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Outlines of the bryophyte vegetation of the Circeo National Park (central Italy)

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Abstract – The results of a phytosociological study on the bryophyte communities occurring in the Circeo National Park are given. The bryophyte associations surveyed are referred to the bryosociological classes *Cladonio-Lepidozietea reptantis, Barbuletea unguiculatae, Grimmietea anodontis, Frullanio dilatatae-Leucodontetea sciuroidis, Neckeretea complanatae* and to the class of vascular plants but more or less rich in bryophytes *Lemnetea minoris*. The associations *Fossombronio angulosae-Phaeocerotetum bulbiculosi, Eurhynchietum praelongi, Aulacomnietum androgyny, Gyroweisio reflexae-Southbyetum nigrellae*, are reported for the first time in Italy. Moreover, the new subassociations *fissidentetosum taxifolii* of the *Selaginello denticulatae-Timmielletum barbuloides* and *drepanocladetosum adunci* of the *Anomodonto viticulosi-Leucodontetum sciuroidis* are described.

Bryophyte Vegetation/Phytosociology/Circeo National Park/Italy

INTRODUCTION

The Circeo National Park is located along the Tyrrhenian coast at the south of Rome, near the south-western limit of the Latium region, extending for about 8.500 hectares in the province of Latina. The main areas of the Park are: the Circeo promontory, the coastal dune facing the Tyrrhenian Sea and bordering a coastal-lakes system and the coastal-plain forest, the wetland (Fig. 1). The National Park was instituted in 1934 in order to preserve the remains of the old "pontine" marshes from the transformations due to the agricultural practices. In 1977, for the uniqueness of this environment, the Circeo National Park was included in the net of the "reserves of biosphere" of UNESCO.

ENVIRONMENTAL FEATURES

The Circeo promontory reaches 541 m a.s.l.; its southern slope, facing the sea, is called "Quarto caldo" and is constituted by calcareous rocks dating back to the Lower Lias, while in the northern slope, called "Quarto freddo", marl limestone and white "selciferi" limestone of the median Lias are widespread.

The coastal dune extends along the Tyrrhenian coast from the slopes of the promontory and for about 25 km northwards to Capo Portiere. It geologically

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consists in a continuous series of sandy reliefs constituted by grey and yellowish sand of recent formation. Next to the dune there is a wetland consisting in four coastal lakes and areas which are seasonally flooded. The forest, today called "Selva di Circe", is a remain of the old "Selva di Terracina" and extends for 3.000 hectares. It represents the most characteristic plain forest in Italy, with a natural vegetation dominated by the presence of deciduous oaks. This forest remain is located on a large old coastal dune dating back to the lower Palaeolithic, which is formed by yellow-reddish sand that are loose, superficially and more or less cemented sand with manganese and iron pan in the deeper layers. In spite of the hydraulic reclaiming, due to the geo-morphological features of this area, still today peculiar marshy areas called "piscine", i.e. "Piscina della Verdesca" and "Piscina delle Bagnature", seasonally flooded by meteoric waters, occur.

Moreover, the natural environment of the Park is enriched by important archeological finds dating back to the Roman period, as the residential complex of Domitian's Villa.

From the climatic point of view, the park is characterized by a marked summer aridity generally extending from May to August. The southern slope of the promontory is characterized by an upper thermomediterranean bioclimate with an ombrotype verging from lower humid to upper subhumid, while the northern slope of the promontory and the "pontina" plain (including the coastal lakes and the forest) is of the lower mesomediterranean type with upper subhumid ombrotype. (Aleffi *et al*., 1998).

Phanerogamic vegetation

The vegetation of the northern slope of the promontory is represented by the association *Orno-Quercetum ilicis* Horvatic 1958, while the southern one is characterized by a mosaic of high and low maquis, garrigue, and pseudosteppes with *Ampelodesmos mauritanicus* (Poiret) Dur. *et* Sch. The high maquis is referred to the association *Myrto-Pistacietum lentisci* (Molinier 1954 em. O. Bolòs 1962) Rivas Martinez 1975 (Blasi *et al*., 1994). The vegetation of the coastal dune, in its most ancient and consolidate part, is represented by a typical Mediterranean community linked to the coastal sandy habitat and characterized by the occurrence of *Juniperus oxycedrus* L. subsp. *macrocarpa* (S. *et* S.) Ball. (Marinucci *et al*., 1980-81; Blasi & Spada, 1984). The plain forest consists in a deciduous oak wood dominated by *Quercus cerris* L. and *Q. frainetto* Ten. with scattered *Q. robur* L. and *Q. petraea* (Mattuschka) Liebl. stands, referable to the alliance *Quercion frainetto* Horvat 1954 (Padula, 1985). Moreover, in the pools ("Piscina della Verdesca", "Piscina delle Bagnature"), a hygrophytic wood referred to the association *Fraxino-Quercetum roboris* Gellini, Pedrotti *et* Venanzoni 1986 is found (Pedrotti & Gafta, 1996). Finally, within the pool some floating communities of the class *Lemnetea minoris* R. Tx. *ex* O. Bolòs *et* Masclans 1955 occur.

METHODOLOGY

The bryovegetational study has been carried out following the plant sociological methods of Braun-Blanquet (1964). However, the sociability index was not employed, due to the protonematic growth of bryophytes. Altitude, surface and total cover were quoted in each relevé; the cover of each *taxon* has

been reported 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 relevés were made on surfaces of mostly 10-20 dm^2 as homogenous as possible. Syntaxonomic arrangement and nomenclature mostly follow Marstaller's synsystematic proposal (2006), according to the International Code of Phytosociological Nomenclature (Weber *et al.* 2000). The taxa nomenclature follows Ros *et al.* (2007) for hepatics and anthocerotes, and Hill *et al.* (2006) for mosses.

RESULTS AND DISCUSSION

The examination of the phytosociological relevés has allowed finding some terricolous, saxicolous and epiphytic bryophyte communities that will be discussed in detail later.

As regards the terricolous associations, on the northern slope of the Circeo promontory, along the paths in the ambit of *Orno-Quercetum ilicis*, the association *Selaginello denticulatae-Timmielletum barbuloidis* occurred in its typical aspect and its subassociation *fissidentetosum taxifolii*. Instead, on the southern slope of the promontory, in the ambit of the maquis and its stages of degradation, some associations of *Grimaldion fragrantis* could be found, such as *Barbuletum convolutae*, typical of the trodden paths; *Astometum crispi* was found under the shrubs of *Ampelodesmos mauritanicus,* together with *Trichostomo brachydontii-Didymodontetum vinealis*, which is typical of the maquis. In the coastal dune with *Juniperus oxycedrus* subsp. *macrocarpa*, the psammophilous association *Tortello flavovirentis-Trichostometum crispuli* was recorded, and at Braccio Molella, within a *Quercus ilex* wood, *Pogonatetum aloidis* and *Fossombronio angulosae-Phaerocerotetum bulbiculosi* were found, the latter association being more exigent in edaphic humidity. On deep soil and in shadier habitat of the coastal dune and of the plain forest within *Fraxino-Quercetum roboris*, the association *Eurhynchietum praelongi* was found. Finally, on the ruins of the Domitian's Villa the terricolous *Gyroweisio reflexae-Southbyetum nigrellae* occurred. The ruderal and more xerophilous associations also found in this site were: the saxicolous *Tortuletum marginatae* and the terri-saxicolous *Didymodonto vinealis-Tortuletum muralis*, which also occurred on the ruins of "bosco Circeo".

As regards the epiphytic vegetation, in the coastal dune, on the trunks of *Quercus ilex* and *Q. cerris* the associations *Leptodonto smithii-Leucodontetum sciuroidis* and *Syntrichietum laevipilae* were found. The plain flooded forest, the most interesting area from the naturalistic point of view, hosted *Anomodonto viticulosi-Leucodontetum sciuroidis*, occurring in its typical aspect and with the peculiar hygro-hydrophilous subassociation *drepanocladetosum adunci*; moreover, *Aulacomnietum androgyni*, a typical association of rotting impaired bark, was sporadically found.

Description of the communities

Terricolous bryophyte communities

Pogonatetum aloidis v. Krusenstjerna *ex* Philippi 1956 (Tab. 1)

This association was found on taluses on slightly humified soil in little exposed areas at Braccio Molella, the most ancient and consolidate area of the

Table 1. ***Pogonatetum aloidis*** v. Krusenstjerna *ex* Philippi 1956.

Relevé number	1	2	3	4	5	6	7	8	9	10	11
Size of relevé (dm^2)	20	15	20	10	10	20	30	10	10	15	10
Cover (%)	60	40	30	35	35	20	35	45	70	40	85
Inclination (°)	30	40	40	30	30	40	50	30	30	20	20
Exposure	SW	SE	SW	SW	NW	NE	SE	E	SE	S	SE
Number species	7	7	5	6	6	5	6	6	5	8	4
Characteristic species of association											
Pogonatum aloides	3	2	1	2	2	1	2	3	4	1	5
Characteristic species of alliance (***Dicranellion heteromallae***)											
Fissidens bryoides	2	1	+	1	.	1	1	.	1	.	.
Calypogeia fissa	.	.	.	+	1	.	1	1	.	.	.
Fossombronia angulosa	.	+	.	.	.	+	+	1	.	.	.
Kindbergia praelonga	.	.	1	.	.	.	.	.	.	+	1
Epipterygium tozeri	.	.	+	.	.	+	.	.	.	1	.
Characteristic species of order and class (***Diplophylletalia albicantis, Cladonio digitatae-Lepidozietea reptantis***)											
Lophocolea heterophylla	1	1	.	+	1	.	.	+	1	1	1
Hypnum jutlandicum	+	.	1	1	.	1	+	.	.	+	.
Other species											
Plagiomnium affine	2	+	.	1	+	.	1	+	.	.	.
Reboulia hemisphaerica	1	1	.	.	+	.	.	1	+	1	.
Phaeoceros laevis	.	1	.	.	+	.	.	.	+	.	.
Fissidens viridulus	.	.	.	.	.	.	.	.	.	1	1
Cephaloziella dentata	.	.	.	.	.	.	.	.	.	2	.

Relevés origin.- Rel. 1-4: Braccio Molella, 5 m, 41°16'07"N, 13°02'45"E; rel 5-9: Braccio Molella, 15 m, 41°16'29"N, 13°03'29"E; rel. 10, 11: Braccio Molella, 20 m, 41°16'23"N, 13°03'34"E.

dune. On the whole, it is a terricolous, meso-xerophilous, photo-sciophilous, acidophilous association. It is referred to the alliance *Dicranellion heteromallae*, whose characteristic species here quoted are those ones that, for their occurrence and ecology, are of particular significance in the Mediterranean territories. In Italy *Pogonatetum aloidis* is only known from Sicily (Privitera & Puglisi, 2004).

Fossombronio angulosae-Phaeocerotetum bulbiculosi Guerra, Gil *et* Varo 1981 (Tab. 2)

The association occurs on moist, not humified soil with high inclination (60°-80°), on taluses at Braccio Molella along the border of the coastal lake "Lago di Sabaudia" in the ambit of *Quercus ilex* wood. *Fossombronio angulosae-Phaeocerotetum bulbiculosi* replaces *Pogonatetum aloidis* on more moist soil. It is a terricolous, acidophilous, mesophilous, photo-sciophilous association. Up to now this association is known only from the Iberian Peninsula and is here reported for the first time from Italy.

Eurhynchietum praelongi Nörr 1969 (Tab. 3)

It grows on deep, humid and shady soil of both the pools and Braccio Molella in a quite dense phanerogamic vegetation represented by a high maquis dominated by the *Juniperus oxycedrus* L. ssp. *macrocarpa* and *Quercus ilex*. It is

Table 2. ***Fossombronio angulosae-Phaeocerotetum bulbiculosi*** Guerra, Gil *et* Varo 1981.

Relevé number	1	2	3	4	5	6	7	8	9
Size of relevé (dm^2)	10	15	20	20	15	20	10	10	15
Cover (%)	70	40	50	50	45	50	70	65	50
Inclination (°)	70	80	60	50	70	70	60	70	80
Exposure	N	NE	N	N	NW	E	NE	E	N
Number species	6	7	7	6	4	6	7	5	7
Characteristic species of association									
Phymatoceros bulbiculosus	3	2	2	1	2	1	3	2	2
Fossombronia angulosa	2	.	2	2	+	2	+	3	1
Characteristic species of suballiance and alliance (***Fissidenti serrulati-Fossombronienion angulosae, Dicranellion heteromallae***)									
Epipterygium tozeri	1	+	.	+	2	2	.	1	+
Cephaloziella turneri	.	1	1	1	.	+	1	.	+
Scapania compacta	.	1	+	.	.	.	1	+	1
Pogonatum aloides	+	.	1	.	.	.	.	+	.
Characteristic species of order and class (***Diplophylletalia albicantis, Cladonio digitatae-Lepidozietea reptantis***)									
Lophocolea heterophylla	1	+	.	2	1	.	2	.	2
Fissidens taxifolius	.	1	+	.	.	+	+	.	.
Other species									
Plagiomnium affine	.	1	1	.	.	1	+	.	.
Entosthodon attenuatus	1	.	.	+	.	.	.	.	+

Relevés origin.- Rel. 1-4: Braccio Molella, 20 m, 41°16'23"N, 13°03'34"E; rel. 5-9: Braccio Molella, 15 m, 41°16'29"N, 13°03'29"E.

Table 3. ***Eurhynchietum praelongi*** Nörr 1969.

Relevé number	1	2	3	4	5	6	7
Size of relevé (dm^2)	10	15	20	10	20	5	10
Cover (%)	50	70	45	50	70	70	80
Inclination (°)	20	-	30	-	20	-	-
Exposure	N	-	NE	-	NW	-	-
Number species	5	4	5	5	4	5	4
Characteristic species of association							
Kindbergia praelonga	3	4	3	3	4	4	4
Characteristic species of suballiance and alliance (***Brachythecienion velutini, Dicranellion heteromallae***)							
Fissidens taxifolius	2	+	1	1	.	1	2
Calypogeia fissa	.	.	+	.	1	+	.
Ditrichum pallidum	.	1	.	.	.	.	.
Characteristic species of order and class (***Diplophylletalia albicantis, Cladonio digitatae-Lepidozietea reptantis***)							
Lophocolea heterophylla	+	+	.	2	1	1	1
Isothecium myosuroides	1	.	1	+	.	.	.
Other species							
Fissidens dubius	.	.	1	+	.	+	.
Oxyrrhynchium speciosum	.	.	.	.	.	.	1
Plagiomnium elatum	+	.	.	.	+	.	.

Relevés origin. – Rel. 1-3 Border of the pool "Piscina della Verdesca", 35 m, 41°20'30"N, 13°02'10"E; rel. 4, 5: Border of the pool "Piscina delle Bagnature", 30 m, 41°20'33"N, 13°01'55"E; rel. 6,7: Braccio Molella, 10 m, 41°16'24"N, 13°02'59"E.

a terricolous, mesophilous, sciophilous association. This finding represents the first record of this association in Italy.

Barbuletum convolutae Hadàc *et* Šmarda 1944 (Tab. 4)

This association has been observed on shady and slightly humid soil of trodden path at the southern slope of Circeo promontory. It is a terricolous, meso-xerophilous, photo-sciophilous community, growing on nutrient-enriched soil and preferably subject toa strong human impact. The floristic analysis showed the occurrence of *Barbula convoluta* and sporadically *Didymodon acutus*, which are the characteristic species of the association. In Italy the association was only known from Sicily (Privitera & Puglisi, 2004).

Astometum crispi Waldheim 1947 (Tab. 5)

It occurs on the southern slope of the promontory, growing on soil under the shrubs of *Ampelodesmos mauritanicus*. The association, terricolous and photo-sciophilous, is floristically dominated by *Weissia longifolia* and sporadically *Weissia brachycarpa*, with a set of characteristic of higher units. In Italy it was only known from Sicily (Lo Giudice & Galesi, 2001).

Trichostomo brachydontii-Didymodontetum vinealis Privitera *et* Puglisi 1989 (Tab. 6)

This association colonizes dry and quite shady soil covered by the maquis of *Myrto-Lentiscetum* on the southern slope of the promontory. It is a terricolous, xerophilous, sub-sciophilous association. Characteristic species of the association

Table 4. ***Barbuletum convolutae*** Hadàc et Šmarda 1944.

Relevé number	1	2	3	4	5	6	7	8
Size of relevé (dm^2)	20	30	20	15	20	20	30	20
Cover (%)	50	65	50	55	70	75	80	30
Inclination (°)	-	10	-	-	-	-	-	10
Exposure	-	S	-	-	-	-	-	SE
Number species	6	5	5	6	5	6	4	5
Characteristic species of association								
Barbula convoluta	3	4	3	3	4	4	4	2
Didymodon acutus	.	.	+	1	.	.	.	+
Characteristic species of alliance (***Grimaldion fragrantis***)								
Weissia controversa	1	+	.	1	1	1	2	.
Weissia longifolia	.	.	1	.	.	+	.	+
Characteristic species of order and class (***Barbuletalia unguiculatae***, ***Barbuletea unguiculatae***)								
Didymodon luridus	+	+	.	2	1	1	1	.
Barbula unguiculata	1	.	1	+	.	.	.	1
Didymodon vinealis	.	1	.	.	+	.	+	1
Trichostomum brachydontium	+	+	.	.	.	1	.	.
Other species								
Bryum caespiticium	.	.	1	+	.	+	.	.
Tortella flavovirens	+	.	.	.	+	.	.	.

Relevés origin. – Rel. 1-3: Via della Vasca Moresca (S slope of promontory), 105 m, 41°13'44"N, 13°03'01"E; rel. 4, 5: locality Valle Caduta (S slope of promontory), 110 m, 41°14'01"N, 13°02'38"E; rel. 6-8: locality Batteria (S slope of promontory), 50 m, 14°13'47"N, 13°02'44"E.

Table 5. ***Astometum crispi*** Waldheim 1947.

Relevé number	1	2	3	4	5	6
Size of relevé (dm2)	10	7	5	5	3	5
Cover (%)	25	30	25	40	30	40
Inclination (°)	-	10	-	20	-	-
Exposure	-	W	-	SE	-	-
Number species	4	6	5	5	5	5
Characteristic species of association						
Weissia longifolia	1	2	1	2	1	2
Weissia brachycarpa	.	+	1	.	+	.
Characteristic species of alliance, order and class (***Grimaldion fragrantis, Barbuletalia unguiculatae, Barbuletea unguiculatae***)						
Weissia controversa	.	1	+	1	.	+
Barbula unguiculata	1	1	.	2	2	.
Dicranella howei	.	.	1	.	+	2
Barbula convoluta	+	.	.	1	+	.
Didymodon vinealis	.	1	.	+	.	1
Trichostomum crispulum	+	.	.	.	.	1
Other species						
Gyroweisia reflexa	.	+	+	.	.	.

Relevés origin. – Rel. 1-4: locality Valle Caduta (S slope of promontory), 110 m, 41°14'01"N, 13°02'38"E; rel. 5, 6: via della Vasca Moresca (S slope of promontory), 80 m, 41°13'44"N, 13°02'55"E.

Table 6. ***Trichostomo brachydontio-Didymodontetum vinealis*** Privitera et Puglisi 1989.

Relevé number	1	2	3	4	5	6	7
Size of relevé (dm^2)	15	10	5	10	5	15	10
Cover (%)	50	30	65	50	80	60	50
Inclination (°)	-	-	10	-	10	-	20
Exposure	-	-	SE	-	S	-	S
Number species	6	6	5	5	6	6	6
Characteristic species of association							
Trichostomum brachydontium	3	2	3	3	4	3	3
Didymodon vinealis	.	+	1	1	.	1	+
Characteristic species of alliance (***Grimaldion fragrantis***)							
Weissia controversa	1	.	.	.	2	+	1
Characteristic species of order and class (***Barbuletalia unguiculatae, Barbuletea unguiculatae***)							
Didymodon luridus	2	.	.	+	1	2	+
Pleurochaete squarrosa	.	1	.	.	+	1	1
Trichostomum crispulum	1	.	1	1	+	.	.
Didymodon acutus	+	1	2	.	.	1	.
Barbula unguiculata	.	1	2	2	.	.	.
Other species							
Tortula muralis	1	1	.	.	1	.	+

Relevés origin. – Rel. 1, 2: via della Vasca Moresca (S slope of promontory), 140 m, 41°13'44"N, 13°01'12"E; rel. 3-6: locality Crocette (S slope of promontory), 260 m, 41°13'55"N, 13°04'21"E.

are *Didymodon vinealis* and *Trichostomum brachydontium*, the latter being considered a cognate species of the maquis. In Italy the association is known from Sicily and Southern mainland Italy (Privitera & Puglisi, 2004; Puglisi, 1995).

Gyroweisio reflexae-Southbyetum nigrellae Guerra *et* Gil 1982 *ex* Marstaller 2006 (Tab. 7)

This association was described on humid protosoil of shady artificial walls at Domitian's Villa. It is as terricolus, sciophilous, basiphilous, mesophilous to meso-hygrophilous community, and is here signaled for the first time for Italy.

Tortello flavovirentis-Trichostometum crispuli Brullo, Lo Giudice *et* Privitera 1991 (Tab. 8)

This association occurs on the coastal dune (Duna di Paola), on shady and consolidated soil covered by the vegetation with *Juniperus oxycedrus* ssp. *macrocarpa*. In Italy it was known from Sicily, Basilicata and Sardinia (Brullo *et al*., 1991; Privitera & Puglisi, 2004).

Selaginello denticulatae-Timmielletum barbuloides Cano, Guerra *et* Ros 1997 (Tab. 9)

This association colonizes quite humid soil along the paths on the northern slope of the promontory. Ecologically, it is a terricolous, photo-sciophilous to sciophilous, mesophilous community. The association is referred to the alliance *Homalothecio aurei-Pleurochaetion squarrosae*. Marstaller (2006) transfers this alliance to the order *Pleurochaeto squarrosae-Abietinelletalia abietinae* Marstaller 2002 and the class *Pleurochaeto squarrosae-Abietinelletea abietinae* Marstaller 2002. For the occurrence of a set of characteristic species of *Barbuletalia unguiculatae* and *Barbuletea unguiculatae*, we prefer to maintain the

Table 7. ***Gyroweisio reflexae-Southbyetum nigrellae*** Guerra et Gil 1982 *ex* Marstaller 2006.

Relevé number	1	2	3	4	5
Size of relevé (dm^2)	5	5	7	10	5
Cover (%)	30	45	45	50	40
Inclination (°)	20	10	20	20	30
Exposure	N	NE	NE	S	SE
Number species	7	5	6	6	4
Characteristic species of association					
Gyroweisia reflexa	1	2	2	3	2
Gyroweisia tenuis	2	.	+	+	.
Characteristic species of alliance (***Cephaloziello baumgartneri-Southbyion nigrellae***)					
Southbya nigrella	1	2	1	+	2
Cephaloziella baumgartneri	+	.	.	1	1
Characteristic species of order and class (***Barbuletalia unguiculatae, Barbuletea unguiculatae***)					
Weissia controversa	1	.	1	1	+
Barbula unguiculata	1	1	2	.	.
Fissidens viridulus	.	1	+	1	.
Other species					
Bryum argenteum	+	1	.	.	.

Relevés origin. – Rel. 1-5: Domitian's Villa, 5 m, 41°16'06"N, 13°02'22"E.

Table 8. ***Tortello flavovirentis-Trichostometum crispuli*** Brullo, Lo Giudice et Privitera 1991.

Relevé number	1	2	3	4	5	6
Size of relevé (dm^2)	10	20	15	10	10	7
Cover (%)	30	45	40	30	65	50
Inclination (°)	10	-	-	-	-	-
Exposure	NW	-	-	-	-	-
Number species	5	6	5	6	4	6
Characteristic species of association						
Trichostomum crispulum	2	3	3	2	3	3
Characteristic species of alliance (***Tortellion flavovirentis***)						
Tortella flavovirens	1	+	1	1	2	1
Trichostomum brachydontium	.	1	+	.	.	+
Characteristic species of order and class (***Barbuletalia unguiculatae, Barbuletea unguiculatae***)						
Didymodon luridus	1	1	.	1	2	1
Pleurochaete squarrosa	+	.	1	+	1	.
Barbula unguiculata	.	1	+	1	.	.
Other species						
Bryum caespiticium	.	+	.	+	.	1
Bryum capillare	1	.	.	.	.	+

Relevés origin. – Rel. 1-6: Duna di Paola, 5 m, 41°16'15"N, 13°01'47"E.

Table 9. ***Selaginello denticulatae-Timmielletum barbuloidis*** Cano, Guerra et Ros 1997.

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13
Size of relevé (dm^2)	20	30	30	15	15	10	10	15	20	20	15	10	10
Cover (%)	90	65	65	30	45	80	30	90	50	100	90	85	80
Inclination (°)	-	20	20	20	15	-	-	10	15	45	45	30	45
Exposure	-	N	NE	E	SE	-	-	S	E	SE	NW	NE	N
Number species	7	6	7	3	6	5	7	6	8	7	7	7	6
Characteristic species of association													
Timmiella barbuloides	1	.	2	1	2	.	2	1	2	1	+	+	.
Selaginella denticulata	3	2	1	2	+	2	.	3	2	3	2	2	4
Subass. Fissidens taxifolius	.	.	.	.	.	.	.	.	.	3	4	4	3
Characteristic species of alliance (***Homalothecio aurei-Pleurochaetion squarrosae***)													
Pleurochaete squarrosa	4	3	3	2	1	4	.	4	1	.	.	+	.
Scleropodium touretii	.	2	1	.	1	.	1	2	.	4	2	1	1
Characteristic species of order and class (***Barbuletalia unguiculatae, Barbuletea unguiculatae***)													
Didymodon fallax	+	1	1	.	.	1	1	.	1	.	.	.	1
Trichostomum brachydontium	1	.	.	.	.	1	.	+	.	+	1	.	+
Fissidens viridulus	.	.	+	.	1	.	1	1	.	1	.	.	.
Trichostomum crispulum	1	.			.	.	+	.	1	.	1	1	.
Didymodon vinealis	.	.	1		.	+	.	.	+	.	.	.	.
Other species													
Scorpiurium circinatum	2	+	.	.	2	.	+	.	1	.	.	+	.
Lunularia cruciata	.	1	.	.	.	.	.	.	+	1	+	.	1

Relevés 1-9: subass. *typicum*; relevés 10-13: subass. *fissidentetosum taxifolii*
Relevés origin. – Rel. 1-5: Mezzomonte (N slope of promontory), 60 m, 41°14'73"N, 13°03'22"E; rel. 6-9: presso Torre Paola (N slope of promontory), 40 m, 14°14'51"N, 13°02'07"E; rel. 10-13: locality Quarto Freddo, tra Oliveto e Torre Paola (N slope of promontory), 140 m, 41°14'29"N, 13°03'04"E.

alliance in these latter syntaxa. In Italy the association is only known from a few localities of Southern mainland Italy (Privitera & Puglisi, 1999).
Variability: *fissidentetosum taxifolii* **subass. nov**. (Tab. 9, *holosyntypus*: rel.12).
On soil of taluses protected by a dense phanerogamic vegetation, which is represented by the association *Orno-Quercetum ilicis*. In conditions of greater shadow and moisture, it is possible to differentiate a sub-association characterized by the abundant occurrence of *Fissidens taxifolius*.

Terri-saxicolous and Saxicolous bryophyte communities

Didymodonto vinealis-Tortuletum muralis Privitera *et* Puglisi 1996 (Tab. 10)

The association was found in open, sunny places, on the ruins of the ancient Domitian's Villa and on limestone outcrops with accumulated soil on the southern slope of the promontory. It is a terri-saxicolous, photophilous, xerophilous association, widespread in anthropic areas. In Italy it has been reported from Sicily and Southern mainland Italy (Privitera & Puglisi, 1999, 2004).

Tortuletum marginatae v. Hübschmann 1973 (Tab. 11)

This association was found on the vertical artificial walls of the ruins of the Domitian's Villa. It is a saxicolous, basophilous, photo-sciophilous, meso-xerophilous community with an urbaniphilous character. In Italy *Tortuletum marginatae* was known from Sicily (Privitera & Puglisi, 2004).

Table 10. ***Didymodonto vinealis-Tortuletum muralis*** Privitera *et* Puglisi 1996.

Relevé number	1	2	3	4	5	6	7	8	9	10	11
Size of relevé (dm^2)	5	5	5	4	3	5	10	5	4	5	10
Cover (%)	50	30	60	85	35	40	50	30	80	55	45
Inclination (°)	-	-	-	-	-	-	10	-	-	10	-
Exposure	-	-	-	-	-	-	S	-	-	SW	-
Number species	7	5	7	6	5	5	5	6	4	5	6
Characteristic species of association											
D Tortula muralis	3	2	3	4	2	3	3	2	4	3	3
Characteristic species of alliance, order and class (***Grimaldion fragrantis, Barbuletalia unguiculatae, Barbuletea unguiculatae***)											
Didymodon vinealis	2	1	.	+	1	+	+	1	.	2	+
Didymodon luridus	+	.	1	2	.	1	.	+	+	.	.
Weissia controversa	.	1	+	.	.	.	1	.	1	+	1
Barbula unguiculata	.	.	2	1	+	+	.	1	.	1	.
Dicranella howei	.	.	.	.	.	.	1	1	2	.	1
Didymodon fallax	1	+	.	.	1	.	.	.	.	.	.
Trichostomum brachydontium	.	.	.	+		1	.	.	.	.	.
Trichostomum crispulum	.	.	1	.	.	.	.	.	.	.	+
Barbula convoluta	+	.	1	.	.	.	.	.	.	.	.
Other species											
Bryum argenteum	1	.	1		2	.	.	.	.	.	1
Bryum caespiticium	+	1	.	2	.	.	.	.	.	1	.
Tortella nitida	.	.	.	.	.	.	1	+	.	.	.

Relevés origin. – Rel. 1-5: Domitian's Villa, 5 m, 41°16'06"N, 13°02'22"E; rel. 6-8: ruins "bosco Circeo" (S slope of promontory), 155 m, 41°14'187"N, 13°03'41"E; rel. 9-11: via della Vasca Moresca (S slope of promontory), 120 m, 41°13'45"N, 13°03'04"E.

Table 11. ***Tortuletum marginatae*** v. Hübschmann 1973.

Relevé number	1	2	3
Size of relevé (dm^2)	10	10	15
Cover (%)	40	40	30
Inclination (°)	70	90	90
Exposure	N	NE	E
Number species	4	4	5
Characteristic species of association			
Tortula marginata	2	3	2
Charcateristic species of alliance, order and class (***Grimmion tergestinae, Grimmietalia anodontis, Grimmietea anodontis***)			
Tortula muralis	1	1	+
Didymodon rigidulus	.	+	1
Other species			
Bryum caespiticium	2	.	+
Bryum argenteum	+	1	.
Gyroweisia tenuis	.	.	+

Relevés origin. – Rel. 1-4: Domitian's Villa, 5 m, 41°16'06"N, 13°02'22"E.

Epiphytic bryophyte communities

Syntrichietum laevipilae Ochsner 1928 (Tab. 12)

This association has been described on the middle and middle-higher parts of the trunks of *Quercus ilex* L. at the northern slope of the promontory. It is a corticicolus, thermophilous, xerophilous association, found preferably on neutral or acidic phorophytes, in open woods with a low anthropic impact. In Italy

Table 12. ***Syntrichietum laevipilae*** Ochsner 1928.

Relevé number	1	2	3	4
Size of relevé (dm^2)	5	10	5	5
Cover (%)	30	30	45	40
Exposure	S	SE	S	W
Phorophyte	Qi	Qi	Qi	Qi
Number species				
Characteristic species of association				
Syntrichia laevipila	2	1	3	2
Characteristic species of alliance, order and class (***Syntrichion laevipilae***, ***Orthotrichetalia***, ***Frullanio dilatatae-Leucodontetea sciuroidis***)				
Orthotrichum diaphanum	+	1	.	1
Zygodon rupestris	.	1	.	2
Frullania dilatata	1	.	1	.
Orthotrichum affine	.	+	1	.
Other species				
Bryum capillare	+	.	.	+
Homalothecium sericeum	.	.	1	.

Phorophytes: Qi: *Quercus ilex*.
Relevés origin. – Rel. 1-4: locality Mezzomonte (N slope of promontory), 60 m, 41°14'73"N, 13°03'22"E.

it is known to be widespread in northern Italy and Sicily (Gerdol, 1982; Philippi, 1983; Lo Giudice, 1991; Privitera & Puglisi, 2006).

Leptodonto smithii-Leucodontetum sciuroidis Privitera *et* Puglisi 1996 (Tab. 13)

This association occurs on the basal to middle part of the trunks of *Quercus cerris* at Colle Campora, and on *Q. ilex* on northern slope of the promontory in quite open wood. It is a corticolous, photo-sciophilous, meso-xerophilous community, preferring tree boles in open sites with a low anthropic impact. The association occurs in more mesic conditions than *Syntrichietum laevipilae*. In Italy it was known from Sicily, Umbria and Sardinia (Privitera & Puglisi, 1996).

Anomodonto viticulosi-Leucodontetum sciuroidis Wiúniewski 1930 (Tab. 14)

This association is common on the middle trunk of *Quercus cerris*, *Q. robur*, *Fraxinus oxycarpa*, on the border of the pools, where the phanerogamic vegetation is dense. It behaves as a corticolous, sciophilous, markedly mesophilous community. The characteristic species of the association, *Neckera complanata*, is accompanied by some characteristics of higher units, as well as by some transgressive species of the class *Frullanio dilatatae-Leucodontetea sciuroidis*, showing here the epiphytic character of the association. The syntaxon was known in Italy from the regions Trentino Alto Adige, Friuli Venezia Giulia and Sicily (Privitera & Puglisi, 2004).

Table 13. ***Leptodonto smithii-Leucodontetum sciuroidis*** Privitera et Puglisi 1996.

Relevé number	1	2	3	4	5	6	7	8	9	10	11
Size of relevé (dm^2)	10	20	15	10	10	15	5	10	20	15	15
Cover (%)	80	40	30	50	30	30	60	55	50	75	70
Exposure	N	NE	E	W	E	SE	SW	SE	SW	S	E
Phorophytes	Qc	Qc	Qc	Qc	Qc	Qc	Qc	Qi	Qi	Qi	Qi
Number species	5	3	4	5	3	4	8	5	7	6	5
Characteristic species of association											
Leucodon sciuroides	4	3	1	2	2	2	3	3	2	4	3
Characteristic species of alliance (***Fabronion pusillae***)											
Leptodon smithii	+	.	1	.	.	1	+	+	1	1	2
Pterogonium gracile	.	.	2	2	.	+	+	.	+	.	.
Characteristic species of order and class (***Orthotrichetalia, Frullanio dilatatae-Leucodontetea sciuroidis***)											
Zygodon rupestris	1	1	+	2	.	+	+	1	.	1	.
Frullania dilatata	.	.	.	.	1	.	+	+	.	+	1
Radula complanata	.	.	.	.	1	.	+	1	1	1	.
Orthotrichum diaphanum	.	.	.	.	.	1	+	.	2	.	1
Other species											
Hypnum cupressiforme var. cupressiforme	1	+	.	1	.	.	+	1	.	1	.
Homalothecium sericeum	2	.	.	1	.	.	.	.	+	.	.
Scorpiurium circinatum	.	.	.	.	.	.	+	.	1	.	1
Plagiomnium elatum	.	.	1	.	.	.	.	.	.	.	.

Phorophyte: Qc *Quercus cerris*, Qi *Quercus ilex*.
Relevés origin. – Rel. 1-7: Colle Campora, 25 m, 41°21'09"N, 13°00'04"E; ril 8-11: locality Quarto Freddo, tra Oliveto e Torre Paola (N slope of promontory), 140 m, 41°14'29"N, 13°03'04"E.

Table 14. ***Anomodonto viticulosi-Leucodontetum sciuroidis*** Wiúniewski 1930.

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Size of relevé (dm^2)	10	15	20	10	5	10	10	5	10	10	10	20	20	10	5	10
Cover (%)	60	30	40	60	45	50	75	30	35	50	70	35	75	70	50	85
Exposure	N	N	NE	E	E	W	NW	E	SE	NW	SW	N	NE	N	NW	NE
Phorophytes	Qc	Qc	Fo	Fo	Fo	Fo	Fo	Fo	Fo	Qr	Qr	Qr	Qc	Qf	Qr	Qc
Number species	7	6	6	7	5	7	5	5	4	6	5	7	5	6	6	8
Characteristic species of association																
Neckera complanata	1	1	+	2	2	+	4	1	2	1	3	1	+	1	+	+
Subass.																
Drepanocladus aduncus	.	.	.	.	.	.	.	.	.	.	.	2	4	4	3	4
Charcateristic species of alliance, order and class (***Neckerion complanatae***, ***Neckeretalia complanatae***, ***Neckeretea complanatae***)																
Homalothecium sericeum	3	+	2	1	2	.	1	.	1	1	+	.	1	+	1	.
Metzgeria furcata	.	.	.	+	.	.	.	1	.	3	1	1	.	1	+	2
Zygodon rupestris (D)	2	.	1	.	1	1	.	.	.	.	.	+	.	.	.	.
Porella platyphylla	.	.	1	.	.	1	.	+	.	.	.	.	.	.	.	.
Transgressive of the class ***Frullanio dilatatae-Leucodontetea sciuroidis***																
Radula complanata	1	1	.	2	.	2	1	.	.	1	2	1	.	.	.	+
Frullania dilatata	.	.	.	+	1	2	1	.	.	.	.	+	.	.	1	+
Frullania tamarisci	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1
Leptodon smithii	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	
Orthotrichum affine	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Syntrichia laevipila	.	.	.	.	.	+	.	.	.	.		.	.	.	.	.
Other species																
Kindbergia praelonga	+	1	.	.	.	.	1	2	2	1	.	+	1	.	1	+
Hypnum cupressiforme var. *cupressiforme*	1	.	2	1	1	.	.	1	1	.	.	.	.	1	.	.
Hypnum cupressiforme var. *filiforme*	.	.	+	2	.	2	.	.	.	1	2	.	.	.	.	.
Hypnum cupressiforme var. *resupinatum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Dialytrichia mucronata	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.

Phorophytes: Qc *Quercus cerris*; Qr *Quercus robur*; Qf *Quercus frainetto;* Fo *Fraxinus oxycarpa*.
Relevés 1-11: subass. *typicum*; rel. 12-16: subass. *drepanocladetosum adunci*.
Relevés origin. – Rel. 1, 2, 15, 16: pool "Piscina delle Bagnature", 30 m, 41°20'33"N, 13°01'55"E; ril. 3-11, 12-14: pool "Piscina della Verdesca", 35 m, 41°20'30"N, 13°02'10"E.

Variability: ***drepanocladetosum adunci*** **subass. nov**. (Tab. 14, ***holosyntypus***: rel. 14). From the base up to middle trunk of *Quercus robur*, *Q. cerris* and *Q. frainetto*, occurring within the pools, it is possible to find a sub-association characterized by *Drepanocladus aduncus*, species typically growing in or by pools, marshes, ponds. This is a peculiar hygrophilous and hygro-hydrophilous bryophyte vegetation colonizing the part of the trunks just emerging from the water surface.

Aulacomnietum androgyni v. Krusenstjerna 1945 (Tab. 15)

This particular epiphytic association was found sporadically on the rotting, impaired bark of *Quercus cerris* along the borders of the "Piscina della Verdesca" in the ambit of the *Fraxino-Quercetum roboris*. It behaved as a

Table 15. ***Aulacomnietum androgyni*** v. Krusenstjerna 1945.

Relevé number	1	2	3
Size of relevé (dm^2)	5	10	5
Cover (%)	80	30	70
Exposure	NW	NE	E
Phorophyte	Qc	Qc	Qc
Number species	3	4	3
Characteristic species of association			
Aulacomnium androgynum	4	2	4
Characteristic species of order and class (***Cladonio digitatae-Lepidozietalia reptantis, Cladonio digitatae-Lepidozietea reptantis***)			
Lophocolea heterophylla	1	.	1
Hypnum jutlandicum	.	1	.
Other species			
Hypnum cupressiforme	2	+	1
Hypnum cupressiforme var. resupinatum	.	1	.
Phorophyte: Qc *Quercus cerris*			
Relevés origin. – Rel. 1-3 borders of the pool "Piscina della Verdesca", 35 m, 41°20'30"N, 13°02'10"E.			

corticolous, meso-hygrophilous association. Floristically poor, it is characterized by *Aulacomnium androgynum* accompanied by few characteristic species of the class *Cladonio digitatae-Lepidozietea reptantis*. *Aulacomnietum androgyni* is here reported for the first time from Italy.

Aquatic bryophyte communities

Ricciocarpetum natantis Segal 1963 em. Tüxen 1974 (Tab. 16)

As for the hydrophilous vegetation, the occurrence of *Ricciocarpetum natantis* that had been previously reported by Blasi & Spada (1984) and Scoppola *et al*. (1988), is confirmed. The association, floristically very poor, was found floating within the pool Piscina della Verdesca, where the water eutrophism is facilitated by litter accumulation from the *Fraxinus* canopy (Scoppola *et al*., 1988). *Ricciocarpetum natantis* shows a low tolerance to pollution, and behaves as a

Table 16. *Ricciocarpetum natantis* Segal 1963 *em.* Tüxen 1974.

Relevé number	1	2
Size of relevé (dm^2)	20	10
Cover (%)	80	70
Number species	3	3
Characteristic species of association		
Ricciocarpos natans (L.) Corda	5	4
Characteristic species of higher units		
Lemna minor L.	.	1
Lemna trisulca L.	1	.
Other species		
Drepanocladus aduncus	+	1
Relevés origin. – Rel. 1, 2: pool "Piscina della Verdesca", 35 m, 41°20'30"N, 13°02'10"E.		

sensitive community, which confirms the good state of "health" of this site. In Italy, it was known from Lazio, Umbria and Trentino Alto Adige (Pedrotti, 1979; Scoppola, 1982; Scoppola *et al*., 1988; Prosser & Sarzo, 2003).

CONCLUSIONS

The results of this study have pointed out that the great bryophyte vegetation diversity of the Circeo National Park reflects the multiplicity and diversity of habitats, part of a mosaic of ecosystems with a high landscape value. This investigation provides *data* showing the situation of a Mediterranean area with many natural communities and some aspects suggesting a certain anthropic disturbance mostly localized to the archeological ruins of the Domitian's Villa and "bosco Circeo", such as *Tortuletum marginatae*, *Didymodonto vinealis-Tortuletum muralis*, *Gyroweisio reflexae-Southbyetum nigrellae*. Among the natural bryophyte vegetation, represented by *Pogonatetum aloidis*, *Fossombronio angulosae-Phaeocerotetum bulbiculosi*, *Syntrichietum laevipilae*, *Leptodonto smithii-Leucodontetum sciuroidis*, we emphasize also the occurrence of very interesting and valuable communities in the pools of the costal-plain forest, sites where the access is not allowed except for study purposes. In particular, these communities are: *Eurhynchietum praelongi*, *Aulacomnietum androgyni* and *Anomodonto viticulosi-Leucodontetum sciuroidis*, in its typical aspect and its new subassociation *drepanocladetosum adunci*. All these communities represent, similarly to the coastal-plain forest, examples of vegetation that are unique in Italy. The finding in the same area of the rare association *Ricciocarpetum natantis* also confirms the naturalistic interest of these sites.

The occurrence of many natural associations testifies the great importance of the Circeo National Park as refuge and safeguard area for these associations of great naturalistic value.

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Annex 1. Syntaxonomical scheme

Cl. Cladonio digitatae-Lepidozietea reptantis Ježek *et* Vondrácek 1962
- O. Diplophylletalia albicantis Philippi 1963
  - Al. Dicranellion heteromallae Philippi 1963
    - *Pogonatetum aloidis* v. Krusenstjerna *ex* Philippi 1956
    - *Fossombronio angulosae-Phaeocerotetum bulbiculosi* Guerra, Gil *et* Varo 1981
    - *Eurhynchietum praelongi* Nörr 1969
- O. Cladonio digitatae-Lepidozietalia reptantis Ježek *et* Vondrácek 1962
  - Al. Tetraphidion pellucidae v. Krusenstjerna 1945
    - *Aulacomnietum androgyni* v. Krusenstjerna 1945

Cl. Barbuletea unguiculatae Mohan 1978
O. Barbuletalia unguiculatae v. Hübschmann 1960
Al. Grimaldion fragrantis Šmarda *et* Hadàc 1944
Barbuletum convolutae Hadàc *et* Šmarda 1944
Didymodonto vinealis-Tortuletum muralis Privitera *et* Puglisi 1996
Astometum crispi Waldheim 1947
Trichostomo brachydontii-Didymodontetum vinealis Privitera *et* Puglisi 1989
Al. Cephaloziello baumgartneri-Southbyion nigrellae Guerra *et* Gil 1982
Gyroweisio reflexae-Southbyetum nigrellae Guerra *et* Gil 1982 *ex* Marstaller 2006
Al. Tortellion flavovirentis Guerra *ex* Guerra *et* Puche 1984
Tortello flavovirentis-Trichostometum crispuli Brullo, Lo Giudice *et* Privitera 1991
Al. Homalothecio aurei-Pleurochaetion squarrosae (Ros *et* Guerra 1987) Marstaller 1993
Selaginello denticulatae-Timmielletum barbuloides Cano, Guerra *et* Ros 1997
– subass. *typicum*
– subass. *fissidentetosum taxifolii* subass. nov.
Cl. Grimmietea anodontis Hadàc *et* Vondrácek *in* Ježek *et* Vondrácek 1962
O. Grimmietalia anodontis Šmarda *et* Vaněk *ex* Klika 1948
Al. Grimmion tergestinae Šmarda *ex* Klika 1948
Tortuletum marginatae v. Hübschmann 1973
Cl. Frullanio dilatatae-Leucodontetea sciuroidis Mohan 1978
O. Orthotrichetalia Hadàc *in* Klika *et* Hadàc 1944
Al. Syntrichion laevipilae Ochsner 1928
Syntrichietum laevipilae Ochsner 1928
Al. Fabronion pusillae (Barkman 1958) Gil *et* Guerra 1981
Leptodonto smithii-Leucodontetum sciuroidis Privitera *et* Puglisi 1996
Cl. Neckeretea complanatae Marstaller 1986
O. Neckeretalia complanatae Ježek *et* Vondrácek 1962
Al. Neckerion complanatae Šmarda *et* Hadàc *ex* Klika 1948
Anomodonto viticulosi-Leucodontetum sciuroidis Wiúniewski 1930
– subass. *typicum*
– subass. *drepanocladetosum adunci* subass. nov.
Cl. Lemnetea minoris R. Tx. *ex* O. Bolòs *et* Masclans
O. Lemnetalia minoris R. Tx. *ex* O. Bolòs *et* Masclans
Al. Lemnion trisulcae Den Hartog *et* Segal *ex* Tüxen *et* Schwabe *in* Tüxen 1974
Ricciocarpetum natantis Segal 1963 *em*. Tüxen 1974