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Changes of species diversity of phytoplankton and physicochemical water parameters in annual cycles in the urban Lake Jeziorak Mały

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Abstract

The study was conducted on net phytoplankton in the littoral zone of the urban Lake Jeziorak Mały (Mazurian Lakeland) in annual cycles during the 1998-2003 period. The relation between the species diversity (Shannon-Weaver index) of blue-greens, diatoms, and green algae and their abundance and water temperature and orthophosphate concentration were analyzed in annual cycles. The lowest index of blue-greens was noted in July when abundance was at the maximum. The highest numbers of diatoms were recorded in October at low species diversity. However, the highest index of green algae species diversity was noted in September at the maximum abundance. Similar tendencies were noted for blue-greens and green algae. Increased water temperatures were followed by a decrease in the species diversity index while an increase in orthophosphate concentration was followed by an increase in this index. A slight increase in the diatom species diversity index was noted at an increased water temperature and a decreased orthophosphate concentration.

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INTRODUCTION

Phytoplankton has a short vegetation season thus it responds quickly to environmental changes; this is manifest in the increase or decrease in species diversity, abundance, or the numbers of particular taxonomic groups and variations in their structure (Kawecka and Eloranta 1994, Zębek 2004).

Species diversity is defined as the relative abundance of particular species (Kawecka and Eloranta 1994). Differences in biocenotic diversity are determined based on Thienemann's Principles (Remmert 1985, Lampert and Sommer 1996):

1. The greater the diversity of conditions in a locality, and the closer they are to normal optima, the larger the number of species is that comprise the community.
2. 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.

The urban Lake Jeziorak Mały might be an example of a strongly eutrophic water body where net phytoplankton communities are often dominated by blue-greens throughout the year (Zębek 1998, 2005a, 2005b, 2006).

The aim of the present study was to determine changes in the species diversity of net phytoplankton as related to water temperature and orthophosphate concentration in the littoral zone of the urban Lake Jeziorak Mały in annual cycles.

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 municipal sewage from the town of Iława. Effluents have been treated at a local wastewater treatment plant since 1991, and work to restore the lake begun in 1997 has been ongoing and includes the installation of separators for the pretreatment of storm water influents and a fountain-based water aeration system.

Samples were collected monthly from April to October during the 1998-2003 period at six sites located in the littoral zone. The samples were collected with a 10 dm^3 calibrated bucket (20 l at each site), filtered through a no. 30 plankton net, and preserved in Lugol's solution followed by a 4% formaldehyde solution. A total of 226 samples were collected. The following physicochemical water parameters were determined: temperature (°C) – with a HI 9143 oxygen

meter; orthophosphate concentration ($mgPO_4$ dm^{-3}) – with a NOVA 400 spectrophotometer.

Quantitative and qualitative determinations of phytoplankton were performed with an Alphaphot YS2 NIKON optical microscope at magnifications of ×10, ×20, ×40, and ×60. The specimens were counted in a 1 ml plankton chamber, and their number is given in dm^3.

The species diversity from the net phytoplankton community was analyzed to calculate the Shannon-Weaver index, which provides information on the species abundance and the distribution of particular phytoplankton species. An increase in species diversity for calculating this index is followed by an increase in the number of species and the settlement of individual species in the sample. The relation between the species diversity of blue-greens, diatoms, and green algae and their abundance and water temperature and orthophosphate concentration were analyzed in annual cycles. In the analysis, means were applied that represented the sum of the numbers of individuals, while physicochemical parameters were divided by the number of measurements.

RESULTS AND DISCUSSION

According to the objective of the study, changes in the Shannon-Weaver species diversity index calculated for blue-greens, diatoms, and green algae in annual cycles were analyzed with respect to water temperature and orthophosphate concentration. Based on the data in Table 1, differences were determined in this index of particular phytoplankton groups. The highest mean

Table 1

Mean annual Shannon-Weaver species diversity indices and physicochemical water parameters in the littoral zone of Lake Jeziorak Mały (means for the 1998-2003 period)

Parameters	blue-greens	diatoms	green algae
species diversity index (bit $indiv^{-1}$)	1.020	2.523	2.213
number of species	20	92	88
abundance (indiv. dm^{-3})	16681	8827	553
water temperature (ºC)	18.3		
orthophosphate concentration ($mgPO_4$ dm^{-3})	0.34		

annual species diversity index was noted for diatoms (2.523 bit indiv.$^{-1}$), while it was somewhat lower for green algae (2.213 bit indiv.$^{-1}$) and the lowest for blue-greens (1.020 bit indiv.$^{-1}$). The number of species were 92, 88, and 20, respectively. Among the studied groups of phytoplankton, the highest mean annual abundance was recorded for blue-greens (16681 indiv. dm^{-3}), followed by diatoms (8827 indiv. dm^{-3}), and then the lowest for green algae (553 indiv. dm^{-3}) at a mean annual water temperature of 18.3°C and an orthophosphate concentration of 0.34 mg PO_4dm^{-3}.

Heinonen (1980) reported similar Shannon-Weaver index calculations for phytoplankton that ranged from 3.46 to 3.60 bit indiv.$^{-1}$ for 94 species in a eutrophic lake; however, in a hypertrophic lake this figure was 3.03 bit indiv.$^{-1}$ for 92 species. Eloranta (1986) also recorded an index level of 2.76 bit indiv. $^{-1}$ in a eutrophic lake. This may suggest that the species diversity index values noted in Lake Jeziorak Mały are characteristic for eutrophic lakes.

In the 1998-2003 period in Lake Jeziorak Mały, differences in the diversity index for particular groups of phytoplankton were observed in annual cycles. The data shown in fig. 1 indicate that the highest index of blue-greens was in May (1.447 bit indiv.$^{-1}$) and the lowest was in July (0.290 bit indiv.$^{-1}$), while for diatoms it was August (2.930 bit indiv.$^{-1}$) and May (2.191 bit indiv.$^{-1}$), and for green algae it was September (2.698 bit indiv.$^{-1}$) and May (1.855 bit indiv.$^{-1}$), respectively.

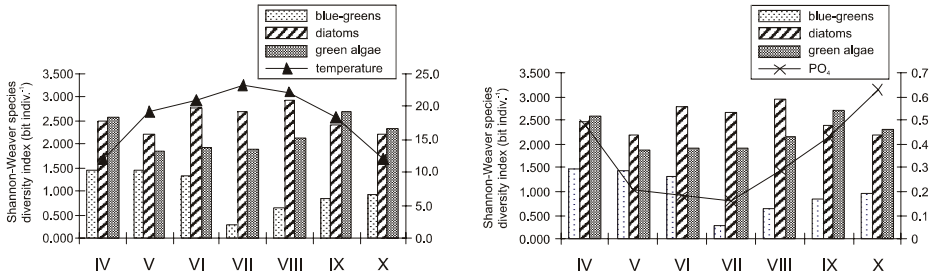

Fig. 1. Shannon-Weaver species diversity indices for phytoplankton by water temperature and orthophosphate concentration in annual cycles in the urban Lake Jeziorak Mały (means from the 1998-2003 period).

Relations throughout annual cycles were observed between the diversity index of blue-greens, diatoms, and green algae and water temperature and orthophosphate concentration. Similar tendencies were noted for blue-greens and green algae. An increase in water temperature (from 12.0°C to 23.2°C) was followed by a decrease in the diversity index from April to July. The opposite was also observed; a decrease in water temperature (from 22.2°C to 12.1°C) was

followed by an increase in the index from August to October. Different situations were observed regarding orthophosphate concentration. In the April-July period, a decline in orthophosphate concentration (from 0.48 mg PO_4dm^{-3} to 0.16 PO_4dm^{-3}) was accompanied by a decrease in the species diversity index, while an increase in this nutrient (from 0.29 PO_4dm^{-3} to 0.63 PO_4dm^{-3}) was followed by an increase in the index from August to October. The situation regarding diatoms was different, and the diversity index was almost stable. A small increase in the index along with an increase in water temperature was noted in the May-June period, while a decrease in the index was noted from August to October when water temperatures dropped. Decreases in water orthophosphate concentration were accompanied, however, by an increase in the diversity index (Fig. 1).

Jeppensen et al. (2000) established the link between phytoplankton species diversity and phosphorus concentrations in the waters of shallow eutrophic lakes. The highest Shannon-Weaver index (2.3 bit indiv. dm^{-3}) was recorded at phosphorus levels of 0.05 to 0.1 mgP dm^{-3} when diatoms and blue-greens predominated, while at values above 0.4 mg P dm^{-3} green algae and diatoms predominated. This can suggest that particular groups of phytoplankton reached their highest diversity in other months: blue-greens in May, diatoms in August, green algae in September. Moreover, blue-greens and green algae reacted similarly while diatoms did so differently to water temperature and the orthophosphate concentration, as is confirmed by changes in the diversity index.

Figure 2 presents the relations observed between the species diversity index and the abundance of the studied phytoplankton groups in Lake Jeziorak Mały

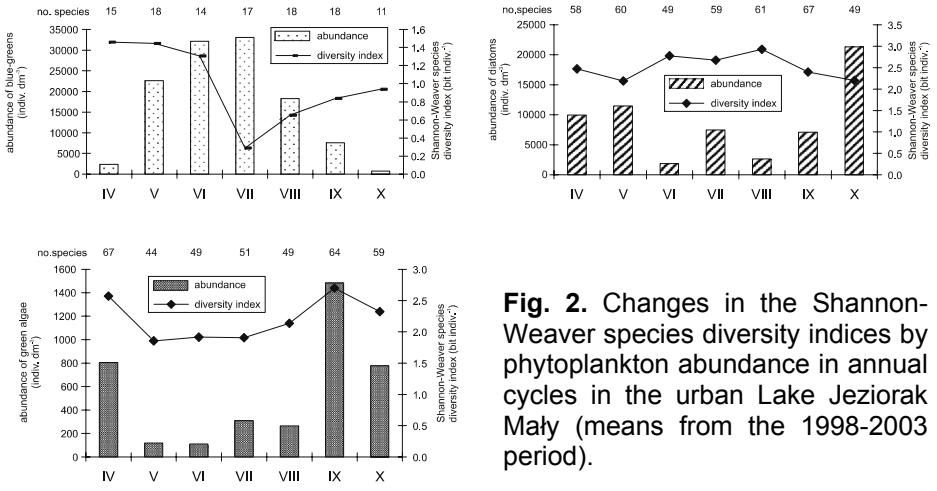

Fig. 2. Changes in the Shannon-Weaver species diversity indices by phytoplankton abundance in annual cycles in the urban Lake Jeziorak Mały (means from the 1998-2003 period).

in the 1998-2003 period. In the case of blue-greens, the lowest Shannon-Weaver index was noted in July at maximum abundance (33066 indiv. dm^{-3}) and a high number of species (17). This situation could have resulted from the domination of one species (*Planktolyngbya brevicellularis*), which was reported in earlier works (Zębek 1998, 2005a, 2005b, 2006).

According to Reynolds (1988), a decrease in the species diversity of phytoplankton that also occurred in summer could have been caused by the mass occurrence of one species from the genus *Oscillatoria* sp. In Lake Jeziorak Mały, diatoms reached maximum abundance in October (21322 indiv. dm^{-3}) at low species diversity (2.199 bit individ.$^{-1}$) and at 49 species. During this season, high abundance was noted of diatoms from the genera *Fragilaria* spp. (*F. delicatissima, F. crotonensis, F. capucina, F. ulna*) and *Aulacoseira* spp. (*A. granulata*, *A. granulata* var. *angustissima*). Low water temperature and the considerable concentrations of nutrients such as silicon, calcium, and orthophosphates could have favored the development of this phytoplankton group (Zębek, in press). However, in the case of green algae the highest diversity index was noted in September at maximum abundance (1484 indiv. dm^{-3}) and a high number of species (64). In this group high abundance was attained by algae from the genera *Chlamydomonas* spp., *Monoraphidium* spp. *(M. concortum, M. griffithii), Koliella* spp., and *Pediastrum duplex.* This may suggest that in September there were favorable conditions for the development of green algae, such as a high mean water temperature (18.4°C) and a high total nitrogen content (a mean of 2.9 mg N dm^{-3} for the 2001-2003 period; Zębek, unpublished data). Rojo and Cobelas (2001) also reported that green algae and Pyrrophyta predominated at a high Shannon-Weaver index level of 2 to 3.5 bit indiv.$^{-1}$ in September.

The results of the analysis presented above indicate that in the littoral zone of Lake Jeziorak Mały the phytoplankton community could be indirectly shaped by blue-greens, which, in comparison to diatoms and green algae, reached the highest abundance and the lowest species diversity. This situation occurred particularly in the summer season when blue-greens contributed to reducing the orthophosphate concentration in the water and competed for resources of this nutrient with other phytoplankton groups. In the spring and fall seasons, however, when the lower water temperatures did not favor the development of blue-greens, diatoms and green algae predominated as was confirmed by their high abundance and high species diversity indices.

REFERENCES

Eloranta P., 1986, *Phytoplankton structure in different lake types in central Finland,* Holarctic Ecology 9: 214-224

Heinonen P., 1980, *Quantity and composition of phytoplankton in Finish inland waters*, Publ. Res. Inst., Nat. Board of Waters, 37: 1-91

Jeppensen E., Jensen J.P., Sondergaard M., Lauridsen T., Landkildehus F., 2000, *Trophic structure, species richness and biodiversity in Danish lakes: changes along a phosphorus gradient*, Freshwater Biology, 45: 201-218

Kawecka B., Eloranta P.V., 1994, *Zarys ekologii glonów wód słodkich i środowisk lądowych,* Wydawnictwo Naukowe PWN, Warszawa

Lampert W., Sommer U., 1996, *Ekologia wód śródlądowych,* Wydawnictwo Naukowe PWN, Warszawa

Remmert H., 1985, *Ekologia,* Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa

Reynolds C.S., 1988, *The concept of ecological succession applied to seasonal periodicity of freshwater phytoplankton*, Verh. Internat. Verein. Limnol., 23: 683-691

Rojo C., Cobelas M.A., 2001, *Phytoplankton structure and dynamics at daily temporal scale: Response to the thermal overturn,* Arch. Hydrobiol., 151(4): 549-569

Zębek E., 1998, *Water temperature of the littoral zone during the domination of the blue – green algae Planktothrix agardhii and Limnothrix redeckei in the composition of phytoplankton in the polytrophic lake Jeziorak Mały*, Oceanological Studies, Polish Academy of Sciences National Scientific Committee on Oceanic Research, 1: 53-59

Zębek E., 2004, *Species biodiversity of net phytoplankton as an indicator of trophic changes in the urban lake Jeziorak Mały,* Teka Kom. Ochr. Kszt. Środ. Przyr., 1: 316-321

Zębek E., 2005a, *Qualitative and quantitative changes of blue-green algae vs. physicochemical water parameters in the urban Lake Jeziorak Mały*, Oceanological and Hydrobiological Studies, 34(1): 39-56

Zębek E., 2005b, *Annual succession patterns of blue-green algae vs. physicochemical water parameters in the urban Lake Jeziorak Mały in the years 1998-2003 period*, Oceanological and Hydrobiological Studies, 36(4): 33-46

Zębek E., 2006, *Qualitative changes of Planktolyngbya brevicellularis, Limnothrix redekei and Aphanizomenon gracile in the annual cycle vs. physicochemical water parameters in the urban Lake Jeziorak Mały*, Oceanological and Hydrobiological Studies, 35(1): 67-82