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ORIGINAL RESEARCH PAPER

Veronico beccabungae-Mimuletum guttati, a new plant community in Slovakia

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Abstract

Vegetation with high coverage by the alien species *Mimulus guttatus* was studied in the hilly regions of central Slovakia in 2015 and 2016. The floristic composition of these stands was recorded in ten phytosociological relevés corresponding to the *Veronico beccabungae-Mimuletum guttati* (alliance *Glycerio-Sparganion*) association. This association was reported for the first time in Slovakia in this study. This association was found to be closed or almost closed (mean coverage value of herb layer = 92%) and formed relatively species-rich stands (15 species per relevé), usually in narrow and small patches along the upper parts of streams and their spring areas in uplands at altitudes from 561 to 1,048 m. Localities with the *Veronico beccabungae-Mimuletum guttati* association were characterized by typical mountain climates, with both relatively low mean annual air temperature (5.5°C) and high mean annual precipitation (885 mm). While water temperature (~13°C) of these habitats varied considerably among streams (7.4–19.9°C), their herbaceous vegetation preferred neutral to slightly alkaline water (pH = 6.1–7.5) with low amounts of soluble mineral matter (~72.6 μS cm^{-1}). This kind of vegetation was most often developed on sites with coarser sediments (stone, gravel, and sand) formed from crystalline bedrock. A comparison of vegetation data of the *Veronico beccabungae-Mimuletum guttati* association across Central Europe demonstrated considerable floristic variability among regions.

Keywords

alien species; ecological conditions; phytosociology; streams; Western Carpathians; wetland vegetation

Introduction

Plant invasions represent considerable problems for the conservation of biodiversity in natural habitats and ecosystem functioning worldwide that have biological, social, and economic consequences. Previous comparative studies focusing on the level of invasions across various types of habitats demonstrated fairly consistent patterns showing that individual habitats differ considerably in their invasibility (i.e., susceptibility to invasion). Several ecological processes have been proposed to explain these patterns, but propagule pressure and habitat properties like resource partitioning between resident and alien species have received the most attention [1]. European freshwater habitats have previously been considered to be partially resistant to plant invasions [2,3], but Pyšek et al. [4] suggested that wetlands, particularly riparian habitats, can host almost the same number of non-native plant species as urban ones.

In Slovakia, the last few decades have been a period in which intensive floristic and phytosociological research on wetlands was done, which has produced valuable data on the occurrence and vegetation affinities of alien plants (e.g., [5,6]). Although the species richness of alien plants in wetlands is relatively low compared to that of other nontree types of vegetation [7], new records of alien flora are still reported [8–10]. Their occurrence can be temporary due to the temporal changes in ecological conditions typical for these habitats, but several species can survive in Slovak freshwater habitats for a long time. One such plant is *Mimulus guttatus*, a species native to North and Central America that has been known to be in Slovakia for more than 100 years. The first reliable evidence is a specimen collected in 1881 (herbarium of Slovak National Museum, BRA) from the area surrounding the town of Kremnica in central Slovakia [11,12], where it most likely escaped from gardens. It is thought that it was brought to Kremnica (as well as to other localities in Slovakia) by German miners. *Mimulus guttatus* grows as a typical wetland plant species in several localities in central Slovakia, with its occurrence concentrated in the Slovenské rudohorie (Slovak Ore Mountains) [11,13]. In North America, *M. guttatus* inhabits various freshwater habitats with cold and flowing waters at altitudes up to 4,100 m. It commonly colonizes a wide range of substrates with pH values ranging from slightly acidic to slightly alkaline [14]. Similar habitat preferences have been also reported in Central Europe, where it usually thrives along small streams or in ditches, springs, and the littoral zone of ponds with clear and cold waters in hilly regions [13,15–18]. Although *M. guttatus* is able to grow in various wetland plant communities in Europe, only a single association in which this species codominates the community, the *Veronico beccabungae-Mimuletum guttati* (alliance *Glycerio-Sparganion*) association, has been found. This association was described for the first time by Niemann [15] in the hilly region of Thüringen in Germany. In addition to this occurrence in Germany [15,19], this community has been also documented in relevés for areas in the Czech Republic and Poland [17,18,20].

We studied vegetation stands in which *Mimulus guttatus* occurred in the hilly regions of central Slovakia traditionally assigned to the *Veronico beccabungae-Mimuletum guttati* association in surrounding countries, with the aim to (***i***) characterize their species composition and ecology, and (***ii***) compare them with similar vegetation types from other parts of Central Europe.

Material and methods

Phytosociological relevés were sampled using the traditional Zürich-Montpellier approach in the Veporské vrchy (Vepor Mountains), Slovakia (Fig. 1), which are known for the abundant occurrence of *Mimulus guttatus* there [11,13]. Only stands in which *Mimulus guttatus* was present and that had homogeneous areas of at least 2 m^2 were sampled. Stands were sampled in June of 2015 and 2016. The coverage of each plant species was recorded using a 9-degree Braun-Blanquet cover/abundance sampling scale [21]. In total, data from ten phytosociological relevés were collected and stored in the database software TURBOVEG [22]. Environmental variables (Tab. 1) were also recorded for each sampling site as follows: (***i***) water-related variables including depth (mean of three measurements per site), temperature, pH, and conductivity were measured using a Eutech Instrument (CyberScan Series 600); (***ii***) substrate type (mud, sand, gravel, or stone) was noted; (***iii***) climatic characteristics including mean annual air temperature and mean annual precipitation were quantified based on records from the period of 1961–1990; and (***iv***) geological bedrock type was identified based on raster values computed in the GRASS GIS environment. The climatic data were provided by the Slovak Hydrometeorological Institute. Geological bedrock type was identified from geological maps of Slovakia (1:50,000; State Geological Institute of Dionýz Štúr). In addition, longitude, latitude, and altitude were recorded in the field using GPS equipment (Garmin GPSmap 62).

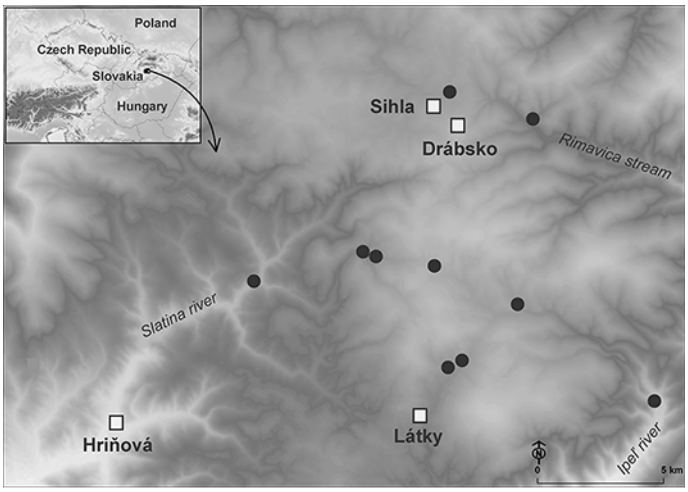

Fig. 1 Locations of the studied stands of the *Veronico beccabungae-Mimuletum guttati* association in Slovakia. Bold circles are the localities of phytosociological relevés.

Tab. 1 Descriptive statistics of ecological factors for the *Veronico beccabungae-Mimuletum guttati* in Slovakia.

Relevé number	Altitude (m)	Annual mean air temperature (°C)	Annual mean precipitation (mm)	Water depth (cm)	Water temperature (°C)	Water pH	Water conductivity (μS/cm)	Substrate*	Bedrock**
1	901.0	5.4	905.0	2–7	10.9	6.1	68.5	sa, m	Deposits
2	892.0	4.9	944.6	0–8	9.6	7.1	49.0	g, sa, m	Granodiorites
3	906.0	5.2	947.1	0–3	18.2	7.0	90.3	st, g	Fluvial sediment
4	1,048.0	4.9	956.4	0–4	7.4	6.4	54.0	g, sa, m	Deluvial-fluvial sediment
5	836.0	5.4	905.0	0–1	12.3	7.1	83.5	st, g, sa	Granodiorites
6	895.0	6.3	795.8	0–5	9.6	7.1	77.0	g, sa, m	Deposits
7	607.0	6.3	793.1	0–1	19.9	7.3	84.2	st, g, sa	Granodiorites
8	839.0	5.2	933.2	0–3	13.0	7.2	62.0	st, g, sa	Granodiorites
9	815.0	5.3	895.8	5–10	10.3	7.5	64.8	g	Deluvial-fluvial sediment
10	561.0	6.4	773.3	0–3	10.1	7.1	121.0	g, sa	Fluvial sediment
Mean	830.0	5.5	884.9	3.0	13.0	7.0	72.6	.	.
Max	1,048.0	6.4	956.4	0.0	19.9	7.5	121.0	.	.
Min	561.0	4.9	773.3	10.0	7.4	6.1	49.0	.	.

* m – mud; sa – sand; g – gravel; st – stone. ** Deposits – sandy loam and sandy slope deposits with rock debris; granodiorites – biotite tonalites and granodiorites.

To compare the species composition of *Veronico beccabungae-Mimuletum guttati* assemblages throughout Central Europe, hierarchical cluster analysis of Bray–Curtis dissimilarity index values calculated from logarithmically transformed species data (group linkage method = flexible beta with β = −0.25) and detrended correspondence analysis (DCA) were used. For these analyses, we used published phytosociological information from Germany, the Czech Republic, and Poland [15,16,18], as well as unpublished relevés from Slovakia, for a total of 55 relevés. Diagnostic species of each relevé group (cluster) were determined according to the combined concepts of frequency and fidelity to measure the species concentration in vegetation units [23]. Species were only included in the list of diagnostic species if they simultaneously showed (***i***) a phi coefficient (Φ) ≥0.20 and significant occurrence in a particular cluster (Fisher's exact test, $p < 0.05$), (***ii***) frequency ≥30% in a particular cluster, (***iii***) difference in frequencies among clusters of more than 20%, and (***iv***) frequency <50% in other clusters where they were not diagnostic. DCA was performed using detrending by segments, logarithmic transformation of the species coverage values, and down-weighting of rare species. Ellenberg indicator values (EIV) for moisture, soil nutrients, pH, continentality, light, and temperature [24] were plotted into DCA as supplementary variables. Cluster analysis was performed using PC-ORD [25], operated through the software JUICE [26]. DCA was run in the program CANOCO 5.0 [27].

Plant species names were standardized according to the checklist of the vascular and nonvascular plants of Slovakia [28], whereas the nomenclature of plant communities followed that of Mucina et al. [29] except for the *Veronico beccabungae-Mimuletum guttati* Niemann ex Jehlík 2000 association.

Results

All the recorded stands in Slovakia were dominated by *Mimulus guttatus*, and also less frequently by *Veronica beccabunga*, with regular admixtures or subdominance of hygrophilous plant species, such as *Glyceria notata*, *Mentha longifolia*, *Myosotis scorpioides* agg., and *Poa trivialis*. These species were accompanied by *Cardamine amara*, *Epilobium obscurum*, *Juncus effusus*, *Ranunculus repens*, *Scirpus sylvaticus*, and *Stellaria alsine* (Tab. 2). These herbaceous stands were closed or almost closed (the mean coverage value of the herb layer was 92%) and relatively species-rich (with 15 species per relevé,

Tab. 2 Species composition of the *Veronico beccabungae-Mimuletum guttati* in Slovakia. Only species with at least 20% constancy are shown in the table (other species and localities of relevés are presented in Appendix S1).

Relevé number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**C (%)**
Number of all species	**13**	**13**	**19**	**13**	**12**	**16**	**21**	**17**	**17**	**9**	
Veronico beccabungae-Mimuletum guttati, Glycerio-Sparganion											
Mimulus guttatus	5	4	4	4	4	4	3	3	3	1	100
Veronica beccabunga	.	.	1	r	b	1	1	3	3	4	80
Glyceria notata	.	a	a	a	.	b	.	1	.	+	60
Glyceria declinata	1	.	.	.	.	.	.	1	.	.	20
Hygrophilous species*											
Myosotis scorpioides agg.	+	+	b	a	+	1	+	a	1	1	100
Poa trivialis	+	+	1	1	+	+	b	a	+	.	90
Ranunculus repens	+	+	.	+	.	+	+	+	+	+	80
Mentha longifolia	.	1	b	.	+	.	1	1	+	1	70
Stellaria alsine	.	.	.	.	1	+	1	1	+	.	50
Epilobium obscurum	r	.	+	.	.	.	+	+	a	.	40
Juncus effusus	+	.	.	.	.	.	+	+	1	.	40
Cardamine amara	+	.	+	+	.	.	+	.	.	.	40
Scirpus sylvaticus	.	.	.	1	.	+	.	+	.	+	40
Chaerophyllum hirsutum	.	+	.	a	+	.	.	.	1	.	30
Agrostis stolonifera	.	.	.	.	1	.	+	.	+	.	30
Juncus conglomeratus	.	a	.	.	.	+	+	.	.	.	30
Caltha palustris	.	.	.	.	.	+	.	1	1	.	30
Galium palustre	1	.	.	+	.	+	.	.	.	.	30
Epilobium tetragonum	.	.	.	.	.	+	.	.		1	20
Brachythecium rivulare (E0)	.	.	.	1	.	.	.	.	1	.	20
Carex canescens	.	1	.	.	.	+	.	.	.	.	20
Juncus articulatus	.	+	.	.	.	+	.	.	.	.	20
Cirsium palustre	.	.	+	.	.	+	.	.	.		20
Carex nigra	+	.	+	.	.	.	.	.	.	.	20
Other species											
Prunella vulgaris	+	.	+	+	.	.	.	.	.	.	30
Rumex obtusifolius	.	.	.	.	.	.	+	+	.	.	20
Equisetum arvense	.	.	.	.	.	.	.	+	.	r	20
Deschampsia cespitosa	+		.	.	.	.	.	.	1	.	20
Lychnis flos-cuculi	.	.	.	.	.	+	.	+	.	.	20
Acetosa pratensis	.	.	+	.	.	.	.	+	.	.	20
Carex leporina	.	+	.	+	.	.	.	.	.	.	20
Cerastium holosteoides	.	+	+	.	.	.	.	.	.	.	20
Trifolium pratense	.	.	+	.	+	.	.	.	.	.	20

Legend: C – constancy; * *Molinio-Arrhenatheretea*, *Montio-Cardaminetea*, *Phragmito-Magnocariceta*, and *Scheuchzerio-Caricetea fuscae*.

with an average area of ~4 m²). They usually formed narrow and small patches along the upper parts of streams and their spring areas (Fig. 2). These stands were recorded in hilly regions at altitudes of 561–1,048 m, with typical mountain climates, i.e., low mean annual air temperature (5.5°C) and high mean annual precipitation (885 mm). Running water in streams and springs was relatively cold (~13°C), but temperatures ranged from 7.4°C to 19.9°C among the studied streams. This kind of vegetation preferred neutral to slightly alkaline water (pH = 6.1–7.5), with low amounts of soluble mineral matter (~72.6 μS cm^{-1}). Such stands were developed mainly on sites with coarser sediments (stone, gravel, and sand) formed from crystalline bedrock, while mud substrate was only found occasionally (Tab. 1).

Our cluster analysis of Central European data split the relevés into three well-defined floristic clusters. Cluster 1 was differentiated by the presence of the wetland plants *Chaerophyllum hirsutum*, *Lotus uliginosus*, and *Veronica beccabunga*, and comprised relevés from Germany, Slovakia, and also partially from the Czech Republic. Cluster 2 included all stands from Poland, with numerous marsh species present. Both Clusters 1 and 2 contained plant taxa typical of wet and spring habitats, such as *Cardamine amara*, *Galium palustre*, *Myosotis scorpioides* agg., and *Stellaria alsine*. Finally, Cluster 3 included eutrophic marsh habitats in the Czech Republic, which were differentiated by an abundant set of ruderal species, such as *Artemisia vulgaris*, *Poa annua*, *Polygonum arenastrum*, and *Solidago canadensis* (Tab. 3 and Fig. 3).

The first DCA axis was most strongly correlated with the EIV for temperature (r = 0.73), followed by the EIVs for nutrients (0.70), and continentality (0.64), while the EIV for moisture (−0.69) was closely related to the second DCA axis (Fig. 3B). The DCA axes explained 18.7% and 51.2% of species variability and species–environment data, respectively.

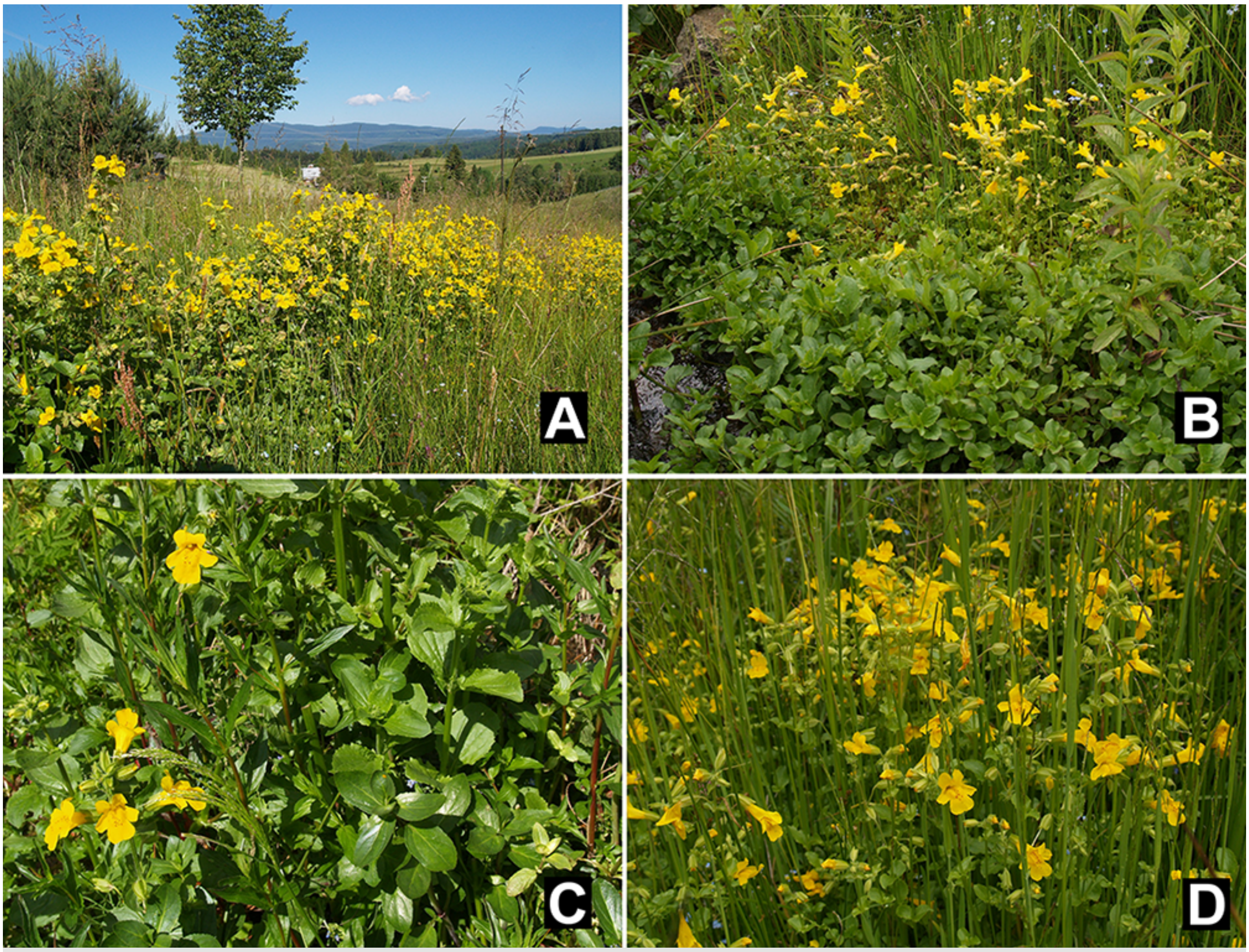

Fig. 2 Vegetation of *Veronico beccabungae-Mimuletum guttati* in studied localities: (**A**) town of Hriňová, settlement Biele Vody (Tab. 1, Rel. 1); (**B,D**) village of Látky, Chocholná (Tab. 1, Rel. 6); (**C**) village of Látky, settlement Paseky (Tab. 1, Rel. 9). All photos: R. Hrivnák.

Tab. 3 Shortened synoptic table of *Veronico beccabungae-Mimuletum guttati* from Central European countries. Diagnostic species are sorted according to decreasing fidelity values. Only species with at least 10% frequency in the whole dataset are shown.

Group No.	**1**	**2**	**3**
No. of relevés	**30**	**21**	**4**
Diagnostic species of clusters			
Chaerophyllum hirsutum	33$^{50.0}$	.$^{---}$	.$^{---}$
Lotus uliginosus	33$^{43.8}$	5^{---}	.$^{---}$
Veronica beccabunga	70$^{38.9}$	33^{---}	25^{---}
Berula erecta	.$^{---}$	81$^{86.0}$	.$^{---}$
Lemna minor	.$^{---}$	76$^{82.5}$	.$^{---}$
Mentha aquatica	.$^{---}$	71$^{79.1}$	.$^{---}$
Carex rostrata	3^{---}	52$^{61.5}$	.$^{---}$
Impatiens glandulifera	.$^{---}$	38$^{53.9}$	.$^{---}$
Phragmites australis	.$^{---}$	38$^{53.9}$	.$^{---}$
Brachythecium rivulare (E0)	17^{---}	57$^{53.4}$	.$^{---}$
Acetosa pratensis	10^{---}	48$^{51.0}$	.$^{---}$
Carex paniculata	.$^{---}$	33$^{50.0}$	.$^{---}$
Bidens frondosa	13^{---}	5^{---}	100$^{87.8}$
Myosoton aquaticum	3^{---}	24^{---}	100$^{82.4}$
Persicaria lapathifolia	.$^{---}$	29^{---}	100$^{81.6}$
Tussilago farfara	.$^{---}$	.$^{---}$	75$^{81.6}$
Taraxacum sect. *Ruderalia*	.$^{---}$	.$^{---}$	75$^{81.6}$
Polygonum arenastrum	.$^{---}$	.$^{---}$	75$^{81.6}$
Solidago canadensis	.$^{---}$	.$^{---}$	75$^{81.6}$
Rorippa palustris	.$^{---}$	33^{---}	100$^{79.1}$
Poa palustris	3^{---}	.$^{---}$	75$^{78.7}$
Persicaria hydropiper	.$^{---}$	38^{---}	100$^{76.6}$
Phalaroides arundinacea	23^{---}	24^{---}	100$^{72.1}$
Epilobium hirsutum	.$^{---}$	14^{---}	75$^{70.0}$
Lycopus europaeus	10^{---}	5^{---}	75$^{69.6}$
Plantago uliginosa	.$^{---}$	24^{---}	75$^{63.3}$
Leersia oryzoides	.$^{---}$	.$^{---}$	50$^{63.2}$
Rumex maritimus	.$^{---}$	.$^{---}$	50$^{63.2}$
Salix caprea	.$^{---}$	.$^{---}$	50$^{63.2}$
Rumex obtusifolius	20^{---}	5^{---}	75$^{62.7}$
Solanum dulcamara	.$^{---}$	5^{---}	50$^{58.1}$
Poa annua	.$^{---}$	5^{---}	50$^{58.1}$
Artemisia vulgaris	.$^{---}$	10^{---}	50$^{53.5}$
Tanacetum vulgare	.$^{---}$	14^{---}	50$^{49.2}$
Other species			
Mimulus guttatus	100^{---}	100^{---}	100^{---}
Cardamine amara	53^{---}	90$^{60.2}$	.$^{---}$
Ranunculus repens	60^{---}	52^{---}	75^{---}
Myosotis scorpioides agg.	57^{---}	57^{---}	.$^{---}$
Glyceria fluitans	47^{---}	38^{---}	50^{---}
Stellaria alsine	53^{---}	33^{---}	.$^{---}$

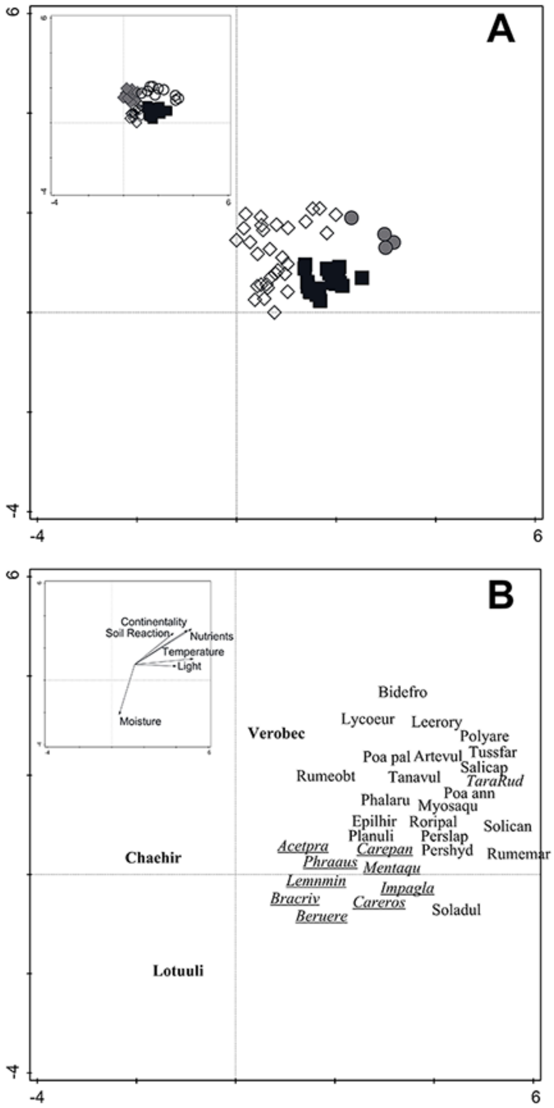

Fig. 3 DCA ordination diagrams of samples and species with passive projection of EIV showing the first two ordination axes: (**A**) samples divided by cluster analysis (country division in left corner); (**B**) diagnostic species of the clusters (EIV in left corner). (**A**) Diamonds (Cluster 1 in Tab. 3), black squares (Cluster 2), shaded circles (Cluster 3); left corner: shaded diamonds (Slovakia), empty diamonds (Germany), empty circles (Czech Republic), and black squares (Poland). (**B**) Bold script (Cluster 1), underline italic script (Cluster 2), normal script (Cluster 3). Acetpra – *Acetosa pratensis*; Artevul – *Artemisia vulgaris*; Beruere – *Berula erecta*; Bidefr – *Bidens frondosa*; Bracriv – *Brachythecium rivulare*; Carepan – *Carex paniculata*; Careros – *Carex rostrata*; Chaehir – *Chaerophyllum hirsutum*; Epilhir – *Epilobium hirsutum*; Impagla – *Impatiens glandulifera*; Leerory – *Leersia oryzoides*; Lemnmin – *Lemna minor*; Lotuuli – *Lotus uliginosus*; Lycoeur – *Lycopus europaeus*; Mentaqu – *Mentha aquatica*; Myosaqu – *Myosoton aquaticum*; Pershyd – *Persicaria hydropiper*; Perslap – *Persicaria lapathifolia*; Phalaru – *Phalaroides arundinacea*; Phraaus – *Phragmites australis*; Planuli – *Plantago uliginosa*; Poa ann – *Poa annua*; Poa pal – *Poa palustris*; Polyare – *Polygonum arenastrum*; Roripal – *Rorippa palustris*; Rumemar – *Rumex maritimus*; Rumeobt – *Rumex obtusifolius*; Salicap – *Salix caprea*; Soladul – *Solanum dulcamara*; Solican – *Solidago canadensis*; Tanavul – *Tanacetum vulgare*; TaraRud – *Taraxacum* sect. *Ruderalia*; Tusifar – *Tussilago farfara*; Verobec – *Veronica beccabunga*.

Tab. 3 Continued

Galium palustre	40 ---	33 ---	. ---
Urtica dioica	13 ---	43 ---	75 ---
Poa trivialis	40 15.4	. ---	50 ---
Agrostis stolonifera agg.	30 ---	19 ---	25 ---
Mentha longifolia	40 31.5	. ---	25 ---
Juncus effusus	17 ---	29 ---	. ---
Caltha palustris	17 ---	24 ---	. ---
Achillea ptarmica	20 ---	14 ---	. ---
Epilobium obscurum	30 47.1	. ---	. ---
Juncus bufonius	3 ---	33 22.4	25 ---
Scirpus sylvaticus	17 ---	14 ---	. ---
Iris pseudacorus	3 ---	29 41.1	. ---
Lythrum salicaria	. ---	29 19.8	25 ---
Scrophularia umbrosa	. ---	24 ---	50 ---
Symphytum officinale	. ---	24 ---	50 ---
Epilobium roseum	20 37.8	. ---	. ---
Veronica anagallis-aquatica	3 ---	24 36.4	. ---
Equisetum palustre	7 ---	19 ---	. ---
Galium uliginosum	17 ---	5 ---	. ---
Glyceria notata	20 37.8	. ---	. ---
Cratoneuron filicinum (E0)	. ---	29 45.9	. ---
Bidens tripartita	. ---	29 45.9	. ---

Number of hidden species is 78. Sources of relevés: Cluster 1 – Niemann [15] (Tab. 7, Rels 1–8, 10–15), Hrivnák et al. (this paper, Tab. 2, Rels 1–10), Blažková [16] (Tab. 1, Rels 5–10); Cluster 2 – Sobisz et al. [18] (Tab. 2, Rels 1–21); Cluster 3 – Blažková [16] (Tab. 1, Rels 1–4).

Discussion

The distribution of *Mimulus guttatus* in Slovakia seems to be well known [11,13], but the *Veronico beccabungae-Mimuletum guttati* association was overlooked by studies for several years. Although relevés with the vascular plant species most often co-occurring with *M. guttatus* have been published (e.g., those with *Veronica beccabunga* and *V. anagallis-aquatica*) [13], we did not find any available phytosociological relevés for this plant community in any literature or vegetation databases [30]. This vegetation type almost exclusively creates narrow and small-scale patches, either along the upper parts of streams or in wet places around spring areas in hilly regions. However, new information on the association *Veronico beccabungae-Mimuletum guttati* can be expected to be found in other habitats and regions of Slovakia, primarily in hilly areas where *M. guttatus* occurs [13,31]. Similar habitats with ecological properties close to those in Slovakia are known from other European countries, such as Great Britain, Germany, the Czech Republic, and Poland [15–18,20,32], as well as from the native range of *M. guttatus* in North America [14]. However, the species' habitat niche in these countries is much broader than in Slovakia. Additionally, *M. guttatus* is able to grow in other habitat types than just those associated with streams. For example, Stosik [33] recorded this species on extensive pasture land in Poland, and Lukács et al. [34] reported it in thermal spring waters in Hungary. In North America, it commonly occupies freshwater habitats, but is only marginally present in semi-terrestrial ones [14]. Similarly, the availability of data on the bedrock types, climatic conditions, and water or soil pH of habitats bearing *Veronico beccabungae-Mimuletum guttati* stands is highly variable throughout the distributional range of this species [14,15].

Central European herbaceous vegetation stands with high coverage by *M. guttatus* showed strong variation in the composition of their floristic spectra. In spite of this, we did observe strong similarity between the species compositions of phytosociological relevés from Slovakia and those of *Veronico beccabungae-Mimuletum guttati* reported in the original diagnosis of this association [15]. There were only slight differences in the presence of certain species. More specifically, species such as *Epilobium roseum* and *Lotus corniculatus* were recorded only in German relevés, whereas other wetland species (e.g., *Epilobium obscurum*, *Glyceria notata*, *Poa trivialis*, and *Stellaria alsine*) were lacking there. These species' presence or absence reflected local ecological conditions, but they did not have any effect on final syntaxonomical interpretations at the association level. Our data together with those of relevés from Germany and partially those from the Czech Republic [15,16] placed in the first cluster were differentiated by specific combinations of spring species. Several other wetland species, such as *Achillea ptarmica*, *Caltha palustris*, *Cardamine amara*, *Galium palustre*, *Juncus effusus*, *Myosotis scorpioides* agg., and *Stellaria alsine* showed the floristic similarity of this cluster with the second cluster comprised of relevés from Poland [18]. The third cluster, with only a few relevés from the Czech Republic [16], had a distinct species composition. The first two clusters matched the *Veronico beccabungae-Mimuletum guttati* association and the differences between them demonstrated intra-association variability, while the species composition of Cluster 3 placed it in a transient position between the marsh vegetation of the class *Phragmito-Magnocaricetea* and the summer-annual pioneer vegetation of seasonally flooded habitats of the class *Bidentetea* [19,35]. If the country of origin of the vegetation plots is taken into account, clear differentiation among vegetation plots in the ordination diagram is obvious. Vegetation data from Slovakia were closer to the phytosociological material sampled in Germany and the Czech Republic (and in some cases, they overlap with each other) due to lower floristic variability among these areas compared with that of relevés from Poland and a few relevés from the Czech Republic.

Conclusions

The present study reports the first record of the association *Veronico beccabungae-Mimuletum guttati* in Slovakia. Its species composition and habitat conditions were primarily similar to vegetation data sampled in Germany and partially also in the Czech Republic, but the presence of several hygrophilous species also showed similarity with data from Poland. Comparisons of vegetation data of the association across Central Europe showed obvious intra-association variability. In Slovakia, small-scale stands were found along streams and their spring areas in a region with a typical mountain climate.

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Supplementary material

The following supplementary material for this article is available at http://pbsociety.org.pl/journals/index.php/asbp/rt/suppFiles/asbp.3587/0:

Appendix S1 Species with occurrence only in one relevé and localities of relevés.

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