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Bryophytic vegetation of fragile and threatened ecosystems: the case of the Mediterranean temporary ponds in inland Central Italy

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Abstract

The first overview of the bryophytic vegetation of the Mediterranean temporary ponds in Umbria region is reported. Phytosociological relevés were carried out in a scattered system of ephemeral pools, where seasonal fluctuation in the water level is the main driving factor. By applying Braun-Blanquet's approach to sample the bryo-communities and multivariate analysis tools to analyse data, the identification of some bryophyte communities was possible, one of which is here described as new association. It is *Entosthodon fascicularidis-Archidium alternifolium* ass. nova, referable to the class *Psoretea decipiens*. The other bryo-communities have been framed into the classes *Cladonia digitatae-Lepidozietea reptantis*, *Ceratodonto purpurei-Polytrichetea piliferii* and *Psoretea decipiens* again.

Key words: biodiversity, conservation, habitat 3170*, moss vegetation, phytosociology.

Introduction

The temporary ponds are "usually small (<10 ha in area) and shallow wetlands which are characterized by an alternation of flooded and dry phases, and whose hydrology is largely autonomous. They occupy depressions, often endorheic, which are flooded for a sufficiently long period to allow the development of hydromorphic soils and wetland-dependent aquatic or amphibious vegetation and fauna communities" (Ramsar Convention, 1971; Ramsar Convention Bureau, 2002). Another important component is that the flooded period typically alternates with dry phases, a condition that prevents the development of species and communities from the permanently wet habitats.

These peculiar habitats are characterized by specific environmental and hydroecological conditions, where a basic role is played by the length of the flooded period together with the waterdepth, the pond size and its slope. Different ecological conditions give rise to different types of temporarily wet habitats, from waterlogged soils and flat ponds, which get totally dry in early spring, to basin-shaped ponds, whose bottom keeps wet till the start of summer (Gigante *et al.*, 2007, 2013b; Ernandes & Marchiori, 2013). Deil (2005) proposed several ecological models, distinguishing waterlogged, amphibic, shallow and deep submerged aquatic conditions on the ground of the amplitude of water-level fluctuations in relation to soil surface. In large and deep ponds, water can persist till full summer and different types of habitats, from temporarily to permanently flooded, can often be found in contact

with each other, depending on the length of the wet period.

The ephemeral wetland habitats have a very wide distribution all over the world, although they are always rather localized and represented by very restricted areas of occurrence (Deil, 2005).

Similar ephemeral wetlands are widespread in most of the world's Mediterranean-climate regions: the west coasts of North and South America, the Mediterranean Basin, South Africa, and Southern Australia (Barbour *et al.*, 2005). Their distributional range, according to Deil (2005), includes the Mediterranean Basin and the sub-humid areas on both sides of the Tropic of Cancer. In the subtropical regions, the wet season is mostly spring and the pools desiccate in early summer (seasonal pool habitat).

Temporary ponds are present in Mediterranean and Submediterranean Italy, however, their actual distribution is restricted and very localized, due to their peculiar ecology as well as to human impact and environmental changes and climate change (Gigante *et al.*, 2007, 2013b; Bagella *et al.*, 2010; Bagella & Caria, 2012, 2013; Poponessi *et al.*, 2014).

The Mediterranean temporary wet habitats are fragile environments, being closely dependent on water fluctuations and frequently localized in small surface areas. Even though recently there is an increasing awareness of the importance of these types of environments, not always appropriate safeguard measures are being taken (Grillas, 2004a).

The Mediterranean temporary ponds represent a very important biotope for bryophytes. One of the features

that allows them to succeed in these environments is the ability to tolerate long periods of dehydration without suffering any physiological damage. Bryophytes also have the ability to protect the soil from excessive dehydration and erosion, thus promoting the establishment of vascular species, particularly amphibious species of the *Isoëto-Nanojuncetea* class. Indeed, the vegetation of European ephemeral wetlands has been assigned to the class *Isoëto-Nanojuncetea* Br.-Bl. et Tüxen ex Westhoff, Dijk et Passchier 1946 (Pietsch, 1973; Philippi, 1977; Brullo & Minissale, 1998; Deil et al., 1999; Deil, 2005), often neglecting the prominent role of the bryophytic *taxa*. In fact, in many botanical studies the cryptogams are skipped, although this taxonomic group is very important just because it contributes considerably to the total biomass of the ephemeral wetland vegetation by even modifying the vascular germination conditions (Deil, 2005).

The plant species present in the temporary ponds depend to a large extent on the type of substrate beneath the pond, on the water depth and the duration of flooding. In general they are all conditioned by a short life cycle and are able to produce seeds and spores (in the case of bryophytes) in the short favourable season (Ruiz, 2008). The ecological factors that mostly influence the affirmation and diversity of the bryophytic populations in temporary wetlands are temperature, oligotrophy and the water regime (Cogoni et al., 2009).

In Italy, the first studies on the bryophytic vegetation have been carried out by several researchers in different time periods (e.g. Giacomini, 1939; Hèbrard, 1978; Cortini Pedrotti, 1982; Cortini Pedrotti, 1985; Privitera, 1989, 1990; Lo Giudice, 1991; Aleffi, 1992a; Aiello et al., 1997; Puglisi et al., 1991; Puglisi, 1995; Puglisi et al., 2006) with reference to scattered areas in Sicily, Abruzzo and Calabria. A strong improvement to the knowledge of the phytocoenotic aspects of bryophytes has been given by a huge syntaxonomic overview for the whole of Italy (Puglisi & Privitera, 2012) and further developments have been added by the recent European Vegetation Checklist (Mucina et al., 2016) that takes into account also the bryophytic *syntaxa*.

In Umbria Region, the bryophytic component of these habitats has been studied only with reference to the flora (Aleffi, 1992b; Cortini, 1985; Ellis et al., 2015; Ellis et al., 2016; Poponessi et al., 2016; Ellis et al., 2017) while an overview of the bryophytic communities is still missing, to date. This is the first contribution focusing on bryophytic assemblages in this type of ecosystems.

Aims of the present study are: i) to improve the knowledge about the bryo-vegetation of the Mediterranean temporary ponds in central Italy and ii) to point out the species with a prominent role in colonizing the different micro-environments.

Study area

The study was carried out in the lowlands west of Lake Trasimeno in Umbria (inland central Italy) at Piana di Ferretto (N: 43°9.957', S: 11°59.667'), a flat area near Castiglione del Lago, which is very particular in terms of its ecology (Fig. 1). The area belongs to the Mediterranean Bioclimate with transitional traits to the sub-Mediterranean variant of the temperate bioclimate (Gigante & Venanzoni, 2007; Pesaresi et al., 2014). The substratum is represented by sandy-clayey Plio-Pleistocenic sediments which generate oligotrophic soils. The dominant soils are represented by leached decarbonated sandy-argillaceous types (Giovagnotti et al., 2003).

The investigations focused on a system of Mediterranean temporary ponds categorized as a priority habitat under the EU Directive 92/43/EEC and listed in Annex I with the code 3170*. The site has been selected as a SAC (Special Area of Conservation) belonging to Natura 2000 (IT5210020). These pond systems are exclusively powered by rainwater, distributed in an area of more than two hectares, where crops, pig farms and oak forests are alternated (Gigante et al., 2007). Data on the bryological vegetation are here provided for the first time, specifically regarding the Mediterranean temporary pond systems of this area.

Materials and methods

The bryophytic vegetation surveys were carried out in the spring period of the years 2015 and 2016. The sampling sites were scattered in the system of temporary ponds of the study area, taking into account the different micro-habitats characterized by different eco-hydrological conditions. The ponds locations were known and already investigated with reference to their vascular component (Gigante et al., 2007, 2013b). As concerns the sampling methodology, the



Fig. 1 - The study area, located in the western sector of Umbria Region.

phytosociological approach of Braun-Blanquet (1979) was adopted, based on the collection of complete lists of species and estimates of the related cover values, by way of a 9-values alpha-numerical scale (Westhoff & Van Der Maarel, 1978), adopting the subdivision of the value "2" into three distinct ranges: "2m", "2a" and "2b" (Barkman *et al.*, 1964). A total amount of 59 phytosociological relevés were carried out in standard 10x10 cm² areas. The relevés took into account only the bryophytic component. The occurrence of vascular species, generally represented only by the first leaves due to the phenological shift compared to the bryophytes, has been annotated and reported as total number. For each plot, basic geographic and ecological details of the sampling areas have been recorded: geographic coordinates, slope, exposure, total cover of the vegetation, total cover of the bryophytes. Additionally, the number of total species per relevé has been calculated and reported. The relevés have been stored in the vegetation plot database VegItaly (Gigante *et al.*, 2012; Landucci *et al.*, 2012; Venanzoni *et al.*, 2012).

After a first critical review of the 59 carried out relevés, seven of them have been removed since they referred to extremely species-poor communities, in some cases monospecific, and not appropriate to be used for a phytosociological characterization. For this reason they have not been included in the multivariate analyses and they are only briefly commented in the results. For the statistical analyses, 52 relevés have been used to produce a "21 rows (species) x 52 columns (relevés)" matrix, after a transformation of the cover values according to Westhoff & Van Der Maarel (1978). The differences among relevés have been measured by applying the complete link algorithm (Orloci, 1978) and the Euclidean distance as dissimilarity measure. The analyses have been performed by using the SynTax 5.02 package (Podani, 1995). Groups of similar relevés have been identified based on the dendrogram clusters and interpreted on the ground of a cross-check of their floristic composition with the available literature. They have been referred to bryo-phytosociological units at the association level. When no correspondence to already described *syntaxa* was possible, new associations or sub-associations have been proposed, complying with the rules of the International Code of Phytosociological Nomenclature (Weber *et al.*, 2000). For the syntaxonomic framing of the bryo-communities, we followed the standards proposed by Puglisi & Privitera (2012) and the most recent updates provided by Mucina *et al.* (2016). The cited nomenclature of vascular *syntaxa* follows Biondi & Blasi (2013) and Biondi *et al.* (2014). The statistical significance of the differences between variables (number and cover of bryophytic vs. vascular species) in the identified groups of relevés was analyzed by applying nonparametric statistical methods (Mann-Whitney U-Test) by using

the software *Analyst Soft StatPlus*, mac v2009.

For each detected bryo-community, a description is hereafter reported which includes also notes on the co-occurrence of vascular *taxa*. For the Bryophytes the used nomenclature follows Ros *et al.* (2007) for Marchantiophyta and Ros *et al.* (2013) for Bryophyta. For the critical genera we used Aleffi & Schumacker (1995) and Hodgetts (2015). For the vascular species, nomenclature is updated according to the most recent reviews (Conti *et al.*, 2005) and matches with the database AnArchive (Lucarini *et al.*, 2015).

Results

The results of the multivariate analyses are shown in Fig. 2. The dendrogram highlights eight clusters that have been attributed to seven bryo-communities. The phytosociological relevés, grouped based on their similarity as indicated by the dendrogram, have been organized in tables showing the single observed bryo-communities. Data have been analyzed by way of a huge comparison with bibliographic data, in order to interpret and define the phytocoenotic arrangement of the observed communities. The identified bryo-communities are here described with reference to their ecological, taxonomic and syntaxonomic features, grouped according to the phytosociological class. Additionally, a comparison of number and cover values of bryophytic vs. vascular *taxa* for each bryo-community is reported in Figs. 3 and 4.

Description of the bryo-communities

Vegetation of the class Psoretea decipiensis Mattick ex Follmann 1974

ENTOSTHODONO FASCICULARIDIS-ARCHIDIETUM ALTERNIFOLIUM ass. nova

(*Holotypus*: rel. n. 2, Tab.1; Cluster I)

This community is the most widespread and abundant in the temporary pools of Ferretto. It was found on waterlogged soil, on very changeable slopes (around 18±7° on average). It is characterized by the abundant presence of *Archidium alternifolium* and *Entosthodon fascicularis*, both acrocarpous mosses which give the community its typical physiognomy. These two species are typical of the Mediterranean temporary ponds. Some thalloid and small leafy liverworts are associated to this community, such as *Riccia sorocarpa*, *R. subbifurca*, *Fossombronia pusilla*. The cover is high, ranging between 60-90% (87% on average), and the number of bryophytic species varies from 3 to 5. *Archidium alternifolium* was often observed colonizing the bottom of the pond, after the disappearance of surface water, lasting also during the dry period and still detectable in August. Sometimes, the bottom of the ponds is first colonized by species of *Algae* (uni-

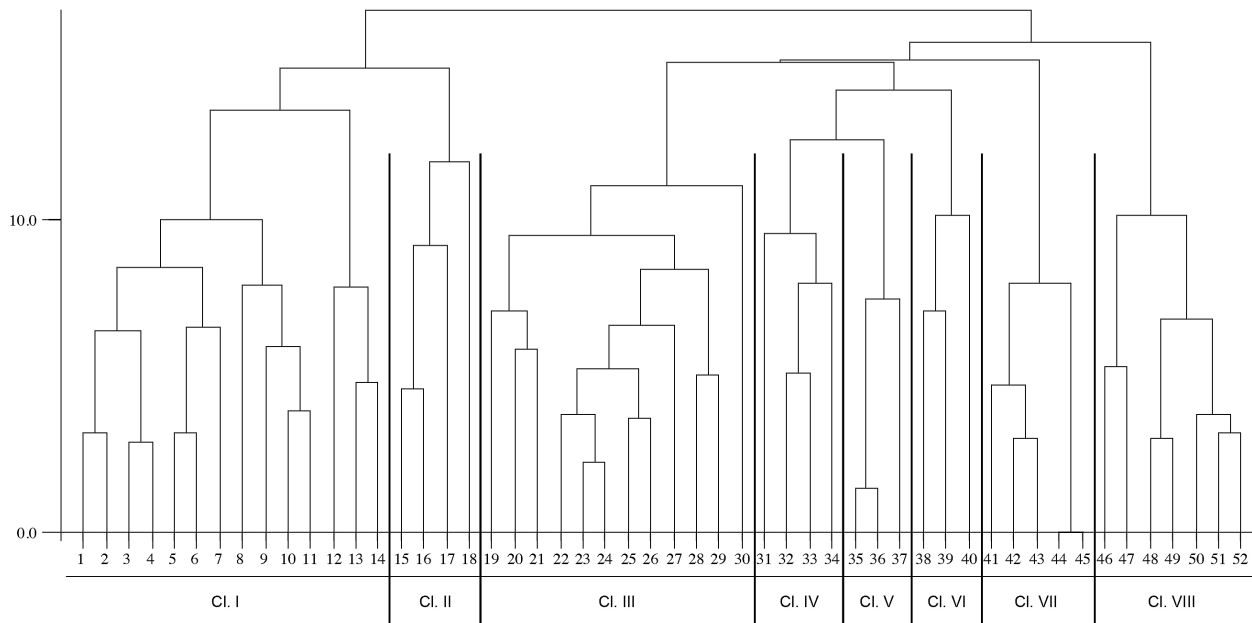


Fig. 2 - Dendrogram derived from the multivariate analysis of the phytosociological relevés (Complete Link, Euclidean Distance).

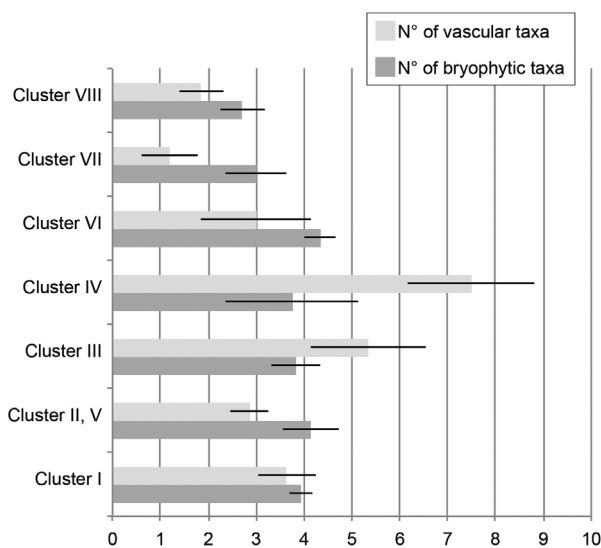


Fig. 3 - Number of bryophytic and vascular *taxa* per relevé in the surveyed bryo-communities (average values \pm SE); no statistically significant difference was detected.

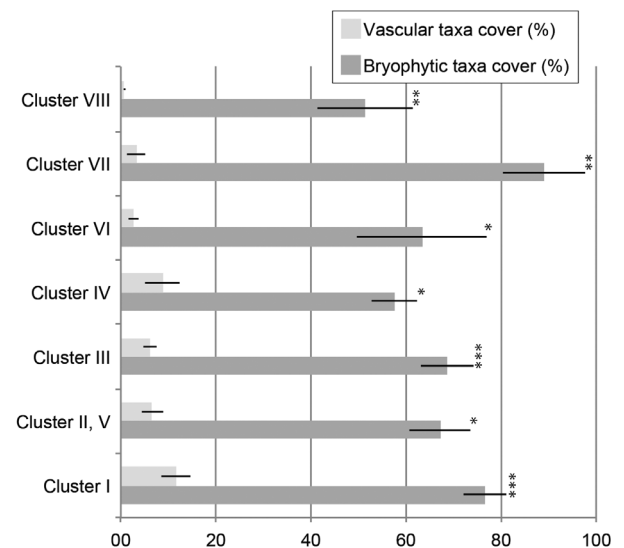


Fig. 4 - Cover values (%) of bryophytic and vascular *taxa* per relevé in the surveyed bryo-communities (average values \pm SE; the statistically significant differences are pointed out: "*" = $p < 0.05$; "***" = $p < 0.001$; p values refer to Mann-Whitney U Test).

identified), showing a fast, ephemeral phenology and completely disappearing when the top sediment gets dry. Soon after, *Archidium alternifolium* colonizes the microhabitat and can persist, coexisting with the annual vascular phytocoenoses which colonize the same micro-environment in late spring.

Archidium alternifolium and *Entosthodon fascicularis* are indicated as characteristic species of the new association. Both are typical elements of the dwarf moss communities that colonize temporary pools (Grillas, 2004a). From an ecological point of view, both the

dominant species prefer acid-subneutrophilic and temporarily flooded soils (Dierßen, 2001). On the whole, this ephemeral community behaves as terricolous and sub-acidophilic. The vascular presence is rather irrelevant, both in number and cover values (Figs. 3 and 4), mostly due to young individual fronds of *Isöetes histrix* L. and initial leaves of *Solenopsis laurentia* (L.) C. Presl.

Archidium alternifolium is considered a typical species of the class *Campylopodetea vaporarii* Brullo et al. 2004 (Mucina et al., 2016; Puglisi & Privitera, 2012),

Tab. 1 - Cluster I - *Entosthodon fascicularidis*-*Archidietum alternifolium* ass. nova.

Relevé number	1	2*	3	4	5	6	7	8	9	10	11	12	13	14	Presence	
N° vascular species	4	3	11	4	4	4	2	3	2	3	4	2	3	2		
N° bryophytic species	4	4	3	3	5	5	4	5	4	3	5	4	4	1		
Slope (°)	30	0	0	0	1	0	60	0	25	0	45	20	70	0		
Exposure (°)	130	-	-	-	310	-	100	-	290	-	228	110	220	-		
Total cover (%)	98	98	50	75	75	90	70	95	98	85	95	95	80	90		
Cover Bryophytes (%)	90	90	45	45	75	80	57	85	95	80	90	90	70	90		
Cover Vascular (%)	10	10	5	30	2	10	10	10	3	5	5	5	15	3		
Diagnostic species of the association																
<i>Archidium alternifolium</i>	4	4	3	3	4	4	3	4	4	3	2b	2a	+	.		13
<i>Entosthodon fascicularis</i>	2a	2b	+	+	.	.	.	2a	2m	1	1	4	4	5		11
Diagnostic species of higher units																
<i>Fossombronia pusilla</i>	1	2m	.	.	1	1	1	2a	3	3	4	.	1	.	10	
<i>Riccia sorocarpa</i> var. <i>sorocarpa</i>	.	.	+	.	1	1	.	.	.	.	.	.	.	.	3
<i>Fossombronia caespitiformis</i> subsp. <i>multispira</i>	.	.	.	.	.	.	+	.	2m	.	.	.	.	.	2
<i>Riccia subbifurca</i>	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1
Other species																
<i>Ptychostomum pseudotriquetrum</i>	+	.	.	.	.	1	2a	.	.	.	.	+	2a	.	5
<i>Pseudoscleropodium purum</i>	.	+	.	.	.	.	.	2m	.	.	1	.	1	.	4
<i>Tortella squarrosa</i>	.	.	.	.	+	1	.	.	.	.	.	.	.	.	2
<i>Fissidens curvatus</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1
<i>Imbriobryum alpinum</i>	.	.	.	.	.	.	.	2a	.	.	.	.	.	.	1
<i>Calliergonella cuspidata</i>	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1

while *Entosthodon fascicularis* is considered typical of the class *Psoretea decipiens* Mattick ex Follmann 1974 (Mucina *et al.*, 2016). Indeed, also Puglisi & Privitera (2012) included an association dominated by *Entosthodon fascicularis* in the alliance *Phascion cuspidati* Waldheim ex v. Krusenstjerna 1945 of the class *Psoretea*. Based on a comparable combination of species, recently Puglisi *et al.* (2015a) described a *Pleuridio acuminati*-*Archidietum alternifolii* Puglisi & Privitera in Puglisi *et al.* 2015 but they included it in the alliance *Dicranellion heteromallae* Philippi 1963 of the class *Cladonio digitatae*-*Lepidozietea reptantis* Ježek & Vondráček 1962. However, for the observed community, based on the floristic combination and on the syntaxonomical role of the dominant species, we think that the arrangement in the class *Psoretea decipiens* Mattick ex Follmann 1974 (syn.: *Barbuletea unguiculatae* Mohan 1978) is more suitable. This is also confirmed by the relevant presence of *Fossombronia pusilla*, also a typical *taxon* of the class *Psoretea decipiens* (Mucina *et al.*, 2016).

Based on the available literature, there is no bryo-community already described suitable for the attribution of the observed community. For this reason, a new association called *Entosthodon fascicularidis*-*Archidietum alternifolium* is here proposed. For their abundant presence and frequency, *Archidium alternifolium*, *Entosthodon fascicularis* and *Fossombronia pusilla* are proposed as diagnostic species of the association. Compared to the recently described *Pleuridio acuminati*-*Archidietum alternifolii* Puglisi & Privitera 2015 in Puglisi *et al.* 2015, the here described community is more hygrophilous; the dominant species show

a slightly nitrophilic attitude (Dierßen, 2001). The new association is referred to the order *Barbuletea unguiculatae* von Hübschmann 1960 and the alliance *Phascion cuspidati* Waldheim 1944.

Archidium alternifolium is a rare species in Italy and is considered threatened in several European Countries (Puglisi *et al.*, 2015a; Hodgetts, 2015).

RICCIO SOROCARPAE-FUNARIETUM FASCICULARIS Lecoite 1978 *FOSSOMBRONIETOSUM* Lecoite 1978 (Tab. 2; Clusters II and V)

The association was described by Lecoite (1978) as a rather pioneer, open community developed on partially bare, wet loamy soils, with a remarkable component of annual bryophytes. It has a NW-European distribution, generally in areas with (sub-)oceanic climates (Gueli & Lo Giudice, 2007). The subassociation *fossombroniotosum* was described for Normandy (France), with reference to wetter micro-habitats and is considered more hygrophilous than the *typicum* (Lecoite, 1978). It was reported from Sicily by Puglisi *et al.* (2015a).

Characteristic *taxa* of the *Riccio sorocarphae-Funarietum fascicularis typicum* are *Riccia sorocarpa* var. *sorocarpa* and *Entosthodon fascicularis*, while the subassociation *fossombroniotosum* is characterized by both *Fossombronia pusilla* and *F. caespitiformis* subsp. *multispira* (Puglisi *et al.*, 2015a). It should be noted that Lecoite (1978, p. 295 and Tab. III) in the original typification of the subassociation indicated as differential species *Fossombronia* cf. *pusilla*, and explained this uncertainty with a note where he declared that the observed individuals were sterile and thus not

Tab. 2 - Clusters II, V - *Riccio sorocarphae-Funarietum fascicularis* Lecointe 1978 *fossombronietosum* Lecointe 1978.

Relevé number	15	16	17	18	35	36	37	
N° vascular species	2	1	3	3	4	3	4	
N° bryophytic species	2	3	7	5	4	4	4	
Slope (°)	0	3	60	50	0	0	0	
Exposure (°)	-	120	90	20	-	-	-	
Total cover (%)	85	60	85	90	60	65	70	Presence
Cover Bryophytes (%)	85	50	85	85	55	60	60	
Cover Vascular (%)	1	5	4	6	5	5	10	
Character species of the association								
<i>Entosthodon fascicularis</i>	.	1	2a	2a	.	.	.	3
<i>Riccia sorocarpa</i> var. <i>sorocarpa</i>	.	.	.	.	2b	2b	3	3
Differential species of the subassociation								
<i>Fossombronia pusilla</i>	5	3	3	2a	.	.	.	4
<i>Fossombronia caespitiformis</i> subsp. <i>multispira</i>	.	.	2b	.	2a	2b	2a	4
Other species								
<i>Pseudoscleropodium purum</i>	+	.	1	2a	.	.	.	3
<i>Archidium alternifolium</i>	.	+	1	.	.	.	1	3
<i>Ptychostomum pseudotriquetrum</i>	.	.	1	2a	.	.	.	2
<i>Tortula subulata</i>	.	.	.	.	2b	2a	.	2
<i>Imbricium alpinum</i>	.	.	.	.	1	1	.	2
<i>Ephemerum serratum</i>	.	.	+	.	.	.	.	1
<i>Calliergonella cuspidata</i>	.	.	.	4	.	.	.	1
<i>Campylopus pilifer</i>	.	.	.	.	.	.	1	1

identifiable at the species level.

In the study area we recognize in this bryo-community two very different aspects, both dominated by mesophytic and subneutrophytic *taxa*, colonizing damp and shady soils, rich in clay, on rather changeable slopes (around $16 \pm 10^\circ$ on average). Their remarkable difference is also pointed out by the dendrogram (Fig. 2) that splits these relevés into 2 very diverse groups. One type (Tab. 2, rels. 35-37) is dominated by *Fossombronia caespitiformis* subsp. *multispira* together with *Riccia sorocarpa*, localized on waterlogged clayey-sandy soils in the clearings of the heathlands. The bryophytic component is represented by *Tortula subulata*, *Imbricium alpinum*, *Archidium alternifolium* and *Campylopus pilifer*. The cover is high, ranging between 60-70% (65% on average), and the number of bryophytic species per relevé always 4. The second type (Tab. 2, rels. 15-18) is dominated by *Fossombronia pusilla*, accompanied by *Entosthodon fascicularis*, *Archidium alternifolium*, *Ptychostomum pseudotriquetrum* and *Pseudoscleropodium purum* and colonizes waterlogged clayey soils along the borders of small ponds. The cover is generally high (80% on average), and the average number of bryophytic species per relevé is 4. Also in this case the vascular presence is very low, both in number and cover values, basically due only to sporadic fronds of *Isöetes histrix* (Figs. 3 and 4). *Fossombronia caespitiformis* subsp. *multispira* is present in only one relevé of the second type. The dominant species of the association (*Entosthodon fascicularis*) is present only in the first type. We can interpret these facies of the subassociation as extremely impoverished aspects, compared to the original description of the subassociation (Lecointe, 1978). Also reports from the

Sicilian territory show rather species-poor communities, where the supposed dominant *taxon* *Entosthodon fascicularis*, is often present with low cover values (Gueli et al., 2007). The *syntaxon* is included in the alliance *Phascion cuspidati*.

This is the first report of this bryophytic vegetation type for the territory of Umbria Region. In Italy, the association is known from Sicily (Lo Giudice, 1995; Privitera & Puglisi, 1996). The subassociation *typicum* was reported in Italy only from Sicily (Puglisi & Privitera, 2012); the subassociation *fossombronietosum* was reported for the first time by Puglisi et al. (2015a), on moist volcanic soil, also in Sicily. According to Puglisi et al. (2015a), this bryo-community appears to be tolerant to human disturbance, behaving as mesophytic and euhemerobic.

RICCIETUM GOUGETIANAE Marstaller 1993 (Tab. 5; Cluster VI)

Riccia gougetiana is a diagnostic species for the alliance *Mannion androgynae*, which refers to Mediterranean spring vegetation rich in thalloid liverworts, with a subneutrophytic ecology (Puglisi & Privitera, 2012). This species shows the life form "solitary thalloid" and a typical "shuttle" life strategy, as reported by Puglisi et al. (2015a, 2016).

This community, described by Marstaller (1993) for South Hungary, is here signalled for the first time for the bryophyte vegetation of Umbria Region. Formerly, it was reported for Sicily, Latium and Sardinia (Puglisi et al., 2015a). According to Puglisi et al. (2015a) this bryo-community is often associated to the presence of *Isöetes histrix*.

It is an ephemeral, meso-hygrophytic and thermophytic community, where the prevalent liverworts are represented by species of the *Riccia* genus (*R. gougetiana*, *R. subbifurca*). This genus is distinctive for the Mediterranean region and is especially typical of the Mediterranean temporary ponds (Grillas, 2004b). In the study area this community was observed on subacid sandy/clayey soils, on flat substrata (slope 0°). The total cover is rather changeable, ranging between 45-95% (66% on average), and the number of bryophytic species varies from 4 to 5. The vascular presence is low and heterogeneous, with irrelevant cover (Figs. 3 and 4).

RICCIETUM CANALICULATAE Puglisi & Privitera in Puglisi, Minissale, Sciandrello & Privitera 2015 (Tab. 7; Cluster VIII)

Riccietum canaliculatae, recently described based on recordings from Latium and Sardinia, is one of the most typical bryophyte community of the Mediterranean ponds (Puglisi et al., 2015a).

The present report is the first in the territory of Umbria region. It has been observed along the borders of

large, flat ponds (average slope $3\pm 3^\circ$) where it colonizes areas with changeable water levels, showing a high degree of tolerance for the temporary emerged conditions. The clayey soil maintains always a certain degree of humidity even after the end of the flooded period.

From an ecological point of view, it can be considered as a terricolous, meso-thermophytic, hygro-hydrophytic, ephemeral community (Puglisi *et al.*, 2015a). The stands sampled in Ferretto represent an impoverished aspect, probably due to the transitional climatic conditions between Mediterranean and Temperate climate. For this reason, the number of bryophytic species is always low (ranging from 1 to 5) and many typical *taxa* indicated by Puglisi *et al.* (2015a) have not been observed. Among the most frequent species we can mention *Archidium alternifolium*, *Ephemerum crassinervium*, *Ptychostomum pseudotriquetrum*, *Entosthodon fascicularis* and *Calliergonella cuspidata* (Tab. 7). The total cover is very changeable, ranging from 25 to 85% (50% on average). The role of the vascular *taxa* is quantitatively irrelevant (Figs. 3 and 4); the most frequently observed species are *Isöetes histrix*, *Alisma plantago-aquatica* L. and *Gratiola officinalis* L.

Vegetation of the class Cladonio digitatae-Lepidozietaea reptantis Jezek et Vondráček 1962

GONGYLANTHETUM ERICETORUM Puglisi, Costa & Privitera 2012 (Tab. 3; Cluster III)

The vegetation dominated by *Gongylanthus ericetorum* was observed on waterlogged shady soils in the forest clearings, on flat locations (slope 0°), often in contact with *Calluna vulgaris* providing shady sheltered sites. It was sampled in May and June, showing a slightly delayed phenology compared to the other bryo-communities. *Gongylanthus ericetorum* is constantly present with abundant cover values (between 50-95%, 78% on average). The number of bryophytic species varies from 2 to 7 (Tab. 3). The vascular presence is remarkable in number but quantitatively irrelevant (Figs. 3 and 4); the most frequently observed species are, besides *Isoetes histrix*, *Hypochaeris glabra* L. and *Serapias lingua* L.

A bryo-community dominated by *G. ericetorum* was first observed in Vulcano island (Puglisi *et al.*, 2006) and later described in Cilento as *Gongylanthetum ericetorum* Puglisi, Costa & Privitera, 2012 (Puglisi *et al.*, 2012). The comparison with the phytosociological tables reported in those studies, points out that the surveyed community is rather species-poor (Tab. 3). In both Cilento and Vulcano (Puglisi *et al.*, 2006, 2012), *Pleuroidium acuminatum* is frequently present and sometimes abundant, while in the study area this taxon was never observed in co-occurrence with *Gongylanthus ericetorum*.

To date, this association has been reported in Italy

Tab. 3 - Cluster III - *Gongylanthetum ericetorum* Puglisi, Costa & Privitera 2012.

Relevé number	19	20	21	22	23	24	25	26	27	28	29	30	Presence
N° vascular species	8	9	5	1	2	1	4	4	12	6	11	13	
N° bryophytic species	6	3	6	3	3	2	3	2	7	5	4	2	
Slope (°)	0	0	1	2	-	0	0	0	0	1	1	1	
Exposure (°)	-	-	10	0	0	-	-	-	-	10	10	10	
Total cover (%)	50	72	70	80	95	95	95	95	55	75	65	60	95
Cover Bryophytes (%)	40	70	70	70	75	95	95	55	70	65	55	90	
Cover Vascular (%)	10	2	2	10	15	1	1	1	5	1	5	5	
Character species of the association													
<i>Gongylanthus ericetorum</i>	2b	3	1	4	4	5	5	4	4	2b	2a	3	12
Other species													
<i>Archidium alternifolium</i>	2b	+	1	.	1	+	1	.	.	+	.	.	7
<i>Riccia sorocarpa</i> var. <i>sorocarpa</i>	.	.	+	.	.	.	.	.	.	+	3	1	4
<i>Fossombronia pusilla</i>	+	2b	1	.	.	.	.	.	.	.	.	.	3
<i>Fossombronia caespitiformis</i> subsp. <i>multispira</i>	+	.	.	1	.	.	.	.	.	+	.	.	3
<i>Imbricium alpinum</i>	.	.	.	.	1	.	.	.	1	+	.	.	3
<i>Cephalozia rubella</i>	.	.	+	.	.	.	.	.	.	.	.	.	4
<i>Entosthodon fascicularis</i>	1	.	.	.	.	.	.	.	.	.	.	.	1
<i>Riccia subbifurca</i>	+	.	.	.	.	.	.	.	.	.	.	.	1
<i>Dichranodonthium asperulum</i>	.	.	3	.	.	.	.	.	.	.	.	.	1
<i>Hypnum jutlandicum</i>	.	.	.	1	.	.	.	.	.	.	.	.	1
<i>Pseudoscleropodium purum</i>	.	.	.	.	.	.	+	.	.	.	.	.	1
<i>Campylopus introflexus</i>	.	.	.	.	.	.	.	+	.	.	.	.	1
<i>Polytrichum juniperinum</i>	.	.	.	.	.	.	.	.	1	.	.	.	1
<i>Hypnum cupressiforme</i>	.	.	.	.	.	.	.	.	1	.	.	.	1
<i>Pleuroidium acuminatum</i>	.	.	.	.	.	.	.	.	+	.	.	.	1
<i>Riccia crozalsii</i>	.	.	.	.	.	.	.	.	.	2a	.	.	1
<i>Campylopus brevipilus</i>	.	.	.	.	.	.	.	.	.	.	3	.	1
<i>Fossombronia</i> sp.	.	.	.	.	.	.	.	.	.	.	1	.	1

only for Sicily and Campania, where it was observed in different environments compared to Ferretto area: in Vulcano it was located on humid shady soils (Puglisi *et al.*, 2006) while in Cilento and Vallo di Diano National Park it was noticed on shady soil covering rocky slopes of cliffs, in damp hollows on coastal heaths and on roadside banks near the sea (Puglisi *et al.*, 2012). Ecologically, *Gongylanthetum ericetorum* behaves as a meso-hygrophytic association, colonizing acid or sub-neutrophytic soils. At a higher hierarchical level, the association is included in the alliance *Dicranellion heteromallae*.

Vegetation of the class Ceratodonto purpurei-Polytrichetea piliferi Mohan 1978

IMBRIBRYUM ALPINUM-DOMINATED BRYO-COMMUNITY (Tab. 4; Cluster IV)

Imbricium alpinum often acts as pioneer in unshaded areas, both on acidic to slightly base-rich rocks and on open, wet sandy soils (Jansen & Menezes De Sequeira, 1999; BBS, 2010).

The species has been recently reported for the area of Ferretto (Poponessi *et al.*, 2016). The surveyed bryo-community dominated by *Imbricium alpinum* has been observed on sandy-clayey waterlogged soils in the drying phase, in open areas and clearings in the *Calluna vulgaris*-dominated heathlands (*Danthonio-Callunetum* Pedrotti 1982). The cover values are medium-high, ranging from 55 to 95% (70% on average), and the number of bryophytic species varies from 1 to 7. The presence of the vascular component is quantitatively irrelevant, however this bryo-community is the

Tab. 4 - Cluster IV - *Imbribryum alpinum*-dominated bryo-community.

Relevé number	31	32	33	34	
N° vascular species	3	1	2	0	
N° bryophytic species	5	1	2	7	
Slope (°)	1	0	0	0	
Exposure (°)	300	-	-	-	
Total cover (%)	95	55	70	60	
Cover Bryophytes (%)	65	55	65	60	
Cover Vascular (%)	25	1	5	2	Presence
Character species					
<i>Imbribryum alpinum</i>	2a	3	4	3	4
Diagnostic species of higher units					
<i>Polytrichum juniperinum</i>	2a	.	.	.	1
Other species					
<i>Fossombronia caespitiformis</i> subsp. <i>multispira</i>	3	.	2a	.	2
<i>Gongylanthus ericetorum</i>	1	.	.	2a	2
<i>Archidium alternifolium</i>	+	.	.	+	2
<i>Riccardia chamaedryfolia</i>	.	.	.	2a	1
<i>Pleuroidium acuminatum</i>	.	.	.	+	1
<i>Cephaloziella rubella</i>	.	.	.	+	1
<i>Phaeoceros laevis</i>	.	.	.	+	1

Tab. 5 - Cluster VI - *Riccieta gougetiana* Marstaller 1993.

Relevé number	38	39	40	
N° vascular species	3	1	5	
N° bryophytic species	4	4	5	
Slope (°)	0	0	0	
Exposure (°)	-	-	-	
Total cover (%)	57	45	95	
Cover Bryophytes (%)	55	44	90	
Cover Vascular (%)	2	1	5	Presence
Character species of the association				
<i>Riccia gougetiana</i>	2b	2a	5	3
Diagnostic species of higher units				
<i>Fossombronia caespitiformis</i> subsp. <i>multispira</i>	2b	2b	.	2
<i>Riccia subbifurca</i>	2b	.	.	1
Other species				
<i>Tortula subulata</i>	+	2a	.	2
<i>Archidium alternifolium</i>	.	+	1	2
<i>Imbribryum alpinum</i>	.	.	+	1
<i>Hypnum cupressiforme</i> var. <i>cupressiforme</i>	.	.	+	1
<i>Tortella tortuosa</i> var. <i>tortuosa</i>	.	.	+	1

one with the highest observed number of vascular *taxa* (7 ± 1 on average).

In Portugal *Imbribryum alpinum* is the dominant *taxon* of the thermo-bryophytic association *Holco gayani-Bryetum alpini* Jansen in Jansen & Menezes De Sequeira 1999, belonging to the class *Isoëto-Nano-juncetea*. It is a vegetation type rich in vascular annual species, with a very different ecology compared to the bryo-communities observed in the study area, since it colonizes rocky granitic outcrops in the Oro- and Supra-Mediterranean Bioclimatic Belts (Jansen & Menezes De Sequeira, 1999). In Italy, Privitera (1990) described the subassociation *bryetosum alpini* of the association *Scapanio compactae-Polytrichetum juniperini* Privitera 1990, of the alliance *Dicranellion heteromallae* (Philippi 1956) Philippi 1963, reported for Madonie and Peloritani Mountains (Privitera & Puglisi, 2004). However, in the study area *Scapania compacta* is absent and *Imbribryum alpinum* was found together with *Polytrichum juniperinum* only in one location,

showing a closer relation with *Gongylanthus ericetorum*, *Fossombronia caespitiformis* subsp. *multispira* and *Archidium alternifolium* (Tab. 4).

Puglisi et al. (2015a) report *Imbribryum alpinum* as a companion species in the association *Riccieta canaliculatae*, but in our study area the two species grow in very different locations, being *Riccieta canaliculatae* linked to clayey, wetter soils often in shady locations. Mucina et al. (2016) indicate the species *Imbribryum alpinum* as a diagnostic *taxon* for the class *Ceratodonto purpurei-Polytrichetea piliferi* Mohan 1978. On the ground of the little information available considering the small amount of performed relevés, we treat this community only at the level of order and refer it to *Polytrichetalia piliferi* von Hübschmann 1975.

CAMPYLOPUS INTROFLEXUS - DOMINATED BRYO-COMMUNITY (Tab. 6; Cluster VII)

Campylopus introflexus is an alien, native to the southern hemisphere (Lambdon, 2008) and currently diffused in the southern part of South America and in Africa and parts of Australia as well as along the Pacific, Atlantic, and Indian Ocean where it is considered native (Klinck, 2009). In 1956 it arrived to Italy and recently was detected also in Umbria, Latium up to Sicily (Puglisi et al., 2015b; Poponessi et al., 2016; Ellis et al., 2017). It is included among the 100 worst aliens in the world (www.europe-aliens.org) since it can harm other species, occupying their space or preventing their growth (Hahn 2006). Its ecological tolerance is wide and the growth sites vary from region to region. In Umbria it prefers a predominantly acidic soil where it reproduces mostly vegetatively, more rarely with sporophytic production. It is currently still a rare *taxon* in Italy, but it has been observed in the fragile context of the Priority Habitat 3170* (Puglisi et al., 2015a; Poponessi et al., 2016).

The *Campylopus introflexus*-dominated vegetation

Tab. 6 - Cluster VII - *Campylopus introflexus*-dominated bryocommunity .

Relevé number	41	42	43	44	45	
N° vascular species	0	2	0	1	3	
N° bryophytic species	4	5	2	2	2	
Slope (°)	0	0	85	0	0	
Exposure (°)	-	-	32	-	-	
Total cover (%)	100	65	100	100	100	
Cover Bryophytes (%)	100	60	100	100	90	
Cover Vascular (%)	0	5	0	1	10	Presence
Character species						
<i>Campylopus introflexus</i>	4	3	5	4	4	5
Diagnostic species of higher units						
<i>Campylopus atrovirens</i>	3	.	.	.	.	1
Other species						
<i>Polytrichum juniperinum</i>	+	.	.	3	3	3
<i>Pseudoscleropodium purum</i>	.	1	+	.	.	2
<i>Hypnum cupressiforme</i> var. <i>cupressiforme</i>	+	.	.	.	.	1
<i>Ptychostomum capillare</i>	.	2b	.	.	.	1
<i>Atrichum undulatum</i>	.	1	.	.	.	1
<i>Archidium alternifolium</i>	.	+	.	.	.	1

Tab. 7 - Cluster VIII - *Riccietales canaliculatae* Puglisi & Privitera in Puglisi, Minissale, Sciandrello & Privitera 2015.

Relevé number	46	47	48	49	50	51	52	
N° vascular species	0	1	1	3	3	3	2	
N° bryophytic species	3	5	3	2	1	3	2	
Slope (°)	3	20	0	0	0	0	0	
Exposure (°)	120	110	-	-	-	-	-	
Total cover (%)	85	70	65	30	35	35	25	Presence
Cover Bryophytes (%)	85	70	65	30	35	35	25	
Cover Vascular (%)	0	0.1	0.1	0.1	0.1	0.1	0.1	
Character species of the association								
<i>Riccia canaliculata</i>	5	4	3	2a	3	2b	2b	7
Diagnostic species of higher units								
<i>Ephemerum crassinervium</i> subsp. sessile	2a	2a	.	.	.	.	.	2
<i>Entosthodon fascicularis</i>	.	1	.	.	.	.	.	1
Other species								
<i>Archidium alternifolium</i>	+	2a	+	.	.	+	1	5
<i>Calliergonella cuspidata</i>	.	.	2b	2a	.	.	.	2
<i>Ptychostomum pseudotriquetrum</i>	.	1	.	.	.	1	.	2

is here reported for the first time for Umbria region. In Italy, so far, it has only been observed for Circeo National Park and Nettuno in Latium (Puglisi *et al.*, 2015a). In the study site, this community is located in areas outside the ponds, where changes in the water level do not affect the soil humidity, which is only influenced by precipitation. In the surveyed system of Mediterranean temporary ponds this community is the only one without liverworts, being characterized only by the presence of acrocarpous mosses (*Polytrichum juniperinum*, *Campylopus atrovirens*, *Ptychostomum capillare*, *Archidium alternifolium* and *Atrichum undulatum*) and pleurocarpous creeping mosses (*Pseudoscleropodium purum* and *Hypnum cupressiforme* var. *cupressiforme*), in accordance with the remarks of Puglisi *et al.* (2015a).

The cover values of the surveyed bryo-community are generally very high (90-100%) and the number of bryophytic species is rather poor, ranging between 2 and 5. The dominant species is considered a characteristic taxon of the alliance *Campylopodion polytrichoidis* of the class *Ceratodonto purpurei-Polytrichetea piliferi* Mohan 1978 (Puglisi *et al.*, 2015a; Mucina *et al.*, 2016). The presence of vascular *taxa* is very sporadic (Figs. 3 and 4).

Comparing our data with the relevés carried out by Puglisi *et al.* (2015a) in Latium, a similarity can be noticed, as concerns structure, floristic composition and ecology, but more phytosociological data are needed to clarify the correct syntaxonomic placement of this community.

Other bryophytic recordings in the area

The seven species-poor or monospecific relevés not included in the statistic analyses can be mentioned as valuable records of the occurrence of some poorly known bryophytic *taxa* in the region. They are reported in Tab. 8 and are dominated by the species

Physcomitrium pyriforme (rels. A, B), *Pseudoscleropodium purum* (rels. C, D, E), *Pleuroidium acuminatum* (rels. F, G).

Physcomitrium pyriforme has a pioneer character and colonizes wet, muddy, nutrient-rich soils, and can frequently develop in disturbed, secondary sites (Puglisi & Privitera, 2012). In the study area it is not very frequent but has been observed in several locations, along the borders of small ditches, on sandy-muddy wet soils.

Pseudoscleropodium purum occupies the outermost zones of the surveyed ponds not directly affected by the water, near the *Campylopus introflexus*-dominated bryo-community, on acidic, seasonally moist sandy soils, on steep slopes. The species is always strongly dominant, as also reported by Von Hübschmann (1986) in similar environmental conditions, forming a dense, thick monospecific moss layer.

Pleuroidium acuminatum is a pioneer species typical of bare soils, preferentially colonizing acidic substrata (Atherton *et al.*, 2010). It has been observed along the banks of temporary rivulets, on wet clayey soils on very steep slopes, always developing a monodominated layer.

Discussion and conclusion

The present study represent the first phytosociological survey ever on bryophytic communities in inland Central Italy. The reported results provide a remarkable contribution to the knowledge of the bryophytic aspects of vegetation, a field which only recently came under the attention of vegetation scientists (Puglisi *et al.*, 2015a). It should be said that this first overview was possible thanks to the huge work of syntaxonomic rearrangement carried out by Puglisi & Privitera (2012), since in former periods no reference frame for these peculiar types of phytocoenoses was available. More recently, a further improvement to their phytosociological interpretation was provided by Mucina *et al.*

Tab. 8 - Other bryophytic recordings.

Relevé number	A	B	C	D	E	F	G
N° vascular species	0	0	5	5	8	1	2
N° bryophytic species	1	1	2	2	2	1	3
Slope (°)	55	60	85	70	75	10	70
Exposure (°)	40	20	300	40	320	240	250
Total cover (%)	95	100	75	95	95	70	75
Cover Bryophytes (%)	95	97	75	95	90	60	70
Cover Vascular (%)	3	3	1	0,1	5	15	5
Dominant species							
<i>Pseudoscleropodium purum</i>	5	5	.	.	.	.	.
<i>Physcomitrium pyriforme</i>	.	.	4	5	5	.	.
<i>Pleuroidium acuminatum</i> Lindb.	.	.	.	.	.	4	3
Other species							
<i>Archidium alternifolium</i>	.	.	2a	.	.	.	.
<i>Pseudoscleropodium purum</i>	.	.	.	+	+	.	.
<i>Archidium alternifolium</i> (Hedw.) Mitt.	.	.	.	.	.	.	2a
<i>Imbriobryum alpinum</i> (Huds. ex With.) N. Pedersen	.	.	.	.	.	.	2b

(2016), who validated, systematized and gave ecological interpretation to a huge number of bryo-*syntaxa*, at the European scale.

All the here analyzed *syntaxa* are reported for the first time for Umbria region. With reference to the other regions of Italy, *Riccietum canaliculatae*, *Riccio-Funarietum funarietosum* and *Riccietum gougetianae* were already known for Latium and/or Sicily (Lo Giudice, 1995; Privitera & Puglisi, 1996, 2004; Gueli et al., 2007; Lo Giudice & Bonanno, 2010; Puglisi et al., 2015a), and the present observations enlarge their distribution range. One association is newly described for the first time.

As a consequence of the fact that the study area is located in a transitional territory from the climatic point of view, and that the Mediterranean traits of its climate result rather smoothed (Gigante & Venanzoni, 2007; Pesaresi et al., 2014), the floristic composition of the observed bryo-communities is often impoverished, compared to occurrences of the same *syntaxa* in Mediterranean and subcoastal areas. This phenomenon, due to ecological and biogeographic reasons, is well known also for the vascular vegetation types colonizing the same habitat (Gigante et al., 2013) and even for very different vegetation types (see, e.g., Venanzoni & Gigante, 2000, 2007; Biondi et al., 2003). It is also worth of interest the fact that some of these communities have been defined as Atlantic-Mediterranean (e.g. Puglisi & Privitera, 2004; Puglisi et al., 2012), a biogeographic trait that can be noticed also with reference to the vascular phytocoenoses of other types of habitat present in the same area, for instance the *Calluna vulgaris*-dominated heathlands (Pedrotti, 1982).

This study offers a contribution to knowledge and understanding of the Annex I priority habitat 3170* (Biondi et al., 2012), whose bryophytic component has often been neglected although representing an emblematic feature of the whole habitat type and a very important indicator, especially with reference to habitat monitoring and management (Bagella et al., 2007, 2009, 2013, 2016; Cogoni et al., 2009; Gigante et al., 2016). In particular, the observed bryophytic *taxa* showed very diverse phenology compared to vascular *taxa*. Some of them have an early development and

tend to disappear before the optimal period to carry out phytosociological relevés of the vascular phytocoenoses, while others appear later in time and persist in late spring. On the other side, for other bryo-*taxa* the values of presence and coverage remain almost unchanged throughout the investigated period and longer. Several bryophytic species show an early, late-winter development and largely disappear or reduce their cover values before the vascular communities reach their maximum level of development (half/end of May). In many cases this has as a consequence the impossibility to include bryophytes in the vegetation relevés, or to detect their role in the ecosystem in a quantitative way. A possible solution in order to catch the whole biodiversity of these delicate environments would be to repeat relevés both in the early and late spring period.

The bryophyte *taxa* typically occurring in these delicate habitats are mostly represented by ephemeral liverworts (especially belonging to the genus *Riccia*), which have a life cycle dependent on variations of humidity and fluctuations in climatic conditions. Similar observation have been done also in other regions of Italy (Puglisi & Privitera, 2012) and France (Grillas et al., 2004a; Grillas et al., 2004b). These species are typically well-equipped for facing the extreme alternation of dry and wet condition which are by definition typical of the Mediterranean temporary ponds. For instance, the shuttle strategy is characteristic of all those species that have a short life cycle, closely dependent on the favorable environmental conditions of spring rains. However, drastic changes in the precipitation regime and net reduction of rainwater income can seriously affect their survival ability. The high dependence of these bryo-communities on the climatic conditions shows their high vulnerability towards climatic changes (Desamore et al., 2012). As emphasized by Álvarez-Cobelas et al. (2005), the changes in rainfall distribution would strongly alter the hydrogeological regime of temporary ponds. So it is necessary to monitor the frequency and intensity of the rains to prevent changes in these fragile ecosystems, in order to avoid the loss of their functions as temporary wetlands and their associated flora and fauna (Ruiz, 2008).

Syntaxonomic scheme

PSORETEA DECIPIENTIS Mattick ex Follmann 1974

BARBULETALIA UNGUICULATAE von Hübschmann 1960

Phascion cuspidati Waldheim 1944 nom. inval. ad interim

Entosthodon fascicularidis-*Archidietum alternifolium* ass. nova

Riccio sorocarpace-*Funarietum fascicularis* Lecointe 1978 *fossombronietosum* Lecointe 1978

Mannion androgynae Ros et Guerra 1987

Riccietum gougetianae Marstaller 1993

Riccietum canaliculatae Puglisi & Privitera in Puglisi, Minissale, Sciandrello & Privitera 2015

CLADONIO DIGITATAE-LEPIDOZIETEA REPTANTIS Jezek et Vondráček 1962
 DIPLOPHYLLLETALIA ALBICANTIS Philippi 1963
Dicranellion heteromallae Philippi 1963
Gongylanthetum ericetorum Puglisi, Costa & Privitera 2012

CERATODONTO PURPUREI-POLYTRICHETEA piliferi Mohan 1978
 POLYTRICHETALIA PILIFERI von Hübschmann 1975
Campylopodion polytrichoidis Giacomini 1951
Imbribryum alpinum-dominated community
Campylopus introflexus-dominated community

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Appendix: Localities and dates of the relevés

- Tab. 1 - rels. 1-2, 5-9, 11-13: Podere Coccolargo, 2016-05-05; rel. 3, Podere Marella, 2015-04-01; rels. 4,10,14: Podere Monelli, 2016-05-12.
- Tab. 2 - rel. 15: Podere Monelli, 2016-05-12; rels. 16-18: Podere Coccolargo, 2016-05-05; rels. 35-37: Podere Monelli, 2016-05-12.
- Tab. 3 - rels. 19-20, 23-25: Podere Monelli, 12-05-2016; rels. 21-22, 26-27, 29: Le 7 Strade, 2016-05-05; rels. 28, 30: Podere Coccolargo, 2015-04-01.
- Tab. 4 - rels. 31, 33: Podere Monelli, 2016-05-12; rels. 32, 34: Le 7 Strade, 2016-04-08.
- Tab. 5 - rels. 38-39: Podere Monelli, 2016-05-12; rel. 40: Le 7 Strade, 2016-05-05.
- Tab. 6 - rels. 41-45: Podere Monelli, 2016-05-12.
- Tab. 7 - rels. 46-47: Podere Coccolargo, 2016-06-28; rels. 48-52: Podere Coccolargo, 2015-05-27.
- Tab. 8 - rels. A-B: Podere Coccolargo, 2016-05-05; rels. C-E: Podere Monelli, 2016-05-12; rels. F-G: Le 7 Strade, 2016-05-05.