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## Updates on the bryophyte flora of the lowland woods and temporary ponds west of Lake Trasimeno (Central Italy)

### Abstract

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A study of the bryophytes of the lowlands west of Lake Trasimeno, a very peculiar territory for its geological, biogeographical and bioclimatic traits, was carried out. The data here reported were collected in a mosaic of woods and Mediterranean temporary ponds, the latter indicated as priority natural habitats under the Habitats Directive 92/43/EEC with the code 3170\*. Research led to the identification of 44 taxa of bryophytes (13 liverworts and 31 mosses), among which 5 liverwort and 8 moss species are new records for the Umbria region, while one is confirmed. Particularly interesting is the presence of 13 liverwort taxa considered, according to the European Committee for Conservation of Bryophytes (ECCB), under threat at different levels in Europe. The study offers new outcomes on neglected aspects of the flora of central Italy and represents a considerable improvement of the floristic, biogeographical and ecological understanding of its bryophytic component.

*Key words:* liverworts, mosses, Habitats Directive 92/43/EEC, ecology, Umbria, Mediterranean.

### Introduction

Temporary wet ecosystems are, by definition, amphibious systems whose maintenance depends on alternation of wet and dry periods during the year (Deil 2005). From the bryological point of view, these environments are poorly investigated although they accommodate rare taxa whose presence depends on their peculiar hydrogeological conditions (Cogoni & al. 2009).

The distributional range of these habitats includes the Mediterranean Basin; they are present in Mediterranean and Submediterranean Italy (Biondi & al. 2009, 2012), however, their actual occurrence is restricted and very localized, due to their intrinsically peculiar ecology as well as to human impact and environmental changes, including climate change (Gigante & al. 2007, 2013b; Bagella & al. 2010; Bagella & Caria 2012, 2013; Poponessi & al. 2014b). For these reasons they are very precious habitats, hosting fragile ecosystems.

Bryological data from the wide area surrounding the study site date back to several decades ago (Cortini Pedrotti 1985; Aleffi 1992), except for a recent survey by Poponessi & al. (2014a) and Ellis & al. (2015). The vascular component has been studied in the 80s (Pedrotti & al. 1980; Pedrotti 1982) and recently reorganized in an updated phytosociological framework including six amphibian vegetation types belonging to the phytosociological alliances *Isoëtion duriei* Br.-Bl. 1936, *Cicendio filiformis-Solenopsis laurentiae* Brullo & Minissale 1998, *Eleocharition acicularis* Pietsch 1967 and *Ranunculo ophioglossifolii-Oenanthion fistulosae* De Foucault 2012 (Gigante & al. 2013b). These vegetation syntaxa include, respectively, the Mediterranean ephemeral spring blooming communities, the acidophilous Mediterranean-Atlantic spring blooming communities, the Continental communities of fluctuating water with loamy or silty-clayey soils and the hygrophilous Atlantic-Mediterranean meadows on clayey nutrient-rich substrata (Biondi & al. 2014).

### Study area

The study area is represented by the Piana di Ferretto in Central Italy (Fig. 1), a large flat territory between 260 and 320 m a.s.l. on the west side of the Lake Trasimeno (Perugia, Umbria), the largest lake in Peninsular Italy. It is a site with a remarkable conservational value, for flora and fauna as well as for plant communities (Landucci & al. 2011, 2013; Gigante & al. 2013a; Velatta & al. 2014), some of which currently at serious risk (Reale & al. 2012). Due to the occurrence of several Habitats included in the Annex I to the 92/43/EEC Directive (besides the already mentioned 3170\*, also 4030, 6420, 91M0 and 92A0) the site has been designated as a S.A.C. belonging to Natura 2000 (IT5210020).

The geologic substratum is represented by sandy-clayey Plio-Pleistocenic sediments originating oligotrophic, leached and decarbonated soils (Giovagnotti & al. 2003). In the rain period the argillaceous fraction of the soils retains water and causes flooding conditions. The resulting pond system is scattered over an area of about 2,500 Ha, interspersed in a complex mosaic of forests, heaths, agricultural fields and small settlements. The ponds are purely fed by rainwater and get totally dry during the summer drought period.

From the bioclimatic point of view, the area belongs to the Mediterranean Bioclimate (Mesomediterranean belt), with transitional traits to the Submesomediterranean Variant of the Temperate Bioclimate (Gigante & Venanzoni 2007).

### Materials and methods

A total of four sampling sites in the study area have been repeatedly investigated in the period February-June of the years 2012-2015. These areas are representative of the eco-mosaic of temporary pools and host a well-developed range of different pool typologies, according to Gigante & al. (2013b). In order to take into account a wide range of different ecological conditions, all the types of temporary pools present in the area have been monitored, including waterlogged soils, shallow flat ponds and basin-shaped ponds with steep borders, according to Deil (2005). In each sampling site, a changeable number of ponds was present, from a minimum of 8 to a maximum of 20.

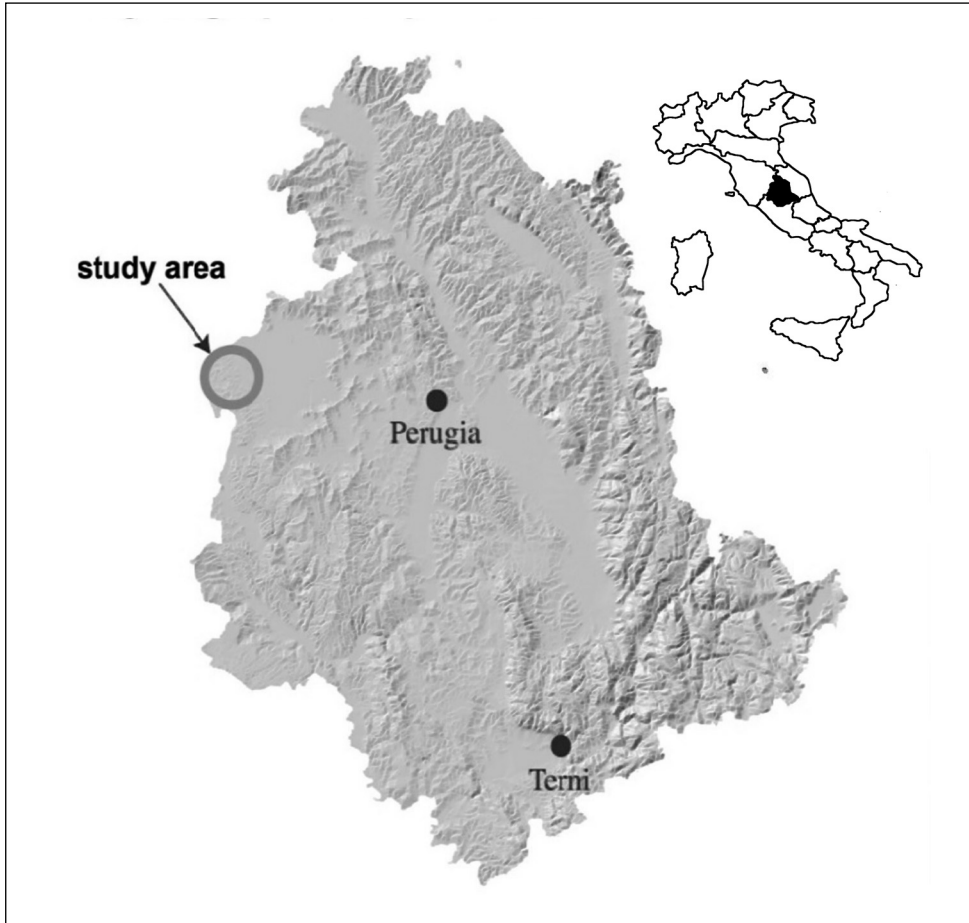


Fig. 1. Physiographic Map of Umbria and study area (modified from LIDAR DTM of Umbria Region, freely available at <http://www.pcn.minambiente.it/GN/en/>).

The Universal Transverse Mercator (UTM) coordinates of the centroids and the used acronyms for each site are indicated in Table I.

The *exsiccata* were stored in the Herbarium PERU of the Department of Chemistry, Biology and Biotechnologies, University of Perugia and labels are available on the web at <http://www.anarchive.it> (Panfili & al. 2004; Lucarini & al. 2015). The nomenclature of taxa follows Söderström & al. (2016) for the liverworts and Ros & al. (2013) for the mosses.

## Results

The research allowed the identification of 44 bryophyte taxa: 13 liverworts and 31 mosses. According to Aleffi & al. (2008) and Ellis & al. (2016), 5 liverworts and 9 mosses are new

records for the Umbria Region and one moss is confirmed. The complete list of the identified bryophytes is reported hereafter. Each taxon is listed in alphabetical order, with a short description of its habitat in each location where it was collected (locations are indicated by the acronym reported in Table I). The new taxa for the Umbria region are marked with an asterisk (\*), the symbol “#” indicates a confirmation of the presence in the region.

Table 1. Collecting localities and coordinates of mosses and liverworts taxa.

Station	Coordinates	Acronym
Podere Coccolargo	43°10'24.26"N-12°00'02.13"E	PC
Podere Marella	43°10.083'N-11°58.267'E	PM
Monelli	43°9.933'N-11°59.638'E	MO
Le 7 Strade	43°9.576'N-12°0.288'E	7S

## List of taxa

### LIVERWORTS

*Cephaloziella rubella* (Nees) Warnst. PC and 7S: very localized and rare on waterlogged soil with *Isöetes histrix* Bory, drying phase.

\**Fossombronia caespitiformis* De Not. ex Rabenh. subsp. *multispira* (Schiffn.) J.R.Bray & D.C.Cargill. MO: moderately abundant, on waterlogged soil with *Isöetes histrix*.

*Fossombronia pusilla* (L.) Nees. PC: moderately abundant, on clayey-sandy waterlogged soil with *Isöetes histrix* and on partially shaded pool systems with *Callitricho-Ranunculetum*; PM: moderately abundant, on waterlogged soil with *Isöetes histrix*.

*Fossombronia wondraczekii* (Corda) Dumort. ex Lindb. MO: very localized, along the edge of ponds with *Callitricho-Ranunculetum*.

*Gongylanthus ericetorum* (Raddi) Nees. PC and PM: very localized, on clayey-sandy waterlogged soil with *Isöetes histrix*, drying phase; MO: very localized, on waterlogged soil shadowed by *Calluna vulgaris* (L.) Hull; 7S: widespread but always with a few individuals, on waterlogged soil with *Isöetes histrix*, drying phase.

#*Phaeoceros laevis* (L.) Prosk. 7S: very localized, on waterlogged soil with *Isöetes histrix*, drying phase.

\**Riccardia chamedryfolia* (With.) Grolle. PC: very localized, on waterlogged soil with *Isöetes histrix*, drying phase.

*Riccia beyrichiana* Hampe MO: very localized, on waterlogged soil digged by wild boars.

\**Riccia canaliculata* Hoffm. PC: abundant, on waterlogged clayey soil in the shadow of *Pinus pinea* L.; PM: at the edge of a clayey pond.

\**Riccia crozalsii* Levier. 7S: very localized, on waterlogged soil with *Isöetes histrix*.

*Riccia gougetiana* Durieu & Mont. var. *gougetiana*. MO: widespread but always with a few individuals, on waterlogged soil digged by wild boars.

*Riccia sorocarpa* Bisch. PC, PM and MO: widespread but always with a few individuals, on waterlogged clayey-sandy soil with *Isöetes histrix*, sometimes on soil digged by wild boars.

\**Riccia subbifurca* Warnst. ex Croz. PC and MO: widespread but always with a few individuals, on waterlogged soil with *Isöetes histrix* and on clayey and clayey-sandy waterlogged soils.

#### MOSSES

*Anomodon viticulosus* (Hedw.) Hook. & Taylor. MO: abundant, on dry soil at the edge of the wood.

*Archidium alternifolium* (Hedw.) Mitt. PC and PM: abundant, on waterlogged soil, sometimes on soil digged by wild boars; MO: widespread but always with a few individuals; 7S abundant on waterlogged soil, with *Isöetes histrix*, drying phase.

*Atrichum undulatum* (Hedw.) P.Beauv. PC: widespread but always with a few individuals, on waterlogged soil with *Isöetes histrix*; MO: abundant, on waterlogged soil in drying phase.

*Barbula unguiculata* Hedw. MO: very localized, on bare soil in glades with *Calluna vulgaris*.

*Calliergonella cuspidata* (Hedw.) Loeske. PC and MO: abundant, on waterlogged soil; PM: on the border of a basin-shaped pool.

*Campylopus brevipilus* Bruch & Schimp. PC: very localized, on waterlogged soil.

\**Campylopus introflexus* (Hedw.) Brid. MO: abundant, on waterlogged soil, drying phase, and in a large glade.

\**Campylopus pilifer* Brid. MO: very localized, in a wooded glade with *Campylopus introflexus*.

\**Dicranella cerviculata* (Hedw.) Schimp. MO: very localized, on acidic flat soil in between the heath.

\**Dicranella staphyлина* H.Whitehouse: PC: very localized, on acidic flat soil.

*Dicranum scoparium* Hedw. MO: abundant, in a wooded glade.

*Didymodon luridus* Hornsch. MO: abundant, on a moist slope at the border of a basin-shaped pond.

*Entosthodon fascicularis* (Hedw.) Müll.Hal. PC, PM and MO: widespread but always with a few individuals, on waterlogged soil, sometimes on soil digged by wild boars.

\**Ephemerum recurvifolium* (Dicks.) Boulay. MO: widespread but always with a few individuals, on waterlogged soil.

*Fissidens bryoides* Hedw. var. *bryoides*. MO: very localized, on a moist slope at the border of a basin-shaped pond.

*Fissidens dubius* P.Beauv. MO: very localized, on a moist slope at the border of a basin-shaped pond.

*Funaria hygrometrica* Hedw. MO: very localized, along the edge of a basin-shaped pool.

*Hypnum cupressiforme* var. *lacunosum* Brid. MO: abundant, in a wooded glade.

*Imbribryum alpinum* (Huds. ex With.) N. Pedersen. MO: abundant, on waterlogged soil with *Isöetes histrix*, drying phase; 7S: on clayey waterlogged soil.

- \**Plagiomnium ellipticum* (Brid.) T.J.Kop. MO: widespread but always with a few individuals, on a moist slope at the border of a basin-shaped pond.
- Pleurozium acuminatum* Lindb. 7S: widespread but always with a few individuals, on waterlogged soil with *Isöetes histrix*, drying phase.
- \**Pohlia nutans* (Hedw.) Lindb. MO: widespread but always with a few individuals, on waterlogged soil.
- Polytrichum formosum* Hedw. MO: abundant, on acidic and dry soil, in a wooded glade.
- Polytrichum juniperinum* Hedw. MO: abundant, in between the heath.
- Pseudoscleropodium purum* (Hedw.) M.Fleisch. PC: very common, on waterlogged soil, drying phase; MO: very common, in between the heath.
- Ptychostomum capillare* (Hedw.) D.T.Holyoak & N.Pedersen. PM and MO: widespread but always with a few individuals, on waterlogged soil in drying phase and in between the heath.
- Ptychostomum pseudotriquetrum* (Hedw.) J.R. Spence & H.P. Ramsay var. *pseudotriquetrum*. PC, PM and MO: abundant, on waterlogged soil with *Isöetes histrix*, drying phase.
- \**Racomitrium ericoides* (Brid.) Brid. 7S: abundant, on drying soil.
- Tortella squarrosa* (Brid.) Limpr. MO: localized, in a dry *facies* of *Serapio-Isöetetum*.
- Tortula muralis* Hedw. MO: localized, along the edge of a basin-shaped pool.
- Tortula truncata* (Hedw.) Mitt. MO: localized, along the edge of a basin-shaped pool.

## Discussion

The here reported bryophytic survey shows a high level of floristic and biogeographical diversity for a Mediterranean temporary pond system in central inland Italy. It significantly improves the knowledge of a territory, which was already known for providing peculiar habitats for rare and endangered taxa, especially as concerns the liverworts (Hugonnot & Hébrard 2004). Indeed, among the collected species, particularly interesting is the finding of thirteen liverworts included in the *Checklist and country status of European bryophytes – towards a new Red List for Europe* (Hodgetts 2015). They present different levels of threat, according to the IUCN categories and criteria (IUCN 2014).

The liverworts *Fossombronina caespitiformis* subsp. *multispira*, *F. wondraczekii* and *Riccia beyrichiana* are considered Critically Endangered (CR) for Italy (Hodgetts, 2015). The first is assigned to the Tropical-Temperate phytogeographical element (Dierßen 2001).

The distribution range of *F. caespitiformis* subsp. *multispira* is still rather poorly known because its taxonomy has only recently been elucidated (Lockhart & al. 2012). Both the known subspecies (*F. caespitiformis* subsp. *multispira* and *F. caespitiformis* subsp. *caespitiformis*) occur in nearly all of the Mediterranean countries and in Madeira and the Canary Islands (Ros & al. 2007). In Italy it is quite rare; in particular, in the North it was formerly known only in Liguria on the basis of old records (Aleffi & al. 2008).

As concerns *Fossombronina wondraczekii*, in Europe it is assigned to the Circumboreal phytogeographical element, and is a mesohydrophilous, photo-sciaphilous and terricolous species (Dierßen 2001; Aleffi & Esposito 2005). Ellis & al. (2015) recently confirmed the presence of this taxon in Central and Northern Italy, including Umbria. In the South, *F. wondraczekii* is present also in Campania and Sicily, as reported by Aleffi & al. (2008).

The rich group of taxa belonging to the genus *Riccia*, mainly distributed in the Mediterranean region, is common in the habitat types “Mediterranean temporary ponds” (3170\*) and “Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean with *Isöetes* spp.” (3120) (Grillas & al. 2004b; Cogoni 2009).

In these habitats many species of rare bryophytes at the national or regional level can be found, however still little is known about both their phenology and conservation status (Hugonnot & Hébrard 2004). Most species show an “annual shuttle” life strategy (e.g. *Riccia* sp. pl., *Fossombronia* sp. pl., *Ephemerum* sp. pl.), which mainly consists of seasonality of reproduction, large spores with small dispersal capacity and absence of innovations (asexual propagation). This strategy perfectly fits to a habitat which is present only for a short period but which predictably reappears within the same spot or in the neighborhood, hosting the same community (During 1979).

The presence of species of the genus *Riccia* in the study area is very interesting.

For some taxa the edge of the temporary pools is a favourable habitat: it is the case, e.g., of *Riccia sorocarpa* var. *sorocarpa*, *R. subbifurca*, *R. beyrichiana*, *R. crozalsii*, *R. canaliculata*, according to Hugonnot & Hébrard (2004).

*Riccia beyrichiana* was reported for the first time for Umbria by Cortini Pedrotti (1985) on sandy soils in the area around the Lake Trasimeno; its present discovery in the MO site confirms the presence in the region. In Italy it is reported in Piedmont, Lombardy, Apulia and Sardinia, (Aleffi & al. 2008). Its range includes North America, North and Central Europe (Düll, 1983), the Iberian Peninsula, France, Corse, Sardinia, Italy, Malta and Greece (Ros & al. 2007).

*Riccia canaliculata* and *R. crozalsii* are considered Endangered (EN) in Italy (Hodgetts 2015). The first is very rare in the Italian territory, it is reported in Lazio and Sardinia on the basis of new records (Aleffi & al. 2008).

*Riccardia chamedryfolia* is considered Vulnerable (VU) in Italy, according to Hodgetts (2015).

Other species considered Near Threatened (NT) according to Hodgetts (2015) are: *Riccia subbifurca* and *Phaeoceros laevis*, respectively a new record and a confirmation for Umbria region (Aleffi & al. 2008), *Riccia gougetiana* var. *gougetiana*, *R. sorocarpa* var. *sorocarpa*, *Cephaloziella rubella*, *Fossombronia pusilla* and *Gongylanthus ericetorum*.

At the sites PM and MO it was possible to observe how the areas disturbed by the presence of wild boars, have been colonized especially by liverwort species belonging to the *Riccia* genus. This type of soil disturbance seems to affect in particular the vascular and bryophytic component of the pools, however the action of the animals, by originating new bare surfaces, favors the settlement of entities of the genus *Riccia* (Grillas & al. 2004b).

The present study refers only to floristic aspects, however in Italy there is a recent impulse to the study of bryophytic coenoses from a phytosociological point of view (Puglisi & Privitera 2012).

In the study area, aspects referable to the bryophyte-dominated community *Riccietum gougetianae* Marstaller 1993, recently reported for the first time for Italy by Puglisi & al. (2016), were frequently observed. They seem to be quite spread in habitats with moist soils, often associated with the presence of *Isöetes histrix*. Interesting samples of the recently described association *Riccietum canaliculatae* Puglisi & Privitera 2016 were also observed. This is a typical community of the Mediterranean ponds and in the study area it

develops on largely bare clayey wet deposits. Traces of *Riccio sorocarpae-Funarietum fascicularis* Lecoq 1978 *fossombronietosum* Lecoq 1978, *Pleuridio acuminatae-Archidietum alternifolii* Puglisi & Privitera 2016 and *Campylopus introflexus*-dominated community were also noticed in the area. The last community, as also indicated by Puglisi & al. (2016), does not typically belong to the Mediterranean pond system. Indeed, it was observed in areas where the substrate is generally drier, close to the forest edge.

Among the moss species characteristic of these environments the following ones can be mentioned: *Archidium alternifolium*, *Imbricobryum alpinum*, *Ptychostomum pseudotriquetrum* var. *pseudotriquetrum*, *Entosthodon fascicularis*, *Tortula truncata*, *Campylopus introflexus* (Grillas & al. 2004a; Hugonnot & Hébrard 2004).

*Dicranella cerviculata* is a new report to Umbria region. It was recently reported from the Abruzzo region (Puglisi & al. 2011).

*Campylopus introflexus* in Europe is considered a neophytic moss, from the Southern hemisphere (Hill & al. 2006). According to the most recent European distributional data, the presence of the species is documented for Turkey (Blockeel & al. 2009a), Estonia (Vellak & al. 2009), Corsica (Cogoni & al. 2009), and Spain (Ellis & al. 2013), showing a remarkable enlarging of its distribution area.

Other species rare in Italy according to Aleffi & al. (2008), worth to be mentioned, are *Dicranella staphylina*, *Ephemerum recurvifolium*, *Pleuridium acuminatum* and *Campylopus brevipilus*.

This study provides basic floristic and chorological information for the realization and definition of the Italian Red , currently in progress (Rossi & al. 2014). It offers an updated overview of the bryological flora of Mediterranean temporary ponds in central Italy and contributes significantly to improve the knowledge of a floristically rich territory in a frequently neglected taxonomic field.

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