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EFFECT OF RECREATION ON DIVERSITY OF LITTORAL BENTHIC MACROINVERTEBRATES IN LAKES

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Abstract

Water-based recreation making use of the assets offered by the lakes. The impact of recreational activities on the macroinvertebrate communities in the littoral zone was investigated by comparing sites that had been altered for recreational purposes with sites that had not been used for this purpose. The study was conducted on fourteen lowland lakes situated in the north-eastern region of Poland. A semi-quantitative method was used to sample the infralittoral macroinvertebrates at the recreationally used site and two reference sites. The results obtained indicate that the development of recreational facilities has a moderate impact on macroinvertebrate assemblages. Significant differences (Wilcoxon test, $p < 0.05$) were identified in the macroinvertebrate assemblages of the compared sites in eight of the fourteen studied lakes. The observed biodiversity was predominantly lower compared to the reference sites, and the differences in community structure may be the result of the homogeneity of the littoral habitats. In part of the lakes surveyed, macroinvertebrate communities were found to be similar between those used for recreation and sites that had been transformed for recreational functions.

Introduction

Recreational opportunities are a primary reason people choose to visit lakes and the fact that people benefit from access to natural and manmade water bodies is well documented (Doi et al. 2013, Venohr et al. 2018, Schafft et al. 2021). Inland waters are a popular destination due to their greater accessibility compared to marine waters for the majority of people (Meyer et al. 2021). The impact of recreation on aquatic ecosystems is variable and depends on a number of factors, including the species involved, the location, and the way in which recreation is managed. In general, the

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effects of water-based activities have been found to be negative, particularly concerning their influence on plants (O'TOOLE et al. 2009, MEYER et al. 2021), aquatic invertebrates (SCHMITT et al. 2007), fish (MEYERHOFF et al. 2019) and birds (YALDEN 1992, MCFADDEN et al. 2017). It has been demonstrated that water-based recreational activities can cause stress to aquatic ecosystems, which in turn affects the diversity, composition and abundance of freshwater organisms (VENOHR et al. 2018). The effects of water-based recreational activities have been particularly well-documented for boating (SMITH et al. 2019, HOUSER et al. 2021), swimming (SCHAFFT et al. 2021) and angling (LEWIN et al. 2006, O'TOOLE et al. 2009, NIKOLAUS et al. 2021).

The shores of lakes play an important role in the functioning of lake ecosystems and are characterised by high biodiversity. Littoral zones are distinguished by a complex spatial structure and variable environmental conditions, which provide habitats for a diverse range of water invertebrate species (STRAYER and FINDLAY 2010). The impact of human activity on the littoral zone has significant implications for the diversity of lake ecosystems, with the unique assemblage of benthic organisms in this zone being particularly vulnerable to disruption (BRAUNS et al. 2007). Macroinvertebrates play a crucial role in the littoral zone of lakes, and the composition of the benthos community is closely linked to the prevailing habitat conditions. Unfortunately, there is a limitation in the available information concerning the impact of recreational sites on the habitat and the diversity of the fauna at the lake's shoreline (BRAUNS et al. 2007, SMITH et al., 2019, SPYRA and STRZELEC 2019, ARVA et al. 2021).

The aim of this study was to assess the impact of water-based recreation on the richness, abundance and composition of the littoral macroinvertebrate communities in lowland lakes. In particular, my objective was to respond to the following questions: 1. Does recreational alteration of the littoral influence the taxonomic richness, abundance and composition of macroinvertebrate assemblages? 2. Does the littoral zone, as a site for water recreation, affect the taxonomic diversity of macroinvertebrates?

Material and Method

Study area

The investigation was conducted on 14 lakes situated in the northeastern region of Poland (Figure 1). The majority of the lakes under survey were situated within the Vistula River catchment basin (11 lakes), with

a further three located within the Pregola River catchment basin. In accordance with the typology proposed by SOLON et al. (2018), four lakes are situated within the macroregion of the Masurian Lake District, while those located in the Wel River basin are within the macroregion of the Chełmińsko-Dobrzyńskie Lake District, and Lake Płaskie is within the macroregion of the Iławska Lake District. Of the lakes under investigation, this is the largest, with a surface area of 620 ha. A part of the Lake Płaskie area is protected under the European environmental protection network Natura 2000 and the Iława Lake District Landscape Park. The surface areas of Lakes Majcz Wielki and Ławki range from 100 to 200 ha. The surface areas of Lakes Kuc and Stryjewskie are less than 100 ha. The largest of the lakes situated within the Wel River catchment area is Lake Dąbrowa Wielka, which has a surface area of 615 ha. The surface areas of lakes Rumian, Dąbrowa Mała, Tarczyńskie, Grądy and Lidzbarskie range from 100 to 200 ha, while the remaining lakes are smaller than 100 ha (i.e., lakes Hartowieckie, Kiełpińskie and Zarybinek). Five of the lakes are situated within the boundaries of the Welski Landscape Park. The lakes were selected to represent a range of water-based recreational activities.

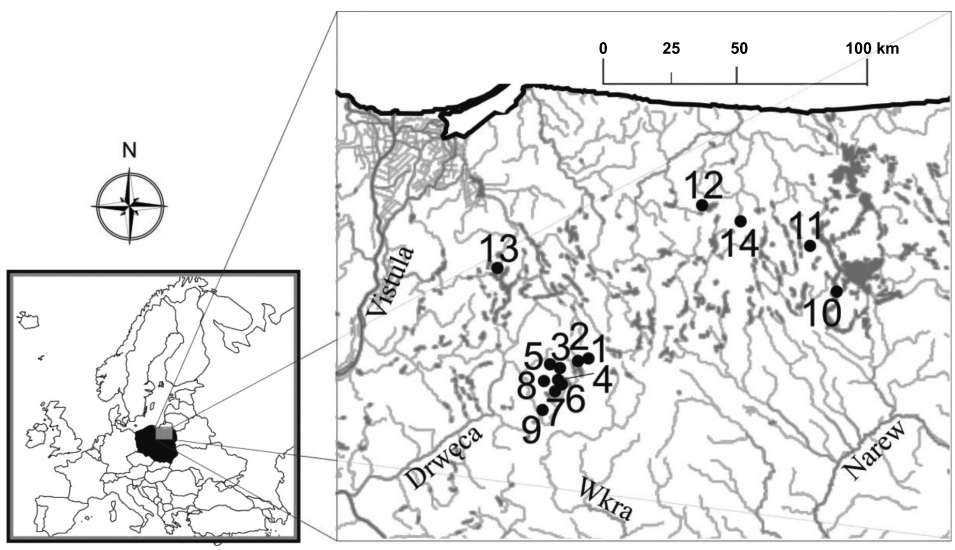

Fig. 1. The study area showing location of lake sampling sites 1 – Dąbrowa Wielka; 2 – Dąbrowa Mała; 3 – Rumian; 4 – Zarybinek; 5 – Hartowieckie; 6 – Tarczyńskie; 7 – Grądy; 8 – Kiełpińskie; 9 – Lidzbarskie; 10 – Majcz Wielki; 11 – Kuc; 12 – Ławki; 13 – Płaskie; 14 – Stryjewskie

Methodology

The impact of recreational activities on the littoral macrozoobenthos was assessed by comparing areas that were subject to high levels of trampling or physical disturbance with those that were less intensively used in the infralittoral zone of selected lowland lakes. In order to provide a representative sample of the range of impacts induced by recreational use, three sites were selected within each lake. One site has been designated in a location that has been modified for recreational purposes. Two reference stations were located at the boundaries between the sandy impacted area and the natural vegetated shoreline, which was dominated by reed and rush. Sampling points with and without recreational transformation were selected in close proximity to one another, taking into account the substratum and riparian vegetation, as these factors have the potential to influence the distribution of aquatic fauna. The bottom fauna were sampled in autumn (October 2009 – lakes 1–9, October 2011 – lakes 10–14, Figure 1) using a semiquantitative method, with samples taken at a depth of between 0.5 and 0.75 m. The material was sampled using a Surber sampler. The specimens were then picked from the sediments and identified in the laboratory to the lowest possible taxonomic level, with the exception of lakes 10–14, in which the chironomids were determined to the subfamily level.

Statistical analysis

The benthic macroinvertebrate community was first analysed by calculating abundance, taxonomic richness, the Shannon diversity index (H′) and the Pielou evenness index (E) for each site. Data were analyzed using the MultiVariate Statistical Package 3.13 (Kovach 2007).

The Wilcoxon non-parametric rank-sum test was used to check for significant differences between values of taxa abundances of macroinvertebate assemblages at sampling site turned into recreational place as compared to the other sites at each lake. Comparison of benthos assemblages was conducted only within stations at different impact level. All possible pairs of elements (sites within one lake, not mixed) were tested. The statistical evaluation of the data was carried out with Statistica 13.1 statistical package (TIBCO Software Inc., 2017).

Results

A lower infralittoral species richness was observed at 40% of the surveyed lakes (Figure 2), indicating a potential impact on the biodiversity of

these coastal ecosystems. In two cases, the number of taxa at the impacted site and the taxonomically poorer reference site were found to be non-significantly different. The highest number of taxa was identified at the site situated within the bathing area of Lake Dąbrowa Wielka.

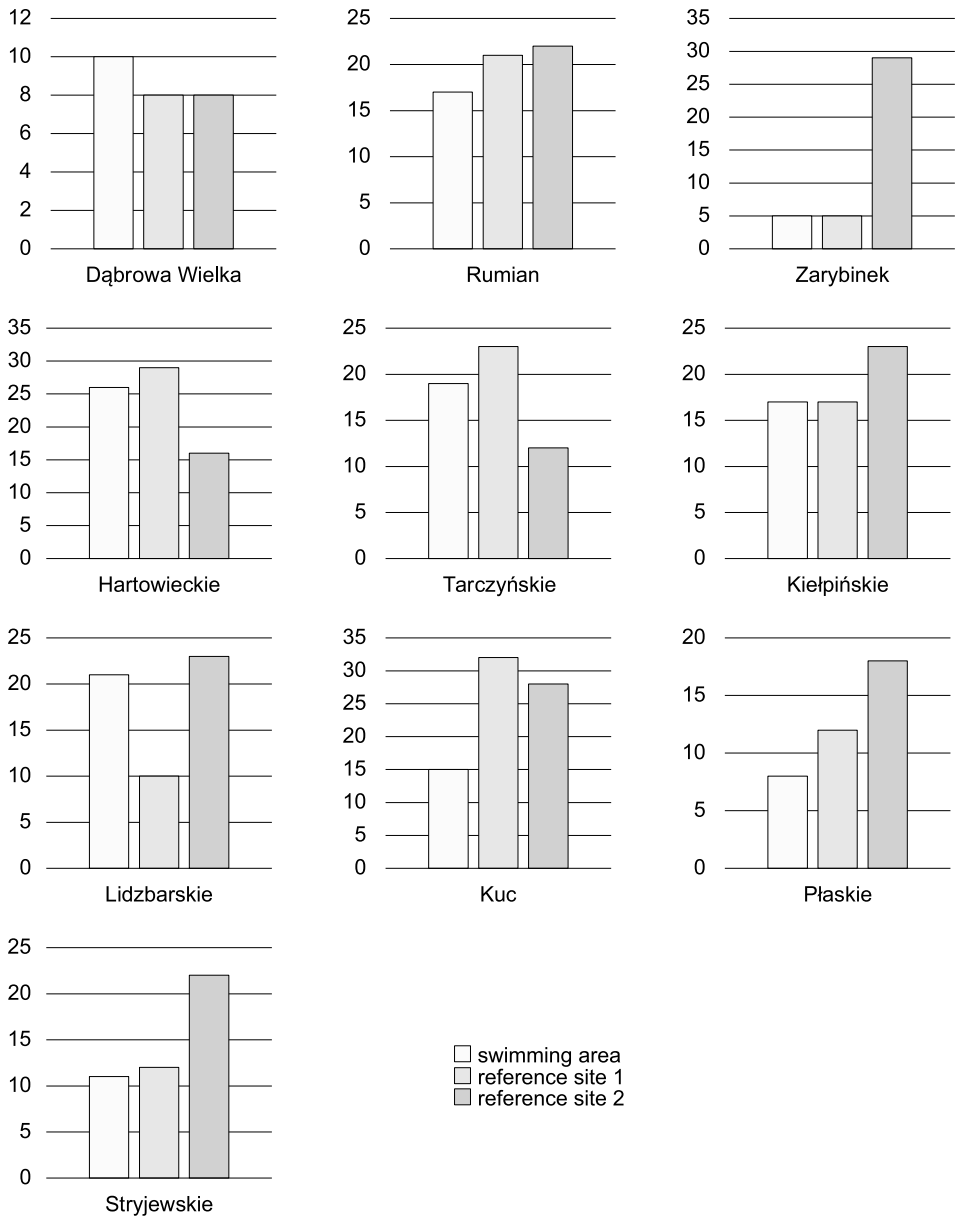

Fig. 2. Comparison of taxa richness (S) among sites within studied lakes with swimming area

Similarly, a comparison of the taxonomic richness of the lakes with boat ramp sites revealed that in half of the lakes, the fewest taxa of littoral fauna were observed at impacted sites (Figure 3). The greatest number of taxa were observed in Lake Dąbrowa Mała at boat ramp sites.

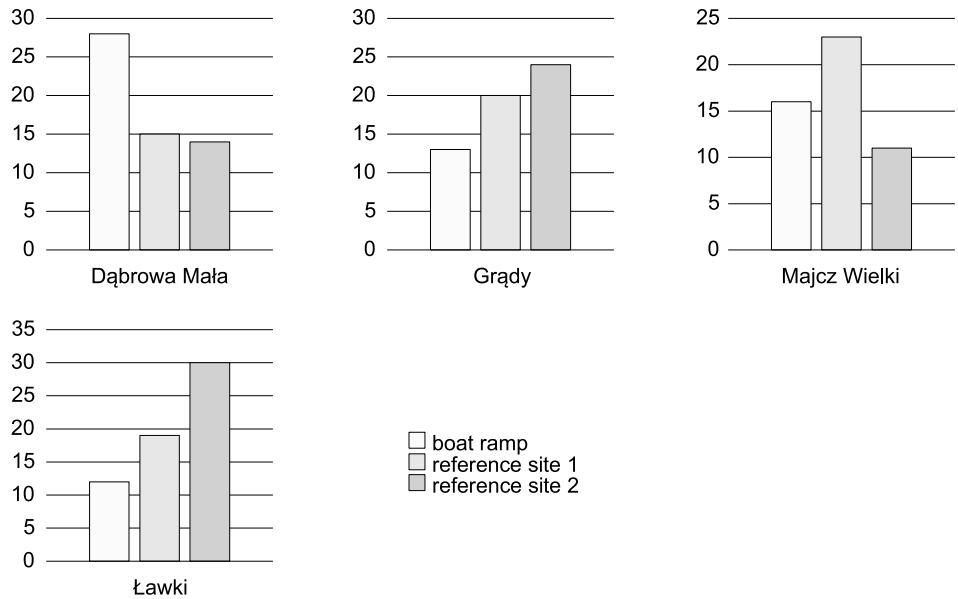

Fig. 3. Comparison of taxa richness (S) among sites within studied lakes with boat ramp

A comparison of the structure of macroinvertebrate assemblages based on taxon abundances revealed statistically significant differences between impacted and reference sites for eight of the fourteen lakes under study (Table 1). Significant differences were observed in the faunal assemblages of lakes Kuc and Dąbrowa Mała when the impacted site was compared with both reference sites.

The Shannon diversity index values of macroinvertebrate assemblages in the lakes under investigation ranged from 0.25 at the site with recreational activities in Lake Tarczyńskie to 1.33 at one of the reference sites in Lake Kuc. The diversity of bottom fauna was lowest at the site located in the bathing area for five lakes (Figure 4). In the case of Lakes Hartowieckie and Lidzbarskie, the highest biodiversity was recorded at the impacted site. Among the four lakes with boat ramps, the value of the Shannon diversity index was lowest on impacted sites for three of them; the opposite was the case for Lake Dąbrowa Mała (Figure 5).

Table 1

Results of Wilcoxon sign rank test for differences between macroinvertebrate assemblages at stations where a recreation activity takes place and in the reference area. Statistically significant rows are bold

Lake	Recreation impact	Reference site	*N*	Wilcoxon test (Z)	*p* value
Dąbrowa Wielka	swimming area	1	14	0.628	0.530
		2	9	1.599	0.110
Rumian	swimming area	1	26	0.952	0.341
		2	22	0.503	0.615
Zarybinek	swimming area	1	9	0.296	0.767
		2	**30**	**3.898**	**<0.001**
Hartowieckie	swimming area	1	36	0.652	0.514
		2	**26**	**2.159**	**0.031**
Tarczyńskie	swimming area	1	24	0.400	0.689
		2	21	1.164	0.244
Kiełpińskie	swimming area	1	24	0.929	0.353
		2	33	1.483	0.138
Lidzbarskie	swimming area	**1**	**26**	**2.781**	**0.005**
		2	38	0.109	0.913
Kuc	swimming area	**1**	**38**	**3.009**	**0.003**
		2	**31**	**2.312**	**0.021**
Płaskie	swimming area	1	16	0.103	0.918
		2	21	1.286	0.198
Stryjewskie	swimming area	1	19	0.402	0.687
		2	**24**	**3.457**	**0.001**
Dąbrowa Mała	boat ramp	**1**	**28**	**4.179**	**<0.001**
		2	**27**	**3.676**	**<0.001**
Grądy	boat ramp	1	22	1.542	0.123
		2	**25**	**3.054**	**0.002**
Majcz Wielki	boat ramp	1	29	1.438	0.150
		2	20	0.747	0.455
Ławki	boat ramp	1	24	0.629	0.530
		2	**36**	**2.129**	**0.033**

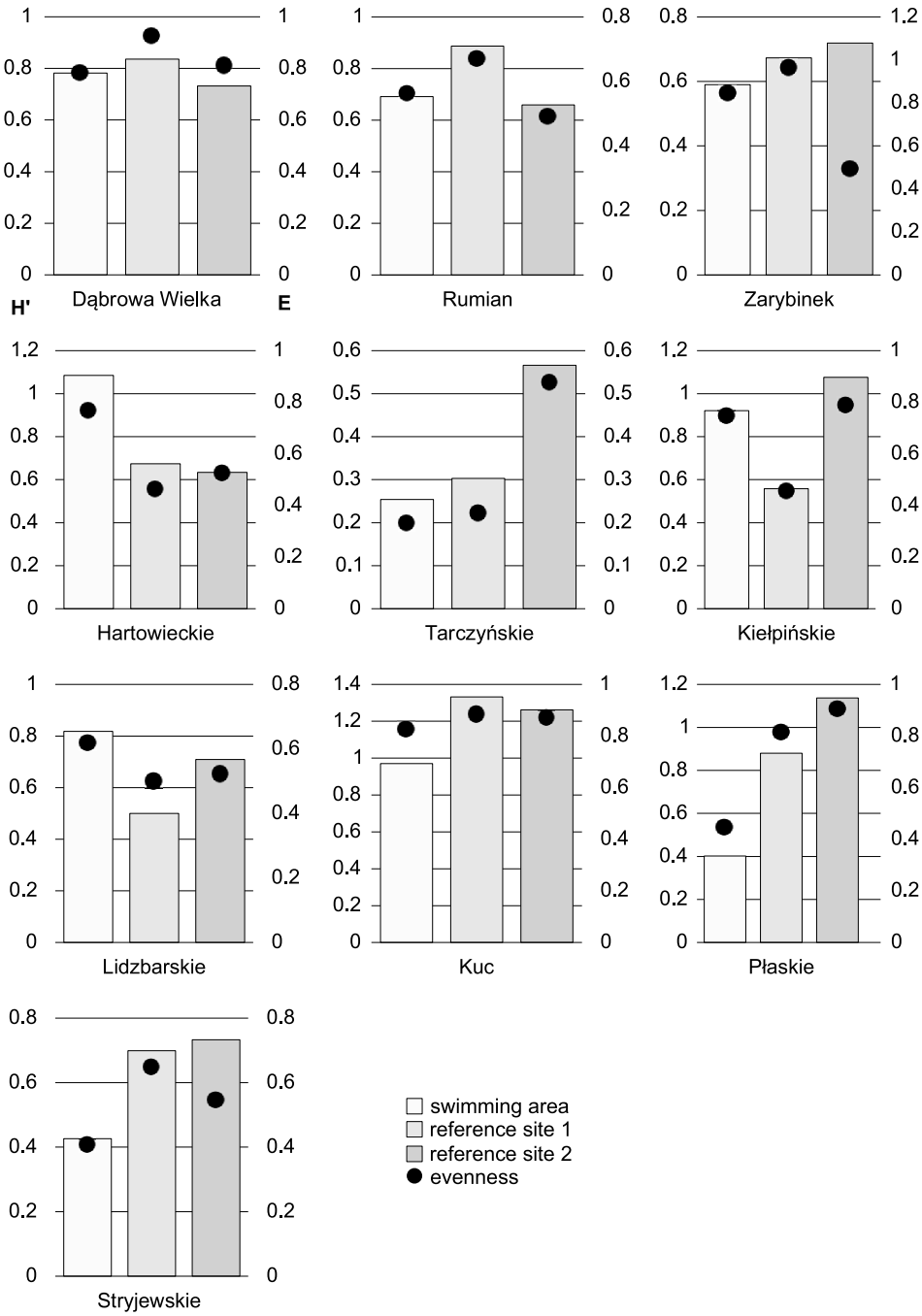

Fig. 4. Results of Shannon-Weaver index (H') and Evenness (E) for the studied stations in the lakes with swimming area

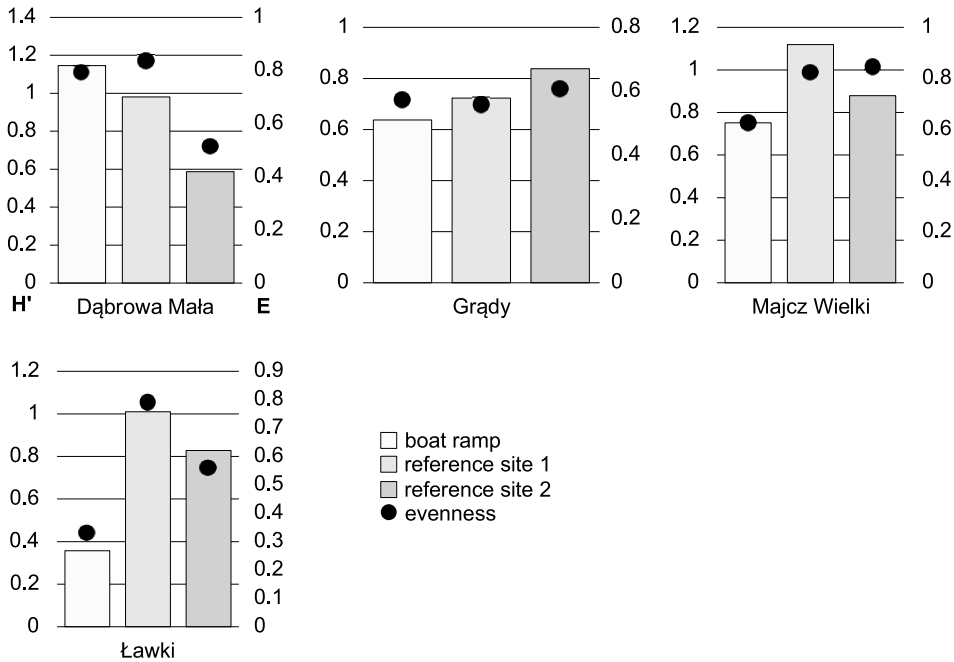

Fig. 5. Results of Shannon-Weaver index (H') and Evenness (E) for the studied stations in the lakes with boat ramp

Discussion

Despite observing a general reduction in the taxonomic diversity of species at sites where recreational activities were taking place, this decline was not evident in all lakes. This may be the result of a number of factors. The conversion of shoreline to beach results in the absence of riparian trees. Furthermore, the presence of a boat ramp on the shoreline has an additional impact, as it eliminates the vegetation that would otherwise facilitate boat launching. This restricts access to plant litter, which would otherwise provide a food source for the habitat and a food base for shredders (SOLIMINI et al. 2006). Consequently, the infralittoral species richness and abundance of Ephemeroptera, Trichoptera and shredders were markedly reduced on the beaches in comparison to the natural shorelines (BRAUNS et al. 2007). Macrophytes provide shelter for the fauna and serve to compensate for the influence of water movements on invertebrate fauna (TOLONEN et al. 2001). The mosaic of habitat types present in the littoral zone of lakes creates a high spatial heterogeneity. However, the annual timing of strong macrophyte development often coincides with the summer months, when water recreation peaks (VERHOFSTAD and BAKKER

2019). The impact of recreational activities on lake ecosystems is generally less significant than other environmental factors (SCHAFFT et al. 2024). A lake shore used during the season for recreational activities such as bathing or for boat access is subject to repeated disruption from human activity, including trampling and increased wave action (SOLIMINI et al. 2006). The present study demonstrates that in more than half of the lakes surveyed, the lowest levels of taxonomic diversity were observed in areas that have been altered for recreational use.

SMITH et al. (2019) reports that littoral macroinvertebrate assemblages occurring in large but relatively shallow lakes were not significantly influenced by boating-related activity. However, the results of the present study demonstrated greater differences between the results obtained for the impacted and reference sites for the boat ramp lakes. In addition to wave stress, increased turbidity and light limitations have been identified as factors that disturb the water environment by ramp boats (SOLIMINI et al. 2006, SMITH et al 2019).

The highest value of the Shannon diversity index at one of the reference sites in Lake Kuc can be attributed to the highest number of taxa observed across all the studied lakes (KOSZAŁKA and JABŁOŃSKA-BARNA 2020). Furthermore, diversity at both other sites was also relatively high. Additionally, the high evenness values at all sites in this lake indicate a very equal share of taxa in the community.

The situation in which the greatest number of taxa were identified at induced sites in both lakes Dąbrowa, which are situated in close proximate locations, would indicate a need for further investigation.

This study attempted to assessing the impact of transforming the littoral habitat for zoobenthos. Although differences in taxa diversity and composition as well as in richness were detected for benthic invertebrates, translating these observations as strong response to water-based recreation effects should be interpreted with caution. The present study has some limitations. For instance, due to insect life cycles, it is not possible to carry out the survey in summer during the high tourist season. Survey coverage of more lakes would be needed to more fully assess the impact of the shoreline altered into a bathing area and boat ramp on macroinvertebrate communities.

Conclusions

The present study has demonstrated that the development of recreational areas has a moderate impact on macroinvertebrate assemblages.

The observed biodiversity was predominantly lower in comparison to reference sites, and the differences in community structure are attributable to the homogeneity of littoral habitats. In some of the lakes surveyed, macroinvertebrate communities exhibited similarities between areas with low and high recreational use.

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