

The macrophyte flora and vegetation of the Paučko lake (mt. Konjuh)

Flora Makrofita i Vegetacije Paučkog jezera (Planina Konjuh)

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ABSTRACT

The study presents the first data on biodiversity of macrophyte flora and vegetation of Paučko Lake, which is recognized as an area of great natural, landscape and hydrological value in the Protected Landscape "Konjuh". Paučko Lake has a small surface and it's located at 711 m a.s.l. in the catchment area of the Drinjača River. The aquatic and marsh vegetation were studied during spring and summer in 2018 using the traditional Zürich-Montpellier approach. The vegetation of Paučko Lake is comprised of aquatic and marsh associations of the classes *Potamogetonetea* Klika in Klika et Novák 1941 and *Phragmito-Magnocaricetea* Klika in Klika et Novák 1941. The following aquatic and marsh plant associations were identified: *Myriophyllo-Potametum* Soó 1934, *Scirpo-Phragmitetum australis* W. Koch 1926, *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donseelaar et al. 1961, *Schoenoplectetum lacustris* Chouard 1924, *Typhetum latifoliae* Lang. 1973 and *Scirpetum silvatici* Ht et H-ić prov. (in Ht et al. 1974). Rare vulnerable taxa *Thelypteris palustris* Schott and *Menyanthes trifoliata* L. were recorded in emerged littoral communities, whose habitats are under successional changes caused by excessive macrophyte overgrowth by competitor species. Restoration measures are necessary to be taken to preserve the habitats of endangered species of the Paučko Lake.

Key words: biodiversity, flora, Konjuh, macrophytes, Paučko Lake, vegetation

INTRODUCTION - Uvod

Macrophytes play an important structuring role in shallow freshwater bodies by reducing water turbidity, competing with phytoplankton by taking up nutrients from the water, enhancing the density of surface-associated organisms, changing oxygen conditions, having a significant impact on phosphorus and nitrogen dynamics and pH. Macrophytes have an importance for the food web

interactions and environmental quality of lakes (Scheffer & Jeppesen, 1998). Studies of the aquatic and marsh communities in Bosnia and Herzegovina have been known for the Hutovo blato Natural park (Jasprica & Carić, 2002; Jasprica et al., 2003), Bardača (Kovačević & Stojanović, 2008), Sava river basin floodplains (Redžić et al., 2009), Velika Tišina (Bjelčić, 1954), karstic rivers (Lasić et al., 2014) and several mine pit lakes (Kamberović & Barudanović, 2011; 2012; Kamberović et al., 2014). Shallow

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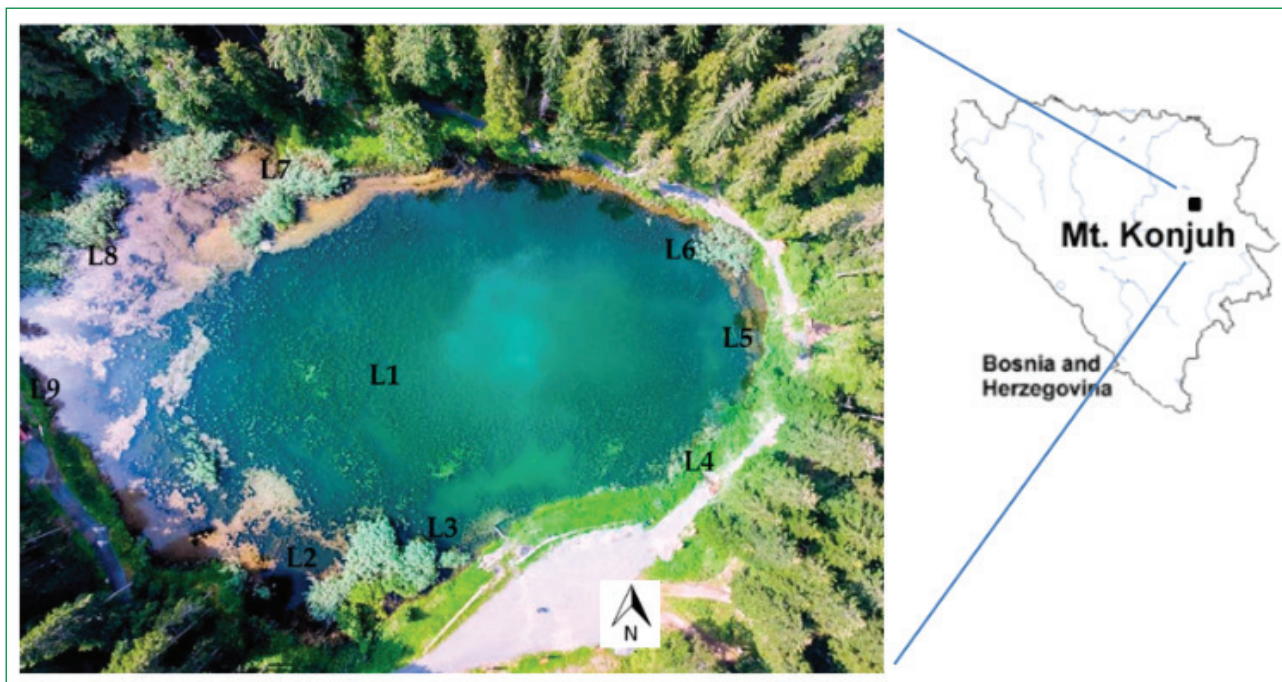


Figure 1. Study area – Paučko Lake (photo by Almir Čamdžić)
Slika 1. Područje istraživanja - Paučko jezero (fotografija Almir Čamdžić)

mountain lakes of Bosnia and Herzegovina are often densely overgrown with macrophytic vegetation. Paučko Lake, which is recognized as an area of natural, landscape and hydrological value of the Protected Landscape Konjuh in north-eastern Bosnia and Herzegovina (Vujačević et al. 2013) is a good example of this process. The previous research of the Paučko Lake as a wider locality site is known from the initial study on biodiversity of the Protected Landscape “Konjuh” (Public Institution Protected Landscape Konjuh, 2017), while detailed data on the floristic diversity and vegetation of this lake is missing. Previous floristic research on the Konjuh Mountain was conducted by Ritter-Studnička (1963) focusing on the vegetation on serpentines and peridotites, by Kamberović (2015), and Kamberović et al. (2016) focusing on algae and macrophytes in spring ecosystems. The objective of this paper is to describe floristic composition of the aquatic and marsh plant communities of the Paučko Lake, with a special emphasis on the conservation status of the plants and associations.

MATERIAL AND METHODS – Materijal i metode

Methods

Phytocenological relevés were carried out using the Zürich–Montpellier approach in two vegetation seasons in 2018 (Braun-Blanquet, 1964). Determination of plants was done according to the following literature: Tutin et al. eds. (1964–1993), Domac (2002) and Javorka & Csapody (1979).

The nomenclature of syntaxa follows Barudanović et al. (2015), Mucina et al. (2016) and Šumberová et al. (2011). Sociability of plant species and environmental factors (temperature, humidity, soil acidity, nitrification, light, continentality, and salinity) are given according to Ellenberg (Borhidi, 1993). Threatened plant species of the investigated sites are determined in accordance with Đug et al. (2013).

Study area

Paučko Lake is a small lake located at 711 m a.s.l. in the catchment area of the Drinjača River in the Protected Landscape Konjuh, north-eastern Bosnia and Herzegovina (N 44°14'01.61'', E 18°36'05.51''). It's fed from two streams and its surface is 0.44 km² (Vujačević et al. 2013). The area is characterized by moderate-continental climate (Stefanović et al., 1983). Phytocenological researches were done on nine locations, marked on the Figure 1 as L1–L9.

RESULTS AND DISCUSSION – Rezultati i diskusija

Flora and vegetation of the Paučko Lake

The macrophyte flora is comprised of 30 taxa in total. The dominant aquatic submerged macrophyte is the eurasian water-milfoil *Myriophyllum spicatum* L., which covers almost the entire bottom of the lake in the summer aspect. It is a competitive species, which forms a mono-



Figure 2. The common macrophyte taxa of the Paučko Lake 1 - *Myriophyllum spicatum* L., 2 - *Phragmites australis* (Cav.) Steud., 3 - *Typha latifolia* L., 4 - *Menyanthes trifoliata* L., 5 - *Thelypteris palustris* Schott, 6 - *Knautia sarajevensis* (Beck) Szabó., 7 - *Scirpus sylvaticus* L., 8 - *Carex paniculata* L., 9 - *Cirsium palustre* (L.) Scop., 10 - *Epilobium parviflorum* Schreber., 11 - *Epilobium hirsutum* L., 12 - *Lycopodium europaeus* L.

Slika 2. Uobičajni taksoni makrofita Pučkog jezera 1 - *Myriophyllum spicatum* L., 2 - *Phragmites australis* (Cav.) Steud., 3 - *Typha latifolia* L., 4 - *Menyanthes trifoliata* L., 5 - *Thelypteris palustris* Schott, 6 - *Knautia sarajevensis* (Beck) Szabó., 7 - *Scirpus sylvaticus* L., 8 - *Carex paniculata* L., 9 - *Cirsium palustre* (L.) Scop., 10 - *Epilobium parviflorum* Schreber., 11 - *Epilobium hirsutum* L., 12 - *Lycopodium europaeus* L.

dominant plant community at the Paučko Lake. Besides the above-mentioned species, very abundant were the following taxa: *Typha latifolia* L., *Phragmites australis* (Cav.) Steud., *Scirpus sylvaticus* L., *Carex paniculata* L. and *Solanum dulcamara* L. A total of two identified taxa are listed as threatened, *Menyanthes trifoliata* L. and *Thelypteris palustris* Schott (a vulnerable threat category). Both taxa are recorded on the southern shore of the lake. *Menyanthes trifoliata* has a declining population size trend in neighbouring countries Hungary, Italy and Croatia where it is classified as an endangered species (<http://www.iucnredlist.org/details/163993/0>). According to Đug et al. (2013), this species had been recorded in Bosnia and Herzegovina in several karst fields and peats. The species *Thelypteris palustris* typically grows on fine substrates, peat bogs, shores of ponds and alluvial deposits along the river. It comes in a reed community at the Paučko Lake in an islet plant community.

During the investigation, we recorded only one endemic species *Knautia sarajevensis* (Beck) Szabó. The most common macrophyte taxa are shown on the Figure 2.

The vegetation of the Paučko Lake is comprised of six plant associations within two classes.

Class: POTAMOGETONETEA Klika in Klika et Novák 1941
 Order: Potamogetonalia Koch 1926
 Alliance: Potamogetonion Libbert 1931
 1. Ass. *Myriophyllo-Potametum* Soó 1934
 Class: PHRAGMITO-MAGNOCARICETEA Klika in Klika et Novák 1941
 Order: Phragmitetalia Koch 1926
 Alliance: *Phragmition communis* Koch 1926
 2. Ass. *Scirpo-Phragmitetum australis* W. Koch 1926
 3. Ass. *Typhetum latifoliae* Lang. 1973
 4. Ass. *Schoenoplectetum lacustris* Chouard 1924
 Order: Magnocaricetalia Pignatti 1953
 Alliance: *Magnocaricion elatae* Koch 1926
 5. Ass. *Scirpetum silvatici* Ht et H-ić prov. (in Ht et al. 1974).
 Alliance: *Carici-Rumicion hydrolapathi* Passarge 1964
 6. Ass. *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donselaar et al. 1961

The following taxa are characteristic for vegetation classes Potamogetonetea and Phragmito-Magnocaricetea: *Myriophyllum spicatum* L., *Phragmites australis* (Cav.) Steud., *Typha latifolia* L., *Menyanthes trifoliata* L., *Schoenoplectus lacustris* (L.) Palla, *Sparganium erectum* L., *Thelypteris palustris* Schott, *Solanum dulcamara* L., *Carex paniculata* L., *Scirpus sylvaticus* L., *Lycopodium europaeus* L., *Veronica beccabunga* L., *Epilobium hirsutum* L., *Epilobium parviflorum* Schreber., *Hypericum tetrapterum* Fr., and *Cirsium palustre* (L.) Scop..

Species compositions of all recorded communities are summarised in the Table 1.

Table I. The phytocenological relevés of aquatic and marsh vegetation of the Paučko Lake

Associations	1		2		3		4				5		6	
Relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Localities	1	1	6	8	5	5	7	7	2	2	3	3	4	9
Date 2018	17.5.	14.8.	14.8.	14.8.	17.5.	14.8.	17.5.	14.8.	17.5.	14.8.	17.5.	14.8.	14.8.	14.8.
Water depth (cm)	90	90	30	50	30	20	20	20	30	30	-	-	-	-
Area of relevé (m ²)	50	50	50	50	20	20	50	50	20	20	100	100	50	50
Density (%)	60	70	80	100	70	60	70	70	40	50	100	100	100	100
Taxa														
Characteristic species of the ass. of the alliance														
Potamogetonion														
<i>Myriophyllum spicatum</i> L.	4.5	4.5	2.2				2.2	1.2	1.2					
Characteristic species of the ass. of the alliance <i>Phragmition communis</i>														
<i>Phragmites australis</i> (Cav.) Steud.			5.5	5.5					1.2		4.4	4.5		
<i>Typha latifolia</i> L.					1.2	+1	4.4	4.5	1.1	2.2	+1	1.2		+1
<i>Menyanthes trifoliata</i> L.									3.2	2.1	+1	+1		
<i>Schoenoplectus lacustris</i> (L.) Palla					3.3	3.3								
<i>Sparganium erectum</i> L.								+1						
Characteristic species of the ass. of the alliance <i>Carici-Rumicion hydrolopathi</i>														
<i>Thelypteris palustris</i> Schott											2.2	2.3		
<i>Solanum dulcamara</i> L.			+1	+1	2.3	1.1	1.1		1.1	+1	1.1	+1	+1	+1
Characteristic species of the ass. of the alliance <i>Magnocaricion elatae</i>														
<i>Carex paniculata</i> L.			1.3		1.3	+3	3.3	2.3	1.3	1.3			+3	+2
<i>Scirpus silvaticus</i> L.				1.3				+1					4.5	5.5
Characteristic species of the ass. of the class <i>Phragmito-Magnocaricetea</i>														
<i>Lycopus europaeus</i> L.			+1			+1	1.2	+1	1.1	+1			1.1	+1
<i>Veronica beccabunga</i> L.								+1					+1	
<i>Epilobium hirsutum</i> L.						+1		+1					+1	+1
<i>Epilobium parviflorum</i> Schreber.													+1	
<i>Hypericum tetrapterum</i> Fr.													+1	
<i>Cirsium palustre</i> (L.) Scop.								+1						
Accessory species														
<i>Athyrium filix-femina</i> (L.) Roth.														+1
<i>Salix cinerea</i> L.											1.2	2.3		1.1
<i>Eupatorium cannabinum</i> L.						+1						+1	+1	
<i>Angelica sylvestris</i> L.								+1			1.1	+1		
<i>Galeopsis speciosa</i> Mill.														1.2
<i>Juncus effusus</i> L.													+2	+1
<i>Juncus inflexus</i> L.													+2	
<i>Lysimachia nummularia</i> L.									1.2				+1	1.1
<i>Mentha longifolia</i> (L.) L.													1.1	
<i>Pteridium aquilinum</i> (L.) Kuhn														+1
<i>Ranunculus repens</i> L.											+1		+1	
<i>Sonchus asper</i> (L.) Hill ssp. Asper.													+1	
<i>Urtica dioica</i> L.													+1	
<i>Knautia sarajevensis</i> (Beck) Szabó.														+1

Associations:

- 1 - *Myriophyllo-Potametum* Soó 1934
- 2 - *Scirpo-Phragmitetum australis* W. Koch 1926
- 3 - *Schoenoplectetum lacustris* Chouard 1924

4 - *Typhetum latifoliae* Lang. 1973.5 - *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donselaar et al. 19616 - *Scirpetum silvatici* Ht et H-ić prov. (in Ht et al. 1974)

Ass. **Myriophyllo-Potametum** Soó 1934 comprises vegetation of rooted macrophytes of mesotrophic and eutrophic freshwater bodies at low and mid-altitudes of temperate Eurasia (Mucina et al., 2016). The floristic composition of this association at Paučko Lake is made of only one species - *Myriophyllum spicatum*, indicating low diversity and a disturbed ecosystem function of the lake (Figure 3a). Similar to the situation on the Paučko Lake, Eurasian water milfoil took a dominant role in the colonization processes of macrophytes in pit lakes in north-eastern Bosnia (Kamberović & Barudanović, 2012).

Ass. **Scirpo-Phragmitetum australis** W. Koch 1926 comprises reed swamp vegetation of mesotrophic and eutrophic standing freshwater bodies of boreo-temperate Eurasia (Mucina et al., 2016). It grows on coastal areas in the northern and north-eastern shores of the lake with the water depth of 0.3 - 0.5 m. The floristic composition is made of dense stands of *Phragmites australis*, and several less abundant taxa (*Carex paniculata*, *Myriophyllum spicatum*), or pioneer species of secondary successions (*Solanum dulcamara*, *Lycopus europaeus*). Due to the small depth of the lake, the community penetrates into the open water surface and has a high potential of causing an overgrowth of the lake (Figure 3b). In comparison with stands on Natural park Hutovo Blato (Jasprica et al., 2003) with 12 to 20 taxa, and those on the shores of pit lakes (Kamberović et al., 2014), with 8 to 26 taxa, communities on the Paučko Lake are less diverse (5 taxa).

Ass. **Schoenoplectetum lacustris** Chouard 1924 is dominated by *Schoenoplectus lacustris*, a leafless species that forms sparse stands. It occurs on the eastern shore of the lake in water depths of 0.3 m. It forms a discontinuous zone between the open water and littoral sedge vegetation. The community has poor floristic composition with only seven taxa (Figure 3c).

Ass. **Typhetum latifoliae** G. Lang 1973 was observed at two sites on the Paučko Lake - on the southern and northern coast, in shallow water. It's dominated by *Typha latifolia*. The community at the southern shore is important for conservation, as it is inhabited with vulnerable species in B&H - *Menyanthes trifoliata* L. On the other hand, high overgrowing potential of cattail community on the northern shore was observed (Figure 3d).

Ass. **Scirpetum silvatici** Ht et H-ić prov. (in Ht et al. 1974) is a sedge-bed marsh vegetation on oligotrophic to mesotrophic organic sediments of temperate Europe. It grows on almost the entire coastal area of the lake and relies on reed or cattail communities at the Paučko Lake. The community consists of the highest number of taxa compared to the other described communities, dominantly *Scirpus silvaticus* and *Carex paniculata* (Figure 3e).

Ass. **Thelypterido palustris-Phragmitetum australis** Kuiperex van Donselaar et al. 1961 belongs to the alliance *Carici-Rumicion hydrolapathi* Passarge 1964., or herbland vegetation on non-stabilized organic substrates in mesotrophic waters of boreal and temperate Eurasia. The association grows on an islet of 50 m² on the Paučko Lake (Figure 3f). It is dominated by *Phragmites australis*, with participation of the wetland fern. It is a rare vegetation type of mesotrophic fishponds in northern and southern Bohemia (Czech Republic) where it occurs as floating islets in 30–100 cm deep water. This marsh type has not been recorded earlier in Bosnia and Herzegovina, and it is valuable because of the plant species, e.g. *Menyanthes trifoliata* and *Thelypteris palustris*.



Figure 3. Identified plant associations at the Paučko Lake – a) *Myriophyllo-Potametum* Soó 1934, b) *Scirpo-Phragmitetum australis* W. Koch 1926, c) *Schoenoplectetum lacustris* Chouard 1924; d) *Typhetum latifoliae* G. Lang 1973, e) *Scirpetum silvatici* Ht et H-ić prov. (in Ht et al. 1974), f) *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donselaar et al. 1961

Slika 3. Idnetificirane biljne asocijacije Pučkog jezera a) *Myriophyllo-Potametum* Soó 1934, b) *Scirpo-Phragmitetum australis* W. Koch 1926, c) *Schoenoplectetum lacustris* Chouard 1924; d) *Typhetum latifoliae* G. Lang 1973, e) *Scirpetum silvatici* Ht et H-ić prov. (in Ht et al. 1974), f) *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donselaar et al. 1961

Ecological analysis of associations

Ecological indexes of plant species from the analyzed communities indicate that studied communities appear on alkaline ($R=6.5-8$), non-salinated ($S<1$), well exposed to sunlight or shaded occasionally ($L=5.7-7.25$), briefly flooded or submerged ($W=7.9-12$) and mesotrophic soils ($N=5-7$) with moderate heat requirements of their habitats ($T=5.1-5.8$). Communities are characterized by a large proportion of sub-oceanic species which find their main areal in Central Europe ($K=3-4$) (Figure 4). In comparison with other studied communities, ass. *Myriophyllo-Potametum* has the lowest requirement for light,

whilst ass. *Schoenoplectetum lacustris* has the highest requirement for nitrogen in soil. Results of ecological analysis of identified marsh communities are very similar to the research of Kamberović et al. (2014) on marsh communities of pit lakes in north-eastern Bosnia.

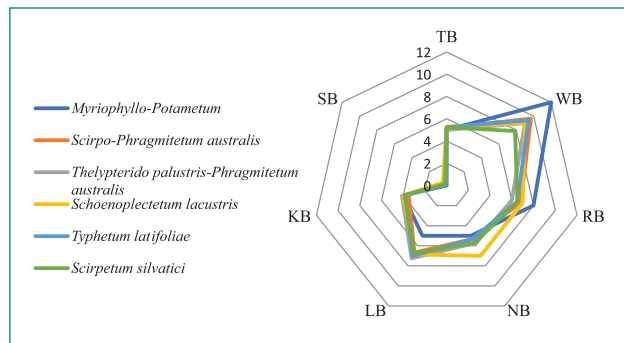


Figure 4. Ecological analysis of the studied associations (T - temperature, W - humidity, R - soil acidity, N - nitrification, L - light, K - continentality, S - salinity)

Slika 4. Ekološka analiza proučavanih asocijacija (T - emperatura, W - vlažnost, R - kiselost tla, N - nitrifikacija, L - svjetlost, K - kontinentalnost, S - salinitet)

Biological spectrum and sociability of plant species

The most dominant life forms are hydrophytes and hemicriptophytes. Geophytes, chamaephytes, and especially therophytes had the lower contribution (Figure 5). Comparing the biological spectrum, the studied communities are more similar to the stands in Serbia studied by Polić (2006), and Croatia (Stančić, 2010), than those on artificial pit lakes in north-eastern Bosnia (Kamberović et al., 2014), due to the high contribution of therophytes in pit lake marsh communities.

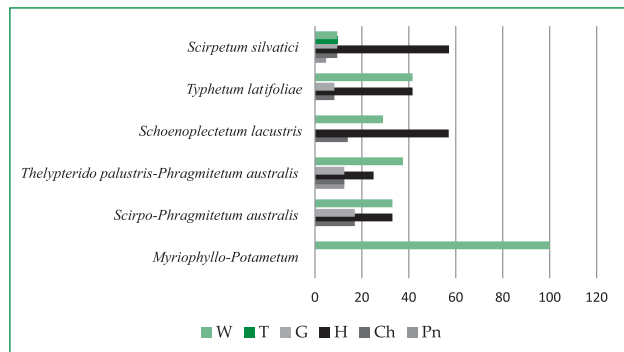


Figure 5. The biological spectrum of the studied associations: W – hydrophytes, T - therophytes, G - geophytes, H – hemicriptophytes, Ch - chamaephytes, Pn – phanerophytes

Slika 5. Biološki spektar proučavanih asocijacija: W - hydrophytes, T - therophytes, G - geophytes, H - hemicriptophytes, Ch - chamaephytes, Pn - phanerophytes

Analyzing the spectrum of sociability of the plant species, the most frequent are competitive taxa and pioneering elements of secondary successions (Figure 6). Associated plant species had less contribution. Several taxa belong to the group of sensitive indicators (*Thelyperis palustris*, *Menyanthes trifoliata*, *Veronica beccabunga*). On the other hand, competitor species such as *Phragmites australis*, *Typha latifolia* and submerged *Myriophyllum spicatum* play an important role in the intense process of plant overgrowth of the lake.

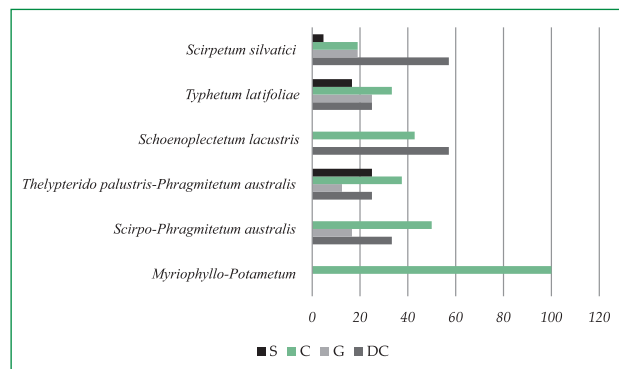


Figure 6. The social behaviour types spectrum of the studied associations S - sensitive species, C - competitors, G - associated plant species, DC - pioneer species of secondary successions

Slika 6. Spektar tipova društvenog ponašanja proučavanih asocijacija S - osjetljive vrste, C - konkurenti, G - pridružene biljne vrste, DC - pionirske vrste sekundarnih sukcesija

Exploring the possibility of using helophytes as bioindicators of lake overgrowth based on long-term changes, Lawniczak-Malińska and Achtenberg (2018) concluded that lakes which currently exhibit the highest degree of overgrowth were shown to have been affected by intensive littoral growth for over 100 years. Overgrowth of helophytes on the Paučko Lake, followed by the production of submerged plants have a tendency of reducing the water surface and gradual succession of the lake into a swamp ecosystem. High productivity plants characterized by a fast growth rate, lead to the large coverage of vegetation with low taxonomic differentiation (Liira et al., 2010). This process is observed on the Paučko Lake, where the common reed, cattail and eurasian water-milfoil dominate in plant communities, and can gradually lead to the disappearance of the rare and vulnerable taxa.

CONCLUSION - *Zaključak*

Paučko Lake is under high pressure caused by gradual shallowing and overgrowth by competitor species. All the while the high proportion of emerged and submerged macrophytes characterizes lake overgrowth. Six plant associations were recognized, within which a rare community *Thelypterido palustris-Phragmitetum australis* is observed. Rare vulnerable taxa were recorded in emerged littoral communities, whose habitats are under successional changes caused by excessive macrophyte overgrowth. Restoration measures are necessary to be taken in order to prevent the gradual disappearance of the lake.

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SAŽETAK

Studija predstavlja prve podatke o biodiverzitetu makrofitne flore i vegetacije jezera Paučko, koje je u zaštićenom pejzažu "Konjuh" prepoznato kao područje velike prirodne, pejzažne i hidrološke vrijednosti. Paučko jezero ima malu površinu i nalazi se na 711 m nadmorske visine, u slivu rijeke Drinjače. Vodena i močvarna vegetacija proučavana je tokom proljeća i ljeta 2018. godine koristeći tradicionalni Zürich-Montpellier pristup. Vegetaciju Paučkog jezera čine vodene i močvarne asocijacije klasa *Potamogetonetea* Klika u Kliki et Novák 1941. i *Phragmito-Magnocaricetea* Klika u Kliki et Novák 1941. Identifikovane su sljedeće asocijacije vodenih i močvarnih biljaka: *Myriophyllo-Potametum* Soó 1934, *Scirpo - Phragmitetum australis* W. Koch 1926, *Thelypterido palustris-Phragmitetum australis* Kuiperex van Donselaar et al. 1961, *Schoenoplectetum lacustris* Chouard 1924, *Typhetum latipholiae* Lang. 1973. i *Scirpetum silvatici* Ht i H-ić prov. (u Ht i dr. 1974). Rijetki osjetljivi taksoni *Thelypteris palustris* Schott i *Menyanthes trifoliata* L. zabilježeni su u priobalnim zajednicama u nastajanju, čija su staništa pod sukcesivnim promjenama uzrokovanim prekomjernim prerastanjem makrofita od konkurentskih vrsta. Potrebne su mjere restauracije kako bi se očuvala staništa ugroženih vrsta jezera Paučko.