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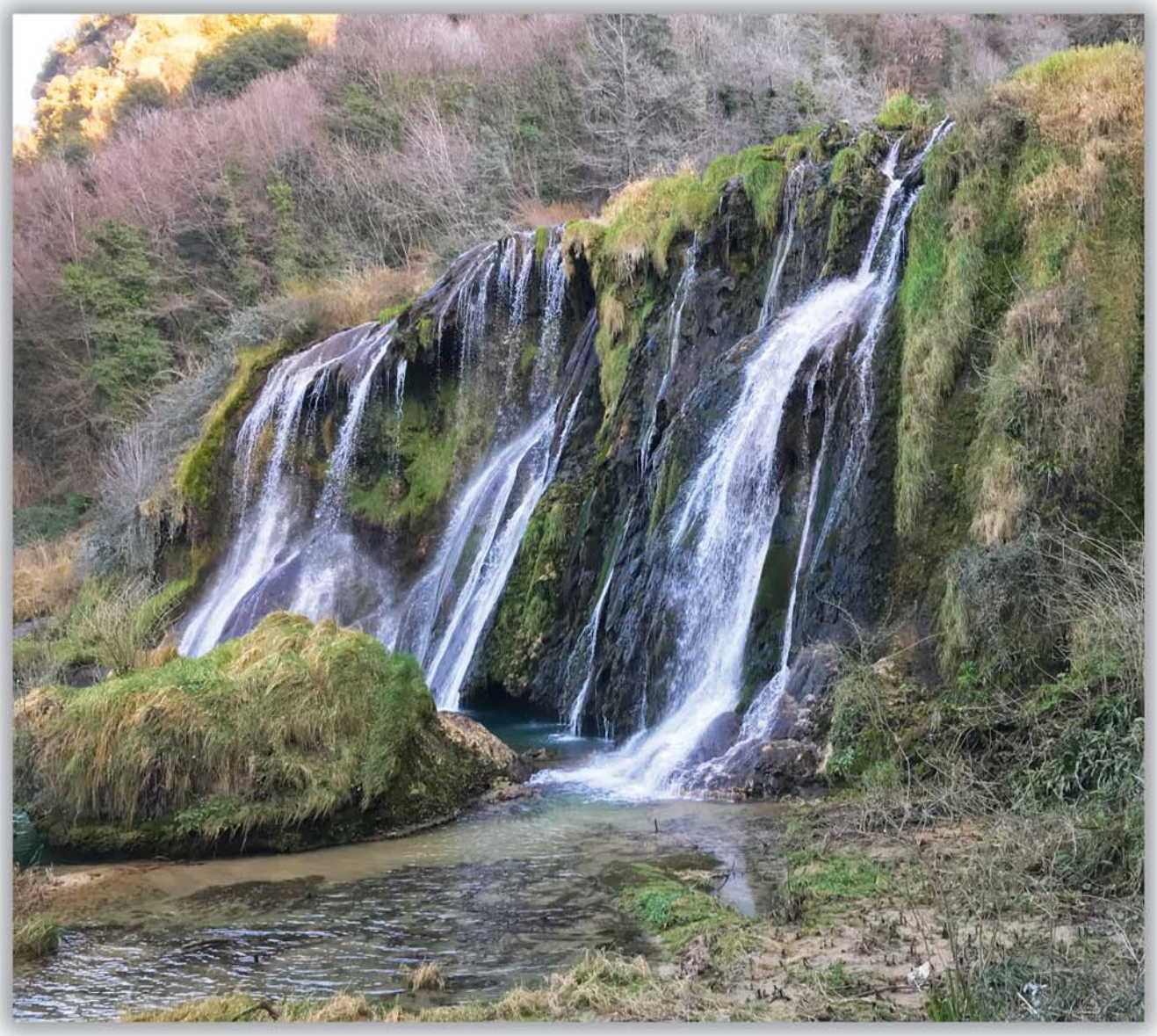

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Phytosociology and life syndromes of bryophyte communities from Sicilian caves, a clear example of relationship between bryophytes and environment

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Abstract
A phytosociological study on the bryophytes found in many lava and karst caves of Sicily was carried out. The surveyed communities, recognized at the entrance, in the liminar and subliminar zones of the caves, include the *Rhabdoweisietum fugacis, Pohlietum crudae* subass. *timmietosum bavaricae*, *Bartramietum ithyphyllae*, *Pohlio crudae-Amphidietum mougeotii* and *Pohlio annotinae-Brachythecietum velutini* (class *Cladonio digitatae-Lepidozietea reptantis*), *Rhynchostegielletum algirianae* (class *Ctenidietea mollusci*), *Scorpiurietum circinati* (class *Pleurochaeto squarrosae-Abietinelletea abietinae*), *Riccio glaucae-Anthocerotetum crispuli* and *Plagiochasmo rupestris-Targionietum hypophyllae* (class *Barbuletea unguiculatae*), found in the lava caves. By contrast, the *Selaginello denticulatae-Timmielletum barbuloidis* (class *Pleurochaeto squarrosae-Abietinelletea abietinae*), *Weissietum tortilis* (class *Barbuletea unguiculatae*), *Eucladio verticillati-Adiantetum capilli-veneris* and *Thamnobryo alopecuri-Phyllitidetum scolopendrii* (class *Adiantetea capilli-veneris*), were found in the karst caves. Among these, *Pohlio crudae-Amphidietum mougeotii* and *Rhynchostegielletum algirianae* are the only associations with a troglophile character, which survive in the semi-darkness of the subliminar zone. The associations were examined from a synecological, synhierarchical and chorological point of view. A life form and life strategy analysis of all communities reflect the response of plant functional types towards the environmental demands. Most communities are characterized by only few but specific life syndromes, which can be seen as an ecological expression of the growing sites, the diverse characters and requirements of the various species and populations. Especially the prevailing life forms perfectly reflect the light conditions, one of the key stone factors of plants of cave communities.

Key words: bryophyte vegetation, caves, ecology, life forms, life strategies, Sicily.

Introduction

Caves represent a peculiar habitat of great attractiveness and of historical, landscaping, naturalistic and conservation meaning. Indeed, according to the Natura 2000 network of the European Union (Habitats Directive 92/43/ EC), caves fall within the Habitat 8310 Caves not open to the public and the Habitat 8320 Fields of lava and natural excavations and, therefore, are important for the plant conservation (Gigante *et al*., 2016). The caves are characterized by many physical and ecological factors leading to a selection of the flora and vegetation, especially in less enlightened parts. As light diminishes, so does ability of the plant to meet its light compensation point. Through this gradient, it is possible to see that flowering plants are the least tolerant, followed then by ferns and bryophytes, and at last algae. Nevertheless, even though the deep, dark environments of caves seem like they could never support plant life, certain types of plants can thrive in that environment. Among these plants, bryophytes are the most significant taxonomical group able to adapt to the hard environmental conditions of the cave habitat. With this regard, several bryological studies were carried out, emphasizing the significant role of the bryophytes in the colonization of caves (Tosco, 1957-1958, 1968-1969; Cortini Pedrotti, 1978; Lo Giudice & Privitera, 1981, 1983). Conversely, the knowledge on the bryophyte vegetation is still limited (Lo Giudice & Privitera, 1987; Privitera & Puglisi, 1996). Therefore, this poorness of data together with the interest generated by the peculiarity of the habitat has led us to undertake an extensive investigation on the bryophyte vegetation of the Sicilian caves. In Sicily there are karst caves, volcanic caves, caves in the gypsum, as well as artificial cavities. The karst caves are spread across the Island, while the volcanic caves are concentrated on the Etna and on some Circumsicilian volcanic islets.

Study sites

Several volcanic caves, karst caves, as well as some artificial cavities of Sicily were investigated. In particular, the studied volcanic caves are located on the Mt. Etna. Due to the basic lava and the mainly effusive activity, most of the Etnean caves are lava tubes (natural conduits formed by flowing lava which moves

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beneath the hardened surface of a lava flow), while the others are rheogenetic fissures and in few cases pneumatogenetic explosive caves (Licitra, 1993). Except the Palombe cave, which is a rheogenetic fissure, all the investigated caves are lava tubes. The karst caves, distributed in the territories of Trapani, Palermo and Syracuse, are generated by the corrosive action of the waters flowing on soluble carbonate rocks. The karst caves of Trapani and Palermo territory are mainly composed by outcrops of Mesozoic calcarenites and dolomites; the caves of the Syracuse territory are essentially constituted by outcrops of sedimentary rocks made up of Myocenic limestones (Ruggeri, 2016). Finally, the artificial caves are represented by some old stone quarries inside the Paradise Latomia in the Syracuse city. The studied caves are placed at altitudes ranging from seal level to 1,750 m a.s.l. (Tab. 1).

From the bioclimatic point of view, the Sicily is characterized by a Mediterranean climate, diversified on the basis of the altitudes and slopes. The average annual temperature is 17-18° C in the coastal areas, decreasing to 10° C in the mountain areas, especially in the northeast of the Island; in the cacuminal area of the Mt. Etna the values decrease to 5° C. Precipitation is concentrated in autumn and winter with an average of 500-700 mm/year. In some coastal territories, the values are lower than 500 mm/year, while on the mountains reach 1,000 mm/year up to 1,300 mm/year in the highest sites in the northeast of the Island (Brullo *et al*., 1996). According to the bioclimatic classification of Rivas-Martínez *et al*. (2011), the bioclimate of the investigated sites is of the Mediterranean pluviseasonal oceanic, ranging from lower thermomediterranean to upper supramediterranean thermotype and from lower dry to lower humid ombrotype (Pesaresi *et al*., 2014).

Tab. 1 - List of the investigated caves.

	Caves	Altitude	Location
LAVA CAVES	Via S. Gregorio cave	210 m a.s.l.	37° 33' 37" N, 15° 07' 34" E
	Micio Conti cave	280 m a.s.l.	37° 33' 38" N, 15° 07' 01" E
	Cantarella cave	300 m a.s.l.	37° 33' 42" N, 15° 06' 54" E
	Immacolatella I cave	300 m a.s.l.	37° 33' 36" N, 15° 06' 39 E
	Immacolatella II cave	300 m a.s.l.	37° 33' 37" N, 15° 06' 39" E
	Immacolatella III cave	295 m a.s.l.	37° 33' 35" N, 15° 06' 41" E
	Immacolatella IV cave	295 m a.s.l.	37° 33' 35" N, 15° 06' 41" E
	Forcato cave	670 m a.s.l.	37° 46' 48" N, 15° 08' 46" E
	Del Santo cave	1030 m a.s.l.	37° 42' 31" N, 14° 52' 35" E
	Intraleo cave	1370 m a.s.l.	37° 43' 08" N, 14° 54' 33" E
	Coniglio cave	1375 m a.s.l.	37° 41' 56" N, 15° 03' 14" E
	Cassone cave	1400 m a.s.l.	37° 41' 55" N, 15° 02' 57" E
	Ladri cave	1540 m a.s.l.	37° 46' 16" N, 15° 04' 18" E
	Palombe cave	1575 m a.s.l.	37° 49' 35" N, 15° 01' 43" E
	Tre livelli cave	1625 m a.s.l.	37° 41' 56" N, 15° 01' 59" E
	Faggi cave	1660 m a.s.l.	37° 41' 21" N, 15° 00' 39" E
	Case del Vescovo cave	1675 m a.s.l.	37° 41' 47" N, 15° 01' 33" E
	Lamponi cave	1750 m a.s.l.	37° 49' 04" N, 15° 00' 40" E
KARST CAVES	Rope-Makers' Cave	15 m a.s.l.	37° 04' 36" N, 15° 16' 34" E
	Ear of Dionysius	20 m a.s.l.	37° 04' 34" N, 15° 16' 32" E
	Mt Cofano cave	34 m a.s.l.	38° 06'16" N, 12° 39' 34" E
	Monello cave	115 m a.s.l.	37° 01' 04" N, 15° 09' 33" E
	Mt Palatimone cave	255 m a.s.l.	38° 05'13" N, 12° 42' 30" E
	Mt Sparagio cave	310 m a.s.l.	38° 02'17" N, 12° 47' 38" E
	Garrone	1030 m a.s.l.	38° 00' 09" E, 13° 15' 57" E

Material and methods

The bryovegetational study, which follows the plant sociological method of Braun-Blanquet (1964), is based on literature data and inedited data. As regards the unpublished data, the field work was carried out during 2014-2017 years; the season of the collection was spring or late spring.

It is specified that in these caves there are no artificial light resources, therefore the occurrence and distribution of bryophytes is essentially determined by the amount of natural light that can penetrate inside. According to Tosco (1957-58, 1968-69) and Cortini Pedrotti (1978), we have distinguished an outside area corresponding to the entrance, a liminar zone from the entrance to a depth where the light reaches ½ of the external light intensity, and a subliminar zone with even more reduced brightness (less than ½ of the external light intensity).

The cover of each taxon is estimated according to the following values: + (<1%), 1 (1-10%), 2 (10.1-25%), 3 (25.1-50%), 4 (50.1-75%), 5 (75.1-100%).The phytosociological relevés were made on the entrance, vault, floor, and lateral walls of the caves.

The analysis of life forms and life strategies (synecological analysis) follow the concepts of Mägdefrau (1982; life forms) and During (1979), Frey & Kürschner (1991 and Kürschner & Frey (2013; life strategies), who established a key stone character system that impressively reflect the correlation of ecological site conditions and prevailing *taxa*/communities. For each species and category the mean percentage cover (MPC) values of the biological and ecological parameters within the association is calculated, based on the cover values (cf. Frey & Kürschner, 1991; Puglisi *et al*., 2012, 2013a, 2013b).

The syntaxonomic arrangement and nomenclature follow Puglisi & Privitera (2012); the nomenclature of the *taxa* follows Söderström *et al*. (2016) for liverworts and Ros *et al*. (2013) for mosses.

Results and discussion

Communities of lava caves

1) *RHABDOWEISIETUM FUGACIS* Schade ex Neumayr 1971 (Tab. 2)

This temperate-montane association was found in the liminar zone of the Palombe cave where it colo-

Tab. 2 - *Rhabdoweisietum fugacis* Schade ex Neumayr 1971.

Relevé number	1	2	3	4
Altitude (dam a.s.l.)	157	157	157	157
Size of relevé (dm^2)	15	10	15	20
Cover (%)	75	60	55	35
Number of species	5	5	5	4
Char. Association				
Rhabdoweisia fugax	3	3	3	2
Char. Alliance (*Diplophyllion albicantis*)				
Cynodontium bruntonii	.	.	+	1
Other species				
Isothecium alopecuroides	2	2	1	1
Bartramia pomiformis	2	1	+	.
Fissidens bryoides	+	1	.	1
Amphidium mougeotii	1	+	1	.

nized surface irregularities of the lateral sides where a thin layer of soil is accumulated. This cave, which is of rheogenetic fissure type, is located in the northern slope of the Mt. Etna at 1,575 meters of altitude; it is considered one of the most studied and the best known cave of the Mt. Etna. From an ecological point of view, *Rhabdoweisietum fugacis* can be considered as a terri-saxicolous, mesophytic, sciophytic association. The physiognomy is due to some acrocarpous mosses with caespitose *habitus* (short turfs dominating) and to the pleurocarpous *Isothecium alopecuroides*. Floristically, the association is characterized by *Rhabdoweisia fugax*, a boreal-montane species very rare in Italy, occurring in Sicily only within the Palombe cave of the Mt. Etna and on the Peloritani Mts. The association belongs to the *Diplophyllion albicantis*, a humo-epilithic, mesophytic, sciophytic and markedly sciophytic alliance diffused in the montane belt (Puglisi & Privitera, 2012). *Rhabdoweisietum fugacis* is reported from Switzerland, Germany (Marstaller, 1988, 2006), France (Bardat & Hauguel, 2002), Serbia (Sabovljević, 2008), Austria (Schlüsslmayr, 2011), northern Italy (Lombardy) and Sicily within the Palombe cave (Puglisi & Privitera, 2012).

2) *POHLIETUM CRUDAE* Privitera & Puglisi 1996 subass. *TIMMIETOSUM BAVARICAE* Privitera & Puglisi 1996 (Tab. 3)

It is a terricolous, meso-hygrophytic, sciophytic community, described for the Lamponi cave, a lava tube located on the northern slope of the Mt. Etna at 1,750 meters of altitude; here it was found on the cave floor in the liminar and subliminar zones. This community exclusively consists of mosses, with dominance of the acrocarpous component with caespitose *habitus* (life forms: short turf and tall turf, cf. Tab. 16). The surfaces vary from 3 dm^2 to 10 dm^2; the cover is quite high ranging from 65% to 100%, exceptionally 45% in the relevé 3. The subassociation is characterized by *Timmia bavarica*, a subcontinental-dealpine species, associated to the characteristic of the association *Pohlia cruda* and to a set of species of higher units (alliance

Tab. 3 - *Pohlietum crudae* Privitera & Puglisi 1996 subass. *timmietosum bavaricae* Privitera & Puglisi 1996.

Relevé number	1	2	3	4	5	6	7	8	9
Altitude (dam a.s.l.)	175	175	175	175	175	175	175	175	175
Size of relevé (dm^2)	5	10	5	4	3	4	5	5	4
Cover (%)	80	75	45	85	100	65	85	70	90
Number of species	6	4	5	6	6	4	4	4	3
Char. Association									
Pohlia cruda	2	1	1	2	1	2	2	2	3
Char. Subassociation									
Timmia bavarica	3	3	2	2	4	3	4	3	4
Char. Alliance (*Pohlion crudae*)									
Brachytheciastrum collinum	1	.	+	2	2	1	.	.	.
Char. Order (*Diplophylletalia albicantis*)									
Pohlia annotina	2	3	2	.	.	.	.	.	.
Other species									
Brachytheciastrum velutinum	.	.	.	+	.	.	+	2	1
Amphidium mougeotii	.	+	.	2	1	.	.	+	.
Thamnobryum alopecurum	1	.	.	.	.	.	2	1	.
Syntrichia ruralis	.	.	.	3	2	.	.	.	.
Rosulabryum capillare	.	.	1	.	1	.	.	.	.
Homalothecium sericeum	1	.	.	.	.	1	.	.	.

and order). The community is referred to the *Pohlion crudae*, a terri-humicolous, mesophytic, sciophytic to markedly sciophytic alliance, included in the order *Diplophylletalia albicanti*s and class *Cladonio digitatae-Lepidozietea reptantis* (Puglisi & Privitera, 2012). The *Pohlio crudae-Bartramietum ithyphyllae* subass. *timmietosum bavaricae* was described for the Lamponi cave (Privitera & Puglisi, 1996) and its occurrence in the same site is here confirmed.

3) *BARTRAMIETUM ITHYPHYLLAE* v. Krusenstjerna 1945 (Tab. 4)

It is a chasmophytic, acidophytic, mesophytic, sciophytic association found in the liminar and subliminar zones of the Ladri and Lamponi caves at altitudes of 1,540 m and 1,750 m a.s.l. respectively. This association was found in fissures and concavities of rocks scattered on the floor of the caves. The surfaces are small, ranging from 2 to 5 dm^2; the cover ranges from 65% and 75%, with exception of 35% in the relevé 5. Characteristic of association is *Bartramia ithyphylla*, a Boreo-arctic montane species reaching on the Mt. Etna the altitudinal record of 2,500 meters. *Bartramia ithyphylla* is accompanied by a set of character species of higher units (alliance, order and class) some of which are very interesting from a phytogeographical point of view, such as *Isopterygiopsis pulchella*, a strongly sciophytic species occurring in Sicily only within some caves of the Mt. Etna. As well as the previous community, *Bartramietum ithyphyllae* is included in the alliance *Pohlion crudae* of the order *Diplophylletalia albicantis*, class *Cladonio digitatae-Lepidozietea reptantis*. *Bartramietum ithyphyllae*, described by Krusenstjerna (1945) for Sweden. In Italy it is known from the Rhaetian Alps and Sicily (Mt. Etna; Puglisi & Privitera, 2012).

Tab. 4 - *Bartramietum ithyphyllae* v. Krusenstjerna 1945.

Relevé number	1	2	3	4	5
Altitude (dam a.s.l.)	154	154	154	175	175
Size of relevé (dm^2)	5	5	4	3	2
Cover (%)	70	65	75	65	35
Number of species	5	5	6	4	6
Char. Association					
Bartramia ithyphylla	3	3	4	3	2
Char. Alliance (*Pohlion crudae*)					
Isopterygiopsis pulchella	1	+	.	.	.
Pohlia cruda	2	1	1	.	.
Char. Order and Class (*Diplophylletalia albicantis*, *Cladonio digitatae-Lepidozietea reptantis*)					
Pohlia annotina	.	2	1	1	.
Cephaloziella divaricata	.	.	.	.	1
Other species					
Ceratodon purpureus	1	.	+	2	1
Rosulabryum capillare	.	.	1	1	+
Brachytheciastrum velutinum	1	.	.	.	1
Microeurhynchium pumilum	.	1	+	.	.
Porella cordaeana	.	.	.	.	+

4) *POHLIO CRUDAE-AMPHIDIETUM MOUGEOTII* Privitera & Puglisi 1996 (Tab. 5)

It is the most typical association characterizing the lava caves of high altitude between 1,370 m and 1,750 a.s.l. It was found on the floor side walls and vault in the liminar zone of Lamponi, Palombe, Ladri, Casa del Vescovo, Cassone, Coniglio, Faggi and Intraleo caves and in the subliminar zone of the Palombe and Ladri caves. Ecologically it behaves as a terricolous, meso-hygrophytic, markedly sciophytic community; it can be classified as a community with troglophilous character. The surfaces are small, ranging from 3 to 5 dm^2, exceptionally 8 or 10 dm^2 in the relevés 3,2 and 4 respectively. The cover is high, ranging from 45% to 100%, with the average cover of 75%; the species number varies between 4 and 9. The *Pohlio crudae-Amphidietum mougeotii* is floristically characterized by *Amphidium mougeotii*, a Boreal-montane species, rare in central and southern Italy, occurring in Sicily only within the caves of Mt. Etna (Privitera & Puglisi, 1997). To this species a set of characteristics of higher units (alliance, order and class) is associated; among these, besides the above mentioned *Isopterygiopsis pulchella*, it is to emphasize the occurrence of *Brachytheciastrum collinum*, an Arctic-montane species very rare in Italy, found in Sicily only on the Mt. Etna. The *Pohlio crudae-Amphidietum mougeotii* is referred to the alliance *Pohlion crudae* of the order *Diplophylletalia albicantis*, class *Cladonio digitatae-Lepidozietea reptantis*. This association is known only for the caves of the Etna.

5) *POHLIO ANNOTINAE-BRACHYTHECIETUM VELUTINI* Privitera & Puglisi 1996 (Tab. 6)

The *Pohlio annotinae-Brachythecietum velutini* is a xero-mesophytic, photo-sciophytic to sciophytic asso-

Tab. 5 - *Pohlio crudae -Amphidietum mougeotii* Privitera & Puglisi 1996.

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Altitude (dam a.s.l.)	137	137	137	137	175	175	175	175	175	175	175	157	157	157	157	154	154	154	160	167	140	137	137	166
Size of relevé (dm^2)	5	10	8	10	5	5	3	4	4	3	5	4	3	5	5	3	3	4	5	4	4	5	5	5
Cover (%)	90	70	80	50	55	60	90	80	100	60	65	95	85	65	80	50	90	100	55	45	90	80	80	85
Number of species	4	7	4	4	6	6	4	5	6	4	7	5	4	5	5	7	9	9	5	4	4	5	5	5
Char. Association																								
Amphidium mougeotii	4	3	4	2	2	3	2	2	3	2	3	2	2	1	1	2	2	1	2	3	5	2	4	4
Char. Alliance (*Pohlion crudae*)																								
Pohlia cruda	3	3	2	1	1	+	.	1	.	.	.	.	.	.	.	1	2	2	3	1	+	.	.	2
Brachytheciastrum collinum	.	.	.	.	.	.	2	3	3	2	1	.	.	.	.	.	.	.	.	.	.	.	.	
Isopterygiopsis pulchella	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	1	.	.	.	.	.	
Char. Order and Class (*Diplophylletalia albicantis*, *Cladonio digitatae-Lepidozietea reptantis*)																								
Bartramia ithyphylla	.	.	.	.	1	+	+	.	1	.	+	.	.	.	.	.	.	.	.	.	.	2	1	.
Pohlia annotina	+	1	.	2	2	1	.	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1
Cephaloziella divaricata	.	+	1	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	+	.	.	.	.
Other species																								
Tortula subulata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	.	.	+	1	2
Bartramia pomiformis	.	.	.	.	.	.	.	.	.	.	.	2	1	1	2	.	1	2	.	.	.	.	.	.
Rosulabryum capillare	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.	.
Homalothecium sericeum	.	.	.	.	.	1	.	1	2	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1
Distichium capillaceum	.	.	.	.	.	.	3	2	2	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Oyrrhynchium hians	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	.	.	.	.	.	.
Entosthodon pulchellus	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	2	1	.	.	.	.	.	.	.
Scleropodium touretii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	3	1	.
Isothecium alopecuroides	.	.	.	.	.	.	.	.	.	.	.	3	3	2	3	.	.	.	.	.	.	.	.	.
Philonotis arnellii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	2	.	.	.	1	1	.
Porella cordaeana	.	+	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Fissidens bryoides	.	.	.	.	.	.	.	.	.	.	.	+	1	.	+	+	.	.	.	.	.	.	.	.
Cynodontium bruntonii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.	.
Sporadic species	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0

Tab. 6 - *Pohlio annotinae-Brachythecietum velutini* Privitera & Puglisi 1996.

Relevé number	1	2	3	4	5	6	7
Altitude (dam a.s.l.)	162	162	162	162	154	154	154
Size of relevé (dm^2)	20	30	10	10	10	20	20
Cover (%)	70	100	100	75	65	80	90
Number of species	5	5	6	5	4	5	6
Char. Association							
Brachytheciastrum velutinum	3	4	3	3	3	4	4
Char. Alliance (*Pohlion crudae*)							
Isopterygiopsis pulchella	.	.	.	.	.	1	1
Pohlia cruda	2	1	.	.	.	.	.
Char. Order (*Diplophylletalia albicantis*)							
Pohlia annotina	+	2	+	.	+	.	1
Other species							
Tortula subulata	.	.	2	3	.	1	.
Amphidium mougeotii	.	.	.	.	2	1	2
Ceratodon purpureus	.	.	.	.	1	.	+
Rosulabryum capillare	.	.	2	+	.	.	.
Sporadic species	2	2	2	2	0	1	1

Tab. 7 - *Scorpiurietum circinati* Giacomini 1951.

Relevé number	1	2	3	4	5	6	7	8	9
Altitude (dam a.s.l.)	30	28	28	21	30	30	30	103	103
Size of relevé (dm^2)	10	10	5	5	6	5	10	10	10
Cover (%)	70	60	70	65	50	75	35	60	45
Number of species	5	5	4	4	5	5	3	4	3
Char. Association									
Scorpiurium circinatum	4	3	4	3	2	3	2	3	3
Char. Alliance (*Homalothecio aurei-Pleurochaetion squarrosae*)									
Scleropodium touretii	2	2	1	2	.	.	1	2	+
Rhynchostegium megapolitanum	.	.	.	.	1	2	.		
Char. Order and Class (*Pleurochaeto squarrosae-Abietinelletalia abietinae*, *Pleurochaeto squarrosae-Abietinelletea abietina* e)									
Tortella squarrosa	1	1	2	1	2	1	.	.	.
Other species									
Timmiella anomala		+	1	.	.	.	.	.	.
Rosulabryum capillare	+			.	+	+	.	.	.
Epipterygium tozeri	+	1	.	1	1	2			
Didymodon vinealis	.	.	.	.	.	.	.	1	+
Isothecium alopecuroides	.	.	.	.	.	.	1	+	

ciation, found in the liminar zone of the Tre Livelli and Ladri caves at 1,620 m and 1,540 m of altitude, respectively. The physiognomy is mostly imprinted by the pleurocarpous *Brachytheciastrum velutinum*, which characterizes the association from the floristic point of view, too. The surfaces vary from 10 dm^2 to 20 dm^2, exceptionally 30 dm^2; the cover is high, ranging from 65% to 100%. The *Pohlio annotinae-Brachythecietum velutini* belongs to the alliance *Pohlion crudae* of the order *Diplophylletalia albicantis*, class *Cladonio digitatae-Lepidozietea reptantis*. This association is known only for Sicily.

6) *SCORPIURIETUM CIRCINATI* Giacomini 1951 (Tab. 7)

It is an association widespread in low altitude caves of the Mt. Etna, *i.e.* Immacolatella I, Immacolatella III, Micio Conti and Via S. Gregorio caves (210-300 m a.s.l.), but also recognized in the Santo cave at an altitude of 1030 m. In these caves the *Scorpiurietum circinati* was found on earth-covered rocks at the entrance and in the liminar zone. Reported for the first time by Giacomini (1951) for the Italian Alps where it colonized calcareous substrates, nevertheless it does not appear to be strictly linked to this substrate. Ecologically, it is a xero-mesophytic and photo-sciophytic community, showing relatively broad ecological exigencies. The surfaces ranges from 5 dm^2 to 10 dm^2, the cover from 35% to 75%. The *Scorpiurietum circinati* is referred to the alliance *Homalothecio aurei-Pleurochaetion squarrosae* (Ros & Guerra 1987) Marstaller 1993 of the class *Pleurochaeto squarrosae-Abietinelletea abietinae* Marstaller 2002. The characteristic species is *Scorpiurium circinatum*, a Mediterranean species, accompanied by a group of characteristics of higher units (alliance, order and class). The association is reported for northern Italy (Giacomini, 1951) and northern France (Caillet *et al*., 2010); it is here signaled for the first time for Sicily.

7) *RHYNCHOSTEGIELLETUM ALGIRIANAE* Giacomini 1951 (Tab. 8)

A saxicolous, thermophytic, mesophytic or mesohygrophytic, sciophytic or markedly sciophytic association, found in several low-altitude caves (30-300 m a.s.l.) both of lava and karst nature. In particular, the Rhynchostegielletum algirianae was detected in the liminar zone of the Mt. Palatimone, Mt. Sparagio, Cofano, Monello, Via S. Gregorio and Micio Conti caves, and in the liminar and subliminar zone of the Immacolatella I, Immacolatella II, Immacolatella III, Immacolatella IV caves. The community is poor in species, the number varies between 2 and 4, exceptionally 5 in the relevés 1 and 20. The community is physiognomycally and floristically characterized by *Rhynchostegiella tenella*, a small pleurocarpous moss species (Mediterranean) always associated to *Fissidens gracilifolius*. The association belongs to the alliance *Fissidention gracilifolii* Neumayr 1971 corr. Marstaller 2001 of the order *Ctenidietalia mollusci* Hadàc & Šmarda ex Klika 1948 and class *Ctenidietea mollusci* v. Hübschmann ex Grgić 1980. The *Rhynchostegielletum algirianae* is known from France (Bardat & Hauguel, 2002), N Italy (Giacomini, 1951) and Sicily (Privitera & Puglisi, 2004; Puglisi, 2010)

8) *PLAGIOCHASMO RUPESTRIS-TARGIONIETUM HYPOPHYLLAE* v. Hübschmann 1971 (Tab. 9)

The *Plagiochasmo rupestris-Targionietum hypophyllae* is a Mediterranean-Macaronesian association, found on shallow soil, along the access line of some low-altitude lava tube caves (280-290 m a.s.l.).

Tab. 8 - *Rhynchostegielletum algirianae* Giacomini 1951.

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Altitude (dam)	25	25	3	21	30	30	30	30	30	30	30	30	30	30	30	11	11	31	28	28	28
Size of relevé (dm^2)	5	10	5	3	5	3	4	5	5	5	3	3	5	3	3	5	3	5	5	10	3
Cover (%)	55	75	50	100	100	85	80	100	85	80	75	50	60	65	80	85	100	100	90	65	100
Number of species	5	4	2	4	4	3	3	4	4	3	3	3	2	3	3	4	3	4	4	5	4
Char. Association and Alliance (*Fissidention gracilifolii*)																					
Rhynchostegiella tenella	3	4	3	5	5	4	4	5	4	4	4	3	3	3	4	4	5	5	4	3	5
Fissidens gracilifolius	1	+	.	1	2	1	+	1	1	1	1	1	2	2	1	1	+	1	2	2	1
Other species																					
Epipterygium tozeri	.	.	.	.	+	1	.	+	1	1	.	+	.	.	+	.	.	.	1	+	.
Fossombronia pusilla	.	.	.	.	+	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Scorpiurium circinatum	1	.	.	2	.	.	.	.	.	.	+	.	.	1	.	.	.	.	.	.	1
Lunularia cruciata	.	.	.	1	.	.	.	.	+	.	.	.	.	.	.	1	.	.	.	.	.
Fissidens viridulus	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+
Trichostomum brachydontium	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Gemmabryum caespiticium	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Timmiella anomala	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	1	.
Rhynchostegiella litorea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Gymnostomum calcareum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.

Ecologically it behaves as a xerophytic, photophytic or photo-sciophytic association. The physiognomy of the community is mostly due to the presence of some thalloid liverworts, such as *Targionia hypophylla*, *Plagiochasma rupestre* and locally *Mannia androgyna*, mixed with *Fossombronia pusilla* and a rich contingent of acrocarpous mosses. The *Plagiochasmo rupestris-Targionietum hypophyllae* is floristically characterized by the Mediterranean liverworts *Targionia hypophylla* and *Plagiochasma rupestre*, associated to a set of species of higher units (alliance and order), among which *Trichostomum brachydontium* prevails. The community is referred to the *Mannion androgynae* Ros & Guerra 1987, a Mediterranean alliance characterized by spring associations that are rich in thalloid hepatics. This alliance is included in the order *Barbuletalia unguiculatae* v. Hübschmann 1960 of the class *Barbuletea unguiculatae* Mohan 1978. The *Plagiochasmo rupestris-Targionietum hypophyllae* is cited for Switzerland, Iberian Peninsula, France, northern Italy and Sicily (Privitera & Puglisi, 1996; Bardat & Hauguel, 2002; Puglisi & Privitera, 2012).

Tab. 9 - *Plagiochasmo rupestris-Targionietum hypophyllae* v. Hübschmann 1971.

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12
Altitude (dam)	28	28	29	29	29	29	29	29	29	29	29	-
Size of relevé (dm^2)	2	3	5	5	3	3	4	4	5	5	5	2
Cover (%)	80	100	100	70	90	90	50	80	75	50	75	90
Number of species	7	7	9	7	8	7	6	5	4	8	5	6
Char. Association												
Targionia hypophylla	2	3	2	2	3	3	2	3	3	2	3	3
Plagiochasma rupestre	1	.	3	2	1	2	.	.	.	1	.	+
Char. Alliance and Order (*Mannion androgynae*, *Barbuletalia unguiculatae*)												
Trichostomum brachydontium	.	.	1	.	1	1	2	3	3	2	2	3
Fissidens viridulus	.	.	+	1	1	+	.	.	.	.	.	.
Mannia androgyna	2	2	.	.	.	.	.	.	.	.	.	.
Timmiella anomala	1	+	.	.	.	.	.	.	.	.	.	.
Other species												
Scorpiurium circinatum	1	1	1	2	2	1	1	+	1	+	+	2
Fossombronia pusilla	2	3	3	2	3	3	+	.	.	1	2	1
Rosulabryum capillare	.	.	.	.	.	.	+	1	.	1	.	.
Tortella squarrosa	.	.	+	.	+	.	.	.	.	.	.	.
Tortella inclinata	.	.	.	.	.	.	.	.	1	1	.	2
Bartramia aprica	.	.	.	.	.	.	1	2	.	1	+	.
Scleropodium touretii	.	.	2	1	1	2	.	.	.	.	.	.
Bryum donianum	2	2	.	.	.	.	.	.	.	.	.	.
Epipterygium tozeri	.	2	1	.	.	.	.	.	.	.	.	.
Grimmia trichophylla	.	.	.	+	.	.	.	.	.	.	.	.

9) *RICCIO GLAUCAE-ANTHOCEROTETUM CRISPULI* Koppe ex Neumayr 1971 (Tab. 10)

The *Riccio glaucae-Anthocerotetum crispuli* was found on moist and shady soil at the entrance of the Cantarella and the Immacolatelle lava caves at 300 m of altitude, behaving as a terricoluos, mesophytic, sciophytic community. Structurally, the hornworts play a prominent role, with *Phaeoceros laevis* prevailing. The surfaces vary from 5 to 15 dm^2 and the cover from 50% to 100% with an average cover of about 72%. The characteristics of association are *Phaeoceros laevis*, present with high cover values, *Fossombronia wondraczekii* and *Anthoceros agrestis*. To these species a well-represented set of characteristics of higher units (alliance, order and class) area associated. The *Riccio glaucae-Anthocerotetum crispuli* is referred to the *Phascion cuspidati* Waldheim ex v. Krusenstjerna 1945, grouping communities of disturbed soils with a strong human impact; this alliance is included in the order *Barbuletalia unguiculatae* of the class *Barbuletea unguiculatae*. This temperate association is known in Austria, France, Germany and Sicily (Bardat & Hauguel, 2002; Schubert, 2009; Schlüsslmayr, 2011; Puglisi & Privitera, 2012).

Tab. 10 - *Riccio glaucae-Anthocerotetum crispuli* Koppe ex Neumayr 1971.

Relevé number	1	2	3	4	5	6
Altitude (dam)	30	30	30	30	30	30
Size of relevé (dm^2)	10	5	10	15	10	5
Cover (%)	50	65	100	75	70	75
Number of species	5	7	5	9	7	5
Char. Association						
Phaeoceros laevis	1	3	4	3	4	4
Fossombronia wondraczekii	.	.	2	1	.	1
Anthoceros agrestis	2	1	.	.	.	.
Char. Alliance (*Phascion cuspidati*)						
Anthoceros punctatus	1	2	1	+	+	.
Riccia glauca	.	.	.	+	1	+
Ephemerum minutissimum	.	+	.	.	.	.
Char. Order and Class (*Barbuletalia unguiculatae*, *Barbuletea unguiculatae*)						
Fissidens viridulus	+	1	1	2	+	1
Riccia sorocarpa	.	+	.	+	1	.
Gemmabryum dichotomum	2	.	.	.	.	.
Other species						
Scorpiurium circinatum	.	.	2	2	1	.
Timmiella anomala	.	.	.	+	+	.
Gemmabryum caespiticium	.	1	.	1	.	1

Communities of karst caves

10) *SELAGINELLO DENTICULATAE-TIMMIELLETUM BARBULOIDIS* Cano, Ros & Guerra 1997 (Tab. 11)

A community floristically characterized by *Timmiella barbuloides* and *Selaginella denticulata*, a small prostrate Pteridophyte growing on moss carpets. The physiognomy is heterogeneous for the presence of acrocarpous and pleurocarpous mosses on which the flattened stems of *Selaginella denticulata* creep. The moss component is essentially represented by *Timmiella barbuloides*, accompanied by *Scorpiurium circinatum* and *Rhynchostegium megapolitanum*, characteristics of alliance. The *Selaginello denticulatae-Timmielletum barbuloidis* is a terricolous, photo-sciophytic to sciophytic, mesophytic community, found at the entrance of the karst cave of Mt. Palatimone cave, located at 250 m of altitude. The cover varies between 45% and 60%, with an average number of 5 species. Synsystematically, this association is included in the alliance *Homalothecio aurei-Pleurochaetion squarrosae* (Ros & Guerra 1987) Marstaller 1993 of the order *Pleurochaeto squarrosae-Abietinelletalia abietinae* Marstaller 2002 and class *Pleurochaeto squarrosae-Abietinelletea abietinae* Marstaller 2002. This is a Mediterranean association known from Spain (Cano *et al*., 1997; Garcia-Zamora *et al*., 2000), northern Africa (Ros *et al*., 1990), central and southern Italy (Privitera & Puglisi, 1999, 2009) and the circumsicilian islet Linosa (Puglisi, 2010).

Tab. 11 - *Selaginello denticulatae-Timmielletum barbuloidis* Cano, Ros & Guerra 1997.

Relevé number	1	2	3
Altitude (dam)	25	25	25
Size of relevé (dm^2)	10	10	5
Cover (%)	60	45	50
Number of species	5	6	4
Char. Association			
Timmiella barbuloides	3	2	3
Selaginella denticulata	+	1	.
Char. Alliance (*Homalothecio aurei-Pleurochaetion squarrosae*)			
Scorpiurium circinatum	2	.	1
Rhynchostegium megapolitanum	.	1	+
Other species			
Gemmabryum caespiticium	1	1	+
Didymodon luridus	+	1	.
Rosulabryum torquescens	.	1	.

11) *WEISSIETUM TORTILIS* Neumayr 1971 (Tab. 12)

This association, as well as the previous one, was detected along the line of access of a cave, the Mt Palatimone cave located at 250 meters of altitude. Here it was found in rock crevices with accumulated soil, behaving as a terricolous, xerophytic, photophytic, preferably basophilous association. The vegetation cover ranges from 50% to 75%, with a species number of 3-4. The association is composed almost exclusively by acrocarpous mosses; the only pleurocarpous is *Scorpiurium circinatum*, which is occasionally present. The association is floristically characterized by *Weissia condensa*, a Mediterranean species accompanied by a group of characteristics of higher unit (order), such as *Didymodon luridus*, *Trichostomum brachydontium*, *Fissidens viridulus*, *Timmiella anomala* and *Weissia controversa*. The *Weissietum tortilis* is included in the *Grimaldion fragrantis* Šmarda & Hadàc 1944, an alliance typically found in disturbed sites on oligotrophic, basic soils, belonging to the order *Barbuletalia unguiculatae* and class *Barbuletea unguiculatae*. It is a

Tab. 12 - *Weissietum tortilis* Neumayr 1971.

Relevé number	1	2	3	4	5
Altitude (dam)	25	25	25	25	25
Size of relevé (dm^2)	5	7	5	10	10
Cover (%)	65	50	75	60	50
Number of species	4	4	3	3	4
Char. Association					
Weissia condensa	3	2	4	3	2
Char. Order (*Barbuletalia unguiculatae*)					
Didymodon luridus	+	.	1	.	1
Trichostomum brachydontium	.	2	.	1	.
Fissidens viridulus	.	.	.	.	1
Timmiella anomala	2	.	.	.	.
Weissia controversa	.	1	.	1	.
Other species					
Rosulabryum capillare	.	1	.	.	2
Gemmabryum caespiticium	.	.	1	.	.
Scorpiurium circinatum	1	.	.	.	.

South temperate-Mediterranean association known from some C and S European territories (*e.g.* v. Hübschmann, 1986; Bardat & Hauguel, 2002; Marstaller, 2006; Sabovljević, 2008). In Italy it was known from southern Italy and Sicily (Privitera & Puglisi, 2004; Puglisi, 2010; Puglisi *et al*., 2012).

12) *THAMNOBRYO ALOPECURI-PHYLLITIDETUM SCOLOPENDRII* Brullo, Privitera & Puglisi 1992 (Tab. 13)

This association was observed on inclined walls within the Garrone cave, in ecological conditions characterized by low light and high environmental humidity, behaving as a basophytic, sciophytic, meso-hygrophytic community. The structure of the community is bistratified for the occurrence of a bryophyte layer, mostly represented by pleurocarpous mosses with dendroid and creeping habit, on which some chormophytes are planted. The vegetation cover is high (average cover 88%) on surfaces of 50 dm^2, with an average number of about 6 species. Characteristics of the association are *Thamnobryum alopecurum*, a tree-like moss typically found in shady areas, and *Phyllitis scolopendrium* subsp. *scolopendrium*, a pteridophyte with Circumboreal distribution. To these species *Pellia endiviifolia*, and *Phyllitis sagittata*, characteristics of higher units, are associated. The *Thamnobryo alopecuri-Phyllitidetum scolopendrii*, previously included in the alliance *Adiantion capilli-veneris*, is here transferred, for its ecology and floristic composition, to the alliance *Polysticho setiferi-Phyllitidion scolopendri* Ubaldi ex Ubaldi & Biondi 2014, belonging to the order *Adiantetalia capilli-veneris* Br.-Bl. ex Horvatić 1939 and class *Adiantetea capilli-veneris* Br.-Bl. in Br.-Bl., Roussine & Nègre 1952. This association is known from southern Italy and Sicily (Brullo *et al*., 1992).

13) *EUCLADIO VERTICILLATI-ADIANTETUM CAPILLI-VENERIS* Braun-Blanq. ex Horvatić 1934 (Tab. 14)

This bryo-pteridophytic association was detected within the Dyosius' ear and the Rope-Makers' cave; these are two stone quarries located within the Archaeological park of Neapolis in Syracuse, probably dating back to the fifth century BC and where signs of the former quarrying activity can still be seen. Within these caves, the *Eucladio verticillati-Adiantetum capilli-veneris* was observed along the lateral walls and the vault in the liminar zone. Ecologically, it is a chasmocomophytic, basiphytic, hygrophytic, photo-sciophytic to sciophytic vegetation, that tolerates long periods of summer drought. This community is composed by a an extensive mat of bryophytes, mostly consisting of *Eucladium verticillatum* and *Pellia endiviifolia*, on which the pterydophyte *Adiantum capillus-veneris* is planted. The *Eucladio verticillati-Adiantetum capilli-veneris* is floristically characterized by *Eucladium verticillatum*, an European temperate moss species, constantly associated to *Adiantum capillus veneris* and also to *Pellia endiviifolia* and *Samolus valerandi*. The association is included in the alliance *Adiantion capilli-veneris* Br.-Bl. ex Horvatić 1939 of the order *Adiantetalia capilli-veneris* and class *Adiantetea capilli-veneris*. As the chorology, this association shows a Circum-Mediterranean distribution; it was already signaled for the Dyosius' ear and the Rope-Makers' cave (Puglisi, 1997) and its occurrence in the same sites is here confirmed.

Life syndromes

Life forms and life strategies

With respect to the plant functional types (life forms, life syndromes, morphological-anatomical key stone characters) the communities of the lava and karst caves give insights in the mechanisms of habitat maintenance, establishment, re-establishment and dispersal of the species and communities. Main characters

Tab. 13 - *Thamnobryo alopecuri-Phyllitidetum scolopendrii* Brullo, Privitera & Puglisi 1992.

Relevé number	1	2	3
Altitude (dam)	103	103	103
Cover (%)	85	100	80
Number of species	5	8	6
Char. Association			
Thamnobryum alopecurum	3	3	2
Phyllitis scolopendrium	+	2	+
Char. All., Ord. and Class (*Polysticho setiferi-Phyllitidion scolopendri*, *Adiantetalia capilli-veneris*, *Adiantetea capilli-veneris*)			
Pellia endiviifolia	+	1	.
Phyllitis sagittata	.	1	+
Other species			
Microeurhynchium pumilum	1	2	1
Kindbergia praelonga	.	2	3
Oxyrrhynchium speciosum	1	.	.
Didymodon vinealis	.	.	+
Parietaria diffusa	.	+	.
Cymbalaria pubescens	.	+	.

Tab. 14 - *Eucladio verticillati-Adiantetum capilli-veneris* Braun-Blanq. ex Horvatić 1934.

Relevé number	1	2	3	4	5	6	7	8	9
Altitude (m)	15	15	15	15	20	20	15	15	15
Size of relevé (dm^2)	5	10	10	15	10	15	10	15	20
Cover (%)	100	80	80	80	90	90	90	90	80
Number of species	4	4	4	4	2	3	4	4	3
Char. Association, Alliance and Order (*Adiantion capilli veneris*, *Adiantetalia capilli veneris*)									
Eucladium verticillatum	4	3	4	4	5	5	4	3	4
Adiantum capillus veneris	4	4	3	2	3	4	4	5	3
Pellia endiviifolia	3	3	+	1	.	.	2	+	1
Samolus valerandi	.	.	+	.	.	+	.	1	.
Other species									
Kindbergia praelonga	1	+	.	+	.	.	.	.	.
Oxyrrhynchium speciosum	.	.	.	.	.	.	1	.	.

used for the analysis shown in Tab. 15 are life span (avoidance vs. tolerance strategy of the gametophyte), breeding system, main reproductive effort (sexual vs. asexual reproduction) and dispersal strategies [small spores (< 25µm) providing chance dispersal vs. large spores (> 25 µm) indicating decreasing long-range dispersal and achory]. Despite the analysis reveals a high variety of life forms and life strategies (Tabs. 15-17), most communities, however, are characterized by only few but specific life syndromes, which can be seen as an ecological expression of the growing sites, the diverse characters and requirements of the various species and populations.

Fugitives

Fugitives comprises ephemeral or annual, mostly gregarious and/or short-turf forming species with a high sexual reproductive effort which is not related to seasonal aspects. As they are mostly photophytic and concentrate on highly unpredictable sites that exist only for a short period, they are rare to absent in the rocky cave communities analysed. The very few

Tab. 15 - Characters, life forms and life strategies of taxa [1 frequent within the 1st year; 2 frequent within the 2nd – 4th year; ( ) character of the genus; [ ] data uncertain; a annual; ab axillary bulbils; ac achorous strategy; a/r absent or rare; bl brood leaves; cb caducous branches; cu cushion; D dioicous; de dendroid; Dps pseudodioicous; fa fan; fD flagelliforme diaspores; fl fragmentation of leaves/caducous leaves; Ge gemmae; lr long range dispersal; m mat; M monoicous; Mat autoicous; Mpar paroicous; Msyn synoicous; p pauciennial/pluriennial; pe perennial; pGe protonemal gemmae; Rhg rhizoid gemmae; so solitary,, gregarious plants growing in clumps; sr short range dispersal; sT short turf; Tf fragmentation of the thallus; tT tall turf; tu tubers; w weft; abbreviations of the life strategies: AnS annual shuttle specues; C colonists; F fugitives; PaS short-lived shuttle species; PeS perennial shuttle species; PS perennial stayers; as with high asexual reproductive effort ("vegetative"); m with moderate or rare sexual and asexual reproductive effort ("passive"); pa pauciennial; s with high sexual reproductive effort ("generative")].

Species	Life form	Life cycle	Sexual reproduction	Breeding system	Spores (Ø in µm)	Asexual reproduction	Dispersal strategy	Life strategy
MARCHANTIOPHYTA								
Aytoniaceae								
Mannia androgyna	m	p	2	Mat	60-75	[Tf]	sr,lr–ac	**PaS**
Plagiochasma rupestre	m	p	2	M	70-90	a/r	sr,lr–ac	**PaS**
Cephaloziellaceae								
Cephaloziella divaricata	m	p	2	D	(6-12)	Ge	sr,lr	**Cs,as**
Fossombroniaceae								
Fossombronia pusilla	m	a,p	1	M	38-60	a/r	sr,lr–ac	**AnS**
Fossombronia wondraczekii	m	a,p	1	M	30-56	a/r	sr,lr–ac	**AnS**
Lunulariaceae								
Lunularia cruciata	m	p	a/r	D	18-24	Ge	sr,lr	**Cas**
Pelliaceae								
Pellia endiviifolia	m	p,pe	2	D	40-50 x 70-80	cb,Tf	sr,lr–ac	**PaS**
Porellaceae								
Porella cordaeana	m	p,pe	a/r	D	[>25]	a/r	sr,lr–ac	**PeSm**
Ricciaceae								
Riccia glauca	m	a	1	M	80-96	a/r	sr,lr–ac	**AnS**
Riccia sorocarpa	m	p	1	D	80-120	a/r	sr,lr–ac	**PaS**
Targioniaceae								
Targionia hypophylla	m	p,pe	2	Mat	55-80	a/r	sr,lr–ac	**PaS**
BRYOPHYTA								
Amphidiaceae								
Amphidium mougeotii	sT	p,pe	a/r	D	10-12	a/r	sr,lr	**PSm**
Bartramiaceae								
Bartramia aprica	sT	pe	2	Msyn	26-32	a/r	sr,lr–ac	**PeSs**
Bartramia ithyphylla	sT	pe	2	Msyn	34-40	a/r	sr,lr–ac	**PeSs**
Bartramia pomiformis	tT	pe	2	Mat,Msyn	20-26	a/r	sr,lr	**PSs**
Philonotis arnellii	sT	pe	a/r	D	c .28	cb	sr,lr–ac	**PeSas**
Brachytheciaceae								
Brachytheciastrum collinum	m	pe	2	Mat	8-13	a/r	sr,lr	**PSs**
Brachytheciastrum velutinum	w	pe	2	Mat	13-16	a/r	sr,lr	**PSs**
Brachythecium salebrosum	w	pe	a/r	Mat	12-18	a/r	sr,lr	**PSm**
Homalothecium sericeum	w	pe	a/r	D	11-22	a/r	sr,lr	**PSm**
Kindbergia praelonga	w	pe	a/r	D	16-22	a/r	sr,lr	**PSm**
Microeurhynchium pumilum	w	pe	2	D	12-15	a/r	sr,lr	**PSs**
Oxyrrhynchium hians	w	pe	a/r	D	12-18	a/r	sr,lr	**PSm**

Oxyrrhynchium speciosum	w	pe	1	Mat,Msyn	c. 16	a/r	sr,lr	**PSs**
Rhynchostegiella litorea	w	pe	1	Mat	10-15	a/r	sr,lr	**PSs**
Rhynchostegiella tenella	w	pe	1	Mat	10-15	a/r	sr,lr	**PSs**
Rhynchostegium megapolitanum	m	pe	2	Mat	12-16	a/r	sr,lr	**PSs**
Scleropodium touretii	w	pe	a/r	D	11-18	a/r	sr,lr	**PSm**
Scorpiurium circinatum	w	pe	a/r	D	[< 25]	a/r	sr,lr	**PSm**
Bryaceae								
Bryum donianum	sT	p	a/r	D	12-14	a/r	sr,lr	**Cs**
Gemmabryum caespiticium	sT	p	2	D	10-14	Rhg	sr,lr	**Cs,as**
Gemmabryum dichotomum	sT	p	a/r	D	8-16	Ge,Rhg	sr,lr	**Cas**
Imbribryum alpinum	sT	p	a/r	D	12-14	Rhg	sr,lr	**PSas**
Rosulabryum capillare	sT	p	1	D	9-15	Rhg	sr,lr	**Cs,as**
Rosulabryum torquescens	sT	p	1	D	10-16	Ge,Rhg	sr,lr	**PSs,as**
Distichiaceae								
Distichium capillaceum	sT	p,pe	1	Mpar	17-22	a/r	sr,lr	**PSs**
Ditrichaceae								
Ceratodon purpureus	sT	p	2	D	10-14	a/r	sr,lr	**Cs**
Ephemeraceae								
Ephemerum minutissimum	so,sT	a	1	Dps	50-65	a/r	sr,lr–ac	**AnS**
Fissidentaceae								
Fissidens bryoides	sT	p,pe	1	Mat	10-14	a/r	sr,lr	**PSs**
Fissidens gracilifolius	sT	pe	2	Mat	9-14	a/r	sr,lr	**PSs**
Fissidens viridulus	sT	p,pe	2	Mat,D	8-15	a/r	sr,lr	**PSs**
Funariaceae								
Entosthodon pulchellus	sT	a	2	Mat	20-28	a/r	sr,lr	**F**
Grimmiaceae								
Grimmia trichophylla	cu,sT	pe	a/r	D	10-14	Ge	sr,lr	**PSas**
Hypnaceae								
Hypnum cupressiforme	w	pe	2	D	13-19	a/r	sr,lr	**PSs**
Isopterygiopsis pulchella	w	pe	2	Mat	8-10	Ge	sr,lr	**PSs,as**
Lembophyllaceae								
Isothecium alopecuroides	w	pe	2	D	12-16	a/r	sr,lr	**PSs**
Mniaceae								
Epipterygium tozeri	sT	p	a/r	D	14-20	a/r	sr,lr	**F**
Pohlia annotina	sT	p	a/r	D	14-22	ab	sr,lr	**Cas**
Pohlia cruda	sT	p	2	D	18-24	a/r	sr,lr	**Cs**
Pohlia lutescens	sT	p	a/r	D	[< 25]	ab,Rhg	sr,lr	**Cas**
Pohlia nutans	sT	p	2	Mpar	13-18	a/r	sr,lr	**Cpa**
Neckeraceae								
Thamnobryum alopecurum	fa,de	pe	[2]	D	10-16	a/r	sr,lr	**PSs**
Polytrichaceae								
Polytrichum juniperinum	tT	pe	2	D	8-12	a/r	sr,lr	**PSs**
Pottiaceae								
Didymodon insulanus	sT	p	a/r	D	c. 10	a/r	sr,lr	**Ci**
Didymodon luridus	sT	p	2	D	12-16	a/r	sr,lr	**Cs**
Didymodon vinealis	sT	pe	2	D	10-13	a/r	sr,lr	**Cs**
Eucladium verticillatum	sT	p,pe	[2]	D	12-14	pGe	sr,lr	**PSs,as**
Gymnostomum calcareum	sT	p,pe	a/r	D	8-10	a/r	sr,lr	**PSs**
Syntrichia ruralis	tT	p,pe	2	D	10-12	a/r	sr,lr	**PSs**
Timmiella anomala	sT	pe	2	Mat,D	8-13	a/r	sr,lr	**PSs**
Timmiella barbuloides	sT	pe	2	M	10-13	a/r	sr,lr	**PSs**
Tortella inclinata	sT	pe	a/r	D	10-16	[fD]	sr,lr	**PSas**
Tortella squarrosa	tT	p,pe	a/r	D	10-13	bl	sr,lr	**PSas**
Tortula subulata	sT	p	1	Mat	16-20	a/r	sr,lr	**PSs**
Trichostomum brachydontium	sT,tT	p,pe	a/r	D	14-18	± fl	sr,lr	**PSm**
Weissia condensa	sT	p	2	Mat	14-24	a/r	sr,lr	**Cs**
Weissia controversa	sT	p	2	Mat	16-20	a/r	sr,lr	**Cs**
Rhabdoweisiaceae								
Cynodontium bruntonii	tT	p	2	Mat	15-19	Rhg	sr,lr	**Cs,as**
Rhabdoweisia fugax	sT	p	2	Mat	14-20	a/r	sr,lr	**Cs**
Timmiaceae								
Timmia bavarica	tT	pe	[2]	Mat	10-18	a/r	sr,lr	**PSs**
ANTHOCEROTOPHYTA								
Anthocerotaceae								
Anthoceros agrestis	m	a	1	M	42-62	a/r	sr,lr–ac	**AnS**
Anthoceros punctatus	m	a	1	M	36-48	a/r	sr,lr–ac	**AnS**
Notothyladaceae								
Phaeoceros laevis	m	a	1	D	30-46	tu	sr,lr–ac	**AnS**

examples within the cave communities that follow this life syndrome are *Entosthodon pulchellus* and *Epipterygium tozeri*, both with very low cover values (Tabs. 16, 17).

Colonists

Many investigations have shown that rock communities, especially those of sunny sites, as well as communities growing on anthropogenic sites and as pioneer communities (primary succession stages) are the domain of the colonists life strategy (cf. Kürschner 2004, and summary in Kürschner & Frey 2013). Colonists are characterized by a generally low gametophyte longivety (often pauciennial), an often high asexual reproduction by rhizoid gemmae and leaf gemmae for a rapid establishment, a regular formation of sporophytes and the production of numerous small spores (< 25µm in diameter). Strongly correlated to these characters are the life forms short turf and tall turf, as typical for many acrocarpous mosses. Within pleurocarpous colonists, the life form mat is dominant. Due to the rocky and mostly shady site conditions of most of the cave communities, colonists here are rare (Tabs. 16, 17), with two exceptions: both, the *Rhabdoweisietum fugacis* of the lava caves and the *Weissietum tortilis* of the karst caves are dominated by colonists with a high sexual reproductive effort, reaching MPC values of 53.2 % resp. 70.5 % (Tabs. 16, 17). The numerous small spores facilitate long-range dispersal, a rapid establishment on the thin soil layers in rock crevices and at the same time a wider distribution between the often isolated caves.

Shuttle species

Typical for the shuttle species strategy [*e.g.*, annual shuttle species (AnS); short-lived shuttle species (PaS); perennial shuttle species (PeS)] are large spores (> 25 µm in diameter), decreasing long-range dispersal. Achory and short-range dispersal are promoted, and the *taxa* often remain present in the nearby soil diaspore bank which provides a safeguard for years with unfavourable conditions. At the same time, the species are able to "shuttle" between nearby sites (rock outcrops, fissures, cracks) which prove to be successful for re-establishment. It can be observed in many communities dominated by numerous marchantioids of seasonally dry sites, xeric protosoils, amongst rock boulders and exfoliating knobs, underlying disturbance. It is therefore not surprising, that the *Riccio glaucae-Anthocerotetum crispuli* of the moist and shady, often disturbed soils with strong human influence at the entrance of the Cantarella and the Immacolatella lava caves and the more xerophytic, widely distributed Mediterranean-Macaronesian *Plagiochasmo rupestris-Targionietum hypophyllae* have a high proportion of shuttle species (Tab. 16). The high portion of perennial shuttle species in the *Bartramietum ithyphyllae* of the Ladri and Lamponi caves is founded on the dominance of the character species *Bartramia ithyphylla*. Correlated with this result is a high proportion of short turfs within this community.

Tab. 16 - Life forms, life strategies and reproductive strategies of *taxa* around lava caves (mean percentage cover values in %; for abbreviations see Tab. 15).

		Communities of lava caves								
Associations		**Rhabdoweisietum fugacis**	**Pohlietum crudae timmietosum bavaricae**	**Bartramietum ithyphyllae**	**Pohlio crudae-Amphidietum mougeotii**	**Pohlio annotinae-Brachythecietum velutini**	**Scorpiurietum circinati**	**Rhynchostegielletum algirianae**	**Plagiochasmo rupestris-Targonietum hypophyllae**	**Riccio glaucae-Anthocerotetum crispuli**
Life forms										
solitary plants	so	-	-	-	-	-	-	-	-	< 0.1
cushion	cu	-	-	-	-	0.5	-	-	< 0.1	-
short turf	sT	65.4	31.1	89.3	70.4	37.3	9.6	12.9	21.5	15.3
tall turf	tT	13.9	54.3	-	5.1	0.8	10.6	< 0.1	7.9	-
mat	m	-	6.0	2.2	8.2	-	4.2	1.4	58.1	76.5
weft	w	20.7	4.8	8.5	16.3	61.4	75.6	85.6	12.4	8.1
fan	fa	-	1.9	-	-	-	-	-	-	-
dendroid	de	-	1.9	-	-	-	-	-	-	-
Life strategies										
Annual shuttle species (AnS)		-	-	-	-	-	-	0.7	18.2	74.9
Fugitives (F)		-	-	-	1.3	-	6.5	1.5	2.1	-
Colonists (C)										
Cs,as		3.2	1.6	6.1	2.9	3.1	0.5	< 0.1	1.2	3.9
Cs		53.2	17.6	18.6	11.3	8.1	1.3	-	3.0	-
Cas		-	8.7	9.2	3.6	4.4	-	0.6	-	3.5
Cpa		-	-	-	-	1.1	-	-	-	-
Ci		-	-	-	-	2.9	-	-	-	-
Short-lived shuttle species PaS)		-	-	-	-	-	-	-	40.1	1.6
Perennial shuttle species (PeS)										
PeSs		-	-	57.6	2.0	-	-	-	2.7	-
PeSas		-	-	-	2.8	-	-	-	-	-
PeSm		-	-	0.2	1.7	-	-	-	-	-
Perennial stayers (PS)										
PSs, as		-	-	2.2	0.7	2.1	-	-	-	-
PSs		37.5	67.3	6.1	22.6	68.1	6.7	95.2	1.9	8.0
PSas		-	-	-	0.3	1.1	10.5	-	2.9	-
PSm		6.1	4.8	-	50.8	9.1	74.5	1.9	27.9	8.1
Reproductive strategy										
sexual (generative)		92.3	87.7	86.5	39.0	82.8	14.8	97.5	68.6	86.5
asexual (vegetative)		1.6	9.5	13.3	8.5	8.1	10.7	0.6	3.5	5.4
moderate (passive)		6.1	4.8	0.2	52.5	9.1	74.5	1.9	27.9	8.1

Perennial stayer

By contrast to the perennial shuttle strategy, perennial stayers have smaller spores (< 25µm in diameter), providing chance dispersal (short-range, step-by-step, long range dispersal). In general, the gametophytes

are stress tolerant, high competitors and show a high morphological plasticity (Kürschner & Frey, 2013). Many pleurocarpous mosses follow this life strategy that often dominate late succession stages on long lasting, ecological balanced sites. This strategy is typical for most of the cave associations, with the exceptions given above. A high sexual reproductive effort can be seen in the *Pohlietum crudae* subass. *timmietosum bavaricae* and *Pohlio annotinae-Brachythecietum velutini*, whereas the *Pohlio crudae-Amphidietum mougeotii* and *Scorpiurietum circinati* are dominated by *taxa* with a moderate to low reproductive effort. Within the latter two associations sexual reproduction of most of the key stone species is rare and habitat maintenance by clonal growth (an asexual reproduction mode) can be observed (*e.g.*, *Amphidium mougeotii*, *Homalothecium sericeum*, *Scorpiurium circinatum*, *Scleropodium touretii*). In addition, formation of gemmae (*e.g.*, *Isopterygiopsis pulchella* with cylindrical axillary gemmae) is frequent.

Perennial stayers with high asexual reproductive effort are typically for the *Rhynchostegielletum algirianae*, correlated with the life form weft, indicating shady site conditions with low light, the *Selaginello denticulatae-Timmielletum barbuloidis*, the *Thamnobryo alopecuri-Phyllitidetum scolopendrii* with a high proportion of dendroids (*e.g.*, *Thamnobryum alopecurum*) and fan-forming pteridophytes, and the *Eucladio verticillati-Adiantetum capilli-veneris*. At the same time the latter association shows a high proportion of perennial stayers with both, high sexual and asexual reproductive effort, as one of the character species, *Eucladium verticillatum* forms protonemal gemmae. These specialized propagules increase the potential for initial establishment and localized dispersal, especially in cases where sporophytes are rarely produced (Frey & Kürschner, 2011). Beside the short turfs of *Eucladium*, the community is dominated by the fans of *Adiantum capillis-veneris*. Associate is a vascular plant, *Samolus valerandi*. This species has seeds with a water soluble mucilage seed coat, favouring short-range dispersal.

Perennial stayers with moderate or low sexual and asexual reproduction (PSm) reach higher proportions only in the *Thamnobryo alopecuri-Phyllidetum scolopendrii* (*e.g.*, *Kindbergia praelonga*). As a morphological reaction within this community on the site ecology, a high proportion of wefts, fans, and dendroids occurs (Tab. 17). These life forms perfectly embrace the environmental site conditions (shade) maximizing photosynthetic light capture (Bates, 1998). In addition, the dispersal strategy of the associated vascular plants *Cymbalaria pubescens* and *Parietaria diffusa* in this community are of interest. In *Cymbalaria*, the capsules and seeds are dispersed to suitable microsites (rock fissures) often by recurved fruiting pedicels, growing away from the sunlight (negative phototropic reaction) and hidden the seeds in rock fissures. This can be seen as an achorous tendency evolved convergent with the large spores of the shuttle strategy of bryophytes. The seeds of *Parietaria* are dispersed by ants (myrmechory), providing short- and long-range dispersal.

Tab. 17 - Life forms, life strategies and reproductive strategies of *taxa* around karst caves (mean percentage cover values in %; for abbreviations see Tab. 15); 1) incl. *Selaginella denticulata*; 2) incl. vascular plants; 3) incl. *Phyllitis scolopendtrium*/*P. sagittata*; 4) incl. *Samolus valerandi*; 5) incl. *Adianthum capillis-veneris*; 6) incl. ferns and vascular plants; 7) incl. *Adiantum capillis-veneris* and *Samolus valerandi*.

		Communities of karst caves			
Associations		**Selaginello denticulatae-Timmielletum barbuloidis**	**Weissietum tortilis**	**Thamnobryo alopecuri-Phyllidetum scolopendrii**	**Eucladio-Adiantetum**
Life forms					
solitary plants	so	-	-	-	-
cushion	cu	-	-	-	-
short turf	sT	74.8	93.6	0.4	51.2
tall turf	tT	-	4.2	-	0.6[4)]
mat	m	9.7[1)]	-	4.4[2)]	7.5
weft	w	15.5	2.2	41.8	1.1
fan	fa	-	-	43.7[3)]	39.6[5)]
dendroid	de	-	-	20.4	-
Life strategies					
Annual shuttle species					
(AnS)		-	-	-	-
Fugitives (F)		-	-	-	-
Colonists (C)					
Cs,as		9.1	10.6	-	-
Cs		4.8	70.5	0.4	-
Cas		-	-	-	-
Cpa		-	-	-	-
Ci		-	-	-	-
Short-lived shuttle species					
(PaS)		-	-	3.5	7.5
Perennial shuttle species (PeS)					
PeSs		-	-	-	-
PeSas		-	-	-	-
PeSm		-	-	-	-
Perennial stayers (PS)					
PSs,as		4.2	-	-	51.2
PSs		66.4[1)]	8.3	71.6[6)]	40.7[7)]
PSas		-	-	-	-
PSm		15.5	10.6	24.5	0.6
Reproductive strategy					
sexual (generative)		77.8[1)]	84.1	75.5	73.8
asexual (vegetative)		6.7	5.3	-	25.6
moderate (passive)		15.5	10.6	24.5	0.6

Dispersal strategies

Prevailing dispersal strategy in the communities is the formation of sporophytes with numerous small spores (sexual reproductive effort), indicating long-range dispersal. Caves in the wider vicinity can thus be easily reached by wind-blown spores and a successful establishment of new populations and communities is achieved.

Asexual reproduction is relatively high within the *Eucladio verticillati-Adiantetum capilli-veneris*, due to the formation of protonemal gemmae by one of the key stone species, *Eucladium verticillatum*. Field experiments have shown that establishment from spores in natural habitats is rare (Miles & Longton 1990). Asexual reproduction, either by specialized propagules or clonal growth therefore is important for habitat maintenance of populations and communities.

A high mean percentage cover value (74.5 %, Tab. 16) of moderate or low (passive) reproduction characterizes the *Scorpiurietum circinati*, found on earth-covered, shady rocks which is dominated by many pleurocarous mosses (Tab. 7). Most of these *taxa* are able to tolerate environmental stress and habitat maintenance is achieved by clonal growth.

Shuttle species, with a strong tendency to achory mainly concentrate on two communities: the *Riccio glaucae-Anthocerotetum crispuli* and the *Plagiochasmo rupestris-Targionietum hypophyllae*. Both are dominated by mat forming hornworts and liverworts. These *taxa* are characterized by very large spores (up to 120 µm in diameter, Tab. 15) and achieve their survival and establishment by formation of a diaspore bank in the surrounding of the mother plant ("save vicinity"; see summary in Kürschner & Frey, 2013).

Conclusions

The bryophyte vegetation of the Sicilian caves is represented by 13 communities, of which 4 refer to the karst caves, 9 to the lava caves (including the *Rhynchostegielletum algirianae*, which is infrequently present also in the karst caves). The investigated karst caves are almost exclusively located at low altitude and host associations referred to different phytosociological classes. The *Weissietum tortilis* (class *Barbuletea unguiculatae*) and *Selaginello denticulatae-Timmielletum barbuloidis* (class *Pleurochaeto squarrosae-Abietinelletea abietinae*) were detected at the entrance; in particular, the former community is more subject to the human disturbance, the latter is instead located in more protected sites with a decreasing degree of light (Fig. 1). The strictly basiphytic communities *Eucladio verticillati-Adiantetum capilli-veneris* and *Thamnobryo alopecuri-Phyllitidetum scolopendrii* (class *Adiantetea capilli-veneris*) were found in the liminar zone of some caves located at sea level and 1,030 m of altitude respectively. Both associations are linked to a high edaphic humidity, with *Thamnobryo alopecuri-Phyllitidetum scolopendrii* demanding in high air humidity too.

The lava caves are distributed at different altitudes up to 1,750 m a.s.l. At low altitudes the *Plagiochasmo rupestris-Targionietum hypophyllae* and *Riccio glaucae-Anthocerotetum crispuli* (class *Barbuletea unguiculatae*) were found at the entrance of the caves where the anthropic disturbance is present, while the *Rhynchostegielletum algirianae* (class *Ctenidietea mollusci*) occurs in the liminar and subliminar zones (Fig. 1). The last association, widespread in several caves, is the only association with troglophile character found in the low-altitude caves. The *Scorpiurietum circinati* (class *Pleurochaeto squarrosae-Abietinelletea abietinae*) is also widespread; it is localized at low and medium altitudes where it colonizes the entrance and specially the liminar zone.

The high-altitude lava caves host only mountain communities referred to the class *Cladonio digitatae-Lepidozietea reptantis*. Apart from the scarcely diffused *Rhabdoweisietum fugacis*, belonging to the alliance *Diplophyllion albicantis*, the other surveyed communities are referred to the alliance *Pohlion crudae*, localized in the mountain and high-mountain belts of the Mt. Etna. Among these communities, the *Pohlio annotinae-Brachythecietum velutini* was found only in the liminar zone, while the *Pohlietum crudae* subass. *timmietosum bavaricae*, *Bartramietum ithyphyllae* and *Pohlio crudae-Amphidietum mougeotii* reach also the subliminar zone. The last association, which is widespread, for its clearly troglophile character, represents the most typical association of the high-altitude caves. With decreasing light the *Pohlio crudae-Amphidietum mougeotii* and *Rhynchostegielletum algirianae* are the only communities that survive in the semi-darkness of the subliminal zone.

The life syndromes and adaptive traits within the cave communities are in good accordance with previous studies and repeatedly indicate the response of functional types towards environmental demands (*e.g.*, Kürschner, 2004; Kürschner & Frey, 2013; Puglisi *et al*., 2016). Light supply for the maintenance of photosynthesis is one of the key stone factors for cave communities and it is therefore not surprising that life forms play an important role for the occurrence and distribution of bryophytes growing in caves. Independently from substrate character (lava rock vs. karst rock), in general an increase of mat-, weft-, fan-, or dendroid-forming *taxa* with decreasing light support can be observed, as typical for the liminar and subliminar cave zones. By contrast, short turf-, tall turf or cushion-forming *taxa* dominate the more sun-exposed communities of the entrance and transition to the liminar zone.

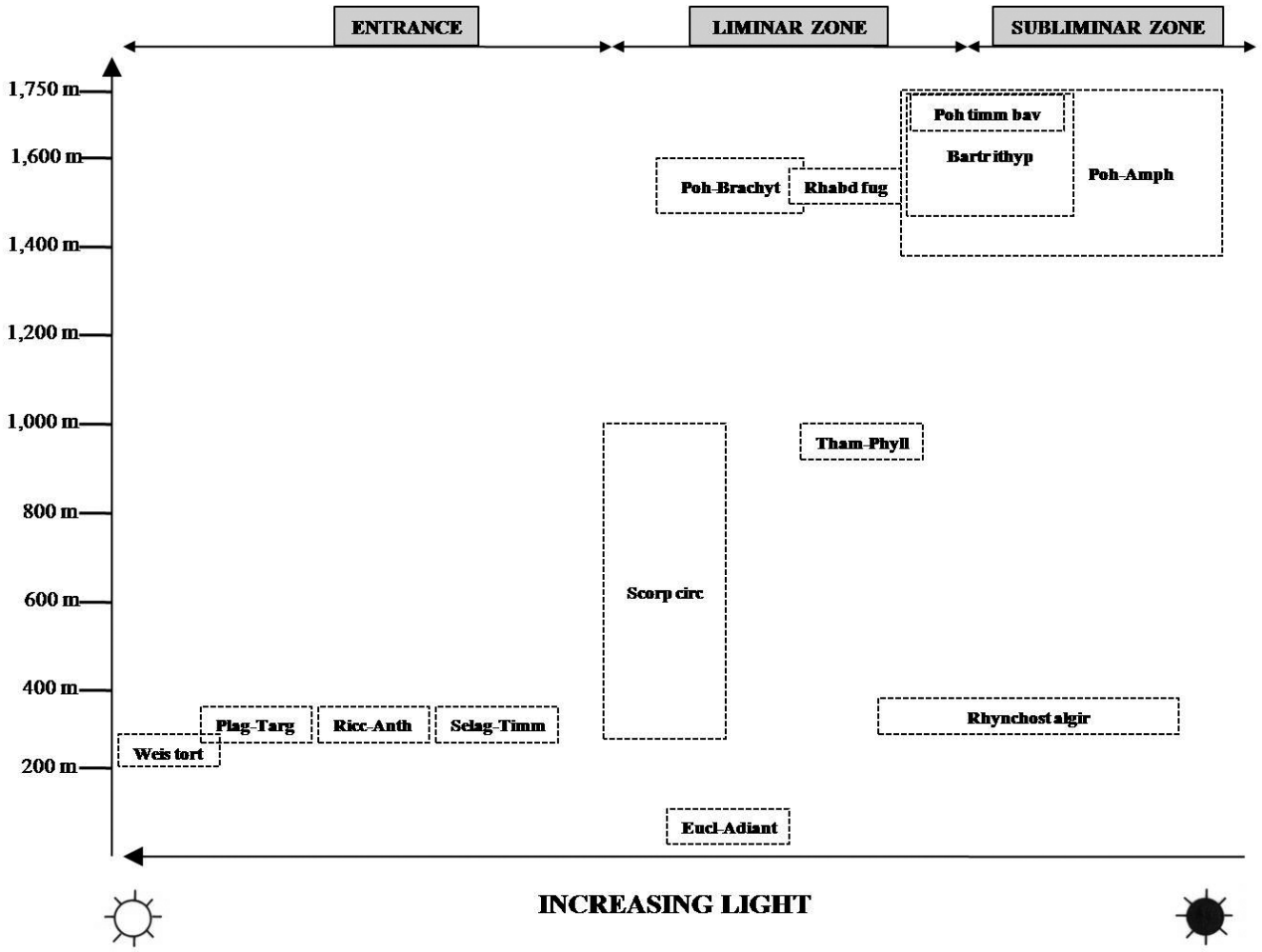

Fig. 1 - Distribution of the bryophyte communities in relation to the altitude and increasing light. Abbreviations: Weiss tort = *Weissietum tortilis*; Plag-Targ = *Plagiochasmo rupestris-Targionietum hypophyllae*; Ricc-Anth = *Riccio glaucae-Anthocerotetum crispuli*; Selag-Timm = *Selaginello denticulatae-Timmielletum barbuloidis*; Scorp circ = *Scorpiurietum circinati*; Eucl-Adiant = *Eucladio verticillati-Adiantetum capilli-veneris*; Rhynch alg = *Rhynchostegielletum algirianae*; Thamn-Phyll = *Thamnobryo alopecuri-Phyllitidetum scolopendrii*; Poh-Brachyt = *Pohlio annotinae-Brachythecietum velutini*; Rhabd fug = *Rhabdoweisietum fugacis*; Poh timm bav = *Pohlietum crudae* subass. *timmietosum bavaricae*; Bartr ithyp = *Bartramietum ithyphyllae*; Poh-Amph = *Pohlio crudae-Amphidietum mougeotii*.

Concerning life strategies, *taxa* following a "generative" perennial stayer strategy clearly dominate the cave communities. The frequent sporophyte production and the release of numerous small spores is a safeguard for most *taxa* and ensure the dispersal and distribution of cave communities in the vicinity of rocky sites.

Colonists, as indicators of first succession stages, pioneer communities or disturbed sites dominate the *Rhabdoweisietum fugacis* and *Weissietum tortilis*, whereas shuttle species (with larges spores and formation of a soil diaspore bank) are - with exception of the *Bartramietum ithyphyllae* - frequent in the communities of the entrance area of the caves (*Plagiochasmo-Targonietum*; *Riccio-Anthocerotetum*) with greater human influence. Apart from that, these strategies are of no significant value for cave communities.

Considering the uniqueness of the cave habitat and the interest deriving from the study of the bryophyte component, this peculiar habitat offered the opportunity to increase the knowledge on the bryoflora and bryovegetation of Sicily. Despite the contributions that have brought the discovery of interesting records (*e.g.*, Privitera & Puglisi, 1997, 2002), it is important that the investigation continues and is extended also to the past in order to highlight the historical value of the local biodiversity, recently re-evaluated as concerns the phanerogamic component (*e.g.*, Pulvirenti *et al*., 2015; Costa *et al*., 2016a, 2016b). These studies, aimed at the discovery and conservation of floristic and vegetational emergencies, represent a valuable tool to enrich Sicilian and Italian naturalistic heritage.

Syntaxonomic scheme

CLADONIO DIGITATAE-LEPIDOZIETEA REPTANTIS Ježek & Vondrácek 1962
DIPLOPHYLLETALIA ALBICANTIS Philippi 1963
Diplophyllion albicantis Philippi 1956
Rhabdoweisietum fugacis Schade ex Neumayr 1971
Pohlion crudae Privitera & Puglisi 1996
Pohlietum crudae Privitera & Puglisi 1996
timmietosum bavaricae Privitera & Puglisi 1996
Bartramietum ithyphyllae v. Krusenstjerna 1945
Pohlio crudae-Amphidietum mougeotii Privitera & Puglisi 1996
Pohlio annotinae-Brachythecietum velutini Privitera & Puglisi 1996

PLEUROCHAETO SQUARROSAE-ABIETINELLETEA ABIETINAE Marstaller 2002
PLEUROCHAETO SQUARROSAE-ABIETINELLETALIA ABIETINAE Marstaller 2002
Homalothecio aurei-Pleurochaetion squarrosae (Ros & Guerra 1987) Marstaller 1993
Selaginello denticulatae-Timmielletum barbuloidis Cano, Ros & Guerra 1997
Scorpiurietum circinati Giacomini 1951

BARBULETEA UNGUICULATAE Mohan 1978
BARBULETALIA UNGUICULATAE v. Hübschmann 1960
Grimaldion fragrantis Šmarda & Hadàc 1944
Weissietum tortilis Neumayr 1971
Phascion cuspidati Waldheim ex v. Krusenstjerna 1945
Riccio glaucae-Anthocerotetum crispuli Koppe ex Neumayr 1971
Mannion androgynae Ros & Guerra 1987
Plagiochasmo rupestris-Targionietum hypophyllae v. Hübschmann 1971

CTENIDIETEA MOLLUSCI v. Hübschmann ex Grgić 1980
CTENIDIETALIA MOLLUSCI Hadàc & Šmarda ex Klika 1948
Fissidention gracilifolii Neumayr 1971 corr. Marstaller 2001
Rhynchostegielletum algirianae Giacomini 1951

ADIANTETEA CAPILLI-VENERIS Br.-Bl. in Br.-Bl., Roussine & Nègre 1952
ADIANTETALIA CAPILLI-VENERIS Br.-Bl. ex Horvatic 1939
Adiantion capilli-veneris Br.-Bl. ex Horvatić 1939
Eucladio verticillati-Adiantetum capilli-veneris Braun-Blanq. ex Horvatić 1934
Polysticho setiferi-Phyllitidion scolopendri Ubaldi ex Ubaldi & Biondi 2014
Thamnobryo alopecuri-Phyllitidetum scolopendrii Brullo, Privitera & Puglisi 1992

References

Bardat J. & Hauguel J.-C., 2002. Synopsis bryosociologique pour la France. Cryptogamie, Bryologie 23 (4): 279-343.

Bates J.W., 1998. Is "life form" a useful concept in bryophyte ecology? Oikos 82: 223-227.

Braun-Blanquet J., 1964. Pflanzensoziologie - Grundzüge der Vegetationskunde, 3. Aufl. - Springer, Berlin.

Brullo S., Privitera M. & Puglisi M., 1992. *Thamnobryo alopecuri-Phyllitidetum scolopendrium*, nuova associazione centro-mediterranea della classe *Adiantetea*. Arch. Bot. Ital. 68 (1/2): 35-43.

Brullo S., Scelsi F., Siracusa G. & Spampinato G., 1996. Caratteristiche bioclimatiche della Sicilia. Giorn. Bot. Ital. 130 (1): 177-185.

Caillet M., Ferrez Y. & Vadam J.-C., 2010. Sur quelques taxons et syntaxons originaux de la flore idanienne. Les Nouvelles Archives de la Flore jurassienne et du nord-est de la France 8: 4-13.

Cortini Pedrotti C., 1978. La florula briologica della Grotta di Monte Cucco (Appennino Umbro-Marchigiano. Lav. Soc. Ital. Biogeogr. 5: 1-11.

Costa R.M.S., Pavone P., Carbonaro R.A. & Pulvirenti S., 2016a. Francesco Cupani's Panphyton Siculum. The rediscovery of a copy with handwritten corrections by his pupil Antonio Bonanno. Acta Botanica Gallica: Botany Letters 163 (2): 203-206.

Costa R.M.S., Pavone P., Caruso R. & Pulvirenti S., 2016b. Diachronic analysis of biodiversity: Study of a herbarium "reviewed" by Francesco Cupani

(1657-1710) at the end of the 17th century. Plant Biosystems 150 (4): 834-845.

Cano M. J., Guerra J.& Ros R. M., 1997. Bryophyte vegetation of Alicante Province (SE Spain). Nova Hedwigia 64 (1-2): 197-230.

During H.J., 1979. Life strategies of bryophytes: a preliminary review. Lindbergia 5: 2-18.

Frey W. & Kürschner H., 1991. Lebensstrategien von terrestrischen Bryophyten in der Judäischen Wüste. Bot. Acta 104: 172-182.

Frey W. & Kürschner H., 2011. Asexual reproduction, habitat colonization and habitat maintenance in bryophytes. Flora 206: 173-184.

Garcia-Zamora P., Ros R.M. & Guerra J., 2000. Vegetación de las sierras de Filabres, Cabrera, Alhamilla y Cabo de Gata (Almería, SE de España). Cryptogamie, Bryol. 21 (1): 19-75.

Giacomini V., 1951. Ricerche sulla flora briologica xerotermica delle Alpi italiane. Vegetatio 3: 1-123.

Gigante D., Attorre F., Venanzoni R., Acosta A.T.R., Agrillo E., Aleffi M., Alessi N., Allegrezza M., Angelini P., Angiolini C., Assini S., Azzella M.M., Bagella S., Biondi E., Bolpagni R., Bonari G., Bracco F., Brullo S., Buffa G., Carli E., Caruso G., Casavecchia S., Casella L., Cerabolini B.E.L., Ciaschetti G., Copiz R., Cutini M., Del Vecchio S., Del Vico E., Di Martino L., Facioni L., Fanelli G., Foggi B., Frattaroli A.R., Galdenzi D., Gangale C., Gasparri R., Genovesi P., Gianguzzi L., Gironi F., Giusso Del Galdo G., Gualmini M., Guarino R., Lasen C., Lastrucci L., Maneli F., Pasta S., Paura B., Perrino E.V., Petraglia A., Pirone G., Poponessi S., Prisco I., Puglisi M., Ravera S., Sburlino G., Sciandrello S., Selvaggi A., Spada F., Spampinato G., Strumia S., Tomaselli M., Tomaselli V., Uzunov D., Viciani D., Villani M., Wagensommer R.P. & Zitti S., 2016. A methodological protocol for Annex I Habitats monitoring: the contribution of Vegetation science. Plant Sociology 53(2): 77-87.

Hübschmann A. v., 1986. Prodromus der Moosgesellschaften Zentraleuropas. Bryophytorum Bibliotheca 32: 1-413.

Krusenstjerna E. von, 1945. Bladmossvegetation och Bladmossflora i Uppsala Trakten. Acta Phytogeographica Suecica 19: 1-267.

Kürschner H., 2004. Life strategies and adaptations in bryophytes from the Near and Middle East. Turk. J. Bot. 28: 73-84.

Kürschner H. & Frey W., 2013. Life strategies in bryophytes - a prime example for the evolution of functional types. Nova Hedwigia 96: 83-116.

Licitra G.M., 1993. Volcanism and caves of Mt. Etna: a brief report. Proceedings of the Third International Symposium on Vulcanospeleology: 93-100.

Lo Giudice R. & Privitera M., 1981. Contributo alla conoscenza della brioflora cavernicola dell'Etna. Arch. Bot. e Biogeogr. Ital. 57 (1-2): 171-192.

Lo Giudice R. & Privitera M., 1983. Sulla brioflora di alcune grotte etnee (Grotta Forcato, Grotta delle Palombe, Grotta dei Ladri). Arch. Bot. e Biogeogr. Ital. 59 (3-4): 137-157.

Lo Giudice R. & Privitera M., 1987. Sulla florula e vegetazione briofitica della Grotta Garrone (M.te Pizzuta) Piana degli Albanesi. Boll. Acc. Gioenia Sci. Nat. 20 (330): 165-170.

Mägdefrau K., 1982. Life forms of Bryophytes. In: Smith A.J.E. (ed.), Bryophyte Ecology: 45-58. Chapman & Hall, London.

Marstaller R., 1988. Bryosoziologische Untersuchungen am Koberfels bei Burgk, Kreis Schleiz 34. Beitrag zur Moosvegetation Thüringens. Hercynia, N.F. 25: 349-372.

Marstaller R., 2006. Moosgesellschaften im Tal der Weißen Elster zwischen Greiz und Wünschendorf (Landkreis Greiz). 112. Beitrag zur Moosvegetation Thüringens. Herzogia 19: 245-289.

Miles C.J. & Longton R.E., 1990. The role of spores in reproduction of mosses. Bot. J. Linnean Soc. 104: 149-173.

Pesaresi S., Galdenzi D., Biondi E. & Casavecchia S., 2014. Bioclimate of Italy: application of the worldwide bioclimatic classification system. Journal of Maps 10: 538-553.

Privitera M. & Puglisi M., 1996. La vegetazione briofitica dell'Etna (Sicilia, Italia). Braun-Blanquetia 19: 1-59.

Privitera M. & Puglisi M., 1997. Noteworthy orophilous mosses from Mount Etna (Sicily). Bocconea 5 (2): 905-911.

Privitera M. & Puglisi M., 1999. Bryophyte vegetation of the badlands from the Aspromonte massif (S Italy). Nova Hedwigia 69 (1/2): 195-210.

Privitera M. & Puglisi M., 2002. Some interesting records for the Italian moss flora. Cryptogamie, Bryologie 23 (2): 171-179.

Privitera M. & Puglisi M., 2004. La vegetazione briofitica della Sicilia. Braun-Blanquetia 34: 129-141.

Privitera M. & Puglisi M., 2009. Outlines of the bryophyte vegetation of the Circeo National Park (central Italy). Cryptogamie, Bryologie 30 (1): 91-107.

Puglisi M., 1997. Bryophyte vegetation on the archaeological sites of Syracuse (SE Sicily). Arch. Geobot. 3 (2): 201-211.

Puglisi M., 2010. Contribution to the bryophyte vegetation of the Pelagian Archipelago: the Island of Linosa (Sicily Channel, Italy). Nova Hedwigia Beihefte 138: 257-282.

Puglisi M., Costa R. & Privitera M., 2012. Bryophyte coastal vegetation of the Cilento and Vallo di Diano National Park (S Italy) as a tool for ecosystem assessment. Plant Biosystems 146 Suppl.: 309-323.

Puglisi M., Kürschner H. & Privitera M., 2013a. Saxi-

colous bryophyte communities of mountain areas of Greece: phytosociology, ecology, life forms and life strategies. Nova Hedwigia 97 (1-2): 159-178.

Puglisi M., Kürschner H. & Privitera M., 2013b. Syntaxonomy, life forms and life strategies of the bryophyte vegetation of the Carnic Alps (NE Italy). Nova Hedwigia 96 (3-4): 325-349.

Puglisi M., Kürschner H. & Privitera M., 2016. The mountain and high-mountain bryophyte vegetation of the Pollino National Park (Southern Italy): syntaxonomy and ecology. Nova Hedwigia 103: 385-413.

Puglisi M. & Privitera M., 2012. A synopsis of the Italian bryophyte vegetation. Cryptogamie, Bryol. 33 (4): 357-382.

Pulvirenti S., Indriolo M.M., Pavone P. & Costa R.M.S., 2015. Study of a pre-Linnaean herbarium attributed to Francesco Cupani (1657-1710). Candollea 70 (1): 67-99.

Rivas-Martínez S., Rivas Sáenz S. & Penas A., 2011. Worldwide Bioclimatic Classification System. Global Geobotany 1: 1-634+4 Maps.

Ros R.M., Jiménez M. & Guerra J., 1990. On the chorology, synecology and syntaxonomy of some terricolous bryophytic communities from northern Africa. Nova Hedwigia 50 (1-2): 65-79.

Ros R.M., Mazimpaka V., Abou-Salama U., Aleffi M., Blockeel T.L., Brugués M., Cros R.M., Dia M.G., Dirkse G.M., Draper I., El-Saadawi W., Erdağ A., Ganeva A., Gabriel R., González-Mancebo J.M., Granger C., Herrnstadt I., Hugonnot V., Khalil K., Kürschner H., Losada-Lima A., Luís L., Mifsud S., Privitera M., Puglisi M., Sabovljević M., Sérgio C., Shabbara H.M., Sim-Sim M., Sotiaux A., Tacchi R., Vanderpoorten A. & Werner O., 2013. Mosses of the Mediterranean, an annotated checklist. Cryptogamie Bryol. 34: 99-283.

Ruggeri R., 2016. Speleological and Speleogenetic Aspects of the Monti di Capo S. Vito (Sicily) - Influenece of Morphotectonic Evolution. Springer, 267 p.

Sabovljević M., 2008. The preliminary survey of the bryophyte vegetation in Serbia. Bulletin of the Natural History Museum 1: 101-112.

Schlüsslmayr G., 2011. Soziologische Moosflora des Mühlviertels (Oberösterreich). Stapfia 94: 1-480.

Schubert R., 2009. Synopsis der Moosgesellschaften Sachsen-Anhalts. Schlechtendalia 18: 1-158.

Söderström L., Hagborg A., Von Konrat M., Bartholomew-Began S., Bell D., Briscoe L., Brown E., Cargill D.C., Costa D.P., Crandall-Stotler B.J., Cooper E.D., Dauphin G., Engel J.J., Feldberg K., Glenny D., Gradstein S. R., He X., Heinrichs J., Hentschel J., Ilkiu-Borges A.L., Katagiri T., Konstantinova N.A., Larraín J., Long D.G., Nebel M., Pócs T., Puche F., Reiner-Drehwald E., Renner M.A.M., Sass-Gyarmati A., Schäfer-Verwimp A., Segarra Moragues J.G., Stotler R.E., Sukkharak P., Thiers B.M., Uribe J., Váňa J., Villarreal J. C, Wigginton M., Zhang L. & Zhu R-L., 2016. World checklist of hornworts and liverworts. PhytoKeys 59: 1-828.

Tosco U., 1957-1958. Contributi alla conoscenza della vegetazione e della flora cavernicola italiana. I. Cenni preliminari sulla vegetazione delle caverne con particolare riguardo alla Briofite. Le Grotte d'Italia, ser. 3° 2: 1-34.

Tosco U., 1968-1969. La vegetazione delle grotte di Castellana (Bari) con cenni di speleo botanica generale. Le Grotte d'Italia, ser. 4° 2: 69-180.

Appendix I: Sporadic species

Tab. 5 - Rel. 1: Kindbergia praelonga 1. Rel. 2: Pohlia lutescens 1, Syntrichia ruralis 1. Rel. 3: Hypnum cupressiforme 1. Rel. 4: Kindbergia praelonga 1. Rel. 19: Ceratodon purpureus 1, Imbribryum alpinum 1.

Tab. 6 - Rel. 1: Didymodon insulanus 2, Brachythecium salebrosum +. Rel. 2 Trichostomum brachydontium 1, Polytrichum juniperinum +. Rel. 3: Didymodon vinealis 2, Scleropodium touretii 1. Rel. 4: Grimmia trichophylla 1, Ptychostomum imbricatulum +. Rel. 6: Syntrichia ruralis +. Rel. 7: Pohlia nutans 1.

Appendix II: Relevés dates and localities

Tab. 2 - Rels. 1-4 correspond to rels. 1-4 in Tab. 16 in Privitera & Puglisi, 1996.

Tab. 3 - Rels. 1-3: Lamponi cave, 2015-05-16 (37°49'04" N, 15°00'40" E); rels. 4-9 correspond to rels. 1-6 in Tab. 11a in Privitera & Puglisi, 1996.

Tab. 4 - Rels. 1-3: Ladri cave, 2014-04-21 (37°46'16" N, 15°04'18" E); rels. 4, 5 correspond to rels. 11,12 in Tab. 12 in Privitera & Puglisi, 1996.

Tab. 5 - Rels. 1-4: Intraleo cave, 2017-05-31 (37°43'08" N, 14°54'33" E); rels. 5, 6: Lamponi cave, 2015-05-16 (37°49'04" N, 15°00'40" E); rels. 7-11 correspond to rels. 6-10 in Tab. 13 in Privitera & Puglisi, 1996; rels. 12-15 correspond to rels. 11-14 in Tab. 13 in Privitera & Puglisi, 1996; rels. 16-18 correspond to rels. 15-17 in Tab. 13 in Privitera & Puglisi, 1996; rel. 19: Case del Vescovo cave, 2015-05-16 (37°41'47" N, 15°01'33" E); rel. 20 corresponds to rel. 18 in Tab. 13 in Privitera & Puglisi, 1996; rel. 21 corresponds to rel. 19 in Tab. 13 in Privitera & Puglisi, 1996; rels. 22, 23 correspond to rels. 20, 21 in Tab. 13 in Privitera & Puglisi, 1996; rel. 24: Faggi cave, 2015-05-16 (37°41'21" N, 15°00'39" E).

Tab. 6 - Rels. 1-4 correspond to rels. 1-4 in Tab. 14 in Privitera & Puglisi, 1996; rels. 5-7 correspond to rels. 15-17 in Tab. 14 in Privitera & Puglisi, 1996.

Tab. 7 - Rel. 1: Immacolatella III cave, 2016-04-03 (37°33'35" N, 15°06'41" E); rel. 2, 3: Micio Conti cave, 2015-03-29 (37°33'38" N, 15°07'01" E); rel.

4: Via S. Gregorio cave, 2016-04-03 (37°33 37" N, 15°07'34" E); rel. 5, 6: Immacolatella I cave, 2016-04-03 (37°33'36" N, 15°06'39" E); rels. 7-9: Del Santo cave, 2014-05-11 (37°42'31" N, 14°52'35" E).

Tab. 8 - Rels. 1-2 Mt Palatimone cave 2015-04-24 (38°05'13" N, 12°42'30" E; rel. 3: Mt Cofano cave 2015-04-24 (38°06'16" N, 12°39'34" E); rel. 4 corresponds to rel. 1 in Tab. 50 in Privitera & Puglisi, 1996; rels. 5-7 correspond to rels. 2-4 in Tab. 50 in Privitera & Puglisi, 1996; rels. 8, 9 correspond to rels. 5, 6 in Tab. 50 in Privitera & Puglisi, 1996; rels. 10-13 correspond to rels. 7-10 in Tab. 50 in Privitera & Puglisi, 1996; rels. 14, 15 correspond to rels. 11, 12 in Tab. 50 in Privitera & Puglisi, 1996; rels. 16, 17: Monello cave, 2016-04-17 (37°01'04" N, 15°09'33" E); rel. 18: Mt Sparagio cave 2015-04-24 (38°02'17" N, 12°47'38" E); rels. 19-21: Micio Conti cave, 2015-03-29 (37°33'38" N, 15°07 01" E).

Tab. 9 - Rels. 1, 2 correspond to rels. 11, 12 in Tab. 26 in Privitera & Puglisi, 1996; rels. 3-6 correspond to rels. 13-16 in Tab. 26 in Privitera & Puglisi, 1996; rels. 7-12 corredspond to rels. 19-24 in Tab. 26 in Privitera & Puglisi, 1996.

Tab. 10 - Rel. 1: Piano Immacolatelle, 2016-04-03 (37°33'40" N, 15°06'37" E); rel. 2: Piano Immacolatelle, 2016-04-03 (37°33'39" N, 15°07'04" E); rels. 3-6 correspond to rels. 1-4 in Tab. 19 in Privitera & Puglisi, 1996.

Tab. 11 - Rels. 1-3: Mt Palatimone cave entrance 2015-04-24 (38°05'13"N, 12°42'30" E).

Tab. 12 - Rels. 1-5: Mt Palatimone cave 2015-04-24 (38°05'13" N, 12°42'30" E).

Tab. 13 - Rel. 1 corresponds to rel. 8 in Tab. 1 in Lo Giudice & Privitera, 1987; rel. 2 corresponds to rel. 10 in Tab. 1 in Lo Giudice & Privitera, 1987; rel. 3 corresponds to rel. 12 in Tab. 1 in Lo Giudice & Privitera, 1987.

Tab. 14 - Rels. 1-4 correspond to rels. 1-4 in Tab. 13 in Puglisi, 1997; rels. 5, 6 correspond to rels. 5, 6 in Tab. 13 in Puglisi, 1997; rels. 7-9: Rope-Makers' Cave, 2016-03-28 (37°04'36" N, 15°16'34" E).