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Changes of summer phytoplankton communities in Lake Swarzędzkie in the 2000-2003 period

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Abstract

The aim of this study was to characterize the summer phytoplankton communities in the hypertrophic Lake Swarzędzkie in the 2000-2003 period and to determine their connection with the physico-chemical parameters of water quality. The highest abundance of phytoplankton and the highest concentrations of chlorophyll *a* were noted in summer 2003 during a bloom of Oscillatoriaceae. The extremely high biomass of Cyanobacteria corresponded with the highest water temperature and nitrate values. The total biomass was the highest in August 2002, but this was due to the dominance of Dinophyta. Oscillations in phytoplankton abundance and biomass in Lake Swarzędzkie in the summers of 2000-2003 as well as the different structure of dominant species in each year resulted in the instability of the ecosystem.

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INTRODUCTION

The phytoplankton of the polluted Lake Swarzędzkie has been under investigation since 1971 (Buczyńska et al. 1973, 1985; Pułyk and Szulczyńska 1998). The functioning of this ecosystem has been disturbed for many years by the direct inflow of wastewaters and very high amounts of nutrients. Human activity in the catchment area of Lake Swarzędzkie has resulted in the heavy pollution of the waters and hypertrophy. Water blooms caused mainly by filamentous or colonial Cyanobacteria reflected this phenomenon (Pułyk and Szulczyńska 1998).

Although the direct loading of wastewaters was diverted from Lake Swarzędzkie in 1991, point sources of pollution and the high load of nutrients released from the catchment area still have a degrading impact on its waters (Szyper et al. 1994, Kowalczewska-Madura 2003). This lake is highly unstable, and the dynamics of phytoplankton development are unpredictable. The aim of the current study was to characterize the summer phytoplankton communities in Lake Swarzędzkie in the 2000-2003 period and determine their connection with physico-chemical parameters of water quality.

STUDY SITES AND METHODS

Lake Swarzędzkie is a medium-sized (area 93.7 ha), very shallow (mean depth 2.6 m), post-glacial reservoir. It is located in the northwestern part of the town Swarzędz near its border with the city of Poznań. This lake is supplied with water by the River Cybina and Mielcuch Stream. The total catchment area of the lake is 17,826 ha, the greatest part of which is comprised of fields and pastures (75%) and forests (18%) while 5.3% is inhabited (Szyper et al. 1994).

Water samples for phycological and chemical analyses were collected monthly from the surface layer of the water column of the investigated lake from July to September in the 2000-2003 period. In each case, transparency, water temperature, and conductivity were measured *in situ*.

Phycological analyses included assessing the abundance and biomass of phytoplankton as well as estimating the Shannon-Weaver and evenness biodiversity coefficients. After being fixed in Lugol's solution, the phytoplankton was counted in 9 ml sedimentation chambers with a Zeiss-Telaval 31 inverted microscope according to Utermöhl (1958). Biomass was estimated from the cell numbers and specific volumes (Kawecka and Eloranta 1994). Dominants were determined based on the percentage contribution of biomass. Dominant species were those that made a contribution exceeding 10% of the total phytoplankton biomass (Nixdorf et al. 2003).

The concentration of chlorophyll *a* was analyzed using the Lorenzen method after acetone extraction (Polish Standard 1986). Standard methods were used for analyses of concentrations of orthophosphates, ammonium nitrogen, and nitrate (Dojlido 1995).

RESULTS

The structure of phytoplankton communities in Lake Swarzędzkie

The most abundant group of phytoplankton in the 2000-2003 period were Cyanobacteria. During 2001 and 2002, the phytoplankton abundance was composed of few groups. Cyanobacteria, Chlorophyta, and Cryptophyta were better represented than others. Extremely high phytoplankton abundance was noted in 2003 (18 – 74 x 10^3 ind. ml^{-1}), especially in August and September, when a dense bloom of filamentous Cyanobacteria was noted in Lake Swarzędzkie (Fig. 1a).

The biomass of phytoplankton in the 2000-2002 period was comprised largely by Bacillariophyceae, Chlorophyta, Cyanobacteria, and Cryptophyta. The lowest biomass was noted in July and September 2002; however, there was a peak in biomass in August 2002 (above 99 mg l^{-1}) due to the dominance of Dinophyta. The highest Cyanobacteria biomass was noted in summer 2003 (Fig. 1b).

The structure of dominants was different in each investigated season. In July 2000, the dominant species were *Coelastrum microporum* Näg. in A. Braun (16.82% of total biomass), *Pediastrum tetras* (Ehr.) Ralfs (11.92%), and *Pediastrum duplex* Meyen v. *duplex* (11.54%) that belonged to Chlorophyta. In the two subsequent months, Bacillariophyceae and Cyanobacteria were co-dominants in Lake Swarzędzkie: *Cyclotella* sp. (20.11%) and *Spirulina minima* A. Wurtz. (11.21%) in August, *Planktothrix agardhii* (Gom.) Anagn. et Kom. (22.66%) and *Cyclotella* sp. (20.56%) in September.

In July 2001 the structure of dominant phytoplankton species was the same as in July 2000. In August the greatest contribution to the total biomass was from *Ceratium furcoides* (Levander) Langhans (10.12%) and *Cyclotella* sp. (10.03%), while in September 2001 it was from *Cryptomonas curvata* Ehr. emend. Penard (20.25%) and again *Cyclotella* sp. (10.11%).

In July 2002 the dominant species were *Crucigenia tetrapedia* (Kirchn.) W. et G.S. West (14.01%) and *Phacotus lenticularis* (10.40%) from Chlorophyta as well as the diatom *Aulacoseira granulata* (Ehr.) Simonsen (10.05%). In August the dominants were two species of Dinophyta - *Ceratium furcoides* (48.52%) and *Ceratium hirundinella f. austriacum* (Zederbaum) Bachmann (31.71%). In

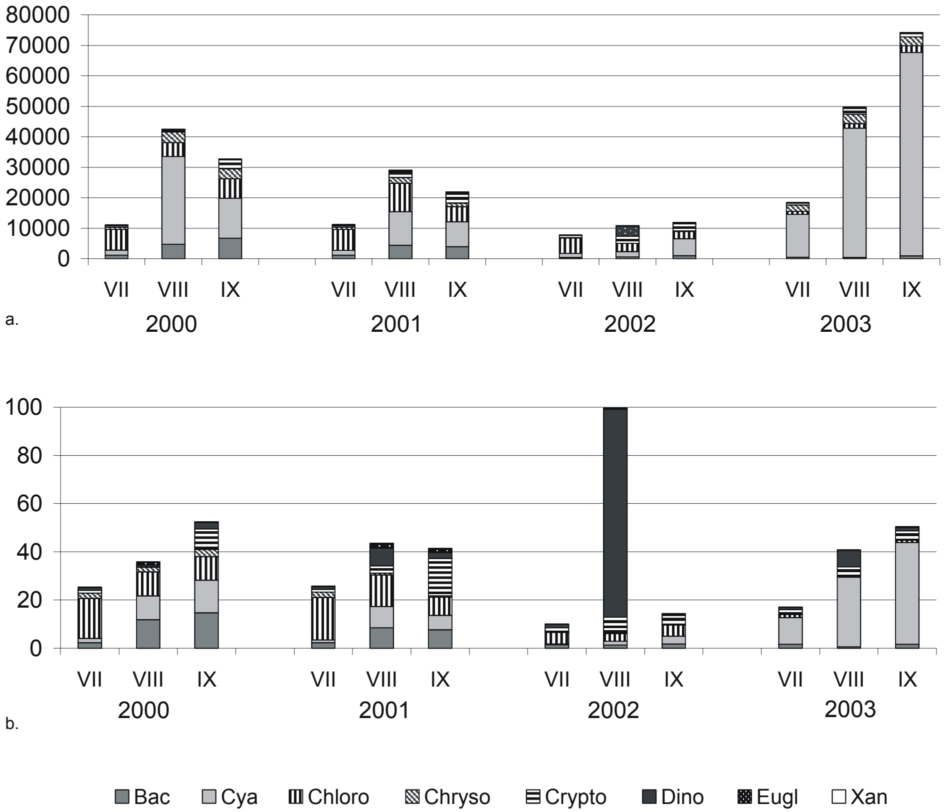

Fig. 1. Abundance [ind. ml^{-1}] (a) and biomass [mg l^{-1}] (b) of phytoplankton in Lake Swarzędzkie in 2000-2003.

September 2002 the dominants were *Aphanizomenon gracile* Lemm. (12.10%) and *Coelastrum astroideum* De Not. (11.03%).

In each investigated month of 2003 the only phytoplankton dominants in Lake Swarzędzkie were two species of filamentous, non-N_2-fixing Cyanobacteria - *Limnothrix redekei* (Van Goor) Meff. and *Planktothrix agardhii*. Their contribution to the total biomass was 23.39 and 20.76% in July, 37.65 and 15.96% in August, and 51.86 and 29.38% in September, respectively.

The values of the Shannon-Waver and evenness biodiversity coefficients were relatively high in Lake Swarzędzkie during the investigated period (2.28 – 5.05 and 0.35 – 0.80, respectively). Generally, the highest values of these two coefficients were noted in 2000 and 2001, and the lowest in 2003 and in August 2002, during the dominance of Cyanobacteria and Dinophyta (Table 1).

Table 1

Selected biological and physico-chemical parameters of water in Lake Swarzędzkie

Parameters	2000			2001			2002			2003		
	VII	VIII	IX	VII	VIII	IX	VII	VIII	IX	VII	VIII	IX
Shannon-Weaver	4.55	4.48	3.91	5.57	5.05	4.73	4.42	2.36	4.25	3.73	3.30	2.28
evenness	0.74	0.73	0.64	0.74	0.80	0.74	0.81	0.41	0.81	0.59	0.52	0.35
chlorophyll *a* [$\mu g\ l^{-1}$]	37.4	63.1	82.11	66.4	83.84	90.94	29.24	97.12	63.08	85.34	155.60	241.80
transparency [m]	1.1	0.5	0.6	0.9	0.9	0.85	0.8	0.6	0.8	0.65	0.5	0.47
temperature [ºC]	18.8	22.5	13.22	21.4	20.3	15.1	22.4	23.1	14.3	24.5	23.6	17.6
conduct. [$\mu S\ cm^{-1}$]	754	657	697	691	635	586	699	580	605	583	578	590
$N\text{-}NH_4$ [$mg\ l^{-1}$]	0.28	0.08	0.28	0.74	0.64	1.09	0.59	0.57	0.80	0.30	0.50	0.45
$N\text{-}NO_3$ [$mg\ l^{-1}$]	0.10	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	0.30	0.40	0.55
$P\text{-}PO_4$ [$mg\ l^{-1}$]	0.07	n.d.	n.d.	0.25	n.d.	0.34	n.d.	0.19	0.16	n.d.	0.11	0.18

n.d. – not detected

Characteristics of physico-chemical parameters of water in Lake Swarzędzkie

The highest transparency in the water column of Lake Swarzędzkie was noted in July 2000 at 1.1 m, and the lowest was in September 2003 at only 0.47 m. This phenomenon was connected with the abundant development of phytoplankton and very high concentration of chlorophyll *a* – 241.80 $\mu g\ l^{-1}$ (Table 1). The lowest value of chlorophyll *a* (29.24 $\mu g\ l^{-1}$) was noted in July 2002. Generally, the lowest water temperatures were noted in September of each investigated year. In the summer months of July and August temperatures usually exceeded 20ºC, with the exception of July 2000. The highest temperatures were noted in 2003. The values of conductivity were diversified during investigated period. The highest were noted in summer 2000, and the lowest in 2003. There were very low concentrations of nitrate in the water of Lake Swarzędzkie in the 2000-2002 period. In contrast, in 2003 the concentration of this nutrient exceeded 0.2 mg l^{-1}. The smallest amount of orthophosphates and ammonium nitrogen were noted in 2000, while the highest were noted in 2001 (Table 1).

DISCUSSION

Oscillations of phytoplankton abundance and biomass in Lake Swarzędzkie in the summers of 2000-2003 as well as the different structure of dominant species in each year resulted in the instability of the ecosystem. However, the values of biodiversity coefficients in Lake Swarzędzkie were relatively high (Table 1). The values of the Shannon-Weaver and evenness coefficients, especially in the 2000-2002 period, were higher in Lake Swarzędzkie in comparison with other highly eutrophic or hypertrophic European lakes (Eloranta 1993, Pádisak 1993, Stefaniak 2005). According to Romo and Miracle (1995), low diversities are related to stable states, while higher diversities correspond to periods of unstable states.

Reynolds et al. (1993) hypothesized that diversity is high or increases in warm water when species replacement rates are rapid. There is a relationship between community change rates and diversity: the faster a community changes, the higher are diversity increases (Reynolds 1984). Very high rates of community change are common in hypertrophic ecosystems and result in transient states of community organization (Uhlmann 1980). It is very likely that such phenomenon occurred in Lake Swarzędzkie in the 2000-2002 period. The rate of phytoplankton community change was high; different dominants were noted each month. Furthermore, the dynamics of succession in following years was unpredictable. The dominance of chlorophytes in July was the only characteristic phytoplankton pattern noted in Lake Swarzędzkie in the 2000-2002 period. They were replaced by Cyanobacteria in 2000 and Dinophyta in 2001 and 2002. *Ceratium* sp. out competed Cyanobacteria in the nutrient competition in the summers of 2001 and 2002 probably due to its ability to migrate vertically. In the case of orthophosphates and nitrate depletion in the epilimnion, their uptake is possible from the metalimnion. *Ceratium* sp. can migrate up to 5 m per day (Frempong 1984).

The lowest transparency with a simultaneous peak of chlorophyll *a* as well as the lowest values of the biodiversity coefficients in September 2003 resulted from the Cyanobacteria bloom. The dominance of filamentous Cyanobacteria was better expressed in 2003 than in previous years. However, *Spirulina minima* reached dominance in August 2002, *Planktothrix agardhii* in September 2000, and *Aphanizomenon gracile* in September 2002. The high biomass of blue-green algae in summer 2003 resulted from higher water temperatures in comparison with the previous years. Moreover, the abundant development of this phytoplankton group was influenced by high concentrations of nitrate (Table 1). This nutrient is especially important for the growth of non-N_2-fixing Cyanobacteria on reservoir surfaces in summer (Walsby and Klemer 1974, Klemer 1976, Gibson et al. 2000). Lake Swarzędzkie, as a shallow polymictic and very fertile water body, provides favorable conditions for the development of Cyanobacteria. In each month of 2003 the only dominants in phytoplankton were two filamentous species *L. redekei* and *P. agardhii*. The occurrence of species representing the family *Oscillatoriaceae* in phytoplankton is an indicator of a very high trophic status (Van Liere and Mur 1980). The phenomenon of co-domination of *P. agardhii* and *L. redekei* in shallow, fertile reservoirs is well documented in the literature (Zevenboom and Mur 1980; Rücker et al. 1997; Messyasz 1998; Zębek 1998; Nõges et al. 2003a,b; Ott et al.

2003). The results of research conducted in Estonian and Danish lakes suggested the higher trophic requirements of *P. agardhii* as compared with *L. redekei*. The last species occurs in reservoirs at earlier stages of eutrophication and can be replaced by *P. agardhii* when a higher trophic status is reached (Nõges et al. 2003b).

It is likely that during very hot summers species from the genera *Planktothrix* and *Limnothrix* will dominate the phytoplankton of the polymictic Lake Swarzędzkie in coming seasons. *Planktothrix agardhii* seems to prefer warm water >20°C (Van Liere, Mur 1980; Berger, Sweers 1988), therefore abundant populations of this species are noted in late summer or early fall (Skulberg 1978). One of the main factors responsible for Oscillatoriaceae dominance in shallow lakes is low-light tolerance (Zevenboom, Mur 1980; Romo, Miracle 1994; Montealegre et al. 1995; Mur, Schreurs 1995). Turbidity caused by constant mixing favors the occurrence of *P. agardhii* and *L. redekei*, which are known as 'turbulent species' (Scheffer et al. 1997, Dokulil and Teubner 2000). Efficient competition with eukaryotic phytoplankton, inedibility, and allelopathy are other factors that may also affect Oscillatoriaceae dominance in lakes (Zevenboom, Mur 1980; Sommer 1981; Infante and Abella 1985; Scheffer 2001).

Despite the diversion of direct sewage loading, the lake is degraded due to the long-term influx of large amounts of organic and inorganic pollutants mainly from the area of Swarzędz. Large nutrient loads have accumulated in the lake sediments and still affect water quality at the present (Kowalczewska-Madura and Gołdyn 2005).

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