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Dynamics of the phytoplankton community in mesotrophic Lake Borówno

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Key words: lake, trophic status, phytoplankton, biomass.

Abstract

The phytoplankton in Lake Borówno has never been included in phycological studies. The objective of our research was qualitative and quantitative analysis with reference to physicochemical parameters. Qualitative and quantitative analysis of phytoplankton assemblages were performed in 2004 and 2009. A total of 117 taxa were identified in Lake Borówno: *Cyanoprocaryota* – 35, *Cryptophyta* − 2, *Euglenophyta* − 1, *Pyrophyta* – 3, *Chrysophyceae* − 4, *Bacillariophyceae* – 25, *Chlorophyta* − 47. The bottom of the shallow water was covered with meadows of Charophyceae, with the dominant species *Chara vulgaris* L.

Biomass of the phytoplankton varied from 1.23 mg dm^{-3} in April to 5.74 mg dm^{-3} in August 2009. *Ceratium hirundinella* (O.F.Müller) Bergh was the dominant taxon during the whole season, but during summer another co-dominant taxon, *Microcystis aeruginosa* (Kütz.)Kütz., occurred.

The quality parameters, phytoplankton biomass, chlorophyll-*a* concentration and TSI indicate the mesotrophic character of the lake. The blue-green algae blooms, which are the major problem for preserving the good conditions of water in lakes, were not observed either in 2004 or 2009.

INTRODUCTION

Algae are excellent indicators of the water environmental conditions. Since the 19th century they have been used to determine the level of pollution in inland and sea waters. Based on the species and quantitative composition of most algae groups, we are able to study the progress in the evolution of water bodies and their ecological conditions. At present, algae are the main biological parameters used in environmental assessment reports.

So far, the phytoplankton of Lake Borówno has not been described in detail. The objective of the research undertaken in 2004 and 2009 was to investigate the communities of planktic algae in the lake, their structure, and their quantitative and dominance relations with reference to physicochemical parameters important for the water quality. The dynamics of changes in the phytoplankton dominance structure in time should accurately reflect the water conditions. Five years between sampling and phytoplankton analysis can indicate significant changes in the functioning of a lake.

When compiling the phycological material, the lists of species with assigned functional groups were used; the groups are characteristic of specific environmental conditions (Reynolds 1984), (Reynolds et al. 2002). This largely facilitates the assessment of ecological conditions in the water body without requiring labor-intensive autecological studies.

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LAKE DESCRIPTION

Lake Borówno is located ca. 15 km north of Bydgoszcz, on the Świecka Highland, on the Krajeńskie Lakes. This is a small lake with an area of 43.8 ha, a maximum depth of 14.1 m, with no outlet, and with more than 77% of the surrounding lands in agriculture.

Phytolittoral covers 38% of the entire lake area. The outermost bays are entirely covered with Chara meadows. They are dominated by *Chara vulgaris* L, which is accompanied by the less abundant *Nitellopsis obtusa* (Desv.) J. Groves, *Myriophyllum spicatum* L., and *Typha angustipholia* L. (Szatten 2009).

In the Świecka Upland, Lake Borówno is the only lake with waters of low trophic status. It is used intensively for tourism.

MATERIALS AND METHODS

Samples for phycological and physicochemical analysis were collected once a month from May to September in 2004, from one location. In 2009, samples were collected on average at monthly intervals from spring to early autumn, from three measurement points (Fig. 1). The first site was located next to a public swimming pool „WDW Żagiel" (depth 5.0 m), the second one in a bay near ROD (Family Garden Allotments) in the town of Nekla (depth 10.30 m), and the third one at the lake's maximum depth (depth 12.05 m).

Qualitative samples of phytoplankton were collected with a no. 25 plankton net. They were preserved in situ with Lugol's solution. Uncondensed quantitative samples were collected from the epilimnion with a Limnos sampler.

The number of algae was determined with the use of an inverted microscope in sedimentation chambers of 10 ml capacity according to Utermöhl (1958). The biomass was determined by the volumetric method assuming that 1 mm^3 = 1 mg of fresh algae mass.

Concentration of chlorophyll-*a* was determined by the Strickland and Paersons method (1968) modified by Lorenzen (1967).

Analysis of the physicochemical properties of the water was also performed within parameters that are particularly reflected in the biotic zone of the ecosystem. Sampling sites and dates were identical with those from the research on phytoplankton. These analyses were performed according to relevant valid standards.

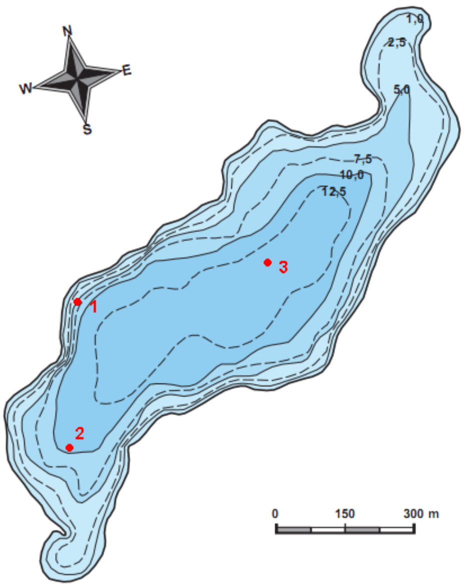

Fig. 1. Lake Borówno – bathymetric map. 1-3: numbers of sampling sites.

RESULTS

Physicochemical properties of water

Secchi disk visibility in the examined water samples, collected from Lake Borówno in 2004 and 2009, ranged from the lowest value of 2.4 m in July 2004 to the highest value of 5.35 m in July 2009. The average value of this index was 4.88 m for all locations throughout the study period. A large difference of 2.88 m in the average visibility was recorded in 2004, with much higher water transparency in 2009 – on average 5.09 m. According to this index, however, these results indicated very good ecological conditions of the water in the studied ecosystem.

Electrolytic conductivity in the waters of Lake Borówno fluctuated from 395 µS cm^{-1} in July 2009 to 720 µS cm^{-1} in July 2004. There was also a significant difference in the values of this index during the studied years. The average value in 2004 was 622 µS cm^{-1}, while in 2009 it was 425 µS cm^{-1}.

Each time the results indicated mesotrophic waters in the lake.

In 2004, water reactivity in Lake Borówno ranged from 6.9 to 7.2. In 2009, pH had the highest value in spring – 8.6. From June to late September it was balanced at all sites at the level of 7.4.

The temperature and oxygen profiles indicated a partially stratified lake, where only the deepest place in the lake (site 3) was characterized by complete stratification at the end of summer. No hypoxia was observed at the bottom of the lake.

The content of the main biogenic substances in the water were determined based on the concentration of total nitrogen and phosphates. The content of total nitrogen in the surface layer ranged from 1.2 to 1.4 $mgN_{tot}\,dm^{-3}$ in spring, and from 1.05 to 1.15 $mgN_{tot}\,dm^{-3}$ in summer. Concentrations of phosphates fluctuated in the following seasons throughout the study period. The concentration of phosphates had the highest value in spring at 0.029 $mgP\text{-}PO_4\,dm^{-3}$, and in summer ranged from 0.001 to 0.011 $mgP\text{-}PO_4\,dm^{-3}$. Low concentrations of biophilous elements in the waters of Lake Borówno do not exceed the so-called threshold values for the optimal development of phytoplankton, accepted by several authors (Kajak 1979, Kawecka & Eloranta 1994, Bajkiewicz-Grabowska 2006).

Species structure of phytoplankton

A total of 117 algae taxa were identified in the samples from 2004 and 2009, including the Chara species that are characteristic of this lake. *Chlorophyta* – 47, *Cyanoprokaryota* – 35, and *Bacillariophyceae* – 25 were most frequently represented. They were accompanied by *Chrysophyceae* – 4 taxa, *Pyrophyta* –3 taxa and 1 species from *Euglenophyta*. Changes in the number of taxa during particular months of the research period are presented in Figures 2 and 3.

The outermost bays of the lake basin are entirely covered with Chara meadows dominated by *Chara vulgaris*.

Taxa from Cyanoprokaryota – *Anabaena flos-aquae* Bréb. ex Born. et Flah., *Microcystis aeruginosa* (Kütz.) Kütz., *Oscillatoria tenuis* Ag. ex Gom., *Woronichinia naegeliana* (Unger) Elenkin, Dinophyta – *Ceratium hirundinella* (O.F.Müller) Bergh and *Peridinium* sp,. Bacillariophyceae – *Asterionella formosa* Has., *Cyclotella* sp., *Fragilaria crotonensis* Kitton, and Chlorophyta – *Pediastrum boryanum* (Turp.) Menegh were most constant in the studied samples. The identified taxa are presented in Table 1.

In 2004, taxa of blooming cyanobacteria were found in phytoplankton, including *Microcystins*, *Woronichinia*, and *Anabaena*, which in the adjacent ecosystems of field and forest ponds (situated in the drainage basin of the lake) formed August water blooms (Paczuska 2009). Nevertheless, their quantitative contribution in Lake Borówno was insignificant. In 2009, the species richness of cyanobacteria in phytoplankton considerably increased, both in qualitative and quantitative terms.

Most of the algae taxa occurring in the plankton of Lake Borówno are cosmopolitan and prefer meso- and eutrophic waters.

No rare species were found in the species composition of phytoplankton from Lake Borówno, nor were any species not previously found in Tuchola Forest by other authors recorded. Also, taxa

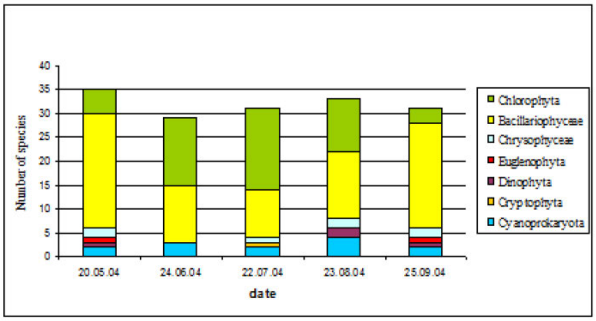

Fig. 2. Number of plankton algae species in Lake Borówno in 2004.

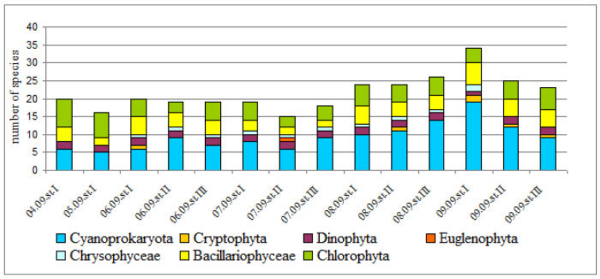

Fig. 3. Number of plankton algae species in Lake Borówno in 2009.

Table 1

The dominance structure of algal taxa in Lake Borówno in 2009.

Sampling month in 2009	Biomass ($mg\,dm^{-3}$)	Dominantion and subdominantion	Participation (%)
April	1.23	*Ceratium hirundinella* *Peridinium* sp.div. other taxa	49.14 39.48 11.38
May	1.35	*Ceratium hirundinella* *Peridinium* sp.div. other taxa	60.04 24.12 15.84
June	3.3	*Ceratium hirundinella* other taxa	85.73 14.27
July	5.39	*Ceratium hirundinella* *Microcystis aeruginosa* *Peridinium* sp.div. other taxa	38.78 34.57 16.09 10.56
August	5.74	*Ceratium hirundinella* *Peridinium* sp.div. other taxa	76.28 11.32 12.40
September	2.47	*Ceratium hirundinella* *Microcystis aeruginosa* other taxa	59.97 9.41 30.62

typical of the littoral zone were observed in the water column (e.g. *Pinnularia maior* (Kütz.) Rabh., *Zygnema* sp. or *Mougeotia* sp.).

Biomass of phytoplankton

Low biomass of phytoplankton ranged from 1.23 mg dm^{-3} in April 2009 to the maximum value of 5.74 mg dm^{-3} in August the same year (Fig. 4). In all cases the main biomass of spring and summer plankton was composed of one species: *Ceratium hirundinella*. Strong dominance of this species was accompanied in the summer by the subdominant cyanobacterium *Microcystins aeruginosa*. The dominance structure of the phytoplankton biomass in the lake is presented in Table 1.

The summer plankton was dominated by species from the functional group L_M: *Ceratium hirundinella* and *Microcystins aeruginosa*, as well as species from the group P – *Fragilaria crotonensis*. The functional group L_M is characteristic of the epilimnion in well-mixed water bodies and is tolerant of CO_2 deficiency. Diatoms from the P group occur in similar conditions, but are sensitive to silica deficiency (Reynolds 1984, Reynolds et al. 2002). Both *Ceratium hirundinella* and cyanobacteria represent S-strategy; they are long-lived and tolerant of deficiencies in biogenic substances, and occur in waters with stable ecological conditions. The accompanying taxa from the group L_o – *Peridinium, Woronichinia*, and *Merismopedia* – may occur in summer even in oligotrophic waters (Padisák et al. 2009), (Wilk-Woźniak 2009).

In spring 2009, concentrations of chlorophyll-*a* in the phytoplankton of Lake Borówno were high, up to the maximum value of 36.1 mg m^{-3} recorded in May. In summer, the concentrations of chlorophyll-*a* were lower, averaging ca. 13 mg m^{-3}. Concentrations of chlorophyll-*a* calculated in previous years (WIOŚ – Provincial Inspectorate of Environmental Protection – 2009) and in 2009 are presented in Figure 5.

The recorded concentrations of chlorophyll-*a* in the phytoplankton at particular sites mostly do not confirm the low values of phytoplankton biomass calculated at those sites during the studied period.

Only spring concentrations of chlorophyll-*a* are much higher than the threshold values of chlorophyll-*a* (10 mg m^{-3}) accepted by Kajak (1979) and others (Kawecka & Eloranta 1994), (Lampert & Sommer 1996) for a eutrophic state.

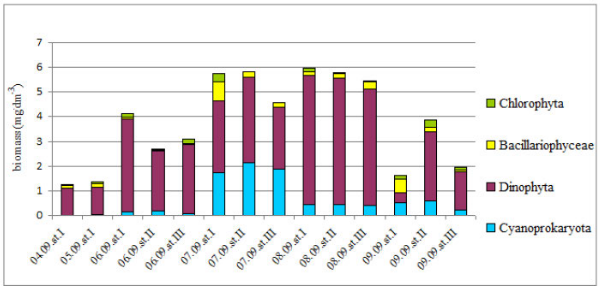

Fig. 4. Changes in phytoplankton biomass in Lake Borówno in 2009.

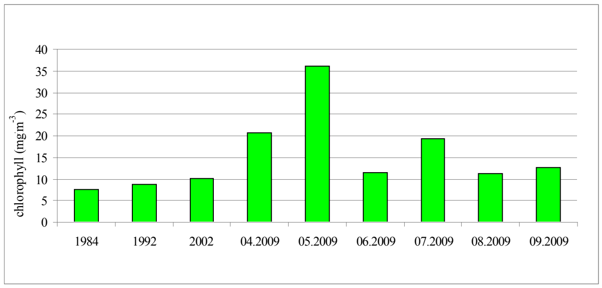

Fig. 5. Changes in the chlorophyll-*a* concentration in the phytoplankton of Lake Borówno.

Discussion

The dynamics of changes observed over the studied years in the structure and quantitative relations of phytoplankton was insignificant. This may indicate minor changes in the dynamic system of waters in Lake Borówno over a longer time. According to Padisák et al. (2009), dominant algae in the summer plankton from the functional group L_M, including *Ceratium hirundinella* and *Microcystins aeruginosa*, and co-dominant algae from the functional group L_o attributed to mesotrophic conditions, i.e. *Peridinium, Woronichinia* and *Merismopedia*, may occur in summer even in oligotrophic waters.

The comparison of long-term changes in quantitative and qualitative phytoplankton characteristics may, however, indicate the beginning of blue-green algae expansion. In 2009 the species richness of cyanobacteria in phytoplankton considerably increased, both qualitatively and quantitatively (Fig. 2 and 3).

In the near future, this may have an adverse effect on the recreational value of Lake Borówno. At present, this kind of situation is observed in the waters of the nearby Koronowo Reservoir (Wiśniewska 2010a, Wiśniewska et al. 2010b).

Based on the species composition, biomass of phytoplankton and concentration of chlorophyll-*a*, Lake Borówno was classified as mesotrophic.

This conclusion is additionally supported by the trophic state indices (TSI) calculated for the lake waters, based on the Secchi disc (SD) visibility expressed in meters, the concentration of chlorophyll-*a* in mg m^{-3} and the concentration of total phosphorus (TP) in mg dm^{-3} according to Carlson's formulas (1977), which range from 0 to 100 and reflect the trophic state of waters from extremely oligotrophic to hypertrophic. Here are the examples of the indices' mean values calculated in 2009:

$$TSI_{(SD)} – 37.35$$
$$TSI_{(Chl\text{-}a)} – 58.31$$
$$TSI_{(TP)} – 30.43$$

According to Carlson's classification (l.c.), Lake Borówno can be classified as moderately eutrophic only through the index expressed as the concentration of chlorophyll-*a*. Other parameters expressed by TSI indices classify the lake's waters between meso- and eutrophic.

Indices used for the assessment of the ecological state of Lake Borówno confirm values for mesotrophic conditions accepted by other authors (Bajakiewicz-Grabowska 2006).

Both low biomass and dominance of dinoflagellates indicate good, stable water conditions in Lake Borówno.

In the course of the research, no algal blooms were observed, neither abundant occurrence of cyanobacteria nor diatoms, which at present are the major problem for preserving the good conditions of lake waters.

REFERENCES

Bajkiewicz-Grabowska E. (2010). Assessment of the ecological state of lakes as proposed by the *Polish limnological Society, Limnol. Rev.* 10(3-4):105-116. DOI: 10.24.78/f10194-011-0012-6

Carlson, R.E. (1977). A trophic state index for lakes. *Limnol. and Oceanogr.,* 22(2), 361-369.

Kajak, Z. (1979), *Eutrophication of lakes*. Warszawa: PWN.

Kawecka B., Eloranta P.V.(1994). *The algae ecology of freshwater and terrestrial environment* [Zarys ekologii glonów wód slodkich i środowisk lądowych] PWN, Warszawa.

Lampert W., Sommer U. (1996). *Limnoecology.* [Ekologia wód śródlądowych] PWN, Warszawa.

Lorenzen, C. J. (1967). Determination of chlorophyll and pheo-pigments spectrophotometric equations. *Limnol. and Oceanogr.,* 12, 343-346.

Paczuska B. (2009). The problem of eutrophication of astatic water ecosystems of Świecie Upland [in:] Understanding the Requirements for Development of Agricultural Production and Rural Areas in Kuyavian-Pomeranian Province as Result of Scientific Research. University of Technology and Life Sciences Press, Bydgoszcz

Padisák, J. Ć., Crossetti L. O. & Naselli-Flores L.(2009). Use and misuse in the application of the phytoplankton functional classification: a critical review with updates, *Hydrobiologia* 621,1–19.DOI: 10.1007/s10750-008-9645-0

Reynolds, C. S., Huszar V., & Kruk C., Naselli-Flores L. & Mell S. (2002). Towards a functional classification of the freshwater phytoplankton. *Journal of Plankton Research* 24, 5, 417-428. DOI:10.1093/plankt/24.5.417.

Reynolds, C.S. (1984). *The ecology of freshwater phytoplankton,* Cambridge: Cambridge University Press.

Strickland, J. D. H., Parsons, T. R. (1968). *A practical handbook of seawater analysis.* Ottawa: Fish. Res. Board of Canada.

Szatten D. (2009). Stan jakości wód jeziora Borówno w 2009 roku. Wojewódzki Inspektorat Ochrony Środowiska w Bydgoszczy. *[Water purity in Lake Borówno in 2009 year.* Provincial Inspectorate of Environmental Protection in Bydgoszcz]

Utermöhl, H. (1958). *Zur Vervollkommung der quantitativen Phytoplankton - Methodik,* Mitt. Internat. Verein. Limnol., 9, 5-46.

Wiśniewska M. (2010a) *Fitoplankton nizinnych zbiorników zaporowych. [Phytoplankton of the lowland dam reservoir]* [in:] Diagnozowanie stanu środowiska – Metody badawcze-prognozy. Tom IV pod .red. J.K.Garbacza. Oficyna Wyd. ARTKAMI Bydgoszcz.

Wiśniewska M., Puszkiewicz K.& Ziólkowski K. (2010b). *Fitoplankton w ocenie trofii Zbiornika Koronowskiego [Phytoplankton in the evaluation of water trophy in the Koronowski Reservoir].* Ekologia i Technika, nr 1 (104) Rok XVIII, Bydgoszcz

Wojewódzki Inspektorat Ochrony Środowiska w Bydgoszczy, 2009, Raport o stanie środowiska województwa kujawsko-pomorskiego, [Provincial Inspectorate of Environmental Protection in Bydgoszcz. (2009). Raport o stanie środowiska województwa kujawsko-pomorskiego

Wilk-Woźniak, E. (2009). *Changes in phytoplankton communities and the life strategies of artificially changed aquatic ecosystems.* Kraków: Studia Naturae 55, IOP PAN.

Plate 1

Cyanoprocaryota: 1-*Anabaena flos-aquae*, 2- *A. lemmermanii*, 3-*Cylindrospermum maius*, 4-*Limnothrix redekei*, 5-*Lyngbya hironymusii*, 6-*Microcystis aeruginosa*, 7-*M. flos-aquae*, 8-*Planktothrix agardhii*, 9-*Snowella lacustris*, 10-*Woronichinia naegeliana*; **Dinophyta:** 11-*Ceratium hirundinella*, 12-*Peridinium* sp. div.

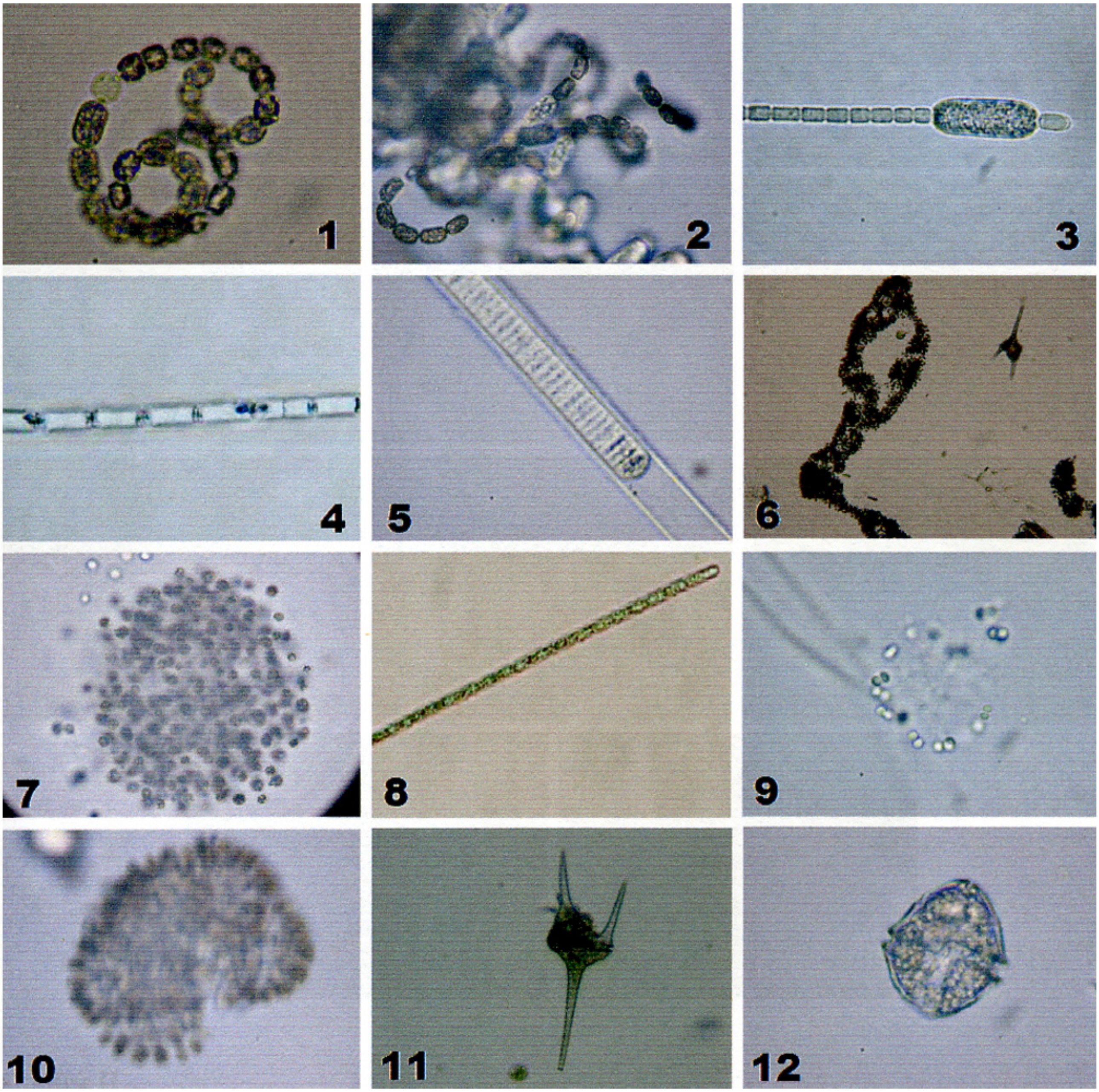

Plate 2

Chrysophyceae: 13-*Dinobryon divergens*, 14-*D. sociale*, **Bacillariophyceae:** 15-*Aulacoseira granulate*, 16-*Cyclotella* sp., 17- *Fragilaria capucina*, **Chlorophyta:** 18-*Botryococcus braunii*, 19-*Closterium aciculare*, 20-*Cosmarium* sp., 21-*Pediastrum boryanum*, 22-*Staurastrum gracile*, 23-*Zygnema* sp.