Oceanological and Hydrobiological Studies
International Journal of Oceanography and Hydrobiology
Vol. XXXVIII, No. 1

Institute of Oceanography | (93-101) | University of Gdańsk
ISSN 1730-413X | 2009 | eISSN 1897-3191

DOI 10.2478/v10009-009-0008-6
Original research paper

Received: *July 05, 2008*
Accepted: *November 07, 2008*

Changes in the phytoplankton community of a lake restored with phosphorus inactivation (Lake Głęboczek, northern Poland)

Bożena Jaworska[1,3], Helena Gawrońska[2], Michał Łopata[2]

[1]Chair of Applied Ecology, University of Warmia and Mazury
ul. Oczapowskiego 5, 10-957 Olsztyn, Poland
[2]Chair of Environment Protection Engineering
University of Warmia and Mazury
ul. Oczapowskiego 5, 10-957 Olsztyn, Poland

Key words: lake, phytoplankton, eutrophication, restoration

Abstract

The study applied qualitative and quantitative phytoplankton analysis as a tool for determining algal community characteristics and identifying the directions and general trends of changes caused by the restoration of Lake Głęboczek through phosphorous inactivation before and during its application.

The method applied in the studied lake aimed at reducing phosphorous availability through the chemical precipitation of its excess mineral forms in the water body and limiting their mobility in the bottom sediments. Restoration efforts led to shifts in the phytoplankton domination structure followed by the inhibition of blue-green algae development. In consequence, a significant decrease was recorded in the growth rate of the phytoplankton community.

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[3] Corresponding author: *bozena.jaworska@uwm.edu.pl*

INTRODUCTION

Halting degradation processes in reservoirs is possible on condition that the causes of eutrophication and sources of pollution are eliminated; however, even then, the application of additional lake renewal or restoration methods is recommended (Lossow 1997, 1998; Klapper 2003).

Progressing eutrophication as well as any attempt to inhibit its pace or eliminate its undesirable effects always impacts the structure and functioning of the particular components of freshwater ecosystems (McQueen et al. 1986, Currie 1990, Lau and Lane 2002). These changes have also a remarkable impact on algal associations (Reynolds 1984, 2000; Burchardt 1994). Shifts in phytoplankton composition and taxonomic structure as well as plankton growth rates indicate not only lake trophy or the pace of eutrophication in a reservoir but also the effectiveness of the applied method of lake protection or restoration (Padisák and Reynolds 1998, Bürgi and Stadelmann 2002).

The aim of the current study was the perform qualitative and quantitative analyses of shifts in algal associations and to determine the main trends and directions of recorded changes induced by the application the phosphorous inactivation method in Lake Głęboczek.

MATERIALS AND METHODS

The studied site, Lake Głęboczek, is a relatively small (19.1 ha), shallow (maximal depth – 5.6 m, average depth – 3.3 m) reservoir located in northern Poland (Fig. 1) (Cieściński 1991). The lake is a strongly eutrophic water body

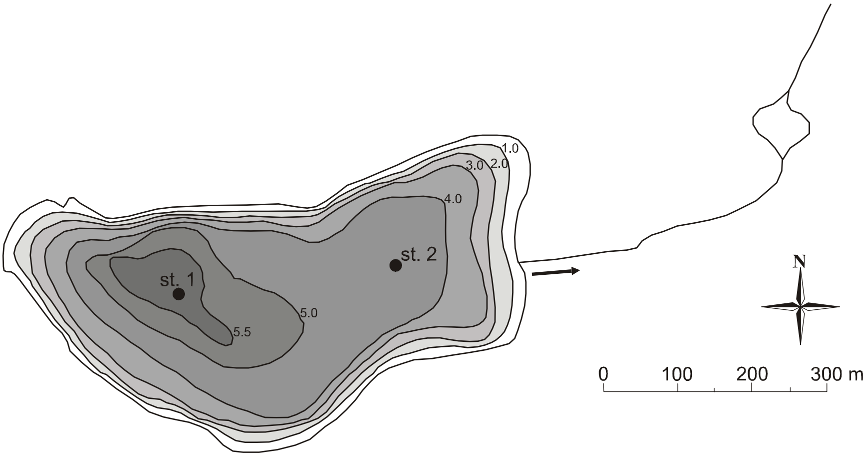

Fig. 1. Location of sampling sites in Lake Głęboczek.

that is particularly susceptible to degradation and has been subjected to various restoration or renewal efforts (Goszczyński 2000). In the 2001-2003 period, the phosphorous inactivation method was applied twice in October 2001 and April 2003 (Lossow et al. 2002, Łopata and Gawrońska 2006).

The phytoplankton studies were conducted from spring 2001 to fall 2003 at two sites in three consecutive periods from May to October 2001, prior to restoration, from October 2001 to April 2003, following restoration stage one, and from May 2003 to October 2003, after restoration stage two. Samples were collected from the water column from the surface to a depth of 5 m with a Ruttner sampler and a plankton net. The initial qualitative phytoplankton analysis was performed on living material collected with the plankton net. Further qualitative and quantitative phytoplankton analyses were performed on fixed, condensed samples of biological material samples collected from the lake. Phytoplankton numbers were calculated with the drop method, and phytoplankton biomass was estimated by estimating cell volume and calculated as the product of phytoplankton number, the mean volume of particular taxa, and the mass density of individuals. Sample analyses were performed according to the methods by Starmach (1989).

RESULTS

Before restoration with the phosphorous inactivation method, the Lake Głęboczek phytoplankton community was strongly dominated by a blue-green algae community with high species diversity and biomass. As early as in spring, Cyanobacteria constituted 60-70% of the overall phytoplankton biomass that exceeded 20 mg dm^{-3} (Figs. 2, 3). The dominating forms were species from the genera *Planktothrix* and *Limnothrix* and later also *Microcystis*, the development of which led to two fold increase in the total algal biomass. In summer, the cyanobacteria growth rate was still high so that even the abundant occurrence of *Ceratium hirundinella* did not limit their development (Table 1).

No sooner than in fall, following stage one lake restoration, was the inhibition of cyanobacteria growth recorded. This resulted in a two fold decrease in phytoplankton biomass followed by a gradually decreasing share (in mass) of cyanobacteria in the community. Consequently, Bacillariophyceae was noted as the dominant plankton in spring, followed by the development of Chlorophyta that comprised up to 60% of the total biomass. This was the same value that was achieved by cyanobacteria in the previous year. The contribution of cyanobacteria to total biomass dropped to 12% in the present year, which was five times lower than that in spring 2001 (Fig. 2). In summer, *Ceratium hirundinella* (Pyrrophyta) took the prevailing role in the community. Its fast development and relatively high individual body weight caused a significant

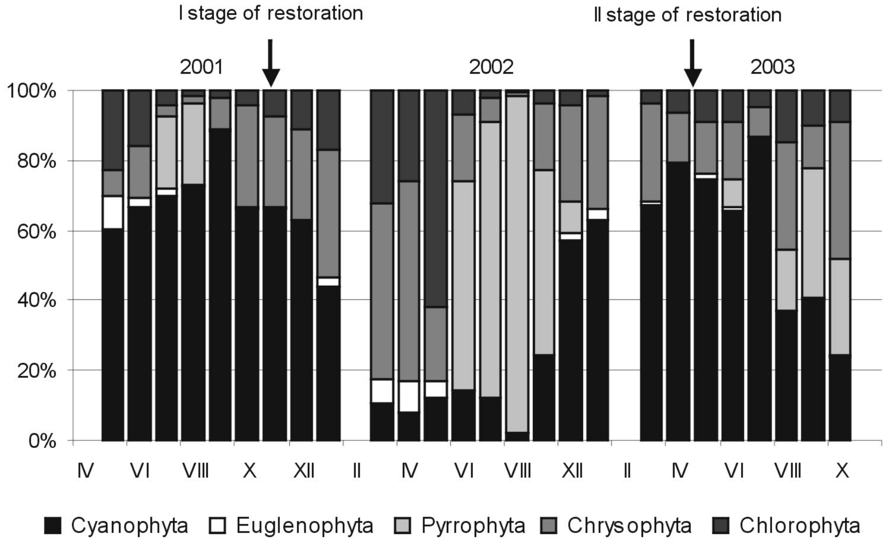

Fig. 2. The share (%) of particular systematic groups in the total phytoplankton biomass in Lake Głęboczek.

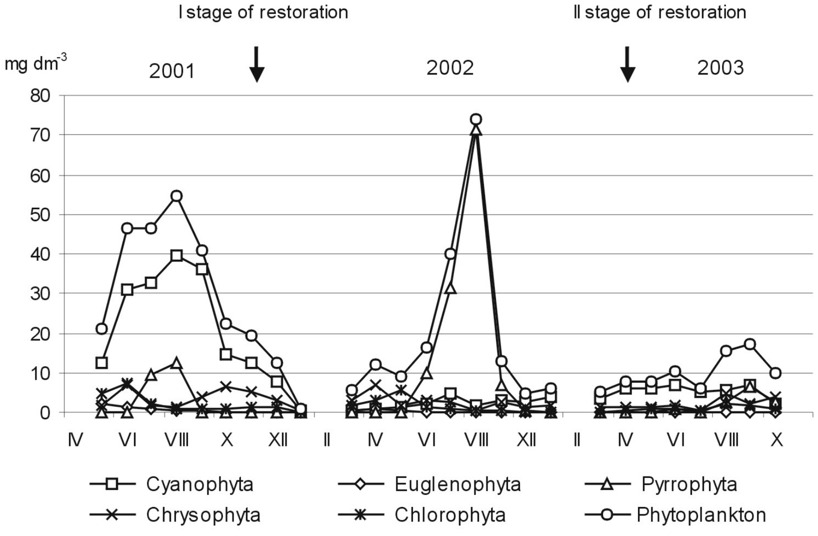

Fig. 3. The total phytoplankton biomass in Lake Głęboczek versus the biomass of the particular systematic groups.

Table 1

The share (%) of dominating taxa in the total phytoplankton biomass (D) and their frequency (F)

Taxa	2001	2001	2002	2002	2003	2003
	D (%)	F (%)	D (%)	F (%)	D (%)	F (%)
Cyanobacteria						
Aphanocapsa incerta (Lemm). Cronb.& Kom.			1.9	16.7		
Anabaena flos-aquae (Lyngb.) Breb.	1.3	33.3				
Limnothrix planctonica (Wołosz.) Meff.	1.8	50.0				
Limnothtrix redekei (Van Goor) Meff.	1.1	33.3			10.2	83.3
Microcystis aeruginosa Kütz.	13.7	83.3	3.7	66.7	21.8	50.0
Microcystis wesenbergii (Kom.) Kom.in Kondrat.	2.3	50.0				
Microcystis viridis (A. Br.) Lemm.	1.7	33.3				
Pseudanabaena limnetica Lemm.	1.2	50.0				
Planktothrix agardhii (Gom.) Anagn.& Kom.	31.1	100.0	4.1	66.7	15.1	83.3
Woronichinia compacta (Lemm.) Kom.& Hind.	2.2	33.3				
Woronichinia naegeliana (Unger) Elen.	4.0	33.3	0.9	33.3		
Euglenophyta						
Trachelomonas spp.	1.9	50.0	1.2	33.3		
Pyrrophyta						
Ceratium hirundinella (O. F. Müll.) Duj.	6.5	33.3	46.2	66.7	11.9	33.3
Chrysophyta						
Bacillariophyceae						
Asterionella formosa Hass.			9.2	66.7	3.1	16.7
Aulacoseira granulata (Ehr.) Sim.	5.5	50.0	5.1	33.3	9.2	50.0
Aulacoseira islandica (O.Müll) Sim.	2.5	50.0	2.3	16.7	1.1	16.7
Fragilaria capucina Desm.						
Fragilaria ulna var. acus (Kütz.) Lange-Bert.	3.0	50.0	2.1	33.3	4.9	33.3
Chlorophyta						
Closterium limneticum Lemm.			2.1	16.7		
Pediastrum boryanum (Turp.) Meneg.	1.8	50.0	1.7	33.3	1.7	33.3
Pediastrum duplex Meyen	1.2	50.0	1.2	33.3	1.2	33.3
Phacotus lenticularis (Ehr.) Stein	2.0	33.3	1.5	16.7		
Scenedesmus spp	1.0	16.7	1.2	16.7	0.9	33.3
Sphaerocystis planctonica (Kors.) Bourr.			0.8	16.7		

increase in phytoplankton biomass (70 mg dm^{-3}) while inhibiting cyanobacterial development and limiting the risk of their strong domination throughout that year (Fig. 3). In summer 2002, the blue-green algae biomass was more than ten fold lower than it had been in the same period in 2001. It remained unchanged until the following spring when stage two of lake restoration began. One of the results of repeated restoration efforts was the continued significant inhibition of phytoplankton development. Despite the fact that some cyanobacteria taxa dominated even in the spring and *Ceratium hirundinella* again took the prevailing role in the community in summer, the intensity of phytoplankton growth was remarkably lower than in 2002 (Table 1). The overall algal biomass reached barely 17 mg dm^{-3} in 2003, which was four fold lower than the respective value recorded in 2002 and almost 70% lower than the phytoplankton biomass recorded in the period prior to lake restoration with the phosphorous inactivation method (Fig. 3).

DISCUSSION

The effects of restoration or other efforts aimed at improving water quality result from changes either in the physicochemical parameters of or biocenotic relations in a functioning ecosystem. Despite the fact that a particular method is designed to improve selected parameters, the results obtained modify the direction of the overall processes occurring in lakes (Lammens 1999, Bürgi and Stadelmann 2002, Mathes et al. 2003).

The restoration attempts applied in the 2001-2003 period in Lake Głęboczek were aimed at inactivating the phosphorus in the ecosystem. Some changes were also noted in other abiotic parameters (Lossow et al. 2002, Łopata 2005, Łopata and Gawrońska 2006). Consequently, phytoplankton composition, taxonomic structure, and dynamics underwent modifications. Prior to restoration, cyanobacteria dominated strongly, which is typical of lakes with a high trophic status (Reynolds 2000), and they often constituted more than 50% of total plankton and occurred in the community from early spring to late fall. Their development formed an overall dynamics pattern of total algal biomass that exceeded 7-8 mg dm^{-3} a few times, which is the value regarded as the boundary for eutrophic lakes (Spodniewska 1978, 1979). The application of the phosphorous inactivation method that results in the elimination of reactive phosphorous, which is the fundamental nutrient that stimulates phytoplankton growth (Schindler 1978, Zdanowski 1982), and, thus, it directly affected the development of the algal community. In Lake Głęboczek, the limitation of phytoplankton growth resulted in a more than two fold decrease in biomass after first stage restoration, and a three fold algal biomass reduction after the second stage. The inhibition of phytoplankton development during restoration with phosphorus inactivation usually progresses gradually and is accompanied by simultaneous shifts in the phytoplankton domination structure (Perakis et al. 1995; Padisák, Reynolds 1998). In Lake Głęboczek, the common, abundant cyanobacteria community was slowly replaced by other algal groups.

Pyrrophyta, with the dominant *Ceratium hirundinella*, periodically took the leading role; this is often recorded in lakes with a very high trophic status (Reynolds 1984, Burchardt 1994). The domination of *Eratium hirundinella* in Lake Głęboczek was also recorded previously, before restoration, but was accompanied by the abundant development of cyanobacteria, mainly that from the genus *Microcystis* (Wiśniewska and Skałecki 2001). The elimination of cyanobacteria from the community might have resulted from the fact that they prefer a low N/P ratio (Shapiro 1990, Lafforgue et al. 1995) since one of the effects of phosphorous inactivation was a decrease in the available phosphorous form in the lake (Marsden 1989) followed by changes in its ratio to nitrogen content (Łopata 2005). The elimination of cyanobacteria progressed gradually due to their lower half-saturation constants for phosphorous uptake (Saphiro 1990) and higher phosphatase activity (Giraudet et al. 1997), which renders this group capable of efficiently mineralizing organic phosphorous, a product of their own metabolism or that of competitive algal groups or zooplankton (Elser et al. 1987). Consequently, cyanobacteria can better secure higher amounts of total phosphorous for their own needs and maintain them at constant levels than can other algae (Jensen and Andersen 1992). This ensures that they can develop even in unfavorable, phosphorous-limited conditions. However, this strategy did not succeed during the process of phosphorous inactivation in Lake Głęboczek where blue-green algae failed to hold the dominant position.

The method applied to limit reactive phosphorous content through the chemical precipitation of excess of mineral phosphorous and its stabilization in bottom sediments led to shifts in the domination structure of the algal community and the inhibition of blue-green algae growth that finally resulted in a significant drop in phytoplankton development. The changes might indicate the decreasing trophic state of the lake that can only be maintained if phosphorous content limits phytoplankton growth. Therefore, it is necessary to monitor the lake periodically to ensure that the results achieved are stable and to not overlook the potential need for further lake restoration.

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