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DEVELOPMENT OF POTENTIALLY TOXIGENIC CYANOBACTERIA IN A SMALL, HYDRO-MORPHOLOGICALLY TRANSFORMED LAKE INCLUDED INTO THE WIEPRZ-KRZNA CANAL SYSTEM (EASTERN POLAND)

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Summary. Development of potentially toxigenic cyanobacteria was studied over two years (2012–2013) in Lake Dratów transformed into storage reservoir, supplied periodically with nutrient-rich waters from the Wieprz-Krzna canal. In the hydro-morphologically transformed lake with a regulated water level, from spring to autumn physic-chemical conditions supported cyanobacterial blooms of various species composition. In spring N_2- fixing cyanobacterium *Aphanizomenon flos-aqauae* (Nostocales) predominated, while in summer and autumn of both years three species of *Microcystis* (Chroococcales) and one species of Oscillatoriales (*Planktolyngbya limnetica*, only in autumn seasons) contributed to the highest degree in cyanobacterial abundance. The obtained results with the comparison with the data from years 2004–2005 indicated that in Lake Dratów cyanobacterial blooms are perennial and very stable in terms of species composition.

Key words: toxigenic cyanobacteria**,** regulated lake, *Microcystis* bloom, eutrophication

INTRODUCTION

Mass development of planktonic cyanobacteria has become a common phenomenon in shallow water bodies [O'Neil *et al.* 2012] both natural [Toporowska *et al.* 2010, Kokociński *et al.* 2011] and artificial [Briand *et al.* 2002, Grabowska and Pawlik-Skowrońska 2008, Pawlik-Skowrońska *et al.* 2013].

Especially, blooms of toxigenic cyanobacteria like *Microcystis* spp., *Dolichospermum* spp., *Aphanizomenon* spp., *Woronichinia* spp. and *Planktothrix* spp. are real threat for freshwater ecosystems due to their harmful influence on biocenoses [Pflugmacher 2004, Pawlik-Skowrońska *et al.* 2012, Toporowska *et al.* 2014]. A range of substances (hepatotoxins, neurotoxins, dermatotoxins, enzyme inhibitors) produced by cyanobacteria are a threat for humans and animals using cyanobacteria containing waters [Ibelings and Havens 2008, Chen *et al.* 2009]. Increasing fertility of water in small and shallow lakes and retention reservoirs supports perennial blooms of cyanobacteria and water bodies located in agricultural areas can be especially affected.

The aim of this work was to study qualitative and quantitative structure of cyanobacterial assemblage in the water of the transformed Lake Dratów with periodically regulated water level.

STUDY AREA, MATERIALS AND METHODS

Lake Dratów included in the Wieprz-Krzna canal system (Łęczyńsko-Włodawskie Lake District, E. Poland) is relatively small (168 ha), shallow (max. depth 3.3 m; av. depth 1.8 m), polymictic water body, transformed by enlargement, embankment and construction of inflow and outflow sluices, periodically supplied with nutrient-rich waters from the River Wieprz.

Water sampling for physic-chemical characteristic and qualitative and quantitative determination of cyanobacterial assemblages was conducted in vegetative periods over the years 2012–2013. 0.5 dm^3 of surface water (0–0.5 m) was sampled randomly in 3 sites in the central area of the lake. Both fresh and conserved samples containing phytoplankton were studied for taxonomical identification. The abundance of cyanobacteria was determined microscopically in a 1 ml phytoplankton chamber. Physic-chemical parameters were determined according to Hermanowicz [1976] and PN-ISO 10260 [2002]. Water transparency was determined by means of Secchi disc. Trophic status of the lake was evaluated using the index (TSI) according to Carlson [1977].

RESULTS AND DISCUSSION

Both hydro-morphological parameters (shallowness, nutrient loadings with canal water) and physic-chemical conditions (average water temperature 16.3–17.5°C, high biogenic (N, P) compounds concentration) supported in the vegetation seasons of the years 2012 and 2013 (Tab. 1) mass development of cyanobacteria of the orders Nostocales, Oscillatoriales and Chroococcales (Fig. 1). TSI determination revealed that in the study period the trophic status of the lake was very high

(77–81), even higher than in the natural, hypertrophic (TSI = 65–79) Lake Syczyńskie in Lubelskie Highland [Toporowska and Pawlik-Skowrońska 2014]. Very low water transparency (av. 0.28 m) found in the lake was a consequence of the mass phytoplankton development. As reported by Solis *et al.* [2009] similar

Table. 1. Physical-chemical parameters of water in Lake Dratów in 2012 and 2013 (average values)

Parameters	2012	2013
Water temperature, °C	17.5	16.3
Transparency, m	0.28	0.28
Conductivity, μS cm^{-1}	265	129
pH	8.9	8.3
$N\text{-}NH_4$, mg L^{-1}	0.133	0.085
$N\text{-}NO_3$, mg L^{-1}	0.060	0.096
$P\text{-}PO_4$, mg L^{-1}	0.035	0.024
P tot., mg L^{-1}	0.245	0.191
TSI av., $_{SD,\ Chl\ a,\ TP}$	81	77

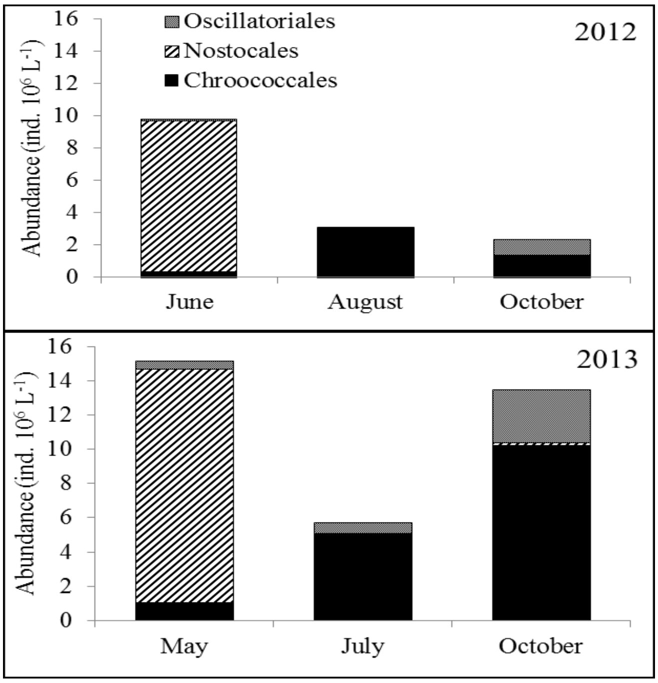

Fig. 1. Changes in abundance of particular cyanobacterial groups in Lake Dratów in 2012 and 2013

Table 2. Seasonal and yearly changes in the structure of cyanobacteria in Lake Dratów in 2012 and 2013

Taxa	2012			2013		
	June	August	October	May	July	October
Dolichospermum flos-aquae [a)]	+					
D. crassum [a)]	+	+	+	+	+	
D. lemmermannii [a)]				+		
D. planctonicum [a)]		+				
Aphanizomenon flos-aquae [a)]	+++++	++		+++++		
Aph. gracile [a)]	+		++			
Aphanocapsa holsatica		+++	+++	+++	++	+++
A. delicatissima	++				+	
Aphanothece clathrata		++			+++	++
Aph. minutissimum				+++		+++
Coelosphaerium minutissimum						+
Chroococcus sp. 1	+					
Chroococcus sp. 2		+	++			
Cuspidothrix elenkinii [a)]			+		+	+
Gomphosphaeria sp. [a)]					++	
Limnothrix redekei	+					
Merismopedia warmingiana					++	+
Microcystis aeruginosa [a)]	++	+++	+	+	+	+
M. flos-aquae [a)]				+		
M. wesenbergii [a)]	+	++	++++	++	+++	++
M. viridis [a)]	+	++++	+++	++	++++	++
M. cf. *botrys* [a)]	+	++				
Planktolyngbya brevicellularis				++	++	
P. limnetica [a)]	+		++++		++	+++
Planktothrix agardhii [a)]			++			
Pseudanabaena mucicola						++
Woronichinia naegeliana [a)]	+	++		+		
Total number of taxa (number of potentially toxic taxa)	13 (10)	11 (8)	10 (8)	11 (8)	12 (7)	11 (5)

[a)] Potentially toxic taxa. Contribution in the total cyanobacterial abundance: +++++ > 50%; ++++ 25–49%; +++ 10–24%; ++ 1–9%; + <1%.

low water transparency occurred in this lake in previous years (2004–2006). Among cyanobacteria, filamentous N_2-fixing Nostocales quantitatively predominated in spring. Their abundance was very high and ranged from 1×10^7 ind. L^{-1} in 2012 to 1.4×10^7 ind. L^{-1} in 2013. Cyanobacterial mass development (especially Nostocales) in spring was also observed in other lakes and dam reservoirs [Grabowska and Pawlik-Skowrońska 2008]. In summer and autumn seasons, several species of Chroococcales with an admixture of filamentous Oscillatoriales were the most abundant cyanobacteria. In 2013, their abundance that reached $0.5–1 \times 10^7$ ind. L^{-1} considerably increased in comparison with 2012 (Fig. 1). In spring--autumn 2012, from 10 to 13 species of planktonic cyanobacteria, and in 2013, from 11 to 12 species were found (Tab. 2). Among them, dependent on the season, 5–10 species were potentially toxigenic. For example, in the hypertrophic Lake Syczyńskie (E. Poland) dominated with *Planktothrix agardhii* (Gomont) Anagnostidis et Komárek (Oscillatoriales) in the years 2006–2009 cyanobacteria species richness ranged from 23 to 34, but only six of them were potentially toxigenic [Toporowska and Pawlik-Skowrońska 2014]. In spring of both years, *Aphanizomenon flos-aquae* Ralfs ex Bornet et Flahault (Nostocales) comprised over 50% of the total cyanobacterial abundance, while *Dolichospermum* spp. had negligible contribution (<1%). In summer and autumn different species of *Microcystis* (Chroococcales) predominated in the total cyanobacterial abundance (24–49%). Among Oscillatoriales – *Planktolyngbya limnetica* (Lemmermann) Komárková-Legnerová et Cronberg contributed to the highest degree in the cyanobacterial abundance. The contribution of other potentially toxigenic cyanobacteria, such as *Aphanizomenon gracile* (Lemmermann) Lemmermann, *Microcystis flos-aquae* (Wittrock) Kirchner, *Woronichinia naegeliana* (Unger) Elenkin, *P. agardhii* ranged < 1–9% of the total cyanobacterial abundance (Tab. 2). The obtained results are in agreement with previous observations from years 2004–2005 reported by Solis *et al.* [2009]. It strongly suggests that species structure of the assemblage of potentially toxic cyanobacteria in the transformed Lake Dratów is very stable and blooms formed by these species are perennial. The specific species composition with a dominance of *Microcystis* spp. and not *P. agardhii* suggests also that water mixing and turbulence in the „regulated" Lake Dratów is rather slight, because *P. agardhii* prefers turbulent conditions [Scheffer *et al.* 1997].

CONCLUSION

In the „regulated" hypertophic Lake Dratów, transformed to water storage reservoir and supplied periodically with waters via the Wieprz-Krzna canal, blooms of potentially toxigenic cyanobacteria such as *Aphanizomenon flos-aqauae* and *Microcystis* spp. are a typical phenomenon, stable and perennial over many years. It became a real threat for both aquatic biocenosis and water users.

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ROZWÓJ POTENCJALNIE TOKSYCZNYCH SINIC W MAŁYM, HYDRO-MORFOLOGICZNIE PRZEKSZTAŁCONYM JEZIORZE SYSTEMU KANAŁU WIEPRZ-KRZNA (WSCHODNIA POLSKA)

Streszczenie. Rozwój potencjalnie toksycznych sinic badano w latach 2012–2013 w jeziorze Dratów, przekształconym w zbiornik retencyjny oraz zasilanym okresowo przez bogate w związki biogenne wody Kanału Wieprz-Krzna. W hydro-morfologicznie przekształconym jeziorze, z regulowanym poziomem wody, od wiosny do jesieni fizykochemiczne warunki wspierały rozwój zakwitów sinicowych o różnej strukturze gatunkowej. Wiosną dominowała wiążąca azot atmosferyczny sinica *Aphanizomenon flos-aqauae* (Nostocles), podczas gdy latem i jesienią najwyższy udział w ogólnej liczebności sinic osiągnęły trzy gatunki *Microcystis* (Chroococcales) oraz jeden gatunek Oscillatoriales (*Planktolyngbya limnetica*, tylko jesienią). Uzyskane wyniki w porównaniu z danymi z lat 2004–2005 wskazują, że w przekształconym jeziorze Dratów nawracające zakwity sinic są bardzo stabilne pod względem składu gatunkowego.

Słowa kluczowe: toksynotwórcze sinice, regulowane jezioro, zakwit *Microcystis*, eutrofizacja