Steciana

2014, Vol. 18(4): 191–197
doi:10.12657/steciana.018.021

www.up.poznan.pl/steciana

ISSN 1689-653X

PHYTOPLANKTON SUCCESSION IN AN ARTIFICIAL, PERIODICALLY DRAINED SMALL WATER BODY

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(Received: July 22, 2014. Accepted: September 26, 2014)

Abstract. This study was undertaken to monitor the course of a secondary succession of phytoplankton in temporary water bodies, based on a man-made periodically drained pond. Results of phycological analyses showed, that small Chlorophyceae from the order Chlorococcales predominated qualitatively throughout the study period. Chlorophyceae, e.g. stress-resistant *Haematococcus pluvialis*, developed best as the first algae (after the pond was re-filled). In the next stages of diatom succession (*Ulnaria ulna*) predominated quantitatively, followed by the longest period of Cyanobacteria (*Aphanothece elabens*) predominance, replaced again by Chlorophyceae (*Tetraëdron minimum* and *Oocystis lacustris*). Total abundance of algae, similarly as that of Cyanobacteria, were positively correlated with temperature and pH of water.

Key words: Cyanobacteria, Chlorophyceae, Chlorococcales, *Haematococcus pluvialis*, *Aphanothece elabens*, pond

INTRODUCTION

Small water bodies are characterised by rapid succession processes of organisms colonising them, such as e.g. phytoplankton. Due to the limited depth and size of these water bodies they offer conditions conducive to the development of planktonic algae (rapid heating of water, advantageous access to light, abundance of nutrients and their easy transfer to the productive surface zone). Additionally, frequently drained water bodies due to their intermittent character create habitats distinctly different from those found in permanent waters. Periodical drainage of water, removal of vegetation and bottom sediments are major factors modifying succession processes in these ecosystems (Falkowski & Nowicka-Falkowska 2006 a, b).

The phytoplankton of temporary waters is very specific, dominated by species adopted to variable and often extreme environmental conditions (Marrone et al. 2006, Naselli-Flores & Barone 2012). Local instability may promote the exceptionally high species richness frequently observed in ephemeral habitats. The individual and interacting impacts of factors influencing community structure and dynamics in temporary ponds are largely unknown (Waterkeyn et al. 2008, Naselli-Flores & Barone 2012, Blanco et al. 2013).

Following re-filling of a water body the phytoplankton community is re-established, originating mainly from spores contained at the bottom. This process of colonisation seems to be crucial for the future shape of the community.

An example of such water bodies is provided by a small, man-made water body located at the Collegium Maximum building of the Poznań University of Life Sciences, which was created in order to enhance the aesthetic value of the campus area. Every year in the summer season a relatively rapid deterioration of water quality is observed, caused by blooms of planktonic *Chlorophyceae* (unpublished data).

The aim of this study was to monitor the succession of algae from the moment the pond was re-filled with water and to determine the effect of such factors as pH and temperature of water on algal development.

STUDY AREA

The man-made pond investigated in this study is located at the campus of the Poznań University of Life Sciences, at Wojska Polskiego street behind the Collegium Maximum building (Fig. 1).

Every year it is filled with water for the period from April to November and then it is drained. The

Fig. 1. View of the investigated water body in 2012 (Phot. M. Golcz-Polaszewska)

pond is 257 m^2 and 0.5 m deep. Single vascular plant specimens (*Cyperus papirus* L., *Nymphaea* L.) are planted in the pond. Coniferous trees from the genera *Pseudotsuga*, *Pinus* and *Thuja* as well as scarce shrubs such as e.g. *Berberis* L. are growing in the vicinity of the water body. Crucian carps are released to the pond every year.

MATERIALS AND METHODS

Samples for the qualitative and quantitative analyses were collected 14 times, bi-weekly (between 24th April to 23th October, 2012), from the water surface layers. Each time water pH and temperature were measured using a digital pH meter (Hanna model). The samples for qualitative phytoplankton analyses were concentrated using a plankton net (40 μm mesh size), and those for quantitative analyses were taken using plastic bottle (1 liter) and than fixed with Lugol's solution and concentrated to a volume of 5 ml by sedimentation. They were analysed in the laboratory under a light microscope, using 20× and 40× objectives.

Taxonomic keys employed in the identification included: Starmach 1966, 1968, 1974, 1989, Hindák 1984, 1988 a, b, 2005, Krammer & Lange-Bertalot 1986, 1988, 1991 a, b, Popovský & Pfiester 1990, Komárek & Anagnostidis 1998.

The abundance of the phytoplankton was determined applying the Fuchs-Rosenthal chamber. Single cells and algal cenobia were treated as individual organisms. In the case of trichomes a single individual was considered to be 100 μm long, and in the colony forming cyanobacteria *Aphanothece elabens* to cover the area of 400 μm^2.

The dominant taxa were defined as those accounting for 10% or more of the total phytoplankton abundance in a given sample.

To analyse the relationship between the phytoplankton abundance and physico-chemical water properties, the Spearman correlation coefficients were calculated (significance at $p < 0.05$). The data were processed with STATISTICA 6.0 PL 2002 software (Statistica… 2002).

RESULTS AND DISCUSSION

In the investigated water body, pH fluctuated between 6.3 and 10.3, and temperature between 9.5°C and 22.5°C (Table 1). Considerable and rapid changes in pysico-chemical parameters of water are typical of small water bodies.

Table 1. Temporal changes in water pH and temperature in the investigated water body in 2012

Date	24.04	8.05	22.05	5.06	19.06	3.07	17.07	31.07	14.08	28.08	11.09	25.09	9.10	23.10
pH	7.4	7.83	9	8.65	9.6	9.8	10.3	10.3	9.78	8.77	6.7	6.4	6.45	6.34
Temperature (°C)	12.5	14.7	20	14.3	21.5	22.5	17.9	21.5	17.3	17.1	17.3	12.1	9.5	10.2

Table 2. Taxonomic composition of phytoplankton in the studied water body

Cyanobacteria
Aphanothece elabens (Brèbisson ex Meneghini) Elenkin
Chroococcus turgidus (Kützing) Nägeli
Johannesbaptistia sp.
Oscillatoria sp.
Chlorophyceae
Actinastrum hantzchii Lagerheim
Cosmarium rectangulare Grun. in Rabenhorst
Crucigenia tetrapedia Hindák
Haematococcus pluvialis Flotow
Oocystis borgei Snow
Oocystis lacustris Chodat
Pandorina morum Müller
Pediastrum boryanum (Turpin) Meneghini
Planktonema lauterbornii Schmidle
Scenedesmus dimorphus (Turpin) Kützing
Scenedesmus obliquus (Turpin) Kützing
Tetraedron minimum (A. Braun) Hansgirg
Bacillariophyceae
Amphora ovalis Kützing
Cymbella affinis Kützing
Gomphonema intricatum Kützing
Gomphonema truncatum Ehrenberg
Navicula radiosa Kützing
Nitzschia acicularis W. Sm.
Nitzschia palea Kützing
Rhopalodia gibba Ehrenberg
Ulnaria acus (Kützing) M. Aboal in Aboal
Ulnaria ulna (Nitzsch) P. Compère
Dinophyceae
Gymnodinium sp.
Katodinium sp.
Peridinium sp.
Woloszynskia pascheri (Suchlandt) von Stosch
Chrysophyceae
Synura sp.

Phycological studies revealed the presence of 31 phytoplankton species (Table 2), which belonged to five taxonomic groups (Cyanobacteria, Chlorophyceae, Bacillariophyceae, Dinophyceae and Chrysophyceae). In terms of taxa numbers, the Chlorophyceae was the dominant group (Fig. 3). Their share in the total number of phytoplankton taxa was 39% (Fig. 2, 3). Among *Chlorophyceae* predominated the species from the order *Chlorococcales*, which develop well in shallow aquatic ecosystems, at the abundance of nutrients (Reynolds 1984, Kawecka & Eloranta 1994, Lee 1999, Maraşlioğlu et al. 2011, Nowrouzi & Valavi 2011). Predominance of small planktonic forms is usually noted in the early stage of succession or in extreme habitats (Catalan et al. 2006, Tavernini et al. 2009, Pęczuła et al. 2014). The share of Bacillariophyceae was also considerable (32%). The highest number of algae taxa was recorded in the initial stages of succession (Fig. 3), shortly after the pond was filled with water. A similar trend was described by Michaloudi et al. (2012) who stated that phytoplankton species richness in a temporary lake increased within a few months after inundation. A reduction in the species number in July and August coincided with the massive development of *Cyanobacteria* and *Chlorophyceae*.

The highest frequency of the algae species in the analysed pond was recorded for a blue-green algae *Aphanothece elabens* and also such *Chlorophyceae* as *Cosmarium rectangulare*, *Haematococcus pluvialis*, *Oocystis lacustris* and *Pediastrum boryanum*. Among diatoms *Rhopalodia gibba* and *Amphora ovalis*, i.e. species preferring basic water reaction and fertile waters, were recorded most frequently (van Dam 1994, Antón-Garrido et al. 2013).

Quantitative analysis of phytoplankton showed the predominance of *Chlorophyceae* in the spring and autumn seasons, while in the summer period (19.06–28.08) *Cyanobacteria* constituted a vast majority (Fig. 4, 5). The share of diatoms in the initial sampling period increased up to June 5th (Fig. 4). In the later period of the study water temperature increased considerably and then diatoms were replaced by cyanobacteria. According to Nowrouzi & Valavi (2011) and Lűrling et al. (2013), diatoms are adapted to lower temperatures than cyanobacteria. Literature data also indicate that the quantitative development of *Bacillariophyceae* occurs in the spring period in conditions of low water temperatures (Reynolds 1996, Mutshinda et al. 2013), high water turbidity, and low availability of light. *Nitzschia palea* and *Ulnaria ulna* were found in the greatest numbers in the initial stage of sample collection. These diatoms are indicators of fertile and contaminated waters (van Dam 1994, Trobajo et al. 2009). Starting from the time the pond was re-filled an upward trend was observed for the

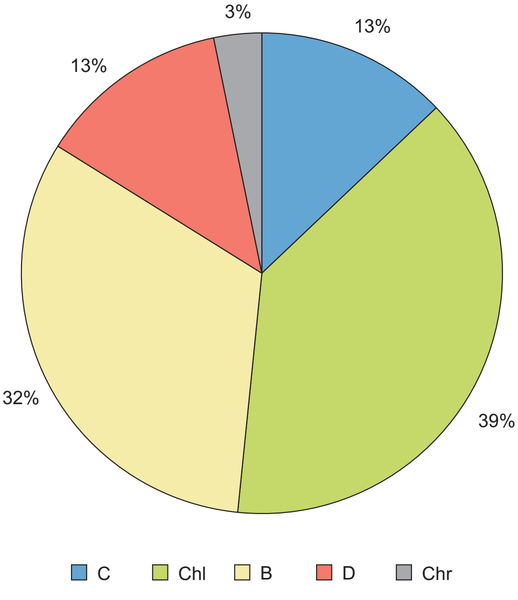

Fig. 2. Percentage contributions of particular systematic groups to the number of phytoplankton taxa in the investigated water body in 2012 (C – Cyanobacteria, Chl – Chlorophyceae, B – Bacillariophyceae, D – Dinophyceae, Chr – Chrysophyceae)

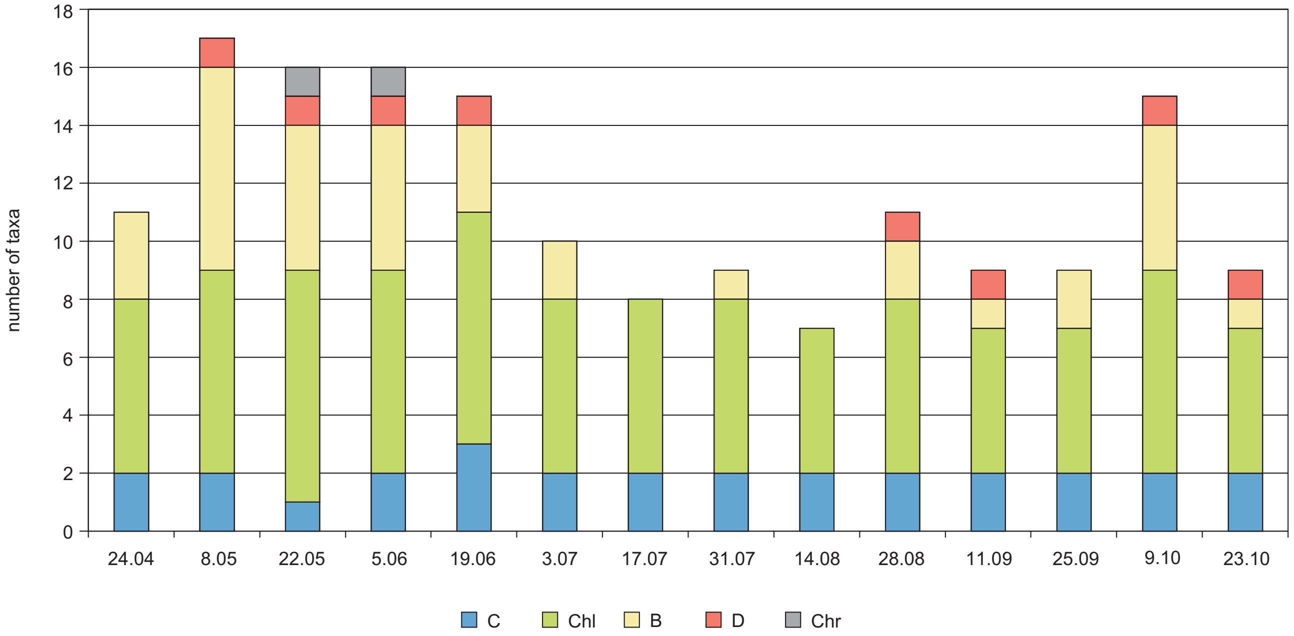

Fig. 3. Temporal changes in the number of phytoplankton taxa in the investigated water body in 2012 (C – Cyanobacteria, Chl – Chlorophyceae, B – Bacillariophyceae, D – Dinophyceae, Chr – Chrysophyceae)

total abundance of algal specimens until mid-July, followed by a downward trend. The maximum number of individuals was 5736 indiv./ml and it was recorded on 17.07.2012, when the abundance of Cyanobacteria was also highest in the entire sampling period (3740 indiv./ml, Fig. 5). The increase in the total number of phytoplankton individuals, including Cyanobacteria, was connected with an increase in temperature and pH of water in the summer period. This was confirmed by statistical analyses, which showed significant positive correlations between water temperature and the phytoplankton and Cyanobacteria abundance (r = 0.606 and r = 0.712, respectively) and dominant species: *Aphanothece elabens* and *Oocystis lacutris* (r = 0.747 and r = 0.533, respectively). According to Nowrouzi & Valavi (2011) chlorophytes increase under high temperatures, just as blue-green algae. Significant positive correlations were also recorded between pH and total abundance of phytoplank-

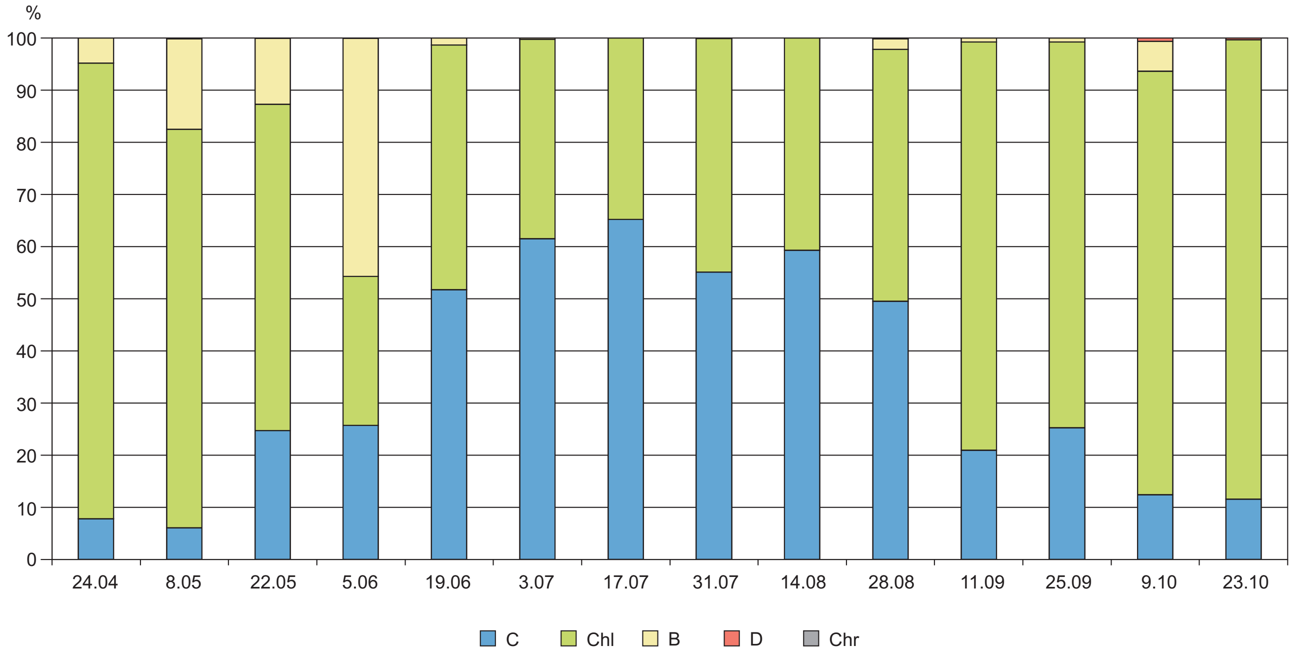

Fig. 4. Percentage contributions of particular systematic groups to the number of phytoplankton individuals in the studied water body in 2012 (C – Cyanobacteria, Chl – Chlorophyceae, B – Bacillariophyceae, D – Dinophyceae, Chr – Chrysophyceae)

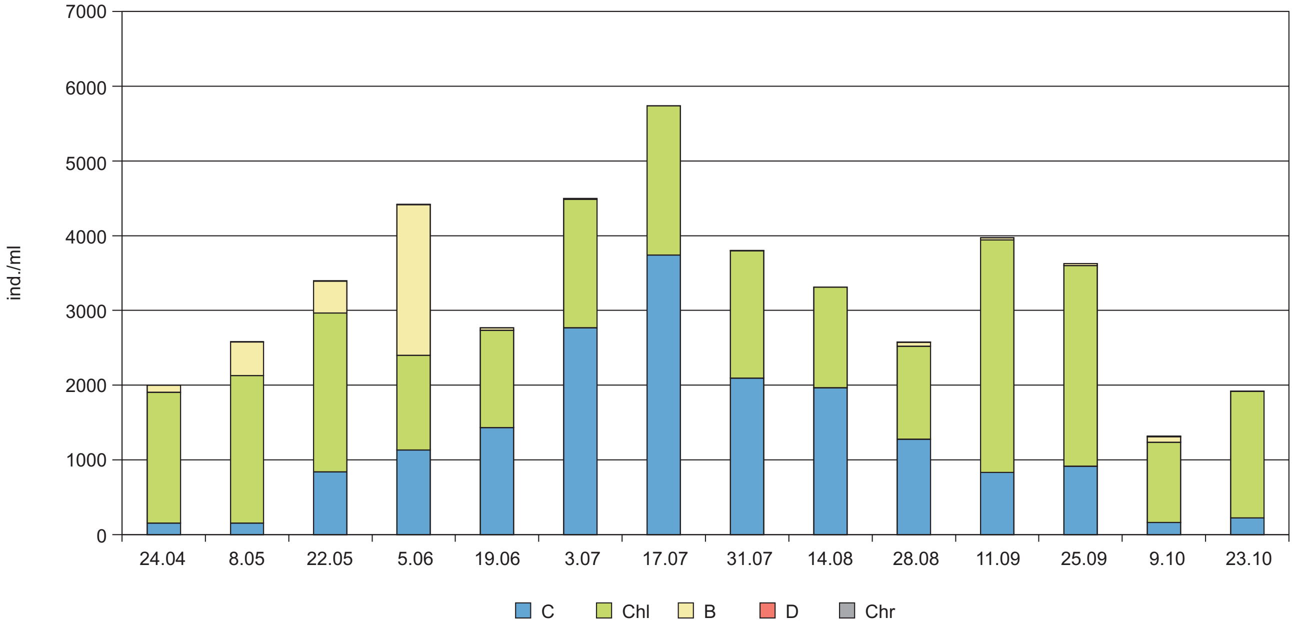

Fig. 5. Temporal changes of phytoplankton abundance in the studied water body in 2012 (C – Cyanobacteria, Chl – Chlorophyceae, B – Bacillariophyceae, D – Dinophyceae, Chr – Chrysophyceae)

Table 3. Structure of phytoplankton dominants in the investigated water body in 2012

Species	24.04	8.05	22.05	5.06	19.06	3.07	17.07	31.07	14.08	28.08	11.09	25.09	9.10	23.10
Haematococcus pluvialis	+	+												
Cosmarium rectangulare			+											
Ulnaria ulna				+										
Aphanothece elabens					+	+	+	+	+	+				
Tetraëdron minimum											+		+	+
Oocystis lacustris												+		

ton and Cyanobacteria (r = 0.570 and r = 0.819, respectively) and a species *Aphanothece elabens* (r = 0.841). According to Reynolds et al. 2002 this species, similarly as most Cyanobacteria, develops well in alkaline waters. Alternatively, increases in algal abundance may increasing pH (Mutshinda et al. 2013). In sum, changes in phytoplankton abundance often cause changes in environmental parameters.

The structure of dominant species in the analysed water body fluctuated with time (Table 3). *Chlorophyceae* predominated in the initial stage of succession, followed successively by diatoms, *Cyanobacteria* (*Aphanothece elabens*, Fig. 6) and again *Chlorophyceae*. The first dominant species after the pond was re-filled with water was a green alga *Haematococcus pluvialis* (Fig. 7), a ubiquitous microalga occurring mainly in ephemeral small fresh water pools (Klochkova et al. 2013). At that time a red water colouring was observed in the pond, caused by the accumulation of a ketocarotenoid astaxanthin in algal cells of *Haematococcus pluvialis*. Astaxanthin

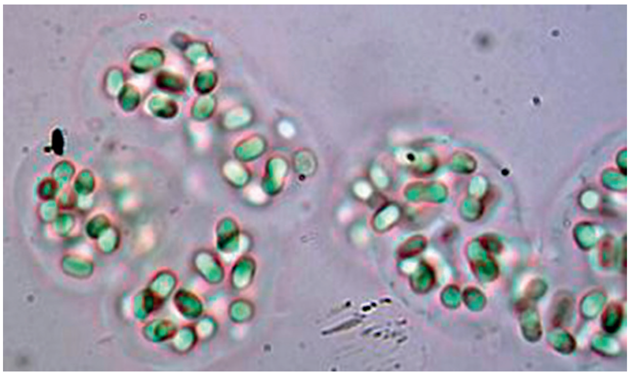

Fig. 6. *Aphanothece elabens*

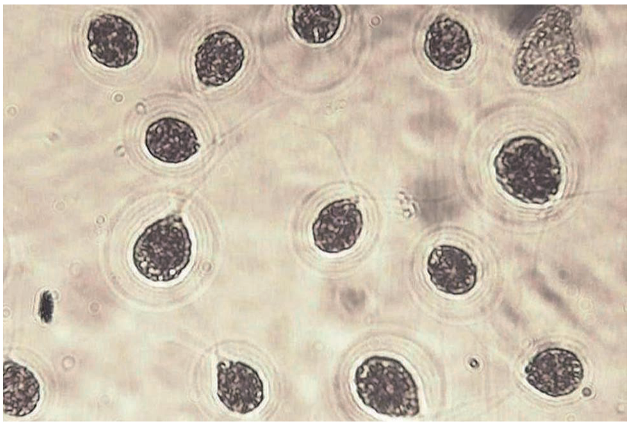

Fig. 7. Motile bi-flagellated cells of *Haematococcus pluvialis*

accumulation in *Haematococcus* was reported to be induced under stress connected with unfavourable growth conditions such as nutrient deficiency (N or P), variations of temperature and other factors (Sarada et al. 2002, Dominguez-Bocanegra et al. 2004). Thanks to these characteristics *Haematococcus pluvialis* seems to be a good pioneering species in the initial stage of phytoplankton succession in the analysed water body.

A large share of *Chlorophyceae* and *Cyanobacteria,* in the analysed water body, as well as a considerable number of species preferring eutrophic waters, indicate high concentrations of nutrients in water. Moreover, the predominance of rapidly proliferating taxa with the *r* type development strategy showed liable environmental conditions typical of shallow aquatic ecosystems. The primary cause for eutrophication and massive development of algae was connected most probably with the introduction of fish to the analysed water body. Feed for fish as well as fish droppings found in the water are considerable sources of biogens, greatly enriching water and stimulating algal development (Sipaúba-Tavares et al. 2011). An additional aspect promoting intensive development of phytoplankton was connected with the limited share of macrophytes, which compete with algae for light and nutrients (Kosten et al. 2011).

Undertaken investigations provided a contribution to the development of methods to prevent and/or control algal blooms in such water bodies and will broaden our knowledge on the ecology of planktonic algae, pioneering species and the species resistant to environmental stress.

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