Arch. Pol. Fish. (2009) 17: 267-278
DOI 10.2478/v10086-009-0019-7

RESEARCH ARTICLE

Seasonal changes in net phytoplankton in two lakes with differing morphometry and trophic status (northeast Poland)

Received – 16 March 2009/Accepted – 02 July 2009. Published online: 30 December 2009; ©Inland Fisheries Institute in Olsztyn, Poland

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Abstract. The aim of the present study was to identify seasonal changes in net phytoplankton communities as indicators of the trophic state in two lakes with differing morphometry and trophic states. These studies were conducted in Lake Maróz from May to November 1995 and 1996 and in Lake Jeziorak Mały in 1996 and 1997. Differences in the abundance, biomass, species diversity, and dominant taxa of particular groups of phytoplankton between these lakes were analyzed. Lake Jeziorak Mały, which has a smaller area and shallower depth, is more susceptible to degradation than is Lake Maróz. The results of studies confirm that there are differences in the net phytoplankton communities and physiochemical water parameters in the studied lakes. The abundance of blue-greens (60760 indiv. dm^{-3}), dominated by *Limnothrix redekei* (Van Goor) Meffert, noted from May to October was almost nine-times higher in Lake Jeziorak Mały. The oxygen deficiency in the spring season and low mean visibility (0.7 m) also confirmed that this lake is polytrophic, while the lower abundance of blue-green algae (7022 indiv. dm^{-3}), the great abundance of dinoflagellates, and the higher mean visibility (2.12 m) in Lake Maróz indicated that these waters are mesoeutrophic.

Keywords: lake, net phytoplankton, trophic state, thermal and oxygen conditions

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Introduction

The eutrophication of waters, and all the negative consequences, are accelerated by anthropogenic factors. Primarily, these include discharges of municipal and industrial sewage into surface waters, and inflows from the catchment area of waters rich in nutrients and other substances (Kajak 1979, Hillbricht-Ilkowska 1986). Excessive quantities of nutrients in water bodies might result in the mass occurrence of some planktonic alga species, such as *Aphanizomenon flos-aque* (L.) Ralfs, *Microcystis aeruginosa* (Kütz.) Lemmermann, *Asterionella formosa* Hassall, and *Ceratium hirundinella* (O.F. Müller) Bergh., which often cause blooms in waters (Vollenveider 1968, Spodniewska 1979, Bucka 1989). One consequence of this is the decomposition of organic matter in the waters that often cause oxygen deficits, which, in turn, can resuspend nutrients from the sediments to the water, thus causing secondary pollution of water bodies (Lampert and Sommer 1996). These processes vary widely in lakes with differing morphometry.

Planktonic algae are subject to ecological succession. Lampert and Sommer (1996) define succession as an orderly process of directional changes in the species structure of the biocenosis, which may proceed for several hundred, or even several thousand years, or which may be a regular and repeatable sequence of changes in the biocenosis, resulting from cyclical environmental changes (*e.g.*, annual phytoplankton). The phenomenon is affected by a variety of factors such as seasonal changes in water temperature and intensity of solar radiation or water mixing and the resuspension of biogenic elements, including phosphorus, from sediments (Sommer et al. 1986, Reynolds 1993).

Lakes Maróz and Jeziorak Mały are examples of water bodies with differing morphometry and trophic status. The preliminary results of studies of qualitative and quantitative changes in phytoplankton in 1996 were presented at the XVII International Symposium of the Phycological Section of the Botanical Society (Zębek et al. 1998); this work focused on biomass and dominant taxa. The aim of the study was to identify seasonal changes in the net phytoplankton community as an indicator of trophic status as related to morphometric features and environmental conditions in lakes Maróz and Jeziorak Mały.

Materials and Methods

Study area

Lakes Maróz and Jeziorak Mały are located in the Mazurian lake district in northeast Poland. According to Stangenberg's typology cited in Ciepielewski (1971), Lake Maróz is an eutrophic water body and covers a total area of 332.5 ha and has a maximum depth of 41 m (Table 1). The catchment is largely forested. Numerous small summer houses, camping areas, and holiday centers are situated around the lake, which are used mainly in the summer. During the period studied, there was no sewage treatment plant in the vicinity of the lake, which meant that the lake was subjected to intense, regular inputs of raw sewage. For many years, the Marózka River, which flows through the lake, was a source of sewage inflows from neighboring localities (Zdanowski et al. 2006). Moerover, the sandy-gravely bottom underwent silting (Wilkońska and Żuromska 1982, Wilkońska et al. 1994). According to Korycki (1963), the Lake Maróz littoral zone was dominated by the vascular plant *Phragmites communis* Trin., which occupied an area of 15.7 ha along the shoreline.

Table 1
Limnological parameters of lakes Maróz and Jeziorak Mały (Korycki 1963, Cydzik and Soszka 1988)

Parameter	L. Maróz	L. Jeziorak Mały
Surface area (ha)	332.5	26.0
Volume of lake (thous. m^3)	39566.2	890.9
Maximum depth (m)	41	6.4
Mean depth (m)	11.9	3.4
Maximum length (m)	5580	805
Maximum width (m)	1200	365
Length of shore line (m)	18000	2330
Mean Secchi disc transparency (m)	2.12	0.70
Giziński's coefficient of mixing	0.7	0.9

The urban Lake Jeziorak Mały covers a total area of 26 ha and has a maximum depth of 6.4 m (Table 1). According to Spodniewska (1986), and based on investigations of phytoplankton communities in 1978, this lake is classified as a polytrophic water body. For many decades the lake received untreated municipal sewage from the town of Iława (about 30,000 inhabitants). Since 1991, however, municipal sewage has been treated at a local wastewater treatment plant. In 1997, part of the lake shores were covered with concrete or reinforced with fascine, and a considerable part of the bottom was covered in stones and gravel. In the 1996-1997 period, about 10% of the littoral zone was overgrown by vascular plants, mainly *Phragmites communis*, *Scirpus lacustris* (L.), *Acorus calamus* L., and *Glyceria aquatica* (L.) Wahlb., and at this time the bottom was muddy and covered with decomposing plant debris.

Phytoplankton sampling and analysis

As is done in other ecological studies such as Vezina and Pace (1994) and Nassar and Shams El-Din (2006), the net phytoplankton fraction used as the trophic status indicator was that above 30 μm (Lampert and Sommer 1996). Samples were collected monthly (May, June, August, September, October, November) in 1995 and 1996 in Lake Maróz, and from May to November 1996 and 1997 in Lake Jeziorak Mały. The samples were collected with a Toń 5-liter plankton sampler in the pelagic zone. The samples were poured through a 30 μm mesh plankton net, and then preserved with Lugol's solution and a 4% formaldehyde solution. A total of 28 samples were collected. The following physiochemical water parameters were determined: temperature (°C) and oxygen concentration (mg O_2 dm^{-3} with a HI 9143 DO meter (Hanna Instruments, Italy) and Secchi disc transparency (m). Because of the different morphometry of the lakes (total area, depth; Table 1), the mixing coefficient was calculated as proposed by Giziński (1978):

$$M = 4.4 \times \sqrt{d} \times Gs^{-1}$$

where, d – length of run-up of waves in km, Gs – mean depth.

Quantitative and qualitative determinations of phytoplankton were performed in a 1 ml plankton chamber with an BIOLAR optical microscope (PZO Warsaw, Poland) at magnifications of 10x, 20x, and 40x. Phytoplankton biomass was calculated for biovolume by comparing algae to their geometrical shapes (Rott 1981); abundance and biomass are given per 1 dm^3. For the analysis, abundance and biomass means of phytoplankton were used to represent the sum of the abundance or biomass respectively, divided by the number of samples. The Shannon-Weaver species diversity index was analyzed based on the abundance of the phytoplankton community (Kawecka and Eloranta 1994).

Results

Lakes characteristics

In comparison to Lake Jeziorak Mały, Lake Maróz has a total area that is approximately 12-times larger and a water volume that is approximately 44-times higher. The lake is six-times deeper at the maximum depth and three-times the mean depth, and its shoreline is more than seven-times longer than that of Lake Jeziorak Mały. Differences in other coefficients were also recorded; mean Secchi disc visibility was three-times higher in Lake Maróz. However, in Lake Jeziorak Mały the mixing coefficient recorded was about 0.2-times higher (Table 1).

Physiochemical water parameters

Changes in water temperature and surface layer oxygenation in the pelagic zone and water column were analyzed in lakes Maróz and Jeziorak Mały to provide a comparative background for the net phytoplankton communities. Changes in surface layer water temperature in the pelagic zone were similar from May to October in the two lakes. Water temperature increased from May to August, when it reached the maximum (22.1 and 25.1°C, respectively); it then decreased to 12°C from August to October. Water temperature was higher in Lake Jeziorak Mały than in Lake Maróz. The highest differences in water temperature of almost 4°C were noted in May (17.3 and 13.4°C, respectively), while the most similar temperatures were recorded in October (Fig. 1).

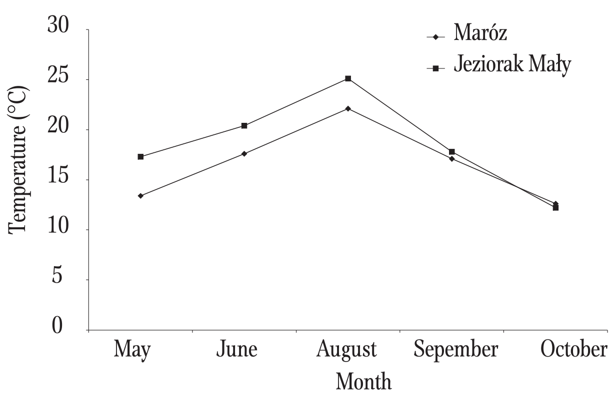

Figure 1. Mean water temperature in the surface layer of the pelagic zone lakes Maróz and Jeziorak Mały in 1996. Data according Szymańska (2002), and Zębek (2002).

The surface layers of the pelagic zone were more oxygenated in Lake Maróz than in Lake Jeziorak Mały, especially in the spring (May) and autumn (September, October); the oxygen content was higher by about 1 mg O_2 dm^{-3} and almost 6 mg O_2 dm^{-3}, respectively. In the summer months (July, August), the opposite was observed, because oxygen content was higher in Lake Jeziorak Mały than in Lake Maróz

(11.7 and 9.6 mg O_2 dm^{-3}, respectively). Differences in the oxygenation of the water column were also recorded. Oxygen deficits in the bottom layer were noted from May to September in Lake Jeziorak Mały (at a depth of 4 m) and from August to October in Lake Maróz (at a depth of 10 m; Fig. 2a and 2b).

respectively). However, the opposite was noted with regard to biomass, the mean total of which was 0.093 mg dm^{-3} in Lake Maróz and 0.068 mg dm^{-3} in Lake Jeziorak Mały (Table 2).

The abundance and biomass of phytoplankton were dominated by blue-greens (92.83 and 75.00%, re-

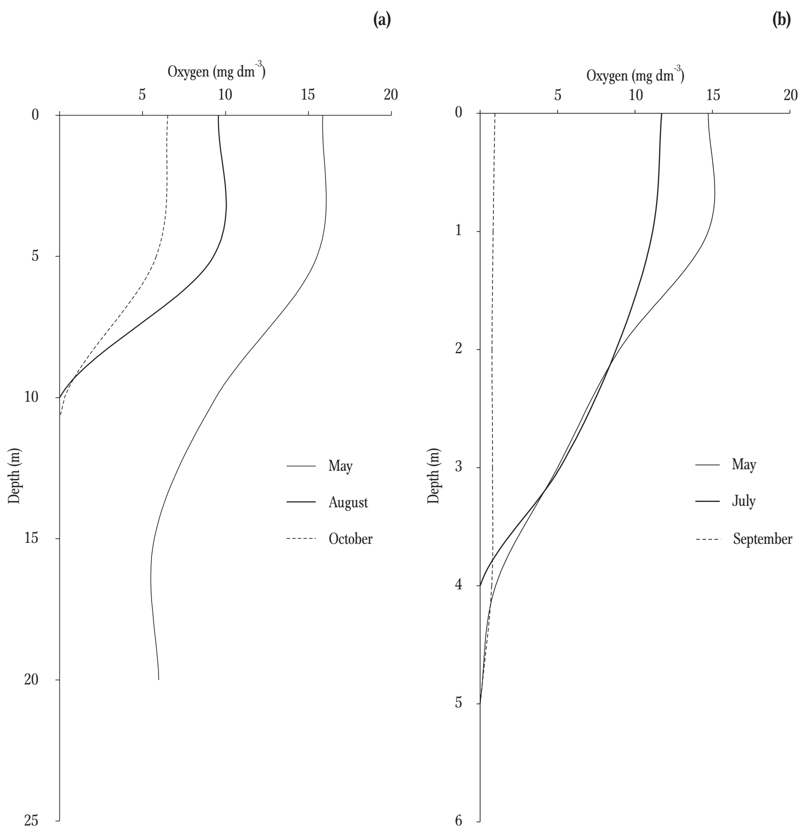

Figure 2. Oxygen stratification in lakes Maróz (a) and Jeziorak Mały (b) in 1996. Data according Szymańska (2002), and Zębek (2002).

Net phytoplankton
General characteristics

The following taxonomic groups of phytoplankton were recorded in Lake Maróz in 1995 and 1996 and Lake Jeziorak Mały in 1996 and 1997 in the surface layer of the pelagic zone: Cyanophyta; Bacillariophyceae; Chlorophyta; Dinophyceae; Chrysophyceae; with additional groups Euglenophyta and Cryptophyceae. The mean total abundance of phytoplankton in Lake Jeziorak Mały was five-times that of Lake Maróz (65457 and 13177 indiv. dm^{-3}, spectively) in Lake Jeziorak Mały. The other groups contributing to the total phytoplankton abundance and biomass included diatoms (5.94%) and dinoflagellates (11.76%). While blue-greens also dominated the total abundance of phytoplankton in Lake Maróz, in comparison to Jeziorak Mały abundance was nine-times lower at a proportional level of 53.28%. Dinoflagellates dominated the biomass (65.60%) accompanied by green algae (16.12%) (Fig. 3). The Shannon-Weaver species diversity index noted in Lake Maróz was nearly as twice as high as that in Lake Jeziorak Mały (at 61 and 85 taxa; Table 2).

Table 2
Mean abundance and biomass and species diversity indices for phytoplankton in 1995 and 1996 in Lake Maróz and in 1996 and 1997 in Lake Jeziorak Mały

Phytoplankton group	L. Maróz		L. Jeziorak Mały	
	abundance (indiv. dm^{-3})	biomass (mg dm^{-3})	abundance (indiv. dm^{-3})	biomass (mg dm^{-3})
Cyanophyta	7022	0.008	60760	0.051
Bacillariophyceae	3966	0.006	3883	0.004
Chlorophyta	173	0.015	327	0.002
Dinophyceae	1155	0.061	226	0.008
Chrysophyceae	850	0.002	34	0.001
Remaining groups*	11	0.001	227	0.002
Total	13177	0.093	65457	0.068
Number of taxa	61		85	
Shannon-Weaver diversity index	3.159		1.732	

* remaining – Euglenophyta i Cryptophyceae

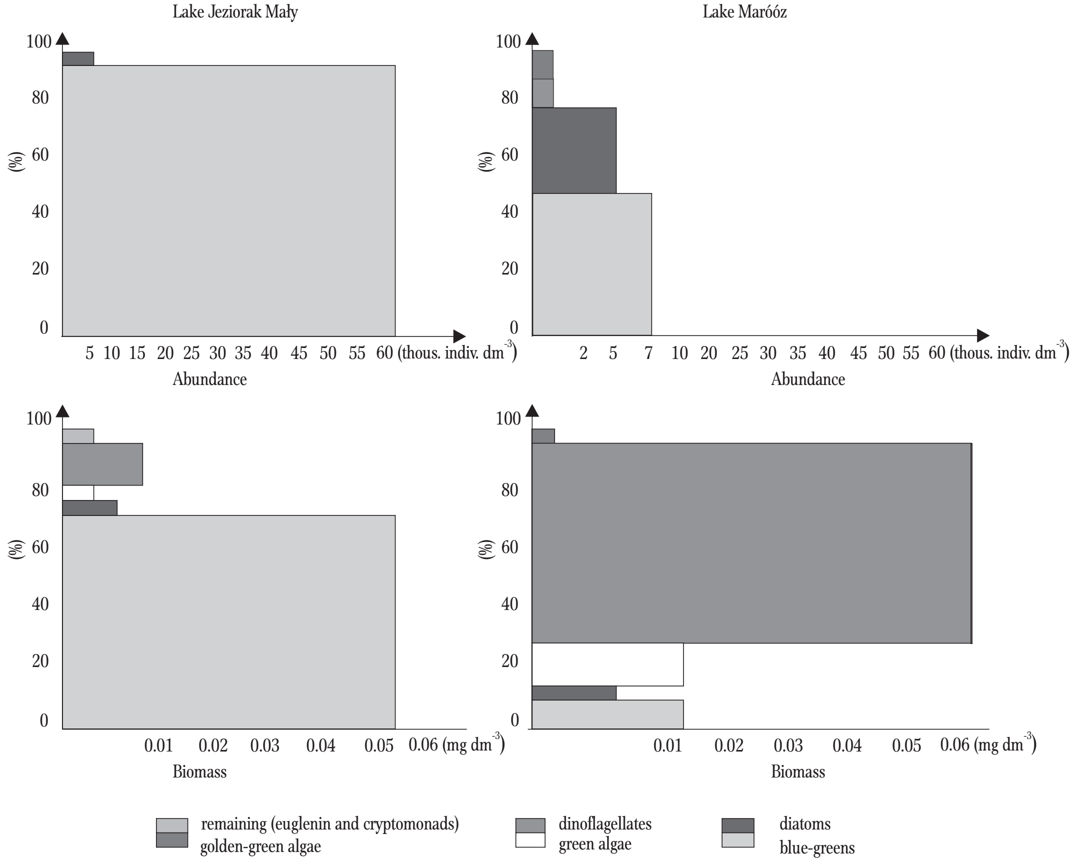

Figure 3. Relation between mean abundance and biomass of the taxonomic groups of phytoplankton in 1996-1997 (Lake Jeziorak Mały) and 1995-1996 (Lake Maróz).

Seasonal changes in the abundance and biomass of phytoplankton

Blue-greens dominated the total abundance of phytoplankton from May to October and the total biomass from May to September in Lake Jeziorak Mały. The abundance and biomass of the algae group increased from May to July (maximum – 98.70 and 96.60%, respectively), then decreased from August to November (Fig. 4). In comparison to Lake Jeziorak Mały, the increase in blue-green abundance and biomass was shifted in time and happened from September to November (maximum – 88.40 and 70.89%, respectively). The abundance and biomass of phytoplankton was dominated by diatoms in the spring season (May) in Lake Maróz, and in the fall season (November) in Lake Jeziorak Mały. An increase in the abundance of diatoms (maximum – 86.59%) and in the biomass of green algae (maximum – 74.56%) were observed from May to June in Lake Maróz, whereas the domination of green algae at a level of 56.93% was noted just in November in Lake Jeziorak Mały. The abundance and biomass of dinoflagellates (maximum – 49.69 and 96.76%, respectively) also increased in Lake Maróz in the summer season (from June to August); they decreased in the fall (September and October). A considerable proportion of golden-green algae at (47.11% of the total abundance of phytoplankton) was noted in this lake. As an accompanying taxa, increased dinoflagellate biomass was shifted in time (August and September). However, cryptomonads dominated in October and accounted for 72.08% of the total biomass of phytoplankton in this lake (Fig. 4).

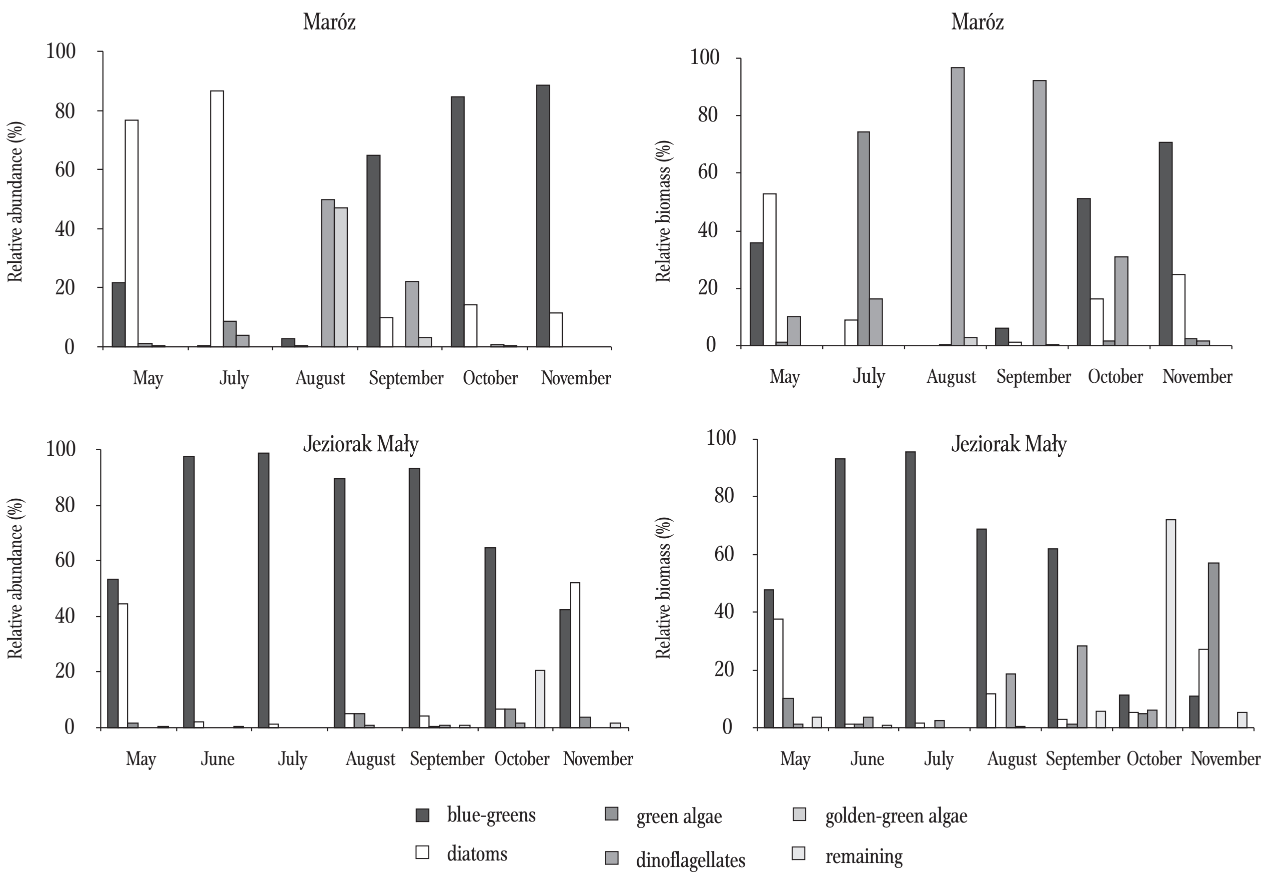

Figure 4. Seasonal variability in the mean proportion of taxonomic groups in the total abundance and biomass of phytoplankton in 1995-1996 (Lake Maróz) and 1996-1997 (Lake Jeziorak Mały).

Dominant taxa of the phytoplankton community

In the spring season (May), the highest abundance among the blue-greens community was reached by the genera *Phormidium* spp. (Maróz) and *L. redekei* (Jeziorak Mały).The highest abundance of diatoms and green algae taxa – *Fragilaria crotonensis* Kitton (4968 indiv. dm^{-3}) and *Chlamydomonas* spp. (448 indiv. dm^{-3}), respectively, were also noted in Lake Jeziorak Mały (Fig. 5). The highest abundance of the taxa of these algae groups – *F. crotonensis* (4447 indiv. dm^{-3}), *A. formosa* (5118 indiv. dm^{-3}), and *Spirogyra* sp. (813 indiv. dm^{-3}), was noted in Lake Maróz in June. *A. formosa* reached the highest abundance in August in Lake Jeziorak Mały. There was a rapid increase in the abundance of the blue-greens *L. redekei* in July (309300 indiv. dm^{-3}) and *Planktolyngbya brevicellularis* Cronberg & Komarek in August (20880 indiv. dm^{-3}) in summer in Lake Jeziorak Mały (Fig. 5). However, during this period in Lake Maróz, there was an increase in the abundance of *C. hirundinella* (dinoflagellate) and the genus *Dinobryon* sp. (golden-green alga), which peaked in August at 6438 and 6167 indiv. dm^{-3}, respectively. In Lake Jeziorak Mały, the genus *Dinobryon* sp. also appeared in August, as did *C. hirundinella* in September, but the abundance was lower than in Lake Maróz. In fall, the abundance of the species of the blue-green group (*L. redekei* and *P. brevicellularis*) decreased in Lake Jeziorak Mały, while *L. redekei* increased rapidly in Lake Maróz peaking in October. However, the abundance of this species was almost nine-times lower (34200 indiv. dm^{-3}) than that in

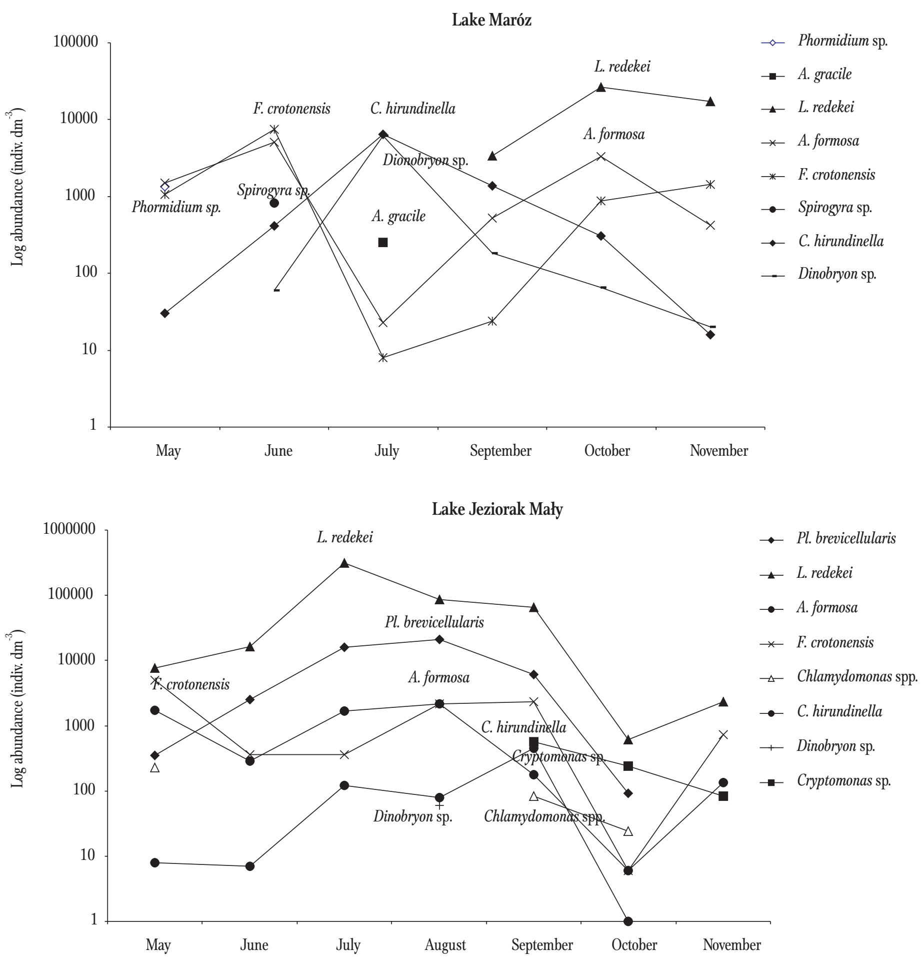

Figure 5. Mean abundance of dominant taxa in the total abundance of phytoplankton from May to November in 1995-1996 (Lake Maróz) and 1996-1997 (Lake Jeziorak Mały).

Lake Jeziorak Mały. The highest taxa abundance of cryptomonads and green algae groups – *Cryptomonas* sp. (September) and *Koliella variabilis* (Nygaard) Hindak (November), also occurred in autumn in Lake Jeziorak Mały (Fig. 5).

Discussion

The trophic status of lakes can be affected by morphometry and the character of the catchment area. Both the morphometric features and characters of the catchment basins of lakes Maróz and Jeziorak Mały differ. Lake Maróz has a large surface area, a deeper maximum depth, and a largely forested catchment area, while Lake Jeziorak Mały has a small surface area, a shallow depth, and an urban catchment area (Table 1). Because of these features, the waters of Lake Jeziorak Mały warm more quickly than those of Lake Maróz, as is confirmed by the higher water temperatures in the former, especially in the spring and summer seasons (Fig. 1). Moreover, summer thermal stratification was not noted in Lake Jeziorak Mały. The waters of shallow water bodies are subject to continuous mixing, and the Giziński (1978) mixing coefficient for this lake is very high at 0.9 (Table 1). According to the Stangenberg classification (Stangenberg 1936 cited in Jankowski 1966), this lake is polimictic, while according to Wiszniewski (Wiszniewski 1953 cited in Jankowski 1966) it is a polimictic pond–type lake. Lake Maróz is deep, and water mixing is slower. The mixing coefficient for this lake was lower (0.7) in comparison to that of Lake Jeziorak Mały (Table 1). The rapid increase in water temperature in May in Lake Jeziorak Mały might have indirectly influenced the spring oxygen deficit (Fig. 2b). In comparison to Lake Jeziorak Mały, the oxygen deficit at the bottom was noted later (August) in Lake Maróz (Fig. 2a), and this could have been related to increased sewage inflows during the summer tourist season. According to Barone and Naselli-Flores (2003), shallow lakes have a greater tendency to increase in tropic status than do large lakes. This was true of Lake Jeziorak Mały, which was more susceptible to degradation because of its small size and shallow depth than was Lake Maróz with its larger surface area and greater depth.

Phytoplankton is one of the crucial coefficients of trophic status in lakes. According to Spodniewska (1986), differences in the dynamics of phytoplankton development in shallow and deep lakes is partly because of different depths. In shallow lakes, the short vegetation period and intensive water mixing can resuspend biogenic elements from the sediments (Wiśniewski 1995). In deep lakes, the dynamics of changes in phytoplankton development are wider and depend to a greater degree on the irradiation of the water layers. The resuspension of sediments in Lake Jeziorak Mały was an additional source of phosphorus that could have stimulated the development of blue-greens (Zębek 2002), especially during periods of oxygen deficit at the bottom. An additional factor in the development of algae might also have been high water temperature in spring and fall, which was almost 4°C higher than in Lake Maróz (Fig. 1). The abundance of blue-greens was almost nine-times higher in Lake Jeziorak Mały than in Lake Maróz (Table 2).

In highly eutrophic pond-type lakes, increased water turbidity can result from the mass occurrence of algae and the intense mixing of waters during spring and fall circulation, which leads to increased organic matter release from the sediments to the water column (Kawecka and Eloranta 1994). This occurred in Lake Jeziorak Mały, where intensive water mixing and blue-green development could possibly have caused decreased turbidity. A considerably lower mean Secchi disc visibility (0.7 m) was noted in this lake than in Lake Maróz (2.12 m; Table 1). According to Pillsbury et al. (2002), an increase in the irradiation of waters stimulates the development of some filamentous green algae. In Lake Maróz, the high mean transparency could have favored the development of some taxonomic groups of phytoplankton such as green algae, which reached 16.25% of the total phytoplankton biomass (Fig. 3).

Species diversity is a measure of the fertility of a water body, and it is defined as the relative abundance of particular species (Kawecka and Eloranta

1994). The greater the diversity of conditions and the closer they are to normal optima, the larger the number of species; however, the more the conditions deviate from normal, hence from the normal optima of most species (even temporarily only), the smaller the number of species is which occur there and the greater the dominance is of some species (e.g., blue-greens) (Remmert 1985, Lampert and Sommer 1996). A lower Shannon-Weaver index was noted in Lake Jeziorak Mały than in Lake Maróz (at 85 and 61 taxa, respectively) (Table 2), which means that the phytoplankton community was dominated by one species of blue-greens – *L. redekei* (Fig. 5).

According to Reynolds (1984), the domination of blue-greens confirms the high trophic status of a lake. Numerous authors have recorded the domination of this algae group in late spring and summer in shallow eutrophic and polytrophic lakes. Spodniewska (1986) noted an increase in the abundance of blue-greens as early as in the spring in a shallow eutrophic, pond-type lake, while Nixdorf (1994) recorded the maximum biomass of prokaryotic algae in May and July. The domination of blue-greens in the total phytoplankton abundance and biomass at 92.83and 75.00%, respectively (Fig. 3), from May to October in 1996 and 1997 in Lake Jeziorak Mały might confirm the polytrophic status of this water body. The continuous mixing of waters, as mentioned previously, could possible be an additional source of phosphorus when this element is resuspended from the sediments. The phytoplankton community could be shaped indirectly by blue-greens, which, in comparison to diatoms and green algae, reached higher abundance and biomass (Fig. 3). This occurred especially in the summer, when blue-greens contributed to reducing the phosphorus content of the water, thus competing with other taxonomic groups of algae (Zębek 2005). However, the shift of blue-green domination to the autumn (September, October, November) (Fig. 4) in Lake Maróz could have been linked to the high input of this biogenic element during the tourist season in summer and the subsequently, slowly cooling water.

The blue-green communities in lakes Jeziorak Mały and Maróz were dominated by *L. redekei* from May to November in 1996-1997 and 1995-1996, respectively (Zębek 1998). The accompanying taxa included *P. brevicelullaris*, and *Phormidium* spp. and *A. gracile*, respectively (Fig. 5). According to Reynolds (1984) and Wernicke and Nicklish (1986), *L. redekei* is typical of hypertrophic waters while *A. gracile* is a typical mesotrophic water species; however, according to Cronberg and Komarek (1994), *P. brevicellularis* develops first in mesotrophic and eutrophic waters. The maximum abundance of *L. redekei* was noted in July in Lake Jeziorak Mały, but not until October in Lake Maróz. The highest abundance of *P. brevicelullaris* and the genus *Phormidium* spp. were noted in May, and that of *A. gracile* was observed in August (Fig. 5). Numerous authors have also reported maximum abundances of blue-green species in spring and summer. Nixdorf (1994) reported the peak abundance of *L. redekei* from April to May in a shallow eutrophic lake, while Laugaste et al. (1996) did so in August in a mesotrophic lake. Nixdorf et al. (2003) recorded the highest abundance of *P. limnetica* in August and of *A. gracile* in July and August in a shallow eutrophic lake. Reynolds et al. (2002) classified the following blue-greens as *Planktothrix agradhii*, *Pseudanabaena* spp., and the species of the genus *Limnothrix* as functional group S_1. The species belonging to this group develop in waters that are frequently turbulent with low irradiation. They are often accompanied by *A. gracile*. This species system of functional group S_1 was identified in the phytoplankton of Lake Jeziorak Mały, which confirms that this lake is highly eutrophic with frequent water mixing.

The greatest abundance in the diatom community was noted in lakes Maróz and Jeziorak Mały from May to November in 1995-1996 and 1996-1997, respectively, and the species were *F. crotonensis* and *A. formosa.* The highest abundance of *F. crotonensis* was reached in May in Lake Jeziorak Mały and in November in Lake Maróz, while that of *A. formosa* occurred in August and June, respectively (Fig. 5). Van Dam et al. (1994) classified *F. crotonensis* as a mesotrophic water species. Laugaste et al. (1996) reported the domination of this species in a mesotrophic lake, and Guzowska and Gasse (1990) reported it in a polytrophic lake located in an urban catchment area. Huszar et al. (2003) recorded a great abundance of *F. crotonensis* at lower water temperatures (15°C) in spring. However, *A. formosa* often occurs in the plankton, causing blooms in eutrophic lakes (Siemińska 1964 cited in Bucka 1989). According to Reynolds (1986) and Van Dam et al. (1994), the diatom is a cryophilic species, which occurs in early spring at a water temperature of 4°C, but its can grow intensively from June to October at water temperatures between 16 and 20°C (Bucka 1989). Laugaste et al. (1996) reported the domination of *A. formosa* in spring in a mesotrophic lake.

According to Reynolds (1978), while dinoflagellates are characteristic of eutrophic water bodies, they do not occur in hypertrophic waters. They can comprise from 30 to 75% of the biomass in eutrophic lakes (Bucka 1989). The proportion of this algae group in the total phytoplankton biomass was 65.60% in Lake Maróz and 11.76% in Lake Jeziorak Mały (Fig. 3). Numerous authors have reported the mass occurrence of dinoflagellates in spring (Spodniewska 1974 cited in Bucka 1989) and summer (Gligora at al. 2003) in eutrophic lakes. However, Munawar et al. (1991) observed the domination of diatoms first, followed by that of golden-green algae and dinoflagellates in spring, and then a decrease in the abundance of diatoms, golden-green algae, and green algae in summer in a mesotrophic lake. A similar situation occurred in Lake Maróz (Fig. 4). The annual pattern of the succession of dominants in nutrient-rich lakes often follows the dinoflagellate to blue-green pattern (Bucka 1989), as it occurred in Lake Maróz.

Spirogyra sp. achieved the highest abundance of all green algae communities in June in Lake Maróz, while *Chlamydomonas* spp. (May) and *K. variabilis* did so in November in Lake Jeziorak Mały (Fig. 5). Celewicz-Gołdyn (2005) recorded the occurrence of *Spirogyra* sp. in the pelagic zone of a shallow eutrophic lake. *Chlamydomonas spp.* is also a genus typical of eutrophic lakes. Reynolds (1986) reported a great abundance of *Chlamydomonas* spp. at low water temperatures, and Nixdorf (1994) did the same in summer during the water mixing in the epilimniom of a eutrophic lake.

Among the dinoflagellates in lakes Maróz and Jeziorak Mały, the highest abundance was of *C. hirundinella* in August and September, respectively (Fig. 5). The mass occurrence of this species has been noted in spring (Noges and Laugaste 1998) and in summer in a mesotrophic lake (Huszar et al. 2003) and a shallow eutrophic lake (Gligora et al. 2003). A great abundance of golden-green algae was also noted in August in Lake Maróz, while cryptomonads were noted in October in Lake Jeziorak Mały (Fig. 3). The highest abundance of golden-green algae was recorded for the genus *Dinobryon* sp., while among cryptomonads it was of the genus *Cryptomonas* spp. The high biomass of *Dinobryon* sp. was noted in spring in a mesotrophic lake (Laugaste et al. 1996) and in November in a mesoeutrophic lake (Naselli-Flores and Barone 2000). However, the genus *Cryptomonas* spp. often occurs in eutrophic waters (Sládeček et al. 1958 cited in Bucka 1989, Barone and Naselli-Flores 2003).

The data and literature cited above regarding the ecological requirements of the dominant taxa of phytoplankton and their order of occurrence from May to November, confirm that lakes Maróz (in 1995 and 1996) and Jeziorak Mały (in 1996 and 1997) have different trophic statuses The domination and high abundance of taxa that are typical of highly eutrophic waters, such as *L. redekei* and *Chlamydomonas* spp. in Jeziorak Mały, indicate that the lake is polytrophic. Although *L. redekei* also occurred in great abundance in Lake Maróz, its abundance was still considerably lower (almost nine-times) than it was in Lake Jeziorak Mały. However, the domination of dinoflagellate species *C. hirundinella* and the great abundance of the genus *Dinobryon* sp. in the summer in Lake Maróz indicates that these waters are mesoeutrophic.

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Streszczenie

Sezonowe zmiany fitoplanktonu sieciowego w dwóch jeziorach o zróżnicowanej morfometrii i trofii (północno-wschodnia Polska)

Celem pracy było określenie różnic pomiędzy sezonowymi zmianami zbiorowisk fitoplanktonu sieciowego jako wskaźnika trofii w dwóch jeziorach o zróżnicowanej morfometrii i trofii. Badania prowadzono od maja do listopada w latach 1995 i 1996 w jeziorze Maróz oraz 1996 i 1997 w jeziorze Jeziorak Mały. Analizowano różnice w liczebności, biomasie, różnorodności gatunkowej i taksonach dominujących poszczególnych grup taksonomicznych fitoplanktonu pomiędzy tymi jeziorami. Jezioro Jeziorak Mały ze względu na mniejszą powierzchnię i głębokość jest jeziorem bardziej podatnym na degradację niż Maróz. Wyniki badań świadczą o zróżnicowaniu w zbiorowiskach fitoplanktonu sieciowego i fizyczno-chemicznych parametrach wody w badanych jeziorach. W jeziorze Jeziorak Mały odnotowano prawie 9-krotnie wyższe liczebności sinic (60760 osobn. dm^{-3}), które dominowały *(Limnothrix redekei)* od maja do października, a także deficyty tlenowe w sezonie wiosennym oraz niską średnią widzialność (0,7 m), co może świadczyć o politroficznym charakterze wód tego zbiornika. Natomiast niższe liczebności sinic (7022 osobn. dm^{-3}), liczne występowanie bruzdnic i wyższa średnia widzialność (2,1 m) w jeziorze Maróz wskazują mezo-eutroficzny charakter wód.