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Phytoplankton structure of two small lakes – changes after a decade

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Abstract

The species composition, biomass, and size structure of phytoplankton in Lake Modre and Lake Obrowo Małe in the Bytów Lake District (northern Poland) were studied to assess changes in their phytoplankton communities over a decade. The structure of phytoplankton in both lakes changed remarkably. The high contributions of chrysophytes to the phytoplankton biomass in 1993, which attested to the low trophic state of both lakes, were replaced in 2004 by high contributions of green algae in Lake Modre and of cyanobacteria in Lake Obrowo Małe. Picoplanktonic cells, particularly picocyanobacteria, reached higher abundance and made the highest contribution to total phytoplankton biomass in the lake with the lower trophic state.

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INTRODUCTION

Although phytoplankton varies in taxonomic composition and size structure, traditionally attention has focused mainly on larger organisms such as nanoplankton and microplankton. Mainly due to methodological difficulties, picoplanktonic organisms have usually been neglected. Only after the popularization of epifluorescence microscopy in the 1980s did reports on the size structure of all phytoplankton, including picoplankton, begin appearing in the literature. Many reports have shown that the contribution of picoplankton to the total phytoplankton biomass decreases with increasing trophic states (Stockner 1991, Weisse 1993). In Poland, however, the complete size structure of phytoplankton has been studied in few lakes. Some of the first lakes thus investigated are located in the Polish part of Pomerania, where such investigations were initiated in 1993 (Szeląg-Wasielewska 1994, 1997). These studies have been repeated recently in several lakes, which permits analyzing changes in their phytoplankton structure.

The aim of the present study was to describe the phytoplankton community and to assess changes in its structure over a decade with a particular focus on picoplanktonic cells. In order to make a phytoplankton comparison, water samples from two neighboring lakes were used. During the decade between sampling, one of the lakes was subjected to strong anthropogenic stress, but the second was not.

SITE DESCRIPTION

Lakes Modre and Obrowo Małe are located in the Bytów Lake District (northern Poland), 13 km northeast of Bytów. Their surface areas are 4.7 and 10.5 ha and maximal depths are 13.7 and 12 m, respectively. Both lakes, with slightly acidic waters, have no surface outflow and their catchments are covered by pine forests. They are called *Lobelia* lakes because of their specific vegetation (Szmal 1959). In the early 1990s, Kraska et al. (1992) classified Lake Modre as oligotrophic and Lake Obrowo Małe as oligo-mesotrophic based on analyses performed at the beginning of summer stratification. Typical thermal stratification is observed in both lakes. In the period between sampling, Lake Modre was subjected to strong anthropogenic stress, including stocking with fish and fish farming, whereas the nearby Lake Obrowo Małe was not strongly affected. The trophic state of the first lake increased and was classified as mesotrophic, while that of Lake Obrowo Małe decreased to oligotrophy (Kraska et al. 2004).

MATERIALS AND METHODS

Water samples for phytoplankton analysis were taken from the surface layer in September 1993 and 2004 as well as from the meta- and hypolimnion in 2004. Samples for the study of nano- (2-20 μm) and microplankton (>20 μm) were preserved in Lugol's solution and analyzed under an inverted microscope after sedimentation in settling chambers according to the method by Wetzel and Likens (1991) at magnifications of 40×, 150×, and 600×. The water samples analyzed for picoplankton (0.2-2.0 μm) were fixed in buffered glutaraldehyde (final concentration 1-2%) and stored in darkness at 4°C. Samples were filtered onto 0.2 μm black polycarbonate filters (Nuclepore), and then the filters were analyzed using an Olympus BX-60 System Microscope with a BX-FLA epifluorescence attachment (which was purchased by the Foundation for Polish Science within the scope of the SUBIN Program). Usually a magnification of 1500× was used, but when colonial cells were present lower magnifications were used (300× or 600×) and a larger surface or the whole surface area of the filter was investigated. Optic filter sets for green, blue, and ultra-violet excitation were used (MacIsaac, Stockner 1993). Picoplanktonic cells were classified as prokaryotic or eukaryotic on the basis of autofluorescence color, cell shape and size, and the presence of chloroplasts. Two groups of picocyanobacteria, single cells and colonies with diverse colonial morphology, were identified. The abundance of organisms was expressed as the number of cells per 1 ml. The volume of organisms was estimated based on microscopic measurements of their size, and then their biomass was expressed as wet weight assuming that a volume of 10^6 μm^3 is equivalent to 1 μg.

RESULTS AND DISCUSSION

In Lake Modre the mean phytoplankton biomass (1.5 mg l^{-1}) was about four times higher than in Lake Obrowo Małe (0.36 mg l^{-1}). Nevertheless, in both lakes the maximum biomass was recorded in the metalimnion (Fig. 1). In Lake Modre it reached nearly 2 mg l^{-1}, mainly thanks to *Gonyostomum semen* (Ehr.) Diesing, whose contribution to the total phytoplankton biomass in that zone was 78%. In the hypolimnion, its contribution to the total biomass was also high (75%), but its biomass was three times lower than in the metalimnion. In the earlier study, this species was not recorded in Lake Modre, although it was observed in many other *Lobelia* lakes (Szeląg-Wasielewska 2003). *G. semen*, as reported by Arvola et al. (1999), is abundant in the phytoplankton of small mid-forest lakes with dark water. This species is regarded as characteristic for small mid-forest water bodies that are subject to eutrophication (Kawecka, Eloranta

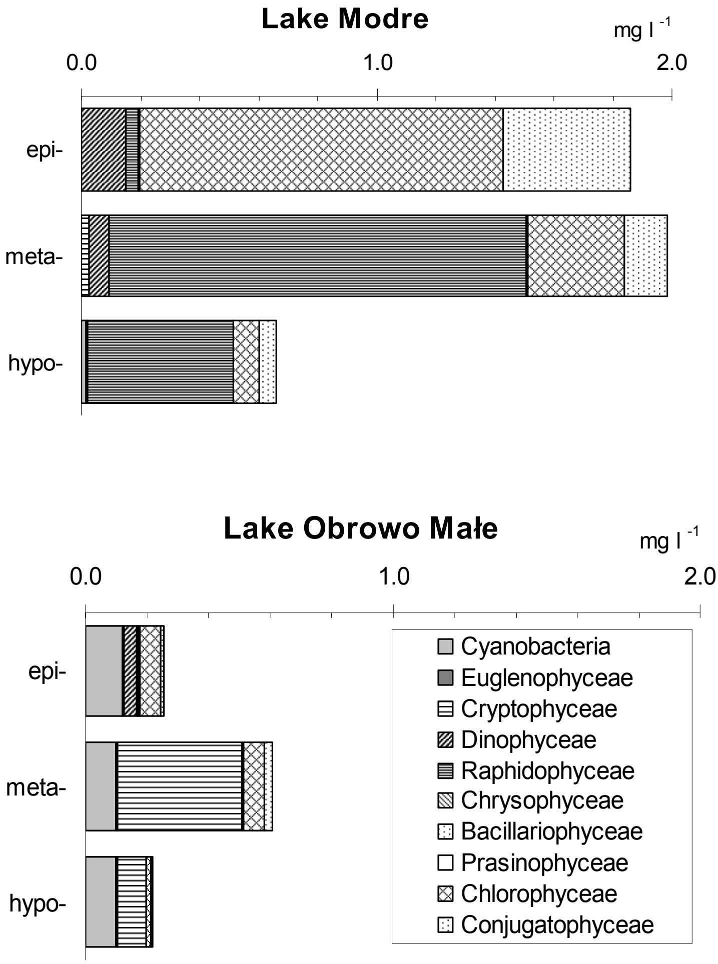

Fig. 1. Vertical variation in the biomass (mg l^{-1}) of phytoplankton taxonomic groups in the studied lakes in September 2004.

1994). In contrast, the epilimnion of Lake Modre was dominated by green algae, which accounted for 89% of the total biomass. Such a distribution of phytoplankton biomass in this lake is confirmation of earlier reports (e.g., Turpin 1988) that phototrophic flagellates tend to accumulate in deeper water layers such as the meta- and hypolimnion.

In Lake Obrowo Małe, the maximum biomass in the metalimnion resulted from a large population of another flagellate, the cryptomonad *Cryptomonas* *phaseolus* Skuja, whose contribution to the total biomass reached 65% (Fig. 1). This species, as reported by Starmach (1974), inhabits waters containing hydrogen sulfide and is often accompanied by other organisms that oxidize sulfur. In this lake, in contrast to Lake Modre, a high proportion of the biomass (14-46%) was contributed by cyanobacteria. Picoplanktonic cells dominated in cyanobacterial populations. The densities and biomass of picocyanobacteria varied with in a rather small range from 1.8×10^5 to 1.9×10^5 cells ml^{-1} and from 0.10 to 0.12 mg l^{-1}, respectively. The highest value was recorded in the epilimnion (Table 1), where about 19% of cells formed colonies. Deeper down, in the meta- and hypolimnion, the contribution of colonial cyanobacteria to picophytoplankton abundance was insignificant. Picoplanktonic green algae were not abundant and their contribution to picophytoplankton biomass did not exceed 1% in any thermal layer. In contrast, the Lake Modre eukaryotic

Table 1

Cell number and biomass of picocyanobacteria (Pcy) and eukaryotic picoplankton (E-PP) in the epilimnion of the studied lakes.

Parameter	Group	Lake			
		Modre		Obrowo Małe	
		1993	2004	1993	2004
Abundance 10^3 cells ml^{-1}	Pcy	7.25	0.99	12.89	191.34
	E-PP	-	0.84	-	0.26
Biomass mg l^{-1}	Pcy	0.004	0.001	0.007	0.117
	E-PP	-	0.004	-	0.001

picoplankton was more numerous, particularly in the hypolimnion, where *Choricystis minor* (Skuja) Fott exceeded the density of 7×10^3 cells ml^{-1}. This confirms that eukaryotic picoplankton prefer colder and more fertile waters (Weisse 1993).

In the size structure of phytoplankton the larger cells, whose size exceeded 2 μm, i.e. nano- and microplankton, made a very high contribution to the total biomass in Lake Modre (nearly 100%), except in the hypolimnion, where picoplankton contributed 6%. In contrast, the contribution of picoplankton to phytoplankton biomass in Lake Obrowo Małe was high (maximum 46%, mean 36%) (Fig. 2). The lower contribution of picoplankton in the metalimnion (17%) could have resulted from the grazing pressure of mixotrophic flagellates of the genus *Cryptomonas*. Together with other consumers, e.g. colorless flagellates and rotifers, they are considered to be important factors controlling picoplankton abundance (Stockner et al. 2000).

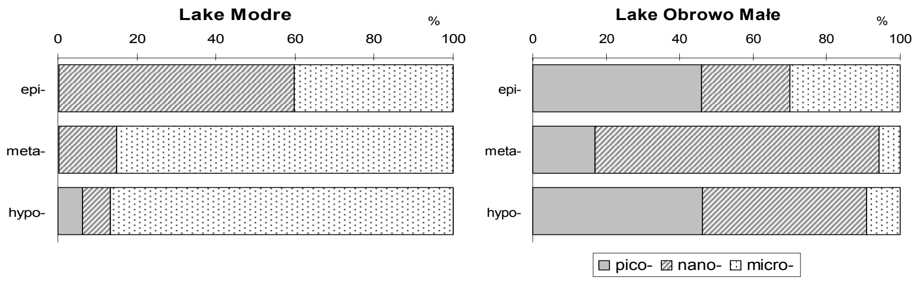

Fig. 2. Vertical variation in the biomass (mg l^{-1}) of phytoplankton size fractions in the studied lakes in September 2004.

Earlier research on the phytoplankton in the epilimnion of both lakes in 1993 indicated that phytoplankton biomass in Lake Modre was nearly three times as high as in Lake Obrowo Małe. Chrysophytes, mainly *Dinobryon pediforme* (Lemm.) Steinecke, comprised 98% of it. At the same time, in Lake Obrowo Małe no group dominated so clearly, but the main contributors to total biomass were again chrysophytes (35%), accompanied mainly by green algae and dinophytes (Table 2). In the samples collected in 2004 for the present study, the contribution of chrysophytes to the phytoplankton biomass in Lake Modre decreased to about 1%, while that of green algae increased to about 90%. In Lake Obrowo Małe the contribution of chrysophytes to phytoplankton biomass decreased to 2%, but the contribution of green algae did not change. Instead, the contribution of cyanobacteria in this lake increased ten times to about 40%. Cyanobacteria were classified as picoplankton due to their small size.

Phytoplankton biomass in both lakes in 1993 was dominated by microplanktonic organisms (Szeląg-Wasielewska 1994). In contrast, the 2004 Lake Modre phytoplankton biomass was dominated by nanoplankton, while that in Lake Obrowo Małe was dominated by picoplankton (Fig. 2). The higher abundance of picocyanobacteria and the increased contribution of picophytoplankton to the total phytoplankton biomass in Lake Obrowo Małe can be explained by the decrease (probably temporary) in its trophic level. In turn, the negligible contribution of picocyanobacteria to phytoplankton biomass in Lake Modre is probably due to its increased trophic level caused by the intensified anthropogenic stress on that ecosystem. This is consistent with the report by Weisse and Mindl (2002), who found that picocyanobacteria are highly sensitive bioindicators of contaminant stress.

Table 2

Five most important taxa in the phytoplankton biomass in the epilimnion of the studied lakes in September 1993 and 2004. The values in brackets are contribution (%) of the taxa to total biomass

Lake Modre		Lake Obrowo Małe	
Name of taxa	**Biomass mg l^{-1}**	**Name of taxa**	**Biomass mg l^{-1}**
1993			
Dinobryon pediforme (Lemm.) *Steinecke*	5.083 (98.3)	*Dinobryon divergens* Imhof	0.399 (18.5)
Merismopedia punctata Meyen	0.042 (0.80)	*Dinobryon bavaricum* Imhof	0.301 (16.4)
Peridinium sp.	0.009 (0.17)	*Gymnodinium* sp.	0.259 (14.1)
Synechocystis sp.	0.007 (0.14)	*Quadrigula closterioides* (Bohlin) Printz	0.254 (13.8)
Oocystis nephrocystoides Fott et Čado	0.003 (0.06)	*Gonyostomum semen* (Ehr.) Diesing	0.188 (10.2)
2004			
Coenochloris mucosa (Korš.) Hindák	1.099 (59.0)	*Synechocystis* sp.	0.095 (36.9)
Staurodesmus extensus (Anders.) Teiling	0.318 (17.1)	*Elakatothrix gelatinosa* Wille	0.044 (17.1)
Gymnodinium sp.	0.092 (4.9)	*Gymnodinium* sp.	0.042 (16.3)
Elakatothrix gelatinosa Wille	0.062 (3.3)	*Quadrigula* sp.	0.010 (3.9)
Quadrigula sp.	0.058 (3.1)	*Cryptomonas marssonii* Skuja	0.005 (1.9)

CONCLUSION

The phytoplankton structure in both of the studied lakes changed remarkably over the decade. The high contribution of chrysophytes to phytoplankton biomass in 1993, which attested to the low trophic state of both lakes, was replaced in 2004 by high contributions of green algae in Lake Modre and of cyanobacteria in Lake Obrowo Małe. The changes observed indicate that the trophic levels had increased in Lake Modre and decreased in Lake Obrowo Małe since a high contribution of picocyanobacteria to total phytoplankton is considered characteristic of lakes with low trophic levels. Besides, this study showed that in lakes with a relatively low trophic level a large proportion of phytoplankton biomass is concentrated in the deeper layers of water, which is associated with changes in species composition. Thus, it is necessary to analyze the entire vertical water column.

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