



Biogeographic traits of the bryophyte flora of Serbia

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ABSTRACT: The biogeography of bryophytes present in Serbia is analysed for the first time in this paper. Bryophyte spectra in different regions and units within the country are compared with each other, as well as with the Southeast European spectrum. The obtained results show similarities and differences in comparison with Southeast European bryophyte spectra, reveal certain biogeographical peculiarities of Serbia's bryophytes and indicate regions of the country with an under-recorded bryoflora. The biogeographical characteristics of bryophytes also suggest a strong overlap with local climate types. These results should be taken into consideration when preparing a national strategy for conservation and management of bryophyte diversity.

KEYWORDS: distributional element, range types, mosses, liverworts

Received: 02 August 2019

Revision accepted: 02 October 2019

UDC: 582.32:582.321:574.9(497.11)

DOI: <https://doi.org/10.2298/BOTSERB1902143P>

INTRODUCTION

One of the fundamental tasks of biogeography is to detect patterns and trends in the modern distribution of taxa (LOIDI *et al.* 2010). While there are studies focused on the influence of climate and other factors determining the richness and elevational distribution of bryophytes, much rarer are those exploring regional patterns of species distribution.

The Serbian bryophyte flora has been intensively studied over the last few decades (PANTOVIĆ & SABOVLJEVIĆ 2017a). However, for Serbia and the area of Southeast Europe in general, there are no ecological and biogeographical studies of bryophytes. Although there are still many gaps in the bryological exploration of certain areas of Serbia, by summing up all known data on the distribution of bryophyte species occurring in Serbia, we were able to analyse the geography of Serbia's bryophyte flora for the first time.

Compared to the vascular plants, bryophytes tend to have wider ranges that are often trans-continental (MEDINA *et al.* 2011). Cosmopolitan distributions are also relatively frequent (SHAW & GOFFINET 2000; VANDERPOORTEN & GOFFINET 2009), but on the other hand,

there are many examples of limited distributions of bryophytes (FRAHM 2008). About 60% of all bryophyte families have a world-wide distribution, which indicates their great phylogenetic age (FRAHM 2012). For example, the majority of boreal bryophyte species like peat-mosses (*Sphagnum* spp.) and feather mosses [*Hylocomium splendens* (Hedw.) Schimp., *Pleurozium schreberi* (Brid.) Mitt. and *Ptilium crista-castrensis* (Hedw.) De Not.] have a more or less continuous distribution throughout northern parts of North America, Europe and Asia. Temperate bryophytes also have intercontinental ranges, but they are more discontinuous and disjunctive (SHAW 2001). The pattern of disjunction between North America and Europe is present among many temperate species. Interestingly, North America and Europe share many genera and species as well; in some areas, species composition can be up to 70% identical (CRUM & ANDERSON 1981; FRAHM & VITT 1993). Studies of bryophyte phylogeography and phylogenetics based on variable molecular markers over a certain geographic area suggest that many disjunct distribution patterns are likely formed by processes such as short-distance dispersal, rare long-distance dispersal events, extinction, recolonisation and diversification (HEINRICHS *et al.* 2009).

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Bryophytes, among which many are poikilohydrous, directly depend on rainfall and precipitates. Therefore, on a larger geographical scale, the macroclimate predicts bryophyte species distributions, as well as bryophyte-dominated ecosystems (MATEO *et al.* 2013). However, within these wide ranges of many bryophytes, each taxon has highly specific requirements, and some can be locally rare (SCHOFIELD & CRUM 1972), appearing only on a certain microhabitat type.

The aim of this study was to investigate patterns of the types of ranges of bryophytes present in Serbia and their overlapping in relation to the local climate.

MATERIAL AND METHODS

Percentages of each range type were calculated and compared for the whole country (1), each of the six regions of Serbia (2) and (for comparison on a larger scale) the region of Southeast Europe (3). Southeast Europe includes the whole territories of Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Greece, Montenegro, North Macedonia, Romania, Serbia, Slovenia and the European part of Turkey, as in SABOVLJEVIĆ & NATCHEVA (2006) and SABOVLJEVIĆ *et al.* (2008). Percentages were calculated for mosses and liverworts separately, and jointly for all bryophyte species as well.

Species range types follow DÜLL (1984, 1985, 1992) for mosses and DÜLL (1983) for liverworts. For clearer display of the results, all range types were classified into six main groups (Table 1): arctic (arc), boreal (bor), Mediterranean (med), oceanic (oc), continental (cont) and temperate (temp). Taxa without a specified range type (e.g., *Conocephalum salebrosum*) were not included in the analysis.

The list of species present in Serbia is based on SABOVLJEVIĆ & NATCHEVA (2006), SABOVLJEVIĆ *et al.* (2008) and the *Bryo* database (PANTOVIĆ & SABOVLJEVIĆ 2017a).

For purposes of this study, regions of the Republic of Serbia (MARKOVIĆ 1970; SARIĆ 1992) were grouped into the following six larger geographical regions (Fig. 1): Vojvodina (V), Western Serbia (WS), Central Serbia (CS), Eastern Serbia (ES), Southern Serbia (SS) and Kosovo and Metohija (KM).

The Republic of Serbia is a country located in South-east Europe. It consists of three political and geographical units, namely Vojvodina in the north, Kosovo and Metohija in the south and Central Serbia between the previous two. Due to its geographical position and rather South European tendency, the climate of Serbia varies from moderate continental in northern to continental in central parts of the country (LALIĆ *et al.* 2013). Additionally, the climate of the country varies regionally and locally due to its geographic location and influences of relief, terrain exposition, the presence of river systems, altitude, vegetation or even urbanisation (SMILAGIĆ *et al.* 2013).



Fig. 1. Geographical regions considered in the analysis.

Northern Serbia (Vojvodina province), as the southernmost part of the Pannonian plain, is mainly flat; it is characterised by low altitudes, except for two island mountains - Vršачki breg (641 m) and Fruška gora (539 m). Apart from macro relief and geological bedrock, Vojvodina differs from the rest of the country in having a specific continental climate type defined by great temperature extremes - very cold winters and warm summers. Annual precipitation is light (520-590 mm), with a drought period during summer and the early autumn months (STEVANOVIĆ & STEVANOVIĆ 1995).

Moving to the south of the country, the relief becomes more hilly and heterogeneous. The mountain systems are of different origin, with very diverse geological bedrock, soil and hydrological conditions. The highest peak in Serbia is Đeravica (2656 m), in the Prokletije Mountains (Kosovo and Metohija). A typical mountain climate is present in the highest mountain areas of Serbia. Here, winters are harsh - long and cold (mean annual temperature is from 0.5 to 5°C), often with heavy snowfall. Rainfall is highest in spring and summer.

The rest of the country is characterised by a temperate-continental climate. However, differences in el-

evation, and influences (or proximity) of the Eurasian landmass, the Atlantic Ocean and the Mediterranean Sea result in climatic variations within the country. For example, due to stronger influence of the humid Atlantic climate, the western and southwestern parts have higher annual precipitation (720-900 mm) than eastern parts of the country (620-760 mm). The central and eastern parts of Serbia are under significant Mediterranean influences from the south (through the Drim, Vardar and Morava river valleys), and continental climate from the east. The warmer and drier sub-Mediterranean climate type is present in southern and southeastern parts of the country.

RESULTS

Distribution of range types within Serbia

Liverworts. The dominant range type among liverworts in Serbia is boreal (37%), followed by temperate (26%) and oceanic (23%), while the types least present are the Mediterranean (8%) and arctic (6%) ones. No continental range type is known among liverworts of Serbia. Further analysis of the distribution of range types showed regional specificities. For example, the highest number of temperate and Mediterranean species is observed in the northern Serbian province of Vojvodina. On the other hand, the fewest arctic and boreal species are recorded in this area. Except in the

Vojvodina province, temperate and boreal areal types are present in almost equal percentages in the other main units of the country. Oceanic species are most numerous in Western Serbia (19%). Their frequency declines towards drier parts of the country (Fig. 2a). Local differences are also observed for liverworts of the arctic range type, which are most common in the mountainous areas of Eastern Serbia (5%), quite rare in other parts of the country (1%) and so far not observed in Southern Serbia or the region of Kosovo and Metohija. The under-recorded area of Kosovo and Metohija (PANTOVIĆ & SABOVLJEVIĆ 2017b) lacks any records of Mediterranean liverworts as well, probably due to the absence of bryological investigations.

Mosses. In Serbia, the boreal range type is dominant (29%) among mosses. After the boreal type, the most frequent range types are oceanic (23%), temperate (20%), arctic (12%) and Mediterranean (12%), while least numerous are species of the continental range type (4%). However, differences are observed on the regional scale. The Vojvodina province is characterised by the highest percentage of temperate and Mediterranean mosses. In contrast to this, arctic (16%) and boreal (40%) species are most numerous in the region of Kosovo and Metohija. Oceanic mosses are most numerous in Western Serbia (19%), the same as for liverworts.

More detailed percentages for liverwort and moss range types are shown in Table 2 and Fig. 2.

Table 1. Six main groups of range types with included subgroups. Abbreviations: alp - alpine, arc - arctic; bor - boreal, c. - central, dealp - dealpine, e. - eastern, euoc - euoceanic, cont - continental, med - Mediterranean, mont - montane, n. - northern, oc - oceanic/Atlantic, pont - pontic, s. - southern, subalp - subalpine, subarc - subarctic, subbor - subboreal, subcont - subcontinental, submed - submediterranean, suboc - suboceanic, subtrop - subtropic, temp - temperate, w. - western.

Main groups of range types	Included range types
Arctic	Arc, arc-alp, dealp, dealp-subarc, subalp, subalp(-subarc), subarc, subarc-alp, subarc-dealp, subarc-subalp, subarc-subalp/dealp, subarc-mont
Boreal	Bor, bor(-mont), bor-dealp, bor-cont(-mont), bor-mont, bor-montdealp, bor-subalp, subbor, subbor(-mont), subbor-mont, w. bor, w. bor-mont, w. subbor-mont, w. submont-mont
Mediterranean	e. submed, e. submed-mont, med, med-oc, submed, submed(-mont), submed-mont, submed-oc, submed-suboc, submed-suboc(-mont), submed-suboc-mont, w. med-mont, w. submed-mont
Oceanic	Euoc, euoc-mont, euoc-submed, n. suboc, n. suboc-mont, n. oc, n.oc(-mont), n. oc-subalp, n. suboc, n. suboc(-mont), n. suboc-alp, n. suboc-mont, oc, oc-med, oc-med-mont, oc-mont, oc-submed, rsuboc-mont, s. suboc-mont, s. euoc/subtrop-mont, s. euoc-mont, s.suboc, suboc, suboc(-mont), suboc(-submed), suboc-dealp, suboc-med, suboc-mont, suboc-subalp, suboc-submed, suboc-submed-mont
Continental	Cont, cont(-med), cont-mont, cont-subalp, n. subcont, n. subcontdealp, n. subcont-mont, n. subcont-mont/dealp, pont-mont, subcont, subcont(-mont), subcont-mont, subcont-mont/dealp, subcont-submed-dealp, subcont-med-mont/dealp
Temperate	e. temp, n. temp, s. temp, temp, temp(-mont), temp-mont, temp-subalp, w. temp, w. temp-mont

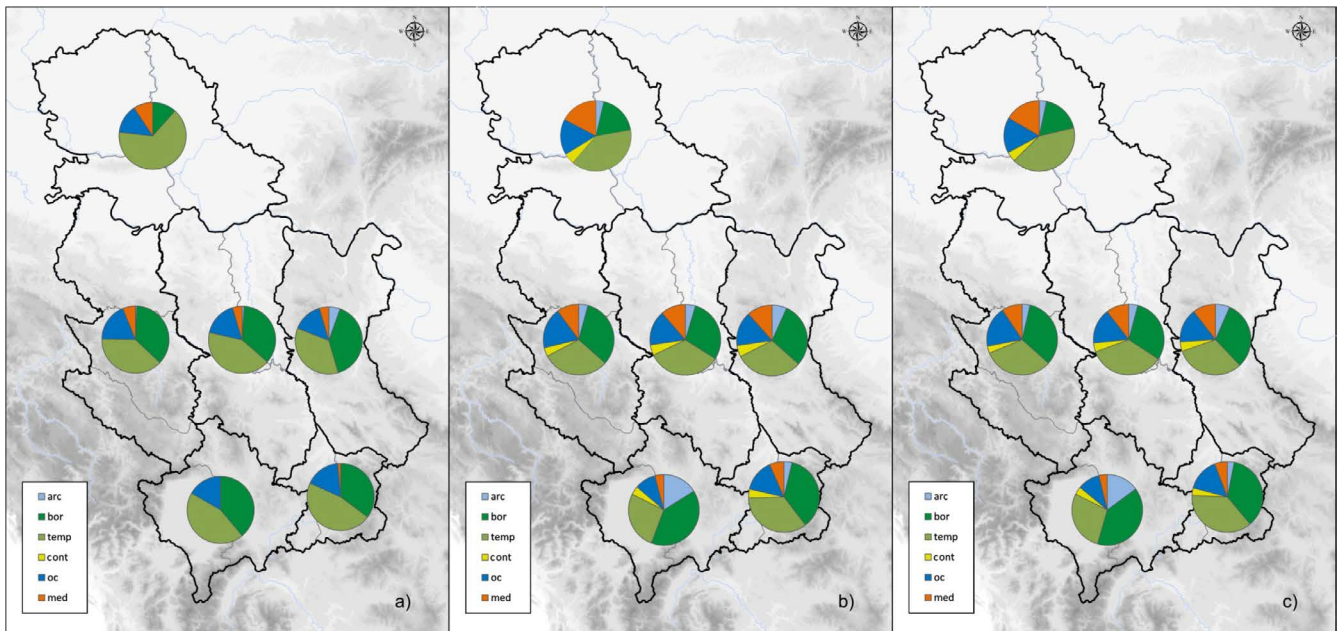


Fig 2. Regional differences in distribution of range types of a) liverworts b) mosses and c) bryophytes in Serbia.

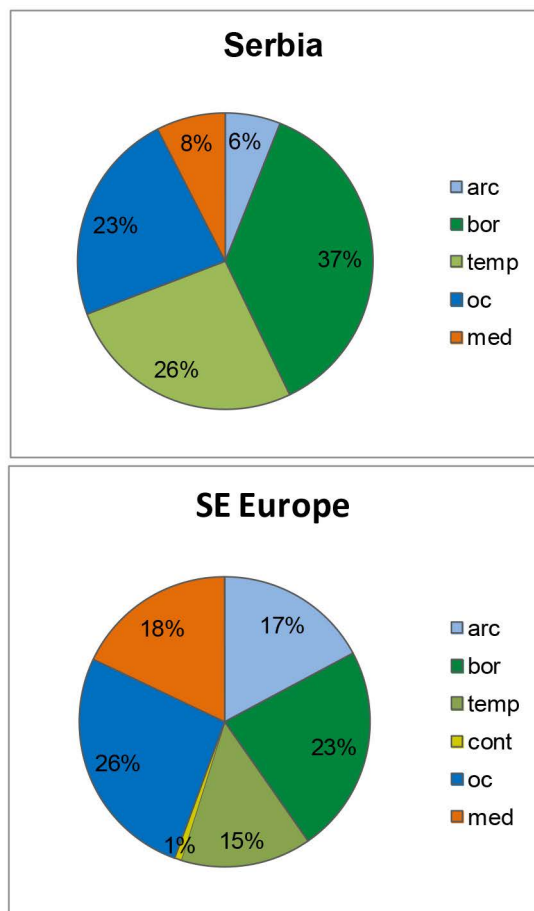


Fig. 3. Comparison of liverwort range types in Serbia and Southeast Europe.

Comparison with the spectrum of Southeast Europe

Liverworts. The majority of liverwort species in Serbia belong to the boreal range type (37%), followed by the temperate (26%), oceanic (23%), Mediterranean (8%) and arctic (6%) types. In the region of Southeast Europe, the most common range type is the oceanic one (26%), followed by the boreal (23%), Mediterranean (18%), arctic (17%), temperate (15%) and continental (1%) types.

Compared to Southeast Europe (Fig. 3), arctic and Mediterranean liverworts are less common in Serbia, while boreal and temperate species are present in higher percentages in Serbia. Oceanic species are slightly less present in Serbia. Continental liverworts are not observed in Serbia, while in the region of Southeast Europe they represent only 1% of all known liverwort species.

Mosses. In the moss flora of Serbia, the most common species are ones of the boreal range type (29%), followed by species of the oceanic (23%), temperate (20%), arctic (12%), Mediterranean (12%) and continental (4%) types. Among mosses in the region of southeastern Serbia, oceanic and boreal species are equally present in a large percentage (24% each), followed by arctic (20%), temperate (16%), Mediterranean (12%) and continental (4%) species.

The distribution of moss range types in Serbia is rather similar to that observed in Southeast Europe. The greatest differences are recorded for arctic species, which are less common in Serbia compared to their percentage in the region of Southeast Europe. Also, boreal and temperate species are present in higher percentages in Serbia (Fig. 4).

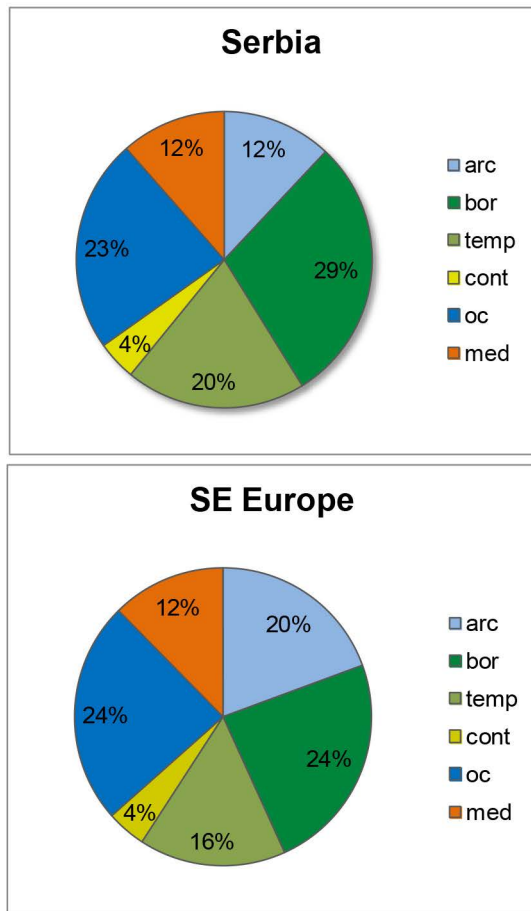


Fig. 4. Comparison of moss range types in Serbia and Southeast Europe.

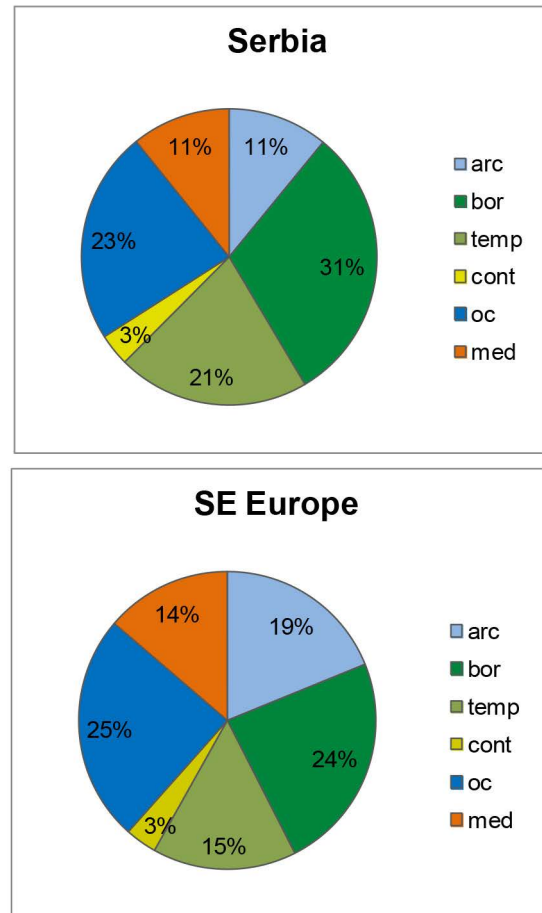


Fig. 5. Comparison of total bryophyte range types in Serbia and Southeast Europe.

Table 2. Frequencies of range types of liverworts (L), mosses (M) and all bryophyte species jointly (B). Results are shown for different regions of Serbia (V - Vojvodina, WS - Western Serbia, CS - Central Serbia, ES - Eastern Serbia, SS - Southern Serbia, KM - Kosovo and Metohija, SRB - the whole country) and for the region of Southeast Europe (SEE) as well.

	Arctic			Boreal			Temperate			Continental			Oceanic			Mediterranean		
	L	M	B	L	M	B	L	M	B	L	M	B	L	M	B	L	M	B
V	0%	4%	3%	12%	19%	18%	65%	39%	41%	0%	5%	5%	14%	16%	16%	9%	17%	17%
WS	1%	4%	4%	36%	32%	33%	38%	31%	32%	0%	4%	3%	19%	19%	19%	6%	10%	9%
CS	1%	5%	4%	35%	29%	30%	42%	34%	35%	0%	5%	4%	17%	16%	16%	5%	11%	11%
ES	5%	7%	7%	40%	30%	31%	35%	31%	32%	0%	5%	4%	15%	16%	15%	5%	11%	11%
SS	0%	4%	3%	35%	36%	36%	47%	35%	37%	0%	4%	3%	17%	15%	15%	1%	6%	6%
KM	0%	16%	15%	39%	40%	40%	44%	26%	28%	0%	4%	3%	17%	10%	10%	0%	4%	4%
SRB	6%	12%	11%	37%	29%	31%	26%	20%	21%	0%	4%	3%	23%	23%	23%	8%	12%	11%
SEE	17%	20%	19%	23%	24%	24%	15%	16%	15%	1%	4%	3%	26%	24%	25%	18%	12%	14%

Spectrum of bryophyte distribution. Of the total number of all bryophyte species present in Serbia, the most common are boreal species (31%), followed by oceanic (23%), temperate (21%), arctic (11%) and Mediterranean (11%) taxa. The least represented are continental species (3%). In the region of Southeast Europe, the most common bryophytes are those with oceanic (25%), boreal (24%), arctic (19%), temperate (15%), Mediterranean (14%) and continental (3%) distributions. The spectra of distribution of Serbian bryophytes differ significantly from those observed in Southeast Europe (Fig. 5) with respect to the presence of arctic species (less present in Serbia) and boreal species (more present in Serbia).

DISCUSSION

The analysed spectra of bryophyte distribution clearly show high accordance of the presence of distributional types with the climate and relief conditions prevailing in the geographical region of Serbia. The altitudinal and latitudinal distribution of bryophyte species corresponds to their temperature preferences and precipitation requirements. For example, Mediterranean species are associated with a warm and often dry environment, the distribution of Atlantic species implies a connection with rather more humid conditions, whereas boreal and arctic species prefer cool conditions.

Compared to other parts of Serbia, the Vojvodina province is distinguished by its specific geological bedrock, relief and climate. These macro-ecological peculiarities have led to the development of a flora that is distinct, not only in regard to the composition and richness of species, but with respect to their abundance as well. The fact that Vojvodina has the the largest number of Mediterranean species (of both liverworts and mosses) can be explained by its relatively dry climate with rather hot summers. Moreover, the Vojvodina province has several xeric habitat types like sands and loess cliffs, which are important for many rare bryophytes. The province's specific climate and mainly lowland relief can explain the high percentage of temperate species, with only a few arctic species known there. Moreover, differences in the level of bryological exploration of Serbian territory in the past cannot be excluded from these considerations and should be taken into account as well.

Arctic species are most numerous in the highest areas of Serbia - alpine areas in the regions of Kosovo and Metohija and Eastern Serbia, which are under influence of the harsh mountain climate. However, the region of Kosovo and Metohija lacks records of arctic liverwort species, which is probably a result of insufficient exploration of the area, its southern position and Mediterranean influence, lack of knowledge about specific taxa and (sometimes) their short life-cycle and seasonal development. The lack of bryological investigation in the lowland area could also explain the absence of Medi-

terranean liverworts in Kosovo and Metohija and their relatively small share in Southern or Eastern Serbia. It should be noted that Southern Serbia is one of the least explored parts of the country, which unquestionably has influenced present knowledge about bryophyte range types there.

Oceanic species are present with the highest percentage in western and southwestern parts of Serbia, which are characterised by the highest levels of precipitation in the country and its even distribution throughout the year. A decrease in occurrence of the oceanic range type is observed towards parts of the country with lower mean annual precipitation and longer drought periods - primarily its eastern regions, but northern and southern ones as well. This can also explain the slight increase in abundance of Mediterranean species in eastern parts of the country.

The share of range types in Serbia is very similar to that in the region of Southeast Europe in the cases of mosses and all bryophytes considered jointly, while significant differences are evident where liverworts are concerned. This can be explained by the significant lack of knowledge about the distribution of taxa within this group of bryophytes in Serbia.

As a mostly hilly and mountainous country, Serbia has a high percentage of boreal and temperate species, even greater than compared to the whole region of Southeast Europe. Also, the less extensive presence of areas with alpine habitats (above 2000 m) in Serbia is the reason for fewer arctic species compared to Southeast Europe.

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Botanica SERBICA



REZIME

Biogeografske odlike flore briofita Srbije

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U radu je prikazana prva analiza biogeografskih karakteristika briofita prisutnih u Srbiji. Biogeografski spektar briofita poređen je između regiona Srbije, kao i sa spektrom jugoistočne Evrope. Dobijeni rezultati pokazali su sličnosti i razlike u poređenju sa spektrom jugoistočne Evrope, ukazujući na osobenosti Srbije, ali i njene briofloristički nedovoljno istražene regione. Biogeografske karakteristike brioflore su, takođe, u skladu sa lokalnim klimatskim tipovima. Dobijene rezultate treba uzeti u obzir prilikom pripremanja nacionalne strategije konzervacije i upravljanja briološkim bogatstvom.

KLJUČNE REČI: briofloristički geoelementi, areal tipovi, mahovine, jetrenjače