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Distribution, ecology and threat status evaluation of *Sphagnum* species in Serbia

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Summary: The *Sphagnum* flora of Serbia represented by 24 species is relatively rich, but they are rare and of scattered distribution. Many species have not been recorded in the course of recent field investigations and some other were newly found. The habitats of these species are under pressure, and the sphagna suffer from both global and local environmental changes. In the present study, all data concerning sphagna in Serbia including distribution, ecology and threat status for each species are summarized with the aim to give a new effort in conservation of these EU Habitats Directive listed species.

Keywords: *Sphagnum*, distribution, Serbia, threat status

Peat-mosses (Sphagna) grow in specific habitat types of a particular hydrology regime and cool and fresh climate. These habitat types are mainly spreading azonally and interzonally within boreal conifer forests (taiga), cool or mild maritime zones or in open areas with polar vegetation types (tundra) and their key species from the genus *Sphagnum* are included in the EU Habitats Directive, Annexes 1, 2 and 5.

In southern Europe, such habitats are restricted to small scattered areas in the highlands. Serbia (88 361 km^2) lies in the central part of the Balkan peninsula. According to Lazarević (2013), mires and mire complexes in Serbia occupy 0.014% (ca. 1 250 ha) of the country, out of which less than 10% comprise *Sphagnum* species (Fig. 1). Investigations of mire habitats including sphagna mires in Serbia has a long history and many Serbian scientists have been exploring these habitats since the end of 19th century till nowadays (reviewed in Lazarević 2013). However, very few focused on bryophytes (e.g. Jurišić 1901; Simić 1901; Košanin 1909). Some data on the presence of *Sphagnum* in Serbia can also be found in Pavletić (1955), Popović (1966), Martinčić (1968), Ranđelović et al. (1998) and Ranđelović & Zlatković (2010). In the last two decades intensive bryological research was carried out in Serbia, which gave new insights into the current distribution of sphagna in Serbia (Sabovljević & Stevanović 2000; Papp & Sabovljević 2002; Papp et al. 2004; Papp & Erzberger 2005; Papp et al. 2012; Papp et al. 2014). Up to date, 24 species from the genus *Sphagnum* have been found in Serbia. In this paper, we present an account of the distribution, ecological remarks and threat status of *Sphagnum* species currently known in Serbia.

Materials and methods

Chorological data

For the present study all chorological data concerning floristic bryophyte studies in Serbia from both literature and herbarium collections [BEO, BEOU, BP and Predrag Lazarevics' private

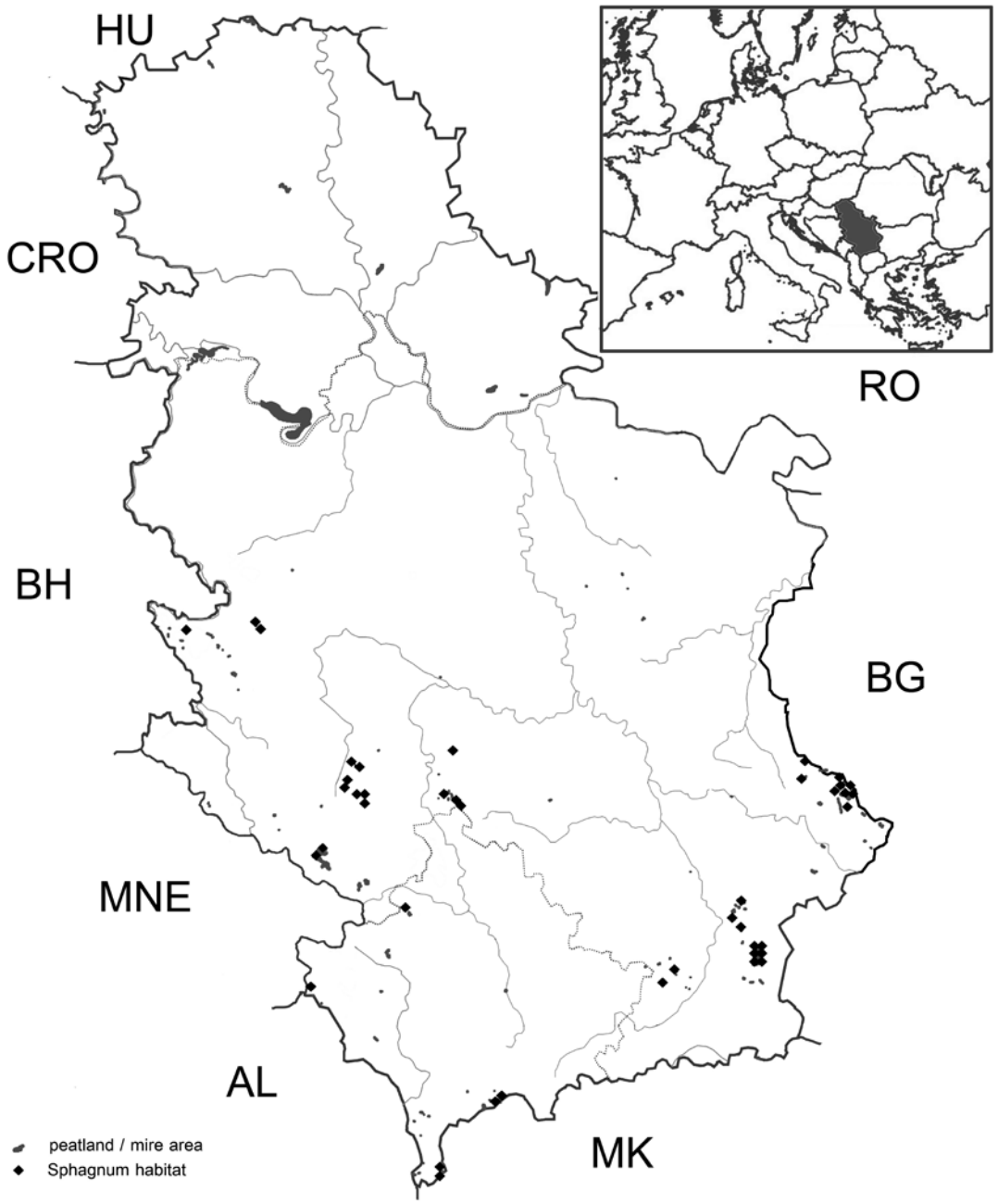

Figure 1. Mires (gray areas) and the *Sphagnum* sites (black dots) in Serbia.

collection] were checked for *Sphagnum* specimens. All specimens were revised. Distribution maps for each of the species were obtained using the 10 × 10 km squares in the UTM system. These maps show (I) pre-1990 records not found in recent studies, (II) pre-1990 records re-found in the recent studies and (III) post-1990 records not found previously.

Localities and distribution maps are presented for each taxon, except for *S. molle* Sull. and *S. papillosum* Lindb., which were cited for Serbia by Martinčič (1968), but without precise locality (Appendix 1).

Records of the *S. recurvum* complex could not be assigned to currently accepted species (Flatberg 1992; Sastad et al. 1999) without checking herbarium specimens. Nomenclature follows Ros et al. (2013).

Threat status evaluation

According to the current Bryophyte Red List of Serbia and Montenegro (Sabovljević et al. 2004), all *Sphagnum* species known for Serbia are categorized as VU (vulnerable). Threat statuses of the species were re-evaluated according to the IUCN (2014) criteria, bearing in mind the guidelines for using these criteria on bryophyte species given by Hallingbäck et al. (1998). Criterion B2 was applied for all of the species, thus threat status was determined based on species area of occupancy along with observed decline of habitats and/or number of populations. As suggested by Hallingbäck et al. (1998) and Hodgetts (2014), only recent findings were taken into account when evaluating species; in our study specimens found after 1990 were considered as relevant.

Ecological analysis

To identify the main environmental variables affecting species distribution and diversity, a canonical correspondence analysis (CCA) was carried out using CANOCO 5 programme (Ter Braak & Smilauer 2012). Altitude, geological bedrock (basic, schistose and acidic bedrock) and 19 bioclimatic parameters were tested as descriptors of *Sphagnum* richness and distribution. The values of bioclimatic variables were extracted from WorldClim database (Hijmans et al. 2005) using DIVA-GIS 7.5 software (Hijmans et al. 2012).

A table with the list of species, their threat category and criteria together with the number of old and recent findings (prior and post 1990) is given (Table 1).

Results and discussion

Species distribution

Most common species found in almost all mire complexes in Serbia are *S. palustre, S. squarrosum* and *S. subsecundum*, although a decline in the distribution of *S. palustre* has been noticed. On the other hand, the rarest species found only in one locality during the past 25 years are *S. cuspidatum, S. fuscum, S. obtusum*, *S. rubellum* and *S. warnstorfii*. Of these, *S. cuspidatum* had a considerably wider distribution in the past. Yet, in recent studies it has not been re-found on many mire complexes in Serbia (e.g. Kopaonik Mt., Prokletije Mt., Stara Mt. and Vlasina region). For other species and their detailed distribution maps see Appendix 1.

As mentioned above, *S. molle* and *S. papillosum* are cited for Serbia, but without precise locality. Recent field studies did not provide new data or findings. In SE Europe, *S. papillosum* occurs in Bulgaria, Bosnia and Herzegovina, Croatia, Romania and Slovenia (Sabovljević et al. 2008). This species grows in open acidic mires, often found together with *S. majus*, *S. magellanicum*, *S. flexuosum* and *S. fallax* (Laine at al. 2011). On the other hand, *S. molle* is a much rarer species having a more oceanic tendency. In SE Europe it is known only from Macedonia (Sabovljević et al. 2008) and has been excluded from Hungary (Erzberger & Papp 2004) and Romania (Dihoru 2004). It grows in open oligotrophic bogs and is difficult to find, especially when mixed with similar species such as *S. subnitens* and *S. compactum* (Daniels & Eddy 1985). However, both species are possibly present in Serbia.

Table 1. *Sphagnum* species recorded in Serbia, with its threat new threat status, presence in UTM squares (10 × 10 km), prior and post 1990 and in both, as well as IUCN criteria applied for new threat status.

Name of the taxon	New threat category	Used IUCN criteria	Total square number	1990+ squares
Sphagnum angustifolium (C.E.O. Jensen ex Russow) C.E.O.Jensen	EN	B2ab(iii)	3	3
Sphagnum auriculatum Schimp.	EN	B2ab(iii)	5	4
Sphagnum capillifolium (Ehrh.) Hedw.	EN	B2ab(iii, iv)	12	4
Sphagnum centrale C.E.O. Jensen	VU	B2ab(iii)	7	7
Sphagnum contortum Schultz	EN	B2ab(iii, iv)	8	5
Sphagnum cuspidatum Ehrh. ex. Hoffm.	CR	B2ab(iii, iv)	7	1
Sphagnum fallax (H. Klinggr.) H. Klinggr.	VU	B2ab(iii, iv)	12	6
Sphagnum flexuosum Dozy & Molk.	VU	B2ab(iii, iv)	8	6
Sphagnum fuscum (Schimp.) H. Klinggr.	CR	B2ab(iii, iv)	2	1
Sphagnum girgensohnii Russow	VU	B2ab(iii, iv)	9	5
Sphagnum inundatum Russow	EN	B2ab(iii)	2	2
Sphagnum magellanicum Brid.	EN	B2ab(iii, iv)	8	2
Sphagnum molle Sull.	DD			
Sphagnum obtusum Warnst.	CR	B2ab(iii, iv)	4	1
Sphagnum palustre L.	VU	B2ab(iii, iv)	16	7
Sphagnum papillosum Lindb.	DD			
Sphagnum platyphyllum (Lindb. ex Braithw.) Warnst.	EN	B2ab(iii, iv)	5	2
Sphagnum rubellum Wilson	CR	B2ab(iii, iv)	3	1
Sphagnum russowii Warnst.	EN	B2ab(iii)	2	2
Sphagnum squarrosum Crome	VU	B2ab(iii, iv)	17	11
Sphagnum subnitens Russow & Warnst.	EN	B2ab(iii)	2	2
Sphagnum subsecundum Nees	VU	B2ab(iii, iv)	17	12
Sphagnum teres (Schimp.) Ångstr.	EN	B2ab(iii, iv)	10	5
Sphagnum warnstorfii Russow	CR	B2ab(iii)	2	1

Vlasina region was, and still is, the biggest single mire complex in Serbia, although now it is greatly fragmented. For *Sphagnum*, it is the richest single mire complex: 14 species were reported for this region in a comprehensive study of the flora and vegetation of Lake Vlasina and its surroundings by Ranđelović & Zlatković (2010). Nevertheless, only 8 species were found in the recent intensive field work of this area (Papp et al. 2012). The greatest *Sphagnum* diversity recorded is in Kopaonik Mt. (17 species), Golija Mt. (13), Tara Mt. (12) and Stara Planina Mt. (12) (Jurišić 1901; Simić 1901; Košanin 1909; Grebenščikov 1950; Pavletić 1955; Čolić & Gigov 1958; Čolić 1965; Popović 1966; Mišić et al. 1978; Jovanović-Dunjić & Jovanović

1986; Gajić 1988, 1989; Gajić et al. 1989–90; Papp & Sabovljević 2002; Papp et al. 2004; Papp & Erzberger 2005; Ivančević et al. 2007), recently somewhat less diverse. Prokletije and Šar Planina Mts., marked as European biodiversity hotspots, with numerous scattered high mountain mires, springs, glacial lakes, glaciers, snowbelts and other noted potential *Sphagnum* sites, have a relatively small number of recorded *Sphagnum* species: Prokletije Mt. (10) and Šar Planina Mt. (8) (Stanković-Tomić 1969; Ranđelović et al. 1998; Sabovljević & Stevanović 2000; Martinčić 2006).

During our novel field investigations,we found one new *Sphagnum* site, previously not cited in literature or documented comprising *Sphagnum* species. It is situated in W Serbia on Maljen Mt., in village Divčibare (*Sphagnum subsecundum* N 44.11137, E 19.99274). The habitat is open hygrophilic meadow and at present under construction pressure. Therefore hydrology of the habitats is changing.

Threat status

Based on recent field works, revisions of old herbarium collections, chorological data from literature, threat status of the species has been re-evaluated and updated.

Out of 24 *Sphagnum* species known for the country of Serbia, five are Critically Endangered (CR), ten Endangered (EN), seven Vulnerable (VU) and two lack sufficient information hence assigned to the Data Deficient (DD) category. Thus, *S. cuspidatum* Ehrh. ex. Hoffm., *S. fuscum* (Schimp.) H. Klinggr., *S. obtusum* Warnst., *S. rubellum* Wilson and *S. warnstorfii* Russow are considered CR; *S. angustifolium* (C.E.O. Jensen ex Russow) C.E.O. Jensen, *S. auriculatum* Schimp., *S. capillifolium* (Ehrh.) Hedw., *S. contortum* Schultz, *S. inundatum* Russow, *S. magellanicum* Brid., *S. platyphyllum* (Lindb. ex Braithw.) Warnst., *S. russowii* Warnst., *S. subnitens* Russow & Warnst. and *S. teres* (Schimp.) Ångstr. are considered EN and *S. centrale* C.E.O. Jensen, *S. fallax* (H. Klinggr.) H. Klinggr., *S. flexuosum* Dozy & Molk., *S. girgensohnii* Russow, *S. palustre* L., *S. squarrosum* Crome, *S. subsecundum* Nees are considered VU (Table 1).

Sphagnum molle Sull. and *S. papillosum* Lindb. are cited for Serbia without precise localities. Recent investigation did not obtain any new findings, so these two species cannot be listed into any threat category and thus should be considered Data Deficient (DD) (Table 1).

Ecology

In Europe, *Sphagnum* species richness (total of 52 taxa in Europe) shows a gradient of decrease from boreal region towards the north and the south as well as from west to the east. This can be due to a more continental climate and to more uniform topographic conditions. Boreal vegetation belt, ocean influence and elevation are shown to be important factors for distribution pattern of *Sphagnum* species richness in Europe (Séneca & Söderström 2009).

Serbia occupies only 2% of the total European territory, but comprises 46% (24 out of 52) *Sphagnum* taxa known in Europe. Considering this, Serbia is relatively rich in *Sphagnum* flora. On the other hand, due to its very splitted distribution with isolated, restricted and fragile localities, often affected by anthropogenic factors, *Sphagnum* species and their habitats should be considered threatened in Serbia.

In Serbia, *Sphagnum* species are most common within mire vegetation, represented by class. *Scheuchzerio-Caricetea fuscae* (Nordh. 1936) R.Tx. 1937. Sometimes they can also be diagnostic,

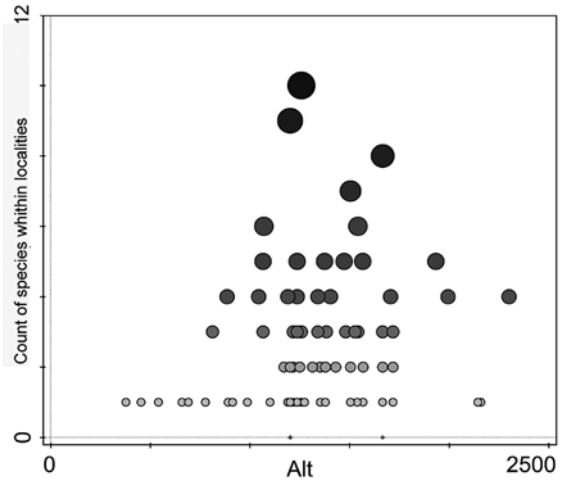

Figure 2. The *Sphagnum* species richness per site in altitudinal range profile of Serbia.

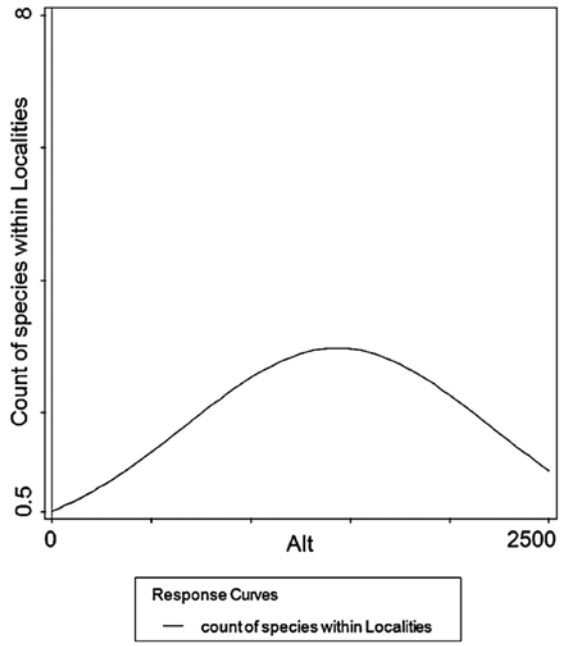

Figure 3. The distribution curve of species richness in altitudinal range of Serbia.

dominant or characteristic species (e.g. *Sphagno-Equisetetum fluviatilis* V. Ranđelović 1994, *Carici-Sphagno-Eriophoretum* R. Jovanović 1978, *Sphagno nemorei-Caricetum rostratae* V. Ranđelović 1998, *Caricetum goodenowii* Penev, *Drosero-Caricetum stetllulatae* Ht. 1950, *Caricetum limosae* Br.-Bl. 1921). Sphagna can also be found within beech and conifer forests on suitable wet micro-habitats, rarely and sporadically on wet meadows or near streams (e.g. *Sphagno-Piceetum subalpinum* Mišić 1986, *Fagetum moesiacae montanum* Blec. et Lakusic 1970, *Salici-Alnetum viridis* Čolić 1962, Mišić et Popović 1964, *Potentillo-Salicetum rosmarinifoliae* V. Ranđelović 1994, *Molinietum coeruleae sensu lato*, *Hygronardetum strictae* Pusc-Soroc 1963, *Cardamino-Rumici Calthetum* R. Jov. 1971, *Deschampsietum subalpinum* Ht. 1956, *Coccineo-Deschampsietum*

Ht. 1935, *Scirpetum silvatici* Schwick. 1944). Beside mire vegetation, *Sphagnum* species can be occasionally found within forest vegetation.

In Serbia, sphagna occur at altitudes at and above the beech forest zone. According to previous literature data, several *Sphagnum* species (*S. palustre, S. capillifolium* and *S. girgensohnii*) were also recorded in lower altitudes, e.g. Žuta bara on Kotlenik Mt. near Kraljevo on ca. 320 m (Marinković & Gajić 1956); Županjac near Lajkovac on ca. 200 m (Pavletić 1955); Majdanpek on ca. 350 m (Jurišić 1901); Blace Lake on ca. 410 m (Pavletić 1955); Obličko Lake on ca. 520 m (Cvijić 1896). However, we could not confirm these citations neither by herbarium specimens nor by new field investigations. It is interesting that all *Sphagnum* records below 600 m have not been confirmed in the past 50 years or more. The highest altitudes reached by *S. capillifoliun*, *S. teres*, *S. auriculatum*, *S. denticulatum*, *S. cuspidatum* are on Prokletije and Šara mountains, at about 2100 m (Ranđelović et al. 1998; Sabovljević & Stevanović 2000; Martinčič 1980, 2006). Figures 2 and 3 clearly show that *Sphagnum* species diversity in Serbia reaches its maximum at moderate altitudes. The richest sites in Serbia are Vlasina, Blato in SE Serbia and Tara, Crveni potok in W Serbia.

Separate CCA using only climatic factors and forward selection of variables showed that the two main bioclimatic factors affecting distribution of *Sphagnum* species in Serbia are the average temperature of the wettest and the average temperature of the driest period of the year (Figs 4, 5). On the t-value biplot with Van Dobben circles drawn (CanoDraw) for *mean temperature of the wettest quarter* variable (Fig. 5a) it is shown that *S. magellanicum*, *S. auriculatum* and *S. warnstorfii* are negatively correlated to this variable, hence prefer sites with wet and relatively cold microclimate, while *S. centrale* and *S. flexuosum* are positively correlated and hence prefer

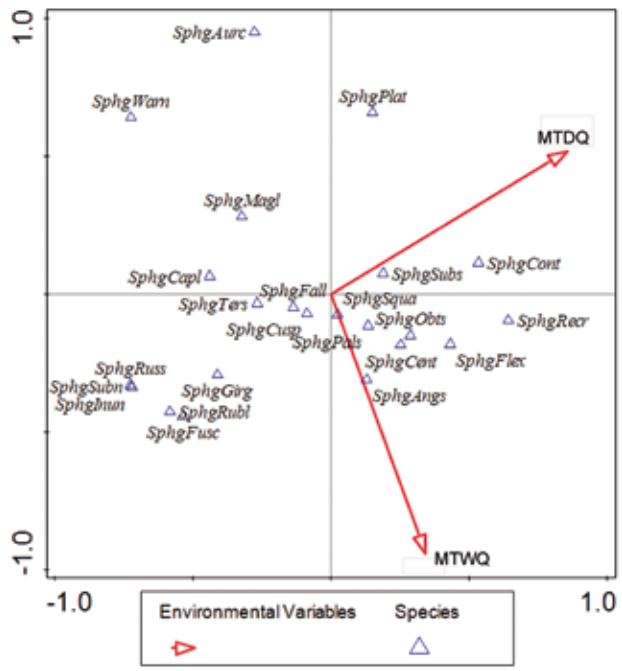

Figure 4. Ordination diagram of CCA using two main climatic factors affecting the *Sphagnum* species appearance in Serbia. MTWQ – mean temperature of wettest quarter and MTDQ – mean temperature of driest quarter (Adjusted explained variation is 6.0%).

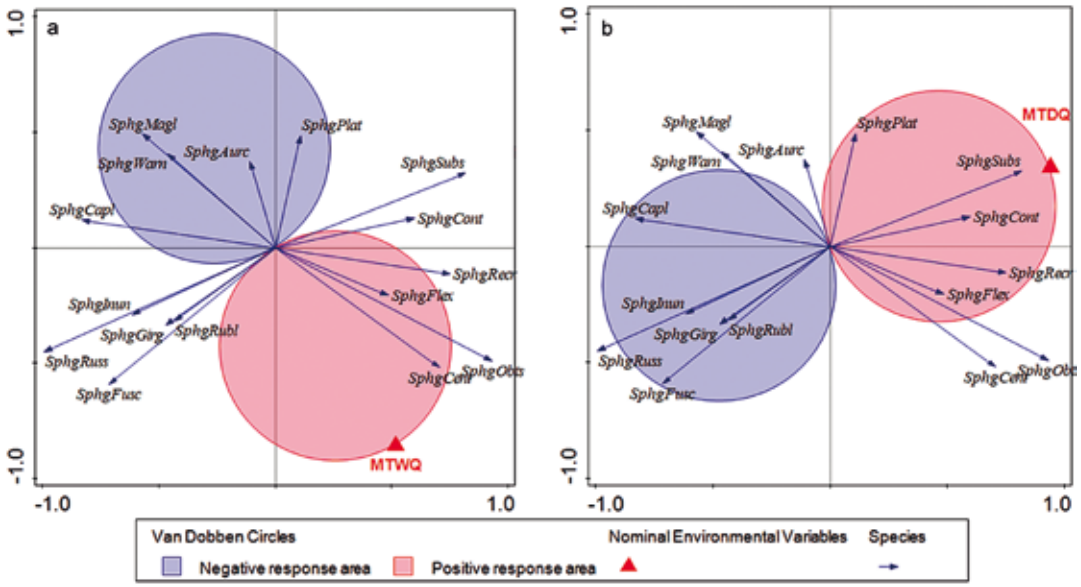

Figure 5. T-value biplot of two main climatic factors affecting the *Sphagnum* species appearance in Serbia. a – Van Dobben circles drawn for MTWQ variable and b – Van Dobben circles drawn for MTDQ variable.

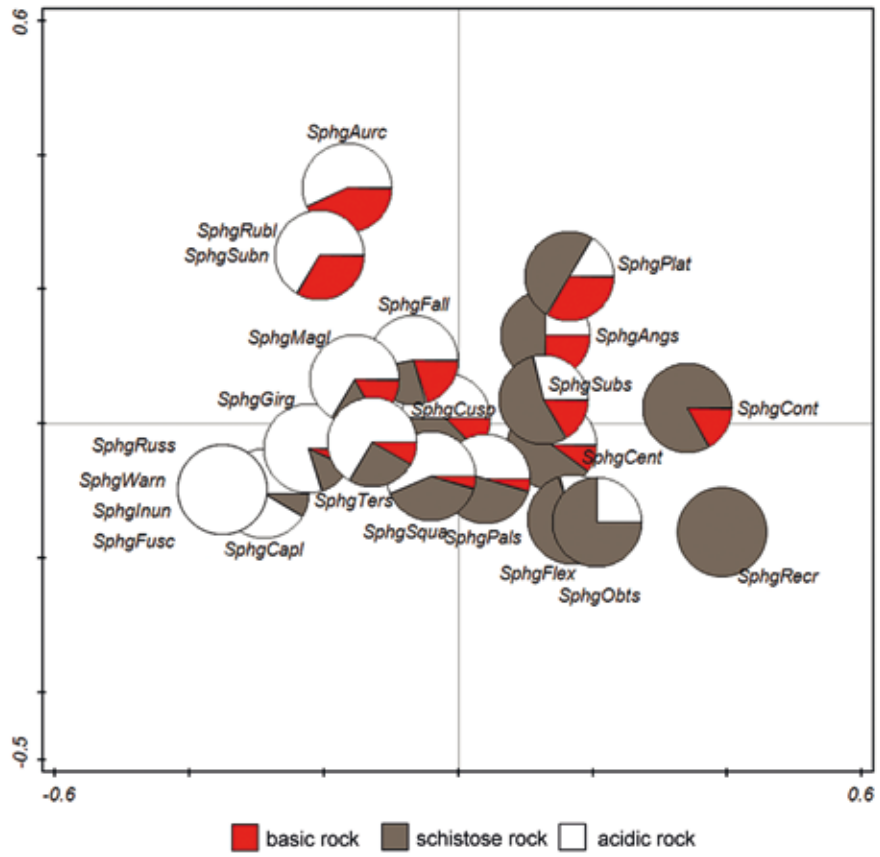

Figure 6. Species pie plot displaying the appearance of Serbian *Sphagnum* species onto three different bedrocks within an ordination space of CCA made using different bedrocks as a factor.

relatively warmer and drier mire sites in Serbia. When Van Dobben circles are drawn for the *mean temperature of the driest quarter* variable (Fig. 5b), it can be seen that *S. contortum*, *S. flexuosum*, *S. platyphyllum*, *S. subsecundum* and *S. recurvum* compl. occur in sites with a drier and warmer microclimate. On the other hand, *S. capillifolium*, *S. inundatum*, *S. girgensohnii*, *S. rubellum* and *S. russowii* can be found in cooler and more humid microsites.

Most mountain areas in Serbia seem to have prevalently basic bedrocks. However, the vegetation above, in synergy with air humidity, substrate moisture, precipitation and coldness can significantly change the pH value of mires, and thus favors the appearance of *Sphagnum* species, as for example on the Pešter plateau. Amongst Serbian sphagna, four species are strictly acidophilic as shown in the species pie diagram (Fig. 6): *S. russowii*, *S. warnstorfii*, *S. inundatum* and *S. fuscum.*

Sphagnum auriculatum, *S. fuscum*, *S. inundatum*, *S. russowii*, *S. subnitens* and *S. warnstorfii* prefer sites with a higher precipitation throughout the year (Fig. 7).

Threat factors and protection

Typical threat factors of *Sphagnum* habitats in Serbia are changes of natural hydrological regime (springs capture for water supply, irrigation canals, drainage), degradation of forest ecosystems,

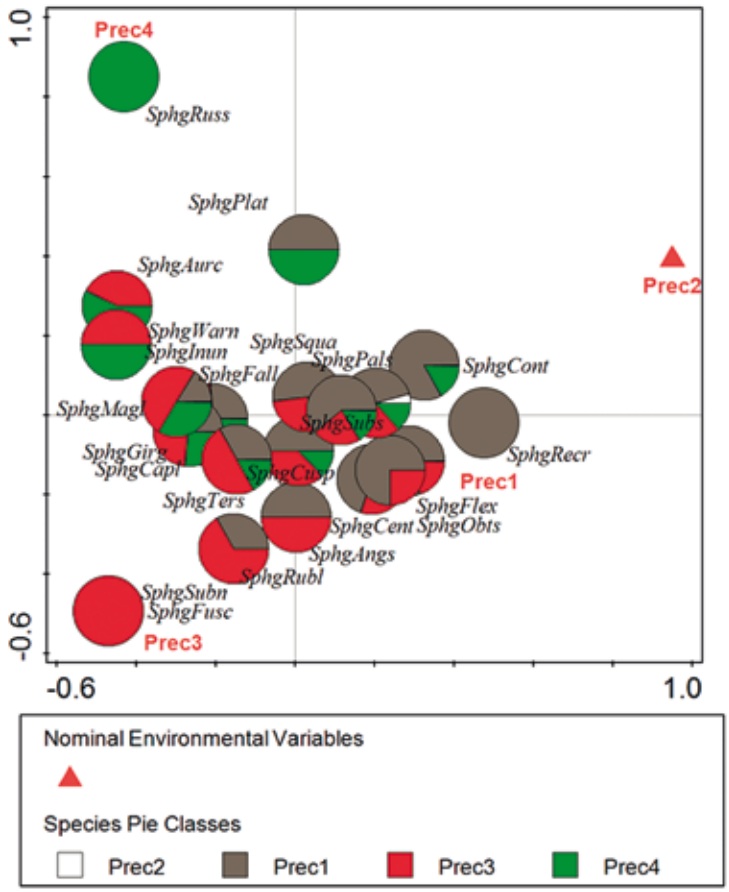

Figure 7. Species pie plot diagram displaying relative abundance of Serbian *Sphagnum* species CCA ordinated by amount of mean annual precipitation. Precipitation was divided into four even groups, with Prec1 beeing the smallest and Prec4 the highest amount of precipitation.

spread of agricultural land and more recently significant development of mountain tourism. Probably the best studied area with degradation of mountain mires including *Sphagnum* habitats is the Vlasina Lake. This mire complex was considered the largest mountain mire in Serbia and the Balkan peninsula. The original mire area was estimated at around 350 ha (Cvijić 1896) or around 10.5 km^2 of marshy and wet meadows, including 3 km^2 of peat land (Stanković & Laušević 1996). After World War II (1949–1958), Vlasina mire was submerged within a hydro-accumulation with only about 30 ha still remaining as potential *Sphagnum* sites, together with 8–10 ha of floating peat islands (Momčilović-Petronijević et al. 2009). The only remaining active peat extraction area in Serbia is on the Pešter plateau. There was no bryological or any other biodiversity research before drainage and peat extraction in the centre of the Pešter peat land area. Today *Sphagnum* patches are present on surrounding, less impacted areas, but peat layer studies confirmed the presence of *Sphagnum* spp. on excavation cites in historical times (Bogdanović et al. 1973). However, without precise data it can only be speculated about the potential damage done to former *Sphagnum* habitats in this area. At present, only six species of *Sphagnum* are known from Pešter plateau. Unlike other different wetland areas in Serbia that are often affected with non-native and invasive species, especially at lower altitudes, the remaining *Sphagnum* habitats are not threatened by those. As an exception, allochtonous pine (*Pinus wallichiana*) was recorded within the small *Sphagnum* mire Okolište on Jelova Gora Mt., originated from nearby forest plantations. Succession to *Molinia caerulea* grasslands was observed on the karstic areas in Pešter plateau and other geological substrate (e.g. Jelova Gora Mt., Tara Mt.), often caused or supported by human activity. In recent time, aggressive tourism development has been a very strong factor for degradation of *Sphagnum* habitats. Even within protected areas such as Kopaonik National Park or Jabučko Ravnište on the Stara Planina Mt., development of tourism and ski resorts strongly affected the remaining *Sphagnum* habitats. Currently, there is no evidence for global warming effects on *Sphagnum* habitats in Serbia, so this phenomenon can still be considered as potential threat.

All species of *Sphagnum* are strictly protected in Serbia by current national legislation and are also internationally protected within the EU Habitats Directive. It is estimated that more than 90% of *Sphagnum* habitats in Serbia are within some kind of protection. In practice, formal protection is completely passive. There is no active maintenance of habitats and no restoration projects are carried out. In recent times, Belgrade Bryophyte Bryology Group has started working on *Sphagnum* reintroduction, population strengthening measures and *ex situ* protection.

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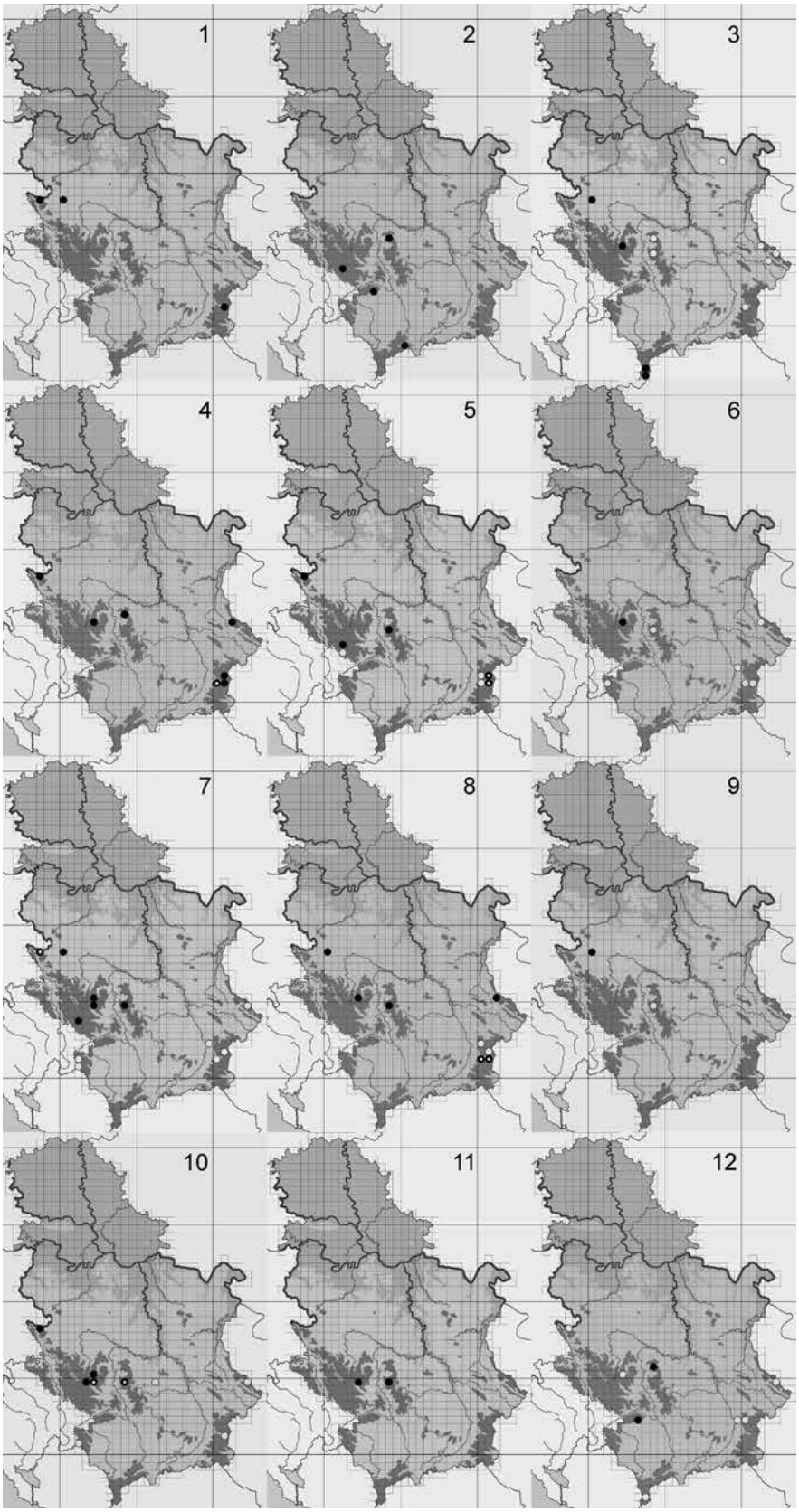

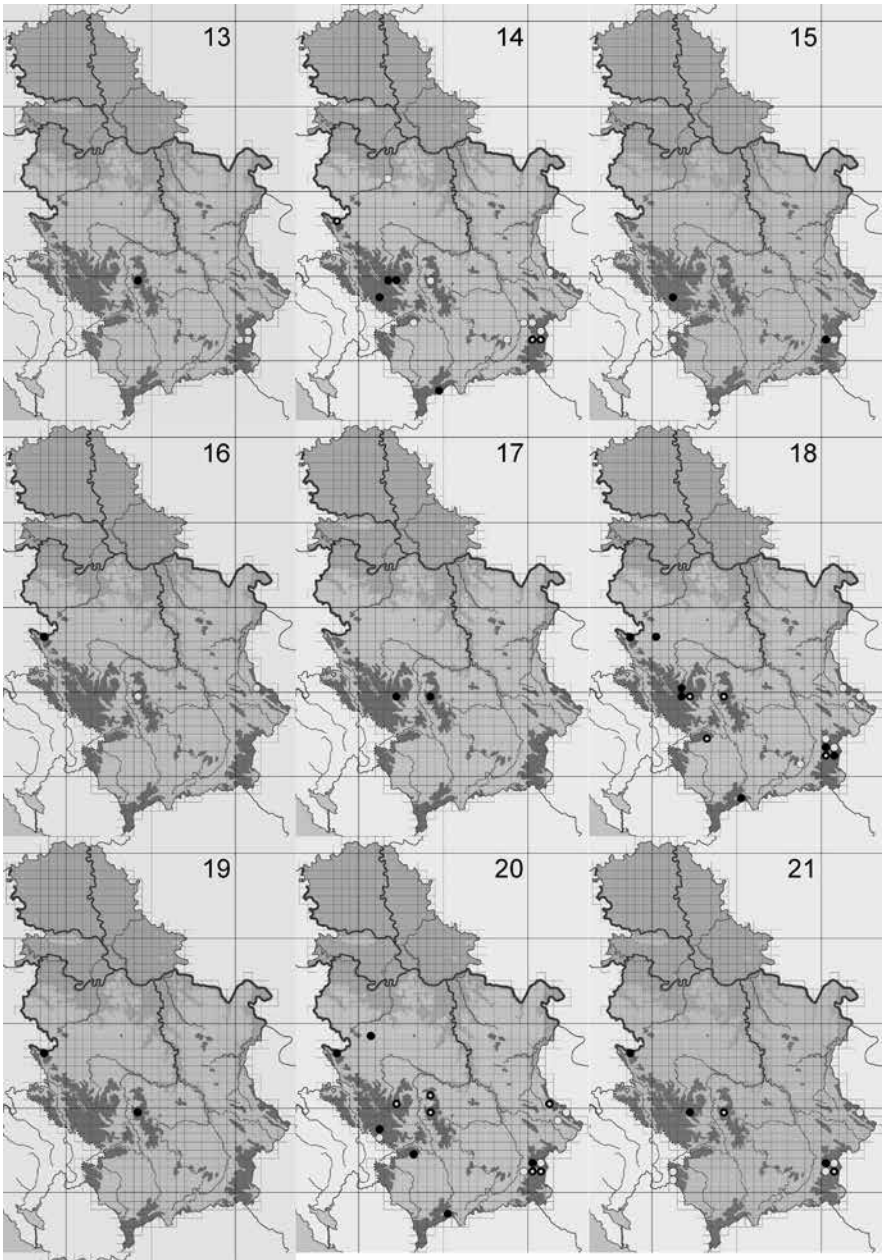

Appendix 1.

Distribution maps of *Sphagnum* species in Serbia.

○ Old records (before 1990) ● New records (after 1990)
◘ Old records, confirmed in recent times

1 – *S. angustifolium,* 2 – *S. auriculatum,* 3 – *S. capillifolium,*
4 – *S. centrale,* 5 – *S. contortum,* 6 – *S. cuspidatum,*
7 – *S. fallax,* 8 – *S. flexuosum,* 9 – *S. fuscum,*
10 – *S. girgensohnii,* 11 – *S. inundatum,*
12 – *S. magellanicum,* 13 – *S. obtusum,* 14 – *S. palustre,*
15 – *S. platyphyllum,* 16 – *S. rubellum,* 17 – *S. russowii,*
18 – *S. squarrosum,* 19 – *S. subnitens,* 20 – *S. subsecundum,*
21 – *S. teres,* 22 – *S. warnstorfii.*