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WATER QUALITY ASSESSMENT IN THE POZNAŃ SOŁACKIE PONDS BASED ON PHYCOLOGICAL STUDIES CONDUCTED IN 2012

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ABSTRACT. Detailed phycological analysis aimed at the assessment of water quality in the Sołacki Park ponds in Poznań was performed during the vegetative season of 2012. Qualitative analysis revealed the presence of a total of 294 phytoplankton taxa (244 in the Mały Pond and 246 in the Duży Pond), most of which were green algae (total 32%) and diatoms (33%). However, quantitative evaluation showed that in the summer both ponds were dominated by green algae and in the fall by filamentous cyanobacteria. The highest phytoplankton abundance occurred in the fall (13 291 ind./ml in the Mały Pond and 20 288 ind./ml in the Duży Pond), when the proportion of blue-green algae was the greatest. The dominant species were: *Ulnaria acus*, *Crucigenia tetrapedia*, *Tetraedron minimum*, *Planktothrix agardhii* and *Pseudanabaena limnetica*. Significant share of green algae of the order *Chlorococcales*, cyanobacteria and diatoms, indicator algae for eutrophy and meso- or polysaproby, suggested high fertility and significant pollution of the investigated ponds. This study confirms the need for continuous monitoring of the Sołackie Ponds, as well as periodic reclamation treatments in order to reduce eutrophication and improve water quality.

KEY WORDS: phytoplankton, water quality, pond, Bacillariophyceae, Chlorophyta, Cyanoprokaryota

INTRODUCTION

Park ponds in urban areas constitute an important part of the landscape. They regulate hydrographic conditions, improve parkland microclimate and enhance the ecological, landscape and aesthetic values of a park (Lewińska 2000, Małecki 2009, Małecka and Staszewski 2011). Therefore, maintaining good quality of pond waters, which are often exposed to over-fertilization and excessive algae growth, is particularly important.

The Sołackie Ponds, located in the Sołacki Park in Poznań, are shallow, artificial reservoirs created by damming the Bogdanka river, the left-bank tributary of the Warta. Phycological studies carried out in 1999-2000 (Messyasz and Jurgońska 2003), revealed a large share of green algae and cyanobacteria, and confirmed the eutrophic nature of the ponds.

Poor quality of water in the Sołackie Ponds has been so far due to the fact that they are the last reservoir collecting sludge and contaminations carried by the Bogdanka before reaching the Warta. Their last reclamation took place in 2005-2006, and the previous one in 1995-1996.

The aim of this study was the assessment of water quality of two Sołackie Ponds (Mały and Duży), based on qualitative and quantitative analysis of phytoplankton, including indicator species.

According to the Water Framework Directive of the European Union, phytoplankton is one of the key factors that should be taken into account when assessing the ecological status of waters. Algal communities are sensitive to physical and chemical conditions of water and quickly respond to environmental changes, being good indicators of trophy, saproby or water pH (Reynolds 2000). Therefore, phycological research will help to determine current ecological status of the ponds and to introduce appropriate measures aimed at their reclamation and protection.

STUDY AREA AND METHODS

The investigated ponds (Mały Pond – 1 and Duży Pond – 2, Fig. 1) are located in the Sołacki Park, in the north-western part of Poznań. The park covers an area of 14.60 hectares, between the streets Małopolska and Litewska and Nad Wierzbakiem and Niestachowska.

The ponds have elongated shape and their total area is about 3.26 ha. The coastline is 1050 m long (Łęcki 1990). The Mały Pond's area is 0.2 ha^2 and its depth is 1.3-1.5 m, while the Duży Pond covers 3.22 ha^2 and is 1.5-2 m deep (Messyasz and Jurgońska 2003). The ponds' bottom is heavily silted.

Samples for phycological analysis were collected from the surface layer of the pelagic zone (Fig. 1) in both ponds. The study was conducted between June 15th to October 19th, 2012, at two week intervals. Each time water pH and temperature were measured. The samples for qualitative phytoplankton analysis were concentrated using a plankton net, and those

Fig. 1. Location of the Sołackie Ponds (pond 1 – Mały Pond, pond 2 – Duży Pond)

for quantitative analysis were fixed at once with Lugol's solution, and concentrated to a volume of 5 ml by sedimentation.

Planktonic algae taxonomic determination was based on the following keys: Starmach (1966, 1968, 1972, 1974, 1983, 1989), Hindák (1984, 1988 a, b), Krammer and Lange-Bertalot (1986, 1988, 1991 a, b), Popovský and Pfiester (1990), Wołowski (1998), Komárek and Anagnastidis (2005), Wołowski and Hindak (2005) and Bąk et al. (2012).

Phytoplankton individuals were counted under a light microscope in the Fuchs-Rosenthal chamber. Single cells and algae coenobia 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 cyanobacterium *Microcystis* sp. to cover the area of 400 μm^2. The dominant taxa were defined as those accounting for 15% or more of the total abundance in a given sample.

Ecological characteristics of diatoms was based on the scale described by van Dam et al. (1994), taking into account the trophic status, saprobity and pH.

Taxonomic similarity of the two ponds was calculated according to the Jaccard formula (Kawecka and Eloranta 1994).

RESULTS AND DISCUSSION

Changes in pH and temperature are presented in Table 1. Water pH fluctuated between 6.6 and 7.8. The lowest pH in both ponds was noticed in autumn. Water temperature in summer was about 20°C, and significant drop was observed in autumn (Table 1).

Qualitative analysis of the phytoplankton structure in the Sołackie Ponds revealed the presence of a total of 294 phytoplankton taxa (244 in the Mały Pond and 246 the Duży Pond). Phycoflora of both ponds comprised mostly green algae and diatoms (Fig. 2, 3), as in 1999-2000 (Messyasz and Jurgońska 2003).

Taxonomic similarity coefficient for the studied ponds was 72%, which indicates only minor differences in terms of species composition. However, there were found species, which occurred only in one pond:

Table 1. Temporal changes in water temperature and pH values in the Sołackie Ponds in 2012

	Mały Pond										Duży Pond									
Date	15.06	28.06	13.07	27.07	10.08	24.08	07.09	21.09	05.10	19.10	15.06	28.06	13.07	27.07	10.08	24.08	07.09	21.09	05.10	19.10
pH	7.1	7.5	7.4	7.4	7.4	7.2	7.1	6.7	6.7	6.6	7.2	7.8	7.5	7.8	7.7	7.1	7.2	6.7	6.8	6.7
Temperature (°C)	19	17	21	24	20	19	16	13	13	10	19	18	21	24	20	20	17	14	13	10

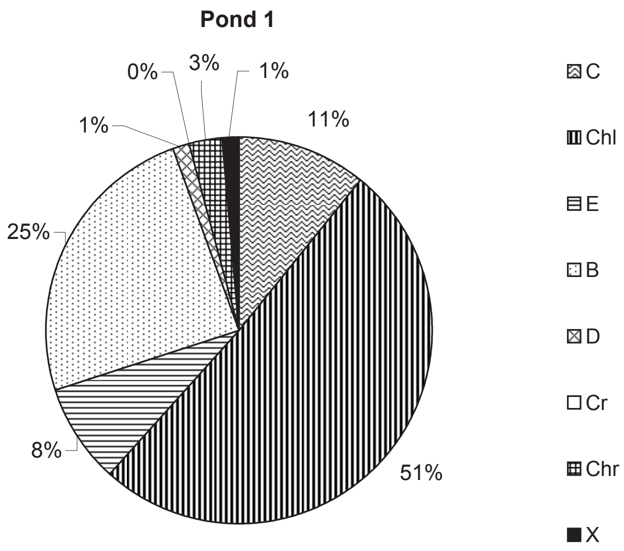

Fig. 2. Percentage contributions of particular systematic groups of algae to the total number of phytoplankton taxa in the Mały Pond in 2012 (C – Cyanoprokaryota, Chl – Chlorophyta, E – Euglenophyta, B – Bacillariophyceae, D – Dinophyceae, Cr – Cryptophyceae, Chr – Chrysophyceae, X – Xanthophyceae)

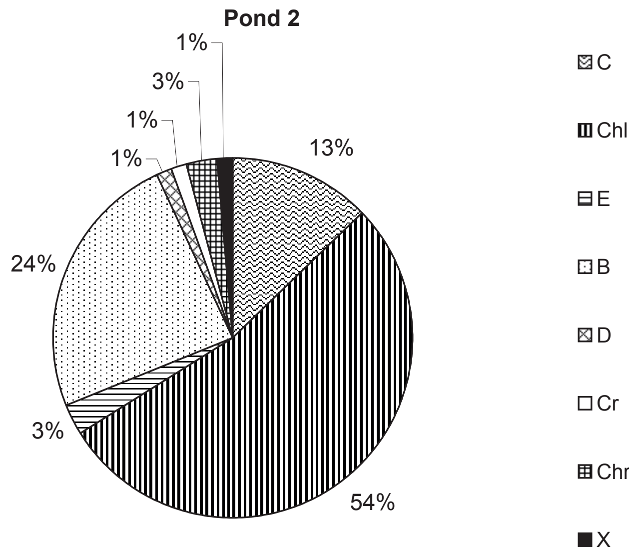

Fig. 3. Percentage contributions of particular systematic groups of algae to the total number of phytoplankton taxa in the Duży Pond in 2012 (C – Cyanoprokaryota, Chl – Chlorophyta, E – Euglenophyta, B – Bacillariophyceae, D – Dinophyceae, Cr – Cryptophyceae, Chr – Chrysophyceae, X – Xanthophyceae)

Anabaena affinis Nygaard, *Aphanizomenon issatschenkoi* (Usačev) Proškina-Lavrenko, *Chroococcus dispersus* Lemm., *Oscillatoria tenuis* Agardh, *Cosmarium rectangulare* Grun. in Rabenh., *Desmodesmus armatus* Hindák, *Dictyosphaerium ehrenbergianum* Komarék, *Oocystidium ovale* Korshikov, *Scenedesmus ellipticus* Hindák, *Staurodesmus triangularis* Lagerh., *Euglena deses* Ehr., *Euglena hemichromata* Skuja, *Euglena* sp., *Euglena spirogyra* Ehr., *Trachelomonas* sp., *Achnanthes exigua* Grun., *Achnanthes* sp., *Amphora pediculus* (Kütz.) Grun., *Epithemia turgida* (Ehr.) Kütz., *Fragilaria construens* (Ehr.) Grun., *Fragilaria crotonensis* Kitt., *Hantzschia abundans* Lange-Bertalot, *Navicula hungarica* Grunow, *Pinnularia* sp., *Rhopalodia gibba* Ehr., *Stephanodiscus hantzchii* Grun., *Stephanodiscus* sp., *Surirella linearis* W. Sm., *Surirella grunowii* Kulikovskiy, Lange-Bertalot, Witkowski, *Fragilaria dilatata* (Brèb.) Lange-Bertalot and *Polyedriopsis* sp. in Mały Pond, and also *Anabaena solitaria* Kleb., *Anabaena spiroides* Kleb., *Closterium aciculare* T. West, *Closterium moniliferum* Ehr. ex Ralfs, *Desmodesmus opoliensis* (P.G. Richter) Hegew., *Eudorina elegans* Ehr., *Koliella longiseta* (Vischer) Hindák, *Oocystis* sp., *Tetrastum glabrum* Roll., *Treubaria setigera* (W. Archer) G.M. Sm., *Euglena caudata* Hübner, *Euglena pascheri* Swirenko, *Lepocinclis ovum* Ehr., *Phacus caudatus* Hübner, *Trachelomonas globularis* Lemm., *Trachelomonas manginii* Deflandre, *Amphora* sp., *Cymatopleura solea* (Bréb.) W. Sm., *Cymbella tumida* (Brèb.) Van Heurck, *Fragilaria* sp., *Gomphonema acuminatum* Ehr. var. *acuminatum*, *Gomphonema* sp., *Sellaphora pupula* (Kütz.) Mereschkowsky, *Nitzschia* sp., *Stauroneis anceps* Ehr., *Peridiniopsis* sp., *Peridinium cunningtonii* (Lemm.) Lemm., *Rhodomonas tenuis* Skuja, *Dinobryon* sp., *Tetraedriella spinigera* Skuja, in the Duży Pond.

Eighty seven and 86 taxa of green algae, and 78 and 71 diatoms taxa were found in the Mały and Duży ponds, respectively. Moreover, a relatively high proportion of euglenoids and cyanobacteria was reported (Fig. 2, 3), while the other taxonomic groups (Dinophyceae, Cryptophyceae, Chrysophyceae and Xanthophyceae) were represented only by single species.

Large number of phytoplankton species is common for ponds, because the typical pond species (e.g. euglenoids) are accompanied by lake species (Messyasz and Jurgońska 2003). Among the green algae found in the investigated reservoirs were the representatives of Volvocales *(Eudorina elegans* Ehr., and *Pandorina morum* (O.F. Müll.) Bory), which are typical for ponds rich in nutrients (Burchardt 2010). Five species of *Pediastrum* genus were detected, which are common for shallow, fertile or alkaline lakes and ponds (Pasztaleniec and Poniewozik 2004, Bucka and Wilk-Woźniak 2007, Kowalska and Wołowski 2010, Weckström et al. 2010, Krienitz and Bock 2012). A considerable share in the species composition and great frequency of green algae, mainly from the order of *Chlorococcales* (genera *Actinastrum*, *Coelastrum*, *Crucigenia*, *Monoraphidium*, *Scenedesmus* and *Tetraedron*), indicate not only a considerable amount of nutrients, but also unstable environmental conditions. Species of *Coelastrum* genus are characteristic of eutrophic waters (Reynolds 1984), similarly as the representatives of *Scenedesmus* (Burchardt 2010).

Considering the fluctuations in the number of algal taxa over time, there was a gradual increase in their total number on consecutive sampling days in the summer in the Mały Pond (Fig. 4). The highest number of species was recorded on September 21st (119 taxa), and a significant decrease in the number of taxa in this pond was observed in the fall (Fig. 4). In the Duży Pond the range of a total number of taxa was wider, and the maximum number of taxa (118) was found on August 10th.

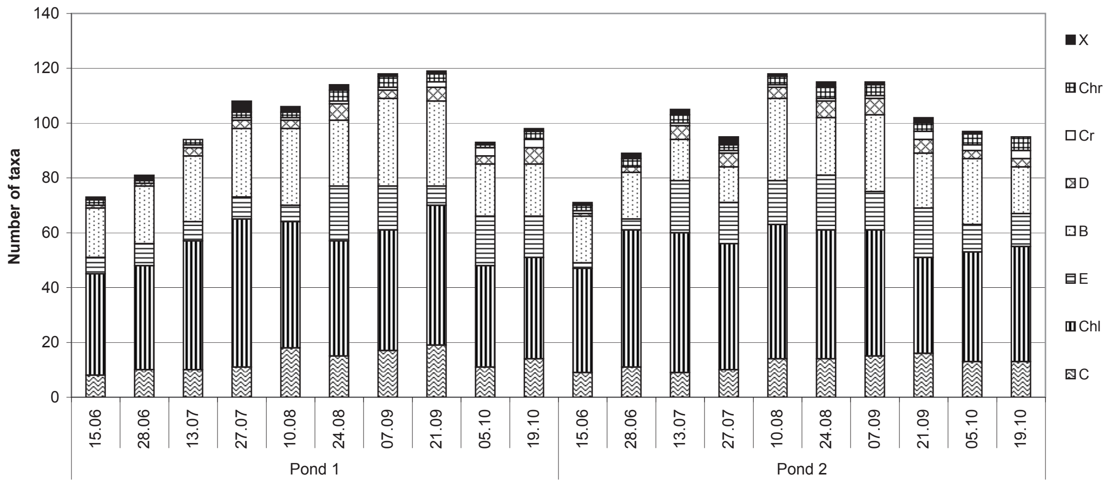

Fig. 4. Temporal changes in the number of phytoplankton taxa in the Mały Pond and Duży Pond in 2012 (C – Cyanoprokaryota, Chl – Chlorophyta, E – Euglenophyta, B – Bacillariophyceae, D – Dinophyceae, Cr – Cryptophyceae, Chr – Chrysophyceae, X – Xanthophyceae)

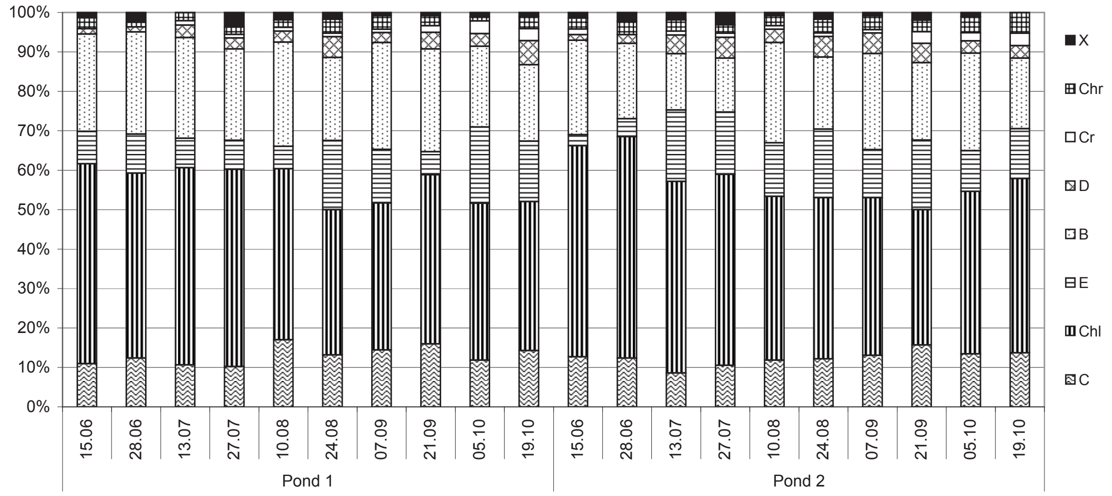

Fig. 5. Temporal changes in percentage contributions of particular systematic groups of algae to the total number of phytoplankton taxa in the Mały Pond and Duży Pond in 2012 (C – Cyanoprokaryota, Chl – Chlorophyta, E – Euglenophyta, B – Bacillariophyceae, D – Dinophyceae, Cr – Cryptophyceae, Chr – Chrysophyceae, X – Xanthophyceae)

In both ponds the lowest number of taxa was observed on the first day of sampling (Fig. 4). The percentage of individual taxonomic groups of phytoplankton in both ponds followed a similar pattern (Fig. 5). Throughout the study a qualitative domination of green algae and diatoms was noticed. Only in the Duży Pond, on July 13th, the highest proportion of green algae and euglenoids was observed. Compared to the other phytoplankton groups the proportion of euglenoids was the most variable over time (Fig. 5). The most numerous genus was *Euglena*, represented by 18 taxa, but the representatives of *Trachelomonas* (12 taxa) and *Phacus* (10 taxa) were also identified. Wilk-Woźniak and Pociecha (2005) and Pliński and Wołowski (2008) claim that the species of *Euglena* genus prefer heavily contaminated water, as opposed to the species of *Phacus* genus. A large proportion of the euglenoid taxa, typical for shallow and small reservoirs, indicates an elevated concentration of dissolved organic matter in the ponds (Kawecka and Eloranta 1994, Wołowski and Kowalska 2009). The investigated ponds yielded a significant share (100% in the Duży Pond) of chrysophytes *Synura uvella* Korschikov and *Dinobryon sociale* Krieger. *Synura uvella,* like the euglenoids, prefers water rich in organic matter (Bucka and Wilk-Woźniak 2007). *Dinobryon sociale* is common in lakes and ponds in summer (Starmach 1968).

The most abundantly represented diatom genera were *Fragilaria* and *Navicula*, and the largest frequency and abundance was reported for *Ulnaria acus* (Kütz.) N. Aboal, *Melosira varians* Agardh and *Nitzschia palea* Kütz., typical for eutrophic water (van Dam et al. 1994). According to Fore and Grafe (2002) and Bellinger et al. (2006), *N. palea* is a species typical for contaminated (polysaprobic) water rich in phosphorus, and thus its presence indicates poor water quality in the ponds. Trobajo et al. (2009) reports that this species is

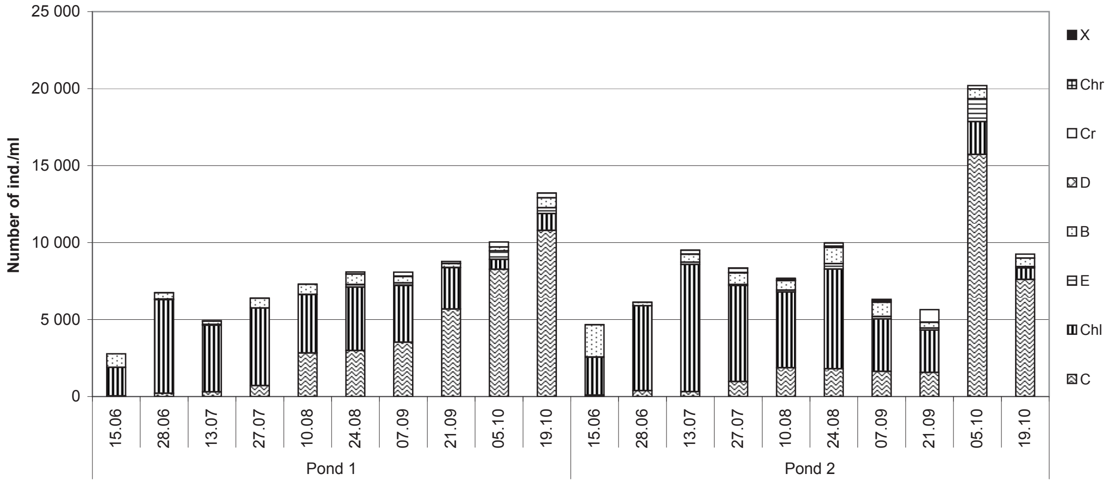

Fig. 6. Temporal changes of phytoplankton abundance in the Mały Pond and Duży Pond in 2012 (C – Cyanoprokaryota, Chl – Chlorophyta, E – Euglenophyta, B – Bacillariophyceae, D – Dinophyceae, Cr – Cryptophyceae, Chr – Chrysophyceae, X – Xanthophyceae)

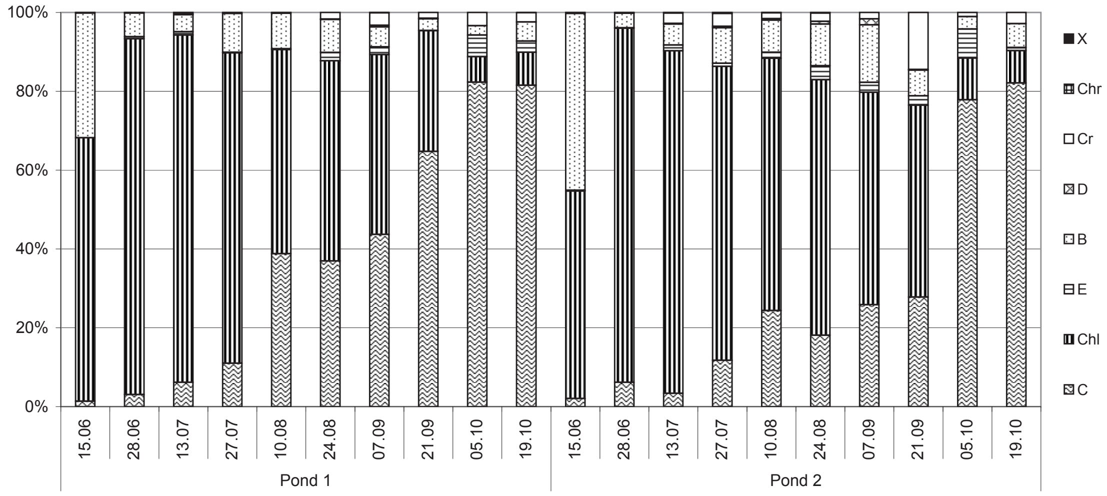

Fig. 7. Temporal changes in percentage contributions of particular systematic groups of algae to the total number of phytoplankton individuals in the Mały Pond and Duży Pond in 2012 (C – Cyanoprokaryota, Chl – Chlorophyta, E – Euglenophyta, B – Bacillariophyceae, D – Dinophyceae, Cr – Cryptophyceae, Chr – Chrysophyceae, X – Xanthophyceae)

an indicator of hypertrophic water. Most diatoms found in the studied ponds were typical of alkaline and eutrophic waters, and indicative of α-mesosaproby.

Quantitative analysis of phytoplankton in both ponds showed a clear predominance of green algae in the summer and blue-green algae in autumn (Fig. 6). Total number of algae in the Mały Pond followed an upward trend over time, and the maximum (13 291 ind./ml) was observed in autumn, on the last sampling day (Fig. 6). High phytoplankton abundance on that day was due to high abundance of cyanobacteria *Pseudanabaena limnetica* (Lemm.) Kom. (6688 ind./ml) and *Planktothrix agardhii* (Gom.) Anagn. et Kom. (3432 ind./ml). It was found that over time the proportion of green algae decreased, while the share of cyanobacteria enlarged (Fig. 7). The fluctuations of a total number of algae individuals were larger in the Duży Pond than in the Mały Pond (Fig. 6), but the maximum number (20 288 ind./ml) was detected on October 5th. Such a large algae abundance on that day was due to the massive growth of *P. agardhii* (15 048 ind./ml). Reynolds (1996) states that the water bodies inhabited by *P. limnetica* and *P. agardhii* are of eutrophic nature and are usually less than 10 meters deep, which was confirmed in this study. The work of Stefaniak et al. (2005) also showed that *P. agardhii* is characteristic of shallow and fertile water. According to Reynolds et al. (2002), this species belongs to S1 functional group, which favor turbid mixed layers. It is well known that blue-green algae thrive in water rich in nitrogen compounds, particularly ammonium nitrogen (Tõnno and Nõges 2003). Rojo and Alvarez-Cobelas (1994) and Burchardt et al. (2009) claim that the presence of *P. limnetica* and *P. agardhii* is conditioned by high concentration of ammonium ions in water. Massive growth of blue-green algae in the Sołackie Ponds in autumn

Table 2. Structure of phytoplankton dominants of the investigated ponds in 2012

Date	Mały Pond	Duży Pond
15.06	*Tetraedron minimum*	*Ulnaria acus*
28.06	*Tetraedron minimum*	*Crucigenia tetrapedia*
13.07	*Tetraedron minimum*	*Crucigenia tetrapedia*
27.07	*Tetraedron minimum*	*Tetraedron minimum*
10.08	*Tetraedron minimum*	–
24.08	–	*Actinastrum hantzschii*
07.09	*Planktothrix agardhii*	–
21.09	*Planktothrix agardhii*	*Planktothrix agardhii*
05.10	*Planktothrix agardhii*	*Planktothrix agardhii*
19.10	*Pseudanabaena limnetica*	*Pseudanabaena limnetica*

was also probably due to alkaline or neutral pH of their water, and weak intensity of solar radiation. According to literature data (Shapiro 1990) cyanobacteria prefer alkaline water. Reynolds et al. (2002) proved that the above-mentioned species of blue-green algae are abundant in water bodies with poor sunlight access. Therefore they may dominate in the algal communities due to their high adaptability to light scarcity, and the ability to move within the water column (Reynolds 1994). Concentration of nutrients (especially ammonium nitrogen) in the studied ponds was apparently high enough that even a substantial drop in water temperature in the fall (Table 1) did not diminish the cyanobacteria growth (Nixdorf 1994).

The share of diatoms in both ponds was the highest on June 15th (Fig. 7), when high abundance of *Ulnaria acus* (736.2 ind./ml in the Mały Pond and 1188 ind./ml in the Duży Pond) was observed. In central Europe this species occurs in alkaline lakes and flowing waters with average and higher trophic state (Bąk et al. 2012)

The structure of dominant species in the investigated ponds was fairly stable, especially in the Mały Pond (Table 2). In summer, the dominant plankton species were common green algae of the *Chlorococcales* order, while in autumn, they were filamentous cyanobacteria.

CONCLUSIONS

Phycological studies conducted in the Sołackie Ponds showed the reservoirs were dominated by cosmopolitan species, typical of eutrophic (green algae, cyanobacteria and diatoms), contaminated (e.g. *Euglena* genus, *Nitzschia palea)* and rich in organic matter (euglenoids and *Synura uvella)* waters. Massive growth of filamentous cyanobacteria in the fall suggested also high content of ammonium ions in water. Large phytoplankton species richness is characteristic for pond ecosystems.

To preserve the natural and aesthetic values of the ponds, they should be subject to ongoing monitoring and periodic reclamation. Bottom sediments removal reduces the accumulation of organic matter in ponds (Yuvanatemiya et al. 2011) and prevents long-term and frequent water blooms that are a sign of ecological imbalance. Intensive growth of algae in the studied reservoirs is also favoured by almost complete lack of macrophytes. They are (especially the submerged macrophytes) a filter trapping and limiting the phytoplankton growth and they exert a positive effect on water quality.

REFERENCES

Bąk M., Witkowski A., Żelazna-Wieczorek J., Wojtal A.Z., Szczepocka E., Szulc K., Szulc B. (2012): Klucz do oznaczania okrzemek w fitobentosie na potrzeby oceny stanu ekologicznego wód powierzchniowych w Polsce. Biblioteka Monitoringu Środowiska, Warszawa.

Bellinger B.J., Cocquyt Ch., O'Reilly C.M. (2006): Benthic diatoms as indicators of eutrophication in tropical streams. Hydrobiologia 573: 75-87.

Bucka H., Wilk-Woźniak E. (2007): Glony pro- i eukariotyczne zbiorowisk fitoplanktonu w zbiorowiskach wodnych Polski Południowej. Instytut Ochrony Przyrody PAN, Kraków.

Burchardt L. (2010): Klucz do oznaczania gatunków fitoplanktonu jezior i rzek. Przewodnik do ćwiczeń laboratoryjnych i badań terenowych. Bogucki Wyd. Nauk., Poznań.

Burchardt L., Goździcka-Józefiak A., Messyasz B., Gąbka M., Dondajewska R., Lamentowicz Ł., Rybak A. (2009): Wpływ gradientu temperatury i żyzności wody na strukturę fitoplanktonu Jeziora Góreckiego (Wielkopolski Park Narodowy) w okresie zlodzenia zimowego. In: Wielkopolski Park Narodowy w badaniach przyrodniczych. Eds B. Walna, L. Kaczmarek, M. Lorenc, R. Dondajewska. Poznań--Jeziory: 11-26.

van Dam H., Mertens A., Sinkeldam J. (1994): A coded checklist and ecological indicators values of freshwater diatoms from the Netherlands. Neth. J. Aquat. Ecol. 28, 1: 117-133.

Fore L.S., Grafe C. (2002): Using diatoms to assess the biological condition of large rivers in Idaho (USA). Freshw. Biol. 47: 2015-2037.

Hindák F. (1984): Studies on the Chlorococcal Algae (Chlorophyceae). Vol. 3. VEDA Publishing House of the Slovak Academy of Sciences, Bratislava.

Hindák F. (1988 a): Studies on the Chlorococcal Algae (Chlorophyceae). Vol. 4. VEDA Publishing House of the Slovak Academy of Sciences, Bratislava.

Hindák F. (1988 b): Studies on the Chlorococcal Algae (Chlorophyceae). Vol. 5. VEDA Publishing House of the Slovak Academy of Sciences, Bratislava.

Kawecka B., Eloranta P.V. (1994): Zarys ekologii glonów wód słodkich i środowisk lądowych. Wyd. Nauk. PWN, Warszawa.

Komárek J., Anagnastidis K. (2005): Cyanoprokaryota. 2. Teil: Oscillatoriales. Süsswasserflora von Mitteleuropa. Vol. 19/2. VEB Gustav Fischer Verlag, Heidelberg, Berlin.

Kowalska J., Wołowski K. (2010): Rare *Pediastrum* species (Chlorophyceae) from Polish costal lakes. Acta Soc. Bot. Pol. 79: 225-233.

Krammer K., Lange-Bertalot H. (1986): Bacillariophyceae. Süsswasserflora von Mitteleuropa. Vol. 2/1. VEB Gustav Fischer Verlag, Jena.

Krammer K., Lange-Bertalot H. (1988): Bacillariophyceae. Süsswasserflora von Mitteleuropa. Vol. 2/2. VEB Gustav Fischer Verlag, Jena.

Krammer K., Lange-Bertalot H. (1991 a): Bacillariophyceae. Süsswasserflora von Mitteleuropa. Vol. 2/3. VEB Gustav Fischer Verlag, Jena.

Krammer K., Lange-Bertalot H. (1991 b): Bacillariophyceae. Süsswasserflora von Mitteleuropa. Vol. 2/4. VEB Gustav Fischer Verlag, Jena.

Krienitz L., Bock Ch. (2012): Present state of the systematics of planktonic coccoid green algae of inland waters. Hydrobiologia 698: 295-326.

Lewińska J. (2000): Klimat miasta. Zasoby, zagrożenia, kształtowanie. Inst. Gosp. Przestrz. Kom., Kraków.

Łęcki W. (1990): Zwiedzamy Poznań. Wyd. PTTK „Kraj", Warszawa.

Małecka I., Staszewski Z. (2011): Wpływ stawów i cieków w kaliskim parku miejskim na środowisko. Zesz. Nauk. Inż. Ląd. Wod. Kształt. Środ. 3: 17-24.

Małecki Z. (2009): Wpływ zbiornika zaporowego Pokrzywnica na mikroklimat w zlewni Pokrzywnicy, prawobrzeżnym dopływie Prosny. Ochr. Środ. Zas. Nat. 39: 103-115.

Messyasz B., Jurgońska M. (2003): Struktura gatunkowa fitoplanktonu w cyklu rocznym w Stawach Dużym i Małym (Park Sołacki, Poznań). Rocz. AR Pozn. 354, Bot. 6: 132-145.

Nixdorf B. (1994): Polymixis of a shallow lake (Grosser Muggelsee, Berlin) and its influence on seasonal phytoplankton dynamics. Hydrobiologia 275/276: 173-186.

Pasztaleniec A., Poniewozik M. (2004): *Pediastrum* species (Hydrodictyaceae, Sphaeropleales) in phytoplankton of Sumin Lake (Łęczna-Włodawa Lakeland). Acta Soc. Bot. Pol. 73: 39-46.

Pliński M., Wołowski K. (2008): Flora Zatoki Gdańskiej i wód przyległych (Bałtyk Południowy). Eugleniny-Euglenophyta (Euglenoids). Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk.

Popovský J., Pfiester L.A. (1990): Dinophyceae (Dinoflagellida). Süsswasserflora von Mitteleuropa. Vol. 6. VEB Gustav Fischer Verlag, Heidelberg, Berlin.

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

Reynolds C.S. (1994): The long, the short and the stalled: on the attributes of phytoplankton selected by physical mixing in lakes and rivers. Phytoplankton in turbid environments: rivers and shallow lakes. Eds J.P. Descy, C.S. Reynolds, J. Padisak. Hydrobiologia 289: 9-21.

Reynolds C.S. (1996): The plant life of the pelagic. Verh. Int. Ver. Limnol. 26, 1: 97-113.

Reynolds C.S. (2000): Phytoplankton designer – or how to predict compositional responses to trophic state change. Hydrobiologia 424: 123-132.

Reynolds C.S., Huszar V.L.M., Kruk C., Naselli-Flores L., Melo S. (2002): Towards of functional classification of the freshwater phytoplankton. J. Plankton Res. 24: 417-428.

Rojo C., Alvarez-Cobelas M.A. (1994): Population dynamics of *Limnothrix redekei, Oscillatoria lanceaformis, Planktothrix agardhii* and *Pseudanabaena limnetica* (Cyanobacteria) in a shallow hypertrophic lake (Spain). In: Nutrient dynamics and biological structure in shallow freshwater and brackish lakes. Eds E. Mortensen et al. Hydrobiologia 275/276: 165-171.

Shapiro J. (1990): Current beliefs regarding dominance of blue-greens: the case for the importance of CO_2 and pH. Verh. Int. Ver. Limnol. 24: 38-54.

Starmach K. (1966): Cyanophyta – Sinice, Glaucophyta – Glaukofity. Flora słodkowodna Polski. Vol. 2. PWN, Warszawa.

Starmach K. (1968): Chrysophyta I. Chrysophyceae-Złotowiciowce oraz wiciowce bezbarwne – zooflagellata wolnożyjące. Flora słodkowodna Polski. Vol. 5. PWN, Warszawa.

Starmach K. (1972): Zielenice nitkowate: Ulotrichales, Ulvales, Prasiolales, Sphaeropleales, Cladophorales, Chaetophorales, Trentepohliales, Siphonales, Dichotomosiphonales. Flora słodkowodna Polski. Vol. 10. PWN, Warszawa-Kraków.

Starmach K. (1974): Cryptophyceae, Dinophyceae, Raphidiophyceae. Flora słodkowodna Polski. Vol. 4. PWN, Warszawa-Kraków.

Starmach K. (1983): Euglenophyta. Flora słodkowodna Polski. Vol. 3. PWN, Warszawa-Kraków.

Starmach K. (1989): Plankton roślinny wód słodkich. Metody badania i klucze do oznaczania gatunków występujących w wodach Europy Środkowej. PWN, Warszawa-Kraków.

Stefaniak K., Kokociński M., Messyasz B. (2005): Dynamics of *Planktothrix agardhii* (Gom.) Anagn. et Kom. blooms in polimictic Lake Laskownickie and Grylewskie (Wielkopolska region) Poland. Ocean. Hydrobiol. Stud. 34, 3: 125-136.

Tönno I., Nõges T. (2003): Nitrogen fixation in a large shallow lake: rates and initiation conditions. Hydrobiologia 490: 23-30.

Trobajo R., Clavero E., Chepurnov V.A., Sabbe K., Mann D.G., Ishihara S., Cox E.J. (2009): Morphological, genetic and mating diversity within the widespread bioindicator *Nitzschia palea* (Bacillariophyceae). Phycologia 48: 443-459.

Weckström K., Weckström J., Yliniemi L.M., Korhola A. (2010): The ecology of *Pediastrum* (Chlorophyceae) in subarctic lakes and their potential as paleobioindicators. J. Paleolimnol. 43: 61-73.

Wilk-Woźniak E., Pochiecha A. (2005): Różnorodność organizmów planktonowych w rezerwacie wodnym Wiślisko Kobyle utworzonym w starorzeczu Wisły (Polska płd.). In: Starorzecza jako istotny element ekosystemu rzecznego. Ed. M. Jezierska-Madziar. Wyd. Akademii Rolniczej im. Augusta Cieszkowskiego w Poznaniu, Poznań: 38-52.

Wołowski K. (1998): Taxonomic and environmental studies on Euglenophytes of the Kraków-Częstochowa upland (Southern Poland). Fragm. Florist. Geobot. Suppl. 6: 3-192.

Wołowski K., Hindak F. (2005): Atlas of Euglenophytes. VEDA Publishing House of the Slovak Academy of Sciences, Bratislava.
Wołowski K., Kowalska J. (2009): Eugleniny i inne glony występujące w stawie Ogrodu Botanicznego UJ. Fragm. Florist. Geobot. Pol. 16, 1: 145-154.
Yuvanatemiya V., Boyd C.E., Thavipoke P. (2011): Pond bottom management at commercial shrimp farms in Chantaburi Province, Thailand. J. World Aquacult. Soc. 42, 5: 618-632.

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