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## Bryophyte diversity in Augusta-Priolo territory (South-Eastern Sicily)

### Abstract

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The bryophyte flora of two areas adjacent to the petrochemical pole of Augusta-Priolo in the South-Eastern Sicily was investigated: Punta Cugno and the Nature Reserve Saline di Priolo. A biological and ecological analysis was made, showing: the predominance of species of the Mediterranean phytogeographical element, with prevailing life strategy colonist and life form turf; the low occurrence of species sensitive to pollutants and the high occurrence of species tolerant human impact. The occurrence of some species of phytogeographical interest, deserving protection, was detected. They are *Didymodon sicculus*, *Ditrichum pusillum*, *Tortula solmsii*, *Tortula viridifolia*. For these species the IUCN category for Sicily is proposed too.

*Key words:* Bryophytes, Biological/ecological analysis, Environmental quality, Augusta-Priolo territory.

### Introduction

In the last times an increasing rate of extinction was both recorded for animal and plant species; this is quite worrying especially considering that the causes of this loss are mainly linked to human activity (Manes & Capogna 2005). These threats lead to a deterioration and impoverishment of the ecosystems and local extinction of species, primarily the most sensitive and vulnerable, such as the endemic and rare species (Blasi & al. 2010). The biodiversity conservation often conflicts with the needs of man and the efforts to reconcile them converge in appropriate International Conventions, agreement and strategic plans, as the Bern Convention, the CBD and the Directive 92/43/EEC with the Natura 2000 network.

In this context a study, addressed to the knowledge and conservation of the bryophyte diversity of the South-eastern Sicily, was carried out. In particular, the survey was aimed to investigate the bryoflora of two neighboring coastal areas adjacent the petrochemical complex district of Augusta-Priolo: the area of Punta Cugno and the Nature Reserve Saline di Priolo, a Site of Community Importance and a Special Protection Area within the Natura 2000 Network (Fig. 1). Both areas are localized within the industrial triangle of

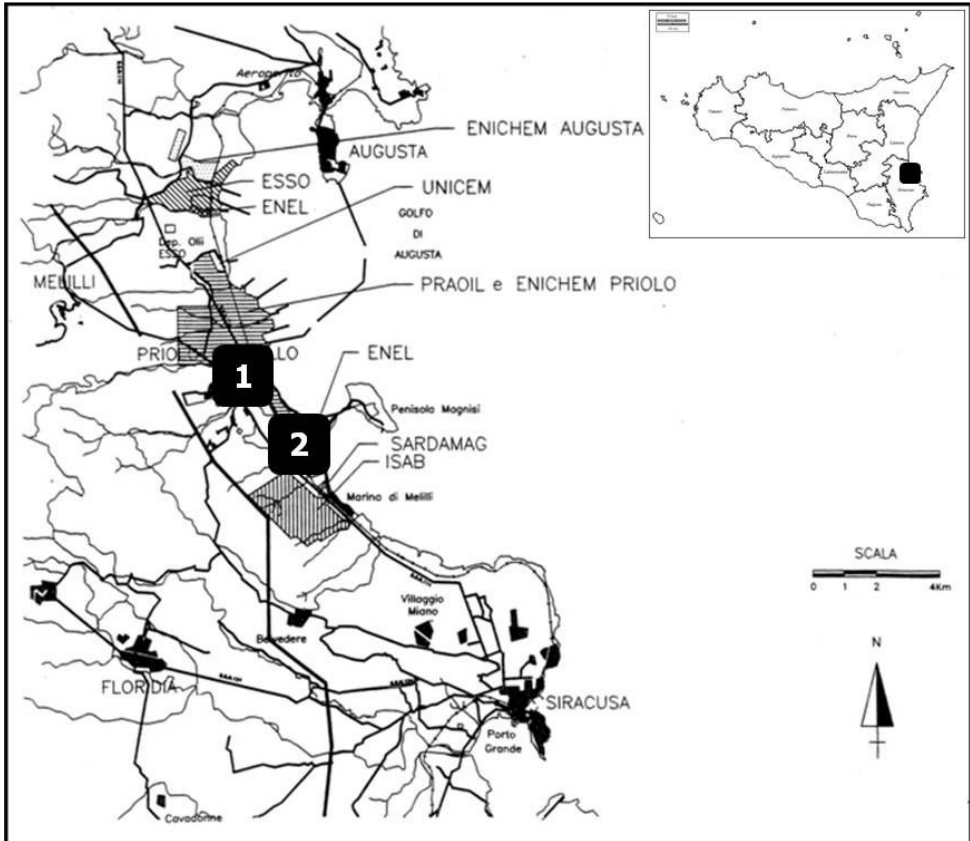


Fig. 1. Location of the investigated areas. 1: Punta Cugno; 2: Nature Reserve Saline di Priolo.

Augusta-Melilli-Priolo (Syracuse province), a territory with a particularly fragile ecosystem balance due to the rate of environmental pollution.

The investigated territory falls within the margin of the northeastern Hyblaean plateau; this constitutes a carbonate Meso-Cenozoic massif, with volcanic intercalations, lying on the African continental crust. The lithostratigraphic sequence of the area consists of alternating layers of sedimentary deposits and volcanoclastic levels lying on a Miocene carbonate base (Lazzari 2011).

The area is included in the Mediterranean climatic region and is characterized by a Mediterranean pluvisessional oceanic bioclimate (Rivas Martínez & al. 2004). For the climatic data we refer to the meteorological station of Augusta (70 m a.s.l.). In particular, the thermotype is thermomediterranean with mean annual temperature of 18.4°C and the ombrotype is dry with mean annual precipitations of 538.1 mm.

*PUNTA CUGNO* - The site includes lands previously occupied by a traditional agricultural mosaic, now uncultivated, with the recolonization of maquis with *Ceratonia siliqua* L.,

*Myrtus communis* L., *Pistacia lentiscus* L., *Prasium majus* L., *Rhamnus alaternus* L., prevailing. The surrounding area is characterized by agricultural terrains mostly characterized by the presence of arable crops, citrus and olive groves.

*NATURE RESERVE SALINE DI PRIOLO* - The Reserve consists of a large coastal pond corresponding to the ancient reservoirs of seawater. The wetland is separated from the sea by a narrow dune cordon extending, in the middle part, in a short isthmus connected with the Peninsula Magnisi, of calcareous origin. As regards the flora, along the sandy coastline it is possible to observe the presence of some psammophytes, e.g. *Achillea maritima* (L.) Ehrend. & Y. P. Guo, *Cakile maritima* Scop., *Calystegia soldanella* L., *Echinophora spinosa* L., *Eryngium maritimum* L., *Pancreatium maritimum* L., *Salsola soda* L. In the saltens it is possible to find *Ruppia maritima* L., *Sarcocornia fruticosa* (L.) A. J. Scott, *Suaeda maritima* (L.) Dumort. The reeds, not very dense, are mainly constituted by *Phragmites australis* (Cav.) Steud.

## Material and methods

The field work was carried out in the spring of the years 2010 and 2013 with excursions during maximum sporification period (March, April).

The analysis of the bryoflora was made by using the next data:

- the chorological elements, following Hill & Preston (1998); each element is specified by the major biome (Mediterranean, Southern-temperate, Temperate, Wide-temperate, Boreo-temperate, Boreal-montane, Wide-boreal, Boreo-arctic montane, Arctic-montane) and eastern limit category in Eurasia (Circumpolar, Eurasian, Eurosiberian, European, Suboceanic, Oceanic, Hyperoceanic);
- three ecological indices, following Hill & al. (2007): moisture (F) with values ranging from 1 (indicator of extreme dryness) to 12 (normally submerged); substrate acidity (R), with values ranging from 1 (indicator of extreme acidity) to 9 (on substrata with free calcium carbonate, mainly chalk and limestone); Nitrogen (N) with values ranging from 1 (indicator of extremely infertile sites) to 7 (plant often found in richly fertile places);
- the life strategy according the classification of During (1979) and Frey & Kürschner (1991);
- the life form follows the concept in Mägdefrau (1982) and the classification of Hill & al. (2007);
- the sensibility to SO<sub>2</sub> according to the classification of Rao (1982);
- the sensibility to human impact taken from Dierßen (2001), gathered in three groups according to Kürschner & al. (2007) and Puglisi & al. (2012): species showing a low human impact (ahemerobic, oligohemerobic, a-oligohemerobic species, oligo-meso-hemerobic), species showing a moderately strong human impact (mesohemerobic and meso-euhemerobic species), species showing strong human impact (euhemerobic, poly-hemerobic, eu-polyhemerobic and hemerophilous species). The species with a wide range (i.e. a-euhemerobic, oligo-euhemerobic, meso-polyhemerobic) were not considered for their insignificance.

The nomenclature of the species follows Ros & al. (2013) for the mosses and Ros & al. (2007) for the liverworts. The distribution in the Italian regions is taken from Aleffi & al. (2008).

The specimens are kept in CAT Herbarium.

## Results and discussion

In the study areas a total of 39 *taxa* (Tab. 1) were found with the ratio liverwort/mosses very low (0.03), with the prevalence of the *Pottiaceae* family (60%). The high incidence of this family is due to the high number of species adapted to dry climates and therefore tolerant of long droughts, such as the Mediterranean coast territories and the urban areas, where there is a considerable rate of pollution. The second most numerous family is represented by the *Bryaceae* (13%), a large acrocarpous moss family. The other moss families are: *Brachytheciaceae* (8%) *Grimmiaceae* and *Fissidentaceae* (5% each), *Dicranaceae*, *Ditrichaceae* and *Funariaceae* (3% each).

As regards the phytogeographical analysis, the Mediterranean element, including Oceanic Mediterranean, Suboceanic Mediterranean and Eurasian Mediterranean species, prevails (59%), in agreement with the geographical position of the investigated areas. The Mediterranean element is followed by the Southern-temperate element (17.9%), with European, Eurosiberian and Circumpolar species, the Wide-temperate element (12.8%), with European and Circumpolar species, the Circumpolar Boreo-temperate (7.8%) and Circumpolar Temperate species (2.5%).

The ecological analysis overall reveals a xerophytic bryoflora with the occurrence of many species indicators of dry and extremely dry sites, (F values ranging from 1 to 3) e.g. *Aloina aloides*, *Bryum radiculosum*, *Dicranella howei*, *Didymodon acutus*, *D. sicculus*, *D. vinealis*, *Grimmia pulvinata*, *G. trichophylla*, *Microbryum rectum*, *M. starckeanum*, *Pseudocrossidium hornschurchianum*, *Ptychostomum torquescens*, *Tortella nitida*, *Tortula brevissima*, *Tortula muralis*, *Weissia condensa*. Regarding the values of the reaction to substrate acidity (R), the flora is mostly composed by species typical of basic or strongly basic substrata (corresponding to R values ranging from 6 to 8). As the values for Nitrogen (N), that are a general indication of fertility, the bryoflora overall reflects a site with medium nutrient content (N values 4-5).

As concerns the life strategy a strong occurrence of colonist species is observed (69.2%), including colonist with sexual reproductive effort (Bg) which are predominant, pauciannual colonist (Ba), colonist with asexual reproductive effort (Bv), colonist with asexual and sexual reproductive effort (Bv,g), colonist with basitonic innovations; these species can be regarded as pioneers colonizing hard environments prevailing in dry and sun-exposed sites or underlying a strong disturbance (Frey & Kürschner 1991; Kürschner & Erdağ 2008; Kürschner & Frey 2013; Puglisi & al. 2012, 2015). The colonist life strategy is followed by the perennial stayers (17.9%), which are typical of undisturbed stable environments (Kürschner & Erdağ 2008; Kürschner & Frey 2013; Puglisi & al. 2013a, 2013b, 2014); they include in the investigated areas the perennial stayers with high sexual reproductive effort (Ag), high asexual reproductive effort (Av), high asexual and sexual reproductive effort (Av,g), low asexual and sexual reproductive effort (Ap). The other life strategies are the annual shuttle (10.3%) and short-lived shuttle (2.6%). The shuttle species are found in habitat with seasonal fluctuations that can be tolerated as spore stage (Kürschner & Parolly 1999; Lo Giudice & Bonanno 2010; Kürschner & Frey 2013). An analysis carried out in the Natural Reserve Cava Grande del Cassibile (SE Sicily) has emphasized a lower percentage of colonist species (38%) and higher percentage of perennial stayers (33%, unpublished data).

Table 1. List of species found in both studied areas, indicating for each of them, chorotypes, ecological indices, life strategy, life form, sensibility to SO<sub>2</sub>, and human impact tolerance.

Taxa	Saline di Priolo	Punta Cugno	Chorotypes	Ecological indices		Life strategy	Life forms	Sensibility to SO <sub>2</sub>	Human impact
				F	N				
				R					
<i>Aloina aloides</i> (Koch ex Schultz) Kindb.	-	●	European Southern-temperate	3	3	Bg	Ts	Txt	oligo-euhemerobic
<i>Aloina ambigua</i> (Bruch & Schimp.) Linpr.	●	-	European Southern-temperate	4	3	Bg	Ts	Txt	oligo-mesohemerobic
<i>Barbula convoluta</i> Hedw.	●	●	Circumpolar Wide-temperate	4	5	Bv	Tf	Txp	eu-polyhemerobic
<i>Barbula unguiculata</i> Hedw.	●	●	Circumpolar Wide-temperate	5	5	Bg	Tf	Txp	meso-polyhemerobic
<i>Bryum dichotomum</i> Hedw.	●	●	European Wide-temperate	5	7	Bv,g	Tf	Txp	a-euhemerobic
<i>Bryum radiculosum</i> Brid.	●	●	Suboceanic Mediterranean	3	5	Bv	Tf	Txt	meso-euhemerobic
<i>Dicranella howei</i> Renaud & Cardot	●	●	Suboceanic Submediterranean	3	-	Bg	Tf	Txt	meso-euhemerobic
<i>Didymodon acutus</i> (Brid.) K. Saito	-	●	Circumpolar Southern-temperate	3	2	Bv	Tf	Txp	meso-euhemerobic
<i>Didymodon luridus</i> Hornsch.	-	●	Suboceanic Mediterranean	4	4	Bg	Tf	Txp	meso-euhemerobic
<i>Didymodon steculus</i> M.J.Cano, Ros, García-Zamora & J.Guerra	●	-	Eurasian Mediterranean	3	-	Ba	Tf	Txt	-
<i>Didymodon vinealis</i> (Brid.) R.H.Zander	●	●	European Southern-temperate	3	4	Bg	Tuft	Txp	meso-euhemerobic
<i>Ditrichum pusillum</i> (Hedw.) Hampe	-	●	Circumpolar Boreo-temperate	5	3	Av,g	Ts	Txt	meso-euhemerobic
<i>Entosthodon attenuatus</i> (Dicks.) Bryhn	●	●	Oceanic Mediterranean	7	3	Pe	Ts	Txt	oligo-mesohemerobic
<i>Fissidens bryoides</i> Hedw. var. <i>bryoides</i>	●	●	Circumpolar Temperate	5	5	Bg	Tf	Txt	oligo-euhemerobic
<i>Fissidens viridulus</i> (Sw.) Wahlb. var. <i>viridulus</i>	-	●	Circumpolar Wide-temperate	5	6	Bg	Tf	Txp	oligo-euhemerobic

Table 1. continued.

<i>Fossombronina caespitiformis</i> De Not. ex Rabenh.	-	•	Eurasian Mediterranean	6	5	4	Pe	Sc	Txt	meso-euhemerobic
<i>Grimmia pulvinata</i> (Hedw.) Sm.	•	•	Circumpolar Southern-temperate	1	8	4	Ba	Cu	Txt	meso-euhemerobic
<i>Grimmia trichophylla</i> Grev.	-	•	Circumpolar Wide-temperate	1	2	2	Av	Cu	S	oligo-mesohemerobic
<i>Gyroweisia reflexa</i> (Brid.) Schimp.	-	•	Oceanic Mediterranean	5	7	3	Bv.g	Tf	Txt/S	oligo-mesohemerobic
<i>Microbryum rectum</i> (With.) R. H. Zander	•	•	Oceanic Mediterranean	3	7	3	-	Ts	Txt	meso-euhemerobic
<i>Microbryum starckeanum</i> (Hedw.) R. H. Zander	•	-	Suboceanic Mediterranean	3	7	3	Pe	Ts	Txt	meso-euhemerobic
<i>Oxyrrhynchium schleicheri</i> (R. Hedw.) Röhl.	•	-	Suboceanic Mediterranean	5	6	4	Ap	Mr	S	oligo-mesohemerobic
<i>Pseudocrossidium hornschuchianum</i> (Schultz) R. H. Zander	•	-	Euro Siberian Southern-temperate	3	7	5	Bi	Tf	Txt	mesohemerobic
<i>Psychostomum capillare</i> (Hedw.) D. T. Holyoak & N. Pedersen	•	•	Circumpolar Boreo-temperate	4	7	4	Bv.g	Tf	Txp	oligo-euhemerobic
<i>Psychostomum imbricatulum</i> (Müll. Hal.) D. T. Holyoak & N. Pedersen	•	•	Circumpolar Boreo-temperate	4	6	5	Bv	Tf	Txp	meso-euhemerobic
<i>Psychostomum torquescens</i> (Bruch & Schimp.) Ros & Mazimpaka	•	•	Oceanic Mediterranean	3	7	3	Bv.g	Tf	Txt	oligo-euhemerobic
<i>Rhynchostegiella tenella</i> (Dicks.) Limpr. var. <i>tenella</i>	-	•	Suboceanic Mediterranean	4	8	5	Ag	Mr	S	a-oligohemerobic
<i>Rhynchostegiella megapolitanum</i> (Blandow ex F. Weber & D.Mohr) Schimp.	•	•	Suboceanic Mediterranean	4	7	5	Ag	Mr	Txt	Mesohemerobic
<i>Timmia barbuloidea</i> (Brid.) Mönk.	-	•	Suboceanic Mediterranean	4	8	-	Ag	Tf	Txt	a-euhemerobic
<i>Tortella flavovirens</i> (Bruch) Broth. var. <i>flavovirens</i>	•	•	Suboceanic Mediterranean	5	7	4	Bg	Tuft	Txt	oligo-mesohemerobic
<i>Tortella nitida</i> (Lindb.) Broth.	-	•	Oceanic Mediterranean	2	9	2	Ap	Tuft	Txt	meso-euhemerobic
<i>Tortula brevissima</i> Schiffn.	-	•	Eurasian Mediterranean	2	-	-	Ba	Tf	Txt	mesohemerobic
<i>Tortula marginata</i> (Bruch & Schimp.) Spruce	•	•	Oceanic Mediterranean	4	8	5	Ba	Tf	Txp	euhemerobic
<i>Tortula muralis</i> Hedw.	•	•	Circumpolar Southern-temperate	2	8	5	Ba	Tf	Txp	meso-polyhemerobic
<i>Tortula solmsii</i> (Schimp.) Limpr.	-	•	Oceanic Mediterranean	5	6	4	Ba	Tf	Txt	euhemerobic
<i>Tortula viridifolia</i> (Mitt.) Blockeel & A. J. E. Sm.	•	-	Oceanic Mediterranean	5	6	4	-	Tf	Txt	meso-euhemerobic
<i>Trichostomum brachydonium</i> Bruch	•	•	Suboceanic Mediterranean	5	7	3	Pk	Tf	Txt	a-mesohemerobic
<i>Trichostomum crispulum</i> Bruch	-	•	Circumpolar Southern-temperate	4	8	3	Bi	Tf	S	a-mesohemerobic
<i>Weissia condensa</i> (Voit) Lindb. var. <i>condensa</i>	-	•	Suboceanic Mediterranean	2	9	2	Bg	Tf	Txt	meso-euhemerobic

The life form turf is strongly predominant (61.5%), followed by a much lower percentage of turf scattered (15.4%), tuft and mat rough (7.7% each), cushion (5.1%) and solitary creeping (2.6%). The high percentage of turf, a life form typical of man-disturbed habitat (Lo Giudice & al. 1997; Gueli & al. 2004; Lo Giudice & Bonanno 2010), is due to the high presence of *Pottiaceae* adapted to dry and sunny habitats (Lo Giudice & al. 1997; Werner & al. 2004). In the Natural Reserve Cava Grande del Cassibile, the percentage of the life form turf is lower (40%, unpublished data).

Respect to the sensibility to SO<sub>2</sub>, the toxitolerant species prevail (61.5%), followed by the toxiphilous (28.2%); the sensitive are represented only by a percentage of 10.2%. Apart from the percentage of the toxitolerant species, normally represented even in degraded and anthropic areas, the occurrence of the toxiphilous contingent and above all the low percentage of sensitive are an indication of a disturbed territory with a rate of disturbance stronger than that detected in other Sicilian protected areas, e.g. in the Natural Reserve Cavagrande del Cassibile (toxiphilous 22%, sensitive 34%), in the Integral Natural Reserve Grotta Monello (toxiphilous 23.5%, sensitive 32.4%), (Corradino & al. 2013; Privitera & al. 2010). Moreover, an exclusive presence of markedly and moderately resistant to pollution species was detected at Milazzo and surroundings (N Sicily) where a thermoelectric power plant and an oil refinery are localized (Privitera & Puglisi 1995).

Likewise, in relation to the hemerophobic-hemerophilous gradient, expressing the intensity of human impact to which the species underlie, the species showing a moderately strong human impact prevail (62.9%), followed, with a considerable distance, by species with low (25.9%) and strong human impact (11.2%). A comparison with the Natural Reserve Cavagrande del Cassibile shows in this area a bryoflora with a higher percentage of species with low human impact (33%, Corradino & al. 2013).

#### *SPECIES OF PHYTOGEOGRAPHICAL INTEREST*

In the frame of this research some interesting species were found *Didymodon sicculus*, *Ditrichum pusillum*, *Tortula solmsii*, *Tortula viridifolia*; they are added to the valuable bryophyte flora of Sicily pointed out in many studies (e.g. Privitera & Puglisi 2002, 2009; Campisi & al. 2006; Dia & Campisi 2006, 2009; Puglisi 2009; Puglisi & al. 2013c).

***Tortula viridifolia*** - A subneutrophytic, psammophytic and halophytic species, typical of salt meadows and upper saltmarsh, subject to at most only very occasional tidal inundation or of cliffs receiving some salt spray (Dierßen 2001). *Tortula viridifolia* was found at Nature Reserve “Saline di Priolo” in low loose tufts along the dune cordon together with *Microbryum starckeanum* (Hedw.) R. H. Zander and *Tortella flavovirens*. *Tortula viridifolia* is, as indicated in Table 1, an Oceanic Mediterranean species, signaled in Italy from Sardinia and Sicily and with a single old report by Zodda (1909) in the Campania region in the southern peninsula (Ros & al. 2013); in Sicily it is a rare species, occurring only in the Island of Lipari (Aeolian archipelago), in the islet of Lachea (eastern coast), at Pace del Mela (Messina territory) and the hinterland of the Catania province (Lo Giudice & Privitera 1989; Privitera & Puglisi 1995; Gueli & al. 2004; Privitera & al. 2008). It is included in the Red List of bryophytes of Spain and considered as a Vulnerable species (Brugués & González Mancebo 2012). In Italy it was considered Endangered (Cortini Pedrotti & Aleffi 1992). Following the new 2012 IUCN *criteria* we propose to consider this species as Vulnerable (D2) in Sicily.

***Tortula solmsii*** (Schimp.) Limpr. - A subneutrophytic-basiphytic, hygrophytic-xerophytic species (Dierßen 2001) found at Punta Cugno in rock crevices. *Tortula solmsii* is a Mediterranean-Atlantic species restricted to countries fringing the Mediterranean Sea, the Atlantic Islands (Canary Islands, Madeira and Azores), reaching its northernmost stations on the southern coast of England (Porley 2013). In Italy it is signaled only from the Campania region, Sardinia and Sicily, where it is fairly diffused. The species, considered Vulnerable in Italy (Cortini Pedrotti & Aleffi 1992), is listed as Rare in Europe (ECCB, 1995). Considering the phytogeographic importance, we propose for Sicily the attribution of the IUCN category LC-att.

***Didymodon sicculus*** - It is a subneutrophytic, highly xerophytic and photophytic species, well adapted to the peculiarity of the Mediterranean climate (Dierßen 2001). The species was found on trodden soil at Saline di Priolo together with *Aloina ambigua* (Bruch & Schimp.) Limpr. and *Dicranella howei*. Despite *Didymodon sicculus* is a rather recently described species (Cano & al. 1996), it is signalled in a lot of localities of the Mediterranean region (Ros & al. 2013). In Italy it is reported only from few localities of central and southern peninsula and from Sicily, where it was found in the island of Linosa of the Pelagian archipelago and the hinterland of the Catania province (Gueli & al. 2004; Puglisi & al. 2004). It seems that the saline habitat is an important factor for the establishment of this species and for this reason it could be considered a facultative halophyte or halotolerant (Dierßen, 2001; Papp & al., 2012). The finding of the species in the Saline of Priolo on saline soil should confirm this hypothesis. For the phytogeographic interest of the species we propose for Sicily the IUCN category LC-att.

***Ditrichum pusillum*** (Hedw.) Hampe - An acidophytic-subneutrophytic, mesophytic species found in disturbed sites on sandy soil, especially along roadsides (Dierßen 2001). In the investigated area, it was collected at Punta Cugno along a trodden path where it grew in short scattered turfs together with *Didymodon luridus* Hornsch. and *Dicranella howei*. It is a Boreo-temperate species, not widespread in the Mediterranean region. In Italy it is signaled in many northern and central regions, while in the South only old reports from the Calabria region are known; in Sicily it is only signaled from the Egadi archipelago (Carratello 2001, 2004, 2007). The new record represents the first for the Sicily Island. It is included in the Red List of bryophytes of Spain and considered as Vulnerable (Brugués & González Mancebo 2012). For Sicily we propose the IUCN category Vulnerable (D2).

## Conclusion

The analysis of the results shows in the investigated areas a typically Mediterranean, xerophytic bryophyte flora characterized by species with prevailing life strategy colonist, life form turf, markedly or moderately resistant to pollution. On the whole the floristic composition reflects an anthropic disturbance to which the close petrochemical complex contributes. This is confirmed by the comparisons with other areas where no industry is present, such as the Natural Reserves Cava Grande del Cassibile and Grotta Monello, both located in south-eastern Sicily. Instead, it shows some affinities with the bryoflora of Milazzo and surroundings, located close to a thermoelectric power plant and an oil refinery.



Nevertheless, some species of phytogeographical interest, such as *Didymodon sicculus*, *Ditrichum pusillum*, *T. solmsii* and *Tortula viridifolia* were found. Thus, the task of the scientific community is the conservation of these species over time by appropriate measures of protection and safeguard, already adopted with the institution of the Nature reserve and to be extended in the surrounding territory. The naturalistic interest of the investigated areas could partially redeem the degradation of an area already too penalized by industrial settlements.

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