

ESTIMATION OF POTENTIAL LOADS OF CONTAMINANTS GENERATED BY BEACH TOURISM ON LAKE ZAGŁĘBOCZE IN TWO SUMMER SEASONS, 2008 AND 2010

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Summary. The high nature and landscape values of lake Zagłębcze in the Łęczna-Włodawa Lakeland, reflected also in the considerable tourist interest, determined its inclusion in the Polesie Protected Landscape Area. The objective of the study was to estimate the amounts of biogenic substances potentially introduced into the lake in relation to the bathing-beach recreation, and analysis of the tourist capacity, related with the numbers of tourists taking their rest on the lake beaches in the summer seasons of 2008 and 2010. During the period of the study the numbers of tourists on the two main beaches of lake Zagłębcze did not result in exceeding the physical carrying capacity index, the natural tourist capacity of the lake, nor the index for open bathing zones, which was related with a relatively small potential influx of biogenic substances of recreational origin to the lake. A larger number of tourists was noted in the summer season of 2010.

Key words: lake, biogenic compounds, tourist capacity, recreation, tourism

INTRODUCTION

In recent years tourism has become one of the fastest developing branches of the economy, reflecting the dynamics and range of social and civilisation development. It is also a powerful instrument of regional policy, permitting the equalisation of social and economic differences [Anasiewicz 2004].

The development of tourism is largely determined by the level of tourism infrastructure development, as well as by the touristic attractiveness of a given location, and primarily its nature and landscape values. Thus tourism remains in close relation to the natural environment, and at the same time causes its transformations, more frequently negative ones. A favourable compromise between environmental protection and benefiting from the values of the environment is,

therefore, ensured by the model of balanced tourism that does not exceed the compensation capacity of nature [Lijewski *et al.* 2002].

The Łęczna-Włodawa Lakeland, with its diversity of area forms of nature conservation, determined by its high nature and landscape values, is one of the most important tourism regions of the Lublin Region, predisposing the area to many kinds of tourism and recreation [Świeca *et al.* 2007, Brzezińska-Wójcik *et al.* 2009, Krukowska and Krukowski 2009, Maślanko *et al.* 2011, Krukowski and Krukowska 2013].

Among the ecosystems of the Lakeland with exceptional tourism values, the prime position of that of the lakes, and among those, due to their outstanding environmental values – lakes Piaseczno, Białe Włodawskie, Krasne, Rogóźno, Białskie and Zagłębcze, frequented by tourists in great numbers [Krukowska and Krukowski 2009].

The increasing numbers of tourists using the beaches of many of the lakes of the Lakeland, combined with increase in the area of investment lands and with excessive recreational pressure around them, frequently causes exceeding of the natural tourism capacity of those objects [Chmielewski 2001].

Since lakes are ecosystems whose functioning depends on the influx of allochthonic substances from their drainage basins, on their metabolism and accumulation in the reservoirs [Bajkiewicz-Grabowska 2002], excessive influx of biogenic compounds (including those of recreational origin) to lake waters intensifies the process of eutrophication, causing a change in the abiotic and biotic elements of the ecosystems [Serafin 2009]. In consequence, the values of the physicochemical parameters of the waters frequently decrease, which results in, among other things, reduced possibility of tourist and recreational use of lakes.

The role of biogenic substances of tourist and recreational origin in the fertilisation of water reservoirs is often emphasised in hydrobiological publications [Vollenweider 1971, Kajak 1979, Bajkiewicz-Grabowska 1987, Kalff 2001, Kubiak and Tórz 2005], but the analyses are usually limited to the estimation of biogenic compounds inflowing from recreationally developed areas in the balance. Probably due to the relatively low share of recreation in the balance of nutrients [e.g. Ławniczak *et al.* 2010], no distinction is being made for the components of such impact, e.g. the pressure of bathing-beach recreation. The nearly closed ecological system of lakes, causing the inclusion of contaminants introduced even once in the cycle of matter causes, however, that even small amounts of biogenic compounds affect the quality of waters and may destabilise the biocenotic elements, e.g. macrophytes or invertebrate fauna, in the lake littoral [Soszka 2010].

Determination of all the components of the balance of biogenic compounds and reduction of their load supplying the lakes is therefore of fundamental importance for the improvement of water quality, for counteracting the degradation

of lake ecosystems, and consequently for the possibility of their economic use [Ławniczak *et al.* 2010].

The objective of this study was analysis of tourist movement on Lake Zagłębcze in the aspect of the amounts of biogenic compounds and organic wastes of recreational origin potentially introduced into the ecosystem, and on the tourist capacity, based on the numbers of tourists on the beaches of the lake in the summer seasons of 2008 and 2010.

MATERIALS AND METHODS

Lake Zagłębcze is situated in the south-western part of the Łęczna-Włodawa Lakeland, in the District of Łęczna, commune of Ludwin, between two localities: Jagodno and Lejno.

In the limnological aspect, lake Zagłębcze is a small water body, with area of 59 ha and capacity of approx. 4300 thousand m³, that due to its maximum depth of 25 m is classified among the deep reservoirs of the Lakeland. Lake Zagłębcze represents the dimictic, b-mesotrophic type of lake, with weakly varied shoreline [Fijałkowski 1959, Harasimiuk *et al.* 1998].

The reservoir under study was originally an inland lake. Within the framework of hydrotechnical works related with the Wieprz-Krzna Canal, the lake was partially surrounded with dykes and included in the network of melioration ditches by digging, on the north side, an outflow ditch functioning at high water levels. On the south-east side there is a periodically functioning artificial ditch draining the nearby forest and grassland areas [Cyzdik *et al.* 2000].

Apart from the southern bank and a small section of the marshy south-western shore, lake Zagłębcze is surrounded with a belt of sandy and turfey beach or recreation purposes. The drainage basin of the lake has a decidedly agricultural-forest character. Approximately 75% of its area is occupied by meadows, pastures, arable fields and fallows, forests constituting over 20% of the area. Lands developed for recreation are adjacent to the lake shores from the east side [Harasimiuk *et al.* 1998].

Due to the nature and landscape attractiveness, lake Zagłębcze and its neighbourhood have been included in the Polesie Protected Landscape Area, established in 1983 [Krukowska 2009], and along with lakes Piaseczno, Białe Włodawskie, Krasne, Rogóżno and Bialskie constitutes an exceptionally attractive tourism-recreation object, visited by large numbers of tourists [Krukowska 2009, Krukowska and Krukowski 2009].

The combination of protected areas with a high concentration of tourist traffic is known as the MacCannell Effect [2002], consisting in that protected areas which become a tourist attraction at the same time, through increased tourist

traffic, cause the destruction of those nature values that they generate [Maślanko *et al.* 2011].

The assessment of the potential loads of biogenic substances generated by tourism and bathing-beach recreation on lake Zagłębcze was performed in the summer seasons of 2008 (8 dates between 29th June and 13th July) and 2010 (8 dates between 6th July and 20th July), on the basis of numerical analysis of the numbers of tourists taking their rest in the shore zone of the lake, on its two main beaches – one situated on the north-east bank of the lake, with direct access by car, and the second, larger, situated on the east side, immediately before the recreational resort situated there, with recreation infrastructure and social facilities.

The tourists were counted on specific survey dates, between 10 and 12 am and 3 and 5 pm, 15–17, and the results were averaged for the day, for the whole study period, and for both beaches.

On the basis of the numbers of tourists taking their rest on lake Zagłębcze during the period of the study the estimated amounts of biogenic substances introduced by them into the lake were calculated. In the calculations we used materials from the Project of Twin Cooperation between the EU and Poland (PL 2005/IB/EN/03) within the framework of the module „Extension of the System of Sanitary Supervision in the area of the Quality of Waters”. Based on that source it was assumed that 100 bathers potentially introduce to the water 0.1 kg of nitrogen, 5 dm³ of urine, 30 dm³ of sweat, 50 g of insoluble organic contaminants and 400 g of soluble organic contaminants expressed as the use of KMnO₄ [Prędoła 2007].

For the amount of phosphorus getting into the water during bathing the index of Szyper and Zaniewska [1984] was adopted, equal to 0.457g of P per person.

The results concerning the numbers of tourists were subjected to simple statistical analysis, taking into account the mean value, standard deviation (*SD*), and the coefficient of variation (*V*) as a measure of the scatter of the results.

In addition, the index of physical carrying capacity (*PCC*) was calculated for lake Zagłębcze; that index defines the largest possible number of tourists on a given area in any specified time, that does not cause negative changes of the natural environment [Pawlikowska-Piechotka 2009].

The calculations were made using the formula of Ciefuentes Arias [1992], after Kowalczyk and Derek [2010]:

$$PCC = A \times V/a \times Rf,$$

where:

A – area available for the tourists (beach);

V/a – number of tourists per 1 m², resting comfortably [Tran Nghi *et al.* 2007], for the beaches of lake the value adopted was 5 m² per tourist, i.e.

V/a = 0.2 person · m⁻²;

Rf – coefficient – a quotient of time during which the area is made available for the tourists and the mean duration of stay of a tourist; the adopted time

of accessibility to the beaches was 16 hours, and the mean duration of stay of one tourist 5 h, therefore $Rf = 3.2$.

The additional index applied was the index of tourist capacity for open bathing areas, at 20 m²/person, above which value there appears excessive tourist pressure on the lake ecosystem [Owsiak *et al.* 2003]. The water area for the bathers was calculated on the basis of a 30 m belt into the shore water surface of the lake, along the whole shoreline of the lake (approx. 86190 m²). The calculations took into account the average number of tourists on the lake during a day, assuming that each sunbather on the beach was also a bather during his/her stay.

RESULTS AND DISCUSSION

In the two summer seasons studied, 2008 and 2010, the maximum number of persons taking their rest on the beaches of lake Zagłębcze did not exceed 2000, attaining an average diurnal number for the season of 2008 equal 537 persons, and a slightly higher value for 2010, equal to 615 persons (Tab. 1). During the study period the intensity of tourist traffic on lake Zagłębcze did not, therefore, exceed the maximum value of the index of anthropogenic impact on the environment, defined as 8 (in the 1–8 scale) for numbers above 3200 tourists simultaneously exerting an effect on a lake ecosystem [after Maślanko *et al.* 2011].

Table 1. Mean diurnal numbers of tourists on beaches of lake Zagłębcze, with oscillation ranges and total numbers in the summer seasons of 2008 and 2010

Zagłębcze Lake	2008	2010
Range	26–1955	326–1203
Mean daily	537.25	615.12
<i>SD</i>	649.45	365.2
<i>V</i> , %	120.88	59.37
Total	4298	4921

The lower than in years preceding the study period [Chmielewski 2000] number of tourists taking their rest on the beaches of lake Zagłębcze could have been a resultant of worse weather conditions and the general social-economic transformations in Poland that could determine other choices of rest and recreation destinations – e.g. more attractive trips abroad. There could also take place an increased tourist pressure on the developed areas around the lake, at the expense of beach tourism.

The highest intensity of tourist traffic in the region of the Łęczna-Włodawa Lakeland is observed from mid-July to the middle of August, when even up to 36 thousand tourists visit the Lakeland [Chmielewski 2000].

A similar trend was noted during the study period. On weekends the numbers of persons on the beaches of lake Zagłębcze were over 50% greater than on week days. In the summer season of 2008 the highest number of tourists was recorded on Sunday the 13th of July (1955 persons), while in the summer of 2010 – on Saturday the 10th of July (1203 persons). That tendency caused high values of the coefficient of variation (Tab. 1), indicating notable scatter of results related to the numbers of tourists taking their rest on lake Zagłębcze for the successive dates of survey in the summer seasons of 2008 and 2010. Greater differences were noted in July 2008, when the value of the coefficient of variation (V) reached 121% (Tab. 1).

In the summer season of 2008 tourists using the beaches of lake Zagłębcze could potentially introduce to the lake waters diurnal averages of approx. 537 g of nitrogen, slightly above 245 g of phosphorus, approx. 188 dm³ physiological secretions and excretions, and more than 2.4 kg of organic compounds (Fig. 1–3). In the season of 2010 the estimated amounts of nutrients introduced were higher by about 15%, with notably greater oscillation ranges (see Fig. 1–3) related with the large variation in the numbers of tourists on the successive dates of survey. When the results are extrapolated for the whole summer season of 2008 (90 days), the estimated amount of introduced biogenic elements (N and P) attains nearly 71 kg (48.35 kg N and 22.1 kg P), that of physiological secretions almost 17 thousand dm³, and that of organic compounds is above 43.5 kg.

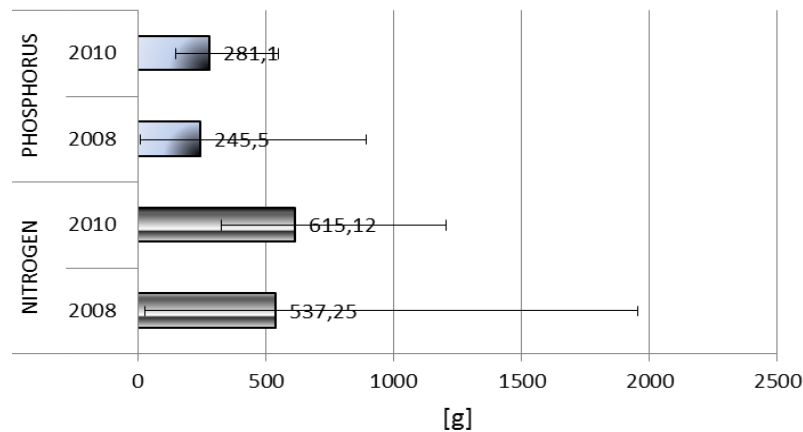


Fig. 1. Mean diurnal values of biogenic compounds potentially introduced by bathers on the beaches into the waters of lake Zagłębcze, with variation ranges in the summer seasons of 2008 and 2010

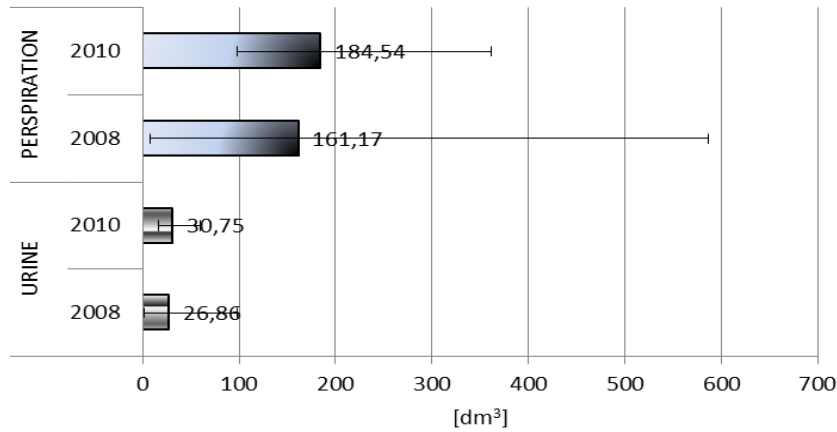


Fig. 2. Mean diurnal values of organic secretions potentially introduced by bathers on the beaches into the waters of lake Zagłębcze, with variation ranges in the summer seasons of 2008 and 2010

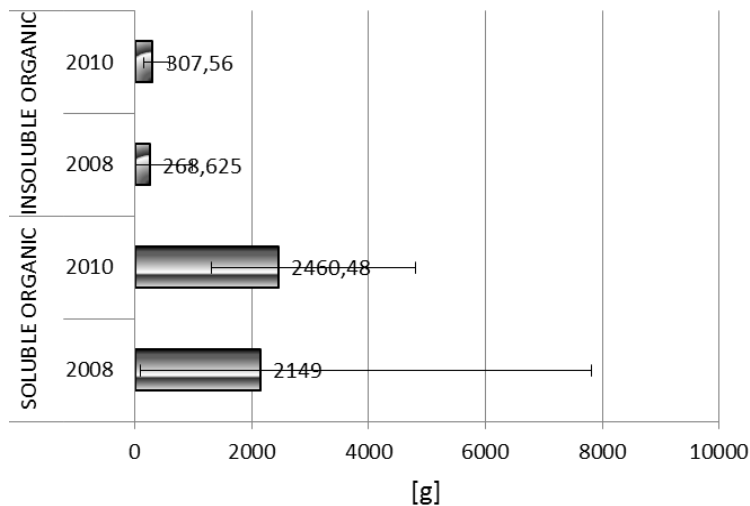


Fig. 3. Mean diurnal values of organic compounds, soluble and insoluble, potentially introduced by bathers on the beaches into the waters of lake Zagłębcze, with variation ranges in the summer seasons of 2008 and 2010

The data on the potential load of N and P of bathing zone-beach origin, concerning lake Zagłębcze in the summer seasons of 2008 and 2010, can be compared with – adopted after Soszka [2010] – unit coefficients of export of area loads of nutrients from drainage basin areas under use of various character ($\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$). Due to the relatively large area of the drainage basin of lake Zagłębcze – 463.6 ha [after Furtak and Sobolewski 1998], the total estimated load of nitrogen and phosphorus originating from beach tourism on lake Zagłębcze in

the summer seasons of 2008 and 2010 had only a slight contribution to the supply of the lake in nutrients. The estimated load of biogenic substances generated by the arable fields (57.5 ha) in the drainage basin of lake Zagłębcze (coefficient $9.0 \text{ kg N} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$) is $517.5 \text{ kg N} \cdot \text{year}^{-1}$ and $17.25 \text{ kg P} \cdot \text{year}^{-1}$ (coefficient $0.3 \text{ kg P} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$). In the case of the drainage basin areas occupied by meadows and pastures (162.3 ha) the corresponding values were as follows: $486.9 \text{ kg N} \cdot \text{year}^{-1}$ (coefficient $3.0 \text{ kg N} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$) and $32 \text{ kg P} \cdot \text{year}^{-1}$ (coefficient $0.2 \text{ kg P} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$), and for the forest areas (157.6 ha) – $236.4 \text{ kg N} \cdot \text{year}^{-1}$ (coefficient $1.5 \text{ kg N} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$) and $15.76 \text{ kg P} \cdot \text{year}^{-1}$ (coefficient $0.1 \text{ kg P} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$).

The index of physical carrying capacity (*PCC*) calculated for the beaches of lake Zagłębcze attained a maximum of 1084.75 persons a day for the smaller beach and 3254 persons for the main beach, giving a total for the whole lake of $PCC_{tot.} = 4339.75$ persons per day, resting comfortably without detrimental effects to the lake ecosystem. The numbers of tourists noted both for the summer season of 2008 and for that of 2010 for lake Zagłębcze did not exceed the value of index *PCC*.

It is worth noting that in the 1990's the frequency of tourists taking their rest on lake Zagłębcze exceeded the natural tourist capacity of the reservoir by a factor of 2.5 to 3, and already in those times the tourist pressure caused changes in the phyto-cenoses surrounding the lake [Chmielewski 2000], which – however – did not result in changes concerning the lake itself [Grzywna 2002]. That was an effect of the high compensation capabilities of lake Zagłębcze [Kornijów *et al.* 1995], related to the favourable morphological conditions of the lake basin and its drainage basin (considerable depth, full thermal stratification, low annual water exchange percentage, absence of point sources of contaminants, or the dominance of forests) that permit, in spite of the strong recreational pressure, to maintain high stability of all of the physicochemical properties of its waters (category I, II of susceptibility to degradation and class I, II in the Lake Quality Evaluation System) [Grzywna 2002].

Similarly, the index of tourist capacity calculated for open bathing zones according to Owsiak *et al.* [2003] did not exceed the threshold value for the lake ecosystem, of $1 \text{ person} \cdot 20 \text{ m}^2 \cdot \text{day}^{-1}$, both for the summer season of 2008 ($0.124 \text{ person} \cdot 20 \text{ m}^2 \cdot \text{day}^{-1}$) and for the summer of 2010 ($0.142 \text{ person} \cdot 20 \text{ m}^2 \cdot \text{day}^{-1}$).

CONCLUSIONS

1. During the study period the numbers of tourists taking their rest on the beaches of lake Zagłębcze were slightly higher in the season of 2010, confirming the tendency of prevalence of weekend tourism over week-day rest and recreation.

2. The relatively low pressure of bathing and beach tourism on lake Zagłębcze was reflected in correspondingly small amounts of biogenic compounds potentially introduced into the lake waters.

3. In both summer seasons, 2008 and 2010, the threshold levels of the tourist capacity index and the physical carrying capacity index of lake Zagłębcze and of the index calculated for its open bathing zones were not exceeded.

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OCENA POTENCJALNYCH ŁADUNKÓW ZANIECZYSZCZEŃ GENEROWANYCH
PRZEZ TURYSTYKĘ PLAŻOWĄ NAD JEZIOREM ZAGŁĘBOCZE
W DWÓCH SEZONACH LETNICH, 2008 I 2010

Streszczenie. Wysokie walory przyrodniczo-krajobrazowe jeziora Zagłębcze na Pojezierzu Łęczynsko-Włodawskim potwierdzone również znacznym zainteresowaniem turystycznym zdeterminowały jego włączenie do Poleskiego Obszaru Chronionego Krajobrazu. Celem pracy była ocena ilości związków biogenych dostających się potencjalnie do jeziora w związku z rekreacją kąpieliskowo-plażową oraz analiza chłonności turystycznej związanej z liczbą turystów wypoczywających na plażach jeziora w sezonach letnich 2008 r. i 2010 r. W okresie badań liczebność turystów na dwóch głównych plażach jeziora Zagłębcze nie wpłynęła na przekroczenie wskaźników turystycznej chłonności fizycznej oraz indeksu dla stref kąpielisk otwartych, co wiązało się z relatywnie niewielkim potencjalnym wpływem substancji biogenych pochodzenia rekreacyjnego do jeziora. Wyższą liczebność turystów zanotowano w sezonie letnim 2010.

Słowa kluczowe: jezioro, związki biogenne, chłonność turystyczna, rekreacja, turystyka