and species composition will be explained and discussed in taxonomic order.

C y a n o p h y t a (Fig 9)

Before restoration blue-green algae were most important in the Lake Trummen plankton community. Blue-greens always dominated during summer, forming very dense blooms. They caused great problems not only in the lake ecosystem (oxygen deficiency, fish kills), but also for people living in the surrounding area with nauseous smell from the lake and affluent. In 1970 the biomass was reduced to 5 % of the pre-restoration value (Fig 9). During the eleven years of investigation 36 species of blue-green algae were found. However, only 7 coccoid and 10 filamentous blue-green algae were of quantitative importance.

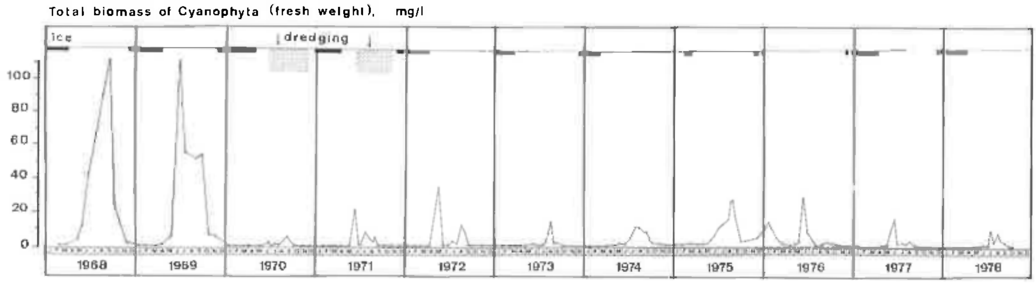


Fig 9. Blue-green algal biomass in Lake Trummen 1968-1978.

Chroococcales (Fig 10)

Microcystis

Microcystis spp. formed the heavy water-blooms in July-September 1968-1969. They did not disappear completely until the lake was ice-covered. The quantitatively most dominant species during these years in order of importance were: *M. aeruginosa*, *M. viridis* and *M. wesenbergii*. In the colonies of *Microcystis* several other algae occurred, especially *Pseudanabaena mucicola*, *Aphanothece nidulans* var. *endophytica* and small diatoms, e.g. *Nitzschia palea*. The epiphytic *Salpingoeca frequentissima* and *Chlamydomonas* spp. were quite frequent during this time.

The blue-green algae diminished, and *Microcystis* became less dominant already in summer 1970 when restoration started. The reduction started with *M. viridis*, with *M. aeruginosa* as the next species. In 1976-1978 only *M. wesenbergii* appeared in measurable amounts, and only a few colonies of the other *Microcystis* species were observed (Fig 10).

Aphanocapsa, *Aphanothece*, *Cyanodictyon*, *Synechococcus* (Fig 10)

The small coccoid blue-greens were rare before restoration, but became more important afterwards. *Aphanocapsa delicatissima* and *Aphanothece clathrata* appeared in larger quantities 1972 and have since then become progressively more common. *Synechococcus vantieghemi* was observed in large quantities 1974, but disappeared later.

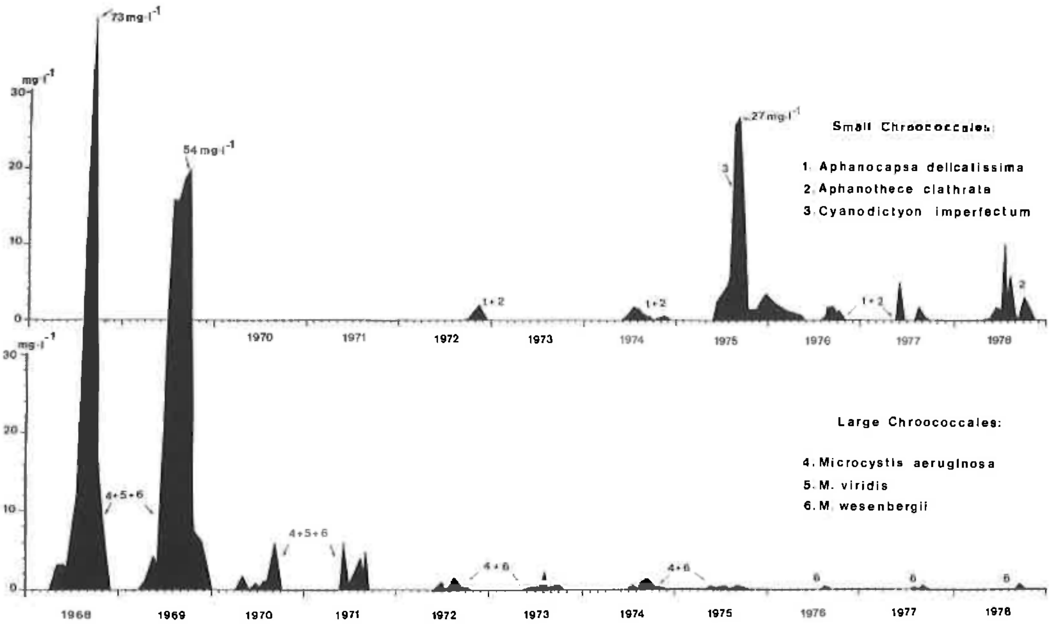


Fig 10. Biomass of small and large Chroococcales in Lake Trummen 1968-1978.

In 1975 a real waterbloom of blue-green algae occurred in Lake Trummen for the first time after restoration. The bloom lasted the whole summer and maximum was reached in the beginning of September. It was present in the lake until May 1976, but not until 1979 the alga could be identified as a new species of the genus *Cyanodictyon*.

Cyanodictyon imperfectum (Cronberg & Weibull 1980) is a small (0.4 - 1.0 µm) chroococcal blue-green alga. The spherical cells are in pairs and form loose filaments embedded in a mucilaginous sheath. The filaments can form bundles or net-like colonies. The only genus with these characteristics is *Cyanodic-*

tyon described by Pascher (1914). The alga from Trummen is included in this genus. The small size gives *Cyanodictyon imperfectum* a bacteria-like appearance. The organism grew under aerobic conditions in the lake and contained chlorophyll *a*, features which clearly characterize it as a blue-green alga. The cells have the ability to precipitate iron-oxide that forms rings between pairs of cells (Appendix III; Fig 19-22). The Fe-precipitate was analysed with EDS-analysis (p. 20).

Nostocales

Filamentous blue-green algae w i t h o u t h e t e r o - c y s t s (Fig 11, Appendix III; Fig 23-27).

In 1968 and 1969 *Oscillatoria agardhii* was most frequent during summer, but it disappeared from the lake after the restoration and has not been found since 1972. On the other hand *Oscillatoria limnetica* var. *acicularis* developed during 1976 and 1977. It was found throughout the year with a maximum in June. In May, 1972, an *Oscillatoria* sp. (ø = 1.6 μm) occurred for a brief period. It developed a large biomass, the highest recorded for any blue-green alga after restoration. Since then this *Oscillatoria* has not been found.

Lyngbya limnetica (Fig 11) appeared during the whole period of investigation. During 1970-1973 there was a quantitative reduction of *Lyngbya*, but later it increased again.

Raphidiopsis mediterranea, an interesting blue-green alga, (Fig 11) developed in July 1968-1969 and appeared in the *Microcystis* bloom. It disappeared completely after restoration (Cronberg 1973), but is common in the two lakes Växjösjön and Södra Bergundasjön, situated downstream from Lake Trummen. This alga has long thin trichomes (ø = 3 μm) and pointed ends (Appendix III; Fig 23-26). It can produce intercalary spores on the trichomes. *Raphidiopsis mediterranea* is common in tropical lakes, but perhaps this alga has been mixed up with *Cylindrospermopsis raciborskii* (Wolosz.) Seenayya and Subba Raju (= *Anabaenopsis raciborskii* Wolosz.). The generic characteristics that separates these species are the presence or abscence of heterocysts. *Cylindrospermopsis* has terminally situated heterocysts, while *Raphidiopsis* does not have any at all. In Lago Paranoá, Brasilia, *Cylindrospermopsis raciborskii* formed dense blooms. In this lake the species rarely produced heterocysts (Cronberg 1977) as the nitrogen concentration in the water was high. However, in bioassay experiments, when the heterocyst-free alga was exposed to increased phosphorus concentrations, it developed heterocysts and got the characteristics of *Cylindrospermopsis*. Now the question is, if *Raphidiopsis* is a heterocyst-free *Cylindrospermopsis*. This problem has to be solved by means of experiments.

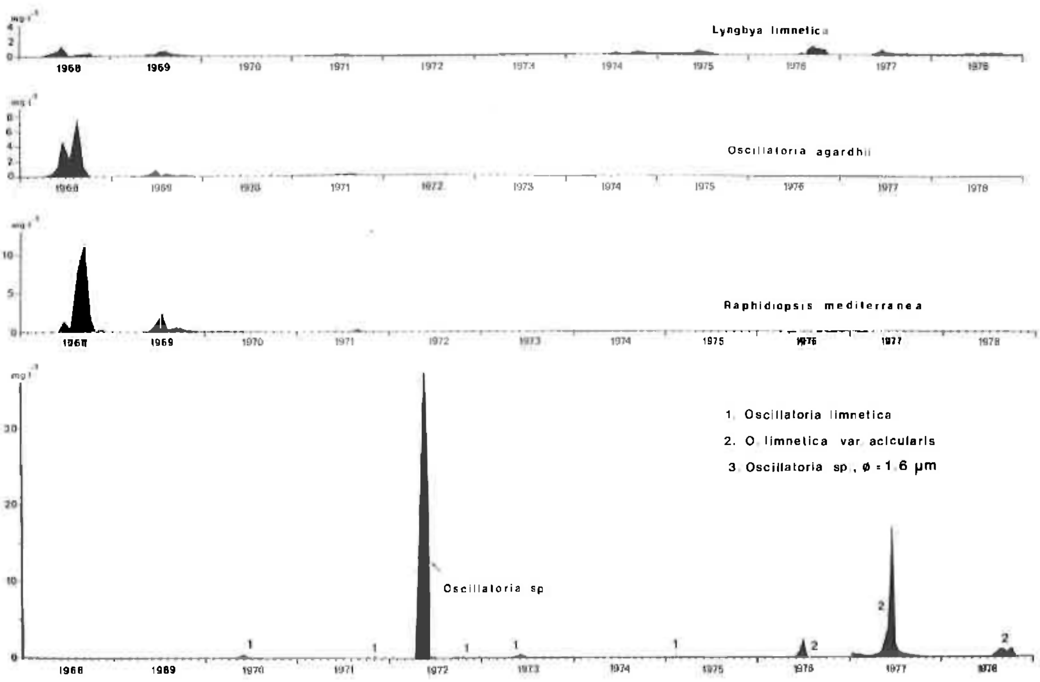


Fig 11. Biomass of blue-green algae (Nostocales) without heterocysts in Lake Trummen 1968-1978.

Filamentous blue-green algae w i t h h e t e r o c y s t s

Aphanizomenon (Fig 12)

In June 1969 *Aphanizomenon flos-aquae* developed the highest biomass maximum recorded during the whole investigation period. However, after restoration it was replaced in 1972 by *A. gracile* . Since 1972 this species has developed blooms of short duration. *A. gracile* survived in winter 1975-1976, being abundant under the ice, but it did not develop heterocysts during this period. In June, 1976, *A. gracile* reached a maximum of 30 mg/l, but the following years only small biomass values were found.

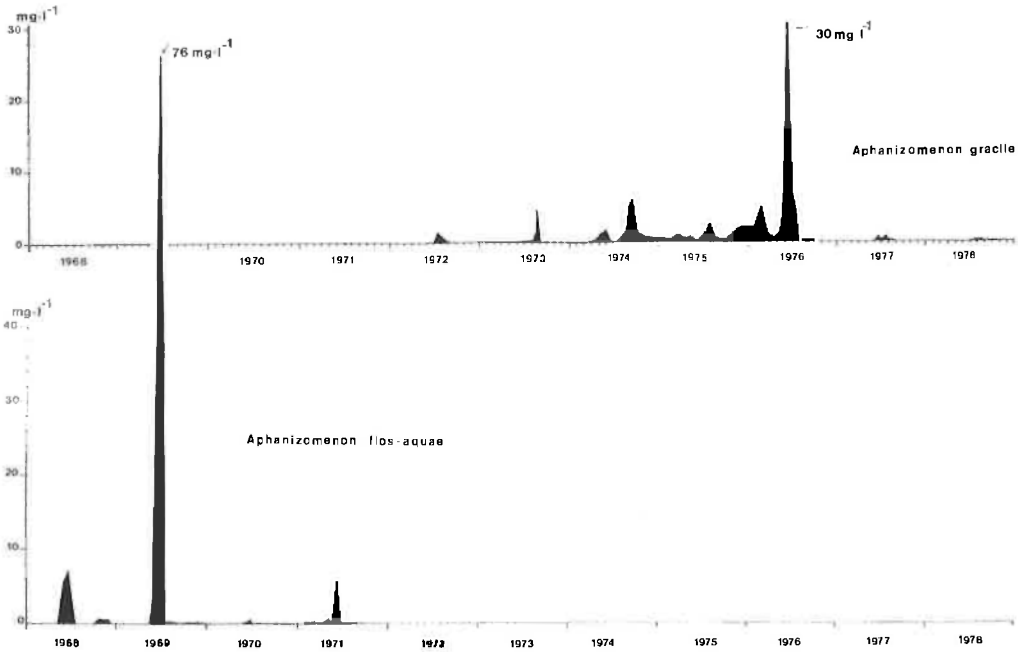


Fig 12. Biomass of *Aphanizomenon* in Lake Trummen 1968-1978.

Anabaena (Fig 13, Appendix III; Fig 28-29).

Before restoration two species of *Anabaena* were frequent, viz. *A. spiroides* and *A. solitaria* f. *smithii*. After restoration they almost disappeared. On the other hand *A. lemmermannii* started to develop during the restoration summers 1970-1971, reached high maxima 1972-1974, but diminished the following years. *Anabaena viguieri* appeared for the first time in 1972. Since then the biomass increased until 1975. The following summers occurrence was irregular. In 1976 and 1978 only a few colonies were found.

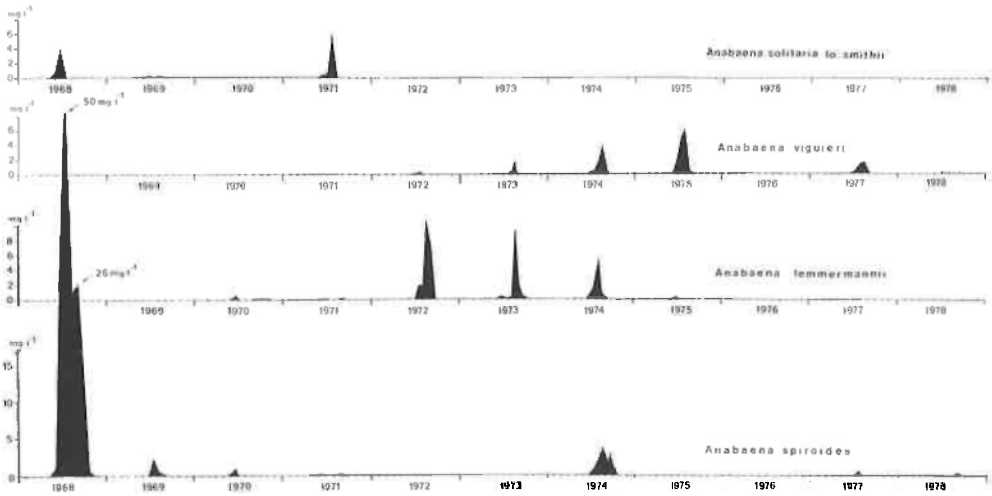


Fig 13. Biomass of *Anabaena* in Lake Trummen 1968-1978.

Summary of changes in the blue-green algal community following restoration.

Disappeared:	*Oscillatoria agardhii, Raphidiopsis mediterranea, Anabaena solitaria* f. *smithii, Aphanizomenon flos-aquae.*
Reduced biomass:	*Anabaena spiroides, Microcystis* spp.
Indifferent:	*Lyngbya limnetica, Oscillatoria limnetica.*
Increased biomass:	*Aphanizomenon gracile, Aphanocapsa delicatissima, Aphanothece clathrata, Anabaena lemmermannii, Oscillatoria limnetica* var. *acicularis.*
Species likely new to Lake Trummen:	*Synechococcus vantieghemi, Anabaena viguieri.*
Species nova:	*Cyanodictyon imperfectum.*

C h l o r o p h y t a (Fig 14)

Before restoration green algae developed large biomass maxima in spring and autumn. During the restoration, especially in 1971, the biomass of green algae increased, and the maximum occurred during summer. Many different species were present at that time, each with relatively high biomass during a short period (Fig 14). However, after 1972 green algae diminished in number. The seasonal pattern from the years before restoration reappeared with spring and autumn maxima in e.g. 1977.

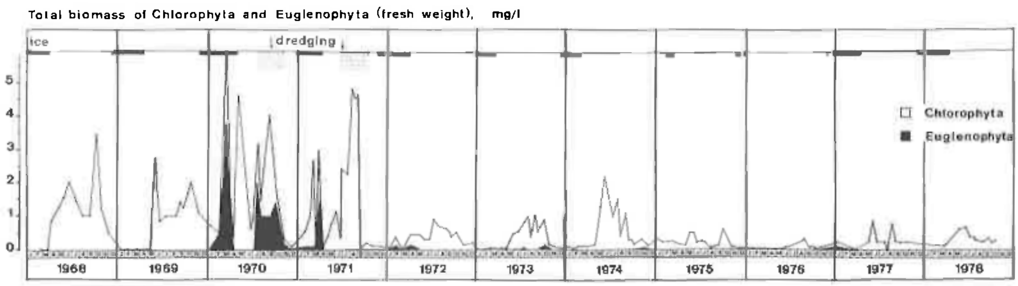


Fig 14. Biomass of green algae and Euglenophyta in Lake Trummen 1968-1978.

More than 100 species of green algae (Appendix I, Tables 2-4) were identified in Lake Trummen 1968-1978, while 17 species appeared in measurable amounts (Fig 15-18). The most important genera were *Scenedesmus* and *Pediastrum*, which appeared in the lake every year (Fig 15-16), and occasionally developed a large biomass.

Volvocales (Fig 15)

Volvocales were represented by 17 species. Only *Chlamydomonas* spp. and *Chlorogonium maximum* appeared in measurable amounts. They were most frequent before and during restoration and diminished thereafter. *Chlamydomonas* and especially *Chlorogonium maximum* belonged to the vernal flora.

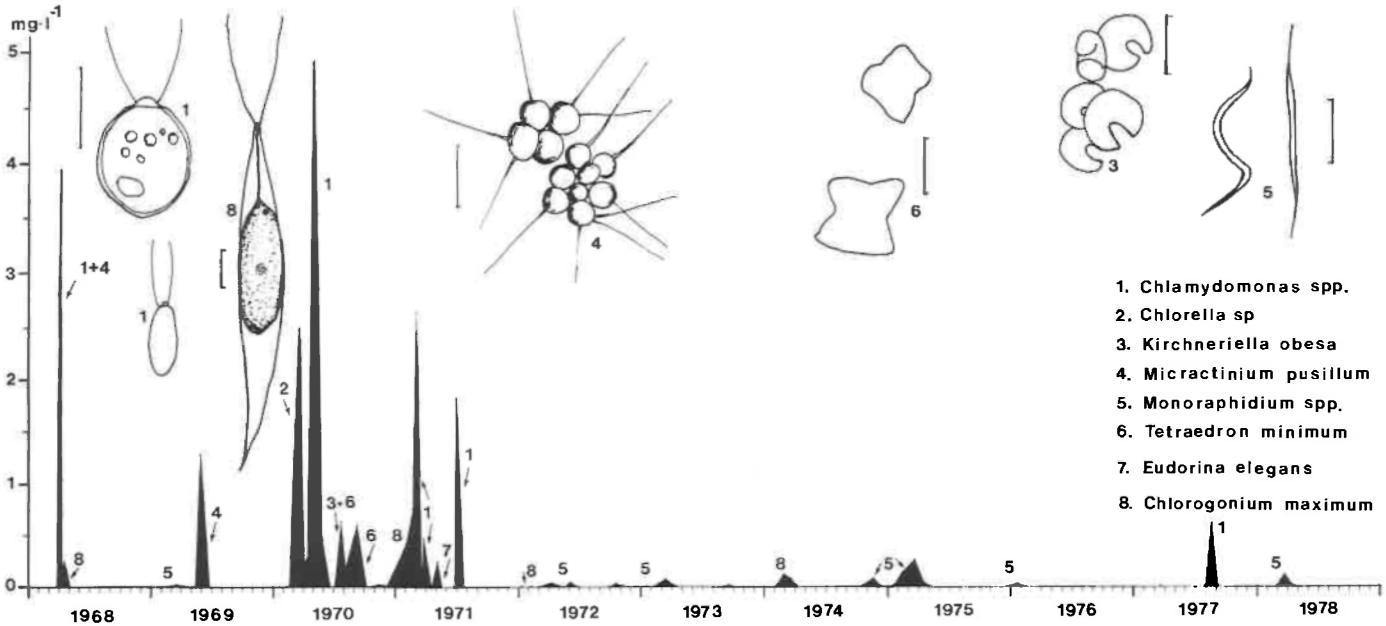


Fig 15. Biomass of Volvocales and some Chlorococcales in Lake Trummen 1968-1978 and the different species observed. Scale = 10 μm.

Tetrasporales

During the whole investigation period species belonging to Tetrasporales were rare in Lake Trummen. Only three species were identified. *Chlamydocapsa* appeared on several occasions before and after restoration (Appendix I).

Chlorococcales (Fig 16-17)

In Lake Trummen 75 species belonging to Chlorococcales were identified, but few occurred in greater amounts. Many species were found only occasionally (Appendix I).

Pediastrum (Fig 16)

Species of *Pediastrum* were common during the whole investigation period. Before and after restoration they were most frequent in spring and autumn, but during the restoration period they dominated in summer.

Pediastrum boryanum was the dominant *Pediastrum* species before restoration, but its biomass decreased thereafter. *P. duplex* and *P. gracillimum* appeared in great numbers during the restoration period. The highest maximum recorded (4.4 mg/l) was in August, 1971, when most of the macrophyte vegetation was removed from the littoral zone. In 1972-1975 *P. biradiatum* was frequent, and during the last few years *P. angulosum* and *P. tetras* increased in number.

Thunmark (1945 a) described *Pediastrum limneticum* and *P. gracillimum* as new species from Lake Trummen. These have now been included in *P. duplex* var. *duplex* (Parra Barrientos 1979), but I still use the name *P. gracillimum* in my algal list. However, it probably belongs to *P. duplex* var. *duplex*, too. In the new revision of *Pediastrum* there are, unfortunately, no SEM-micrographs of *P. gracillimum* that could be compared with mine (Appendix III; Fig 39).

Many forms of *P. boryanum* and *P. duplex* were recorded (Appendix III, Fig 30-40).

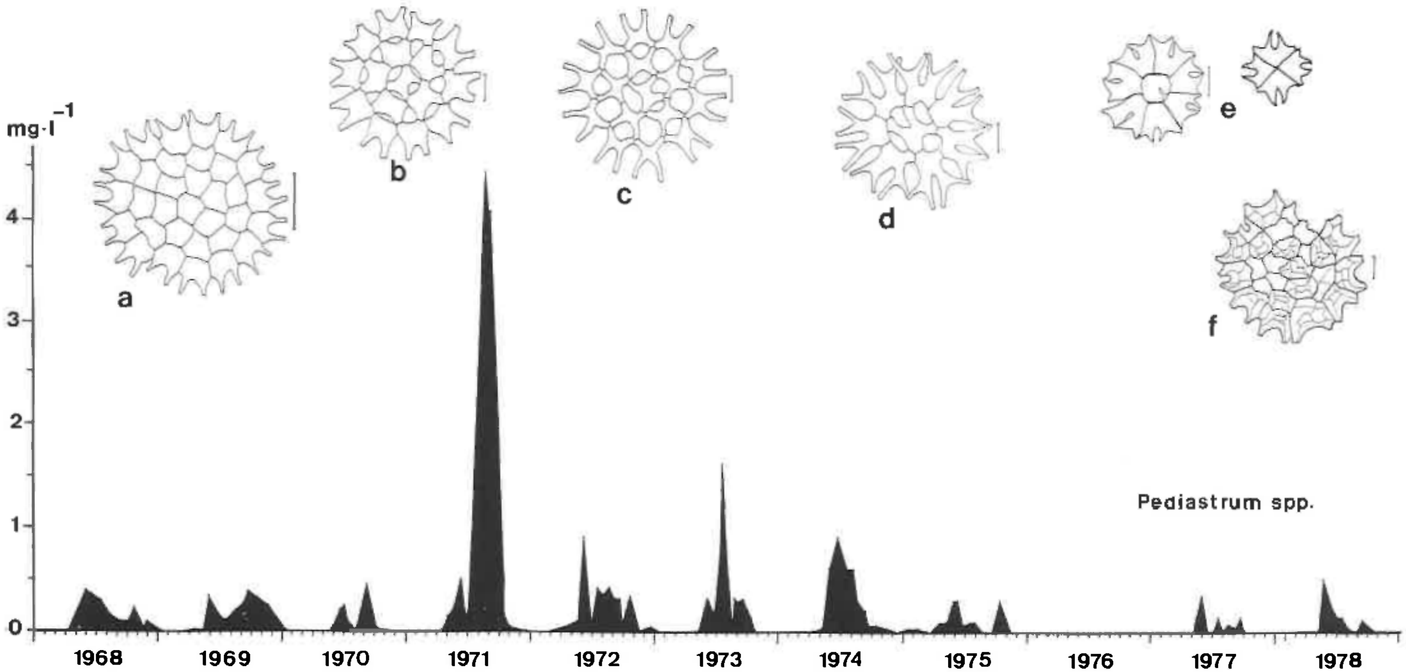


Fig 16. Biomass of *Pediastrum* and the different species observed in Lake Trummen, 1968-1978. Scale = 10 µm.

a) *P. boryanum*
b) *P. duplex*
c) *P. gracillimum*
d) *P. biradiatum*
e) *P. tetras*
f) *P. angulosum*

Scenedesmus (Fig 17)

After restoration the biomass of *Scenedesmus* decreased, and the species composition changed. During the whole observation period the genus was represented with 21 species. Some of them were identied with EM (Appendix III, Fig 42-52 and 54-57).

Before restoration the most common species were: *S. abundans*, *S. acuminatus*, *S. arcuatus*, *S. armatus*, *S. oahuensis*, and *S. quadricauda*. After restoration they all decreased. It is, however, interesting that during the course of restoration the number of large *Scenedesmus* species decreased while the number of small species, such as *S. subspicatus*, increased. After restoration the size of *Scenedesmus* cells also decreased.

Since this investigation started a new method for identification of *Scenedesmus* species has been developed. Komárek & Ludvik (1972) devised a new system for identification, where LM and TEM studies were combined with culture technique. For further taxonomic studies culturing is necessary. The ultrastructure of the cell wall is of the greatest importance for taxonomic determinations.

When I started the investigation, I used traditional LM studies, but later I tried to combine this with EM studies. However, it was not possible to work through the old material again, so only some species have been identified with EM.

The genus *Scenedesmus* consists of more than 200 species and 1000 varieties and forms (Hegewald 1979 b). Only few of these taxonomical units have been revised with EM. Problems arose during the identification of the species from Lake Trummen as no EM-micrographs had been published, which were identical with those obtained from that lake, e.g. *S. lefevrii*, *S. arvernensis* (Appendix III; Fig 43, 54). Probably many more species were represented in Lake Trummen than recorded here (Ap-

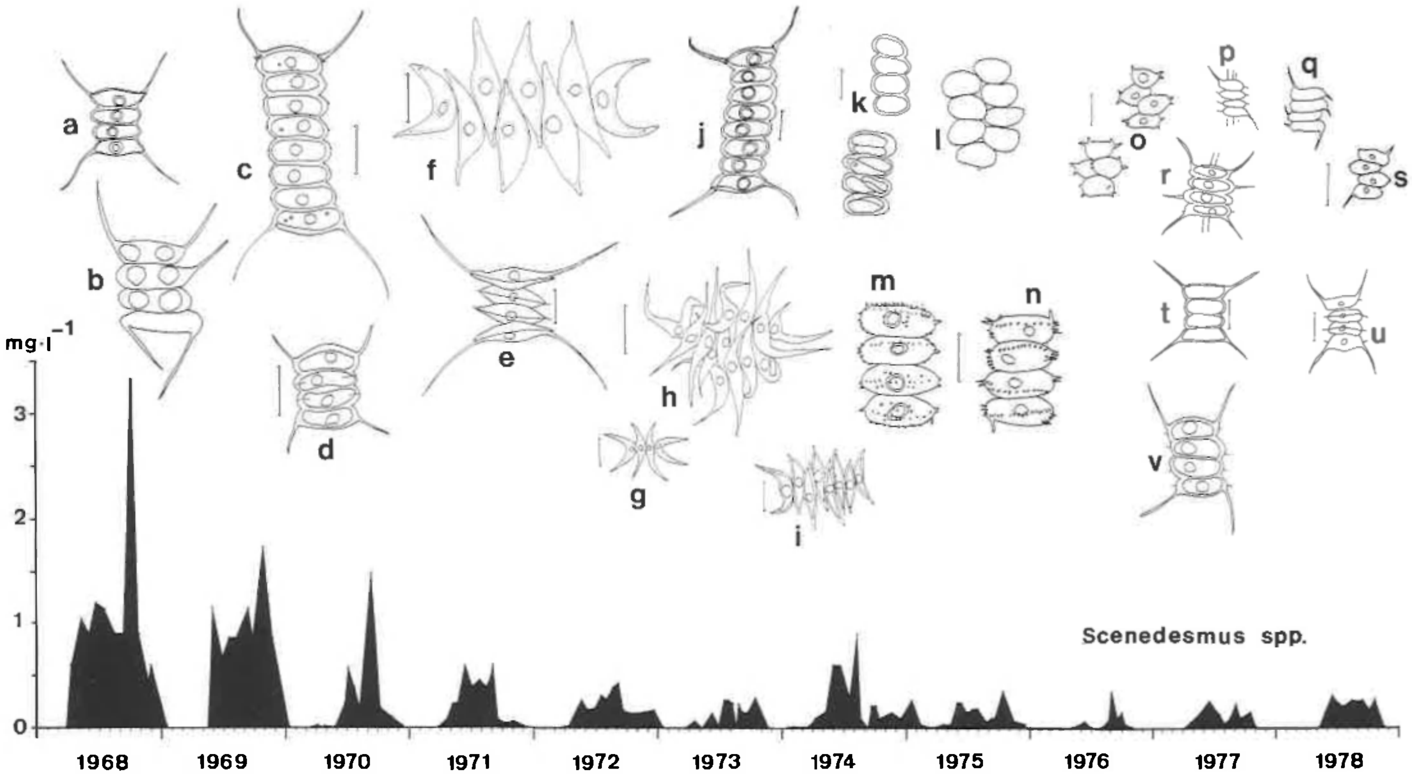


Fig 17. Biomass of *Scenedesmus* and the different species observed in Lake Trummen, 1968-1978. Scale = 10 µm.

a) *S. opoliensis*
b) *S. oahuensis*
c) " "
d) *S. armatus*
e) *S. carinatus*
f-i) *S. acuminatus*
j) *S. quadricauda*
k) *S. ecornis*
l) *S. arcuatus*
m) *S. arvernensis*
n) *S. lefevrii*
o) *S. denticulatus*
p) *S. subspicatus*
q) *S. pannonicus*
r) *S. abundans*
s) *S. intermedius* var. *bicaudatus*
t) *S. quadricauda*
u) *S. armatus*
v) *S. quadricauda* var. *quadrispina*

pendix I, Table 2-3). After restoration the large species were replaced by small ones impossible to identify with LM. It was impossible to separate the species *S. abundans*, *S. spinosus* and *S. subspicatus*, which therefore from the beginning were all called *S. abundans*. By means of EM it was later on possible to identify *S. subspicatus* and *S. abundans*, but I did not find any *S. spinosus*.

Other frequent Chlorococcales (Fig 15, 18-20)

Before restoration *Micractinium pusillum* and *Chlorella* sp. formed blooms in Lake Trummen just after ice break-up. After restoration they were not found in measurable amounts.

During the whole investigation period *Monoraphidium* spp. appeared annually in winter and early spring, but always in small quantities. *Eudorina elegans*, *Kirchneriella obesa* and *Tetraedron minimum* formed short blooms only during the restoration period. They appeared, however, in small numbers during the summer in all years 1968-1978.

Zygnematales (Desmids) (Fig 21)

After restoration the desmids increased both qualitatively and quantitatively. Sixteen species were identified but only six were quantitatively important. They all appeared during summer.

Staurastrum was the dominant genus. *S. paradoxum* var. *parvum*, *S. uplandicum* and *S. tetras* were frequent and occurred in small numbers now and then during the whole investigation period. *S. pseudopelagicum* was found in Lake Trummen several times 1974-1975.

After restoration *Closterium limneticum*, *C. acutum* var. *variabile*, *Staurodesmus* spp. and *Teilingia granulata* appeared, sometimes in measurable amounts.

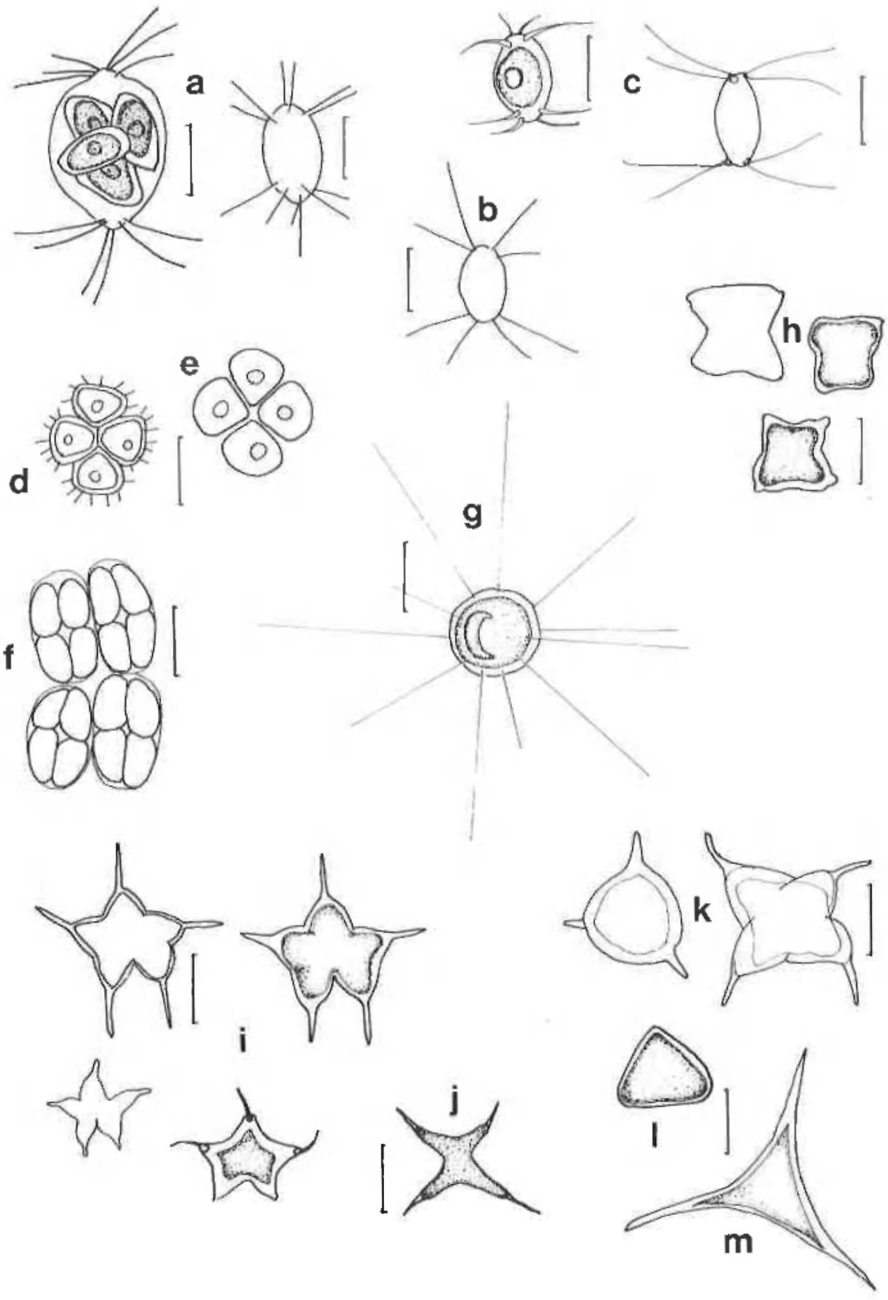


Fig 18. a) *Chodatella citriformis*
b) C. *subsala*
c) C. *griffitsii*
d) *Tetrastrum staurogeniaeforme*
e) *Crucigenia quadrata*
f) *Crucigeniella rectangularis*
g) *Golenkinia radiata*
h) *Tetraedron minimum*
i) *T. caudatum*
j) *T. arthrodesmiforme*
k) *T. incus*
l) *T. trigonum*
m) *T. trigonum* var. *gracile*

Scale = 10 µm

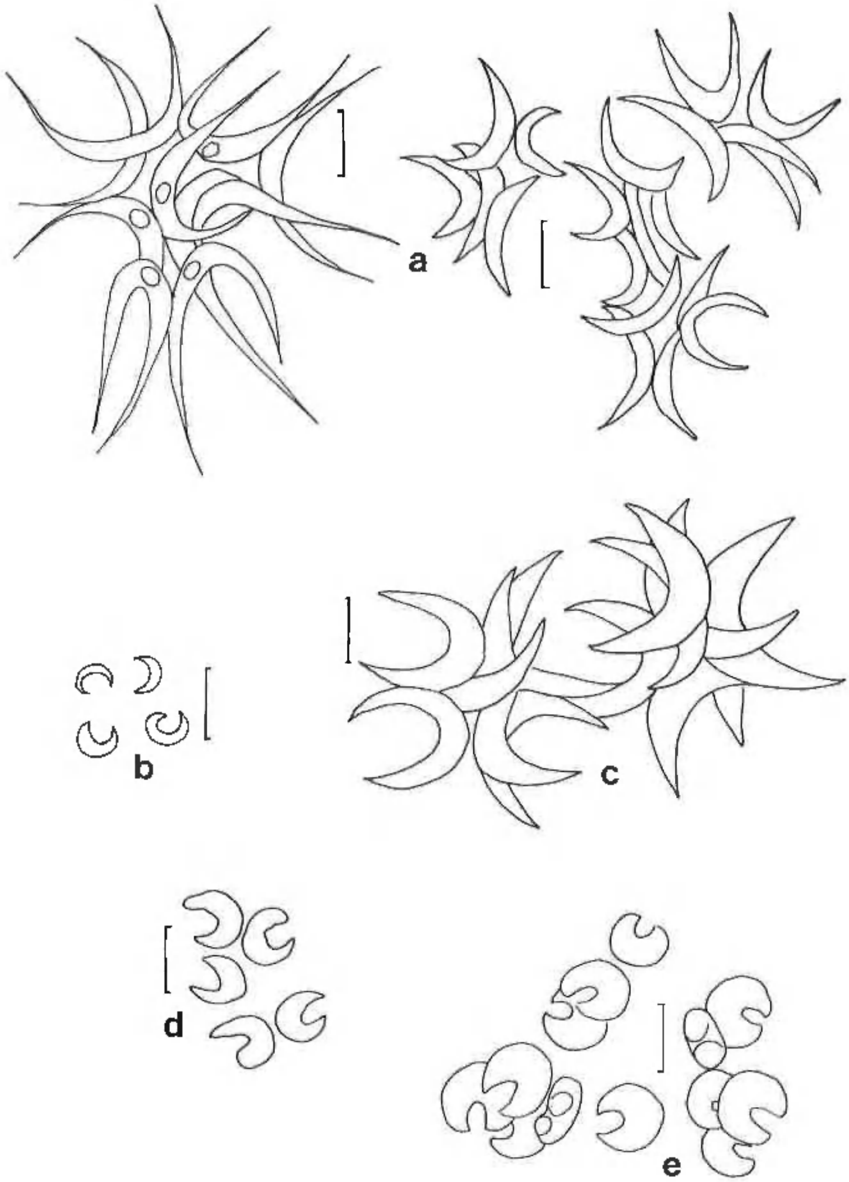


Fig 19. a) *Ankistrodesmus gracilis*
b) A. *nannoselene*
c) A. *bibraianus*
d) *Kirchneriella lunaris*
e) K. *obesa*

Scale = 10 μm

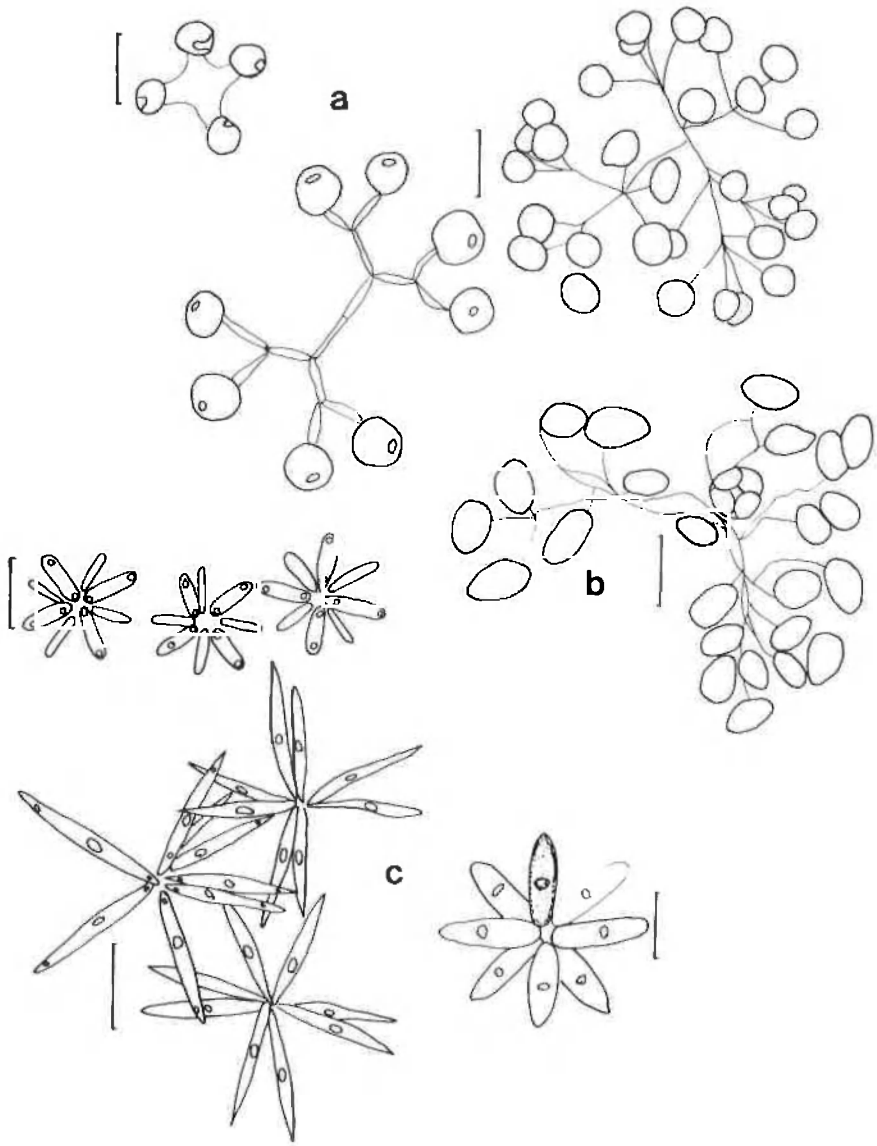


Fig 20. a) *Dictyosphaerium pulchellum*
b) *D. ehrenbergianum*
c) *Actinastrum hantzschii*

Scale = 10 µm

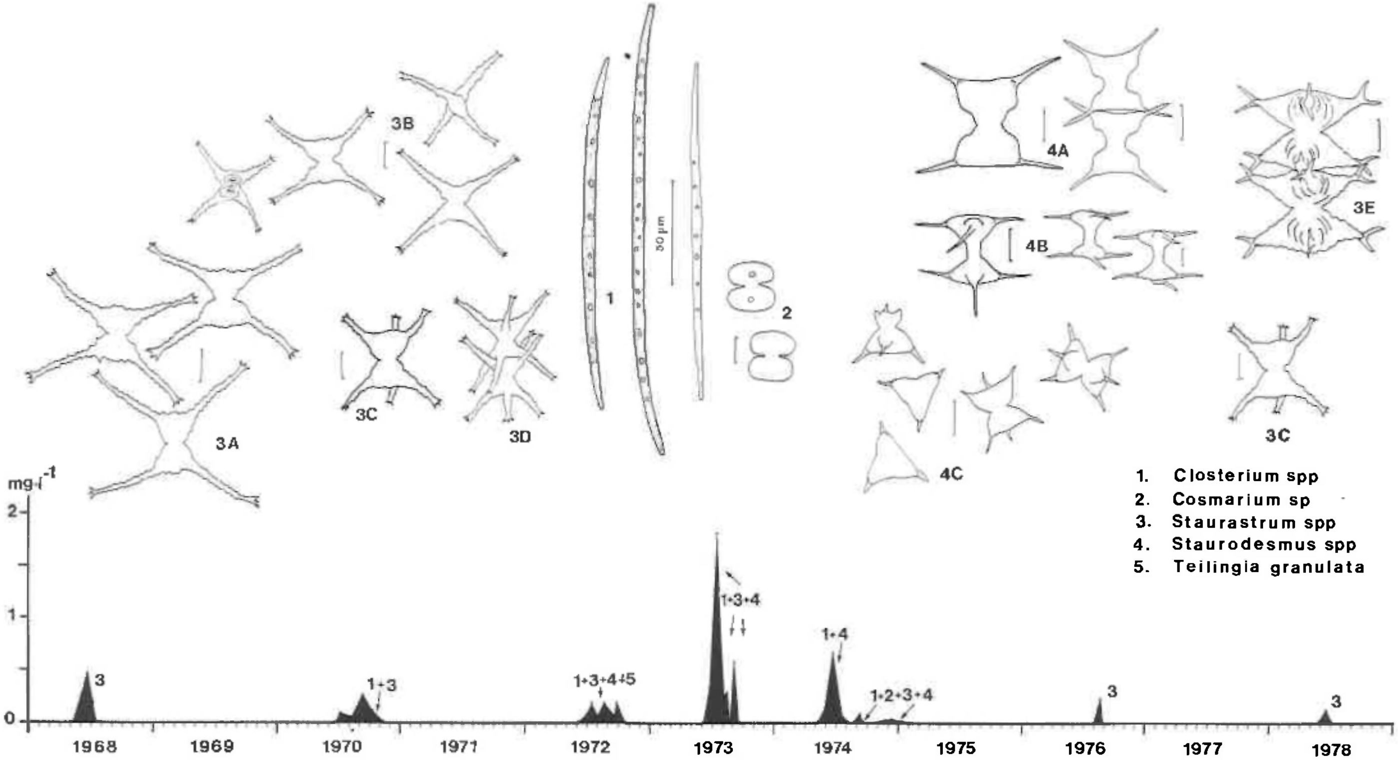


Fig 21. Biomass of Zygnematales and the different species observed in Lake Trummen, 1968-1978.
Scale = 10 µm

1) *Closterium limneticum*
2) *Cosmarium tenue*
3A) *Staurastrum uplandicum*
3B) *S. tetracerum*
3C) *S. polymorphum* var. *divergens*
3D) *S. paradoxum* var. *parvum*
3E) *S. pseudopelagicum*
4A) *Staurodesmus extensus*
4B) *S. mammilatus*
4C) *S. patens*

Summary of changes in green algal community after restoration.

Reduced biomass:	*Pediastrum boryanum*, *Scenedesmus* spp., *Chlamydomonas* spp. *Micractinium pusillum*, *Chlorella* sp.
Indifferent:	Many chlorococcal green algae.
Increased biomass:	*Pediastrum biradiatum*, *P. angulosum*, *Staurodesmus* spp. *Closterium* spp.
Species likely new to Lake Trummen:	*Teilingia granulata*, *Staurastrum pseudo-pelagicum*.

E u g l e n o p h y t a (Fig 14)

Before restoration the euglenoids were rare. They increased drastically during the restoration period and decreased again thereafter. Altogether 19 species were identified. *Trachelomonas volvocina*, *T. verrucosa*, *T. hispida* and *Euglena acus* were most common (Appendix III, Fig 167-172) and formed blooms. The genus *Phacus* was represented by several species, but usually at low density (Appendix I). In February 1972, however, *Phacus similis* (Fig 22) appeared in great amounts under the ice.

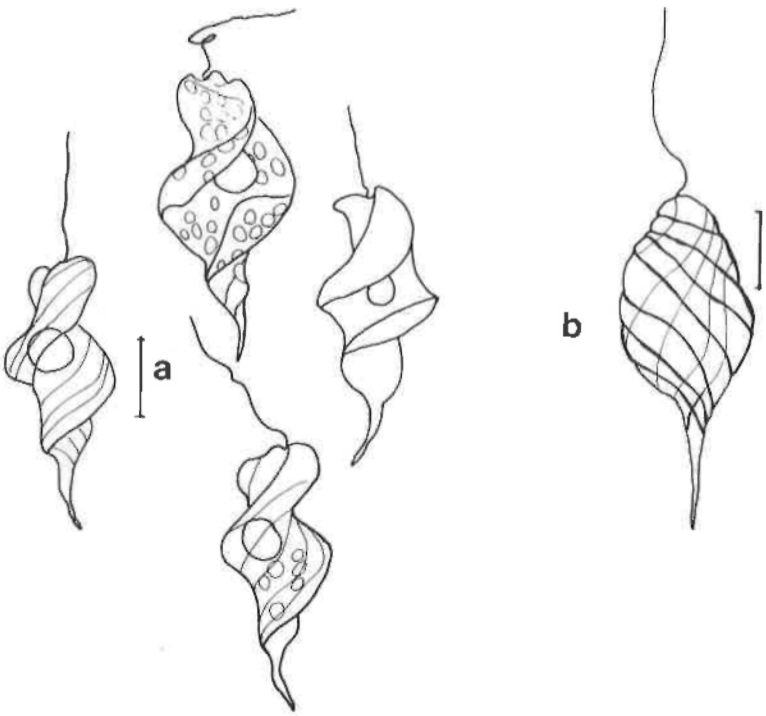


Fig 22. a) *Phacus similis*, b) *P. pyrum*.
Scale = 10 μm

C h r o m o p h y t a

Chrysophyceae (Fig 23, Table 6)

Before restoration few species belonging to Chrysophyceae occurred at low density in Lake Trummen. After restoration they increased both quantitatively and qualitatively.

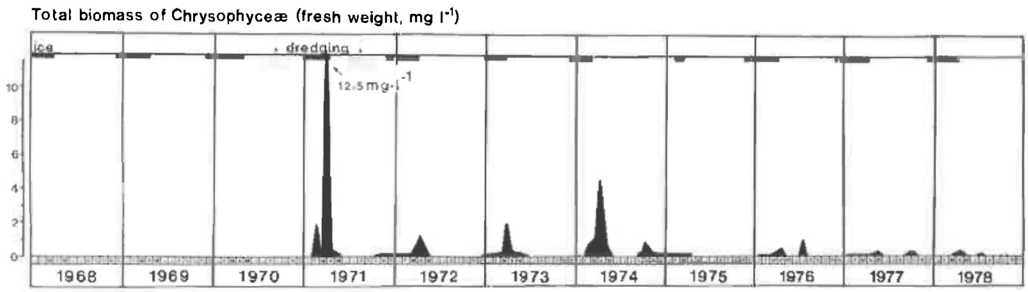


Fig 23. Biomass of Chrysophyceae in Lake Trummen 1968-1978.

The most dominant genera were *Dinobryon*, *Mallomonas* and *Synura*. As a rule *Synura* and *Mallomonas* did not appear in quantity at the same time but alternated (Fig 24-25). However, in spring, 1971, blooms of *Mallomonas* and *Synura* appeared simultaneously just before ice-break, when the highest biomass of Chrysophyceae (12.5 mg/l) was recorded for the whole investigation period. After 1971 Chrysophyceae regularly developed a spring bloom, but the biomass diminished each year (Fig 23). Before restoration eleven species were observed, but from 1971 onwards, the number of species increased to 50.

Table 6. Number of species in different orders of Chrysophyceae.

Taxonomic group	Number of species
Chrysophyceae	
Rhizochrysidales	3
Chromulinales	6
Ochromonadales	35
Prymnésiales	1
Monosigales	4
Isochrysidales	1

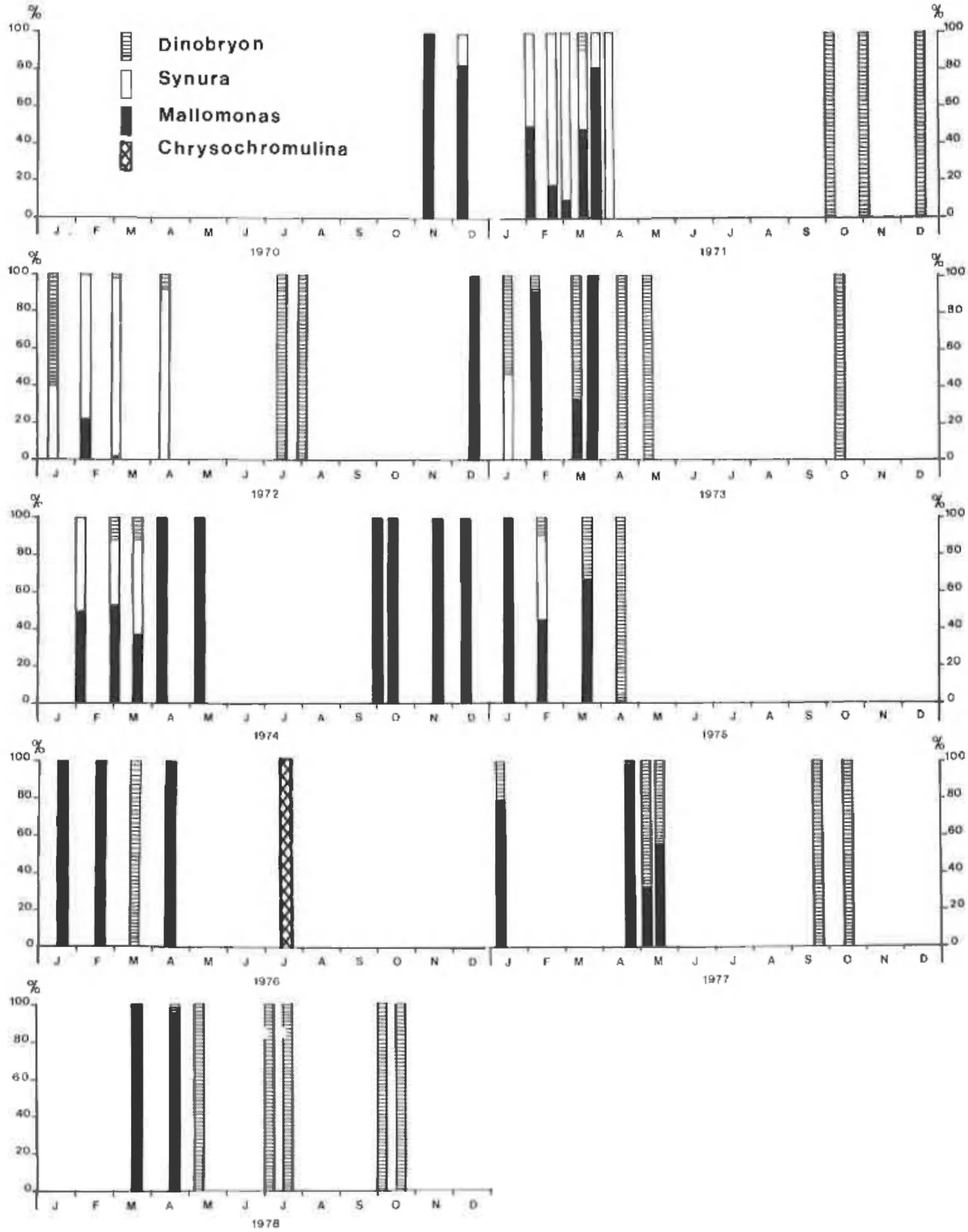


Fig 24. Percentage abundance of different genera of Chrysophyceae in Lake Trummen 1968-1978.

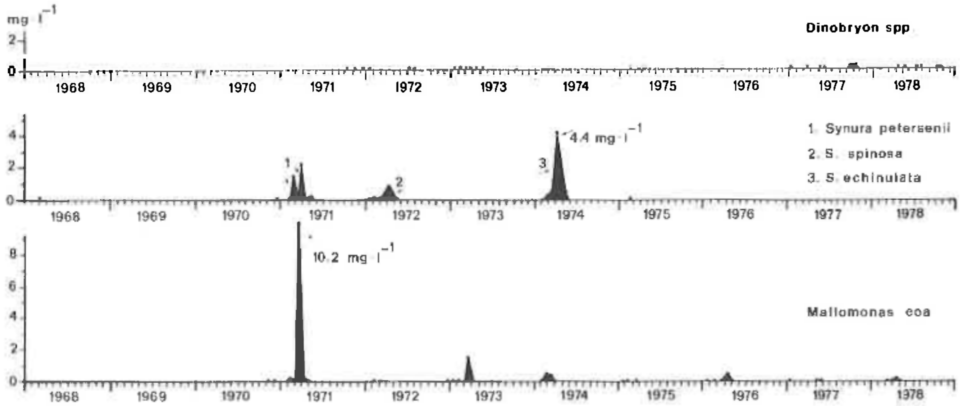


Fig 25. Biomass of *Dinobryon* spp., *Synura* spp. and *Mallomonas eoa* in Lake Trummen 1968-1978.

In phytoplankton counting many of the small Chrysophyceae were included in the group "undetermined µm-algae". They were too few to be enumerated separately and sometimes impossible to identify in the inverted microscope. Many Chrysophyceae can be identified to species only with EM (e.g. Synuraceae).

Rhizochrysidales

This group was represented by *Rhizochrysis limnetica* and *Bitrichia* spp. *Rhizochrysis limnetica* appeared sparsely both before and after restoration. In spring, 1976 and 1977, *Bitrichia chodati* and *B. ollula*, respectively, were observed for the first time. They have increased in number since then.

Chromulinales

Chromulina spp. was found during the whole investigation period at low density in spring. The cells were not identified to species.

After restoration *Chrysococcus* spp. appeared in the lake. The biomass increased and in spring, 1976, *Chrysococcus triporus* formed a bloom under the ice. This alga has not been reported from Sweden earlier (Appendix III; Fig 68-70).

Ochromonadales

This order includes the families Dinobryaceae and Synuraceae (scaled Chrysophyceae), which were the most important Chrysophyceae in Lake Trummen.

1. Dinobryaceae (Fig 25)

After restoration the biomass of Dinobryaceae increased and several species new to the lake were recorded. After spring, 1973, *Chrysolykos planctonicus* was found, but always in low numbers (Appendix III; Fig 139). However, as this species has a very thin lorica, it is difficult to observe and can easily be overlooked.

Species of *Dinobryon* were found during the whole period of investigation. Before restoration *Dinobryon divergens* was the most common species. To some extent it was replaced by *D. cylindricum*, which is now the most common *Dinobryon* species in Lake Trummen (Appendix III; Fig 72). After restoration *D. bavaricum*, *D. crenulatum*, *D. sociale* and *D. suecicum* became more frequent but were always found in low numbers.

Sometimes *Dinobryon* spp. appeared together with the scaled Chrysophyceae (Fig 24), but more often after the spring maximum of *Synura* and *Mallomonas*, or in summer and autumn.

2. Synuraceae (Fig 25)

Synuraceae includes the Chrysophyceae covered with silica scales, bristles and/or spines. It is a very important group in oligotrophic lakes in the south Swedish uplands. Some Synuraceae, however, are also common in eutrophic lakes, These algae must be identified with the help of EM (Appendix III; Fig 63-67, 73-134) and, therefore, can only be counted in groups in the inverted microscope, i.e. *Synura* spp., *Mallomonas* spp. One exception is *Mallomonas eoa*, which developed very characteristic cysts, easily identified with LM.

Synura

During the 1960s *Synura petersenii* (samples re-checked by me with EM) was sometimes found in great quantities, e.g. March, 1961, as reported by Björk & Digerfeldt (1965). *Synura* was, however, not recorded during the pre-investigation period 1968-1970. In February 1971, *S. petersenii* formed a bloom under the ice, and a high biomass was recorded (2.3 mg/l). During 1972 only few *S. petersenii* colonies were found, but instead a great number of *S. spinosa*. In April, 1974, the highest biomass of *Synura* (4.4 mg/l) was recorded. On this occasion *S. echinulata* dominated. The other *Synura* species appeared only in low numbers. After 1974 *S. echinulata* has been the most common *Synura* in Lake Trummen.

Mallomonas spp. (Fig 25. Appendix III; Fig 73-116)

Before restoration only a few species of *Mallomonas* were observed at low densities. Altogether 15 species of Mallomonas were identified in Lake Trummen, four species before and eleven after restoration. *Mallomonas trummensis* (Cronberg 1975) and *M. torquata* (Asmund & Cronberg 1979) were described as *species novae*.

In spring, 1971, following restoration, a dense bloom of *Mallomonas eoa* appeared together with *Synura petersenii* (Fig 25). During the spring period samples of phytoplankton were taken at intervals of a few days. It was, therefore, possible to observe cyst development in *M. eoa*, which started when the population reached its maximum (10.2 mg/l). Ten per cent of the *Mallomonas* cells developed cysts. When the ice broke up and water temperature rose to 6^{o}C, the population of *M. eoa* disappeared completely (Cronberg 1973 b, 1980).

After 1972 the spring blooms of *Mallomonas* decreased in size, but instead more species were represented.

In 1970 and 1974 *M. akrokomos* and *M. acaroides* were found in autumn (Cronberg 1980). During the last few years (1976-1978) *M. acaroides*, *M. crassisquama* and *M. tonsurata* were recorded during the summer at the same time as blue-green algae became less dominant.

Chrysosphaerella (Appendix III; Fig 63-66)

After 1973 *Chrysosphaerella brevispina* was observed in the spring plankton. It forms small smooth cysts. During the summers 1972 and 1973 *Chrysosphaerella multispina* was recorded in low numbers.

Paraphysomonas (Appendix III; Fig 122-123)

After 1973 *Paraphysomonas vestita* was found every spring. In fact it is one of the most common Chrysophyceae during spring in all types of lakes in south Sweden. *Paraphysomonas* is easily overlooked as it is a colourless Chrysophyceae with minute spines.

Spiniferomonas (Appendix III; Fig 118-119)

After restoration *Spiniferomonas trioralis* was recorded. This alga is also easily overlooked, in this case beacause of its minute size.

Chrysastrella (Appendix III; Fig 71)

In 1973 and 1974 *Chrysastrella paradoxa* was found in Lake Trummen. This is a Chrysophyceae species with uncertain taxonomic position. It is only known in the cyst stage.

Prymnésiales (Appendix III; Fig 135-136)

After restoration of Lake Trummen *Chrysochromulina parva* (Chrysophyceae) sometimes appeared in large amounts during the summer. The identification of this alga was verified with EM investigations (Appendix III; Fig 135-136). In Lugol-fixed samples the haptonema and 2 flagella were left on the cell and the alga could be identified. In the formalin-fixed or fresh samples, however, the haptonema was most often lost and the cells deformed.

Monosigales

Aulomonas purdyi was found in 1976-1978 in small quantities. The alga is difficult to observe and can easily be overlooked. Before restoration *Codosiga*, *Desmarella* and *Salpingoeca* were frequent. *Salpingoeca* grew as an epiphyte on colonies of *Microcystis* and *Melosira*.

Isochrysidales

In 1971 and 1974 *Hymenomonas roseola* was found occasionally when other Chrysophyceae were studied with EM. This species was never observed in the light microscope (Appendix III; Fig 137-138).

Summary of changes in the Chrysophyceae community after restoration.

Decreased biomass:	*Dinobryon divergens*, *Synura petersenii*, *Codosiga botrys*, *Desmarella moniliformis*, *Salpingoeca frequentissima*.
Increased biomass:	*Dinobryon cylindricum*, *Mallomonas acaroides* var. *striatula*, *M. akrokomos*, *M. crassisquama*, *M. eoa*, *M. heterospina*, *M. reginae*, *M. tonsurata*, *Synura echinulata*, *S. spinosa*
Species likely new to Lake Trummen:	*Bitrichia chodati*, *B. ollula*, *Chrysococcus triporus*, *Chrysolykos planctonicus*, *Chrysosphaerella* spp.
Species novae:	*Mallomonas trummensis*, *M. torquata*.

Diatomophyceae (Fig 26)

Before restoration the diatoms appeared with both spring and autumn maxima and high biomass. After restoration the seasonal pattern changed. Diatoms became more frequent during the summer, but the total biomass decreased. With the exception of 1971 species composition of diatoms has been almost the same during the whole investigation period. The dominant genera were *Melosira*, *Synedra*, *Nitzschia*, *Stephanodiscus* and *Asterionella*.

As the diatoms are almost impossible to identify to species in the inverted microscope, they have been counted in groups as *Melosira* spp., *Synedra* spp., etc. When the diatoms appeared in large numbers, preparations were made for species identification. The percentage distribution of the species was determined. Most of the diatoms now recorded from Lake Trummen have already been reported by Digerfeldt (1972) in his palaeolimnological investigation. However, some additional planktic species were identified during this long-term study. In 1971 the highest number of species was recorded. This coincided with the period when macrophyte vegetation was removed from the lake and the littoral zone cleaned. As a result of dredging and removal of vegetation the benthic or periphytic diatoms belonging to *Pennales* increased in plankton and were dispersed from the littoral zone into the pelagial. In the following years the diatom flora was restricted to the same number of planktic species as before restoration.

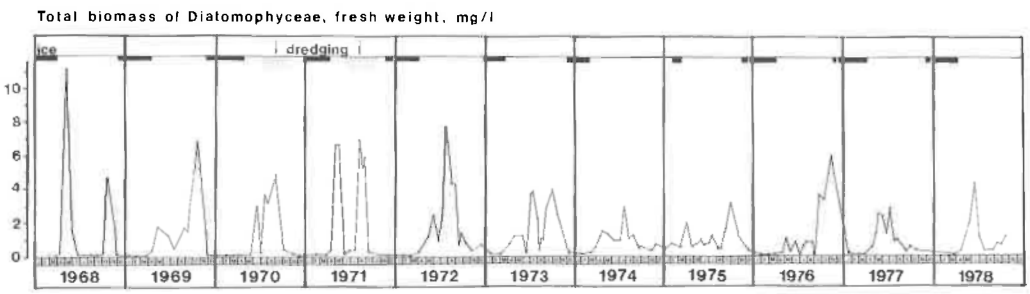


Fig 26. Biomass of diatoms in Lake Trummen 1968-1978.

In total 85 diatom species were identified in Lake Trummen. From these only 35 % are considered obligate planktic species. The rest consisted of periphytic or benthic species appearing in low numbers. The quantitatively important diatoms are presented below, and the rare species are listed in Appendix I.

Centrales

Melosira (Fig 27. Appendix III; Fig 146-155)

Melosira was the most important diatom genus in Lake Trummen. Before restoration *Melosira* formed spring and autumn maxima with high biomass. After restoration it appeared during the summer, and the biomass was reduced by 57 %. No changes in *Melosira* species composition were seen during the investigation period. The same species have dominated, viz. *Melosira ambigua*, *M. granulata* var. *angustissima* and *M. italica*.

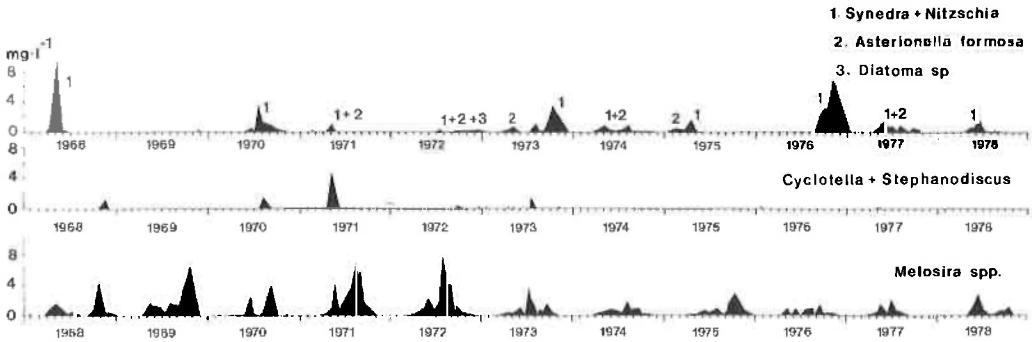


Fig 27. Biomass of different diatoms in Lake Trummen 1968-1978.

Cyclotella and *Stephanodiscus* (Appendix III; Fig 140-145, 156-161)

In the quantitative analyses *Cyclotella* and *Stephanodiscus* were counted in the same group because of the difficulty in separating the genera in the inverted microscope. From studying the diatom preparations, it was, however, obvious that the dominant species were *Stephanodiscus hantzschii*, *Cyclotella comta* and *C. meneghiniana*. Before and during restoration centric diatoms were more common than after, especially

Stephanodiscus hantzschii. After restoration only a few cells of this species have been recorded, but instead *Cyclotella* spp. have increased.

Rhizosolenia

After restoration *Rhizosolenia longiseta* was recorded in low numbers but seems to have increased. During 1978 this species formed a bloom in the southern bay of Lake Trummen, Skirviken, and large numbers were dispersed to the main lake. *Rhizosolenia longiseta* is characteristic and common in adjacent oligotrophic lakes.

Pennales (Fig 27)

Most species belonging to this order (Appendix I, Table 6) were rare in Lake Trummen. The common genera were *Asterionella*, *Nitzschia*, *Synedra* and *Tabellaria*, all of which were little affected by restoration. They appeared irregularly during the period 1968-1978, sometimes with high biomass.

Asterionella formosa appeared during the whole period but was more frequent during the last few years. It occurred often together with *Diatoma*. These two were counted in the same group.

Nitzschia acicularis, *N. gracilis*, and *Synedra acus* var. *angustissima* appeared together and formed blooms irregularly during all the investigated years. Before restoration *N. palea* was frequent, but decreased in number after. Few changes in biomass, however, were recorded in connection with restoration.

Synedra berolinensis was the only species of Pennales that showed an increase in number after restoration.

Obviously *Melosira* spp. and *Synedra* spp. have similar environmental requirements (including nutrient demands) as they appeared together, but neither of these species achieved high biomass when occurring together.

Summary of changes in the diatom community after restoration.

Decreased biomass:	*Melosira* spp., *Nitzschia palea*, *Stephanodiscus hantzschii*.
Indifferent:	*Synedra* spp., *Nitzschia* spp.
Increased biomass:	*Asterionella formosa*, *Cyclotella* spp., *Rhizosolenia longiseta*, *Synedra berolinensis*.

Xanthophyceae

The Xanthophyceae were only represented by a few species. *Pseudostaurastrum limneticum* and *Ophiocytium capitatum* were the most common (Fig 28). They were found occasionally in net samples but never reached measurable numbers. *Pseudostaurastrum* was more frequent before restoration.

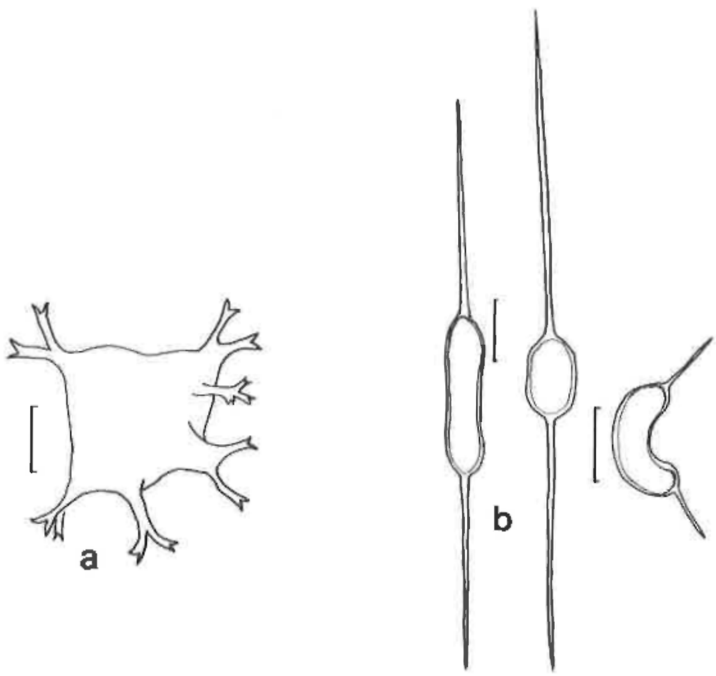


Fig 28. a) *Pseudostaurastrum limneticum* b) *Ophiocytium capitatum*. Scale 10 µm

P y r r h o p h y t a (Fig 29)

Pyrrhophyta includes the Cryptophyceae and Dinophyceae. Before and during restoration both groups were frequent and reached high maxima for short periods. After restoration they decreased drastically.

Altogether eleven species were identified, but the true number is probably greater. As most identification of algae from Lake Trummen was made with fixed material, it was not possible to identify *Cryptomonas* or *Gymnodinium* to species. Most of them are soft-walled and must be identified alive (if they at all are identifiable), as they contract and change appearance during fixation. *Cryptomonas* and *Gymnodinium* have, therefore, only been counted in groups according to size.

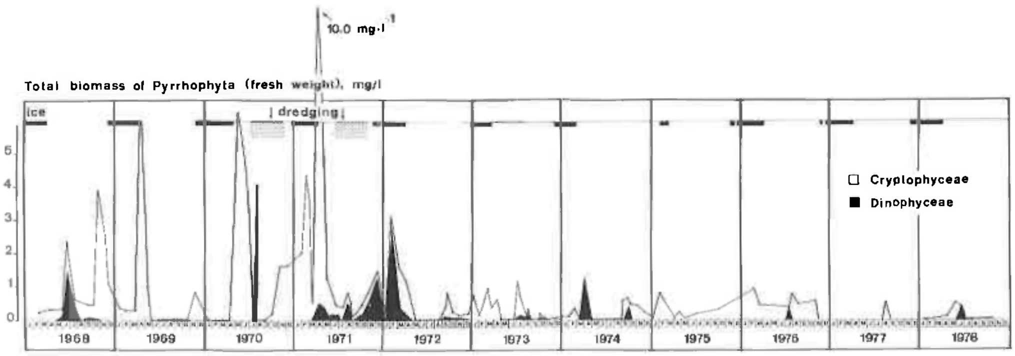


Fig 29. Biomass of Pyrrhophyta in Lake Trummen 1968-1978.

<u>Dinophyceae</u> (Fig 29-30)

Representatives for this group were *Gymnodinium* spp. and *Peridinium* spp. They formed short blooms irregularly during the period 1968-1972 but decreased in number during the last few years.

The most common Dinophyceae was a *Peridinium* sp. (Fig 30). It is characterized by a very thin theca. The plates were impossible to see in the light microscope. They were studied with SEM, but no more information was gained from the electron micrographs (Appendix III; Fig 177). During the last few years *Peridinium* sp. decreased, whereas the species *Peridinium inconspicuum* and *P. cunningtoni* have appeared.

Cryptophyceae (Fig 29-30)

Before and during restoration the cryptomonads were very frequent. They developed high maxima during spring and autumn with the large *Cryptomonas erosa*, *C. ovata* and *C. curvata* as the dominating species. After restoration *Cryptomonas* species decreased in number, and the seasonal distribution changed. Cryptomonads are now common during summer, and the large species have been replaced by small species, e.g. *Cryptomonas phaseolus*, *C. marssonii* and especially *Chroomonas acuta*. During the last few years *Chroomonas acuta* has increased quantitatively, and it is at present the most important cryptomonad (Appendix III; Fig 173-176).

Effort was devoted to the identification of the small cryptomonads, which appeared in great numbers during and after restoration. From Lake Trummen seven species were identified, but more were certainly present. The cryptomonads must be identified in living condition but most of the analysed samples were formalin- or Lugol-fixed. In spring, 1970, a large population of small cryptomonads appeared and SEM-investigations were made. The alga had a blue-green chloroplast and a cell size of 4-7 x 10-15 µm. The ultrastructure of the cell wall included a hexagonal pattern of ridges with ejectosomal pores. These are characteristic for the genus *Chroomonas* (Santore 1977) and the species was identified as *Chroomonas acuta*. My SEM-micrographs are also identical to those published by Hickel (1975) which were made on material

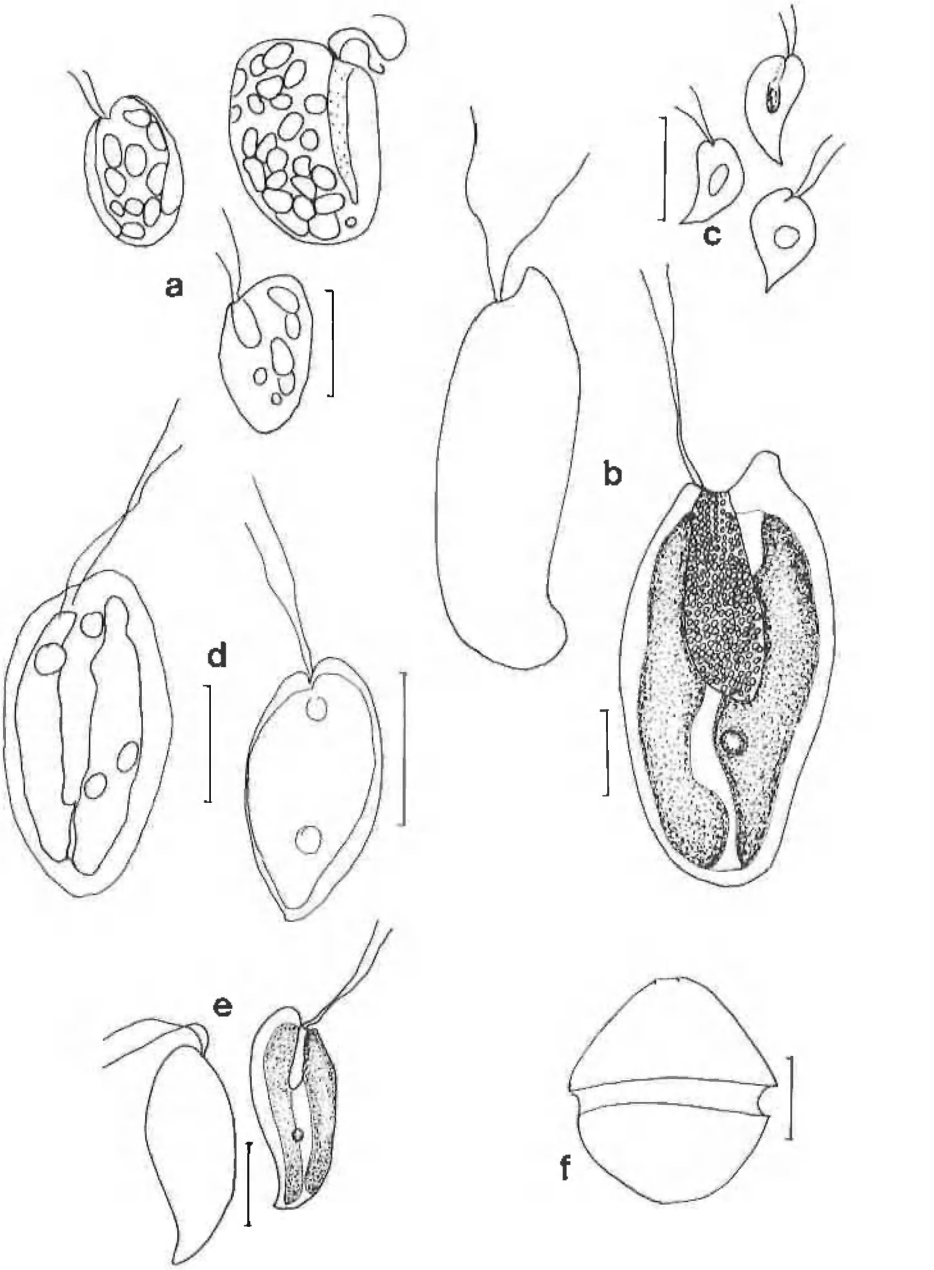


Fig 30. a) *Cryptomonas phaseolus* b) *C. curvata* c) *Chroomonas acuta* d) *Cryptomonas erosa* e) *C. marssonii* f) *Peridinium* sp.

Scale = 10 µm

from those lakes in Holstein (Germany) from which Utermöhl (1925) described this species.

The cryptomonads must, however, be studied with TEM and SEM, as the inner ultrastructure of the cell wall differs too (Santore 1977). *Chroomonas acuta* from Lake Bysjön (Scania, southernmost Sweden) was studied with both methods. The investigated specimen showed similar ultrastructure of the cell wall as those from Lake Trummen.

For comparison it might be mentioned that *Cryptomonas marssonii* (Appendix III; Fig 175-176) had no hexagonal pattern on the cell wall and the ejectosomal pores were evenly distributed on the cell.

Summary of changes in the Pyrrhophyta community after restoration.

Decreased biomass: *Cryptomonas curvata, C. ovata.*
Increased biomass: *Cryptomonas marssonii, Chroomonas acuta, Peridinium cunningtoni, P. inconspicuum.*

U n d e t e r m i n e d μ m - a l g a e (Fig 31)

This is an artificial group where undetermined small algae were counted in size groups, viz. 2-12 μm (Appendix II; Table 1-11). Small cryptomonads, chrysomonads, green and blue-green algae were assigned to the μm-algae (Lund 1961).

Before restoration the μm-algae appeared distinctly in a spring and an autumn maximum. During the restoration μm-algae increased and became more frequent in summer. After 1974 the μm-algae decreased in number and did not show regular seasonal variation. During the last few years small chrysomonads were common, and especially *Chrysochromulina parva* appeared in great quantities during the summer 1976-1978.

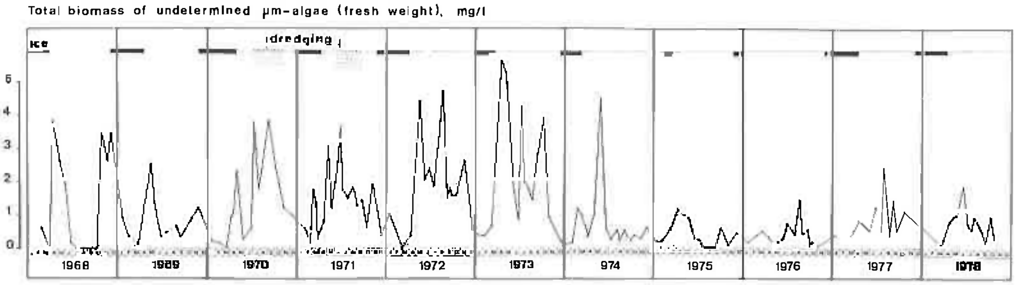


Fig 31. Biomass of undetermined µm-algae in Lake Trummen 1968-1978.

R a p h i d o p h y t a

In July, 1971, *Gonyostomum semen* formed a bloom in the south bay, Skirviken. Some cells were also found in the pelagic part of Lake Trummen.

C o l o u r l e s s   f l a g e l l a t e s

Only one genus belonging to the colourless flagellates has been identified, viz. *Tetramitus*. It appeared in large numbers 1972 and 1974. The alga is heterotrophic and fed on diatoms, especially *Synedra* and *Nitzschia* in Lake Trummen. The *Tetramitus* cell enclosed totally the diatom frustule and dissolved the contents. Sometimes *Tetramitus* cells with enclosed diatoms were more frequent than "free" diatoms. Obviously this alga could reduce an entire diatom population.

S p e c i e s c o m p o s i t i o n (Fig 32)

More species of blue-green and green algae were represented in Lake Trummen before than after restoration. The decrease in connection with restoration was mainly in the orders Chroococcales and Chlorococcales. After restoration, on the other hand, the number of Chrysophyceae species has increased threefold. The number of species of Pyrrhophyta, Diatomophycaeae and Xanthophyceae has remained more or less the same during the whole investigation period.

It is quite evident that the number of periphytic and benthic species has been reduced (Chlorococcales), while planktic species have increased (Chrysophyceae) in connection with restoration.

From phytoplankton species composition it is clear that restoration has induced an oligotrophication that is continuing year by year. Lake Trummen now has more species which are frequent in the surrounding oligotrophic lakes than before restoration.

S p e c i e s d i v e r s i t y (Fig 33-34)

A community with high diversity is, of course, more stable with more ecological niches than a community with low diversity. The latter is unstable because it is more sensitive to changes in the environment (Odum 1971). During plankton blooms usually few species contribute to the high biomass, which means that species diversity is low. This was the situation in Lake Trummen before restoration.

During June to September, 1968-1978, species diversity was investigated. Brillouin's index was used, and the diversity was expressed in bits/cell (Fig 33). Weighted mean diversity has been calculated for the period June 15 - September 15 (Fig 34).

To get more information about the changes, the total biomass was divided by the number of species counted. This quotient was then plotted against time (Fig 35). The curve for the period 1968-1978 shows, that drastic changes took place even if the diversity was the same. In this connection it ought to be reminded of the fact that the species before restoration had larger cell volumes than those occurring after.

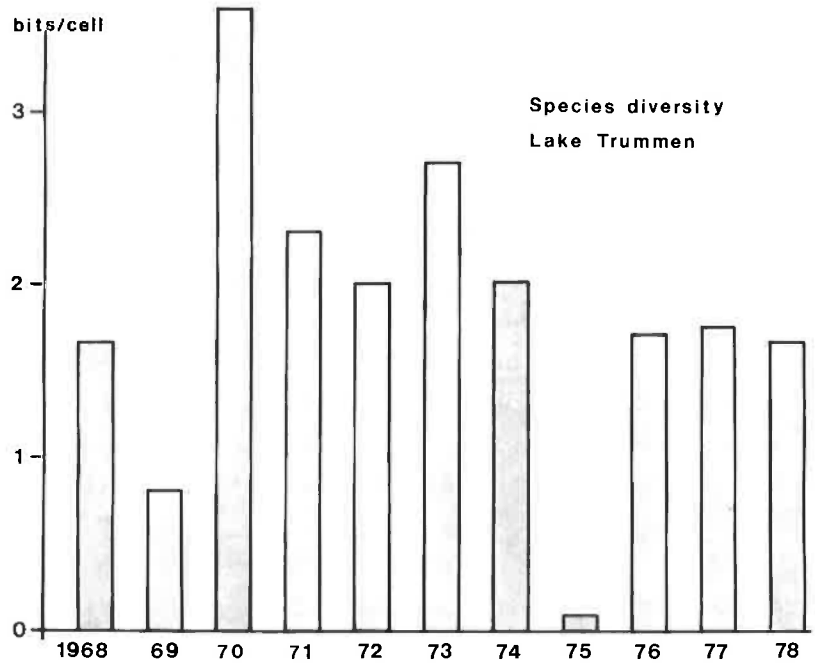


Fig 34. Species diversity (Brillouin's index), calculated as weighted mean values from the period June 15 - September 15, 1968-1978.

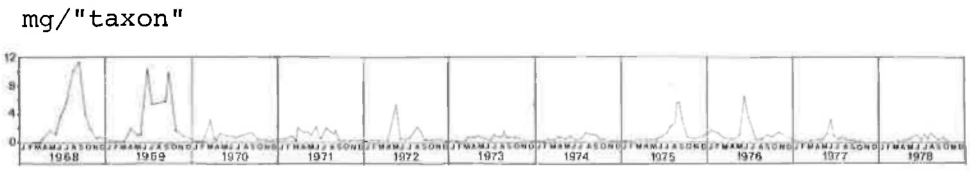


Fig 35. The mean biomass per "taxon", Lake Trummen 1968-1978.

FOOD-WEB EXPERIMENTS

I. INTRODUCTION

The effect of planktivorous fish on species composition of zooplankton is well known (Hrbáček 1962, Brooks & Dodson 1965). When fish are absent or in low numbers the predation on zooplankton is, of course, zero or low. Zooplankton can then develop without or with small losses and graze on phytoplankton. A reduction of the biomass of phytoplankton means an increase in transparency. The resulting effect is similar to oligotrophication. On the other hand, large numbers of fish result in an increased predation on zooplankton which results in an increase in phytoplankton.

Zooplankton are divided in macro- and microfiltrators (Burns 1969, Gliwicz 1969). To macrofiltrators belong large Cladocera with the ability to take in particles 10-20-(30) µm in size and to microfiltrators small Cladocera which feed on particles 1-3-(5) µm in size (Kryuchkova 1976). Rotifers feed on small particles, e.g. algae, mostly with a size smaller than 12 µm (Wetzel 1975). Large species, however, feed on larger particles than smaller species do.

In the unrestored Lake Trummen the long and cold winter of 1969-1970 resulted in a very serious fish kill in early spring caused by oxygen deficiency under the ice. In May-June 1970 the phytoplankton biomass was smaller than the previous year. These changes were interpreted as implying increased grazing by zooplankton on phytoplankton because nearly all coarse fish was killed (Dr. Gunnar Andersson, personal communication). In early summer phytoplankton was dominated by cryptomonads and small green algae, especially *Chroomonas acuta* and *Chlorella* sp.

The restoration resulted in drastic reductions in concentrations of nutrients and biomass of phytoplankton. It seemed as if the reduction continued to a more or less steady state in 1972-1974, i.e. the first three years following restoration. In 1975, however, the phytoplankton biomass increased again. In the spring of that year a large number of small fish from Lake Växjösjön invaded Lake Trummen. In Lake Trummen the increased number of small fish must have resulted in an increased predation on zooplankton. The biomass of phytoplankton, especially the blue-green alga *Cyanodictyon imperfectum* increased synchronously. The bloom lasted the whole summer.

The observations made in Lake Trummen led to studies on the qualitative and quantitative relations among fish, zooplankton and phytoplankton. Investigations on induced environmental changes were included as well and the food-web experiments started in 1975 with enclosures stocked with different species of fish *in situ* in Lake Trummen (Andersson *et al.* 1978). In 1976 a full-scale experiment with fish reduction started in Lake Trummen.

Data on environmental factors and zooplankton are put at my disposal by Dr G. Andersson.

II. MATERIAL AND METHODS

1. Description of the enclosures

In 1975-1978 experiments with fish were performed in enclosures in Lake Trummen. The effects on water chemistry, phyto- and zooplankton were studied (Andersson *et al.* 1978, Andersson 1979 a and b). The enclosures were made of wooden frames and PVC tubes covered with plastic sheeting. They were pressed down ca. 30 cm into the sediment at a water depth of 2.2 m. The enclosures (diameter 3 m, height 2.8 m) were open to the sediment and to the atmosphere. They extended 20-40 cm above the water surface and isolated a volume of about 15 m^3 of lake water (Andersson *et al. op. cit.*).

2. Experimental design and problems

Two (1975-1976) and six (1977-1978) enclosures were used. They were stocked with fish according to Table 7. In one enclosure the fish were prevented from feeding on the benthos by a net suspended 20 cm above bottom. The enclosures were installed in the middle of June and were removed in October. In 1976 and 1977 similar experiments were performed in Lake Bysjön, a lake located in the southernmost province of Sweden, Scania (Andersson *et al. op. cit.*).

Table 7. Biomass of fish (g/m^2) in the enclosures. Fish length 10-20 cm.

Year	No fish	Bream Roach	(Bream Roach)*	Bream	Roach	Perch	Experimental period
1975	0	40	-	-	-	-	June-Oct.
1976	0	90	-	-	-	-	June 10-Oct. 7
1977	0	50	50	50	50	50	June 16-Oct. 17
1978	0	50	50	50	50	50	June 16-Oct. 19

*Fish excluded from sediment by a net.

There were some difficulties during the first period of experimentation. In early summer 1975 several rips appeared in the enclosure walls. After repairs and restocking fish the enclosures worked from July 15 through September. During 1976 both enclosures were polluted by excrement from birds resting on the walls of the enclosures. This was later prevented. Some perch entered the fish-free enclosure in August through a hole in the plastic film but were removed in early September. In 1977 some of the fishes died of fungal infection. The enclosures were then restocked. After some heavy rains the enclosures flooded, the water level rose and the water in the enclosures came in contact with that of the lake. During 1978 the experiments were performed without any disturbances. Although these minor difficulties occurred during the first experimental periods the results were consistent.

3. Sampling

Mixed water samples (0-1.5 m in depth) were collected every other week using a plexiglass tube (diameter 34 mm). From these, subsamples were taken for chemical and biological analyses.

Quantitative samples for phytoplankton investigations were fixed with Lugol's solution and counted as described above (p. 13).

III. RESULTS

1. Enclosure experiments with fish.

1975 (Fig 36-37)

During the summer 1975 *Cyanodictyon imperfectum* appeared in Lake Trummen, forming a bloom (5-27 mg/l) as described above (p. 30). In the enclosure stocked with bream and roach *Cyanodictyon* increased and dominated the whole period.

In the enclosure without fish, on the other hand, *Cyanodictyon* disappeared and the total biomass of phytoplankton decreased drastically. Instead small cryptomonads, mainly *Chroomonas acuta*, developed.

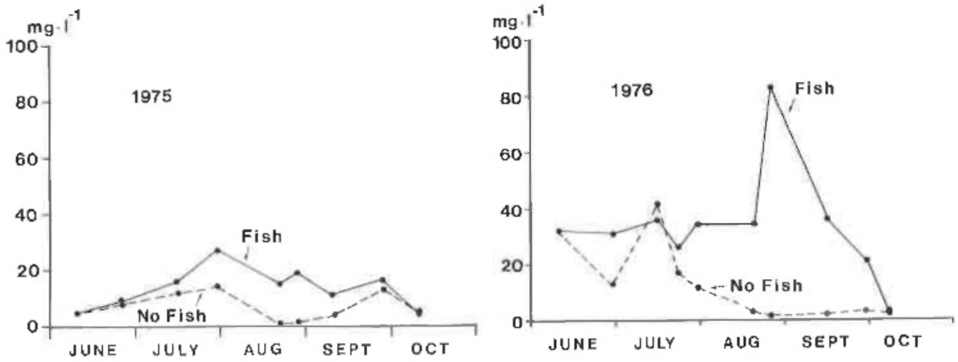


Fig 36. Phytoplankton biomass in the enclosures stocked with fish (bream + roach) and without fish, June - October, 1975 and 1976.

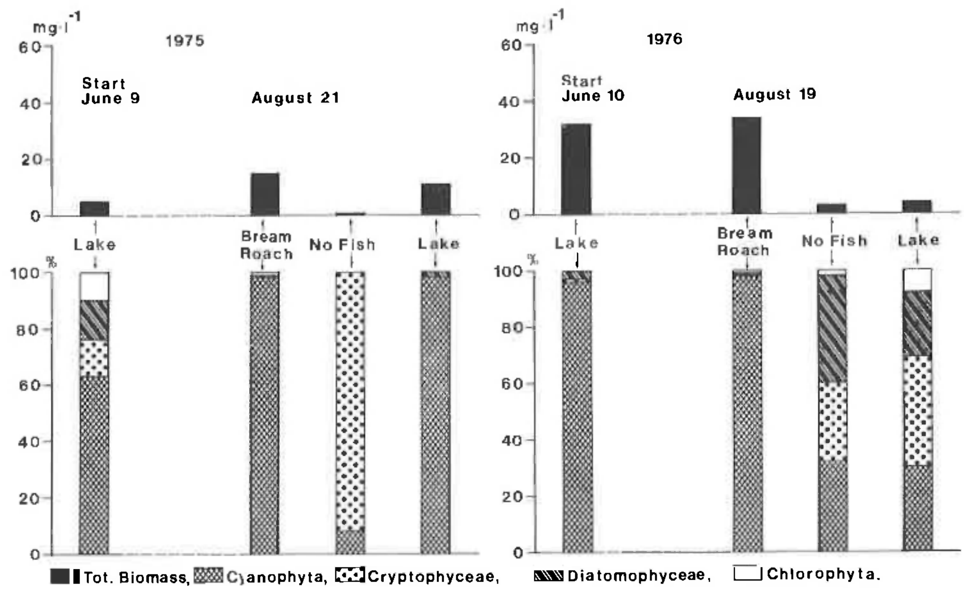


Fig 37. Phytoplankton biomass and percentage distribution in Lake Trummen and the enclosures stocked with fish (bream + roach) and without fish after 2 1/2 months' exposure, 1975 and 1976.

In the enclosure stocked with fish the number of *Daphnia*, Oligochaeta, and Ceratopogonidae was reduced, while these organisms increased and the number of rotifers decreased in the enclosures without fish.

1976 (Fig 36-37)

When the experiments started in June, 1976, the phytoplankton in Lake Trummen was dominated by *Aphanizomenon gracile* (10.1 mg/l). Due to enrichment from birds (*Larus ridibundus*) the biomass of phytoplankton increased in both enclosures during July and a population of large cryptomonads developed together with *Aphanizomenon*. In the end of July, however, the fish enclosure developed a bloom of *Microcystis aeruginosa* and *Oscillatoria agardhii*, while in the fish-free enclosure the phytoplankton almost disappeared and only some small blue-green algae and cryptomonads were found. In August large differences in phytoplankton biomass and species composition were recorded between the two enclosures. Generally, however, the results were consistent with those of 1975.

In the enclosure with fish *Daphnia* disappeared, while small Cladocera (*Chydorus sphaericus*) and rotifers (*Lecane* sp.) increased. In the enclosure without fish a large population of *Daphnia cucullata* appeared. The number of rotifers decreased.

1977 (Fig 38-39)

Phytoplankton in Lake Trummen was dominated in June by blue-green algae, mainly *Oscillatoria limnetica* var. *acicularis* (22 mg/l, Fig 39). The enclosure stocked with both bream and roach maintained a bloom of blue-green algae the whole summer. A great number of chlorococcal green algae was also found in the enclosure.

On the other hand, in the enclosure where bream and roach were restricted from feeding on the bottom, there was a reduction in phytoplankton. Blue-green algae dominated in the beginning but were replaced by cryptomonads.

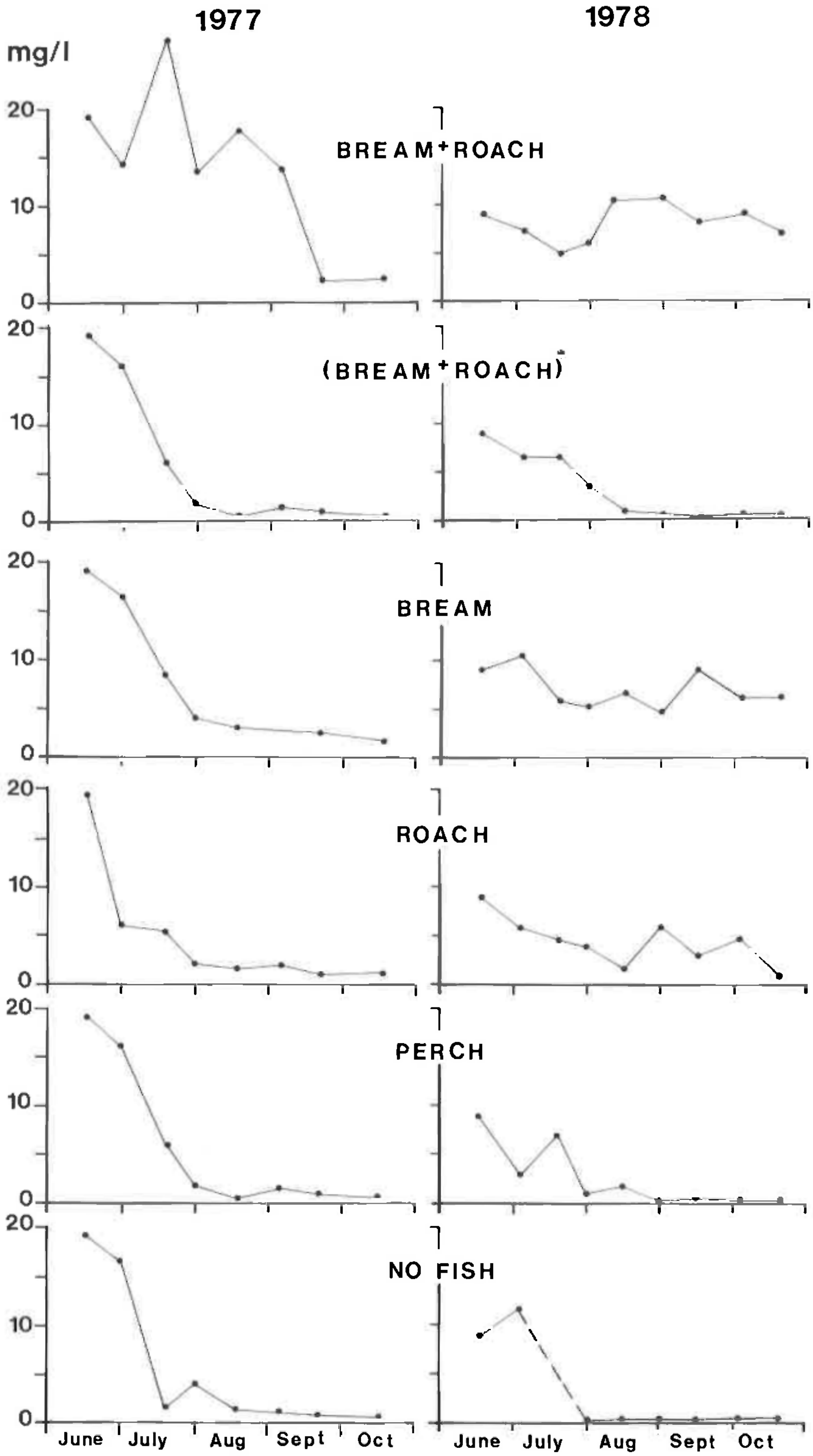


Fig 38. Phytoplankton biomass in the enclosures stocked with different species of fish, 1977 and 1978.
*Fish excluded from sediment by a net.

In the enclosure with only bream the high biomass of blue-green algae was successively reduced and a mixed population of *Oscillatoria limnetica* var. *acicularis*, *Scenedesmus* spp. and *Melosira* sp. developed.

In the enclosure with only roach the phytoplankton biomass was reduced. There was a shift from blue-green algae in June to diatoms in July, when *Synedra* sp. and *Stephanodiscus* sp. dominated. In August this population was replaced by cryptomonads.

The enclosure with perch and the one without fish had a similar change in phytoplankton. In July the blue-green algae were replaced by cryptomonads. A small population of cryptomonads was then kept in these enclosures during the whole period.

1978 (Fig 38-39)

In June 1978 when the enclosures were placed in Lake Trummen the phytoplankton was dominated by *Melosira* sp., *Synedra* sp. and *Aphanothece clathrata* (9 mg/l).

In the enclosure with bream and roach the blue-green algae dominated during the whole period. A dense bloom of *Microcystis aeruginosa* and other blue-green algae appeared in August.

In the enclosure where bream and roach were excluded from the sediment by a net, the phytoplankton biomass decreased and the blue-green algae were replaced by cryptomonads. Periphyton on the walls of the enclosure increased and *Mougeotia* sp. and *Cosmarium* spp. were recorded.

The enclosure with only bream had a high biomass of blue-greens and chlorococcal green algae during the summer.

In the enclosure with roach the relatively high biomass of phytoplankton was maintained during the experimental period. Blue-green algae dominated but also many other species contributed to the biomass.

In the enclosure with perch and the one without fish the phytoplankton biomass decreased. The blue-green algae disappeared and were replaced by cryptomonads.

1977 and 1978

The fungal infection in 1977 made the interpretation difficult. In 1978 the enclosure experiments were, however, run without any disturbances. Therefore, when summarizing the results, data from 1978 is mainly dealt with. The enclosures stocked with the same species of fish showed similar phytoplankton development. After two months' exposure the effects on nutrient concentrations, phytoplankton and zooplankton can be summarized as follows.

Bream and roach stocking caused an increase in the number of small cladocerans (*Chydorus sphaericus* and *Bosmina longirostris*) and rotifers (*Keratella cochlearis*, *Lecane* sp.). The concentrations of tot-P and tot-N and the biomass of phytoplankton, especially blue-green and chlorococcal green algae increased. The total effect was a marked eutrophication.

In the enclosure with bream and roach excluded from the bottom, the fish preyed on planktonic Cladocera which decreased in number. This had, however, little effect on phytoplankton biomass and nutrient concentration. No eutrophication was recorded in this enclosure, in contrary to that in which bream and roach could reach bottom and search for food in the sediment.

In the enclosure stocked with bream, *Bosmina longirostris* and *Filinia longiseta* were most common after two months. Nutrient concentrations and phytoplankton biomass was high. Cryptomonads dominated, 1977, and blue-green algae and chlorococcal green algae 1978.

In the enclosure with roach, *Bosmina longirostris* appeared in small amounts while rotifers, especially *Filinia longiseta*, were frequent. Phytoplankton biomass was, in 1978, kept at a relatively high level. In 1977, however, disturbances appeared (fungal infection of the fish) and results from this enclosure were similar to those of the fish free during some periods.

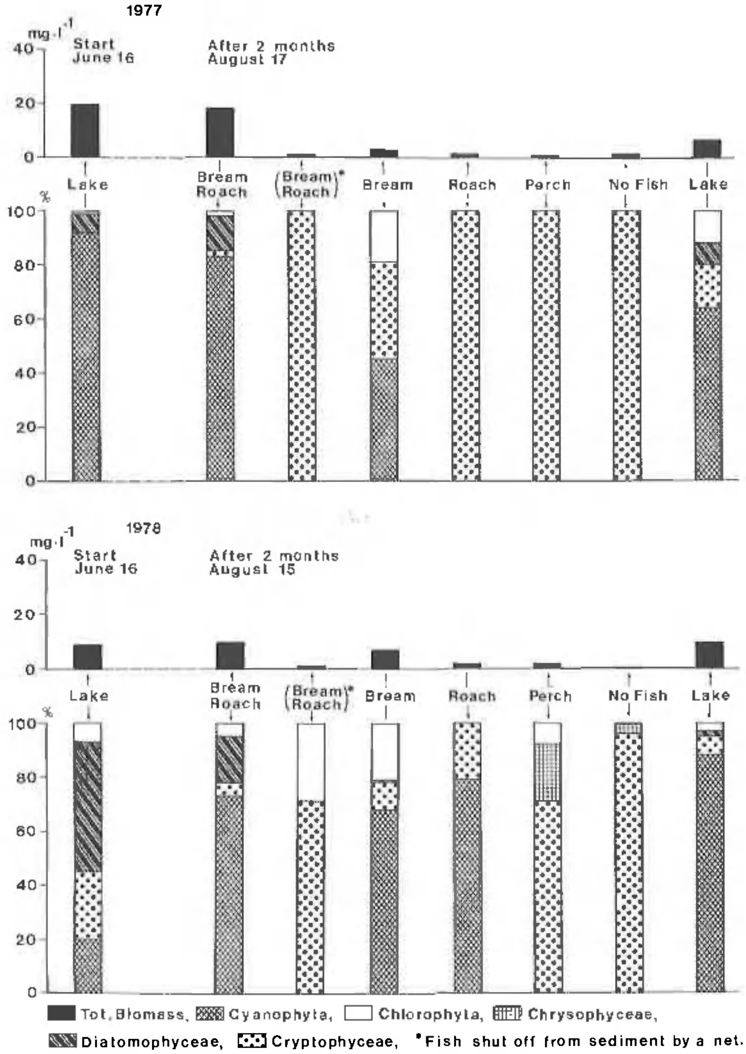


Fig 39. Phytoplankton biomass and percentage distribution in Lake Trummen and the enclosures stocked with different species of fish after 2 months' exposure, 1977 and 1978.
*Fish excluded from sediment by a net.

The enclosure with perch showed an increase in the number of *Daphnia cucullata*, 1977, and of *Bosmina coregoni* 1978, but reduced number of rotifers. Phytoplankton nearly disappeared and only small cryptomonads were left. The concentrations of tot-P and tot-N were reduced and thus an overall oligotrophication took place.

The enclosure without fish developed a large population of *Daphnia cucullata* but few rotifers. Nutrient concentrations and phytoplankton biomass decreased. Altogether an oligotrophication was recorded.

Stomach analyses of different species of fish from the enclosures 1977 showed that bream preferred *Chydorus sphaericus*, roach *Daphnia* and perch copepods.

2. Whole lake experiment

In April 1976 the elimination of coarse fish, such as small bream and roach using a fyke-net was started. All predaceous fish were returned to the lake again.

The removal of coarse fish resulted in a decrease in tot-P, tot-N and phytoplankton biomass, while the number of Cladocera increased. In the spring 1977 a large number of fish immigrated to Lake Trummen from Lake Växjösjön. Therefore the effect of the elimination of coarse fish must have been reduced. During 1976-1978 13.4 Mg fish was caught in Lake Trummen, mainly with net.

The whole-lake experiment is still (1980) in progress. The results will be presented at a later date.

LIMNOLOGICAL SYNTHESES

In this long-term whole-lake study in Lake Trummen, the phytoplankton development was dependent on:

1) sampling technique;
2) climatic factors such as cold or warm winter/spring, hot or rainy summer;
3) rapid reduction in nutrient concentrations induced by sediment removal;
4) inoculation of algae to plankton from sediments and macrophytes; and,
5) interactions of fish and zooplankton.

1) Influence of sampling technique

In order to document most changes in a developing phytoplankton community, samples should be taken with short intervals, at several points in the lake and at various depths. For practical and economical reasons this is seldom possible, limitations must be considered and it is therefore necessary to determine the optimal sampling technique for every individual lake.

Phytoplankton is unevenly distributed in a lake, especially if it stratifies during summer. The phytoplankton community fluctuates seasonally and among years. Algae can form blooms of high maxima which are followed by rapid reduction (Barica 1975, Coveney *et al.* 1977). Lund (1979) and Bailey-Watts (1979) closely followed the phytoplankton development in Blelham Tarn for 32 and in Loch Leven for 9 years, respectively. They studied the phytoplankton on weekly basis and were able to record rapid seasonal fluctuations as well as long-term changes in the development.

In the present investigation it was of less interest to record continuously the rapid fluctuations in water chemistry and phytoplankton development, but more to elucidate the long-term changes induced by restoration. In 1968-1969 samples were taken for phytoplankton investigation at different places and depth. However, Trummen is a shallow and exposed lake, that rarely stratifies, and since it was shown that chlorophyll α concentrations from different depths were similar (Gelin & Ripl 1978), plankton sampling was restricted to the central part of the lake at 0.2 m depth. Dr Gunnar Andersson collected weekly samples during 1969-72 for zooplankton investigations from 20 stations in the lake. This was done with a tube that collected water from surface to 10 cm above bottom. These latter samples were mixed and subsamples withdrawn for phytoplankton analyses. In the mixed samples the number of *Melosira* spp. was counted and compared with the monthly samples taken at 0.2 m depth (Fig 40).

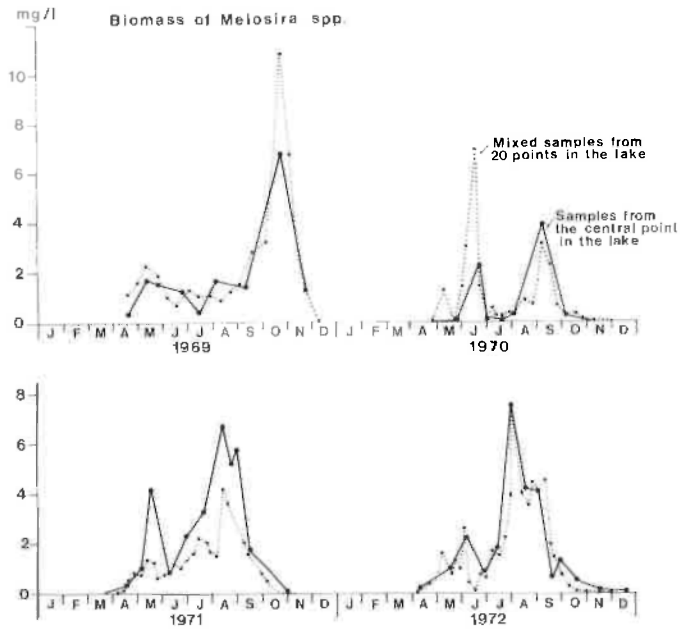


Fig 40. Biomass of *Melosira* in Lake Trummen 1969-1972.
●———● Monthly samples from 0.2 m at the central point in the lake.
●·········● Weekly samples from 20 points in the lake taken with a tube from surface to 10 cm above bottom.

The comparison showed that both methods gave similar results. In 1969 the biomass maximum in October was higher with the 20 station sampling than that obtained at the central point. In 1970 two spring maxima were lost because monthly sampling was not sufficient. In 1971 the biomass recorded at the central point was higher than that obtained from the mixed whole lake samples. In 1972 the agreement between the central point samples and the mixed samples was very good. These examples reflect the problems and accuracy in sampling methods and must be kept in mind when evaluating the changes in the phytoplankton community presented in this paper.

During calm days in summer, blue-green algae can be concentrated at the surface, and they can collect into sheltered bays, etc. These phenomena may occur and remain unrecorded in both weekly and monthly sampling. Together with these fluctuations diurnal changes can also be of great importance (Coveney *et al.* 1979). Such errors in sampling must be taken into consideration when studying phytoplankton. However, in investigations continuing several years, long-term changes can be recorded and evaluated with reliability.

2) Influence of climatic factors

Lake Trummen has been studied by limnologists since the 1940's, and intensely investigated since 1968. Before restoration the conditions in the lake were quite stable during the summers. Heavy water blooms of blue-green algae, primarily *Aphanizomenon*, *Anabaena* and *Microcystis*, dominated (Thunmark 1945 a, Björk & Digerfeldt 1965). However, during spring the phytoplankton community altered from year to year. Thus in 1960 centric diatoms and small green algae dominated, while in 1961 *Synura petersenii* was most abundant (Björk & Digerfeldt 1965). These fluctuations in the vernal flora might be due to influence of climatic factors, such as a hard or a mild winter/spring with much snow and ice *contra* no snow and short periods with ice cover. The Chrysophyceae

(*Synura* and *Mallomonas*) seem to be favoured by periods of short ice-cover followed by open water in early spring as in 1971.

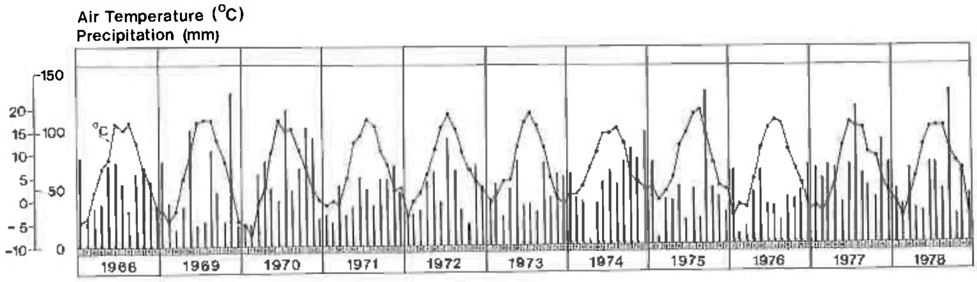


Fig 41. Air temperature and precipitation, 1968-1978.

During the winter 1969-1970 the ice covered period was long and as a result of oxygen deficiency a fish-kill occurred in the spring. Most coarse fish died and the predation on zooplankton was minimized. This resulted in increased grazing on phytoplankton and the phytoplankton community changed. Only small amounts of cryptomonads and green algae were found, partly because of unusually warm weather.

3) Influence of restoration procedure - nutrient reduction

The thorough palaeolimnological investigations by Digerfeldt (1972) gave valuable information about the history and development of Lake Trummen. Several thousand years after the deglaciation the lake had a high nutrient level and productivity. By time the concentrations of nutrients were reduced and the lake was successively approaching the oligotrophic stage. From the beginning of this century the lake became polluted. The worst pollution period was 1936-1958, when the lake received sewage water from the town and a flax factory.

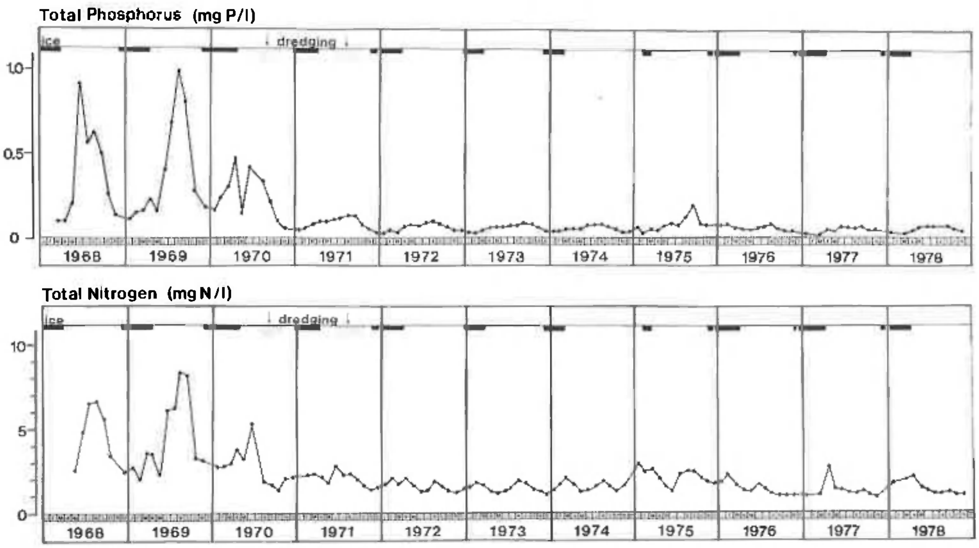


Fig 42 a. Concentrations of phosphorus and nitrogen in Lake Trummen 1968-1978.

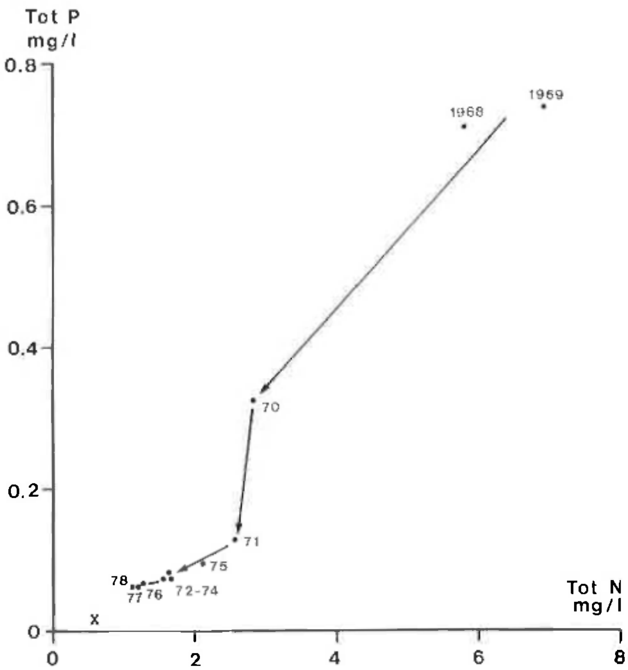


Fig 42 b. Changes in nutrient concentrations in Lake Trummen following restoration in 1970-1971.

Weighted mean values for the summer period (15 June - 15 September). X = mean value of 412 samples from 250 lakes in the surrounding area (Kronoberg county). Raw data from W. Ripl and Länsstyrelsen i Kronobergs län. - From G. Andersson 1979 b.

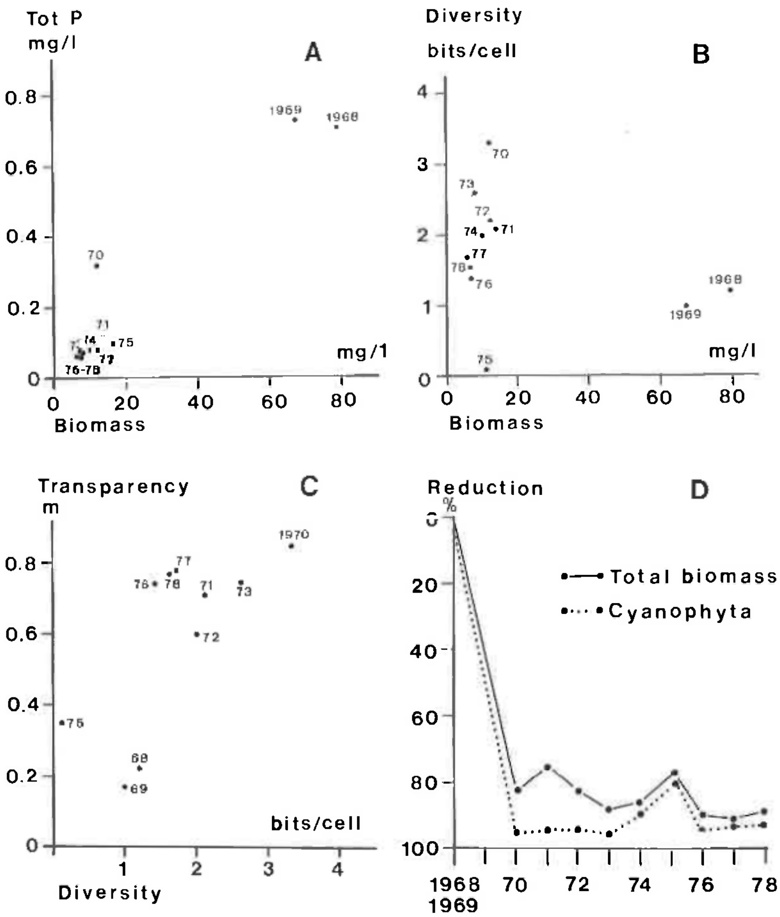


Fig 43. A) Changes in tot-P and biomass of algae.

B) Changes in species diversity (Brillouin's index and biomass of algae.

C) Changes in transparencey and species diversity.

D) Percentage reduction in total biomass and Cyanophyta after restoration.

Lake Trummen 1968-1978 (weighted mean values from June 15 to September 15).
1968 and 1969 = before restoration,
1970 and 1971 = during restoration,
1972 to 1978 = after restoration.

In 1958 all sewage water was diverted from the lake, and although the external loading was eliminated, the lake did not recover during the 1960's, i.e. the lake was irreversibly damaged. The restoration was planned in the middle of the 1960's (Björk 1966) and performed 1970-1971. The pre-investigations (1968-1969) of Lake Trummen indicated that the uppermost 0.5 m sediment caused a severe internal loading (Bengtsson & Fleischer 1971). When the 0.5 m black nutrient-rich sediment layer was removed, 1970-1971, the internal loading was minimized, which resulted in a rapid decrease in nutrient concentrations (Fig 42). The concentrations of tot-P and tot-N were reduced by 90 % and 70 %, respectively (Andersson 1979 b). In 1975, a slight increase in nutrient concentrations and phytoplankton biomass was recorded. Since 1975 the nutrient concentrations have decreased even more and stabilized on a level close to that of the oligotrophic lakes in the area (= x in Fig 42b). This rapid decrease in nutrients induced a dramatic reduction in phytoplankton biomass (Fig 43 A and D). A total of about*50 Mg of phosphorus and 450 Mg of nitrogen were removed from the lake through the suction dredging of the top sediment layer (Andersson *op. cit.*). Sediment removal induced a reduction mainly in the blue-green algal community (Fig 9, 50). By 1970 the blue-green algal biomass was less than 5 % of the pre-restoration value. Before restoration the biomass of phytoplankton was high, the species diversity low, i.e., few species contributed to the biomass. The restoration induced a reduction in biomass but an increase in species diversity (Fig 43 B). The structure of the phytoplankton community was changed and more species were found after the dredging. However, during 1976-1978 the diversity decreased even though the biomass was low. The latter resulted from changes in the species composition as small colony forming blue-green algae appeared.

*Mg = megagram

Table 8. Lake Trummen, water and plankton analyses.

Weighted mean values of chemical, physical and biological parameters for the summer period (June 15 - September 15), 1968-1978.
Partly unpublished data from Gunnar Andersson.

	Pre-investigation period 1968-69	Restoration period 1970-71	Post-investigation period 1972-75	Follow-up investigation period 1976-78
Transparency cm	20	76	58	76
Turbidity JTU	55	19	18	9
Conductivity µs/cm 20°C	145	163	192	232
Alkalinity mekv/l	547	304	278	427
Tot-P µg/l	725	227	81	64
PO_4-P µg/l	185	68	9.5	8.7
Tot-N mg/l	6.4	2.7	1.8	1.2
NO_3-N µg/l	10.4	9.0	5.2	3.4
NH_4-N µg/l	57	96	25	22
SiO_2 mg/l	5.8	0.9	1.5	0.6
Total biomass mg/l	73	13	12	7
Species diversity bits/cell	1.1	2.7	1.7	1.5

The reduction in phytoplankton biomass through restoration, resulted in greater transparency, from 20 to 75 cm (with the exception for 1975), which gave Lake Trummen a better light climate. Submersed vegetation reappeared, the photosynthetic zone increased and the phytoplankton productivity changed (Fig 43 C, 44). The mean annual primary production of the total phytoplankton community decreased from 370 g C $\cdot$ $m^{-2} \cdot yr^{-1}$ (1968-1969) to 225 g C $\cdot$ $m^{-2} \cdot yr^{-1}$ (1972-1973) after restoration (Gelin & Ripl 1978).

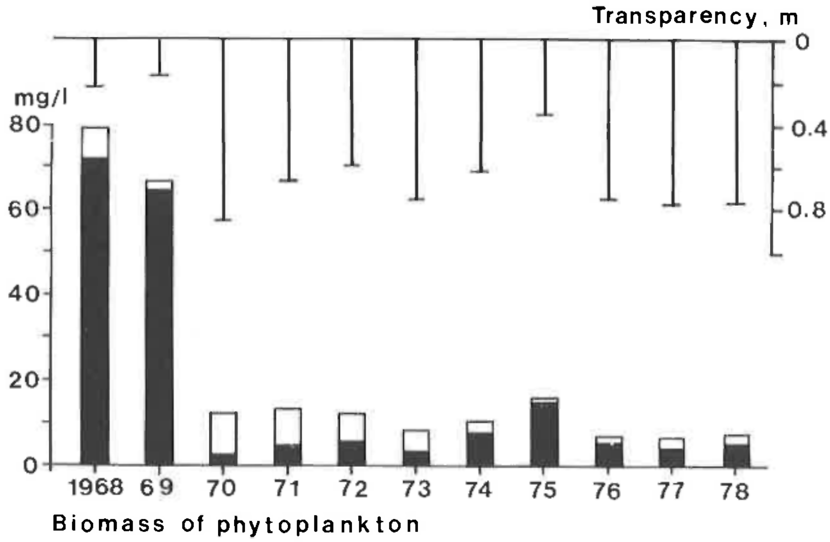


Fig 44. Changes in phytoplankton biomass and transparency in Lake Trummen 1968-1978 following restoration in 1970-1971.

Weighted mean values of total biomass of phytoplankton (whole column) and biomass of blue-green algae (black column) for the summer period (15 June - 15 Sept.).

Following restoration, a succession from nutrient demanding blue-green algal species as *Microcystis* spp., *Oscillatoria agardhii*, *Aphanizomenon flos-aquae*, *Anabaena solitaria* f. *smithii* and *A. spiroides* have been replaced by *Aphanothece clathrata*, *Anabaena viguieri*, *Aphanizomenon gracile* and *Oscillatoria limnetica* var. *acicularis*, which have lower nutrient demands. All these species have smaller cells and may be more effective at assimilating nutrients (Gelin & Ripl 1978). Although primary production decreased following restoration the proportion of production attributed to the nannoplankton (<10 µm) fraction increased.

The restoration changed the seasonal pattern of the diatom community (Fig 26). Though biomass of diatoms was reduced, they became more frequent during summer. The typical spring flora of centric diatoms 1960 (Björk & Digerfeldt 1965) and of *Melosira* and/or *Synedra* 1968-1969, disappeared and was replaced by Chrysophyceae, especially species belonging to *Synura* and *Mallomonas*.

After restoration the oxygen conditions in Lake Trummen improved (Andersson 1979 b) and favoured the Chrysophyceae which can develop under the ice and during low light conditions, while diatoms have higher temperature demands. Following restoration, the Chrysophyceae appeared early in the spring, but when the temperature rose they were replaced by the diatoms (Fig 46b).

Diatoms have been more common during the summers since 1970. This may be a result of reduction in nutrient concentrations, since freshwaters respond to excess nutrients with blue-green algal blooms. However, under lower nutrient conditions diatoms can compete with the blue-green algae.

Conversely, blue-green algae may excrete substances which are inhibitory to diatoms. Keating (1978) found that diatoms did not develop when blue-green algae were present in Linsley Pond. She performed bioassay experiments with cell-free filtrates of lake water sampled during periods of blue-green blooms which were inoculated with diatoms isolated from the lake. These bioassay experiments showed an apparent inhibitory effect of blue-green algae on diatom growth. When comparing the appearance of the blue-green algal blooms with those of the diatoms in Lake Trummen, they were not synchronous. Therefore the blue-green algae might have had an inhibitory effect on diatoms of Lake Trummen. However, there was a close connection between the diatom development and the silica concentrations in the lake (Fig 45). When the silica concentration was high, the diatom blooms developed. At the diatom maximum the SiO_2-concentration was reduced to zero (Fig 45). Before restoration silica concentrations were higher and larger diatoma maxima were recorded than after restoration. The latter may also be of importance for the development of diatoms.

The biomass of *Melosira*, *Synedra* and *Nitzschia* was plotted against the temperature to see if these diatoms, which were the most frequent diatoms in Lake Trummen, were favoured during certain temperature conditions (Fig 46). They appeared from 0.1 to 24^{o}C and high biomasses could be recorded between 2 and 20^{o}C. However, they were most frequent between 8 and 18^{o}C. Conversely, Chrysophyceae were most frequent within the temperature range 0.5 to 10^{o}C.

These results indicate that many factors may be responsible for influencing seasonal distribution of diatoms, but probably a combination of biotic, abiotic and climatic factors is involved. The qualitative and quantitative reduction of blue-green algae is easier to explain by a decrease in nutrients induced by the restoration.

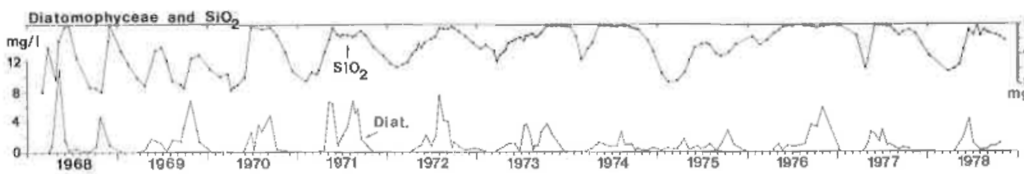


Fig 45. Biomass of diatoms and concentrations of SiO_2, Lake Trummen 1968-1978.

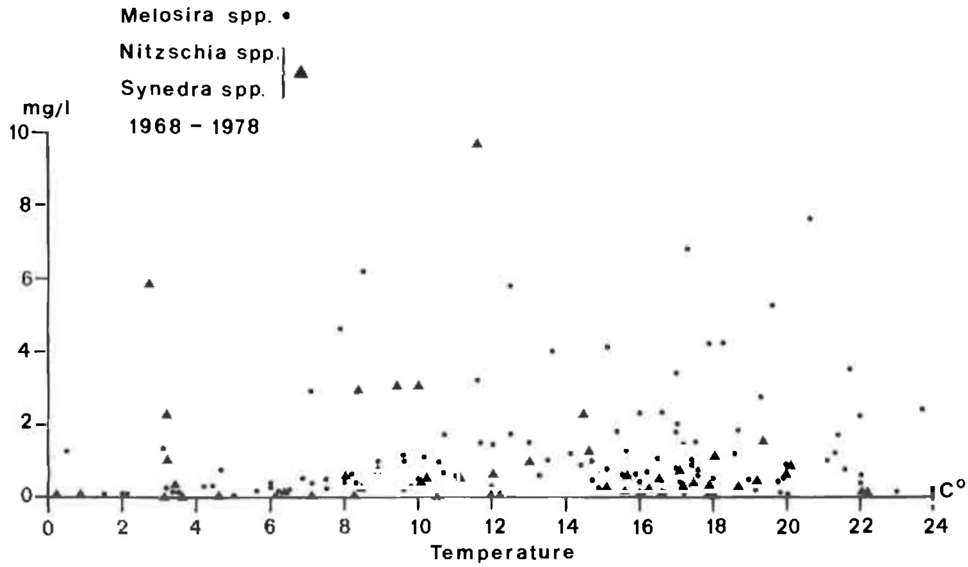


Fig 46 a. Biomass of diatoms and water temperature, Lake Trummen, 1968-1978.

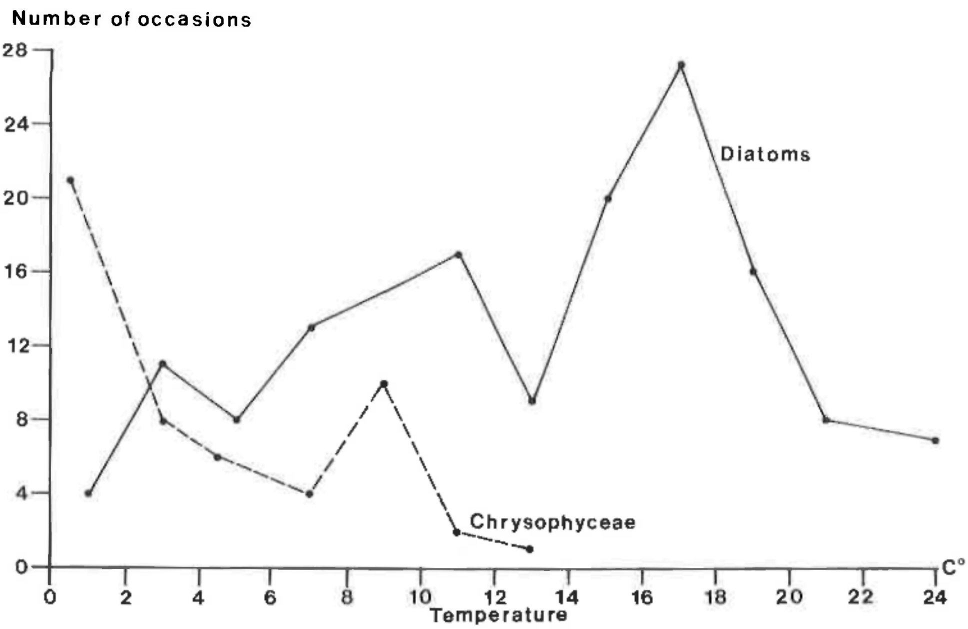


Fig 46 b. Number of occasions when diatoms and Chrysophyceae were present in countable amounts at different temperatures, 1968-1978.

4) Inoculation of algae to plankton from sediment and macrophytes

As seen in e.g. Fig 42 the sediment removal caused a dramatic reduction in nutrient concentrations. At the same time as the top sediment layer was removed, cysts, spores, auxospores, zygots, hormogonia, etc., resting cells of algae and other organisms belonging to the actual plankton community also were eliminated.

Before restoration the sediment in Lake Trummen was periodically anaerobic up to the surface layer, e.g. during warm summer days and in winter when the lake was ice-covered. After restoration the oxygen conditions have improved considerably (Andersson 1979 b). Some blue-green algae (*Microcystis* spp.) are reported to survive better under anaerobic conditions (Sirenkov *et al.* 1969). The disappearance of the heavy blooms of *Microcystis* in connection with the restoration may at least partly be a result of the improved oxygen conditions.

The cysts and other resting cells can survive for many years in the sediment, before they "hatch". In the polluted Lake Trummen the sedimentation rate was 8 mm/year (Digerfeldt 1972) and cells were rapidly covered in the sediment. Once burried they may have been prevented from germinating.

In sediments algae with visible chloroplasts can be viable for many years. Stockner & Lund (1970) investigated the viability of algae in sediment cores from different lakes in the English Lake District (Ullswater, Esthwaite Water and Windermere, South Basin). They tested the viability through culturing algae from the cores and found viable diatom cells from samples with an age of 175-275 years. Livingstone & Jaworski (1980) succeeded in growing *Aphanizomenon* and *Anabaena* akinetes from sediment with an age of up to 18 and 64 years, respectively. They showed that akinetes of blue-green algae have not only a temporary or overwintering function but may also ensure long-term survival.

When the top sediment layer was removed from Lake Trummen old sediment surfaces were exposed. Bengtsson & Fleischer (1971) showed that the exposed brown sediment was nutrient poor and similar to the sediment in the nearby intact oligotrophic Lake Hinnasjön, used as a reference lake to Lake Trummen. No investigation was made to test if the diaspores deposited in the brown sediment were still viable.

After restoration some species, such as *Oscillatoria agardhii*, *Raphidiopsis mediterranea*, *Aphanizomenon flos-aquae* and *Anabaena solitaria* f. *smithii*, disappeared completely and some species decreased drastically, e.g. *Microcystis aeruginosa* and *Anabaena spiroides*. It is most probable that akinetes and hormogonia of these species were removed together with the sediment.

It is most likely that the "new" bottom uncovered in the restored Lake Trummen did contain only few resting cells of eutrophic species. After restoration another blue-green algal community was established with *Aphanocapsa delicatissima*, *Aphanothece clathrata*, *Anabaena viguieri* and *A. lemmermannii* as dominating species. Especially *Aphanothece clathrata* and *Anabaena lemmermannii* are common in adjacent oligotrophic lakes.

Based on palaeolimnological investigations (Digerfeldt 1975, 1977 and Battarbee & Digerfeldt 1976) Lake Växjösjön is known to have similar limnological and phytoplankton record as Lake Trummen. In connection with these investigations this author studied algal remains (diatoms excluded) in a sediment core from the surface down to 2.6 m depth (present time to 1100 AD). The investigation gave many interesting results (Cronberg 1980, 1981) for comparison with Lake Trummen. Chlorococcal green algae and cysts of Chrysophyceae were identified and counted. Best preserved were species of the genera *Pediastrum*, *Scenedesmus*, *Anabaena* (Fig 47) and *Mallomonas* (Fig 48).

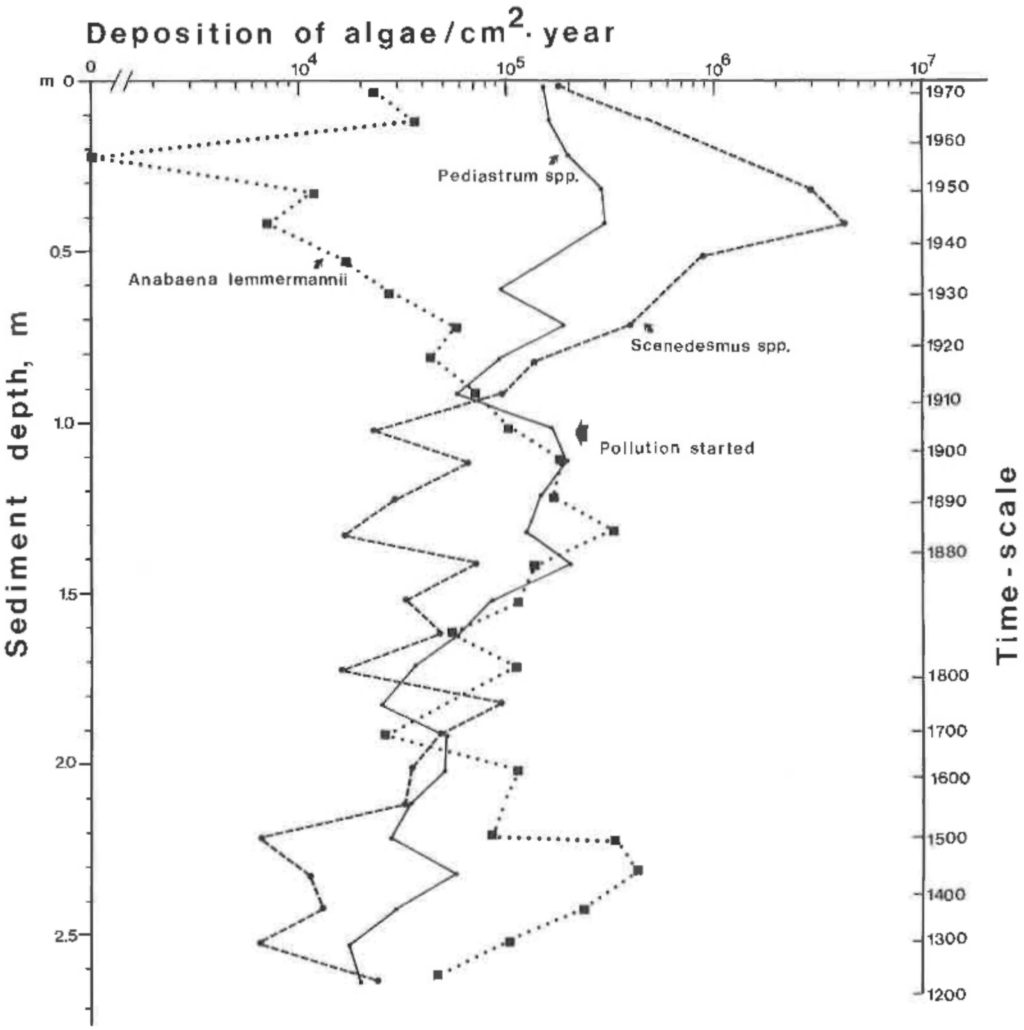


Fig 47. Deposition of algae/cm^2·year in Lake Växsjösjön 1200-1970.

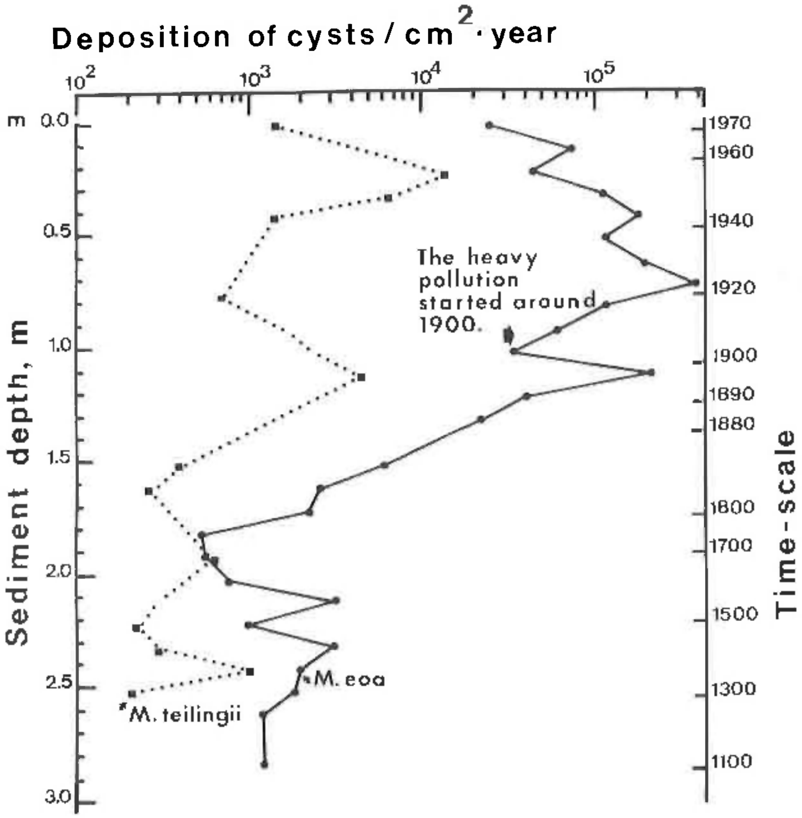


Fig 48. Deposition of *Mallomonas* cysts/cm^2·year in Lake Växjösjön 1100-1970.

The quantitative development of *Anabaena lemmermannii*, *Pediastrum* and *Scenedesmus* was quite stable until the beginning of this century when the pollution started. Between 1900 and 1910 the algal community changed. The number of *Scenedesmus* species increased much, reached maximum in 1940-1950 and then decreased again. *Anabaena lemmermannii* reacted in the opposite direction. This alga almost disappeared from the lake between 1950 and 1960 but increased later. *Pediastrum* increased continuously until 1940-1950. *Scenedesmus* and *Pediastrum* thus reacted positively to pollution and increased, while *Anabaena* reacted in the opposite way and disappeared during the worst pollution period.

Before restoration of Lake Trummen both *Scenedesmus* and *Pediastrum* were most common, but decreased after restoration. *Anabaena lemmermannii* was found only after restoration and then in increasing numbers.

In spring, 1971, i.e. after the suction dredging of Lake Trummen, large maxima of *Synura* and especially *Mallomonas eoa* appeared. If we look at the Lake Växjösjön sediment core (Fig 48), we can see at about 0.5 - 1.0 m depth that *Mallomonas eoa* was very frequent. It can be assumed that Lake Trummen had a similar cyst layer beneath the removed top layer and that a new bottom very rich in cysts was exposed. In the spring, 1971, when the conditions were appropriate, these cysts hatched and developed a maximum. Chrysophyceae cysts are very resistant, probably more resistant than diatoms, and it is, therefore, most likely that the rich population of *M. eoa* arose from old cysts.

Before restoration Björk & Digerfeldt (1965) reported a rich population of *Synura petersenii* in Lake Trummen during early spring. In 1971 it appeared in large quantities and formed blooms. In spring 1972 few *S. petersenii* were recorded, but instead *S. spinosa* was most common. In spring 1974 the largest population of *Synura* during the whole investigation period was recorded. The dominant species at this time was *S. echinulata*. Only few *S. spinosa* occurred and *S. petersenii* was very rare. From 1974 *S. echinulata* is the most common *Synura* species in Lake Trummen, while in surrounding eutrophic or slightly polluted lakes *S. petersenii* is most frequent. Kristiansen (1975) found that *S. petersenii* is the most common *Synura* species in Denmark, while the other species mentioned above have a more restricted distribution.

Munch (1980) investigated diatoms and scales of Chrysophyceae in sediments from Hall Lake, Washington, USA. She found that before the European settlement in the area at the end of the last century, the lake was oligotrophic with a rich development of *Mallomonas caudata* and *M. crassisquama*. The oligotrophic lake was after arrival of Europeans influenced by human activities, *Mallomonas caudata* disappeared first, while *Synura lapponica* and *S. echinulata* increased. At that time the lake was probably acidified because of wood-cutting and pollution from a sawmill. In 1963 a road was constructed around the lake. Due to changes in environmental conditions *M. crassisquama* disappeared and *S. spinosa* and later *S. petersenii* increased. Obviously *S. petersenii* replaced the other more oligotrophic *Synura* and *Mallomonas* species. In summary, Munch (*op. cit.*) found that the Chrysophyceae flora changed due to eutrophication.In Lake Trummen the reverse adjustment was recorded, i.e. *Synura petersenii* was replaced by more oligotrophic species, viz. *S. spinosa* and *S. echinulata*.

During 1971 many diatoms and chlorococcal green algae of different genera appeared in Lake Trummen. This was probably a result of the removal of macrophyte vegetation (rooted and plaur formations). In the littoral zone many periphytic and benthic algae were growing. When the macrophytes were removed these algae were dispersed into the water. In 1971 the largest number of benthic diatoms were recorded in the lake. *Pediastrum* also increased and the highest maximum for this genus was recorded. Many species of *Pediastrum* and *Scenedesmus* are more periphytic and benthic than planktic and were most common during circulation periods in spring and autumn with the exception for 1971 (*cf.* Korde 1961, p. 527; Parra 1979, p. 130).

The occurrence of different species of *Pediastrum* and their distribution in Lake Växjösjön sediment was studied (Fig 47 and 49). *Pediastrum* increased slightly from 2.5 m depth and upwards to the sediment surface. The percentage distribution of *Pediastrum* species was rather constant from 2.6 to 1.4 m (corresponding to the period 1300-1800). Further upwards changes occurred as *P. boryanum* var. *pseudoglabrum* and

P. boryanum var. *boryanum* increased in number, while *P. angulosum* decreased and nearly disappeared from the lake. *P. duplex* was reduced around 1910, when the heavy pollution started.

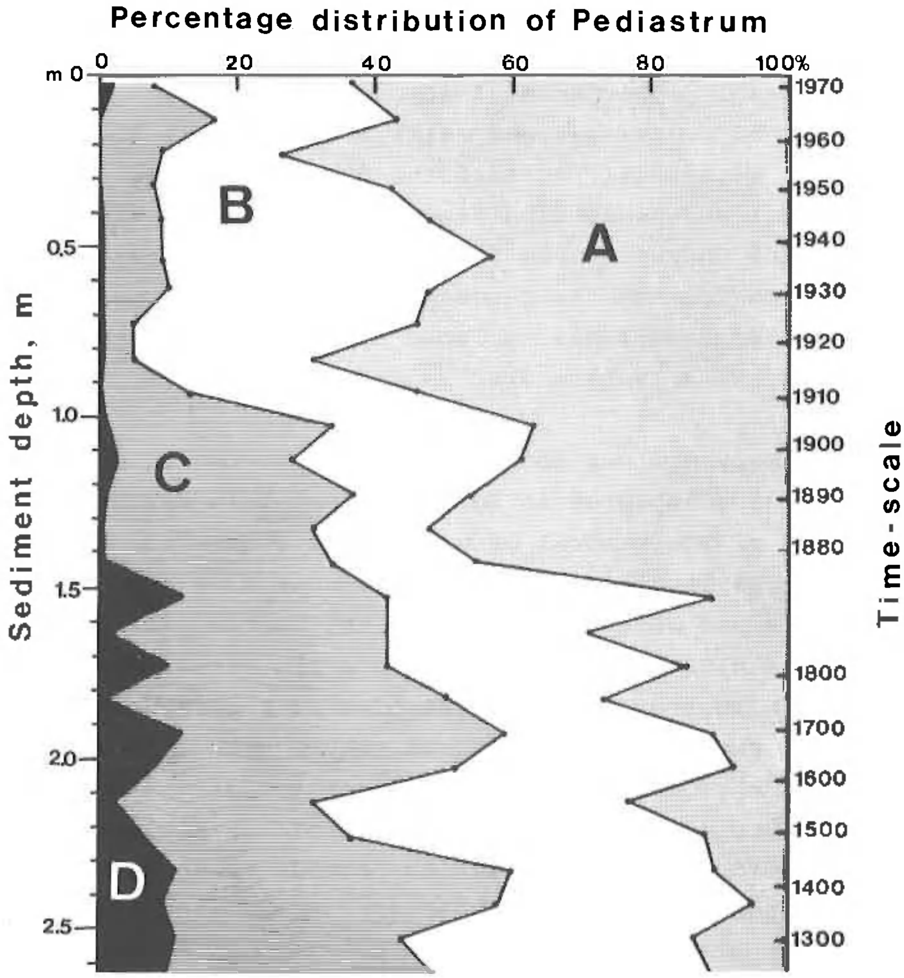


Fig 49. Percentage distribution of the genus *Pediastrum* in the sediment of Lake Växjösjön.

A. *Pediastrum boryanum* var. *pseudoglabrum*.
B. *P. boryanum* var. *boryanum*.
C. *P. duplex*, *P. tetras* and undetermined damaged coenobia.
D. *P. angulosum*.

In Lake Trummen the opposite development has occurred in connection with the restoration. *Pediastrum boryanum* has decreased and was replaced by *P. duplex* and *P. biradiatum*. During the early 1980's *P. angulosum* has reappeared. The investigations in the lakes Växjösjön and Trummen have shown that the *Pediastrum* species have quite different environmental requirements. The most eutrophic species is *P. boryanum* var. *pseudoglabrum*, whereas *P. boryanum* var. *boryanum* and *P. duplex* have lower nutrient demands. *P. angulosum* is an oligotrophic species, being the most common *Pediastrum* species in adjacent oligotrophic lakes.

5) Interactions of fish and zooplankton

In the enclosure experiments with different species of fish and without fish the results were in accordance with earlier experiences (Hrbáček 1962, Brooks & Dodson 1965). The predation of planktivorous fish resulted in zooplankton communities dominated by rotifers and some large cladocerans. The phytoplankton community changed and the biomass of bluegreens increased. When fish were absent the herbivorous zooplankton increased in abundance while the biomass of phytoplankton was reduced. Only small populations of different cryptomonads were present. Presence of fish also affected the chemical and physical conditions in the enclosures. Tot-P and tot-N increased while the Secchi disc transparency decreased.

When enclosures were stocked with different species of fish, different results were obtained. Bream and roach together caused the largest effect in terms of eutrophication. The phytoplankton community appearing in the bream plus roach enclosure was similar to that in Lake Trummen before restoration. Bream and roach separately affected the system in the same direction but not to the same degree.

The activity of bream browsing for food in the sediment resulted in release of nutrients and dispersal of benthic algae into the water. The turbidity increased and more chlorococcal green algae appeared.

The stocking with perch resulted in more oligotrophic conditions characterized by large herbivorous zooplankters and small phytoplankton populations of cryptomonads. In the experiments in Lake Trummen and Lake Bysjön (Andersson *et al.* 1978) the effect of fish was similar. Shapiro *et al.* (1975), however, got the reverse result in their experiments with perch, viz. an increase in algal biomass. This might depend on the fact that they used fingerling perch with the similar food habits as roach, while perch of larger size, predating on copepods, was used in Lake Trummen. Shapiro *et al.* (*op. cit.*) got increased chlorophyll concentrations but they have not given any information about the species composition of phytoplankton.

J. Fott (1975) recorded that during the spring of 1972 a reduction in phytoplankton biomass occurred in Smyslov Pond. During this period the prevailing algae were small cryptomonads and the zooplankton community was dominated by large filter feeders, namely *Daphnia pulicaria* and *D. hyalina*. These zooplankters were grazing heavily on the phytoplankton. Fott made *in situ* enclosure studies on phytoplankton and *Daphnia* from the lake. He found that the elimination rate by zooplankton was in balance with the growth rate of cryptomonads (1.0-1.3 doublings/day). Therefore, a small population of cryptomonads could be maintained in spite of the heavy grazing pressure.

The enclosure without fish and that with perch developed similar plankton composition. The blue-green algae community was replaced by cryptomonads. The maintenance of the population of cryptomonads in the enclosures with perch and without fish as well as in the lake after the fish kill in 1970 might be explained in the same way. As seen above, the food habits of fish and zooplankton (Porter 1977) could regulate the frequency and species composition of phytoplankton both in the enclosure and in the lake.

Concluding comments

Through the restoration of Lake Trummen the nutrient concentrations were reduced drastically in 1970-1971 and a stability in the ecosystem seemed to have been achieved 1972-1974. In 1975 the blue-green alga *Cyanodictyon imperfectum* formed blooms the whole summer and a slight increase in nutrient concentrations was recorded. In spring that year coarse fish immigrated upstream from Lake Växjösjön to Lake Trummen. The increased predation of fish on zooplankton together with the warm summer was probably the causes of this blue-green algal bloom.

From the results in this study it is obvious that the restoration induced enormous changes in the phytoplankton community. The external loading was eliminated in 1958, but no real improvements were observed. The lake had been loaded with an up to 0.5 m thick nutrient-rich sediment and a luxuriant macrophyte vegetation. The nutrients deposited in the sediments and assimilated by the macrophyte vegetation recirculated within the ecosystem.

When sewage water from the polluted Lake Norrviken outside Stockholm (Ahlgren 1978, Ahlgren *et al.* 1979) was diverted 1969-1970, the conditions in the lake improved and the lake successively recovered. The nutrient concentrations decreased while the species diversity of phytoplankton increased (Tinnberg 1979). Ahlgren *et al.* (*op. cit.*) showed that the recovery of Lake Norrviken was initially caused by a dilution and later by decreased release of nutrients from the sediments.

The restoration of Lake Trummen caused an extremely rapid decrease in nutrients and phytoplankton biomass (Fig 42 - 44). The suction dredging of the nutrient-rich sediment (1970-1971) and the removal of macrophyte vegetation (1971) induced the change from a hypertrophic to a eutrophic lake, which successively is approaching the state characteristic for the surrounding oligotrophic lakes.

The combination of sudden nutrient reduction and alterations in the presence of diaspores caused instant changes in the phytoplankton community. The following successive changes are results of adjustments in the interrelations within the ecosystem. The results from the food-web experiments indicate that control of fish populations can be useful in lake management. In investigations of this kind the climatic variations cause temporal changes, a "background noise", possibly to distinguish only in long-term studies.

SUMMARY

A. WHOLE-LAKE STUDY (Fig 50, Appendix III; Fig 1-12)

1. Before restoration high phytoplankton biomass was recorded, especially during the summer. After restoration the biomass was reduced by 75 % as calculated from mean annual values.

2. Before restoration the blue-green algae formed dense blooms from June to September. After restoration their biomass decreased drastically by 85 %. Some species disappeared completely, viz. *Anabaena solitaria* f. *smithii*, *Aphanizomenon flos-aquae* and *Raphidiopsis mediterranea*. Other species, as *Anabaena spiroides* f. *crassa*, *A. spiroides* f. *spiroides* and *Microcystis* spp. showed reduced biomass. Furthermore, some species increased in biomass, which was true for *Anabaena lemmermannii*, *Aphanocapsa delicatissima*, *Aphanothece clathrata* and new species were recorded, viz. *Cyanodictyon imperfectum*, *Oscillatoria limnetica* var. *acicularis* and *Synechococcus vantieghemi*. Among the algae new to Lake Trummen *Cyanodictyon* occasionally formed blooms.

   After restoration the number of species belonging to Chroococcales diminished, while the number of Nostocales remained more or less unchanged.

   In connection with the restoration the blue-green algal flora changed character, as large-sized species were replaced by small-sized species, e.g. *Aphanizomenon flos-aquae* by *A. gracile*, *Microcystis* spp. by *Aphanothece clathrata* and *Aphanocapsa delicatissima*, *Anabaena spiroides* by *A. lemmermannii*, *Oscillatoria agardhii* by *O. limnetica* var. *acicularis*, and *Anabaena solitaria* f. *smithii* by *A. viguieri*.

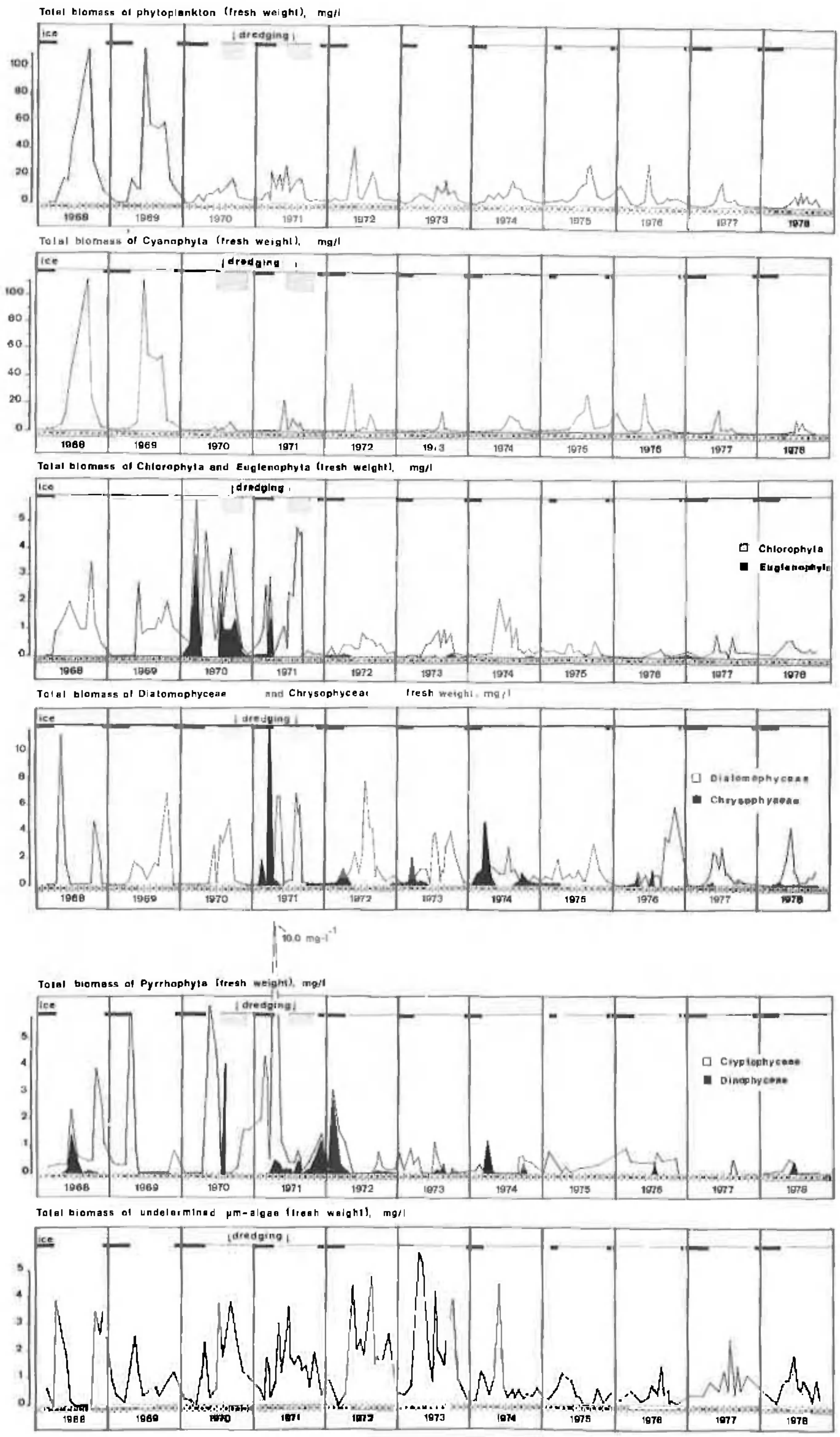


Fig 50. Phytoplankton biomass in different groups of algae, Lake Trummen, 1968-1978. Note the different scales.

3. Before restoration the biomass of green algae was high. It increased during the restoration period, but afterwards it decreased gradually. Before restoration green algal biomass was high during spring and autumn. After restoration green algae became more common during summer. Species belonging to Chlorococcales were far the most frequent green algae, but after restoration their number successively decreased. This is the case with *Pediastrum boryanum*, while *P. biradiatum* and *P. angulosum* increased. The number of *Scenedesmus* was reduced and changes in species composition were recorded within this genus. The coenobia of Chlorococcales have diminished in size after restoration. Some eutrophic green algae showed considerable decrease as, for example, *Chlamydomonas* spp., *Micractinium pusillum*, *Golenkinia radiata* and *Chlorella*. The desmids, on the other hand, increased after restoration both qualitatively and quantitatively. The oligotrophic species *Staurastrum pseudopelagicum* appeared after restoration together with some *Staurodesmus*.

4. Before restoration the Euglenophyta were not observed but appeared frequently during the restoration. From 1972 to 1978 they were recorded during the cold period of the year, with low biomass. Most common species were *Trachelomonas* spp.

5. Before restoration only a few Chrysophyceae were found. *Synura petersenii* was recorded by Björk & Digerfeldt (1965) in Lake Trummen during spring 1961. The first spring after restoration, however, a drastic increase in *Synura petersenii* and *Mallomonas eoa* was recorded. The maximum appeared just before the break-up of the ice.

   Since 1971 Chrysophyceae have been recorded in early spring, sometimes when the lake was still covered by ice. The spring maxima have, however, successively declined quantitatively year by year. The number of *Dinobryon* spp. and *Mallomonas* spp. have increased during the summer. Before restoration 11 species were recorded, while now about 50 species are found.

6. Before restoration the diatoms appeared in spring and autumn with high biomass. After restoration they became more frequent during summer but with reduced biomass. *Melosira* spp. have been the most common diatom all the time. Before restoration *Stephanodiscus hantzschii* was frequent. During the last years the frequency of this species has, however, decreased.

7. Before restoration high cryptomonad biomass was recorded during spring and autumn. During the restoration period (1970-1971) large cryptomonads were most frequent during summer. In 1977-1978 the biomass was reduced and large cryptomonads were replaced by small ones, e.g. *Chroomonas acuta*.

   The representation of Dinophyceae (*Gymnodinium*, *Sphaerodinium*) has been reduced after restoration. During the last years more oligotrophic species have appeared, i.e. *Peridinium inconspicuum* and *P. cunningtonii*.

8. The collective group "undetermined µm-algae" had a high biomass before and during restoration. From 1975 and onwards they have decreased in number and at present mainly small species contribute to the biomass.

9. The species diversity was low before restoration. It increased during restoration, but then the diversity again decreased, especially in 1975, when *Cyanodictyon imperfectum* formed a dense bloom.

10. The species composition has changed in connection with

the restoration. Totally, the number of Chroococcales and Chlorococcales has been reduced. On the other hand the number of planktic species, especially of the Chrysophyceae, have increased. Species characteristic of very eutrophic lakes have disappeared and many species common in adjacent oligotrophic lakes have been recorded also in Lake Trummen during the last years.

11. The sediment analyses in Lake Växjösjön revealed changes in the phytoplankton community in connection with pollution and eutrophication. The plankton investigations in Lake Trummen have recorded the reverse development, i.e. the changes taking place in connection with oligotrophication following restoration.

12. The phytoplankton community structure clearly indicates that restoration implied a meiotrophication. The changes continually taking place after the restoration follow the same trend.

B. FOOD-WEB EXPERIMENTS (Appendix III; Fig 13-18)

In the experiments with fish population control the plankton development in enclosures has been compared with that in the lake.

1975-1976

The tentative enclosure experiments 1975 and 1976 showed that phytoplankton developed differently in the two enclosures (Fig 36), namely:

1. In the enclosure with fish (bream and roach) the blue-green algae increased and formed blooms. The zooplankton was dominated by *Chydorus sphaericus*, *Bosmina longirostris* and many rotifers.

2. In the enclosure without fish a reduction in phytoplankton biomass was recorded. The blue-green algae disappeared and were replaced by small cryptomonads 1975, and a mixed population of blue-greens, green algae and cryptomonads, 1976 (Fig 37). *Daphnia cucullata* increased while rotifers decreased. When the predation from fish was eliminated, the daphnids developed and the grazing on phytoplankton was nearly complete.

1977-1978

In the experiments of 1977 and 1978 the enclosures were stocked with different species of fish (Table 7). The aim of the experiments was to see if there was a selective predation on zooplankton and zoobenthos and how this affected the phytoplankton.

1. Bream plus roach resulted in an increase in the biomass of blue-green algae. A plankton bloom appeared with *Microcystis aeruginosa* and *Oscillatoria agardhii* as the most frequent species after two months (Fig 39). Many chlorococcal green algae were also recorded. The zooplankton was dominated by small Cladocera, *Chydorus sphaericus*, and rotifers. The concentrations of tot-P and tot-N increased, eutrophication took place and the conditions in the enclosure were approaching those of Lake Trummen before restoration with *Microcystis* and *Oscillatoria* bloom. The effect of bream was quite clear. This fish was searching for food in the sediment. The activity resulted in an increase in nutrients and a development of chlorococcal green algae.

2. Bream and roach restricted from the sediment did not cause any increase in phytoplankton biomass or nutrients (Fig 39). On the contrary the biomass of phytoplankton decreased and small cryptomonads became most frequent. Zooplankton was

dominated by small Cladocera, *Chydorus sphaericus*, *Bosmina longirostris* and rotifers.

3. In the enclosure with bream the nutrient concentrations of tot-P and tot-N was high. Dense populations of blue-green and green algae developed in the enclosure during the experimental period. Most common zooplankters were *Bosmina longirostris*, *Chydorus sphaericus* and small rotifers.

4. In the enclosure with roach, blue-green algae and cryptomonads dominated. Concentrations of tot-P, tot-N and phytoplankton biomass was lower than in enclosures with bream plus roach or only bream, but higher than in that with perch. The number of Cladocera was low while rotifers were numerous. Dominating zooplankton species were *Bosmina longirostris* and *Filinia longiseta*.

5. The enclosure with perch resulted in a reduction in nutrients and phytoplankton biomass (Fig 39). Blue-green algae disappeared totally and were replaced by small cryptomonads. Zooplankton was dominated by large *Daphnia cucullata*.

6. The enclosure without fish gave similar results as the enclosure with perch (Fig 39). Phytoplankton biomass was reduced. A small population of cryptomonads was maintained during the whole experimental period and even chrysomonads appeared. *Daphnia cucullata* increased and dominated.

7. The results from the experimental series clearly showed that bream and roach together caused a eutrophication and resulted in conditions approaching Lake Trummen before restoration, i.e. high nutrient concentrations, high biomass of phytoplankton - blue-greens and chlorococcal green algae - and large numbers of small Cladocera and rotifers.

8. On the other hand in enclosures without fish or perch oligotrophication took place. The number of *Daphnia* increased and the grazing of phytoplankton resulted in a reduction in algal biomass and nutrient concentrations.

9. In the enclosures with fish the macrobenthos decreased. Oligochaeta and Chironomidae dominated and the predation on these groups were non-selective. Especially bream searched for food in the sediments.

10. In the fish-free enclosure, densities of macrobenthos increased, as they were not exposed to predation. In the lake itself this did not occur during the investigation period.

C. WHOLE-LAKE EXPERIMENT

The whole-lake experimental reduction of coarse fish by selective removal resulted in reduced tot-P and tot-N concentrations, increased number of Cladocera (Andersson 1979 a) and some reduction in phytoplankton biomass. The whole-lake experiment is still (1980) going on and can therefore not yet be fully evaluated.

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APPENDIX I

List of species

Table 1–7

Table 1. THE OCCURRENCE OF PHYTOPLANKTON IN LAKE TRUMMEN, 1968-1978, IN RELATION TO RESTORATION.

D = dominant, 3 = very common, 2 = common, 1 = single and - = not recorded.

	Before		During		After						
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
BACTERIOPHYTA											
Beggiatoa alba (Vaucher) Trevis.	1	-	-	-	-	1	1	-	-	-	-
Gallionella ferruginea Ehrenb.	-	-	-	1	-	-	-	-	-	-	-
Planctomyces bekefii Gimesi	1	1	1	1	1	2	2	1	1	1	1
CYANOPHYTA											
Chroococcales											
Aphanocapsa delicatissima W. et G.S. West	2	3	2	2	2	2	2	1	2	2	1
A. elachista W. et G.S. West	1	1	-	-	-	-	-	-	-	-	-
A. pulchra (Kütz.) Rabenh.	2	2	2	1	-	-	-	-	-	-	-
Aphanothece clathrata W. et G.S. West	3	2	2	2	2	2	2	2	3	3	3
A. ellipsoidea (Schröd.) Bourr.	-	-	1	-	2	-	-	-	1	-	-
A. nidulans P. Richt.	1	1	-	-	-	-	-	-	1	-	-
A. nidulans var. endophytica W. et G.S. West	2	2	1	1	1	1	1	1	1	1	1
A. stagnina (Spreng.) Brunnt.	1	1	1	-	-	1	-	-	-	-	-
Chroococcus limneticus Lemm.	3	2	2	-	1	1	2	1	-	1	-
C. minimus (Keissl.) Lemm.	1	1	1	-	-	1	-	-	-	-	-
C. minutus (Kütz.) Näg.	2	1	2	1	1	-	1	-	-	-	-
C. turgidus (Kütz.) Naeg.	1	-	-	-	-	1	-	1	-	-	-
Cyanodictyon imperfectum Cronb. et Weib.	-	-	-	-	-	-	1	D	2	-	-
Gomphosphaeria lacustris Chod.	1	-	-	-	-	-	1	1	-	1	2
G. naegeliana (Ung.) Lemm.	2	2	2	2	2	-	2	2	1	1	1
Merismopedia tenuissima Lemm.	3	2	-	-	-	-	-	-	-	-	-
M. glauca (Ehrenb.) Kütz.	-	1	1	-	-	-	-	-	-	-	-
Microcystis aeruginosa Kütz.	D	D	2	2	1	1	1	1	1	1	1
M. incerta Lemm.	2	-	-	-	-	-	1	1	-	1	-
M. viridis (Brunnt.) Lemm.	3	3	2	2	1	1	1	1	1	1	1
M. wesenbergii Kom. in Kondr.	3	3	1	2	1	-	2	2	2	1	1
Synechococcus vantieghemi (Pringsh.) Bourr.	-	1	-	-	1	-	3	-	-	-	-
Nostocales											
Anabaena lemmermannii P. Richt.	2	2	1	1	2	2	2	1	1	1	1
A. solitaria f. smithii Kom.	3	3	2	2	2	1	1	1	-	1	-
A. spiroides var. crassa Lemm.	2	2	-	-	-	-	-	-	-	-	-
A. spiroides var. spiroides Kleb.	D	3	1	1	1	1	2	1	-	1	1
A. viguieri Denis et Frémy	-	-	-	-	-	-	3	3	1	1	2
Aphanizomenon flos-aquae (L.) Ralfs	3	D	1	1	-	-	-	-	-	-	-
A. gracile Lemm.	-	-	-	-	1	1	3	2	3	1	1
Lyngbya limnetica Lemm.	3	3	2	1	1	1	1	2	1	2	1
Oscillatoria agardhii Gom.	D	2	1	1	-	-	-	-	-	-	-
O. limnetica Lemm.	1	1	1	1	1	1	1	1	1	1	1
O. limnetica var. acicularis Nygaard	1	-	1	-	-	1	-	1	1	2	2
O. tenuis Ag.	1	-	1	-	-	-	1	-	1	-	-
Pseudanabaena mucicola (Naum. et Hub.) Bourr.	2	2	1	1	1	1	1	1	1	1	1
Raphidiopsis mediterranea Skuja	D	3	1	1	-	1	-	-	-	-	-

Table 2. THE OCCURRENCE OF PHYTOPLANKTON IN LAKE TRUMMEN, 1968-1978, IN RELATION TO RESTORATION.

D = dominant, 3 = very common, 2 = common, 1 = single and - = not recorded.

	Before		During		After						
CHLOROPHYTA	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Volvocales											
Aulacomonas hyalina Skuja	1	-	-	-	-	-	-	-	-	-	-
Carteria sp.	-	-	-	-	-	1	-	1	1	-	-
Chlamydomonas subcaudata Wille	-	1	-	-	-	1	-	-	-	-	-
Chlamydomonas spp.	3	3	3	2	1	1	1	1	1	1	1
Chlorogonium maximum Skuja	1	-	-	1	1	1	1	1	1	1	-
Eudorina elegans Ehrenb.	1	1	2	2	1	-	-	1	-	-	-
Gonium pectorale O.F. Müller	-	-	-	1	-	-	-	-	-	-	-
G. sociale (Duj) Warming	2	1	-	-	-	-	-	-	-	-	-
Pandorina morum Bory	1	-	-	-	-	-	-	1	-	-	-
Phacotus lenticularis (Ehrenb.) Stein	-	-	-	-	-	1	-	-	-	-	-
Pteromonas aculeata Lemm.	1	1	-	-	-	-	-	-	1	-	-
P. angulosa Lemm.	-	-	1	-	-	-	-	-	-	-	-
P. rectangularis Lemm.	1	-	-	-	-	-	-	-	-	-	-
Scourfieldia complanata G.S. West	1	2	2	1	1	1	1	2	1	1	1
Spermatozopsis exultans Korch.	-	-	-	-	-	-	-	-	1	-	-
Sphaerellopsis fluviatilis (Stein) Pasch.	-	-	-	-	-	-	-	-	-	1	-
Volvox aureus Ehrenb.	-	-	-	-	-	-	-	1	1	-	-
Tetrasporales											
Chlamydocapsa planctonica (W. et G.S. West) Fott	1	-	1	1	1	-	-	-	-	-	-
Paulschulzia pseudovolvox (Schulz) Skuja	-	-	-	-	1	-	-	-	-	-	-
Pseudosphaerocystis lacustris (Lemm.) Novak	-	-	-	-	-	1	-	-	-	-	-
Chlorococcales											
Actinastrum hantzschii Lagerh.	2	2	1	-	-	-	-	-	-	-	1
Ankistrodesmus bibraianus (Reinsch) Korsh.	2	2	-	1	1	2	1	2	1	1	1
A. falcatus (Corda) Ralfs.	2	-	2	1	1	1	-	1	-	1	-
A. gracilis (Reinsch) Korsh.	2	2	1	1	1	2	1	1	1	1	1
Ankistrodesmus nannoselene Skuja	-	-	1	-	1	1	-	-	1	1	1
Ankyra ankora (G.M. Smith) Fott	-	-	-	-	-	-	-	-	-	1	-
Botryococcus braunii Kütz.	-	-	1	1	1	2	2	1	-	1	1
Chodatella chodatii Bern.	-	-	1	-	-	-	-	-	-	-	-
C. citriformis (Snow) G.M. Smith	2	2	1	-	-	1	1	1	1	-	-
C. genevensis Chod.	-	-	-	-	-	-	-	1	2	-	-
C. griffithsii Fott	1	1	-	-	1	-	-	-	-	1	-
C. longiseta (Lemm.) Wille	1	-	-	-	-	-	-	-	-	-	-
C. subsalsa Lemm.	1	-	-	-	-	-	-	-	-	-	-
Chlorella sp.	-	-	D	-	-	-	-	-	-	-	-
Coelastrum cambricum Archer	2	1	-	-	-	1	-	-	-	-	-
C. reticulatum (Dang.) Senn.	1	-	-	-	-	-	-	-	-	-	-
C. sphaericum Nag.	2	3	2	1	2	2	1	2	1	1	1
Crucigenia fenestrata (Schmidle) Schmidle	-	-	-	-	1	-	-	-	-	-	-
C. quadrata Morren	1	-	-	-	-	-	-	-	-	-	-
C. tetrapedia (Kirchn.) W. et G.S. West	1	1	1	-	1	-	-	-	-	-	1
Crucigeniella apiculata (Lemm.) Kom.	-	-	-	-	-	-	-	1	-	-	-
C. pulchra (W. et G.S. West) Kom.	-	-	-	-	1	-	-	-	-	-	-
C. rectangularis (Näg.) Kom.	-	-	1	-	1	-	-	-	1	-	-
Dictyosphaerium ehrenbergianum Näg.	1	-	1	-	1	1	1	1	-	-	-
D. elegans Bachm.	1	1	1	1	-	1	-	-	-	-	-
D. pulchellum Wood	3	2	3	2	2	3	2	3	2	2	2
Elakatothrix gelatinosa Wille	1	-	1	-	1	-	-	1	-	1	1
Franceia ovata (France) Lemm.	-	-	1	-	-	-	1	-	-	-	1
Golenkinia radiata Chod.	2	3	2	-	1	1	-	-	-	1	1

Table 3. THE OCCURRENCE OF PHYTOPLANKTON IN LAKE TR.MMEN, 1968-1978, IN RELATION TO RESTORATION.

D = dominant, 3 = very common, 2 = common, 1 = single and - = not recorded.

	Before		During		After						
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Kirchneriella contorta (Schmidle) Bohl.	1	1	-	-	1	1	-	-	1	1	-
K. lunaris (Kirchn.) Möb.	2	2	1	-	2	1	-	-	1	1	1
K. obesa (W. West) Schmidle	1	2	2	1	-	1	1	1	-	-	-
Micractinium pusillum Fres.	3	3	3	3	2	3	2	3	2	1	1
Monoraphidium arcuatum (Korsh.) Hind.	-	-	-	-	-	-	-	-	-	1	-
M.contortum (Turp.) Kom.- Legn.	2	1	1	-	3	3	2	3	2	2	1
M. setiforme (Nyg.) Kom.-Legn.	2	2	2	1	2	2	2	2	3	2	1
Oocystis lacustris Chod.	2	1	1	1	-	2	2	-	-	1	-
Pediastrum angulosum Racib.	1	1	1	2	2	2	3	3	1	1	3
P. biradiatum Meyen	3	3	2	2	3	3	3	3	2	2	1
P. boryanum (Turp.) Menegh.	3	3	3	2	3	3	3	3	3	2	2
P. duplex Meyen	2	3	3	2	2	3	3	3	2	1	2
P. gracillimum Thunm.	1	2	3	3	-	-	1	1	-	1	1
P. tetras (Ehrenb.) Ralfs	2	2	1	1	1	2	2	2	2	2	1
Polyedriopsis spinulosa (Schmidle) Schmidle	-	-	-	-	-	1	1	-	-	1	1
Scenedesmus abundans (Kirchn.) Chod.	3	3	3	3	2	3	3	3	3	2	2
S. acuminatus (Lagerh.) Chod.	3	3	3	3	3	3	3	3	2	2	2
S. acutus (Meyen) Chod.	2	1	-	-	-	-	-	-	-	-	-
S. arcuatus Lemm.	3	3	2	1	1	1	-	-	-	-	-
S. armatus Chod.	3	3	3	1	-	-	1	1	1	1	1
S. arvernensis Chod.	2	2	2	-	-	-	1	-	-	-	-
S. brasiliensis Bohl.	-	1	-	-	-	-	-	1	-	-	-
S. carinatus (Lemm.) Chod.	2	2	2	1	-	1	2	-	-	1	-
S. costato-granulatus Skuja	-	-	-	-	-	1	-	1	-	-	-
S. denticulatus Lagerh.	2	2	2	1	1	2	2	1	-	1	-
S. dispar (Brēb.) Rabenh.	-	2	1	1	1	2	1	1	1	1	-
S. ecornis (Ralfs) Chod.	1	1	2	-	-	-	-	-	-	-	-
S. intermedius var. bicaudatus Hortob. f.	-	1	-	-	-	-	-	-	-	-	-
S. lefevrii Defl.	1	-	-	1	-	-	1	-	-	1	-
S. oahuensis (Lemm.) G.M. Smith	3	3	2	2	-	1	1	1	-	1	-
S. opoliensis P. Richt.	1	1	1	1	2	2	2	2	1	2	1
S. pannonicus Hortob.	-	1	-	-	-	-	-	-	-	-	-
S. quadricauda (Turp.) Brēb.	3	3	3	2	3	3	3	2	2	1	1
S. quadricauda var. quadrispina (Chod.) G.M. Smith	-	-	-	-	-	-	-	1	-	-	-
S. serratus (Corda) Bohl.	2	1	1	1	1	1	1	1	-	1	-
S. subspicatus Chod.	-	1	-	-	-	-	1	-	1	1	1
Sphaerocystis schroeteri Chod.	-	-	-	-	-	1	-	-	-	-	-
Tetraedron arthrodesmiforme (G.S. West) Wolosz.	1	1	-	-	-	-	-	-	-	-	-
T. caudatum (Corda) Hansg.	2	-	-	1	1	2	1	2	1	1	1
T. incus (Teil.) G.M. Smith	1	-	-	-	-	1	1	-	-	-	-
T. minimum (Brunnt.) Hansg.	3	3	3	1	2	3	3	3	2	1	1
T. triangulare Korsh.	1	1	-	-	-	-	-	-	-	-	-
T. trigonum (Näg.) Hansg.	1	-	1	-	1	1	1	1	1	-	-
Tetrastrum heteracanthum (Nordst.) Chod.	-	-	-	-	-	-	-	1	1	-	-
T. staurogeniaeforme (Schröd.) Lemm.	2	2	-	-	1	1	-	2	-	-	1
Treubaria setigera (Archer) G.M. Smith	1	1	1	1	1	1	1	1	1	1	1

Table 4. THE OCCURRENCE OF PHYTOPLANKTON IN LAKE TRUMMEN, 1968-1978, IN RELATION TO RESTORATION.

D = dominant, 3 = very common, 2 = common, 1 = single and - = not recorded.

	Before		During		After						
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Zygnematales											
Closterium acutum var. variabile (Lemm.) Krieg.	-	-	1	-	1	2	2	2	1	1	1
C. limneticum Lemm.	-	-	1	1	1	1	1	1	-	-	1
C. polystictum Nyg.	-	-	1	-	-	1	-	-	-	-	-
Cosmarium cfr. tenue Archer	-	-	-	-	-	1	1	1	-	-	1
Staurastrum cingulum (W. et G.S. West) G.M. Smith	1	-	-	-	-	1	-	-	-	-	-
S. micron W. et G.S. West	-	-	-	-	1	-	-	1	-	-	-
S. paradoxum var. parvum W. West	2	2	2	1	2	3	2	2	1	2	1
S. polymorphum var. divergens Nyg.	-	-	-	-	-	1	1	-	-	1	-
S. pseudopelagicum W. et G.S. West	-	-	-	-	-	-	1	1	-	-	-
S. tetracerum Ralfs	1	1	1	1	2	1	1	1	-	1	1
S. uplandicum Teil.	1	1	1	-	2	2	2	1	1	1	1
Staurodesmus aversus (Lund.) Lillier	-	-	-	-	-	1	-	-	-	-	-
S. extensus (Borge) Teil.	-	-	1	-	2	2	1	-	-	-	-
S. mammilatus (Nordst.) Teil.	-	-	-	1	-	1	1	1	-	-	-
S. patens (Nordst.) Croasd.	-	-	1	-	1	2	-	1	1	1	-
Teilingia granulata (Roy et Biss.) Bourr.	-	-	-	-	2	2	1	1	1	2	2
EUGLENOPHYTA											
Astasia sp.	-	-	-	-	-	-	1	-	-	-	-
Colacium vesiculosum Ehrenb.	-	1	1	2	1	-	-	-	1	1	-
Euglena acus Ehrenb.	2	2	2	2	2	2	2	1	1	1	-
E. viridis Ehrenb.	-	-	-	1	-	-	-	-	-	-	-
Lepocinclis cymbiformis Playf.	-	-	-	-	-	1	-	-	-	-	-
Phacus contortus Bourr.	-	-	1	1	-	-	-	-	-	-	-
P. ephippion Pochm.	-	-	-	-	1	1	-	1	-	-	-
P. hamatus Pochm.	-	-	-	-	-	1	-	-	-	-	-
P. helikoides Pochm.	-	-	-	-	-	1	-	1	-	1	-
P. pleuronectes (O.F. Muller) Duj.	1	-	-	-	-	-	-	-	-	-	-
P. pyrum (Ehrenb.) Stein	-	-	-	-	-	1	-	1	-	-	-
P. similis Christen	-	-	-	-	2	-	-	-	-	-	-
P. suecicus Lemm.	-	-	1	1	1	1	-	-	-	-	1
P. tortus (Lemm.) Skv.	-	1	1	1	2	1	-	-	-	-	-
P. triqueter (Ehrenb.) Duj.	-	-	-	-	-	-	1	1	-	-	-
Trachelomonas elliptica (Playf.) Defl.	-	-	-	-	-	-	-	-	-	1	-
T. hispida (Perty) Stein em. Defl.	1	1	-	1	1	1	1	-	-	-	-
T. rotunda Swir. em. Defl.	1	2	3	1	-	-	-	-	-	-	-
T. verrucosa Stokes	-	1	1	-	1	2	2	2	2	1	-
T. volvocina Ehrenb.	1	1	1	1	1	2	2	2	2	2	1
PYRRHOPHYTA											
Cryptophyceae											
Chroomonas acuta Uterm.	1	1	2	1	3	2	2	3	3	2	2
Cryptomonas curvata Ehrenb.	2	2	1	1	2	1	1	1	1	1	1
C. erosa Ehrenb.	1	1	1	1	2	2	1	1	1	1	1
C. marssonii Skuja	1	1	1	1	1	1	1	2	2	1	1
C. ovata Ehrenb.	2	2	1	1	1	1	1	1	1	1	1
C. phaseolus Skuja	1	1	2	2	2	2	2	1	1	1	1
Katablepharis ovalis Skuja	1	1	1	1	1	1	1	2	2	2	2
Dinophyceae											
Gymnodinium spp.	1	1	2	2	1	1	1	1	1	1	1
Peridinium cunningtonii (Lemm.) Lemm.	-	-	-	-	-	-	-	-	1	1	-
P. inconspicuum Lemm.	-	-	-	-	-	1	-	1	1	1	1
Peridinium sp.	1	1	1	3	3	2	2	1	1	1	1

Table 5. THE OCCURRENCE OF PHYTOPLANKTON IN LAKE TR MMEN, 1968-1978, IN RELATION TO RESTORATION.

D = dominant, 3 = very common, 2 = common, 1 = single and - = not recorded.

CHROMOPHYTA	Before		During		After						
Chrysophyceae	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Rhizochrysidales											
Bitrichia chodatii (Reverd.) Chod.	-	-	-	-	-	-	-	-	1	1	1
B. ollula (Fott) Fott	-	-	-	-	-	-	-	-	-	1	1
Rhizochrysis limnetica G.M. Smith	1	1	-	-	-	-	-	-	-	-	1
Chromulinales											
Bikosoeca crystallina Skuja	-	-	-	1	-	1	1	-	-	-	1
B. cylindrica (Lackey) Bourr.	-	-	-	-	-	-	-	-	-	1	1
Chromulina spp.	1	1	1	1	1	1	1	1	1	1	1
Chrysococcus minutus (Fritsch) Nyg.	-	-	-	-	-	1	1	-	1	1	-
C. rufescens Klebs.	-	-	-	-	-	1	1	1	1	1	1
C. triporus Mack	-	-	-	1	-	-	1	-	2	1	1
Ochromonadales											
Chrysastrella paradoxa Chod.	-	-	-	-	-	1	1	-	-	-	-
Chrysolykos planctonicus Mack	-	-	-	-	-	1	1	1	1	1	1
Chrysosphaerella brevispina Korsh.	-	-	-	-	-	1	1	1	1	1	1
C. multispina Bradl.	-	-	-	-	1	1	-	-	-	-	-
Dinobryon bavaricum Imhof	-	1	-	1	1	1	1	1	1	1	1
D. crenulatum W. et G.S. West	-	-	-	-	-	1	-	1	-	-	-
D. cylindricum Imhof	-	-	-	1	1	1	1	1	1	1	1
D. divergens Imhof	2	2	1	1	1	1	1	1	1	1	1
D. sociale Ehrenb.	1	1	1	-	-	-	1	1	1	-	-
D. suecicum Lemm.	-	-	-	1	1	1	-	-	1	-	1
Mallomonas acaroides var. striatula Asmund	1	-	-	1	1	1	1	-	1	1	1
M. akrokomos Ruttn. in Pasch.	-	-	-	-	-	1	1	1	1	-	1
M. annulata Harris	-	-	-	1	-	-	-	-	1	-	-
M. crassisquama (Asmund) Fott	-	-	-	-	1	1	1	1	1	1	1
M. elongata Reverd.	-	-	-	-	-	1	1	-	-	-	-
M. eoa Takah.	1	-	-	D	1	3	2	1	1	1	1
M. heterospina Lund	-	-	-	1	1	1	1	-	1	-	-
M. papillosa Harris et Bradl.	-	-	-	-	-	-	-	-	-	1	-
M. reginae Teil.	1	1	1	1	1	-	1	-	-	-	1
M. striata Asmund	-	-	-	-	-	-	1	-	-	-	1
M. teilingii (Teil.) Conr.	-	-	-	1	1	1	1	-	-	-	-
M. tonsurata Teil. em. Krieg.	1	-	-	1	1	1	-	-	-	1	-
M. tonsurata var. alpina Asmund	-	-	-	1	1	1	1	-	1	-	-
M. torquata Asmund et Cronb.	-	-	-	1	-	1	1	-	-	1	1
M. trummensis Cronb.	-	-	-	1	1	1	1	-	-	-	-
Mallomonopsis elliptica Matv.	-	-	-	-	-	1	-	-	-	1	-
Paraphysomonas vestita (Stokes) de Saed.	-	-	-	-	-	-	1	1	1	1	1
P. imperforata Lucas	-	-	-	-	-	1	-	-	-	-	1
Pseudokephyrion conicum (Schill.) Schmid	-	-	-	-	-	1	1	-	-	-	-
P. pseudospirale Bourr.	-	-	-	-	-	1	1	-	-	-	-
Spiniferomonas trioralis Takah.	-	-	-	-	-	-	1	1	1	1	1
Synura echinulata Korsh.	-	-	-	1	1	1	3	1	1	1	1
S.petersenii Korsh.	-	-	-	D	1	1	1	1	1	1	1
S. spinosa Korsh.	-	-	-	1	3	1	1	1	1	1	1
Uroglena volvox Ehrenb.	-	-	-	1	1	1	1	-	-	-	1
Prymnesiales											
Chrysochromulina parva Lack.	-	-	-	-	1	1	1	1	2	2	2
Monosigales											
Aulomonas purdyi Lack.	-	-	-	-	-	-	-	-	1	1	1
Codosiga botrys (Ehrenb.) Kent	1	-	-	-	-	-	-	-	-	-	-
Desmarella moniliformis Kent	1	-	-	-	1	1	-	-	-	-	-
Salpingoeca frequentissima (Zach.) Lemm.	2	2	1	1	1	1	1	1	1	1	1
Isochrysidales											
Hymenomonas roseola Stein	-	-	-	1	-	-	1	-	-	-	-

Table 6. THE OCCURRENCE OF PHYTOPLANKTON IN LAKE TRUMMEN, 1968-1978, IN RELATION TO RESTORATION.

D = dominant, 3 = very common, 2 = common, 1 = single and - = not recorded.

CHROMOPHYTA	Before		During		After						
Diatomophyceae	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Centrales											
Cyclotella comta (Ehrenb.) Kütz.	1	1	1	1	1	1	1	1	1	1	2
C. meneghiniana Kütz.	1	1	1	1	1	2	1	1	1	-	2
C. pseudostelligera Hust.	1	-	-	-	-	1	-	1	1	-	2
C. stelligera Cleve et Grun.	-	-	1	1	1	1	-	1	1	1	1
C. stelligeroides Hust.	1	1	-	1	1	1	-	1	1	1	2
Melosira ambigua (Grun.) O. Müller	3	3	2	2	2	2	2	2	2	2	2
M. distans (Ehrenb.) Kütz.	-	3	-	-	-	-	1	-	-	-	1
M. granulata var. angustissima O. Müller	3	3	3	3	3	3	3	3	3	3	3
M. granulata var. muzzanensis Meister	-	-	-	1	1	-	-	-	-	-	-
M. italica (Ehrenb.) Kutz.	1	3	1	2	3	1	1	1	1	3	3
M. italica ssp. subarctica O. Müller	1	-	1	-	-	1	-	-	-	-	-
Rhizosolenia longiseta Zach.	-	-	-	-	-	1	-	-	-	-	1
Stephanodiscus rotula (Kutz.) Hendey	-	-	-	-	1	-	-	-	-	-	-
S. dubius (Fricke) Hust.	1	-	-	-	-	-	-	-	-	-	-
S. hantzschii Grun.	2	2	1	2	1	1	1	1	1	1	1
S. tenuis Hust.	-	1	1	1	1	-	-	-	-	1	1
Pennales											
Achnanthes exigua Grun.	-	-	1	1	1	-	-	-	-	-	-
A. exiqua var. heterovalvata Krasske	-	-	-	-	-	1	-	-	-	-	-
A. lanceolata var. rostrata Hust.	-	-	1	1	-	-	-	-	-	-	-
A. linearis W. Smith	-	-	-	1	-	1	-	1	-	-	-
A. microcephala Kutz.	-	-	-	1	1	-	-	-	1	-	-
A. recurvata Hust.	-	-	-	1	-	1	-	1	-	1	1
Amphora ovalis var. libyca (Ehrenb.) Cleve	-	-	-	-	1	-	-	-	1	-	-
Anomoeoneis exilis var. lanceolata Mayer	-	-	-	-	1	-	-	-	-	-	-
Asterionella formosa Hassall	1	2	2	1	2	1	2	2	2	2	3
Caloneis silicula (Ehrenb.) Cleve	-	-	-	-	-	-	-	-	-	-	1
Cocconeis placentula Ehrenb.	-	-	-	1	-	-	-	-	-	-	-
Cymbella cistula (Hempr.) Grun.	-	-	-	1	-	-	-	-	-	-	-
C. turgida (Greg.) Cleve	1	1	-	-	-	-	-	-	-	-	-
C. ventricosa Kutz.	-	1	1	1	-	1	-	1	-	1	-
Diatoma vulgare Bory	-	1	1	1	1	-	-	1	-	-	-
Diploneis marginestriata Hust.	-	-	-	1	-	-	-	-	-	-	-
D. ovalis (Hilse) Cleve	-	-	-	1	-	-	-	-	-	-	-
Eunotia flexuosa Kutz.	-	-	1	-	-	-	-	-	-	-	-
E. lunaris (Ehrenb.) Grun.	-	-	-	-	1	-	-	-	-	-	-
E. pectinalis (Kütz.) Rabenh.	1	-	-	-	-	-	-	-	1	-	-
E. praerupta Ehrenb.	-	-	-	1	-	-	-	-	-	-	-
E. veneris (Kütz.) O. Muller	-	-	-	-	-	1	-	-	1	-	1
Fragilaria capucina Desmaz.	-	-	-	1	1	-	-	-	-	-	-
F. construens (Ehrenb.) Grun.	2	2	1	1	1	1	-	1	-	-	1
F. construens var. binodis (Ehrenb.) Grun.	-	2	1	1	1	1	-	-	-	-	1
F. construens var. venter (Ehrenb.) Grun.	1	1	1	1	1	1	-	1	1	1	2
F. crotonensis Kitton	-	-	1	1	-	-	-	1	-	-	-
F. intermedia Grun.	-	1	1	-	-	1	-	-	1	1	-
F. pinnata Ehrenb.	-	-	1	1	1	2	-	1	-	1	1
F. virescens Ralfs	-	-	-	1	1	1	1	1	1	-	-
Meridion circulare Agardh	-	-	-	1	-	-	-	-	-	-	-
Navicula contenta Grun.	-	-	-	-	-	-	-	-	1	-	-
N. cuspidata Kutz.	-	-	-	-	-	-	-	-	-	-	1
N. gastrum Ehrenb.	-	-	-	-	1	-	-	-	-	-	-
N. muralis Grun.	-	1	1	1	-	1	-	1	-	-	-

Table 7. THE OCCURRENCE OF PHYTOPLANKTON IN LAKE TRUMMEN, 1968-1978, IN RELATION TO RESTORATION.

D = dominant, 3 = very common, 2 = common, 1 = single and - = not recorded.

	Before		During		After						
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Navicula pseudoscutiformis Hust.	-	-	-	1	1	1	-	1	1	1	-
N. pupula var. rectangularis (Greg.) Grun.	-	-	-	1	1	-	-	-	-	-	-
N. radiosa Kütz.	-	-	-	1	-	-	-	-	-	-	-
N. rhynchocephala Kütz.	-	-	-	-	-	-	-	1	-	-	-
N. schoenfeldii Hust.	-	-	-	-	-	-	-	-	-	-	1
N. seminulum Grun.	-	1	-	1	-	1	-	1	1	1	2
N. seminulum var. intermedia Hust.	-	-	-	1	-	-	-	1	-	-	-
N. subatomoides Hust.	-	1	-	-	1	-	-	-	-	-	1
Nitzschia acicularis W. Smith	2	-	-	1	-	-	-	1	2	-	-
N. gracilis Hantzsch	-	-	-	-	-	-	2	1	-	-	-
N. palea (Kütz.) W. Smith	2	2	1	2	1	1	-	1	-	-	1
N. tryblionella var. victoriae Grun.	-	-	-	-	-	-	-	1	-	-	-
Pinnularia gibba Ehrenb.	-	-	-	-	-	-	-	1	-	-	-
P. hemiptera (Kütz.) Cleve	-	-	-	-	-	-	-	-	-	1	-
P. interrupta W. Smith	-	1	-	-	-	-	-	-	-	-	-
P. maior Kutz.	-	-	1	1	-	1	-	-	-	1	-
P. mesolepta (Ehrenb.) W. Smith	1	-	-	-	-	1	-	-	1	-	-
P. nodosa Ehrenb.	-	-	-	1	-	-	-	-	-	-	-
P. viridis (Nitzsch) Ehrenb.	1	-	-	-	-	-	-	-	-	-	-
Stauroneis anceps Ehrenb.	-	-	-	-	-	1	-	-	-	-	-
S. phoenicenteron Ehrenb.	-	-	-	-	1	-	-	-	-	-	-
Synedra acus var. angustissima Grun.	2	1	1	1	1	2	1	1	3	2	2
S. berolinensis Lemm.	1	2	1	1	1	2	1	2	1	2	2
S. nana Meister	1	-	-	1	-	1	-	1	2	2	1
S. parasitica W. Smith	-	-	-	1	1	1	-	-	-	-	-
S. parasitica var. subconstricta Grun.	-	-	-	1	1	1	-	-	-	-	-
S. rumpens Kutz.	-	-	-	-	-	-	-	1	-	1	1
S. ulna (Nitzsch) Ehrenb.	-	-	1	1	1	1	1	-	-	-	-
S. ulna var. danica (Kütz.) Grun.	-	1	-	1	-	-	1	1	1	-	2
Tabellaria fenestrata (Lyngb.) Kutz.	-	2	-	1	1	2	-	1	1	1	1
T. fenestrata var. asterionelloides Grun.	-	-	-	-	1	1	-	-	-	-	-
T. flocculosa (Roth) Kütz.	1	1	1	2	2	2	1	1	1	1	2
Tetracyclus lacustris Ralfs	-	-	-	1	-	-	-	-	-	-	-
Thalassionema nitzschioides Grun.	-	-	-	-	-	2	-	-	-	-	-
Xanthophyceae											
Goniochloris mutica (A. Braun) Fott	1	1	-	-	-	-	-	-	-	-	-
Pseudostaurastrum hastatum (Reinsch) Chod.	-	-	-	-	1	1	-	-	-	-	-
P. limneticum (Borge) Chod.	2	2	1	1	1	1	1	1	1	1	1
Ophiocytium capitatum Wolle	-	1	-	-	1	1	-	-	-	-	-
RAPHIDOPHYTA											
Gonyostomum semen (Ehrenb.) Dies.	-	-	-	1	-	-	-	-	-	-	-
COLOURLESS FLAGELLATES with uncertain position											
Protomonadales											
Tetramitus sp.	-	-	-	3	-	3	-	-	-	-	-

APPENDIX II

Volumes of plankton algae

Table 1–2

Biomass of algae

Table 3 –13

Table 1. Volumes of plankton algae in Lake Trummen 1968-1978.

	Formula	Height µm	Breadth µm	Length µm	Diametre µm	Volume µm³
CYANOPHYTA						
Nostocales						
Anabaena lemmermannii, cell	sphere	-	-	-	5	65
" " , spore	cylinder	-	8	18	-	997
A. solitaria var. smithii	sphere	-	-	-	6.4	137
A. spiroides f. crassa	"	-	-	-	10	523
A. spiroides f. spiroides	"	-	-	-	6	113
A. viguieri	"	-	-	-	6.4-7	137-180
Aphanizomenon flos-aquae	cylinder	-	-	-	3.2-4.2	8-14/µm
A. gracile	"	-	-	-	2-3.6	3-10/µm
Lyngbya limnetica	"	-	-	-	1-2	1-3/µm
Oscillatoria agardhii	"	-	-	-	3.8	11/µm
O. limnetica	"	-	-	-	2	3/µm
O. limnetica var. acicularis	"	-	-	-	1.5-2	2-3/µm
Oscillatoria sp. (May, 1972)	"	-	-	-	2	3/µm
Raphidiopsis mediterranea	"	-	-	-	3.7	11/µm
Chroococcales						
Aphanocapsa delicatissima	sphere	-	-	-	1-1.8	1-3/µm
Aphanothece clathrata	cylinder	-	1	2.4	-	3/cell, 300/colony
A. ellipsoides	"	-	1.2	4.8	-	5.4/cell, 220/colony
Chroococcus cfr minimus	sphere	-	-	-	2	4/cell, 200/colony
Chroococcus sp.	"	-	-	-	3	14
Cyanodictyon imperfectum	"	-	-	-	0.5-1	0.52-2
Microcystis aeruginosa	"	-	-	-	4	33
M. wesenbergii	"	-	-	-	6	113
Synechococcus vantieghemi	cylinder	-	1.5	3	-	5.4
CHLOROPHYTA						
Chlamydomonas spp.	sphere	-	-	-	11-20	700-4200
Chlorella sp.	"	-	-	-	6	92
Chlorogonium maximum	rotational ellipsoid	-	11-12	83-96	-	4000-6000
Closterium acutum var. variabile	" "	-	4	40	-	340
C. limneticum	" "	-	5	62-150	-	1220-2900
Cosmarium sp.	" "	-	14	12	-	600
Elakatothrix	" "	-	2.4	30	-	90
Eudorina elegans	sphere	-	-	-	8.4	310
Kirchneriella obesa	cylinder	2.4	-	-	5	50
Micractinium pusillum	sphere	-	-	-	4	33
Monoraphidium spp.	rotational ellipsoid	-	1.2-3.6	20-36	-	14-244
Pediastrum spp.	cylinder	3.5-4	-	-	30-40	2500-5050
Scenedesmus spp.	4 rotational ellipsoids	-	8.6-15	11-20	-	136-785
Staurastrum uplandicum	2 prisms + 4 cylinders	6	15	20	-	1200
S. paradoxum var. parvum	2 pyramids + 6 cylinders	-	12	14	-	1200
Staurodesmus extensus	2 prisms	5	17	18	-	1500
S. patens	2 pyramids	12	13	16	-	500
Teilingia granulata	2 rotational ellipsoids	-	6	8	-	300
Tetraedron minimum	parallelepiped	3	10	10	-	300

Table 2. Volumes of plankton algae in Lake Trummen 1968-1978.

	Formula	Height µm	Breadth µm	Length µm	Diametre µm	Volume $µm^3$
EUGLENOPHYTA						
Astasia sp.	rotational ellipsoid	-	9	62	-	2000
Euglena acus	" "	-	9	48-69	-	1530-2100
Phacus spp.	ellipsoid	4	15	30	-	1271
Trachelomonas spp.	sphere	-	-	-	12-18	900-3500
CHROMOPHYTA						
Chrysophyceae						
Codosiga botrys	rotational ellipsoid	-	8	12	-	106
Chrysochromulina parva	sphere	-	-	-	3.6	24
Desmarella moniliformis	rotational ellipsoid	-	5	7	-	70
Dinobryon spp.	" "	-	6-7	12-15	-	170-385
Mallomonas eoa, cell	" "	-	3.6-5.9	18-25	-	92-382
" " , cyst	" "	-	8-9	13	-	435-823
Mallomonas spp.	" "	-	8.6-10	14	-	300-550
Synura spp.	" "	-	7-8	10-12	-	260-400
Diatomophyceae						
Centrales						
Cyclotella spp. Stephanodiscus spp.	cylinder	4	-	-	6-12	110-450
Melosira spp.	"	-	-	-	3-5.4	7-23/µm
Pennales						
Asterionella formosa, Diatoma vulgare	parallel epiped	1.8-3	1.8-4	18-33	-	58-400
Synedra berolinensis	" "	2	3	24	-	140
Synedra spp. Nitzschia spp.	" "	2-3	2.3-4.5	19-170	-	300-1742
PYRRHOPHYTA						
Chroomonas acuta	rotational ellipsoid	-	4-7.4	10-15	-	90-430
Cryptomonas sp. (large size)	" "	-	15-18	30-35	-	3900-6000
Cryptomonas sp. (middle size)	" "	-	11-14	21-27	-	1340-2975
Cryptomonas sp. (small size)	" "	-	7-10	15-19	-	290-750
Katablepharis ovalis	" "	-	6	9	-	170
Gymnodinium sp.	sphere	-	-	-	10-12	523-904
Peridinium sp.	"	-	-	-	20-25	4000-8000
"	rotational ellipsoid	-	17	21	-	3176
Tetramitus ?	sphere	-	-	-	12-15	904-1770
µm-algae	"	-	-	-	2	4
" "	"	-	-	-	3	14
" "	"	-	-	-	4	33
" "	"	-	-	-	5	65
" "	"	-	-	-	6	113
" "	"	-	-	-	7	180
" "	"	-	-	-	8	268
" "	"	-	-	-	12	904

Table 3.

TRUMMEN 1968: Phytoplankton mg/l (fresh weight)

SPECIES / DATE		28/2	25/3	8/4	7/5	30/5	19/6	16/7	15/8	10/9	3/10	24/10	22/11	28/1'
Anabaena solitaria fo. smithii		-	-	-	-	0.61	3.84	0.04	0.05	-	-	-	-	-
A. spiroides		-	-	-	0.03	0.98	23.03	49.50	24.90	25.99	7.23	[illegible]	-	-
Aphanizomenon flos-aquae		0.003	-	-	0.10	5.71	7.08	0.28	-	-	-	0.55	0.52	0.46
Lyngbya limnetica		-	-	0.09	-	0.59	1.38	0.13	0.22	0.44	-	0.07	0.16	0.09
Oscillatoria agardhii		-	-	-	0.42	1.23	4.51	2.30	7.76	1.24	-	-	-	-
Raphidiopsis mediterranea		-	-	-	0.03	0.02	1.13	0.40	8.31	11.30	1.67	0.08	0.03	-
Microcystis, Chroococcus		0.001	-	-	2.80	2.80	2.24	11.90	48.50	72.6	16.5	9.40	-	1.2
Chlamydomonas spp.		-	-	2.15	-	-	-	-	-	-	-	-	-	-
Chlorogonium maximum		0.004	-	0.22	-	-	-	-	-	-	-	-	-	-
Micractinium pusillum		-	-	1.71	-	-	-	-	-	-	-	-	-	-
Monoraphidium spp.		0.003	0.002	0.02	-	-	-	-	-	-	-	-	0.01	-
Pediastrum spp.		-	-	-	0.21	0.40	0.36	0.30	0.15	0.10	0.10	0.35	0.04	0.10
Scenedesmus spp.		-	0.001	0.60	1.05	0.90	1.20	1.14	0.90	0.90	3.36	0.90	0.45	0.60
Staurastrum spp.		-	-	-	-	0.24	0.48	-	-	-	-	-	-	-
Euglena acus		0.004	-	0.02	-	-	-	-	-	-	-	-	-	-
Phacus spp.		0.001	-	-	-	-	-	-	-	-	-	-	-	-
Codonosiga botrys		0.001	-	-	-	-	-	-	-	-	-	-	-	-
Desmarella moliniformis		0.001	-	-	-	-	-	-	-	-	-	-	-	-
Synura spp.		0.001	-	-	-	-	-	-	-	-	-	-	-	-
Cyclotella, Stephanodiscus		-	-	-	-	-	-	-	-	-	-	-	1.24	-
Melosira spp.		0.002	-	0.74	1.50	1.09	0.20	0.48	0.12	0.08	0.70	4.63	0.24	0.49
Synedra, Nitzschia		-	-	0.06	9.60	0.45	-	-	-	-	-	0.06	0.21	0.39
Chroomonas acuta		-	-	-	-	-	-	-	-	-	-	-	1.10	1.15
Cryptomonas spp.		0.24	-	0.31	-	-	-	0.15	-	0.26	0.31	3.88	0.63	-
Peridinium sp.		-	-	-	-	0.32	2.36	0.47	-	0.19	0.13	-	0.70	-
Undetermined	ø = 3-4	0.23	0.01	-	1.78	1.78	-	-	-	-	-	2.71	1.96	2.87
µ-algae (µm)	ø = 6	0.23	0.01	-	0.79	0.11	0.15	-	-	-	-	0.74	0.68	0.57
	ø = 12	0.18	0.02	-	-	-	-	-	-	-	-	-	-	-
TOTAL BIOMASS		0.9	0.04	5.9	18.3	17.2	48.0	67.1	90.9	113.1	30.0	23.8	7.9	8.0

Table 6.

TRUMMEN 1971: Phytoplankton biomass mg/l (fresh weight)

SPECIES / DATE	3/2	23/2	2/3	17/3	25/3	16/4	4/5	18/5	9/6	25/6	30/6	21/7	12/8	25/8	31/8	15/9	5/10	2/11	15/12
Anabaena lemmermannii	-	-	-	-	-	-	-	-	0.01	0.01	0.01	-	-	0.03	0.16	0.09	-	-	-
A. solitaria fo. smithii	-	-	-	-	-	-	-	-	0.27	0.44	0.42	5.75	-	-	-	-	-	-	-
Anabaena spiroides	-	-	-	-	-	-	-	-	0.06	-	-	-	0.02	0.11	0.11	-	-	-	-
Aphanizomenon flos-aquae	0.05	0.02	0.27	0.06	0.03	0.14	0.58	0.19	15.9	0.07	-	0.07	0.04	0.01	-	0.01	-	-	-
Lyngbya limnetica	-	-	-	-	-	-	-	-	-	0.1	0.07	-	0.05	-	-	-	-	-	-
Oscillatoria agardhii	-	-	-	-	-	-	-	-	-	0.03	0.01	-	0.06	0.09	0.09	0.02	-	-	-
Raphidiopsis mediterranea	-	-	-	-	-	-	-	-	0.03	-	-	-	0.02	0.21	0.19	0.01	-	-	-
Oscillatoria limnetica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.14	0.02
Microcystis, Chroococcus	-	-	-	-	-	-	-	-	6.24	1.3	1.35	2.04	4.1	2.49	4.77	-	-	-	-
Chlamydomonas spp.	0.42	0.75	2.64	0.07	0.46	-	-	-	-	-	1.81	-	-	-	-	-	-	-	-
Chlorogonium maximum	-	0.28	-	0.05	1.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eudorina elegans	-	-	-	-	-	-	-	0.25	-	-	-	-	-	-	-	-	-	-	-
Monoraphidium spp.	-	-	-	0.002	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum spp.	-	-	-	-	-	-	0.15	0.2	0.5	0.12	0.2	1.6	4.4	4.0	4.0	-	0.16	0.04	-
Scenedesmus spp.	-	-	-	-	-	0.08	0.23	0.23	0.6	-	0.39	0.45	0.39	0.48	0.6	0.09	0.03	0.06	-
Euglena acus	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trachelomonas spp.	0.11	-	-	0.22	1.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Desmarella moniliformis	-	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dinobryon spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	0.05	0.05
Mallomonas eoa	0.06	0.33	0.01	0.11	10.2	0.28	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallomonas spp.	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synura spp.	0.07	1.5	0.26	0,1	2.32	0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Asterionella formosa	-	-	-	-	-	-	0.11	-	-	-	-	-	-	-	-	-	-	-	-
Cyclotella, Stephanodiscus	-	-	-	-	-	-	4.82	2.2	-	-	-	-	-	-	-	-	-	-	-
Melosira spp.	-	-	0.01	-	0.02	0.27	0.99	4.22	0.84	1.8	2.3	3.42	6.8	5.22	5.8	1.74	0.98	0.04	-
Nitzschia, Synedra	-	0.08	-	-	-	-	0.84	0.12	-	-	-	-	-	-	-	-	-	-	-
Chroomonas acuta	-	-	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cryptomonas sp.	2.0	4.29	3.47	0.5	6.7	8.62	9.54	1.04	0.35	0.21	0.07	0.35	0.21	-	0.08	0.05	0.08	0.06	0.06
Peridinium sp.	-	-	-	-	0.29	0.58	0.43	0.15	0.28	0.24	0.32	-	0.56	0.52	-	0.15	0.29	0.74	1.34
Tetramitus sp.	-	-	1.45	0.35	-	-	-	-	-	1.8	1.08	-	-	-	-	0.36	-	-	-
Undetermined ø = 3-4	0.53	0.17	0.27	0.3	0.23	0.72	0.95	0.63	1.12	0.89	0.53	-	1.32	1.58	1.25	0.79	0.26	1.05	0.1
μ-algae (μm) ø = 6	-	-	-	0.14	-	-	0.42	0.52	1.24	0.68	0.17	-	0.45	0.01	-	0.23	0.34	0.85	0.23
ø = 12	-	-	-	0.5	-	-	1.72	-	-	-	-	1.47	-	-	-	-	-	-	-
Total biomass	3.2	7.4	8.4	2.5	22.7	10.8	20.9	9.9	27.5	7.9	8.7	15.1	18.4	14.7	17.0	3.5	2.2	3.0	1.9

Table 7.

TRUMMEN 1972: Phytoplankton biomass (fresh weight)

SPECIES / DATE		13/1	9/2	2/3	10/4	18/5	5/6	28/6	14/7	1/8	18/8	5/9	19/9	26/9	18/10	16/11	19/12
Anabaena lemmermannii		-	-	-	-	-	0.002	-	1.81	1.79	12.5	7.53	-	-	-	-	-
A. viguieri		-	-	-	-	0.01	0.004	-	0.33	-	-	-	-	-	-	-	-
Aphanizomenon gracile		-	-	-	-	-	0.02	0.09	1.26	-	0.20	0.03	0.03	-	-	-	-
Oscillatoria agardhii		-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-
Oscillatoria spp.		0.01	-	-	0.03	35.4	0.23	0.04	-	-	-	-	0.002	0.001	0.001	-	0.06
Microcystis, Chroococcus		-	-	-	-	-	-	0.71	-	0.34	0.41	0.92	0.32	0.39	-	-	-
Aphanothece ellipsoidea		-	-	-	-	-	-	-	-	-	-	-	0.04	0.02	0.96	2.1	-
Chlorogonium maximum		0.01	0.01	0.004	0.08	-	-	-	-	-	-	-	-	-	-	-	-
Closterium limneticum		-	-	-	-	-	-	-	-	-	-	-	0.06	0.03	-	-	-
Monoraphidium spp.		-	-	-	-	-	0.05	-	-	-	-	-	-	-	0.03	0.01	0.01
Pediastrum spp.		-	-	-	0.04	0.1	0.08	0.06	0.41	0.34	0.42	0.31	0.31	0.07	0.34	-	0.04
Scenedesmus spp.		-	-	-	0.02	0.27	0.17	0.19	0.31	0.27	0.39	0.43	0.16	0.15	0.14	0.14	0.17
Staurastrum spp.		-	-	-	-	-	-	0.04	0.18	-	0.14	-	-	0.04	-	-	-
Staurodesmus spp.		-	-	-	-	-	-	0.03	-	-	-	-	-	0.09	-	-	-
Teilingia granulata		-	-	-	-	-	-	-	0.01	0.06	0.05	-	-	0.03	-	-	-
Euglena acus		-	0.003	0.01	0.17	-	-	-	-	-	-	-	-	-	-	-	-
Phacus spp.		0.01	0.34	0.001	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Trachelomonas spp		-	0.01	0.01	-	-	-	-	-	-	-	-	0.02	-	-	-	-
Dinobryon spp.		0.03	-	0.002	0.08	-	-	-	0.01	0.03	-	-	-	-	-	-	-
Mallomonas spp.		-	0.02	0.003	-	-	-	-	-	-	-	-	-	-	-	-	0.001
Synura spp.		0.02	0.07	0.12	0.98	-	-	-	-	-	-	-	-	-	-	-	-
Cyclotella, Stephanodiscus		-	-	-	-	-	-	-	-	-	-	-	-	-	0.23	-	0.04
Diatoma vulgare		-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.03	-	0.02
Melosira spp.		-	-	-	0.17	1.0	2.28	0.78	1.82	7.63	4.17	4.1	0.6	1.3	0.48	0.12	0.14
Nitzschia, Synedra		-	-	-	-	-	-	-	0.33	-	-	-	-	0.01	0.01	0.08	0.33
Cryptomonas spp.		0.13	0.36	1.03	0.99	-	-	-	-	-	-	0.37	0.16	0.66	0.11	0.06	0.15
Peridinium sp.		0.07	2.7	0.59	0.19	-	-	-	-	-	-	0.16	0.21	0.10	0.10	-	0.02
Undetermined	ø = 3-4	0.17	0.18	0.01	0.34	0.34	0.89	0.78	0.28	0.44	0.57	0.18	0.35	0.24	0.24	-	0.20
µ-algae (µm)	ø = 6	0.79	0.05	-	-	1.28	1.02	1.28	0.17	1.72	2.39	0.76	1.24	0.45	0.34	0.45	0.11
	ø = 12	-	0.36	-	-	2.8	0.14	0.3	1.36	1.39	1.74	0.54	-	0.9	-	-	0.18
TOTAL BIOMASS		1.2	4,1	1.8	3.2	41.2	4.9	4.3	8.4	14.0	23.0	15.3	3.5	4.5	3.0	3.0	1.5

Table 8.

TRUMMEN 1973: Phytoplankton mg/l (fresh weight)

SPECIES / DATE		16/1	7/2	10/3	21/3	17/4	7/5	5/6	26/6	10/7	17/7	5/8	16/8	22/8	4/9	18/9	11/10	1/11	20/12
Anabaena lemmermannii		-	-	-	-	0.05	0.03	0.07	0.26	-	0.07	0.26	4.1	9.19	1.83	0.46	0.01	-	-
A. viguieri		-	-	-	-	-	-	-	0.02	-	-	0.5	1.7	0.002	-	-	-	-	-
Aphanizomenon gracile		-	-	-	-	-	-	0.03	0.01	-	-	0.21	1.39	4.31	-	-	-	-	0.02
Lyngbya limnetica		-	-	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria agardhii		-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	0.01	-	-	-
Oscillatoria limnetica		-	-	-	-	-	-	0.37	-	-	-	-	-	-	-	0.1	0.1	-	-
Microcystis, Chroococcus		-	-	-	-	-	-	0.36	-	0.4	0.24	2.4	0.32	0.42	0.27	1.28	0.12	-	-
Closterium acutum var. variabile		-	-	-	-	-	-	-	-	0.17	0.37	-	-	-	-	-	-	-	0.003
C. limneticum		-	-	-	-	-	-	-	-	-	-	0.26	0.29	-	0.58	-	-	-	-
Elakatothrix gelatinosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-
Monoraphidium spp.		0.01	0.003	0.07	0.05	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.01
Pediastrum spp.		-	-	-	-	-	-	0.32	0.16	0.8	1.6	0.48	0.04	0.32	0.28	0.36	0.15	0.1	
Scenedesmus spp.		-	-	-	-	0.06	-	0.15	0.02	0.27	0.27	0.24	0.02	0.24	0.15	0.15	0.3	0.06	-
Staurastrum spp.		-	-	-	-	-	-	-	0.24	-	-	-	-	-	-	-	0.05	-	-
Staurodesmus spp.		-	-	-	-	-	-	-	0.09	1.65	0.9	-	-	-	-	-	-	-	-
Trachelomonas spp.		-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	0.33	-	-
Dinobryon spp.		0.003	0.001	0.04	0.02	0.06	0.2	-	-	-	-	-	-	-	-	-	0.02	-	-
Mallomonas eoa		0.004	0.01	0.02	1.78	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asterionella formosa		0.21	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	0.002
Cyclotella, Stephanodiscus		0.03	-	-	-	0.07	0.03	-	-	-	1.41	-	-	-	-	-	-	0.04	0.03
Diatoma vulgare		-	0.001	-	-	0.03	-	-	-	-	-	-	-	-	-	-	0.04	-	-
Melosira spp.		-	0.001	-	0.24	0.42	0.32	1.02	0.02	3.5	2.16	0.97	0.09	0.7	0.62	1.55	0.37	0.04	-
Nitzschia, Synedra		0.07	-	-	-	0.12	0.69	-	-	-	0.12	1.07	0.09	0.17	0.18	1.03	3.4	2.26	-
Chroomonas acuta		0.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cryptomonas spp.		0.36	0.09	0.9	0.3	0.6	-	-	-	1.09	0.45	-	-	-	-	-	-	0.02	0.02
Peridinium sp.		-	0.003	-	-	-	-	-	-	-	0.24	-	0.12	0.28	-	-	0.15	-	-
Tetramitus sp?		-	-	-	-	-	-	-	-	-	-	-	-	-	0.81	1.81	2.66	-	-
Undetermined	ø = 3-4	0.38	0.33	0.5	1.62	2.44	3.4	1.82	0.59	1.25	1.49	0.96	1.09	1.06	1.06	0.73	0.86	0.86	0.16
µ-algae (µm)	ø = 6	-	-	0.06	0.57	1.36	1.81	0.003	0.23	1.13	0.57	0.79	0.45	0.34	0.45	0.22	0.33	-	-
	ø = 12	-	-	0.07	-	1.81	-	-	-	1.81	-	-	-	-	-	-	-	-	-
TOTAL BIOMASS		1.4	0.4	1.7	4.6	7.0	6.5	4.1	1.6	12.1	9.9	8.1	9.7	17.0	6.2	7.8	8.9	3.4	0.2

Table 9.

TRUMMEN 1974: Phytoplankton mg/l (fresh weight)

SPECIES / DATE	3/1	5/2	28/2	19/3	8/4	7/5	28/5	20/6	17/7	7/8	19/8	10/9	19/9	2/10	12/10	19/11	12/12
Anabaena lemmermannii	-	-	-	-	-	0.05	0.03	0.03	1.56	5.46	0.91	0.13	-	-	-	-	-
A. viguieri	-	-	-	-	-	0.002	0.01	-	0.45	2.14	3.81	0.24	-	-	-	-	-
A. spiroides	-	-	-	-	-	-	-	-	1.05	2.62	3.66	1.57	2.82	1.05	0.79	-	-
Aphanizomenon gracile	0.02	-	-	0.01	0.14	1.20	1.52	0.02	0.10	0.76	1.32	4.92	5.58	2.1	1.13	0.52	0.38
Lyngbya limnetica	-	-	-	-	-	-	-	-	0.18	-	-	-	0.17	0.20	0.35	-	0.02
Aphanothece clathrata	-	-	-	-	-	-	-	-	0.20	0.83	0.86	-	-	-	-	-	-
Microcystis aeruginosa	-	-	-	-	-	-	-	-	0.39	-	1.11	1.66	-	0.28	-	-	-
Aphanocapsa delicatissima	-	-	-	-	-	-	-	0.43	0.47	0.42	-	0.54	0.39	-	0.09	-	-
Synechococcus vantieghemi	-	-	-	-	-	-	-	0.43	1.09	0.17	-	-	-	-	-	0.4	-
[illegible]ogonium maximum	-	-	0.12	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-
Closterum acutum var. variabile		-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	0.02	0.03
Cosmarium sp.	-	-	-	-	-	-	-	0.48	-	-	-	-	-	-	-	-	-
Monoraphidium spp.	0.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-
Pediastrum spp.	-	-	-	-	-	0.03	0.6	0.9	0.6	0.6	0.3	0.21	0.06	0.06	0.06	0.03	-
Scenedesmus spp.	-	0.01	-	0.01	0.09	0.15	0.6	0.6	0.3	0.9	0.09	-	0.21	0.21	0.09	0.15	0.09
Staurastrum, Staurodesmus	-	-	-	-	-	-	0.12	0.17	0.07	-	-	0.9	-	-	-	-	-
Trachelomonas volvocina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-
Dinobryon spp.	-	-	0.08	0.10	0.01	-	-	-	-	-	-	-	-	-	-	-	-
Mallomonas spp.	-	0.01	0.36	0.32	-	-	-	-	-	-	-	-	-	0.17	0.72	0.13	0.06
Synura spp.	-	0.01	0.24	0.44	4.4	0.58	-	-	-	-	-	-	-	-	-	-	-
Asterionella formosa	-	-	-	0.02	0.18	0.16	-	0.02	0.02	0.01	0.02	0.04	0.08	0.01	0.02	0.02	0.46
Cyclotella, Stephanodiscus	-	-	-	0.03	-	-	-	-	-	-	-	-	-	-	-	0.02	-
Melosira spp.	-	-	-	-	0.16	0.44	0.76	0.65	0.42	1.82	0.83	0.92	0.94	0.21	0.35	0.04	0.07
Synedra spp.	-	-	-	-	0.09	0.6	0.27	0.04	0.3	0.9	0.04	0.04	-	0.01	0.08	0.02	-
Chroomonas acuta	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.08	-	0.08	-
Cryptomonas spp.	0.06	0.06	0.3	0.04	-	-	-	-	-	-	-	-	-	-	0.4	0.3	0.24
Gymnodinium, Peridinium	-	-	-	-	1.22	-	-	-	-	-	-	-	0.32	0.63	-	-	-
Undetermined ø = 2-4	0.07	0.13	1.16	0.99	0.32	0.99	0.99	0.73	0.22	0.52	0.17	0.46	0.33	0.17	0.36	0.26	0.60
μ-algae (μm) ø = 6-12	-	-	-	-	-	-	3.50	-	-	-	-	-	-	-	-	-	-
TOTAL BIOMASS	0.2	0.2	2.3	2.0	6.6	4.2	8.4	4.5	7.4	17.1	13.1	11.6	11.2	5.2	4.4	2.12	2.0

Table 10.

TRUMMEN 1975: Phytoplankton mg/l (fresh weight)

SPECIES / DATE	16/1	12/2	18/3	16/4	6/5	27/5	9/6	25/6	15/7	29/7	21/8	27/8	9/9	17/9	10/10	3/11	17/12
Anabaena lemmermannii	-	-	-	-	-	-	0.01	0.28	-	-	-	-	-	0.04	-	-	-
A. viguieri	-	-	-	-	-	-	0.09	1.49	5.04	5.94	0.05	0.13	0.01	-		-	-
Aphanizomenon gracile	0.4	0.31	0.85	0.29	0.60	0.17	0.05	0.44	1.34	2.39	0.63	0.48	0.29	0.41	0.26	1.25	1.88
Lyngbya limnetica	0.08	0.01	0.03	-	0.09	0.22	0.47	0.51	0.25	0.18	-	-	-	-	0.02	-	-
Aphanocapsa delicatissima	0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microcystis aeruginosa	-	-	-	-	-	0.50	-	0.17	0.44	-	0.22	0.55	0.28	0.39	-	-	-
Oscillatoria limnetica	-	0.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyanodictyon imperfectum	-	-	-	-	-	0.30	2.6	3.28	4.68	4.73	15.0	25.79	27.20	18.41	1.51	1.35	3.12
Closterium acutum var. var.	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monoraphidium spp.	0.01	0.14	0.26	0.04	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum spp.	0.03	0.03	-	0.09	0.09	0.3	0.3	0.06	0.09	0.09	-	-	-	-	0.3	-	-
Scenedesmus spp.	0.27	0.03	-	0.03	0.03	0.24	0.24	0.15	0.18	0.15	0.06	0.06	0.09	0.09	0.36	0.06	0.03
Dinobryon spp.	-	0.002	0.01	0.04	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallomonas spp.	0.03	0.01	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synura spp.	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asterionella formosa	0.14	0.46	0.26	0.36	-	-	-	-	-	-	-	-	-	-	-	0.04	0.01
Melosira spp.	0.08	-	0.07	0.21	0.18	0.39	0.72	0.36	0.57	0.95	0.18	0.18	0.66	1.24	2.94	0.81	0.10
Synedra spp.	-	-	-	1.14	0.10	0.10	-	-	-	-	-	-	-	-	-	0.16	-
Chroomonas acuta	-	0.1	-	0.04	0.2	-	-	-	0.14	-	-	-	-	-	-	-	-
Cryptomonas spp.	0.03	0.68	-	-	-	-	-	-	-	-	-	-	-	-	0.33	-	-
Katablepharis sp.	-	0.09	-	0.4	-	-	-	-	-	-	-	-	-	-	0.53	-	-
Undetermined ø - 2-4 μ-algae (μm)	0.22	0.14	0.57	0.76	0.92	0.89	0.63	0.34	0.26	-	-	-	-	-	0.05	0.08	0.43
Total biomass	1.4	2.2	2.1	3.4	2.2	3.1	5.1	7.1	13.0	14.4	16.1	27.2	28.5	20.6	6.3	3.8	5.6

Table 11.

TRUMMEN 1976: Phytoplankton mg/l (fresh weight)

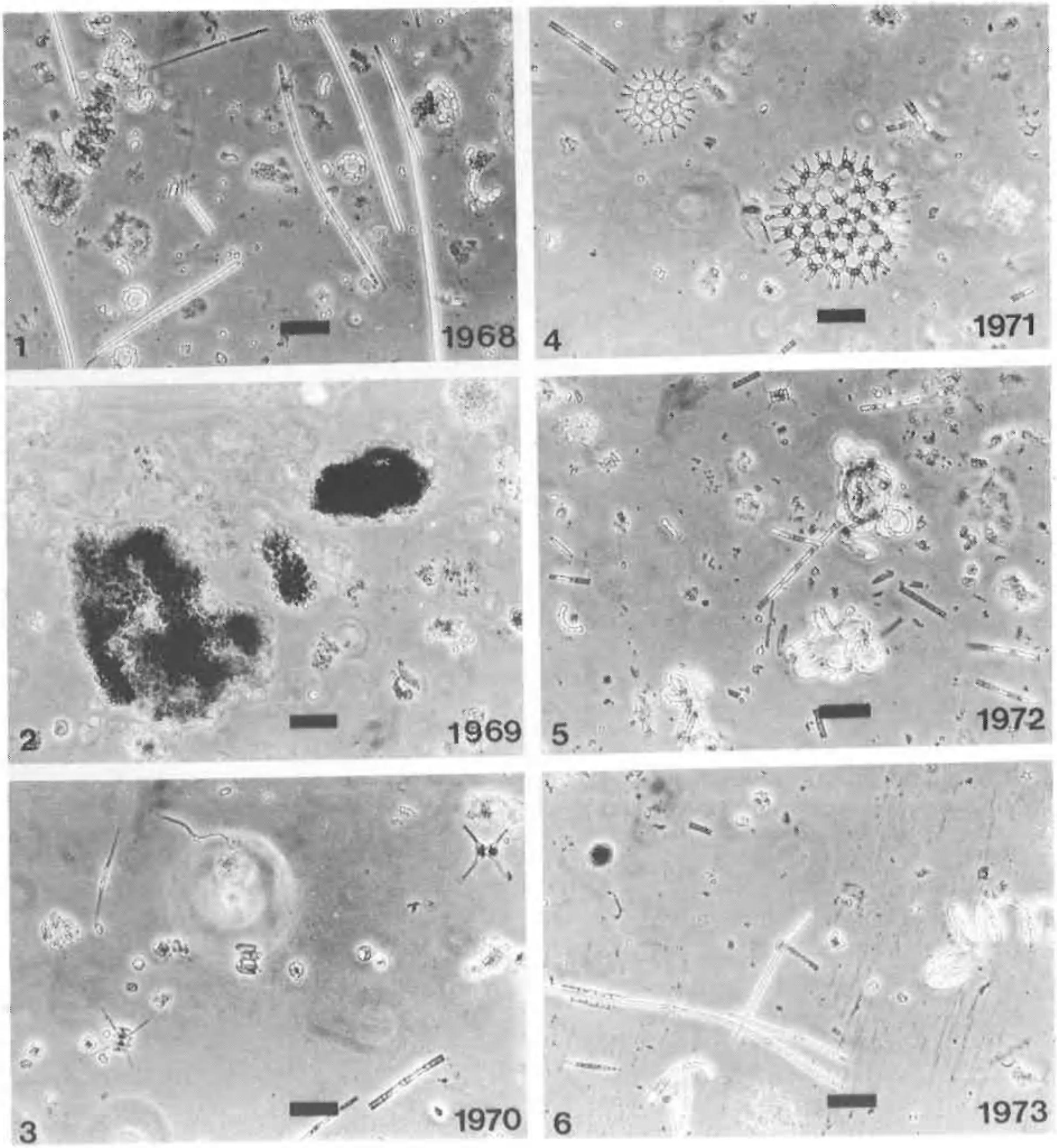
SPECIES / DATE	20/1	20/2	15/3	14/4	4/5	20/5	10/6	29/6	15/7	29/7	19/8	25/8	15/9	29/9	7/10	2/11
Aphanizomenon gracile	1.86	4.58	1.0	0.36	1.04	3.63	30.1	6.99	4.20	0.34	0.09	-	0.14	0.06	0.03	-
Lyngbya limnetica	-	-	-	-	-	-	-	-	-	0.17	0.06	0.56	1.10	0.83	0.80	0.60
Oscillatoria limnetica var. acicularis			-	-	-	-	0.63	2.38	-	-	-	-	-	-	-	-
Aphanothece clathrata	11.1	-	-	-	-	-	-	-	-	-	0.56	1.70	1.64	1.08	1.33	-
Cyanodictyon imperfectum	2.24	1.66	1.21	0.86	0.73	-	-	-	-	-	-	-	-	-	-	-
Microcystis aeruginosa	-	-	-	-	-	-	-	-	-	-	0.43	-	-	-	-	-
Monoraphidium spp.	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scenedesmus spp.	-	-	-	-	-	0.02	0.06	-	-	-	0.06	0.36	0.09	0.15	0.03	-
Staurastrum sp.	-	-	-	-	-	-	-	-	-	-	0.24	-	-	-	-	-
Dinobryon cylindricum	-	-	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallomonas eoa	0.01	0.05	0.003	0.59	-	-	-	-	-	-	-	-	-	-	-	-
Asterionella formosa	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclotella sp.	0.003	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Melosira spp	0.01	-	-	0.17	1.0	0.13	0.84	-	0.66	0.84	0.85	-	1.35	0.31	0.25	-
Synedra spp.	-	-	-	-	0.04	-	-	-	-	-	-	-	2.28	3.09	3.09	5.94
Choomonas acuta	-	0.43	0.47	-	-	-	-	-	-	0.23	-	0.23	-	-	-	0.19
Cryptomonas spp.	-	0.51	-	-	-	-	-	-	-	0.54	-	0.27	-	-	-	0.40
Peridinium sp.	-	-	-	-	-	-	-	-	0.41	-	-	-	-	-	-	-
Undetermined ø = 3-4	0.21	0.40	0.53	0.34	0.15	0.22	0.31	0.76	1.06	0.45	0.47	0.43	0.59	0.13	0.23	0.10
µ-algae (µm) ø = 12	-	-	-	-	-	-	-	-	-	-	0.99	-	-	-	-	-
TOTAL BIOMASS	15.5	7.6	3.3	2.3	3.0	4.0	31.9	10.1	6.3	2.6	3.74	3.6	7.2	5.7	5.8	7.2

APPENDIX III

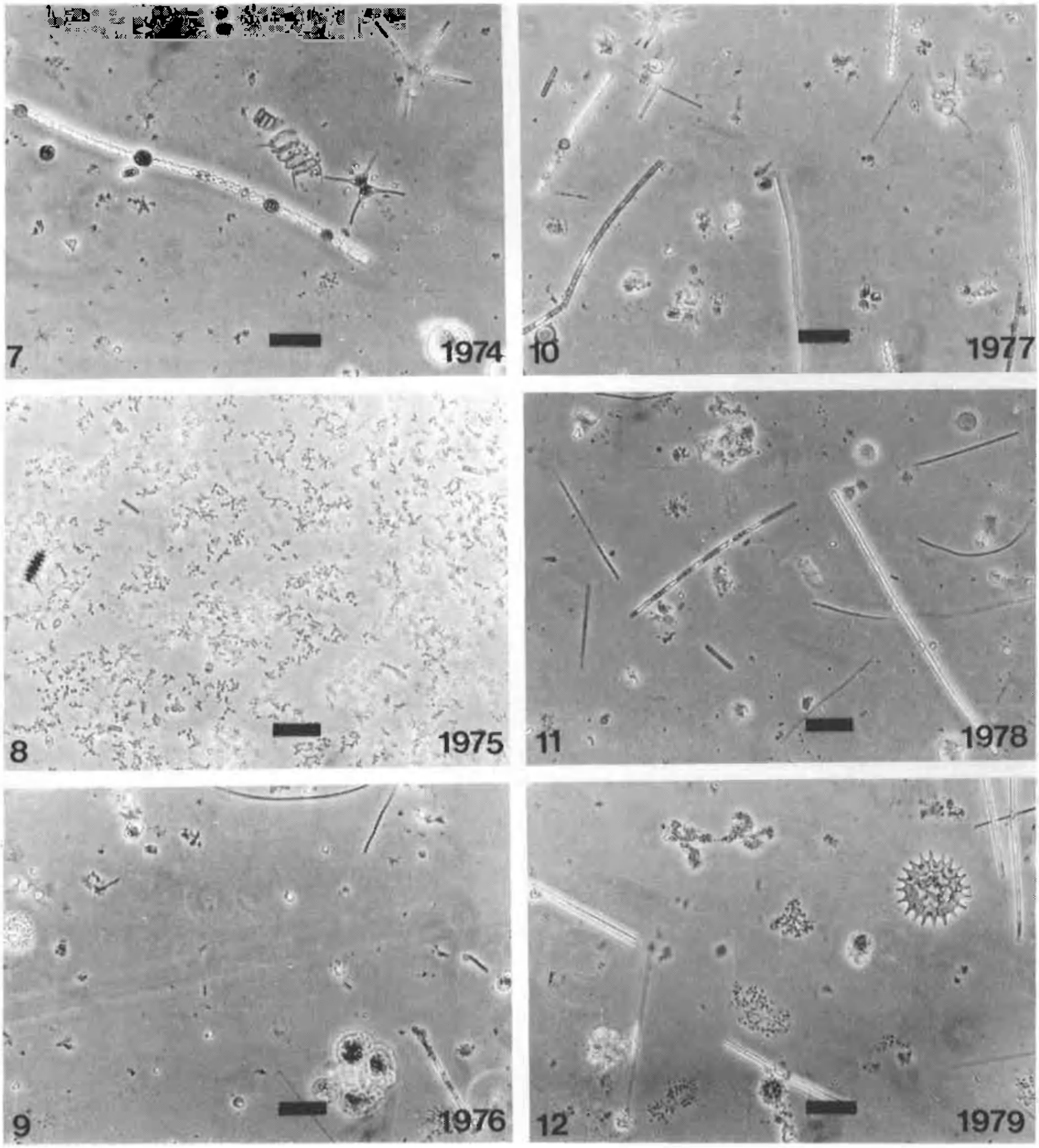
Micrographs of plankton algae
Fig 1–177

Illustrations printed with contribution from

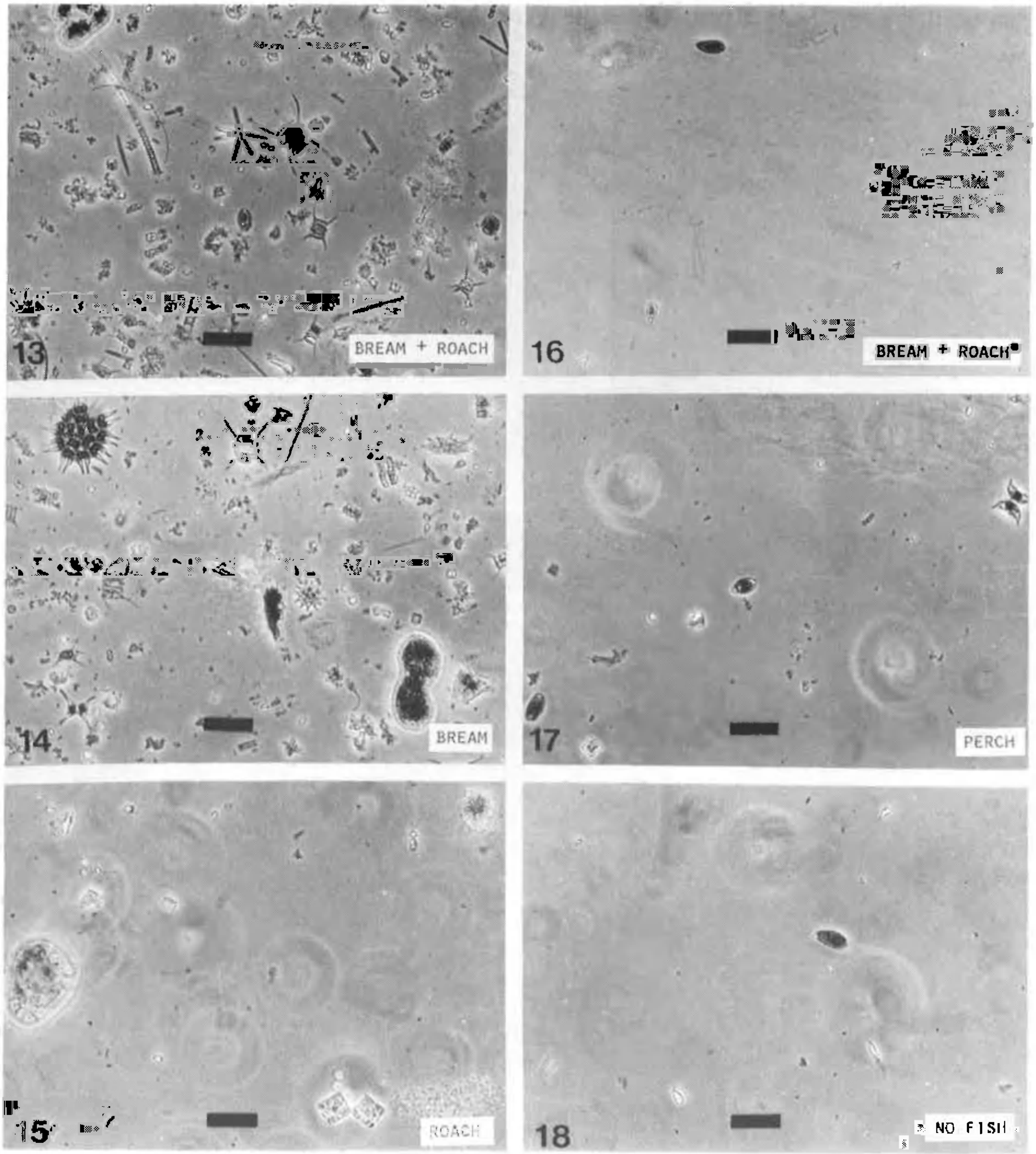
LÄNGMANSKA KULTURFONDEN



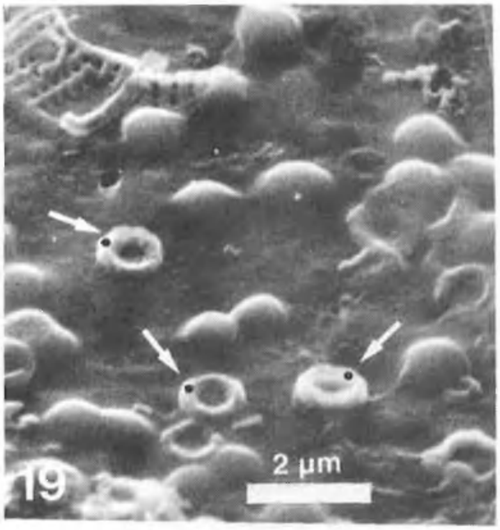
1-6. The phytoplankton community in Lake Trummen during August, 1968-1973. Equal volumes of original samples used. All micrographs have the same magnification. Scale = 50 µm.

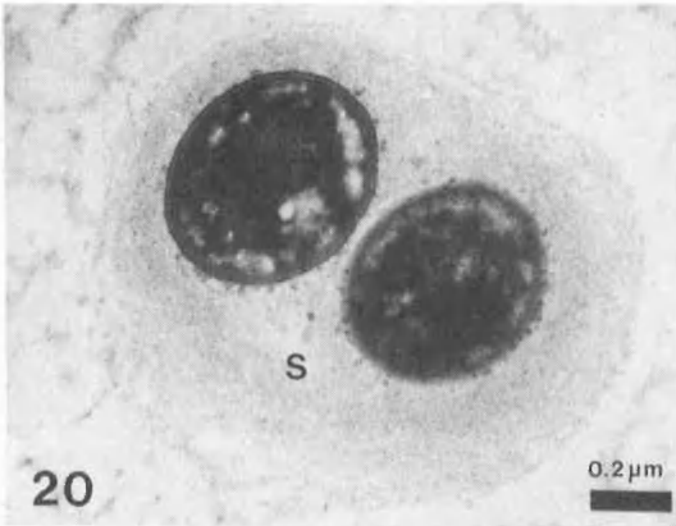


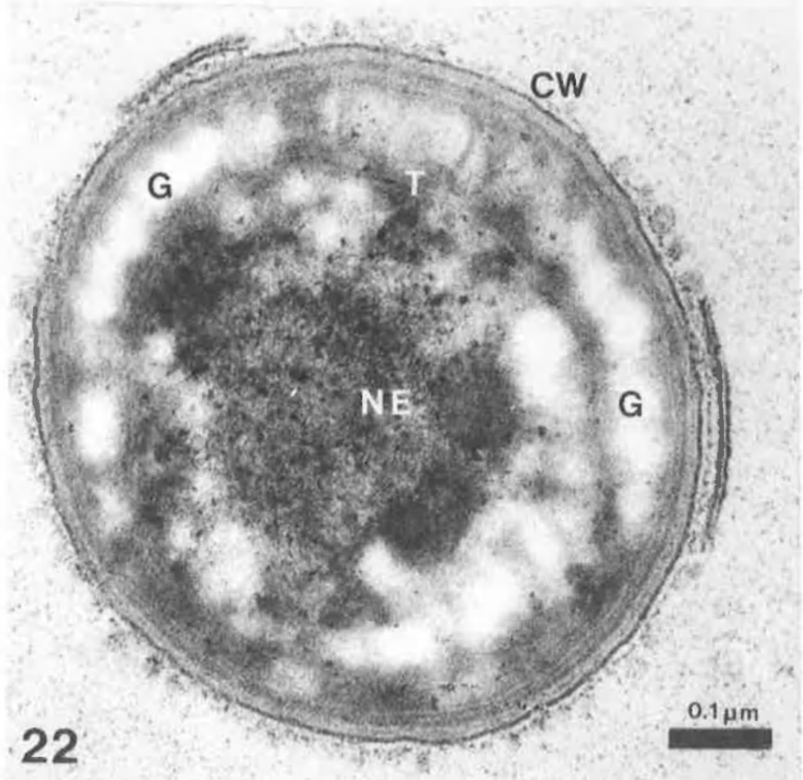
7-12. The phytoplankton community in Lake Trummen during August, 1974-1979. Equal volumes of original samples used. All micrographs have the same magnification. Scale = 50 μm.



13-18. The phytoplankton community in the enclosures stocked with different species of fish, August 30, 1978. * = Fish excluded from sediment by a net. Equal volumes of original samples used. All micrographs have the same magnification. Scale = 50 µm.

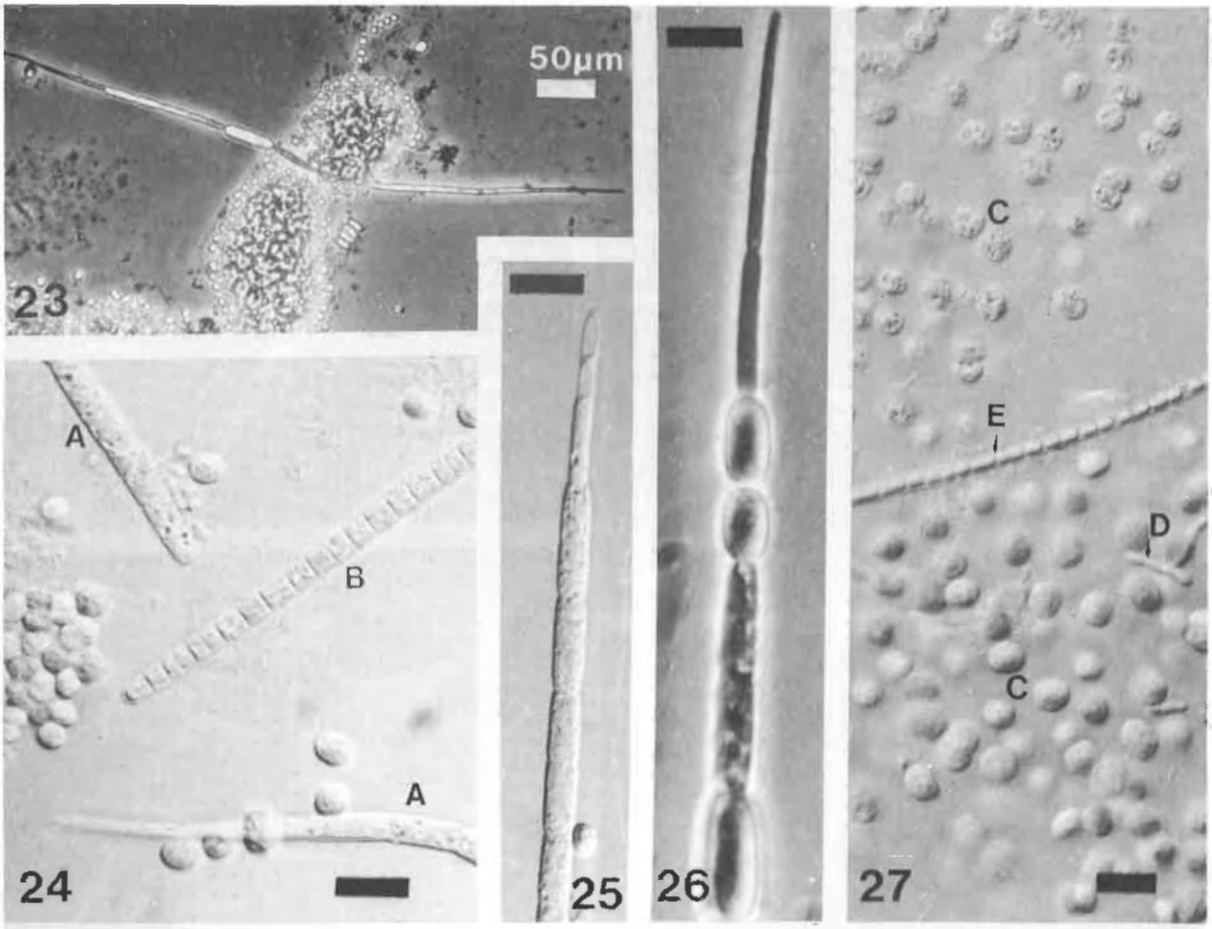


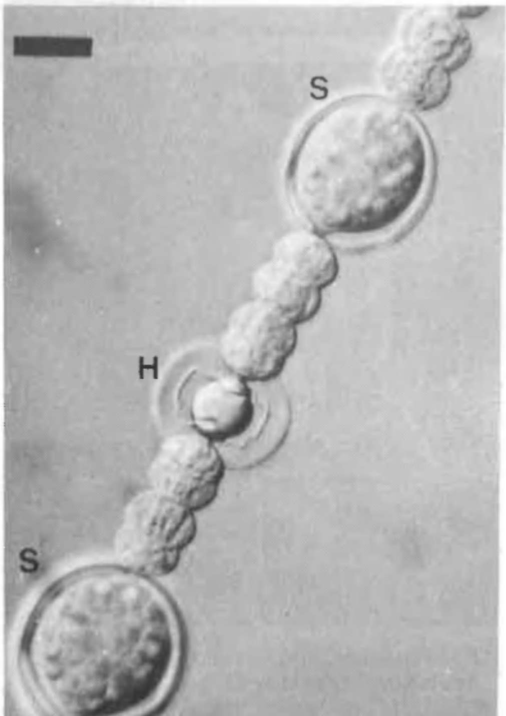


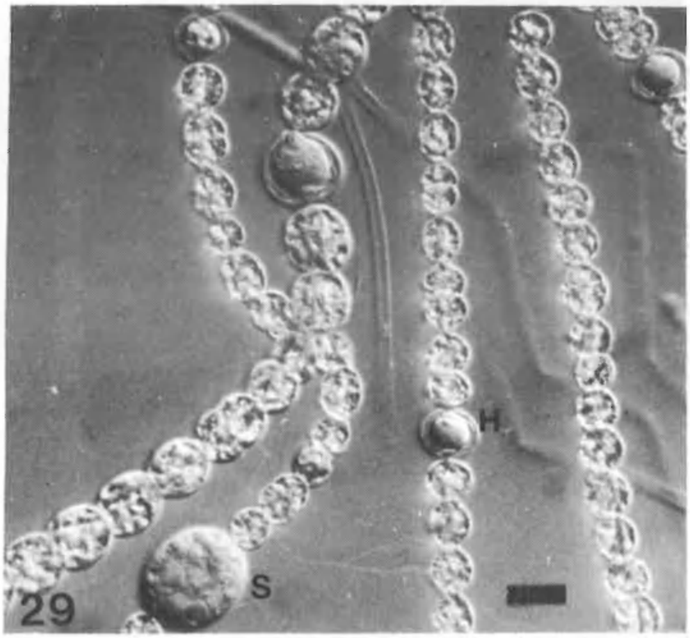


Cyanodictyon imperfectum

19. Cells with iron oxide rings; the sites for X-ray analysis are indicated
20. A normal cell pair in mucus (S)
21. Cells in pairs, forming filaments surrounded with sheath (S)
22. The ultrastructure of a cell showing the 4 layered cell wall (CW), nuclear equivalents (NE), unstructured granules (G) and thylakoids (T)







Raphidiopsis mediterranea (23-26)

23. Trichome with pointed ends and spores

24. Trichome ends of R. *mediterranea* (A), *Oscillatoria agardhii* (B)

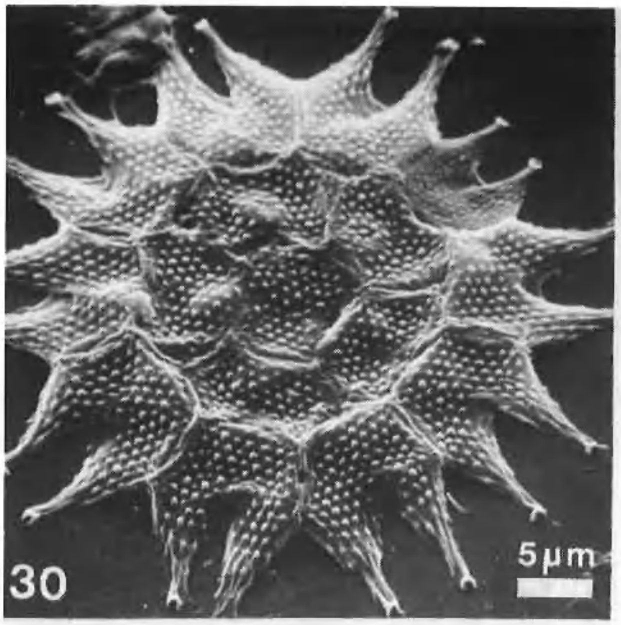
25. Trichome with pointed and empty end cells

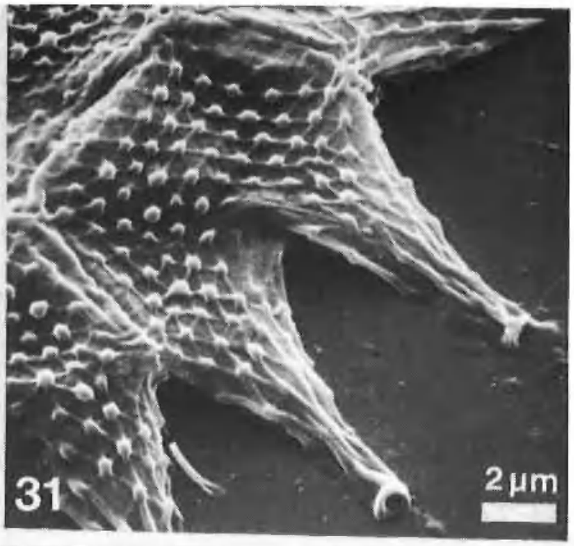
26. Trichome with 3 spores

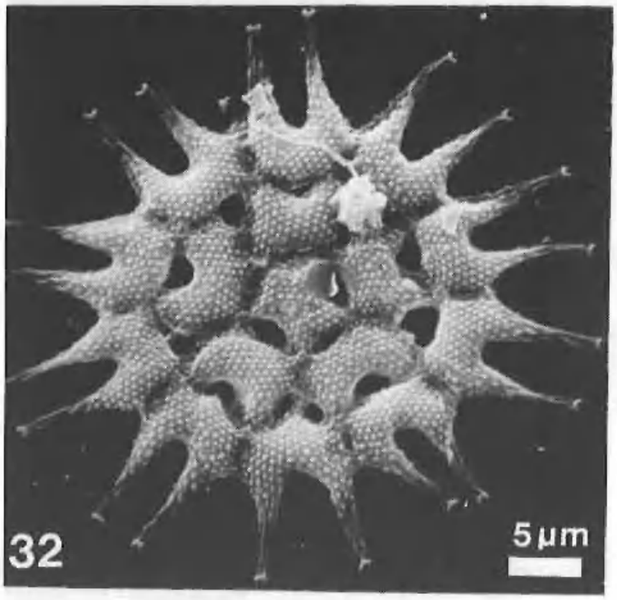
27. *Microcystis aeruginosa* (C), *Pseudanabaena mucicola* (D), *Lyngbya limnetica* (E)

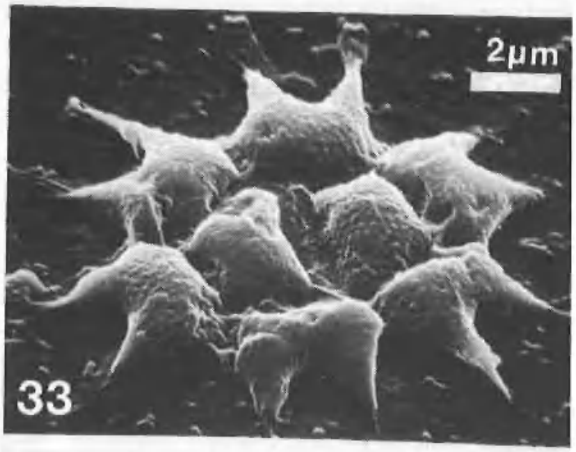
28. *Anabaena solitaria* f. *smithii* with spores (S) and heterocyst (H)

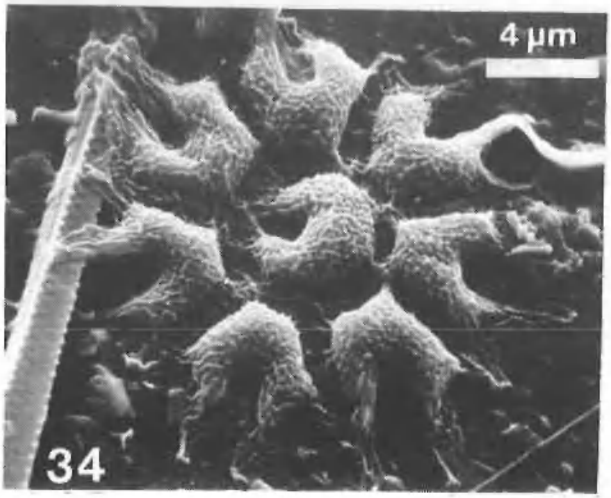
29. *Anabaena viguieri* with spore (S) and

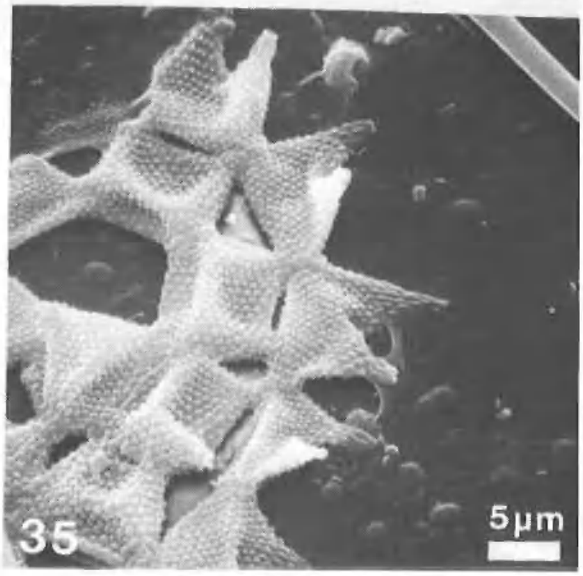












30. *P. boryanum* var. *boryanum*

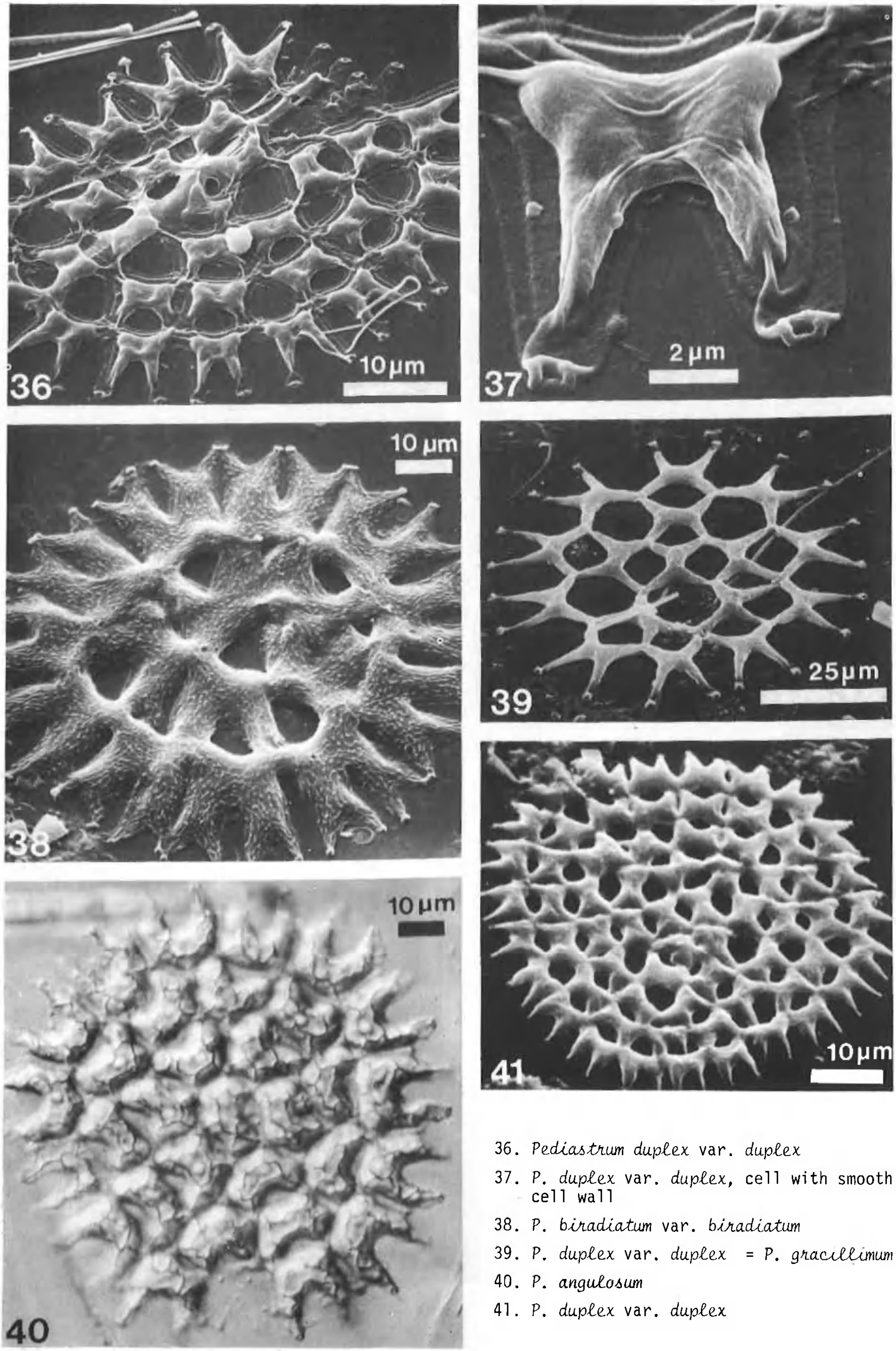
31. *P. boryanum* var. *boryanum*, cell with netlike ultrastructure

32. *P. boryanum* var. *perforatum*

33. *P. boryanum* var. *pseudoglabrum*

34. *P. tetras*

35. *P. boryanum* var. *cornutum*



36. *Pediastrum duplex* var. *duplex*

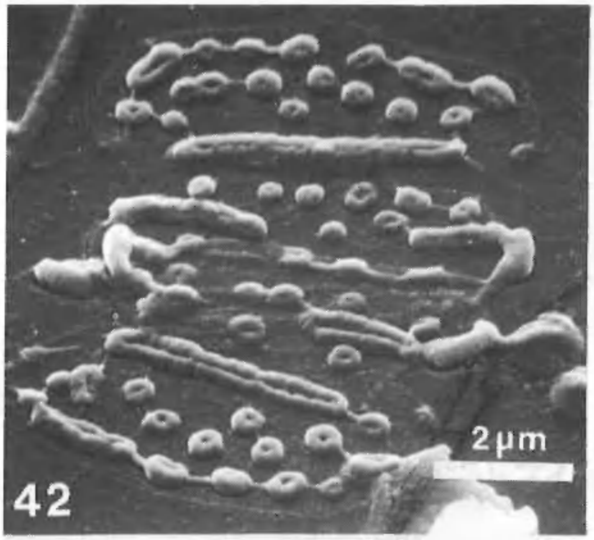
37. *P. duplex* var. *duplex*, cell with smooth cell wall

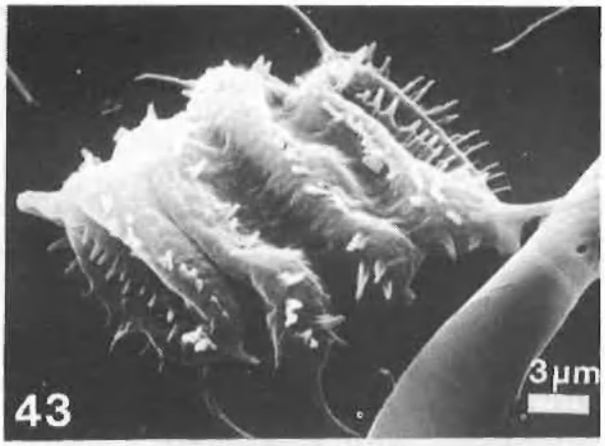
38. *P. biradiatum* var. *biradiatum*

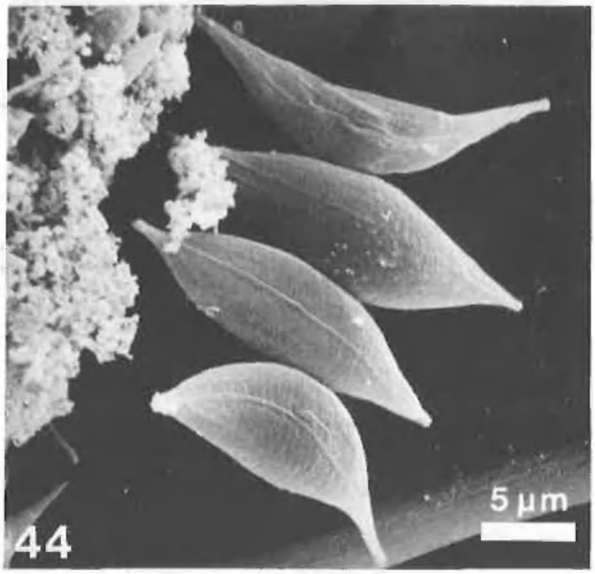
39. *P. duplex* var. *duplex* = *P. gracillimum*

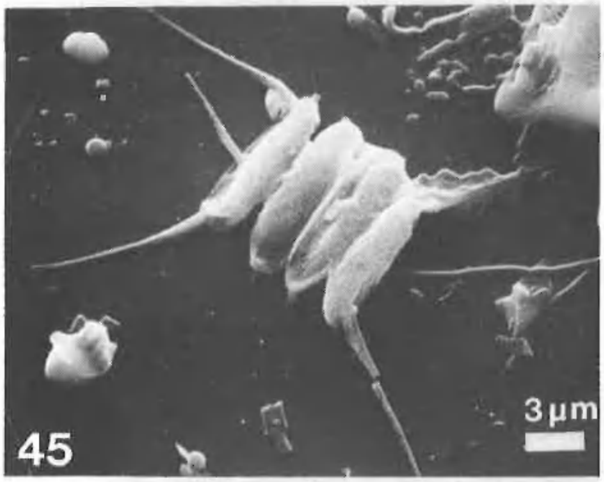
40. *P. angulosum*

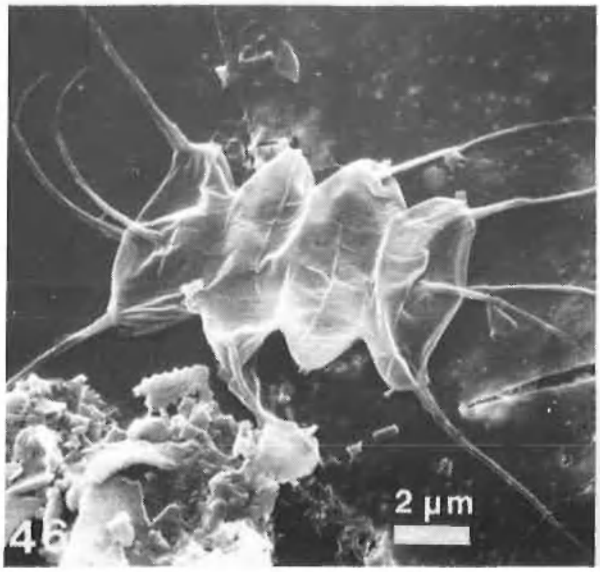
41. *P. duplex* var. *duplex*

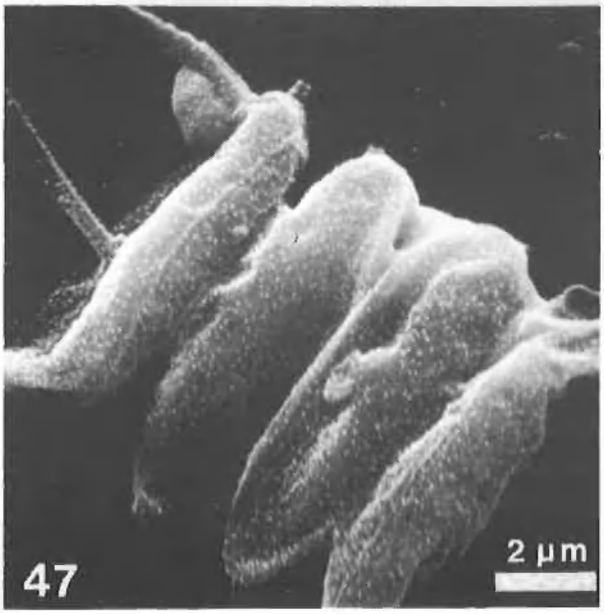










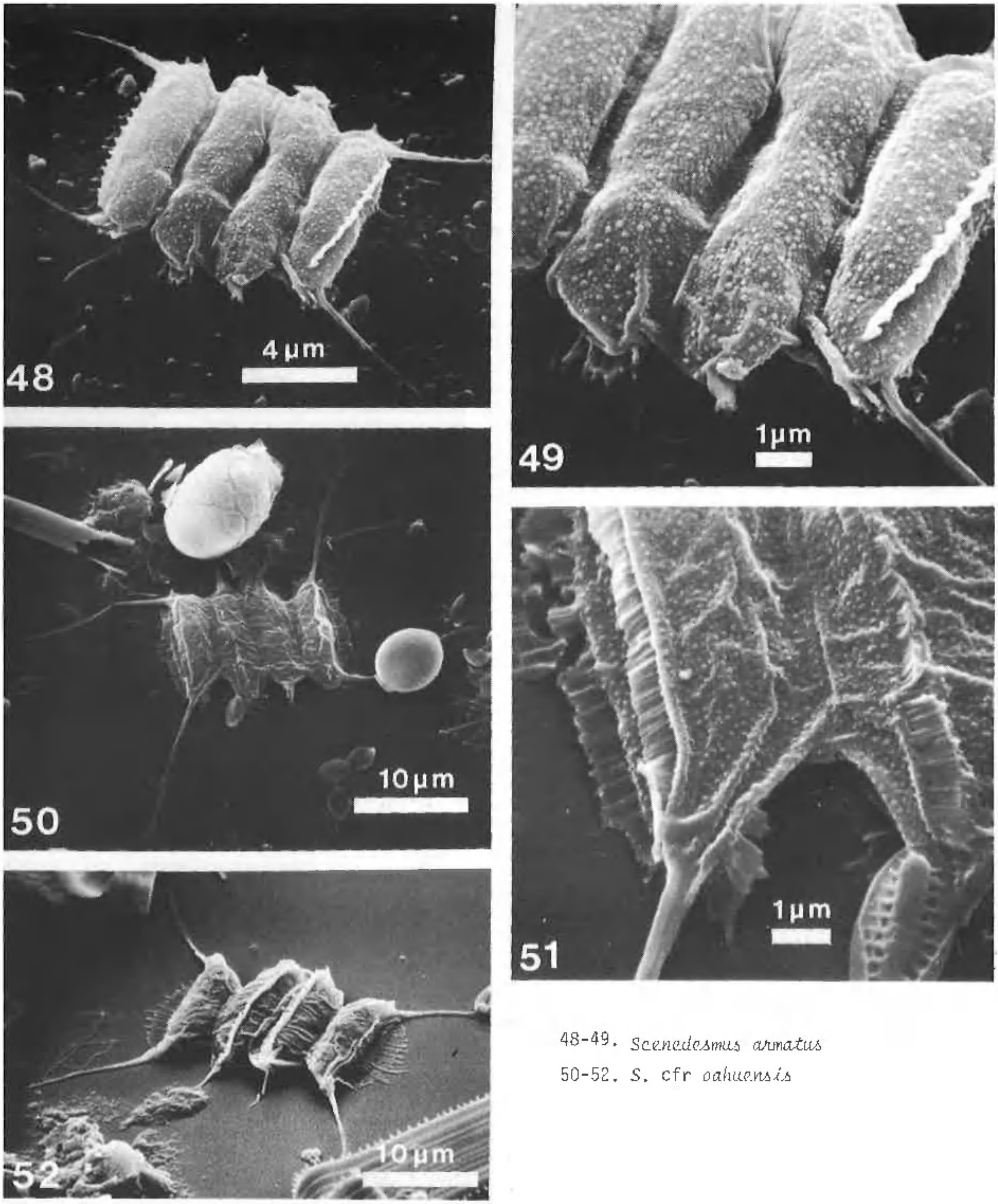


42. *Scenedesmus costato-granulatus*

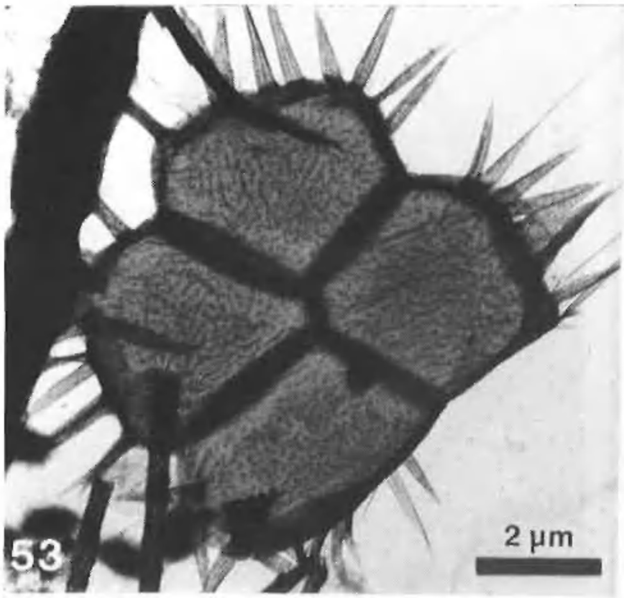
43. *S. lefevrii*

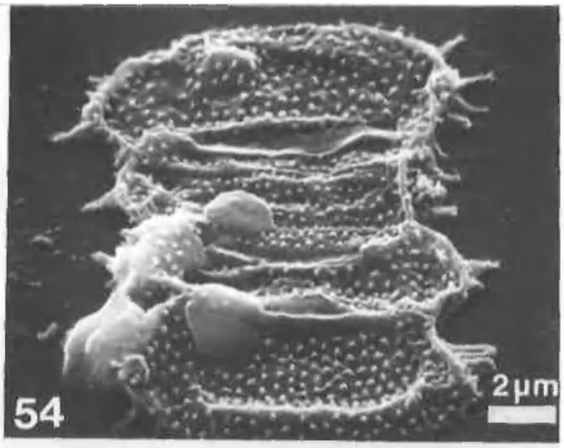
44. *S. acuminatus*

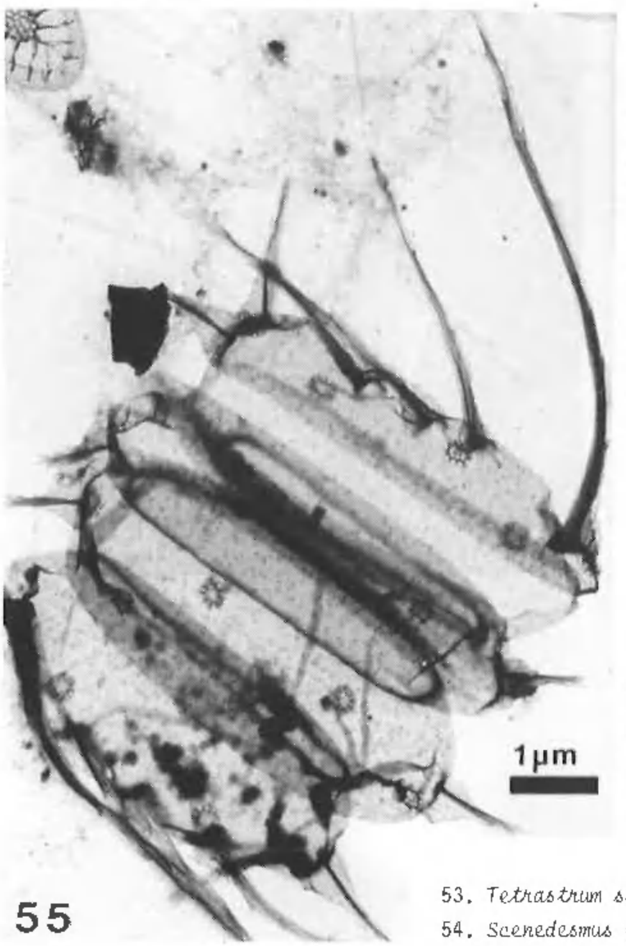
45-47. *S. abundans*

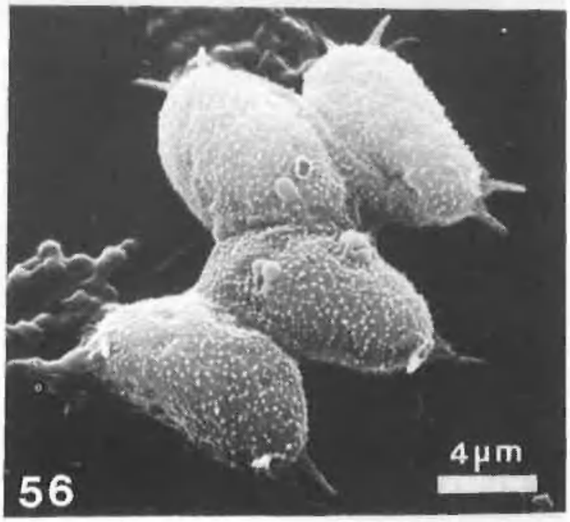


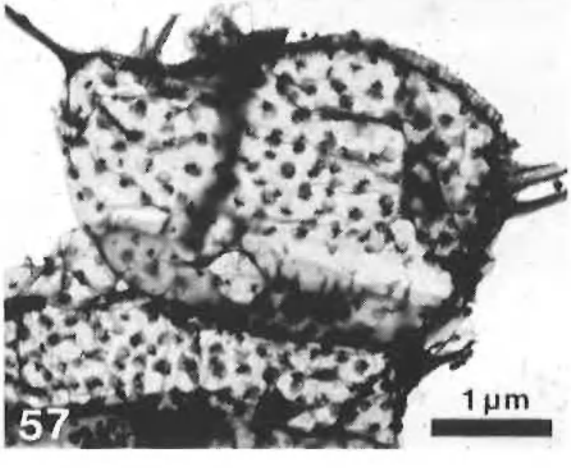
48-49. *Scenedesmus armatus*
50-52. *S.* cfr *oahuensis*



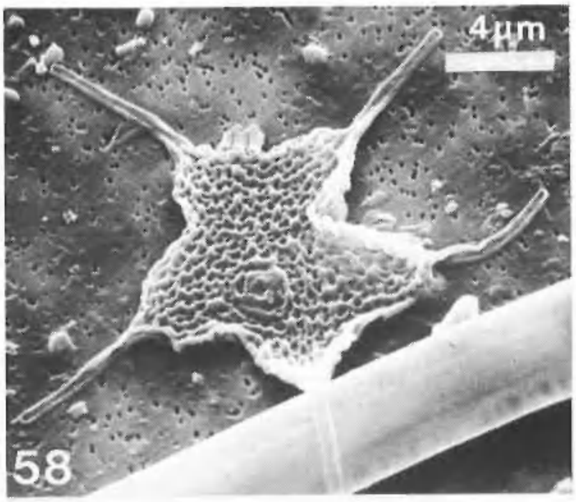


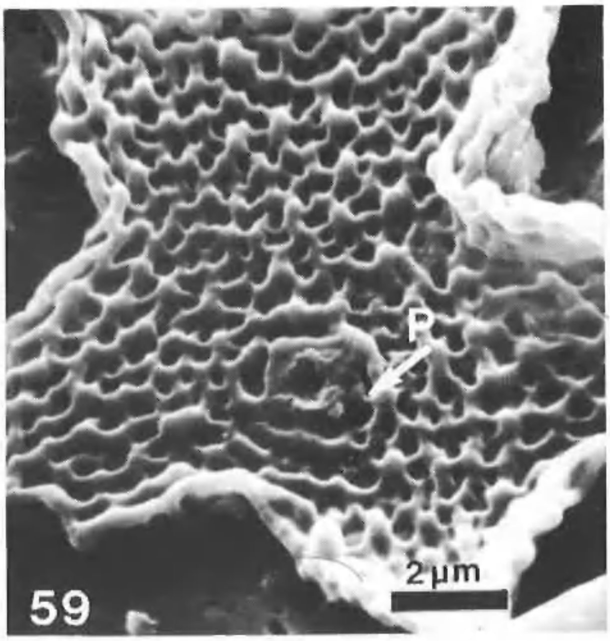


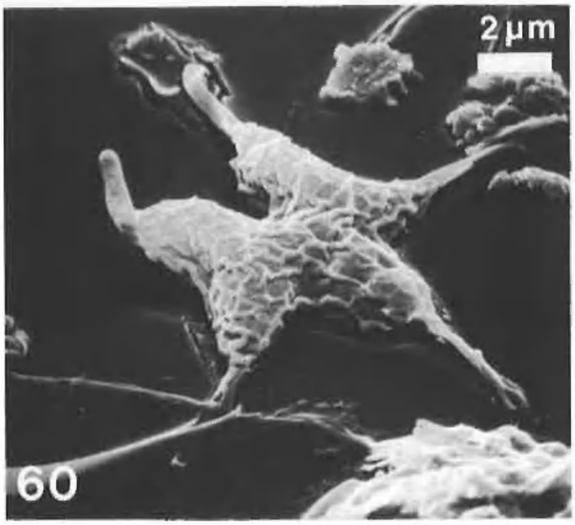


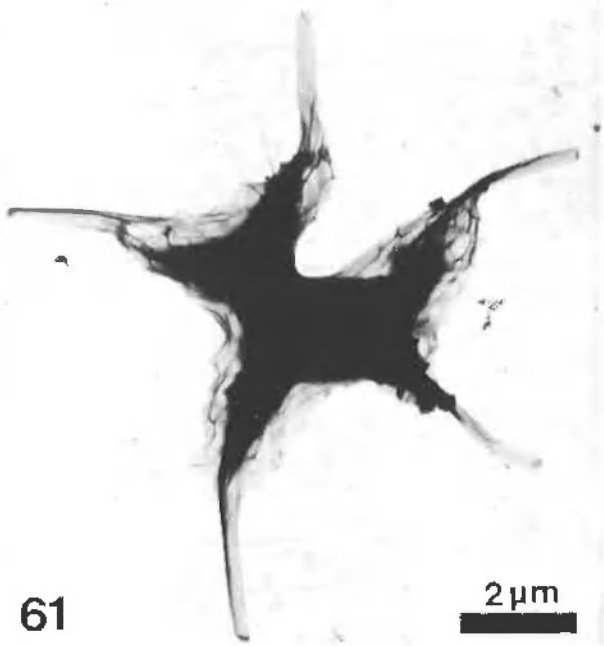


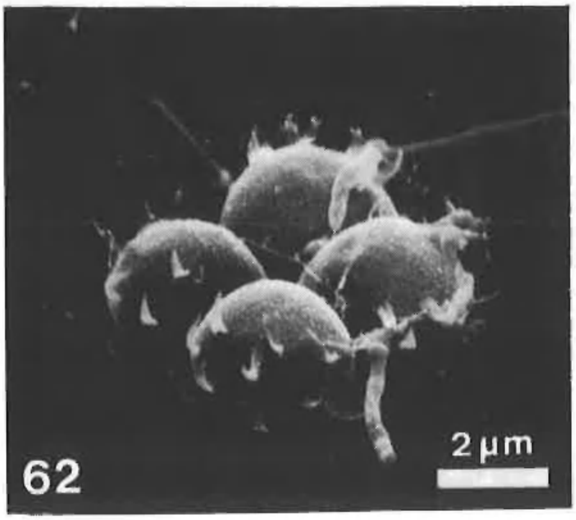
53. *Tetrastrum staurogeniaeforme*
54. *Scenedesmus* cfr *arvernensis*
55. *Scenedesmus subspicatus*
56-57. *S. denticulatus*









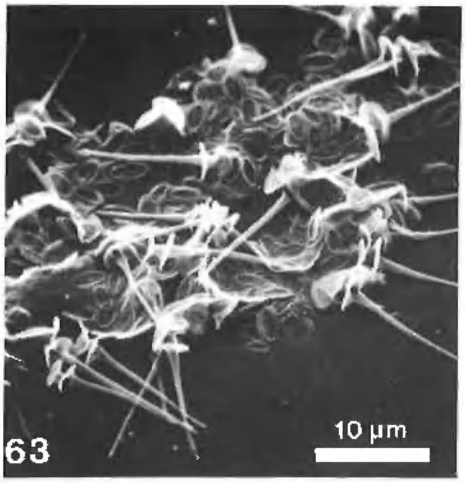


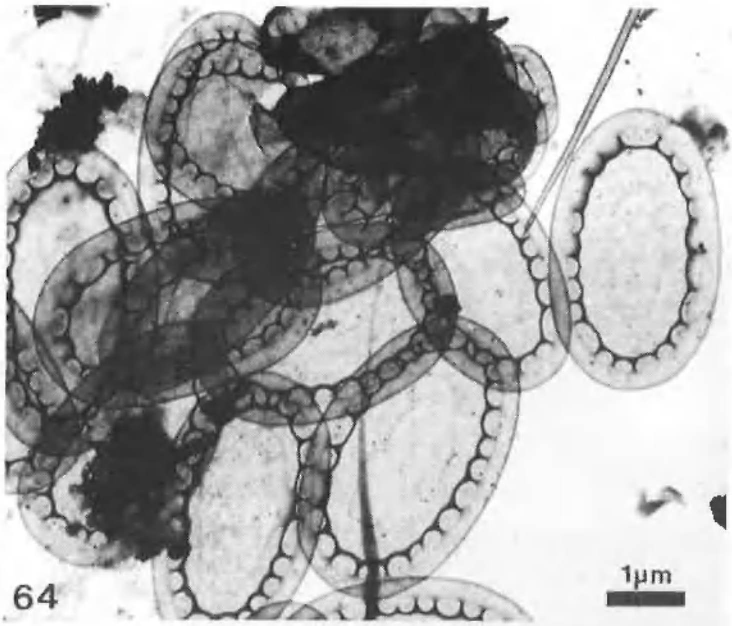
Tetraedron caudatum

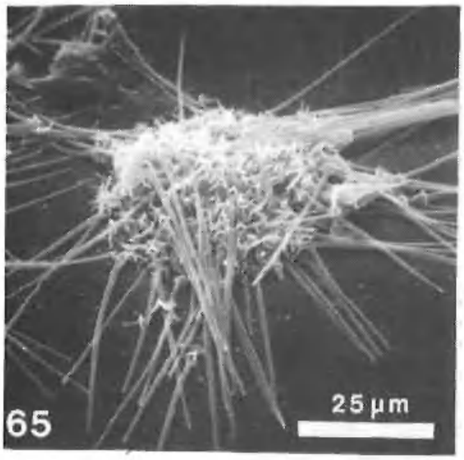
58-59. Complete cell with netlike ultrastructure and pyrenoid (P)

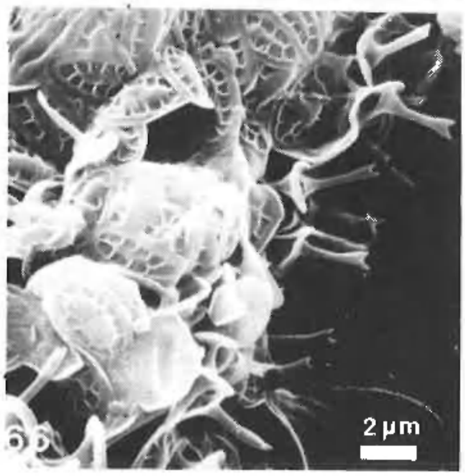
60-61. Cell with different ultrastructure

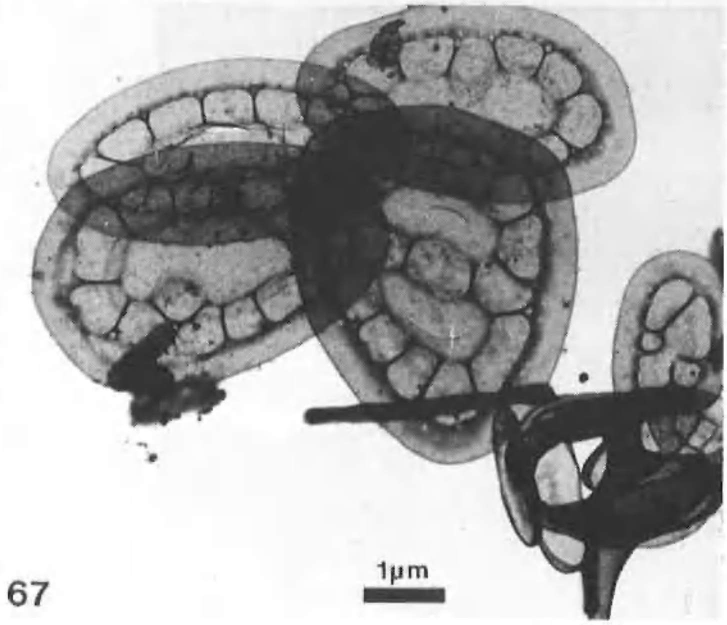
62. *Tetrastrum* sp. complete coenobium









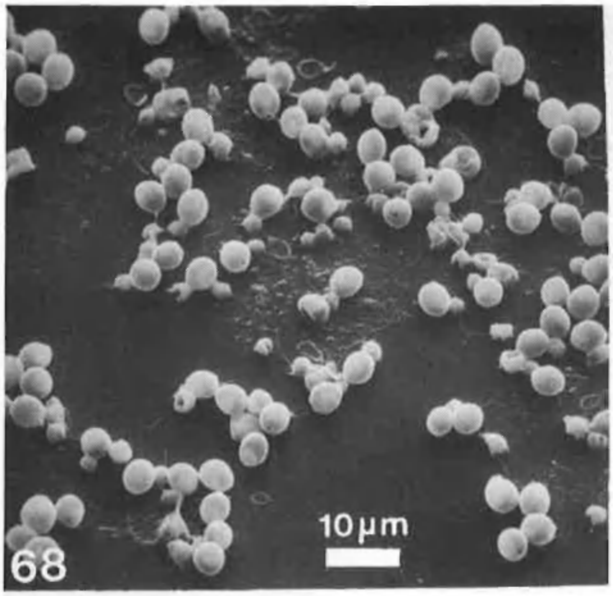


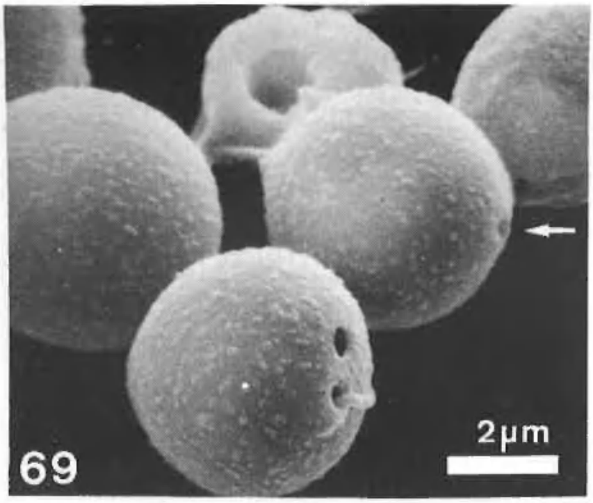
Chrysosphaerella brevispina

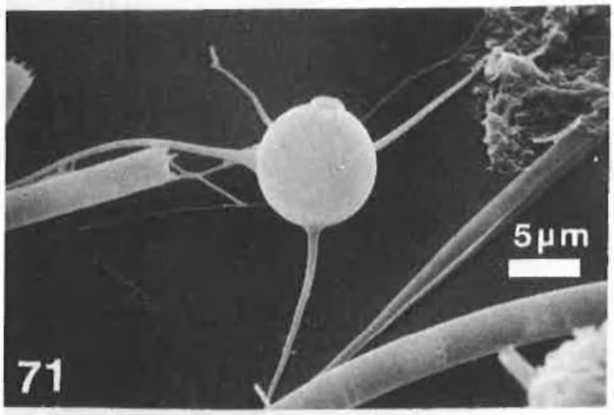
63. Colony with body scales and spines
64. Body scales

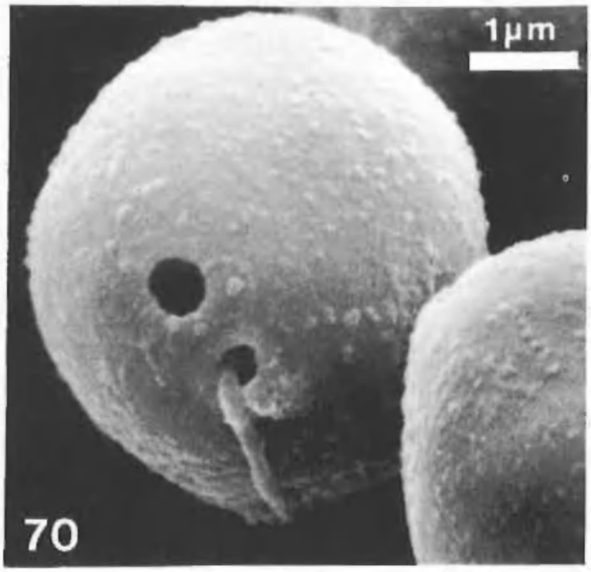
Chrysosphaerella multispina

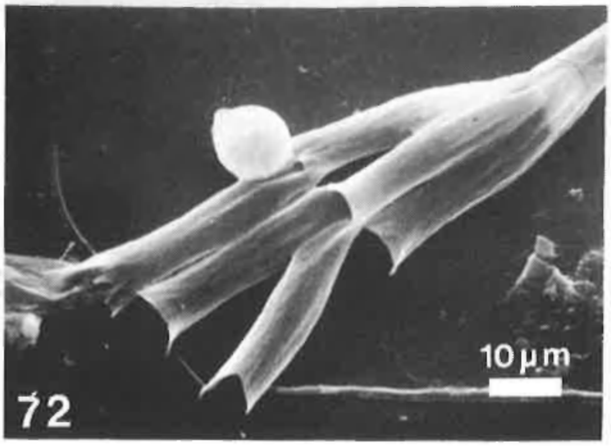
65-66. Colony with body scales, short and long spines
67. Body scales and basal part of spines











Chrysococcus triporus

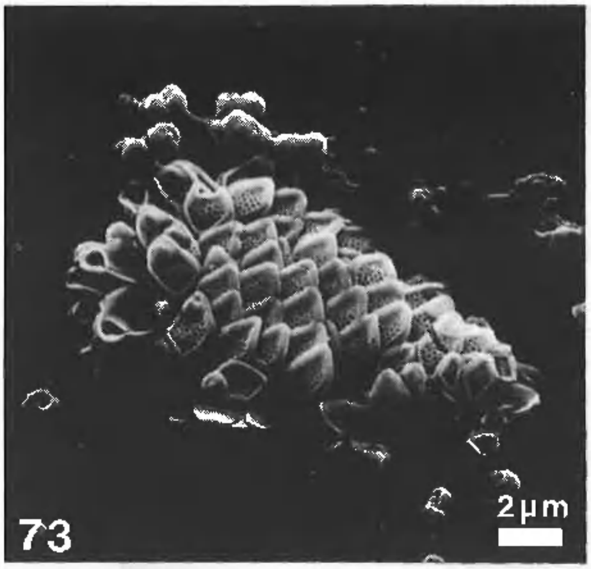
68. Mass development of *C. triporus*

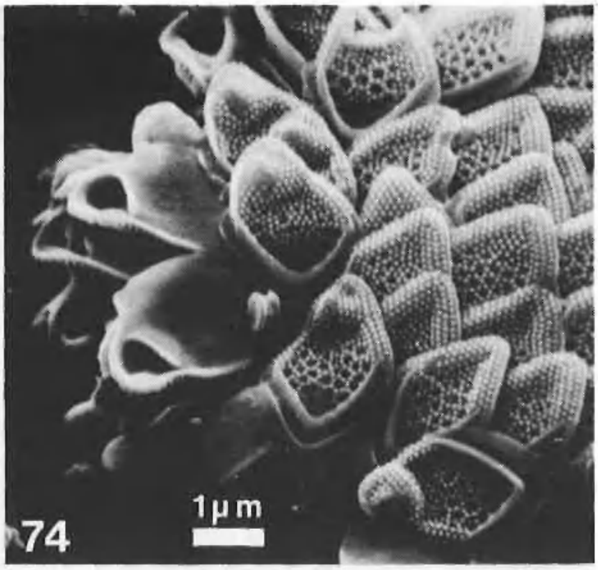
69. Cell with 2 pores, one having the flagellum; indicated cell shows the third pore

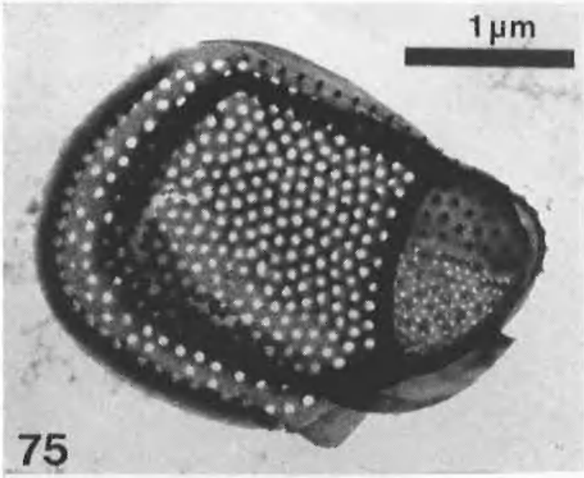
70. The flagellum protruding from the small pore

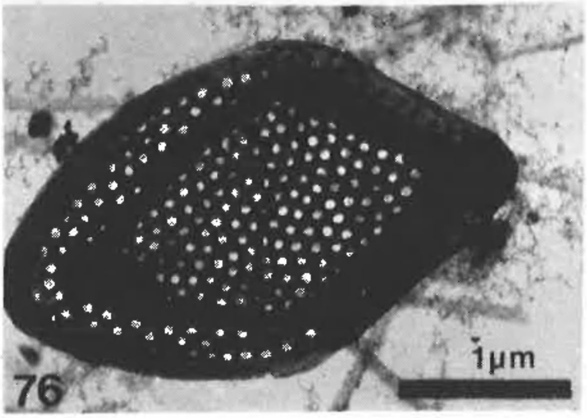
71. *Chrysastrella paradoxa*

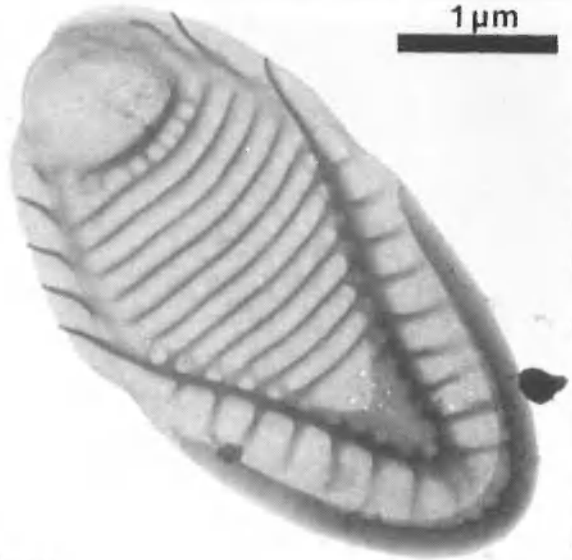
72. *Dinobryon cylindricum* with a cyst











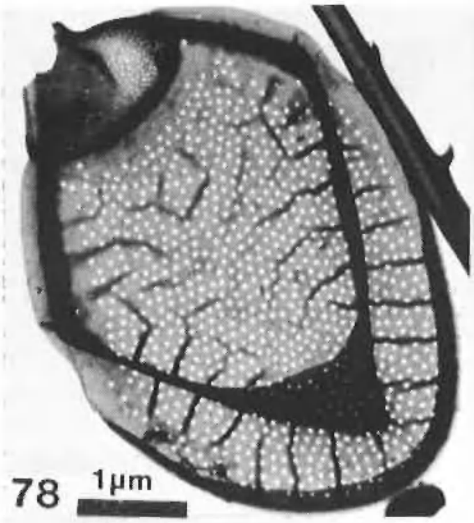
77

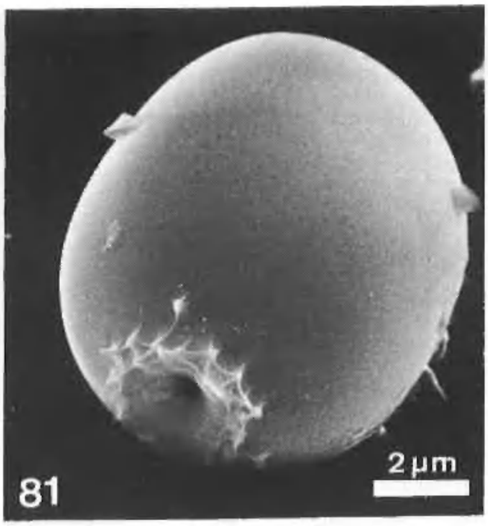
Mallomonas annulata

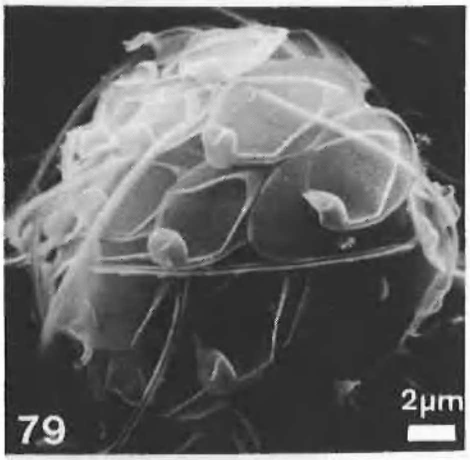
73-74. Cell with scales, bristles missing
75. Apical scale
76. Body scale

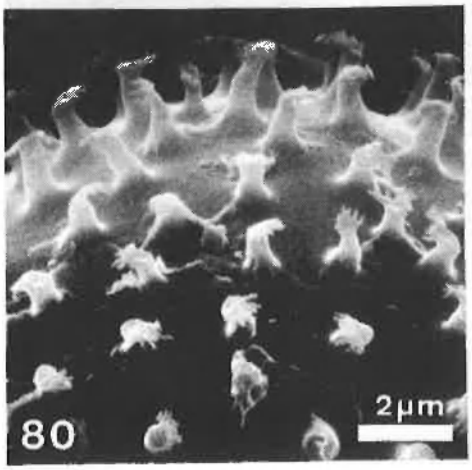
Mallomonas striata

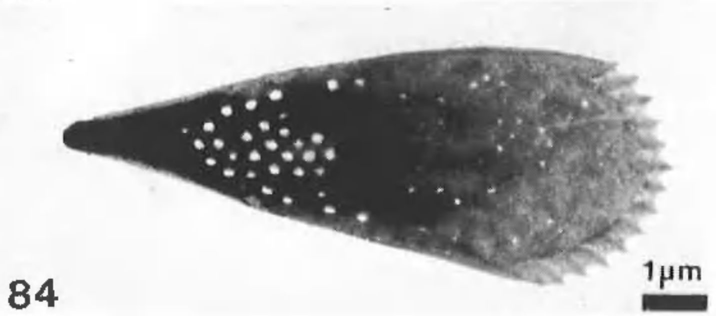
77. Body scale









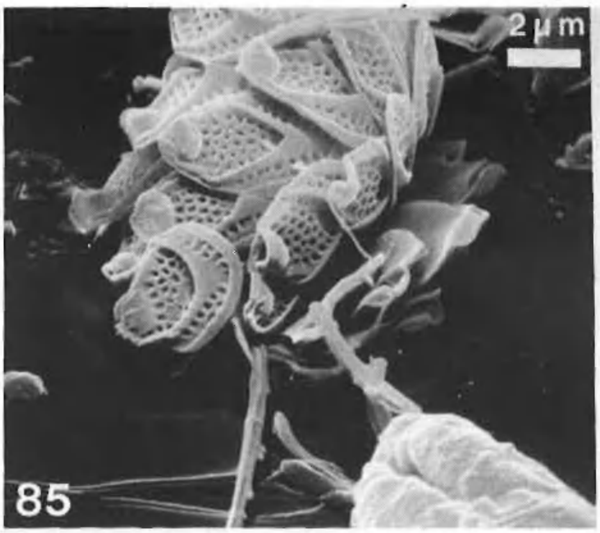


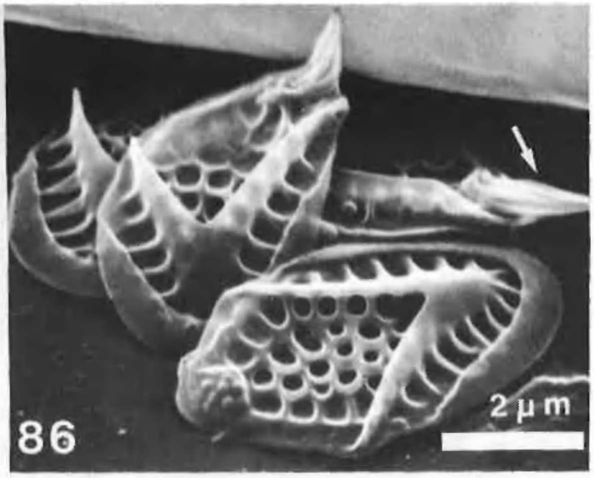
Mallomonas acaroides var. *striatula*

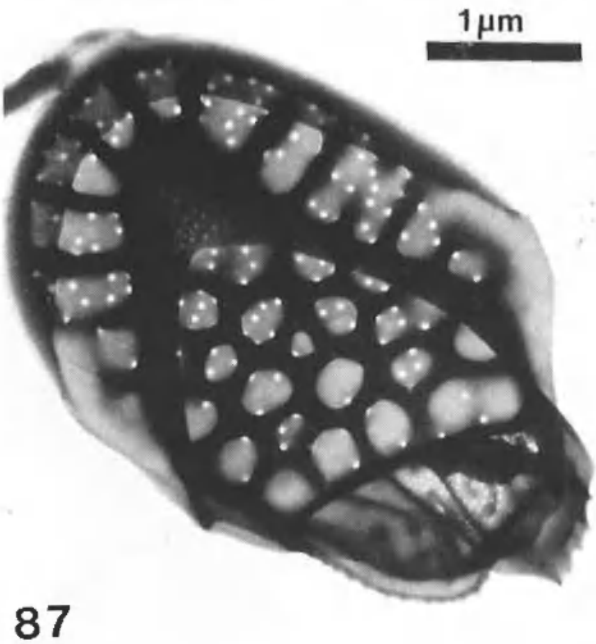
78. Body scale
79. Cell with cyst inside
80. Mature cyst with spines fully developed

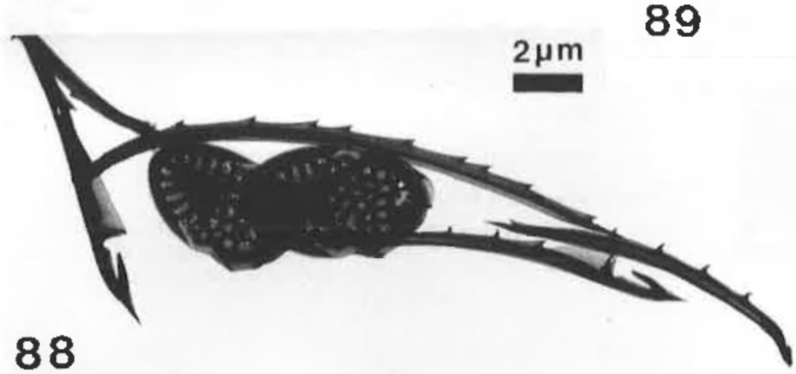
Mallomonas akrokomos

81. Mature cyst with pore open
82. Apical scale
83. Body scale
84. Basal scale







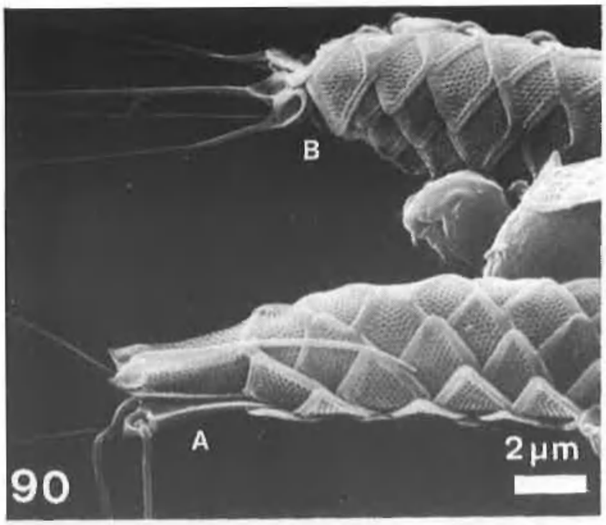


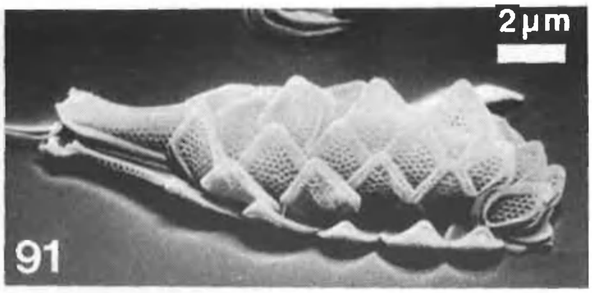
Mallomonas crassisquama

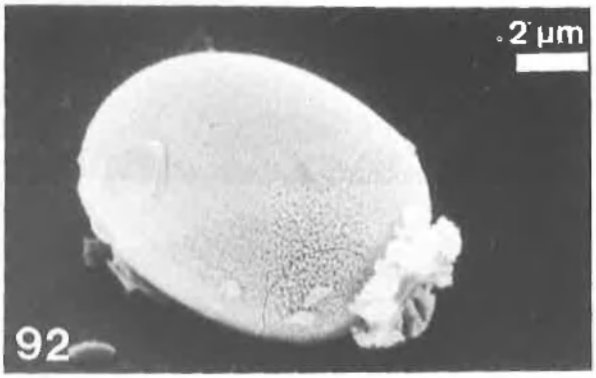
85. Apical part of a cell
86. Two basal scales with spines
87. Body scale
88. Helmet and serrated bristles and two body scales

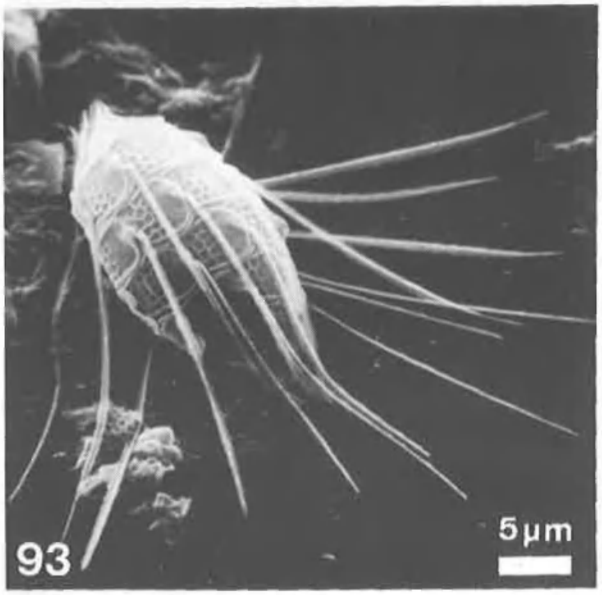
Mallomonas elongata

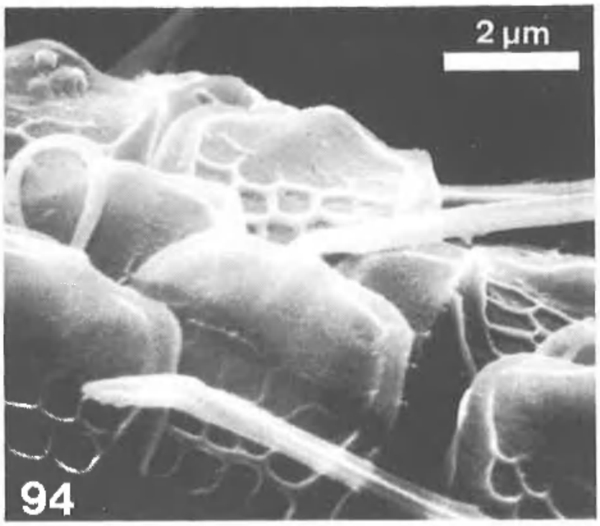
89. Body scale

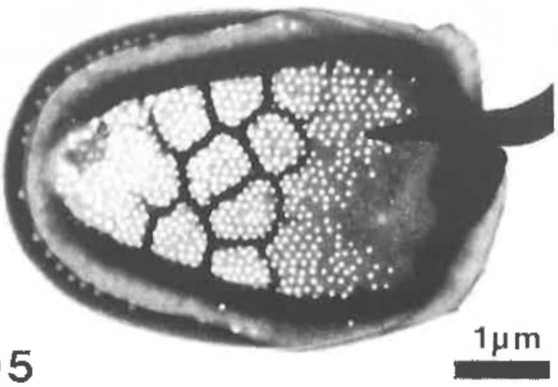












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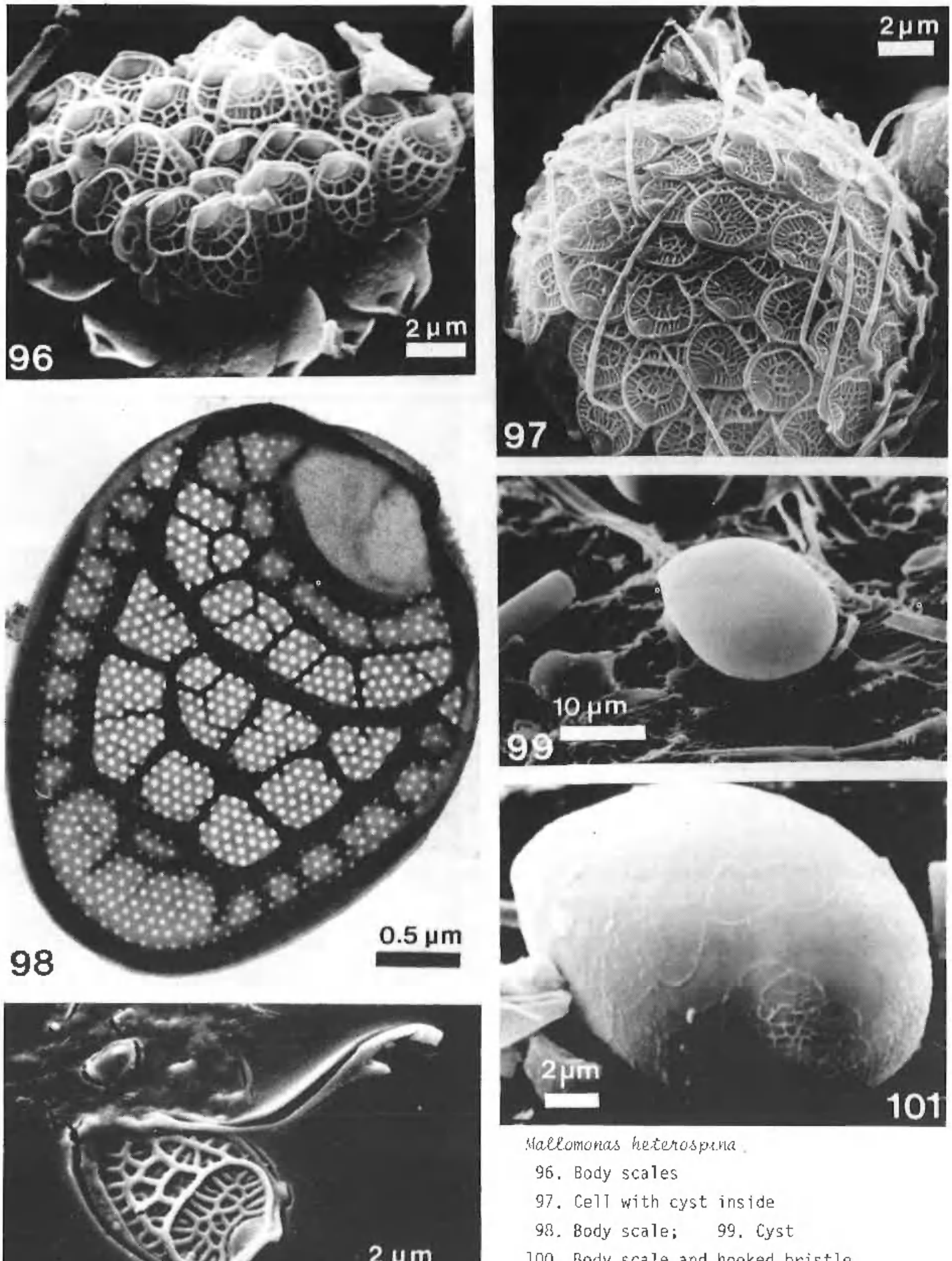
Mallomonas eoa

90. Apical (A) and basal (B) part of a cell
91. Cell missing basal spines
92. Cyst with remaining scale

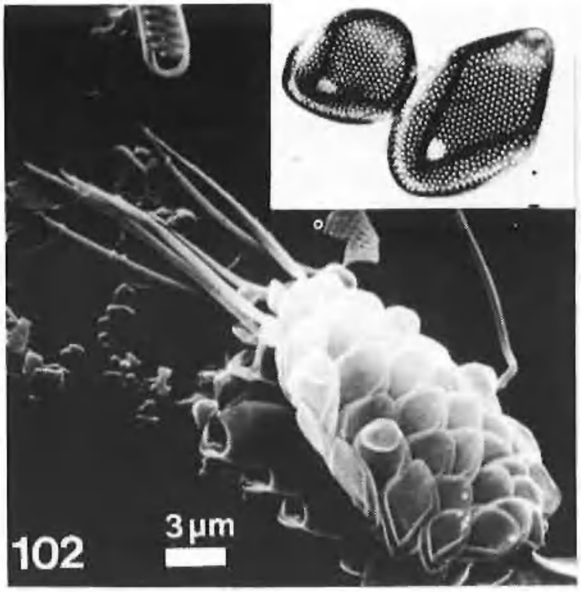
Mallomonas reginae

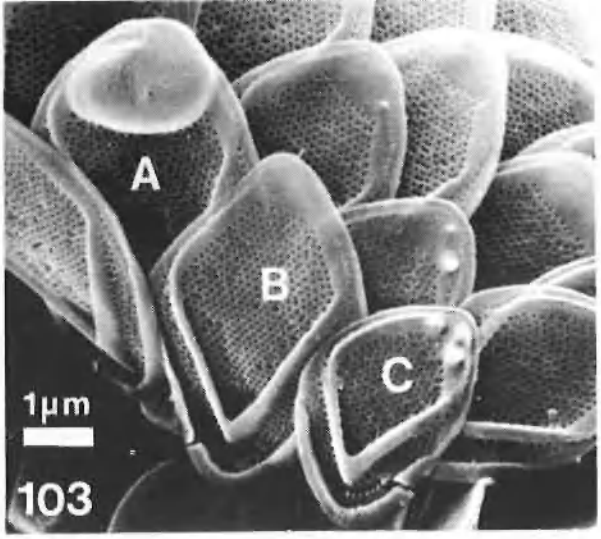
93. Complete cell
94. Body scales with bristles inserted
95. Body scale

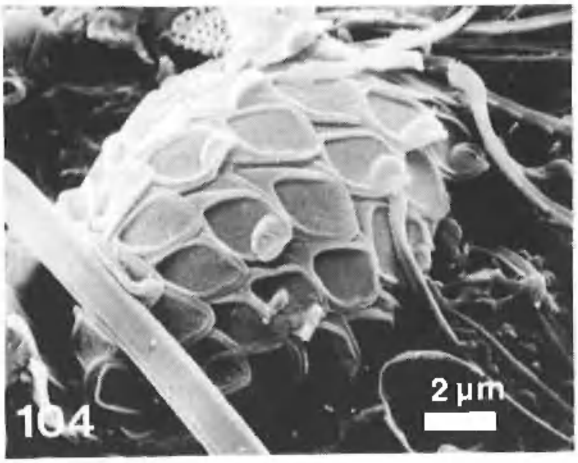


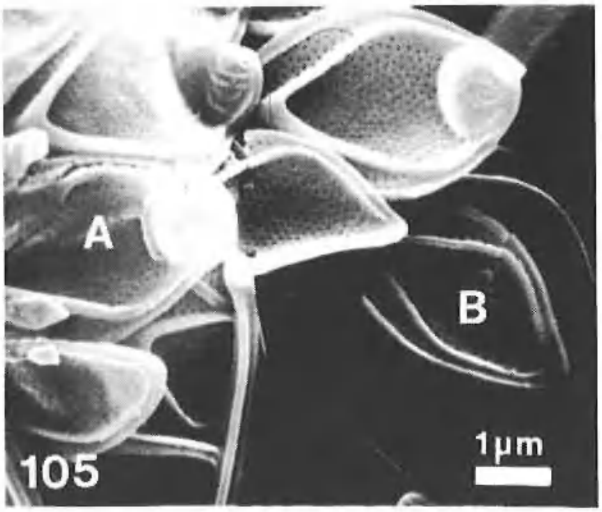
Mallomonas heterospina

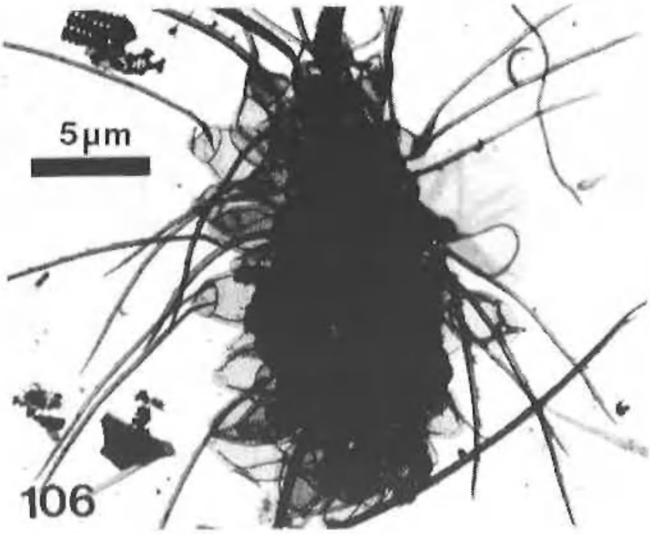
96. Body scales
97. Cell with cyst inside
98. Body scale; 99. Cyst
100. Body scale and hooked bristle
101. Cyst with remaining scales











Mallomonas tonsurata

102. Cell with bristles concentrated at the apical part. Inserted: body scales with typical "window" on the base of the shield

103. *Tripartitae* scale (A), body scale (B) and basal scales with short spines (C)

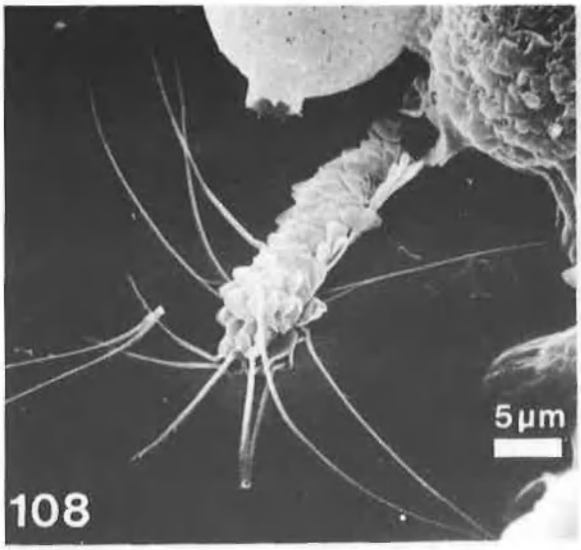
Mallomonas tonsurata var. *alpina*

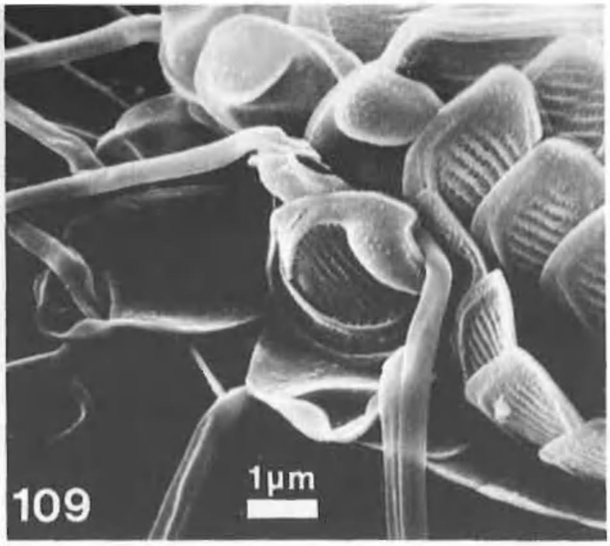
104. Cell with scales and bristles

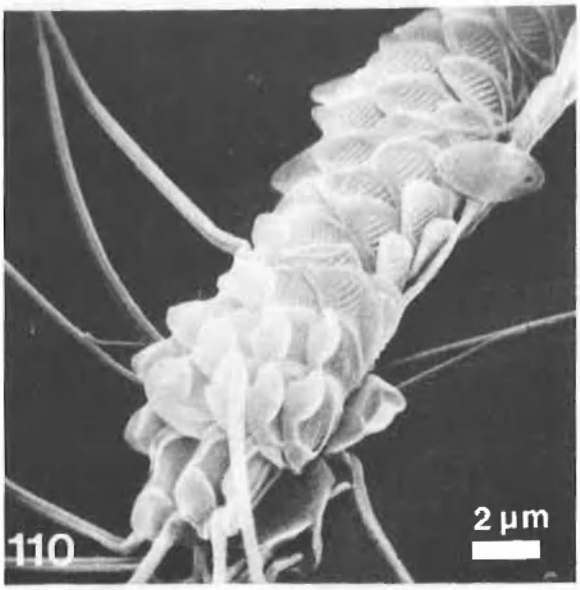
105. *Tripartitae* scales (A) and body scales (B)

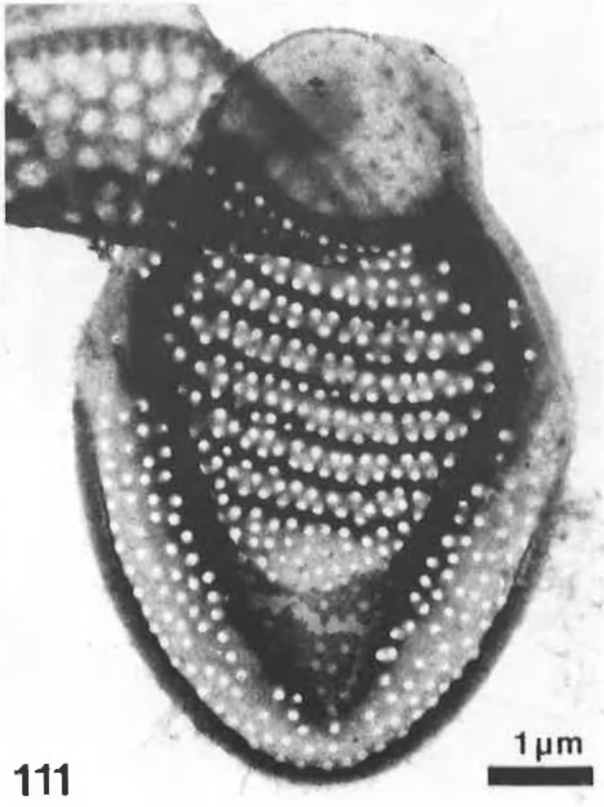
106. Cell with bristles spread over the whole body

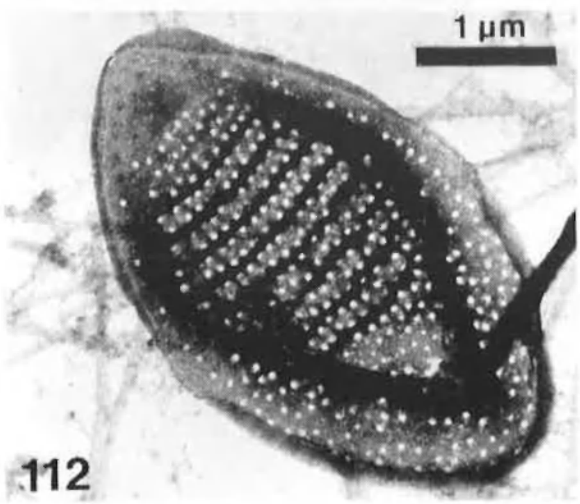
107. *Tripartitae* scales with serrated bristles attached











Mallomonas trummensis

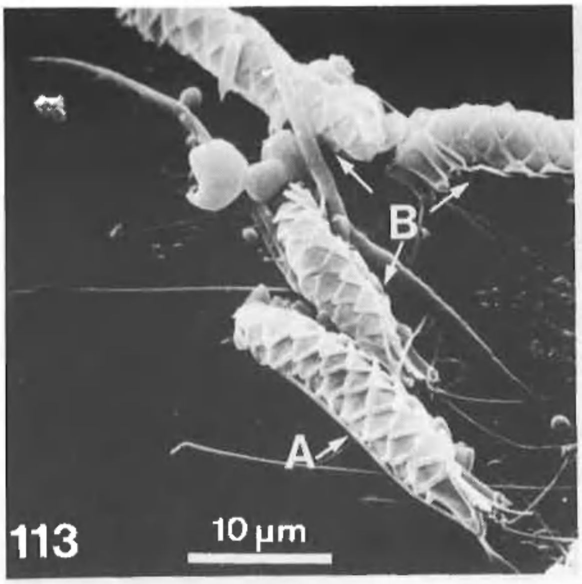
108. Cell with serrated and smooth bristles at the apical end

109. *Tripartitae* scales with bristles

110. Only apical scales have dome and bristle

111. Apical scale

112. Body scale



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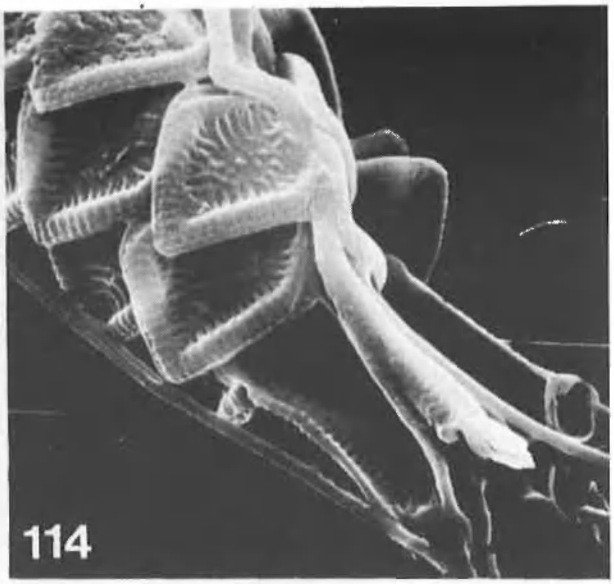

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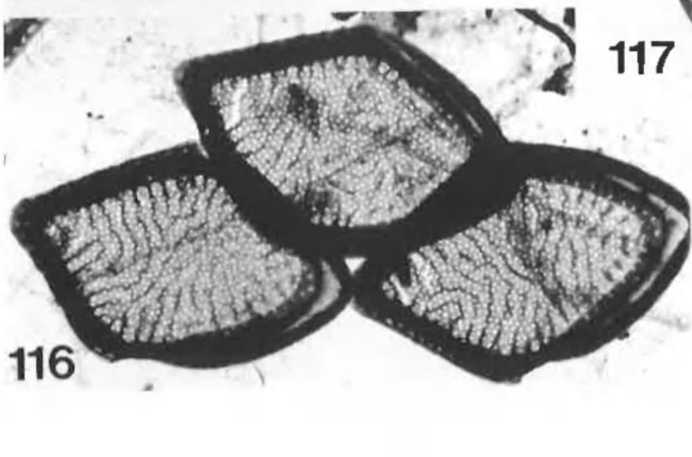
115



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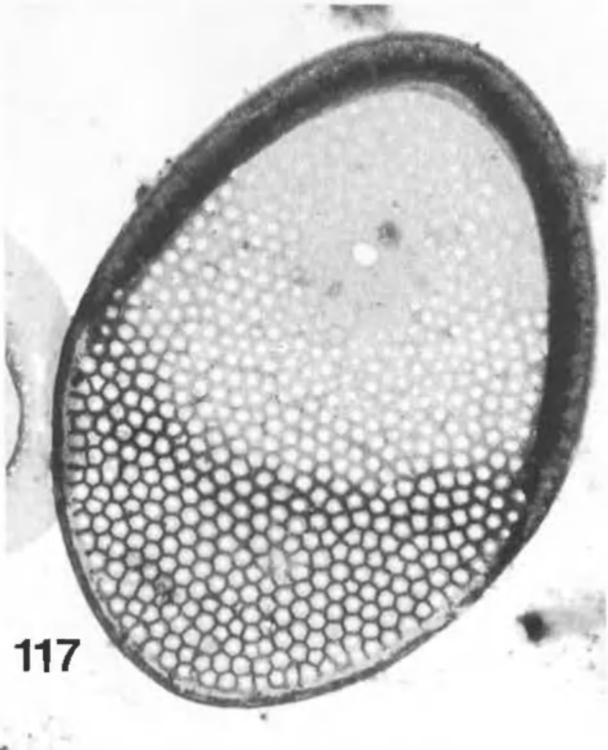

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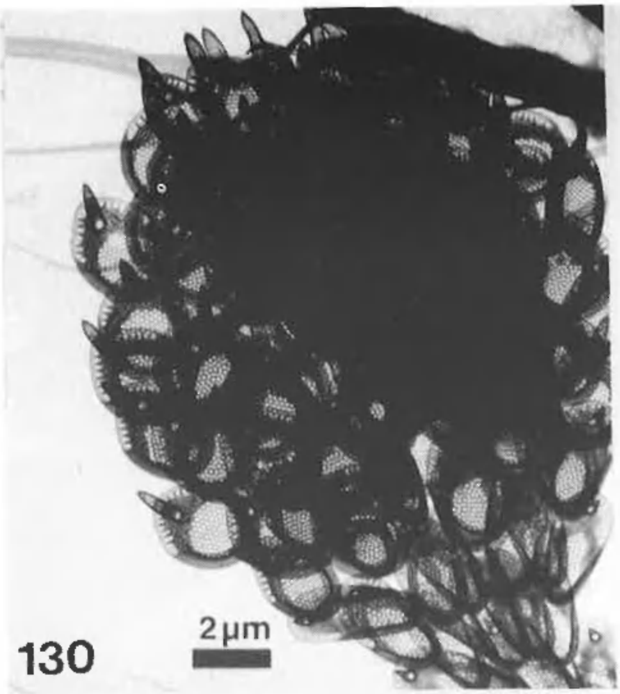
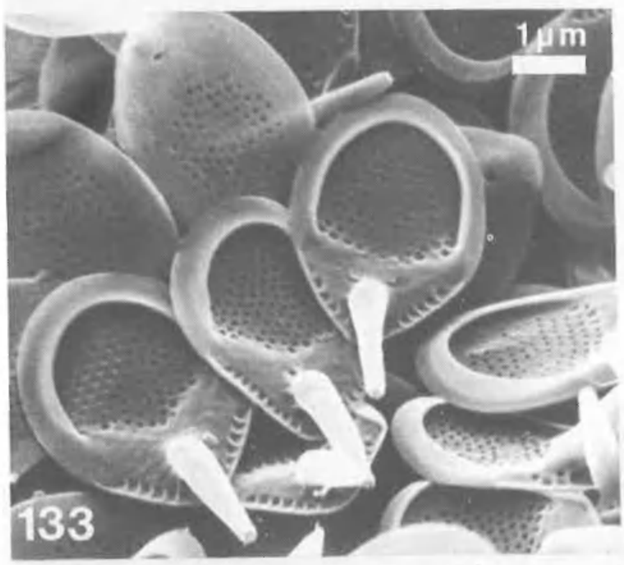
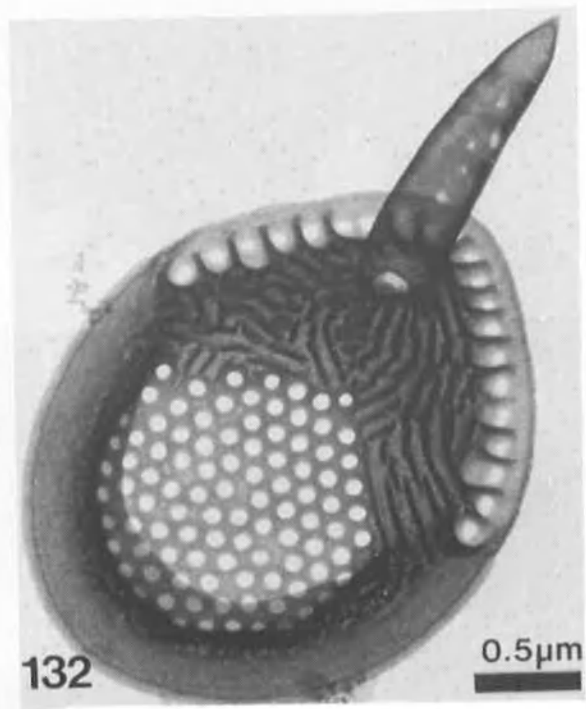
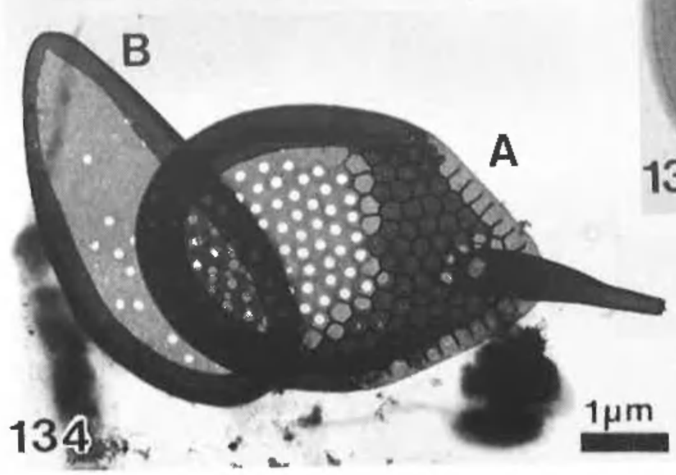
Mallomonas torquata

113. *M. torquata* (A) and *M. eoa* (B)
114. Apical part of a cell
115. Cyst with remaining body scales
116. Body scales
117. *Mallomonopsis elliptica*, body scale









Synura echinulata

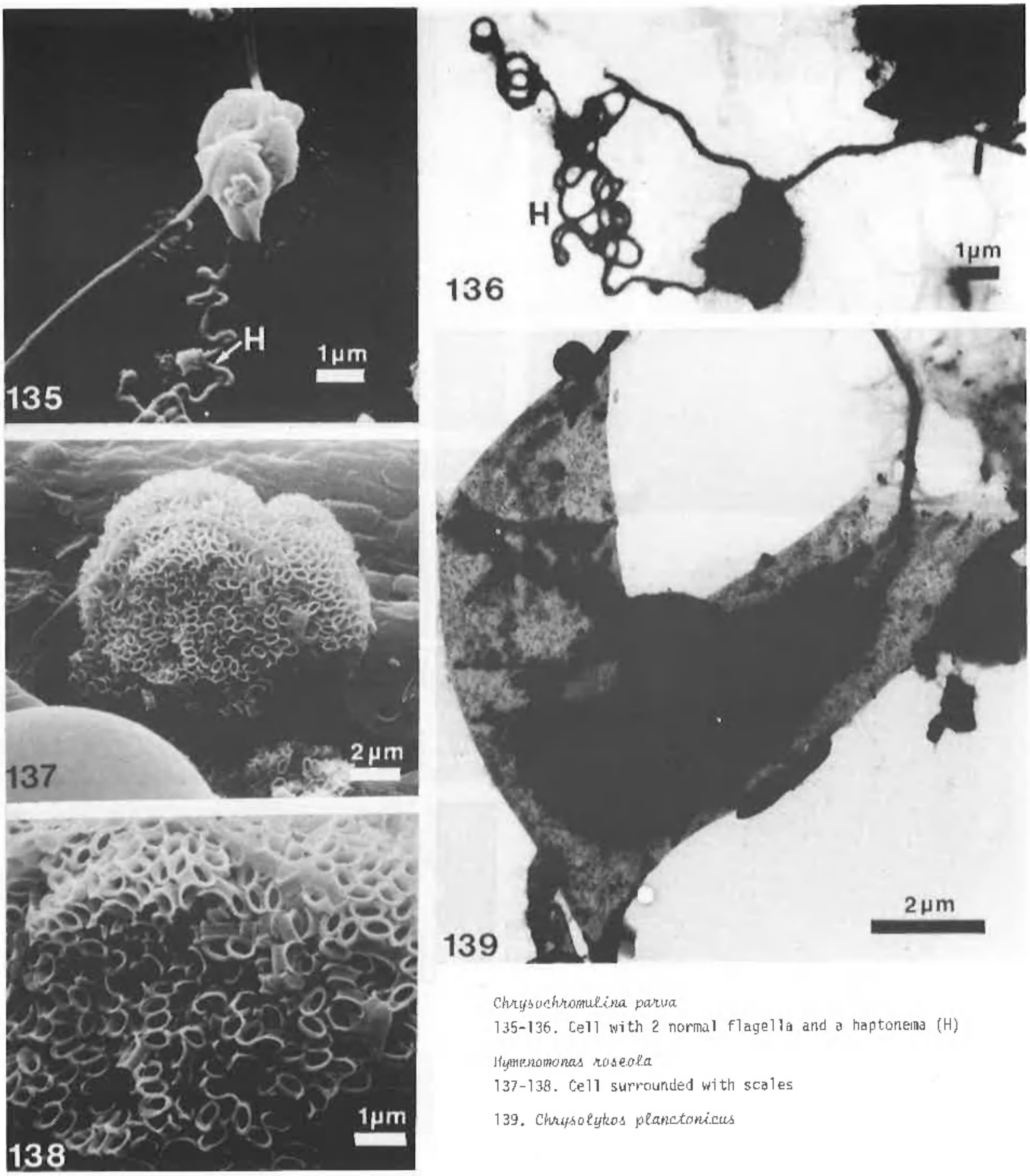
130. Complete cell

131. Basal scales; 132. Apical scale

Synura spinosa

133. Apical scales

134. Apical scale (A) and basal scale (B)



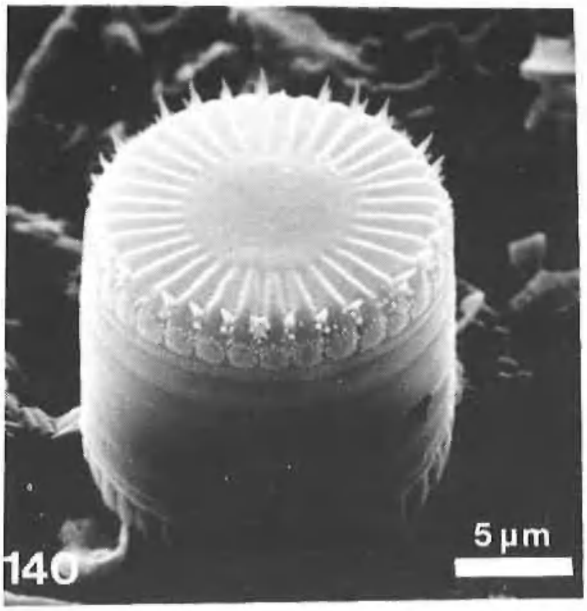
Chrysochromulina parva

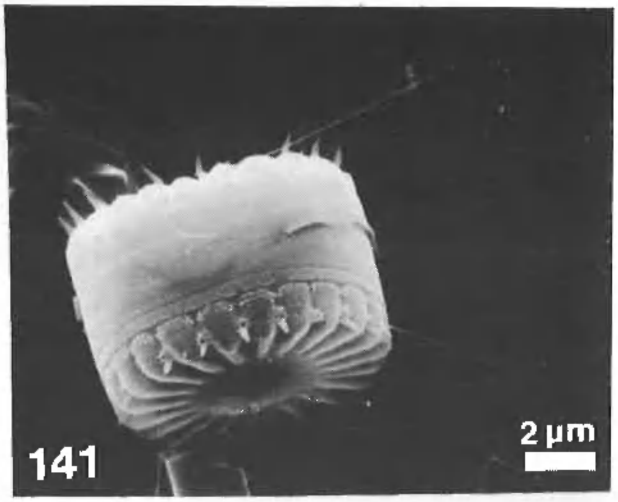
135-136. Cell with 2 normal flagella and a haptonema (H)

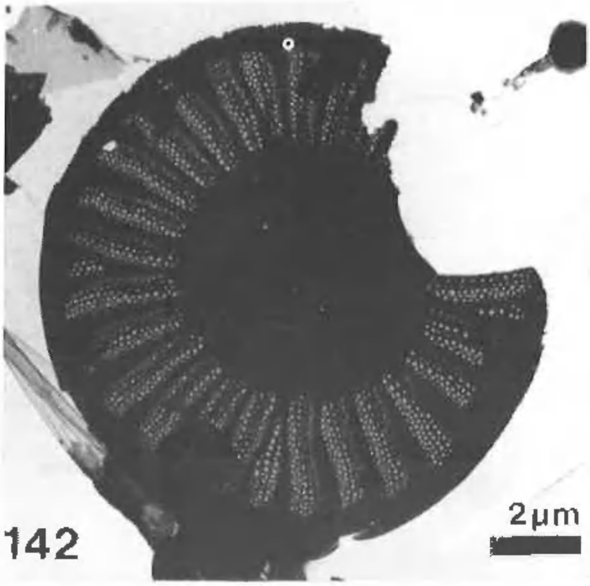
Hymenomonas roseola

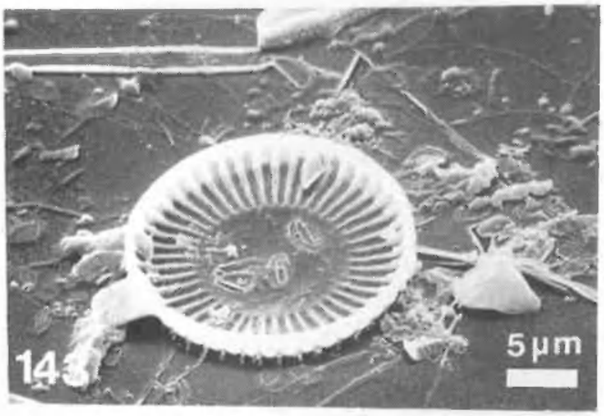
137-138. Cell surrounded with scales

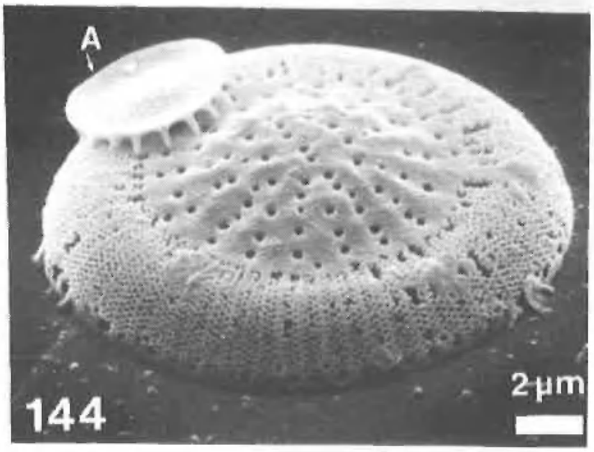
139. *Chrysolykos planctonicus*

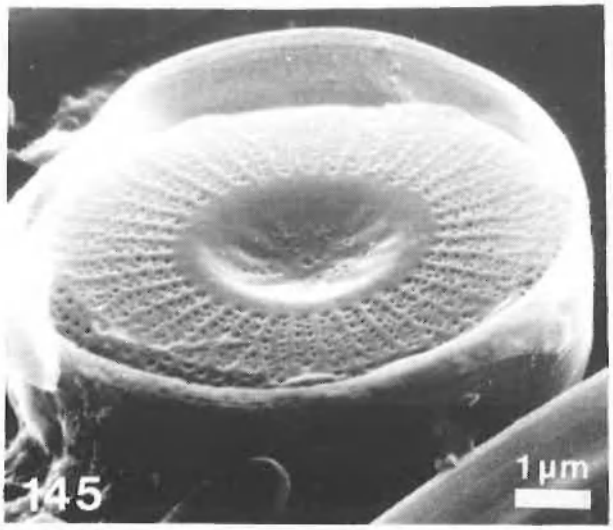








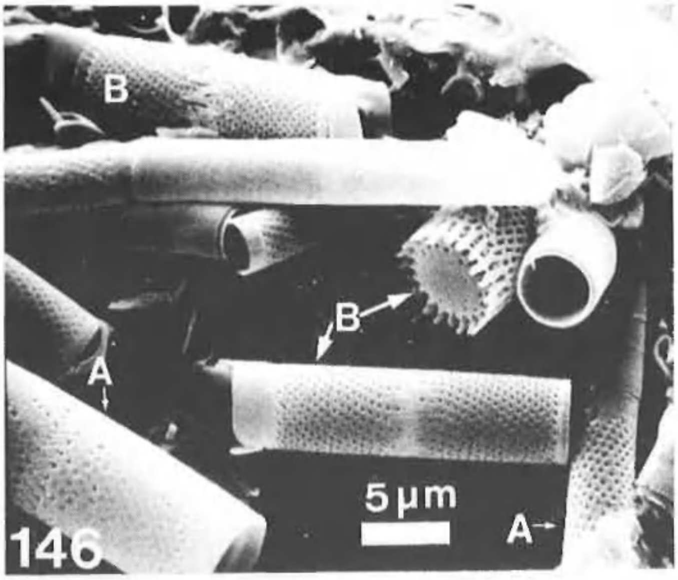


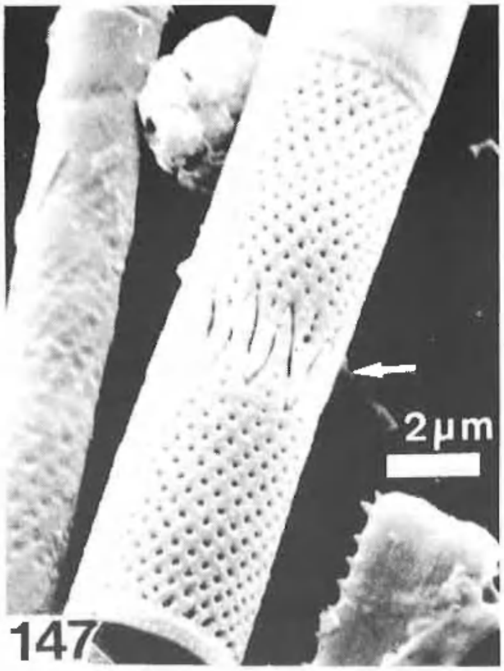


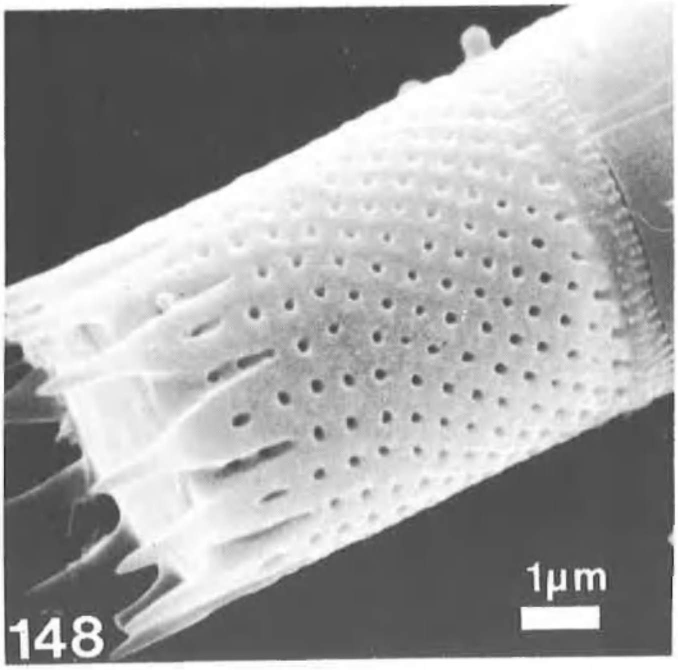
140-143. *Cyclotella meneghiniana*

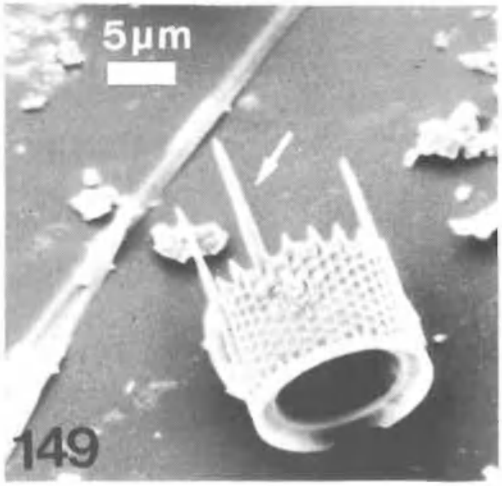
144. *Cyclotella comta* and *Stephanodiscus hantzschii* (A)

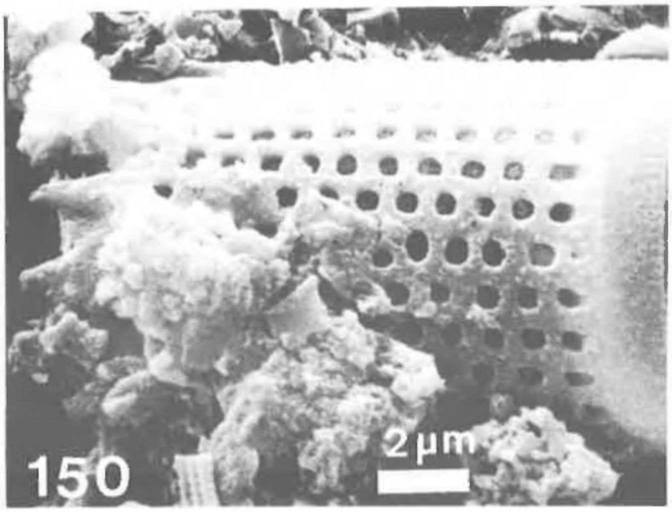
145. *Cyclotella pseudostelligera*









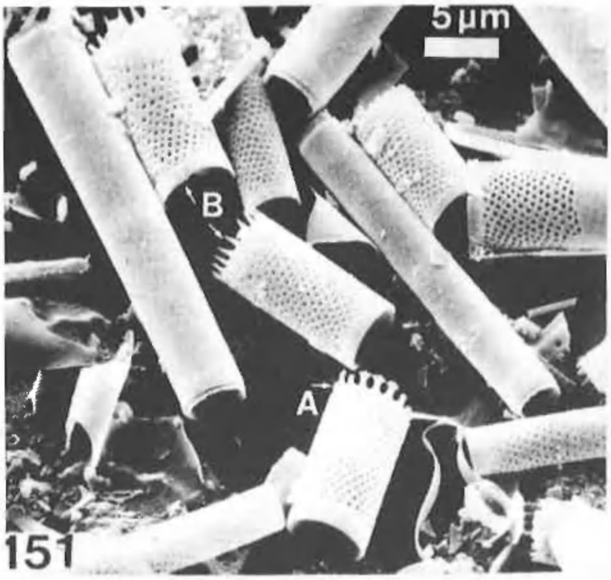


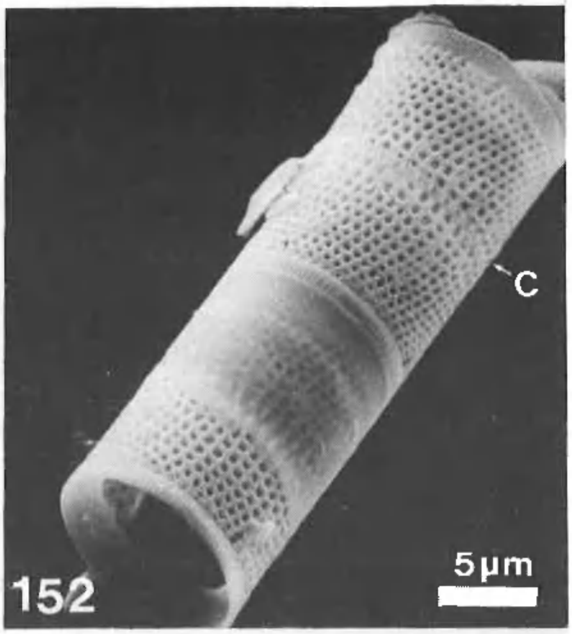
146. Mass development of *Melosira*; *M. ambigua* (A) and *M. italica* subspec. *subarctica* (B).

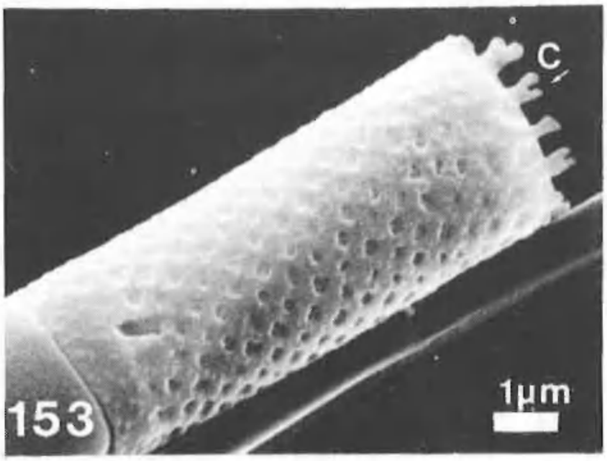
147-148. *M. italica* subspec. *subarctica*; observe the pointed interlocking spines between cells.

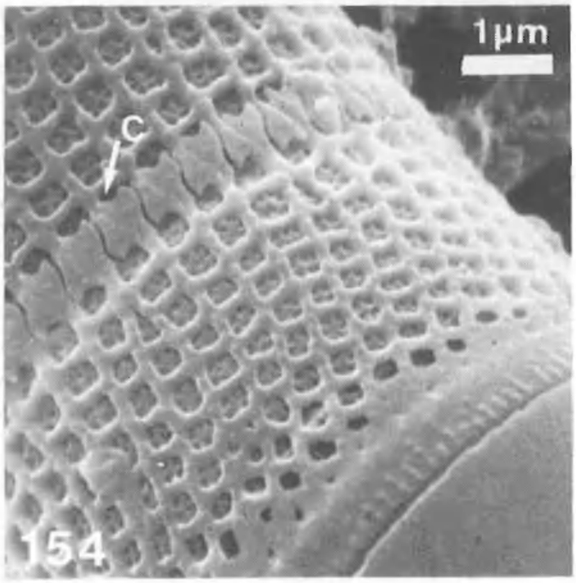
149. *M. granulata*; terminal frustule with long spines.

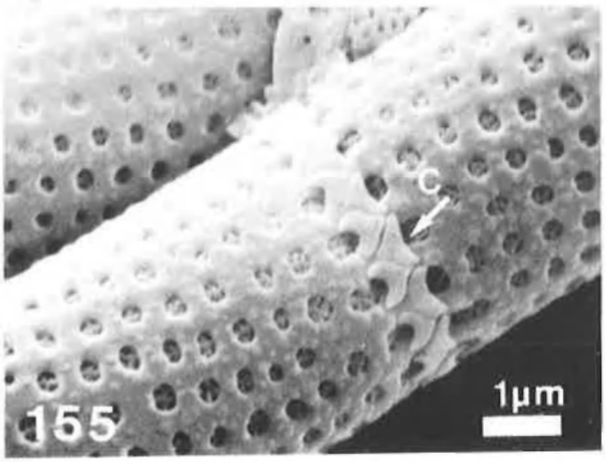
150. *M. granulata* showing the straight parallel rows with large pores.





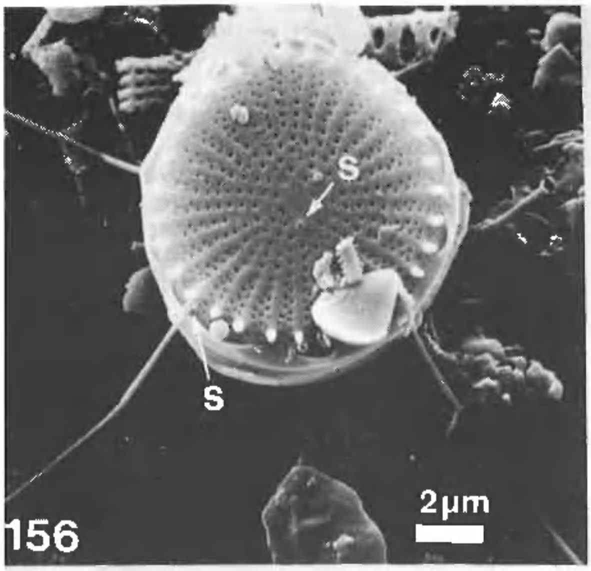


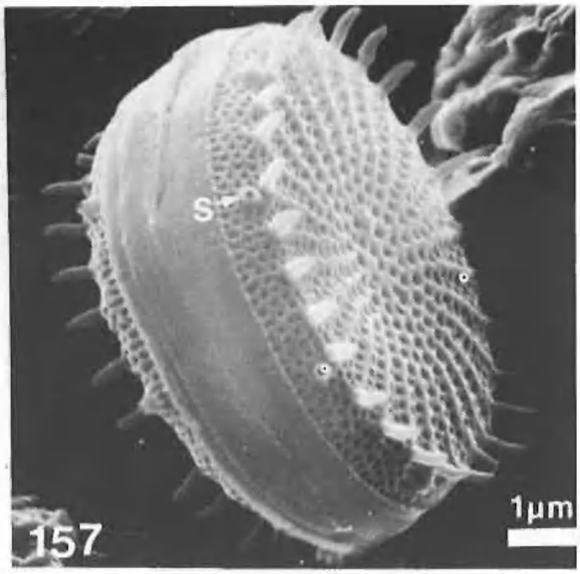


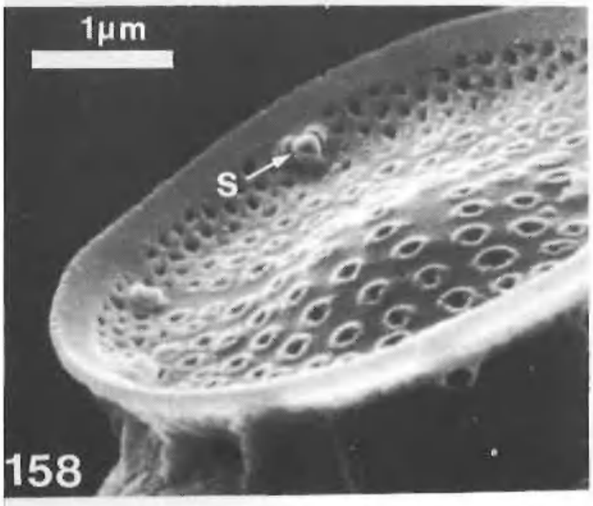


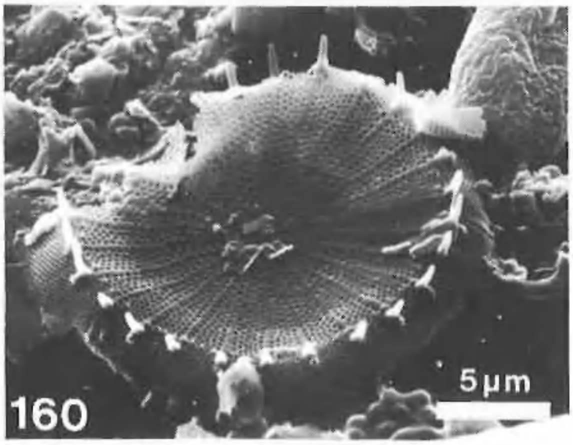
151. Mass development of *Melosira*; *M. ambigua* (A) and *M. italica* subspec. *arctica* (B).

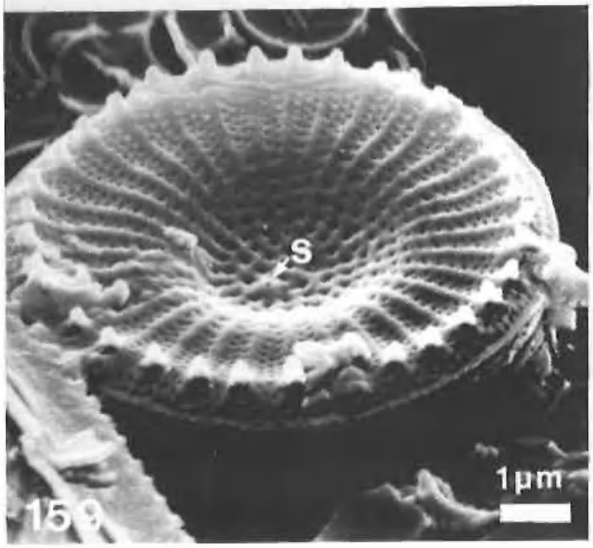
152-155. *M. ambigua*; observe the bifid interlocking spines (C).

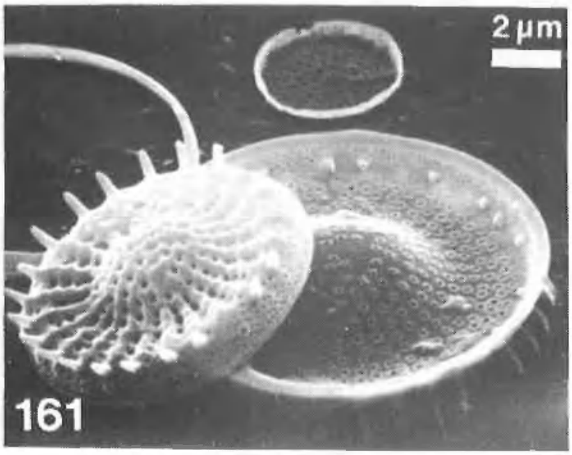








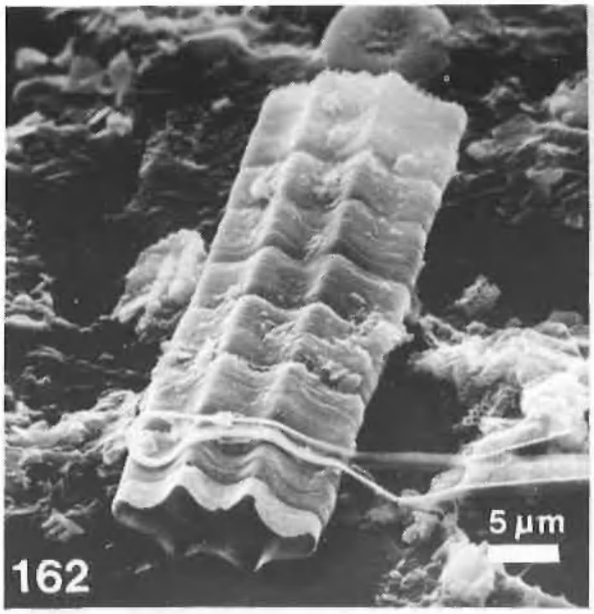


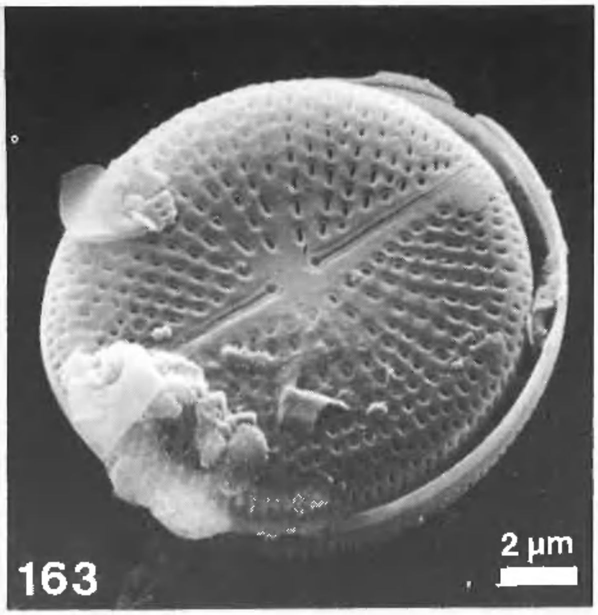


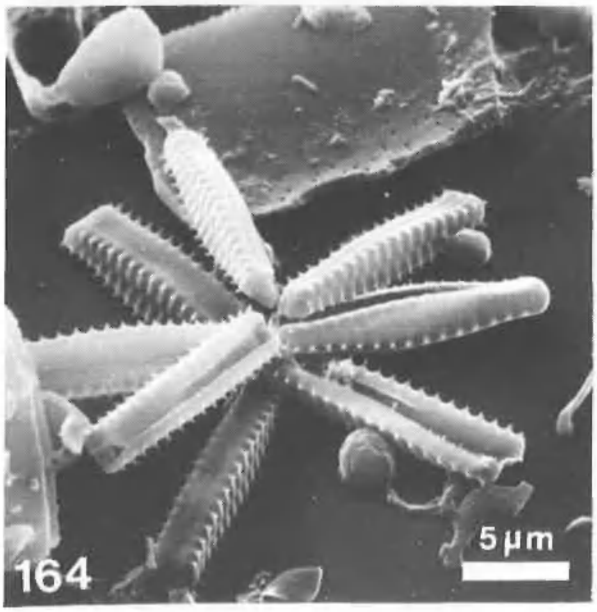
156-159. *Stephanodiscus hantzschii* with strutted processes (S)

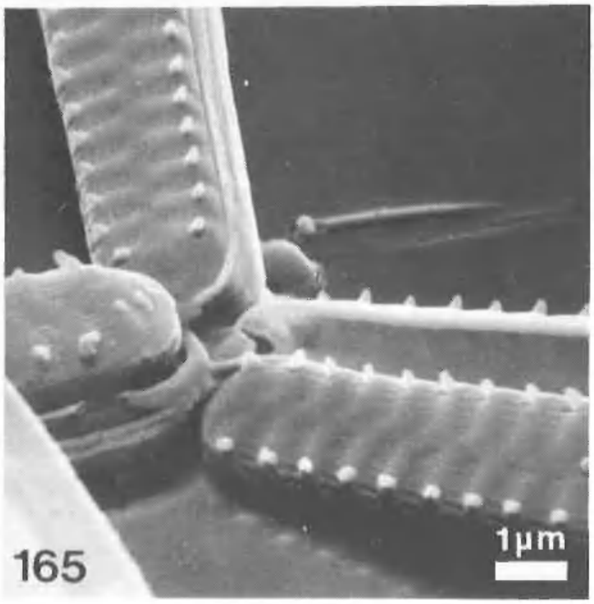
160. *Stephanodiscus* cfr *tenuis*

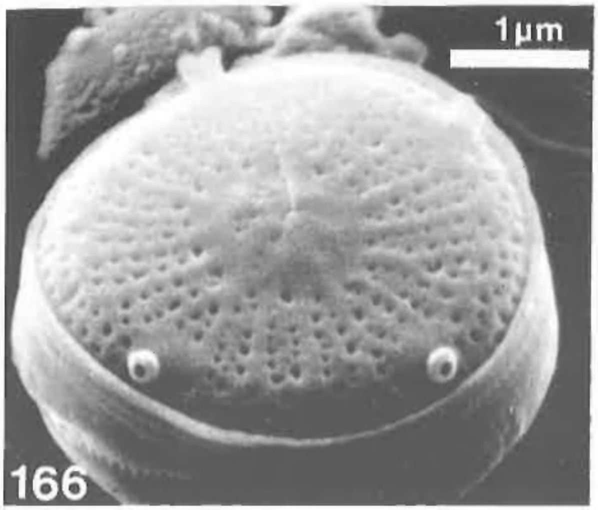
161. *Stephanodiscus astraea* var. *minutula*









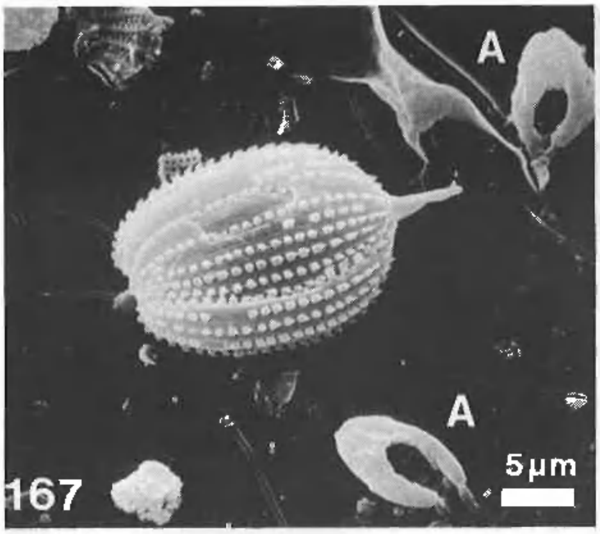


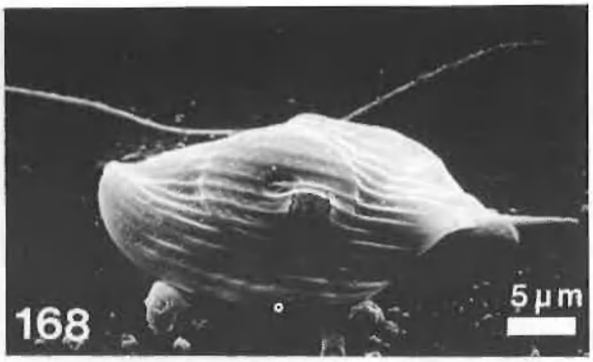
162. *Fragilaria construens* var. *binodis*, a colony

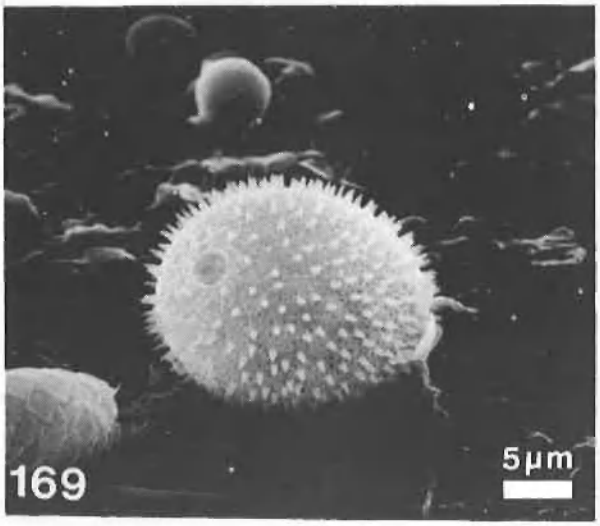
163. *Navicula pseudoscutiformis*

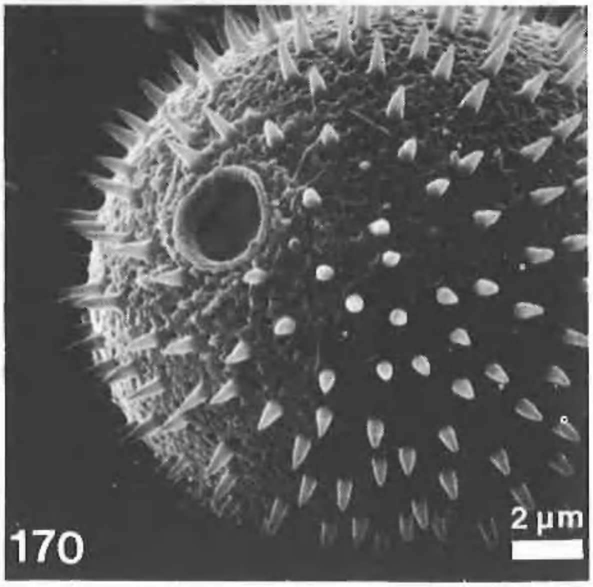
164-165. *Synedra berolinensis*

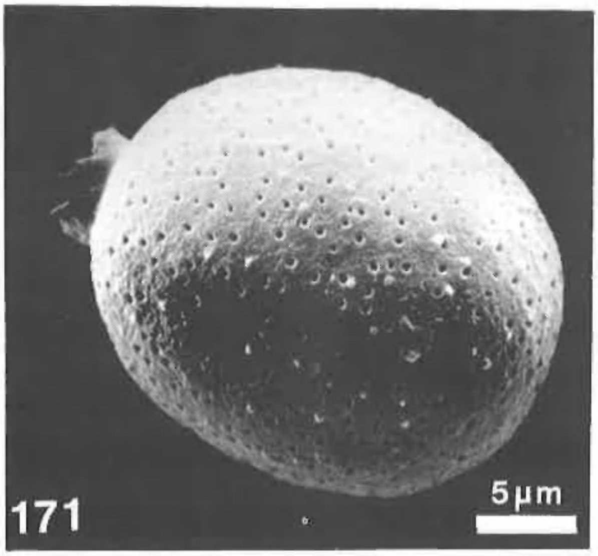
166. *Cyclotella* sp.

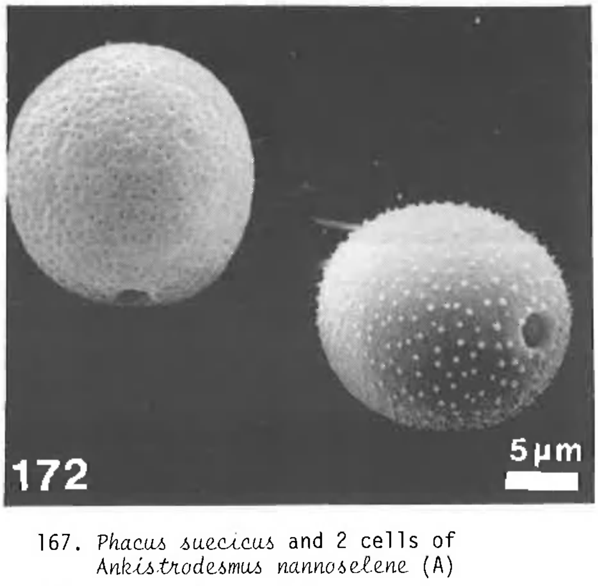












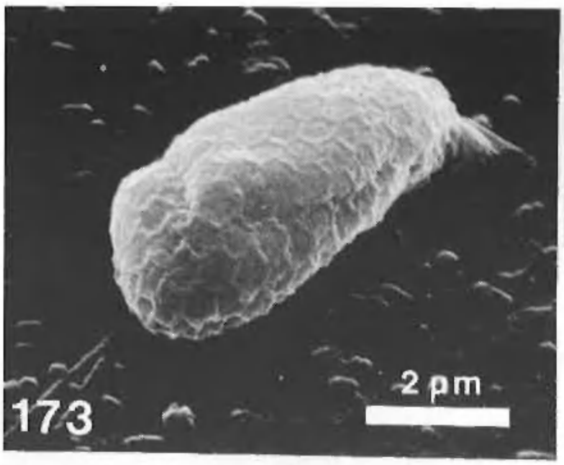
167. *Phacus suecicus* and 2 cells of *Ankistrodesmus nannoselene* (A)

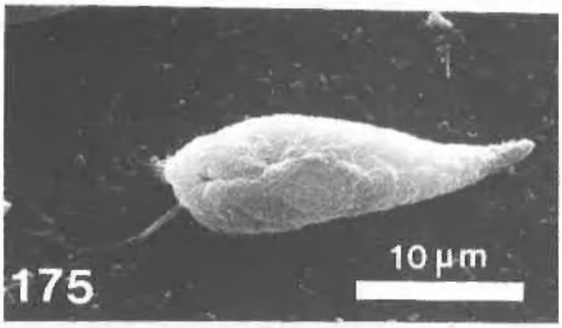
168. *Phacus pleuronectes*

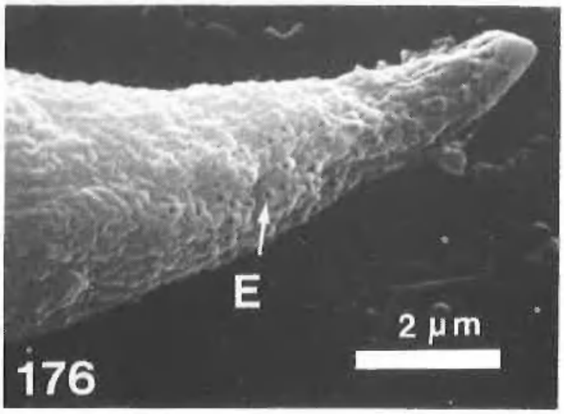
169-170. *Trachelomonas hispida*

171. *Trachelomonas* cfr *planctonica*

172. *Trachelomonas verrucosa*, 2 cells



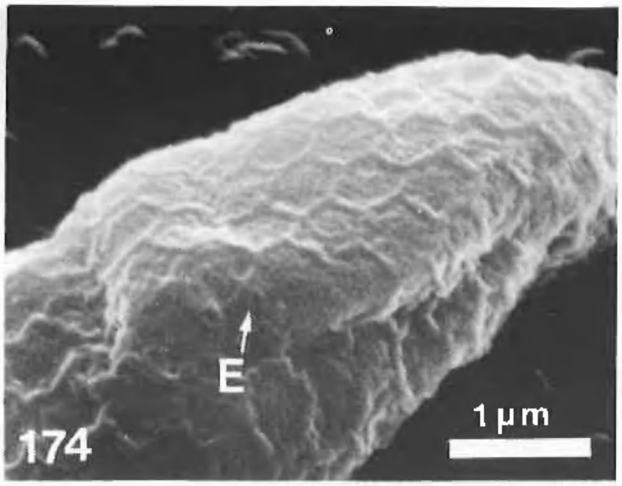


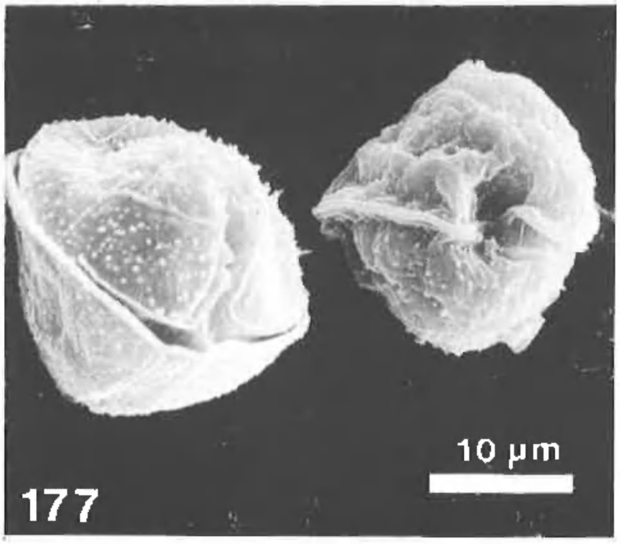


Chroomomas acuta

173. Complete cell

174. Cell wall with hexagonal pattern and ejectosomal pores (E)





Cryptomonas marssonii

175. Complete cell

176. Cell with ejectosomal pores (E)

Sphaerodinium sp.

177. Two cells

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