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SEASONAL CHANGES IN THE PALNKTONIC AND PERIPHYTIC DIATOMS WITH RELATION TO PHYSIOCHEMICAL WATER PARAMETERS IN THE LITTORAL ZONE OF THE LAKE JEZIORAK MAŁY

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Abstract. Studies on net phytoplankton and plant periphyton were conducted in the littoral zone of the Lake Jeziorak Mały (Mazurian Lakeland) in 2002 and 2003. Species diversity and similarity between the planktonic and periphytic diatom communities; changes in their abundance and biomass with respect to water temperature, oxygenation, electrolytic conductivity and biogene concentrations (PO_4, Ca and Si) and dominant taxa in the total diatom biomass of these communities from April to October were analyzed. Despite high trophy of the lake was affirmed a high species diversity of both communities and dominant taxa typical of meso and eutrophic waters. The relation was observed between the communities of planktonic and periphytic diatoms, confirming that the coefficient of similarity (69%) and common dominant in the summer season (*D. vulgaris* – as a typical component of plant periphyton).

Key words: lake, littoral zone, planktonic and periphytic diatoms

INTRODUCTION

The ecoton (littoral) zones of lakes have wide structural variety with various dynamics of ecological processes and are particularly sensitive to changes in environmental conditions and anthropogenic pressures [Radwan *et al.* 1998]. The littoral zone is an effective biofilter of pollutions inflowing from the catchment [Burchardt 1998, Hillbricht-Ilkowska and Pieczyńska 1993 cited in Radwan *et al.* 1998]. The effectiveness of stopping invading biogenic elements depends on the diversity of the inhabiting plant and animal biota, including periphyton communities [Reynolds 1988]. In the periphyton communities, the great majority of phytoplankton are diatoms [Bohr and Miotk 1979, Hansson 1990]. The urban Lake Jeziorak Mały is an example of a highly eutrophic water body, where the littoral zone is anthropogenic diverse. The aim of the present study was to determine seasonal changes in the planktonic and periphytic diatoms with respect to physiochemical water parameters and relation between these communities in the anthropogenic diverse littoral zone of the Lake Jeziorak Mały, and was conducted during 2002 and 2003.

RESEARCH AREA, MATERIALS AND METHODS

The urban Lake Jeziorak Mały covers a total area of 26 ha (maximum depth 6.4 m, mean depth 3.4 m, water volume 891 000 m^3). For many decades the lake received untreated municipal sewage from the town of Iława. Since 1991, however, effluent has been treated at a local wastewater treatment plant. Work to improve the lake water quality began in 1997 and has been ongoing since that time, including the installation of separators for the pretreatment of storm water influent, and a fountain-based water aeration system.

Samples were collected monthly from April to October 2002 and 2003, at six sites located in the littoral zone: separators (two sites situated at pipe outlets, which drain storm water), stations with stony-gravel substrates (two sites with stones and rubble constructed in 1997) and stations overgrown by vascular plants (two sites with no anthropogenic transformation, which have muddy bottoms covered with rotting plant remnants).

The samples of net phytoplankton were collected with a 10 dm^3 calibrated bucket (20l at each site), filtered through a no. 30 plankton net, and preserved in Lugol's solution followed by a 4% formaldehyde solution. The plant periphyton was scraped from the pipes and stones (1 cm^2) and from macrophyte leaves (cut off 5 cm length) and preserved in formaldehyde and ethanol solution. A total of 144 samples were collected in 2002 and 2003. The following physicochemical water parameters were determined: temperature (^oC), oxygen content (mg O_2 l^{-1}) (using an HI 9143 oxygen meter), electrolytic conductivity (μS cm^{-1}) (using a CONMET 1 conductometer), and orthophosphate (mg PO_4 l^{-1}), silicon (mg Si l^{-1}) and calcium (mg Ca l^{-1}) concentrations (using a NOVA 400 spectrophotometer).

Diatom samples were prepared following standard procedures, as described by Battarbee [1986 cited in Stoermer *et al.* 1987]. Qualitative and quantitative determinations of diatoms were performed with an Eclipse 800 optical microscope at 20×, 40×, 60× and 100× magnifications, under oil immersion. The specimens were counted in a 1 ml plankton chamber. Diatom biomass was calculated for biovolume by comparing algae to their geometrical shapes [Rott 1981]. Abundance and biomass of planktonic diatoms were given per 1l and periphytic diatoms per 1 cm^2. Shannon-Weaver species diversity index and Jaccard similarity coefficient between the species composition of the planktonic and periphytic diatoms were analyzed [Shannon-Weaver 1949 and Jaccard 1912 cited in Kawecka and Eloranta 1994] at assumption that the value above 60% confirm the similarity of these communities. In the analysis, means were applied that represented the sum of the abundance of individuals or the biomass of diatoms divided by the number of measurements.

RESULTS

In the litoral zone of Lake Jeziorak Mały in 2002 and 2003, the periphytic diatoms reached higher proportion in the total abundance and biomass of periphytic algae than the planktonic diatoms in the total abundance and biomass of net phytoplankton (abundance 84.92% and 15.26% and biomass 39.64% and 9.67%, respectively) at mean water temperature 18.4°C, oxygen content 7.75 mg O_2 l^{-1}, electrolytic conductivity 382 µS cm^{-1}, orthophosphates 0.46 mg PO_4 l^{-1}, calcium 97 mg Ca l^{-1} and silicon 0.79 mg Si l^{-1}. In the case of periphytic diatoms in comparison to planktonic diatoms, was noted also higher Shannon-Weaver species diversity index (4.2639 bit $ind.^{-1}$ and 4.0030 bit $ind.^{-1}$, respectively) for 63 and 57 taxa. The Jaccard coefficient defining similarity between the species composition of these communities was 69% (Tab. 1).

Table 1. Abundance and biomass of planktonic and periphytic diatoms and species diversity and similarity indicies in the littoral zone of the Lake Jeziorak Mały (means of the years 2002 and 2003)

Parameters	Planktonic diatoms	Periphytic diatoms
Abundance, ind. l^{-1}/ind. cm^{-2}	3655	1665596
Proportion in the total abundance of phytoplankton/periphytic algae, %	15.26	84.92
Biomass, mg l^{-1}/mg cm^{-2}	0.0086	1.2322
Proportion in the total biomass of phytoplankton/periphytic algae, %	9.67	39.64
Number of taxa	57	63
Shannon-Weaver species diversity index, bit·$ind.^{-1}$	4.0030	4.2639
Jaccard similarity coefficient, %	69	

Two abundance peaks of the planktonic and periphytic diatoms (May and Sepember, June and September, respectively) were noted in the studied period. The maximum abundance of planktonic diatoms was in September (7914 ind. l^{-1}) and the periphytic diatoms in June (2421894 ind. cm^{-2}). In the case of biomass,

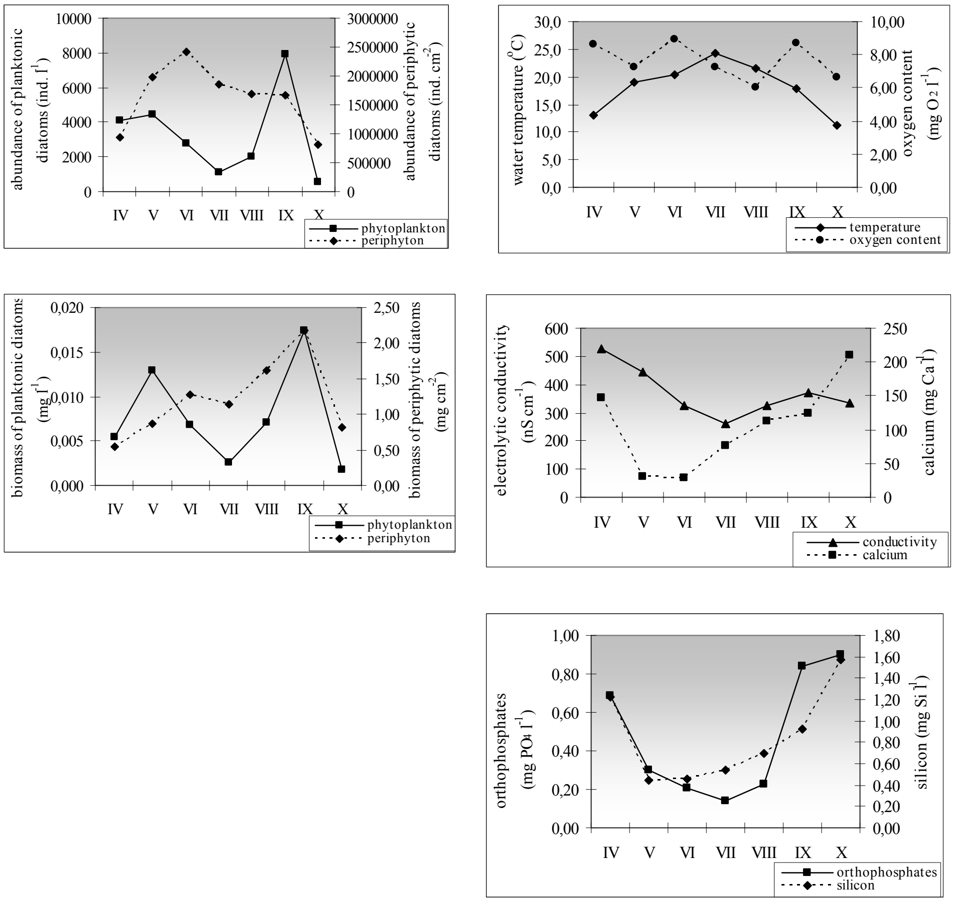

Fig. 1. Abundance and biomass of planktonic and periphytic diatoms and physiochemical water parameters from April to October in the littoral zone of the Lake Jeziorak Mały (means of the years 2002 and 2003)

both planktonic and periphytic diatoms, the maximum reached in September (0.0174 mg l^{-1} and 2.1765 mg cm^{-2}, respectively). An increase in the diatom abundance and biomass of both communities was followed by a decrease in water temperature and an increase in oxygenation, electrolytic conductivity and biogene concentrations (PO_4, Ca and Si), especially from July to September (Fig. 1).

In the spring season, in the case of biomass, the planktonic diatoms was dominated by the genus *Fragilaria* spp. [*F. crotonensis* Kitton and *F. delicatissima* (W. Smith) Lange-Bertalot], and the periphytic diatoms by small forms such as *Nitzschia frustulum* (Kütz.) Grunow in Cleve & Grunow and *Navicula gregaria* Donkin. In the summer season, in the plankton dominated large forms of diatoms (*Fragilaria acus*, *Diatoma vulgaris* Bory and *Rhizosolenia* sp.), however in

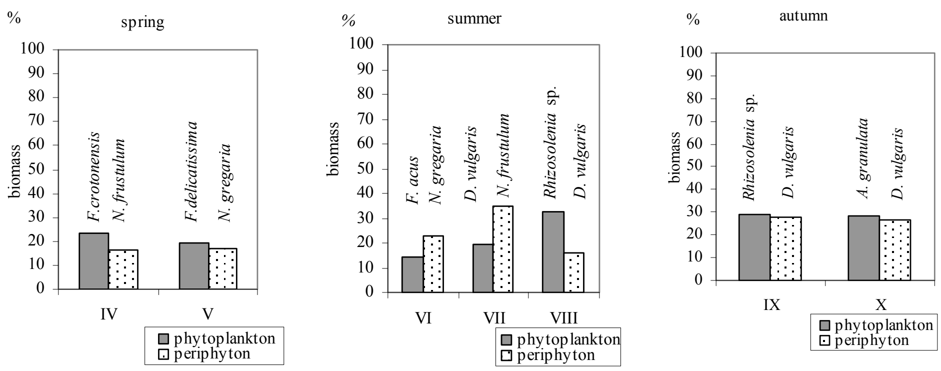

Fig. 2. Dominant taxa in the total biomass of planktonic and periphytic diatoms from April to October in the littoral zone of the Lake Jeziorak Mały (means of the years 2002 and 2003)

the periphyton in turn *N. gregaria, N. frustulum* and *D. vulgaris*. In the autumn season, the plankon was dominated by the genus *Rhizosolenia* sp. in September and *Aulacoseira granulata* (Ehrenberg) Simonsen in October. In this period among the periphyton, *D. vulgaris* still reached the highest proportion in the total biomass (Fig. 2).

DISCUSSION

The littoral zones of shallow lakes with small surfaces and classified as polytrophic, are usually overgrown by macrophytes (reeds, sweet flag, bulrush). However, the littoral zone of Lake Jeziorak Mały was anthropogenically transformed with the installation of separators and the piling up of stones and gravel, which results in new habitats being created for animals and plants, including plant periphyton. In the periphyton communities, the great majority of phytoplankton are diatoms [Bohr and Miotk 1979]. In Lake Jeziorak Mały in 2002 and 2003, the proportion of diatoms in the total abundance and biomass of periphytic algae (84.92 and 39.62%) was higher than in the planktonic algae (39.64% and 9.67%) (Tab. 1). Kuczyńska-Kippen *et al.* [2004] recorded a lower proportion of diatom level of 39% in the total abundance of epiphytic periphyton. However, Romo and Miracle [1994] reported higher proportion of diatoms in the total biomass of phytoplankton (35%) and in the total abundance of phytoplankton (40%) in a shallow eutrophic lake. The above data and cited literature suggest that in Lake Jeziorak Mały, the proportion of diatoms in the total abundance and biomass of phytoplanton was somewhat lower than has noted for eutrophic lakes. This fact could be caused by the great abundance of blue-greens (to 90% of the total abundance of phytoplankton) [Zębek 2005]. However, in the case of periphytic diatoms, in comparison to literature data were noted higher differences in both abundance and biomass, could be relate with higher differences in the substrates (pipes, stones and macrophyte leaves), which were habitat for plant periphyton.

Plankton in the littoral zone are often accompanied by forms of periphytic algae, including diatoms, which are might possibly influence the increase in their species diversity [Millie and Lowe 1981]. Shannon-Weaver species diversity indicies were noted on the level from 3.46 to 3.60 bit ind. $^{-1}$ in a eutrophic lake [Heinonen 1980]. In Lake Jeziorak Mały, the indicies calculation for periphytic and planktonic diatoms were higher and ranged above 4 bit. ind.$^{-1}$ (Tab. 1). This may suggest that the transformation littoral zone of the lake, which results in new habitats (pipes, stones) being created for plant periphyton, could influence the increase in species diversity of the periphytic and planktonic diatoms. Moreover, the similarity of species composition between these communities on the level of 69% can indicate the relation between periphytic and planktonic diatoms.

Seasonal changes in the abundance and biomass of both planktonic and periphytic diatoms in strongly eutrophic lakes may be affected by a variety of factors such as water temperature, oxygenation, phosphor, silicon and calcium concentrations [Reynolds 1986, Krebs 1996]. Dominance of planktonic diatoms has been reported often in spring and autumn seasons [Dokulil and Padisak 1994]. Diatoms better development at lower water temperatures [Reynolds 1986] and high silicon concentration [Nixdorf 1994]. In Lake Jeziorak Mały, a decrease in water temperature and an increase in oxygen content, electrolytic conductivity, orthophosphate, calcium and silicon concentrations could favor the development of diatoms of both communities, especially from July to September. The communities, maximum biomass reached in September. In the case of planktonic diatoms, maximum of abundance was noted also in September and periphytic diatoms in June (Fig. 1). This fact could be caused by the differences in the mean biomass of a single individual of dominant taxa of the diatoms. In the spring and summer seasons (from April to August), the highest proportion in the total biomass reached small forms of the diatoms such as *Nitzschia frustulum* and *Navicula gregaria*, and from August to October – *D. vulgaris* of larger biomass of a single individual (Fig. 2). Moreover, in the spring season, in the planktonic diatom community the highest proportion in the total biomass reached the genus *Fragilaria* spp. (*F. crotonensis* and *F. delicatissima*) and in the summer and autumn seasons in turn *F. acus*, *Rhizosolenia* sp. and *A. granulata*, which in the literature they are often have been reported as dominants of phytoplankton in these periods [Danilov and Ekelund 2001, Poulickova *et al.* 2004]. According to Van Dam *et al.* [1994] the dominant taxa of diatoms of both communities are typical of meso and eutrophic waters.

In Lake Jeziorak Mały, *D. vulgaris* was a common dominant of both communities and often occurs in the littoral zone of lakes [Goma 2004] as a component of plant periphyton [Kuczyńska-Kippen *et al*. 2004, Zębek 2008]. In shallow water bodies the frequent mixing waters maybe cause that the species typical of benthos (periphyton) can often step out in plankton in the pelagic zone

[Burchardt and Messyasz 2004]. In the studied lake, the dominance of *D. vulgaris* in both communities can confirm their similarity and relation between these diatoms, which results was the rinsing fragments of plant periphyton from pipes during flow of storm waters, and from stones and submerged macrophytes.

CONCLUSION

The anthropogenically transformation of the littoral zone of Lake Jeziorak Mały with the installation of separators and the piling up of stones and gravel, being created new habitats for plant periphyton, could influence an increase in the species diversity of periphytic and planktonic diatoms and relationships between these communities, confirming that the species similarity and the common dominant *Diatoma vulgaris*.

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SEZONOWE ZMIANY OKRZEMEK PLANKTONOWYCH I PERYFITONOWYCH NA TLE FIZYCZNO-CHEMICZNYCH PARAMETRÓW WODY W STREFIE BRZEGOWEJ JEZIORA JEZIORAK MAŁY

Streszczenie. Badania fitoplanktonu sieciowego i peryfitonu roślinnego prowadzono w strefie brzegowej jeziora Jeziorak Mały w latach 2002 i 2003. W pracy analizowano różnorodność gatunkową i podobieństwo pomiędzy zbiorowiskami okrzemek planktonowych i peryfitonowych, zmiany ich liczebności i biomasy na tle temperatury wody, natlenienia, przewodności elektrolitycznej wody i zawartości biogenów (PO_4, Ca i Si) oraz taksony dominujące w ogólnej biomasie okrzemek tych zbiorowisk w sezonie od kwietnia do października. Pomimo wysokiej trofii jeziora, stwierdzono wysoką różnorodność gatunkową obu zbiorowisk oraz taksony dominujące, typowe dla wód mezo- i eutroficznych. Stwierdzono relacje pomiędzy zbiorowiskami okrzemek peryfitonowych a planktonowych, o czym może świadczyć współczynnik podobieństwa (69%) oraz wspólny dominant w sezonie letnim (*D. vulgaris* – typowy składnik peryfitonu roślinnego).

Słowa kluczowe: jezioro, strefa brzegowa, okrzemki planktonowe i peryfitonowe