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Red-list of liverwort and hornwort species of Serbia: 2024 assessment

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ABSTRACT:
The new extinction risk assessments of hornwort and liverwort species of Serbia have been completed. Based on the available data, 40% of Serbian liverwort flora is under threat (status 2024). Additionally, 11% of Serbian liverwort flora is considered to be Data Deficient (DD) 11% Near Threatened (NT). These findings clearly indicate the urgent need for field investigation and species biology research in order to define the major threats and adequate conservation measures.

Keywords:
threat assessment, conservation, bryophyte, extinction risk

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INTRODUCTION

Being the second biggest group of terrestrial plants after angiosperms, bryophytes are remarkably heterogeneous organisms sharing a life cycle with the dominant haploid as a green plant. This very high diversity is reflected not only in the number of species worldwide, but also in the anatomical, biochemical, morphological, developmental, physiological and ecological features they exhibit. Within the bryophytes, liverworts and hornworts as well as mosses are considered as distinct phyla. Although some authors propose the existence of additional phyla within bryophytes, for the purpose of red-listing in this study we will present threat assessment for all hornwort and liverwort species so far known to form part of Serbian bryophyte flora.

Serbian bryophyte flora currently comprises one hornwort and 138 liverwort taxa (132 species, 4 subspecies and 2 varieties) (Pantović *et al.* 2020).

Since bryophytes (including liverworts and hornworts) are known to be good indicators of environmental changes, the assessment of their threatened status according to the IUCN criteria provides valuable insights not only into the conservation status of individual species, but also the state of the ecosystems they inhabit.

Liverworts are a lesser-known group than mosses, and in general, bryophyte flora studies are underrepresented in Serbia when compared to tracheophytes, due to the low interest shown by decision makers and financial bodies historically (e.g. Sabovljević *et al.* 2001; Pantović & Sabovljević 2017). However, they are affected by environmental changes and represent a significant national resource on a par with other groups of organisms settling in Serbia.

The first ever red list of Serbia was compiled jointly for Serbia and Montenegro more than 20 years ago (Sabovljević *et al.* 2004). Since then, the intensification of research has led to the accumulation of knowledge on the appearance and distribution of species, and an extensive and geo-referenced database has thus been developed, allowing us to make new threat assessments.

MATERIAL AND METHODS

The modern nomenclature and contemporary taxonomical approach for liverworts and hornworts given in Pantović *et al.* (2020) is followed in this study. The threat assessment of all taxa present in Serbia is made by applying the criteria set out by the IUCN (2012a, b, 2022). The peculiarities and special issues regarding bryophyte assessment (e.g. individual equivalents) are considered based on the guidance provided by Hallingbäck *et al.* (1998) and Bergamini *et al.* (2019).

Criteria B and D were mainly applied in our study due to the lack of data on population trends or other relevant features for the majority of taxa in Serbia, but other criteria were also incorporated where possible. The species assessments were carried out nationally applying the IUCN regional approach bearing in mind the presence of neighbouring populations and their threatened status as well as spread potential. Additionally, ecological requirements and habitat preferences were also taken into consideration (Dierssen 2001; Hugonnot & Chavoutier 2021) as well as the age of the record or report (Pantović *et al.* 2020). For those species not recently recorded and unconfirmed by recent field investigations and/or herbarium specimens, the category of DD (data deficient) was retained. The year 1990 was used as the cut-off date between old and recent records. The continuously expanding BRYO database was used as a data source for distribution since it includes both literature and herbarium records (Pantović & Sabovljević 2017), the data from the huge Balkan collection of bryophytes deposited within the Hungarian Natural History Museum in Budapest (BP) and the Belgrade University Bryophyte Collection (BEOU-Bryo), as well as recent surveys conducted by the authors. Actual and potential threats for each species were considered as well as their presence in the protected areas and the existence of conservation measures. The extent of occurrence (EOO) and area of occupancy (AOO) were calculated following the confirmation of the distributional data using the open source application GeoCAT (Geospatial Conservation Assessment Tool) with the calculation grid (2 × 2 km) in accordance with the European scale (Hodgetts *et al.* 2019). The data on the European risk of extinction status were taken from Hodgetts *et al.* (2019) and at the national level for countries and regions in Europe from Hodgetts & Lockhart (2020). A taxon was considered Regionally Extinct (RE) only if it was a target of recent field investigations where no occurrences were found. Alternatively, the status for such species remained DD and/or Possibly Extinct (PE).

RESULTS AND DISCUSSION

Over the past 20 years of revived but non-intensive bryological field research in Serbia, there has been a significant accumulation of knowledge on species occurrence and distribution, along with the recording of new species for the country. In the study carried out by Sabovljević *et al.* (2004), only 79 liverwort species were identified in Serbia. Almost two decades later, we are now aware of an additional 52 liverwort and one hornwort species documented in Serbia (Pantović *et al.* 2020). However, the real distribution, occurrence and threatened status update in Serbia remains obscured for many species.

Based on the latest knowledge, the threatened status for the hornwort and liverwort species of Serbia is given in Table 1. The threatened status of some species has been decreased/increased based on population abundance in nearby areas/countries as suggested by the IUCN (2012a, b, 2022).

The current red-list (2024) of hornwort and liverwort species in Serbia comprises one Possibly Extinct (PE) (the only known hornwort), two Critically Endangered (CR), 17 Endangered (EN), 34 Vulnerable (VU), 15 Near Threatened (NT) and 15 Data Deficient (DD) species. The total number of liverwort taxa under threat (CR+EN+VU) is 53. In comparison with the assessment from 2004 (Sabovljević *et al.* 2004), it seems that with accumulation of knowledge, the percentage of threatened taxa in Serbia has increased from 31.65% to 40%. However, the prevalence of missing data, rendering many records older than the cut-off threshold (1990) for numerous species, has resulted in a significant increase in DD species (Table 2). The contemporary data has led to a decrease in the percentage of CR taxa, although 2 taxa remain within this category. In terms of the EN category, the real number of taxa has increased, while the percentage has changed only slightly. The total number of VU taxa has more than doubled.

Based on the available data, the new extinction risk assessment of hornwort and liverwort species is rather high (40%). The number of taxa which may soon be considered under threat (NT) is also high (11.2%). Additionally, over 10% of Serbian liverwort flora is data deficient (DD). The current list reflects the investigation rate and the available data sets. However, in the light of rapid environmental changes, the need for the conservation of this group is escalating. Thus, there is an urgent need for field investigation and species biology research in order to define the major threats, adequate conservation measures, and the active protection of the liverwort and hornwort flora of Serbia.

Table 1. List of species of hornworts and liverworts present in Serbia with the assessed threatened status in 2024 (VU – Vulnerable; EN – Endangered; CR – Critically Endangered; NT – Near Threatened; DD – Data Deficient; PE – Possibly Extinct; LC - Least Concern). The species marked with an asterisk are those whose assessment has been corrected (increased/decreased) based on the population abundance in nearby areas/countries. Two asterisks signify taxonomical problems or species complex.

Species	Assessment ratio	IUCN categorization in Serbia (status 2024)
HORNWORT		
Phaeoceros laevis (L.) Prosk.		DD/PE
LIVERWORTS		
Aneura pinguis (L.) Dumort.		LC
Apopellia endiviifolia (Dicks.) Nebel & D. Quandt		LC
Barbilophozia barbata (Schmidel ex Schreb.) Loeske		LC
Barbilophozia hatcheri (A. Evans) Loeske		LC
Barbilophozia lycopodioides (Wallr.) Loeske		LC
Barbilophozia sudetica (Nees ex Huebener) L. Söderstr., De Roo & Hedd.		LC
Bazzania tricrenata (Wahlenb.) Lindb.	B1ab(i,ii,iv) / B2a	EN
Bazzania trilobata (L.) Gray	B2ab(i,ii,iii,iv)	EN
Blasia pusilla L.	D2*	EN
Blepharostoma trichophyllum (L.) Dumort.		LC
Calypogeia azurea Stotler & Crotz	B2	NT
Calypogeia fissa (L.) Raddi	D2*	NT
Calypogeia integristipula Steph.	B2ab(i,ii,iv)	EN
Calypogeia muelleriana (Schiffn.) Müll. Frib.	B2ab(i,ii,iv)	EN
Calypogeia suecica (Arnell & J. Perss.) Müll. Frib.	B2ab(i,ii,iii)	CR
Cephalozia bicuspidata (L.) Dumort.	B2*	LC
Cephaloziella divaricata (Sm.) Schiffn.		LC
Cephaloziella rubella (Nees) Warnst.	D2	VU
Cephaloziella stellulifera (Taylor ex Spruce) Schiffn.	D2*	EN
Cephaloziella varians (Gottsche) Steph.	D2**	VU (DD)
Chiloscyphus pallescens (Ehrh. ex Hoffm.) Dumort.		LC
Chiloscyphus polyanthos (L.) Corda		LC
Cololejeunea calcarea (Lib.) Schiffn.		LC
Cololejeunea rossettiana (C. Massal.) Schiffn.		LC
Conocephalum conicum (L.) Dumort.		LC
Conocephalum salebrosum Szweykowski, Buczkowska & Odrzykoski		LC
Crossocalyx hellerianus (Nees ex Lindenb.) Meyl.		DD
Diplophyllum albicans (L.) Dumort.	B2ab(ii,iv), D2	VU
Diplophyllum obtusifolium (Hook.) Dumort.	B2ab(ii,iv), D2	EN
Fossombronia pusilla (L.) Nees	D2	VU
Fossombronia wondraczekii (Corda) Lindb.	D2	VU
Frullania dilatata (L.) Dumort.		LC
Frullania fragilifolia (Taylor) Gottsche *et al.*		DD
Frullania tamarisci (L.) Dumort.		LC
Fuscocephaloziopsis catenulata (Huebener) Váňa & L. Söderstr.	D2	VU
Fuscocephaloziopsis lunulifolia (Dumort.) Váňa & L. Söderstr.	D2	VU
Gymnocolea inflata (Huds.) Dumort.	D2	VU
Gymnomitrion concinnatum (Lightf.) Corda	D2	VU
Isopaches bicrenatus (Schmidel) H. Buch	B2ab	NT
Jungermannia atrovirens Dumort.	D2*	NT
Jungermannia pumila With.	D2*	EN
Lejeunea cavifolia (Ehrh.) Lindb.		LC
Lepidozia reptans (L.) Dumort.		LC
Liochlaena lanceolata Nees	B2a	NT
Lophocolea bidentata (L.) Dumort.		LC

Lophocolea heterophylla (Schrad.) Dumort.		LC
Lophocolea minor Nees		LC
Lophozia ascendens (Warnst.) R. M. Schust.	B2ab(i,ii,iii,iv)	VU
Lophozia guttulata (Lindb. & Arnell) A. Evans	D2	VU
Lophozia ventricosa (Dicks.) Dumort.		LC
Lophozia wenzelii (Nees) Steph.	D2	VU
Lophoziopsis excisa (Dicks.) Konstant. & Vilnet	B2ab(ii,iv)	EN
Lophoziopsis longidens (Lindb.) Konstant. & Vilnet	D2	VU
Lunularia cruciata (L.) Lindb.		LC
Mannia fragrans (Balbis) Frye & L. Clark	B2ab(i,ii,iv)	EN
Marchantia paleacea Bertol.	D2	VU
Marchantia polymorpha L.		LC
Marchantia polymorpha L. subsp. *montivagans* Bischl. & Boisselier	D2*	NT
Marchantia polymorpha L. subsp. *ruderalis* Bischl. & Boisselier		LC
Marchantia quadrata Scop.		LC
Marsupella emarginata (Ehrh.) Dumort.	D2*	EN
Marsupella funcki (F. Weber & D. Mohr) Dumort.	D2	VU
Mesoptychia badensis (Gottsche ex Rabenh.) L. Söderstr. & Váňa	B2a	NT
Mesoptychia bantriensis (Hook.) L. Söderstr. & Váňa	B2a	NT
Mesoptychia collaris (Nees) L. Söderstr. & Váňa	B2a	NT
Mesoptychia heterocolpos (Thed. ex Hartm.) L. Söderstr. & Váňa	D2	VU
Mesoptychia turbinata (Raddi) L. Söderstr. & Váňa	D2	VU
Metzgeria conjugata Lindb.		LC
Metzgeria furcata (L.) Dumort.		LC
Metzgeria pubescens (Schrank) Raddi		LC
Microlejeunea ulicina (Taylor.) A. Evans	D2	VU
Mylia taylorii (Hook.) Gray	D2*	EN
Nardia compressa (Hook.) Gray		DD
Nardia scalaris Gray	B2a	NT
Neoorthocaulis attenuatus (Mart.) L. Söderstr., De Roo & Hedd.		DD
Neoorthocaulis floerkei (F. Weber & D. Mohr) L. Söderstr., De Roo & Hedd.	D2	VU
Nowellia curvifolia (Dicks.) Mitt.		LC
Obtusifolium obtusum (Lindb.) S.W. Arnell	D2	VU
Oxymitra incrassata (Brot.) Sergio & Sim-Sim	B2ab(i,ii,iii,iv)	CR
Pedinophyllum interruptum (Nees) Kaal.		LC
Pellia epiphylla (L.) Corda		LC
Pellia neesiana (Gottsche) Limpr.		LC
Plagiochila asplenioides (L. emend. Taylor) Dumort.		LC
Plagiochila porelloides (Torrey ex Nees) Lindenb.		LC
Porella arboris-vitae (With.) Grolle	D2	VU
Porella baueri (Schiffn.) C. E. O. Jens.	**	DD
Porella cordaeana (Huebener) Moore		LC
Porella obtusata (Taylor) Trevis.		DD
Porella platyphylla (L.) Pfeiff.		LC
Ptilidium cilliare (L.) Hampe		DD
Ptilidium pulcherimum (Weber) Vain.		LC
Radula complanata (L.) Dumort.		LC
Radula lindenbergiana Gottsche ex C. Hartm.	D2	VU
Reboulia hemisphaerica (L.) Raddi		LC
Riccardia incurvata Lindb.	D2	VU
Riccardia latifrons (Lindb.) Lindb.	D2	VU
Riccardia multifida (L.) Gray.		LC
Riccardia palmata (Hedw.) Carruth.		LC
Riccia canaliculata Hoffm.	D2	VU

Riccia ciliata Hoffm.	**	DD
Riccia ciliifera Link ex Lindenb.		LC
Riccia crystallina L. emend. Raddi		DD
Riccia fluitans L.		LC
Riccia frostii Austin		DD
Riccia glauca L.		LC
Riccia gougetiana Durieu & Mont.	**	DD
Riccia nigrella DC	D2*	EN
*Riccia sorocarp*a Bisch.		LC
Ricciocarpos natans (L.) Corda	B2a	NT
Scapania aequiloba (Schwägr.) Dumort.	B2ab(ii,iv)*	VU
Scapania aspera Bernet & M. Bernet		LC
Scapania calcicola (Arnell & J. Press.) Ingham	B2ab(ii,iv)	NT
Scapania curta (Mart.) Dumort.	B2ab(ii,iv)	EN
Scapania cuspiduligera (Nees) Müll. Frib.	D2*	EN
Scapania irrigua (Nees) Nees	B2a	NT
Scapania lingulata H. Buch	B2ab(ii,iv)	EN
Scapania mucronata H. Buch	B2ab(ii,iv)	VU
Scapania nemorea (L.) Grolle		LC
Scapania paludosa (Müll. Frib.) Müll. Frib.		DD
Scapania praetervisa Meyl.	D2	VU
Scapania scandica (Arnell & H. Buch) Macvicar	D2	VU
Scapania subalpina (Nees ex Lindenb.) Dumort.		DD
Scapania umbrosa (Schrad.) Dumort.	B2ab	NT
Scapania undulata (L.) Dumort.		LC
Schistochilopsis incisa (Schrad.) Konstant.	D2*	NT
Solenostoma gracillimum (Sm.) R.M. Schust.	B2a	NT
Solenostoma hyalinum (Lyell) Mitt.	D2	VU
Solenostoma obovatum (Nees) C. Massal.		DD
Solenostoma sphaerocarpum (Hook.) Steph.		DD
Sphenolobus minutus (Schreb.) Berggr.	D2	VU
Syzygiella autumnalis (DC.) K. Feldberg, Váňa, Hentschel & Heinrichs	D2	VU
Trichocolea tomentella (Ehrh.) Dumort.	B2ab(ii,iii,iv)	EN
Trilophozia quinquedentata (Huds.) Bakalin	B2ab(ii,iv)	VU
Tritomaria exsecta (Schmidel) Loeske	D2	VU

Table 2. A comparison of the threatened liverwort and hornwort taxa in Serbia in 2004 and 2024

Category	**2004, number of assessed taxa 79 (ratio)**	**2024, number of assessed taxa 134 (ratio)**
RE / PE	0/79 (-)	1/134 (0.007)
CR	2/79 (0.025)	2/134 (0.015)
EN	9/79 (0.114)	17/134 (0.126)
VU	14/79 (0.177)	34/134 (0.254)
NT	5/79 (0.063)	15/134 (0.112)
DD	1/79 (0.013)	15/134 (0.112)
LC	48/79 (0.608)	50/134 (0.373)

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REZIME

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Crvena lista vrsta jetrenjača i rožnjača Srbije: procena ugroženosti 2024

Marko S. Sabovljević, Jovana P. Pantović, Pavel Širka, Milorad M. Vujičić, Aneta D. Sabovljević i Beáta Papp

U radu se navodi nova procena ugroženosti vrsta jetrenjača i rožnjača Srbije. Na osnovu svih dostupnih podataka, procenjuje se da je oko 40% jetrenjača Srbije u nekom statusu ugroženosti (stanje 2024). Takođe, za 11% flore jetrenjača Srbije nema dovoljno podataka da bi se procenio njihov status ugroženosti (DD), a gotovo isto toliko jetrenjača je na korak da uđe u neku od kategorija ugroženosti (NT). Sve ovo jasno navodi da su terenska istraživanja, kao i istraživanja biologije vrsta hitno potrebna, kako bi se adekvatno definisali glavni problemi ugrožavanja, ali i predložile adekvatne mere zaštite.

Ključne reči: procena ugroženosti, konzervacija, briofite, rizik od nestajanja