

THE EFFECT OF INCREASING TOURISM PRESSURE ON THE STABILITY OF PHYSICOCHEMICAL AND BIOLOGICAL PARAMETERS IN LAKE ROTCZE

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Summary. Changes in the structure of land use and changes in physical-chemical and biological properties of water within twenty years were analyzed in the shallow, macrophyte-dominated lake Rotcze (Łęczna–Włodawa Region). Biological analyses were based on the studies of abundances and species composition of phytoplankton. In the analyzed period, there was observed the rapidly developing of touristic infrastructure. Despite the increasing pressure of tourism, physicochemical properties of water, abundance and composition of phytoplankton were characterized by high stability and confirmed the persistence of moderate eutrophic state.

Key words: lake, catchment, phytoplankton, tourism

INTRODUCTION

Lakes together with adjacent littoral zones are attractive recreational areas. Landscape transformations around lakes usually consist in changes of agricultural lands into areas with recreational infrastructure. Recreational infrastructure implemented in drainage basins of most lakes negatively affects aquatic ecosystems, mainly because of the location and high concentration of different types of objects. It has been proved that tourism carrying capacity of many lakes in the Łęczna-Włodawa Lakeland was exceeded more than 4 times [Chmielewski 2009].

This results in the destruction of reed-bed, meadow and even forest vegetation, which affects the ecological status and functioning of a given lake.

The research on changes in the community of aquatic macrophytes in lakes of the Łęczna-Włodawa Lakeland revealed significant reconstruction of phytolittoral, mostly in lakes with tourism infrastructure [Ciecierska and Radwan 2002, Sender 2009].

The catchment management and the catchment nature affect the pool of nutrients flowing into lakes, which result in faster or slower eutrophication. The causes and symptoms of eutrophication are thoroughly investigated and described [OECD 1982, Nürnberg 2001].

Eutrophication is the most common threat to inland aquatic ecosystems, and is mainly caused by the overload of biogenic substances in a given ecosystem [Kalff 2001].

The objective of this study was to analyse the variability of physicochemical factors, as well as the amount and the composition of phytoplankton in Lake Rotcze during 20 years. In addition, changes in the catchment land-use of the studied lake were analysed. Particular attention was paid to the development of tourism infrastructure around the lake.

STUDY AREA AND METHODS

Lake Rotcze is located in the western part of the Łęczna-Włodawa Lake-land. It is an eutrophic waterbody with an area of 42.7 ha and the maximum depth of 4.3 m [Radwan and Kornijów 1998]. The catchment area of Lake Rotcze is 160 ha, and Ohle's coefficient – 3.43 [Furtak *et al.* 1998].

Natural susceptibility and resistance to degradation of this lake in 1995–2000 was classified within category III [WIOŚ 2005].

Approximately 70% of the water surface in Lake Rotcze is covered with macrophytes, including mainly elodeids (submerged aquatic plants) and charophytes [Sugier and Lorens 2002]. The dominance of macrophytes is more favourable for the functioning of eutrophic lakes compared to algal blooms; the latter reduce the physicochemical and biological parameters of water by minimizing the use and nature value of a given lake in much shorter time and to a larger extent [Scheffer *et al.* 1998]. Whereas macrophytes are very sensitive to mechanical injuries, and thus they lose the competition with developing algae [Ozimek 1992].

Values of the basic physicochemical parameters (SD, EC, pH), and the numbers and quantity composition of algae in Lake Rotcze were compared for three periods (the 1990s, 2000 and 2012). Measurements and water sampling were conducted in the pelagic zone in summer (July–August). Samples for chemical and biological analysis were collected with a 2 dm³ Ruttner sampler, from which 0.25 dm³ subsamples were extracted. Measurements of SD, pH, EC were taken directly in the lake. Concentration of chlorophyll *a* was determined by the spectrophotometric method (Nusch 1980), and the abundance of phytoplankton – by Utermöhl's method [Vollenweider 1969]. Changes in the catchment land-use structure of Lake Rotcze were followed on a 1 : 25 000 map [Harasimiuk *et al.* 1998] and on a map drawn by the authors using the software Q GIS 1.71, based on aerial photographs from 2009 with a pixel size of 50 cm (www.geoportal.gov.pl).

RESULTS AND DISCUSSION

Changes in the catchment land-use structure of Lake Rotcze were analysed for the period of 33 years; they are compiled in Table 1. In the 1970s, meadows and grazing lands dominated (32.45%) followed by arable lands (26.2%) [Furtak *et al.* 1998]. Meadows and grazing lands were located in the northwestern

Table 1. Land use of the catchment of Lake Rotcze

Cover type	% share in the catchment area in 1976 (according to Furtak <i>et al.</i> 1998)	% share in the catchment area in 2010 (by aerial photographs in 2009)
Lake	29.13	28.34
Meadows and pastures	32.45	15.61
Bushes and plantings	08.82	30.22
Arable land	26.20	9.91
Buildings	0.54	4.01
Recreational areas	1.38	10.49
Beach	0.00	0.32
Others	1.48	1.09

Table 2. Values of selected physicochemical and biological parameters in the three time periods

Parameters	Period		
	1990	2000	2012
Visibility by Secchi disc, m	1.0	2.3	1.4
Electrolitic conductivity, $\mu\text{S cm}^{-1}$	n.d.	188	163
pH	7.4	9.0	8.5
Chlorophyll <i>a</i> , $\mu\text{g dm}^{-3}$	n.d.	13.4	13.8
Phytoplankton abundance, ind. 10^3 dm^{-3}	188.0	677.6	227.4

n.d. – not determined

part of the drainage basin bordering on the lake shoreline at about three-quarters of its length. Arable lands were located mainly in the northeastern part of the drainage basin. In the 1970s, the recreational infrastructure was negligible and covered ca. 1% of the area. Single rural buildings were located also along the road (Tab. 1). After more than 30 years, the area of meadows, grazing lands and agricultural lands was significantly reduced (often more than 50%) in favour of recreational infrastructure. The area of bushes and woodlots increased by ca. 30% as a consequence of fast succession in meadows and fields that have been used to a small extent only.

Lake Rotcze is not appealing for tourists because of its morphometry (small in area, relatively shallow and accessible from the eastern side only). Due to the fact, however, that the volume and tourism carrying capacity of many lakes in the Lakeland was exceeded several times, i.e. even 6–8 times [Maślanko *et al.* 2011], less appealing lakes, like Lake Rotcze, are extensively used for tourism. The increasing tourism pressure on the lake is also reflected in the number of sunbathers. On the sunny day of 29 July 2012 at 11 a.m., there were ca. 615 persons at the lake, i.e. twice as many as reported in 1985–1995 [Chmielewski and Jankowska 2009].

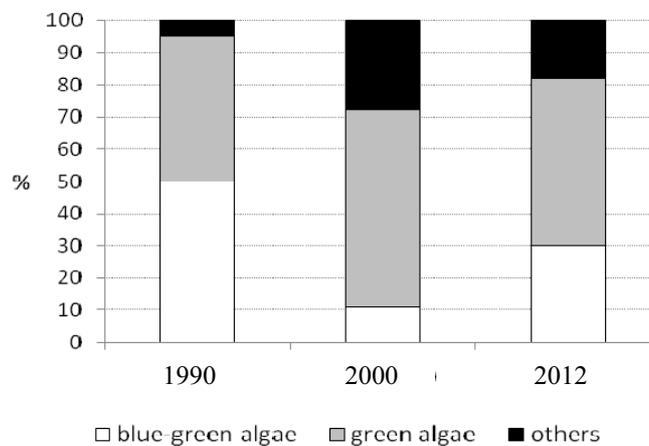


Fig. 1. Percentage share of taxonomic groups in phytoplankton numbers of Lake Rotcze in the three time periods

Despite the tourism pressure that increases every year, the water in the lake is relatively transparent, sometimes above 2 m (Tab. 2). Good penetration of light (down to the bottom over a large area) promotes the development of submerged macrophytes, which effectively reduce the growth of planktonic algae. In the last ten years (2000–2012), chlorophyll *a* concentration in the water and the numbers of planktonic algae had small values (Tab. 2), which is characteristic of lakes in the initial eutrophic stage [Kawecka and Eloranta 1994, OECD 1982].

Relatively small numbers of planktonic algae resulted also from the fact that Lake Rotcze is a macrophyte-dominated waterbody. Furthermore, the initial eutrophication process in Lake Rotcze was evidenced by the species structure of algae. Green algae have a significant contribution in the community of planktonic algae for thirty years, while cyanobacteria – only small contribution (Fig. 1). In the last ten years, *Closterium diana*, *Staurastrum planctonicum* and *Closterium acutum* were the most abundant species. These species often dominate or co-dominate in moderately eutrophic waters [Reynolds 2006]. Cyanobacteria quantitatively dominated in the phytoplankton only the 1990s (Fig. 1), and *Aphanothece clathrata* and *Coelomorion pusillum* were the dominant species.

The cyanobacterium *Aphanothece clathrata* frequently occurs in summer in the water with large amounts of light, both in meso- and eutrophic lakes [Wojciechowska and Solis 2009]. The good ecological status of Lake Rotcze is reflected also in the phytoplankton index PSI (Phyto-See-Index) calculated based on the biomass [Paształeniec and Poniewozik 2010].

CONCLUSION

1. The analysis of changes in the catchment land use revealed a rapid development of tourist infrastructure.
2. As evidenced by the comparison of physicochemical parameters, the structure and the number of planktonic algae, the ecosystem of Lake Rotcze has been very stable over the twenty years.
3. The stability of the lake, despite low resistance to degradation, may result from its macrophyte nature and the catchment area, which allows only for the development of tourist infrastructure on the eastern side.
4. Scattered distribution of tourism infrastructure (holiday resorts, cottages, beaches and small catering establishments) is very favourable for every lake ecosystem.

English language corrected by Ewa Kaźmierczak

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WZROST PRESJI TURYSTYCZNEJ A STABILNOŚĆ PARAMETRÓW FIZYCZNO-CHEMICZNYCH I BIOLOGICZNYCH W JEZIORZE ROTCZE

Streszczenie. W płytkim, makrofitowym jeziorze Rotcze (Pojezierze Łęczyńsko-Włodawskie) przeanalizowano zmiany w strukturze użytkowania zlewni oraz zmiany parametrów fizyczno-chemicznych i biologicznych wody w okresie dwudziestu lat. Analizy biologiczne oparto na badaniach ilości i składu gatunkowego fitoplanktonu. W analizowanym okresie wykazano duże zmiany w zlewni, wynikające z szybko rozwijającej się infrastruktury turystycznej. Pomimo wzrastającej presji turystycznej, wartości parametrów fizyczno-chemicznych oraz struktura i ilość fitoplanktonu charakteryzowały się dużą stabilnością i potwierdzały utrzymywanie się stanu umiarkowanej eutrofii.

Słowa kluczowe: jezioro, zlewnia, fitoplankton, turystyka