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Research Article

A Study in The Seasonal Variation of Phytoplankton in Hafik Lake (Sivas, Turkey)

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Abstract: The seasonal variations in composition of the phytoplankton of Hafik lake was studied from April 1986to June 1987. *Bacillariophyta, Chlorophyta,* and *Cyanophyta* were the most abundant components of the phytoplankton community. *Chrysophyta, Cryptophyta, Dinophyta,* and *Euglenophyta* were found in low numbers. Diatoms showed an increase in spring but were scarce in summer and autumn. *Cyclotella meneghiniana* Kuetz. and *Cyclotella ocellata* Pant. were the most frequent species. *Chlorophyta* was the next most abundant group and showed greater numbers in spring than in autumn and summer. *Chlamydonomonas, Oocytis,* and *Scenedesmus* species were the main algae. *Cyanophyta* members *(Gloeocapsa, Chroococcus, Oscillatoria)* were present but relatively scarce.

Key Words: Lake, Phytoplankton, Seasonality

Hafik Gölü Fitoplanktonunun Mevsimsel Değişimi

Özet: Hafik gölünün fitoplankton kompozisyonundaki mevsimsel değişimler Nisan 1986 dan Haziran 1987 ye kadar çalışılmıştır. *Bacillariophyta, Chlorophyta,* ve *Cyanophyta* fitoplankton komunitesinde en fazla bulunan alg grupları idi. *Chrysophyta, Cryptophyta, Dinophyta,* ve *Euglenophyta* üyeleri daha az sayılarda bulunmuşlardır. Diyatomeler ilkbaharda bir artış göstermiş fakat yaz ve sonbaharda azalmıştır. *Cyclotella meneghiniana* Kuetz. ve *C. ocellata* Pant. diğer diyatome türlerine göre daha sık bulunmuşlardır. Diyatomelerden sonra en çok bulunan grup *Chlorophyta* olmuş ve bu grup ilkbaharda, yaz ve sonbahara göre daha fazla sayıda gözlenmiştir. *Chlamydomonas, Oocystis* ve *Scenedesmus Chlorophyta'* yı temsil eden başlıca türleri oldukları saptanmıştır. *Cyanophyta* üyeleri ise diğerler gruplara göre daha az gözlenmişlerdir.

Anahtar Sözcükler: Göl, Fitoplankton, Mevsimsel değişim.

Introduction

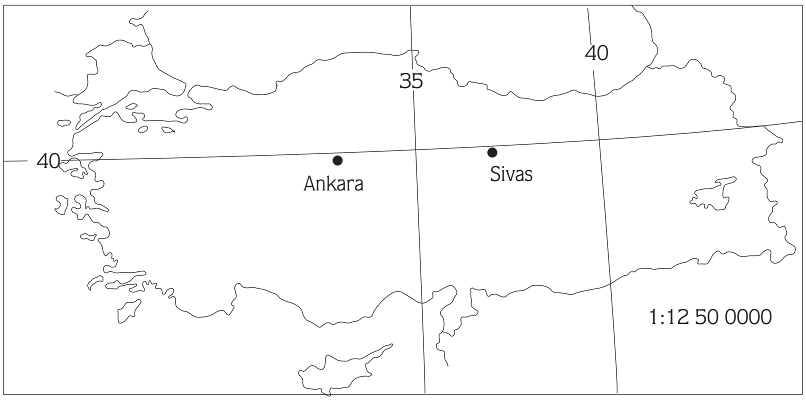
Since seventies, increasing attention has been given to algal studies (1, 2, 3). No limnological study on the freshwaters of Sivas region has been done previously which gives a general, quantitative description of the annual phytoplankton succession. Therefore, the present study aimed to examine the taxonomic structure and observed successional patterns in relation to general knowledge of phytoplankton dynamics, to provide preliminary information on the lake.

The study site

Hafik lake is in the North-East of Turkey, with a distance of 42 km from Sivas, at an altitude of 1290 m. There is no habitation in the catchment area but surrounded by agricultural land. The average depth is 3 m. Its surface area is 750,000 m^2 and a volume of about 2.250.000 m^3. A small spring enters at its northern end. There is a small outflow. During spring, and late autumn and by the end of winter, the lake receives surface run-of and glacial snowmelt from the surrounding land. The amount of ground water entering was determined during the study. The climate is semiarid, very cold and sub-mediterranean (4). Winter is generally cold, and there is long period of snow cover. Rain mainly occures in spring; the summer is arid. The lake freezes almost every winter for one or two months. The lake was formed by subsidence (5). The local geology consists of gravels, conglomerates, limestones, gypsums, marl, and mudstones (5). The location of the lake is given in Figure 1.

Materials and Methods

Three stations were chosen in order to represent the lake. First station was almost in the middle of the lake. Second station was marked close to the inflow on the North and the third station was chosen near to the outflow on the East. Water and algal samples



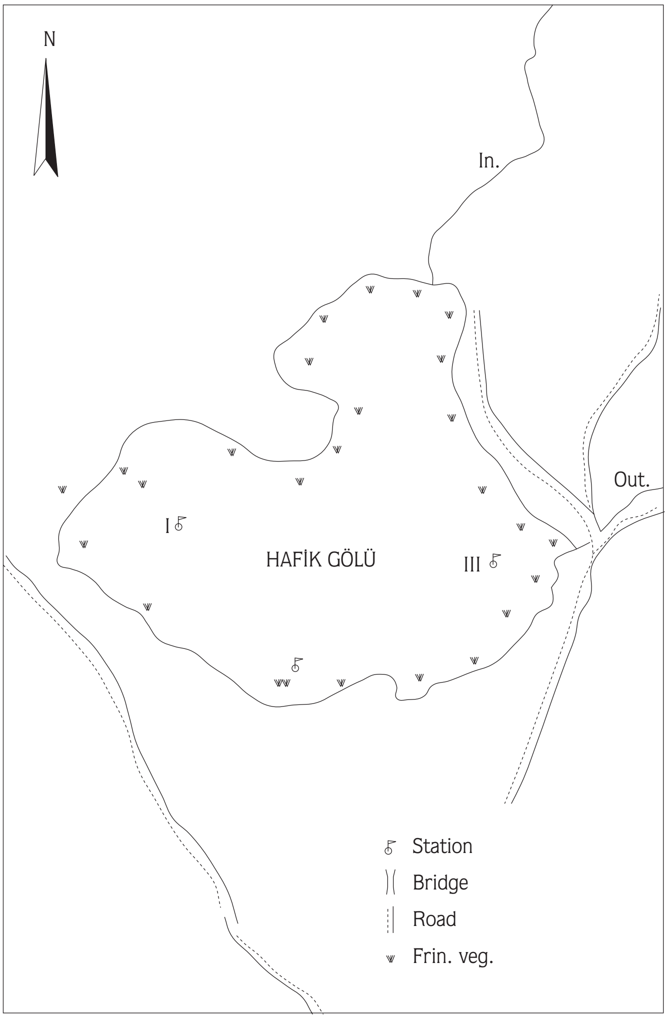


Figure 1. Map of the lake and catchment area and its location in Turkey. Abbreviations are: In. = inflow; Out. = outflow; Frin. veg. = Fringing vegetation.

were taken montly from May 1986 to June 1987 using a two litre Nansen water sampler. Samples were taken from the surface and at 1.5 m depth. Water temperature and oxygen concentration were measured directly with a combined resistance thermometer/oxygen probe (YSI 51B Model) at surface of the stations. Conductivity was measured by means of Jenway (Model (4070) conductivimeter. pH was measured with a Schott Gerate (CG 818 Model) pH metre. Ca^{++}, Mg^{++}, Total alkalinity were determined by titration methods of (6). Phytoplankton was counted after preservation with Lugol's iodine, with an inverted microscope (7). Identifications were made at X400 using a calibrated eyepiece graticule.

Results

Maximum annual temperature was 20ºC in July 1987. The lake was frozen from mid November 1986 to March 1987, whilst the temperature was 1ºC underneath the ice cover from top to bottom. pH varied between 7.4 (March 1987) and 9 (June 1986). Dissolved oxygen concentrations varied between 6.2-14.10 mg l^{-1}. Dissolved oxygen concentrations were higher in winter months than in summer months. The seasonal change of temperature and dissolved oxygen concentrations are given in Figure 2.

Conductivity was relatively high (1000 µS cm^{-1}) for a mountain lake probably caused by high summer evaporation and high retention time of water. Total alkalinity varied between 1.0-1.5 meq. l^{-1}. The mean concentrations of Ca, Mg, and Conductivity are given in Table

Phytoplankton

A total of 173 phytoplanktonic taxa was recorded. These taxa included 89 diatoms *(Bacillariophyta)*, 46 chlorophytes *(Chlorophyta)*, 23 blue-green *(Cyanophyta)*, 6 euglenoids *(Euglenophyta)*, 2 dinoflagellates *(Pyrrophyta)*, 1 chrysophyte *(Chrysophyta)* and 1 cryptomonad *(Cryptophyta)*. The floristic list is given in appendix.

The seasonal variations of three major algal groups are shown in Figure 3. Almost 70% of the total phy-

Table 1. The mean concentrations of seasonal variation of Ca^{++}, Ca^{++}, and Conductivity measured during the study period in Hafik lake. (-) indicates no measurement taken.

Sampling Dates	Ca^{++} (mg l^{-1})	Mg^{++} (mg l^{-1})	Conductivity (µS cm^{-1})
25 April 1986	-	-	-
20 June 1986	-	-	890
25 August 1986	176	23	780
20 September 1986	153	16	897
22 October 1986	107	16	887
19 November 1986	166	25	940
20 December 1986	125	18	880
07 March 1987	102	19	1200
29 March 1987	150	41	1080
09 April 1987	190	16	953
09 May 1987	201	21	830
23 June 1987	174	23	1000
06 July 1987	149	27	810

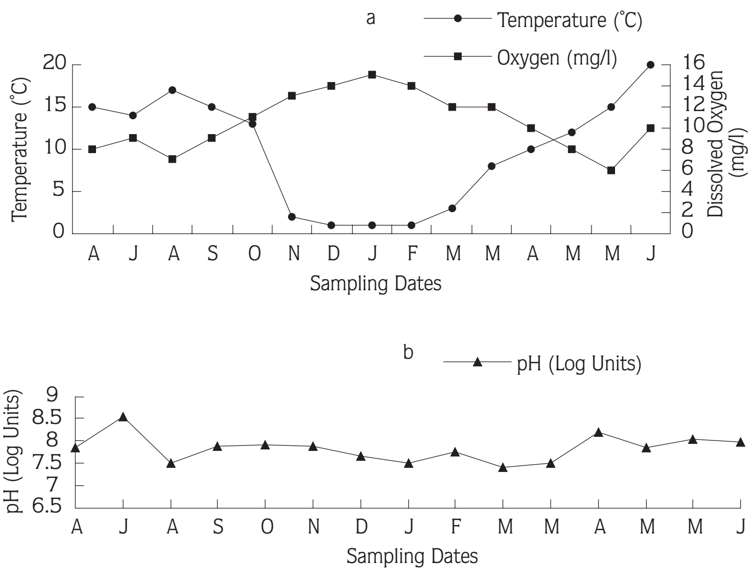


Figure 2. The seasonal variations of water temperature and dissolved oxygen concentration (a), and pH (b) of Hafik lake.

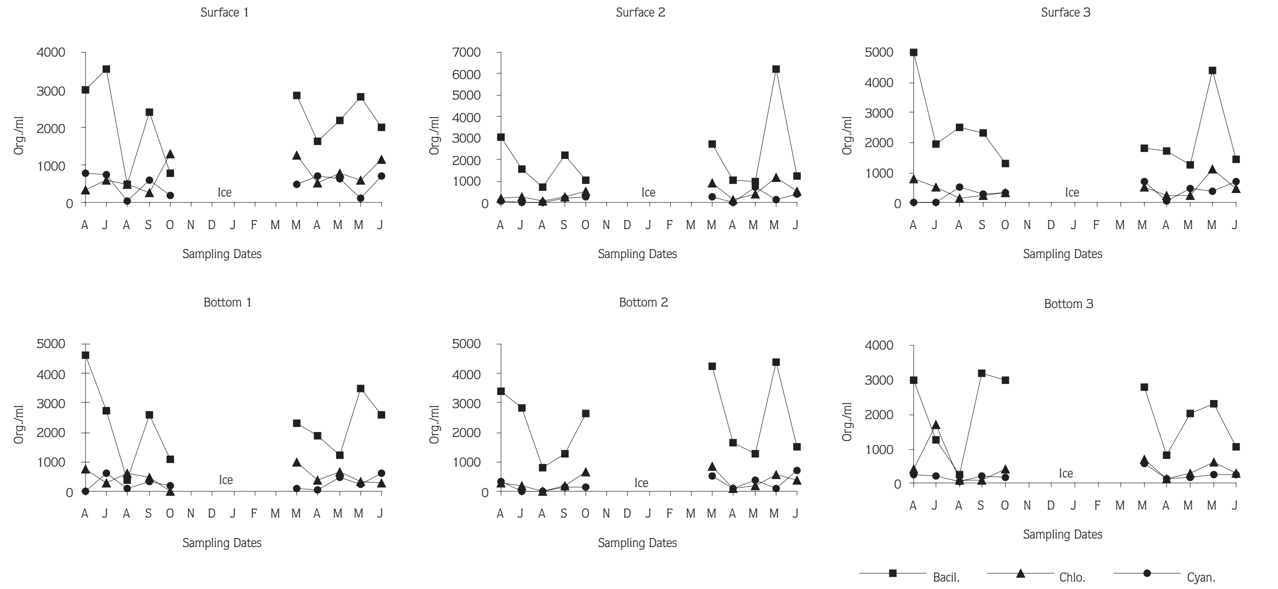


Figure 3. The seasonal variations of major phytoplanktonic groups at three surface and bottom (1.5 m) stations. The abbreviations for the legends are; Bacil.: Bacillariophyta, Chlo.: *Chlorophyta*, Cyan.: *Cyanophyta*

toplankton were recorded to be diatoms. *Cyclotella meneghiniana* and *C. ocellata* were the most abundant diatoms, followed by *Navicula*, *Cymbella*, and *Synedra* spp. Diatoms were recorded at between 3000-5000 org/ml at the beginning of the study at all stations. During summer 1986, diatoms showed a decreasing trend. After summer an increase in diatom numbers was detected till early autumn. *Cyclotella* and *Cymbella* spp. were present in the water under the ice cover. After the ice melted, *Bacillariophyta* were found in quite high numbers in all stations representing 67% of total organisms. This group then declined dramatically until the end of spring 1987. The highest number of total phytoplankton was recorded at the second station on 23 May 1987 with a value of 7569 org/ml. Diatoms constituted between 71-80% of total organisms. *Navicula radiosa*, *Cymbella prostrata*, *Navicula bicephala* and *Synedra ulna* were the most freqently recorded species of diatoms.

In early spring 1986, *Chlorophyta* represented 14% of the total organisms. The proportion did not change markedly, except in the bottom sample of the third station (47%) throughout the summer and autumn. *Chlamydomonas*, *Oocystis*, *Selenastrum* spp. were observed during the period of ice cover in very early spring 1987. The proportion of *Chlorophyta* was 26% of the total number at the surface waters whilst it was 31% at the bottom samples of the third station which was greatly represented by *Chlamydomonas epiphytica* with 754 org/ml. In general the group showed a dramatic decline towards mid spring and then gradually increased in parallel with diatoms until the end of spring. By summer, chlorophytes showed a decrease again. *Chlamydomonas*, *Oocytis*, and *Selenastrum* spp. were the most abundant members of *Chlorophyta.*

Cyanophyta numbers were small and changed little throughout the study period. They reached a maximum of only 34% of the total phytoplankton on 9 May 1987. *Chroococcus varius*, *Gloeocapsa rupestris*, *Dactylococcopsis acicularis* and *Synechococcus aeruginosus* were the most important species of *Cyanophyta.*

Discussion

The phytoplankton species composition and its succession in Hafik lake is similar to that of in other lakes in central Turkey. The phytoplankton is characteristically dominated by two species of *Bacillariophyta.* These are *Cyclotella ocellata* and *C. meneghiniana* which have been postulated as indicator species of oligotrophic lakes (8). They were found to be important components of the phytoplankton communities in Beytepe (9), Mogan (10), Kurboğazı (1), and Altınapa (2) lakes as well as Hafik lake.

In an environment with temporally variable species composition, dominance is achieved by these species with the greatest excess of growth over loss. Among growth factors, a high Si: P ratio has been shown to favour diatoms over others; however, owing to the slow recycling of silicon, diatom growth will quickly reduce the Si: P ratio and change the environmental conditions in favour of other taxa, unless deep mixing increases the import of Si from deeper water layers (11). A similar phenomenon was observed in Hafik lake in spring 1987, where *Chlorophyta* and *Cyanophyta* increased after a peak of diatoms.

The distribution of phytoplankton, and deep mixing were considerably influenced by strong wind throughout the period of study of Hafik lake. This may have helped to increase silica concentrations in the water. The experiments of Reynolds et al. (12). have clearly demonstrated that artificial mixing in large enclosures ("Lund tubes") could either prolong diatom dominance or induce new increases of diatoms. The dominance of diatoms in Hafik lake throughout the examination period could be due to the maintenance in suspension of small diatoms by mixing thereby reducing the sinking rate. Species of *Amphora, Cymbella, Navicula* and *Nitzschia* were also important and often found in the phytoplankton of Hafik lake which are mainly benthic diatoms. This could be due to strong mixing detaching these algae because of lake being exposed to wind. The same has been shown by analysis of interannual differences in the otherwise regular succession of phytoplankton in Lake Constance (13).

Chlorophytes featured in the spring phytoplankton growth under icer cover, but their contribution to planktonic biomass was small in comparison to that of *Bacillariophyta* in the lake. Hobbie (14) has shown similar results in Alaskan arctic tundra lakes. The reason for the decrease in late spring was probably increased rainfall that helped to increase of water volume and carried inorganic suspance matter into the lake. Although we were not able to identify them at the species/genus level because of their very small size (20 µm) nanophlankton belong *Chlorophyta* were the main components and were found in March and May. Chlorophytes formed the second dominant algal group with reasonably high species diversity but low biomass. The lake shows more or less the same features as substropical polymictic lakes (15) despite the temperature differences.

Well known as "pioneer organisms" *Cyanophyta* are characteristically initial colonizers and are the dominant phytoplankton in such inhospitable habitats as recently filled volcanic craters, geothermal pools, alpine and boreal ponds, and highly polluted (either with organic and/or inorganic wastes) as well as in less extreme lake and river systems (16). It has been well documented that as a group *Cyanophyta* have a distinct preference for neutral to alkaline waters (17, 18). They were not however prominent in Hafik lake. The reasons for this were possibly being nutrient limitation other than physical effects.

The ratio of species numbers in certain algal groups;

Cyanophyceae + Chlorococcales + Centrales + Euglenales/Desmidiales

is an indicator of the trophic level of a lake (19). If the ratio is less than 1, the lake is accepted as being oligotrophic, whereas if it is greater than 3, the lake is accepted as being eutrophic. This ratio was found to be 8.8 for Hafik lake, indicating that it is eutrophic. However, indicator species of *Bacillariophyta* and unicellular algae (20) which are usually common components of the smaller-sized cell fractions of phytoplankton in oligotrophic lakes were frequently found in the phytoplankton of Hafik lake. Although we were not able to have any measurements of nutrient concentrations, and therefore the discussion of nutrient ratios and thereby driven phytoplankton succession remain pure speculation, we believe that this work may provide valuable information of interest to later ecological studies on specific lakes or as part of a comparative study including a range of different lakes.

Acknowledgment

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Appendix

Divisio: BACILLARIOPHYTA

Class: CENTROBACILLARIOPHYCEAE

Cyclotella meneghiniana Kuetz.

C. ocellata Pant.

Class: PENNATIBACILLARIOPHYCEAE

A chnanthes deflexa Reim.

A. flexella (Kütz.) Brun.

A. lanceolata Breb.

A. minutissima Kütz.

Amphora ovalis var. pediculus Kütz.

A sterionella formosa Hassall

var. gracillima (Hantz.) Grun.

Caloneis amphisbaena (Bory) Cleve

C. limosa (Kütz.)

C. silicula (Ehr.) Cleve

Cocconeis placentula Ehr.

Cymatopleura elliptica (Breb.) W. Smith

C. solea (Breb.) W. Smith

Cymbella cistula (Ehr.) Kirchn.

var. cistula var. gibbosa Brun.

C. cymbiformis Ag. C. ehrenbergii Kütz.

C. hauckii V. Heurck var. hauckii

C. inaequalis (Ehr.) Rabh.

C. laevis Naeg. ex. Kütz.

C. minuta Hilse ex. Rabh.

var. pseudogracilis (Choln.) Reim.

var. silesiaca (Bleisch ex. Rabh.) Reim.

C. prostrata (Berk.) Cleve

C. turgida (Gregory) Cleve

C. turgidula Grun.

C. ventricosa Kütz.

Denticula elegans Kütz.

D. lauta J. W. Bail. var. lauta

D. tenuis Kütz.

D. thermalis Kütz.

Diatoma elongatum Agardh

D. vulgare Bory var. brevis Grun.

Epithemia adnata (Kütz.) Breb.

var. adnata

E. intermida Fricke

E. sorex Kütz.

E. turgida (Ehr.) Kütz.

Eunotia arcus Ehr.

E. monodon Ehr.

E. pectinalis (Kütz.) Rabenhorst

E. praerupta Ehr. var. inflata Grunow

Fragillaria constricta Ehr. var. constricta

F. construents (Ehr.) Grunow

var. subsalina Hust.

f. crotenensis Kitton

F. pinnata Ehr.

var. trigona (Brun. u. Heribaud) Hust.

F. virescens Ralfs.

Frustulia rhomboides (Ehr.) deToni

Gomhonema olivaceum (Lyng.) Kütz.

G. parvulum Kütz.

G. truncatum Ehr.

var. capitatum (Ehr.) Patr.

G. tenellum Kütz. var. tenellum

G. ventricosum Gregory

Gyrosigma acuminatum (Kütz.) Rabh.

Hanzschia amphioxys (Ehr.) Grun.

Mastoglia elliptica Agardh

Navicula arvensis Hust. var. arvensis

N. bicephala Hust. var. bicephala

N. cryptocephala Kütz.

N. integra (W. Smith) Ralfs.

N. minima Grun.

N. pupula Kütz.

N. radiosa Kütz.

N. reinhardtii Grun.

N. spicula (Dickie) Cleve

Neidium dubium (Ehr.) Cleve

Nitzschia acuta Hantz.

N. palea (Kütz.) W. Smith

N. recta Hantz.

N. spectabilis (Ehr.) Ralfs.
N. vermicularis (Kütz.) Grun.
Pinnularia lata (Breb.) Smith
P. maior (Kütz.) Rabh. var. maior
P. viridis (Nitzsch) Ehr.
Staurneis anceps f. gracilis Rabh.
S. nobilis Schum. var. nobilis
Surirella ovalis Breb.
S. ovata Kütz.
Synedra actinastroides Lemm.
S. affinis Kütz.
var. faciculata (Kütz.) Grun.
S. amphicephala Kütz.
S. capitata Ehr.
S. delicatissima W. Smith
var. delicatissima
S. rumpens Kütz.
S. tenera W. Smith var. tenera
S. ulna (Nitz.) Ehr.
var. amphiryncus (Ehr.) Grun.
var. biceps (Kütz.) Kirchn.
Tabellaria binalis (Ehr.) Grun.
T. fenestrata (Lyngb.) Kütz.
Divisio: CHLOROPHYTA
Class: CHLOROPHYCEAE
Volvocaceae
Chlamydomonas angulosa Dill
C. cienkowskii Schmidle
C. epiphytica G.M. Smith
C. globosa Snow
C. pseudopetryi Pascher
C. snowii Printz
C. sphagnicola Fritsch & Takeda
Haematococcus lacustris (Girod.) Rostafinski
Ulothricaceae
Ulothrix zonata (Webr & Mohr) Kuetz.
Chlorococcacaee
Actinastrum hantzschii Lager.
var. elongatum G.M. Smith
Ankistrodesmus brauni (Naeg.) Brunnthaler
A. falcatus (Corda) Ralfs.
A. spiralis (Turner) Lemm.
Closteriopsis longissima Lemm.
Crusigenia irregularis Wille
Kirchneriella subsoitaria G.S. West
Nephrocytium agardhanum Naeg.
N. lunatum W. West
Oocystis elliptica W. West
O. parva West & West
O. parva West & West
O. pussilla Hansgrig
Pediastrum araneosum (Racip.) G.M. Smith
P. boryanum (Turp.) Meneghini
P. integrum Naeg.
P. tetras (Ehr.) Ralfs.
var. tetraodon (Corda) Rabenhorst
Ouadrigula lacustris (Chod.) G.M. Smith
Scenedesmus acuminatus (Lag.) Chodat.
var. tetradesmoides G.M. Smith
S. arcuatus Lemm.
var. platydisca G.M. Smith
S. bernardii G.M. Smith
S. bijuga (Turp.) Lagerheim
var. flexuosus (Lemm.) Collins
S. dimorphous (Turp.) Kuetz.
S. falcatus Chod.
S. incrassatulus Bohlin
S. quadricauda (Turp.) de Breb.
var. longispina (Chod.) G.M. Smith
Selenastrum miutum (Naeg.) Collins
S. westii G.M. Smith
Cladophoraceae
Cladophora fracta (Dillw.) Kuetz.
C. glomerata (L.) Kuetz.
Tetrasporaceae
Gloecytis major Gerneck ex Lemm.
Elakatothrix viridis (Snow.) Printz.
Desmidiaceae
Cosmarium botrytis Menegh.
C. formosulum Hoffmann
var. nathorstii (Boldt) West & West
C. regnellii Wille
C. reniformae (Ralfs.) Arch.
Staurastrum cyclacanthum West & West
S. crenulatum var. brittanicum Messik.
Chrysophyceae
Dynobryon sertularia Ehr.
Cryptophyceae
Cryptomonas ovata Ehr.
CYANOPHYTA
Cyanophyceae
Aphanocapsa elachista West & West
A. endophytica G.M. Smith
Aphanothece microscopica Naeg.
A. saxicola Naeg.
Chrocooccus dispersus (Keissl.) Lemm.
var. minor G.M. Smith
C. limneticus Lemm.
var. distans G. M. Smith
C. minor (Kuetz.) Naeg.
C. minutus (Kuetz.) Naeg.
C. turgidus (Kuetz.) Naeg.
C. varius A. Braun
Dactylococcopsis acicularis Lemm.
D. facicularis Lemm.
D. raphidioides Hansgirg
Gloeocapsa rupestris Kuetz.
Gloeothece linearis Naeg.
Merismopedia punctata Meyen
M. tenuissima Lemm.
Microcytis aeruginosa Kütz.
M. incerta Lemm.
Synechococcus aeruginosus Naeg.
Calothrix fusca (Kuetz.) Bornet & Flahault
Oscillatoria limosa C. A. Agardh
PYRROPHYTA
Dinophyceae
Ceratium hirundinella (Muell.) Dujardin
Peridinium cinctum (Muell.) Ehr.
EUGLENOPHYTA
Euglenophyceae
Euglena acus Ehr.
E. elongata Schewiakoff
E. gracilis Klebs
E. oxyuris Schmarda
Phacus orbicularis Huebner
Trachelomonas similis Stokes