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Marshland vegetation of the order *Phragmitetalia* on shores of mine pit lakes in north-eastern Bosnia and Herzegovina

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***Abstract*:**

Kamberović, J., Barudanović, S., Mašić, E., Dedić, A.: ***Marshland vegetation of the order Phragmitetalia on shores of mine pit lakes in north-eastern Bosnia and Herzegovina. Biologica Nyssana, 5 (1), Septemeber 2014: 1-10.***

Marshland vegetation of the order *Phragmitetalia* W. Koch 1926 on the four mine pit lakes in the wider area of Tuzla was investigated during 2008. In total, two plant communities were noted. On the lakes Suhodanj, Mušićko and Šićki Brod association *Typhetum latifoliae* G. Lang 1973 were recorded, within which was noted 33 plant species. On the shores of lakes Ramićko and Šićki Brod the dominant association was *Phragmitetum australis* Schmale 1939, within which were determined 32 plant species. This paper analyzes the life forms and bioindicator values of plant species. The research results indicate a successful process of colonization by macrophyte species on absolutely degraded habitats such as mine pit lakes.

Key words: bioindicators, biodiversity, colonization, mine pit lakes, vegetation, wetlands

***Apstrakt*:**

Kamberović, J., Barudanović, S., Mašić, E., Dedić, A.: ***Močvarna vegetacija reda Phragmitetalia na obalama kopovskih jezera u severoistočnoj Bosni i Hercegovini.. Biologica Nyssana, 5 (1), Septemebar 2014: 1-10.***

Močvarna vegetacija reda *Phragmitetalia* W. Koch 26 istraživana je u toku 2008. godine na obalama četiri kopovska jezera šireg područja Tuzle. Na istraživanom području određene su dve biljne zajednice. Na jezerima Suhodanj, Mušićko i Šićki Brod prisutna je zajednica *Typhetum latifoliae* G. Lang 1973, u sklopu koje je zabeleženo prisustvo 33 biljne vrste. Na obalama jezera Ramićko i Šićki Brod dominantna je zajednica *Phragmitetum australis* Schmale 1939, gde su određene 32 biljne vrste. U radu su analizirane životne forme, bioindikatorske vrednosti i socijabilnost biljnih vrsta. Rezultati istraživanja upućuju na uspešan proces kolonizacije močvarnih biljnih vrsta na apsolutno degradiranim staništima, kao što su kopovska jezera.

Key words: bioindikatori, biodiverzitet, kolonizacija, kopovska jezera, vegetacija, vlažna staništa

Introduction

Plant communities of the order *Phragmitetalia* represent clearly defined zone of emersal vegetation on shores of lakes, ponds and river valleys (Ranđelović *et al*., 2007; Polić, 2006). They develop on wetlands, gley soils, often peaty soils, with intensive reduction processes (Redžić *et al.*, 2009). In Bosnia and Herzegovina they are spread on the area of Hutovo Blato, Bardača, Ždralovac, Velika and Mala Tišina near Bosanski Šamac, some parts of the lake Modrac and are fragmented around many small lakes (Redžić *et al*., eds., 2008). Studies of plant communities of the class *Phragmitetea* in Bosnia and Herzegovina have been known for a sub-Mediterranean area (Jasprica *et al.*, 2003), where in Hutovo Blato 11 plant communities from three vegetation alliances were determined.

In addition to the above mentioned natural habitats, emergent hydrophytes in progradation processes also inhabit shores of anthropogenically-formed lakes. Examples are numerous pit lakes, created in the process of surface coal mining. Pit lakes have the potential to conserve wetland biodiversity (Barudanović & Kamberović, 2008), being overgrown by vegetation of submerged hydrophytes (Kamberović & Barudanović, 2012) and weed vegetation (Barudanović & Kamberović, 2011). Since the community structure of emergent hydrophytes on the shores of pit lakes in Tuzla region is insufficiently known, this paper aims to (i) determine the structure of communities from the order *Phragmitetalia* at artificially formed habitats, (ii) compare these communities with the structure of communities at natural habitats and (iii) assess the ecological characteristics of the habitat on the basis of ecological indexes.

Study area

The research on marshland vegetation was carried out in 2008 in northeastern Bosnia and Herzegovina on the shores of four pit lakes: Suhodanj Lake (SU, **Fig. 1**), Mušićko Lake (MJ, **Fig. 2**), Ramićko Lake (RJ, **Fig. 3**) and Šićki Brod Lake (ŠB, **Fig. 4**). Lakes were formed during the period from 1982-1987 and each have their own water regime. The lakes Suhodanj and Ramićko were created by damming the flow of surface water with the tailings material on a partly degraded terrain. The lakes Mušićko and Šićki Brod were formed in the final crater after the cessation of surface coal mining. Basic characteristics of the

Figure 1. Lake Suhodanj (SU)

Figure 2. Lake Mušićko (MJ)

Figure 3. Lake Ramićko (RJ)

Figure 4. Lake Šićki Brod (ŠB)

Table 1. The basic characteristics of the researched lakes (Kamberović, 2010)

Lakes	Suhodanj (SU	Šićki Brod (ŠB)	Mušići (MJ)	Ramići (RJ)
Year of origin	1985	1987	1982	1983
Elevation (m)	293	207	357	378
Geographic coordinates	44°23`37``N 18°38`41``E	44°31`42``N 18°34`44``E	44°23`45``N 18°30`24``E	44°25`06``N 18°25`29``E
Lake's surface (ha)	2.5	20.8	5.53	6.2
Max. lake's depth (m)	18	33	6	18
Geological basis	marl	sandy	marl	marl and serpentine

Table 2. The physical and chemical parameters of water quality of the studied lakes in August 2008

Indicators	SU	ŠB	MJ	RJ
Water temperature (^{0}C)	26	25.5	24	26
Turbidity (NTU)	1.5	1.3	2.5	3.5
pH	8.1	8.2	7.8	8.3
Total alkalinity (mg $CaCO_3L^{-1}$)	157	147	287	172
Carbonate hardness (°dH)	8.8	8.3	16.1	9.7
Noncarbonated hardness (°dH)	11.2	8.3	40.3	0.1
Total hardness (°dH)	20.2	26.5	56.4	9.8
Dissolved oxygen (mgL^{-1})	10	8.7	10.2	8.5
Oxygen saturation (%)	116	109	127	104
$KMnO_4$ consumption (mgL^{-1})	10.5	14.2	12.6	17.2
Total nitrogen (mgL^{-1})	0.18	0.02	1.46	0.18
Ammonium (mgL^{-1})	0.16	0.02	0.59	0.16
Nitrite (mgL^{-1})	0.018	0.004	0.424	0.004
Nitrate (mgL^{-1})	0	0	0.45	0.02
Calcium (mgL^{-1})	44.1	122	222.4	31.1
Magnesium (mgL^{-1})	60.2	40.7	110	23.7
Electrical conductivity (µS/cm)	535	682	1562	280

studied lakes are given in **Tab. 1**. The research area belongs to the temperate - continental climate region. The average temperature varies from 9^0C to 10.6^0C, and the annual precipitation ranges from 830 L/m^2 to 1.150 L/m^2 (Smajić, 2007).

Material and methods

Phytocenological relevés of coastal vegetation were carried out using the Zűrich–Montpellier school in three vegetation seasons (Braun-Blanquet, 1964). Phytocenological relevés from the spring season with the designation of the lake are additionally marked with the letter "a", the summer season with the letter "b" and the autumn season with the letter "c". Determination of plants is done on the basis of herbarium materials according to the relevant floras (Tutin et al., eds., 1964-1993, Domac, 2002, Javorka & Csapody, 1979). The cover of taxa was determined using the numerical scale according to Westhoff - Van der Maarel (Kojić et al., 1997), and syntaxonomic affiliation of associations according to Lakušić et al. (1977). Life forms of plant species are taken from Oberdorfer (1979). Sociability of plant species and environmental factors (temperature, humidity, soil acidity, nitrification, light, continentality and salinity) are given according to Ellenberg (Borhidi, 1993).

The research of physical/chemical properties of water was done on the field and in the laboratory. The water temperature and the pH of water were

measured on the field, while other physical/chemical parameters (turbidity, total alkalinity, carbonate hardness, noncarbonated hardness, total hardness, dissolved oxygen, oxygen saturation, $KMnO_4$ consumption, total nitrogen, ammonium, nitrite, nitrate, calcium, magnesium, electrical conductivity) were determined in the laboratory of the Institute for chemical engineering in Tuzla, by the standard procedure of the American Health Organization (APHA, AWWA & WEF, 1995).

In the statistical analysis we used complete - linkage clustering method in PRIMER 6 (Clarke & Gorley, 2006). The diversity of assemblages was quantified with the Shannon-Wiener Diversity Index by the use of the BioDiversity Pro version 2 software packages (McAleece et al., 1997).

Results and discussion

Physico-chemical analysis of water

The water of all four researched lakes has a weak alkaline reaction (pH 7.8-8.3). Most pit lakes in the world have an acid reaction of water (Nixdorf et al., 2005). Velagić-Habul et al. (2005) concluded that neutralisation and acidification in mining lakes of the Tuzla area are to date producing a cirumneutral water quality. Investigated lakes except Lake Mušićko have sufficient oxygen regime and generally low concentrations of nutrients. Lake Mušićko has the highest level of water hardness, high calcium and magnesium concentrations, high value of electrical conductivity and the highest value of total nitrogen (**Tab. 2**). Previous studies (Kamberovic & Barudanović, 2012) found that the lakes Suhodanj and Šićki Brod are characterized by oligo-/ß-mesosaprobic status of water with submerged vegetation of *Charophyta*. Lakes Mušićko and Ramićko have ß-mesosaprobic water status and are partially overgrown with vegetation of the alliance *Magnopotamion*.

Marshland vegetation

Marshland vegetation of the order *Phragmitetalia* W. Koch 1926 in the study area is represented with the alliance *Phragmition australis* W. Koch 1926 and two plant association: *Typhetum latifoliae* G. Lang 1973 and *Phragmitetum australis* Schmale 1939.

The community *Typhetum latifoliae* G. Lang 1973 occurs in habitats with shallow water (up to 0.5 meters deep) at the lakes Suhodanj, Mušićko and Šićki Brod (**Tab. 3**). It is most developed at the lake Mušićko and has a dominant role in the appearance of the lake scenery. Besides broadleaf cattail *(Typha latifolia*), in this community also occur other semiaquatic plants: *Mentha aquatica*, *Lycopus europaeus*, *Alisma plantago-aquatica*, *Typha angustifolia* and *Juncus effusus*. This community is a very widespread community of shallow parts of water pools with a quiet eutrophic water (Stančić, 2010). Mostly it represents the transition between the water vegetation and the vegetation of reed beds. Communities of cattail are resistant for a longer period of drying, salinization and water pollution (Polić, 2006).

The community *Phragmitetum australis* Schmale 1939 occurs on some more drained terrain compared to the previous community and it was identified at two lakes. On the lake Šićki Brod it grows over the northwestern lake shore and has a significant role in progradation processes, while at Ramićko lake occurs in the form of a narrow zone on the west shore. The floristic composition is dominated by common reed *Phragmites australis,* while all other species are represented with clearly low covering degree (**Tab. 4**).

Determination of plant communities was confirmed by cluster analysis. Clearly separated two clusters indicate differentiation in two plant communities, while the subgroups are formed in relation to the research sites (**Fig. 5**). The floristic composition of the association changes over the year. Relevés in the spring season have lower number of species compared to the summer and autumn relevés when terrestrial plant species occure. In cluster analysis, in addition to the original, for comparison purposes we included also results of other similar research. From the dendrogram is evident that the community of reed beds on the lake Šićki Brod is most similar to stands in Serbia and Croatia (Lazić et al., 2005, Polić, 2006, Stančić, 2010) with which it shares only three common characteristic plant species of the order *Phragmitetalia* (*Phragmites australis*, *Mentha aquatica* and *Lycopus europaeus*). The community of reed beds on Ramićko lake is most similar to the stands in the sub-mediterranean part of Bosnia and Herzegovina (Jasprica et al., 2003) with which it has four plant species in common (*Phragmites australis*, *Scirpus sylvaticus, Potentilla reptans* and *Calystegia sepium*). The communities of cattail at pit lakes in comparison with other studies do not show a great similarity, except for those on the lake Šićki Brod. Differences in the structure of the examined communities are pronounced because of the participation of some characteristic plant species at the localities in Serbia, Croatia and Herzegovina (e.g. *Glyceria maxima, Acorus*

calamus, Scirpus lacustris) that are absent at pit lakes.

Table 3. Association *Typhetum latifoliae* G. Lang 1973 in littoral of studied pit lakes (the cover of taxa is given according to Westhoff - Van der Maarel)

Association	***Typhetum latifoliae* G. Lang 1973**									
Relevé number	1	2	3	4	5	6	7	8	9	degree of presence
The locality	MJa	MJb	MJc	SUa	SUb	SUc	ŠBa	ŠBb	ŠBc	
Area of relevé (m^2)	50	50	50	50	50	50	30	30	30	
Density (%)	60	85	85	80	95	90	90	95	95	
Char. Ass.										
Typha latifolia L.	8	9	9	8	8	8	8	8	8	V
Typha angustifolia L.	3	3	3	7	7	7				IV
Phragmites australis (Cav.) Trin. ex Steud.	5	5	5							II
Char. Alliance *Phragmition*, Char. Order *Phragmitetalia* & Char. Class										
Mentha aquatica L.	3	3	3	2	2	3				IV
Lycopus europaeus L.	3	3	3	2	3	3				IV
Alisma plantago-aquatica L.	3	3	3	2	3	3				IV
Sparganium erectum L.	3	3	3							II
Carex vulpina L.	3	3	2							II
Lythrum salicaria L.				2	2	2				II
Phalaris arundinacea L.							2	3	3	II
Epilobium palustre L.								2	3	II
Companions										
Cyperus fuscus L.	2	3	3		2	2	2	2	2	V
Ranunculus repens L.	2	2	3	2						III
Juncus effusus L.	3	3	3							II
Lysimachia vulgaris L.	3	2	2							II
Inula britannica L.	2	2	3							II
Eupatorium cannabinum L.	2	3	3							II
Elymus repens (L.) Gould				2	3	3				II
Potentilla reptans L.				2	2	2				II
Plantago major L.				2	2	2				II
Equisetum telmateia Ehrh.							2	3	3	II
Erigeron annuus (L.) Pers.							2	2	2	II
Tussilago farfara L.							2	2	2	II
Artemisia vulgaris L.							2	2	2	II
Polygonum persicaria L.							2	2	2	II
Rumex sanguineus L.	2	3								II
Poa pratensis L.		2	2							II
Prunella vulgaris L.		2	2							II
Bidens tripartita L.					2	2				II
Polygonum lapathifolium L.					3	3				II
Carex hirta L.	3									I
Mentha pulegium L.			2							I
Lycopus exaltatus L.							2			I

Table 4. Association *Phragmitetum australis* Schmale 1939 in littoral of studied pit lakes (the cover of taxa is given according to Westhoff - Van der Maarel)

Association	***Phragmitetum australis* Schmale 1939**						
Relevé number	1	2	3	4	5	6	
The locality	ŠBa	ŠBb	ŠBc	RJa	RJb	RJc	degree of presence
Area of relevé (m^2)	30	30	30	50	50	50	
Density (%)	80	90	90	100	100	100	
Char. Ass.							
Phragmites australis (Cav.) Trin. ex Steud.	9	9	9	9	9	9	V
Typha latifolia L.	3	3	3				III
Char. Alliance *Phragmition*,							
Char. Order *Phragmitetalia* & Char. Class							
Lycopus europeus L.	2	2	2	2	2	2	V
Alisma plantago-aquatica L.	2	2	2	2	2	2	V
Epilobium palustre L.		2	2		2	3	IV
Mentha aquatica L.	2	2	2				III
Sparganium erectum L.				2	2	2	III
Scirpus sylvaticus L.				2	2	2	III
Lythrum salicaria L.					3	3	II
Companions							
Ranunculus repens L.	3	2	2	3	3	3	V
Poa pratensis L.	2	2	3				III
Salix purpurea L.	2	2	2				III
Equisetum palustre L.		2	2		2	2	IV
Elymus repens (L.) Gould				5	5	5	III
Potentilla reptans L.				3	3	3	III
Agrostis stolonifera L.				3	3	3	III
Calystegia sepium /L./R.Br.				5	5	5	III
Plantago altissima L.				2	2	2	III
Tanacetum vulgare L.		2	2				II
Conyza canadensis (L.) Cronquist		2	2				II
Cyperus fuscus L.					2	2	II
Eupatorium cannabinum L.					3	3	II
Mentha pulegium L.					3	2	II
Bidens tripartita L.					3	3	II
Polygonum mite Schrank					3	3	II
Polygonum lapathifolium L.					2	2	II
Echinocystis lobata (Michx.) Torr. & A.Gray					5	5	II
Atriplex patula Srn.					3	3	II
Trifolium repens L.					3	3	II
Sonchus arvensis L.					2	3	II
Pastinaca sativa L.					2	2	II
Verbena officinalis L.					2	2	II

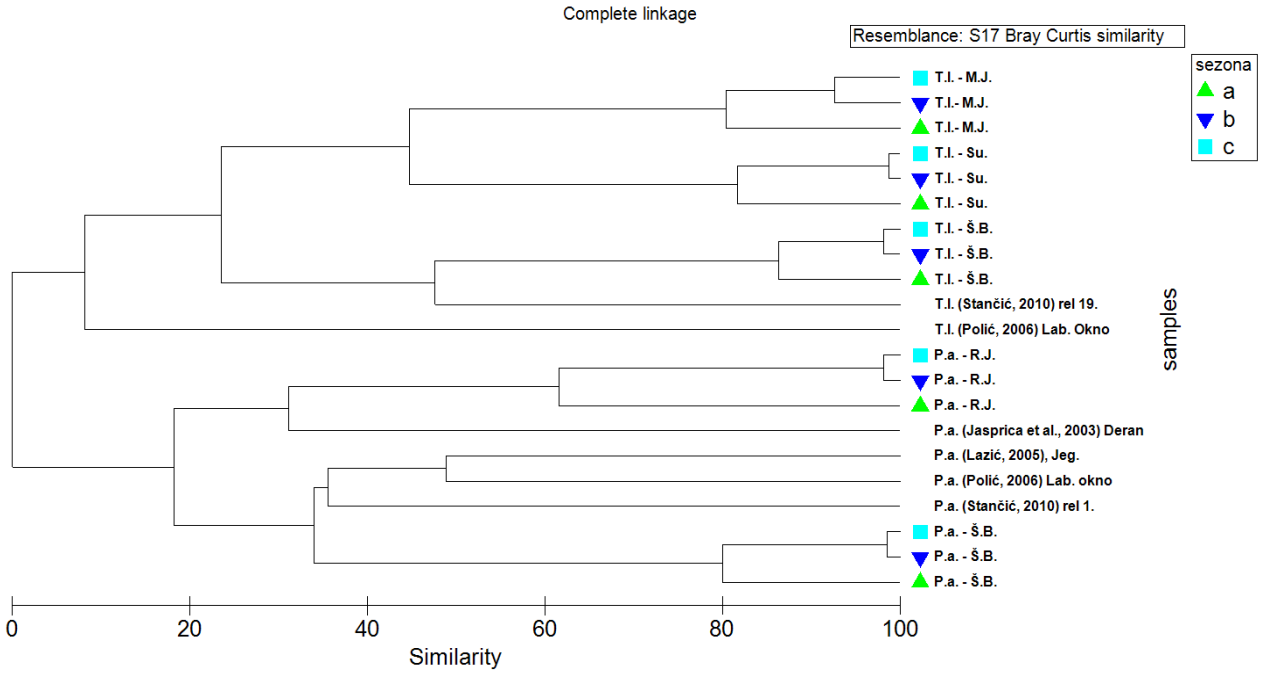

Figure 5. Dendrogram of the original (MJ, SU, ŠB and RJ) and campared relevés (Stančić, 2010, Polić, 2006, Jasprica et al., 2003, Lazić 2006), Complete linkage cluster analysis. P.a. - *Phragmitetum australis;* T.l. - *Typhetum latifoliae*.

Biodiversity of associations

As part of the order *Phragmitetalia* at the researched sites, a total of 50 plant species were determined. The value of Shannon -Wiener Diversity Index ranges from 2.10 to 3.15 (**Fig. 6**). Within the community *Typhetum latifoliae* were recorded 33 plant species, and the largest number of species was observed on the lake Mušićko (19). In the community *Phragmitetum australis* were determined 32 plant species. Here we observed largest deviations in biodiversity with a small number of species at the lake Šićki Brod (13), which is probably caused by unfavorable pedological conditions (sandy soil and poor water regime).

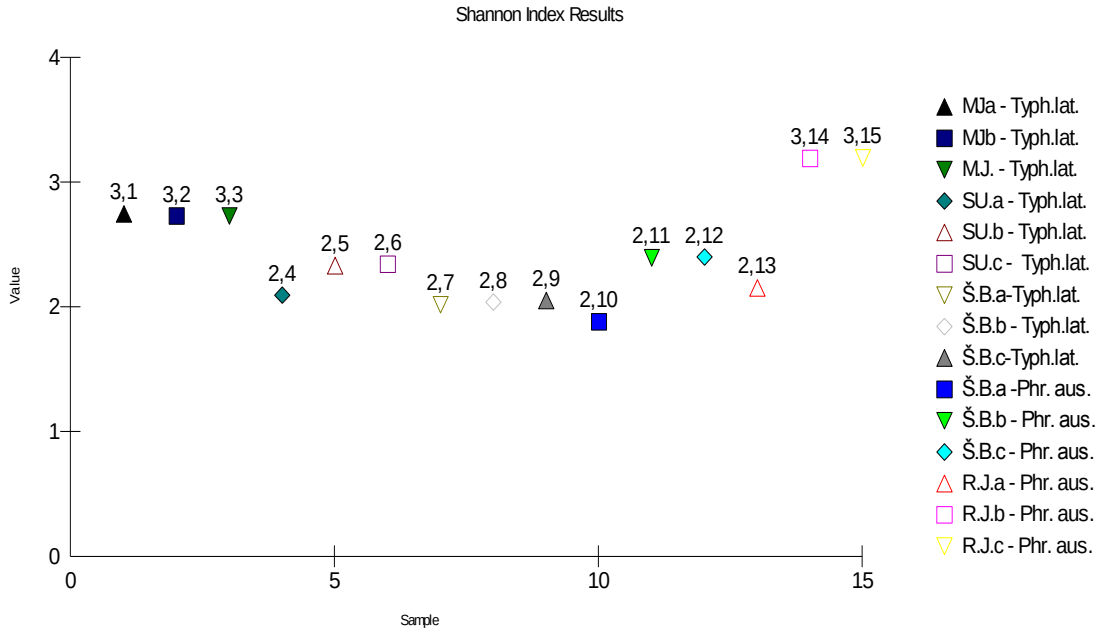

Figure 6. The values of Shannon - Wiener Diversity Index

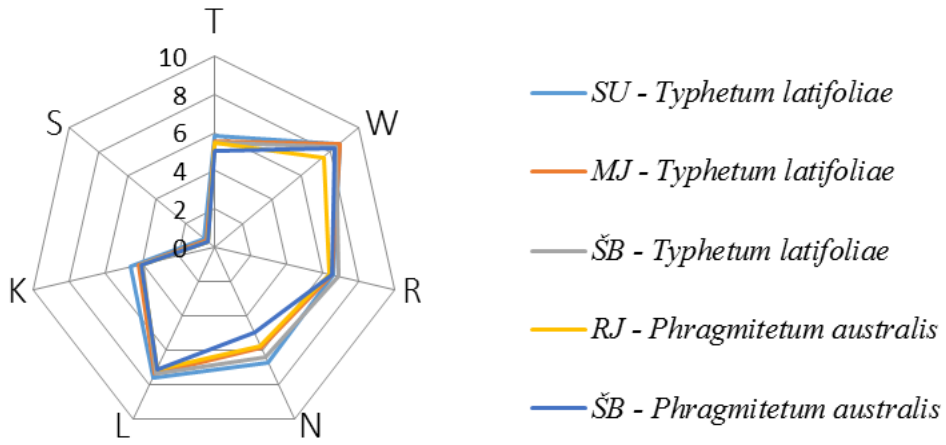

Figure 7. Ecological analysis of the studied association
(T-temperature, W-humidity, R-soil acidity, N-nitrification, L-light, K-continentality, S-salinity)

Ecological analysis of associations

Ecological indexes of plant species from the analyzed communities indicate that stands appear on alkaline (R=6.3-6.8), non-salinated (S=0.5-0.7), well exposed to sunlight or shaded occasionally (L=7.1-7.6), briefly flooded (W=7.5-8.7) and mesotrophic soils (N=5-6.7). Habitat requirements about heat are moderate (T=5.1-5.8), and are characterized by a large proportion of sub-oceanic species which find their main areal in the Central Europe (K=4-4.6) (**Fig. 7**).

Comparing ecological indexes of the studied communities with the stands in the "Labudovo okno", all values are in close ranges, except for the humidity index, which was lower for the pit lakes habitats (W = 7.5 - 8.7), indicating a less favorable hydro regime.

Biological spectrum and sociability of plant species

In the studied communities at the localities of the lakes Suhodanj and Šićki Brod the most dominant life form are hydrophytes (up to 46.15%), while hemicryptophytes are dominant at other sites (up to 44.8%) (**Fig. 8**).

Compared to the stands of the order *Phragmitetalia* in Serbia (Polić, 2006) and Croatia (Stančić, 2010), where the dominance in the stands is achieved by hydrophytes, hemicryptophytes and geophytes, in the communities on pit lake shores the share therophytes is not negligible (7.69 - 25.92%). This phenomenon makes the community's response to frequent changes in water levels and to periods of drought during the summer months.

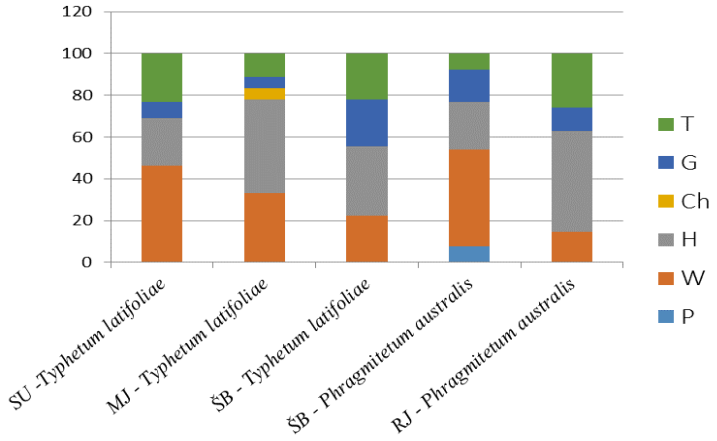

Figure 8. The biological spectrum of the studied association
(T - Therophytes, G - Geophytes, Ch - Chamaephytes, H - Hemicriptophytes, W - Hydrophytes, Pn - Phanerophytes)

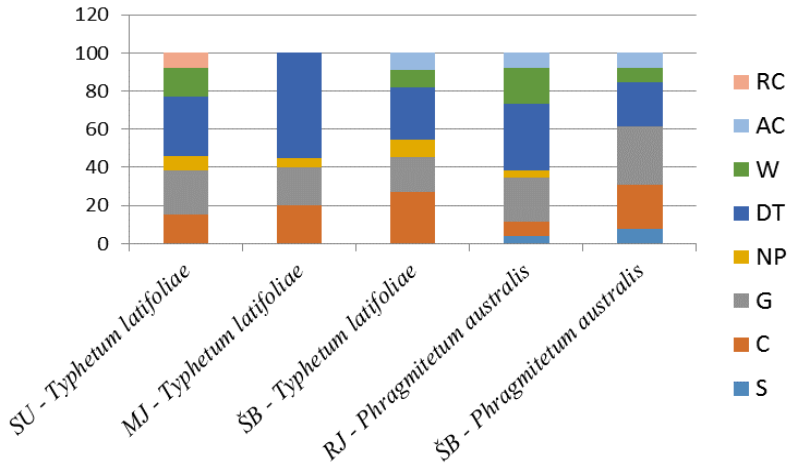

Figure 9. The social behavior types spectrum of the studied association

(AC - invasive species, RC - ruderal competitors, W - weed species, DC - pioneer species of secondary successions, G - associated plant species, C - competitors, S - sensitive species)

The spectrum of sociability of the plant species indicates the state of the natural vegetation progradation. Analysis of the spectrum of plant species sociability indicates that the most frequent are pioneering elements of secondary successions (DT = 23.07 - 55%) and associated plant species (G=18,18-30,76%). A lower frequency have the competitor plant species (C = 7.69 - 27.23) and they are most numerous in the communities on the lake Šićki Brod (**Fig. 9**). Weed plant species are also present *(Plantago major, Bidens tripartita, Artemisia vulgaris, Atriplex patula, Verbena officinalis* and *Sonchus arvensis)*, and from invasive species there were identified three plant species *(Echinocystis lobata, Conyza canadensis* and *Erigeron annuus).* Randjelovic et al. (2007) emphasize the eurivalence of the community of reed beds for many environmental factors, therefore it is very often penetrated by elements of meadow and weed vegetation. On the shores of pit lakes this phenomenon is very evident, due to close contact of these communities with trampled and ruderal habitats in landfills of tailings, leading to the appearance of invasive plant species.

Progradation process

In natural habitats the communities of reed beds and cattail play a crucial role for the stability and the climax of wetland ecosystems, while in the degraded habitats such as pit lakes they are crucial for the restoration and progradation. Vegetation of cattail often grow over anthropogenic habitats of eutrophic character that had been under water for a long period of time (Stančić, 2010). Among the researched localities it was most developed at the lake Mušićko, which has a minimum depth, a small slope of the southern shore and water of lower quality. At the lakes Suhodanj and Šićki Brod this community grows over a very small area (up to 50 m^2). The factors that prevent its spread are probably variations of water levels and the dominance of communities of the class *Bidentetea tripartitae* (Barudanović & Kamberović, 2011) on the lake Suhodanj and a large slope of the littoral zone on the lake Šićki Brod. The vegetation of reed beds is more eurivalent for the moisture factor. Therefore, at the lakes with large slope of the littoral zone (Šićki Brod and Ramićko lakes), where there are not achieved conditions for communities of cattail, reed beds grow over the coastal region and tolerate longer periods of dryness. Frequent fluctuations of water levels throughout the year and steep banks of pit lakes allow colonization of emersed hydrophytes in fragments only on the flat shores. Therefore the progradation processes in degraded habitats in terms of establishing wetland ecosystems are possible only in lakes with lower slopes of the shore and more or less stable water levels.

Conclusion

On the shores of four pit lakes within the order *Phragmitetalia* there were determined 50 plant species within two plant communities. In phytocenological releves thirteen species characteristic of the association, alliance, order or class were identified. Sociability spectrum of plant species, along with the domination by species of pioneering elements of secondary succession, indicates the state of natural progradation processes. Bearing in mind that pit lakes in the initial stages of

formation are absolutely degraded surfaces, the results of research point to the successful colonization of wetland plant species, whose natural progradation is ongoing.

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