

Presence and abundance of macrophytes in Lake Slivniško jezero

Prisotnost in pogostost makrofitov v Slivniškem jezeru

Aleksandra Golob, Alenka Gaberščik, Mateja Germ

Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, SI-1000 Ljubljana, Slovenia

*correspondence: mateja.germ@bf.uni-lj.si

Abstract: Macrophytes are an important part of the lake biota. They are also bioindicators of environmental conditions. The goal of the present research was to determine species richness and abundance as well as longitudinal and depth distribution of macrophytes in Lake Slivniško jezero. A survey of macrophytes in the whole lake littoral was made, the minimum and maximum depth of taxa were measured and their abundance was estimated as well. We also assessed selected environmental parameters of the littoral and catchment. 22 macrophyte taxa: 9 emergent, 9 submerged and 4 natant macrophytes were determined. The most frequent species were *Phragmites australis*, *Najas marina*, *Myriophyllum spicatum* and *Potamogeton nodosus*. The maximum depth of colonisation was achieved by *Nymphaea alba* (to 2.4 m), while *M. spicatum* and *N. marina* grown to the depth of 1.9 m. According to CCA the distribution of macrophytes was significantly influenced by exposition, bottom slope, sediment type, slope of riparian zone, macroalgae abundance, type of riparian vegetation, completeness of riparian zone, land-use beyond the riparian zone and water turbidity.

Key words: macrophytes, Lake Slivniško jezero, species composition, environmental assessment

Izvleček: Makrofiti igrajo pomembno vlogo pri kroženju snovi in pretoku energije v jezerskih ekosistemih. Že dolgo je znano, da so pokazatelj stanja okolja, kjer uspevajo. Cilj raziskave je bil ugotoviti vrstno zastopanost, razporeditev, pogostost in globino uspevanja makrofitov v litoralu Slivniškega jezera. Na posameznih odsekih smo ocenili določene značilnosti litorala in zaledja Slivniškega jezera. Popisali smo 22 taksonov: 9 emerznih, 9 submerznih in 4 natantne. Najpogosteje zastopane vrste so bile *Phragmites australis*, *Najas marina*, *Myriophyllum spicatum* in *Potamogeton nodosus*. Najgloblje je uspevala vrsta *Nymphaea alba* (povprečno do 2,4 m), do globine 1,9 m sta rastle tudi vrsti *M. spicatum* in *N. marina*. CCA analiza je pokazala, da na razporeditev makrofitov statistično značilno vplivajo naslednji okoljski dejavniki: osončenost, naklon dna, tip sedimenta, naklon brega nad vodo, prisotnost makroalg, vegetacija obrežnega pasu, sklenjenost z lesnatimi ali močvirskimi rastlinami poraslega obrežnega pasu, izraba tal v zaledju in kalnost vode.

Ključne besede: makrofiti, Slivniško jezero, okoljska ocena, vrstna sestava

Introduction

Macrophytes present a base of aquatic food-chains and services in freshwater ecosystems (Scheffer and Jeppesen 2007, Smith 2011). Their basic structural and physiological characteristics are in accordance with the ecological conditions and resources of the aquatic environment (Vukov et al. 2012). Aquatic macrophytes also act as important bioindicators of environmental conditions and long-term ecological changes in water quality (Solimini et al. 2006, Pall and Moser 2009, Dar et al. 2014). It is known that macrophytes can be successfully used as indicators of changes in freshwaters at narrow and wider scales, as they integrate temporal, spatial, chemical, physical and biological qualities of the ecosystem (Balaži et al. 2014). Macrophyte communities in aquatic habitats are characterized by a high spatial and temporal variation of species composition, richness and environmental conditions (Hrivnak et al. 2012). Due to the lower self-purification ability the standing inland waters are more vulnerable to pollution as running waters. The state of each lake or reservoir depends on the hydrological and morphological characteristics, especially on the input of various substances (Remec Rekar 2003). Water storage and flood protection reservoirs have been built worldwide for at least 4000 years in countries without large water bodies (Krolova et al. 2013). Artificial water bodies are mostly built for water supply, to increase flood safety, for the hydro-power generation, and for recreation. Reservoirs differ from natural lakes however studies show that there are also similarities in the operation of the two types of water bodies (Wetzel 2001). Compared to natural lakes, reservoirs have a low residence time and regular water level fluctuations (Alaoui et al. 2013). Problems of reservoirs are communal and industrial waste water and the run-off of nutrients from agricultural areas. Discharge is also very important for the reservoir characteristics and depends on the management of the reservoir. Presence of aquatic macrophytes in a pond alters the physicochemical environment of water (Reddy 1982). On the other hand, water level fluctuations also strongly affect macrophyte growth through erosion and degradation of the substrate due to the washing out of fine particles and nutrient-rich substances (Furey et al. 2004). The

aim of our study was (1) to examine the presence and abundance of different macrophyte taxa, as well as their longitudinal and depth distribution in Lake Slivniško jezero, and (2) to describe prevailing abiotic habitat characteristics of macrophytes.

Materials and methods

Study area

Lake Slivniško jezero was created by damming the Ločnica watercourse by Tratna in 1976, mainly due to protection against flooding of the town Celje and the need for technological water for Ironworks Štore (Štraus 2006). It is eutrophic reservoir and its great advantage over other reservoirs in central and eastern Slovenia is that it is overgrown with seed plants (ARSO 2005). The lake is located southeast from Šentjur at the altitude of 294 m. It is surrounded by hills Rakitovec, Lipovski hrib, Požgani hrib, Gradišče and damm Tratna. Inflows into the lakes are Ločnica and Tratna streams and outflow is Voglajna River. The surface of the reservoir comprises 0.84 km², and it accumulates cca 4 million m³ of water. Maximum depth is 14.5 m, while the average is about 4.8 m (ARSO 2005). The coast around the lake is 7.5 km long, and the size of the catchment areas is estimated to 30 km². The length of the lake is cca 5 km, while its width is from 250 to 500 m (Štraus 2006). Because of the accumulation of silt due to riparian zone overgrown with the macrophytes and due to leaching of soil into the reservoir due to erosion and landslides banks of the lake in recent years, the depth of the reservoir is decreasing (Gobec 2001, Videc 2010).

Lake Slivniško jezero is a popular place of sport fishing because it is very rich in fish populations. Fish, found in the lake, are carp, catfish, roach, pike, perch, tench, nose carp, asp, chub and others. As much as 112 species of birds nest at the lake, mostly wild ducks. In 1992, 35 ha wetland area of the lake was protected (Štraus 2006). Transparency of the lake, water is low, the average value being around 1.1 m.

The survey of macrophytes was carried out in entire littoral (Fig. 1). The surveys were performed from a boat using a rake with hooks to sample plants. Macrophyte species abundance

was estimated using a five-degree scale: 1 = very rare; 2 = infrequent; 3 = common; 4 = frequent; 5 = abundant, predominant (Kohler 1978, Kohler and Janauer 1995) and the relative abundance as well as abundance indices were calculated following the methodology proposed by Pall and Janauer (1995).

Environment assessment

The environmental condition of the lake was assessed in the same segments as macrophytes. We assessed 6 parameters, each describing 4 levels of environmental quality gradient. The parameters included bank structure, slope of riparian zone, its width and completeness and land-use type beyond the riparian zone. The parameter "Bank structure" includes the following categories: no modifications (1), modifications by wood (2), modifications by stones (3) and modifications by concrete (4). Slope of the littoral can be gentle (1), a medium steep (2), a very steep (3), or rectangular or hardened (4). Vegetation of the riparian zone can be forest or wetland species (1), pioneer woody vegetation (2), herbaceous plants (3) no vegetation (4).

Width of the riparian can be more than 30 m (1), between 5 and 30 m (2), less than 5 m an without riparian vegetation (4). The parameter "Completeness of the riparian zone" includes the following categories: without disturbances (1), disturbances every 50 m (2), riparian cone strongly disturbed in all surveyed length of the shore (3) riparian cone without woody or wetland vegetation (4). The parameter "Land use" includes the following categories: catchment is overgrown with forests or wetlands (1), mosaics mown meadows/pasture with a little arable land (2), catchment dominated by arable land, individual houses (3), urban area (houses, factories) (4). In addition we examined the slope of the bank above water surface, slope of the littoral bottom, reach exposition, the presence of filamentous algae and water transparency.

Statistical analysis

Canonical correspondence analysis (CCA) was used to assess the relationship between plant species composition and abundance and environmental parameters. Environmental parameters were coded numerically from 1 to 4. Forward selection

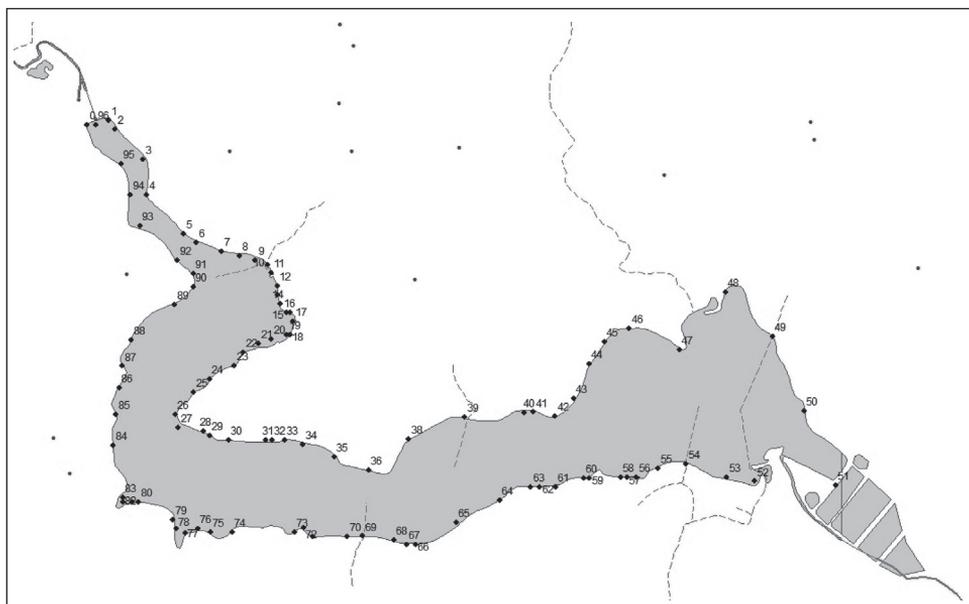


Fig. 1: Examined segments of Lake Slivniško jezero (source: Dragan Abram).

Fig.1. Tloris Slivniškega jezera z označenimi odseki (vir: Dragan Abram).

was used to determine the contribution of each parameter to the variance in species composition. The statistical significance of environmental parameters was tested by the Monte Carlo permutation test. Analyses were performed using Canoco for Windows Version 4.5.

Results

On the whole littoral of Lake Slivniško jezero we recorded 22 taxa of macrophytes of different growth forms (Table 1).

In the most sections we found a high number of macrophytes. A small number of species was determined in the sections where the bank of the water drops sharply and the steepness of the lake bottom is high (segments 2, 4, 6, 82, 83, 84). In sections 51, 52 and 53, we found only one taxa of the macrophyte with high abundance (*Phragmites australis*). The greatest abundance to the majority of sections was given to species *Myriophyllum spicatum*, *Potamogeton nodosus* and *Najas marina* (Figures 2 and 3).

Table 1: The list of the macrophytes in Lake Slivniško jezero and their growth forms.
Preglednica 1: Seznam v Slivniškem jezeru najdenih makrofitov in njihove rastne oblike.

Latin name	Abbreviation	Growth form
<i>Alisma plantago-aquatica</i> L.	Ali pla	he
<i>Caltha palustris</i> L.	Cal pal	he
<i>Ceratophyllum demersum</i> L.	Cer dem	sp
<i>Eleocharis palustris</i> (L.) Roem et Schult	Ele pal	he
<i>Equisetum palustre</i> L.	Equ pal	he
<i>Iris pseudacorus</i> L.	Iri pse	he
<i>Lamprothamnium longifolium</i>	Lam lon	sa
<i>Lemna minor</i> L.	Lem min	ap
<i>Lysimachia nummularia</i> L.	Lys num	he
<i>Mentha aquatica</i> L.	Men aqu	he
<i>Myriophyllum spicatum</i> L.	Myr spi	sa
<i>Najas marina</i> L.	Naj mar	sa
<i>Najas minor</i> All.	Naj min	sa
<i>Nymphaea alba</i> L.	Nym alb	fl
<i>Phragmites australis</i> (Cav.) Trin ex Steud.	Phr aus	he
<i>Potamogeton berchtoldii</i> Fieber.	Pot ber	sa
<i>Potamogeton nodosus</i> Poir.	Pot nod	fl
<i>Potamogeton pectinatus</i> L.	Pot pec	sa
<i>Trapa natans</i> L.	Tra nat	fl
<i>Typha latifolia</i> L.	Typ lat	he
<i>Utricularia australis</i> R. Br.	Utr aus	sa
<i>Utricularia vulgaris</i> L.	Utr aus	sa

Legend: he - helophytes, sp - submerged unrooted macrophytes, sa - submerged rooted macrophytes, ap – natant unrooted macrophytes, fl- natant rooted macrophytes, am - amphibian plants

Legenda: he - helofiti, sp - potopljeni neukoreninjeni makrofiti, sa - potopljeni ukoreninjeni makrofiti, ap - plavajoči neukoreninjeni makrofiti, fl- plavajoči, ukoreninjeni makrofiti, am - amfibijske rastline

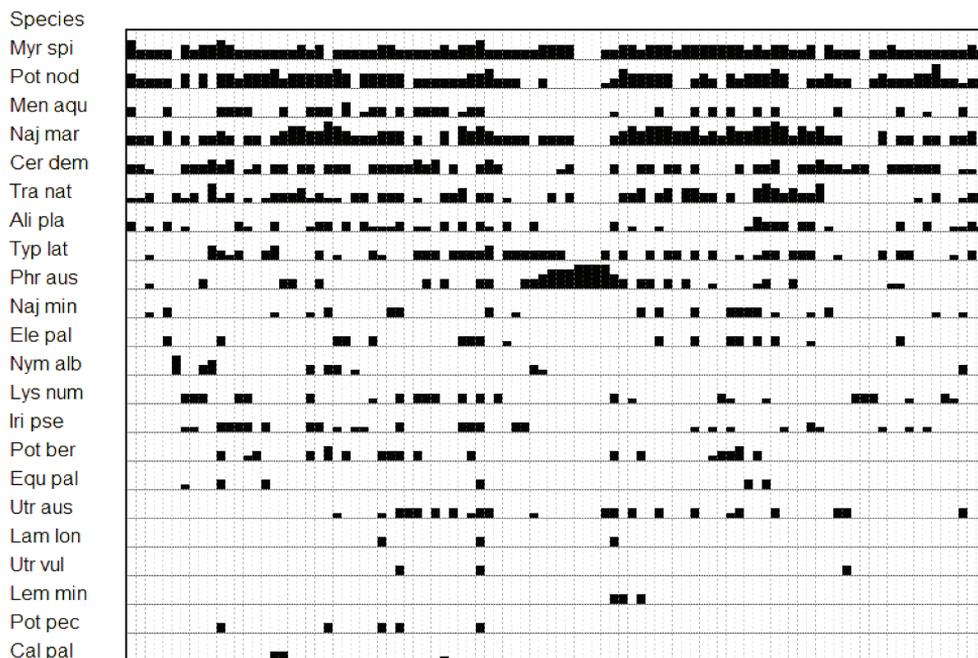


Figure 2: Distribution and abundance of macrophytes in the littoral of Lake Slivniško jezero from the 1st to 96th reach.

Slika 2: Razporeditev in pogostost makrofitov v litoral Slivniškega jezera od 1. do 96. odseka.

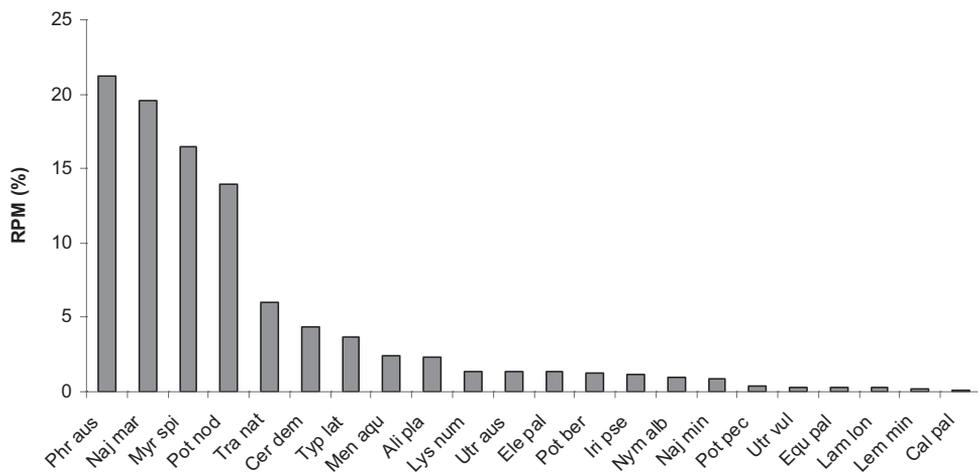


Figure 3: Relative abundance of macrophytes in Lake Slivniško jezero.

Slika 3: Relativna zastopanost makrofitov v Slivniškem jezeru.

The highest relative abundance (RPM) was reached by *Phragmites australis*, and the lowest by *Caltha palustris*. High RPM was reached also by *Najas marina*, *Myriophyllum spicatum* and *Potamogeton nodosus* (Figure 3).

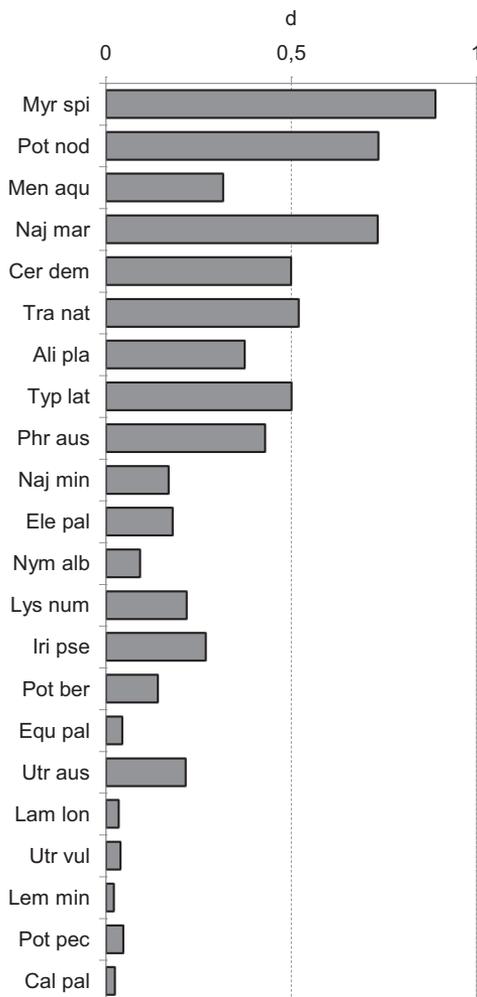


Figure 4: Ratio between relative abundance of single macrophyte per littoral reaches with this species and relative abundance of single macrophyte species per whole littoral length (d) in Lake Slivniško jezero.

Slika 4: Razmerje med relativno zastopanostjo posamezne vrste makrofitov v odsekih z vrsto in njeno relativno zastopanostjo glede na vse odseke (d) v Slivniškem jezeru.

Myriophyllum spicatum thrived on a larger share of littoral (d = 0.89), followed by *Potamogeton nodosus* (d = 0.74) and *Najas marina* (d = 0.73) (Figure 4). On about 50% of the length of the littoral we also found species *Ceratophyllum demersum*, *Trapa natans* and *Typha latifolia*. *Lamprothamnium longifolium*, *Caltha palustris* and *Lemna minor* had the lowest values of d, which means that they occupied the lowest proportion of the length of the littoral (Fig. 4).

Average depth of the macrophytes growth

The highest average maximum depth reached *Nymphaea alba* (2.4 m), which had also the highest average minimum depth of growing (1.6 m). A very wide range of depth of thriving had *Myriophyllum spicatum* (av. min. depth 0.5 m, av. max. depth 1.9 m), *Najas marina* (av. min. depth 0.4 m, av. max. depth 1.9 m) and *Potamogeton nodosus* (av. min. depth 0.4 m, av. max. depth 1.5 m). Helophytes grew on average to the maximum depth to 0.5 m (*Phragmites australis*). Smaller rooted, submerged macrophyte species, such as *Potamogeton berchtoldii* and *P. pectinatus*, thrived on average depth from 0.2 m to 0.4 m, and *Najas minor* even deeper (up to 0.6 m). Submerged rooted species *Utricularia australis* and *U. vulgaris* grew to an average depth of 0.2 m.

Environmental assessment of littoral and the catchment of Lake Slivniško jezero

The proportion of the littoral, presented by certain status of selected parameter of a wider ecological assessment of the Lake Slivniško jezero is presented in Table 3.

A 99% of the length of the lake shore is in natural state. Shore of the lake is mostly with gentle (42.5%) or medium slope (36.9%). At 40.8%, which is approximately 2960 meters long, the riparian zone is covered by forest or wetland plants. 33.2% (2412 m) of riparian zone is grown by pioneer woody vegetation. More than 50 m wide riparian zone with woody or wetland plants extends to 36.9% (2681 m) length of the lake. From 5 to 30 m wide riparian zone with woody or wetland plants extends to 28.6% (2077 m) length of the lake. At 49.9% (3625 m) length of the entire riparian zone with forest or wetland vegetation is

complete without disturbances. 53.3% of the land beyond the riparian zone overgrown with forests or wetlands. At 31.5%, the mosaics mown meadows/pasture with a little arable land is spread, 15.2% is agricultural land, where there is arable land and few individual houses.

Table 3: The proportion of different quality classes (%) of the environmental parameters along the entire littoral in Lake Slivniško jezero.

Tabela 3: Delež litorala, ki predstavlja posamezne kakovostne razrede določenega ekološkega dejavnika Slivniškega jezera.

Parameter / Quality class	% of the whole length of the littoral belt			
	1	2	3	4
Bank structure	99.0	0.3	0.7	0
The slope of riparian zone	42.5	36.9	19	1.6
Vegetation of the riparian zone	40.8	33.2	24.8	1.2
Width of the riparian zone	36.9	28.6	12.3	22.2

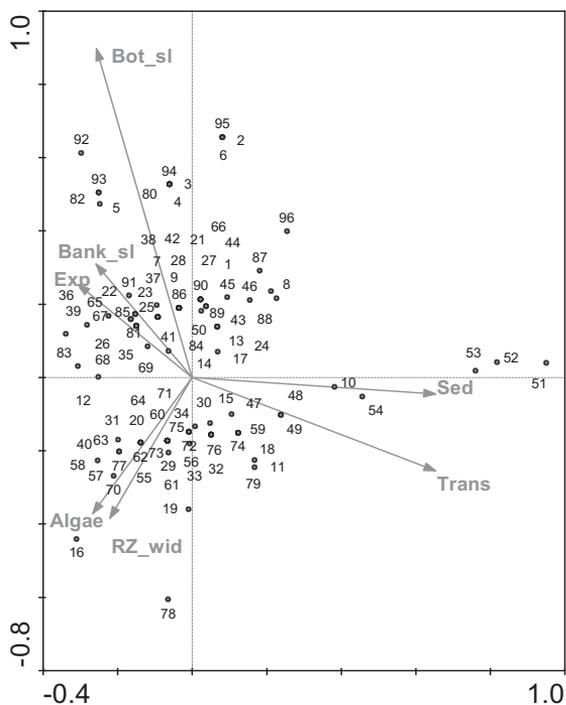


Figure 5: CCA ordination plot showing the relationship between environmental parameters and locations of littoral in Lake Slivniško jezero.

Slika 5: CCA ordinacijski diagram, ki prikazuje razmerje med okoljskimi parametri in lokacijami litorala v Slivniškem jezeru.

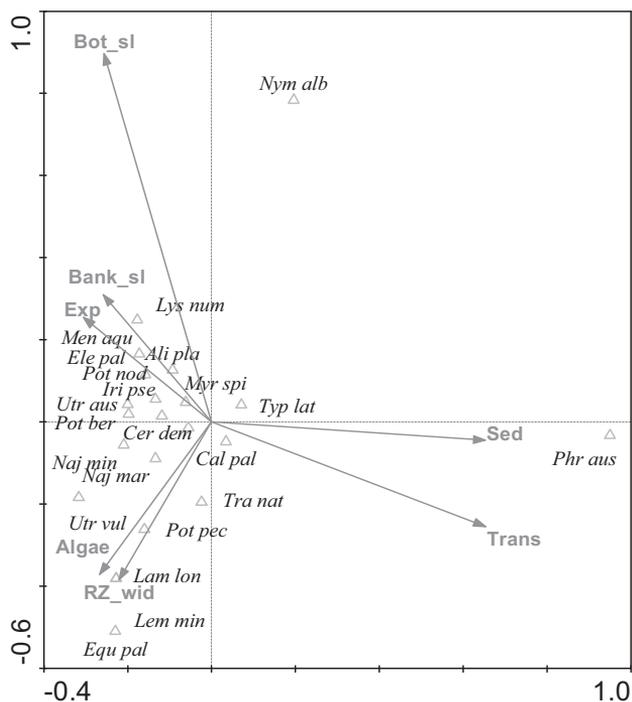


Figure 6: CCA ordination plot showing the relationship between environmental parameters and the distribution and abundance of macrophytes in Lake Slivniško jezero.

Slika 6: CCA ordinacijski diagram, ki prikazuje odnos med okoljskimi parametri ter razširjenostjo in številčnosti makrofitov v Slivniškem jezeru.

Completeness of the riparian zone	49.9	15.4	12.5	22.2
Land use	53.3	31.5	15.2	0

The effect of environmental factors on the distribution of macrophytes

Table 4: The percentage of variance, explained by each environmental parameter, using canonical correspondence analysis (CCA).

Tabela 4: Odstotek pojasnjene variance s posameznimi okoljskimi parametri s pomočjo kanonične korespondenčne analize (CCA).

Environmental parameter	Abbreviation	Explained variance	p value
Sediment	Sed	7.5	0.001
Presence of filamentous algae	Algae	3.0	0.008
The slope of the littoral bottom	Bot_sl	3.4	0.001
Exposition	Exp	2.6	0.003
Transparency	Trans	3.4	0.024
The slope of the bank	Bank_sl	0.4	0.009
Width of riparian zone	RZ_wid	0.2	0.005

Fig. 5 shows the extent to which selected environmental factors explain the variability of the occurrence and distribution of taxa in Lake Slivniško jezero while Fig. 6 shows the locations in relation to quality gradients of environmental parameters. The proportion of explained variance of species presence and abundance is presented in the Table 4. Environmental factors with the greatest impact on the presence and abundance of macrophyte were type of the sediment, the presence of filamentous algae, the slope of the bottom, exposition and water transparency. In addition, the width of riparian zone and the slope of the bank in littoral also had an impact on the presence and abundance of macrophytes. The taxa that were grouped in the plot occurred at sites with similar environmental conditions. The majority of species were distributed around the center therefore they occupied moderate values of environmental parameters. *Potamogeton pectinatus*, *Utricularia vulgaris* and *Lamprothamnium longifolium* thrived better in places where riparian zone with woody or wetland vegetation was disturbed, while *Nymphaea alba* grew in places with complete riparian vegetation without disturbances. *Lemna minor* occurred more often in places overgrown with dense mass of filamentous algae.

Discussion

In Lake Slivniško jezero 22 species of macrophytes were found, namely nine species of submerged macrophytes, four natant species and nine species of emergent plants.

From emergent macrophytes *Phragmites australis* was dominated regarding relative abundance (Fig. 3). It grew mainly on the eastern part of the lake. Reed stands are among the most productive stands filtering nutrients and other substances before they reach the lake water or sediment (Wetzel 2001). *Typha latifolia* was found in areas not exposed to the winds (Hutchinson 1975). We found this species in places where the shoreline was protected by woody vegetation, or in places with steep bank.

The species *Najas marina* and *Myriophyllum spicatum* achieved the highest relative abundance among submerged and natant species (Fig. 4). Both species occurred evenly throughout the littoral of

the lake, and were found in more than 73% of the lake littoral. Unlike most macrophytes *Najas marina* successfully colonizes soft and unstable substrates (Germ et al. 2008). Soft, sometimes muddy bottom of the Lake Slivniško jezero provides favorable conditions for the growth of this species. *M. spicatum* is a very competitive and successful species and in many lakes it forms monospecific stands (Mazej and Germ 2008). It grows in turbid water, because it has low light compensation point and has the ability to utilize bicarbonate. It often reaches high biomass in waters rich with nitrates and in sites where the sediment is rich in organic matter (Ali and Soltan 2006). These conditions prevailed also in Lake Slivniško jezero. The coexistence of these two species is usually in favour of *M. spicatum* over *N. marina* (Ali and Soltan 2006). In Lake Slivniško jezero the two species are the most common and co-exist in most segments. On the other hand Mazej and Germ (2008) report that *N. marina* replaced the previously dense stands of *M. spicatum* and *Potamogeton crispus* in the lake Velenjsko jezero within a few years. The results suggest that the success of a species in a given aquatic ecosystem depends on the physical, chemical and geo-morphological characteristics of the water and the life strategies of the single species (Mazej and Germ 2008).

High relative abundance was also observed in *Potamogeton nodosus* (Fig. 4), which is typical species for eutrophic water bodies (Preston 2003). Two representatives of the genus *Potamogeton* in Lake Slivniško jezero were also found, namely *P. berchtoldii* and *P. pectinatus*. (Figs. 2 and 3). Both can tolerate high concentrations of phosphorus and nitrogen (Germ et al. 2008). Lehmann et al. (1997) suggest that the *P. pectinatus* grows better in shallow water bodies with muddy, organically rich sediment, which has been shown also in our research. In the stands of *M. spicatum*, *N. marina* and *P. nodosus* we often find *Ceratophyllum demersum*, which grows well in turbid water with a lot of nutrients and where the flow is slow (Šraj-Kržič 2007).

About twenty years ago *Trapa natans* expanded to the whole lake (Gobec 2001). Local policy managers regulated the water level and in a few years its abundance declined. Species was evenly distributed throughout the lake and did not form large monospecific stands.

During our study, we found two carnivorous species *Utricularia australis* and *U. vulgaris*. The appearance of these two species reflected occasional nutrient depletion in the water column due to the intensive growth of other plant species. Both species were found mainly among dense stands of other macrophytes where carnivory can bring competitive advantage, due to the low amount of nutrients in the water column (Horvat et al. 2008).

Depth distribution of macrophytes

Zonation of macrophytes in Lake Slivniško jezero reflects the differences between the species. Emergent species grow on average to a depth of 25 cm. An exception is *Phragmites australis* that colonized littoral to the depth about 45 cm. The zone of submerged rooted species such as *P. pectinatus*, *P. berchtoldii*, *Najas minor* mixed with individual specimens of *C. demersum*, *M. spicatum*, *N. marina* and *P. nodosus* reached the depth of thriving at about 50 cm. On deeper part of the littoral thrived frequently represented species in Lake Slivniško jezero namely *M. spicatum*, *N. marina* and *P. nodosus*. Average maximum depth of thriving of their distribution was up to 2 m.

Some specimens of *M. spicatum* and *N. marina* were found at a depth of 3 m, *N. alba* even at 4 m. However in general, the water transparency in Lake Slivniško jezero was very low, preventing a colonization of macrophytes to the deeper parts of the lake. The maximum depth of the growth of macrophytes is mostly consequence of the water transparency (Wetzel 2001).

The impact of environmental factors on macrophytes in Lake Slivniško jezero

CCA analysis showed that the distribution of macrophytes was significantly affected by the following environmental factors: insolation, the slope of the bottom, the type of the sediment, the slope of riparian zone, the presence of macroalgae in water and vegetation in the riparian zone, the completeness of woody or wetland vegetation in riparian zone, the land use beyond the riparian zone and the turbidity of water (Fig. 6). Bank structure and width of woody or wetland vegetation, did not significantly affect the distribution of macrophytes. In their macrophytes study Balaži

et al. (2014) found out that water temperature, dissolved oxygen, chemical oxygen demand, and phosphorus were the main environmental variables influencing the composition of macrophyte assemblages. Hrivnak et al. (2012) also studied the effect of environmental variables on species richness of macrophytes in 39 Slovak streams. The strongest effects was exerted by the portion of artificial banks, shading by woody vegetation, flexuosity of stream course and the portion of natural land cover in the contact zone of the stream.

Conclusions

The littoral of the Lake Slivniško jezero was overgrown with aquatic plants. Reach and dense stand of plants in Lake Slivniško jezero is great advantage over other reservoirs in central and eastern Slovenia since the plants take up a large amount of nutrients. The highest relative abundance in Lake Slivniško jezero was reached by *Phragmites australis*, *Myriophyllum spicatum*, *Najas marina* and *Potamogeton nodosus*. The latter three were more or less evenly distributed throughout littoral. *P. australis* formed a huge stands at the eastern part of the lake, in other places it occurred only in small patches. The maximum average depth of macrophytes distribution in Lake Slivniško jezero was limited to about 2 m, due the low transparency of lake water. Distribution of macrophytes was significantly affected by insolation, the slope of the bottom, the type of the sediment, the slope of riparian zone, the presence of macroalgae, the type of vegetation in the riparian zone, the completeness of woody or wetland vegetation in riparian zone, the land use beyond the riparian zone and the turbidity of water.

Povzetek

Slivniško jezero je nastalo z zaježitvijo Ločnice pri Tratni leta 1976 zaradi zaščite Celja pred poplavami in za potrebe po tehnološki vodi za Železarno Štore. Na podlagi OECD kriterijev je jezero uvrščeno med evtrofne zadrževalnike.

Namen raziskave je bil ugotoviti, kateri makrofiti uspevajo v Slivniškem jezeru in kakšna je njihova pogostost in njihova razporeditev po

celotnem litoralju jezera. Ugotavljali smo tudi, kateri okoljski dejavniki vplivajo na pojavljanje, pogostost in razporeditev makrofitov v jezeru.

Litoral jezera smo razdelili na 96 odsekov na podlagi razlik v vrstni sestavi ali na podlagi sprememb okoljskih dejavnikov. Na posameznih odsekih, kjer smo popisali prisotnost in pogostost vrst, smo ocenjevali tudi okoljske dejavnike.

Slivniško jezero je na večinskem delu litorala močno poraščeno z vodnimi rastlinami. Našli smo 22 taksonov makrofitov od tega 9 submerznih vrst, 9 emerznih vrst in 4 natantne vrste. Največjo relativno zastopanost so dosegle vrste *Phragmites australis*, *Myriophyllum spicatum*, *Najas marina* in *Potamogeton nodosus*. *M. spicatum*, *N. marina* in *P. nodosus* poleg vrste *Nymphaea alba*

dosegle tudi največjo globino uspevanja. CCA analiza je pokazala, da osončenost, naklon dna, vrsta sedimenta, naklon brega nad vodo, prisotnost makroalg, vegetacija obrežnega pasu, sklenjenost z lesnatimi ali močvirskimi rastlinami poraščene obrežnega pasu, izraba tal v zaledju in kalnost vode, statistično značilno vplivajo na pojavljanje makrofitov v Slivniškem jezeru.

Acknowledgments

This research was financed by the Ministry of Education, Science and Sport, Republic of Slovenia, through the programme "Biology of plants" (P1-0212).

References

- Alaoui, K.S., Galoux, D., Rosillon, F., 2014. Macrophytes: Limitations of using them to assess reservoir status according to the water framework directive. *International Journal of Water Sciences*, 3, 1-11.
- Ali, M.M., Soltan, M.A., 2006. Expansion of *Myriophyllum spicatum* (Eurasian water milfoil) into Lake Nasser, Egypt: Invasive capacity and habitat stability. *Aquatic Botany*, 84, 239-244.
- ARSO (Environmental Agency, Agencija Republike Slovenije za okolje), 2005. Poročilo o kakovosti jezer v letu 2005. Ljubljana, Ministrstvo za okolje in prostor http://www.arso.gov.si/vode/jezera/jezera_2005.pdf [9.12.2010]
- Balaži, P., Hrivn, R., O'heová, H., 2014. The relationship between macrophyte assemblages and selected environmental variables in reservoirs of Slovakia examined for the purpose of ecological assessment. *Polish Journal of Ecology*, 62(3), 541-556.
- Dar, N.A., Pandit, A.K., Ganai, B.A., 2014. Factors affecting the distribution patterns of aquatic macrophytes. *Limnological Review*, 14Fa, 2ct: o7r5s -a8f1 fe.
- Furey, P.C., Nordin, R.N., Mazumder, A., 2004. Water level drawdown affects physical and biogeochemical properties of littoral sediments of a reservoir and a natural lake. *Lake and Reservoir Management*, 20, 280-295.
- Germ, M., Urbanc-Berčič, O., Janauer, G.A., Filzmoser, P., Exler, N., Gaberščik, A., 2008. Macrophyte distribution pattern in the Krka River – the role of habitat quality. *Large Rivers*, 18 (1-2), 145-155.
- Gobec, K., 2001. Ocena onesnaženosti Slivniškega jezera s trent biotskim indeksom. Raziskovalna naloga, Šentjur, Šolski center Šentjur: 22 pp.
- Horvat, B., Urbanc-Berčič, O., Gaberščik, A., 2008. Water Quality and Macrophyte Community Changes in the Komarnik Accumulation Lake (Slovenia). In: Vymazal J. (ed.): *Wastewater Treatment, Plant Dynamics and Management in Constructed and Natural Wetlands*. Springer science + Business Media, pp. 13-22.
- Hrivnák, R., O'heová, H., Gömöry, D., Valachovič, M., Paľove-Balang, P., 2012. Environmental effects on species richness of macrophytes in Slovak streams. *Central European Journal of Biology*, 7(6), 1030-1036. <http://doi.org/10.2478/s11535-012-0090-8>
- Hutchinson, G.E., 1975. *A treatise on Limnology*. Volume III. *Limnological Botany*. John Wiley & Sons Inc. New Yourk, London, Sydney, Toronto, 660 pp.
- Kohler, A., 1978. Methoden der Kartierung von Flora und Vegetation von Süßwasserbiotopen. *Landschaft + Stadt*, 10 (2), 73-85.

- Kohler, A., Janauer, G.A., 1995. Zur Methodic der Untersuchung von aquatischen Makrophyten in Fließgewässern, In: Steinberg Ch., Bernhardt H., Klapper H. (eds.): Handbuch Angewandte Limnologie, Ecomed Verlag, Lansberg/Lech.
- Krolová, M., Čížková, H., Hejzlar, J., Poláková, S., 2013. Response of littoral macrophytes to water level fluctuations in a storage reservoir. Knowledge and Management of Aquatic Ecosystems, (408), 1–21. <http://doi.org/10.1051/kmae/2013042>
- Lehmann, A., Castella, E., Lachavanne, J.B., 1997. Morphological traits and spatial heterogeneity of aquatic plants along sediment and depth gradients, Lake Geneva, Switzerland. Aquatic Botany, 55, 281-299.
- Mazej, Z., Germ, M., 2008. Competitive advantages of *Najas marina* L. in a process of littoral colonization in the lake Velenjsko jezero (Slovenija). Acta Biologica Slovenica, 51 (1), 13-20.
- Pall, K., Janauer, G.A., 1995. Die Makrophytenvegetation von Flußstauen am Beispiel der Donau zwischen Fluß-km 2552,0 und 2511,8 in der Bundesrepublik Deutschland. Arch. Hydrobiol., Suppl. 101, Large Rivers 9 (2), 91-109.
- Pall, K., Moser, V., 2009. Austrian Index Macrophytes (AIM-Module 1) for lakes: A Water Framework Directive compliant assessment system for lakes using aquatic macrophytes. Hydrobiologia, 633, 83-104. <http://doi.org/10.1007/s10750-009-9871-0>
- Reddy, K.R., 1983. Fate of nitrogen and phosphorus in a waste-water retention reservoir containing aquatic macrophytes. Journal of Environment Quality, 12(1), 137. <http://doi.org/10.2134/jeq1983.00472425001200010025x>
- Remec-Rekar, Š., 2003. Jezera. In: Uhan J., Bat M. (eds.): Vodno Bogastvo Slovenije. Agencija Republike Slovenije za okolje.
- Scheffer, M., Jeppesen, E., 2007. Regime shifts in shallow lakes. Ecosystems, 10, 1-3.
- Smith, J.E., 2011. Algae, In: Simberloff D., Rejmanek M. (eds.): Encyclopedia of Biological Invasions, University of California Press, Los Angeles, pp. 11-15.
- Solimini, A.G., Cardoso, A.C., Heiskanen, A., 2006. Indicators and Method for Ecological Status Assessment under Water Framework Development, European Commission: Joint Reseach Center, EUR22314EN, Luxemburg.
- Šraj-Kržič, N., Germ, M., Urbanc-Berčič, O., Kuhar, U., Janauer, G.A., Gaberščik, A., 2007. The quality of the aquatic environment and macrophytes of karstic watercourses. Plant Ecology, 192, 107-118.
- Štraus, M., 2006. 50 let Gospodarjenja z Voglajnskimi Ribiškimi Okolišem. Šentjur pri Celju, Ribiška Družina Voglajna: 44 pp.
- Videc, D., 2010. NIVO, Gradnje in ekologija d.d., Celje
- Vukov, D., Igić, R., Anačkov, G., Janauer, A.G., 2004. The Aquatic macrophytes of "Mali Derdap" (Danube, rkm 1039-999). Internat. Assoc. Danube Res. 35, 421-426.
- Wetzel, R., 2001. Lymnology: Lake and River Ecology. 3 rd edition. Academic Press, San Diego, San Francisco, New Yourk, London, Sydney, Tokyo, 1006 pp.