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EFFECTS OF TOURISM ON LITTORAL PLANTS OF LAKE PROVALA AND BEGEČKA JAMA

ABSTRACT: Wetlands are characterized by a unique combination of ecological factors and are currently facing significant threats, particularly to plant diversity. In 2023, the influence of sports and recreational tourism on plant diversity in the littoral zones of Lake Provala and the Nature Park Begečka Jama was investigated. The diversity of plant species and physical and chemical characteristics of water were analyzed. The results revealed that at sites under pressure, a smaller number of plant species was recorded compared to the control site. According to the PERMANOVA analysis, there is no statistically significant difference between pressured and non-pressured locations. Since sports and recreational tourism is permitted in the studied areas, the findings confirm that they do not have a significant impact on plant diversity.

KEYWORDS: diversity; macrophytes; permanova; recreational tourism; sports tourism; wetlands

INTRODUCTION

In the history of ecological research, biodiversity loss has been identified as a major problem, primarily resulting from the modification of natural habitats due to anthropogenic influences (Sodhy et al., 2006). The International Union for Conservation of Nature (IUCN) has emphasized the importance of ephemeral and small water basins, recognizing them as priority habitats in wetland protection and management systems due to the unique communities of aquatic organisms they support (Radulović and Teodorović, 2011).

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Wetlands are characterized by a unique combination of ecological factors, including hydrological, pedological, microclimatic and mesoclimatic influences, as well as distinctive vegetation (Valk, 2006). These ecosystems rank first in the value of their services among all ecosystems, contributing 47% of the global ecosystem service value, making them one of the most important and productive ecosystems on Earth (Ting Xu et al., 2019).

However, wetlands face significant threats, particularly to plant diversity, which is globally endangered. Rare and threatened species are at high risk of extinction if these threats are not addressed. As 21% of native plant species are specialist in aquatic habitats, the loss of natural wetland ecosystems could have severe consequences for vascular plant diversity (Richardson et al., 2015). Contemporary freshwater ecosystems can be characterized as biodiversity hotspots (Haase et al., 2023), essential for biodiversity conservation. Without enhanced protection, many endangered aquatic species may vanish before the century's end (Williams and Dodd, 1978). Wetlands also provide critical ecosystem services, including climate regulation, flood prevention, soil erosion control, nutrient recycling, biomass production and opportunities for recreation and tourism. These services highlight the vital role wetlands play in maintaining ecological balance and supporting human well-being (Keddy et al., 2009).

The flora of wetlands is essential for numerous reasons. Beyond its role in the food chain, wetland phytocoenoses exhibit high levels of primary production and provide critical habitats for various groups, including periphyton, epiphytic bacteria, macroinvertebrates, fish, and birds (Cronk et al., 2001). Aquatic macrophytes function as bioaccumulators, absorbing nutrients, heavy metals and pesticides from the water. Additionally, they serve as bioindicators, reflecting the state and quality of the environment (Santos et al., 2022).

Wetland flora is threatened by the same factors that endanger ecosystems globally, such as anthropogenic activities including desiccation, degradation, pollution, changes in hydrological regimes, invasive species and tourism development. Sports tourism encompasses recreational activities like sport fishing, boating, swimming and diving (Liddie et al., 1980). Fishing tourism is particularly prominent in these areas due to their favorable fish habitats (Lazić et al., 2008). In addition, lake recreational activities cause physical alterations of the shoreline zone leading to endangerment of natural habitats and littoral communities.

The impact of sports and recreational tourism on freshwater ecosystems is evident in the decline of biodiversity, degradation of flora caused by boat propellers, discharge of wastewater and introduction of non-native species. Therefore, the objective of this study is to examine the effects of sports and recreational tourism on plant diversity in the littoral zones of lakes.

MATERIALS AND METHODS

Field research was carried out in May and June 2023 at two locations, at Lake Provala and Begečka Jama Nature Park. Both researched areas are natural ecosystems, with the exception that Provala Lake is not the protected area,

while Begečka Jama was declared as Nature park – a protected area of the third category (Galamboš, 2011).

Study area

The first research site, Lake Provala, is located on the left bank of the Danube River in the Vojvodina province, southwestern Bačka region, approximately 2 km southwest of Vajska and 2.5 km northwest of Bođani, within the Vajštansko-Bođanski Rit (Figure 1). Lake Provala was formed during a major flood in May 1924, when the water level of the Danube River reached an exceptionally high level. This lake represents a macrophytic type of ecosystem, with a flora comprising 65 plant species that primarily develop in the narrow coastal zone. The plant species are widely distributed, reflecting the relatively uniform conditions typical of aquatic ecosystems (Nikolić, 2005).

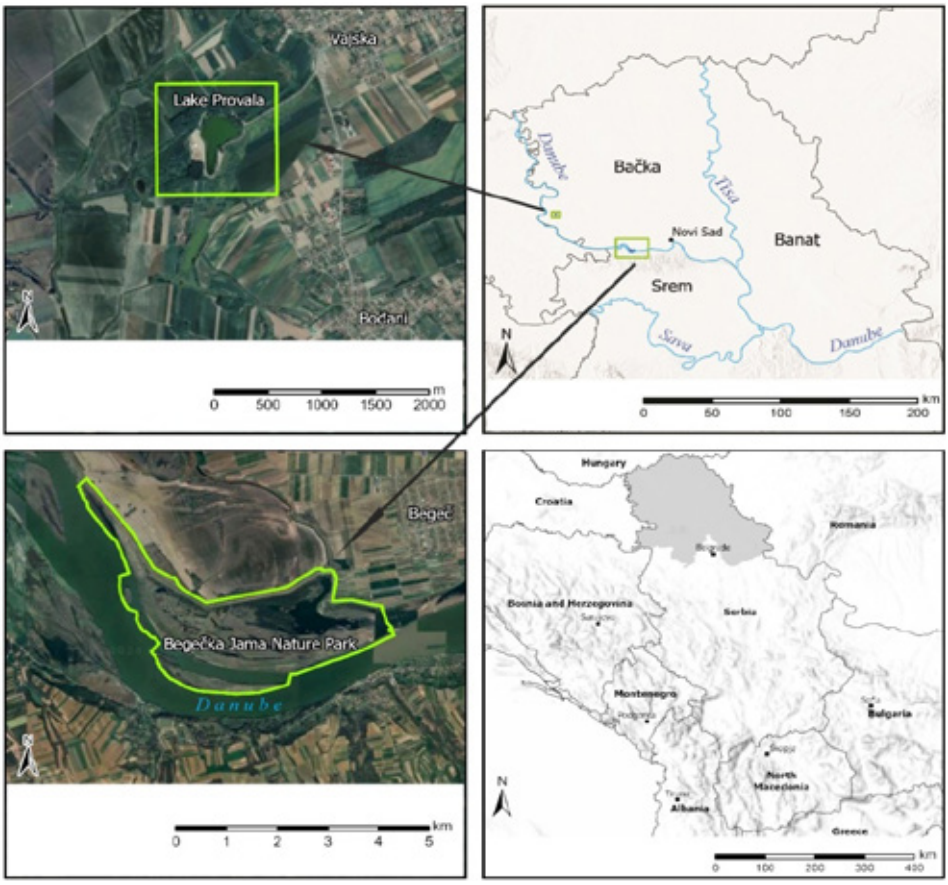

Figure 1. Locations of study area (based on LS, OS, NMA, Geodatastyrelsen, GSA, GSI, OpenStreetMap contributors, and the GIS User Community)

The second research site is the Begečka Jama Nature Park, also situated in the Vojvodina province, southern Bačka region, on the left bank of the Danube River, about 20 km west of Novi Sad. Within the boundaries of the Begečka Jama Nature Park, 125 taxa of higher plants have been recorded, many of which hold national and international significance. For instance, *Nymphaea alba* L. and *Potamogeton nodosus* Poir. are classified as strictly protected species, while *Acorus calamus* L., *Carex acuta* L., *Crataegus nigra* Waldst. & Kit., *Eleocharis acicularis* (L.) Roem. & Schult. and *Trapa natans* L. are listed as protected species (Anonymous, 2016).

Study design

In the littoral zones of each investigated area, two sites were selected: one experiencing pressure from sports and recreational tourism and a control site without such pressure (Figures 2–5). The sites under the pressure at both lakes were exposed to beach-related human activities, involving intensive trampling and sediment disturbance. Although the samples were taken at the beginning of the summer season, the impact of sports and recreational activities was already evident. At each site, the percentage cover of each plant species was determined by analyzing five plots (2 × 2 m), resulting in a total of 20 plots across all sites.

Figure 2. Lake Provala – locality with the influence of sports and recreational tourism (Photo D. Blagojević)

Additionally, the physical and chemical parameters of the water were measured during field research using specialized instruments. Temperature, oxygen saturation and dissolved oxygen levels were measured with a field oximeter, while pH values were determined using a portable pH meter.

Figure 3. Lake Provala – control locality (Photo D. Blagojević)

Figure 4. Begečka Jama Nature Park – locality with the influence of sports and recreational tourism
(Photo D. Blagojević)

Figure 5. Begečka Jama Nature Park-control locality (Photo D. Blagojević)

Data analysis

The Shannon-Weaver index was used to calculate species diversity across all study sites. To quantify dissimilarities in community composition between different sites, Permutational Multivariate Analysis of Variance (PERMANOVA) was employed, using the Bray-Curtis dissimilarity measure with 9999 permutations to test significance. Non-metric Multidimensional Scaling (NMDS) was applied to visualize patterns in community composition and assess the spatial relationships between sites. Additionally, Indicator Species Analysis was conducted to identify species significantly associated with specific sites. All analyses were performed in R version 4.2.2 (R Core Team, 2022), using the packages "vegan" (Oksanen et al., 2022), "ggplot2" (Wickham, 2016), and "indicspecies" (De Cáceres and Legendre, 2009). These methods provided valuable insights into ecological variations among the studied sites, highlighting key patterns in biodiversity and habitat specificity.

RESULTS

The mean values of dissolved oxygen, saturation and pH were highest at Lake Provala (Table 1). The average water temperature was also highest at Lake Provala, particularly in the area under pressure from sports and recreational tourism. However, the highest levels of dissolved oxygen and saturation were recorded at Lake Provala's control site. At Begečka Jama, the site under pressure exhibited a higher mean temperature compared to its control area. Despite these variations, no significant differences were observed in the physical and chemical characteristics of the water between the control and influenced sites.

Table 1. Physical-chemical characteristics of the investigated localities with mean values of physical-chemical water parameters

Measured parameters of the water	Provala Lake		Begečka Jama Nature Park	
	Locality with the pressure	Control locality	Locality with the pressure	Control locality
Temperature (°C)	25.8	25.4	25.1	24.6
Dissolved oxygen (mg/l)	10.11	10.62	10.02	9.18
Saturation oxygen (%)	120.88	129.8	120.0	114.0
pH	8.8	8.8	8.3	8.2

At sites under influence, a smaller number of plant species was recorded, including *Nymphoides peltata* (S. G. Gmel.) Kuntze, *Spirodela polyrhiza* (L.) Schleid., *Potamogeton crispus* L., *Ceratophyllum demersum* L. and *Stuckenia pectinata* (L.) Börner (Tab. 2). In the control area, in addition to these five species, the following were also detected: *Lemna minor* L., *Nuphar lutea* (L.) Sm., *Salvinia natans* (L.) All., *Rorippa amphibia* (L.) Besser and *Persicaria amphibia* (L.) Delarbre.

Table 2. Recorded species on control and influence sites

	Presence of the recorded plant species on the localities	
Plant species	Locality with the pressure	Control locality
Nymphoides peltata	+	+
Spirodela polyrrhiza	+	+
Potamogeton crispus	+	+
Ceratophyllum demersum	+	+
Stuckenia pectinata	+	+
Lemna minor	–	+
Nuphar lutea	–	+
Salvinia natans	–	+
Rorripa amphibia	–	+
Persicaria amphibia	–	+

The two-dimensional configuration of Non-metric Multidimensional Scaling (NMDS) provided a good representation of the community data, with a stress value of 0.07364 after 9999 iterations. This low stress value indicates that the NMDS ordination captured the main patterns of community composition well. The analysis of species composition using PERMANOVA revealed that there was no significant difference in plant structure across different site levels (Pseudo-F=1.8374, p=0.131), suggesting that plant composition did not differ significantly between the sampled sites (Figure 6). According to the Indicator Species Analysis, only one indicator species, *Lemna minor*, was identified for the control sites (p = 0.0108).

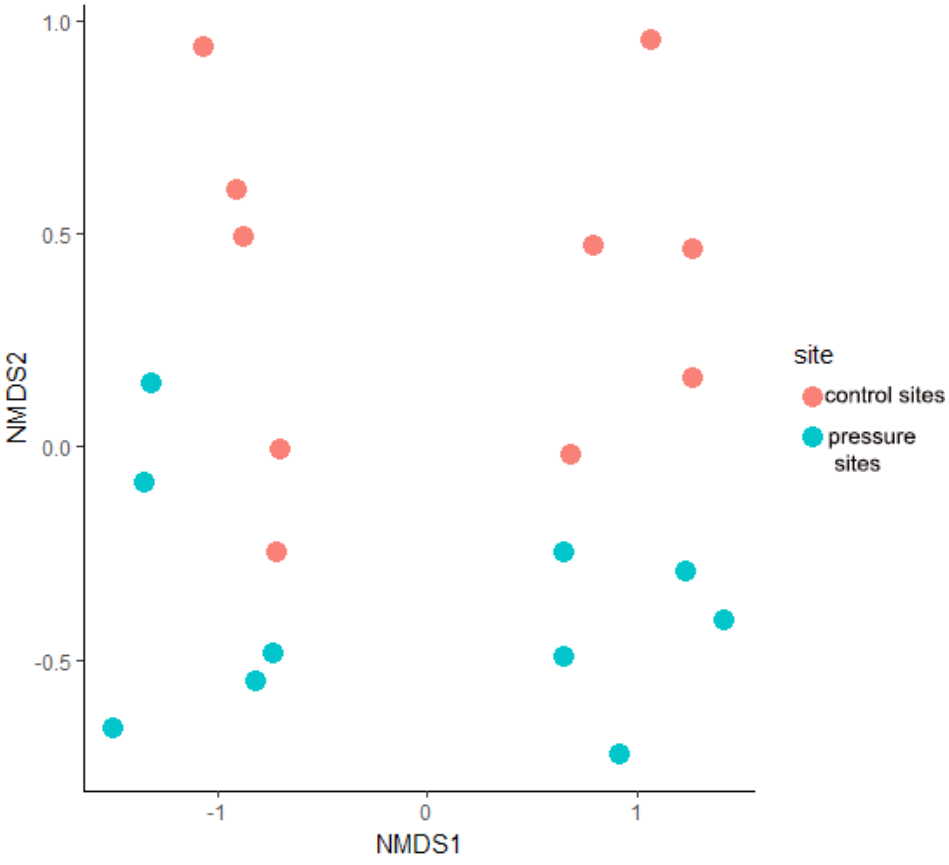

Figure 6. Graphic representation localities with and without influence

DISCUSSION

The presence of aquatic plants in ecosystems positively affects both the living organisms and the properties of water and sediment. They play a crucial

role in providing habitats for macroinvertebrates, fish and birds. Aquatic macrophytes act as bioaccumulators, absorbing various harmful substances and metabolically breaking them down through biodetoxification. For example, *E. canadensis*, *T. natans*, and *C. demersum* are known to accumulate elements such as Mn, Ni, Mo, Cu, Sr and Ba, while *C. demersum* also stores significant amounts of nitrogen. By accumulating and transforming harmful substances, aquatic macrophytes improve the physical, chemical and biological conditions of aquatic ecosystems, making them valuable for phytoremediation. Emergent vegetation also plays a vital role in biologically protecting shorelines from erosive processes. Furthermore, macrophytes contribute significantly to organic production (biomass), the formation of vegetation cover and the process of photosynthesis, which directly supports the functioning of the biosphere (Nikolić, 2005).

The research was conducted in the littoral zones of the lakes, as these are the most productive areas for aquatic plants. While the physical and chemical characteristics of the water showed no significant differences between the investigated sites, plant diversity was notably higher in the control areas (10 species) compared to the sites influenced by sports and recreational tourism (5 species). This suggests that anthropogenic impacts, such as vegetation removal, play a significant role in reducing plant diversity.

In the coastal areas under pressure, vegetation removal often leads to ecosystem degradation and conversion into arable or urban land. Sports and recreational tourism activities, such as commercial and recreational fishing, frequently involve biological, chemical and mechanical (physical) control of aquatic vegetation to increase fish stocks. For example, herbicides are used to create open spaces for fishermen, while mechanical removal of plants is conducted for various purposes (https://www.fao.org/4/X7580E/X7580E13.htm).

Based on the PERMANOVA method for the plant communities in the area of Lake Provala and Begečka Jama, there are no statistically significant differences between sites with pressure and sites without pressure, as confirmed by the *p* values. Furthermore, only one indicator species, *L. minor*, was identified for the control sites. This species typically occupies the early stages of habitat succession and is considered a natural habitat pioneer (Borhidi, 1995). This finding suggests that the control sites may also be impaired.

The research established that sports and recreational tourism did not affect plant diversity. This may be attributed to the fact that fishing is limited and strictly regulated, particularly in Begečka Jama, which is a protected area. Wetlands and aquatic plants serve as critical habitats for fish spawning and shelter. Additionally, coastal and inland wetlands provide essential breeding, nesting, migratory and non-breeding habitats for numerous species of waterfowl, wading birds, shorebirds, mammals, reptiles and amphibians (Nyman, 2011).

CONCLUSION

In this research, the impact of sports and recreational tourism on the diversity of plants in the littoral zones of Lake Provala and Begečka Jama was analyzed.

Greater plant diversity was recorded in the control areas of any investigated locality. Statistical analyses revealed no significant differences in plant diversity between locations exposed to anthropogenic pressure and those without such pressure. Given that sports-recreational tourism is permitted in the studied areas, the findings confirm that it has no significant impact on plant diversity. Recognizing the global importance of aquatic ecosystems is a vital step toward developing strategies for their conservation.

ACKNOWLEDGEMENT

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ОРИГИНАЛНИ ЧЛАНАК
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УТИЦАЈ ТУРИЗМА НА БИЉНЕ ВРСТЕ ПРИОБАЛНИХ ПОДРУЧЈА ЈЕЗЕРА ПРОВАЛА И БЕГЕЧКА ЈАМА

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РЕЗИМЕ: Влажна станишта данас представљају једне од најугроженијих типова станишта, нарочито ако се посматра диверзитет биљака. У овом раду приказан је утицај спортско-рекреативног туризма на диверзитет биљака у литоралној зони језера Провала и Бегечка јама. Истраживања су вршена у периоду од маја до јуна 2023. године. На сваком локалитету, одабрана су места где постоји утицај спортско-рекреативног туризма и места где нема (контрола) и на њима су пописане биљне врста и утврђена је покровност биљног покривача. Такође, на датим местима одређене су физичко-хемијске карактеристике воде. Наши резултати су показали да контролна места имају већи број биљних врста (10) у поређењу са местима где постоји притисак (5). Статистички значајне разлике нису констатоване у физичко-хемијске карактеристике воде између места са притиском и без њега. Такође, применом PERMANOVA анализе потврђено је да не постоје статистички значајне разлике у структури биљних заједница између контроле и места под притиском. Наша истраживања су показала да спортско-рекреативни туризам нема утицаја на диверзитет биљних врста у литоралној зони ова два влажна екосистема.

КЉУЧНЕ РЕЧИ: диверзитет; макрофите; пермутациона мултиваријантна анализа варијансе (PERMANOVA); рекреативни туризам; спортски туризам; влажна подручја