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## Red-list of Italian bryophytes. 1. liverworts and hornworts

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### Abstract

The objective of this study is to provide an updated conservation status of all liverworts and hornworts in the Italian territory, evaluated according to IUCN's Guidelines for Application of IUCN Red List Criteria at Regional Level. Overall, 27.4% of taxa assessed in this study are assigned to a risk category and, therefore, considered threatened in Italy. Four liverworts are considered as Extinct, two liverworts and one hornwort Possibly Extinct at regional level. Moreover, a further 9.8% are assessed as Near Threatened, 10.8% as Data Deficient and 49.7% as Least Concern. Most threats are co-occurring, indicating that many taxa are subjected to a set of correlated adverse processes. The main IUCN major threats identified were natural system modifications (i.e., dam construction, increases in fire frequency/intensity, and water management/use), climate change (mainly increasing frequency of droughts and temperature extremes), agriculture (including pollution from agricultural effluents) and aquaculture.

**Key words:** Biodiversity conservation; IUCN criteria and categories; Italy; IUCN major threats; liverworts and hornworts.

## Introduction

As part of the Mediterranean global biodiversity hotspot, Italy hosts a flora particularly rich of species, the richest in Europe and the second richest after Turkey in the Mediterranean region (Bartolucci et al. 2018). However, Italian plant diversity is strongly threatened by environmental changes caused by the current socio-economic and land use dynamics associated with them, as well as by the increasingly evident global changes. In this context many species need conservation measures, to avoid the loss of biodiversity that considerably affects the ecosystem functioning. The conservation status of plants, animals and fungi is one of the most widely used indicators for assessing the health condition of ecosystems and their biodiversity. With this purpose, the IUCN Red Lists of threatened species are useful conservation tool at the global level, and their value has been widely recognized (e.g., Rodrigues et al. 2006). In recent years, IUCN Red List categories and criteria (2003) have been increasingly used at national or regional levels, and this has been encouraged by the IUCN with the publication of guidelines for national or regional Red Lists (Gärdenfors et al. 2001; IUCN, 2012b).

Recently, a complete red list of the Italian vascular plants was published, where the conservation status of the taxa was assessed according to the IUCN categories and criteria (Orsenigo et al. 2021). As concern bryophytes, the first and so far, only Italian red list was published in 1992 (Cortini Pedrotti & Aleffi 1992) as an excerpt from the Red Book of Plants in Italy (Conti et al. 1992), based on the first IUCN categories drawn up in 1978. This paper reports 496 bryophytes (129 liverworts and 367 mosses) considered at risk in Italy; their degree of threat was examined according to four categories codified by IUCN: “EX” (extinct), “E” (endangered), “V” (vulnerable), “R” (rare). These old IUCN threat categories were replaced by a revised system that abandoned the Rare category and introduced the Critically Endangered category; the sub-Red List category of Near Threatened was also established, and later the categories of Regionally Extinct and Extinct in the Wild were distinguished from Extinct. The implementation in Italy of the new categories and criteria IUCN (2001) led to a new red listing phase of the Italian bryoflora with the publication of some papers regarding the conservation status assessment of single species (e.g. Aleffi 2008a, 2008b; Campisi et al., 2008; Privitera & Puglisi 2008; Aleffi & Privitera 2011; Aleffi & Tacchi 2011; Miserere, 2011a, 2011b; Puglisi & Privitera 2011a, 2011b) and the assessments of a group of bryophytes, most of all included in the Annexes II, IV and V of the “Habitat” Directive 92/43/EEC and the Berne Convention (Rossi et al. 2013).

The publication of the new red list of bryophytes of Europe (Hodgetts et al. 2019) has highlighted even more the need to draw up a comprehensive red list at an Italian level, so the working group for

Bryology of the Italian Botanical Society decided to organize a working team to deal with this. This paper provides the first comprehensive, region-wide assessment of liverworts and hornworts of Italy and it identifies those species that are threatened with extinction at Italian level, so that appropriate policy measures and conservation actions can be taken to improve their status.

## Material and methods

The Italian Red List of Liverworts and Hornworts has assessed the status of all specific and infraspecific taxa reported in the checklist of Italian bryophytes (Aleffi et al. 2020). For its compilation we referred to territory of Italy defined by its current political borders and also including the San Marino Republic and the Vatican City State, as in the aforementioned checklist.

The conservation status of the selected taxa was assessed according to the criteria and categories of IUCN (2012a, 2012b, 2022), and considering the guidelines for bryophytes (Hallingbäck et al. 1998; Hallingbäck 2006; Hodgetts et al. 2019).

The assessments were mostly based on criterion B, since in Italy, as well as in other European countries, data on the bryophyte population trend, useful for the application of criteria A and C, are very scarce. Distribution data were mainly drawn from published and unpublished data, herbarium specimens, and recent field surveys of the Authors.

For all assessment, the following information were collected: updated taxonomic status of taxa; georeferenced distribution records; habitat and ecological requirements; threat category in neighbouring countries and in Europe; actual and potential threats; incidence of old reports not recently confirmed; conservation measures. Distribution data were used for calculating EOO and AOO, obtained through “GeoCAT” (Geospatial Conservation Assessment Tool), (Banchman et al. 2011). GeoCAT is an open source, browser-based tool, developed by Kew Gardens to utilise spatially referenced primary occurrence data and analyse two aspects of the geographic range of a taxon: AOO and EOO; it performs rapid geospatial analysis to ease the process of Red Listing taxa. The grid for the calculation of the Area of Occupancy was 4 km<sup>2</sup> (2 × 2 km). Data on habitat and ecology were drawn from Dierßen (2001), the risk status of *taxa* in Europe from Hodgetts et al. (2019), and for each European country from Hodgetts & Lockhart (2020). The conservation measures considered are indirect (species within natural reserves or parks) in absence of action plans for the protection of individual species in Italy.

Many training workshops promoted by the directive council of the working group for Bryology of the Italian Botanical Society were organized for a preliminary approach to the methodology applied to the bryophytes, and for gathering of distribution data. The resulting finalised IUCN Red List

assessments are a product of scientific consensus concerning species status and are supported by relevant literature and data sources.

Threats were classified according to the IUCN threats classification scheme (IUCN 2012c), and the relative data were used to classify the major threats affecting liverworts and hornworts in Italy. The main threats at local level were identified by means of expert-based observations and available literature.

In applying the IUCN criteria, 1968 has been chosen as the cut-off date to represent the threshold between old and recent records for the purpose of assessing decline, as well as in Aleffi et al. (2020). A taxon was considered regionally Extinct (RE) when it was not recorded in the last 50 years, and when recent field surveys focused on finding the taxon in its historical area of occurrence were unsuccessful. Moreover, following the precautionary approach suggested by Butchart et al. (2006), taxa that were not recorded during the previous three decades, but for which uncertainty regarding extinction remained, were categorized as “Critically Endangered - Possibly Extinct [CR(PE)]”.

The nomenclature and taxonomy follow Hodgetts et al. (2020).

## Results and discussion

Overall, 306 taxa were evaluated (297 species, five subspecies, and four varieties), corresponding to 300 liverworts and six hornworts (Tab. 1). Four species were considered as Regionally Extinct (RE); they are: *Arnellia fennica* (Gottsche) Lindb., *Gymnomitrium adustum* Nees, *G. obtusum* Lindb. and *Radula visianica* C.Massal. Moreover, three species were not recorded in the last three decades years and were, thus, qualified as Critically Endangered (Possibly Extinct) [CR(PE)]; they are: *Notothylas orbicularis* (Schwein.) Sull., *Odontoschisma macounii* (Austin) Underw. and *Schistochilopsis grandiretis* (Lindb. ex Kaal.) Konstant. 15 species (4.9%) are categorized as Critically Endangered (CR), 38 species (12.4%) as Endangered (EN) and 31 species (10.1%) as Vulnerable (VU), (Fig. 1). Additional 30 taxa (9.8%) are classified as Near Threatened (NT) and another relatively large group (33 species, 10.8%) is represented by species of the Data Deficient category (DD); for the last ones, available data reflect their insufficiently known distribution and endangerment and do not allow a reliable assessment. Overall, at the Italian level, 84 taxa (27.4%) are assigned to a risk category. However, this percentage could increase if the DD species, after new investigations, are found to be threatened.

Finally, 152 species (49.7% of the liverwort and hornwort flora of Italy) were assessed as Least Concern (LC).

In Europe, there are currently 461 liverwort and eight hornwort species, of which 22.5% and 25.0%, respectively, are evaluated as threatened (Hodgetts et al. 2019). In Italy, 30 taxa are considered threatened on a European scale (Hodgetts et al. 2019). Only three taxa are not endangered on the Italian territory (*Marchantia paleacea* Bertol., *Moerckia hibernica* (Hook.) Gottsche and *Riccia warnstorffii* Limpr. ex Warnst.). Another three taxa are considered as DD (*Asterella africana* (Mont.) Underw. ex A.Evans, *Gymnomitrium alpinum* (Gottsche ex Husn.) Schiffn. and *Marsupella condensata* (Ångstr. ex C.Hartm.) Lindb. ex Kaal.) and two as NT (*Cephaloziella dentata* (Raddi) Steph. and *Mesoptychia gillmanii* (Austin) L.Söderstr. & Váňa var. *gillmanii*). The remaining 22 taxa are threatened at the Italian level, too. They are: *Cephaloziella phyllacantha* (C.Massal. & Carestia) Müll.Frib., *Cyathodium foetidissimum* Schiffn., *Frullania parvistipula* Steph., and *Radula visianica* C.Massal. categorized in the European Red List of bryophytes (Hodgetts et al. 2019) as CR, *Cephaloziella integerrima* (Lindb.) Warnst., *C. massalongi* (Spruce) Müll.Frib., *Frullania riparia* Hampe, *Mannia californica* (Gottsche) L.C.Wheeler, *Notothylas orbicularis* (Schwein.) Sull., *Riccia atromarginata* Levier var. *atromarginata*, *R. ligula* Steph., *Scapania carinthiaca* J.B.Jack ex Lindb. var. *massalongi* Müll.Frib., and *S. glaucocephala* (Taylor) Austin var. *glaucocephala* as EN, *Cephaloziella elachista* var. *elachista* (J.B.Jack ex Gottsche & Rabenh.) Schiffn., *Frullania jackii* Gottsche, *Isopaches decolorans* (Limpr.) H.Buch, *Mannia fragrans* (Balb.) Frye & L.Clark subsp. *fragrans*, *Mannia triandra* (Scop.) Grolle, *Moerckia blyttii* (Mørch) Brockm., *Pallavicinia lyellii* (Hook.) Gray, *Riccia breidlerii* Jur. ex Steph., and *Scapania verrucosa* Heeg, as VU.

The four species considered extinct in Italy are still present in other European countries and are considered LC at European level, with the exception of *Radula visianica* C.Massal. which is considered CR at European level; of the three CR(PE) species only *Notothylas orbicularis* (Schwein.) Sull. is considered EN at European level.

As regards the distribution of the threatened taxa in the Italian territory, it is possible to observe the highest incidence of taxa in the alpine regions with values ranging from 15.6% to 22.9% (Val d'Aosta, Piemonte, Lombardia, Trentino Alto Adige, Veneto and Friuli Venezia Giulia), emphasizing the importance of mountain habitats for threatened species and their conservation. These data highlight the impact of climate change on the montane flora, and pressure from land use change and tourist developments in the mountain areas. Moreover, many montane species are naturally rare and therefore more susceptible to disappearance. Significant percentages of threatened taxa are also found for Sardinia (10.2%) and Sicily (9.1%) where it is possible to survey

threatened species not only on the mountains but also along the coastal areas (Puglisi et al. 2015), the latter impacted by climate change and human settlements.

#### IUCN MAJOR THREATS

Threats to bryophytes are complex and often difficult to categorise. There are sometimes synergistic effects between threats e.g., between climate change and increased fire frequency, and it is hard to determine which threat is the key driver impacting a bryophyte. In total, it was possible to identify threats for 114 species, in most cases with multiple threats listed for a species. The main threat to the Italian liverwort and hornwort flora is represented by “Natural system modifications” with 75 taxa (corresponding to 65.8%) impacted by this driver of decline (Fig. 2). A total of 47 species are affected by dams and water management and use, that is considered the most common threat to bryophytes across Europe (Hodgetts et al. 2019). This threat includes the abstraction of ground and surface water for different uses, including agricultural, commercial, and domestic uses, and the construction of dams. Species that are water-dependent, and those that grow in wetlands (bogs, marshes, swamps, fens, peatlands) are most at risk from these threats, e.g., *Calypogeia sphagnicola*, *Cephaloziella elachista* var. *elachista*, *Fuscocephaloziopsis leucantha*, *F. macrostachya*, *Harpanthus flotovianus*, *Odontoschisma sphagni*, etc. Bogs and fens are among the most threatened habitats in Europe (Janssen et al. 2016), and so the bryophytes living in these habitats.

“Climate change and Severe Weather” ranked second in the list of threats to liverworts and hornworts in Italy, with 72 taxa (63.2%) impacted by this driver of decline. Under this broad threat, 45 species are estimated to be or will be affected by “Habitat Shifting and Alteration”, 40 taxa by “Droughts” and 18 are considered to be at risk from “Temperature extremes”. Some of the species most likely to be threatened by climate change are those confined to wetlands. Liverworts that are found at high elevations, are probably significantly more prone to the impacts of climate change than other species, as they have nowhere else to go if temperatures increase significantly. The bryophytes of southern Italy and Sicily in general are also at an increasingly higher risk of extinction as the climate becomes warmer and drier; some examples are *Exormotheca pustulosa*, *Riccia atromarginata* var. *atromarginata*, *R. trabutiana*, *Riella notarisii*, *Targionia lorbeeriana*. Already some areas have been affected by desertification, and while many species have strategies for avoiding or tolerating drought (xero-thalloid life syndrome), even these species will be unable to survive in conditions of more extreme desertification.

A total of 23 taxa (20.2%) are affected by “Agriculture and Aquaculture”, with most of them by “Wood and Pulp Plantations” and “Livestock Farming & Ranching”. Most plantations are on sites where there used to be natural or semi-natural forest, so the main species threatened by conversion

of natural forest to plantation woodland are those dependent on the long ecological continuity provided by a stable, humid, natural forest. Specialists of dead wood, such as *Mylia taylorii*, have been particularly impacted, as amounts of deadwood are often very low in managed forests. Generally, land-use conversion practices (including the intensification of agriculture and forestry) are considered the most common threat to biodiversity in undisturbed habitats (IPBES 2018).

18 taxa (15.8%) are impacted by “Human Intrusion and Disturbance”, essentially due to recreational activities, e.g. mountain bikes, hikers, off-road vehicles, etc. 17 taxa (14.9%) are affected by the threat “Residential and Commercial Development”, and in particular by Housing and Urban, and Tourism and Recreation Areas. Taxa occurring in coastal habitats, e.g., *Petalophyllum ralfsii*, *Exormotheca pustulosa*, *Sphaerocarpos europaeus*, resulted more subject to tourism development and disturbance.

Pollution, essentially due to agricultural and silvicultural systems, and air-borne pollutants, (11.4%), Biological Resource Use (logging & wood harvesting) (8.8%), Geological Events (6.1%) and Invasive Non-Native species (1.8%) currently represent minor threats.

## Conclusion

Bryophytes are vulnerable organisms due to their morphology and reproductive modes, have a relatively low growth rate, and are sensitive to drought. Unlike vascular plants, most species are poorly equipped to regulate their water content internally, instead drying out and rewetting rapidly according to external conditions (poikilohydric). Their relatively simple anatomy makes them more vulnerable to atmospheric and soil contamination and therefore they are considered reliable bioindicators for the monitoring of water, soil and air quality (Hallingbäck & Hodgetts 2000).

Many species of bryophytes are threatened at global and continental scales (Vanderpoorten & Hallingbäck 2009; Hodgetts et al. 2019). In recent decades, interest in evaluating the extinction risk and conservation status of bryophytes has led to the elaboration of red lists, which are resource of information essential to guide conservation efforts focused on species.

In this study, we have assessed the liverwort and hornwort flora of Italy with the aim of highlight the most endangered species and identify priorities for conservation. Overall, 27.4% of the Italian liverworts and hornworts is assigned to one of the IUCN threat categories: CR, EN, and VU. Further 20.6% of the species are assigned to NT or DD categories. The last category includes taxa with an insufficiently known distribution, and taxa with many historical localities and have not been sufficiently searched. Although the species under NT and DD are not strictly considered threatened, as the term is applied by IUCN, these categories indicate that these species deserve special attention. They are likely candidates for a threat category when more information is acquired (DD),

or if their habitats change drastically (NT). Therefore, further field, taxonomic, biogeographical, and ecological investigations should be undertaken to fill these gaps.

The proportion of Italian threatened liverwort and hornwort taxa is higher compared to the European continent (21.1% in Hodgetts et al. 2019), and other European or Mediterranean countries, e.g., England and Ireland (18.6%), Portugal (20.3%) and Spain (21.4%), (Hodgetts & Lockart 2020). In Italy, the threatened liverworts are mainly found in the alpine regions, particularly affected by climate change, while the hornworts are predominant along the coastal areas.

The main threats identified are natural system modifications (specially represented by water management and use), climate change (habitat shifting and alteration, increasing frequency of droughts and temperature extremes), agriculture (including pollution from agricultural effluents) and aquaculture, and human intrusion and disturbance. A comparison with the threatened Italian vascular flora shows a greater impact of the climate change on the liverwort and hornwort flora. The majority of liverworts are restricted to habitats that are normally moist and sheltered, depending on an adequate water supply for growth and successful fertilization. Some species are found only in very moist conditions such as bogs, fens, and flushes. Already strongly reduced due to land-use changes, wetlands are also impacted by droughts due to climate change. In fact, many of the taxa most likely to be threatened by climate change are those confined to wetlands.

The results of this study represent a scientific basis to identify the priority of conservation and establish measures for bryophyte conservation that need to be integrated into regular planning and land management procedures and practices.

It is known that red lists are a dynamic tool that evolves with time as species are re-assessed according to new information or situations. They are aimed at stimulating and supporting research, monitoring and conservation action at local, regional, and national levels, especially for threatened, Near Threatened and Data Deficient species. Monitoring of bryophyte populations and their habitats are needed to ensure the protection of bryophyte diversity in the Country. The red list is a first and necessary step to achieve this goal.

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The authors declare no conflict of interest.

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## References

- Aleffi M. 2008a. *Buxbaumia viridis* (Lam. et DC.) Mougl. et Nestl. In: AAVV Flora da Conservare. Iniziativa per l'implementazione in Italia delle categorie e dei criteri IUCN (2001) per la redazione di nuove Liste Rosse. Inform Bot Ital. 40(S1): 135,136.
- Aleffi M. 2008b. *Petalophyllum ralfsii* (Wils.) Nees et Gottsche In: AAVV Flora da Conservare. Iniziativa per l'implementazione in Italia delle categorie e dei criteri IUCN (2001) per la redazione di nuove Liste Rosse. Inform Bot Ital. 40(S1): 139-140.
- Aleffi M, Privitera M. 2011. *Dumortiera hirsuta* (Sw.) Nees. In: AAVV Schede per una Lista Rossa della Flora vascolare e crittogamica italiana. Inform Bot Ital. 43(2): 441-442.
- Aleffi M, Tacchi R. 2011. *Paludella squarrosa* (Hedw.) Brid. In: AAVV Schede per una Lista Rossa della Flora vascolare e crittogamica italiana. Inform Bot Ital 43(2): 443-444.
- Aleffi M, Tacchi R, Poponessi S. 2020. New checklist of the bryophytes of Italy. Cryptogam Bryol. 41:147–195.
- Bachman S, Moat J, Hill AW, De La Torre J, Scot B. 2011. Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. ZooKeys. 150: 117-126.
- Bartolucci, Peruzzi L, Galasso G, Albano A, Alessandrini A, Ardenghi NMG, Astuti G, Bacchetta G, Ballelli S, Banfi E, et al. 2018. An updated checklist of the vascular flora native to Italy. Pl Biosyst. 152 (2): 179-303.
- Butchart SHM, Stattersfield AJ, Brooks TM. 2006. Going or gone: defining 'Possibly Extinct' species to give a truer picture of recent extinctions. Bull Br Ornith Club. 126:7–24.
- Campisi P, Lo Re MG, Dia MG. 2008. *Gigaspermum mouretii* Corb. In: AAVV Flora da Conservare. Iniziativa per l'implementazione in Italia delle categorie e dei criteri IUCN (2001) per la redazione di nuove Liste Rosse. Inform Bot Ital. 40(S1): 137-138.
- Conti F, Manzi A, Pedrotti F. 1992. Libro rosso delle Piante d'Italia. Ministero Ambiente, WWF Italia, Società Botanica Italiana, Roma. 637 pp.
- Cortini Pedrotti C, Aleffi M. 1992. Lista Rossa delle Briofite d'Italia. In: Conti F, Manzi A, Pedrotti F (Eds.), Libro rosso delle Piante d'Italia: 557-637. Ministero Ambiente, WWF Italia, Società Botanica Italiana, Roma.
- Dierßen K. 2001. Distribution, ecological amplitude and phytosociological characterization of European bryophytes. Bryophyt Biblioth. 56: 1–289.
- Gärdenfors U, Hilton-Taylor C, Mace GM, Rodríguez JP. 2001. The application of IUCN Red List criteria at regional levels. Conserv Biol. 15:1206–1212.

- Hallingbäck T. 2006. Application of the IUCN 2001 red listing system to bryophytes. Version 20006.08.28.
- Hallingbäck T, Hodgetts N, Raeymaekers G, Schumacker R, Sérgio C, Söderström L, Stewart N, Váňa J. 1998. Guidelines for application of the revised IUCN threat categories to bryophytes. *Lindbergia* 23: 6-12.
- Hodgetts N, Lockhart N. 2020. Checklist and country status of European bryophytes – update 2020. Irish Wildlife Manuals, No. 123. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland, 214 pp.
- Hodgetts N, Calix M, Englefield E, Fettes N, Garcia Criado M, Patin L, Nieto A, Bergamini A, Bisang I, Baisheva E, et al. 2019. A miniature world in decline: European Red List of Mosses, Liverworts and Hornworts. IUCN, Brussels, Belgium. 87 pp.
- Hallingbäck T, Hodgetts NG. 2000. Mosses, Liverworts, and Hornworts. Status Survey and Conservation Action Plan for Bryophytes. IUCN/SSC Bryophyte Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. 103 pp.
- Hodgetts NG, Söderström L, Blockeel TL, Caspari S, Ignatov MS, Konstantinova NA, Lockhart N, Papp B, Schröck C, Sim-Sim M, et al. 2020. An annotated checklist of bryophytes of Europe, Macaronesia and Cyprus. *J Bryol.* 42 (1): 1-116.
- IPBES. 2018. The IPBES assessment report on land degradation and restoration. Montanarella L, Scholes R, Brainich A (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 744 pp.
- IUCN. 2001. IUCN Red List categories & criteria. Version 3.1. Gland: IUCN.
- IUCN 2012a. IUCN Red List categories and criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge: IUCN Species Survival Commission, IUCN. p. iv þ 32.
- IUCN 2012b. Guidelines for application of IUCN Red List criteria at regional and national levels. Version 4.0. IUCN Species Survival Commission. Gland: IUCN.
- IUCN 2012c. Unified Classification of Direct Threats: Version 3.2. [http://s3.amazonaws.com/iucnredlist-newcms/staging/public/attachments/3127/dec\\_2012\\_guidance\\_threats\\_classification\\_scheme.pdf](http://s3.amazonaws.com/iucnredlist-newcms/staging/public/attachments/3127/dec_2012_guidance_threats_classification_scheme.pdf)
- IUCN 2022. Guidelines for Using the IUCN Red List Categories and Criteria. Version 15.1. Prepared by the Standards and Petitions Committee. Downloadable from <https://www.iucnredlist.org/documents/RedListGuidelines.pdf>.
- Janssen JAM, Rodwell J.S., García Criado M., Gubbay S., Haynes T., Nieto A., Sanders N., Landucci F., Loidi J., Ssymank A., et al. 2016. European Red List of Habitats. Part 2: Terrestrial and freshwater habitats. Publications Office of the European Union, Luxembourg.

- Miserere L. 2011a. *Riccia breidleri* Jur. ex Steph. In: AAVV Schede per una Lista Rossa della Flora vascolare e crittogamica italiana. Inform Bot Ital. 43(2): 447-448.
- Miserere L. 2011b. *Zygodon gracilis* Wilson. In: AAVV Schede per una Lista Rossa della Flora vascolare e crittogamica italiana. Inform Bot Ital. 43(2): 449-450.
- Orsenigo S, Fenu G, Gargano D, Montagnani C, Abeli T, Alessandrini A, Bacchetta G, Bartolucci F, Carta A, Castello M, et al. 2021. Red list of threatened vascular plants in Italy, Plant Biosyst. 155 (2): 310-335.
- Privitera M., Puglisi M. 2008. *Riella notarisii* (Mont.) Mont. In: AAVV Flora da Conservare. Iniziativa per l'implementazione in Italia delle categorie e dei criteri IUCN (2001) per la redazione di nuove Liste Rosse. Inform Bot Ital. 40(S1): 141-142.
- Puglisi M, Privitera M. 2011a. *Calymperes erosum* (Müll.) Hal. In: AAVV Schede per una Lista Rossa della Flora vascolare e crittogamica italiana. Inform Bot Ital. 43(2): 439-440.
- Puglisi M, Privitera M. 2011b. *Rhynchostegium strongylense* (Bott.) W.R.Buck & Privitera. In: AAVV Schede per una Lista Rossa della Flora vascolare e crittogamica italiana. Inform Bot Ital. 43(2): 445-446.
- Puglisi M, Campisi P, Aiello P, Dia MG, Privitera M. 2015. Analysis of the bryophytes diversity of mountain ranges in Sicily. Nova Hedwigia. 100(3-4): 391-405.
- Rodrigues ASL, Pilgrim JD, Lamoureux JF, Hoffmann M, Brooks TM. 2006. The value of the IUCN Red List for conservation. Trends Ecol Evol 21: 71–76.
- Rossi G, Montagnani C, Gargano D, Peruzzi L, Abeli T, Ravera S, Cogoni A, Fenu G, Magrini S, Gennai M, et al. (Eds.). 2013. Lista Rossa della Flora Italiana. 1. Policy Species e altre specie minacciate. Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare.
- Vanderpoorten A, Hallingbäck T. 2009. Conservation biology of bryophytes. In: Goffinet B, Shaw AJ (Eds.), Bryophyte Biology. Cambridge University Press, Cambridge, pp. 487-533.

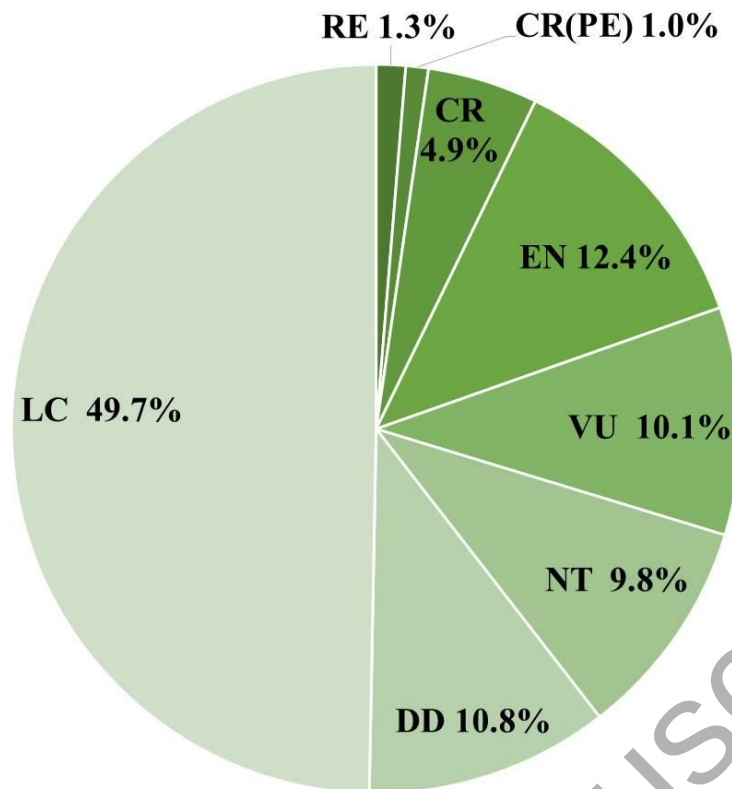


Fig. 1 - Incidence of Red List categories in the Italian liverwort and hornwort flora.

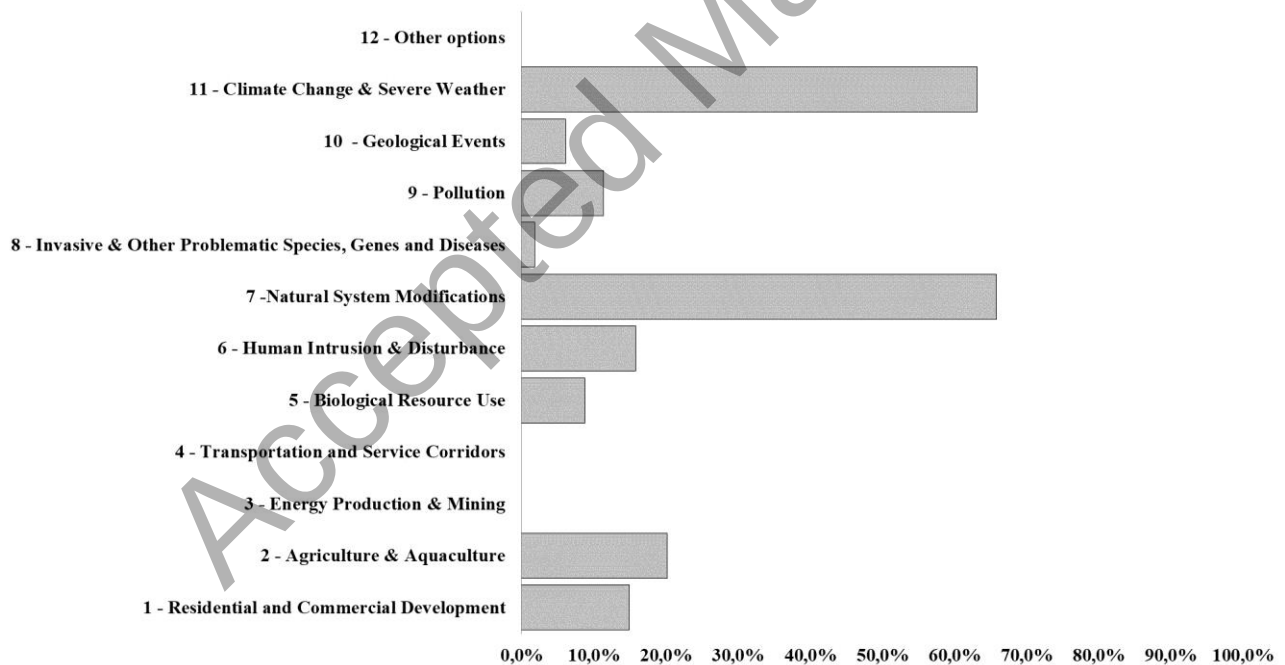


Fig. 2 – Incidence on the Italian liverwort and hornwort flora of the major threat category according to the IUCN Threats Classification Scheme (version 3.2).

Tab. 1 - IUCN Red List status and assessment criteria of the Italian liverworts and hornworts. Threats follow the IUCN Classification Scheme (version 3.2-IUCN 2012c): 1. Residential and Commercial Development, 1.1 Housing & Urban Areas, 1.3 Tourism and Recreation Areas; 2. Agriculture & Aquaculture, 2.1.1 Shifting Agriculture, 2.2 Wood & Pulp Plantations, 2.3 Livestock Farming & Ranching, 2.3.1 Nomadic Grazing, 2.3.3 Agro-Industry Grazing, Ranching or Farming; 5. Biological Resource Use, 5.3 Logging & Wood Harvesting, 5.3.3 Unintentional effects: subsistence/small scale; 6. Human Intrusion & Disturbance, 6.1 Recreational Activities; 7. Natural System Modifications, 7.1 Fire & Fire Suppression, 7.1.1 Increase in Fire Frequency/Intensity, 7.2 Dams & Water Management/Use, 7.2.1 Abstraction of Surface Water (domestic use), 7.3 Other Ecosystem Modifications; 8. Invasive & Other Problematic Species, Genes and Diseases, 8.1 Invasive Non-Native/Alien Species/Diseases; 9. Pollution, 9.3 Agricultural & Forestry Effluents, 9.3.3 Herbicides and Pesticides, 9.5 Air-Borne Pollutants; 10. Geological Events, 10.3 Avalanches/Landslides; 11. Climate Change & Severe Weather, 11.1 Habitat Shifting & Alteration, 11.2 Droughts, 11.3 Temperature Extremes.

| <b>Taxon</b>                                                                                 | <b>Family</b>  | <b>Threat Category</b> | <b>Criteria</b>                        | <b>Threats</b>            | <b>European category</b> |
|----------------------------------------------------------------------------------------------|----------------|------------------------|----------------------------------------|---------------------------|--------------------------|
| <i>Frullania jackii</i> Gottsche                                                             | Frullaniaceae  | VU                     | B2 ab (ii,iii)                         | 5.3;<br>9.5               | VU                       |
| <i>Frullania parvistipula</i> Steph.                                                         | Frullaniaceae  | EN                     | B2 ab (i,ii, iii, iv)                  | 5.3;<br>7.3               | CR                       |
| <i>Fuscocephaloziopsis catenulata</i> (Huebener) Váňa & L.Söderstr. subsp. <i>catenulata</i> | Cephaloziaceae | EN                     | B2 ab (ii,iii,iv)                      | 5.3;<br>7.2               | LC                       |
| <i>Metzgeria violacea</i> (Ach.) Dumort.                                                     | Metzgeriaceae  | EN                     | B2 ab (i, ii, iii, iv)                 | 5.3;<br>6.1;<br>9.2       | LC                       |
| <i>Microlejeunea ulicina</i> (Taylor) Steph.                                                 | Lejeuneaceae   | VU                     | B2 ab (i, ii, iii, iv)                 | 5.3;<br>6.1               | LC                       |
| <i>Mylia taylorii</i> (Hook.) Gray                                                           | Myliaceae      | EN                     | B2 ab (i, ii, iii, iv)                 | 2;<br>5.3;<br>6.1         | LC                       |
| <i>Scapania apiculata</i> Spruce                                                             | Scapaniaceae   | CR                     | B1ab (i,ii,iii,iv) + 2ab (i,ii,iii,iv) | 5.3;<br>11.1              | NT                       |
| <i>Scapania glaucocephala</i> (Taylor) Austin var. <i>glaucocephala</i>                      | Scapaniaceae   | EN                     | B1 ab (i, ii, iii)                     | 5.3;<br>11.1              | EN                       |
| <i>Syzygiella autumnalis</i> (DC.) K.Feldberg, Váňa, Hentschel & Heinrichs                   | Adelantaceae   | NT                     | B2a                                    | 5.3                       | LC                       |
| <i>Tritomaria scitula</i> (Taylor) Jørg.                                                     | Lophoziaceae   | VU                     | B2 ab(ii,ii,iv)                        | 1.3;<br>5.3;<br>3;<br>7.3 | LC                       |