

CONTRIBUTIONS TO THE BRYOPHYTE FLORA OF THE MAVROVO NATIONAL PARK (REPUBLIC OF MACEDONIA)

Beáta PAPP^{1*}, Erzsébet SZURDOKI¹, Jovana PANTOVIĆ² and
Marko SABOVLJEVIĆ²

¹Department of Botany, Hungarian Natural History Museum
H–1431, Budapest, Pf. 137, Hungary; *papp.beata@nhmus.hu

²Institute of Botany and Botanical Garden, Faculty of Biology, University of Belgrade
11000 Belgrade, Serbia

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Abstract: 229 bryophyte taxa (34 liverworts and 195 mosses) were collected in the Mavrovo National Park (Republic of Macedonia). Almost all habitat types maintain diverse bryophyte assemblages containing several species rare on the Balkans or even species of European conservation interest. Three species found (*Buxbaumia viridis*, *Grimmia caespiticia*, and *Pseudoleskea saviana*) are included in the Red data book of European bryophytes. Further eight species are on the candidate list of the new Red data book of European bryophytes and ten species can be regarded as rare on the Balkans.

Key words: European red-listed species, liverworts, mosses, rare bryophytes, the Balkans

INTRODUCTION

The Republic of Macedonia is one of the bryologically poorly explored countries in SE Europe (SABOVLJEVIĆ *et al.* 2001, 2011). Data on the bryophyte flora of the Republic of Macedonia can be found in DÜLL *et al.* (1999), CEKOVA (2005), in the checklists of the SE European and Mediterranean countries (SABOVLJEVIĆ and NATCHEVA 2006, SABOVLJEVIĆ *et al.* 2008, ROS *et al.* 2007, 2013), in MARTINČIĆ (2009), PAPP *et al.* (2011), and PAPP and ERZBERGER (2012). Even short field trips added a lot of new species to the Macedonian bryophyte flora, e.g. 12 new national records (9 liverworts and 3 mosses) during a 2-day trip (PAPP *et al.* 2011), 43 (10 liverworts, 33 mosses) during a 7-day trip (PAPP and ERZBERGER 2012). According to HODGETTS (2015) the Macedonian bryophyte flora consists of 546 taxa (99 hepatics and 447 mosses). Recently, further 27 bryophyte species (7 hepatics and 20 mosses) have been reported for the first time in the Macedonian bryophyte flora from the Mavrovo National Park (PAPP *et al.* 2016). The number of the known bryophyte taxa from the country is

still about 200–250 less than that of the neighbouring countries (Bulgaria: 807, Greece: 723, Serbia: 723) (HODGETTS 2015). Only Albania has lower number of bryophyte taxa (466) according to HODGETTS (2015), which is due to the underexplored bryoflora of this country, too. On the other hand many bryophytes have only one or two records from the Republic of Macedonia, hence there is not enough knowledge to evaluate the threat status of species or to establish a list of important bryophytes from conservation point of view.

With this paper we would like to contribute in the exploration and conservation of the Macedonian bryoflora giving an overview about the bryophyte vegetation of the Mavrovo National Park with special attention to the species of conservation interest.

MATERIAL AND METHODS

Study area

The Mavrovo National Park is situated in the northwestern part of the Republic of Macedonia (Fig. 1). It has been founded in 1948, and covers an area of 73,088 hectares including the Korab, Desat, Šara, Bistra and Krčin mountains, the valley of the river Radika and its tributaries and the lake Mavrovo (BUZAROVSKI 2009).

The area of the Mavrovo National Park represents specific physical-geographic and orographic conditions, related with the altitude. Thus, in its territory various climate types can be recorded; from warm continental climate to alpine climate.

The Mavrovo National Park belongs to the Western Macedonian Geotectonic Unit. The bedrocks, which are of various age and mineralogical structure, could be grouped into three geological formations: Paleozoic metamorphic and volcanic rocks, Mesozoic limestone rocks, and Quaternary slates (<http://npmavrovo.org.mk/клима-2>).

Altogether 86 mountain peaks higher than 2,000 m are situated within the boundaries of the national park. The other most significant relief formations are the river beds with canyons and caves. For instance, within the Radika River watershed, altogether 16 canyons and 42 caves are known. The whole territory of the protected area of the national park basically is included in the watershed of the Radika River. The total length of the Radika River course is 64.7 km and its watershed encompasses an area of 879.8 km². Besides the rivers and streams other hydrological formations are also present: springs, glacial lakes, temporary pools, and the reservoir-lake Mavrovsko Ezero (Mavrovo lake) (<http://npmavrovo.org.mk/хидрологија-и-хидрографија>).

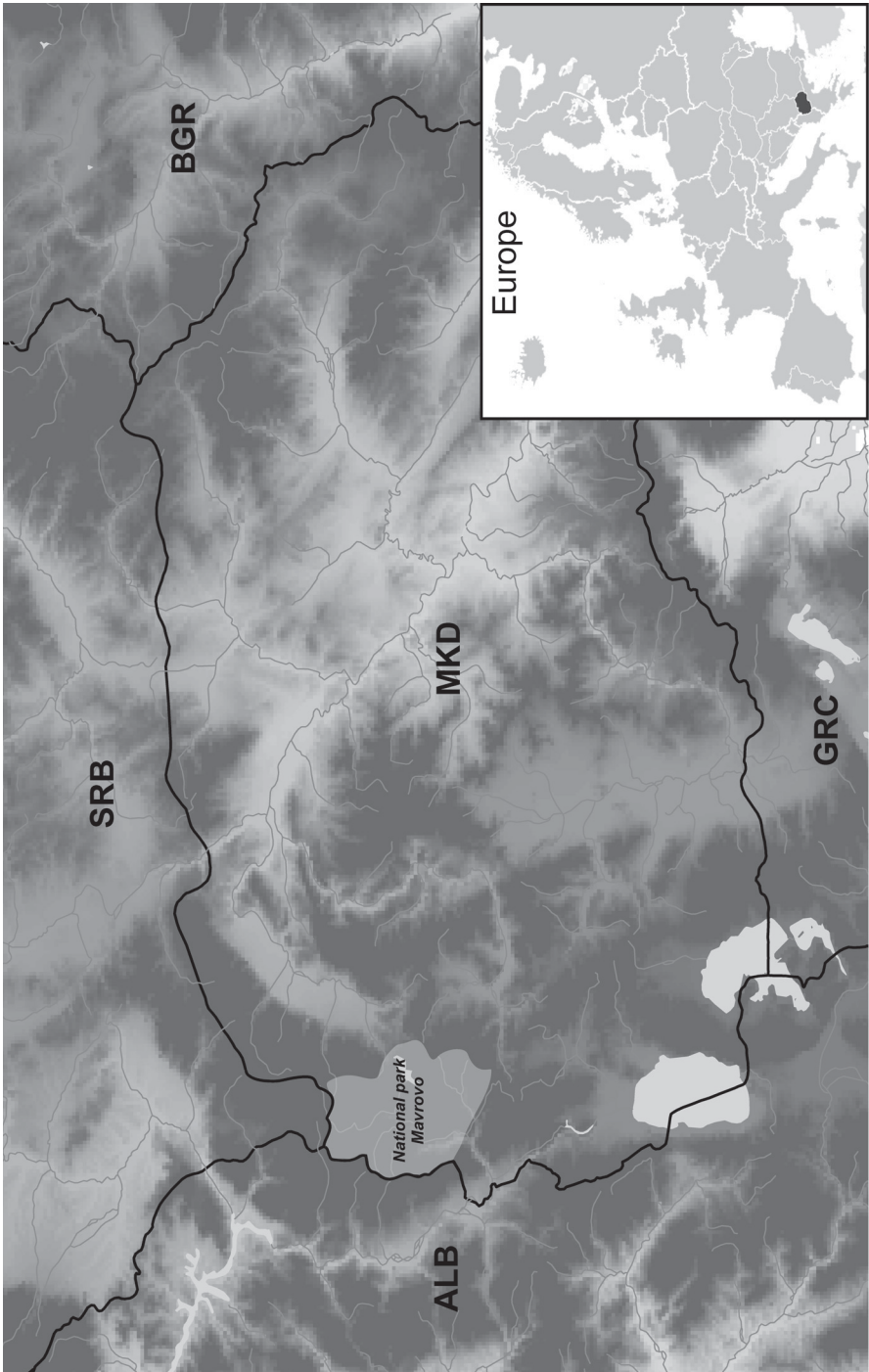


Fig. 1. Location of the investigated sites.

The Mavrovo National Park has high species diversity. For instance, it has a rich flora of vascular plants, with over 1,400 species recorded up to date. Many of these taxa are rare boreal and arctic-montane elements, and many are rare or endemic in the Republic of Macedonia. Floral and faunal elements with Ponto-Mediterranean (Eastern Mediterranean) biogeographic origin are predominant, followed by the species with boreal and arctic-montane origin, of which the relict-mountain entities are frequent and abundant (<http://npmavrovo.org.mk/инвертебрална-фауна>).

Methods

Our collecting trips were made in June 2013 and July 2014. All main habitat types, such as wetlands, streams and riverbanks, calcareous and siliceous rock formations, grasslands and forests were investigated, and bryophytes collected from different substrates (soil, exposed and shaded rocks, tree bark, and decaying wood).

The specimens are preserved in the Herbarium of the Hungarian Natural History Museum, Budapest (BP) and Belgrade University Herbarium (BEOU). Nomenclature follows GROLLE and LONG (2000) for liverworts with the exception of *Conocephalum salebrosum*, which follows SZWEYKOWSKI *et al.* (2005), and HILL *et al.* (2006) for mosses, except for *Polytrichum commune* var. *perigoniale*, in which case KOPERSKI *et al.* (2000) is followed. European distribution of the species is given according to DÜLL (1983, 1984, 1985).

Site details in the Mavrovo National Park

1. In Mavrovo village, 41.650833° N, 20.735611° E, 1,265 m, 16.06.2013.
2. Between Mavrovo and Galičnik villages, 41.643278° N, 20.699° E, 1,690 m, 17.06.2013.
3. In Galičnik village, 41.591472° N, 20.64725° E, 1,710 m, 17.06.2013.
4. Between Mavrovo and Galičnik villages, 41.612833° N, 20.679194° E, 1,620 m, 17.06.2013.
5. Between Mavrovo and Galičnik villages, 41.647806° N, 20.704639° E, 1,670 m, 17.06.2013.
6. Towards Debar, at Mavrovska River along the road to Sveti Petka, 41.735194° N, 20.671778° E, 965 m, 18.06.2013.
7. Towards Debar, at Mavrovska River along the road to Sveti Petka, 41.728583° N, 20.673028° E, 965 m, 18.06.2013.
8. Towards Debar, junction of Radika River and Mavrovska River, 41.723361° N, 20.670389° E, 925 m, 18.06.2013.
9. Towards Debar, along Radika River at the road to Nistrovo, 41.712917° N, 20.657694° E, 905 m, 18.06.2013.
10. Towards Debar, *Abieto-Fagetum* forest at the dam, 41.701306° N, 20.735111° E, 890 m, 18.06.2013.
11. Towards Galičnik village, at Toni voda meadows on the way to Lazaropole village, 41.636222° N, 20.708639° E, 1,690 m, 03.07.2014.
12. From Toni voda meadows to Lazaropole village, 41.633083° N, 20.718083° E, 1,670 m, 03.07.2014.

13. From Toni voda meadows to Lazaropole village, 41.625139° N, 20.72625° E, 1,720 m, 03.07.2014.
14. From Toni voda meadows to Lazaropole village, around Solumnica, 41.581278° N, 20.805611° E, 1,850 m, 03.07.2014.
15. Rostusha village, Duf canyon, 41.607639° N, 20.600861° E, 800 m, 04.07.2014.
16. Rostusha village, Duf canyon, around the waterfall, 41.603167° N, 20.597889° E, 800 m, 04.07.2014.
17. In Rostusha village, 41.610611° N, 20.599194° E, 820 m, 04.07.2014.
18. In Mavrovo village, 41.649944° N, 20.736528° E, 1,240 m, 04.07.2014.

RESULTS AND DISCUSSION

229 bryophyte taxa (34 liverworts and 195 mosses) were recorded in the Mavrovo National Park. The complete list of the species can be found in the Appendix.

Bryophyte vegetation and its conservation merit

Wetlands

In the wetlands above 1,500 m a.s.l. several boreal, subboreal species are characteristic, e.g. *Scapania irrigua*, *Aulacomnium palustre*, *Brachythecium rivulare*, *Bryum schleicheri*, *Calliergon cordifolium*, *Campylium stellatum*, *Climacium dendroides*, *Dichodontium palustre*, *Philonotis caespitosa*, *Ph. fontana*, *Ph. seriata*, *Plagiomnium elatum*, *P. ellipticum*, *Polytrichum commune* var. *commune*, *P. commune* var. *perigoniale*, *Scorpidium cossonii*, *Warnstorfia exannulata*. Some of these above mentioned species can be regarded as rare on the Balkans and red-listed in many SE European countries (HODGETTS 2015), like *Dichodontium palustre*, *Philonotis caespitosa*, *Plagiomnium ellipticum*, *Scorpidium cossonii*. The subarctic-subalpine *Palustriella decipiens* can also be mentioned here. Besides these a sub-Atlantic, sub-Mediterranean species of European conservation interest (being on the candidate list of the new Red data Book of European bryophytes) (HODGETTS 2015), *Fontinalis hypnoides*, was also collected in a rivulet crossing the wet meadows of Toni voda. Another species of European conservation interest found here is *Bryum turbinatum*, a species of temperate zone of Europe.

Rivers, streams

Along Radika River and its tributaries mainly calcicole aquatic, riparian species occur, like the boreal-subboreal *Gymnostomum aeruginosum*, *Hygrohypnum luridum*, *Pohlia wahlenbergii*, the temperate *Conocephalum salebrosum*, *Jungermannia atrovirens*, *Pellia endiviifolia*, *Cratoneuron filicinum*, *Didymodon sinuosus*, *Palustriella commutata*, *Platyhypnidium riparioides*, the sub-Mediterranean, sub-

Atlantic *Cinclidotus fontinaloides*, *Didymodon spadiceus*, *Orthotrichum cupulatum* var. *riparium*, *Rhynchostegiella curviseta*.

Further calcicole sub-Mediterranean, sub-Atlantic species appear on wet limestone rocks at a source area, e.g. *Cololejeunea rossettiana*, *Eucladium verticillatum*, *Gymnostomum calcareum*, *Gyroweisia tenuis*. On a wet siliceous rock a species of European conservation interest (HODGETTS 2015), *Bryum mildeanum*, was found and it was its first record in the Republic of Macedonia (PAPP *et al.* 2016).

Limestone alpine grasslands

Limestone bedrock is frequent in the region, but siliceous outcrops also occur. On limestone rocky places, in grasslands above 1,200 m a.s.l. several boreal species can be found. e.g. *Preissia quadrata*, *Barbilophozia lycopodioides*, *Scapania calcicola*, *Ditrichum gracile*, *Bartramia ithyphylla*, *Bryum elegans*, *Distichium capillaceum*, *Pseudoleskea incurvata*, *Pseudoleskeella catenulata*, *Sanionia uncinata*. Besides them, subarctic, subalpine liverworts also appear, which are rare on the Balkans lacking or being red-listed in many SE European countries (HODGETTS 2015), like *Athalamia hyalina* and *Leiocolea heterocolpos*. Subarctic, subalpine mosses as *Encalypta rhaptocarpa*, *Ptychodium plicatum*, *Syntrichia norvegica*, and a northern subcontinental, dealpine element, *Timmia bavarica*, also lives in this habitat. Some Mediterranean, sub-Mediterranean, sub-Atlantic species were also found here, like *Riccia ciliifera*, *Didymodon luridus*, *Entosthodon muhlenbergii*, *Grimmia anodon*, *Syntrichia handelii*, *Schistidium brunnescens* subsp. *griseum*, *Tortula inermis*, *Weissia condensa*.

Siliceous alpine grasslands

The siliceous outcrops also maintain a bryophyte assemblage rich in boreal species, e.g. *Barbilophozia hatcheri*, *Lophozia sudetica*, *L. wenzelii*, *Coscinodon cribrerosus*, *Grimmia alpestris*, *Schistidium pruinosum*, and in subarctic, subalpine elements as *Grimmia anomala*, *G. caespiticia*, *Polytrichastrum alpinum*, and *Tortula hoppeana*. As limestone bedrock predominates on the Balkans several calcifuge species can be regarded as rare in this region, like *Coscinodon cribrerosus*, *Grimmia anomala*, *Schistidium pruinosum*, which are red-listed in many SE European countries (HODGETTS 2015) and *Grimmia caespiticia*, a species of European conservation interest (HODGETTS 2015), which is included in the Red data book of European bryophytes (ECCB 1995). A sub-Mediterranean, montane element, *Schistidium flaccidum*, red-listed in many SE European countries (HODGETTS 2015) can be also mentioned here.

Shaded limestone rocks

At lower elevation on shaded limestone, lime containing schistose rocks, and in rocky grasslands besides the predominance of common temperate elements, several Mediterranean, sub-Mediterranean, and sub-Atlantic species occur like *Cololejeunea calcarea*, *Scapania aspera*, *Campylophyllum calcareum*, *Cirriphyllum crassinervium*, *Didymodon luridus*, *D. vinealis*, *Homalothecium philippeanum*, *Leptodon smithii*, *Neckera menziesii*, *Plasteurbynchium striatulum*, *Pterogonium gracile*, *Seligeria acutifolia*, *Taxiphyllum wissgrillii*, *Thamnobryum alopecurum*, *Tortella humilis*, *T. nitida*, and *Tortula atrovirens*. *Neckera menziesii* is a species of European conservation interest (HODGETTS 2015), while *Seligeria acutifolia* is rare on the Balkans lacking or being red-listed in many SE European countries (HODGETTS 2015). Some boreal species also appear, like *Leiocolea collaris*, *Abietinella abietina*, *Campyliadelphus chrysophyllus*, *Ditrichum gracile*, *Encalypta ciliata*, *Gymnostomum aeruginosum*, *Mnium stellare*, *Orthothecium intricatum*, *Plagiopus oederianus*, *Pseudoleskeella rupestris*, and *Tortella tortuosa*. *Encalypta ciliata* is rare on the Balkans, red-listed in some SE European countries (HODGETTS 2015); *Pseudoleskeella rupestris* is a species of European conservation interest (HODGETTS 2015) and it was reported for the first time in the Republic of Macedonia from this collection (PAPP *et al.* 2016).

Boreal forests

In an *Abieto-Fagetum* forest two red-listed species in Europe were collected: *Buxbaumia viridis*, a species listed in the Bern Convention and the European Union Habitats and Species Directives and vulnerable in Europe according to the Red data book of European bryophytes (ECCB 1995), was found on decaying wood, while *Pseudoleskea saviana*, a regionally threatened species according to the Red data book of European bryophytes, was collected from siliceous rock. Both of them are not rare on the Balkans as evidenced by several records. *Buxbaumia viridis* has many extant populations in the neighbouring Balkan countries such as Serbia (PAPP *et al.* 2009, 2014), Greece (PAPP *et al.* 2011, TSAKIRI *et al.* 2009), and only near threatened (NT) in Bulgaria (NATCHEVA *et al.* 2006). In the Republic of Macedonia its existing population is known from the Pelister Mts (PAPP and ERZBERGER 2012). *Pseudoleskea saviana* has also a lot of known localities in Serbia (PAPP *et al.* 2009, PAPP and ERZBERGER 2009), Greece, e.g. Voras Mts (PAPP *et al.* 2011), Albania; e.g. District of Korça (PAPP *et al.* 2010), Lura region (MARKA and XHULAJ 2011), Valbona valley (Papp unpublished), and it is not red-listed in Bulgaria (NATCHEVA *et al.* 2006). In the Republic of Macedonia it is known from the Nidže Mts (PAPP *et al.* 2011) and Pelister Mts (PAPP and ERZBERGER 2012).

Epiphytes

The epiphyte bryophyte flora living on deciduous trees (*Acer monspessulanum* L., *Betula pendula* Roth., *Fagus sylvatica* L.) is rich. The main constituents are temperate species, e.g. *Homalothecium sericeum*, *Neckera complanata*, *Orthotrichum affine*, *Syntrichia ruralis*, *S. virescens*. Several other *Orthotrichum* species occur, like the subcontinental *Orthotrichum obtusifolium* and *O. speciosum*, the sub-Atlantic *Orthotrichum lyellii*, *O. shawii*, *O. stramineum*, *O. striatum*, and the subboreal *Orthotrichum pallens*. *Orthotrichum shawii* is a species of European conservation interest known only from Albania and Greece (HODGETTS 2015), and it was reported for the first time in the Republic of Macedonia from this collection (PAPP *et al.* 2016).

CONCLUSIONS

27 bryophyte species (7 hepatics and 20 mosses) have been reported recently from this collection for the first time in the Republic of Macedonia (PAPP *et al.* 2016). These are the following: *Athalamia hyalina*, *Cololejeunea calcarea*, *C. rosettiana*, *Conocephalum salebrosum*, *Jungermannia atrovirens*, *Lophozia badensis*, *Scapania calcicola*, *Brachythecium tommasinii*, *Bryum mildeanum*, *Didymodon spadiceus*, *Ditrichum gracile*, *Gyroweisia tenuis*, *Orthotrichum cupulatum* var. *riparium*, *O. shawii*, *Palustriella falcata*, *Plagiothecium succulentum*, *Pseudoleskeella rupestris*, *Rhynchostegiella curviseta*, *Schistidium brunnescens* subsp. *griseum*, *Seligeria acutifolia*, *S. pusilla*, *Syntrichia calcicola*, *S. handelii*, *S. subpapillosissima*, *Taxiphyllum wissgrillii*, *Tortella fragilis*, and *T. humilis*. The high number of newly recorded species reflects the shortage of knowledge on the Macedonian bryophyte flora and the importance of bryoflora exploration in the region.

The Mavrovo National Park has a rich bryophyte flora due to the geological diversity, high altitudinal range, and climatic variation. Comparing its bryophyte diversity with some other investigated areas nearby in the Republic of Macedonia and in South Serbia, the number of recorded 229 bryophyte taxa is the same as the number of recorded taxa in the Pelister National Park (Republic of Macedonia) (PAPP and ERZBERGER 2012) or in the Kopaonik National Park (Serbia) (PAPP *et al.* 2004) and more than in Pešter plateau (Serbia) (PAPP *et al.* 2014) or at Vlasina lake and its surroundings (Serbia) (PAPP *et al.* 2012). However, more bryophyte taxa (277) were collected in the Golija Biosphere Reserve (Serbia) (PAPP and ERZBERGER 2005).

From conservation point of view the wetlands and rock formations above 1,200 m have outstanding importance. The wetlands are declining habitat types in SE Europe mainly due to climate warming, their extension is decreasing, and

they are continuously loosing the sensitive bryophytes of their species pool (ALEGRO *et al.* 2014, GANEVA 2015, NATCHEVA 2015, PAPP *et al.* 2015). The siliceous outcrops have special conservation interest, because being rare on the Balkans, and their bryophyte flora contains many calcifuge species regarded as rare in this region and red-listed in many SE European countries (HODGETTS 2015). However, almost all habitat types of the Mavrovo National Park maintain diverse bryophyte assemblages containing several species rare on the Balkans or even species of European conservation interest. Three species (*Buxbaumia viridis*, *Grimmia caespiticia*, and *Pseudoleskea saviana*) are included in the Red data book of European bryophytes (ECCB 1995). Further eight species (*Bryum mildeanum*, *B. turbinatum*, *Coscinodon cribrosus*, *Fontinalis hypnoides*, *Neckera menziesii*, *Orthotrichum shawii*, *Pseudoleskeella rupestris*, and *Schistidium pruinosum*) are on the candidate list of the new Red data book of European bryophytes (HODGETTS 2015) and ten species (*Athalamia hyalina*, *Leiocolea heterocolpos*, *Dichodontium palustre*, *Encalypta ciliata*, *Grimmia anomala*, *Palustriella decipiens*, *Philonotis caespitosa*, *Plagiomnium ellipticum*, *Scorpidium cossoni*, and *Seligeria acutifolia*) can be regarded as rare on the Balkans.

Finally, it can be stated that Mavrovo National Park has very valuable bryophyte flora from conservation point of view and we do hope that our investigation can provide useful and important information to the nature conservation.

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Összefoglaló: A Mavrovo Nemzeti Parkban 229 mohafajt (34 májmohát és 195 lombosmohát) sikerült kimutatnunk. A park gazdag mohafőrája a változatos alapkőzetnek, a nagy tengerszint feletti magasságkülönbségeknek és a mikroklíma változatosságának köszönhető. Ennek ellenére mohászati felmérés korábban nem történt a területen. Szinte minden vegetációtípusban diverz mohaközösséget találtunk, és számos balkáni vagy akár európai szinten ritka, veszélyeztetett faj fordul elő. Három faj (*Buxbaumia viridis*, *Grimmia caespiticia* és *Pseudoleskea saviana*) szerepel az Európai Moha Vörös Könyvben. További nyolc faj az új Európai Moha Vörös Könyv potenciális vörös listájának tagja, valamint tíz fajt a Balkánon ritkának tartunk. Különösen fontosak természetvédelmi szempontból az 1200 m tengerszint feletti magasságban található vizes, lápos területek, valamint a szilikátszikla-kibukkanások. A lápok veszélyeztetettek a Balkánon főleg a klímaváltozás miatt; folyamatosan veszítenek területükből, fajösszetételük megváltozik, fajdiverzitásuk csökken, a vízellátottság romlására érzékeny fajok eltűnnek. A szilikátos kőzetek ritkák a Balkánon, ahol főleg meszes kőzetek dominálnak, így a savanyú alapkőzethez kapcsolódó mohaközösségek unikálisak a régióban.

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Appendix 1. Complete list of bryophyte records.

The numerals following the species names refer to the collection sites described above.

Hepaticae

- Athalamia hyalina* (Sommerf.) S. Hatt. – 2, 5: limestone rock; 11: exposed schistose rock
Barbilophozia barbata (Schreb.) Loeske – 10: limestone rock
Barbilophozia hatcheri (A. Evans) Loeske – 11: exposed schistose rock; 14: exposed siliceous rock
Barbilophozia lycopodioides (Wallr.) Loeske – 2, 5: limestone rock; 4: soil among schistose rock
Cephaloziella divaricata (Sm.) Schiffn. – 1, 11: schistose rock; 5: limestone rock
Chiloscyphus polyanthus (L.) Corda – 11: wet meadows along a stream
Cololejeunea calcarea (Lib.) Schiffn. – 9: shaded limestone rock
Cololejeunea rosettiana (C. Massal.) Schiffn. – 8: wet limestone rock
Conocephalum salebrosum Szwedkowski, Buczkowska et Odrzykoski – 9: along the river; 16: limestone rock at the stream
Frullania dilatata (L.) Dumort. – 9: bark *Alnus*; 15: schistose rock and bark of *Prunus avium*
Jungermannia atrovirens Dumort. – 6: at a rivulet; 16: limestone rock at the stream
Leiocolea badensis (Gottsche) Jörg. – 6: at a rivulet; 7: limestone grassland
Leiocolea collaris (Nees) Schljakov – 15: schistose rock; 16: limestone rock at the stream
Leiocolea heterocolpos (Hartm.) H. Buch – 5: limestone rock
Lophocolea heterophylla (Schrad.) Dumort. – 10: limestone rock and decaying wood
Lophocolea minor Nees – 4: limestone grassland
Lophozia sudetica (Nees ex Huebener) Grolle – 11: exposed schistose rock
Lophozia wenzelii (Nees) Steph. – 11: exposed schistose rock
Marchantia polymorpha L. – 1: wet schistose rock
Marsupella funckii (F. Weber et D. Mohr) Dumort. – 11: exposed schistose rock
Metzgeria furcata (L.) Dumort. – 10: limestone, siliceous rock, and decaying wood
Pedinophyllum interruptum (Nees) Kaal. – 5: limestone rock
Pellia endiviifolia (Dicks.) Dumort. – 1: wet schistose rock; 6, 10: at a rivulet; 8: wet limestone rock; 16: limestone rock at the stream
Plagiochila porelloides (Torrey ex Nees) Lindenb. – 2, 5, 10: limestone rock; 9: along the river; 16: limestone rock at the stream
Porella cordaeana (Huebener) Mohr – 2, 10: limestone rock; 4: limestone grassland; 14: exposed siliceous rock
Preissia quadrata (Scop.) Nees – 2: limestone rock; 16: limestone rock at the stream
Radula complanata (L.) Dumort. – 7: limestone grassland; 9: bark *Alnus*; 15: tree bark
Reboulia hemisphaerica (L.) Raddi – 2, 5: limestone rock; 10: siliceous rock
Riccia ciliifera Link ex Lindenb. – 2: limestone rock
Riccia sorocarpa Bisch. – 5: limestone rock

- Riccia sorocarpa* Bisch. var. *beegii* Schiffn. – 2: limestone rock
Scapania aspera M. Bernet et Bernet – 16: limestone rock
Scapania calcicola (Arnell et J. Perss.) Ingham – 2, 5: limestone rock
Scapania irrigua (Nees) Nees – 2: wetland

Musci

- Abietinella abietina* (Hedw.) M. Fleisch. – 6: limestone rock
Amphidium mougeotii (Schimp.) Schimp. – 10: siliceous rock
Anomodon viticulosus (Hedw.) Hook. et Taylor – 6, 8: limestone rock; 8: bark of *Acer*; 15: schistose rock
Aulacomnium palustre (Hedw.) Schwägr. – 2: wetland
Barbula convoluta Hedw. – 1: concrete wall; 5, 12: limestone rock
Barbula unguiculata Hedw. – 1: schistose rock; 2, 6: limestone rock; 3: limestone rockwall; 4: limestone grassland
Bartramia ithyphylla Brid. – 4: soil among schistose rock; 11: exposed schistose rock
Brachytheciastrum velutinum (Hedw.) Ignatov et Huttunen – 2: edge of wet meadow; 3: limestone rockwall; 4: limestone grassland; 6: limestone rock, 10: limestone, siliceous rock, and decaying wood; 11: exposed schistose rock
Brachythecium albicans (Hedw.) Schimp. – 1: soil
Brachythecium glareosum (Bruch ex Spruce) Schimp. – 4: limestone grassland; 5, 10, 12: limestone rock; 8: shaded limestone rock; 11: exposed schistose rock
Brachythecium rivulare Schimp. – 1: wet schistose rock; 2: wetland; 11: wet meadows along a stream
Brachythecium rutabulum (Hedw.) Schimp. – 6, 16: limestone rock; 8: shaded limestone rock; 9: along the river; 10: siliceous rock
Brachythecium salebrosum (Hoffm. ex F. Weber et D. Mohr) Schimp. – 2: edge of wet meadow
Brachythecium tommasinii (Sendtn. ex Boulay) Ignatov et Huttunen – 8, 9: shaded limestone rock
Bryoerythrophyllum recurvirostrum (Hedw.) P. C. Chen – 5, 6, 10: limestone rock; 14: schistose rock
Bryum alpinum Huds. ex With. – 1: schistose rock; 11: wet meadows along a stream and exposed schistose rock
Bryum argenteum Hedw. – 1: schistose rock; 3: limestone rockwall
*Bryum caespiticiu*m Hedw. – 1: soil; 2: limestone rock; 7: limestone grassland
Bryum capillare Hedw. – 7: limestone grassland; 8: shaded limestone rock; 10, 16: limestone rock
Bryum dichotomum Hedw. – 1: schistose rock; 15: schistose rock
Bryum elegans Nees – 12: limestone rock
Bryum mildeanum Jur. – 3: siliceous rock of an artificial wall
Bryum moravicum Podp. – 6: limestone rock; 10: siliceous rock
Bryum pallescens Schleich. ex Schwägr. – 4: limestone grassland; 11: exposed schistose rock
Bryum pseudotriquetrum (Hedw.) P. Gaertn. *et al.* – 2: wetland
Bryum schleicheri DC. – 2: wetland; 11: wet meadows along a stream
Bryum turbinatum (Hedw.) Turner – 1: wet schistose rock; 2: wetland
Buxbaumia viridis (Moug. ex Lam. et DC.) Brid. ex Moug. et Nestl. – 10: decaying wood
Calliergon cordifolium (Hedw.) Kindb. – 11: wet meadows along a stream
Calliergonella cuspidata (Hedw.) Loeske – 2: wetland; 10: along a rivulet; 11: wet meadows along a stream
Campyliadelphus chrysophyllus (Brid.) R. S. Chopra – 6: limestone rock

- Campylium protensum* (Brid.) Kindb. – 16: limestone rock at the stream
Campylium stellatum (Hedw.) Lange et C. E. O. Jensen – 11: wet meadows along a stream
Campylophyllum calcareum (Crundw. et Nyholm) Hedenäs – 9: shaded limestone rock; 10: limestone rock; 15: schistose rock
Ceratodon purpureus (Hedw.) Brid. – 1: schistose rock and soil
Cinclidotus fontinaloides (Hedw.) P. Beauv. – 9: along the river and bark *Alnus*
Cirriophyllum crassinervium (Taylor) Loeske et M. Fleisch. – 8, 16: shaded limestone rock; 9: along the river
Climacium dendroides (Hedw.) F. Weber et D. Mohr – 2: wetland
Coscinodon cribrosus (Hedw.) Spruce – 1: schistose rock
Cratoneuron filicinum (Hedw.) Spruce – 1: wet schistose rock; 6, 10: at a rivulet; 11: wet meadows along a stream; 16: limestone rock at the stream
Ctenidium molluscum (Hedw.) Mitt. – 5: limestone rock; 8, 16: shaded limestone rock
Dichodontium palustre (Dicks.) M. Stech – 11: wet meadows along a stream
Dichodontium pellucidum (Hedw.) Schimp. – 11: schistose rock in the stream
Dicranella rufescens (Dicks.) Schimp. – 1: schistose rock, 8: wet limestone rock
Dicranella varia (Hedw.) Schimp. – 7: limestone grassland; 8: wet limestone rock
Dicranum scoparium Hedw. – 8: shaded limestone rock; 14: exposed siliceous rock
Didymodon fallax (Hedw.) R. H. Zander – 5: limestone rock; 6: at a rivulet; 7: limestone grassland
Didymodon insulanus (De Not.) M. O. Hill – 1: schistose rock
Didymodon luridus Hornsch. – 4: limestone grassland; 6: limestone rock
Didymodon rigidulus Hedw. – 1: concrete wall; 6, 13: limestone rock; 8: wet limestone rock
Didymodon sinuosus (Mitt.) Delogne – 9: along the river
Didymodon spadiceus (Mitt.) Limpr. – 8: wet limestone rock; 16: limestone rock at the stream
Didymodon vinealis (Brid.) R. H. Zander – 8: shaded limestone rock; 16: limestone rock at the stream
Distichium capillaceum (Hedw.) Bruch et Schimp. – 2, 5, 10, 12: limestone rock; 7: limestone grassland
Ditrichum flexicaule (Schwägr.) Hampe – 2, 5, 10: limestone rock; 7: limestone grassland; 9: shaded limestone rock
Ditrichum gracile (Mitt.) Kuntze – 8: shaded limestone rock; 12: limestone rock
Ditrichum pusillum (Hedw.) Hampe – 1: schistose rock
Drepanocladus aduncus (Hedw.) Warnst. – 2: wetland
Encalypta ciliata Hedw. – 15: schistose rock
Encalypta rhaptocarpa Schwägr. – 12: limestone rock
Encalypta streptocarpa Hedw. – 5, 6: limestone rock; 8: shaded limestone rock
Entosthodon mühlenbergii (Turner) Fife – 2, 5: limestone rock
Eucladium verticillatum (With.) Bruch et Schimp. – 8: wet limestone rock
Eurhynchiastrium pulchellum (Hedw.) Ignatov et Huttunen – 2, 5: limestone rock; 4: limestone grassland; 10: siliceous rock; 11: exposed schistose rock
Eurhynchium angustirete (Broth.) T. J. Kop. – 10: limestone rock
Fissidens bryoides Hedw. – 4: limestone grassland; 15: schistose rock
Fissidens dubius P. Beauv. – 16: limestone rock
Fissidens taxifolius Hedw. – 6: at a rivulet; 16: limestone rock at the stream
Fontinalis hypnoides C. Hartm. – 11: wet meadows along a stream
Grimmia alpestris (F. Weber et D. Mohr) Schleich. – 2: schistose rock
Grimmia anodon Bruch et Schimp. – 12: limestone rock
Grimmia anomala Hampe ex Schimp. – 11: exposed schistose rock; 14: exposed siliceous rock

- Grimmia caespiticia* (Brid.) Jur. – 11: exposed schistose rock; 14: exposed siliceous rock
Grimmia laevigata (Brid.) Brid. – 15: schistose rock
Grimmia montana Bruch et Schimp. – 11: exposed schistose rock
Grimmia muehlenbeckii Schimp. – 14: exposed siliceous rock
Grimmia ovalis (Hedw.) Lindb. – 1, 11, 15: schistose rock; 14: exposed siliceous rock
Grimmia pulvinata (Hedw.) Sm. – 1: concrete wall; 3: limestone rockwall; 15: schistose rock
Gymnostomum aeruginosum Sm. – 8, 9: shaded limestone rock; 16: limestone rock at the stream
Gymnostomum calcareum Nees et Hornsch. – 8: wet limestone rock
Gyroweisia tenuis (Hedw.) Schimp. – 8: wet limestone rock
Herzogiella seligeri (Brid.) Z. Iwats. – 10: decaying wood
Homalothecium lutescens (Hedw.) H. Rob. – 1: soil
Homalothecium philippeanum (Spruce) Schimp. – 2, 13: limestone rock; 8: shaded limestone rock
Homalothecium sericeum (Hedw.) Schimp. – 1: concrete wall; 3: limestone rockwall; 6, 12, 16: limestone rock; 8: bark of *Acer*; 15: bark of *Acer monspessulanum*
Homomallium incurvatum (Schr. ex Brid.) Loeske – 8: shaded limestone rock
Hygrohypnum luridum (Hedw.) Jenn. – 6: at a rivulet; 8: wet limestone rock; 9: along the river; 16: limestone rock at the stream
Hylocomium splendens (Hedw.) Schimp. – 8: shaded limestone rock; 16: soil
Hypnum cupressiforme Hedw. – 7: limestone grassland; 9: shaded limestone rock; 10: limestone rock; 15: schistose rock
Isothecium alopecuroides (Lam. ex Dubois) Isov. – 10: siliceous rock and decaying wood; 14: exposed siliceous rock
Leptodon smithii (Hedw.) F. Weber et D. Mohr – 16: limestone rock
Leucodon sciuroides (Hedw.) Schwägr. – 8: shaded limestone rock and bark of *Acer*; 15: schistose rock
Mnium marginatum (Dicks.) P. Beauv. – 6: limestone rock
Mnium stellare Hedw. – 4: limestone grassland; 5, 6: limestone rock; 8: shaded limestone rock; 10: limestone rock and along a rivulet
Neckera bessi (Lobarz.) Jur. – 8, 16: shaded limestone rock
Neckera complanata (Hedw.) Huebener – 6, 16: limestone rock; 8: bark of *Acer*; 15: bark of *Acer monspessulanum*
Neckera crispa Hedw. – 16: limestone rock
Neckera menziesii Drumm. – 8: shaded limestone rock; 10: siliceous rock
Orthothecium intricatum (Hartm.) Schimp. – 8: shaded limestone rock
Orthotrichum affine Schrad. ex Brid. – 8: bark of *Fagus*; 9: bark of *Alnus*; 10: *Abies* branch; 15: bark of *Acer monspessulanum* and *Prunus avium*; 18: bark of *Fagus* and *Betula pendula*
Orthotrichum anomalum Hedw. – 3: limestone rockwall; 15: schistose rock; 16: limestone rock
Orthotrichum cupulatum Hoffm. ex Brid. var. *cupulatum* – 2, 11, 12, 16: limestone rock; 3: limestone rockwall
Orthotrichum cupulatum Hoffm. ex Brid. var. *riparium* Huebener – 9: along the river
Orthotrichum diaphanum Schrad. ex Brid. – 17: bark of *Robinia pseudo-acacia*
Orthotrichum lyellii Hook. et Taylor – 15: bark of *Prunus avium*
Orthotrichum obtusifolium Brid. – 15: bark of *Acer monspessulanum*; 17: bark of *Robinia pseudo-acacia*
Orthotrichum pallens Bruch ex Brid. – 18: bark of *Fagus*
Orthotrichum pumilum Sw. ex anon. – 1: schistose rock; 17: bark of *Robinia pseudo-acacia*
Orthotrichum shawii Wilson – 18: bark of *Betula pendula*

- Orthotrichum speciosum* Nees – 8: bark of *Fagus*; 10: *Abies* branch; 18: bark of *Fagus* and *Betula pendula*
- Orthotrichum stramineum* Hornsch. ex Brid. – 9: bark of *Alnus*; 15: bark of *Acer monspessulanum*; 18: bark of *Fagus* and *Betula pendula*
- Orthotrichum striatum* Hedw. – 1: schistose rock; 8: bark of *Fagus*; 9: bark of *Alnus* and *Prunus avium*; 18: bark of *Fagus* and *Betula pendula*
- Oxyrrhynchium bians* (Hedw.) Loeske – 6: limestone rock; 8, 16: shaded limestone rock
- Palustriella commutata* (Hedw.) Ochyra – 6: at a rivulet; 8: wet limestone rock; 16: limestone rock at the stream
- Palustriella decipiens* (De Not.) Ochyra – 1: wet schistose rock; 2: wetland; 11: wet meadows along a stream
- Palustriella falcata* (Brid.) Hedenäs – 11: wet meadows along a stream
- Philonotis caespitosa* Jur. – 2: wetland
- Philonotis fontana* (Hedw.) Brid. – 1: wet schistose rock; 11: wet meadows along a stream
- Philonotis seriata* Mitt. – 1: wet schistose rock; 2: wetland
- Plagiomnium affine* (Blandow ex Funck) T. J. Kop. – 4: limestone grassland and soil among schistose rock; 8, 16: shaded limestone rock
- Plagiomnium cuspidatum* (Hedw.) T. J. Kop. – 8: shaded limestone rock
- Plagiomnium elatum* (Bruch et Schimp.) T. J. Kop. – 11: wet meadows along a stream
- Plagiomnium ellipticum* (Brid.) T. J. Kop. – 2: wetland; 11: wet meadows along a stream
- Plagiomnium rostratum* (Schräd.) T. J. Kop. – 6, 12: limestone rock; 8: shaded limestone rock; 9: along the river
- Plagiomnium undulatum* (Hedw.) T. J. Kop. – 4: soil among schistose rock; 16: limestone rock at the stream
- Plagiopus oederianus* (Sw.) H. A. Crum et L. E. Anderson – 6: limestone rock; 8: shaded limestone rock
- Plagiothecium cavifolium* (Brid.) Z. Iwats. – 14: exposed siliceous rock
- Plagiothecium succulentum* (Wilson) Lindb. – 10: siliceous rock
- Plasteurhynchium striatulum* (Spruce) M. Fleisch. – 8, 16: shaded limestone rock; 15: schistose rock
- Platyhypnidium riparioides* (Hedw.) Dixon – 6: at a rivulet; 11: wet meadows along a stream; 16: limestone rock at the stream
- Pleurochaete squarrosa* (Brid.) Lindb. – 15: schistose rock
- Pogonatum aloides* (Hedw.) P. Beauv. – 10: soil along the road
- Pohlia andalusica* (Höhn.) Broth. – 2: wetland
- Pohlia annotina* (Hedw.) Lindb. – 1: schistose rock
- Pohlia cruda* (Hedw.) Lindb. – 11: exposed schistose rock
- Pohlia melanodon* (Brid.) A. J. Shaw – 1: wet schistose rock; 4: limestone grassland; 8: wet limestone rock; 10: limestone rock
- Pohlia wahlenbergii* (F. Weber et D. Mohr) A. L. Andrews – 4: limestone grassland; 6, 10: at a rivulet; 15: schistose rock
- Polytrichastrum alpinum* (Hedw.) G. L. Sm. – 1, 11: schistose rock; 4: soil among schistose rock
- Polytrichum commune* Hedw. – 2: wetland
- Polytrichum commune* Hedw. var. *perigoniale* (Michx.) Hampe – 2: wetland
- Polytrichum juniperinum* Hedw. – 2, 5: limestone rock; 11: exposed schistose rock
- Polytrichum piliferum* Hedw. – 1: schistose rock; 14: exposed siliceous rock
- Pseudocrossidium hornscharianum* (Schultz) R. H. Zander – 7: limestone grassland
- Pseudoleskea incurvata* (Hedw.) Loeske – 2, 5, 12: limestone rock; 14: exposed siliceous rock

- Pseudoleskea saviana* (De Not.) Latzel – 10: siliceous rock
Pseudoleskeella catenulata (Brid. ex Schrad.) Kindb. – 13: exposed limestone rock
Pseudoleskeella rupestris (Berggr.) Hedenäs et L. Söderstr. – 9: shaded limestone rock
Pseudoscleropodium purum (Hedw.) M. Fleisch. – 16: soil
Pterigynandrum filiforme Hedw. – 9: bark of *Alnus*; 10: decaying wood; 14: exposed siliceous rock; 15: bark of *Prunus avium*
Pterogonium gracile (Hedw.) Sm. – 15: schistose rock
Pterygoneurum ovatum (Hedw.) Dixon – 7: limestone grassland
Ptychodium plicatum (Schleich. ex F. Weber et D. Mohr) Schimp. – 2: limestone rock
Racomitrium canescens (Hedw.) Brid. – 1: soil; 2: limestone rock
Racomitrium elongatum Ehrh. ex Frisvoll – 4, 11: soil among schistose rock
Rhizomnium punctatum (Hedw.) T. J. Kop. – 10: along a rivulet; 11: wet meadows along a stream
Rhynchostegiella curviseta (Brid.) Limpr. – 16: limestone rock at the stream
Rhytidiadelphus triquetrus (Hedw.) Warnst. – 10: limestone rock
Sanionia uncinata (Hedw.) Loeske – 2: limestone rock; 4: soil among schistose rock
Schistidium apocarpum (Hedw.) Bruch et Schimp. – 1: schistose rock
Schistidium brunnescens Hedw. subsp. *griseum* (Nees et Hornsch.) H. H. Blom – 1: concrete wall; 2, 13: limestone rock
Schistidium confertum (Funck) Bruch et Schimp. – 14: exposed siliceous rock
Schistidium crassipilum H. H. Blom – 6, 16: limestone rock; 9: along the river; 15: schistose rock
Schistidium flaccidum (De Not.) Ochyra – 1, 2, 15: schistose rock
Schistidium helveticum (Schkuhr) Deguchi – 11: limestone rock
Schistidium pruinsum (Wilson ex Schimp.) G. Roth – 11: exposed schistose rock; 14: exposed siliceous rock
Sciuro-hypnum populeum (Hedw.) Ignatov et Huttunen – 10: siliceous rock
Scorpidium cossonii (Schimp.) Hedenäs – 11: wet meadows along a stream
Seligeria acutifolia Lindb. – 16: limestone rock at the stream
Seligeria pusilla (Hedw.) Bruch et Schimp. – 6: limestone rock
Syntrichia calcicola J. J. Amann – 1: concrete wall
Syntrichia handelii (Schiffn.) S. Agnew et Vondr. – 11, 12: limestone rock
Syntrichia norvegica F. Weber – 5: limestone rock; 14: exposed siliceous rock
Syntrichia papillosa (Wilson) Jur. – 17: bark of *Robinia pseudo-acacia*
Syntrichia ruralis (Hedw.) F. Weber et D. Mohr – 1: soil; 2, 5: limestone rock; 3: limestone rock-wall; 7: limestone grassland; 10: limestone and siliceous rock; 11: schistose rock; 15: schistose rock and bark of *Acer monspessulanum*; 17: bark of *Robinia pseudo-acacia*
Syntrichia subpapillosissima (Bizot et R. B. Pierrot ex W. A. Kramer) M. T. Gallego et J. Guerra – 14: exposed siliceous rock
Syntrichia virescens (De Not.) Ochyra – 15: bark of *Acer monspessulanum*
Taxiphyllum wisgrillii (Garov.) Wijk et Margad. – 8: shaded limestone rock
Thamnobryum alopecurum (Hedw.) Gangulee – 8, 16: shaded limestone rock
Timmia bavarica Hessel. – 2, 5: limestone rock
Tortella fragilis (Hook. et Wilson) Limpr. – 7: limestone grassland
Tortella humilis (Hedw.) Jenn. – 15: schistose rock
Tortella inclinata (R. Hedw.) Limpr. – 7: limestone grassland
Tortella nitida (Lindb.) Broth. – 9: shaded limestone rock
Tortella tortuosa (Hedw.) Limpr. – 2, 5, 12, 16: limestone rock; 7: limestone grassland; 8, 9: shaded limestone rock
Tortula atrovirens (Sm.) Lindb. – 15: schistose rock

Tortula hoppeana (Schultz) Ochyra – 11: exposed schistose rock; 14: exposed siliceous rock

Tortula inermis (Brid.) Mont. – 3: limestone rockwall; 4: limestone grassland

Tortula modica R. H. Zander – 3: limestone rockwall

Tortula muralis Hedw. – 3: limestone rockwall

Tortula subulata Hedw. – 3: limestone rockwall; 11, 15: schistose rock

Trichostomum crispulum Bruch – 7: limestone grassland; 15: schistose rock

Warnstorfia exannulata (Schimp.) Loeske – 2: wetland; 11: wet meadows along a stream

Weissia condensa (Voit) Lindb. – 4: limestone grassland; 5, 12: limestone rock

Weissia controversa Hedw. – 1, 15: schistose rock

Zygodon rupestris Schimp. ex Lorentz – 15: schistose rock