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Spring phytoplankton and periphyton composition: case study from a thermally abnormal lakes in Western Poland

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Abstract: Getting to know the response of different groups of aquatic organisms tested in altered thermal environments to environmental conditions makes it possible to understand processes of adaptation and limitation factors such as temperature and light. Field sites were located in three thermally abnormal lakes (cooling system of power plants), in eastern part of Wielkopolska region (western Poland): Pątnowskie, Wąsosko-Mikorzyńskie and Licheńskie. Water temperatures of these lakes do not fall below 10°C throughout the year, and the surface water temperature in spring is about 20˚C. In this study, we investigated the species structure of the spring phytoplankton community in a temperature gradient and analyzed diversity of periphyton collected from alien species (*Vallisneria spiralis*) and stones. 94 taxa belonging to 56 genera of algae (including phytoplankton and periphyton) were determined. The highest number of algae species were observed among Chlorophyta (49), Bacillariophyceae (34) and Cyanobacteria (6). In spite of important differences in temperature in the investigated lakes, taxonomic composition of phytoplankton was comparable. Thermophilic species: *Glochidinium penardiforme* and *Cylindrospermopsis raciborskii* were found in the species structure (blooms were not observed). The obtained data also showed that the biotic surface of *Vallisneria spiralis* was a better substrate for Bacillariophyceae colonization than stones. The examination in the spring season of these thermally altered lakes, indicated the taxonomic composition of phytoplankton typical for eutrophic reservoirs (not heated). There was no replacement of any phytoplankton groups which are characteristic for spring conditions, even if there were changes in the competition dynamics.

Key words: heated lakes, phytoplankton, periphyton, cooling system of water, *Vallisneria spiralis*

1. Introduction

Thermally altered aquatic ecosystems are particularly helpful in answering questions about ecological tolerance and diversified responses of different groups of aquatic organisms. They are a basis for testing ecological requirements of contrasting groups of algae requirements to differentiated thermal gradient.

Thermally non-typical lakes located in the Konin region (central Poland) are recognized as unique ecosystems in Europe. This complex consists of five lakes (two polymictic lakes Gosławskie, Pątnowskie and three dimictic lakes Licheńskie, Wąsosko-Mikorzyńskie and Ślesińskie) and constitutes part of the cooling system of Konin and Pątnów power plants (Fig. 1). Strong interest in the algae of Konin lakes followed the launch of the Konin power plant in 1956 and of the Pątnów power plant in 1964 (e.g. Sosnowska-Półtoracka 1968; Dąmbska 1976; Burchardt 1977; Hillbricht-Ilkowska & Zdanowski 1978, 1988; Socha 1994a, 1994b).

The increase of water temperature in the abovementioned lakes, as a result of heat exchange of water cooling systems, created favorable conditions for the development of thermophilic (tropical) communities of plants and animals as well. For example, hydrophyte *Vallisneria spiralis* L. as a thermophilic and invasive

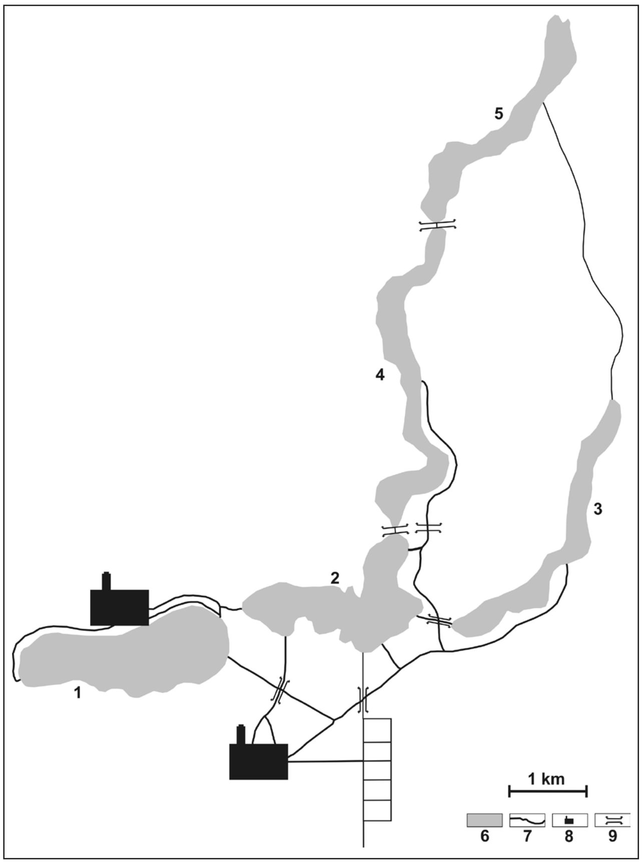

Fig. 1. Map of Konin lakes included into a power plant cooling system at Konin and Pątnów
Explanations: the number indicates the name of the lake, 1 – Gosławskie, 2 – Pątnowskie, 3 – Licheńskie, 4 – Wąsosko-Mikorzyńskie, 5 – Ślesińskie (adapted from Hillbricht-Ilkowska & Zdanowski 1988), 6 – lakes, 7 – supply canals, 8 – power plants, 9 – bridges

species for Poland commonly occurred in the Licheńskie lake for more than 20 years (Gąbka 2002; Hutorowicz & Hutorowicz 2008). In the system of Konin lakes, we can find the total of at least 41 native species (mostly animals) and at least 58 species of unknown origin (Najberek & Solarz 2011).

The occurrence of thermophilic species, especially among macrophytes and algae in Konin lakes, was also reported for phytoplankton assemblages. Burchardt (1977) noted, in the Pątnowskie lake, presence of cyanobacterium *Cylindrospermopsis raciborskii* (Wołoszyńska) Seenaya & Subba Raju, which is recognized as an invasive species in Europe (Padisák 1997; Briand *et al.* 2004; Kokociński *et al.* 2009). Moreover, in the spring and autumn seasons of 2009, the appearance of thermophilic species *Glochidinium penardiforme* (Lindemann) Boltovskoy in all lakes was reported (Messyasz & Neumann 2011). On the other hand, field studies of Socha and Hutorowicz (2009) showed that phytoplankton composition in heated lakes, outlined above, depended on several factors, such as: (*i*) water temperature, (*ii*) water flow and (*iii*) the presence of aquatic plants. They observed cyanobacteria, dinoflagellates, chlorophytes and cryptophytes during summer time, whereas the phytoplankton in winter consisted mainly of Bacillariophyceae. Taking into account these findings, it seems that periods of winter and spring are crucial for the diagnosis of the Konin lakes functioning.

The aim of this study was to (*i)* determine the species structure of the spring phytoplankton community regarding the temperature gradient, (*ii*) and assess compositions of periphyton collected from alien species (*Vallisneria spiralis*) and stones.

2. Material and methods

2.1. Study sites and sampling

Konin lakes are the basis of the external cooling system of the "Pątnów-Konin" power plant. All the lakes and water channels of the system are situated in the basin of the Odra-Warta Rivers in the Wielkopolska-Kujawska lowland. Their total area is 13 km^2 and the agricultural catchment occupies 415 km^2. A characteristic phenomenon of the examined lakes is high water temperature throughout the year. In Lake Licheńskie, water temperature reaches 30˚C (Napiórkowska-Krzebietke 2009) and in hot summer, it may exceed it reaching even 32˚C (Kapusta 2004). Lake Licheńskie has the highest water temperature among the five heated lakes (Bogacka-Kapusta & Kapusta 2013) and it never forms ice cover during winter. The obtained results (~22˚C in May) confirm these principles. High water temperature in Lake Licheńskie is caused by the inflow of warm post-cooling water from Pątnów and Konin Power Plants (Stawecki *et al.* 2007).

In this study, we determined species composition of phytoplankton in three heated lakes: Pątnowskie, Licheńskie and Wąsosko-Mikorzyńskie, in early spring time. These lakes differ in maximum (5.5, 12.6 and 36.5 m, respectively) and mean (2.6, 4.5 and 11.5 m, respectively) depths and mixing type, as outlined above. From each lake, sample sites for the identification of phytoplankton were randomly selected. All samples of water were collected in parallel at each site. Each sample for phytoplankton analysis was placed in 1.0 L sterile plastic containers, preserved using 3 ml of Lugol solution and, next, the material was sedimentated into 10 mL. Community structure was identified using algae classification keys of Komárek and Anagnastidis (1999, 2005), Hindák (1984, 1988, 1996), Hegewald (2000), Krammer and Lange-Bertalot (1991), Lange-Bertalot (1993, 2001). Current taxonomic status of algae was updated using the online database Algae Base (Guiry & Guiry 2014) and ADIAC (Automatic Diatom Identification and Classification).

Epilithic Bacillariophyceae communities were studied from stones and epiphytic Bacillariophyceae from *Vallisneria spiralis* surface collected in Licheńskie

Lake. Macrophytes samples were collected by cutting submerged parts of leaves – 5 replicates were picked. The same numbers of replicates of stones were collected. In the field, the epiphytic and epilithic algae were removed from substratum by scrubbing with a toothbrush (Morin & Cattanoe 1992). The algae were collected into 100 ml plastic containers with distilled water.

To define the percentage similarity of phytoplankton communities between investigated lakes, the Jaccard index was applied.

2.2. Physical and chemical analysis of water

The basic physicochemical parameters of water samples from all sites were analysed. Water temperature, pH, total dissolved solids (TDS), conductivity (EC) and oxygen levels (DO) were measured using SI 6600 V2 data probe (YSI, USA) directly in the field. Water transparency was determined under standard conditions using a Secchi disc. Water for nutrient analysis was sampled by hand from directly under water surface using 1.0 L sterile plastic bottles. Each sample was filtered through a coarse plastic sieve to separate vascular plants from water. Next, water samples were placed in 0.5 L sterile plastic containers, preserved using 0.5 ml chloroform and stored at 4°C. In the laboratory, the samples were filtered through a nitrocellulose microbiological filter with a pore size of 0.45 microns and stored in a freezer at -20 °C.

3. Results

3.1. Taxonomical compositions of phytoplankton and habitat conditions

Three of the examined lakes showed no clear differences in physico-chemical parameters such as: pH, dissolved oxygen, conductivity, total dissolved solids, and visibility of Secchi disc (Table 1). However, these lakes differed slightly in temperature of water; the warmest water was determined in Licheńskie Lake (22.7ºC), while Pątnowskie Lake had the coldest water (19.5ºC). Water in Wąsosko-Mikorzyńskie Lake had intermediate temperature (20ºC) in comparison with other examined lakes. The greatest saturation (up to 118%) was noted in Wąsosko-Mikorzyńskie Lake; however, oxygen content in the other lakes did not fall below 80%. Water in all examined lakes was about 8 pH.

Phytoplankton composition was similar in the three examined lakes (Fig. 2). The percentage of the main groups revealed that, in algal flora, the Chlorophyta (near 80%) was dominant, while others were less (>10%) or poorly represented. The greatest species diversity was observed also among Chlorophyta. We recorded 49 species of chlorophytes which comprised mostly Chlorococcales (38) with only 5 species of Chlamydomonadales, 5 species of Ulotrichales and 1 species of Volvocales. The most numerous genera included *Desmodesmus* (9) and *Pediastrum* (4), while the least numerous ones comprised *Coelastrum* (2), *Tetrastrum* (2), *Oocystis* (2). Bacillariophyceae were represented by 25 taxa, Fragillariophyceae – by 7 and Coscinodiscophyceae – by 2 taxa – among which only 4 species were noted in water, while others (30) belonged to periphytic community. Besides Chlorophyta and Bacillariophyceae, we also noted among phytoplankton a few: Cyanobacteria (5), Xanthophytes (2), Conjugatophytes (1), Dinophytes (2), and Cryptophytes (1). The systematic list of the taxa is contained in the Appendix 1.

The richest and varied lakes, in terms of phytoplankton taxa diversity, were both Licheńskie and Pątnowskie lakes, where respectively, 44 and 42 taxa were noted and 36 - in Wąsosko-Mikorzyńskie (Table 2). Representatives of all investigated algal groups (7) were noted in Pątnowskie Lake and only from 4 groups (Chlorophyta, Charophyta, Cyanobacteria and Xantophyceae) were observed in Wąsosko-Mikorzyńskie Lake.

Jaccard similarity between the studied lakes was about 24%. Only slight differences were determined concerning floristic affinities among the algal communities of the lakes. Jaccard similarity index exhibited low values and uniformity: maximum of 25.2% was found between Pątnowskie and Licheńskie Lakes, minimum – 23.3% – between Wąsosko-Mikorzyńskie and Licheńskie Lakes.

Table 1. Values of physicochemical factors of water for examined lakes

Parameter, unit	Lake Pątnowskie	Lake Wąsosko-Mikorzyńskie	Lake Licheńskie
Temperature [ºC]	19.5	20.0	22.7
pH	8.4	8.4	8.3
DO [%]	107.4	118.0	84.4
DO [mg/L^{-1}]	9.7	10.5	7.2
EC [µS/cm]	386	360	418
TDS [mg/L^{-1}]	279.5	279.0	286.0
SD [m]	1.5	1.6	1.7

Explanations: DO – dissolved oxygen, EC – conductivity, TDS – total dissolved solids, SD – *Secchi* disk

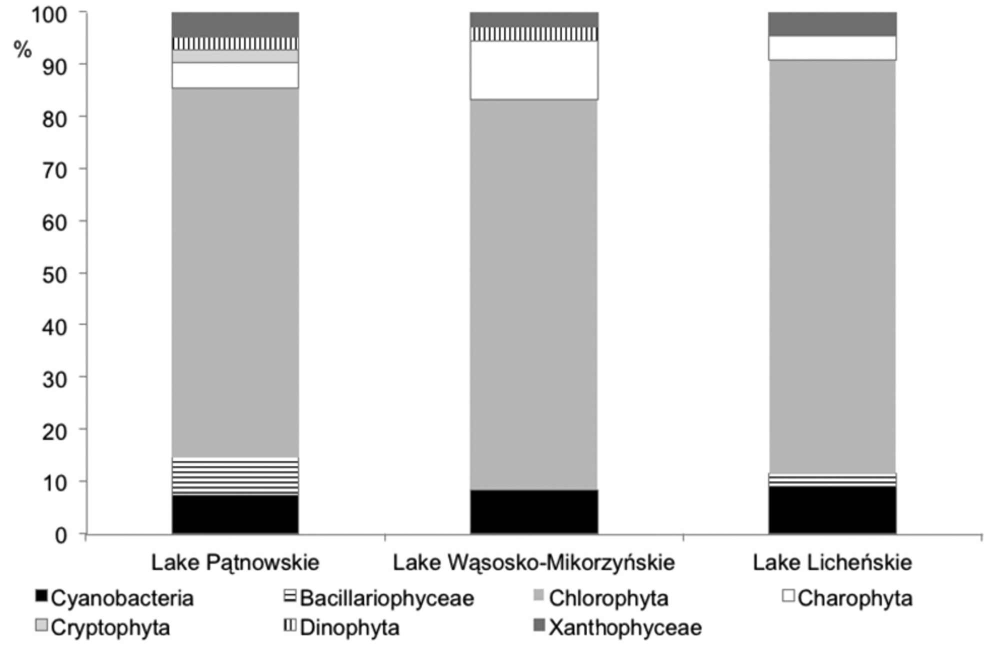

Fig. 2. Percentage participation of different groups of phytoplankton in the three studied lakes

3.2. Periphyton composition

The analysis of periphyton composition also gave interesting results. The surface of *Vallisneria spiralis* was inhabited by 23 taxa and of stones – only by 13 taxa. Bacillariophyceae communities colonizing *Vallisneria* were dominated by *Encyonema prostratum* (Berkeley) Kützing, *Ulnaria ulna* (Nitzsch) P. Compére, *Melosira varians* C. Agardh, *Navicula tripunctata* (O.F. Müller) Bory and *Rhoicosphenia abbreviate* (C. Agardh) Lange-Bertalot. Stone surfaces were much more frequently occupied by: *Cocconeis pediculus* Ehrenberg, *Diatoma ehrenbergii* Kützing and *Rhoicospenia abbreviate* (C. Agardh) Lange-Bertalot. Only 6 identical taxa were determined both on stone and macrophyte surfaces: *Epithemia sorex* Kützing, *Gomphonema* sp., *Melosira varians* C. Agardh, *Navicula cryptocephala* Kützing, *Nitzschia linearis* (C. Agardh) W. Smith and *Rhoicospenia abbreviate* (C. Agardh) Lange-Bertalot (Appendix 1).

4. Concluding remarks and discussion

4.1. Spring composition of phytoplankton

Despite the significant impact of temperature in the studied lakes, the process of seasonal succession of phytoplankton and the relative phytoplankton composition were not associated with the formation of blooms. Spring phytoplankton biomass was at the level of about 8-10 mg l^{-1} (Messyasz, unpublished). In the biomass of phytoplankton, in most sites, mostly green algae of Chlorophyta were dominant. Somewhat less frequent were diatoms. Biomass values of other groups were very low. The greatest values of this index (with Chlorophyta) were recorded in Lake Pątnowskie (5.691 mg l^{-1}; 71% of the total biomass), in Lake Licheńskie (4.001 mg l^{-1}; 42%) and in Lake Wąsosko-Mikorzyńskie (3.880 mg l^{-1}; 52%) (May 2011; data unpublished). Chlorophyta were represented mainly by *Phacotus lenticularis* (Ehr.) Stein, while *Oocystis lacustris* Chodat, *Monoraphidium contortum*

Table 2. Number of taxa in the phytoplankton groups of three studied lakes in 2013

Algae group	Lake Licheńskie	Lake Pątnowskie	Lake Wąsosko-Mikorzyńskie
Cyanobacteria	4	4	3
Bacillariophyceae	1	3	0
Chlorophyta	35	29	27
Charophyta	2	2	4
Cryptophyta	0	1	0
Dinophyta	0	1	1
Xanthophyceae	2	2	1
Total	44	42	36

(Thur.) Kom.-Legn., *Coelastrum astroideum* De Notaris occurred less frequently. There were no blooms of diatoms and dinoflagellates, listed in some eutrophic lakes of western Poland in the spring (Szeląg-Wasielewska 1998; Burchardt & Messyasz 2002). The appearance of algae blooms most often was associated with considerable load of inflowing organic matter from the catchment area, to a lesser extent - with temperature anomalies in the spring.

Long-term changes in the species composition of phytoplankton recorded in the investigated lakes (Socha & Hutorowicz 2009) were related to increasing (*i*) productivity, (*ii*) water flow and (*iii*) water temperature.

The results of this study and literature data (Napiórkowska-Krzebietke 2009) indicated that relatively warmer water in Licheńskie lake high efficacy of the phytoplankton diversity than in other lakes. Although in spring, the lowest species diversity was observed, where the greatest phytoplankton taxonomical diversity in Konin lake falls on summer months (Napiórkowska-Krzebietke 2009). The results of this author showed that there were twice as many phytoplankton taxa in Lake Licheńskie than in Lake Wąsosko-Mikorzyńskie. Our results from the spring period (2013) indicated similar species richness in individual lakes with the largest number of taxa within the green algae group. A similar character of the spring phytoplankton was also found by us in our previous research (May 2011; data unpublished). Large water exchange and water flow in the surface layer of the complex system of these heated lakes can be considered as factors affecting the structure of phytoplankton to a greater extent than the load of nitrogen and high water temperature.

Lakes, canals and ponds located in the vicinity of Konin Power Plant have warmer water than other water ecosystems in this region (Socha & Zdanowski 2001). These water ecosystems constitute a good place for colonization by non-native species, including phytoplankton (Burchardt 1977). Thermophilic species occurring near Konin comprise: *Cylindrospermopsis raciborskii* (Woloszyńska) Seenayya & Subba Raju, *Peridiniopsis berolinense* (Lemmermann) Bourrelly, *P. polonicum* (Woloszyńska) Bourrelly and *P. cunningtonii* Lemmermann (Gąbka & Owsianny 2009). In the spring, we found species such as: *Glochidinium penardiforme* and *Cylindrospermopsis raciborskii* whose optimum growth occurred in warm and eutrophic waters. Behavior of these species in the system of Konin lakes is the subject of detailed analysis. Existing data show a limited impact of these algae taxa on the composition structure and diversity of phytoplankton species of the studied lakes (Messyasz unpublished).

Among phytoplankton groups, Chlorophyta play a major role in the formation of algal biodiversity (Messyasz 2006). The optimum time for the occurrence of green algae is summer and autumn season (Reynolds 1984). In May 2005, Chlorophyta formed 45% of biomass in Lake Licheńskie. The results of heated lakes are visible in changes of phytoplankton structure, because a large group of planktonic species, characteristic for summer, is also present during spring and fall. It is not surprising a large variety of cyanobacteria and eukaryotic algae in the plankton community, which has been observed in the years 1968-1978 during the transformation of the Konin lakes from a natural phase in the anthropogenic. However, their persistence today confirms algal sensitivity to constantly changing environmental conditions.

4.2. Periphyton composition

Great importance, in the assessment of the ecological status of lakes, is attributed to periphytic algae (filamentous green algae, Bacillariophyceae) due to long-term stability of their growth and attachment to the same substrate. Periphytic Bacillariophyceae could overgrow rocks, fragments of macrophytes and surface layers of sediments (Poulíčková *et al.* 2004; Messyasz & Kuczyńska-Kippen 2006; Messyasz 2009). The quantity of epiphytic algae (periphyton communities) strictly depends on the type of surface (Straškraba & Pieczyńska 1970; Ondok 1978). For example, fresh water *Ulva* (macrogreen algae) surface was overgrown by 62 taxa of Bacillariophyceae (Messyasz *et al.* 2012). Bacillariophyceae communities on the surface of *Ulva* thalli were dominated by: *Cocconeis placentula* Ehr., *Melosira varians* Ag., *Navicula cryptocephala* Kütz., *Cyclotella menighiniana* Kütz. and *Gomphonema olivaceum* (Horn.) Bréb. In this study, *Cocconeis placentula* were also dominant on stone surfaces, while *Melosira varians* – on leaves of *Vallisneria spiralis*.

Species diversity of periphyton communities is associated with a variety of hydromacrophytes in the coastal zone of water reservoirs. Different surface of macrophytes, especially extensive patches of *Vallisneria spiralis* and extracellular secretion are the cause of a single species or multi-species sets of Chlorophyta and Bacillariophyceae.

5. Conclusions

The results of our studies from the spring period, from thermally altered lakes indicated taxonomic composition of phytoplankton typical for eutrophic reservoirs (not heated). No replacement of any of the phytoplankton groups characteristic for spring conditions was observed, even if there were changes in the competition dynamics between particular algal groups.

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Appendix 1. The systematic list of the taxa found in three lakes: Lake Pątnowskie[1], Lake Wąsosko-Mikorzyńskie[2], Lake Licheńskie[3] and periphytic Bacillariophyceae: stone – [s], *Vallisneria spiralis* – [v]

Procaryota, Cyanobacteria: Nostocales, Nostocaceae: *Anabaena* (*Dolichospermum*) *planctonica* Brunnth.[2], **Nostocales, Nostocaceae:** *Cylindrospermopsis raciborskii* (Wołoszyńska) Seenaya & Subba Raju[3], **Chroococcales, Synechococcaceae, Aphanothcoideae, Aphanothece:** *Aphanocapsa* (*Anathece*) *incerta* Lemmerm.[1,2,3], **Chroococcales, Merismopediaceae, Gomphosphaerioideae:** *Coelomoron pusillum* (Van Goor) Komárek[3], **Chroococcales, Chroococcaceae:** *Chroococcus* (*Limnococcus*) *limneticus* Lemmerm.[1,2,3], **Chroococcales, Microcystaceae:** *Microcystis aeruginosa* (Kütz.) Kütz.[1]

Eukaryota, Heterokontophyta, Xanthophyceae: Tribonematales, Tribonemataceae: *Heterothrix* sp.[1,2,3], **Mischococcales, Centritactaceae:** *Centritractus belonophorus* Lemmerm.[1,3]
Chlorophyta, Chlorophyceae: Chlamydomonadales, Chlamydomonadaceae: *Chlamydomonas* sp. div.[1,3], **Chlamydomonadales, Phacotaceae:** *Phacotus lenticularis* (Ehrenb.) F. Stein[1,3], *Pteromonas acuminata* Lemmerm.[1,3], **Volvocales, Volvocaceae:** *Pandorina morum* (O.F. Müller) Bory[1], **Chlorococcales, Scenedesmaceae:** *Coelastrum astroideum* De Not.[1,2,3], *C. reticulatum* (P.A. Dang.) Senn[1,2,3], *Crucigenia tetrapedia* (Kirchn.) G. S. West[1,3], *Crucigeniella apiculata* (Lemmerm.) Kom.[1,2,3], *Desmodesmus armatus* (Chod.) Hegew.[1,2,3], *D. abundans* (Kirch.) Hegew.[3], *D. armatus* var. *bicaudatus* (Guglielm.) Hegew.[2], *D. brasiliensis* (Boh.) Hegew.[2], *D. communis* (Hegew.) Hegew.[1,2,3], *D. dispar* (Bréb.) Hegew.[1,2,3], *D. maximus* (W. et G.S. West) Hegew.[1,2,3], *D. opoliensis* (P.G. Richt.) Hegew.[1], *D. pannonicus* (Hortob.) Hegew.[3], *Dicellula planctonica* G. M. Smith[2], *D. geminata* (Printz) Korshikov[3], *Scenedesmus ellipticus* Corda[1,2,3], *S. obtusus* Meyen[2,3], *S. acuminatus* (Lagerh.) Chodat[1,3], *Tetrachlorella alternans* (G.M. Smith) Korshikov[2,3], *Tetrastrum komarekii* Hindák[1,2,3], *T. staurogeniaeforme* (Schroed.) Lemmern.[1,2,3], **Chlorococcales, Selenastraceae:** *Kirchneriella obesa* (W. West) Schmidle[2,3], **Chlorococcales, Hydrodictyaceae:** *Pediastrum boryanum* (Turpin) Menegh.[1,2,3], *P. duplex* Meyen[1,2,3], *P. simplex* Meyen[1,2,3], *P. tetras* (Ehrenb.) Ralfs[2], *Tetraedron caudatum* (Corda) Hansg.[1,3], **Chlorococcales, Chlorococcaceae:** *Planktosphaeria gelatinosa* G.M. Smith[2,3], **Chlorococcales, Dictyosphaeriaceae:** *Coronastrum ellipsoideum* Fott[1], *Dictyosphaerium tetrachotomum* Printz[3], *Pseudodictyosphaerium minusculum* Hindák[2,3], *Westella botryoides* (W. West) De Wild.[1,2,3], **Chlorococcales, Radiococcaceae:** *Coenococcus planctonicus* Korshikov[1,3], **Chlorophyta, Trebouxiophyceae, Chlorellales, Oocystaceae:** *Franceia* cf. *tenuispina* Korshikov[2], *F. ovalis* (Francé) Lemmerm.[3], *Lagerheimia longiseta* (Lemmerm.) Wille[2], *Oocystis lacustris* Chodat[1,2,3], *O. marssonii* Lemmerm.[2,3], *Planctonema lauterbornii* Schmidle[1,3], *Siderocystopsis fusca* (Korshikov)

Swale[1], **Chlorophyta, Trebouxiophyceae, Chlorellales, Chlorellaceae:** *Gloeotila pelagica* (Nygaard) Skuja[1], *Closteriopsis longissima* (Lemmerm.) Lemmerm.[1,3],
Charophyta, Klebsormidiophyceae, Klebsormidiales, Elakatotrichaceae: *Elakatothrix genevensis* (Reverdin) Hindák[2], *E. spirochroma* (Reverdin) Hindák[1,2,3], *E. subacuta* Korshikov[2], **Conjugatophyceae, Desmidiales, Desmidiaceae:** *Staurastrum planctonicum* Teiling[1,2,3],
Dinophyta, Dinophyceae, Dinophycidae, Peridiniales, Peridiniaceae: *Glochidinium penardiforme* (Lindemann) Boltovskoy[2], *Peridinium* sp.[1],
Cryptophyta, Cryptophyceae, Cryptomonadales, Cryptomonadaceae: *Cryptomonas* sp.[1],
Bacillariophyta, Bacillariophyceae: Surirellales, Surirellaceae: *Cymatopleura solea* var. *apiculata* (W. Smith) Ralfs[v], *Campylodiscus hibernicus* Ehrenberg[1], **Thalassiphysales, Catenulaceae:** *Amphora copulata* (Kützing) Schoeman & Archibald[v], *A. ovalis* (Kützing) Kützing[v], **Cymbellales, Cymbellaceae:** *Cymbella lanceolata* (C. Agardh) C. Agardh[v], *C. neocistula* Krammer[v], *Cymbella* sp. 1[v], *Cymbella* sp. 2[v], *Encyonema prostratum* (Berkeley) Kützing[v], *E. ventricosum* (C. Agardh) Grunow[s], **Cymbellales**, **Gomphonemataceae:** *Gomphonema acuminatum* Ehrenberg[v], *G. augur* Ehrenberg[v], *G. truncatum* Ehrenberg[s], *G. parvulum* (Kützing) Kützing[s], *Gomphonema* sp.[vs], **Cymbellales, Rhoicospheniaceae:** *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot[vs], **Naviculales, Naviculaceae:** *Navicula tripunctata* (O.F. Müller) Bory[v], *N. cryptocephala* Kützing[vs], **Rhopalodiales, Rhopalodiaceae:** *Epithemia sorex* Kützing[vs], **Rhopalodiales, Rhopalodiaceae:** *Rhopalodia gibba* (Ehrenberg) O. Müller[v], **Bacillariales, Bacillariaceae:** *Nitzschia linearis* (C. Agardh) W. Smith[vs], *N. sigmoidea* (Nitzsch) W. Smith[v3], *N. recta* Hantzsch[v], **Achnanthales, Cocconeidaceae:** *Cocconeis pediculus* Ehrenberg[s],
Bacillariophyta, Fragilariophyceae: Fragilariales, Fragilariaceae: *Diatoma tenuis* Agardh[v], *D. ehrenbergii* Kützing[s], *Fragilaria capucina* var. *vaucheriae* (Kütz.) Lange-Bertalot[s], *F. dilatata* (Brébisson) Lange-Bertalot[v], *F. parasitica* (W. Smith) Grunow[1], *Ulnaria ulna* (Nitzsch) P. Compére[v]
Coscinodiscophyceae: Melosirales, Melosiraceae: *Melosira varians* C. Agardh.[vs], **Aulacoseirales, Aulacoseriaceae:** *Aulacoseira ambigua* (Grunow) Simonsen.[1]