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PHYTOPLANKTON AS AN ECOLOGICAL CRITERION FOR DIFFERENTIATION OF MID-FOREST LAKES IN SOBIBÓR LANDSCAPE PARK

Władysława Wojciechowska, Michał Solis, Radosław Mencfel

Department of Botany and Hydrobiology, The John Paul II Catholic University of Lublin
Konstantynów str. 1H, 20-708 Lublin, sokol@kul.lublin.pl

Summary. Studies on the ecological status based on the species composition and abundance of phytoplankton in seven mid-forest, humic lakes of Sobibór Landscape Park were done in 2011. With regard to physical-chemical properties of waters the lakes can be divided into two groups: dystrophic, moderately eutrophic (Płotycze, Pereszpa, Orchowe) and eu-/hypertrophic (Wspólne, Koseniec, Brudno, Brudzieniec). Phytoplankton was dominated by flagellates, mainly invasive raphidophyte *Gonyostomum semen*, in dystrophic lakes. Green algae, mainly Chlorococcales, dominated in the second group of lakes but blue-green algae dominated also in lake Brudzieniec. Community of planktonic algae is characterized by a high stability of the 90's of the XX century.

Key words: mid-forest lakes, phytoplankton, flagellates, physical-chemical properties of waters

INTRODUCTION

Mid-forest lakes are often defined as humic because of brown color of waters [Wetzel 2001]. These lakes are usually shallow, with a small area and commonly, due to a high natural value, covered by different forms of nature conservation.

Continuous supply of humic organic matter from the surrounding catchment cause to reduce a amount of light in water and often to acidify waters – modifying also food webs in those ecosystems. Bacteria utilizing dissolved organic matter and detritus-feeding organisms able to consume small particles occurred in a large numbers [Jones 1992]. Phytoplankton may be species-rich and sometimes with of considerable abundance in the mid-forest lakes. In dystrophic lakes with acid water reaction, biomass and species diversity of phytoplankton is rather small, in contrast to eutrophic lakes, which is great [Lepistö and Rosenström 1998]. Large abundances in humic lakes have flagellate algae, among which large part are mixotrophic

organisms, capable of taking organic particles [Salonen and Jokinen 1988].

Ecosystems of mid-forest, small lakes rapidly respond to changes in the surrounding catchment (e.g.: lowering the water level, deforestation), including changes in phytoplankton which is a good indicator of fertility of waters. With increasing trophic status increases the phytoplankton numbers and changes species composition, especially increases the proportion of indicator species for eutrophy [Trifonova 1988].

The aim of this study was to determine the ecological status of the seven humic lakes located in Sobibór Landscape Park based on phytoplankton and selected physical-chemical properties of water.

STUDY AREA AND METHODS

In the eastern part of Łęczyńsko-Włodawskie Lake District, near the border with Ukraine and Belarus, are situated Sobibór Landscape Park (SLP). This is the forest-peat area, with dominating low and transient peat-bogs [Wawer and Urban 1999]. Lakes located in this area are of small surface and shallow, with a maximum depth not exceeding 5–6 m (Tab. 1).

Table 1. Morphometrical properties of lakes and catchments situated on Sobibór Landscape Park [after Radwan and Kornijów 1998]

Lake	Area, ha	Maximum depth, m	Mean depth, m	Catchment area, ha
Płotycze	16.6	8.05	2.2	151.3
Pereszpa	24.3	6.2	3.2	255.8
Orchowe	8.1	1.25*	-	110.8
Wspólne	65.3	2.25	1.4	1782.2
Koseniec	21.0	4.2	1.3	
Brudzieniec	17.8	2.85	1.5	651.4
Brudno	40.8	2.5	1.5	805.9

*own measurement

Phytoplankton studies were conducted during June-July 2011 on seven lakes describing as dystrophic or dystrophic-eutrophic [Radwan and Kornijów 1998]. Water samples were collected as combined with few depths limited to the euphotic zone. At the same time there were performed *in situ* measurements of Secchi disk visibility (SD), pH and conductivity (EC). In laboratory, the concentrations of chlorophyll-a by spectrophotometric method [Nusch 1980] and abundance of phytoplankton by Utermöhl method using inverted microscope were determined [Vollenweider 1969]. The concentration of total phosphorus (TP)

was determined spectrophotometrically after mineralization of water [Hermanowicz *et al*. 1999], and calcium (Ca) content by atomic absorption spectrometry (PN-EN ISO 7980:2000). Water color was determined spectrophotometrically, at the wavelength of 440 nm, in the filtered water sample [Lean 1998]. The fertility of waters was identified based on Carlson index (TSI), calculated as the average of the average calculated for Secchi disk visibilities (TS_{SD}), concentrations of chlorophyll *a* (TS_{CHL}) and total phosphorus (TS_{TP}) [Carlson 1977].

RESULTS AND DISCUSSION

Common features of the studied lakes are their morphometric conditions (small area and depth) and location in forest-bog catchments. However, an analysis of physical-chemical properties of water and of species composition and numbers of phytoplankton indicates that the lakes can be divided into two groups. Lakes Pereszpa, Płotycze and Orchowe can be defined as humic, moderately eutrophic. Group of lakes Wspólne, Koseniec, Brudno and Brudzieniec are more fertile water bodies, eu- or hypertrophic. Legitimacy of this division to lakes with characteristics close to the eutrophy or dystrophy was demonstrated already in the 60's and 70's of the twentieth century [Radwan *et al*. 1971].

Table 2. Values of physical-chemical and biological parameters in lakes defined as dystrophic

parameter \ Lake	Płotycze	Pereszpa	Orchowe
Water color, mg Pt dm^{-3}	163	360	284
pH	6.7	7.2	6.8
EC, µS cm^{-1}	96	98	70
Ca, mg dm^{-3}	7.1	12.8	9.8
TP, µg dm^{-3}	49	62	38
Phyt. number, indv. 10^6 dm^{-3}	1.73	1.41	4.02
Chl *a*, µg dm^{-3}	70	60	23
$TSI_{SD, TP, Chl\ a}$	59	67	64

The supply of humic substances from forest-bog catchment causes the yellow-brown color of waters in all studied lakes. In lakes Płotycze, Pereszpa and Orchowe water's color was 163–360 mg Pt dm^{-3}, the pH of water was about 7, electrolytic conductivity was always < 100 µS cm^{-1} and calcium content in water was low (Tab. 2). On the basis of phosphorus content in water (TP), transparency (SD) and the chlorophyll-a concentration there was calculated average Carlson trophic index (TSI). The values indicated that the three lakes are moderately eutrophic [Carlson 1977]. The structure of phytoplankton was similar in these

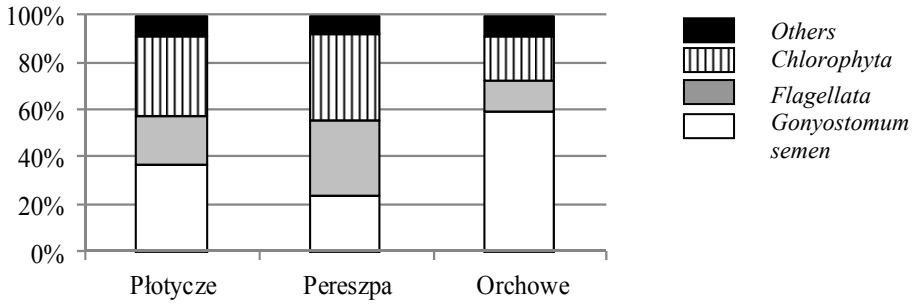

Fig. 1. Composition of phytoplankton in lakes defined as dystrophic

lakes (Fig. 1). The most abundant algae in the phytoplankton were flagellates, contributed approximately 60% the number. Among this group, invasive raphidophyte *Gonyostomum semen* had a large share in total phytoplankton abundance, from 20% (lake Pereszpa) to 60% (lake Orchowe) (Fig. 1). Numbers and species composition of other flagellate algae were also different. The flagellates' community constituted mainly species of the genus *Cryptomonas* in lake Orchowe and dinoflagellate *Peridinium bipes* in lake Płotycze. On the basis of the average cell volume, taxa of *Cryptomonas* spp. (1660 μm^3) can be classified into the small flagellates, and *Peridnium bipes* (47 150 μm^3) to the large flagellates. Flagellate algae, and among them small flagellates, are often very numerous components of the phytoplankton in lakes of brown-colored water [Arvola 1983]. According to classification of phytoplankton to functional groups, *Gonyostomum semen* belongs to Q, and *Cryptomonas* to Y group [Reynolds *et al*. 2002]. Both groups include taxa occurring mainly in small, fertile reservoirs, which often have brown colored water and an excess of organic matter that these organisms may consume. These taxa are also found in other water bodies of Łęczna-Włodawa Lakeland but with a high content of humic substances [Wojciechowska and Solis 2001]. Green algae were also abundant in the three lakes (Fig. 1), whose share in the abundance of phytoplankton was 28–35%. Great numbers of green algae in those lakes were found already in the 90s of the twentieth century [Wojciechowska *et al*. 1996]. In lakes Orchowe and Pereszpa were the most abundant species of small green algae of the order Chlorococcales: *Pediastrum tetras*, *Tetraedron minimum* and *Monoraphidium minutum*, typical of waters with a high fertility [Reynolds 2006]. Besides chlorococcal green algae, in lake Płotycze were also abundant species of the order Desmidiales: *Closterium acutum* and *Staurastrum* spp., indicators of less fertile waters [Rósen 1981].

Lakes with the advanced eutrophication were Wspólne, Koseniec, Brudno and Brudzieniec. Waters of those lakes were more colored (200–378 mg Pt dm^{-3}), with higher contents of Ca (20–40 mg dm^{-3}) and high concentrations of total phos-

Table 3. Values of physical-chemical and biological parameters in lakes defined as eutrophic or hypertrophic

Lake / parameter	Wspólne	Koseniec	Brudzieniec	Brudno
Water color, mg Pt dm^{-3}	218	139	280	378
pH	7.3	8.3	7.9	8.3
EC, µS cm^{-1}	260	232	190	120
Ca, mg dm^{-3}	40.2	40.2	32.0	20.1
TP, µg dm^{-3}	195	103	74	81
Phyt. number, indv. 10^6 dm^{-3}	2.99	10.88	6.48	1.15
Chl-*a*, µg dm^{-3}	72	90	74	110
$TSI_{(SD, TP, Chl-a)}$	75	72	72	74

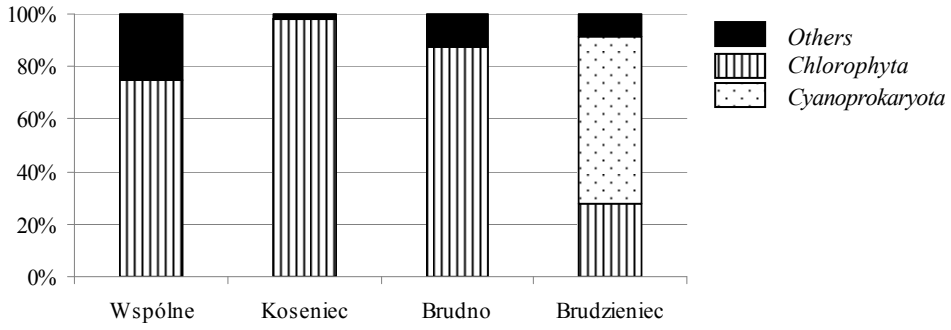

Fig. 2. Composition of phytoplankton in lakes defined as eutrophic or hypertrophic

phorus (TP = 74–195 mg dm^{-3}) (Tab. 3). In all four lakes, the concentrations of chlorophyll *a* (70–110 µg dm^{-3}) confirmed great abundances of phytoplankton and the trophic indices (TSI) confirmed their hypertrophy (Tab. 3). In lakes Wspólne, Koseniec and Brudno phytoplankton was dominated by green algae which contributed 80–100% the abundance of phytoplankton (Fig. 2). Species composition of green algae was the most diverse in lake Wspólne because 10 species had similar numbers, and among others were: *Coelastrum sphaericum*, *Crucigenia apiculata*, *Scenedesmus* spp. *Closterium acutum*. In lake Koseniec phytoplankton was dominated by one green algae – *Coelastrum pseudomicroporum*, whose contribution of total phytoplankton numbers was about 90%. Phytoplankton dominated by one species belonging to genus of *Chlamydomonas* was also found in lake Brudno. Both cyanobacteria and green algae were abundant in lake Brudzieniec (Fig. 2). The most abundant taxa of cyanobacteria were *Planktolyngbya limnetica* and *Microcystis wesenbergii*. The two species of green

algae were dominant: *Scenedesmus acutus* and *S. armatus*. Above mentioned taxa in lakes Wspólne, Koseniec, Brudzieniec and Brudno are reported as typical indicators of advanced eutrophy (Rosenström and Lepistö 1996). Such phenomenon in those lakes has already been ascertained in the early 90's of the XX century [Wojciechowska *et al*. 1996].

CONCLUSIONS

Physical-chemical properties of waters, species composition and numbers of planktonic algae reflect the division of lakes into two groups: humic, moderately fertile, and eu- or hypertrophic.

Phytoplankton communities in all lakes appear the high degree of stability in the last decade.

Presence and mass appearances of invasive species *Gonyostomum semen* were observed in lakes Płotycze, Pereszpa and Orchowe. This situation has existed since the 90s of the twentieth century.

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FITOPLANKTON JAKO EKOLOGICZNE KRYTERIUM ZRÓŻNICOWANIA ŚRÓDLEŚNYCH JEZIOR SOBIBORSKIEGO PARKU KRAJOBRAZOWEGO

Streszczenie. W siedmiu śródleśnych, humusowych jeziorach Sobiborskiego Parku Krajobrazowego prowadzono w 2011 r. badania nad ich stanem ekologicznym na podstawie struktury gatunkowej i zagęszczeni fitoplanktonu. Ze względu na cechy fizyczno-chemiczne wód, jeziora można apodzielić na dwie grupy: dystroficzne, umiarkowanie eutroficzne (Płotycze, Pereszpa, Orchowe) i eu-/hipertroficzne (Wspólne, Koseniec, Brudno, Brudzieniec). W jeziorach dystroficznych w fitoplanktonie dominowały wiciowce, głównie inwazyjny rafidiofit *Gonyostomum semen*. W drugiej grupie jezior dominowały zielenice, głównie chlorokokalne. W jeziorze Brudzieniec zielenice współdominowały również z sinicami. Zbiorowisko glonów planktonowych charakteryzuje się dużą stabilnością od lat 90. XX w.

Słowa kluczowe: jeziora śródleśne, fitoplankton, wiciowce, fizyczno-chemiczne właściwości wód