Bryophyte coastal vegetation of the Cilento and Vallo di Diano National Park (S Italy) as a tool for ecosystem assessment

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Abstract

The bryophyte vegetation of the coastal area of the Cilento and Vallo di Diano National Park has been investigated. The phytosociological study has emphasized the occurrence of many associations of the phytosociological classes Barbuletea unguiculatae, Pleurochaeto squarrosae-Abietinelletea abietinae, Cladonio digitatae-Lepidozietea reptantis, Grimmietea anodontis, and Frullanio dilatatae-Leucodontetea sciuroidis. Among these, Barbuletum convolutae, Didymodonto vinealis-Tortuletum muralis, and Funarietum hygrometricae show a strong human impact. On the contrary, the epiphytic associations (Syntrichietum laevipilae, Leucodonto sciuroidis-Leptodontetum smithii, and Fabronietum pusillae), as well as Tortelletum papillosissimae, Rhynchostegielletum algirianae, Tortello flavovirentis-Trichostometum crispuli, and Rhynchostegietum megapolitani, show a good degree of naturalness and air purity. This is revealed by the bryovegetational analysis based on biological and ecological parameters (life form, ratio St/We, life strategy, sensibility to air pollution and human impact) that can be interpreted to provide useful information about the quality and the health of the environment. Moreover, a new association, Gongylanthetum ericetori, is described here.

Keywords: Bryophyte, vegetation, environmental quality, coastal area, Cilento and Vallo di Diano National Park

Introduction

The Cilento and Vallo di Diano National Park (PNCVD), the second largest park in Italy (181,048,00 ha), is located in the southern part of Italy stretching from the Tyrrhenian coast to inland including a large area of the Southern Campania Apennines. For the uniqueness of this environment, it has been included in the UNESCO list of World Heritage Sites since 1998 and, for its great geological heritage, in the European Geopark Network assisted by UNESCO since 2010. Within the area of the Park, 28 SIC (Siti di Importanza Comunitaria) and 8 ZPS (Zone di Protezione Speciale) are recognized. In particular, the coast, although subject to anthropogenic transformations in sandy areas, presents some of the most interesting areas of the whole Mediterranean basin, especially those characterized by vertical inaccessible cliffs, such as the calcareous Capo Palinuro promontory and the Infreschi coast. The montane landscape is equally interesting; in these areas it is possible to recognize some old-growth forests and persistent woodlands in the majority dominated by Quercus cerris L. and Fagus sylvatica L. that are outstanding hotspots of forest biodiversity (Blasi et al. 2010; Brunialti et al. 2010; Corona et al. 2010; Manes et al. 2010; Marchetti et al. 2010).

In this study, the bryophyte vegetation was used to obtain information on the environmental quality. In fact, the bryophytes play a significant ecological role as pioneer plants in the colonization of hard environments as well as bioindicators in the evaluation of the air quality. The bryophytes, neglected in the past even by botanists, are now being re-evaluated for environmental issues. In this respect, the role of bryophyte vegetation is important in the ecosystems as an intermediary between man and environment.

Study area

The Coast of the Cilento and Vallo di Diano National Park extends from Agropoli to Scario, for about 97 km. The coast consists mainly of rocky cliffs and slopes, with summit altitude between 100 and 500 m above sea level.

Geologically, the area is characterized by different substrates, such as alluvium, sandstone, limestone, and clay. The coastal cliffs consist of dolomites of the...
Lower Liassic and Upper Triassic while the inner cliffs consist of platform limestones, local calcareous re-sediments of the Upper Cretaceous and Middle Liassic (Bonardi et al. 1988). Along the coast, it is possible to recognize three main lithological complexes corresponding to the Carbonatic, Sandstone-conglomeratic, and Marly-clayey systems. The different geological nature of the Park (flysch of Cilento and dolomitic limestone) leads to a very different profile and topography of the coastline which is sweeter to the north (up to Palinuro), and rougher and almost, inaccessible at Capo Palinuro, in the southern sector. 

The coastal area of PNCVD is included in the Mediterranean climatic region and is characterized by a bioclimate Mediterranean pluviseasonal oceanic (Rivas Martinez et al. 2004). For the climatic data, we refer to the meteorological stations of Capo Palinuro (184 m a.s.l.) and Casalvelino (189 m). In particular, the thermotype is thermomediterranean with mean annual temperature of 17.8°C in both the meteorological stations. The mean annual precipitations are 729.7 mm at Capo Palinuro and 1081.49 mm at Casalvelino; on the basis of the precipitation values, the ombrotype ranges from subhumid to humid.

Finally, along the coast, edges of psammophytic vegetation mostly degraded by the intense anthropogenic activities aimed at tourist resort type can be found. They are psammophytic communities with Cakile maritima Scop., Elytrigia juncea (L.) Nevski, Ammophila littoralis (Beauv.) Rothm., Otanthus maritimus (L.) Hoffmann & Link, sometimes including also J. phoenicea.

### Material and methods

The field work was carried out in the coastal area of the Park between Tresino headland and Infreschi Coast (Figure 1).

The bryovegetational study was carried out, in the spring of the years 2010 and 2011, following the plant sociological methods of Braun-Blanquet (1964). The cover of each taxon was reported according to the following values: + (<1%), 1 (1–10%), 2 (10.1–25%), 3 (25.1–50%), 4 (50.1–75%), and 5 (75.1–100%). The phytosociological relevés were made on soil, trodden paths, rocks, rocky fissures, walls, tree bark, in grasslands, shrublands, uncultivated fields, and urban areas. Syntaxonomic arrangement and nomenclature mostly follow Marstaller’s synsystematic proposal (Marstaller 2006), according to the International Code of Phytosociological Nomenclature (Weber et al. 2000) (Appendix 1).

For the synecological analysis, life forms, ratio life forms Short turf/Weft, life strategies, sensibility to SO₂, human impact were considered within each community. The life forms were taken out from Mägdefrau (1982) and Bates (1998), the life strategies from During (1979) and Frey and Kürschner (1991a), ratio St/We from Privitera and Puglisi (2001), sensibility to SO₂ from Rao (1982), Lo Giudice et al. (1997), Privitera et al. (2006, 2010), Puglisi et al. (2009), human impact from Dierssen (2001) (Appendix 2).

For each species, the mean percentage cover (MPC) values of the biological and ecological parameters within the bryophyte association were evaluated (cf. Frey & Kürschner 1991a, 1991b; Parolly & Kürschner 2005, etc.).

The nomenclature of the species follows Aleffi (1964). The cover of each taxon was reported according to the following values: + (<1%), 1 (1–10%), 2 (10.1–25%), 3 (25.1–50%), 4 (50.1–75%), and 5 (75.1–100%). The phytosociological relevés were made on soil, trodden paths, rocks, rocky fissures, walls, tree bark, in grasslands, shrublands, uncultivated fields, and urban areas. Syntaxonomic arrangement and nomenclature mostly follow Marstaller’s synsystematic proposal (Marstaller 2006), according to the International Code of Phytosociological Nomenclature (Weber et al. 2000) (Appendix 1).

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The exsiccata are kept in Herbarium of the Department of Biological, Geological and Environmental Sciences of the University of Catania (CAT).

### Results

#### Phytosociological study

The examination of the phytosociological relevés has allowed finding 15 communities belonging to...
the classes Barbuletea unguiculatae Mohan 1978, Pleurochaeto squarrosae-Abietinelletea abietinae Marschaller 2002, Cladonio digitatae-Lepidozietea reptantis Ježek & Vondrácek 1962, Grimmietea anodontis Hadác & Vondrácek in Ježek & Vondrácek 1962, and Frullanio dilatatae-Leucodontetea sciurodis Mohan 1978. The surveyed communities are briefly discussed below.

**Barbuletum convolutae** Hadác & Šmarda 1944 (Table I)

This association has been observed on shady and slightly humid soil along the beaten pathways at Piano Cupo, Punta Tresino and Punta Infreschi. It is a terricolous, meso-xerophytic, photo-sciophytic community, growing on disturbed soil with medium nutrient content and preferably with strong human impact (Privitera & Puglisi 2009). Rather diffused in C. Europe, in the Mediterranean region it is signaled from Spain, C. Italy and Sicily.

**Trichostomo crispuli-Aloinetum aloidis** Guerra & Varo 1981 (Table II)

A terricolous, meso-xerophytic, photo-sciophytic bryocenosis found on compact, slightly exposed and xeric soil at Punta Tresino and Porto Palinuro in the ambit of the parasteppic vegetation with *Ampelodesmos mauritanicus*. It is a South temperate-Mediterranean association widespread in the Iberian Peninsula, occurring also in France, N. Africa, S. Italy and Sicily.

**Weissietum tortilis** Neumayr 1971 (Table III)

It was found in rock crevices with accumulated soil in open and sunny places at Porto Palinuro, and at Punta Infreschi in the ambit of the coastal maquis.
with dominance of *J. phoenicea*, *P. lentiscus*, *Cistus* sp.pl. *Weissietum tortilis* ecologically behaves as a terricolous, xerophytic, photophytic association. It is a temperate-Mediterranean association known from some Central and Southern European territories and Sicily.

**Table I. Barbuletum convolutae** Hadac & Šmarda 1944.

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---------------|---|---|---|---|---|---|---|
| Altitude (m)  | 112 | 112 | 164 | 231 | 231 | 53 | 43 |
| Surface (dm²) | 15 | 10 | 10 | 25 | 15 | 15 | 20 |
| Cover (%)     | 35 | 45 | 30 | 20 | 60 | 20 | 35 |
| Inclination (°)|  - | - | - | - | 15 | - | - |
| Exposure      |  - | - | - | - | S | - | - |
| Char. assoc.   | Barbula convoluta | 2 | 3 | 2 | 1 | 2 | 1 | 2 |
| Char. alliance, order and class (Grimaldion fragrantis, Barbuletalia unguiculatae, Barbuletea unguiculatae) | Trichostomum crispsulum | + | 1 | . | . | - | 1 |
|              | Barbula unguiculata | . | . | . | + | . | + | 1 |
|              | Didymodon luridus | . | . | 1 | . | . | . | 1 |
|              | Trichostomum triomphans | . | . | . | 1 | . | . | + |
|              | Trichostomum brachydontium | 1 | + | . | . | . | . | . |
|              | Aloina aloides | . | . | . | 1 | + | . | . |
|              | Fissidens viridulus var. viridulus | . | . | . | + | . | + | 1 |
|              | Didymodon fallax | . | . | . | 2 | . | . | . |
|              | Dicranella hotezi | . | . | . | + | . | . | . |
|              | Timmiella barbuloides | + | . | . | . | . | . | . |
| Other species | Psychostomum inbricatum | . | . | + | + | . | 1 | 1 |
|              | Scleropodium tourretii | 1 | . | . | . | . | . | . |
|              | Pleurochaete squarroso | + | . | . | . | . | . | . |

Relevés origin – Rel. 1–2: Piano Cupo N 40° 19’ 09” E 14° 56’ 47.8”; rel. 3: Punta Tresino N 40° 18’ 34.4” E 14° 59’ 19,3”; rel. 4–5: Punta Tresino: N 40° 18’ 56.8” E 14° 59’ 27.8”; rel. 6: Punta Infreschi N 39° 59’ 53.2” E 15° 25’ 25.4”; rel. 7: Punta Infreschi N 39° 59’ 54.3” E 15° 25’ 29.6”.

**Table II. Trichostomo crispuli-Aloinetum aloidis** Guerra & Varo 1981.

| Relevé number | 1 | 2 | 3 | 4 |
|---------------|---|---|---|---|
| Altitude (m)  | 164 | 164 | 164 | 73 |
| Surface (dm²) | 5 | 8 | 5 | 10 |
| Cover (%)     | 60 | 50 | 50 | 80 |
| Inclination (°)| - | - | 10 | - |
| Exposure      | - | - | W | - |
| Charact of. assoc. | Aloina aloides | 1 | 1 | 2 | + |
| Charact. of alliance (Grimaldion fragrantis) | Trichostomum crispsulum | 2 | 1 | + | 3 |
| Charact. of order and class (Barbuletalia unguiculatae, Barbuletea unguiculatae) | Barbula unguiculata | 2 | 1 | 1 | 2 |
|              | Didymodon luridus | . | 1 | + | + |
|              | Didymodon acutus | 1 | 2 | . | . |
|              | Fissidens viridulus | . | + | 1 | . |
|              | Didymodon virealis | . | . | . | 1 |
| Other species | Psychostomum inbricatum | 1 | + | . | . |
|              | Dicranella hotezi | . | + | 1 | . |
|              | Rhyynchostegiella tenella | . | . | . | 1 |
|              | Trichostomum triomphans | 1 | . | . | . |
|              | Scorpiurium cirrhatum | . | . | . | 1 |

Relevés origin – Rel. 1–3 Punta Tresino N 40° 18’ 34.4” E 14° 59’ 19,3”; rel. 4: Porto Palinuro N 40° 01’ 57.9” E 015° 17’ 28.8”.

This association colonizes dry and quite shady soil within the maquis with *P. lentiscus* and *M. communis*. It is a terricolous, xerophytic, sub-sciophytic association. Characteristic species of the association are *Didymodon virealis* and *Trichostomum brachydontium*, the latter being considered a cognate species of the maquis. The association is known from Sicily and Central-Southern peninsular Italy.

**Didymodonto virealis-Tortuletum muralis** Privitera & Puglisi 1996 (Table V)

It was found in open, sunny places, on walls and limestone outcrops with accumulated soil near the settlement of S. Maria Castellabate and Porto Palinuro. It is a terri-saxicolous, photophytic, xerophytic association, widespread in anthropic areas. It has been reported from Central Italy and from many localities of Sicily and Southern peninsular Italy.

**Tortelletum papillosissimae** Puglisi 2010 (Table VI)

The community was found on loose soil and on the rocks with sandy soil accumulated, in dry and more or less exposed places facing the sea in the
Other species

Char. alliance, order and class (Grimaldion fragrantis, Barbuletalia unguiculatae, Barbuletea unguiculatae)

| Psychotomum capillare | 1 | 2 | 2 |
| Trichostomum brachydontium | 2 | + | + |
| Didymodon luridus | . | 1 | 1 |
| Trichostomum crispulum | + | . | 2 |
| Didymodon acutus | 1 | . | . |
| Barbula unguiculata | . | + | 1 |
| Weissia brachycarpa | . | 1 |
| Weissia controversa | . | . | 1 |
| Other species
| Psychotomum imbricatum | 1 | |
| Scopariurn cirratinum | . | . | 1 |

Relevés origin. – Rel. 1: Porto Palinuro N 40° 01′ 54.4″ E 015° 17′ 46.9″; rel. 2: Porto Palinuro: N 40° 02′ 06.2″ E 015° 17′ 24.4″; rel. 3: Punta Infreschi: N 39° 59′ 49.1″ E 015° 25′ 18.2″; rel. 4: Punta Infreschi: N 39° 59′ 53.2″ E 015° 25′ 25.4″.

Table IV. Trichostomo brachydontii-Didymodonetum vinealis Privitera & Puglisi 1989.

| Relevé number | 1 | 2 | 3 |
| Altitude (m) | 19 | 19 | 9 |
| Surface (dm²) | 20 | 15 | 25 |
| Cover (%) | 35 | 70 | 60 |
| Inclination (°) | – | – | 10 |
| Exposure | – | – | S |

Char. association

| Trichostomum brachydontium | 2 | 3 |
| Char. alliance, order and class (Grimaldion fragrantis, Barbuletalia unguiculatae, Barbuletea unguiculatae)
| Psychotomum capillare | 1 | |
| Dicranella hoehii | 1 | . |
| Trichostomum crispulum | + | 2 |
| Barbula unguiculata | . | . |
| Didymodon vinealis | + | 1 |
| Didymodon acutus | . | . |
| Other species
| Psychotomum imbricatum | . | 2 |
| Scopariurn cirratinum | . | . |

Relevés origin. – Rel. 1–2: Trentova N 40° 20′ 34.8″ E 014° 58′ 19.3″; rel. 3: Trentova N 40° 20′ 34.6″ E 014° 58′ 19.5″.

flavovirens, characteristic of Tortello flavovirens, a psammophytic alliance with a Mediterranean-Atlantic distribution. Up to now, this association is known only in Sicily from Linosa Island (Puglisi 2010).

**Tortello flavovirens-Trichostometum crispuli**

Brullo, Lo Giudice & Privitera 1991 (Table VII)

This association occurs on shady and consolidate soil covered by the shrubs in the ambit of the maquis with P. lentiscus, M. communis, Cistus sp. pl. dominant. It is a terricolous, xerophytic, preferably sciophytic community. In the investigated area, it is quite diffused. In Italy, it is known from Sicily, Sardinia and Central-Southern Italy.

**Funarietum hygrometricae** Engel 1949 (Table VIII)

It is a pioneer association typical of nitrified or burnt soils and thus indicated as a pyrophilous association. It was found only at Marina di Camerota on burned soil. Widespread in Central Europe, it is also reported from France, Spain, Morocco, S. Italy and Sicily.

**Rhynchostegietum megapolitani** Puglisi 1995 (Table IX)
This association, floristically very rich, is the most widespread in the investigated area. It was found on dry and very shady soil within the grassland with *A. mauritanicus* and the pinewood *Pistacia-Pinetum halpeenis*. Ecologically, it is a terricollic, xerophytic, markedly scyophytic association. *Rhynchostegieta megapolitani* is included in the alliance *Homalothecio aurei-Plurochaetion squarrosae* (Ros & Guerra 1987) Marstaller 1993 of the order *Auriculio-Aureietum* is included in the alliance *Tortellion flavovirentis* (Puglisi & Privitera ass.) of the alliance *Dicranellion heteromallae*, are associated. A similar vegetation was found at Vulcano Island (Aeolian archipelago) in comparable ecological conditions, where it is reported as *Gongylanthus ericetorum* community (Puglisi et al. 2006); the phytosociological relevés from Vulcano are also reported in Table X. Ecologically, it behaves as a terrico-saxicollic, mesophytic, thermophytic, photophytic community. For its cover values and constant presence, *Gongylanthus ericetorum* is proposed as characteristic of the new association; this species is here signaled for the first time for the Campania region. Due to the floristic composition and due to the ecological features, this community is to place in the above mentioned syntaxa *Fissidenti serrulati-Fossombrion angulosae* and *Dicranellion heteromallae*.

**Schistidio apocarpi-Grimmietum pulvinatae**

Privitera & Puglisi 1996 (Table XI)

A strictly saxicollic, photophytic, xerophytic association colonizing dry and sunny rocks in the clearings of garrigue with *Cistus* sp. pl. and *Calicotome villosa* at Contrada S. Gennaro and Piano Cupo. The association is known from Sicily and S. Italy.

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### Table VI. *Tortelletum papillosissimae* Puglisi 2010.

| Relevé number | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Altitude (m) | 5   | 24  | 10  | 9   | 4   | 20  | 25  | 0   |
| Surface (dm²)| 10  | 15  | 15  | 10  | 15  | 10  | 10  | 10  |
| Cover (%)    | 85  | 75  | 75  | 85  | 45  | 70  | 50  | 75  |
| Inclination (°)| -   | 10  | -   | -   | -   | 15  | -   | -   |
| Exposure     | -   | SE  | -   | -   | -   | S   | -   | -   |

Char. association
- *Tortella flavovirens var. papillosissima*

| Char. alliance (Tortellion flavovirentii) | 1   | 2   |
|------------------------------------------|-----|-----|
| *Trichostomum brachydontium*             | 1   | +   |
| *Tortella flavovirens var. flavovirens*  | +   | 1   |

Char. order and class (Barbuletea unguiculatae, Barbuletea unguiculatae)
- *Psychomotum capillare*
- *Barbula unguiculata*
- *Didymodon acutus*
- *Trichostomum crispiulum*
- *Didymodon hurdis*
- *Fissidens viridulus*
- *Dicranella hoteae*

Other species
- *Scorpiuriom circinatum*
- *Hypnum cupressiforme var. cupressiforme*
- *Pleurochaete squarrosa*
- *Rhynchostegiella tenella*
- *Bryum torquescens*

Relevés origin. – Rel. 1: Punta Licosa N 40° 15' 02.5" E 014° 54' 29.1"; rel. 2: Punta Licosa N 40° 14' 58.0" E 014° 54' 39.0"; rel. 3: Punta Licosa N 40° 14' 20.5" E 014° 55' 13.3; rel. 4: Punta Licosa N 40° 15' 16.5" E 014° 54' 27.7; rel. 5: Porto Palinuro N 40° 01' 48.7" E 015° 16' 35.2; rel. 6: Porto Palinuro N 40° 01' 44.76" E 15° 16.34 49°; rel. 7: Porto Palinuro N 40° 01' 44.59" E 15° 16.32 77°; rel. 8: Punta Infreschi: N 39° 59' 55.3" E 015° 29' 33.6".
Rhynchostegielletum algirianae Giacomini 1950

This association was observed on shaded vertical basic rocks at Punta Licosa and Punta Infreschi within the association Pistacio-Pinetum halepensis De Marco et al. 1984 and at Marina di Camerota within a cave. Rhynchostegielletum algirianae behaves as a saxicolous, mesophytic, markedly sciophytic association. It is known from France, N. Italy and Sicily.
| Relevé number | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|--------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Altitude (m) | 24 | 24 | 24 | 24 | 24 | 80 | 95 | 130| 115| 115| 115| 84 | 84 | 40 | 30 | 24 | 55 | 90 | 147| 115| 130|
| Surface (dm²) | 15 | 20 | 20 | 20 | 10 | 15 | 20 | 10 | 10 | 20 | 15 | 15 | 10 | 20 | 10 | 15 | 20 | 20 | 15 | 10 | 25 |
| Cover (%)     | 95 | 85 | 80 | 45 | 80 | 50 | 60 | 65 | 95 | 85 | 90 | 80 | 100| 70 | 95 | 80 | 65 | 65 | 95 | 85 | 45 |
| Inclination (%)| –  | –  | 10 | –  | –  | –  | 15 | 10 | –  | –  | –  | 10 | –  | –  | 15 | –  | –  | 15 | –  | –  | –  |
| Exposure      | –  | –  | W  | –  | –  | –  | W  | E  | –  | –  | S  | –  | –  | SE | –  | S  | –  | –  | –  | –  |

**Charact. of association**

*Rhynchostegietum megapolitani* Puglisi 1995.

**Charact. of alliance, order and class**

(Homalothece aurae-Pleunchiation squarrosae, Pleunchoeto-Abietinelletalia abietinae, Pleunchoeto-Abietineltece abietinae)

- *Pleunchoe squarrosa*
- *Scorpiurium cincinatum*
- *Scleropodium tournei*
- *Tortella humilis*

**Other species**

- *Trichostomum crispulum*
- *Barbula unguiculata*
- *Dicranella hoveii*
- *Didymodon acutus*
- *Didymodon vincales*
- *Trichostomum brachydontium*
- *Pseudocrenophidium purum*
- *Ptychostomum capillare*
- *Ptychostomum imbricatum*
- *Hyphnum cupressiforme var. cupressiforme*
- *Bryum torquescens*
- *Rhynchosiptella tendla*
- *Kindbergia praetonga*
- *Hyphnum andoi*
- *Didymodon fallax*
- *Fissidens taxifolius ssp. taxifolius*
- *Fissidens viridulus*
- *Timmiella barbuloides*

**Sporadic species:**

- *Pleuridium acuminatum* 1 in rel. 3; *Calypogeia arguta* + in rel. 21.

**Relevés origin:**

- Rel. 1–5: Trentova N 40° 20' 29.7" E 14° 58' 14.2"; rel. 6: Piano della Corte N 40° 18' 17.34" E 4° 58' 34.08"; rel. 7: Piano della Corte N 40° 18' 44.87" E 14° 58' 46.03"; rel. 8: Piano della Corte N 40° 18' 16.5" E 14° 59' 11.9"; rel. 9–11: Piano Cupo N 40° 19' 09.7" E 14° 56' 48.5"; rel. 11–13: Piano Cupo N 40° 19' 05.9" E 14° 56' 29.7"; rel. 14: Punta Licosa N 40° 14' 35.46" E 14° 55' 05.85"; rel. 15: Punta Licosa N 40° 14' 33.56" E 14° 55' 04.35"; rel. 16: Punta Licosa N 40° 14' 58.0" E 14° 54' 39.0"; rel. 17: Punta Licosa N 40° 14' 52.67" E 14° 54' 47.68"; rel. 18: Palinuro al Faro N 40° 01' 27.35" E 15° 16' 26.30"; rel. 19: N 40° 01' 35.36" E 15° 16' 47.3"; rel. 20: Palinuro al Faro N 40° 01' 28.56" E 15° 16' 34.11"; rel. 21: Palinuro al Faro N 40° 01' 31.51" E 15° 16' 42.16".
**Syntrichietum laevipilae** Ochsner 1928 (Table XIII)

This community was found on the middle and middle-higher parts of the trunks of isolated trees of *Quercus ilex* L. at Punta Infreschi and *Olea europaea* L. at Porto Palinuro. It is a corticolus, thermophytic, xerophytic association, quite widespread in Italy.

**Fabronietum pusillae** Ochsner 1936 (Table XIV)

*Fabronietum pusillae* colonizes the middle-high part of trunks *O. europaea* at Porto Palinuro and Marina di Pisciotta. Ecologically, it behaves as a corticolous, thermophytic, meso-xerophytic association, occurring preferably in woods with a low human impact. It was found in less xerophytic conditions than *Syntrichietum laevipilae*. In Italy it is known only from Sicily.

**Leptodonto smithii-Leucodontetum sciuroidis** Privitera & Puglisi 1996 (Table XV)

This association occurs on the basal part of the trunks of *O. europaea* at Porto Palinuro. It is a corticolous, photo-sciophytic, meso-xerophytic com-

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### Table X. Gongylanthetum ericetori ass. nov.

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---------------|---|---|---|---|---|---|---|---|---|
| Altitude (m)  | 9 | 10 | 19 | 4 | 60 | 250 | 250 | 250 | 250 |
| Surface (dm²) | 10 | 5 | 5 | 10 | 3 | 3 | 5 | 4 | 3 |
| Cover (%)     | 40 | 80 | 65 | 70 | 85 | 75 | 50 | 75 | 70 |
| Inclination (°)| 10 | – | – | 10 | | | | | |
| Exposure      | E | – | N | | | | | | |

Charact. of association

*Gongylanthus ericetorum*

| Relevé's origin. – Rel. 1: Trentova N 40° 20’ 34,6” E 014° 58’ 19,5” | rel. 2: Trentova N 40° 20’ 32,8” E 14° 58’ 17,30”; rel. 3: Trentova N 40° 20’ 34,8° E 14° 58’ 19,3”; rel. 4: Porto Palinuro N 40° 01’ 48,7” E 015° 16’ 35,2”; rel. 5–9: Vulcano Island (Aeolian archipelago) from Puglisi et al. (2006, tab. 8, p. 91). |

### Table XI. Schistidio apocarpi-Grimmietum pulvinatae Privitera & Puglisi 1996.

| Relevé number | 1 | 2 | 3 | 4 |
|---------------|---|---|---|---|
| Altitude (m)  | 60 | 60 | 40 | 84 |
| Surface (dm²) | 10 | 5 | 15 | 5 |
| Cover (%)     | 85 | 60 | 50 | 95 |
| Inclination (°)| 60 | 70 | 55 | 30 |
| Exposure      | S | SW | S | S |

Char. association

*Grimmia pulvinata*  
Char. of alliance, order and class (*Grimminion tergestinae, Grimmietalia anodontis, Grimmietea anodontis*)

*Schistidium crassipilum*  
*Tortula muralis*  
*Other species*  

| Relevé's origin. – Rel. 1, 2: Contrada S. Gennaro N 40° 20’ 34,6” E 014° 58’ 00,2” | rel. 3: Contrada S. Gennaro N 40° 18’03,27” E 14° 57’46.98”; rel. 4: Piano Cupo N 40° 19’ 05,9” E 014° 56’ 29.7” |

**Syntrichietum laevipilae** Ochsner 1928 (Table XIII)

This community was found on the middle and middle-higher parts of the trunks of isolated trees of *Quercus ilex* L. at Punta Infreschi and *Olea europaea* L. at Porto Palinuro. It is a corticolus, thermophytic, xerophytic association, quite widespread in Italy.

**Fabronietum pusillae** Ochsner 1936 (Table XIV)

*Fabronietum pusillae* colonizes the middle-high part of trunks *O. europaea* at Porto Palinuro and Marina di Pisciotta. Ecologically, it behaves as a corticolous, thermophytic, meso-xerophytic association, occurring preferably in woods with a low human impact. It was found in less xerophytic conditions than *Syntrichietum laevipilae*. In Italy it is known only from Sicily.

**Leptodonto smithii-Leucodontetum sciuroidis** Privitera & Puglisi 1996 (Table XV)

This association occurs on the basal part of the trunks of *O. europaea* at Porto Palinuro. It is a corticolous, photo-sciophytic, meso-xerophytic com-
munity found preferably in open woods with a low human impact. The association occurs in more mesic conditions than *Syntrichietum laevispila*. The association is known from Sicily, Sardinia and C. Italy.

**Synecological analysis**

**Life forms.** Life form describes the result of the life condition, including growth form, branching pattern, general assemblage of individuals and influence of environment on the population. Life forms and life strategies are closely related to ecological conditions, as emphasized in several studies on bryophyte communities (Kürschner 1994, 2004; Frey & Kürschner 1995; Kürschner et al. 1998; Sabovljević 2004; Parolly & Kürschner 2005; Kürschner et al. 2007; Darell & Cronberg 2011).

In the coastal area of PNCVD, short turf is the strongly prevalent life form in all the association belonging to the phytosociological class *B. unguiculatae* and in the association *Syntrichietum laevispila* of the class *Fruillanio dilatatae-Leucodontetetra sciuroidis* (Table XVI); this category is typical of the acrocarpous mosses and generally increases in xeric, sunny and often disturbed habitats. The life form cushion predominates in the saxicolous association *Schistidio apocarpi-Grimmietum pulvinatae*. The life form weft, occurring in all the associations, strongly prevails in *Rhynchostegietum megaloplitani, Rhynchostegietetum algirianae, Fabronietum pusillae*, found in mesic and more sheltered habitats. The annual species, mostly represented by liverworts, prevail only in the association *Gongylanthatum ericetori*. Finally, the fan life form, attributes to *Leptodon smithii*, predominates in the association *Leptodon smithii-Leucodontetetum sciuroidis*.

**Ratio St/We.** This index was proposed by the authors taking into account the scale of tolerance to the air pollution of the life forms proposed by Gilbert (1970) and it was tested for the evaluation of the human impact in the ecosystems of the Mediterranean region (Privitera & Puglisi 2001; Guglielmo et al. 2003). The value of this index is directly proportional to the increase of human disturbance.

In the coastal area of PNCVD, the highest values of the ratio St/We are found in the associations *Didymodon virealis-Tortuletum muralis, Barbulletum convolutae* and *Funarietum hygrometricae* (Figure 2). The lowest values of the ratio (<5) are found in the
associations Rhynchostegietum megapolitani, Rhynchostegietum tenellae, Syntrichietum laevipilae, Leucodonteto sciuroidis-Leptodontetum smithii and Fabronietum pusillae. The other associations show medium-low values (<18).

Table XIII. Syntrichietum laevipilae Ochsner 1928.

| Relevé number | 1   | 2   | 3   | 4   | 5   | 6   |
|---------------|-----|-----|-----|-----|-----|-----|
| Altitude (m)  | 4   | 10  | 10  | 43  | 10  | 10  |
| Surface (dm²) | 10  | 10  | 5   | 15  | 10  | 15  |
| Cover (%)     | 75  | 80  | 85  | 65  | 75  | 45  |
| Exposure      | S   | E   | SW  | S   | S   | SE  |
| Phorophyte    | Oe  | Oe  | Oe  | Qi  | Qi  | Qi  |
| Char. association | Syntrichia laepliva | 3 | 4 | 4 | 3 | 3 |
| Orthotrichetalia | Frullanion pusillae-Leucodontetalia sciuroidis |
| Zygodon rupestris | 2 | 1 | 2 | . | 2 | 1 |
| Frullania dilatata | 2 | . | 1 | + | . | 2 |
| Leucodon sciuroides | + | 2 | . | . | . | . |
| var. sciuroides Orthotrichum diaphanum | . | . | 1 | . | 2 |
| Pterigynandrum filiforme var. filiforme Fabronia pusilla | . | 1 | 1 | . | . |
| Orthotrichum pumilum Other species Scorpium sendleri | . | . | 1 | . | . |
| Trichostomum crispulum | 1 | 1 | . | . | . |
| Scorpicium cirincatum Other species | . | 1 | . | . | . |

Oe = Olea europaea. Qi = Quercus ilex. Relevés origin. – Rel. 1: Porto Palinuro N 40° 01’ 50.54° E 015° 16’ 27.78°. Oe = Olea europaea. Relevés origin. – Rel. 1–2: Porto Palinuro N 40° 01’ 50.54° E 015° 16’ 27.78°.

Life strategy. The environment provides the major selection pressure on the life cycle strategies. Taking into account the instability of the environment with its fluctuations, During (1979) considered that bryophytes utilize three major trade-offs: few large spores vs. many small spores, survival of stressful season as spores (avoidance) vs. survival as a gametophyte (tolerance), and life span that is negatively correlated with reproductive effort.

In the investigated area, the life strategy colonist markedly prevails in the association of the alliances Grimaldion fragrantis and Tortellion flavovirentis (Table XVI). These species can be considered as pioneers colonizing hard environments; they appear in primary successional series and are important forerunners in soil accumulation and plant succession. They generally are found in dry habitats where the short life span, caused by drought-dependent mortality, is compensated by a high production of small spores. By contrast, the perennial stayers are of typical undisturbed stable environments and are most prominent in later successional series. They occupy habitats that are constant or where the fluctuations can be tolerated by the gametophytes. In the coastal area of PNCVD, the perennial stayers predominate in the epiphytic associations and in the association Rhynchostegietum megapolitani, a post-pioneer association normally occurring on deep soil. The perennial shuttle species strategy combines desiccation tolerant gametophytes with large spores. This strategy is typical of unchanging and constant ecological conditions and long-lasting microsites in hardly disturbed sites where end of habitat is predictable. In the investigated area, these species are present in the epiphytic associations and prevail in the Gongylanthetum ericetor. The annual shuttle
Table XVI. MPC values of life forms, life strategies, sensibility to SO$_2$ and human impact in the bryophyte communities of coastal area of PNCVD.

| Association                  | Barbuletum convolutae | Trihastetum crispulii- | Weissietum tordii- | Didymosinetum tordii- | Trichostemum crassula- | Drabaecetum popillo- | Tortilietum ericetorii | Gymnocetum pumilum | Grimmietum alpinum | Leptodontetum smithitii- | Leucodontetum sciuroidis | Fabronietum pusillae |
|------------------------------|-----------------------|-----------------------|-------------------|----------------------|----------------------|---------------------|-----------------------|---------------------|-------------------|----------------------|----------------------|---------------------|
| Life form                    | Short turf            | 95.6                  | 81.8              | 98.1                 | 94                   | 96                  | 97.1                  | 94.3                | 96                | 23.6                 | 33.7                 | 7.4                 |
|                             | Weft                  | 2                     | 4.8               | 1.9                  | 6                    | 1.9                 | 1.1                   | 1.1                 | 5.7               | 1.7                  | 64.8                 | 1.9                 |
|                             | Cushion               | Ma                    | 2.3               |                      |                      |                     |                       |                     | 5.4               | 81                   | 8.9                  | 72.4                |
|                             | So                    |                      | 1                 |                      |                      |                     |                       |                     | 1.4               |                      |                      |                     |
|                             | An                    | 2.2                   | 4.8               | 1.9                  | 6                    | 1.9                 | 1.1                   | 1.1                 | 5.7               | 1.7                  | 64.8                 | 1.9                 |
|                             | Ta                    | 0.2                   | 1                 |                      | 1.8                  | 1.8                 |                       |                     | 11.4              |                      |                      |                     |
|                             | Fan                   | 2.2                   | 4.8               | 1.9                  | 6                    | 1.9                 | 1.1                   | 1.1                 | 5.7               | 1.7                  | 64.8                 | 1.9                 |
| Life strategy                | Fugitive              | K                     | 2.3               |                      |                      |                     |                       |                     | 5.4               | 81                   | 8.9                  | 72.4                |
|                             | Colonist              | Ma                    | 2.3               |                      |                      |                     |                       |                     | 5.4               | 81                   | 8.9                  | 72.4                |
|                             | Ba                    |                       |                   |                      |                      |                     |                       |                     | 5.4               | 81                   | 8.9                  | 72.4                |
|                             | Bg                    | 20.4                  | 49.3              | 63.7                 | 13                   | 22.3                | 15.5                  | 33                   | 8.8               | 10.1                 | 8                    | 1.6                 |
|                             | Bi                    | 4.7                   | 29.5              | 6.7                  | 11.2                 | 6.5                 | 3.7                   | 48                   | 3.8               | 3.8                  | 1.6                  | 3.4                 |
|                             | Bv                    | 69.9                  | 64.4              | 3.9                  | 13.9                 | 3.8                 | 3.6                   | 3.4                  | 2                 | 7.8                  | 0.1                  |                     |
|                             | Bv,g                  | 15                   | 3.1               | 7.5                  | 4.2                  | 2.8                 | 2.1                   | 1.8                  | 0.1               |                      |                      |                     |
|                             | Pe                    | 0.3                   | 8.6               |                      |                      |                     |                       |                     | 5.4               | 81                   | 8.9                  | 72.4                |
|                             | Pk                    | 2.5                   | 8.8               | 44.9                 | 2.9                  | 7.4                 | 2.1                   | 1.7                  | 0.1               | 11.3                 | 1                    |                     |
|                             | Pg                    | 61                   | 3.1               | 7.5                  | 4.2                  | 2.8                 | 2.1                   | 1.8                  | 0.1               |                      |                      |                     |
|                             | Pr                    | 2.5                   | 8.8               | 44.9                 | 2.9                  | 7.4                 | 2.1                   | 1.7                  | 0.1               | 11.3                 | 1                    |                     |
|                             | Perennial shuttle     | Pe                    | 2.5               | 8.8               | 44.9                 | 2.9                  | 7.4                 | 2.1                   | 1.7               | 0.1                  | 11.3                 | 1                    |                     |
|                             | Perennial stayer      | Ag                    | 2.4               | 0.8                  | 8.4                   | 8.5                  | 56.6                  | 1.6                 | 78.5              | 5.9                  | 72.4                |                     |
|                             |                      | Ap                    | 2.5               | 2.4                  | 1.9                   | 3.1                  | 2.8                   | 10.6                 | 0.7               | 1.6                  | 23.1                 | 8.6                 |
|                             |                      | Av                    | 1.4               | 1                   |                      |                     |                       |                     | 5.4               | 81                   | 8.9                  | 72.4                |
|                             |                      | Av,g                  | 61                 | 3.1               | 7.5                  | 4.2                  | 2.8                 | 2.1                   | 1.8                  | 0.1                  |                      |                      |                     |
| Sensibility to SO$_2$        | Sensitive             | 7.4                   | 33.7              | 6.7                  | 11.1                 | 9.5                 | 58.5                  | 49                   | 21.3              | 11.4                 | 3.5                  | 82                  |
|                             | Toxiphilous           | 77.3                  | 45.5              | 24.7                 | 34.7                 | 82.8                | 18.4                  | 16.4                 | 86.5              | 9                    | 4                    | 5.6                 |
|                             | Toxitolerant          | 15.3                  | 20.8              | 68.6                 | 54.2                 | 7.7                 | 23.1                  | 34.6                 | 13.5              | 69.7                 | 84.6                 | 90.9                |
| Human impact                | Low                   | 9.7                   | 33.6              | 13.6                 | 58                   | 12.6                | 39.4                  | 81.7                 | 1.6               | 72.4                 | 76.7                 | 15.6                |
|                             | Moderate              | 32.2                  | 21.2              | 65.6                 | 24.3                 | 21.2                | 10.7                  | 13.6                 | 5                 | 13.6                 | 13                   | 77.7                |
|                             | Strong                | 52.2                  | 5                  | 1.8                  | 3.2                   | 64.2                | 20.3                  | 77.8                 | 5.4               | 2.1                  | 6.7                  | 8                   |

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and short-lived shuttle strategies are poorly represented in the surveyed associations. These “shuttle species” are found in habitat with seasonal fluctuations that can be tolerated as spore stage. The fugitive strategy is relatively rare, with *Funaria hygrometrica* being one of the few examples; therefore, it appears only in the association *Funarietum hygrometricae*.

**Sensibility to SO₂.** Respect to this parameter, the species was classified as toxiphilous, toxitolerant and sensitive. In the studied area, the toxiphilous element is strongly represented in the associations *Didymodontum vinealis-Tortuletum muralis*, *Barbuletum convolutae*, *Syntrichietum laevipilae*, *Sa-Gp*, *Schistido apocarpi-Grimmietum pulvinatae*, *Ge*, *Gongylanthetum ericetori*, *Lm-Ls*, *Leptodonto smithii-Leucodonto smitiiidae*, *Fb*, *Funarietum hygrometricae*, *Tb-Dv*, *Trichostomo brachydontii-Didymodonetum vinealis*, *Fb*, *Fabronietum pusillae*, *Tc-Aa*, *Trichostomo crisplii-Aloinetum aloidis*.

**Human impact.** In relation to the increasing hemerophobous-hemerophilous gradient, the species reveal a human impact from absent (ahemerobous species) to very strong (polihemerobous and hemerophilous species), with many intermediate states. So, in this consideration, according to Kürschner et al. (2007), the species were gathered in three groups: species showing a low human impact (ahemerobous, oligohemerobous, a-oligohemerobous species, oligo-meso-hemerobous), species showing a moderate human impact (mesohemerobous and meso-euhemerobous species), and species showing a high human impact (euhemerobous, polyhemerobous, eu-polyhemerobous, and hemerophilous species) (Table XVI). The species with a wide range (i.e. a-euhemerobous, oligo-euhemerobous, meso-polyhemerobous) were taken into account in the percentage calculation but omitted in the table.

The results almost overlap with those regarding to sensibility to SO₂. In fact, a strong human impact is detected only by the associations *Didymodontum vinealis-Tortuletum muralis*, *Barbuletum convolutae*, *Funarietum hygrometricae*, while the corticolous *Fabronietum pusillae* and *Leucodonto-Leptodontetum smithii*, as well as *Tortello flavovirentis-Trichostometum crisplii*, *Rhynchostegielletum algirianae*, *Rhynchostegietum megapolitani*, and *Gongylanthetum ericetori* reveal a low human impact.

This index, used for phanerogamic vegetation, is well applicable to bryophyte communities too.

**Discussion**

The results of this study have pointed out a great bryophyte vegetation diversity in the coastal area of
the Cilento and Vallo di Diano National Park, reflecting the multiplicity and diversity of micro- and macro-habitats, part of a mosaic of ecosystems with a high landscape value.

The phytosociological investigation has emphasized the occurrence of 15 bryophyte associations (eight terricolous, three corticolous, two epilithic, and two terri-saxicolous), a number quite elevated for a Mediterranean coastal area. Many associations belong to the class *Barbuletea unguiculatae*, including thermo-xerophytic communities some of which tolerant to human-induced disturbance.

Moreover, this investigation allowed the finding of the new association *Gongylanthetum ericetorum*, a coastal Mediterranean community, belonging to the class *Cladonio digitatae-Lipodiozietea reptantis*, characterized by the rare liverwort *Gongylanthus ericetorum*. Finally, within the surveyed associations some species rare and interesting from a phytogeographical point of view were found too; they are: *Gongylanthus ericetorum*, *Calypogeia arguta*, *Fissidens gracilifolius*, new records for Campania region, and the very rare *Tortella flavovirens var. papillosissima*, new record for peninsular Italy.

The analysis of the bryophyte vegetation, through the application of ecological and biological parameters, has revealed that the associations *Barbuletum convolutae*, *Funarietum hygrometricae*, *Didymodonto vinealis-Tortuletum muralis* can be considered markers of anthropogenic ecosystems; nevertheless, they are not common in the investigated area where they are confined to peculiar microsites.

On the contrary, *Tortelletum papillosissimae*, *Tortello flavovirentis-Trichostometum crispuli*, *Rhyynchostegietum alginariae*, and *Rhyynchostegietum megapolitani*, widespread in the investigated areas, besides the corticolous associations (*Syntrichietum laevipilae*, *Leptodon-Leucodontetum sciuroidis*, *Fabraietum pusillae*), can be considered typical of semi-natural and poorly disturbed habitats. Therefore, the analysis of the bryophyte vegetation overall shows a rather good degree of naturalness and air purity of the coastal ecosystem of the PNCVD.

This investigation provides data showing the situation of a Mediterranean area with many natural communities and few aspects suggesting a certain anthropic disturbance mostly localized near the urban areas. The occurrence of many natural associations testifies the great importance of the Cilento and Vallo di Diano National Park as refuge and safeguard area for these associations of great naturalistic value.

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