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## CONTRIBUTIONS TO THE BRYOPHYTE FLORA OF CROATIA III. PLITVIČKA JEZERA NATIONAL PARK AND ADJACENT AREAS

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Bryological field surveys in Plitvička jezera National Park and adjacent areas (Slunjička river and Vrhovinsko polje karst field) carried out in 2012 and 2013 resulted in a list of 207 species (39 liverworts and 168 mosses). Two species are reported for the first time from Croatia (*Ephemerum minutissimum* and *Pohlia annotina*). Six species are included in the Red data book of European bryophytes (*Buxbaumia viridis*, *Dicranum viride*, *Hamatocaulis vernicosus*, *Anomodon rostratus*, *Rhynchostegiella tenuicaulis* and *Taxiphyllum densifolium*). The first three are listed in the Bern Convention and the EU Habitats and Species Directive as well; in addition, other species, especially *Sphagnum* spp. rare in SE Europe were also located in the area.

Key words: liverworts, mosses, new records for Croatia, threatened species

### INTRODUCTION

This paper represents the continuation of renewed bryological research in Croatia. Although Croatia sometimes considered (e.g. SABOVLJEVIĆ *et al.* 2001) one of the bryologically best-explored countries in SE Europe, the great majority of data comes from before 1960. On the other hand, comparative statistical analysis of the bryophyte diversity in SE Europe showed that in Croatia a significantly higher number of bryophyte species should be expected (SABOVLJEVIĆ *et al.* 2011). Several recent checklists (SABOVLJEVIĆ 2003, 2006, SABOVLJEVIĆ and NATCHEVA 2006, SABOVLJEVIĆ *et al.* 2008) are mainly new summarisations and compilations of the old data with very sporadic new contributions. This situation aroused an urgent need for gathering new data on Croatia's bryophyte species and their distribution. In order to fill this gap the authors have initiated a series of systematic field studies in different regions of Croatia, and have recently pub-

lished contributions to the bryophyte flora of the Gorski kotar Region, and of the Northern Velebit Mts (PAPP *et al.* 2013a, b), as well as list of new taxa for the bryophyte flora of Croatia (PAPP *et al.* 2013c). Hereby, new contributions for the Lika region, more precisely for the Plitvička jezera National Park and some adjacent areas, Vrhovinsko polje karst field and Slunjčica river, are presented.

Regarding previous bryological surveys of the region concerned, only the tuff barriers of Plitvička jezera had been researched in more detail by Croatian botanist Zlatko Pavletić. The majority of his results were published in coauthority with Croatian zoologist Ivo Matoničkin in a series of papers dealing with the biocenoses and ecology of karst rivers and tuff barriers (MATONIČKIN and PAVLETIĆ 1960, 1961, 1963, 1964, PAVLETIĆ 1957). Their species lists for Plitvička jezera are concentrated solely on the tuff barriers, with only 25 bryophyte species (listed in alphabetical order with names used by Pavletić in brackets). These are as follows: Liverworts: *Aneura pinguis* (L.) Dumort., *Conocephalum conicum* (L.) Dumort. (*Fegatela conica* Corda), *Jungermannia atrovirens* Dumort. (*Haplozia riparia* (Teyl.) Dum.) and *Pellia endiviifolia* (Dicks.) Dumort. (*P. fabbroniana* Raddi); Mosses: *Brachythecium rivulare* Schimp. (*B. rivulare* (Bruch.) Br. Eur.), *Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. et Scherb. (*B. ventricosum* Dicks.), *Bryum erythrocarpum* complex (*B. erythrocarpum* Schwägr.), *Cinclidotus aquaticus* (Hedw.) Bruch et Schimp. (*C. aquaticus* Br. Eur.), *Cratoneuron filicinum* (Hedw.) Spruce (*C. filicinum* Roth), *Didymodon tophaceus* (Brid.) Lisa (*D. tophaceus* Jur.), *Eucladium verticillatum* (With.) Bruch et Schimp. (*E. verticillatum* Br. Eur.), *Fissidens taxifolius* Hedw., *Fissidens adianthoides* Hedw., *Fontinalis antipyretica* Hedw. (*F. antipyretica* L.), *Gymnostomum aeruginosum* Sm. (*G. rupestre* Schl.), *Hygroamblystegium tenax* (Hedw.) Jenn. (*H. irriguum* (Wils.) Loeske), *Hymenostylium recurvirostrum* (Hedw.) Dixon (*Gymnostomum curvirostre* (Ehrh.) Lindb.), *Leptodictyum riparium* (Hedw.) Warnst., *Pohlia wahlenbergii* (F. Weber et D. Mohr) A. L. Andrews var. *calcareae* (Warnst.) E. F. Warb. (*Mniobryum calcareum* (Warnst.) Limpr.), *Orthothecium rufescens* (Dicks. ex Brid.) Schimp. (*O. rufescens* Br. Eur.), *Palustriella commutata* (Hedw.) Ochyra (*Cratoneuron commutatum* (Hedw.) Roth), *Philonotis calcarea* (Bruch et Schimp.) Schimp., *Plagiomnium undulatum* (Hedw.) T. J. Kop. (*Mnium undulatum* Weis), *Platyhypnidium riparioides* (Hedw.) Dixon (*P. rusciforme* Fleisch.), *Rhizomnium punctatum* (Hedw.) T. J. Kop. (*Mnium punctatum* Hedw.).

## MATERIAL AND METHODS

### Study area

The area of Plitvička jezera is situated in the mountainous areas of Croatia, on the southern edge of the Mt Mala Kapela. Since 1949 Plitvička jezera are

protected as national park and in 1979 they were proclaimed a World Natural Heritage by UNESCO. The Park covers 29,685 ha, which includes 200 ha occupied by 16 lakes, 13,320 ha by forests and the rest are grasslands, shrublands and other habitat types. The elevation ranges from 367 m to 1,279 m a.s.l. (Seliški vrh peak), with an average altitude of 912 m a.s.l. (BOŽIČEVIĆ 1994, GUŠIĆ and MARKOVIĆ 1974, RIĐANOVIĆ 1994). The climate is moderately warm and moist with warm summers. The average annual precipitation is 1,550 mm with maxima in spring and autumn and the snow cover lasts from November to March. The coldest month is January with an average temperature of 2.2 °C, while the warmest is July (average: 17.4 °C) and the annual average is 7.9 °C (GUŠIĆ and MARKOVIĆ 1974, ZANINOVIĆ 2008). The dominant bedrock is limestone (Triassic, Jurassic and Cretaceous). Different types of beech forests compose the climazonal vegetation, of which beech-fir forests (ass. *Omphalodo-Fagetum sylvaticae*) are the most characteristic and widespread. The forest stands at Čorkova uvala have never been managed thus considered unique in European context (ANIĆ and MIKAC 2008, CESTAR *et al.* 1983, PLAVŠIĆ-GOJKOVIĆ *et al.* 1972, PRPIĆ 1972). The area is home to other forest types developed on moist and wet habitats with *Alnus glutinosa*, *Fraxinus excelsior*, *Salix* spp.; on thermophilous habitats with low forests of *Fraxinus ornus* and *Ostrya carpinifolia*; on steep slopes with *Pinus nigra* and *P. sylvestris*; and on localities with temperature inversion with stands of *Picea abies* (CESTAR *et al.* 1976, VUKELIĆ 2012). The grassland vegetation is also very rich, with many associations mainly determined by levels of water availability and pH (ŠEGULJA 2005). The lake vegetation is characterised by the dominance of various *Chara* species, but other macrophytes and helophytes are also present. Very specific for the lakes are the tuff formations, a complex system of barriers and waterfalls, where aquatic bryophyte communities are dominant. One of the best preserved peat bogs in Croatia, Ljeskovačke bare, with a large population of *Drosera rotundifolia* and other characteristic species (SRDOČ *et al.* 1985, TEŠIĆ *et al.* 1985), is also situated within the park. The total vascular flora counts 1,267 species with many rare, protected and red-listed species of the Croatian flora (KRGÁ 1992).

In the study area we also included Vrhovinsko polje, which is situated outside (precisely, alongside the western border) of Plitvička jezera National Park. It is a typical karst field that has its lowest, central part periodically flooded during winter and early spring. It is covered by grassland vegetation of different communities that show a pattern of distribution closely dependent on water amount and soil pH. Considering the diversity of grassland communities and flora, this is one of the richest and most diverse karstlands in Croatia and therefore from 2013 recognised and protected as Natura 2000 site.

Another locality outside the Park is Slunjčica (or Slušnica) river near the town of Slunj. It is a typical karst river, only 5 km long, with many tuff barriers and clear unpolluted water. It is a tributary of the Korana river, which is flowing out of the Plitvička jezera lakes. It flows into Korana at Rastoke village, where it forms a complex of cascades and waterfalls. Slunjčica River is protected since 1964 as “significant landscape” as well from 2013 as Natura 2000 site.

### Methods

The collecting trips were made in July 2012 and 2013. The researched area is presented in Figure 1, and particular collecting sites are listed in the following text. During the field trips special attention was paid to collect bryophytes in all habitat types. The specimens are deposited in the Bryophyte Herbarium of the Hungarian Natural History Museum, Budapest (BP) and the Herbarium Croaticum of the University of Zagreb (ZA). The nomenclature follows SCHUMACKER and VÁŇA (2005) for liverworts (except *Chiloscyphus pallescens* (Ehrh. ex Hoffm.) Dumort., which follows GROLLE and LONG 2000) and HILL *et al.* (2006) for mosses. New species for the bryophyte flora of Croatia are given according to general checklists of SE Europe and the Mediterranean (ROS *et al.* 2007, 2013, SABOVLJEVIĆ 2003, 2006, SABOVLJEVIĆ and NATCHEVA 2006, SABOVLJEVIĆ *et al.* 2008) and taking into consideration new records (ALEGRO *et al.* 2012, MODRIĆ SURINA *et al.* 2012, PAPP and SABOVLJEVIĆ 2009, PAPP *et al.* 2013a, b, c).

### Collecting sites

1. Plitvička jezera National Park, Čorkova uvala forest reserve, virgin beech-fir forest (ass. *Omphalodo-Fagetum*), 44° 54' 56.8" N, 15° 29' 57.9" E, 950 m, 23.07.2012.
2. Plitvička jezera National Park, Čorkova uvala, *Fraxinus excelsior* trees at the forest house, 44° 54' 51.3" N, 15° 31' 43.9" E, 885 m, 23.07.2012.
3. Slunj town, limestone rocks of barrier at the mill on Slunjčica river, 45° 06' 44.4" N, 15° 35' 13.7" E, 240 m, 22.07.2013.
4. Plitvička jezera National Park, Čorkova uvala, *Fraxinus excelsior* tree at the forest house, 44° 54' 51.3" N, 15° 31' 43.9" E, 885 m, 23.07.2013.
5. Plitvička jezera National Park, Čorkova uvala forest reserve, virgin beech-fir forest (ass. *Omphalodo-Fagetum*), 44° 54' 56.8" N, 15° 29' 57.9" E, 950 m, 23.07.2013.
6. Plitvička jezera National Park, Plitvički Ljeskovac, Ljeskovačke bare, transitional peat bog (ass. *Drosero-Caricetum echinatae*), surrounded by *Molinia caerulea* meadows, tall herb vegetation of wet habitats (community with *Filipendula ulmaria*, *Lythrum salicaria* and *Lysimachia vulgaris*) and beech-fir forest with limestone rocks, 44° 50' 57.8" N, 15° 36' 01.4" E, 640 m, 24.07.2013.
7. Plitvička jezera National Park, Plitvički Ljeskovac, Crna reka rivulet surrounded by stands of *Alnus glutinosa* and tall herb vegetation dominated by *Petasites hybridus*, 44° 50' 31.7" N, 15° 35' 51.9" E, 665 m, 24.07.2013.

8. Vrhovinsko polje karst field, various grassland and meadow communities, 44° 49' 04.6" N, 15° 29' 05.8" E, 770 m, 25.07.2013.
9. Babin potok village, pine forest (ass. *Helleboro nigri-Pinetum sylvestrae*) on steep slope on dolomite bedrock, 44° 50' 16.9" N, 15° 30' 03.1" E, 780 m, 25.07.2013.
10. Plitvička jezera National Park, Medvedak, beech-fir forest (ass. *Omphalodo-Fagetum*), 44° 53' 04.7" N, 15° 37' 57.7" E, 640 m, 26.07.2013.

## RESULTS AND DISCUSSION

207 bryophytes (39 liverworts and 168 mosses) were collected in Plitvička jezera National Park, along the Slunjčica river near the town of Slunj and in Vrhovinsko polje karst field. 11 recorded taxa were recently published as new for Croatia (PAPP *et al.* 2013*a, b, c*) and two are reported here for the first time.

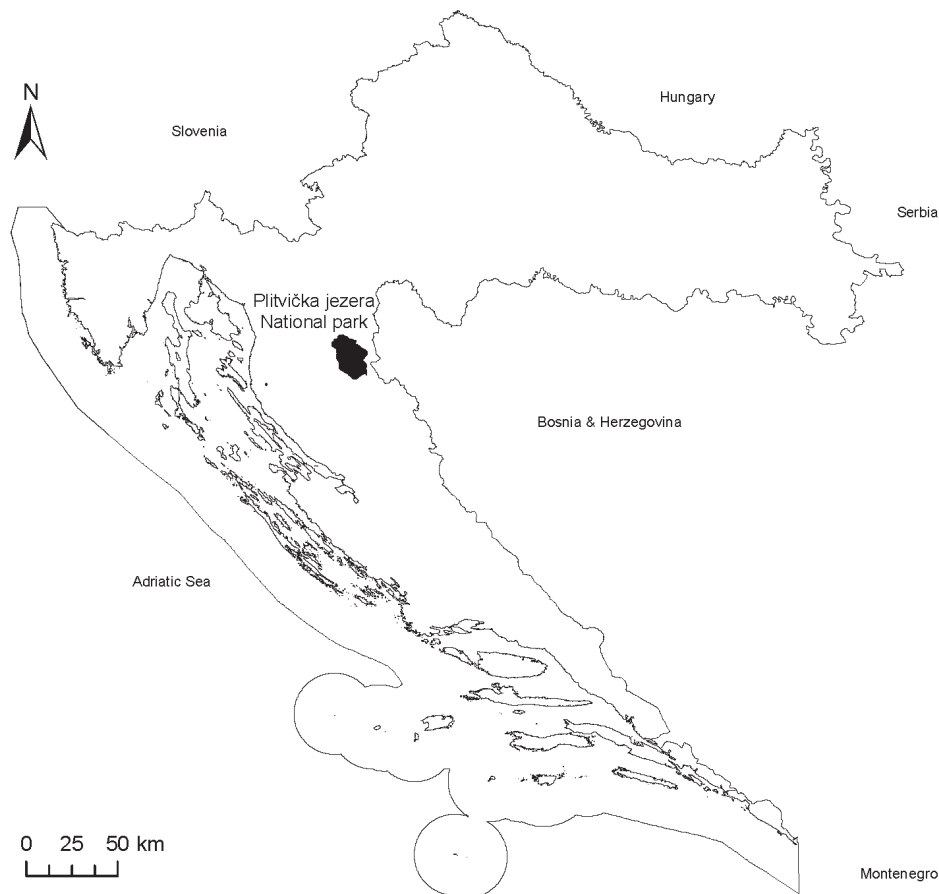


Fig. 1. Location of the study area.

## Hepaticae

- Apometzgeria pubescens* (Schrank) Kuwah. – 1, 5: shaded limestone rock  
*Blepharostoma trichophyllum* (L.) Dumort. – 5: decaying wood  
*Calyptogeia suecica* (Arnell et J. Perss.) Müll. Frib. – 1, 5: decaying wood  
*Cephalozia catenulata* (Huebener) Lindb. – 1, 5: decaying wood  
*Chiloscyphus coadunatus* (Sw.) J. J. Engel et R. M. Schust. – 3, 6: shaded limestone rock  
*Chiloscyphus pallescens* (Ehrh. ex Hoffm.) Dumort. – 3: limestone rock at a mill  
*Chiloscyphus profundus* (Nees) J. J. Engel et R. M. Schust. – 1, 6, 9: decaying wood  
*Cololejeunea calcarea* (Lib.) Schiffn. – 1, 3, 5, 6, 10: shaded limestone rock  
*Cololejeunea rosettiana* (C. Massal.) Schiffn. – 1, 5, 10: shaded limestone rock  
*Conocephalum salebrosum* Szweyk., Buczkowska et Odrzykoski – 1: limestone rock; 3: limestone rock at a mill; 5: shaded limestone rock  
*Frullania dilatata* (L.) Dumort. – 2: bark of *Fraxinus excelsior* tree; 6: shaded limestone rock; 10: bark of *Fagus sylvatica*  
*Frullania tamarisci* (L.) Dumort. – 5: decaying wood; 6: shaded limestone rock  
*Jungermannia gracillima* Sm. – 8: meadow  
*Jungermannia leiantha* Grolle – 1, 5: decaying wood  
*Jungermannia pumila* With. – 3: shaded limestone rock  
*Lejeunea cavifolia* (Ehrh.) Lindb. – 1, 3, 5, 6, 10: shaded limestone rock; 10: bark of *Fagus sylvatica*  
*Lepidozia reptans* (L.) Dumort. – 1, 5: decaying wood  
*Lophozia badensis* (Gottsche) Schiffn. – 6: shaded limestone rock  
*Lophozia bantriensis* (Hook.) Steph. – 1: limestone rock; 6: shaded limestone rock  
*Lophozia incisa* (Schrad.) Dumort. – 1: decaying wood  
*Lophozia longidens* (Lindb.) Macoun – 1: bark of *Abies alba*  
*Marchantia polymorpha* L. subsp. *polymorpha* – 7: limestone rock in the stream  
*Marchantia polymorpha* L. subsp. *montivagans* Bischl. et Boisselier – 7: limestone rock in the stream  
*Metzgeria conjugata* Lindb. – 1, 3, 5, 6, 10: shaded limestone rock; 1: bark of *Fagus sylvatica*  
*Metzgeria furcata* (L.) Dumort. – 5: bark of *Fagus sylvatica*; 9: limestone rock; 10: decaying wood  
*Nowellia curvifolia* (Dicks.) Mitt. – 1, 5: decaying wood  
*Pedinophyllum interruptum* (Nees) Kaal. – 1, 3, 5, 10: shaded limestone rock  
*Pellia endiviifolia* (Dicks.) Dumort. – 3: limestone rock at a mill; 7: limestone rock in the stream; 8: meadow  
*Plagiochila asplenioides* (L. emend. Taylor) Dumort. – 1, 3: shaded limestone rock  
*Plagiochila porelloides* (Torrey ex Nees) Lindenb. – 1, 3, 5, 6, 10: shaded limestone rock; 1, 10: bark of *Fagus sylvatica*; 6: on soil  
*Porella arboris-vitae* (With.) Grolle – 1, 10: bark of *Fagus sylvatica*; 3, 10: shaded limestone rock  
*Porella platyphylla* (L.) Pfeiff. – 1: limestone rock; 5: bark of *Fagus sylvatica*; 10: decaying wood  
*Preissia quadrata* (Scop.) Nees – 6: shaded limestone rock  
*Radula complanata* (L.) Dumort. – 1, 10: bark of *Fagus sylvatica*; 5, 6, 9: shaded limestone rock  
*Riccardia palmata* (Hedw.) Carruth. – 1, 5: decaying wood  
*Scapania aequiloba* (Schwägr.) Dumort. – 6: shaded limestone rock  
*Scapania aspera* M. Bernet et Bernet – 3, 5, 6: shaded limestone rock  
*Scapania irrigua* (Nees) Nees – 8: meadow  
*Tritomaria exsecta* (Schmidel) Schiffn. ex Loeske – 5: decaying wood

## Musci

- Acaulon muticum* (Hedw.) Müll. Hal. – 8: meadow  
*Amblystegium confervoides* (Brid.) Schimp. – 10: shaded limestone rock  
*Amblystegium serpens* (Hedw.) Schimp. – 3: shaded limestone rock and bark of *Acer*; 7: limestone rock at the stream  
*Amblystegium subtile* (Hedw.) Schimp. – 3: bark of *Acer*  
*Anomodon attenuatus* (Hedw.) Huebener – 3, 10: shaded limestone rock  
*Anomodon longifolius* (Schleich. ex Brid.) Hartm. – 1, 10: shaded limestone rock  
*Anomodon rostratus* (Hedw.) Schimp. – 1, 5, 10: shaded limestone rock  
*Anomodon viticulosus* (Hedw.) Hook. et Taylor – 1, 3, 5, 9, 10: shaded limestone rock; 3: bark of *Acer*  
*Antitrichia curtispindula* (Hedw.) Brid. – 5, 10: decaying wood  
*Atrichum undulatum* (Hedw.) P. Beauv. – 1, 3: shaded limestone rock; 8: meadow  
*Aulacomnium palustre* (Hedw.) Schwägr. – 6: peat bog; 8: meadow  
*Barbula crocea* (Brid.) F. Weber et D. Mohr – 6: shaded limestone rock  
*Barbula unguiculata* Hedw. – 7: limestone rock at the stream; 8: meadow  
*Bartramia halleriana* Hedw. – 6: shaded limestone rock  
*Brachytheciastrum velutinum* (Hedw.) Ignatov et Huttunen – 1: bark of *Fagus sylvatica*; 9: on soil  
*Brachythecium mildeanum* (Schimp.) Schimp. – 8: meadow  
*Brachythecium rivulare* Schimp. – 7: limestone rock in the stream; 8: meadow  
*Brachythecium rutabulum* (Hedw.) Schimp. – 1, 5, 10: shaded limestone rock; 1: decaying wood; 3: limestone rock at a mill; 7: limestone rock in the stream; 8: meadow  
*Brachythecium tommasinii* (Sendtn. ex Boulay) Ignatov et Huttunen – 1, 5, 10: shaded limestone rock  
*Bryoerythrophyllum recurvirostrum* (Hedw.) P. C. Chen – 7: limestone rock at the stream  
*Bryum alpinum* Huds. ex With. – 8: meadow  
*Bryum capillare* Hedw. – 1: limestone rock; 6: decaying wood in the meadow; 8: meadow; 9: on soil  
*Bryum elegans* Nees – 8: meadow  
*Bryum moravicum* Podp. – 1, 5: shaded limestone rock; 5: decaying wood; 10: bark of *Fagus sylvatica*  
*Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. et Scherb. – 6: peat bog; 7: limestone rock in the stream; 8: meadow  
*Bryum radiculosum* Brid. – 8: meadow  
*Bryum rubens* Mitt. – 8: meadow  
*Bryum ruderale* Crundw. et Nyholm – 8: meadow  
*Buxbaumia viridis* (Moug. ex Lam. et DC.) Brid. ex Moug. et Nestl. – 1, 5: decaying wood  
*Calliergon giganteum* (Schimp.) Kindb. – 6: peat bog; 8: meadow  
*Calliergonella cuspidata* (Hedw.) Loeske – 6, 8: meadow  
*Campyliadelphus chrysophyllus* (Brid.) R. S. Chopra – 6: shaded limestone rock  
*Campylium stellatum* (Hedw.) Lange et C. E. O. Jensen – 6: peat bog; 8: meadow  
*Campylophyllum calcareum* (Crundw. et Nyholm) Hedenäs – 3, 6: shaded limestone rock; 3: bark of *Acer*  
*Campylophyllum halleri* (Hedw.) M. Fleisch. – 6: shaded limestone rock  
*Campylopus introflexus* (Hedw.) Brid. – 8: margin of meadow  
*Ceratodon purpureus* (Hedw.) Brid. – 8: meadow; 9: on soil  
*Cinclidotus aquaticus* (Hedw.) Bruch et Schimp. – 3: limestone rock at a mill  
*Cinclidotus fontinaloides* (Hedw.) P. Beauv. – 3: limestone rock at a mill  
*Cinclidotus riparius* (Host ex Brid.) Arn. – 3: limestone rock at a mill

- Cirriphyllum crassinervium* (Taylor) Loeske et M. Fleisch. – 3, 5, 10: shaded limestone rock  
*Climacium dendroides* (Hedw.) F. Weber et D. Mohr – 6: decaying wood in the meadow; 8: meadow  
*Cratoneuron filicinum* (Hedw.) Spruce – 3: limestone rock at a mill; 7: limestone rock in the stream; 8: meadow  
*Ctenidium molluscum* (Hedw.) Mitt. – 1, 3, 5, 6, 9, 10: shaded limestone rock  
*Dicranella staphylina* H. Whitehouse – 8: meadow  
*Dicranella varia* (Hedw.) Schimp. – 8: meadow  
*Dicranodontium denudatum* (Brid.) E. Britton – 5: decaying wood  
*Dicranum bonjeanii* De Not. – 6: peat bog; 8: meadow  
*Dicranum montanum* Hedw. – 1, 5: decaying wood  
*Dicranum scoparium* Hedw. – 1, 5, 10: shaded limestone rock; 1: bark of *Fagus sylvatica*; 5: decaying wood; 9: on soil  
*Dicranum tauricum* Sapjegin – 1: decaying wood; 5: bark of *Fagus sylvatica*  
*Dicranum viride* (Sull. et Lesq.) Lindb. – 10: bark of *Fagus sylvatica*  
*Distichium capillaceum* (Hedw.) Bruch et Schimp. – 6: shaded limestone rock  
*Ditrichum flexicaule* (Schwägr.) Hampe – 6: shaded limestone rock  
*Ditrichum gracile* (Mitt.) Kuntze – 6: shaded limestone rock  
*Ditrichum heteromallum* (Hedw.) E. Britton – 8: meadow  
*Drepanocladus aduncus* (Hedw.) Warnst. – 8: meadow  
*Drepanocladus polygamus* (Schimp.) Hedenäs – 6: peat bog; 8: meadow  
*Encalypta streptocarpa* Hedw. – 3, 6, 10: shaded limestone rock; 7: limestone rock at the stream  
*Encalypta vulgaris* Hedw. – 6: soil among limestone rocks  
*Ephemerum minutissimum* Lindb. – 8: meadow  
*Eucladium verticillatum* (With.) Bruch et Schimp. – 3: shaded limestone rock  
*Eurhynchium angustirete* (Broth.) T. J. Kop. – 1, 5, 6, 10: shaded limestone rock; 9: on soil  
*Eurhynchium hians* (Hedw.) Sande Lac. – 1, 3, 6, 10: shaded limestone rock; 7: limestone rock at the stream  
*Eurhynchium striatum* (Hedw.) Schimp. – 3: shaded limestone rock  
*Fissidens adianthoides* Hedw. – 6: peat bog; 8: meadow  
*Fissidens bryoides* Hedw. – 8: meadow  
*Fissidens dubius* P. Beauv. – 1, 3, 5, 6, 10: shaded limestone rock  
*Fissidens taxifolius* Hedw. – 5: shaded limestone rock; 8: meadow  
*Fontinalis antipyretica* Hedw. – 7: limestone rock in the stream; 8: meadow  
*Funaria hygrometrica* Hedw. – 8: meadow  
*Grimmia pulvinata* (Hedw.) Sm. – 6: shaded limestone rock  
*Gymnostomum calcareum* Nees et Hornsch. – 3, 6: shaded limestone rock  
*Gyroweisia tenuis* (Hedw.) Schimp. – 3: shaded limestone rock  
*Hamatocaulis vernicosus* (Mitt.) Hedenäs – 6: peat bog  
*Herzogiella seligeri* (Brid.) Z. Iwats. – 1, 5, 9: decaying wood  
*Homalothecium lutescens* (Hedw.) H. Rob. – 8: meadow  
*Homalothecium philippeanum* (Spruce) Schimp. – 5: shaded limestone rock  
*Homalothecium sericeum* (Hedw.) Schimp. – 1, 3, 6, 9: shaded limestone rock; 1: bark of *Fagus sylvatica*; 5, 10: decaying wood  
*Homomallium incurvatum* (Schr. ex Brid.) Loeske – 1, 3, 5, 10: shaded limestone rock  
*Hylocomiastrum pyrenaicum* (Spruce) M. Fleisch. – 8: meadow  
*Hylocomium splendens* (Hedw.) Schimp. – 1, 5: shaded limestone rock; 6, 9: on soil  
*Hypnum cupressiforme* Hedw. var. *cupressiforme* – 1, 9: shaded limestone rock; 5, 6, 10: decaying wood; 8: meadow; 9: on soil; 1, 10: bark of *Fagus sylvatica*



- Hypnum cupressiforme* Hedw. var. *lacunosum* Brid. – 8: meadow  
*Isoterygiopsis pulchella* (Hedw.) Z. Iwats. – 5: shaded limestone rock  
*Isothecium alopecuroides* (Lam. ex Dubois) Isov. – 1, 5, 6, 9: shaded limestone rock; 1, 5, 10: bark of *Fagus sylvatica*; 10: decaying wood  
*Isothecium myosuroides* Brid. – 1: shaded limestone rock  
*Leptobryum pyriforme* (Hedw.) Wilson – 8: meadow  
*Leskea polycarpa* Hedw. – 3: bark of *Acer*  
*Leucodon sciuroides* (Hedw.) Schwägr. – 2: bark of *Fraxinus excelsior*; 6: shaded limestone rock; 10: bark of *Fagus sylvatica*  
*Mnium marginatum* (Dicks.) P. Beauv. – 1, 3, 10: shaded limestone rock; 7: limestone rock at the stream  
*Mnium stellare* Hedw. – 1, 5: shaded limestone rock; 5: bark of *Fagus sylvatica*; 7: limestone rock at the stream  
*Neckera complanata* (Hedw.) Huebener – 1, 5, 6: shaded limestone rock; 10: bark of *Fagus sylvatica*  
*Neckera crispa* Hedw. – 1, 3, 6, 10: shaded limestone rock; 1, 5: bark of *Fagus sylvatica*; 10: decaying wood  
*Neckera pumila* Hedw. – 6: shaded limestone rock  
*Orthothecium rufescens* (Dicks. ex Brid.) Schimp. – 6: shaded limestone rock  
*Orthotrichum affine* Schrad. ex Brid. – 2: bark of *Fraxinus excelsior*  
*Orthotrichum anomalum* Hedw. – 1: shaded limestone rock  
*Orthotrichum cupulatum* Hoffm. ex Brid. – 6: shaded limestone rock  
*Orthotrichum lyellii* Hook. et Taylor – 2: bark of *Fraxinus excelsior*; 10: bark of *Fagus sylvatica*  
*Orthotrichum obtusifolium* Brid. – 2: bark of *Fraxinus excelsior*  
*Orthotrichum pallens* Bruch ex Brid. – 2: bark of *Fraxinus excelsior*  
*Orthotrichum pumilum* Sw. ex anon. – 2, 4: bark of *Fraxinus excelsior*  
*Orthotrichum speciosum* Nees – 2: bark of *Fraxinus excelsior*  
*Orthotrichum stramineum* Hornsch. ex Brid. – 1: bark of *Fagus sylvatica*  
*Palustriella commutata* (Hedw.) Ochyra – 6: meadow; 7: limestone rock in the stream  
*Palustriella falcata* (Brid.) Hedenäs – 3: limestone rock at a mill  
*Paraleucobryum longifolium* (Hedw.) Loeske – 5: decaying wood  
*Philonotis fontana* (Hedw.) Brid. – 8: meadow  
*Plagiomnium affine* (Blandow ex Funck) T. J. Kop. – 1: shaded limestone rock; 5: decaying wood; 9: on soil  
*Plagiomnium cuspidatum* (Hedw.) T. J. Kop. – 7: limestone rock at the stream; 10: bark of *Fagus sylvatica*  
*Plagiomnium ellipticum* (Brid.) T. J. Kop. – 6: peat bog  
*Plagiomnium rostratum* (Schrad.) T. J. Kop. – 1, 3: shaded limestone rock  
*Plagiomnium undulatum* (Hedw.) T. J. Kop. – 1, 5, 10: shaded limestone rock  
*Plagiopus oederianus* (Sw.) H. A. Crum et L. E. Anderson – 3, 6: shaded limestone rock  
*Plagiothecium cavifolium* (Brid.) Z. Iwats. – 6: shaded limestone rock  
*Plagiothecium nemorale* (Mitt.) A. Jaeger – 1: shaded limestone rock and bark of *Fagus sylvatica*  
*Plagiothecium platyphyllum* Mönk. – 5: decaying wood; 10: shaded limestone rock  
*Plasteurhynchium striatulum* (Spruce) M. Fleisch. – 3, 5: shaded limestone rock  
*Platyhypnidium riparioides* (Hedw.) Dixon – 3: limestone rock at a mill; 7: limestone rock in the stream  
*Pleuroidium acuminatum* Lindb. – 8: meadow  
*Pleuroidium subulatum* (Hedw.) Rabenh. – 8: meadow  
*Pogonatum urnigerum* (Hedw.) P. Beauv. – 8: meadow

- Poblia annotina* (Hedw.) Lindb. – 8: meadow  
*Poblia melanodon* (Brid.) A. J. Shaw – 8: meadow  
*Polytrichastrum formosum* (Hedw.) G. L. Sm. – 1, 5: decaying wood; 6: on soil; 10: shaded limestone rock  
*Polytrichum commune* Hedw. – 8: meadow  
*Polytrichum juniperinum* Hedw. – 8: meadow  
*Polytrichum piliferum* Hedw. – 8: meadow  
*Polytrichum strictum* Menzies ex Brid. – 6: peat bog  
*Pseudoscleropodium purum* (Hedw.) M. Fleisch. – 6, 9: on soil; 8: meadow  
*Pterigynandrum filiforme* Hedw. – 1: bark of *Fagus sylvatica*; 5, 10: decaying wood; 5: shaded limestone rock  
*Pylaisia polyantha* (Hedw.) Schimp. – 3: bark of *Acer*  
*Racomitrium elongatum* Ehrh. ex Frisvoll – 8: meadow  
*Rhizomnium punctatum* (Hedw.) T. J. Kop. – 1, 5: decaying wood  
*Rhynchostegiella tenuicaulis* (Spruce) Kartt. – 1: shaded limestone rock  
*Rhynchostegium murale* (Hedw.) Schimp. – 1, 5, 6, 10: shaded limestone rock  
*Rhytidiadelphus loreus* (Hedw.) Warnst. – 1, 5: shaded limestone rock; 5: decaying wood  
*Rhytidiadelphus squarrosus* (Hedw.) Warnst. – 8: meadow  
*Rhytidiadelphus triquetrus* (Hedw.) Warnst. – 5: shaded limestone rock; 6, 9: on soil  
*Schistidium crassipilum* H. H. Blom – 1, 5, 6, 10: shaded limestone rock  
*Schistidium elegantulum* H. H. Blom – 10: shaded limestone rock  
*Scorpidium cossonii* (Schimp.) Hedenäs – 6: peat bog  
*Seligeria pusilla* (Hedw.) Bruch et Schimp. – 3: shaded limestone rock  
*Sphagnum capillifolium* (Ehrh.) Hedw. – 8: meadow  
*Sphagnum denticulatum* Brid. – 8: meadow  
*Sphagnum flexuosum* Dozy et Molk. – 6: peat bog  
*Sphagnum palustre* L. – 6: peat bog; 8: meadow  
*Sphagnum squarrosus* Crome – 6: peat bog  
*Sphagnum subnitens* Russow et Warnst. – 8: meadow  
*Sphagnum teres* (Schimp.) Ångstr. – 6: peat bog; 8: meadow  
*Syntrichia ruralis* (Hedw.) F. Weber et D. Mohr – 1, 5: shaded limestone rock  
*Taxiphyllum densifolium* (Lindb. ex Broth.) Reimers – 1, 5: shaded limestone rock  
*Taxiphyllum wissgrillii* (Garov.) Wijk et Margad. – 1, 3, 5, 10: shaded limestone rock  
*Tetraphis pellucida* Hedw. – 1, 5: decaying wood  
*Thamnobryum alopecurum* (Hedw.) Gangulee – 1, 3, 5, 10: shaded limestone rock  
*Thuidium assimile* (Mitt.) A. Jaeger – 8: meadow  
*Tomentypnum nitens* (Hedw.) Loeske – 6: peat bog  
*Tortella bambergi* (Schimp.) Broth. – 5: shaded limestone rock  
*Tortella inclinata* (R. Hedw.) Limpr. – 6, 10: soil among limestone rocks  
*Tortella tortuosa* (Hedw.) Limpr. – 5, 6: shaded limestone rock  
*Trichodon cylindricus* (Hedw.) Schimp. – 8: meadow  
*Trichostomum brachydontium* Bruch – 3: shaded limestone rock  
*Ulotia bruchii* Hornsch. ex Brid. – 4: bark of *Fraxinus excelsior*; 10: bark of *Fagus sylvatica*  
*Ulotia crispa* (Hedw.) Brid. – 10: bark of *Fagus sylvatica*  
*Warnstorfia exannulata* (Schimp.) Loeske – 8: meadow  
*Weissia brachycarpa* (Nees et Hornsch.) Jur. – 8: meadow  
*Zygodon rupestris* Schimp. ex Lorentz – 5: bark of *Fagus sylvatica*; 10: decaying wood

### Species reported for the first time from Croatia

During our bryophyte surveys in the period 2011–2012 30 species new for Croatia were found (PAPP *et al.* 2013a, b, c) 11 of which were recorded again during this research: *Conocephalum salebrosum*, *Lophozia longidens*, *Dicranodontium denudatum*, *Plagiothecium platyphyllum*, *Pterigynandrum filiforme*, *Racomitrium elongatum*, *Rhynchostegiella tenuicaulis*, *Trichodon cylindricus*, *Tomentypnum nitens*, *Tortella bambergeri* and *Zygodon rupestris*.

However, the research of the Plitvička jezera lakes and adjacent areas resulted in two additional new species for the Croatian bryophyte flora.

*Ephemerum minutissimum* is a sub-Atlantic species according to DÜLL *et al.* (1999). In SE Europe it is very rare or probably overlooked, known only from the coastal parts of Montenegro (DÜLL *et al.* 1999, SABOVLJEVIĆ *et al.* 2008). In the past it was not separated at species level from the related *E. serratum*, which is known from almost all SE European countries (SABOVLJEVIĆ *et al.* 2008). From the neighbouring countries *E. minutissimum* is known from Hungary, where it is treated as near-threatened (NT) in the national red list (PAPP *et al.* 2010) and from Italy (CORTINI PEDROTTI 1992). Here, the species was found on open soil of meadow edges in Vrhovinsko polje, which is a typical, periodically flooded karstland with a variety of grassland communities determined by water amount and soil pH.

*Pohlia annotina* is a subboreal species (DÜLL *et al.* 1999). It is known from most of the SE European countries (SABOVLJEVIĆ *et al.* 2008), and from Hungary (PAPP *et al.* 2010) and Italy (CORTINI PEDROTTI 1992) as neighbouring countries. This species was also found on soil in Vrhovinsko polje, in its lower, more humid part.

Among the new records for the Croatian bryophyte flora another species, *Campylopus introflexus* needs to be mentioned. It was found for the first time in Croatia during our field trip in 2013 on decaying *Pinus* trunk and on soil at the edge of meadow in Vrhovinsko polje, but this record was published separately (ALEGRO *et al.* 2014). This is an invasive species living on acidic soil, whose expansion started from Britain in 1940 and it keeps spreading towards east (HASSEL and SÖDERSTRÖM 2005). It has already reached northeastern and southeastern Europe according to records from Lithuania (VELLAK *et al.* 2009), Turkey (YAYINTAŞ 2009), and Slovenia (SZÜCS and BIDLÓ 2014). Currently, no other records are known from the Balkans.

### Conservation merits of the bryophyte flora

Plitvička jezera National Park has a high conservation value due to presence of three species (among in total four in Croatian bryophyte flora) listed in

the Bern Convention and the European Union Habitats and Species Directive: *Buxbaumia viridis*, *Dicranum viride* and *Hamatocaulis vernicosus*.

*Buxbaumia viridis* is a boreal, montane species (DÜLL *et al.* 1999) living on well-decayed wood in humid forests. According to the Red data book of European bryophytes (ECCB 1995) it is a vulnerable species. In spite that historical data in Croatia for this species are scarce (BAUMGARTNER 1938, HORVAT 1932), recent field surveys showed that this species is not rare in virgin, but even in managed old-growth beech-fir (ass. *Omphalodo-Fagetum*) and fir (ass. *Blechno-Abietetum*) forests of the Gorski kotar Region and the Northern Velebit Mts (PAPP *et al.* 2013a, b), where it has considerably large populations (20–30 sporophytes on 50–100 trees). The species was found in virgin beech-fir forest in Čorkova uvala, where it inhabits dozens of decayed tree trunks.

*Dicranum viride* is a sub-continental species (DÜLL *et al.* 1999) living as epiphyte on bark of old trees. Historically, it is recorded on the foothills of Mt Papuk (STOIZNER 1870), in the Maksimir park forest in Zagreb (HORVAT 1932) and in Bunjevačka draga in the Velebit Mts (BAUMGARTNER 1938). On the first two localities it was not confirmed during recent field surveys, while the Bunjevačka draga is a mine suspicious area and therefore inaccessible, but Baumgartner's specimen is preserved in the Hungarian Natural History Museum (BP 31775). Therefore, the Medvedak forest in the Plitvička jezera National Park is currently the single known locality of this species in Croatia. Here it grows in beech-fir forest, in a few small patches on beech bark.

*Hamatocaulis vernicosus* is a boreal species (DÜLL *et al.* 1999) growing in oligotrophic and mesotrophic, neutral to slightly acidophilous fens and transitional bogs (NEBEL 2001). To date the single finding site of the species in Croatia is Dubravica peat bog in the Hrvatsko zagorje region (NW Croatia) (HORVAT 1932). It was found there in bog vegetation of ass. *Rhynchosporium albae*. Unfortunately, nowadays this bog is only a small remnant of its previous extent and diversity, with uncertain occurrence of *H. vernicosus*. Therefore, the recently found population in Ljeskovačke bare is the only certainly known and really viable population of this species in Croatia. It was found in transition between bog communities *Drosero-Caricetum echinatae* and *Caricetum lasiocarpae*. The population is vigorous, with typically developed individuals.

Among other species included in the Red data book of European bryophytes *Anomodon rostratus*, *Rhynchostegiella tenuicaulis* and *Taxiphyllum densifolium* should be mentioned.

*Anomodon rostratus* is a sub-Mediterranean-montane species (DÜLL *et al.* 1999) occurring on shaded limestone rocks and rock crevices. In the Red data book of European bryophytes it is treated as rare species (ECCB 1995). It was reported for the first time in Croatia (Velebit Mts) by BAUMGARTNER (1938) and

it was confirmed there during recent surveys (PAPP *et al.* 2013b). Our new record is the first one outside the Velebit Mts. The species was found in beech-fir virgin forests in Čorkova uvala and Medvedak. The plant grows on strongly shaded limestone rocks in the forest interior, especially in dolina bottoms.

*Rhynchostegiella tenuicaulis* is a montane species of the temperate zones of Europe (DÜLL 1985). In the Red data book of European bryophytes (ECCB 1995) it is quoted as insufficiently known. The species is rare in SE Europe, known only from Bulgaria, Greece and Romania (SABOVLJEVIĆ *et al.* 2008). It was recently found in the Velebit Mts on shaded limestone rocks of Štirovača and Jovanovića snižnica ice hole (PAPP *et al.* 2013b, c). In Plitvička jezera National Park it also grows on shaded limestone rocks, in virgin beech-fir forest in Čorkova uvala.

*Taxiphyllum densifolium* is an eastern European species distributed sporadically in a range from Slovakia, Poland, Hungary and Romania extending the Caucasus (FREY *et al.* 2006, VAJDA 1955). Besides Hungary, the only neighbouring country, where it occurs is Serbia (SABOVLJEVIĆ *et al.* 2008). It was recently reported from Croatia; a specimen of *Taxiphyllum wissgrillii*, collected near Fiume (Rijeka) in 1909 was revised to *T. densifolium* (PAPP and SABOVLJEVIĆ 2009). According to the Red data book of European bryophytes (ECCB 1995) it is rare in Europe. We found it in Čorkova uvala in virgin beech-fir forest (ass. *Omphalodo-Fagetum*) on shaded limestone rocks.

Another group of mosses, which is not included in the Red data book of European bryophytes, but of special local importance, are the peat mosses. All *Sphagnum* species in Croatia are rare, each with only a few localities or even a single one. Most of them are threatened due to habitat loss and vegetation succession. In the researched area, seven species were found on two localities. The first is Ljeskovačke bare peat bog, where the following species were documented in a transitional bog belonging to ass. *Drosero-Caricetum echinatae*: *Sphagnum flexuosum*, *S. palustre*, *S. squarrosum* and *S. teres*. The last one is dominant and this population is the largest one in Croatia. The second locality with peat mosses is Vrhovinsko polje karst field, just outside the border of the national park. Here, the peat mosses grow on the lowest part of the karstland, which is periodically flooded, but completely dry during summer time. The following species were found there: *Sphagnum capillifolium*, *S. denticulatum*, *S. palustre*, *S. subnitens* and *S. teres*. Both localities are characterised by open habitats, which are threatened by secondary vegetation succession of local trees and shrubs, which will eventually change the water regime, leading to conditions unsuitable for peat mosses.

*Calliargon giganteum*, *Dicranum bonjeanii*, *Drepanocladus polygamus*, *Plagiommium ellipticum*, *Polytrichum strictum*, *Scorpidium cossonii* and *Tomentypnum nitens* are additional species growing in wet meadows and bogs, rare in SE Europe, and for this reason of special conservation importance.

Beyond all the above, in the researched area there are even more bryophyte species rare in SE Europe, which makes the flora peculiar, biogeographically interesting, and highly important for nature conservation. As to flora elements, they are Atlantic and sub-Atlantic species (*Calypogeia suecica*, *Cephalozia catenulata*, *Barbula crocea*, *Ephemerum minutissimum*, *Isothecium myosuroides*, *Neckera pumila*, *Plagiothecium platyphyllum*, *Ulota bruchii* and *Zygodon rupestris*), native to the temperate zones of Europe with montane character (*Jungermannia pumila*, *Tritomaria exsecta*, *Tortella bambergeri*) or they are boreal, subalpine and subarctic species (*Lophozia badensis*, *L. bantriensis*, *L. longidens*, *Dicranodontium denudatum*, *Hylocomiastrum pyrenaicum*, *Isopterygiopsis pulchella*, *Orthothecium rufescens*, *Pohlia annotina* and *Scorpidium cossonii*).

## CONCLUSIONS

Plitvička jezera National Park and the adjacent regions possess high bryophyte diversity (with 207 recorded species) making this region comparable with other recently researched areas: Gorski kotar Region with 231 taxa and the Northern Velebit Mts with 191 taxa (PAPP *et al.* 2013a, b). Here, the high diversity and the occurrence of many rare species are attributed to the habitat diversity. Most widespread are the different forest communities, with beech-fir forests as the zonal ones and represented by several virgin stands. These stands can support vigorous populations of European red-listed bryophytes, including *Buxbaumia viridis*, *Anomodon rostratus*, *Rhynchostegiella tenuicaulis* and *Taxiphyllum densifolium*. Furthermore, the single known population of *Dicranum viride* in Croatia also thrives in these forests. Also, important habitat types are the wetlands, with tuff-forming waterfalls, rivulets, lakes, fens, peat bogs, wet and periodically flooded meadows. Each of these habitat types support characteristic bryophyte assemblages with many species rare in SE Europe. In a peat bog *Hamatocaulis vernicosus* and several *Sphagnum* species, all rare in Croatia and the Balkans, were found. For the *Sphagnum* species the periodically flooded meadows at Vrhovinsko polje are of special importance. On open soil near the meadow edge in Vrhovinsko polje *Ephemerum minutissimum*, a rare (or probably overlooked) species in SE Europe and new for the Croatian bryophyte flora, was found. *Pohlia annotina* is another new species for the country from the same locality.

It needs to be stressed that Plitvička jezera have great conservation value by the occurrence of three bryophyte species listed in the Bern Convention and the European Union Habitats and Species Directive. Furthermore, the presence of many species generally rare in SE Europe, belonging to different flora elements, also marks the importance of this area for bryophyte diversity and its conservation.

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