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Bryoflora of some well-springs of the Dinaric Alps and Carpathian Karst in Serbia

Abstract

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At 10 well-springs of the Dinaric Alps and Carpathian karsts in Serbia, 123 taxa of bryophytes were recorded: 26 liverworts and 97 mosses. *Porella obtusata*, *Metzgeria furcata* var. *ulvula* and *Fissidens mildeanus* were recorded for the first time to the bryoflora of Serbia.

Introduction

The studies of moss flora in Serbia started in mid-19th century (Pančić 1859). The end of last century saw two treatments of the bryophyte flora with detailed lists of species (Jurišić 1900, Simić 1900). The research continued by Katić (1904) and Košanin (1909). After that, investigations of bryophytes have almost been neglected for forty years but, in the last 50 years, several papers have been published (e.g. Soška 1949, Popović 1966, Gajić & al. 1991, Veljić & Marin 1997).

Karst regions of Serbia (Fig. 1) represent peripheral areas of the large calcareous massifs of the Dinaric Alps and Carpathian-Balkan mts. The greatest part of the region is occupied by limestone (Petrović 1975) lying on massive carbonaceous rocks.

Karst areas are characterized by lack of surface water. The main water sources are underground streams, temporary water flows, and various types of sources. Owing to small thickness and large variation (valleys and canyons) of karst in Serbia, there are many well-springs of varied size. In the karst located in eastern Serbia, there are over 140 well-springs mainly distributed on the valleys. In the western karst region most of them are of valley type (Stevanović 1995). In places with exposed limestone and other rocks, subpodial well-springs are formed. Other divisions of well-springs depend on the outflow, temperature or capacity.

In western Serbia temperate-continental climate prevails, i.e. the zone of humid temperate-continental climate (Illyrian variant) with annual precipitation from 720 to 900 mm. Eastern Serbia is under the influence of semiarid, temperate-continental climate (subcontinental), with annual precipitation from 620 to 760 mm (Stevanović & Stevanović 1995).

In the mountainous karst regions air temperature is below 10 °C. In western Serbia the highest monthly mean temperature is 16-18 °C in June and in eastern Serbia 22-23.5 °C in July. The vegetation belongs to the eastern Balkan region of deciduous oak and beech forests. However, karst regions are almost completely deforested. Fully preserved forests account only for 15% of the area (Petrović 1975).

Since well-springs in Serbia have not been investigated so far, and seem to have a great bryophyte diversity, the aim of our investigation has been to analyse the bryoflora and the floristic similarities and differences between the area of the Dinaric Alps and Carpathian karsts.

Material and methods

Bryophyte specimens were collected in well-springs from 1994 to 1996. Sampling was carried out seasonally (spring, summer, autumn and winter). The specimens were first taken from the water, both at the source and downstream where the typical river bed is formed. Sampling was then performed in circles ever farther from its to the edge of its influence. Bryophytes were collected from rocks exposed to water spray, cliffs above the well-springs, surrounding stones, as well as from the soil between them and the bark of the trees out of water reach, but still subject to air humidity. The voucher specimens are deposited in the Herbarium of the Institute of Botany, Faculty of Biology, University of Belgrade.

Our investigations were done in 10 large well-springs (Fig. 1). In western Serbia (the Dinaric Alps karst) the following 5 well-springs were studied (types according to Petrović 1975, Stevanović 1991).

1. The well-spring of the Banja river; alt. 178 m; 100-1,650 l/sec; water temp. 9 °C; cave type, intermittent.
2. The well-spring of the Gradac river; alt. 265 m; 560-thousands l/sec; water temp. 10 °C; disjunct, ascendant.
3. The well-spring of the Susica river; alt. 530 m; min. 400 l/sec; water temp. 12 °C; disjunct, gravitational.
4. The well-spring of the Rača river; alt. 498 m; min. 60 l/sec; water temp. 19 °C; ascendant, subthermal.
5. The well-spring of the Raška river; alt. 760 m; 50-1,200 l/sec; water temp. 11 °C; disjunct, vauclusienne.

In the karst of eastern Serbia (the Carpathian karst) the following five springs were studied:

6. The Krupajsko well-spring; alt. 240 m; 125 - 6,420 l/sec; water temp. 9-11 °C; valley type, unsheltered.
7. Lisinsko well-spring; alt. 440 m; 120 - 2,160 l/sec; water temp. 12 °C; subpodial.
8. The well-spring of the Grza river; alt. 450 m; 15 - 2,000 l/sec; water temp. 9.4 °C; disjunct, gravitational.
9. The well-spring of the Crni Timok river; alt. 375 m; 75 - 4,320 l/sec; water temp. 8.5 °C; valley type, disjunct.
10. The Dušničko well-spring; alt. 550m; 28 - 3800 l/sec; water temp. 9.5 °C; subpodial, gravitational, dammed.

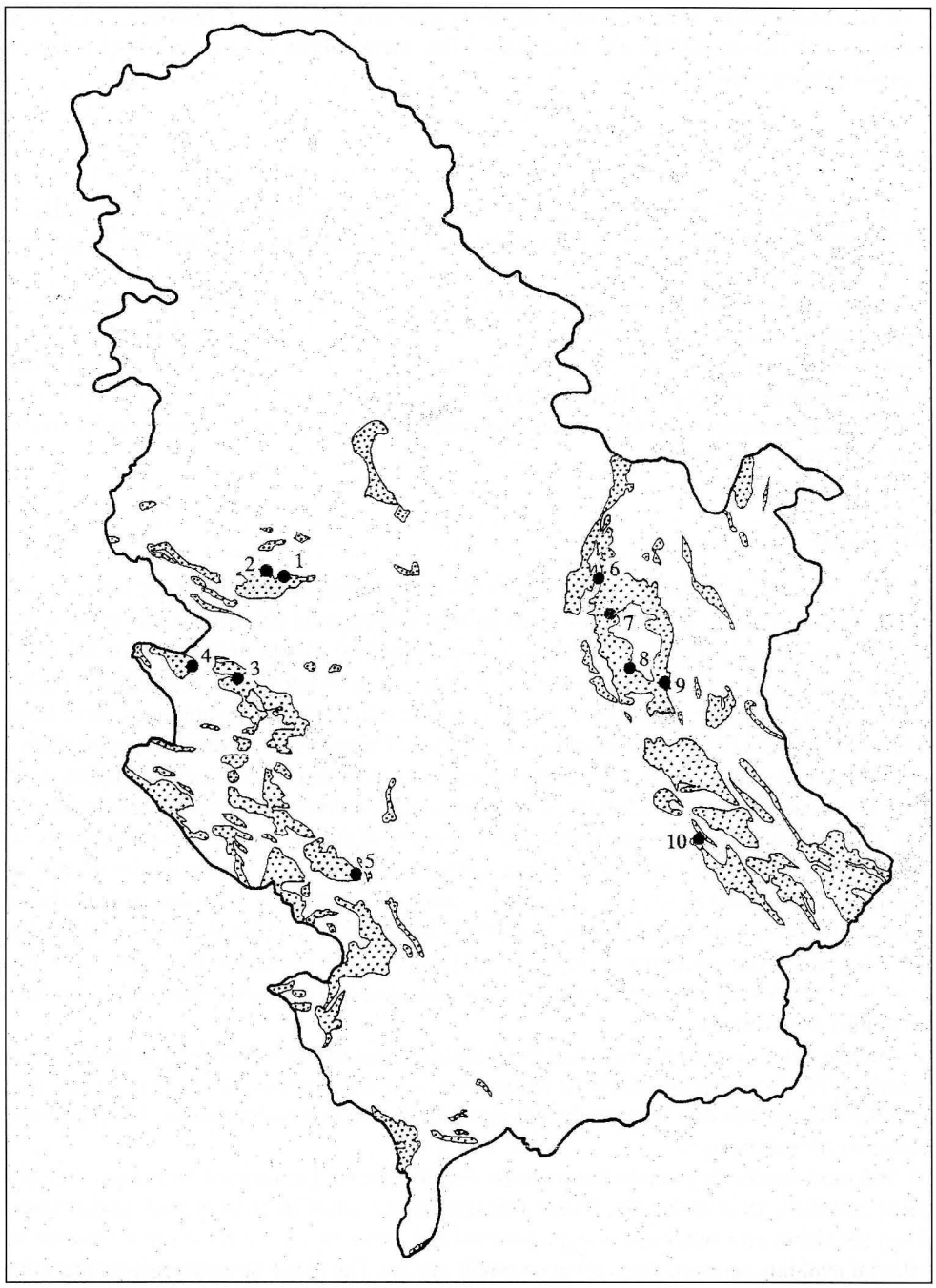

Fig. 1. Distribution of karsts in Serbia with localities of investigated well-springs. (1-Banja, 2-Gradac, 3-Sušica, 4-Rača, 5-Raška, 6-Krupajsko, 7-Lisinsko, 8-Grza, 9-Crni Timok, 10-Dušničko well-spring).

The nomenclature follows Corley & al. (1981) and Corley & Crundwell (1991) for mosses, and Grolle (1983) for liverworts. The infraspecific classification of selected species follows Petrov (1975).

Results

In the above investigated well-springs, 123 taxa were recorded (Table 1) belonging to 67 genera. The *Marchantiopsida* (liverworts) are represented by 26 species of 16 genera, the *Bryopsida* (mosses) by 97 species of 51 genera.

In some cases it was impossible to identify the plants at the species level because of their aberrant morphology: *Barbula* sp., *Eurynchium* sp., etc. The bryoflora of the well-springs contained 4 taxa new to Serbia (marked by an asterisk in the table 1), and some species which are considered rare, endangered, or vulnerable in Europe (ECCB 1995): the hepatic *Porella baueri* and the mosses *Campylium chrysophyllum*, *Drepanocladus sendtneri*, and *Neckera pennata*.

Discussion

The only available paper concerned with the well-springs in the karst of the western part of the Balkan Peninsula deals with well-springs biocoenoses characteristics of the well-spring of the rivers Krka, Una, Zrmanja, Krupa, Crna river, Bijela river and Plitvičko well-spring as well as at the Well-spring near Dubrovnik (Matoničkin & Pavletić 1964). However, in that paper only 10 species of mosses, exclusively the aquatic ones, have been cited. Out of these, 7 are also recorded in our study. Pavletić (1957) cited 5 species of liverworts and 18 species of mosses at the cascades of Plitvička lakes. Pavletić (1959) studied the mosses in the cascades of the Una river and recorded only 14 species (2 liverworts and 12 mosses). This author attributes such a poverty of species to the high illumination of the cascades, only favourable to the heliophylous development. A small number of species recorded in our study at some well-springs, notably at the Dušničko spring, can also be in part attributed to high illumination. Out of the 14 species listed by Pavletić, 8 were also recorded in the present study. Pavletić (1960) recorded 21 mosses in the cascades of the Una and Pliva rivers. Of the 5 liverworts 3 species and of 16 mosses listed only 7 species were also found by us.

Martinez & Ederra (1992) studied the drainage basin of the Irigua river in Spain. They recorded 123 taxa, out of which 40 are liverworts and 83 mosses. In spite of the similar number of taxa found in their study and that recorded in our research only 39 species are common to both studies.

The most diverse bryophyte flora was recorded at the well-springs of the Banja river (44 taxa) and the Crni Timok (44). These well-springs are either of cave or rock shelter type. They are richer in water, occupy a greater area and, since they have great water reserves in internal syphons or lakes, they never or rarely dry up. The place of water emergence from the ground is rather stable and not altered with water quantity. It is usually rimmed on 3 sides with steep cliffs or slopes, covered with dense stand of wood vegetation. For this reason, humidity is constantly high. The poorest bryophyte flora was found at the Dušničko

Table 1. List of taxa found at well-springs (1-Banja, 2-Gradac, 3-Sušica, 4-Raca, 5-Raška, 6-Krupajsko, 7-Lisinsko, 8-Grza, 9-Crni Timok, 10-Dušnicko).

Taxa	Locality (well-spring)									
	B	G	S	R	R	K	L	Gz	CT	D
Marchantiopsida										
Barbilophozia lycopodioides (Wallr.) Loeske						+				
Chiloscyphus pallescens (Ehrh. ex Hoffm.) Dum.			+	+	+			+		
Chiloscyphus polyanthos (L.) Corda var. *polyanthos*		+	+			+			+	
Chiloscyphus polyanthos (L.) Corda var. *rivularis* (Schrad.) Nees									+	
Cololejeunea calcarea (Libert) Schiffn.				+						
Conocephalum conicum (L.) Underw.	+	+		+	+			+		
Frullania dilatata (L.) Dum. var *dilatata*		+		+				+		
Jungermannia atrovirens Dum.					+					
Lejeunea cavifolia (Ehrh.) Lindb.	+			+						
Lophocolea bidentata (L.) Dum.		+								
Lophocolea cuspidata (Nees) Limpr.	+		+		+					
Lophocolea minor Nees						+			+	
Marchantia polymorha L.	+	+	+	+	+	+	+		+	+
Metzgeria conjugata Lindb.				+					+	
Metzgeria furcata (L.) Dum.			+							
**Metzgeria furcata* (L.) Dum. var. *ulvula* Nees						+				
Pedinophyllum interruptum (Nees) Kaal.				+					+	
Pellia sp.								+	+	+
Pellia endiviifolia (Dicks.) Dum.	+	+	+	+	+		+		+	
Plagiochila asplenioides (L.) Dum.	+		+	+		+		+	+	
Porella arboris-vitae (With.) Grolle				+						
Porella baueri (Schiffn.) C. Jens.	+	+	+	+		+	+	+	+	
**Porella obtusata* (Tayl.) Trev.				+						
Radula complanata (L.) Dum.	+		+	+				+		
Scapania aspera M. et H. Bern.			+	+						
Scapania mucronata Buch					+					
Bryopsida										
Amblystegium serpens (Hedw.) B., S. & G.		+				+	+			+
Amblystegium tenax (Hedw.) C. Jens.			+							
Anomodon attenuatus (Hedw.) Hüb.	+					+		+	+	
Anomodon viticulosus (Hedw.) Hook: & Tayl.	+	+	+	+	+		+	+	+	
Atrichum undulatum (Hedw.) P. Beauv.					+	+		+		
Barbula sp.									+	
Barbula unguiculata Hedw.							+			
Brachythecium rivulare B., S. & G.	+		+	+	+	+	+	+	+	+
Brachythecium rutabulum (Hedw.) B., S. & G.	+	+		+	+	+	+			+
Bryoerythrophyllum recurvirostrum (Hedw.)Chen						+	+	+		
Bryum sp.				+					+	
Bryum argenteum Hedw.	+	+			+			+		+
Bryum caespiticium Hedw.	+				+					
Bryum capillare Hedw.					+	+	+		+	
Bryum elegans Nees ex Brid.							+			
Bryum pseudotriquetrum (Hedw.) Gaertn., Meyer & Scherb.				+					+	
Bryum torquescens B. & S.	+				+					
Bryum turbinatum (Hedw.) Turn.						+				
Calliergonella cuspidata (Hedw.) Loeske	+	+			+	+				

Table 1. (continued)

Campylium chrysophyllum (Brid.) J. Lange	+									
Campylium sommerfeltii (Myr.) J. Lange									+	
Cinclidotus aquaticus (Hedw.) B. & S.	+	+	+		+	+	+	+	+	+
Cinclidotus fontinaloides (Hedw.) P. Beauv.	+	+							+	
Cirriphylum tommasinii (Sendtn. ex Boul.) Grout.									+	
Cratoneuron filicinum (Hedw.) Spruce var. *curvicaule* (Jur.) Mönk.				+						
Cratoneuron filicinum (Hedw.) Spruce var. *fallax* (Brid.) Roth			+							
Cratoneuron filicinum (Hedw.) Spruce var. *filicinum*	+	+	+	+	+	+	+		+	+
Ctenidium molluscum (Hedw.) Mitt.	+	+	+	+		+	+	+		
Dicranella heteromalla (Hedw.) Schimp.	+									
Dicranum sp.					+					
Dicranum scoparium Hedw.				+		+		+		
Didymodon fallax (Hedw.) Zander		+								
Didymodon insulanus (De Not.) M. Hill							+			
Didymodon luridus Hornsch. ex Spreng.			+							
Didymodon rigidulus Hedw.	+									
Didymodon sinuosus (Mitt.) Delogne	+									
Didymodon vinealis (Brid.) Zander					+	+				
Ditrichum sp.						+				
Drepanocladus sendtneri (Schimp. ex H. Müll.) Warnst.								+		
Encalypta streptocarpa Hedw.			+		+	+	+	+	+	
Eucladium verticillatum (Brid.) B., S. & G.	+			+						
Eurhynchium sp.					+					
Eurhynchium crassinervium (Wils.) Schimp.	+					+	+		+	
Eurhynchium pulchellum (Hedw.) Jenn.	+									
Eurhynchium striatum (Hedw.) Schimp.		+					+		+	
Eurhynchium striatulum (Spruce) B., S. & G.						+				
Fissidens dubius Beauv.		+		+		+				
**Fissidens mildeanus* Schimp.					+					
Fontinalis antipyretica Hedw.			+			+				
Funaria hygrometrica Hedw.	+									
Grimmia pulvinata (Hedw.) Sm.					+	+	+	+	+	+
Homalia besseri Lob.		+				+	+	+	+	
Homalothecium lutescens (Hedw.) Robins.			+		+		+			
Homalothecium philippeanum (Spruc.) B.,S.&G.	+			+			+	+	+	
Homalothecium sericeum (Hedw.) B., S. & G.		+			+	+			+	+
Hygrohypnum luridum (Hedw.) Jenn.							+			
Hypnum cupressiforme Hedw.	+	+		+	+	+	+	+	+	
Leskea polycarpa Hedw.	+									
Leucobryum glaucum (Hedw.) Ångstr.								+		
Leucodon sciuroides (Hedw.) Schwaegr.								+	+	
Mnium sp.					+					
Mnium marginatum (With.) P. Beauv.	+					+			+	
Mnium stellare Hedw.	+			+						
Mnium thomsonii Schimp.	+								+	
Neckera complanata (Hedw.) Hüb.	+		+	+	+	+		+		
Neckera crispa Hedw.			+	+		+				
Neckera pennata Hedw.				+				+		

Table 1. (continued)

Orthotrichum anomalum Hedw. var. *anomalum*	+	+			+			+	+	+
Orthotrichum anomalum Hedw. var. *saxatile* (Schimp.) Milde							+			
Orthotrichum stellatum Brid.							+			
Palustriella commutata (Hedw.) Ochyra var. *commutata*				+				+		
Palustriella commutata (Hedw.) Ochyra var. *falcata* (Brid.) Ochyra	+			+	+					
Plagiomnium cuspidatum (Hedw.) T. Kop.		+			+	+	+	+	+	
Plagiomnium rostratum (Schrad.) T. Kop.	+	+	+	+	+	+		+	+	+
Plagiomnium undulatum (Hedw.) T. Kop.	+	+	+	+	+	+	+	+	+	
Pleurochaete squarrosa (Brid.) Lindb.		+								
Polytrichum formosum Hedw.								+		
Pottia intermedia (Turn.) Fürnr.										+
Pseudoleskeella catenulata (Schrad.) Kindb.			+			+	+			
Pseudoleskeella nervosa (Brid.) Nyh.							+			
Rhodobryum roseum (Hedw.) Limpr.									+	
Rhynchostegium murale (Hedw.) B., S. & G.	+				+		+			
Rhynchostegium riparoides (Hedw.) Card.	+	+	+		+	+	+		+	+
Rhytidiadelphus triquetrus (Hedw.) Warnst.				+						
Schistidium apocarpum (Hedw.) B., S. & G.		+	+		+		+	+		
Scleropodium purum (Hedw.) Limpr.	+	+								
Scleropodium touretii (Brid.) L. Koch								+		
Taxiphyllum wissgrillii (Garov.) Wijk & Marg.									+	
Thamnobryum alopecurum (Hedw.) Gang.	+		+	+	+		+	+	+	
Thuidium delicatulum (Hedw.) Mitt.		+			+					
Thuidium philibertii Limpr.	+				+					
Tortella tortuosa (Hedw.) Limpr.					+			+	+	
Tortula intermedia (Brid.) De Not.							+		+	+
Tortula muralis Hedw. var. *aestiva* Brid ex Hedw.										+
Tortula muralis Hedw. var. *muralis*	+		+	+	+	+	+	+	+	
Tortula ruralis (Hedw.) Gaertn., Mayer & Scherd.			+		+		+		+	
Tortula subulata Hedw.								+		

* species new to Serbia

well-spring (16 taxa). A low number of taxa was also recorded at the well-springs of the Gradac and Sušica rivers. Both well-springs are of lowland type (water comes up from the ground somewhat above the river bed), much of their area extends downstream of the place of water issue. They are frequently flooded, but also dry up when water level is low. Since both well-springs are well-illuminated, their vegetation is scarce leading to the decrease in moss diversity.

The small number of species common to all localities studied also indicates their great floristic diversity and high bryophyte specificity. Four taxa are new to Serbia; three of them are new liverwort: *Metzgeria furcata* var. *ulvula* (found in Krupajsko well-spring), *Porella obtusata* (found in Rača well-spring) (Table 1) and *P. baueri* which is included in the "Red Data Book of European Bryophytes" as regionally endangered and taxonomically doubtful. The fourth species is the moss *Fissidens mildeanus*, found in Raška well-spring.

Futhermore *Drepanocladus sendtneri*, treated as regionally endangered by ECCB (1995), was found at the well-spring of Grza, whereas *Neckera pennata*, listed as endangered, was found at the well-springs of Rača and Grza.

By comparing floristic lists of bryophytes found at the well-springs of the two studied karsts in Serbia, it may be concluded that almost the same number of moss species occurs in the karst of western (93 taxa) and eastern Serbia (88 taxa). Poverty and specificities of floristic composition of some well-springs analyzed are probably the consequence of microclimatic, historical and human factors affecting the particular habitat.

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