

TROPHIC DIVERSITY OF THREE DEEP LAKES – PIASECZNO, ROGÓŻNO AND KRASNE – IN THE YEARS 2006–2007 (ŁĘCZNA-WŁODAWA LAKE DISTRICT)

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Summary. The aim of the study (2006–2007) in three deep lakes: Piaseczno, Rogóžno and Krasne, was to determine their current trophic status on the basis of calculated Carlson's trophic indices (TSI_{SD} , TSI_{TP} , TSI_{TN} , TSI_{CHL}). Based on the deviations between the values of individual indexes also the potential causes of the limitation of phytoplankton growth were identified. The study showed that the greatest dynamics of changes occurred in the values of the nutrient indexes, which is a symptom of eutrophication in those reservoirs, and in the TSI_{CHL} index, what indicates disorders of the mechanisms of biocenotic stability in those ecosystems. Nevertheless, the lakes retain high water transparency, because the numbers of phytoplankton oscillated within the range typical for mesotrophy (Piaseczno) or moderate eutrophy (Rogóžno, Krasne). Analysis of variation showed that the small amount of phytoplankton in lake Piaseczno may be due to zooplankton grazing, while in lakes Rogóžno and Krasne it is a result of varying levels of available nitrogen in the water during the year.

Key words: deep lakes, trophic state index (TSI), eutrophication

INTRODUCTION

So far lakes Piaseczno, Rogóžno and Krasne, in terms of trophy, are classified as mesotrophic reservoirs [Radwan and Kornijów 1998]. Their morphometric conditions, mainly large depth and capacity, are conducive to the persistence of a lower trophic status. The lakes also show clear symptoms of eutrophication. There are observed summer oxygen deficits in the waters of hypolimnion, an increase of primary production, and changes in the structure of phytoplankton and zoobenthos [Wojciechowski *et al.* 1995, Kornijów 1997, Wojciechowska and Solis 2009].

The level of nutrients and their relationships are related to biological responses of phytoplankton, such as changes of its biomass (e.g. chlorophyll concentrations). Based on this relation we can evaluate the trophic status of a lake, which has great practical importance [Wetzel 2001]. Using the Carlson trophic state indices: TSI_{SD} , TSI_{TP} , TSI_{CHL} [Carlson 1977] and TSI_{TN} [Kratzer and Brezonik 1981] we can describe the abiotic and biotic relations in a water body. Moreover, based on the differences between individual trophic state indices (TSIs) we can determine potential factor or factors limiting the development of algae [Havens 2000, Matthews *et al.* 2002].

The aim of the study presented here was to determine the current trophic status of three deep lakes – Piaseczno, Rogóžno and Krasne – situated in the Łęczna-Włodawa Lake District. On the basis of the calculated Carlson trophic state indexes we defined the trophic status of the lakes and, based on the differences between the values of individual indices, identified the potential causes of limitation of phytoplankton growth.

STUDY AREA, MATERIALS AND METHODS

The study was focused on three dimictic and mesotrophic lakes (Piaseczno, Rogóžno and Krasne) situated in the Łęczna-Włodawa Lake District (Central-Eastern Poland). The morphometric properties of the lakes are presented in Table 1.

Table 1. Morphometric parameters of studied lakes [Harasimiuk *et al.* 1998]

Lake	Area, ha	Max depth, m	Mean depth, m
Rogóžno	57.1	25.4	7.4
Krasne	75.9	33.0	10.8
Piaseczno	84.7	38.8	12.4

All three lakes were studied from April till November in the years 2006 and 2007.

Water samples were taken once a month from the pelagial zone of the lakes using a Ruttner-type water-sampler (2 dm³ capacity). Samples for analyses were always taken from the epilimnion, at depth intervals of 1m (from the surface to 4 m) and pooled into one collective sample.

The concentration of chlorophyll *a* was determined according to the standard method [Nush 1980]. The water transparency was measured using Secchi Disks (SD). The chemical analyses, aimed at estimation of the total fractions of nitrogen and phosphorus (TN and TP), were made in a laboratory according to colorimetric methods [Hermanowicz *et al.* 1999].

Trophic State Indices (TSIs) were calculated using the equations described by Carlson [1977] and Kretzer and Brezonik [1981]. Deviations between TSIs

were calculated by subtracting TSI_{SD} , TSI_{TP} or TSI_{TN} from TSI_{CHL} as described by Carlson [1991] and Havens [1995].

RESULTS AND DISCUSSION

Calculated Carlson trophic index values showed significant seasonal and year-to-year fluctuations (Fig. 1).

In lake Piaseczno minor variations, but always within the extent of mesotrophy, were ascertained for indexes TSI_{CHL} and TSI_{SD} . For indexes related to the content of nutrients (TSI_{TN} , TSI_{TP}) far bigger variations, covering the range from oligo- to hypertrophy, were observed. In the year 2006, the values of TSI_{TN} index were varied only slightly (44–53), while in the year 2007 in a far bigger range (9–46). The reverse situation was ascertained for the TSI_{TP} index. In the first year of study the range of its variations was very large (40–72) and in the following year significantly lower (48–61).

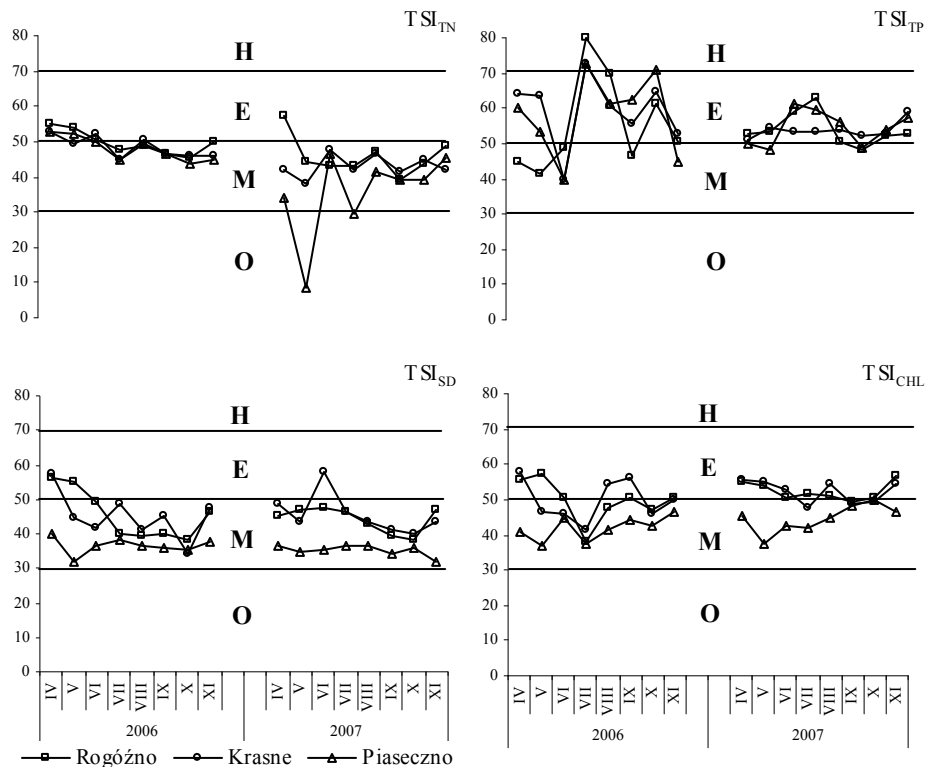


Fig. 1. Differentiation of trophic state indices values: H – heterotrophy, E – eutrophy, M – mesotrophy, O – oligotrophy

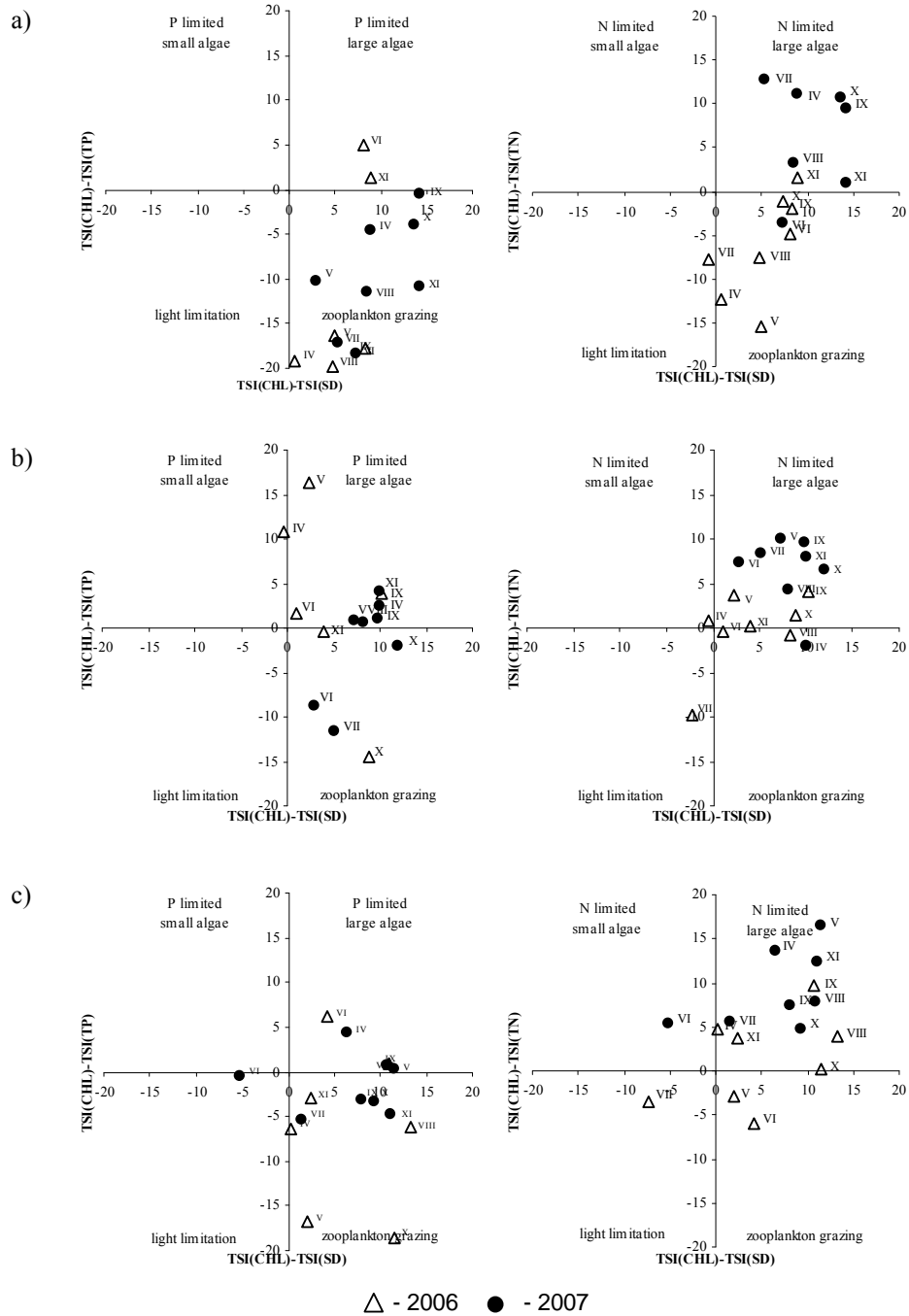


Fig. 2. Diagrams of deviations between trophic index values in lakes: a) Rogóznó, b) Krasne, c) Piaseczno

A higher level of water eutrophication was noted in lakes Rogóžno and Krasne. In most cases, the TSI_{CHL} values, directly related to the ecosystem productivity and TSI_{TP} , were typical for moderate eutrophy (Fig. 1). However, in the year 2006, variations in the TSI_{TP} index values in both lakes were large, from meso- to hypertrophy (Rogóžno 41–80, Krasne 40–73). Values of the other trophic indexes (TSI_{SD} and TSI_{TN}) remained on the level of mesotrophy. Only in spring did those values show a moderate eutrophy (Fig. 1).

According to the modified concept of Carlson [Havens 2000], the deviations between the values of trophic indexes can help to determine the potential causes of limitation of the growth of phytoplankton. Lakes in which $TSI_{CHL} \gg TSI_{TN}$ or TP are inferred to be nutrient-limited algae, except that when $TSI_{CHL} \gg TSI_{SD}$ there are relatively large forms, and when $TSI_{CHL} \ll TSI_{SD}$ there are small forms. Lakes in which $TSI_{CHL} \ll TSI_{TN}$ or TP are inferred to be light limited when $TSI_{CHL} \ll TSI_{SD}$ or zooplankton grazing limited when $TSI_{CHL} \gg TSI_{SD}$.

In the diagrams prepared for lakes Piaseczno, Rogóžno and Krasne deviations between the values of trophic indexes are characterised by a large dispersion, which indicates different possible reasons for the limitation in the growth of phytoplankton (Fig. 2).

During the two years of research, in lake Piaseczno higher amounts of nitrogen and phosphorus (TN: 1.0–3.33 mg dm⁻³, TP: 0.021–0.114 mg dm⁻³) and small algae numbers (1.9–7.0 µg dm⁻³) were noted. This situation may have been caused by zooplankton grazing. However, the reduced nitrogen concentration in water in the year 2007 could also periodically limit the development of phytoplankton (Fig. 2a).

In lakes Rogóžno and Krasne factors potentially limiting the growth of phytoplankton were similar (Fig. 2b, c). During the two-year period, this limitation could be the result of significant fluctuations in nutrients content in the water and occasionally also a result of zooplankton grazing. Possibility of significant limitation by nitrogen was ascertained in the year 2007, in waters of both lakes, when nitrogen content was reduced.

The significant seasonal fluctuations in trophic indexes values in all three lakes are a symptom of eutrophication of their waters and of, associated with this, disorder of biocenotic stability in the water ecosystems [Burchardt 1993]. In lake Piaseczno, this phenomenon has already been observed since 1987 [Wojciechowski *et al.* 1995].

Especially large dynamic changes were observed in the case of biogenic indexes. The reason of that is the supply of increased phosphorus and nitrogen load due to adverse changes in the structure of the drainage basin, such as increase in the building of recreational areas, and desiccation of bogs surrounding the lakes [Chmielewski 2001]. Intensification of eutrophication processes is also a result of natural aging of lakes. The result of this is a decrease in the hypolimnion capacity and appearance of the summer oxygen deficits in the

water, leading to release of phosphate pool from the bottom sediments [Kornijów 1996].

Despite the large amounts of phosphorus and nitrogen in the water, good transparency of water in lakes Piaseczno (4.0–7.2 m), Rogóžno (1.3–4.7 m) and Krasne (1.15–5.9 m) is maintained, mostly in the range typical for mesotrophic lakes [OECD 1982]. Undoubtedly, this is favoured by the large depth of these reservoirs and the related high resistance to eutrophication of their waters.

An analysis of deviations between the values of trophic indexes also showed that the limiting factor for excessive growth of phytoplankton in lake Piaseczno may be grazing by zooplankton and it may be the main factor contributing to the persistence of high water transparency. The studies carried out by Wojciechowska *et al.* [1991] indicated that *Rotatoria* have a significant influence on maintaining of nannoplanktonic algae at constant numbers. In lakes Rogóžno and Krasne this factor is rather the seasonal changes in the amount of available nitrogen in the water.

CONCLUSIONS

1. In lakes Piaseczno, Rogóžno and Krasne great dynamics of variations in trophic indexes in a year and from year to year was observed. In the range typical for mesotrophy only changes of water transparency occur. Abundance of phytoplankton and amounts of phosphorus and nitrogen in the water varied in a far bigger range.

2. Discrepancy between indexes values is a symptom of water eutrophication of these lakes and disorder of the mechanisms of biocenotic stability in their ecosystems.

3. The maintenance of higher water transparency and relatively low phytoplankton abundance in the lakes may be a result of zooplankton grazing (Piaseczno) or variations in the availability of nitrogen compounds (Rogóžno, Krasne).

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ZRÓŻNICOWANIE TROFICZNE TRZECH GŁĘBOKICH JEZIOR
PIASECZNO, ROGÓŻNO I KRASNE W OKRESIE 2006–2007
(POJEZIERZE ŁĘCZYŃSKO-WŁODAWSKIE)

Streszczenie. Celem prowadzonych badań (2006–2007) w trzech głębokich jeziorach: Piaseczno, Krasne i Rogóźno było określenie ich aktualnego stanu troficznego na podstawie wyliczonych indeksów troficznych Carlsona (TSI_{SD} , TSI_{TP} , TSI_{TN} , TSI_{Chl}). W oparciu o odchylenia między wartościami poszczególnych indeksów wytypowano również potencjalne przyczyny limitowania wzrostu fitoplanktonu. Badania wykazały, że największa dynamika zmian występowała w przypadku wartości indeksów biogennych, co jest objawem eutrofizacji wód w tych zbiornikach, oraz indeksu TSI_{Chl} , co wskazuje na zaburzenie mechanizmów stabilności biocenotycznej w tych ekosystemach. Mimo to, jeziora zachowują wysoką przezroczystość wody, gdyż ilość fitoplanktonu utrzymuje się w zakresie typowym dla mezotrofii (Piaseczno) lub umiarkowanej eutrofii (Rogóźno, Krasne). Analiza odchyleń wykazała, że niewielka ilość fitoplanktonu w jeziorze Piaseczno może być utrzymywana w wyniku spasanania przez zooplankton, natomiast w jeziorach Piaseczno i Krasne wpływa na to zróżnicowana w ciągu roku ilość dostępnego azotu w wodzie.

Słowa kluczowe: głębokie jeziora, indeksy troficzne (TSI), eutrofizacja