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# CONTRIBUTION TO THE KNOWLEDGE ON THE VASCULAR FLORA OF AQUATIC AND AMPHIBIOUS HABITATS ALONG THE MODRAC RESERVOIR AND ADJACENT MARSHES (BOSNIA AND HERZEGOVINA)

PRIOLOG POZNAVANJA VASKULARNE FLORE AKVATIČNIH I AMFIBIJSKIH STANIŠTA AKUMULACIJE MODRAC I OKOLNIH MOČVARA (BOSNA I HERCEGOVINA)

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## Abstract

A study of the vascular flora of aquatic and amphibious habitats along the Modrac reservoir and adjacent marshes, Šerićka bara, and Mosorovac bara was conducted during the vegetation season 2018. In total, 68 plant species from 36 families were identified. The families with the highest taxa were *Cyperaceae* and *Lamiaceae*, and the most numerous genera were *Carex* and *Mentha*. The dominant plant life forms were hemicryptophytes and hydrophytes, while in chorological analysis dominated Euroasian floral elements. Generalists, the pioneers of secondary succession, and competitive species were the most common social behavior types of plants. Threatened vulnerable species *Marsilea quadrifolia* L., *Veronica anagallis-aquatica* L., the least concerned species *Butomus umbellatus* L., and species that are protected by Berns convention *Trapa natans* L. were recorded in the researched area. Invasive plant species with predominance of *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Bidens frondosus* L., and *Ambrosia artemisiifolia* L. were common. The researched area is typical for progradational stages and intensive overgrowth of marshes with vegetation of reed and cattail, and a good representation of macrophytes *Trapa natans* L. and *Rorippa amphibia* (L.) Besser in littoral area of Modrac reservoir.

**Key words:** aquatic habitats, diversity, flora, Modrac, Mosorovac bara, Šerićka bara, wet habitats

## 1. INTRODUCTION / UVOD

The Modrac reservoir was created by damming the Spreča River in 1964 in northeastern Bosnia and Herzegovina, to provide a sufficient amount of water for industrial needs, and it is currently used for water supply (Arnautalić, 2006). The reservoir is characterized by a large area, small average depth, seasonal oscillation

of the water level, and meso-eutrophic status of the water (Mihaljević et al., 2000). As a result of several decades of filling with sediments from the rivers that feed the reservoir with water, wetland habitats were formed on its banks, at the river mouths of the Spreča and Turija, also in the vicinity of the reservoir (marshes

Šerička bara and Mosorovac bara). Although these areas are recognized for the protection and conservation of the species and ecosystem diversity in local plans (Official Gazette of the Tuzla Canton 12/18), or as a potential NATURA 2000 area (site BA8300050), they are not yet legally protected. The previous biological studies of the Modrac reservoir and the adjacent wetlands refer to ichthyofauna (Adrović, 2007), fish ectoparasites (Skenderović et al., 2017), ornithofauna (Kulijer & Simić, 2011), phytoplankton, epiphytic diatoms and benthic fauna (Kamberović et al., 2015; Mihaljević et al., 2000; Arnautalić, 2006). Although the flora has often been the subject of numerous studies on reservoirs and wetlands in Bosnia and Herzegovina, e.g. Hutovo Blato (Jasprica & Carić, 2002; Jasprica et al., 2003; Maslo, 2022), Bardača (Kovačević & Stojanović, 2008), Velika Tišina (Bjelčić, 1954), Lake Jablaničko (Kosorić, 1980), Lake Buško (Kosorić, 1985), mine peat lakes (Kamberović & Barudanović, 2012;

Kamberović et al., 2014), lakes on Treskavica (Milanović, 1954), lakes on Zelengora (Milanović, 2017), systematic studies of the flora of the Modrac reservoir and adjacent wetlands were not known. Vascular plants of aquatic and amphibious habitats play an important role in reducing water turbidity, purifying water, enriching water with oxygen, regulating physical and chemical characteristics of water, and food chains, and serving as a habitat for other taxonomic groups (Scheffer & Jeppesen, 1998).

The study aims (i) to contribute to discovering the floristic diversity of vascular plants of aquatic and amphibious habitats along the Modrac reservoir and adjacent marshes, Šerička bara, and Mosorovac bara (ii) to analyze life forms, floral elements, and social behavior types of identified plant species, and (iii) to survey the presence of threatened and invasive species of this area.

## 2. MATERIAL AND METHODS / MATERIJAL I METOD RADA

### 2.1 Study area and fieldwork / Područje istraživanja i terenski rad

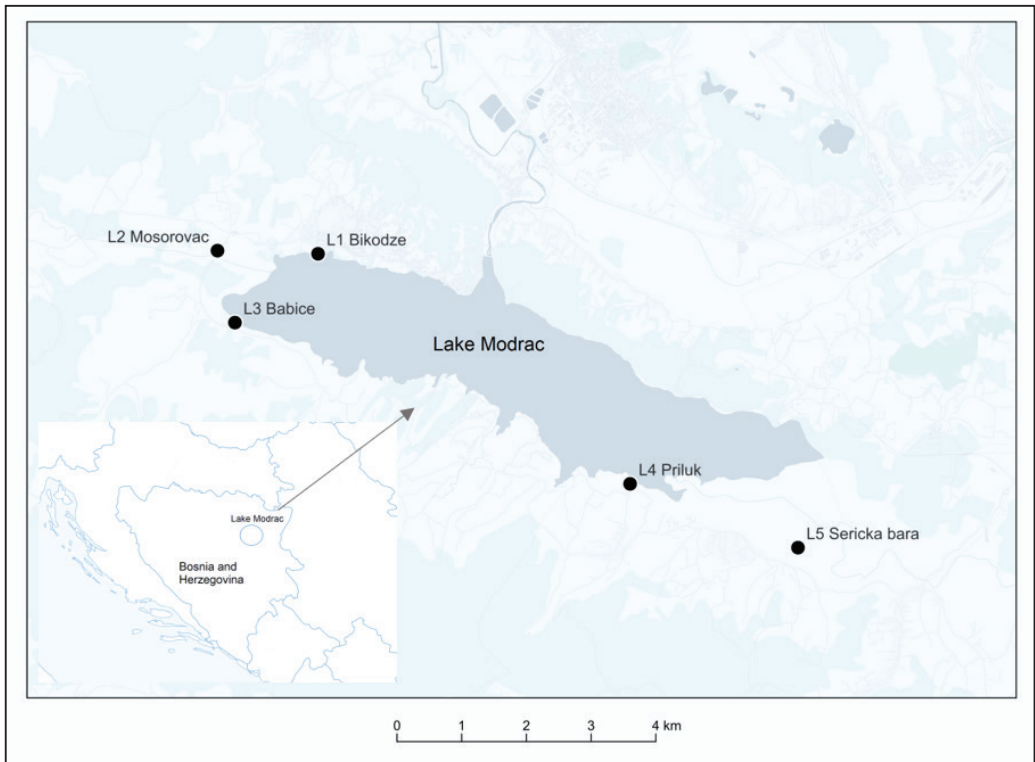
The Modrac reservoir covers 16.69 km<sup>2</sup>, with a maximal length of 10.4 km, a maximal width of 2.4 km, and a maximal depth of 14.94 m (average depth of 5.2 m). The marsh Šerička bara is located along the eastern shore of the Modrac reservoir near the mouth of the Spreča River. It was created as a result of the deposition of sediment by the river Spreča on the originally flooded surface of the Modrac reservoir. It covers an area of 31.87 ha, with a length of 860 m, and an average depth of up to 1 meter. The marsh Mosorovac bara is located near the mouth of the Turia River and has an area of 24.4 ha (Official Gazette of the Tuzla Canton 12/18).

The climate is moderate-continental with clearly differentiated seasons. The mean annual temperature is 10.1°C. The warmest month

is July with a mean average temperature of 19.6°C, and the coldest is January with -0.1°C. The average annual rainfall is 871 mm. The highest precipitation during the year is in June, while the lowest is in February (data for 1971–2000, recorded by the Federal Hydrometeorological Institute of Bosnia and Herzegovina). The research was conducted on the aquatic and amphibious habitats present along the narrow coastal area of the Modrac accumulation (L1, L3, L4), the Mosorovac bara (L2), and Šerička bara (L5) (Figure 1). The submerged vegetation within the class POTAMOGETONETEA Klika in Klika et. Novák 1941 on locations 1, 2, 3, and 4, floating vegetation of the class LEMNETEA O. de Bolòs et Masclans 1955 on location 5, and emerged vegetation within the class PHRAGMITO-MAGNOCARICETEA Klika in Klika et Novák 1941 on all locations were studied in the narrow area along the reservoir and marshes. Locations were monitored

4 times a year, during 2018. Phytocoenological relevés of aquatic and wet habitats were carried out using the Zürich–Montpellier school (Braun-Blanquet, 1964). Although a larger number of phytocoenological relevés were

taken at each location, for a simpler display, the flora is grouped per location in the list. The geocoordinates of all relevés are associated with the coordinates of the phytocoenological relevé that was the richest in species (Table 1).



**Figure 1.** The study area location map / **Slika 1.** Karta istraživanog područja

**Table 1.** Geocoordinates of the investigated localities / **Tabela 1.** Geokoordinate istraživanih lokaliteta

No	Locality / Lokalitet	Latitude [°] N	Longitude [°] E
L1	Bikodže	44.511106	18.476692
L2	Mosorovac	44.511539	18.457161
L3	Babice	44.501567	18.460553
L4	Priluk	44.479211	18.537294
L5	Šerička bara	44.470361	18.569897

## 2.2 Identification of species and data analysis / Identifikacija vrsta i analiza podataka

The plant taxa were identified according to Tutin et al. (1964–1993), Javorka & Csapody (1979) and Domac (2002). The nomencla-

ture of taxa follows the Euro+Med database (<http://ww2.bgbm.org/EuroPlusMed/>). The collected plant material was herbarized and stored in the author's private collection. The basic life forms of the plants were determined

according to Raunkiaer, supplemented by Mueller-Dombois and Ellenberg (Ellenberg, Mueller-Dombois, 1967. in Mueller – Dombois, Ellenberg, 1974.), and Stevanović (1992). The floral elements were given according to Oberdorfer (1991), and social behavior types according to Borhidi (1995). The status of invasive plant species was determined according to lists by Maslo (2016) and Redžić et al. (2008). The threatened status of taxa was de-

termined according to Đug et al. (2013), IUCN version 3.1 ([http://www.iucnredlist.org/static/categories\\_criteria\\_3\\_1](http://www.iucnredlist.org/static/categories_criteria_3_1)), Habitat Directive (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora) and Bern Convention (Council Decision 82/72/EEC of 3 December 1981 concerning the conclusion of the Convention on the conservation of European wild-life and natural habitats).

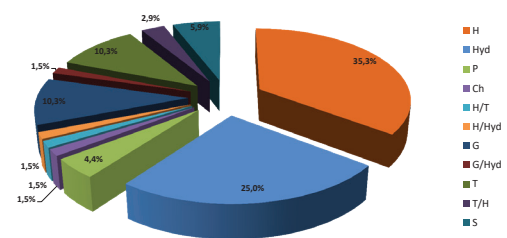
### 3. RESULTS / REZULTATI

68 taxa including 57 genera and 36 families were identified in wetland and aquatic habitats of the Modrac reservoir, Šerićka bara, and Mosorovac bara. The most numerous families were: *Cyperaceae* and *Lamiaceae* (7 taxa each), *Compositae* (6 taxa), *Polygonaceae* and *Plantaginaceae* (4 taxa), and *Poaceae* and *Typhaceae* (3 taxa). The most abundant genera were *Carex* (4) and *Mentha* (3) (Table 2).

The highest number of taxa was recorded at Šerićka bara (46) and Bikodže (32), while the lowest was at Priluk (20). The following taxa were identified at almost all locations: *Alisma plantago-aquatica* L., *Iris pseudacorus* L., *Leersia oryzoides* (L.) Sw., *Lycopus europaeus* L., *Mentha aquatica* L., *Stachys palustris* L., *Typha latifolia* L., *Myriophyllum spicatum* L., *Persicaria amphibia* (L.) Delarbre, *Persicaria hydropiper* (L.) Delarbre, *Phragmites australis* (Cav.) Steud. and *Rorippa amphibia* (L.) Besser.

The analysis of life forms of the flora shows the dominance of hemicryptophytes with 24 (35.29%) and hydrophytes with 17 (25 %) species, followed by significant participation of therophytes and geophytes with 7 species (10.29%) (Figure 2). Dominant hydrophytes in aquatic habitats of the Modrac reservoir were *Trapa natans* L., *Ceratophyllum demersum* L., *Potamogeton gramineus* L. and *Myriophyllum spicatum* L., and of the Mosorovac bara were *M. spicatum* L. *C. demersum* and *Lemna minor* L. However, Šerićka bara is pre-

dominantly inhabited by floating vegetation of *Spirodela polyrhiza* (L.) Schleid. Wet habitats along the Modrac reservoir are characterized by hydrophytes *Phragmites australis* (Cav.) Steud., *Typha latifolia* L., *Rorippa amphibia* (L.) Besser, *Butomus umbellatus* L., and *Eleocharis palustris* (L.) R. Br. while the Mosorovac bara is dominantly inhabited by *T. latifolia*. Wet habitats along the Šerićka bara are characterized by densely developed vegetation of hydrophytes *Phragmites australis* (Cav.) Steud, *T. latifolia*, *Typha angustifolia* L., and geophytes *Equisetum fluviatile* L., *Carex vesicaria* L., and *Iris pseudacorus* L., indicating an intensive process of pond succession and overgrowth.



**Figure 2.** Life form spectrum of the vascular flora of the Modrac reservoir, Šerićka bara, and Mosorovac bara. H - Hemicryptophytes, Hyd - Hydrophytes, P-Phanerophytes, Ch-Chamaephytes, G - Geophytes, T - Therophytes, S – Scandentophytes / Slika 2. Biološki spektar vaskularne flore akumulacije Modrac, Šerićke bare i bare Mosorovac. H – Hemikriptofite, Hyd – Hidrofite, P – Fanerofite, Ch – Hamefite, G – Geofite, T – Terofite, S – Skandentofite

**Table 2.** List of the identified taxa per studied locations (1 - Bikodže, 2 - Mosorovac bara, 3 - Babice, 4 - Priluk, 5 - Šerička bara). **Note:** Abbreviations: SBT – social behavior types (C – competitors, S – Specialists, G – Generalists, NP - Natural pioneers, DT - Disturbance tolerant, W – Weeds, I - Introduced alien species, A – Adventives, RC - Ruderal competitors, AC - Aggressive alien species, invaders), RL FB&H - Red List of Vascular plants of Federation B&H (LC - Least concern, VU – Vulnerable, DD - Date deficient), RL IUCN - Red List of IUCN (LC -Least concern), HD&BC - taxa listed in Habitat Directive\* and Bern Conventionx, IP – invasive plants / **Tabela 2.** Lista identifikovanih biljnih taksona na istraživanjima lokalitetima (1- Bikodže, 2 - Mosorovac bara, 3 – Babice, 4 - Priluk, 5 - Šerička bara). **Napomena.** Skraćenice: SBT - Spektral tipova socijalnog ponašanja (C – kompetitori, S – specijalisti, G – generalisti, NP – prirodni pioniri, DT – Stres tolerantne, W – korovske, I – introdukovane strane vrste, A – adventivne, RC – ruderalni kompetitori, AC – agresivne štrane vrste, osvajači). RL FBiH – Crvene liste vaskularnih biljaka Federacije Bosne i Hercegovine (LC – najmanje zabrinjavajući, VU – ranjivi, DD – nedovoljno podataka), RL IUCN – Crvene liste IUCN (LC – najmanje zabrinjavajući), HD&BC – taksoni navedeni na dodacima Direktive o staništima\* i Bernske konvencijex, IP – invazivne biljne vrste

Taxon	Family	Life form	Floral elements	SBT	RL FB&H	RL IUCN	HD&BC	IP	Locations
<i>Alisma plantago-aquatica</i> L.	Alismataceae	Hyd (a Mes-Meg emer HydT)	euras-smed, kosmop.	G	LC	LC			1,2,3,4
<i>Ambrosia artemisiifolia</i> L.	Compositae	T (a-aut Mes-Meg T scap)	N-Am	AC				*	2, 4, 5
<i>Bidens frondosus</i> L.	Compositae	T (a Mes T scap)	N-Am	AC				*	2, 4, 5
<i>Butomus umbellatus</i> L.	Butomaceae	Hyd (v-a emer HydG rhiz)	euras-med	G	LC	LC			1, 3, 4
<i>Ceratophyllum demersum</i> L.	Ceratophyllaceae	Hyd (a rad sbm HydG)	euras-med	C	LC	LC			1, 2, 3, 4
<i>Carex elata</i> All.	Cyperaceae	H (a Mes-Meg H caesp)	subatl(-smed)	C	LC	LC			1
<i>Carex vulpina</i> L.	Cyperaceae	G (a Mes -Mac G rhiz)	euras(kont)	DT	LC	LC			5
<i>Carex vesicaria</i> L.	Cyperaceae	G (a Mes-Meg G rhiz caesp)	no-euras, circ	C	LC	LC			5
<i>Carex hirta</i> L.	Cyperaceae	G (a Mes-Meg G rhiz caesp)	eurassubozean-smed	DT	LC	LC			1, 5
<i>Callystegia sepium</i> (L.) R. Br.	Convulvulaceae	S (a Meg-Alt SH herb)	euras(subozean)-smed	DT	LC	LC			1, 5
<i>Cyperus serotinus</i> Rottb.	Cyperaceae	G (a Mac-Meg G rhiz/caesp)	euras-smed	NP					1
<i>Echinocystis lobata</i> (Michx.) Torr. & A. Gray	Cucurbitaceae	S (a-aut ST herb)	N-Am	AC				*	2, 4, 5
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	Poaceae	T (a-aut Mes-Meg T caesp)	med-smed-euras-circ	AC					2, 5
<i>Eleocharis palustris</i> (L.) R. Br.	Cyperaceae	Hyd (a Mes-Meg emer HydG rhiz)	no-euras	C	LC	LC			1, 3
<i>Erigeron annuus</i> (L.) Desf.	Compositae	T/H (a Mes-Meg T/H scap anni-bienn)	N-Am	AC				*	2
<i>Equisetum fluviatile</i> L.	Equisetaceae	G (a Meg-Alt G rhiz)	no-euras(subozean),circ	G	LC	LC			5
<i>Gratiola officinalis</i> L.	Plantaginaceae	H (a Mes-Meg H scap)	euraskont-smed	C	LC	LC			1, 3, 5
<i>Galeopsis speciosa</i> Mill.	Lamiaceae	T (a Mes-Meg T scap)	no-euraskont	G					2
<i>Galium palustre</i> L.	Rubiaceae	H (a Mes-Meg H scap)	no-eurassubozean	G	LC	LC			1, 5

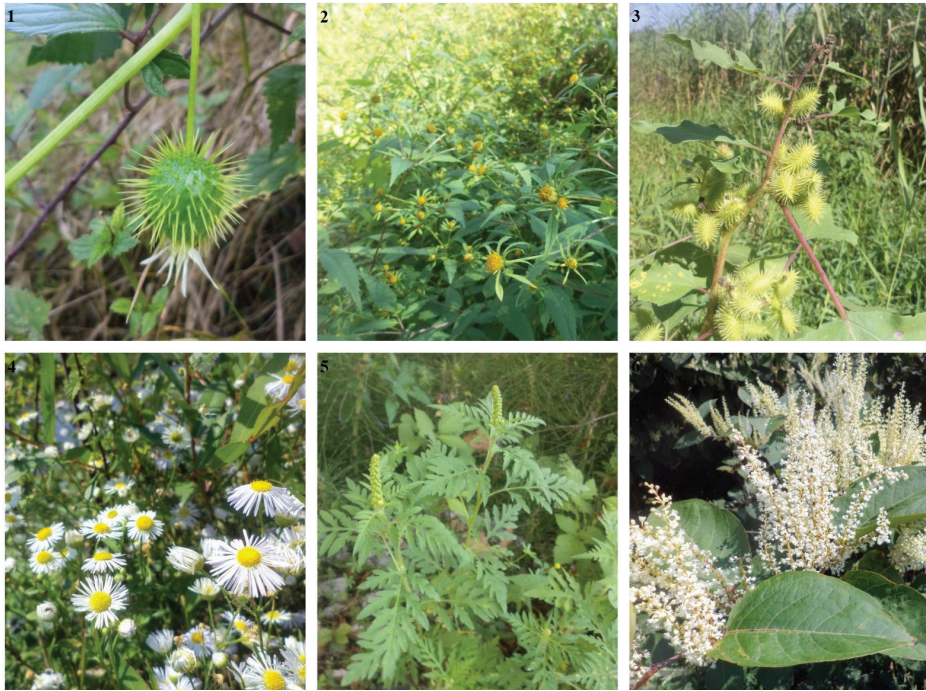
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Taxon	Family	Life form	Floral elements	SBT	RL FR&H	RL IUCN	HD&BC	if	Locations
<i>Humulus lupulus</i> L.	Cannabaceae	S (a S lig)	euras-smed, circ	DT					2, 4
<i>Iris pseudacorus</i> L.	Iridaceae	G (v-a Mac-Meg G rhiz)	euras(subocean)-smed	G		LC			1, 2, 3, 5
<i>Leersia oryzoides</i> (L.) Sw.	Poaceae	H (a Mac-Meg H caesp)	euras(kont)-smed,circ	C		LC			1, 2, 3, 4, 5
<i>Linaria vulgaris</i> Mill.	Plantaginaceae	H (a Mes-Mac H scap)	euras(-smed)	W					5
<i>Lycopus europaeus</i> L.	Lamiaceae	H (a Mes-Meg H scap)	euras-smed	DT		LC			1, 2, 3, 5
<i>Lemna minor</i> L.	Lemnaceae	Hyd (er nat Hyd T)	(no)euras-med, kosmop.	NP		LC			2
<i>Lysimachia nummularia</i> L.	Primulaceae	Ch (a N-Mes Ch herb rept)	eurassubocean-smed(subatl-smed)	DT		LC			3, 5
<i>Lysimachia vulgaris</i> L.	Primulaceae	H (a Mes-Meg H scap)	eurassubocean-smed(subatl-smed)	DT		LC			1, 3, 4
<i>Lythrum salicaria</i> L.	Lythraceae	H/Hyd (a Meg-Alt H scap/emerg HydG rhiz)	eurassubocean, circ.	G		LC			1, 3, 5
<i>Mentha aquatica</i> L.	Lamiaceae	H (a Mes-Meg H scap)	euras-smed(-med)	G		LC			1, 2, 3, 4, 5
<i>Mentha longifolia</i> (L.) L.	Lamiaceae	H (a Mes-Meg H scap)	smed-euras	DT		LC			5
<i>Mentha pulegium</i> L.	Lamiaceae	H (a Mes H scap)	med-smed-eurassubocean	DT		LC			5
<i>Marsilea quadrifolia</i> L.	Marsileaceae	Hyd (v-a rad nat HydG)	(med-)smed-euras(kont)	S	VU	LC	*x		4
<i>Myriophyllum spicatum</i> L.	Haloragaceae	Hyd (a rad sbm HydT)	no-euras-smed, circ	C		LC			1, 2, 3, 4
<i>Nymphoides peltata</i> (S. G. Gmel.) Kuntze	Menyanthaceae	Hyd (a rad nat HydG)	med-smed-eurassubocean	C		LC			1
<i>Najas marina</i> L.	Hydrocharitaceae	Hyd (a rad sbm HydT)	smed, Warm-gemass. kosmop.	C		LC			1
<i>Oenanthe silaifolia</i> M. Bieb.	Apiaceae	H (a Mes-Meg H scap)	smed-med	G		LC			3, 5
<i>Pericaria amphibia</i> (L.) Delarbre	Polygonaceae	G/Hyd (a Mes-Meg G rhiz-scap/rhiz nat HydG)	no-euras, circ	DT		LC			1, 3, 4, 5
<i>Pericaria hydropteris</i> (L.) Delarbre	Polygonaceae	T (a Mes-Meg T scap)	euras-smed	NP		LC			1, 3, 4, 5
<i>Potamogeton gramineus</i> L.	Potamogetonaceae	Hyd (a rad sbm-nat HydT)	no,circ	NP		LC			1
<i>Potentilla reptans</i> L.	Rosaceae	H (a Mes-Meg H rept)	euras-smed	DT					5
<i>Phragmites australis</i> (Cav.) Steud.	Poaceae	Hyd (an Alt emerg HydG rhiz)	no-eurassmed, temp-kosmopol.	C		LC			1, 3, 4, 5
<i>Reynoutria japonica</i> Houtt.	Polygonaceae	G (a-aut Mac-Alt G rhiz)	As	AC					* 1, 2
<i>Rorippa amphibia</i> (L.) Besser	Brassicaceae	H (a Mac-Meg H scap)	euras(-smed)	G		LC			1, 2, 3, 4
<i>Rumex conglomeratus</i> Murray	Polygonaceae	H (a Mes-Meg H scap)	smed(-subatl)	W					5

Taxon	Family	Life form	Floral elements	SBT	RL FB&H	RL IUCN	HD&BC	#	Locations
<i>Salix triandra</i> L.	Salicaceae	P (fo dec Mi-Mes P caesp/scap)	euras(-smed)	G	LC	LC		1, 3, 5	
<i>Salix euxina</i> I. V. Belyaeva	Salicaceae	P (fo dec Mi-Mes P scap)	euras(subocean)	G				5	
<i>Silene latifolia</i> Poir.	Caryophyllaceae	T (v-a Mes-Mac T ros/scap)	euras-smed	DT				2	
<i>Silene flos-cuculi</i> (L.) Clairv.	Caryophyllaceae	H (a Mes-Meg Hscap)	eurassubocean	G				5	
<i>Solidago canadensis</i> L.	Compositae	H (a-aut Mes-Meg H scap)	N-Am	AC				* 5	
<i>Solanum dulcamara</i> L.	Solanaceae	S (a S lig)	euras-smed	DT				1, 3, 5	
<i>Spiradela polyrhiza</i> (L.) Schleid	Lemnaceae	Hyd (er nat HydT)	euras-med,circ	NP	LC	LC		5	
<i>Sparanium erectum</i> L.	Typhaceae	Hyd (v-a Mes-Alt emer HydG rhiz)	euras-smed	C	LC	LC		2	
<i>Scutellaria galericulata</i> L.	Lamiaceae	H (a Mes-Meg H scap)	no-euras, circ	G	LC	LC		5	
<i>Stachys palustris</i> L.	Lamiaceae	H (a Mes-Meg H scap)	(no-)euras(-smed)	DT	LC	LC		1, 2, 3, 4, 5	
<i>Schoenoplectus lacustris</i> (L.) Palla	Cyperaceae	Hyd (a Meg-Alt emer HydG)	(no-)euras-med,circ	C	LC	LC		2,5	
<i>Succisella inflexa</i> (Kluk) Beck	Dipsacaceae	H (a-aut Mac-Mes H scap/ semitros)	gemasskont	G				* 5	
<i>Symphotrichum lanceolatum</i> (Willd.) G. L. Nesom	Compositae	H (a Mes-Meg H scap)	N-Am	A	LC	LC		5	
<i>Thalictrum lucidum</i> L.	Ranunculaceae	H (a Meg-Alt H scap)	gemasskont (-osmed)	G				5	
<i>Trifolium repens</i> L.	Fabaceae	H (a Mi H rept)	eurassubocean-smed	DT				5	
<i>Typha latifolia</i> L.	Typhaceae	Hyd (a Alt emer HydG rhiz)	euras, circ	C	LC	LC		1, 2, 3, 5	
<i>Typha angustifolia</i> L.	Typhaceae	Hyd (a Meg-Alt emer HydG)	euras-smed-med, circ	C	LC	LC		5	
<i>Trapa natans</i> L.	Lythraceae	Hyd (a rad nat HydT)	euraskont-smed	C	LC	LC	x	1, 2, 4	
<i>Urtica dioica</i> L.	Urticaceae	T/H (a Mes-Meg T/H scap)	no-euras, gemass	DT	LC	LC		2, 5	
<i>Veronica beccabunga</i> L.	Plantaginaceae	H (a Ms-Mac H scap)	euras-smed-med	S	LC	LC		2	
<i>Veronica anagallis-aquatica</i> L.	Plantaginaceae	H (a Mes-Meg H scap)	euras-smed-med, gemass	S	VU	LC		3, 5	
<i>Verbena officinalis</i> L.	Verbenaceae	H/T (a Mes-Meg H/T scap)	eurassubocean-smed	W				5	
<i>Viburnum opulus</i> L.	Viburnaceae	P (a Mi-Mes P caesp)	euras(subocean)	G				1	
<i>Xanthium strumarium</i> L.	Compositae	T (a-aut Mes-Meg T scap)	omed-kont	W				* 1, 4, 5	

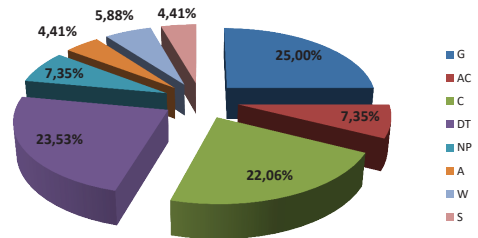




**Figure 3.** Invasive plant species of the wet habitats of the Modrac reservoir, Šerička bara, and Mosorovac bara: 1. *Echinocystis lobata*, 2. *Bidens frondosus*, 3. *Xanthium strumarium*, 4. *Erigeron annuus*, 5. *Ambrosia artemisiifolia*, 6. *Reynoutria japonica* / **Slika 3.** Invazivne biljne vrste vlažnih staništa akumulacije Modrac, Šeričke bare i bare Mosorovac

The analysis of the spectrum of floral elements shows the dominance of Eurasian (45.6%) and Nordic floral elements (11%) (Appendix 1). The following seven invasive plant species were recognized in the researched area: *Ambrosia artemisiifolia* L., *Bidens frondosus* L., *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Erigeron annuus* (L.) Desf., *Reynoutria japonica* Houtt, *Solidago canadensis* L., and *Xanthium strumarium* L. (Figure 3). Most of the invasive species are native to North America.

The analysis of the spectrum of social behavior types stands out as the most represented generalist, stress-tolerant plants of wide ecology (G, 25%), disturbance-tolerant plants of natural habitats (DT, 23.53%), and competitors (C, 22.06%). Aggressive alien species, natural pioneers, native weed species, introduced alien species, adventives, ruderal competitors, and specialists were less than 10% (Figure 4).



**Figure 4.** The social behavior types spectrum of the flora of the Modrac reservoir, Šerička bara, and Mosorovac bara (C – competitors, S – Specialists, G – Generalists, NP - Natural pioneers, DT - Disturbance tolerant, W – Weeds, I - Introduced alien species, A – Adventives, RC - Ruderal competitors, AC - Aggressive alien species, invaders) / **Slika 4.** Spektar tipova socijalnog ponašanja flore akumulacije Modrac, Šeričke bare i bare Mosorovac (C – kompetitori, S – specijalisti, G – generalist, NP – prirodni pioniri, DT – Stres tolerantne, W – korovske, I – introdukovane strane vrste, A – adventivne, RC – ruderalni kompetitori, AC – agresivne strane vrste, osvajači)





**Figure 5.** Threatened taxa of the aquatic and wet habitats of Modrac reservoir, Šerićka bara, and Mosorovac bara: 1. *Marsilea quadrifolia*, 2. *Butomus umbellatus*, 3. *Veronica anagallis-aquatica*, 4. *Trapa natans* / **Slika 5.** Ugrožene vrste močvarnih područja akumulacije Modrac, Šerićke bare i bare Mosorovac

According to the Red List by Đug et al. (2013), three threatened taxa were found: *Marsilea quadrifolia* and *Veronica anagallis-aquatica* (VU), and *Butomus umbellatus* (LC) (Figure 5). A small population of *Marsilea quadrifolia*, a priority species for conservation in the European Union according to the Habitat Directive and Bern convention, was found in the coastal area of Modrac in reed vegetation at the location Priluk. Species *Trapa natans*, listed in the annexes of the Bern Convention, are well represented in aquatic habitats of the Modrac reservoir. According to the IUCN Red List, most identified taxa belong to the least concern species.

*Cyperus serotinus* Rottb. was found on the shores of Modrac at the location of Bikodže. In the absence of data on the distribution of this species in Bosnia and Herzegovina, no conservation status has been established, while in Croatia it is considered a vulnerable species (Nikolić, 2024) (Figure 6).



**Figure 6.** *Cyperus serotinus* / **Slika 6.** *Cyperus serotinus*

#### 4. DISCUSSION / DISKUSIJA

This research was focused on aquatic and amphibious habitats present in the narrow coastal zone of the Modrac reservoir and adjacent marshes, at five selected locations, aiming to provide the initial knowledge about the diversity of plant species in this rarely floristically investigated area. The study recorded 68 species of vascular plants. Marshes Mosorovac bara and Šerička bara were suggested for the protection of flora and ornithofauna diversity in local spatial legislation and documentation (Spatial arrangement plan of the special imprint of a catchment region accumulation of Modrac for 2016 – 2036). Additionally, wetland habitats around the Modrac reservoir were suggested to be a potential Natura 2000 habitat area in Bosnia and Herzegovina (<https://www.fmoit.gov.ba>). The area is still not protected, and data on flora diversity are very scarce and they appear as sporadic records of finding certain species (Đug, 2013).

The Modrac reservoir supplies water from rivers with torrential types of water. It is characteristic of a significant amount of precipitation in the spring and autumn seasons and a very expressed dry period during summer. Besides, consuming the accumulation of water for industrial needs causes a seasonal variation in the water level, reflected by a wide range of wet habitats subject to overgrowth with aquatic and helophytic vegetation. The meso-eutrophic status of the waters additionally contributes to the lake shoreline overgrowth. The biological spectrum of plant life forms also indicates variations in water levels during the year. The dominant appearance of hemicryptophytes matches with macroclimate conditions of researched areas of Bosnia and Herzegovina, the Balkan Peninsula, and the moderate climate zone in similar studies in the region (Milanović, 2017, Kovačević, 2015). Even though the flora of the researched area has hemicryptophytes – hydrophytic character, the significant appearance of geophytes and

transitional therophytes- hydrophytes forms indicate variation in water levels and ecological conditions of habitats throughout the year and dry periods during summer months. The significant participation of therophytes can be connected with the presence of anthropogenically degraded areas and arable land in the researched area and its vicinity. This life form is mostly characteristic of allochthonous and invasive plant species also identified in the researched areas.

Analyzing the social behavior types, the dominant ones were generalists or stress tolerance plants of wide ecology, disturbance-tolerant plants of natural habitats, and competitors. Generalists are plants of a wide ecological range, but not too tolerant to anthropogenic disturbance (e.g. *Alisma plantago-aquatica*, *Iris pseudacorus*, *Mentha aquatica*, *Salix triandra*). Disturbance-tolerant plants of natural habitats as pioneer elements of secondary successions are very abundant in wet habitats along the researched area indicating the progradation process of succession to wetland meadows and forests (*Carex vulpina*, *Humulus lupulus*, *Lycopus europaeus*, *Mentha longifolia*, *Persicaria amphibia*, *Solanum dulcamara*).

Allochthonous invasive species are the second most significant reason that affects the reduction of biodiversity (Vitousek, 1996). The researched area is inhabited by seven invasive species. The highest number of species belongs to the family *Compositae* and originated from North America, which is in agreement with the study of vascular flora in Hutovo blato (Maslo, 2022). The most common were *Echinocystis lobata*, *Bidens frondosus*, *Xanthium strumarium*, and *Ambrosia artemisiifolia*. Invasive *Echinocystis lobata* is a common species in the investigated locations. As scandenophyte, this herbaceous climber quickly overgrows autochthonous vegetation, directly slowing down its growth. Its negative effect on habitats like swamp regions, floodplain

forests, and riparian zones, was recognized in Slovenia, where it is stated to be one of the species with the most negative influence on biodiversity of the above-mentioned areas (Zelnik, 2012). The species is also found in Serbia, first in Vojvodina from where it continued to spread to central, north, and southern-east regions of Serbia (Vasić, 2005). It is also widespread in Croatia, especially in the northern part (Nikolić ed., 2015).

The presence of threatened species in this region indicates the need for the conservation of these wetland areas. Vulnerable *Marsilea quadrifolia* and *Veronica anagallis-aquatica*, are represented within a small population. European protected species *Marsilea quadrifolia*, specified as protected in Annexes II and IV of the Habitat directive is confirmed on location Priluk in vegetation of reeds. Đug et al. (2013) listed several habitats of this species in the Federation of Bosnia and Herzegovina (Plivska jezera, the river banks of Spreča, Bardača, Svilaj, Vojskova, Lončari, Saničani and Prnjavor). *Marsilea quadrifolia* was identified earlier in Bosnia and Herzegovina in Hutovo blato by Maly, but its finding wasn't verified in recent research by Maslo (2022). The location of this species on the Modrac reservoir is not under protection. It is subject to anthropogenic influence by using the coast for water vessels and seasonal variation of water levels, which can lead to the disappearance of the species

from this area. As a species of least concern, *Butomus umbellatus* in locations Bikodže and Priluk build very well-developed plant communities *Butometum umbellati* (Koncz. 1868) Phil. 1973. According to earlier findings (Biodiversity Working Group, 2009), the shoreline of Modrac reservoir, wet habitats of Plivska lakes, and the zone of backwater on location Odžak are considered the most important habitats for this species in Bosnia and Herzegovina. An aquatic macrophyte that covers a significant part of the surface of accumulation Modrac, but is less represented in adjacent wetlands is *Trapa natans*, a species intended for protection by the Bern convention. The Modrac reservoir is well developed on a river mouth of the Spreča and Turia into the lake.

There is also an interesting finding of the species *Cyperus serotinus* on location Bikodže on the wet habitats of the Modrac reservoir. Due to scarce data on its distribution, the species is not listed in the conservation documents of Bosnia and Herzegovina. It can be found on a Red List of Croatia where it is listed as vulnerable. Photographic representations of the species published on the Flora Croatica database (<https://hirc.botanic.hr/>) point to its presence in other wetland habitats of the Tuzla region, especially around Banovići. More detailed research on the distribution of this species in Bosnia and Herzegovina would be necessary to determine its conservation status.

## 5. CONCLUSION / ZAKLJUČAK

Modrac reservoir with adjacent marshes, even though it is a modified water body, provides habitat for various wetland common and threatened species. Threatened taxa were more present at the shoreline of Modrac reservoir than in the adjacent wetlands. They are characterized by a pronounced process of

overgrowth with halophytic vegetation. The results of this paper suggest a need for the integrated management of these ecosystems, considering the conservation of habitats of endangered species. On the other side, it meets the sustainable goals of the original formation of the reservoir.

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## Sažetak

Istraživanje vaskularne flore akumulacije Modrac i okolnih močvarnih područja Šeričke bare i bare Mosorovac vršeno je u toku vegetacijske sezone 2018. godine. Uvrđeno je prisustvo 68 biljnih vrsta iz 36 porodica. Najzastupljenije porodice su bile *Cyperaceae* i *Lamiaceae*, a vrstama najbrojniji rodovi *Carex* i *Mentha*. Dominatne životne forme su bile hemikriptofite i hidrofite, a u horološkoj analizi dominirali su evroazijski florni elementi. Generalist, pioniri sekundarnih sukcesija i kompetitivne vrste su najzastupljenije u socijalnom aspektu flore. Sa konzervacijskog gledišta, evidentirano je prisustvo vulnerabilnih vrsta *Marsilea quadrifolia* L., *Veronica anagallis-aquatica* L., i manje zabrinjavajuće vrste *Butomus umbellatus* L., te vrste zaštićene prema Bernskoj konvenciji *Trapa natans* L. Područje se karakteriše i prisustvom sedam invazivnih vrsta, među kojima su posebno brojne *Echinocystis lobata* (Michx.) Torr. & A. Gray, *Bidens frondosus* L. i *Ambrosia artemisiifolia* L.. Progradacioni stadijumi i intenzivno obrastanje močvarnih ekosistema sa vegetacijom tršćaka i rogozika na vlažnim staništima, prisustvo vodene vegetacije sa *Trapa natans* i *Rorippa amphibia* (L.) Besser i prisustvo vrsta prilagođenih na variranje vodostaja, uz mjestimične dobro ili slabije razvijene zajednice vrsta, od konzervacijskog značaja su florističko obilježje istraživanog područja.

**Ključne riječi:** bara Mosorovac, diverzitet, flora, Šerička bara, vlažna staništa, vodena staništa

## Appendix 1 / Prilog 1

Floral elements of the researched area / Florni elementi na istraživanom području

Floral element	An established number in the entire research area	Total number	Participation (in %)
(med-)smed-uras(kont)	1		
smed, Warm-gemass.kosmop	1		
smed-med	1	5	7,4
smed(-subatl)	1		
smed-uras	1		
eurassubozean-smed(subatl-smed)	2		
eurassubozean, circ.	1	7	10,3
eurassubozean	1		
eurassubozean-smed	3		
no-uras	1		
no-uras, circ	3		
no-uras-smed.circ	1		
no-uras(subozean),circ	1		
no,circ	1	11	16,2
no-uraskont	1		
no-urassubozean	1		
no-urassmed, temp-kosmopol.	1		
no-uras, gemass	1		

Floral element	An established number in the entire research area	Total number	Participation (in %)
euras-smed-med, circ	1		
euras, circ	1		
euras(subozean)	1		
euras-smed, kosmop.	1		
euras-med	2		
euras(kont)	1		
euras(subozean)-smed	2		
euras-smed	7		
euraskont-smed	2		
euras-smed(-med)	1	31	45,6
euras-smed, circ	1		
euras(kont)-smed,circ	1		
euras(-smed)	3		
(no)euras-med, kosmop.	1		
euras-med,circ	1		
(no-)euras(-smed)	1		
(no-)euras-med,circ	1		
euras-smed-med	1		
euras-smed-med, gemass	1		
euras(subozean)	1		
med-smed-eurassubozean	2	3	4,41
med-smed-euras-circ	1		
subatl(-smed)	1	1	1,47
omed-kont	1	1	1,47
gemasskont	1	2	2,94
gemasskont (-osmed)	1		
As	1	1	1,47
N-Am	6	6	8,82
<b>Total number of floral elements: 10</b>			
<b>Total number of individual flora elements: 46</b>			
<b>Total</b>	<b>68</b>	<b>68</b>	