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INVESTIGATION OF COMMON REED REGROWTH ON THE SHORES OF RECREATIONAL LAKES

Ieva Jokubauskaitė, Laura Šukienė, Ingrida Šaulienė

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Common reeds are a perennial grass, a fodder plant and an anti-erosion plant. Despite the positive effect on aquatic ecosystems, reed overgrowths must be maintained. The aim of this study was to identify the impact of water parameters of Bridvaisis, Gaustvinis and Gilius lakes (located in Lithuania) and the influence of recreation on the variation of morphological parameters of common reeds. The high correlation coefficients between the dissolved oxygen concentration and the mean height of reeds (r=-0.79; r=-0.94), the number of internodes (r=-0.83; r=-0.94) and the density of plants (r=-0.91; r=-0.97) were identified in Bridvaisis and Gilius lakes. Analysis of results showed that after mowing, in all three lakes, statistically significant differences were found in the mean height of common reeds between the control and recreational sample area as well as the sample area not influenced by recreation. The difference in the height of common reeds between the sample areas with different recreational effects was statistically insignificant.

Key words: macrophytes, water temperature, dissolved oxygen, leisure, Lithuania.

Ieva Jokubauskaitė, Laura Šukienė, Ingrida Šaulienė. Šiauliai University, P. Višinskio str. 38, 76285 Šiauliai, Lithuania, E-mail: laura.sukiene@su.lt.

INTRODUCTION

The common problem of lake shores is their dense overgrowth with common reeds (*Phragmites australis* (Cav. Trin. Ex. Steud)). Due to the rapid spread of these plants, the overgrowths of reeds occupy sites of other plants, the shores become inaccessible to holidaymakers, eventually lakes silt up. Common reeds are a perennial grass, a fodder plant and an anti-erosion plant (Vilkonis 2008). Plants of this species can reach the height of 500 cm (Earth Observatory 2017) or even 600 cm (Sturtevant 2016). The common reed blooms in July, the seeds mature in September. Every inflorescence produces 1000-2000 seeds and more. Although cases of rare reproduction by seeds occur, usually they reproduce by vegetative plant propagation (Saltonstall 2002). In winter, when the seeds are already formed, the nutrients are transferred to the rhizomes, and the upper part of the plant decays (Niedowski 2000). Reeds can grow and develop in water bodies at depth up to 2.5 m (Urtane 2014).

N. L. Niedowski (2000) states that reeds have a positive influence on aquatic ecosystems. Reeds on the shores reduces waving, which prevents coastal erosion. In the event of floods, plants reduce flooding. Coastal problems of the Curonian Lagoon are solved by natural measures; i.e., planting of the common reed. The compilers of The Curonian Lagoon Coast Assessment and Maintenance Programme (2011) propose to plant reeds only in intensive coastal erosion areas to protect natural and infrastructure objects of special significance. On the other hand, the overgrowths of common reeds are important habitats of Lithuanian fauna. Reeds provide shelter and nutrition base for invertebrates (Bresciani et al. 2011), water birds (Berthold et al. 1993, Tewksbury et al. 2002) living among the reeds.

Despite the positive effect on aquatic ecosystems, reed overgrowths must be maintained. In order to select the most optimal method of destroying common reeds on the shores and to identify the intensity of reed spreading, it is important to evaluate the physical-chemical properties of the lake and identify the influence of these parameters on the intensity of reed growth. Since currently, lakes are an integral part of recreation, it is necessary to consider both reed overgrowth management issues and holidaymakers' possible influence on reed growth. Chinese limnologists identified that the morphological parameters of reeds decrease when plants were affected mechanically (Zhang et al. 2014), which may be related to recreational activities on the shores of the water bodies and direct impact on the intensity of reed growth.

Numerous scientific studies on anatomical, morphological features of reeds (Engloner & Podani 2001, Antonielli et al. 2002, Fogli et al. 2002), the impact of environmental conditions on the development of reeds or macrophytes (Carpenter & Lodge 1986, Ostendorp 1992, Jeppesen et al. 1997, Gasith & Hoyer 1998, Bresciani et al. 2011, Greenwood & MacFarlane 2006) have been performed.

The aim of this study is to identify the impact of physico-chemical water parameters (temperature, transparency, dissolved oxygen) of Bridvaisis, Gaustvinis and Gilius lakes and the influence of recreation on the variation of morphological parameters of common reeds.

MATERIALS AND METHODS

The research was conducted in three different lakes: Bridvaisis, Gaustvinis and Gilius, which are located in the northern part of Lithuania. All three lakes belong to the Nemunas River basin district, the Dubysa River sub-basin. These lakes were chosen as a research object because the lakes differ in the area occupied by water, basin shape, depth, water temperature and transparency. Lake Bridvaisis is located in the central part of Tytuvenai Regional Park and falls into the territory of Tytuvenai town. The lake is characterized by large depth, up to 42.8 meters, but uneven bottom and clear water. The area of the lake reaches 46.5 hectares, and its shelf is narrow and sandy. The shores of the lake are particularly actively visited by holidaymakers. According to the data of the Directorate of Tytuvenai Regional Park (2018), at the summer weekends, the main bathing place in the western part of the lake is visited by up to 1000 holidaymakers per day.

The second lake selected for the research is lake Gaustvinis, stretching in the northern part of Tytuvenai Regional Park. The area of the lake is 124 ha (Montvydienė et al. 2014). It is an open lake: three streams (the Simsa, the Spangupis, the Supyne) and two drainage trenches flow into the lake. The Gryzuva – the left tributary of the Dubysa – flows out of the lake (Montvydienė et al. 2014). The basin of Gaustvinis is of glacial tunnel origin. It is a shallow, hypertrophic lake, all its shallow shores are covered with forest. The bottom is plane, flat, silted. The deepest place of the lake is 3.8 m, the average depth is 2.4 meters. The third lake selected for the research is lake Gilius, the area of which is the least and reaches 36 ha. This lake is not as shallow as Gaustvinis, and its maximum depth is 23 m. The lake is also of glacial tunnel origin, extending in the South-North direction, where in the northern part by a channel it reaches the neighbouring Lake Apusis. The bottom of Gilius is sandy, water is greenish-blue, in autumn it is clearing. On the eastern coast, many springs run into the lake. Most of the lake is covered with a forest belt. This lake is moderately adapted and used for recreation: there are 6 smaller and larger beaches on the lake coast, visited by about 2100 visitors during the summer season of 2017 (Directorate of Tytuvenai Regional Park, 2018). The entire lake is surrounded by Gilius Educational Trail with information stops and rest areas.

To measure the morphological parameters of common reeds, sample areas covering 1 m^2 on the shores of lakes were distinguished. Three types of investigation areas of 1 m^2 were distinguished in each of the lakes. The first type of sample areas were areas influenced by recreation (visited by holidaymakers), during the observation period common reeds were mowed. The second type sample areas were the ones that were not visited by holidaymakers, common reeds were also mowed. The third type sample areas were chosen as control areas; i.e., they were not influenced by recreation and macrophytes in the sample areas were not mowed. In all sample areas, investigations of water temperature and dissolved oxygen concentration in the lake, measurements of morphological characteristics of common reeds (reed height, number of internodes, and density) were carried out and the abundance of lake shore visitors during the investigation was recorded. The transparency of lake water was measured only near the sample areas that were influenced by holidaymakers. The investigation was conducted during the vegetation season in 2017. The periodicity of conducted investigations: three times per week. The last measurement was made in the last week of September. Water transparency was measured using the Secchi disk. Water temperature and the concentration of dissolved oxygen in the lakes were measured by the oximeter HANNA HI 9142. Common reeds were mowed during their most active vegetation period – on the first week of July. Common reeds were mowed with a sickle so that the cut end of the stem is immersed under water about 10 cm (Bjork 2014). The abundance of holidaymakers was recorded to assess the impact of recreation. The observation was carried out three times a week.

Collected data were statistically processed using the SPSS programme. Pearson correlation coefficients and their reliability levels were calculated to establish possible relations between the research data. During the investigation, it was aimed to find out whether changes in the height of common reeds, the number of internodes and the density of plants can be related to the variations in lake water parameters (transparency, temperature, concentration of dissolved oxygen). A one-way ANOVA was conducted to identify the differences in morphological parameters of plants in all investigated sample areas. A Post-Hoc test was used to identify in which areas average parameters of plants differ.

RESULTS

Researched lakes' water measurements show that the selected lakes differ in water temperature, dissolved oxygen concentrations and transparency. Fig. 1 shows the mean values of water temperature and dissolved oxygen, identified in all investigated sample areas of three lakes (May-September, 2017).

Water temperature of lakes in the places of morphological measurements of plants (in the overgrowth of common reeds) differed. In May-July, the highest water temperature, irrespective of the investigated sample area, was found in Gaustvinis (21°C in the control sample area in June), whereas in August-September, the highest water temperature was identified in investigated sample areas of Gilius. During the research period, the mean maximum water temperature reached 22.9°C and was measured in August on the shore of Gilius (in the sample area with recreation). According to the results of the reed regrowth, it is observed that the relatively higher water temperature of Gaustvinis after the mowing of common reeds (in July) could have determined faster growth of common reeds. In August, the lowest water temperature was identified in the investigated sample areas of Bridvaisis. According to morphological measurements of plants (Table 1), the reeds that regrew in these sample areas were the lowest, their density decreased.

Table 1. Morphological characteristics of common reed

Type of investigation area	Average height of common reed, cm		Average number of internodes		Density of plants, plants/m^2	
	Until mowing	Last measurement	Until mowing	Last measurement	Until mowing	Last measurement
Bridvaisis						
Recreation	111.4	45.4	8.1	3.6	62	11
Non-recreation	117.3	54.4	7.9	4.4	70	17
Control	125.5	160.2	7.1	8.2	74	77
Gaustvinis						
Recreation	162.0	74.4	9.1	4.4	44	9
Non-recreation	112.3	75.6	7.0	4.5	90	21
Control	121.0	199.9	6.3	9.2	90	90
Gilius						
Recreation	82.0	71.1	5.0	4.4	61	8
Non-recreation	109.8	0	6.3	0	34	0
Control	127.8	178.3	6.7	8.6	40	41

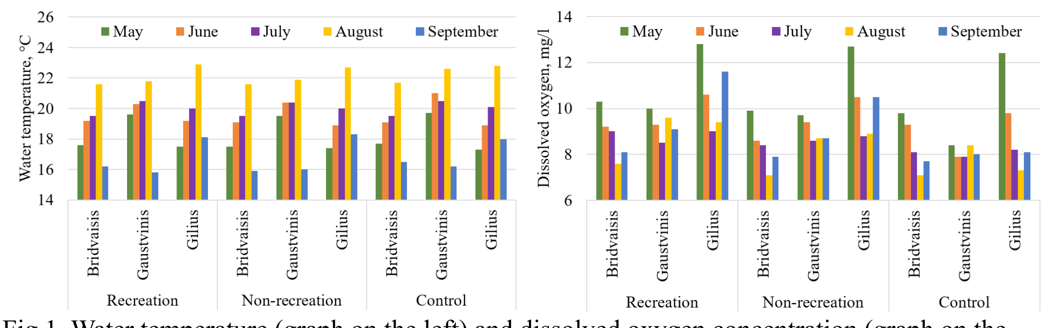

Fig.1. Water temperature (graph on the left) and dissolved oxygen concentration (graph on the right) of Bridvaisis, Gaustvinis and Gilius lakes in May-September, 2017.

The largest unidirectional temperature differences, which did not exceed 2°C in separate months, were identified in the control sample areas of Bridvaisis and Gaustvinis lakes (Fig. 2). Significant differences were also established between water temperatures in the control sample areas of Gaustvinis and Gilius.

More often, Gilius distinguished itself by higher concentration of dissolved oxygen (Fig. 2), regardless of the sample area type or the month. Measurement results demonstrated that the dissolved oxygen concentration was the most similar in sample areas of Bridvaisis and Gaustvinis lakes, except for the sample areas that were not affected by recreational activities, when Bridvaisis distinguished itself by a lower concentration of dissolved oxygen. The difference between the concentration of dissolved oxygen in Bridvaisis and Gilius lakes varied from 0.4 mg/l (in July) to 2.8 mg/l (in May), while the difference between Bridvaisis and Gaustvinis lakes ranged from 0.2 mg/l (in July) to 1.6 mg/l (in August).

During the investigation period, Bridvaisis was the clearest. Its transparency exceeded 200 cm, but varied depending on a month. In May, the mean transparency of Bridvaisis reached 270 cm; in June, 267 cm; in July, 270 cm; in August, 266 cm; in September, 274 cm. Transparency of Gaustvinis was three times less: its mean transparency in separate months of the warm season was 90 cm. Only in August, transparency decreased (86 cm). The transparency of Gilius was less than 200 cm and its fluctuation amplitude was the highest; i.e., 17 cm. In May, mean transparency of Gilius reached 165 cm; in June, 160 cm; in July, 158 cm; in August, 155 cm; in September, 172 cm.

The changes in the height of common reeds, the number of internodes and density were assessed in three lakes in Northern Lithuania visited by holidaymakers at different intensity levels. According to the results of morphological parameters of reeds growing on lake shores (Table 1), it was obtained that the highest mean height of common reeds before cutting of plants was observed in the sample area of Gaustvinis, influenced by recreation (162.0 cm); and the least, in the sample area of Gilius, influenced by recreation (82.0 cm). After mowing of common reeds, the growth increment of plants remained unequal.

Comparing the height of common reeds in different lakes in the sample areas that were influenced by visitors (holidaymakers), it was noticed that in Bridvaisis, which distinguished itself by its depth, reeds after cutting were 1.6 times lower (45.4 cm) than in the investigated sample areas of other two lakes. Considering the situation that before mowing in Bridvaisis the mean height of common reeds was 1.3 times larger than the mean height of reeds in Gilius, it should be stated that after mowing, the lower intensity of regrowth could have been determined by environmental factors, including qualitative parameters of lake water or holidaymakers' activities.

Assessing the mean height of reeds in all three lakes (Table 1), after mowing, the mean height of plants in Bridvaisis was at the lowest value, regardless of the type of sample area. Attention should be drawn to the mean height of reeds in Gaustvinis. After mowing, the reeds in the investigated sample areas on the shores of this lake were the highest. The growth increment in the control field was also the highest (79 cm). According to the obtained results, it can be assumed that the conditions for the growth of common reeds on Gaustvinis were the most favourable. Similar results were also obtained assessing the mean number of internodes. The measurements of plant density showed that before mowing, common reeds had grown most densely on the coastal area of Gaustvinis, not influenced by recreation. The density of plants here was 90 plants/m^2. After mowing, the sample area of Gaustvinis, which was in the area visited by holidaymakers, distinguished itself by the smallest mean density of common reeds (9 plants/m^2).

Having systematised the obtained results and performed Post Hoc test ($p=0.05$), it was identified that after mowing, in all three lakes, statistically significant differences were found in the mean height of common reeds between the control and recreational sample area (69.2-81.1 cm) as well as the sample area not influenced

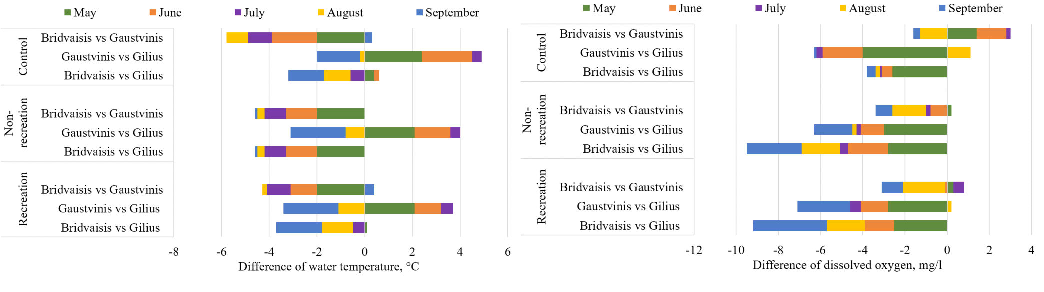

Fig. 2. Differences in water temperature (graph on the left) and dissolved oxygen concentration (graph on the right) of Bridvaisis, Gaustvinis and Gilius lakes in May-September, 2017.

by recreation (70.1-97.2 cm). The difference in the height of common reeds between the sample areas with different recreational effects was statistically insignificant (7.7-16.1 cm). Based on the calculated differences between the number of reed internodes and the density of plants in all three lakes, it was found that after plant mowing, there were statistically significant differences in morphological parameters between the control and recreational sample area and between the control sample area and the one not influenced by recreation. No statistically significant differences between sample areas with different recreational impact were identified. The obtained results allow us to assume that, irrespective of whether the area was visited by holidaymakers or not, the regrowth of common reeds did not differ significantly.

Summarizing the results of correlation coefficients of lake water and morphological parameters of common reeds, statistically significant cases are recorded only between morphological parameters of plants and water saturation with oxygen (Fig. 3). Statistical results demonstrate that in the research territories of Bridvaisis and Gilius lakes, the decreasing concentration of dissolved oxygen in water does not inhibit the development of plants. The high correlation coefficients between the dissolved oxygen concentration and the mean height of reeds (r=-0,79; r=-0.94), the number of internodes (r=-0,83; r=-0.94) and the density of plants (r=-0,91; r=-0.97) were identified. The

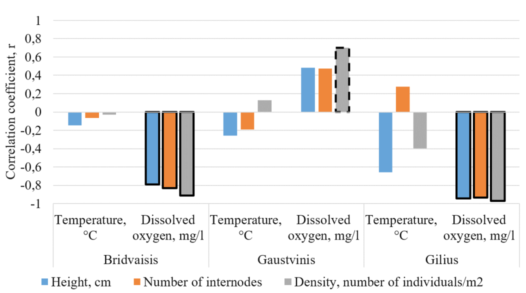

Fig. 3. Correlation coefficients estimated between water quality indicators and morphological parameters of common reeds on the shores of Bridvaisis, Gaustvinis and Gilius Lakes. The boundary of the continuous line side indicates cases where p <0.01; dashed lines, where p <0.05.

identified correlation coefficients between water indicators and the morphological parameters of plants of Gaustvinis did not confirm by the above-mentioned tendencies.

Another factor that could influence the sustainability of common reed populations is active holidaymakers. The number of holidaymakers was recorded not far from the investigated sample areas in Bridvaisis, Gaustvinis and Gilius lakes. Bridvaisis distinguished itself by the number of visitors. The number of holidaymakers who came to rest here was 1.7 times larger than the

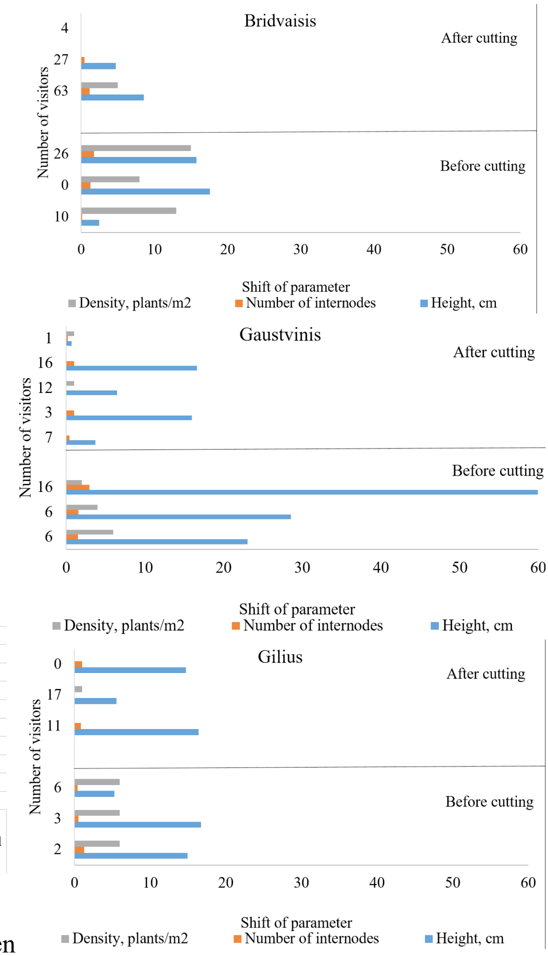

Fig. 4. The number of holidaymakers near Bridvaisis, Gaustvinis and Gilius lakes (in the order from the bottom to the top) and differences in morphological parameters of plants after the holidaymakers' visits.

number of visitors near lake Gaustvinis and 2.4 times larger than near lake Gilius. There was no direct relation between the number of visitors and the morphological parameters of common reeds before and after mowing.

Fig. 4 illustrates differences in the morphological parameters of common reeds, which were calculated 2 weeks after the holidaymakers had visited territories near the investigated sample areas. The data provided demonstrate that the growing flow of visitors did not stop the regrowth of plants. For example, at the time of the largest flow of visitors during the investigation period (63 holidaymakers in the case of Bridvaisis), the height increment of reeds after mowing reached 8.6 cm. Before mowing, when the flow of visitors was 3 and more times less, the height increment of reeds was changing on average from 16 cm (Bridvaisis) to 60 cm (Gaustvinis).

DISCUSSION AND CONCLUSIONS

In the modern dynamic world, lakes are valuable both in their natural and social senses. As a natural complex, the lake provides ecosystem services, therefore, the condition of valuable lakes is often monitored. Changes taking place in the lake and their speed depend on the origin, basin, shape of the lake, on soil, geographic location of the lake and basic rocks of the lake basin, climatic conditions (Komatsu et al 2007, Urtane 2014). The depth of the lake is often described as a value defined by geomorphological processes that took place in the past and current hydroclimatic conditions (Linkevičienė et al. 2008). The development of shallow and very shallow lakes is accelerating. For example, E. Jeppesen et al. (1997) found that the biomass of phytoplankton and zooplankton was higher in shallow lakes than in deep lakes. Higher plants of the lake – macrophytes, most of which consist of common reeds, have the greatest influence on processes taking place in the littoral zone of the lake, when the dead parts of plants deposit on the shore of the lake in the form of detritus (Bjork 2014). They begin accumulating silt, coastal areas are shallowing, the area of water of the lake is decreasing. On the other hand, research confirmed that small or medium-sized lakes have more vegetation (Van Geest et al. 2003, Søndergaard et al. 2005). It should be noted that deep lakes tend to be more oligotrophic and determine lower growth of water macrophytes on the shores than shallow lakes (Gasith & Hoyer 1998). In shallow lakes, more suitable conditions for flourishing of emersed plants are formed. Because emersed plants grow at the depth up to 1.5 m, in the particularly shallow lakes, larger belts or separate areas of emersed plants in shallower places of the lake may form (Urtane 2014). Our research demonstrated that in Gilius, which is of average depth (maximum depth is 23 m; mean, 8.2 m, the Directorate of Tytuvenai Regional Park 2017) and covers the smallest area (36 ha) from all investigated lakes, the mean height of common reeds and the density before cutting were the least. When macrophytes were mowed, the lowest reeds were measured in the deep Bridvaisis. Gaustvinis, the shallowest and covering the largest area, which is three times larger than Gilius, distinguished itself by the least transparency (90 cm), and after mowing the macrophytes, the regrowth of common reeds was the fastest. Already after 2 weeks, the mean height of reeds reached 31 cm. It is believed that in shallow lakes, the sunlight can penetrate to the deepest layers of the lake, this way enabling flourishing of water plants, which through photosynthesis enrich deeper layers of the lake with oxygen (Scheffer & van Nes 2007).

S. R. Carpenter and D. M. Lodge (1986) investigated the relation between oxygen dissolved in water and macrophytes. The scientists stated that common reeds had a positive effect on the concentration of dissolved oxygen in water. Plants release oxygen both through the green parts of the stem and leaves and through the epidermis of roots, at the same time, oxygen penetrates to the deposits settled on the bottom of the lake. Studies conducted in Bridvaisis, Gaustvinis and Gilius lakes demonstrated a linear relation between the growth of common reeds and the concentration of dissolved oxygen in water. It was identified that high stem densities together with a reduction in turbulence reduce dissolved oxygen inside reed communities (Atapaththu et al. 2017). In most cases, Gilius distinguished itself by the highest concentration of dissolved oxygen in water. The results demonstrate that the density of plants on the investigated shore of this lake was the least (41 plants/m^2); i.e., 2 times less than in Gaustvinis, where the concentration of dissolved oxygen was similar to that in Bridvaisis. L. Urtane (2014) points out that the concentration of dissolved oxygen and the dependence of macrophyte growth could be related to the influence of oxygen on phosphorus. If there is enough oxygen in the lake and its near-bottom layer, phosphorus that gets into the near-bottom layer in the water is converted to water-insoluble iron hydroxyphosphate (Urtane 2014), which becomes inaccessible to plants. For this reason, they may be poorer and occupy a smaller area.

In Europe, tourism, large numbers of visitors and recreation in nature are identified as one of the major threats to the state of surface water bodies and their shores (Searight 2017). The main causes are the increased likelihood of the spread of invasive organisms and the mechanical effect of recreation. Intensive walking on the shores often results in trampling of vegetation. Holidaymakers who are bathing and sailing boats muddy the water of the lake, which reduces the transparency of water. The reduced light transmission in water aggravates the photosynthesis of plants in deeper water layers, water saturation with oxygen reduces (Hammitt et al. 2015). Our research demonstrates that visitors did not have a direct impact on the investigated macrophytes. Studies on holidaymakers' impact must include an exhaustive analysis related to the assessment of visitor flows and the extent of the response of plants to stimuli; i.e. the impoverishment rate of communities, the consolidation of monocultures, the resistance of a particular species to the impact or the response time of individuals of the species when the effect is indirect.

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