# PHYTOPLANKTON PRODUCTIVITY IN LITTORAL OF SELECTED LAKES IN ŁĘCZNA-WŁODAWA LAKELAND IN SUMMER 2007–2008

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**Summary.** The study aimed at determining the eutrophication rate in agricultural and agriculturalrecreational littoral of limnologically similar so-called Uściwierskie lakes: lake Bikcze and lake Uściwierz in the Łęczna-Włodawa Lakeland. The survey was conducted in summer, in 2007 and 2008. Values of the following trophy biological indices were measured: gross phytoplankton primary production and chlorophyll *a* concentration, as well as Carlson's Trophy Index (TSIChl *a*) was calculated. The survey was completed with measurements of the principal physicochemical factors of waters. Similar values of studied trophy indices for both lakes during the experiments did not indicate any intensification of eutrophication processes in littoral.

Key words: lake, primary production, chlorophyll a concentration, eutrophication, de-eutrophication

# INTRODUCTION

The water conditions of the Łęczna-Włodawa Lakeland affect the character of ecological transformations and are very susceptible to anthropogenic influences [Chmielewski *et al.* 1995]. That results in disturbances within the biocenotic structure of aqueous ecosystems determining the limnological status of many lakes, including the Uściwierskie lakes: Bikcze, Uściwierz, Uściwierzek, Sumin, Rotcze, Ciesacin.

Lakes Bikcze and Uściwierz, located at about 1 km distance to each other, are situated in the middle of the Lublin province, Ludwin commune, within the Łęczna-Włodawa Lakeland being a part of Polesie Podlaskie macro region, and within the Landscape Park Pojezierze Łęczyńskie and the Natura 2000 network under the code PLH060010. Both lakes are similar with reference to their genesis, limnology, and trophy type, while distinct in view of their catchments management.

Lake Bikcze (Fig. 1), with its maximum depth of 3.3 m and surface area 85 ha, is characterised as a polymictic, eutrophic reservoir of tench-pike type. It represents the 2nd water quality class and the 3rd class of susceptibility to degradation [Report... 2008]. Considering the catchment management structure, natural forms classified as meadows and pastures, as well as arable lands of an area about 18.14 ha dominate [Furtak *et al.* 1998], as well as actively evolving to tall ones – transitional peat-bogs [Wojciechowski 1976, Pogorzelec and Banach 2008]. Due to developing the water system of the Wieprz-Krzna Canal, lake Bikcze was hydro-technically converted into a retention reservoir in 1969. The lake was surrounded with a girdling ditch with northern estuary to the deepened river-bed of Piwonia stream, and connected with the nearby lake Uściwierz from its south. The girdling ditch collects and transports waters infiltrating through the embankments at the dam that in turn allows for water damming in the lake over its natural level [Wojciechowski 1976].



Fig. 1. Localization of study objects and points (fragment of topographic map of Poland, GGK, 136.21, 1977, changed)

Lake Uściwierz (Fig. 1), with maximum depth of 6.6 m and 284.1 ha of surface area, represents the dimyctic, eutrophic, and bream-sander type of a reservoir. It is classified in the 3rd class of susceptibility to degradation and to 2nd and 3rd water quality classes [Report... 2008]. The lake is surrounded by a ring of reed plants rarely broken from its east with sandy dunes for recreation. Analy-

sis of the catchment management structure indicates the domination of grasslands (38.42%) and arable lands (12.26%), with a slight share of recreation areas from its eastern side [Furtak *et al.* 1998]. Hydrotechnical transformations since the end of 50's of the 20th century, associated with the Wieprz-Krzna Canal system, led to a change of the hydrological conditions of the whole area. From eastern, south-eastern, and in part north-western side, the lake is surrounded by a rampart, while the remaining shores were excluded due to the lake-peat-bog complex Uściwierz-Nadrybie-Bikcze. The flow of the Piwonia stream was regulated by means of its connecting with the lake through a system of melioration devices making possible the supply of waters from the Wieprz-Krzna Canal [Chmielewski *et al.* 1995].

## MATERIAL AND METHODS

Measurements of biological trophy indices (phytoplankton gross primary production and chlorophyll *a* concentration) were made in the littoral adjacent to the agricultural sector of lake Bikcze (with prevailing grassland areas) and the agricultural-recreational sector at lake Uściwierz (Fig. 1) several meters away from the shore, on 8 dates during the full summer (July) of 2007 and 2008. The survey points were located at the depth of 0.75 m.

The phytoplankton primary gross production was measured by means of oxygen method using "light" and "dark" vessels [Vollenweider 1969], determining the concentration of oxygen dissolved in water applying the titrimetric (iodometric) Winkler's method [Hermanowicz *et al.* 1976]. The amounts of liberated oxygen for the successive study dates were converted to the amount of carbon assimilated beneath  $1m^2$  of water surface during an hour (mg C<sub>ass</sub> m<sup>-2</sup> h<sup>-1</sup>) and assuming that 1 g of released oxygen corresponds to 0.312 g of assimilated carbon [Strickland 1960]. Achieved results – after conversion to mg C<sub>ass</sub> m<sup>-2</sup> d<sup>-1</sup> (assuming that d = 12 h) – indicated the trophy level of lake waters according to Kajak's criteria [1994].

Chlorophyll *a* concentration (as one of the most important photosynthetic pigments for autotrophic phytoplankton, determining its primary productivity), was assayed by means of spectrophotometry [Nusch 1980] and expressed in mg Chl *a* m<sup>-2</sup>. On the basis of chlorophyll *a* concentration in  $\mu$ g Chl *a* dm<sup>-3</sup>, the Carlson's Trophy Index (TSIChl *a*) was calculated [Carlson 1977].

The field survey was completed with measurements of primary physicochemical factors of littoral waters: electrolytic conductivity ( $\mu$ S cm<sup>-1</sup>), acidity (pH), and oxygen concentration in mg O<sub>2</sub> dm<sup>-3</sup>, using on-field, certified meters or titrimetric techniques [Hermanowicz *et al.* 1976].

### RESULTS

The studies did not reveal any apparent differences of biological trophy indices values for the littoral of both lakes (Figs. 2, 3, 4). Phytoplankton gross primary production for the agricultural littoral of lake Bikcze in summer 2007 oscillated within the range of 11.7–78.0 mg  $C_{ass}$  m<sup>-2</sup> h<sup>-1</sup>, with mean value for the study season = 37.95 mg  $C_{ass}$  m<sup>-2</sup> h<sup>-1</sup> (Fig. 2) (or 455.4 mg Cass m<sup>-2</sup> d<sup>-1</sup>), which indicated the poor trophic character of water within that zone [Kajak 1994]. Its higher values at narrower fluctuation range were recorded in summer 2008 (Fig. 2).



Fig. 2. Mean values and ranges of: phytoplankton gross primary production (mg C<sub>ass</sub> m<sup>-2</sup> h<sup>-1</sup>), chlorophyll *a* concentration (mg Chl *a* m<sup>-2</sup>), and Carlson's Trophy Index (TSIChl *a*) in agricultural littoral of lake Bikcze in summer 2007 and 2008

Chlorophyll *a* concentration was about 1.37-4.23 mg m<sup>-2</sup>, with season mean value of 2.70 mg m<sup>-2</sup> (Fig. 2), which also indicated the lack of any intensified eutrophication process [Kajak 1994]. Slightly higher values of the factor at greater oscillation range were recorded in summer 2007 (Fig. 2).

Low chlorophyll *a* concentration data resulted in TSIChl *a* index at the level of about 37–44, which did not exceed the range characteristic for mesotrophic lakes [Carlson 1977].

For lake Uściwierz, phytoplankton gross primary production amounted to 7.8–72 mg  $C_{ass}$  m<sup>-2</sup> h<sup>-1</sup>, with slightly higher mean for the seasons of 2007–2008: 39.97 mg  $C_{ass}$  m<sup>-2</sup> h<sup>-1</sup> (or 479.64 mg Cass m<sup>-2</sup> d<sup>-1</sup>) (Fig. 3), which determined, as for lake Bikcze, a low eutrophication level [Kajak 1994].

The results of chlorophyll *a* concentrations oscillated around  $1.93-4.40 \text{ mg m}^{-2}$ , at mean value for summer 2.76 mg m<sup>-2</sup> (Fig. 3), which is also characteristic for poor-trophy reservoirs [Kajak 1994].

The TSIChl *a* parameter oscillated within the range of 39–46, with mean for the whole study period at 42.5 (Fig. 3). According to Carlson's criteria [1977], that indicated the mesotrophic character of waters in the studied littoral of lake Uściwierz.



Fig. 3. Mean values and ranges of: phytoplankton gross primary production (mg C<sub>ass</sub> m<sup>-2</sup> h<sup>-1</sup>), chlorophyll *a* concentration (mg Chl *a* m<sup>-2</sup>), and Carlson's Trophy Index (TSIChl *a*) in agricultural-recreational littoral of lake Uściwierz in summer 2007 and 2008



Fig. 4. Mean values gradients of: phytoplankton gross primary production (mg C<sub>ass</sub> m<sup>-2</sup> h<sup>-1</sup>), chlorophyll *a* concentration (mg Chl *a* m<sup>-2</sup>), and Carlson's Trophy Index (TSIChl *a*) for studied littoral of lakes Bikcze and Uściwierz in summer 2007 and 2008



Fig. 5. Mean values, oscillation ranges, and trend lines for: acidity (pH), electrolytic conductivity (μS cm<sup>-1</sup>), and O<sub>2</sub> concentration (mg O<sub>2</sub> dm<sup>-3</sup>) in agricultural littoral of lake Bikcze in summer 2007 and 2008

For the successive study years (2007–2008), the values of biological trophy indicators for the agricultural-recreational littoral of lake Uściwierz underwent similar trends as in the case of lake Bikcze (compare Figs. 2, 3, 4).

Physicochemical properties of waters in the studied littoral of both lakes in summers of 2007 and 2008 were characterised by smaller or larger differences of measured parameters (Figs. 5, 6, 7).

Much higher values of electrolytic conductivity (226–267  $\mu$ S cm<sup>-1</sup>) and oxygen concentration (mean for studied period 11.94 mg O<sub>2</sub> dm<sup>-3</sup>) were recorded for the agricultural-recreational littoral of lake Uściwierz. The pH values were slightly higher in the agricultural littoral of lake Bikcze, ranging to pH = 8.01–9.14, which indicated the supply of alkalising substances from the catchment (Figs. 5, 6, 7).



Fig. 6. Mean values, oscillation ranges, and trend lines for: acidity (pH), electrolytic conductivity (μS cm<sup>-1</sup>), and O<sub>2</sub> concentration (mg O<sub>2</sub> dm<sup>-3</sup>) in agricultural-recreational littoral of lake Uściwierz in summer 2007 and 2008



Fig. 7. Gradients of mean values of: acidity (pH), electrolytic conductivity ( $\mu$ S cm<sup>-1</sup>), and O<sub>2</sub> concentration (mg O<sub>2</sub> dm<sup>-3</sup>) for studied littoral of lakes Bikcze and Uściwierz in summer 2007 and 2008

A tendency of increasing majority of measured physicochemical parameters at both lakes littoral zones was observed for the successive seasons of 2007–2008, with the exception of acidity in lake Bikcze, for which a slight decrease was reported (Figs. 5, 6).

#### DISCUSSION

Changes in the hydrological conditions within the Łęczna-Włodawa Lakeland, associated with the functioning of the Wieprz-Krzna Canal water system, as well as the influence of the Lublin Coal Mine Area, had an impact on the limnological status of lakes and water flows of that area [Michalczyk *et al.* 1995, Serafin 2008].

Lakes Bikcze and Uściwierz underwent hydrotechnical development and changes of hydrological conditions in their catchments, the effects of which may be changes in their limnological status.

This fact can be confirmed by studies upon biological trophy indices: phytoplankton gross primary production, chlorophyll *a* concentration, and Carlson's Trophy Index (TSIChl *a*) in the agricultural littoral of lake Bikcze and the agricultural-recreational littoral of lake Uściwierz in summer of 2007 and 2008.

The achieved results indicate a lack of intensified eutrophication processes in the studied littoral zones, and determined – according to Kajak's criteria [1994] – the poor-trophy character of their waters, despite of these lakes being classified as eutrophic ones. Such a situation may result from low biogens pressure from the catchment: of agricultural origin – no intensive chemistry in agriculture due to economic reasons, as well as of recreational origin having poor effects due to reduced availability of lake shores. The presence of hydrotechnical development (embankments, dams, and girdling ditch), partly separating the waters of the studied lakes from outer supply, is an additional barrier to biogens delivery from the catchments [Wojciechowski 1976, Chmielewski *et al.* 1995].

Low pressure of nutrients from the catchment may be additionally favoured by the presence of active transitional and tall peat-bogs described as grasslands [Furtak *et al.* 1998]. Active transitional or tall peat-bog introduces to lake waters active humic acids, mainly ulmic and fulvic, that adsorb cations of biogenic salts determining the eutrophication. Such a mechanism described for lake Bikcze [Wojciechowski 1976, 1995] may also function in the case of lake Uściwierz, for which similarly classified management forms as for lake Bikcze occupy the major part of its catchment area [Furtak *et al.* 1998].

The poor-trophy water status in the studied lakes may be additionally compensated by the influence of plant communities in the littoral and phytopsammon that build-up biogens within their biomass [Czernaś 2002, Serafin 2004].

Considering the water mineralisation, due to a long-term pressure of various factors, including anthropogenic ones, literature references classify both lakes in so-called 3rd lake group. It can be in part confirmed by high levels of electrolytic conductivity of both lakes littoral waters, and elevated pH values indicating supply of alkalising substances from the catchment – namely in the case of lake Bikcze, which, however, did not determine increased values of biological trophy indices.

### CONCLUSIONS

1. Values of biological trophy indices measured in the studied littoral of lakes Bikcze and Uściwierz did not indicate intensified eutrophication processes and determining their poor-trophy status.

2. Values of studied fertility parameters in the littoral of lakes Bikcze and Uściwierz may indicate de-eutrophication of their waters associated with their hydrotechnical development and, on the other hand, activity of humic acids supplied by active peat-bogs.

3. Elevated values of water electrolytic conductivity and pH in the studied littoral of lakes Bikcze and Uściwierz did not result in an increase of biological trophy indicators values.

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#### PRODUKCJA FITOPLANKTONU W LITORALU WYBRANYCH JEZIOR POJEZIERZA ŁĘCZYŃSKO-WŁODAWSKIEGO W SEZONIE LETNIM 2007–2008

**Streszczenie.** Zbadano tempo eutrofizacji w litoralu rolniczym i rolniczo-rekreacyjnym limnologicznie podobnych jezior: Bikcze i Uściwierz na Pojezierzu Łęczyńsko-Włodawskim, w sezonie letnim 2007–2008. Mierzono wartości biologicznych indeksów trofii: produkcji pierwotnej brutto fitoplanktonu, stężenia chlorofilu *a* oraz wyliczono wskaźnik trofii Carlsona (TSIChl *a*). Badania uzupełniono pomiarem podstawowych czynników fizyczno-chemicznych wód. Podobne dla obu jezior wartości wskaźników trofii w strefie litoralu nie wskazują na nasilenie się procesów eutrofizacji.

Słowa kluczowe: jezioro, produkcja pierwotna, koncentracja chlorofilu a, eutrofizacja, deeutrofizacja