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Asterella africana detected by citizen scientists at its northernmost distribution in Europe (Tuscany, Italy)

Abstract

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The utilisation of citizen science initiatives has become an increasingly essential tool for biodiversity monitoring. Despite this, concerns persist regarding the quality and validation of the data collected. This study presents an approach to integrating citizen science observations with the expertise of bryophyte taxonomy, resulting in the identification of *Asterella africana*, a rare thalloid liverwort, at its northernmost distribution in Europe. The discovery was facilitated by a digital image submitted to iNaturalist and an identification key based solely on vegetative traits. This novel discovery serves to illustrate the significance of naturalistic social network in elucidating biodiversity patterns, even in the case of taxonomically challenging organisms that are possibly expanding in a warming climate.

Key words: *Aytoniaceae*, biogeography, citizen science, climate change, complex thalloid liverworts.

Introduction

Citizen science encompasses a multitude of projects, for example collectively involving millions of participants in the collection and/or processing of biological data across the globe (Kullenberg & Kasperowski 2016). Nevertheless, the veracity of such scientific findings has been called into question due to concerns about the quality of the data, including the credibility and validation of the research, and most notably, the ability of the research to produce peer-reviewed publications (Theobald & al. 2015). One potential solution is to propose a reclassification of these projects, whereby the term "citizen science" is restricted to instances where participants are essentially functioning as sampling devices that observe and count when presented with data in digital form (Davis & al. 2023). However, the identification of taxonomically challenging organisms based on digital images may be either unfeasible or, at the very least, highly uncertain (Casanovas & al. 2014; Prudic & al. 2018; Munzi & al. 2023).

It is uncommon for bryological data gathered through the citizen science initiative to be published in scientific literature (Neyens & al. 2019; Pakeman & al. 2019). Bryophytes are undoubtedly a taxonomically difficult group, primarily for their small size, but complex thalloid liverworts of the *Marchantiales* Limpr. exhibit usually large organs (Bischler, 1998), rendering them suitable for recognition in citizen science through digital images.

In this article, *Asterella africana* (Mont.) Underw. ex A. Evans, a rare and complex thalloid liverwort (order *Marchantiales* Limpr., family *Aytoniaceae* Cavers), was detected by citizen scientists at a location that contributes to a notable phytogeographical extension to north of the current range of the species. This case study exemplifies an efficacious integration between citizen scientists and taxonomical experts.

Materials and Methods

Distribution in Europe

A comprehensive distribution of *Asterella africana* across Europe (excluding Macaronesia) was derived from a synthesis of bibliographic sources.

A. africana was originally known from many sites in Corsica (Bischler & Jovet-Ast, 1973). At first, it was misidentified for the American *Fimbriaria elegans* Spreng. [= *Asterella elegans* (Spreng.) Trevis.] which was recurrently reported for Europe (Long, 2006) and redetermined as *A. africana* by Bischler & Jovet-Ast (1973). Afterwards, *A. africana* was collected in Spain (Rupidera Giraldo & Elias Rivas 1996) and in Portugal (Sérgio & al., 2001). Finally, the species was twice observed in the easternmost part of its geographical range in Greece by Blockeel (2012, 2017).

In Italy, *A. africana* was reported for Sardinia by Bischler & Jovet-Ast (1971-1972) who revised an old herbarium specimen (PC) collected by De Notaris but without any locality. After, Bischler (2004) included Sicily among the distribution area of this taxon, but being this record not supported by specific information, it has been rejected by Michele Aleffi (pers. comm., in Söderström & al., 2007) in the check lists of Italian liverworts (Aleffi & al. 2023). Finally, more recently, *A. africana* has been reported for this isle on Mount Etna (Puglisi & al. 2024).

Detection of the Species

On February 3, 2024, an unknown population of a thalloid liverwort was found during a citizen science exploration of Monti Pisani (Municipality of Asciano, Province of Pisa, Tuscany). During such exploration, a digital image was submitted by the first Author to iNaturalist community (https://www.inaturalist.org/observations/198297882). The image was quickly identified as *A. africana* by the latter Author, thanks to a set of unique vegetative traits (discussed later in the original key based on vegetative traits).

Lately, two field trips were organized by all the Authors for further investigations on potential other populations and to collect samples as herbarium specimens and to perform further microscopic investigations. Microscopic observations were conducted

using a Leitz Diaplan optical microscope at various magnifications. In addition, a survey of the surrounding bryoflora coexisting with the target species and a phytosociological survey of the vascular flora were carried out; phytosociological data were compared with those published by Bertacchi & al. (2004) and syntaxa are according to Mucina & al. (2016). The nomenclature of bryophytes and vascular plants, respectively, adheres to Hodgetts & al. (2020) and to Bartolucci & al. (2024).

Results

Vegetative Traits

Fresh thalli of *A. africana*, together the other two species of the genus *Asterella* occurring in Europe (Hodgetts & al., 2020), have a strong smell of rotten fish when crashed. This unpleasant odour is unique among the European complex thalloid liverworts. Consequently, identifying *Asterella* species from digital images can be frustrating: when sterile, *A. africana* is very similar to a species placed in the same family (*Aytoniaceae*), *Reboulia hemisphaerica* (L.) Raddi. The following key, based on vegetative traits visible in fresh, well-hydrated thalli, can be used conveniently in field to identify species of the genus *Asterella* and *R. hemisphaerica*, including specimens shown in digital images. For examples, the key was used by the latter Author (G. Brusa) for the first recognition of *A. africana* from the digital image submitted on iNaturalist. A more comprehensive key to complex thalloid liverworts (*Marchantiales*) using only vegetative traits is in preparation.

Identification key

1. Appendages of ventral scales projecting beyond the margin along the thallus ——————————————————— → *A. saccata* (Fig. 1)

- Appendages of ventral scales not projecting beyond the margin along the thallus (i.e. present only at the vegetative apex) ——————————— → 2

2. Thalli matt green; margins usually crenate (especially towards the apex); appendages of scales dark purplish ————— → *R. hemisphaerica* (Fig. 2)

- Thalli fresh green; margins edentate or partially sinuate; appendages of scales whitish or pale reddish/purplish ——————————————— → 3

3. Thalli delicate; air pores scarcely visible; dorsal thallus surface with a scant reticulation (especially towards the apex) ————— → *A. africana* (Fig. 3)

- Thalli almost leathery; air pores rather visible; dorsal thallus surface without any reticulation ——————————————— → *A. lindenbergiana* (Fig. 4)

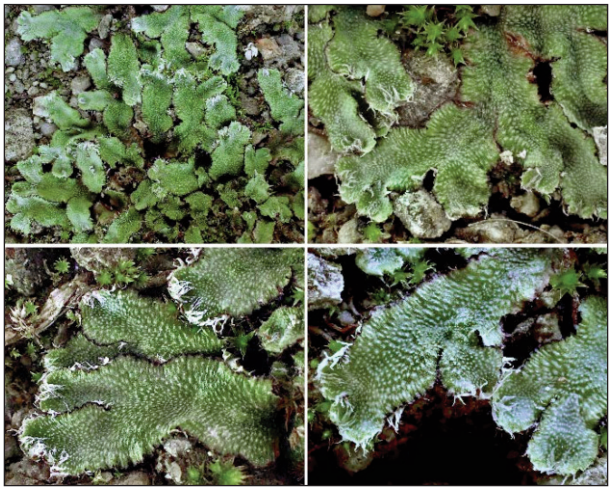

Fig. 1. *Asterella saccata.*

Fig. 2. *Reboulia hemisphaerica.*

New Record

Asterella africana (Mont.) Underw. ex A. Evans (*Aytoniaceae*)

+ TOS: Valle delle Fonti (Asciano, Pisa), water dripping on rocks, (43° 45’ 8” N, 10° 29’ 5” E), 250 m a.s.l. [smell of fish]. 11 February 2024, leg. A. Lelli, det. G. Brusa & M. Tiburtini (PI065213). – Species new for the flora of Tuscany and mainland Italy.

Fig. 3. *Asterella africana.*

Fig. 4. *Asterella lindenbergiana.*

Data on habitat and ecology of new site

The species was discovered along Trail 119 in an area known as “Valle delle Fonti” (Fig. 5) in Asciano (province of Pisa, Tuscany). *A. africana* grows in four main areas, more or less in pure patches: three on eroding slopes on hydrographic left (43.752306° N 10.484988° E; 43.752160° N 10.484776° E; 43.752183° N 10.484492° E) and one along the main path on the bottom of the valley (43.752153° N 10.484304° E). The plants were

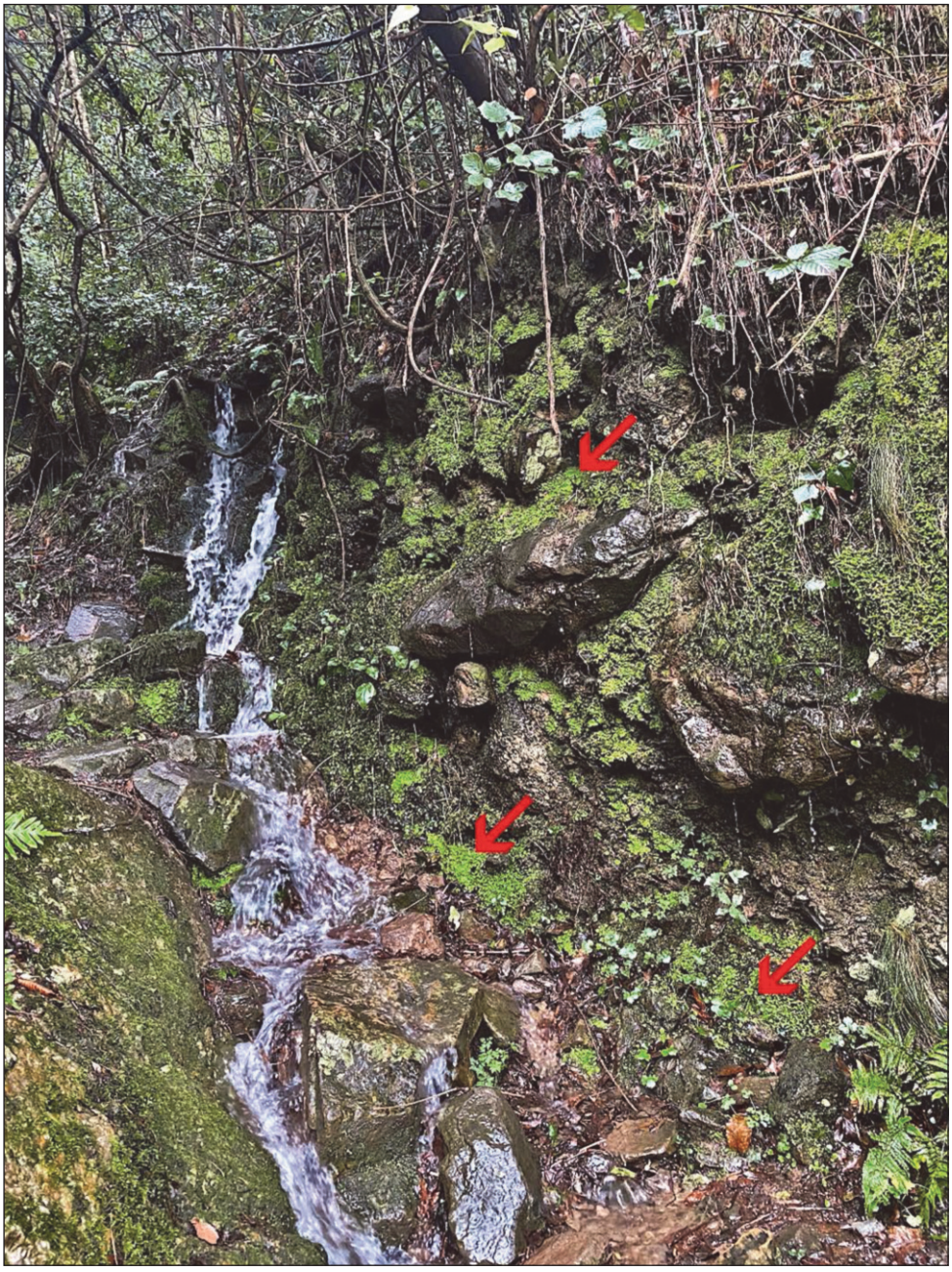

Fig. 5. The forest habitat (*Osmundo-Alnion*) in which *Asterella africana* was discovered. The three arrows indicate the presence of liverwort patches.

Fig. 6. A detailed view of *Asterella africana*, which bears archegoniophores.

almost fertile (Fig. 6) and consistently grew on soil, rarely on rocks that had been coated with a thin layer of soil. The soil was enduringly moist, but not waterlogged, and was always in shade. A specimen was collected and subsequently deposited at the Herbarium Horti Botanici Pisani (PI) with accession code PI065213 (http://erbario.unipi.it/it/erbario/view?id=2078484).

The geological substratum is mainly constituted by sedimentary siliceous rocks (e.g. Verrucano) belonging to "Monte Serra Unit" (Collareta & al. 2023). The bioclimate is upper mesomeditterranean, with a short period of drought during the summer (Pesaresi & al. 2014, 2017). The phytosociological relevés confirmed that the vegetation in the surrounding area belongs to the order *Quercetalia pubescentis-petraeae* Klika 1933 and exactly to the association *Daphno laureolae-Ostryetum carpinifoliae* Arrigoni, 1997 in spatial catenal contact (gorges) with *Alnus glutinosa* (L.) Gaertn. forest probably attributable to the alliance *Osmundo-Alnion* (Br.-Bl. et al. 1956) Dierschke et Rivas-Mart. in Rivas-Mart. 1975 (Bertacchi & al. 2004).

The most prevalent bryophytes growing together with *A. africana* were *Conocephalum conicum* (L.) Dumort., *Fissidens serrulatus* Brid. and *F. ovatifolius* R.Ruthe, *Fossombronia caespitiformis* (Raddi) De Not. ex Rabenh., *Oxyrrhynchium hians* (Hedw.) Loeske, *Plagiomnium undulatum* (Hedw.) T.J.Kop. and *Thamnobryum alopecurum* (Hedw.) Gangulee.

Additional Records

In addition to the records mentioned above, additional information on the occurrence of *A. africana* in Europe, and in particular from Mediterranean isles, has been obtained through the examination of the following two citizen science websites (accessed in May 2024):

- on iNaturalist community:
  - in Sardinia, at coordinates 39.417405° N 9.250125° E (https://www.inaturalist.org/observations/160737461);
  - in Corsica:
    - at coordinates 42.816° N 9.445679° E (https://www.inaturalist.org/observations/213146522);
    - at coordinates 42.928835° N 9.410455° E (https://www.inaturalist.org/observations/212667639);
    - at coordinates 42.928625° N 9.412132° E (https://www.inaturalist.org/observations/212411443);
    - at coordinates 42.966965° N 9.412568° E (https://www.inaturalist.org/observations/210409914);
    - at coordinates 42.966937° N 9.412502° E (https://www.inaturalist.org/observations/210273482);
- on the forum of ActaPlantarum (https://www.actaplantarum.org/forum/viewtopic.php?t=47796), between Capoterra and Sarroch, province of Cagliari in Sardinia (Giuliano Campus, pers. comm.; determined by the last Author).

Following the addition of these supplementary records, the current distribution of *A. africana* in Europe (excluding Macaronesia) is presented in fig. 7. The distribution includes several records from Corsica, downloaded from Global Biodiversity Information Facility (GBIF: https://www.gbif.org/).

Discussion

Several critiques have been directed towards the involvement of citizen science initiatives in the classification of taxa that are challenging from a taxonomic perspective. One example of this is the discrepancy that exists between the results obtained by iNaturalist users and those of experts in lichens (Munzi & al. 2023), organisms that exhibit many features with bryophytes, and consequently, McMullin & Allen (2022) proposed recommendations that can also be applied to other similarly taxonomically difficult taxa. Nevertheless, the role of users with a reasonable level of expertise is of crucial importance on iNaturalist (Callaghan & al. 2022). Moreover, iNaturalist demonstrates how citizen science is playing an increasingly important role in discovering and documenting biodiversity, especially as both land use change and climate change put growing pressure on ecosystems leading to biodiversity loss (Keil & al. 2015). In this context, the discovery of the northernmost site of *A. africana* in Europe provides an illustrative example of the potential for a collaboration between citizen scientists and practised taxonomists: the former can

Fig. 7. The current known distribution of *Asterella africana* in Europe (excluding Macaronesia): red diamonds, data supported by literature; green circles, data provided by the citizen science community.

investigate a vast expanse of territory that the latter are unable to do, especially with taxonomists facing a decline in numbers (Buyck 1999; Löbl & al. 2023). This approach allows for the investigation of the distribution of rare species, which is unquestionably a field of knowledge that is not yet fully understood. Both in Europe and Italy, *A. africana* holds a similar status, being listed on the Red Lists as Data Deficient (DD). This classification emphasises the lack of available information on its distribution (Hodgetts & al. 2023; Puglisi & al. 2023), which citizen science can help to fill.

It is difficult to say whether this phytogeographically unusual finding of *A. africana* in Tuscany is unlikely (see Zanatta & al. 2020) the result of a recent range expansion due to climate change or, more likely, the result of an underestimation of another taxonomically difficult species. Although they are easier to recognize than other liverworts, the distribution of complex thalloid liverworts in Italy is certainly underestimated. This is confirmed by the recent findings of two species new to the Italian flora (Brusa 2023; Brusa & Hugonnot 2019). Furthermore, the utilisation of a simple key, based on characters that are readily observable in field or even from digital images, can facilitate the synergy between citizens and specialists. The aforementioned evidence serves to corroborate the assertion that *A. africana* could be largely overlooked, at least in Italy.

Conclusion

In this article, the complex thalloid liverwort *A. africana* is reported from a new site in Tuscany, extending the northernmost limit of its range by approximately 100 km in Europe. This record represents also the first finding regarding mainland Italy. Both climate change and taxonomical difficulties may play a role in the known biogeographical pattern of *A. africana*, but further investigations are needed to address the question. The involvement of citizen science in the response process can prove to be a pivotal component.

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References

Aleffi, M., Cogoni, A., & Poponessi, S. 2023: An updated checklist of the bryophytes of Italy, including the Republic of San Marino and Vatican City State. – Pl. Biosyst. **157(6):** 1259-1307. https://doi.org/10.1080/11263504.2023.2284136

Arrigoni, P. V. 1997: Documenti per la carta della vegetazione delle Cerbaie (Toscana settentrionale). – Parlatorea **2:** 39-71.

Bartolucci, F., Peruzzi, L., Galasso, G., Alessandrini, A., Ardenghi, N. M. G., Bacchetta, G., & al. 2024: A second update to the checklist of the vascular flora native to Italy. – Pl. Biosyst **158(2):** 219-296. https://doi.org/10.1080/11263504.2024.2320126

Bertacchi, A., Sani, A., & Tomei, P. E. 2004: La vegetazione del Monte Pisano. – Pisa.

Bischler, H. 1998: Systematics and Evolution of the Genera of the *Marchantiales*. – Bryophyt. Bibl. **51:** 1-200.

Bischler, H. 2004: Liverworts of the Mediterranean. Ecology, diversity and distribution. – Bryophyt. Bibl. **61**: 1-252.

Bischler, H. & Jovet-Ast, S. 1971-1972: Les Hépatiques de Sardaigne. Enumeration, notes écologiques et biogéographiques. – Rev. Bryol. Lichénol. **38**: 325-419.

Bischler, H. & Jovet-Ast, S. 1973: Les Hépatiques de Corse. Énumeration, notes écologiques et biogéographiques. – Rev. Bryol. Lichénol. **39:** 43-153.

Blockeel, T. L. 2012: Notes on the bryophytes of the schistose valleys of western Crete, including *Asterella africana* new to Greece, and an assessment of the conservation status of *Rhamphidium purpuratum* and *Jungermannia handelii*. – J. Bryol. **34(4):** 292-296. https://doi.org/10.1179/1743282012Y.0000000024

Blockeel, T. L. 2017: Bryophytes of the Cyclades, Greece: The Flora of the Island of Andros. –Field Bryol. **117:** 36-45.

Brusa, G. 2023: *Mannia controversa* (*Marchantiophyta*, *Aytoniaceae*): un'epatica nuova per la flora italiana. – Rev. Valdôtaine Hist. Nat. **77:** 111-116.

Brusa, G. & Hugonnot, V. 2019: *Mannia californica* (Gottsche ex Underw.) L.C. Wheeler. Pp. 290-291 in Ellis, L.T. & al., New national and regional bryophyte records, 60. – J. Bryol. **41:** 285-299. https://doi.org/10.1179/1743282014Y.0000000115

Buyck, B. 1999: Taxonomists are an endangered species in Europe. – Nature **401:** 321-321. https://doi.org/10.1038/43762

Callaghan, C. T., Mesaglio, T., Ascher, J. S., Brooks, T. M., Cabras, A. A., Chandler, M., & al. 2022: The benefits of contributing to the citizen science platform iNaturalist as an identifier. – PLoS biology **20(11):** e3001843. https://doi.org/10.1371/journal.pbio.3001843

Casanovas, P., Lynch, H. J. & Fagan, W. F. 2014: Using citizen science to estimate lichen diversity. – Biol. Conserv. **171:** 1-8. https://doi.org/10.1016/j.biocon.2013.12.020

Collareta, A., Sorbini, C., Farina, S., Granata, V., Marchetti, L., Frassi, C., Angeli, L. & Bianucci, G. 2023: Reviewing the Palaeontological and Palaeoenvironmental Heritage of the Monti Pisani Massif (Italy): A Compelling History of Animals, Plants and Climates through Three Geological Eras. – Geosci. **13:** 332. https://doi.org/10.3390/geosciences13110332

Davis, L. S., Zhu, L. & Finkler, W. 2023: Citizen Science: Is It Good Science? – Sustainability **15(5):** 4577. https://doi.org/10.3390/su15054577

Hodgetts, N., Cálix, M., Englefield, E., Fettes, N., Criado, M. G., Patin, L., & al. 2023; A miniature world in decline: European Red List of Mosses, Liverworts and Hornworts. – Brussels.

Hodgetts, N. G., Söderström, L., Blockeel, T. L., Caspari, S., Ignatov, M. S., Konstantinova, N. A., & al. 2020: An annotated checklist of bryophytes of Europe, Macaronesia and Cyprus. – J. Bryol. **42(1):** 1-116. https://doi.org/10.1080/03736687.2019.1694329

Keil, P., Storch, D. & Jetz, W. 2015: On the decline of biodiversity due to area loss. – Nat. Comm. **6:** 8837. https://doi.org/10.1038/ncomms9837

Kullenberg, C. & Kasperowski, D. 2016: What is citizen science? – A scientometric meta-analysis. – PloS one **11(1):** e0147152. https://doi.org/10.1371/journal.pone.0147152

Löbl, I., Klausnitzer, B., Hartmann, M., & Krell, F. T. 2023: The silent extinction of species and taxonomists–An appeal to science policymakers and legislators. – Diversity **15(10):** 1053. https://doi.org/10.3390/d15101053

Long, D. G. 2006: Revision of the genus *Asterella* P. Beauv. in Eurasia. – Bryophyt. Bibl. **63:** 1-299.

McMullin, R. T. & Allen, J. L. 2022: An assessment of data accuracy and best practice recommendations for observations of lichens and other taxonomically difficult taxa on iNaturalist. – Botany **100:** 491-497. https://doi.org/10.1139/cjb-2021-0160

Mucina, L., Bültmann, H., Dierßen, K., Theurillat, J. P., Raus, T., Čarni, A., & al. 2016: Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. –App. Veg. Sci. **19:** 3-264. https://doi.org/10.1111/avsc.12257

Munzi, S., Isocrono, D. & Ravera, S. 2023: Can we trust iNaturalist in lichenology? Evaluating the effectiveness and reliability of artificial intelligence in lichen identification. – Lichenologist **55(5):** 193-201. https://doi.org/10.1017/S0024282923000403

Neyens, T., Diggle, P. J., Faes, C., Beenaerts, N., Artois, T. & Giorgi, E. 2019: Mapping species richness using opportunistic samples: a case study on ground-floor bryophyte species richness in the Belgian province of Limburg. – Sci. Rep. **9(1):** 19122. https://doi.org/10.1038/s41598-019-55593-x

Pakeman, R. J., Brooker, R. W., O'Brien, D. & Genney, D. 2019: Using species records and ecological attributes of bryophytes to develop an ecosystem health indicator. – Ecol. Indic. **104:** 127-136. https://doi.org/10.1016/j.ecolind.2019.04.084

Pesaresi, S., Galdenzi, D., Biondi, E. & Casavecchia, S. 2014: Bioclimate of Italy: application of the worldwide bioclimatic classification system. – J. Maps **10:** 538-553. https://doi.org/10.1080/17445647.2014.891472

Pesaresi, S., Biondi, E. & Casavecchia, S. 2017: Bioclimates of Italy. – J. Maps **13:** 955-960. https://doi.org/10.1080/17445647.2017.1413017

Prudic, K. L., Oliver, J. C., Brown, B. V. & Long, E. C. 2018: Comparisons of citizen science data-gathering approaches to evaluate urban butterfly diversity. – Insects **9(4):** 186. https://doi.org/10.3390/insects9040186

Puglisi, M., Galesi, R., Siracusa, G., & Privitera, M. 2024: *Asterella africana* (Mont.) Underw. ex A. Evans, rediscovered in Italy. – Pl. Biosyst., https://doi.org/10.1080/11263504.2024.2320125.

Puglisi M., Campisi P., Aleffi M., Bonini I., Cogoni A., Dia M. G. & al. 2023: Red-list of Italian bryophytes. 1. Liverworts and hornworts. – Pl. Biosyst. **157:** 746-757. https://doi.org/10.1080/11263504.2023.2200791

Rupidera Giraldo, J. L. & Elias Rivas, M. J. 1996: *Asterella africana* (Mont.) Evans (*Aytoniaceae*, *Hepaticae*) en la Peninsula Iberica, novedad para la brioflora de Europa Continental. – Criptogam. Bryol. Lichenol. **17:** 195-201.

Sérgio, C., Cros, R. M., Brugués, M. & Garcia, C. 2001: A brioflora de enclaves com *Prunus lusitanica* L. no Parque Natural da Serra da Estrela. – Bol. Soc. Esp. Briol. **18(19):** 5-14. https://doi.org/10.58469/bseb.2001.61.39.001

Söderström, L., Urmi, E. & Váňa, J. 2007: The distribution of *Hepaticae* and *Anthocerotae* in Europe and Macaronesia-update 1-427. – Cryptogam. Bryol. **28(4):** 299.

Theobald, E. J., Ettinger, A. K., Burgess, H. K., DeBey, L. B., Schmidt, N. R., Froehlich, H. E., & al. 2015: Global change and local solutions: Tapping the unrealised potential of citizen science for biodiversity research. – Biol. Conserv. **181:** 236-244. https://doi.org/10.1016/j.biocon.2014.10.021

Zanatta, F., Engler, R., Collart, F., Broennimann, O., Mateo, R. G., Papp, B., & al. 2020: Bryophytes are predicted to lag behind future climate change despite their high dispersal capacities. – Nat. Commun. **11(1):** 5601. https://doi.org/10.1038/s41467-020-19410-8

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