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Development of toxic *Planktothrix agardhii* (Gom.) Anagn. et Kom. and potentially toxic algae in the hypertrophic Lake Syczyńskie (Eastern Poland)

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Abstract

Long-lasting cyanobacterial blooms occur in the hypertrophic Lake Syczyńskie. Among the phytoplankton, twenty potentially toxic blue-greens belonging to eight genera and one potentially toxic dinoflagellate *Peridinium aciculiferum* f. *inerme* were noted. In the warm seasons of 2004, phytoplankton was predominated by the hepatotoxic cyanobacterium *Planktothrix agardhii* (60-77% of total phytoplankton abundance), which produced microcystins (approx. 1.1 mg MC-LR equiv. g^{-1} DW of scum). In summer and fall the abundance of *P. agardhii* comprised approx. 96% of the abundance of potentially toxic Cyanobacteria.

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INTRODUCTION

Water blooms caused by the massive development of Cyanobacteria have been observed often in eutrophic and hypertophic waters (Dokulil and Teubner 2000, Pawlik-Skowrońska et al. 2004). Some species or strains are dangerous for animals and humans especially due to toxin production (Mankiewicz et al. 2003, Kabziński and Kabziński 2006). Due to long-lasting cyanobacterial blooms in Lake Syczyńskie, the current study focused on annual changes in the development of potentially toxic algae (Cyanobacteria, Dinoflagellatae) in this hypertrophic lake.

STUDY AREA AND METHODS

Lake Syczyńskie is a small (5.6 ha), shallow (2.9 m), hypertrophic water body located in the Łęczyńsko-Włodawskie Lakeland (51° 17' 12'' N, 23° 14' 16" E). Over 80% of the lake catchment is used agriculturally (Kornijów et al. 2002). Surface water samples (0-0.5 m) were collected in the central part of the lake from February to October 2004. Water temperature, transparency (SD), pH, and conductivity were measured. The abundance of phytoplankton was estimated by means of inverted microscopy according to Utermöhl (1958). The total concentration of microcystins in the cyanobacterial scum sampled in fall was determined using gas chromatography/mass spectrometry (GC/MS, Varian) according to Harada et al. (1996) and Kaya and Sano (1999). $N\text{-}NH_4$ was determined by Nessler's method $P\text{-}PO_4$ using ammonium molybdate (Golterman 1971).

RESULTS

The physicochemical conditions in Lake Syczyńskie support the massive development of phytoplankton, especially Cyanobacteria. The water contains high concentrations of $N\text{-}NH_4$ (0.233 – 1.354 mg dm^{-3}) and $P\text{-}PO_4$ (0.033 – 0.911 mg dm^{-3}). In 2004 annual changes in the water parameters were as follows: temperature 1.7 – 20.4°C; pH 8.0 – 8.75; conductivity 511 – 599 μS cm^{-1}; transparency 0.23 – 0.95 m.

The annual range of phytoplankton abundance was 17.1 – 89 10^6 ind. dm^{-3} (Fig. 1). Altogether, 122 taxa were identified, mainly Chlorophyceae (60) and Cyanobacteria (39) (M. Wiśniewska, D. Krupa, B. Pawlik-Skowrońska, R. Kornijów, paper in preparation). Among Cyanobacteria, twenty potentially toxic taxa belonging to eight genera were noted (Table 1). The abundances of these taxa were the lowest in April and the highest in September. In the lake surface water layer (approx. 0.5 m) several potentially hepatotoxic

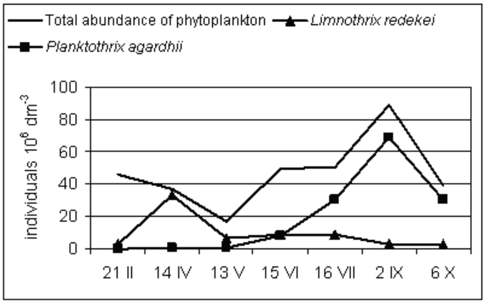

Fig. 1. Seasonal changes in the abundance of dominant cyanobacteria *Planktothrix agardhii* and *Limnothrix redekei* in Lake Syczyńskie.

Table 1

Occurrence and abundance of potentially toxic phytoplankton taxa (except *P. agardhii*) in Lake Syczyńskie in 2004

Date	Taxa	Total abundance (ind.· 10^6 dm^{-3})
21.II	*Snowella lacustris* (Chod.) Kom. et Hind., *Microcystis aeruginosa* (Kütz.) Kütz., *Lyngbya* sp., *Planktolyngbya contorta* (Lemm.) Anagn. et Kom., *Peridinium aciculiferum* f. *inerme* Lemm.	0.54
14.IV	*Anabaena lemmermanii* Richt., *Lyngbya* sp., *Oscillatoria limosa* Ag. ex Gom.	0.04
13.V	*Anabaena heterospora* Nygaard, *Anabaena lemmermanii* Richt., *Aphanizomenon gracile* (Lemm.) Lemm., *Oscillatoria limosa* Ag. ex Gom., *Oscillatoria* sp., *Planktolyngbya limnetica* (Lemm.) Kom.-Legn. et Cronberg	0.48
15.VI	*Anabaena lemmermanii* Richt., *Anabaena solitaria* Kleb., *Anabaena* sp., *Aphanizomenon gracile* (Lemm.) Lemm., *Lyngbya* sp., *Snowella lacustris* (Chod.) Kom. et Hind., *Microcystis aeruginosa* (Kütz.) Kütz., *Oscillatoria* sp., *Planktolyngbya contorta* (Lemm.) Anagn. et Kom., *Planktolyngbya limnetica* (Lemm.) Kom.-Legn. et Cronberg	0.07
16.VII	*Anabaena heterospora* Nygaard, *Anabaena solitaria* Kleb., *Anabaena spiroides* Kleb., *Aphanizomenon gracile* (Lemm.) Lemm., *Lyngbya* sp., *Microcystis aeruginosa* (Kütz.) Kütz., *Oscillatoria terebriformis* Ag., *Oscillatoria* sp., *Planktolyngbya contorta* (Lemm.) Anagn. et Kom., *Planktolyngbya limnetica* (Lemm.) Kom.-Legn. et Cronberg	1.68
2.IX	*Anabaena solitaria* Kleb., *Anabaena spiroides* Kleb., *Aphanizomenon gracile* (Lemm.) Lemm., *Lyngbya* sp., *Snowella lacustris* (Chod.) Kom. et Hind., *Microcystis aeruginosa* (Kütz.) Kütz., *Oscillatoria terebriformis* Ag., *Oscillatoria* sp., *Planktolyngbya contorta* (Lemm.) Anagn. et Kom., *Planktolyngbya limnetica* (Lemm.) Kom.-Legn. et Cronberg	11.25
6.X	*Anabaena lemmermanii* Richt., *Anabaena solitaria* Kleb., *Aphanizomenon gracile* (Lemm.) Lemm., *Snowella lacustris* (Chod.) Kom. et Hind., *Oscillatoria terebriformis* Ag., *Oscillatoria* sp., *Planktolyngbya contorta* (Lemm.) Anagn. et Kom., *Planktolyngbya limnetica* (Lemm.) Kom.-Legn. et Cronberg, *Woronichinia fusca* Skuja	2.41

Cyanobacteria were found; however, *P. agardhii* predominated from June to October (Fig. 1). It replaced the non-toxic filamentous cyanobacterium *Limnothrix redekei* Van Goor which dominated phytoplankton in spring (33.5 10^6 ind. dm^{-3}) (Fig. 1). The surface scum sampled in fall, which consisted almost exclusively of *P. agardhii*, contained considerable amounts of microcystins (approx. 1.1 mg MC-LR equiv. g^{-1} DW of scum). The potentially toxic dinoflagellate *Peridinium aciculiferum* f. *inerme* was also noted but only in winter. Shares of potentially toxic Cyanobacteria and Dinoflagellatae in the total number of phytoplankton taxa ranged from 8.3 to 22.9%, and was the highest in late spring and summer (Fig. 2A). Shares of Cyanobacteria and *P. aciculiferum* f. *inerme* in the total phytoplankton abundance changed depending on season at a range of 0.1-12.6% and 0.17%, respectively (Fig. 2B). In summer and fall, the dominant *P. agardhii* reached 60-77% of the total algal abundance (Fig. 2B) and approx. 96% of the abundance of potentially toxic Cyanobacteria.

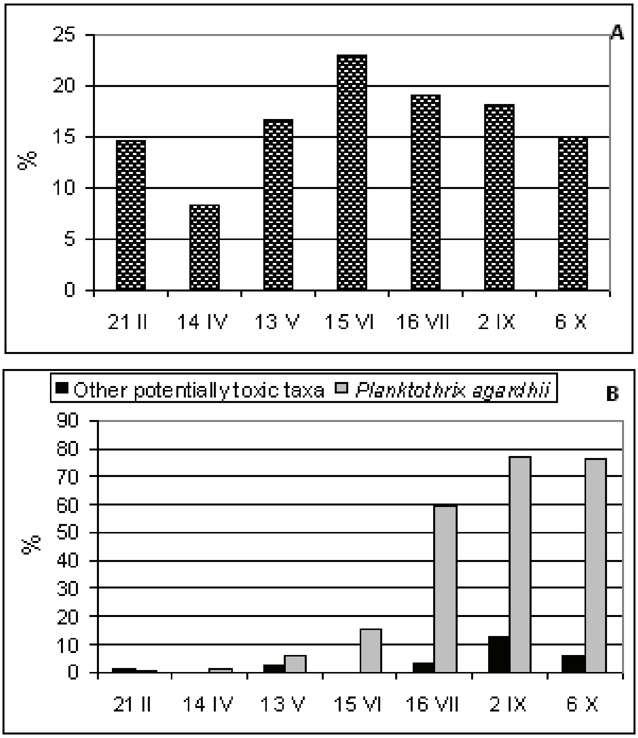

Fig. 2. A – share of potentially toxic taxa (cyanobacteria and dinoflagellate) in the total number of phytoplankton taxa; B – comparison of the share of *Planktothrix agardhii* and other potentially toxic taxa in the total abundance of phytoplankton in Lake Syczyńskie, (set as 100%).

DISCUSSION

To date, over forty species of Cyanobacteria (Burchardt and Pawlik-Skowrońska 2005), three species of freshwater Dinophyceae (Owsianny 2003) and two species of Euglenophyceae (Zimba et al. 2004) are known to be potential toxin producers. In Lake Syczyńskie the richness of potentially toxic phytoplankton taxa was high in all periods except April (Fig. 2A, Table 1). *P. agardhii* and *L. redekei* were present in the surface water throughout the year; however, other Cyanobacteria (mainly *Anabaena* spp. and *Oscillatoria* spp.) were also observed frequently. The share of potentially toxic taxa in the total number of phytoplankton taxa in Lake Syczyńskie (17.5%) was higher than in the hypertrophic Lake Gineitiškės in Lithuania (10.3%) (Kasperoviciene et al. 2005). The share of potentially toxic taxa in the total abundance of phytoplankton was considerably lower in winter and spring than in the other seasons due to the domination of the non-toxic *L. redekei*, which prefers lower water temperatures (Dokulil and Teubner 2000). The highest abundance of potentially toxic Cyanobacteria in September was responsible for the highest total abundance of phytoplankton at that time.

Cyanobacteria can produce cyanotoxins with varied biological activities (Burchardt and Pawlik-Skowrońska 2005). Especially dangerous for animals and humans beings are hepatotoxic microcystins (Mankiewicz et al. 2003, Kabziński and Kabziński 2006). *P. agardhii* is known to be a strong microcystin producer (Akcaalan et al. 2006), though non-toxic strains have also been reported (Mbedi et al. 2005). Although many species or strains of *Anabaena*, *Oscillatoria*, *Microcystis*, *Woronichinia*, and *Snowella* that occur in Lake Syczyńskie were also reported to be potential producers of hepatotoxic microcystins (Burchardt and Pawlik-Skowrońska 2005), the very high concentration of microcystins found in the surface scum consisting of *P. agardhii* suggests that this cyanobacterium is the main producer of hepatotoxins in Lake Syczyńskie. In addition, some *Anabaena*, *Aphanizomenon*, *Oscillatoria*, and *Microcystis* noted in the studied lake may produce neurotoxins, while *Lyngbya* and *Planktolyngbya* are known to be producers of cytotoxins and dermatotoxins. All Cyanobacteria contain lipopolysaccharides (LPS) that possess dermatotoxic activity (Mankiewicz et al. 2003). The dinoflagellate *P. aciculiferum* found in Lake Syczyńskie was previously reported to be a producer of hemolythical toxins lethal to other phytoplankton organisms like *Rhodomonas lacustris* Pascher and Ruttner (Rengefors and Legrand 1997).

Lake Syczyńskie was classified as a "Planktothrix-lake' according to classification of Rücker et al. (1997). It seems that in this lake the predomination of *P. agardhii* and *L. redekei* (Oscillatoriales) over Nostocales in all seasons depends not only on different light and temperature preferences between these taxonomic groups (Dokulil and Teubner 2000), but also on the fact that *P. agardhii* is a stronger competitor at high nitrogen (especially N-NH_4) concentrations (Pawlik-Skowrońska et al. 2004, Stefaniak et al. 2005). The current observations are in agreement with reports on Cyanobacteria domination in other eutrophic/hypertrophic lakes (Rücker et al. 2005). At lower N-NH_4 concentrations (approx. 0.26 mg dm^{-3}), the lowest abundance of *P. agardhii* and the highest abundance of *L. redekei* were found in Lake Syczyńskie in springtime. The massive development of *P. agardhii* and the replacement of *L. redekei* was associated in the lake with increasing concentrations of N-NH_4 and increasing water temperatures. This suggests that *L. redekei* may prefer not only lower temperatures but also lower N-NH_4 concentrations than *P. agardhii*. Such a relationship between N-NH_4 level and development of *L. redekei* and *P. agardhii* was reported previously under laboratory conditions (Nicklisch 1994).

Throughout the year the phytoplankton of Lake Syczyńskie has a considerable abundance of potentially toxic Cyanobacteria, especially the hepatotoxic *P. agardhii* occur. Also in winter the potentially toxic Dinoflagellatae finds optimal conditions for development. This situation is harmful for the lake biocenosis.

REFERENCES

Akcaalan R., Young F.M., Metcal J.S., Morrison L.F., Albay M., Codd G.A., 2006, *Microcystin analysis in single filaments of Planktothrix spp. in laboratory cultures and environmental blooms*, Water Research 40: 1583-590

Burchardt L., Pawlik-Skowrońska B., 2005, *Blue-green algal blooms – interspecific competition and environmental treat*, Wiad. Bot., 49 (1/2): 39-49 (in Polish)

Dokulil M.T., Teubner K., 2000, *Cyanobacterial dominance in lakes*, Hydrobiologia, 438: 1-12

Golterman H.L.,1971, *Methods for chemical analysis of fresh waters*, Blackwell, IBP Handbook no 3, Oxford – Edinburgh, pp. 166

Harada K.I., Murata H., Qiang Z., Suzuki M., Kondo F., 1996, *Mass spectrometric method for microcystins in cyanobacteria*, Toxicon, 34: 701-10

Kabziński K.M., Kabziński K.A., 2006, *Toxic cyanobacterial blooms. Medical effects of contact with cyanobacterial blooms, part VI*, Bioskop, 1: 13-20, (in Polish)

Kasperoviciene J., Koreiviene J., Paskauskas R., 2005, Oceanol. Hydrobiol. Stud., 34 Suppl. 3: 93-104

Kaya K., Sano T., 1999, *Total microcystin determination using erythro-2-methyl-3-(methoxy-d_3)-4-phenylbutyric acid (MMPB-d_3) as the internal standard*, Analytica Chimica Acta, 386: 107-12

Kornijów R., Pęczuła W., Lorens B., Rechulicz J., Sugier P., Paleolog-Demetraki A., Ligęza S., Tarkowska-Kukuryk M., Kowalczyk D., Szafran K., Halkiewicz A., 2002, *Hypertrophication of Lake Syczyńskie (Eastern Poland)*, Limnol. Rev., 2: 209-15

Mankiewicz J., Romanowska-Duda Z., Izydorczyk K., Tarczyńska M., 2003, *Ecological effects of toxic cyanobacterial blooms on the existence of aquatic ecosystems – a survey*, [in:] *Algae* *and Biological State of Water*, Eds. Hołodyński Cz., Łaźniewska I., Acta Botanica Warmiae et Masuriae, 3: 5-9

Mbedi S., Welker M., Fastner J., Wiedner C., 2005, *Variability of the microcystin synthetase gene cluster in the genus Planktothrix (Oscillatoriales, Cyanobacteria)*, FEMS Microbiology Letters 245: 299-306

Nicklisch A., 1994, *Does mortality by nitrogen deficiency influence the succession of Limnothrix redekei and Planktothrix agardhii?*, Verh. int. Ver. Limnol., 25: 2214-217

Owsianny P.M., Stefaniak K., Kokociński M., 2003, *Occurrence of potentially toxic Peridiniopsis polonicum (Dinophyta) in lakes of the Wielkopolska region (Poland)*, [in:] *Algae and Biological State of Water*, Acta Botanica Warmiae et Masuriae, 3: 87-99

Pawlik-Skowrońska B., Skowroński T., Pirszel J., Adamczyk A., 2004, *Relationship between cyanobacterial bloom and anatoxin-a and microcystin occurrence in the eutrophic dam reservoir (SE Poland)*, Pol. J. Ecol., 52 (4): 379-90

Rengefors K., Legrand C., 2001, *Toxicity in Peridinium aciculiferum - an adaptive strategy to outcompete other winter phytoplankton?* Limnol. Oceanogr. 46: 1990-997

Rücker J., Wiedner C., Zippel P., 1997, *Factors controlling the dominance of Planktothrix agardhii and Limnothrix redekei in eutrophic shallow lakes*, Hydrobiologia, 342/343: 107-15

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,* Oceanol. Hydrobiol. Stud., 34 Suppl. 3: 125-36

Utermöhl H., 1958, *Improvement of the quantitative methods for phytoplankton*, Mitt. Int. Ver. Limnol., 9: 1-38, (in German)

Zimba P.V., Rowan M., Triemer R., 2004, *Identification euglenoid algae that produce ichthyotoxin(s)*, Journal of Fish Diseases, 27: 115 – 17