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Planktonic indices in the evaluation of the ecological status and the trophic state of the longest lake in Poland

Ewa A. Dembowska, Paweł Napiórkowski*, Tomasz Mieszczankin, Szymon Józefowicz

Nicolaus Copernicus University, Faculty of Biology and Environmental Protection, Department of Hydrobiology, Lwowska 1, 87-100 Toruń, Poland

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ABSTRACT

Due to the intensive mixing polymictic lakes should be homogenous. However, morphometric diversity and high water dynamics contribute to the differentiation of many parameters in various areas of the lakes. This study analyzes both phytoplankton and zooplankton to assess differences in water quality along the north–south axis of the longest lake in Poland. New phytoplankton indicators were applied for determining the lake's ecological status: the *Q* index based on functional groups and the PMPL (Phytoplankton Metric for Polish Lakes) index based on phytoplankton biomass. TSI_{ROT} index (Rotifer Trophic State Index), which comprises the percentage of species indicating a high trophic state in the indicatory group and the percentage of bacteriovorus in the Rotifera population, was used for zooplankton analysis.

TP content was different at different sites – we observed its gradual increase from the south to the north. Spatial variation of phosphorus did not considerably affect plankton diversity. The phytoplankton was dominated by Oscillatoriales, typical of shallow, well-mixed eutrophic lakes. The ecological status of the lake based on the EQR (Ecological Quality Ratio) was poor or moderate. The zooplankton was dominated by rotifers (at almost all sites), which indicates a eutrophic state of the lake. The values of phytoplankton indices at the studied sites did not differ considerably; the differences resulted more from local conditions such as the contaminant inflow and the macrophyte development than water dynamics.

We have demonstrated that in the lake dominated by filamentous Cyanobacteria the ecological status should be determined according to the PMPL index or other indices dependent on the dominant Cyanobacteria species. Since the *Q* index does not include the functional group S1, the results can lead to the false conclusion that water quality improves with an increased amount of phytoplankton. The high abundance of Cyanobacteria in the lake may have contributed to the poor growth of rotifers.

1. Introduction

Heterogeneity is reflected in the differences between physical, chemical, and biological parameters in various parts of lakes, i.e. the water column (the vertical and horizontal variability), bottom regions, and areas situated close to the shore. The degree of changes observed in the water column depends not only (though mainly) on the intensity of mixing, but also on the inflow of natural or artificial substances. Heterogeneity of water bodies is so important that it determines the frequency and location of sampling.

Plankton analysis is one of the methods used for the assessment of this type of differentiation. Planktonic organisms (algae and zooplankton) are very good bioindicators of water quality (Sládeček, 1983; Duggan et al., 2001; Jekatierynczuk-Rudczyk et al., 2012; Özkundakci et al., 2014). The plankton community structure is affected by water chemistry, lake morphology, and water mixing as well as by anthropogenic changes in lakes and their catchment areas (Dodson et al., 2009). An intense loading of nutrients, especially nitrogen (N) and phosphorous (P), is primarily responsible for eutrophication (Vollenweider, 1968; Schindler, 2006), which induces changes in phytoplankton and zooplankton. An initial increase in the trophic level leads to an increased number of phytoplankton species but when the trophic level rises above a critical value, the number of species decreases, though the abundance and biomass generally continue to increase (Reynolds, 2006).

Summer plankton is considered the most reliable for the assessment of water quality (Padisák et al., 2006; Ejsmont-Karabin, 2012). Lake Jeziorak was selected for this study because it has the features conducive to spatial differentiation, i.e. a large surface area and a remarkable length. The research included the determination of the physical and chemical parameters of water as well as the analysis of phyto- and zooplankton.

* Corresponding author. Tel.: +48 566114450; fax: +48 566114443.
E-mail address: pnapiork@umk.pl (P. Napiórkowski).

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A development of multiple indices contributed to the optimal use of phytoplankton as an indicator. In this study two phytoplankton indices were applied: the Q index, one of the most popular in Europe, developed for Hungarian lakes (Padisák et al., 2006), based on functional groups of phytoplankton featured by Reynolds et al. (2002), Reynolds (2006) and Padisák et al. (2009); and the most recent multimetric PMPL index (Hutorowicz et al., 2011), introduced for the evaluation of the quality of aquatic environments under the EU Water Framework Directive. The latter is an algorithm of the total phytoplankton biomass, Cyanobacteria biomass, and chlorophyll *a* concentration.

According to the EC (2000) only phytoplankton can be used as an indicator of water quality in lakes. However, Jeppesen et al. (2011) maintain that zooplankton, including rotifers, can also be regarded as a good indicator. Since rotifers, opportunistic organisms with short life cycles, respond quickly to environmental changes, they may prove useful for biological monitoring (May and O'Hare, 2005; Lodi et al., 2011; Ejsmont-Karabin, 2012). The use of rotifers as indicators relies on the assumption that differences in their abundance and species composition between the sites are regulated mainly by "bottom–up" forces, not by "top–down" predatory interactions. The Rotifer Trophic State Index (TSI_{ROT}) based on rotifer abundance and species composition was developed recently by Ejsmont-Karabin (2012), who suggests that it should be included in the ecological quality standards of water bodies in Europe. The objective of this study was to evaluate the horizontal heterogeneity of the lake during summer months, when lake conditions remain constant and plankton communities also show relative stability (both qualitative and quantitative).

2. Study area

Jeziorak, a postglacial lake located in eastern Poland (Fig. 1) is the longest (28 km), and sixth largest lake in Poland, with a surface area of 3219 ha (Jańczak, 1997) and a total volume of 141.6 × 10^6 m^3. The lake is shallow with an average depth of 4.1 m, the maximum depth of 12 m, and maximum effective length *ca* 5 km. This polymictic lake is characterized by high water dynamics, caused mainly by wind forces. The lake is fed by numerous streams and very small rivers which do not have a major impact on water dynamics. Slow water inflow contributes to a long lake retention time (about 3 years).

The lake has only several patches of well-developed emergent vegetation, which is typical of eutrophic lakes. The littoral vegetation is not very dense and contains the common reed (*Phragmites communis* L.), reed mannagrass (*Glyceria maxima* (Hartm.) Holmb.), broad stick (*Typha latifolia* L.), yellow water lily (*Nuphar lutea* (L.) Sm.), floating pondweed (*Potamogeton natans* L.), and hornwort (*Ceratophyllum demersum* L.).

The lake catchment is used mainly for agriculture (*ca* 60% of this area), the remaining part is covered with forests. Both the lake and the neighboring areas are used for tourism. The largest urban center in the basin is Iława, the town located at the southern tip of the lake.

3. Materials and methods

During the summer stagnation period in 2011 and 2012 water samples were collected at eight sites, situated along the north–south axis of the lake (Fig. 1).

In total, 14 qualitative phytoplankton samples for the analyses of species composition were collected from the pelagic zone with a plankton net (10 μm mesh diameter) in vertical and horizontal hauls and later preserved in formaldehyde. Phytoplankton was identified using Nikon Alphaphot YS2 light microscope. All samples were processed to species-level identifications, if possible. Algal taxa were identified according to Ettl (1983), Hindák (2008), Javornický (2003), Komárek and Anagnostidis (2007, 2008), Komárek and Fott (1983), Komárek and Komárkowa (2006), Komárek and Zapomèlova (2007, 2008), Krammer and Lange-Bertalot (1986, 1988, 1991a,b), Popovský and Pfiester (1990), Růžička (1977), Starmach (1968, 1974, 1983), Wołowski (1998), Wołowski and Hindák (2005).

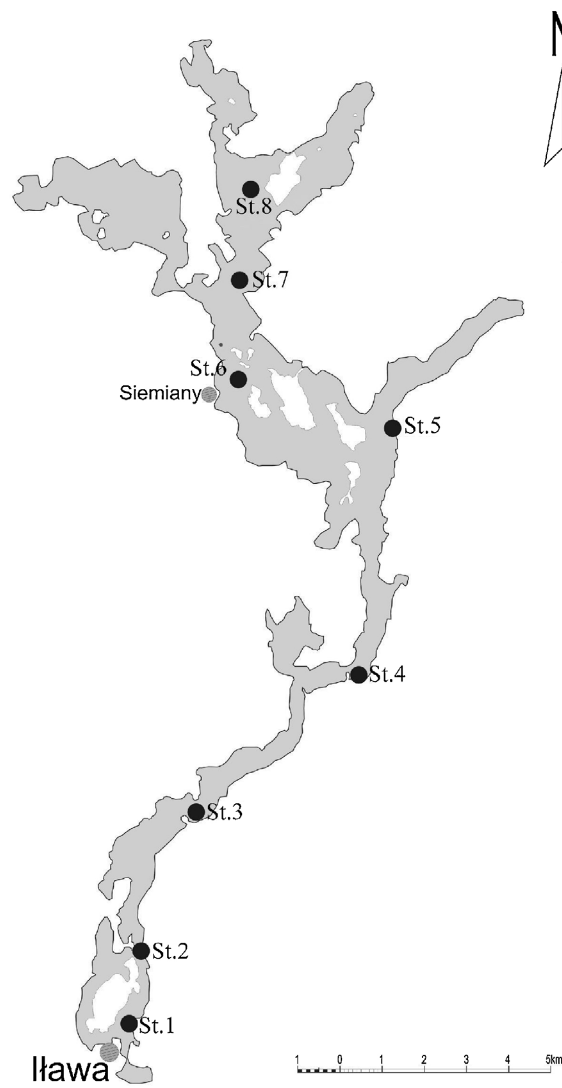

Fig. 1. Map of investigated Lake Jeziorak with sampling sites.

In total, 14 quantitative samples, collected from the surface, i.e. at a depth of *ca* 0.5 m were preserved with Lugol's solution (J in KJ). The algal count was determined with the Utermöhl (1958). The counts of phytoplankton were carried out to the species level whenever possible, using an inverted microscope (MOD-2 PZO). A counting unit was a single cell, filament or colony. The abundance is presented as a number of individuals per liter (N, ind/L). Biovolumes of all algal species were calculated using the volumetric method by Hillebrand et al. (1999) and Sun and Liu (2003) and assuming that 1 mm^3 of algae is equal to 1 mg (Holmes et al., 1969; Elser and Carpenter, 1988). A biovolume is presented as biomass (wet weight) per liter (B, mg/L). Algae were classified into functional groups (FG) as proposed by Reynolds et al. (2002) and updated by Padisák et al. (2009).

Zooplankton was caught using a 5 L sampler. The samples, taken at 1 m intervals from the surface to the bottom of the epilimnion layer, were then pooled together and filtered through a plankton net (25 μm mesh diameter). Ejsmont-Karabin (2012) suggested