

THE BRYOPHYTE DIVERSITY OF LJUBLJANA (SLOVENIA)

MITJA SKUDNIK, ANETA SABOVLJEVIĆ, FRANC BATIČ & MARKO SABOVLJEVIĆ

Abstract. The authors studied the bryophyte flora of the city of Ljubljana (Slovenia), recording 104 bryophyte taxa within the inner ring-road of Ljubljana. The specimens were collected from randomly picked sampling sites during different seasons in 2011 and 2012. Interesting records include *Barbula convoluta* var. *commutata* (Jur.) Husn., *Grimmia trichophylla* Grev., *Leptobryum pyriforme* (Hedw.) Wilson, *Phascum cuspidatum* Hedw. and *Pseudocrossidium hornschurchianum* (Schultz) R. H. Zander, species last recorded in Slovenia more than 60 years ago. Some species rare and endangered in Slovenia were also recorded: *Syntrichia papillosa* (Willson) Jur. and *Lumularia cruciata* (L.) Lindb. *Rhynchostegium rotundifolium* (Scop. ex Brid.) Schimp., a moss red-listed Europe-wide, was recorded in the investigated area.

Key words: urban flora, mosses, liverworts, Ljubljana, Slovenia

Mitja Skudnik, Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia

Aneta Sabovljević, Marko Sabovljević, Institute of Botany and Garden, Faculty of Biology, University of Belgrade, Serbia;
e-mail: marko@bio.bg.ac.rs

Franc Batič, Department of Agronomy, Biotechnical Faculty, University of Ljubljana, Slovenia

INTRODUCTION

The bryophyte flora of towns forms a significant part of urban vegetation, but the available data on them are few (Ron *et al.* 1987; Sabovljević & Sabovljević 2009 and references therein). Urbanization creates a spectrum of preconditions (specific microhabitats) for rich bryophyte floras (Fudali 1994, 1996, 2006; Sabovljević & Grdović 2009). The urban bryophyte vegetation is interesting not only for its floristic composition but also for the presence of rare and significant taxa and for the vegetation relationships, and it presents material of interest from a phytogeographical point of view (Grdović *et al.* 2009). Urban bryophytes can be used as bioindicators for assessment of air quality, and they are accumulators of heavy metals from atmospheric deposition (Giordano *et al.* 2004).

Slovenia is one of Europe's bryologically richest areas, and certainly has the highest bryophyte diversity in Southeast Europe (Sabovljević *et al.* 2001, 2011; Sabovljević 2004). Slovenia has nearly 800 bryophyte species; the exact number varies according to the nomenclature used by various authors (Martinčič 2003; Sabovljević

& Natcheva 2006; Ros *et al.* 2007; Sabovljević *et al.* 2008), and it changes with the addition of new bryophyte records for the country (e.g., Blockeel *et al.* 2009). Despite its relatively small area, Slovenia has almost all biomes of Europe due to its position and orography.

Despite ongoing bryological investigations (Martinčič 2003 and references therein), some places in Slovenia are under-recorded and others are bryologically unknown. More field research is needed.

Slovenia has towns evenly spread over its territory and relatively well preserved nature. After Finland and Sweden it is the third most forested country of Europe, with 62% of its land covered with forest (FAO & JRC 2012). The diversity of the bryophyte flora within urban areas in Slovenia has been neglected. Apart from a few bryophyte records from towns, there has been no research addressing bryophyte diversity in any urbanized area of Slovenia.

Ljubljana is the capital and the largest city in Slovenia. It is situated in the center of the country in the Ljubljana basin between the Alps

and the Dinaric karst region. Ljubljana is inhabited by *ca* 280,000 people in an area of 163.8 km² (Anonymous 2012). The city stretches over an alluvial plain dating to the Quaternary. The nearby older mountainous regions date to the Mesozoic (Triassic) or Paleozoic. Within the city there are hilly regions like those of Tivoli or Golovec. The average elevation of the city is 295 m a.s.l (city center 298 m, city castle 366 m). The main watercourses in Ljubljana are the Sava, Ljubljanica, Gradaščica, Mali Graben, Iška and Iščica rivers.

Ljubljana has an oceanic climate with continental characteristics such as warm summers and moderately cold winters. Average yearly temperature is 10.1°C. July and August are the warmest months with daily highs generally between 25 and 30°C,

and January is the coldest month with temperatures mostly oscillating around 0°C. Annually the city experiences 90 days of frost and 11 days with temperatures above 30°C. Precipitation is relatively evenly distributed through the seasons, although winter and spring are somewhat drier than summer and autumn. Average yearly precipitation is 1393 mm, with 115 rainy days, making Ljubljana one of the wettest European capitals. Snow is common from December to February; on average there are 48 days with snow cover recorded each winter. The city is known for its fog, which is recorded on average 64 days per year, mostly in autumn and winter, and can be particularly persistent during temperature inversions. In summer the weather in the city is influenced by Mediterranean air currents, so the summers are sunny and warm.

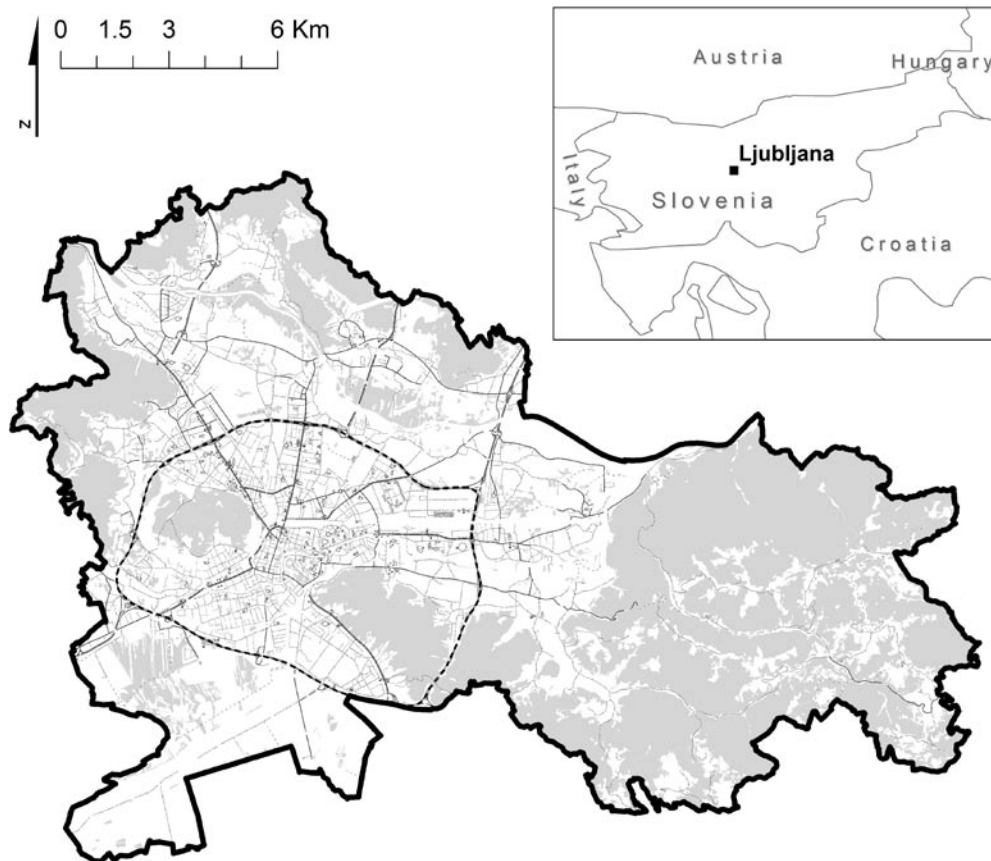


Fig. 1. Location of Ljubljana in Slovenia. Dashed line demarcates the studied area in Ljubljana.

MATERIAL AND METHODS

An extensive bryophyte collection was made in Ljubljana city (within the ring road, Fig. 1) during winter 2011 and spring, summer and autumn 2012. Random sampling was done in different habitats and microhabitats within the urban area, including larger green areas. Nomenclature follows Sabovljevič and Natcheva (2006) for hepatics and Sabovljevič *et al.* (2008) for mosses.

RESULTS

Within the city of Ljubljana, 104 bryophyte taxa were recorded, 90 of which (86.54%) belong to mosses (45 acrocarpus, 45 pleurocarpus mosses) and 14 (13.46%) to hepatics. They are listed below in the bryophyte catalogue. Hepatics and mosses are listed separately and alphabetically. Specimens are deposited in the Belgrade University Herbarium (BEOU) and the Slovenian Forestry Institute in Ljubljana.

BRYOPHYTE CATALOGUE OF LJUBLJANA CITY

LIVERWORTS

1. *Bazzania trilobata* (L.) Grey
2. *Calypogeia fissa* (L.) Raddi
3. *Chiloscyphus polyanthos* (L.) Corda
4. *Cephalozia* sp.
5. *Conocephalum conicum* (L.) Dumort.
6. *Diplophyllum albicans* (L.) Dumort.
7. *Fossombronina* sp.
8. *Lophocolea bidentata* (L.) Dumort.
9. *Lunularia cruciata* (L.) Lindb.
10. *Marchantia polymorpha* L. subsp. *ruderalis* Bischl. & Boissel.-Dub.
11. *Metzgeria furcata* (L.) Dumort.
12. *Pedinophyllum interruptum* (Nees) Kaal.
13. *Porella platyphylla* (L.) Pfeiff.
14. *Radula complanata* (L.) Dumort.

MOSSSES

15. *Abietinella abietina* (Hedw.) M. Fleisch.
16. *Amblystegium serpens* (Hedw.) Schimp.
17. *Atrichum undulatum* (Hedw.) P. Beauv.
18. *Barbula convoluta* Hedw. var. *commutata* (Jur.) Husn.
19. *Barbula covoluta* Hedw.
20. *Barbula unguiculata* Hedw.
21. *Brachytheciastrum velutinum* (Hedw.) Ignatov & Huttunen
22. *Brachythecium albicans* (Hedw.) Schimp.
23. *Brachythecium mildeanum* (Schimp.) Schimp.
24. *Brachythecium rutabulum* (Hedw.) Schimp.
25. *Brachythecium salebrosum* (Hoffm. ex F. Weber & D. Mohr) Schimp.
26. *Bryum argenteum* Hedw.
27. *Bryum caespitium* Hedw.
28. *Bryum capillare* Hedw.
29. *Bryum dichotomum* Hedw.
30. *Bryum moravicum* Podp.
31. *Calliergonella cuspidata* (Hedw.) Loeske
32. *Ceratodon purpureus* (Hedw.) Brid.
33. *Climacium dendroides* (Hedw.) F. Weber & D. Mohr
34. *Cirriphyllum piliferum* (Hedw.) Grout
35. *Dicranella heteromalla* (Hedw.) Schimp.
36. *Dicranella varia* (Hedw.) Schimp.
37. *Dicranum scoparium* Hedw.
38. *Didymodon acutus* (Brid.) K. Saito
39. *Didymodon luridus* Hornsch.
40. *Didymodon rigidulus* Hedw.
41. *Didymodon vinealis* (Brid.) R. H. Zander
42. *Diphyscium foliosum* (Hedw.) D. Mohr
43. *Encalypta streptocarpa* Hedw.
44. *Encalypta vulgaris* Hedw.
45. *Entosthodon fascicularis* (Hedw.) Mull. Hal.
46. *Fissidens bryoides* Hedw.
47. *Fissidens dubius* P. Beauv.
48. *Fissidens taxifolius* Hedw.
49. *Fissidens viridulus* (Sw. ex anon.) Wahlenb.
50. *Fontinalis antipyretica* Hedw.
51. *Funaria hygrometrica* Hedw.
52. *Grimmia pulvinata* (Hedw.) Sm.
53. *Grimmia trichophylla* Grev.
54. *Herzogiella seligeri* (Brid.) Z. Iwats.
55. *Homalothecium sericeum* (Hedw.) Schimp.
56. *Hypnum cupressiforme* Hedw.
57. *Hypnum lacunosum* (Brid.) Hoffm. ex Brid.
58. *Isoetecium alopecuroides* (Lam. ex Dubois.) Isov.
59. *Kindbergia praelonga* (Hedw.) Ochyra
60. *Leptobryum pyriforme* (Hedw.) Wilson
61. *Leskea polycarpa* Hedw.
62. *Leucobryum juniperinum* (Brid.) Mull. Hal.
63. *Mnium thomsonii* Schimp.
64. *Orthotrichum affine* Schrad. ex Brid.
65. *Orthotrichum anomalum* Hedw.
66. *Orthotrichum cupulatum* Hoffm. ex Brid.
67. *Orthotrichum diaphanum* Schrad. ex Brid.
68. *Orthotrichum lyellii* Hook. & Tayl.
69. *Oxyrrhynchium hians* (Hedw.) Loeske

70. *Oxyrrhynchium speciosum* (Brid.) Warnst.
71. *Phascum cuspidatum* Hedw.
72. *Physcomitrella patens* (Hedw.) Bruch. & Schimp.
73. *Plagiomnium affine* (Blandow ex Funck) T. J. Kop.
74. *Plagiomnium cuspidatum* (Hedw.) T. J. Kop.
75. *Plagiomnium rostratum* (Schrad.) T. J. Kop.
76. *Plagiomnium undulatum* (Hedw.) T. J. Kop.
77. *Plagiothecium laetum* Schimp.
78. *Plagiothecium nemorale* (Mitt.) A. Jaeger
79. *Plagiothecium piliferum* (Sw.) Schimp.
80. *Platygyrium repens* (Brid.) Schimp.
81. *Platyhypnidium riparioides* (Hedw.) Dixon
82. *Pogonatum aloides* (Hedw.) P. Beauv.
83. *Pohlia cruda* (Hedw.) Lindb.
84. *Pohlia nutans* (Hedw.) Lindb.
85. *Polytrichastrum formosum* (Hedw.) G. L. Sm.
86. *Pseudocrossidium hornschurchianum* (Schultz) R. H. Zander
87. *Pseudoleskeella catenulata* (Brid. ex Schrad.) Kindb.
88. *Pseudoleskeella nervosa* (Brid.) Nyholm
89. *Pseudoscleropodium purum* (Hedw.) M. Fleisch.
90. *Rhynchostegiellatenella* (Dicks.) Limpr.
91. *Rhynchostegium murale* (Hedw.) Schimp.
92. *Rhynchostegium rotundifolium* (Scop. ex Brid.) Schimp.*
93. *Schistidium apocarpum* compl.
94. *Sphagnum squarrosum* Crome
95. *Syntrichia papillosa* (Willson) Jur.
96. *Syntrichia ruraliformis* (Besch.) Dull
97. *Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr
98. *Thuidium delicatum* (Hedw.) Schimp.
99. *Thuidium recognitum* (Hedw.) Lindb.
100. *Thuidium tamariscinum* (Hedw.) Schimp.
101. *Tortula lanceola* R. H. Zander
102. *Tortula modica* R. H. Zander
103. *Tortula muralis* Hedw.
104. *Tortula subulata* Hedw.

DISCUSSION AND CONCLUSIONS

This study gives the first insight into the bryophyte flora of the city of Ljubljana. Though only the inner city zone (within the ring-road) was the subject area for this investigation, the results show that Ljubljana city has quite a rich bryophyte flora, documented with 104 taxa.

Some species were not expected in the urban area (e.g., *Diphyscium foliosum*), but since Ljubljana has a hilly relief and lush plantlife, well-

functioning hydrological regime and relatively wet climate, and is between pre-Alpic and pre-Dinaric regions, the high number of species and interesting findings are not surprising.

Among the recorded taxa is one red-listed for Europe: *Rhynchostegium rotundifolium* (rare European species, Anonymous 1995). In Ljubljana it was not rare on Golovec hill in the southeastern part of the city and also on Grad hill in the central part. We collected it a few times and the moss bore sporophytes.

According to Martinčič (2003), the last time *Barbula convoluta* var. *commutata*, *Grimmia trichophylla*, *Leptobryum pyriforme*, *Phascum cuspidatum* and *Pseudocrossidium hornschurchianum* were recorded in Slovenia was more than 60 years ago.

Barbula convoluta var. *commutata* was recorded only in the Dinaric region, while *Grimmia trichophylla* was known from the Alpic and pre-Alpic region sixty years ago (Martinčič, 2003). We recorded the first taxon on Grad hill among rocks, and the other one three times in the central/southeastern parts of the inner city. Both taxa are rather under-recorded in Slovenia.

Leptobryum pyriforme was known from various areas in Slovenia (not from Ljubljana), and it is an easily spreading species. The absence of a report for it in more than 60 years is rather the consequence of the lack of bryological field research. Similarly, the two terrestrial species *Phascum cuspidatum* and *Pseudocrossidium hornschurchianum* have been overlooked for a long time but were present in various parts of Ljubljana.

The epiphytic moss *Syntrichia papillosa* and the thalloid liverwort *Lunularia cruciata* are red-listed in the flora of Slovenia (Martinčič 1992).

Syntrichia papillosa is considered rare throughout Slovenia (Besednjak *et al.* 2008). In Ljubljana it is not rare but recorded on many trees throughout the investigated area. It is not clear whether its distribution decreased in the past as a result of air pollution, but nowadays high air humidity and relatively unpolluted air favor that population. The second half of the 20th century is generally regarded as a period of retreat and extinction of epiphytes due to increased air pollution and high exposure to SO₂, NO_x and dust

(e.g., Fudali 2012). There are no historical data for this species in the area of investigation or in Slovenia. In Ljubljana it is now common and abundant and often bears many gemmae, easily spread by insects, snails, slugs, birds or squirrels.

Lunularia cruciata is a rare liverwort outside of its main Mediterranean-Atlantic range but recorded in many European countries, mainly in urban areas. It seems to be spreading northeastward with climate warming (e.g., Sabovljevič & Marka 2009). According to Pavletić (1955) and Düll *et al.* (1999) it is not known in Slovenia. In the checklist of European liverworts (Söderström *et al.* 2002) it is cited for Slovenia. Ros *et al.* (2007) cite records for Slovenia, but from before 1962. Martinčič (2007) explains that these citations are based on records by Loitlesberger (1905) in Gorica (Stračice) and the Soča River bank, areas which nowadays belong to Italy. Martinčič (2007) found herbarium samples kept in LJU, collected by F. Dolšak in Ljubljana (1920 and 1938) with the label *in hortis urbis Ljubljana, subspontanea*. It is not clear whether this was a natural or anthropogenic habitat, but both climate change and manmade habitats favor expansion/invasion of this species. Martinčič (2007) concluded that there is no evidence for the presence of this species in Slovenia for more than 70 years. Here we confirm the presence of *L. cruciata* in various places in Ljubljana: the Botanical Gardens, Prule, Stari trg, Murgle and Tivoli. This species is easily overlooked although easy to identify by its semilunar gemma cups, and it seems to be spreading in Ljubljana at present. It probably occurs in other area of Slovenia as well.

This contribution to the Slovene bryophyte flora points to the need for more field research and analyses even in apparently well studied or species-poor areas. The inner ring-road area of Ljubljana has a rich and interesting bryophyte flora. Such high diversity supports Isermann's (2007) statement that urban bryophyte diversity is highest where moderate environmental conditions (light, water, substrate) prevail, rather than being confined to specific habitats. Further studies will no doubt add more bryophyte species from this and other areas of Slovenia.

REFERENCES

- ANONYMOUS 1995. Red Data Book of European Bryophytes. European Committee for the Conservation of Bryophytes, Trondheim.
- ANONYMOUS 2012. Statistical year book 51. Statistical office of the Republic of Slovenia, Ljubljana.
- BESEDNJAK J., MARTINČIČ A. & JOGAN N. 2008. The bryophyte flora in the vicinity of Branik (quadrant 0148/2). *Hladnikia* 21: 19–28.
- BLOCKEEL T. L., BAKALIN V. A., BEDNAREK-OCHYRA H., OCHYRA R., BUCK W. R., CHOI S., CYKOWSKA B., ERDAD A., ERZBERGER P., KIRMACI M., KÜRSCHNER H., LEBOUVIER M., PAPP B., SABOVLEVIČ M., SABOVLEVIČ A., SCHRÖDER W., SINGH S. M., SUN B.-Y., TOWNSEND C. C., VAŇA J. & YAYINTA O. T. 2009. New national and regional bryophyte records, 20. *J. Bryol.* 31: 54–62.
- DÜLL R., GANEVA A., MARTINČIČ A. & PAVLETIĆ Z. 1999. Contributions to the bryoflora of former Yugoslavia and Bulgaria. IDH-Verlag Bad Münstereifel.
- FAO & JRC. 2012. *Global forest land-use change 1990B2005*, by E.J. LINDQUIST, R. D'ANNUNZIO, A. GERRAND, K. MACDICKEN, F. ACHARD, R. BEUCHLE, A. BRINK, H.D. EVA, P. MAYAUX, J. SAN-MIGUEL-AYANZ & H.-J. STIBIG. FAO Forestry Paper No. 169. Food and Agriculture Organization of the United Nations and European Commission Joint Research Centre. FAO, Rome.
- FUDALI E. 1994. Species diversity and spatial distribution of bryophytes in urban areas – a case study of the city of Szczecin. *Fragm. Florist. Geobot.* 39: 563–570.
- FUDALI E. 1996. Distribution of bryophytes in various urban use complexes in Szczecin. *Fragm. Florist. Geobot.* 41: 717–745.
- FUDALI E. 2006. Influence of city on the floristical and ecological diversity of bryophytes in parks and cemeteries. *Biodivers. Res. Conservation* 1–2: 131–137.
- FUDALI E. 2012. Recent tendencies in distribution of epiphytic bryophytes in urban areas: a Wrocław case study (south-west Poland). *Polish Bot. J.* 57: 231–241.
- GIORDANO S., SORBO S., ADAMO P., BASILE A., SPAGNUOLO V. & COBIANCHI R. 2004. Biodiversity and trace element content of epiphytic bryophytes in urban and extraurban sites of Southern Italy. *Plant Ecology* 170: 1–14.
- GRDOVIČ S., SABOVLEVIČ M. & VITOROVIČ G. 2009. Ecological and distributional consideration of the bryophyte vegetation of urban areas: case study on Belgrade bryophytes. *Journal of Applied Biological Sciences* 3: 46–52.
- ISERMANN M. 2007. Diversity of bryophytes in an urban area of NW Germany. *Lindbergia* 32: 75–81.
- LOITLESBERGER K. 1905. Zur Moosflora der österreichischen Küstenländer I. Hepaticae. *Verh. Zool.-Bot. Ges. Wien* 55: 475–489.

- MARTINČIČ A. 1992. The Red List of Threatened Mosses (Musci) in Slovenia. *Varstvo Narave* **18**: 7–166 (in Slovenian with English summary).
- MARTINČIČ A. 2003. Annotated check-list of the mosses of Slovenia. *Hacquetia* **2**: 91–166.
- MARTINČIČ A. 2007. Critical contributions to the bryophyte flora of Slovenia, 16–23. *Hladnikia* **20**: 17–25.
- PAVLETIĆ Z. 1955. Prodromus flore briofita Jugoslavije. JAZU, Zagreb.
- RON E., MAZIMPAKA V., VINCENTE J., GRANZOW W. & DE LA CERDA J. 1987. Urban bryophytes in Spanish towns. *Symposia Biologica Hungarica* **35**: 727–753.
- ROS R. M., MAZIMPAKA V., ABOU-SALMA U., ALEFFI M., BLOCKEELT L., BRUGUES M., CANOM J., CROSR. M., DIA M. G., DIRKSE G. M., EL SAADAWI W., ERDAG A., GANEVA A., GOLNSALES-MANCEBO J. M., HERRNSTADT I., KHALIL K., KÜRSCHNER H., LANFRANCO E., LOSADA-LIMA A., REFAI M. S., RODRIGUEZ-NUNEZ S., SABOVLJEVIĆ M., SERGIO C., SHABBARA H. M., SIMSIM M. & SÖDERSTRÖM L. 2007. Hepatics and Anthocerotetes of the Mediterranean, an annotated checklist. *Cryptog. Bryol.* **28**: 351–437.
- SABOVLJEVIĆ M. 2004. Comparison of the bryophyte flora of the three southern European mainlands: the Iberian, the Apennine and the Balkan peninsulas. *Braun-Blanquetia* **34**: 21–28.
- SABOVLJEVIĆ M. & GRDOVIĆ S. 2009. Bryophyte Diversity Within Urban Areas: Case Study of the City of Belgrade (Serbia). *International Journal of Botany* **5**: 85–92.
- SABOVLJEVIĆ M. & MARKA J. 2009. The biological evidence of climate changes: a case study of liverwort *Lunularia cruciata* (L.) Dum. ex Lindb. in Serbia. *Bot. Serbica* **33**: 185–187.
- SABOVLJEVIĆ M. & NATCHEVA R. 2006. Check list of the liverworts and hornworts of South-eastern Europe. *Phytologia Balcan* **12**: 169–180.
- SABOVLJEVIĆ M. & SABOVLJEVIĆ A. 2009. Biodiversity within urban areas: a case study on bryophytes of the city of Cologne (NRW, Germany). *Plant Biosystems* **143**: 473–481.
- SABOVLJEVIĆ M., GANEVA A., TSAKIRI E. & STEFANUT S. 2001. Bryology and bryophyte protection in the south-eastern Europe. *Biol. Conservation* **101**: 73–84.
- SABOVLJEVIĆ M., ALEGRO A., SABOVLJEVIĆ A., MARKA J. & VUJIČIĆ M. 2011. An insight into diversity of the Balkan Peninsula bryophyte flora in the European background. *Revue d'Ecologie (Terre et Vie)* **66**: 399–413.
- SABOVLJEVIĆ M., NATCHEVA R., DIHORU G., TSAKIRI E., DRAGIČEVIĆ S., ERDAG A. & PAPP B. 2008. Check-list of the mosses of Southeast Europe. *Phytologia Balcan.* **14**: 159–196.
- SÖDERSTRÖM L., URMI E. & VAŇA J. 2002. Distribution of Hepaticae and Anthocerotae in Europe and Macaronesia. *Lindbergia* **27**: 3–47.

Received 9 April 2013