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The Bryoflora of Castel Volturno Nature Reserve (S-Italy) as indicator of environmental factors of disturbance

Abstract

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The bryophyte flora of Castel Volturno Nature Reserve (Southern Italy) was investigated, and a list of 42 collected species (37 mosses and 5 liverworts) was compiled. *Sematophyllum substrumulosum* (Hampe) Britton is new to the Campania bryoflora. Within the study area, two sectors characterized by different disturbance history and environmental conditions could be clearly recognized on the basis of floristical, chorological and ecological considerations. The sector located in the southern part of the Reserve and characterized by a more heterogeneous and frequently burned vegetation showed the richest bryoflora, with a dominance of the submediterranean element. Water and substrate affinity afford a richer heterogeneity of habitats in this sector, while light seems not to be a limiting factor.

Introduction

The Castel Volturno Nature Reserve encompasses one of the very few tracts of Mediterranean vegetation on sandy dunes that still to be found along the Campania coast. In fact, intense urbanization has caused significant modifications on the coastal landscape with natural vegetation, which is restricted to a few small scattered areas.

The bryophyte flora of Castel Volturno has been rather poorly studied. For this area, Zodda (1909) mentions 5 species collected by Terracciano from 1872 to 1874, and of these 5, *Didymodon tophaceus* (Brid.) Jur. [= *D. tophaceus* (Brid.) Lisa] and *Acrocladium cuspidatum* (L.) Lindb. [= *Calliergonella cuspidata* (Hedw.) Loeske] have not been found again.

This study presents observations on the bryoflora made over the course of three years (1993-1996), and aims to give a comparative analysis of richness and main ecological and chorological features of two floristic sets characterizing two different sectors of the Reserve. Moreover, through a better understanding of bryophyte characters, this study aims to identify the most suitable management practices for the current conservation program.

Study area

The Castel Volturno Nature Reserve is a flat coastal area of about 268 ha located along the Campania coast in southern Italy (40° 57' N; 1° 33' E), with a maximum elevation of 9 m above sea level. This area is characterized by both alluvial and marine deposits, as well as volcanic material from the recent Quaternary (Romano & al. 1994).

The climate is typically Mediterranean with a mean annual temperature of 13.6° C, a mean winter temperature of 6.7° C, and a mean summer temperature of 21° C. The rainfall is 761.3 mm per year, but with precipitations concentrated in autumn and winter seasons. The drought period is limited to three months, according to the Walter and Lieth pluviothermic diagram at the Ischitella meteorological station (15 m a.s.l.) for the period 1974-1983. The dominant winds are west and south-west.

The vegetation of this area manifests a mosaic of plant patches. As shown in the vegetation map of Fig. 1(A), the northern part is characterized by a coppice stand of *Quercus ilex* sparsely mixed with *Pinus pinea* L. and with a shrubby understorey of *Phyllirea angustifolia* L., *Pistacia lentiscus* L., *Myrtus communis* L., *Rhamnus alaternus* L., *Arbutus unedo* L., *Ruscus aculeatus* L. and locally with *Cistus incanus* L. and *C. monspeliensis* L. This formation shows a canopy cover of about 70% with an average height of 6-8 m. *Pinus pinea* plantations are mostly located on the southern part of the area, with a canopy cover of about 80% and an average of 8-10 m. The understorey presents scattered shrubs of *Phyllirea angustifolia*, *Pistacia lentiscus*, *Myrtus communis*, *Rhamnus alaternus*, *Cistus incanus* and *C. monspeliensis*. Different patches of low and high macchia with scattered *Pinus halepensis* Miller trees occur in the Reserve; locally, small gaps in the woody canopy cover show dominance of herbs and bryophytes (Buonanno & al. 1993).

Methodology

The mosaic of vegetation probably is the result of different disturbance histories. Starting in 1974, some characteristic land uses, such as cutting and grazing, were stopped, though fires represent today the main and continuous factor acting on vegetation dynamics. Fig. 1(B) shows the occurrence of fires over the last three decades (seventies, eighties, and nineties). These fires mostly occur in the scrub and pine areas of the southern part; except for a small fire in 1970, the north site of this area has been not burned in the last forty years.

The bryophyte flora was analyzed distinctly within two selected sectors (Site A and B) clearly recognized on the basis of different dominance of vascular vegetation and fire histories as shown in Fig. 1(B).

The list contains all bryophytes species collected by us and the few species collected by Terracciano from 1872 to 1874 (Zodda 1909). The species are listed according to Smith's systematic ordination (1990, 2004). The nomenclature follows Corley & al. (1981), Corley & Crundwell (1991) and Cortini Pedrotti (2001a, 2005) for mosses, and Grolle & Long (2000) and Aleffi (2005) for liverworts. Chorological elements are taken from Düll (1983, 1984, 1985, 1992). The chorological data and the life strategies follows Dierßen (2001). Author abbreviations follows Brummitt & Powell (1992).

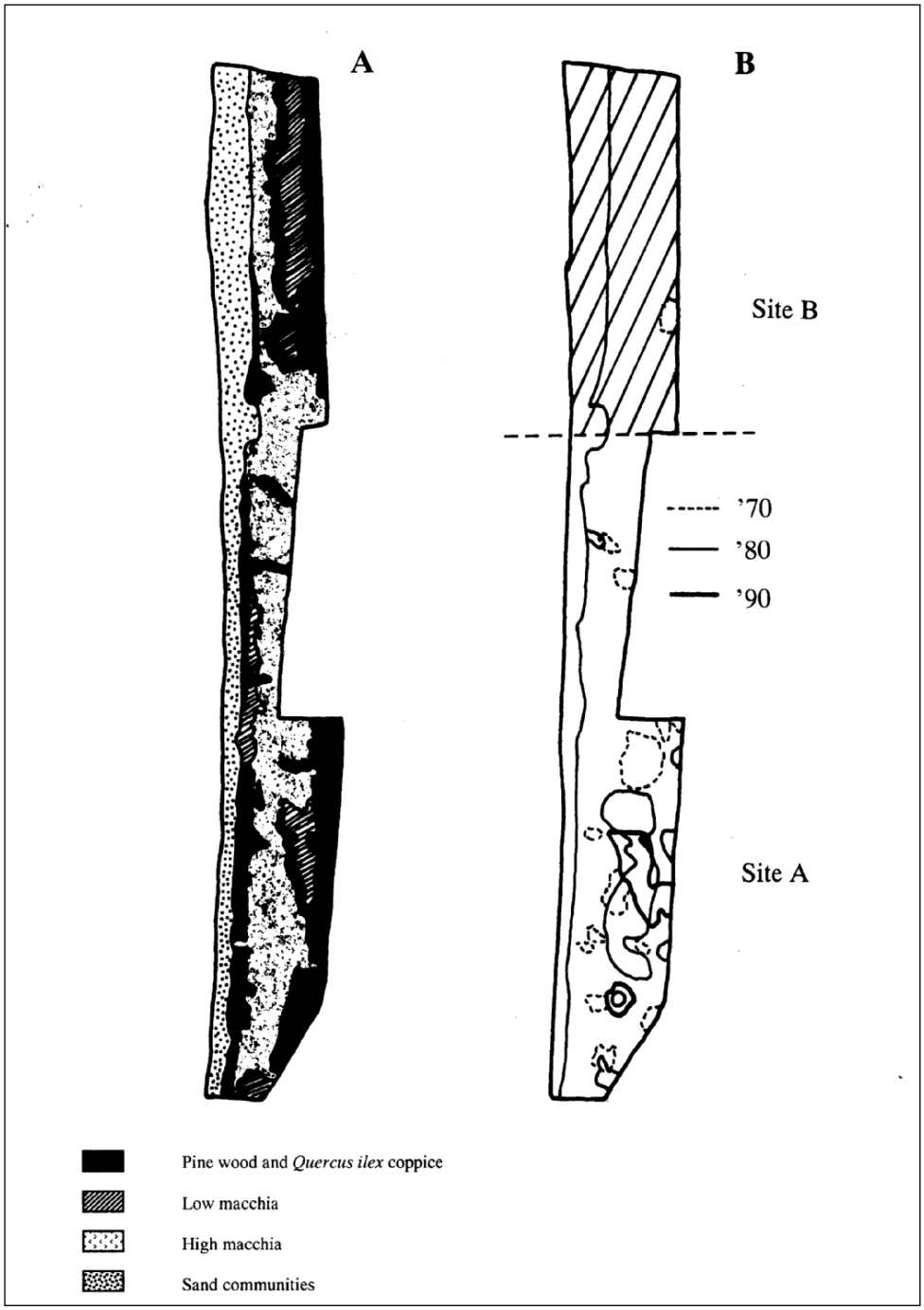

Fig. 1. Vegetation map (**A**) and fire map of the last three decades (**B**) of the Castel Volturno Nature Reserve.

Bryoflora

The Castel Volturno Nature Reserve comprises 5 liverworts and 37 mosses.

Species not found by us but recorded by Terracciano are reported in brackets; those new to Campania are indicated by an asterisk (*).The name is followed by the chorological and ecological characters, and the Reserve sector. In addition, the list indicates the collecting site and frequency of the species in the Reserve, estimated from collections and observations in the field.

The specimens were deposited in the herbarium of the University of Naples [NAP].

Floristic list

HEPATICAE

Fossombronia wondraczekii (Corda) Dumort. ex Lindb. – Circumboreal, Meso-hygrophilous, Photo-sciaphilous, Terricolous, Annual. On burned soil of moist depressions within a scrub stands. Site A. Rather rare.

Frullania dilatata (L.) Dumort. – Circumboreal, Xerophilous, Photophilous, Corticicolous, Mat. On the bark of *Quercus ilex* L. and *Eucalyptus* sp. Site A. Rather rare.

Lophocolea heterophylla (Schrad.) Dumort. – Circumboreal, Meso-hygrophylous, Sciaphilous, Terri-humicolous, Mat. On rotting wood, with *Sematophyllum substrumulosum* within a meso-hygrophilous woodland stands. Site A. Rare.

Radula complanata (L.) Dumort. – Circumboreal, Xero-mesophilous, Sciaphilous, Corticicolous, Mat. On bark of *Quercus ilex* L. Site A and B. Rather rare.

Riccia sorocarpa Bisch. – Circumboreal, Xero-mesophilous, Photophilous, Terricolous, Annual thalloid. On disturbed bare soil and gap of scrubs. Site A and B. Locally common.

MUSCI

[*Acrocladium cuspidatum* (L.) Lindb. = *Calliergonella cuspidata* (Hedw.) Loeske] – "Castel Volturno alla Fossapiatta, sulla riva destra" (Zodda, 1909). Not seen by us.

Barbula convoluta Hedw. – Circumboreal, Xerophilous, Photophilous, Terricolous, Short turf. On recently burned soil. Site A and B. Very common.

Barbula unguiculata Hedw. – Circumboreal, Xerophilous, Photophilous, Terricolous, Short turf. On recently burned soil. Site A and B. Common.

Bryum argenteum Hedw. – Cosmopolitan, Xero-mesophilous, Photo-sciaphilous,

Indifferent, Short turf. On burned soil and roadside. Site A and B. Locally common.

Bryum bicolor Dicks. – Submediterranean, Xerophilous, Photophilous, Terricolous, Short turf. On bare disturbed soil. Site A. Common.

Bryum capillare Hedw. – Circumboreal, Mesophilous, Sciaphilous, Indifferent, Short turf. On bare disturbed soil. Site A and B. Common.

Bryum dunense A.J.E. Sm. ex Withehouse – Oceanic-Submediterranean, Xerophilous, Photophilous, Terricolous, Short turf. On recently burned soil. Site A and B. Locally common.

Bryum radiculosum Brid. – Suboceanic-Mediterranean, Xerophilous, Photophilous, Terricolous, Short turf. On burned soil. Site A. Common.

Bryum ruderale Crundw. & Niholm – Suboceanic, Xerophilous, Photophilous, Terricolous, Short turf. On burned soil. Site A and B. Locally common.

Bryum torquescens Bruch & Schimp. – Suboceanic-Submediterranean, Xerophilous, Photophilous, Terricolous, Short turf. Within gaps of vegetation scrubs. Site A and B. Rather common.

Cheilothela chloropus (Brid.) Limpr. – Oceanic-Mediterranean, Xerophilous, Photophilous, Terri-saxicolous, Short turf. On burned soil. Site A. Rather rare.

Didymodon luridus Hornsch. – Submediterranean, Xero-mesophilous, Photophilous, Terri-saxicolous, Short turf. On bare, disturbed soil. Site A and B. Locally common.

[*Didymodon tophaceus* (Brid.) Jur. fo. *lingulata* Boul. = *D. tophaceus* (Brid.) Lisa] – "Castelvolturno, Mag. 1894" (Zodda, 1909). Not seen by us.

Didymodon vinealis (Brid.) R.H. Zander – Submediterranean, Xerophilous, Photophilous, Indifferent, Short turf. On bare disturbed soil. Site A. Locally common.

Eurhynchium pumilum (Wilson) Schimp. – Suboceanic-Submediterranean, Mesophilous, Sciaphilous, Terri-saxicolous, Mat. On rotting wood, with *Sematophyllum substrumulosum*, within the meso-hygrophilous woodland stands. Site A. Rare.

Eurhynchium schleicheri (R. Hedw.) Jur. – Suboceanic-Submediterranean, Mesophilous, Sciaphilous, Terricolous, Mat. On rotting wood within the meso-hygrophilous woodland stands. Site A. Rare.

Fissidens incurvus Starke – Submediterranean, Mesophilous, Sciaphilous, Terricolous, Short turf. On the tree bases of *Quercus ilex* and disturbed bare soil. Site A and B. Locally common.

Funaria hygrometrica Hedw. – Cosmopolitan, Xero-mesophilous, Photo-sciaphilous, Terricolous, Annual. On recently burned soil. Site A and B. Locally abundant.

Grimmia pulvinata (Hedw.) Sm. – Circumboreal, Xerophilous, Photophilous, Saxicolous, Cushion. On walls. Site A. Rather rare.

Orthotrichum diaphanum Brid. – Circumboreal, Xerophilous, Photophilous, Corticicolous, Short turf. On bark of *Quercus ilex* L. Site A. Rare.

Hypnum cupressiforme Hedw. var. *cupressiforme* – Cosmopolitan, Xero-mesophilous, Photo-sciaphilous, Indifferent, Weft. On soil of open pine woodland. Site A. Rather rare.

Orthotrichum tenellum Bruch ex Brid. – Suboceanic-Submediterranean, Xerophilous, Photo-sciaphilous, Corticicolous, Short turf. On bark of *Quercus ilex* L. Site A and B. Rare.

Pleurochaete squarrosa (Brid.) Lindb. – Submediterranean, Xerophilous, Photophilous, Terri-arenicolous, Tall turf. Gaps of scrubs and open pine woodland. Site A and B. Very common.

Pottia davalliana (Sm.) C.E.O. Jens. – Submediterranean, Xerophilous, Photophilous, Terricolous, Annual. On bare disturbed soil. Site A and B. Locally common.

Pottia recta (With.) Mitt. – Submediterranean, Xerophilous, Photophilous, Terricolous, Annual. On bare disturbed soil. Site A and B. Locally common.

Pseudocrossidium hornschuchianum (Schultz) R.H. Zander – Suboceanic-Submediterranean, Xerophilous, Photophilous, Terri-saxicolous, Short turf. On bare disturbed soil. Site A. Locally common.

Rhynchostegiella litorea (De Not.) Limpr. – Oceanic-Mediterranean, Mesophilous, Sciaphilous, Saxi-corticicolous, Mat. On tree bases of *Quercus ilex* L. Site A and B. Locally common.

Rhynchostegiella tenella (Dicks.) Limpr. – Suboceanic-Submediterranean, Mesophilous, Sciaphilous, Saxi-corticicolous, Mat. On rotting wood within the meso-hygrophilous woodland stands. Site A. Locally common.

Rhynchostegium confertum (Dicks.) Bruch & al. - Submediterranean, Mesophilous, Sciaphilous, Saxi-corticicolous, Mat. On tree bases of *Quercus ilex* L. Site A and B. Common.

Rhynchostegium megapolitanum (Weber & D. Mohr) Bruch & al. – Submediterranean, Xero-mesophilous, Photo-sciaphilous, Terri-arenicolous, Weft. Within gaps of scrub and pine woodland. Site A and B. Common.

Scleropodium purum (Hedw.) Limpr. – Circumboreal, Mesophilous, Sciaphilous, Terri-humicolous, Weft. On soil of open pine woodland. Site A. Rather rare.

Scleropodium touretii (Brid.) L.F. Koch – Oceanic-Submediterranean, Mesophilous, Sciaphilous, Terricolous, Weft. On tree bases of *Pinus halepensis*. Site B. Rather rare.

Scorpiurium circinatum (Brid.) M. Fleisch. & Loeske – Oceanic-Mediterranean, Xero-mesophilous, Photo-sciaphilous, Saxi-corticicolous, Mat. On tree and shrub bases. Site A and B. Common.

**Sematophyllum substrumulosum* (Hampe) E. Britton - Oceanic-Mediterranean, Mesophilous, Sciaphilous, Corticicolous, Mat. On rotting wood within the meso-hygrophilous woodland stands. Site A. Rare.

Syntrichia ruraliformis (Besch.) Cardot – Suboceanic-Submediterranean, Xerophilous, Photophilous, Terri-arenicolous, Tall turf. Within gaps of vegetation scrubs. Site A and B. Common.

Tortella flavovirens (Bruch) Broth. – Suboceanic-Submediterranean, Xerophilous, Photophilous, Terri-arenicolous, Short turf. Within gaps of vegetation scrubs. Site A and B. Very common.

Tortella nitida (Lindb.) Broth. – Suboceanic-Submediterranean, Xerophilous, Photophilous, Terri-saxicolous, Short turf. On bark of *Eucalyptus* sp. in pine woodland. Site A. Rare.

Tortula marginata (Bruch & Schimp.) Spruce – Oceanic-Mediterranean, Xerophilous, Photophilous, Saxicolous, Short turf. On walls. Site A and B. Locally common.

Tortula muralis Hedw. – Circumboreal, Xerophilous, Photophilous, Saxicolous, Short turf. On walls. Site A and B. Locally common.

Results and discussion

In spite of its small area and quite dry soil conditions, the Castel Volturno Nature Reserve hosts a varied bryophyte flora (37 mosses and 5 liverworts).

From a phytogeographical point of view, particularly important is the presence of *Bryum dunense* and *Sematophyllum substrumulosum* (Cortini Pedrotti 2001b). As for *Bryum dunense* this is the fourth record for the Italian peninsula (Esposito & al. 1993; Brullo & al. 1991). A previous report on post-fire bryophyte dynamics (Esposito & al. 1998) noted the higher frequency of this species in very recently burned vegetation and its disappearance in a more than 20 year old stand. *Sematophyllum substrumulosum*, an oceanic-mediterranean species found on rotting wood of a very small meso-hygrophilous woodland stand of site A, was known until this finding only for Tuscany, Latium and Sicily

(Cortini Pedrotti 2001b).

As reported before, this area has been characterized by a long disturbance history. Unfortunately, the lack of extensive bryophyte studies in the past precludes a comparative analysis with the present flora.

Nevertheless, the pattern of post-fire vegetation recovery was clearly influenced by fire intensity. In particular, *Funaria hygrometrica* showed dominance under high fire intensity, but progressively decreased with lowering fire intensities and successional time. An opposite behaviour was shown by *Bryum torquescens* which dominated after low-intensity fires and which appeared in the heavily burned areas only as scattered shoots later on in the succession. Compared to *Funaria hygrometrica* and *Bryum torquescens*, an intermediate behaviour was shown by *Barbula convoluta* and *Bryum dunense*. These two species successfully competed with *Funaria hygrometrica* in the heavily burned areas where a shift of dominance occurred ca. 2 years after fire (Esposito & al. 1999).

The comparison of bryophyte taxa number and percent ratios of major ecological and chorological groups of the flora of two different sectors of the Reserve provides interesting results. As reported in Tab. 1 and 2, sector A shows a greater number of bryophyte families (15) and species (41) than sector B. The greater floristic richness foundin sector A clearly reflects this area's greater habitat heterogeneity, ranging from frequently burned scrubs and *Pinus* spp. plantations to very old meso-hygrophilous woodland vegetation.

This heterogeneity can have a significant impact on the potential number of bryophytes that can establish themselves, as some species are reported to have very specific habitat requirements (Esposito & al. 1993, 1998).

Despite the low number of bryophyte species found in the study area, a wide range of different regeneration strategies was found (Tab. 3). Species that colonize the burnt sites exclusively by spores showed the highest relative cover values in the early successional stages of areas characterized by intense fire. *Funaria hygrometrica* is the most representative species of this group showing a very fast development of gametophytes and extensive

Table 1. List of bryophyte families and their associated species number at site A and B.

Families	**Site A**	**Site B**
Geocalycaceae	1	
Radulaceae	1	
Frullaniaceae	1	
Codoniaceae	1	
Ricciaceae	1	1
Dicranaceae	1	
Fissidentaceae	1	1
Pottiaceae	13	10
Grimmiaceae	1	
Funariaceae	1	1
Bryaceae	7	6
Orthotrichaceae	2	1
Brachytheciaceae	8	5
Hypnaceae	1	
Sematophyllaceae	1	
Total species	**41**	**25**

Table 2. List of bryophyte species and their occurrence at site A and B.

Species	Site A	Site B
Bryum bicolor	x	
Bryum radiculosum	x	
Cheilothela chloropus	x	
Didymodon vinealis	x	
Eurhynchium pumilum	x	
Eurhynchium schleicheri	x	
Frullania dilatata	x	
Grimmia pulvinata	x	
Hypnum cupressiforme	x	
Orthotrichum diaphanum	x	
Pseudocrossidium hornschuchianum	x	
Rhynchostegiella tenella	x	
Scleropodium purum	x	
Sematophyllum substrumulosum	x	
Fossombronia wondraczekii	x	
Lophocolea heterophylla	x	
Tortella nitida	x	
Orthotrichum tenellum	x	x
Radula complanata	x	x
Barbula convoluta	x	x
Barbula unguiculata	x	x
Bryum argenteum	x	x
Bryum dunense	x	x
Bryum capillare	x	x
Bryum ruderale	x	x
Bryum torquescens	x	x
Didymodon luridus	x	x
Fissidens incurvus	x	x
Funaria hygrometrica	x	x
Pleurochaete squarrosa	x	x
Pottia davalliana	x	x
Pottia recta	x	x
Rhynchostegium confertum	x	x
Rhynchostegium megapolitanum	x	x
Scorpiurium circinatum	x	x
Tortella flavovirens	x	x
Tortula marginata	x	x
Tortula muralis	x	x
Tortula ruraliformis	x	x
Riccia sorocarpa	x	x
Rhynchostegiella tenella var. *litorea*	x	x
Scleropodium touretii		x
Total species	**41**	**25**

Table 3. List of species regenerating by spores and/or by vegetative propagules recorded at the sampled plots.

Species	Spores	Vegetative propagules
Barbula convoluta	x	x
Bryum argenteum	x	
Bryum dunense	x	x
Bryum radiculosum		x
Bryum ruderale		x
Bryum torquescens	x	x
Cheilothela chloropus	x	
Didymodon luridus	x	
Fossombronia wondraczekii	x	
Funaria hygrometrica	x	
Pleurochaete squarrosa		x
Pseudocrossidium hornschuchianum	x	
Riccia sorocarpa	x	
Tortella flavovirens	x	x

production of sporophytes.

By contrast, species that produce asexual propagules characterized the later successional stages in the different conditions and pioneer stages of low intensity fires. After the first growing season, gemmae were frequently produced at the leaf bases of *Bryum dunense*. The occurrence of tubers on rhizoids is the most common strategy among colonist species such as *Barbula convoluta*, *Bryum torquescens*, *B. radiculosum* and *B. ruderale*.

A comparative analysis of ecological characters is shown in Fig. 2. According to macro-environmental conditions, both sectors are characterized by the prevalence of xerophilous and photophilous species. Regarding water affinity, the slightly higher values of xero-mesophilous species found in sector B confirm a dominance of older and closed scrubs and coppice vegetation. On the other hand, the occurrence of meso-hygrophilous species, exclusively in sector A, should be related to the presence of a small relict of meso-hygrophilous vegetation (e.g. *Lophocolea heterophylla*) and a recently burned site on dune depressions (e.g. *Fossombronia wondraczekii*).

Concerning substratum type, the terricolous species are prevalent in both sectors. Moreover, according to environmental conditions, the terri-arenicolous group shows higher values in sector B, while indifferent species are clearly higher in more the disturbed site A. Finally, the presence of a small relict of meso-hygrophilous vegetation offers the opportunity for a more diversified substratum type that can be colonized by bryophytes. In this sense, the corticicolous species (12.2%) can be found on the older trees that characterized this stand; moreover, the terri-humicolous species found on rotting wood are also particularly representative of this area, and some of them (*Sematophyllum substrumulosum*) are rather rare in Italy.

The ecological spectra within the major chorological elements (Fig. 3) and the growt form spectrum (Fig. 4) of two closely related floristic sets show interesting results (Düll

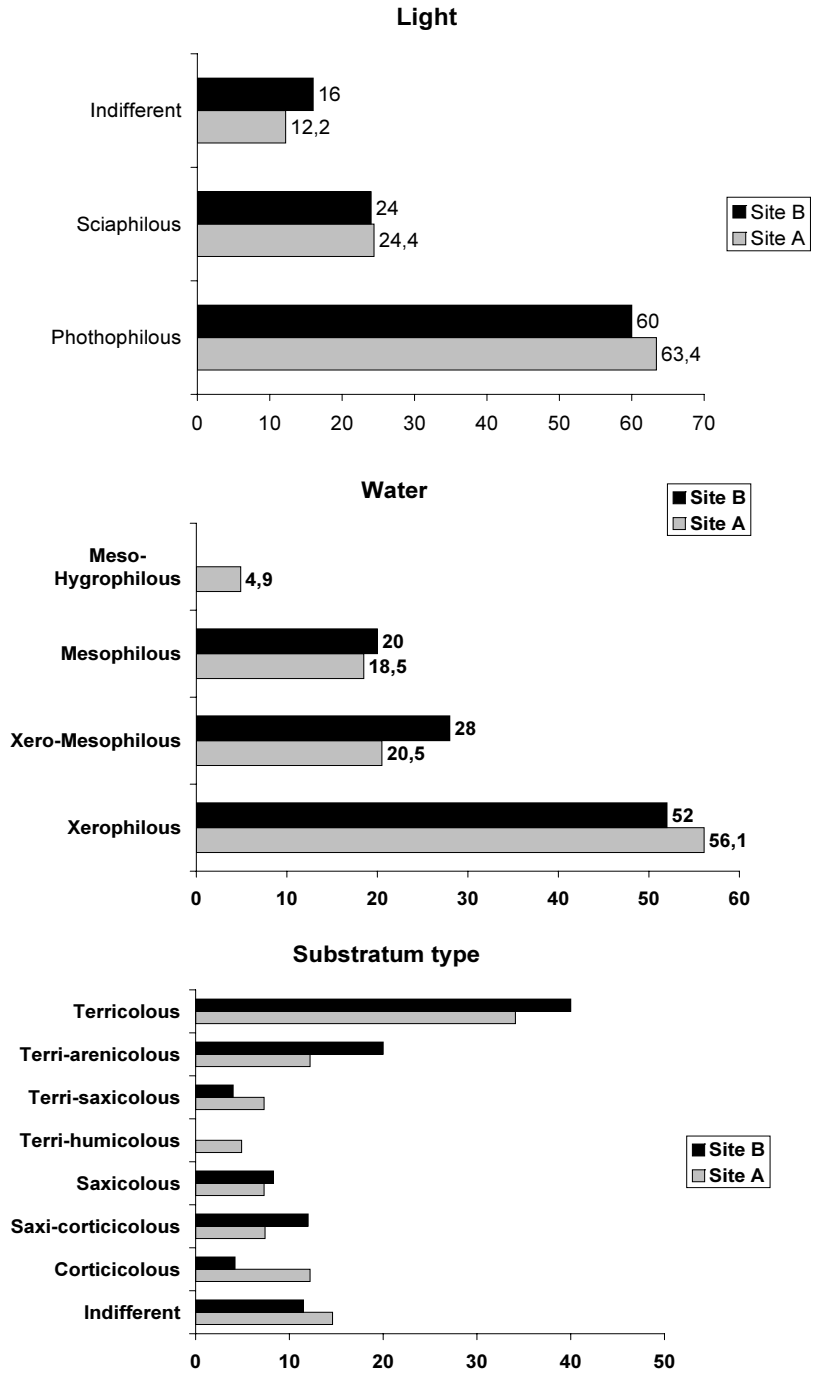

Fig. 2. Comparative analysis of ecological characters (light, water and substratum type).

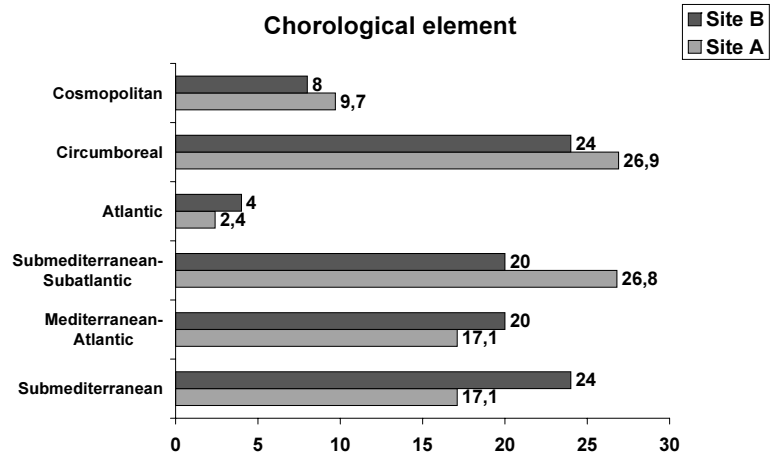

Fig. 3. Ecological spectra within the major chorological elements.

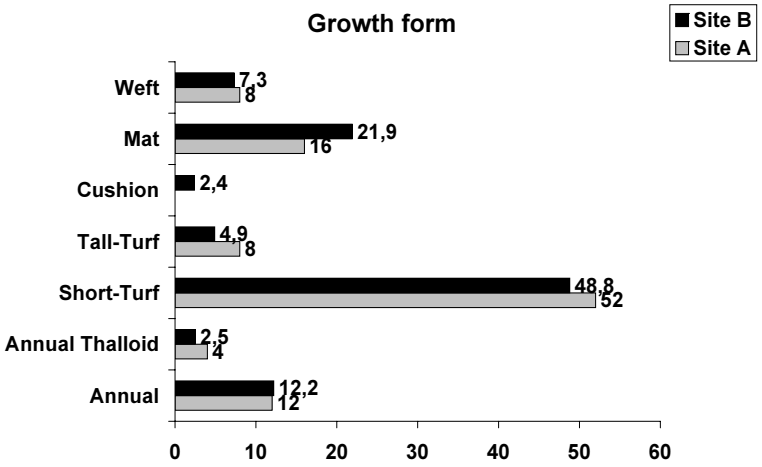

Fig. 4. Growth form spectrum.

1983, 1984, 1985, 1992). In terms of the Mediterranean element, the more homogeneous and less disturbed sector B is characterized by the dominance of Submediterranean (24%) and Mediterranean-Oceanic (20%) groups, while Submediterranean-Suboceanic shows higher values in the more disturbed sector A, where higher values for Circumboreal (26.9%) and Cosmopolitan (9.7%) species are also found.

The results of this study highlight the strong potentiality of bryophyte as effective indicators of environmental factors, including both micro-environmental conditions and disturbance histories of this Reserve.

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