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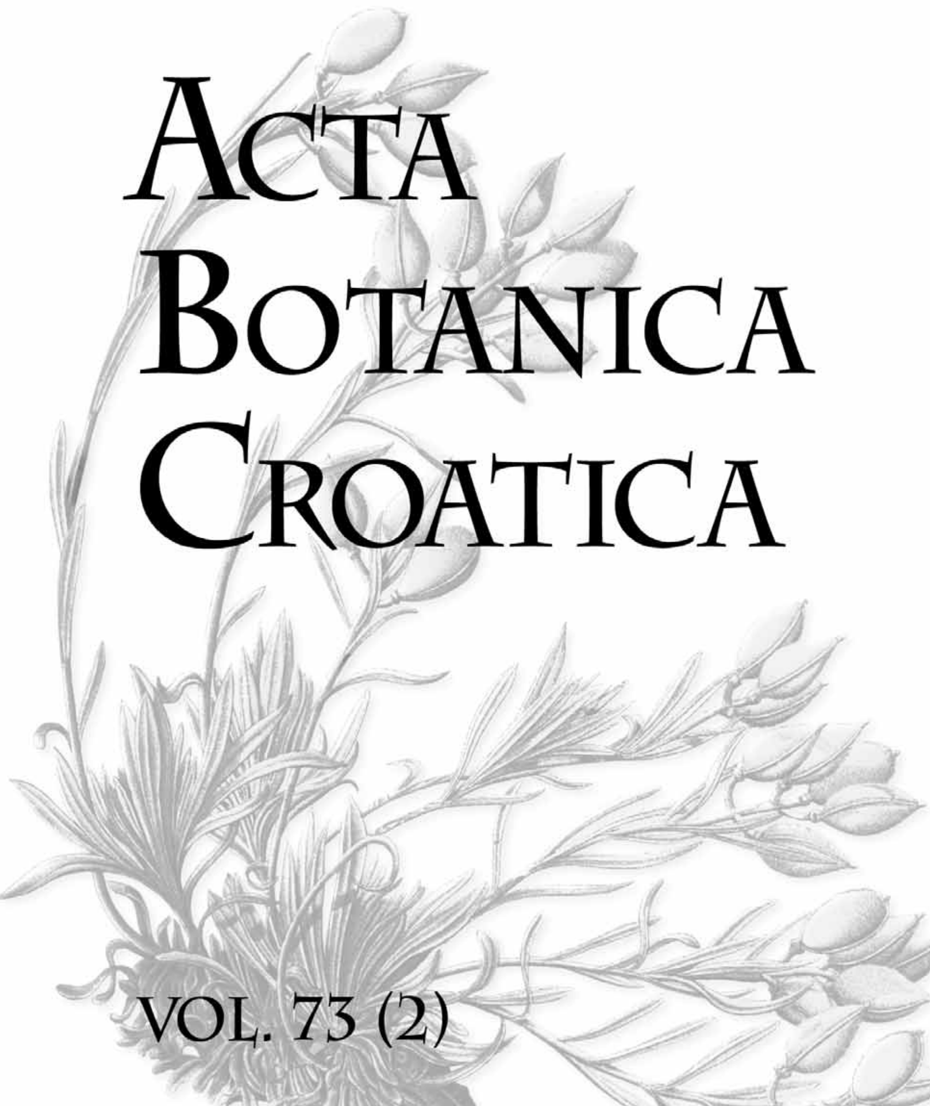

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Distribution patterns and floristic analysis of the *Colymbada tauromenitana* (Guss.) Holub populations in Sicily (Italy)

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Abstracts – *Colymbada tauromenitana* (Guss.) Holub *(Asteraceae)* is a rare paleoendemic, chasmophyte species, occurring on calcareous cliffs in the eastern part of Sicily (Italy). The aim of this work is to analyze the structure and floristic composition of the *C. tauromenitana* community, in order to characterize the diversity of populations in relation to different ecological data. In all, 61 plots were examined. For each plot, the floristic composition and the cover of the species were determined using the standard relevé method. Three vegetation types emerged from canonical components analysis (CCA), correlated to a gradient of environmental conditions ranging from the coast to inland areas. The first group with *Lomelosia cretica* and *Dianthus rupicola* subsp. *rupicola* was correlated to thermo-xerophilous conditions (lower thermo-Mediterranean belt), the second group with *Silene fruticosa* and *Colymbada tauromenitana* was linked to thermophilous conditions (upper thermo-Mediterranean belt) and the third with *Dianthus siculus* and *Odontites bocconei* was correlated to mesophilous conditions (meso-Mediterranean belt). Altitude is the main factor influencing both species richness and floristic composition. The density of *C. tauromenitana* is influenced mainly by rainfall. Finally, we propose a new risk status for this rare species.

Keywords: *Colymbada tauromenitana*, conservation status, distribution, ecology, Italy, paleoendemic, plant diversity, Sicily

Introduction

The high level of plant endemism in the Mediterranean area is related to the environmental heterogeneity, particular climatic conditions, geological and paleogeographic factors as well as millennial human land use (Cowling et al. 1996, Médail and Verlaque 1997, Carmel and Flather 2004, Minissale and Sciandrello 2013).

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Plant conservation strategies are a crucial issue in the Mediterranean area, due to excessive human impact on the natural landscape which in several cases has led to the loss of habitats and endemic species (Schröter et al. 2005, Pisanu et al. 2011, Tomaselli et al. 2012). Sicily is one of the most important centers of plant diversity in the Mediterranean region (Médail and Quézel 1999). With about 3,300 vascular taxa (species and subspecies) according to Giardina et al. (2007), it accounts for nearly 43% of the entire vascular flora of Italy (7,634 species, according to Conti et al. 2005). The importance of the vascular flora of Sicily lies not only in the total number of taxa but also in the considerable number of endemic species (about 13% according to Brullo et al. 2011). Chasmophytes represent one of the most important groups of plants within the flora of Sicily (Davis 1951, Thompson 2005). This ecological group includes one very interesting taxon, *Colymbada tauromenitana* (Guss.) Holub (= *Centaurea tauromenitana* Guss.), a huge plant which grows on the limestone cliffs of the Peloritani district (Pirola 1961, Gramuglio et al. 1985, Brullo et al. 1995). This species is a paleoendemic species exclusive to eastern Sicily (Arena et al. 1975). Currently, populations of *C. tauromenitana* are threatened by human activities, mainly represented by excavations for building, and by invasive plants, especially the expansion of *Opuntia ficus-indica*. The aim of this study is the analysis of the structure and floristic composition of the *C. tauromenitana* community, in order to characterize the diversity of populations in relation to different environmental conditions. These results will be useful for a proper evaluation of its conservation status and for the improvement of actions aimed at the conservation of this rare taxon.

Materials and methods

Study area

The study area includes the Peloritani district, in the eastern part of Sicily (Fig. 1). This area is characterized by mountains of moderate altitude, comprising, from south to north, Monte Tauro (245 m), Monte Petraro (475 m), Castelmola (496 m), Roccella (602 m), Monte Ziretto (381 m), Costa Ogliastro (466 m), Monte Veneretta (884 m), Monte Lapa (771m), Monte Castelluccio (501 m), Monte Pernice (712 m) and Monte Galfa (1,000 m). From a geological viewpoint the study area belongs to the Longi-Taormina and Capo S. Andrea unit. The lower subunit is formed by an epimetamorphic basement capped by Mesozoic-Cenozoic sedimentary cover made up, from bottom to top, of continental redbeds evolving upwards to platform carbonates (Lentini et al. 2000). All *Colymbada tauromenitana* populations are protected by Natura 2000 areas (European Community 1992) with the exception of the M. Petraro site.

Annual precipitation at the sites ranges from 600 to 1,000 mm and mean annual temperature varies between 19–20 °C (along the coast) and 13–14 °C (inner area) (Brullo et al. 1996).

According to the bioclimatic classification proposed by Rivas-Martínez (1993, 2004), the area under study is referred to the Mediterranean pluviseasonal oceanic bioclimate, with thermotypes ranging from the thermo-Mediterranean to the meso-Mediterranean and ombrotypes from the semiarid to lower humid.

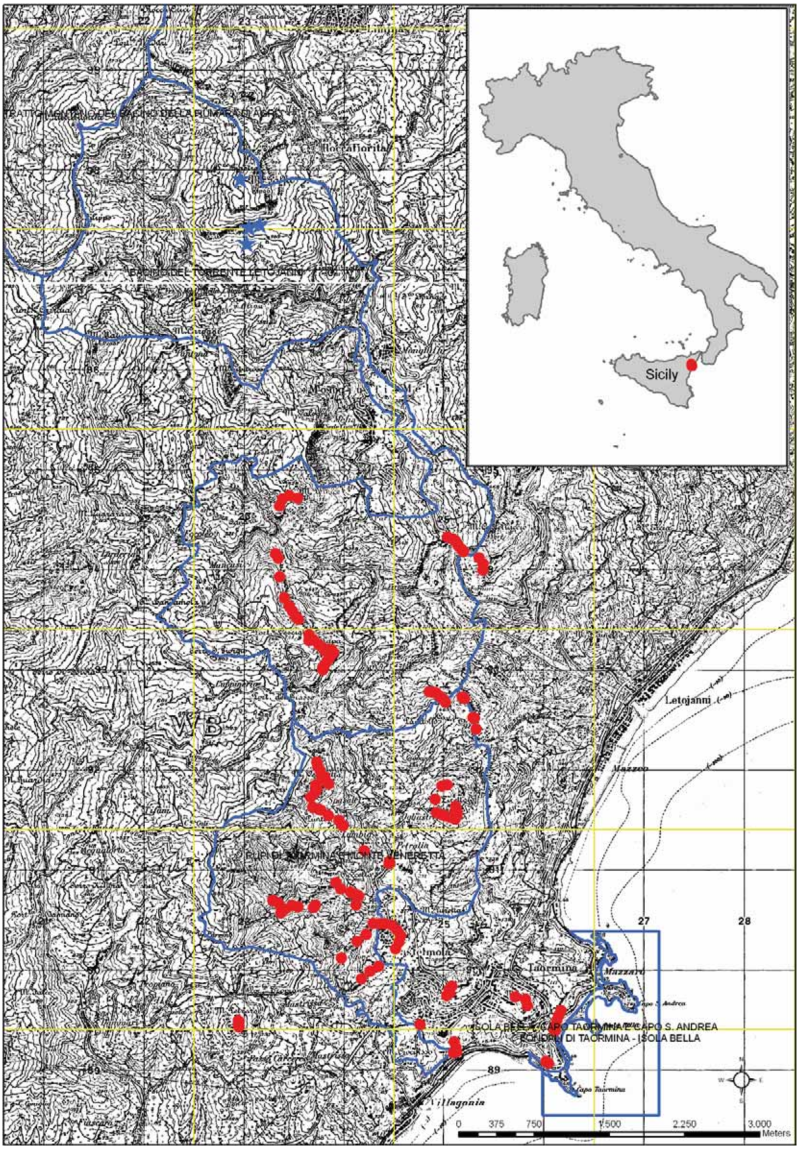

Fig. 1. Study area; red dots show the distribution area of *Erucastretum virgati centauretosum tauromenitanae*; blue stars indicate the distribution area of *Erucastretum virgati dianthetosum siculi*; blue line indicates Natura 2000 areas; yellow grid of 2 × 2 km to assess area of occupancy.

Data analysis

The published data on the distribution of this species (Gussone 1827, Lojacono 1908, Pirola 1961, Gramuglio 1967, Gramuglio et al. 1985) were reviewed and specimens of herbaria from Catania and Palermo were also examined. On the basis of these starting data, all the sites of Sicily in which *C. tauromenitana* has been reported were visited; in addition, other potentially suitable sites for the species were investigated. Our assessment of the Sicilian population size was based on a census in those sites where we found the species. The assignation of *C. tauromenitana* to an IUCN (International Union for Conservation of Nature) risk category (IUCN, 2001), was largely made on a quantitative assessment. The threats to *C. tauromenitana* in each locality were determined from the field observations. A grid of 2 × 2 km was used to assess area of occupancy (AOO, defined as the area within the extent of occurrence, following IUCN (2008) and ROSSI and GENTILI (2008). Conservation status was assessed following IUCN (2008) and the conservation measures adopted or proposed for the species were based on our field observations.

The field work, carried out in order to analyze the structure and composition of the *C. tauromenitana* plant community, was done in 2009–2012 during which 61 plots (10 × 10 m) were made using the standard method of relevés (WESTHOFF and VAN DER MAAREL 1978). Numerical analysis (Cluster Analysis – WPGMA method, Chord coefficient) of relevé was performed using the software package SYN-TAX 2000 (PODANI 2001). Environmental gradients and plant communities were examined with canonical component analysis (CCA), using the PC-ORD, v6, software. In particular, the CCA takes into account different quantitative data such as the distance from the sea (DS), altitude (Altit.), slope of terrain, number of species (N. sp.) and rock type. The original Braun-Blanquet sampling scale (BRAUN-BLANQUET 1964) has been transformed into an ordinal scale, according to VAN DER MAAREL (1979). For the nomenclature of the species, GIARDINA et al. (2007), RAIMONDO and SPADARO (2009) were followed, while phytosociological nomenclature follows BRULLO et al. (2002).

For each taxon, life form and chorological element are reported. The life form follows the Raunkiaer system as proposed by PIGNATTI (1982), while for chorological elements BRULLO et al. (1998a) are followed. The exsiccata (preserved in Botanical Museum of Catania) were studied with the help of Flora Europaea (TUTIN et al. 1964–80), the Italian floras (FIORI 1923–29, PIGNATTI 1982).

Two indexes were chosen to estimate diversity: (1) species richness (SR), i.e., the total number of plant species recorded in a sample plot, and (2) Shannon-Wiener's diversity index (H'). This index takes into account the degree of equitability (J) of the species distribution. SR and H' represent the α-diversity level of the vegetation in relation to the size of the relevé. Spearman rank correlation coefficients were used to evaluate the importance of environmental factors in the distribution of the plant diversity. A p-value of < 0.05 was taken as indicating a statistically significant difference or correlation.

The rock type classification follows LENTINI et al. (2000), which for this area recognizes four types: type 1 – Limestone and dolomite: detritic limestones with rudite clasts of quartz at the base (UT); type 2 – Limestone and dolomite: detritic limestones, biocalcarenites with brachiopods gray and reddish veined (UG); type 3 – Limestone and marl alternation in »Medolo facies« (UTm) and type 4 – »Flysch of Capo d'Orlando« (OMc).

The study of the species and its habitat

C. tauromenitana is a perennial herb or dwarf shrub, with erect stems, 50–100 (120) cm high, branched above. The species is diploid (2n = 2× = 20) (DE SANTIS et al. 1976) and flowers from the second half of May through the first half of July. Dissemination occurs between late July and early August. *C. tauromenitana* does not reproduce vegetatively (pers. observation). The current conservation status of *C. tauromenitana* in Sicily (CONTI el al. 1997) is

»low risk« (LR). According to our data, single individuals of *C. tauromenitana* can survive for several decades.

C. tauromenitana grows on limestone cliffs of the Peloritani district (Sicily) with other endemic species (Arena et al. 1975, Sciandrello et al. 2013a), as *Erucastrum virgatum* (J. et C. Presl) C. Presl, *Dianthus rupicola* Biv. subsp. *rupicola*, *Brassica incana* Ten., *Brassica raimondoi* Sciandr., C. Brullo, Brullo, Giusso, Miniss. et Salmeri, *Anthyllis vulneraria* L. subsp. *busambarensis* (Lojac.) Pignatti, *Antirrhinum siculum* Mill., *Dianthus siculus* C. Presl in J. et C. Presl, *Galium aetnicum* Biv., *Micromeria graeca* (L.) Benth. ex Rchb. subsp. *consentina* (Ten.) Guinea, etc.; it is a member of the highly specialized rupicolous communities of the association *Erucastretum virgati* Brullo et Marcenò 1979 *centauretosum tauromenitanae* Pirola ex Brullo et Marcenò 1979 (*Asplenietea trichomanis* (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977, *Dianthion rupicolae* Brullo et Marcenò 1979). The vegetation pattern of the area is characterized by perennial dry grasslands dominated mostly by caespitose hemicryptophytes, by rupicolous vegetation, rarely shrubby elements that are adapted to different habitats and restricted woods (Sciandrello et al. 2013b).

Results

Distribution and population size

Our investigations confirmed 8 sites with *Colymbada tauromenitana* (Fig. 1): Monte Petraro (Castelmola); Villagonia, Isola Bella and Monte Tauro (Taormina); Castelmola and Roccella (Castelmola); Monte Veneretta (Castelmola); Monte Ziretto and Costa Ogliastro (Castelmola); Monte Lapa (Mongiuffi-Melia); Monte Pernice (Mongiuffi-Melia); Monte Castellaccio (Letojanni, Gallodoro, Mongiuffi Melia). The locality of Capo S. Alessio (Giardina et al. 2007) is not confirmed, while the M. Galfa site, characterized by potentially suitable cliffs for the growth of *C. tauromenitana,* has been carefully explored and the species has not been found. The areas in which the species occur vary between altitudes of 20–800 m, on slopes of 40–90° exposed mainly east, and a distance from the coastline that varies between 30 and 6,000 m. The entire population of *C. tauromenitana* consisted of fewer than 7,200 plants, distributed with variable density (Tab. 1). The current populations of *C. tauromenitana* occupy (AOO) about 28 km^2 (Fig. 1), distributed along the cliffs with the exception of the populations of M. Petraro and M. Castellaccio. The highest density is distributed on the cliffs facing east between M. Veneretta and M. Lapa with about 2,500 individuals (Fig. 2). Other interesting populations with high values of individuals were found in the area of Castelmola, on the cliffs facing east of M. Ziretto-Costa Ogliastro and on the south facing rocks of the Castello di Taormina, while low values were found along the coast, to M. Pernice and M. Petraro. Overall, the narrow distribution area of *C. tauromenitana* is linked to the substrate type (mainly limestone), with the exception of a small population of a few individuals, growing on conglomerate substrates to M. Petraro. We may therefore consider *C. tauromenitana* a narrow endemic of the carbonatic district of Taormina.

Finally, considering the number of individuals, the narrow area and several threats (invasive species, fire, natural collapses and stone extraction), we may conclude that the distribution area of *C. tauromenitana* is highly localized and at risk of further reduction. Therefore, based on the field investigation carried out in the present survey, we propose a new IUCN category, Vulnerable (VU A2ce, B1ab (ii,iii,iv)).

Tab. 1. Sites where *Colymbada tauromenitana* has been located. No. plots – number of plots; No. ind. – number of individuals of *C. tauromenitana*; No. endemic – number of endemic plants; Rock type: UT – Limestone and dolomite with rudite clasts of quartz at the base, UG – Limestone and dolomite with brachiopods gray and reddish veined, UTm – Limestone and marl alternation, OMc – Flysch; No. species, number of species; T med – mean temperature; Rainfall (mm) – annual precipitation.

Locality	No. plots	No. ind.	C. tauromenitana cover (%)	No. endemic	Rock type	Altitude (m)	Sea distance (m)	No. species (average)	T med (°C)	Rainfall (mm)	Main threats
Monte Petraro (Castelmola)	3	80	26	5	OMc	460	2210	21	16–17	700–800	natural collapses, fire
Villagonia (Taormina)	3	280	16	7	UT	25–35	95–130	19	18–19	600–700	invasive plants
Rupe antistante Isola Bella (Taormina)	3	350	16	4	UT	20–70	35–75	16	18–19	600–700	invasive plants
Rupi di Capotaormina	1	30	5	5	UT	60	90	19	19–20	600–700	invasive plants
Monte Tauro e Castello di Taormina	3	750	30	6	UT	350	600	19	17–18	700–800	building, invasive plants
Rupi di Castelmola	5	1000	30	7	UT	480	1600	24	16–17	800–900	invasive plants
Rupi antistanti Castelmola	3	600	26	6	UT	530	1850	24	16–17	800–900	fire and pasture
Roccella (Castelmola)	2	100	25	5	UT	420	1680	22	16–17	800–900	invasive plants
Monte Veneretta (Castelmola)	12	1200	31	9	UT	760–850	2700	26	14–15	900–1000	fire, pasture
Monte Ziretto (Castelmola)	5	800	26	4	UT	530	1200–1400	25	15–16	800–900	fire, pasture
Costa Ogliastro (Castelmola)	5	450	30	5	UT	400–450	1550–1850	20	15–16	800–900	fire, pasture
Monte Lapa (Mongiuìffi Melia)	4	1200	32	6	UT	620–650	3000–3100	28	14–15	900–1000	fire, pasture
Monte Pernice (Mongiuiffi Melia)	4	250	20	8	UTm	500–530	4200	15	15–16	800–900	stone extraction
Monte Castellaccio (Letojanni, Gallodoro, Mongiuffi Melia)	3	350	26	5	UT	250	2500	21	17–18	700–800	natural collapses
Monte Galfa (Roccafiorita, Mongiuffi Melia)	5	0	0	7	UT-UG	720–920	6300–6700	21	13–14	1000–1200	fire, pasture

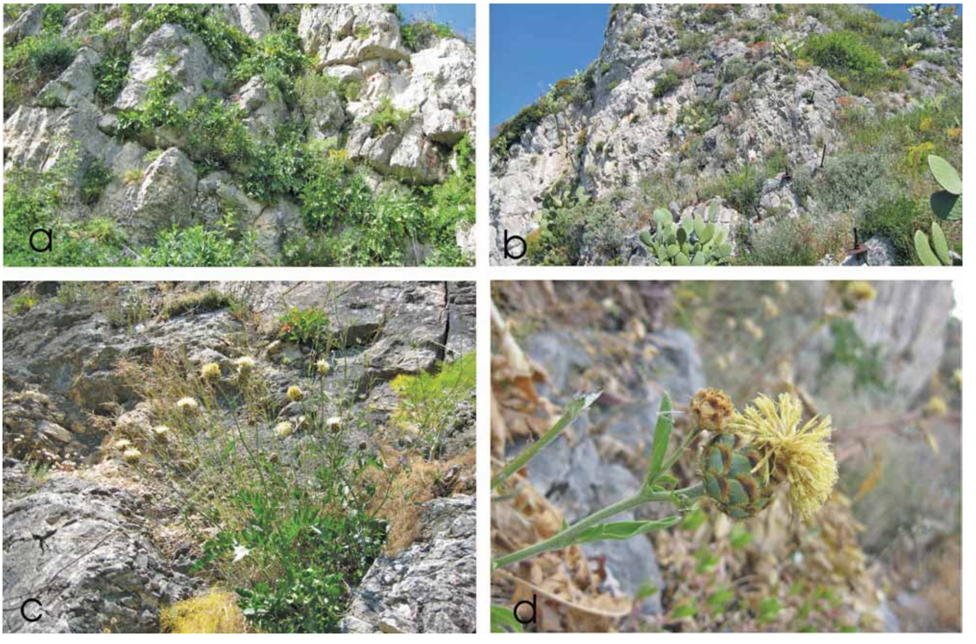

Fig. 2. Rupicolous vegetation with *Colymbada tauromenitana* on limestones outcrops of M. Veneretta (Castelmola) (a); *Colymbada tauromenitana* with the presence of *Opuntia ficus-indica* on cliffs of Taormina (b); plant in its peak flowering time (c, d).

Plant communities and species diversity

In total, 72 species of vascular plants have been recorded on the cliffs of the study area. Most species belong to Mediterranean elements, with the dominant life forms being chamaephytes (35%) and hemicryptophytes (33%), while the therophytes show low values (3%).

The ecological features of the rupicolous plant community may be highlighted by the floristic composition and its variations along a gradient of conditions from the coast to the inland. The results of the cluster analysis (Fig. 3) show two main vegetation groups, each with specific indicator species. Group A (56 relevés) represents the coastal plant communities with *Colymbada tauromenitana*, while group B (5 relevés) represents inland plant communities without *C. tauromenitana*. Within group A, two sub-groups were distinguished: A1, comprising the thermo-mesophilous plant communities, and A2, which includes the thermo-xerophilous plant communities. Within sub-group A1 we can distinguish the rupicolous vegetation of the conglomeratic outcrops (A11) and plant communities of the limestone outcrops (A12), while the sub-group A2 includes the strictly coastal plant communities with sub-halophilous species (A21) and the thermophilous plant communities linked to marine ecological conditions (A22).

The species richness and Shannon-Wiener diversity index indicate that the plant communities near the coast show a moderate diversity with an average SR of 21.7 and an average Shannon-Wiener diversity index of 2.3 (J = 0.73). Both values increase by altitude in

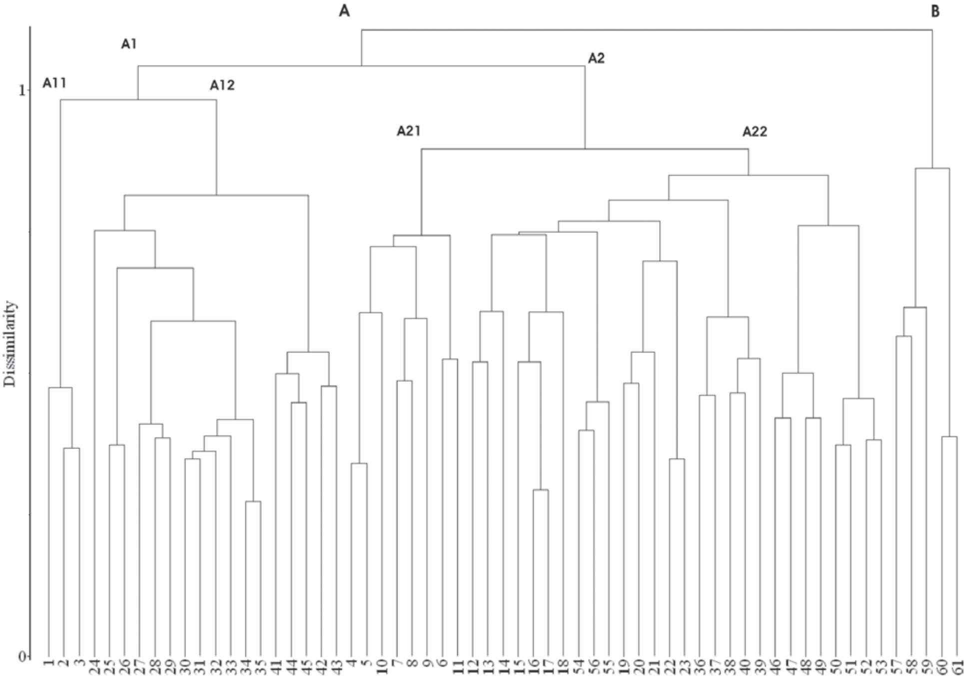

Fig. 3. Dendrogram resulting from cluster analysis of the plots (WPGMA method, Chord coefficient). Plant communities: A1 – *Erucastretum virgati centauretosum tauromenitanae* facies with *Silene fruticosa*; A2 – *Erucastretum virgati centauretosum tauromenitanae* facies with *Lomelosia cretica*; B – *Erucastretum virgati dianthetosum siculi*. 1–61 indicates the plots (relevés).

middle zones with an average of 24 species and a Shannon-Wiener diversity index of 2.5 (J = 0.79). The highest areas (M. Galfa) have a moderate SR of 21 and Shannon-Wiener diversity index of 2.6 (J = 0.84) (Tab. 2).

Tab. 2. Relationship between species richness, standard deviation, equitability, Shannon-Wiener's diversity index and bioclimate zones. 1 – Monte Petraro; 2 – Villagonia, Capotaormina, Isola Bella, M. Tauro and Castello (Taormina); 3 – Roccella and Castelmola; 4 – M. Veneretta; 5 – M. Ziretto and Costa Ogliastro; 6 – M. Lapa; 7 – M. Pernice; 8 – M. Castellaccio; 9 – M. Galfa.

	36 plots (2, 3, 5, 6, 7, 8)	**20 plots (1, 4, 5)**	**5 plots (9)**
	thermomediterranean lower zone	thermomediterranean upper zone	mesomediterranean zone
	0–500 m	400–800 m	800–1000 m
Species richness	21.75	24.1	20.8
Standard deviation	5.5	6.8	3.4
Equitability	0.73	0.79	0.84
Shannon-Wiener's index	2.3	2.5	2.6

Our assumption of plant community differentiation along a gradient of environmental conditions ranging from the coast to inland areas, highlighted by the floristic diversity, is better supported when some concrete environmental variables are introduced and a canonical component analysis (CCA) is conducted. The result of the CCA shows a main gradient of distance of the sea and altitude on axis 1 and a secondary gradient of slope on axis 2 (Fig. 4). The CCA clearly separates on axis 1 (on the left) the strictly coastal plant communities belonging to the thermo-Mediterranean lower bioclimatic range, which prefer thermo-xe-

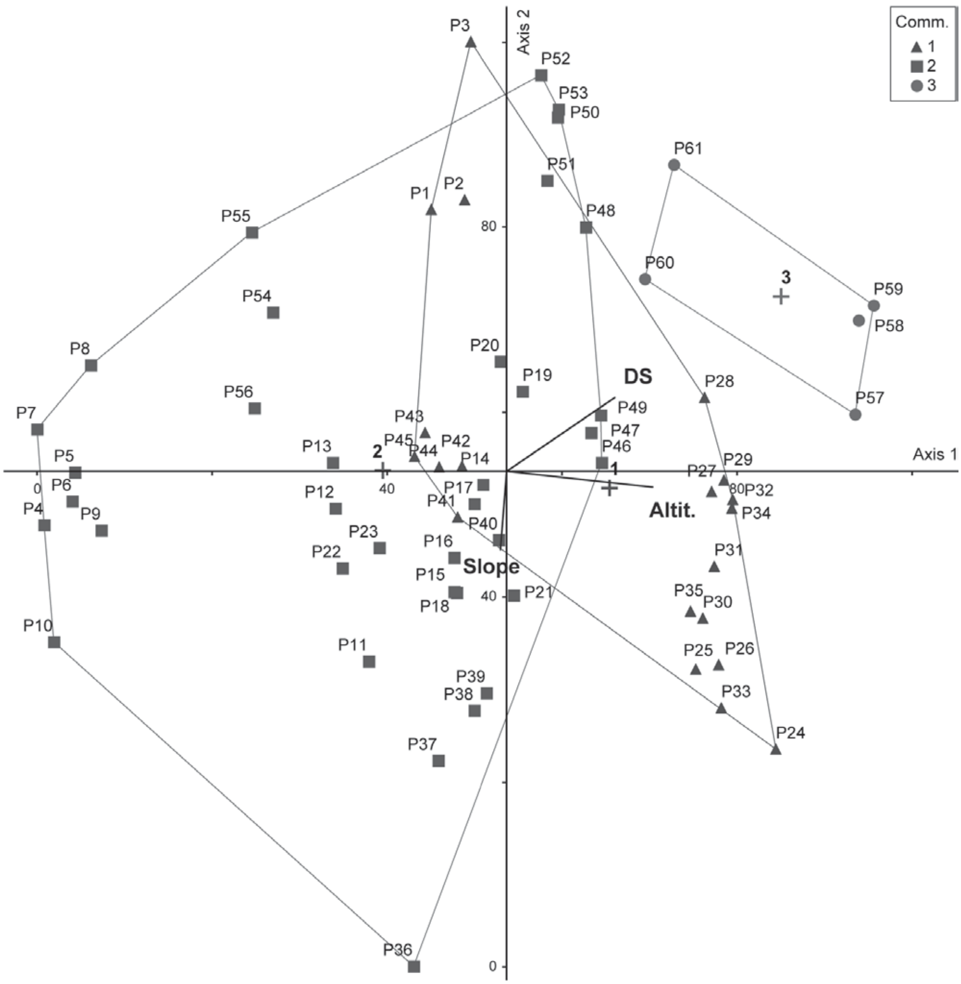

Fig. 4. Canonical correspondence analysis (CCA) plot. Total variance (»inertia«) in the species data: 2.0486; Eigenvalues: axis 1 = 0.272; axis 2 = 0.087. Plant communities (Comm.): 1 – *Erucastretum virgati centauretosum tauromenitanae* facies with *Silene fruticosa* (polygon marked by triangles and centroid 1); 2 – *Erucastretum virgati centauretosum tauromenitanae* facies with *Lomelosia cretica* (polygon marked by squares and centroid 2); 3 – *Erucastretum virgati dianthetosum siculi* (polygon marked by dots and centroid 3). Main gradient: distance from the sea (DS), altitude (Altit.) and slope of terrain. P1–61 indicates the plots (relevés).

rophilous conditions, as demonstrated by the presence and dominance of *Lomelosia cretica* and *Dianthus rupicola* subsp. *rupicola*; in the central part are plant communities belonging to the thermo-Mediterranean upper bioclimatic range that prefer thermophilous conditions, as demonstrated by the presence and dominance of *Silene fruticosa, Athamanta sicula* and *Colymbada tauromenitana,* while on the right there are the mesophilous plant communities belonging to the meso-Mediterranean bioclimatic range, as demonstrated by the dominance of *Dianthus siculus, Ballota hispanica* and *Odontites bocconei*. On axis 2, which correlate with slope, from the bottom up we can observe a reduction of the inclination which reflects a lower number of chasmophilous species.

The Spearman correlation shows a significant correlation between species richness and elevation ($r = 0.62$; $p < 0.05$), but a low correlation with distance from the sea ($r = 0.35$). Moreover, the species richness was significantly correlated with temperature ($r = –0.52$; $p < 0.05$) and rainfall ($r = 0.67$). An important correlation was also observed between *C. tauromenitana* density and rainfall ($r = 0.67$; $p < 0.05$), as well as between *C. tauromenitana* density and species richness ($r = 0.66$; $p < 0.05$), whereas a low correlation with sea distance ($r = 0.23$; $p < 0.05$).

Discussion

Our results indicate that altitude is the main factor influencing both species richness and vegetation composition. This important ecological factor significantly affects also the life forms of the species in response to the hydrothermic gradient linked with altitude (MAHDAVI et al. 2013). The results shows that the lower zones (0–500 m a.s.l.) are characterized by the predominance of chamaephytes (37%), while in the thermo-Mediterranean upper zone (500–800 m a.s.l.) we find a high rate of hemicryptophytes (41%). Probably the predominance of chamaephytic life form in lower zones suggests a particular adaptation to marine conditions (mainly represented by coastal moisture and marine aerosols). In the meso-Mediterranean belt (800–1000 m a.s.l.), due to cold winds, once more the chamaephytic life form predominates (36%) mixed with hemicryptophytes (32%). The results show no significant differences in floristic elements in relation to the three areas identified. In fact from a chorological viewpoint, in these three zones, the floristic element is represented mainly by species with a wide Mediterranean distribution (about 70%), while the endemic element rate is quite constant.

Therefore, in accordance with ODLAND (2009), we can consider the altitudinal gradient a complex environmental gradient associated with variation in several environmental parameters (slope, rocky type, and distance from sea). The moderate diversity and density of the vegetation in the lower zone (lower thermo-Mediterranean belt) may be related to the severe environmental conditions, that on the one hand limit the growth and productivity of some species, and yet on the other can favor the development of a few highly competitive and specialized species, such as *Dianthus rupicola* subsp. *rupicola, Lomelosia cretica, Limbarda crithmoides,* etc. Another serious problem regarding the lower zones is linked to the presence of invasive species such as *Opuntia ficus-indica* (Fig. 2)*,* that, facilitated by man, has colonized the cliffs there at the expense of the natural populations of *C. tauromenitana*. However, high temperature, low precipitation, high evaporation and high salinity are the main environmental constraints that plants face in the lower zone. These ecophysiological stress factors (especially high temperature and low rainfall) explain the moderate species richness at low altitudes. The high diversity and density in the upper zones may largely be related to the high precipitation and moderate temperature that favor the development of many moderately competitive species, such as *Dianthus siculus, Odontites bocconei*, *Colymbada tauromenitana*, *Silene fruticosa, Athamanta sicula* etc.

The extent of the cliffs is another factor that may affect the plant diversity, in particular through habitat heterogeneity and resource availability (Romdal and Grytnes 2007). It is generally expected that in a larger area there is higher habitat heterogeneity and a better chance that larger populations of the species may survive. Most likely, this very significant number of individuals is linked to the large surface area of the rock walls, optimum climatic conditions, the highest degree of naturalness and especially the reduced possibility of anthropogenic habitat destruction. Indeed, the cliffs of M. Veneretta, the largest in the study area, have a high species richness (26) and Shannon-Wiener diversity index (2.57) and probably represent the speciation area of *Colymbada tauromenitana* and its upper altitudinal limit in the Peloritani district. Therefore, we found that the presence of *C. tauromenitana* was strongly correlated to total species richness and especially hot-humid climatic conditions (Arena et al. 1975, Kallimanis et al. 2010).

C. tauromenitana grows mainly on limestone outcrops at altitudes between 20 and 800 m, with several other endemic species. It is a characteristic species of the association *Erucastretum virgati centauretosum tauromenitanae*. The primary habitat of this species is mainly the vertical cliff listed as »Calcareous rocky slopes with chasmophytic vegetation« (COD. 8210, European Community 1992). Moreover, in the study area, this species also grows on rocky slopes (secondary habitat) together with semi-rupicolous low shrub of two different communities: *Euphorbietum dendroidis* at low altitudes and *Micromerio consentinae-Phlomidetum fruticosae* at higher altitudes (Sciandrello et al. 2013b), listed as »Thermo-Mediterranean and pre-desert scrub (COD. 5330, European Community 1992). Considering that dissemination of the some species is favored by the wind and the proximity of a suitable habitat (such as M. Galfa), we might deduce that the altitudinal limit of *C. tauromenitana* (about 800 m) is probably related to the difficulty of the seeds germinating at low temperatures (13 °C) and high rainfall (1,200 m). As concerns the seed dispersal strategy of the rupicolous species of the study area, the strategy of short distance is the most represented on cliffs. The seeds simply fall from the mother plant or are dispersed by swaying movements of the infructescence or by rain drops hitting the capsules. Other possible ways of seed dispersal on cliffs are exozoochory or anemochory over short distances. From a phytosociological point of view, the classification of relevés (On-line Supplement Tabs. 1–3), using cluster analysis and CCA (Figs. 3, 4), displayed three clear vegetation groups, each with typical species that are useful in characterizing the communities. Choosing just one indicator or guiding species for each community, the first is characterized by the presence of *Dianthus rupicola* Biv. subsp. *rupicola* and *Lomelosia cretica* (L.) Greuter et Burdet (indicating a specific altitude range between 0–500 m), the second by the presence of *Silene fruticosa* and *Colymbada tauromenitana* (indicating a specific altitude range between 400–800 m), and in the third the presence of *Dianthus siculus* C. Presl in J. et C. Presl and *Odontites bocconei* (Guss.) Walp. subsp. *bocconei* (indicating a specific altitude range between 800–1,000 m) is significant. Therefore, in relation to the floristic composition differences related to altitude, the populations referred to *Erucastretum virgati* (Brullo and Marcenò 1979) can be divided into three facies, here proposed as:

1. ***Erucastretum virgati*** Brullo et Marcenò 1979 ***centauretosum tauromenitanae*** Pirola ex Brullo et Marcenò 1979, facies with *Lomelosia cretica*: Cluster A2 (0–400 m altitude)

within the thermo-Mediterranean lower belt. This facies is characterized by the dominance of *Dianthus rupicola* subsp. *rupicola* and *Lomelosia cretica*, together with other thermo-rupicolous species of the *Dianthion rupicolae* alliance, such as *Antirrhinum siculum, Brassica incana, Colymbada tauromenitana ect.* and other several thermo-xerophilous species of the *Oleo-Ceratonion* alliance, such as *Euphorbia dendroides*, *Phlomis fruticosa*, *Olea europaea var. sylvestris*, *Prasium majus*, *Teucrium fruticans*, *Ruta chalepensis*, ect. (On-line Supplement Tab. 2).

2. ***Erucastretum virgati*** Brullo et Marcenò 1979 ***centauretosum tauromenitanae*** Pirola ex Brullo et Marcenò 1979, facies with *Silene fruticosa*: Cluster A1 (400–800 m altitude) within the thermo-Mediterranean upper belt. This facies is characterized by the dominance of *Silene fruticosa* and *Colymbada tauromenitana*, together with *Hypochoeris laevigata, Athamanta sicula, Ballota hispanica, Teucrium flavum,* ect., and some thermo-mesophilous species, such as *Bupleurum fruticosum*, *Emerus major* subsp. *emeroides, Fraxinus ornus, Pistacia terebinthus*, *Quercus ilex*, ect. (On-line Supplement Tab. 1).

3. ***Erucastretum virgati*** Brullo et Marcenò 1979 ***dianthetosum siculi*** subass. nova, Characteristics species: *Dianthus siculus* and *Odontites bocconei* subsp. *bocconei,* Holotypus: relevé 61, Cluster B (800–1,000 m altitude) within the meso-Mediterranean belt. This facies is characterized by the dominance of *Dianthus siculus* and *Odontites bocconei* subsp. *bocconei*, together with other rupicolous species of the *Asplenietalia glandulosi* order, such as *Silene fruticosa, Brassica incana, Anthyllis vulneraria* subsp. *busambarensis, Teucrium flavum, Athamanta sicula, Hypochoeris laevigata, Ballota hispanica, Sedum dasyphyllum*, ect. (On-line Supplement Tab. 3).

The limestone cliffs are populated by chasmophilous vegetation ascribed to *Erucastretum virgati,* widespread in the southern sector of the Calabria and eastern part of Sicily with several subassociations geographically well delimited, highlighting the geology and paleogeography connections of the Calabrian Peloritani Arc (BRULLO et al. 1998b, BRULLO et al. 2001).

Overall, endemic species play a central role in biodiversity conservation, because of the habitat loss and climate change, due to their often small population sizes, low genetic diversity and specific habitat requirements (GARGANO et al. 2007, BRULLO et al. 2011, TRIGAS et al. 2012, BRULLO et al. 2013, VANDEPITTE et al. 2013). In line with the objectives of the Habitats Directive, their preservation therefore becomes a priority (MÉDAIL and QUÉZEL 1999, MYERS et al. 2000). In southern Italy the cliffs preserve endemic species of very high phytogeographical and ecological value, used also to characterize well-defined territorial units (BRULLO et al. 1998b, WAGENSOMMER and DI PIETRO 2007, DI PIETRO and WAGENSOMMER 2008, TERZI and D'AMICO 2008, MINISSALE et al. 2013).

Conclusion

In conclusion, the priority conservation measures proposed, based on field observations, for the rupicolous species are: (1) protection of the rupicolous habitat with a high number of endemic species; (2) creation of plant micro-reserves (PMR) or sites of community importance (SCI); (3) planning and land management (regulation of human activities, limitation of fire, eradication of alien species such as *Opuntia ficus-indica* on the cliffs); (4) restoration of damaged habitats; (5) collection of local germplasm for ex situ conservation; (6) promoting the integration of some threatened endemic species (*in situ*/*ex situ*); (7) a regional law on the conservation of endemic species and (8) genetic analysis of the *C. tauromenitana* populations to understand their future maintenance. Furthermore, in order to preserve the native rupicolous species, it is also necessary to plan targeted interventions for removal of invasive species and the prohibition on cultivating these species in neighboring areas.

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