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CONTRIBUTIONS TO THE BRYOPHYTE FLORA OF CROATIA II. THE NORTHERN VELEBIT

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The bryophyte flora of the Northern Velebit (mainly in sites situated inside the National Park) was studied in 2011 and 2012. Special attention was paid to the old-growth and virgin beech-fir and spruce forests and to grasslands and open rocks in the subalpine belt. 191 bryophyte taxa (40 liverworts and 151 mosses) were recorded. Four species are reported here for the first time in Croatia (*Isopterygiopsis muelleriana*, *Pseudoleskea patens*, *Trichodon cylindricus*, *Weissia rostellata*). Six species are included in the Red data book of European bryophytes (*Lophozia ascendens, Anomodon rostratus, Buxbaumia viridis, Pseudoleskea saviana, Rhynchostegiella tenuicaulis*, *Weissia rostellata*). Additional 18 taxa (5 liverworts and 13 mosses) are regarded as rare in Southeast Europe. Based on our documentation of the bryophyte flora the Northern Velebit can be considered as an Important Bryophyte Area in Croatia.

Key words: European redlisted species, liverworts, mosses, new national records, rare bryophytes

INTRODUCTION

Croatia is a Southeast European country at the crossroads of Central Europe, the Balkans and the Mediterranean, involving three main biogeographical regions: 1) Pannonian, 2) Dinaric-Montane (with the highest mountains Dinara 1,831 m, Biokovo 1,762 m and Velebit 1,757 m a.s.l.) and 3) Adriatic-Coastal with over 1,000 islands. The last two are characterised by a wide range of karstic phenomena and belong to the Dinaric mountain system.

The Velebit Mts, a mountain range stretching alongside the Adriatic coast, has a southwest facing foothill area that belongs to the Adriatic-Coastal, Mediterranean region, but the upper belts of the southwestern flanks and all the northwestern slopes belong to the Dinaric-Montane biogeographical region. With over 2,000 taxa of vascular plants and over 70 endemics, the Velebit Mts is one of the most important plant diversity centres in Croatia.

Moreover, the Velebit Mts is one of the bryologically best-researched parts of the country, thanks to Degen's comprehensive work on the flora of the Velebit Mts published in his monumental *Flora Velebitica* (Degen 1936–1938). He was primarily a specialist of vascular plants, so he sent his rich bryological material to J. Baumgartner (mosses) and V. Schiffner (liverworts and *Sphagnum*). Their joint work resulted in an annotated list of over 350 mosses and 80 liverworts with detailed references of localities and habitat types. Degen's herbarium is deposited in the Hungarian Natural History Museum, Budapest.

Degen (1938) also provided the first bryogeography of the Velebit Mts by recognising two bryological regions: 1) littoral, Istrian-Dalmatian region, reaching to 800–900 m a.s.l. and characterised by Mediterranean and southern elements; 2) an upper region stretching above the littoral one and on the entire inland slope. He concluded that the climate is the main factor determining the distribution of bryophytes. Due to the aridity and lack of sheltered habitats, the southwestern slopes have relatively poor bryophyte flora with few species and low abundances, restricted to *terra rossa* depositions in rock crevices, occurring in shrubberies and on sheltered soil between rocks and on tree bark. On the contrary, the upper parts of the mountains, on the southwestern slopes, on poljes in the hinterland, and especially in forests, there is a much richer bryophyte flora that can be comparable in diversity and richness with other mountains on similar geographical latitudes. Interestingly, the main part of the bryophyte flora is central-European-montane element, with only a few alpine species, growing not on the peaks, but in depressions and dolinas characterised by temperature inversion. Only 20 moss species are of alpine or subalpine character, and half of these are very rare with only a single or a few localities to date. However, due to the geological uniformity, calcicolous species prevail, and around 1/7-th of the species can be considered as calcifuge, growing on isolated spots of siliceous rocks, and other habitats with isolated limestone bedrock.

In the present paper a detailed list of bryophytes collected in the Velebit Mts (Northern Velebit National Park and Štirovača) in 2011 and 2012 is provided with remarks on species new for the Croatian bryophyte flora, and on the rare and threatened species.

MATERIAL AND METHODS

Study area

With its total length of 145 km, the Velebit Mts is the longest Croatian mountain range, situated along the northeastern coast of the Adriatic Sea. It is only 10–30 km wide with the highest peak (Vaganski vrh) of 1,757 m a.s.l. The

range extends in a typical Dinaric direction from northwest to southeast and rises almost directly from the Adriatic Sea forming a characteristic wall-like appearance for the coastal Dinarides. Geologically it is dominated by Mesozoic limestone with only small patches of other rock types. Dividing the Adriatic coast from the inland area, the Velebit Mts have various climatic types, from sub-Mediterranean, subalpine to inland continental type. The yearly mean temperature on the Zavižan peak (1,594 m a.s.l.) is 3.5 °C, with a precipitation of 1,898 mm. The whole mountain is protected as "nature park" and within it there are two national parks: "Northern Velebit" and "Paklenica" (the latter in the Southern Velebit).

Štirovača is a complex of five elongated valleys surrounded by mountain slopes over 1,500 m high. It is situated at around 1,100 m a.s.l. in the central part of the Velebit Mts. The northernmost valley is also called Štirovača and it is covered mainly with old-growth spruce forest (mainly *Aremonio-Piceetum*). On the contrary, the next valley, Jovanovića padež, is home to beech-fir forests surrounded by grassland complexes traditionally used as pasture, with a small shepherd settlement nowadays used only for recreational purposes during summer time. On the edge of the valley, within the forest, a unique 20 m deep ice hole can be found called Jovanovića snižnica, with vertical walls and permanent ice on the bottom. Farther to the south its extension is Klepina duliba, unique for one of the last remnants of virgin beech-fir forest (*Omphalodo-Fagetum*) once more common in the area called Štirovača, currently protected as a forest reserve.

Veliki Alan (1,406 m a.s.l.) is the pass between the Northern and Central Velebit situated in the belt of subalpine beech forests (Saxifrago rotundifoliae-Fagenion), for centuries of sheep grazing extensive grasslands of *Sesleria juncifolia* (on wind-exposed positions) and *Festuca bosniaca* (on more wind-protected positions) dominate the landscape. Limestone blocks and rocks are also part of the landscape with specific and peculiar vegetation characterised by many endemic species.

Tudorevo is an uvala (elongated, bowl-like valley) situated on the inland (eastern) side from Veliki Alan pass. It has a shape of ellipsoid bowl stretching in north–south direction. It is 1,200 m long, with the maximum width of 600 m and altitudinal range of 70 m, around 1,300 m a.s.l. on the bottom. In general Tudorevo belongs to the belt of subalpine beech forests (Saxifrago rotundifoliae-Fagenion), but the slopes and bottoms of all three uvalas are covered with secondary grassland complexes traditionally used as pastures. During the last 60 years their traditional use has been completely abandoned and now the process of vegetation succession is evident. With a mosaic of scattered stands of *Festuca paniculata*, dominant grassland communities are *Festucetum bosniacae* on the slopes, while on the deeper, leached soils at the bottom *Nardetum strictae* is developed.

Zavižan is a group of peaks in the Northern Velebit (Veliki Zavižan 1,677 m, Balinovac 1,601 m, Zavižanski Klek 1,620 m, Vučjak 1,645 m, Zalovačko bilo 1,630 m, Pivćevac 1,676 and Velika Kosa 1,620 m a.s.l.). An alpine house with a meteorological station (1,594 m) is situated in the central part, which was a starting point for field trips in the surroundings. Zavižan belongs to the belt of subalpine beech forests (Saxifrago rotundifoliae-Fagenion) with shrub-like stands of mugo pine (*Hyperico grisebachii-Pinetum mugi*) in the upper parts and spruce stands on steep, rocky slopes (*Hyperico grisebachii-Piceetum*). However, as it used to be a summer-time grazing area for centuries, it is covered with extensive grasslands. The most widespread grassland community belongs to ass. *Festucetum bosniacae*. Open rocks and ridges have unique forms of vegetation with many local endemics.

Collecting sites

1. Croatia, Northern Velebit, Klepina duliba, south of Štirovača, virgin *Omphalodo-Fagetum* forest, 44° 31' 42.5" N, 15° 04' 05.0" E, 1,145 m, 25.VII.2011.
2. Croatia, Northern Velebit, Klepina duliba, south of Štirovača, virgin *Omphalodo-Fagetum* forest with limestone rocks, 44° 32' 05.4" N, 15° 04' 02.3" E, 1,140 m, 25.VII.2011.
3. Croatia, Northern Velebit, south of Štirovača, *Aremonio-Piceetum* forest, 44° 32' 05.4" N, 15° 04' 02.3" E, 1,140 m, 25.VII.2011.
4. Croatia, Northern Velebit, 300 m south of Štirovača, *Aremonio-Piceetum* forest, 44° 41' 04.3" N, 15° 03' 14.1" E, 1,140 m, 25.VII.2011.
5. Croatia, Northern Velebit, in Krasno village, 44° 42' 4.6" N, 15° 03' 03.2" E, 800 m, 26.VII.2011.
6. Croatia, Northern Velebit, around Buljma peak at Alan tourist house, 44° 43' 06.5" N, 14° 57' 52.5" E, 1,330–1,450 m, 26.VII.2011.
7. Croatia, Northern Velebit, Jovanovića padež, Jovanovića snižnica ice hole, 44° 40' 42.2" N, 15° 03' 24.2" E, 1,059 m, 24.VII.2012.
8. Croatia, Northern Velebit, Tudorevo, 44° 43' 22.2" N, 14° 59' 11.2" E, 1,355 m, 24.VII.2012.
9. Croatia, Northern Velebit, Zavižan, towards Velika Kosa peak, 44° 48' 50.6" N, 14° 58' 41.4" E, 1,540 m, 25.VII.2012.

Methods

The collecting trips were made in July 2011 and in July 2012, respectively, in the Northern Velebit shown in Figure 1. All main habitat types, such as forests and grasslands were investigated, and bryophytes were collected from different substrates (soil, exposed and shady rocks, tree bark, and decaying wood).

The specimens have been shared between the participating parties and are preserved in the Herbarium of the Hungarian Natural History Museum, Budapest (BP) and the Herbarium Croaticum of University of Zagreb (ZA). The nomenclature follows Grolle and Long (2000) for liverworts and Hill *et al.* (2006) for mosses. New floristical results for the country are given according to the checklists of Southeast Europe and Mediterranean (Sabovljević and

Fig. 1. Location of the study area.

Natcheva 2006, Sabovljević *et al.* 2008, Ros *et al.* 2007) updated with some records included in Degen (1938) and Düll *et al.* (1999), and new records published in Papp and Sabovljević (2009), Modrić Surina *et al.* (2012), Alegro *et al.* (2012).

RESULTS

191 bryophytes (40 liverworts and 151 mosses) were collected in the Northern Velebit. Of the full collection 17 taxa (2 liverworts and 15 mosses) proved to be new to Croatia, of which 13 were published recently (Papp *et al.* 2013*a*) (marked with +) and four are reported here for the first time (marked with ++). The occurrence of 16 liverworts having only very old records according to Ros *et al.* (2007) (marked with *) is confirmed in the country.

Hepaticae

Apometzgeria pubescens (Schrank) Kuwah. – 2: limestone rock
****Barbilophozia barbata*** (Schmidel ex Schreb.) Loeske – 8: limestone grassland
Blepharostoma trichophyllum (L.) Dumort. – 1, 3: decaying wood; 8: limestone grassland
+***Calypogeia muelleriana*** (Schiffn.) Müll. Frib. – 7: decaying wood
****Calypogeia suecica*** (Arnell et J. Perss.) Müll. Frib. – 1, 4: decaying wood
Cephalozia bicuspidata (L.) Dumort. – 3, 4, 7: decaying wood
Cephalozia catenulata (Huebener) Lindb. – 2, 4: decaying wood
Cephaloziella divaricata (Sm.) Schiffn. – 8: limestone grassland
****Chiloscyphus polyanthus*** (L.) Corda – 1: sandstone rock in a rivulet
Cololejeunea calcarea (Lib.) Schiffn. – 2, 3, 7: limestone rock
Cololejeunea rosettiana (C. Massal.) Schiffn. – 2: limestone rock
Conocephalum conicum (L.) Dumort. – 7: limestone rock
Frullania tamarisci (L.) Dumort. – 2: bark of *Fagus*
Jungermannia atrovirens Dumort. – 7: limestone rock
****Jungermannia leiantha*** Grolle – 2, 3, 7: decaying wood
Leiocolea collaris (Nees) Schljakov – 6, 8: limestone grassland; 7: limestone rock
Lejeunea cavifolia (Ehrh.) Lindb. – 2: bark of *Fagus*
Lepidozia reptans (L.) Dumort. – 1: decaying wood
Lophocolea heterophylla (Schrad.) Dumort. – 1: bark of *Abies*; 2, 7: decaying wood
****Lophozia ascendens*** (Warnst.) R. M. Schust. – 1, 2, 7: decaying wood
+***Lophozia longidens*** (Lindb.) Macoun – 1: bark of *Abies*
****Metzgeria conjugata*** Lindb. – 2: limestone rock
Metzgeria furcata (L.) Dumort. – 1: bark of *Fagus*; 7: limestone rock
****Nowellia curvifolia*** (Dicks.) Mitt. – 1, 2, 4, 7: decaying wood
Pedinophyllum interruptum (Nees) Kaal. – 3, 7: limestone rock; 6: limestone grassland
Plagiochila porelloides (Torrey ex Nees) Lindenb. – 1: bark of *Fagus*; 2, 7: limestone rock; 6, 8: limestone grassland
Porella cordaeana (Huebener) Mohr – 1: bark of *Fagus*; 2, 7, 9: limestone rock; 6: limestone grassland and bark of *Fagus;* 8: limestone grassland
Porella platyphylla (L.) Pfeiff. – 5: bark of *Tilia*; 6: limestone grassland; 7: limestone rock
Preissia quadrata (Scop.) Nees – 6, 8: limestone grassland; 9: limestone rock
****Ptilidium ciliare*** (L.) Hampe – 8: limestone grassland
****Ptilidium pulcherrimum*** (Weber) Vain. – 4: decaying wood
Radula complanata (L.) Dumort. – 1: bark of *Fagus*; 9: limestone rock
****Reboulia hemisphaerica*** (L.) Raddi – 6: limestone grassland
****Riccardia palmata*** (Hedw.) Carruth. – 1, 4, 7: decaying wood
Riccia sorocarpa Bisch. – 9: limestone grassland
****Scapania aequiloba*** (Schwägr.) Dumort. – 7: limestone rock
Scapania aspera M. Bernet et Bernet – 6: limestone grassland
****Scapania calcicola*** (Arnell et J. Perss.) Ingham – 6: limestone grassland
****Scapania umbrosa*** (Schrad.) Dumort. – 1, 2, 3, 4, 7: decaying wood
****Scapania undulata*** (L.) Dumort. – 1: sandstone rock in a rivulet

Musci

Anomodon attenuatus (Hedw.) Huebener – 2: limestone rock
Anomodon longifolius (Schleich. ex Brid.) Hartm. – 2: limestone rock

Anomodon rostratus (Hedw.) Schimp. – 2: limestone rock
Anomodon viticulosus (Hedw.) Hook. et Taylor – 2, 7: limestone rock
Antitrichia curtipendula (Hedw.) Brid. – 2, 7: limestone rock
Aulacomnium palustre (Hedw.) Schwägr. – 3: at a pond
Barbula convoluta Hedw. – 8, 9: limestone grassland
Brachytheciastrum velutinum (Hedw.) Ignatov et Huttunen – 3: at a pond; 7, 9: limestone rock
Brachythecium albicans (Hedw.) Schimp. – 7: soil in the forest
Brachythecium glareosum (Bruch ex Spruce) Schimp. – 6, 8: limestone grassland
Brachythecium rivulare Schimp. – 3: at a pond
Brachythecium rutabulum (Hedw.) Schimp. – 1: bark of *Fagus* and decaying wood, 7: limestone rock
Brachythecium salebrosum (Hoffm. ex F. Weber et D. Mohr) Schimp. – 6: limestone grassland
Brachythecium tommasinii (Sendtn. ex Boulay) Ignatov et Huttunen – 2, 7, 9: limestone rock; 6: limestone grassland
Bryoerythrophyllum recurvirostrum (Hedw.) P. C. Chen – 6: limestone grassland; 7: limestone rock
Bryum alpinum Huds. ex With. – 9: limestone grassland
Bryum archangelicum Bruch et Schimp. – 6, 9: limestone grassland
Bryum argenteum Hedw. – 9: limestone grassland
Bryum caespiticium Hedw. – 6, 8: limestone grassland
Bryum capillare Hedw. – 2, 7: limestone rock; 3: at a pond
Bryum elegans Nees – 9: limestone rock
Bryum moravicum Podp. – 1: bark of *Fagus*; 6: limestone grassland and bark of *Fagus*
Bryum pallens Sw. ex anon. – 6, 8: limestone grassland
Bryum pallescens Schleich. ex Schwägr. – 6: limestone grassland
Bryum radiculosum Brid. – 7: soil in the forest
Bryum rubens Mitt. – 7: soil in the forest
Buxbaumia viridis (Moug. ex Lam. et DC.) Brid. ex Moug. et Nestl. – 1, 3, 7: decaying wood; 4: bark of *Abies*
Calliergon cordifolium (Hedw.) Kindb. – 3: at a pond
Calliergonella cuspidata (Hedw.) Loeske – 3: at a pond
Calliergonella lindbergii (Mitt.) Hedenäs – 3: at a pond
Campyliadelphus chrysophyllus (Brid.) R. S. Chopra – 6, 8: limestone grassland
+***Campylium protensum*** (Brid.) Kindb. – 8: limestone grassland
Campylium stellatum (Hedw.) Lange et C. E. O. Jensen – 8: limestone grassland
Campylophyllum halleri (Hedw.) M. Fleisch. – 2, 3, 7: limestone rock; 8: limestone grassland
Ceratodon purpureus (Hedw.) Brid. – 3: at a pond; 8, 9: limestone grassland
Cirriphyllum crassinervium (Taylor) Loeske et M. Fleisch. – 6: limestone grassland
Climacium dendroides (Hedw.) F. Weber et D. Mohr – 3: at a pond
Cratoneuron filicinum (Hedw.) Spruce – 7: limestone rock
Ctenidium molluscum (Hedw.) Mitt. – 2, 7, 9: limestone rock; 6, 8: limestone grassland
Dichodontium pellucidum (Hedw.) Schimp. – 7: limestone rock
Dicranella schreberiana (Hedw.) Dixon – 4: soil
Dicranella varia (Hedw.) Schimp. – 4: soil
Dicranum scoparium Hedw. – 1: bark of *Fagus* and *Abies*; 2, 7: limestone rock; 3: at a pond; 6: limestone grassland
Dicranum tauricum Sapjegin – 1, 2, 3, 4: bark of *Abies*; 7: decaying wood
Didymodon rigidulus Hedw. – 6: limestone grassland; 9: limestone rock
Distichium capillaceum (Hedw.) Bruch et Schimp. – 6: limestone grassland; 7: limestone rock
Distichium inclinatum (Hedw.) Bruch et Schimp. – 8: limestone grassland

Ditrichum flexicaule (Schwägr.) Hampe – 6, 8, 9: limestone grassland
Ditrichum gracile (Mitt.) Kuntze – 3: limestone rock; 6: limestone grassland
Ditrichum heteromallum (Hedw.) E. Britton – 7: soil in the forest
Ditrichum pusillum (Hedw.) Hampe – 7: soil in the forest
Encalypta streptocarpa Hedw. – 2, 7, 9: limestone rock; 6: limestone grassland
Eurhynchium angustirete (Broth.) T. J. Kop. – 2, 7: limestone rock
Fissidens adianthoides Hedw. – 3: at a pond
Fissidens bryoides Hedw. – 3: soil; 8: limestone grassland
Fissidens dubius P. Beauv. – 2, 3, 7, 9: limestone rock; 6, 8: limestone grassland
Fissidens pusillus (Wilson) Milde – 1: sandstone rock in a rivulet
Fissidens taxifolius Hedw. – 3: soil; 8: limestone grassland
Funaria hygrometrica Hedw. – 7: soil
Grimmia pulvinata (Hedw.) Sm. – 6: limestone grassland
Gymnostomum aeruginosum Sm. – 6: limestone grassland; 7: limestone rock
Herzogiella seligeri (Brid.) Z. Iwats. – 1: decaying wood
Homalothecium lutescens (Hedw.) H. Rob. – 9: limestone rock
Homalothecium philippeanum (Spruce) Schimp. – 2: limestone rock
Homalothecium sericeum (Hedw.) Schimp. – 1: bark of *Fagus*; 5: bark of *Tilia*; 6, 8: limestone grassland; 9: limestone rock
Homomallium incurvatum (Schrad. ex Brid.) Loeske – 2: limestone rock
Hygrohypnum luridum (Hedw.) Jenn. – 1: sandstone rock in a rivulet; 7: limestone rock
Hylocomium splendens (Hedw.) Schimp. – 2, 7: limestone rock; 3: at a pond
Hypnum cupressiforme Hedw. – 1: bark of *Abies* and decaying wood; 6: limestone grassland; 7, 9: limestone rock
Hypnum vaucheri Lesq. – 6: limestone grassland
++***Isopterygiopsis muelleriana*** (Schimp.) Z. Iwats. – 7: limestone rock
Isopterygiopsis pulchella (Hedw.) Z. Iwats. – 3: soil among limestone rocks; 7: limestone rock
Isothecium alopecuroides (Lam. ex Dubois) Isov. – 1: bark of *Fagus*; 2, 7, 9: limestone rock
Leucodon sciuroides (Hedw.) Schwägr. – 5: bark of *Tilia*
Meesia uliginosa Hedw. – 8: limestone grassland
Mnium marginatum (Dicks.) P. Beauv. – 2: limestone rock
+***Mnium spinosum*** (Voit) Schwägr. – 2: limestone rock; 3: soil
Mnium thomsonii Schimp. – 2, 7, 9: limestone rock; 6: limestone grassland
Myurella julacea (Schwägr.) Schimp. – 6: limestone grassland
Neckera complanata (Hedw.) Huebener – 2, 7, 9: limestone rock; 6: limestone grassland
Neckera crispa Hedw. – 2, 7: limestone rock
Orthothecium intricatum (Hartm.) Schimp. – 7: limestone rock
Orthothecium rufescens (Dicks. ex Brid.) Schimp. – 7: limestone rock
Orthotrichum anomalum Hedw. – 9: limestone rock
Orthotrichum cupulatum Hoffm. ex Brid. – 6, 8: limestone grassland; 9: limestone rock
Orthotrichum lyellii Hook. et Taylor – 5: bark of *Tilia*
Orthotrichum obtusifolium Brid. – 5: bark of *Tilia*
Orthotrichum stramineum Hornsch. ex Brid. – 1, 2: bark of *Fagus*; 5: bark of *Tilia*
Orthotrichum striatum Hedw. – 5: bark of *Tilia*
Oxyrrhynchium hians (Hedw.) Loeske – 1: soil and sandstone rock in a rivulet; 2, 7: limestone rock; 3: soil
Palustriella falcata (Brid.) Hedenäs – 3: at a pond
Paraleucobryum longifolium (Hedw.) Loeske – 1: bark of *Fagus*

Plagiobryum zierii (Hedw.) Lindb. – 6: limestone grassland; 7: limestone rock
Plagiomnium affine (Blandow ex Funck) T. J. Kop. – 7: limestone rock
Plagiomnium rostratum (Schrad.) T. J. Kop. – 1: bark of *Fagus*; 2: limestone rock and bark of *Fagus*
Plagiomnium undulatum (Hedw.) T. J. Kop. – 2, 7: limestone rock
Plagiopus oederianus (Sw.) H. A. Crum et L. E. Anderson – 3, 7: limestone rock
+***Plagiothecium curvifolium*** Schlieph. ex Limpr. – 1, 3: decaying wood
Plagiothecium denticulatum (Hedw.) Schimp. – 3: decaying wood
Platydictya jungermannioides (Brid.) H. A. Crum – 7: limestone rock and decaying wood
Pleurozium schreberi (Willd. ex Brid.) Mitt. – 3: at a pond
Pohlia cruda (Hedw.) Lindb. – 7: limestone rock; 8: limestone grassland
Pohlia wahlenbergii (F. Weber et D. Mohr) A. L. Andrews – 4: soil; 6: limestone grassland
Polytrichastrum formosum (Hedw.) G. L. Sm. – 1: soil; 3: at a pond
Polytrichum commune Hedw. – 8: limestone grassland
Polytrichum juniperinum Hedw. – 6, 8: limestone grassland
Pseudoleskea incurvata (Hedw.) Loeske – 6, 8: limestone grassland; 9: limestone rock
++***Pseudoleskea patens*** (Lindb.) Kindb. – 9: limestone rock
Pseudoleskea saviana (De Not.) Latzel – 1, 6: bark of *Fagus*
Pseudoleskeella catenulata (Brid. ex Schrad.) Kindb. – 2, 7, 9: limestone rock; 6: limestone grassland
Pseudoleskeella nervosa (Brid.) Nyholm – 6: bark of *Fagus*
Pseudoscleropodium purum (Hedw.) M. Fleisch. – 3: at a pond; 6: limestone grassland
+***Pterigynandrum filiforme*** Hedw. – 1, 6: bark of *Fagus*; 2, 9: limestone rock
Racomitrium canescens (Hedw.) Brid. – 8: limestone grassland
+***Racomitrium elongatum*** Ehrh. ex Frisvoll – 3: at a pond
Rhizomnium punctatum (Hedw.) T. J. Kop. – 1: soil; 7: limestone rock
+***Rhynchostegiella tenuicaulis*** (Spruce) Kartt. – 2, 7: limestone rock
Rhynchostegium murale (Hedw.) Schimp. – 2, 3: limestone rock; 8: limestone grassland
Rhytidiadelphus loreus (Hedw.) Warnst. – 1: bark of *Fagus*; 2, 7: limestone rock; 3: soil
Rhytidiadelphus squarrosus (Hedw.) Warnst. – 3: at a pond
Rhytidiadelphus triquetrus (Hedw.) Warnst. – 2: limestone rock; 3: at a pond; 8: limestone grassland
Sanionia uncinata (Hedw.) Loeske – 3: decaying wood; 7: limestone rock; 8: limestone grassland
Schistidium atrofuscum (Schimp.) Limpr. – 6, 8: limestone grassland
Schistidium brunnescens Hedw. subsp. ***griseum*** (Nees et Hornsch.) H. H. Blom – 6, 8: limestone grassland
Schistidium crassipilum H. H. Blom – 7, 9: limestone rock; 8: limestone grassland
Sciuro-hypnum reflexum (Starke) Ignatov et Huttunen – 1: decaying wood
Seligeria acutifolia Lindb. – 2: limestone rock
+***Syntrichia calcicola*** J. J. Amann – 9: limestone rock
+***Syntrichia handelii*** (Schiffn.) S. Agnew et Vondr. – 6: limestone grassland
Syntrichia ruralis (Hedw.) F. Weber et D. Mohr – 2: limestone rock and bark of *Fagus*; 5: bark of *Tilia*; 7: limestone rock; 8: limestone grassland
+***Syntrichia subpapillosissima*** (Bizot et R. B. Pierrot ex W. A. Kramer) M. T. Gallego et J. Guerra – 6, 9: limestone grassland
Syntrichia virescens (De Not.) Ochyra – 5: bark of *Tilia*
Tetraphis pellucida Hedw. – 2: decaying wood
Thamnobryum alopecurum (Hedw.) Gangulee – 2, 7: limestone rock
Thuidium assimile (Mitt.) A. Jaeger – 3: at a pond
Thuidium tamariscinum (Hedw.) Schimp. – 1: bark of *Abies*; 3, 7: decaying wood; 3: at a pond
+***Tortella bambergeri*** (Schimp.) Broth. – 6: limestone grassland

Tortella inclinata (R. Hedw.) Limpr. – 6, 8: limestone grassland
Tortella tortuosa (Hedw.) Limpr. – 2, 7, 9: limestone rock; 6, 8: limestone grassland
Tortella tortuosa (Hedw.) Limpr. var. ***fragilifolia*** (Hedw.) Limpr. – 7, 9: limestone rock; 8: limestone grassland
++***Trichodon cylindricus*** (Hedw.) Schimp. – 9: limestone rock
Trichostomum crispulum Bruch – 9: limestone rock
Tortula subulata Hedw. – 6: limestone grassland
Ulota bruchii Hornsch. ex Brid. – 1: bark of *Fagus*
Ulota crispa (Hedw.) Brid. – 1: bark of *Fagus*
Weissia condensa (Voit) Lindb. – 6: limestone grassland
Weissia condensa (Voit) Lindb. var. ***armata*** (Thér. et Trab.) M. J. Cano, Ros et J. Guerra – 8: limestone grassland
Weissia controversa Hedw. – 8: limestone grassland
Weissia longifolia Mitt. – 8: limestone grassland
++***Weissia rostellata*** (Brid.) Lindb. – 8, 9: limestone grassland
+***Zygodon rupestris*** Schimp. ex Lorentz – 1, 2: bark of *Fagus*

SPECIES REPORTED FOR THE FIRST TIME IN CROATIA

New species for the Croatian bryophyte flora found in 2011 were published separately in Papp *et al.* (2013*a*). These are: *Lophozia longidens, Mnium spinosum, Plagiothecium curvifolium*, *Pterigynandrum filiforme, Racomitrium elongatum, Rhynchostegiella tenuicaulis, Syntrichia handelii, Syntrichia subpapillosissima, Tortella bambergeri, Zygodon rupestris*. *Calypogeia muelleriana, Campylium protensum, Syntrichia calcicola* are also reported in the above mentioned paper, but the first two species were found in the Gorski kotar Region, while the third one in the Papuk Mts in 2011. In 2012 these were collected in the Northern Velebit, too.

Here we report four additional new taxa for the Croatian bryophyte flora found in 2012 in the Northern Velebit.

Isopterygiopsis muelleriana is a rare sub-Atlantic, montane species (Düll 1985) occurring on limestone boulders and rock crevices usually at high altitudes (Smith 2004). In Southeast Europe, it is known only from Bulgaria, the Former Yugoslav Republic of Macedonia, Romania, and Slovenia (Sabovljević *et al.* 2008). Scattered shoots of the species were found intermixed in a patch of *Isopterygiopsis pulchella* on shaded limestone rock in the Jovanovića snižnica ice hole.

Pseudoleskea patens is a subarctic, subalpine element (Düll 1985) living on shaded limestone rocks, rock crevices at high altitudes (Smith 2004). In Southeast Europe it was known from Bosnia-Herzegovina, Montenegro, Romania, Serbia, and Slovenia (Sabovljević *et al.* 2008), later reported from Greece and the Former Yugoslav Republic of Macedonia (Papp *et al.* 2011). It was collected from limestone rock near Zavižan peak.

Trichodon cylindricus is a subboreal species (Düll 1984). It is known in almost all Southeast European countries (Sabovljević *et al.* 2008) except Albania, Croatia, the Former Yugoslav Republic of Macedonia and the European part of Turkey. Recently it has been also reported from the Former Yugoslav Republic of Macedonia (Papp and Erzberger 2012). It was collected from soil among limestone rocks near Zavižan peak.

Weissia rostellata is a sub-Atlantic species (Düll 1984). In Southeast Europe it is known only from Serbia and Slovenia (Sabovljević *et al.* 2008). In the Northern Velebit it was collected in calcareous grasslands around Tudorevo and Zavižan peak.

CONSERVATION MERITS OF THE BRYOPHYTE FLORA OF THE NORTHERN VELEBIT

The following six species found in the Northern Velebit are included in the Red data book of European bryophytes (ECCB 1995).

Lophozia ascendens is a boreal, montane liverwort (Düll 1983) living on decaying wood in constantly humid forests. It is categorised as rare (R) in the Red data book of European bryophytes (ECCB 1995). It was also collected in the Gorski kotar Region (Papp *et al.* 2013*b*). In the Northern Velebit it was found in the virgin forests around Štirovača and Jovanovića snižnica ice hole.

Anomodon rostratus is a sub-Mediterranean, montane element (Düll 1985) occurring on shaded limestone rocks, rock crevices. It is categorised as rare (R) in the Red data book of European bryophytes (ECCB 1995). In Southeast Europe it was known only from Bulgaria, Romania, Serbia and Slovenia (Sabovljević *et al.* 2008), subsequently reported from Croatia (Papp and Sabovljević 2009) following the revision of herbarium specimens, which were also cited in *Flora Velebitica* (Degen 1938), but this publication was erroneously omitted in Sabovljević *et al.* (2008). The species was found on limestone boulders in the forests around Štirovača.

Buxbaumia viridis is a boreal, montane species (Düll 1984). It also lives on well-decayed wood in humid forests. It is listed in the Bern Convention and the European Union Habitats and Species Directive and it is vulnerable according to the Red data book of European bryophytes (ECCB 1995). It seems to be not rare in the virgin, but also in managed old-growth forests in the Gorski kotar Region. In the Northern Velebit, extensive populations (hundreds of inhabited trees) were found in the virgin forests around Štirovača and a small population (a few colonised trees) at Jovanovića snižnica ice hole.

Pseudoleskea saviana is a species of shaded volcanic rocks, but it is also frequently found on tree bark mainly at the bases of trunks. It is a continental, sub-

alpine species found in the Alps and other areas towards east (Düll 1985). It is categorised as regionally threatened (RT) in the Red data book of European bryophytes (ECCB 1995). It does not appear to be rare in Southeast Europe (Papp *et al.* 2013*b*). In the Northern Velebit, it was collected from beech bark in the forest around Štirovača and Buljma peak near Veliki Alan pass.

Rhynchostegiella tenuicaulis is a montane species of the temperate zones of Europe (Düll 1985). It is included in the Red data book of European bryophytes in the insufficiently known (K) category (ECCB 1995). In Southeast Europe, it is known only from Bulgaria, Greece and Romania (Sabovljević *et al.* 2008). Small patches of the species were found on shaded limestone rocks at Štirovača and around Jovanovića snižnica ice hole.

Weissia rostellata is categorised as rare (R) in the Red data book of European bryophytes (ECCB 1995). We report this moss species for the first time in Croatia in this paper. More details about the European and Southeast European distribution of the species can be seen above. Several patches were found mixed with *Weissia longifolia*, *Bryum archangelicum* on soil among limestone rocks in the grasslands of Tudorevo and Zavižan at high altitude (1,300–1,500 m a.s.l.).

Additional 18 taxa (5 liverworts and 13 mosses) are regarded as rare in Southeast Europe. Part of these were also found in the Gorski kotar Region and are mentioned as Southeast European rarities in Papp *et al.* (2013*b*), including *Calypogeia muelleriana*, *C. suecica*, *Cephalozia catenulata* liverworts, and *Isopterygiopsis pulchella, Orthothecium rufescens, Plagiobryum zierii, Platydictya jungermannioides, Thuidium tamariscinum, Ulota bruchii, Zygodon rupestris* mosses. *Calypogeia suecica, Cephalozia catenulata, Thuidium tamariscinum* seem to be quite frequent on decaying wood in old-growth forests of the Northern Velebit, exemplified by the virgin forests around Štirovača. Here, some rare epiphytes can also be found, e.g. *Ulota bruchii, Zygodon rupestris*. Rare species living on limestone rocks were mainly collected in Jovanovića snižnica ice hole, including *Isopterygiopsis pulchella, Orthothecium rufescens, Plagiobryum zierii, Platydictya jungermannioides.* Most of the above-mentioned species were not rare in the past in the Velebit Mts, evidenced by several specimens deposited in the Degen's herbarium. Only two species (*Isopterygiopsis pulchella*, *Platydictya jungermannioides)* can be regarded as rare in the past, having only one specimen each in our herbarium, from the years 1906 and 1912, respectively. *Calypogeia muelleriana* was recently reported for the first time in Croatia, from Gorski kotar (Papp *et al.* 2013*a*); it was also found in the Northern Velebit on decaying wood fallen into the Jovanovića snižnica ice hole.

Other species rare on the Balkans are the following:

Lophozia longidens is a boreal, montane liverwort (Düll 1983) occurring on siliceous rocks and bark of trees. In Southeast Europe it was known only from

Bulgaria, Romania, Serbia (Sabovljević and Natcheva 2006), and recently discovered in Montenegro (Papp and Erzberger 2010), Greece and Former Yugoslav Republic of Macedonia (Papp *et al.* 2011). It is endangered (EN) in Bulgaria (Natcheva *et al.* 2006). In the Northern Velebit it was collected from *Abies* bark in the forests around Štirovača. This is the first record of the species in Croatia (Papp *et al.* 2013*a*).

Ptilidium ciliare is a boreal liverwort (Düll 1983) living on humid rocks. It is endangered (EN) in Bulgaria (Natcheva *et al.* 2006). In the Northern Velebit it was found in the limestone grassland of a large dolina at Tudorevo. There is no voucher of this species from the past from Croatia in our herbarium (BP).

Distichium inclinatum is a subarctic, subalpine species (Düll 1984) occurring on soil among limestone rocks. It is vulnerable (VU) in Bulgaria (Natcheva *et al.* 2006). In the Northern Velebit, it was collected in the limestone grassland of a large dolina at Tudorevo. In our herbarium (BP) there are a few specimens collected in 1908 and 1909 from two localities in the Velebit Mts.

Isopterygiopsis muelleriana is sub-Atlantic, montane species (Düll 1985) reported for the first time in Croatia in this paper. In Southeast Europe, it is known only from Bulgaria, Former Yugoslav Republic of Macedonia, Romania, Slovenia (Sabovljević *et al.* 2008) and it is vulnerable (VU) in Bulgaria (Natcheva *et al.* 2006) and near threatened (NT) in Romania (Ştefănuţ and Goia 2012). Scattered individuals of the species were found intermixed in a patch of *Isopterygiopsis pulchella* on a shaded limestone rock in Jovanovića snižnica ice hole.

Meesia uliginosa is a boreal species (Düll 1985) living on soil among limestone rocks and in rock crevices. It is vulnerable (VU) in Bulgaria (Natcheva *et al.* 2006), Serbia and Montenegro (Sabovljević *et al.* 2004), and near threatened (NT) in Romania (Ştefănuţ and Goia 2012). In the Northern Velebit, scattered individuals of the species were found in patches of *Lophozia collaris* mixed with *Distichium inclinatum* in the grassland of Tudorevo. There are two specimens of this species in the Degen's herbarium collected in 1912 from two localities in the Velebit Mts.

Schistidium atrofuscum is a subarctic, subalpine species (Düll 1984) living on exposed limestone rocks. It is near threatened (NT) in Bulgaria (Natcheva *et al.* 2006) and Romania (Ştefănuţ & Goia 2012). In the Northern Velebit, it was found in limestone grasslands at high altitudes (1,350–1,450 m a.s.l.). There is one specimen in the Degen's herbarium collected in 1912 in the Velebit Mts.

Seligeria acutifolia is a sub-Mediterranean, montane species (Düll 1984) occurring in limestone rock crevices. It is vulnerable (VU) in Bulgaria (Natcheva *et al.* 2006) and data deficient (DD) in Romania (Ştefănuţ and Goia 2012). In the Northern Velebit, it was found on a shaded limestone boulder in the forests

around Štirovača. There is no specimen of this species from the past from Croatia in our herbarium (BP).

Syntrichia handelii is an East Mediterranean, continental species (Düll 1984). In spite of its distribution range, in Southeast Europe it is known only from Greece, Montenegro (Sabovljević *et al*. 2008) and Albania (Papp *et al.* 2010). It was reported for the first time by the first author from Montenegro and Albania, and these are the only records of the species in these countries. The record from the Northern Velebit was published in Papp *et al.* (2013*a*) as a species new for the Croatian bryophyte flora. Here it was collected in the limestone grassland of Buljma peak near Veliki Alan pass.

CONCLUSIONS

The Velebit Mts is one of the most important centres of vascular flora diversity of Croatia and this fact stands also for the bryophyte diversity. Furthermore, the Velebit Mts is one of the bryologically best-researched parts of Croatia, thanks to the extensive surveys by Degen and the early identifications made by Baumgartner and Schiffner (Degen 1938).

In spite of the geological uniformity (the bedrock is mainly Mesozoic limestone), the diversity of altitudinal belts, the various exposures, and as a result, the climatic conditions on both inland and coastal slopes have enabled the formation of rather diverse habitat conditions and plant communities, which also helped the establishment of high diversity of bryophytes. Our research focused on old-growth and virgin beech-fir and spruce forests, grasslands and open rocks of the subalpine vegetation belt. Therefore, the majority of newly recorded, threatened and rare species belong to boreal and subboreal elements (*Lophozia ascendens*, *L. longidens*, *Buxbaumia viridis*, *Ptilidium ciliare*, *Meesia uliginosa*) and subarctic (*Pseudoleskea patens*, *Distichium inclinatum*, *Schistidium atrofuscum*). However, due to the near-South European position of the researched area, presence of sub-Mediterranean and East Mediterranean elements such as *Anomodon rostratus*, *Seligeria acutifolia* and *Syntrichia handelii* is also evident.

The old-growth forests are of special merit with an abundance of decaying wood, which enabled the thriving of vigorous populations of certain rare species (*Calypogeia suecica, Cephalozia catenulata, Lophozia ascendens*, *Buxbaumia viridis*, *Thuidium tamariscinum*).

The total number of 191 bryophytes (40 liverworts and 151 mosses) is far from the total number of taxa in the area, since a wide range of sub-Mediterranean and Mediterranean-montane habitats (*Quercus pubescens-Ostrya carpinifolia* forests and shrubberies, maritime beech forests, pastures, rocky grasslands,

rocks, remnants of arable fields and small water ponds, etc.) were completely omitted from the target area of the present research.

The diverse bryophyte flora and the fact that the Northern Velebit is protected in the frame of a national park make the Nothern Velebit an ideal candidate for "Important Bryophyte Area".

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