



Research Article

The rock-face vegetation of Montecristo Island: insights into the rupicolous communities of the Tyrrhenian Islands (Italy)*

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Abstract

Montecristo Island, part of the Tuscan Archipelago National Park and strictly protected since 1971, remains one of the Archipelago's least studied islands in terms of vegetation. The only detailed phytosociological study, conducted in the 1980s, did not address several sporadic or spatially restricted plant assemblages, particularly those occurring on cliffs. Our study examines and classifies these poorly known communities from floristic, ecological, and phytosociological perspectives, and compares them with analogous vegetation across the Tuscan Archipelago to clarify their syntaxonomic position.

Forty relevés were collected in 2023–2024 on rock-face habitats using the Braun-Blanquet method. Multivariate analyses identified three distinct chasmophytic-chomophytic vegetation groups. The first consists of high-elevation, north-facing vertical cliffs dominated by *Polypodium cambricum* and several Montecristo endemics, including *Saxifraga montis-christi* and *Hieracium racemosum* subsp. *amideii*; for these stands we propose the new association *Saxifraga montis-christi*-*Polypodietum cambrici*. The second, encompasses low-elevation, thermoxerophilous cliff habitats characterized by *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum*, for which we propose the name *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum* community. The third includes shaded cliffs with ample elevation excluding the extremes, dominated by *Cymbalaria aequitriloba* and *Arenaria balearica*, corresponding to the association *Arenario balearicae*-*Cymbalarietum aequitrilobae*.

Although poorer in species compared to the cliff communities of other Tuscan islands, these habitats contain distinctive bryophytes and several endemic or biogeographically important taxa, fitting within EU Habitat 8220. The study closes a major knowledge gap on Montecristo's rock vegetation and refines the understanding of Tyrrhenian cliff plant communities, proposing syntaxonomical updates above the association level.

Keywords

Asplenetia, chasmophytic, chomophytic, cliffs, *Polypodietea*, Tuscan Archipelago

* Topical Collection: "Vegetation classification: from classic to numeric approaches".

** These authors share the first authorship.

Introduction

The island of Montecristo is a small, granite island located in the Tyrrhenian Sea (Province of Livorno, central Italy). Since 1971, the island has been under a highly restricted protection regime, becoming a State Nature Reserve. It was then included in the list of Biogenetic Reserves in 1977 and subsequently incorporated into the Tuscan Archipelago National Park in 1996. It is classified as “Special Areas of Conservation” (SAC) and “Special Protection Areas” (SPA) under the EU Habitats Directive, with Natura 2000 code: IT5160014. The supervision and management of which have been entrusted to the State Forestry Corps and then to the Carabinieri Biodiversity Grouping. Access is allowed only with special permits, mainly for scientific or conservation purposes. Its isolation and conservation status make Montecristo one of the least disturbed Mediterranean islands, with unique ecological and biogeographical features. However, alien species such as *Ailanthus altissima* are widespread and other exotic tree species were planted in the Cala Maestra area for ornamental purposes. Apart from humans, the only large mammal present is the goat (*Capra aegagrus hircus*). Rats (*Rattus rattus*), present until a few years ago, have been eradicated thanks to a LIFE project.

From the botanical point of view, recent explorations of the island have made it possible to compile a floristic list of 582 specific and subspecific taxa (Siccardi et al. 2025). Moreover, a new species, *Leontodon montecristensis* (Foggi et al. 2025), has been discovered on the vertical cliffs of Monte della Fortezza, representing the island's most localized and restricted endemic plant population. There is a general knowledge of the vegetation of Montecristo Island (Filipello and Sartori 1981; Landi et al. 2007), but there is a lack of in-depth studies on some plant communities present sporadically on the island such as those of the cliffs. Across the Mediterranean, cliff habitats support high levels of endemism (Médail and Verlaque 1997; Lavergne et al. 2004). This pattern reflects low dispersal ability, strong habitat specialization, reduced herbivory, and fragmented distributions of endemic taxa, reinforced by pronounced microclimatic heterogeneity linked to topographic complexity (Thompson 2020). On islands such as Montecristo, geographic isolation and the refuge effect of inaccessible rocky slopes further enhance the evolutionary and conservation significance of cliff vegetation (Médail 2022). Indeed, the Montecristo rocky communities are home to some endemic species, such as *Saxifraga montis-christi* (Mannocci et al. 2016), *Hieracium racemosum* subsp. *amideii* (Gonnelli et al. 2019) and *Leontodon montecristensis* (Foggi et al. 2025), as well as endemic species of the Tuscan Archipelago as *Linaria capraria* and *Limonium sommieranum*. Despite a broad scientific consensus on the remarkable ecological, conservation, and phyto-geographic value of these habitats, assembly rules governing fine-scale niche selection on cliffs remain poorly

studied (de Simone 2020). Their inaccessibility and the technical challenges of extensive sampling have often restricted research to distant observations and empirical deductions (Francini and Messeri 1956; Jung et al. 2019). There is currently a significant gap in the understanding of the rock-faces vegetation on the island of Montecristo, where these endemic species live.

Thus, a detailed study with a specific focus on this type of vegetation is of considerable interest, both from an ecological perspective and for the conservation of plant diversity. In this perspective, our study aims to address this deficit by thoroughly investigating and classifying the rock-faces plant communities in Montecristo Island from a floristic, ecological and phytosociological viewpoint. Furthermore, the research will include a comparative analysis with existing knowledge of similar plant communities found throughout the Tuscan Archipelago, to highlight the affinities and differences among the Montecristo's and other island associations and to contextualize these rupicolous plant communities within a broader syntaxonomic perspective.

Material and methods

Study area

Located in the Tyrrhenian Sea, halfway between the Argentario Promontory and Corsica, the island of Montecristo is the most remote island of the Tuscan Archipelago, lying approximately 63 km from the Italian mainland (Figure 1).

Nearly circular in shape, its coastline is rugged and deeply indented, characterized by steep slopes. The island covers an area of 10.4 km² and features a mountainous landscape, with its highest peaks being Mount Fortezza (645 m a.s.l.) and Collo dei Lecci (563 m a.s.l.). Like much of Giglio Island and Monte Capanne on Elba Island, Montecristo is the result of a shallow magmatic intrusion—a granite pluton—that solidified underground (Innocenti et al. 1997). The granite mass was gradually exposed, forming the island's current granite structure, with soil accumulating primarily in the watersheds and small flat areas. Thus, the soil is relatively homogeneous, derived from granite erosion. As a result, the soil typically sandy, low in calcium and phosphorus, shallow, poorly developed, contain very little organic matter, and is acidic to slightly acidic (Paoli and Romagnoli 1976; Crudele et al. 2005). The climate is characterized by hot, dry summers and mild, rainy winters. However, there is significant local variability, with a cooler and more humid microclimate at higher elevations or in less sun-exposed areas, compared to the coastal zones. The bioclimate is Mediterranean pluvisesonal oceanic, falling within the upper Thermomediterranean and lower Mesomediterranean thermotypes, and characterized by an upper to lower dry ombrothermic regime (Pesaresi et al. 2014, 2017). The entire island exhibits a strong Euroceanic degree of continentality. In recent years, the increase



Figure 1. Map of Montecristo Island and its geographical context within Italy and the Tuscan Archipelago.

in temperatures and the decline in precipitation, as also observed by Crudele et al. (2005), have contributed to the island's depletion of water resources.

Based on the study by Filipello and Sartori (1981), the vegetation is mainly composed of tall and medium-height Mediterranean maquis, dominated by *Erica arborea* and

Erica scoparia, classified to the association *Cladonio verticillatae-Ericetum arboreae* Filipello et Sartori 1981. Open and low maquis-garrigue communities are also frequent, featuring species such as *Salvia rosmarinus*, *Cistus monspeliensis*, *Teucrium marum*, and *Helichrysum italicum*. Some open habitats host therophytic grasslands belonging to the

class *Helianthemetea guttati* Br.-Bl. 1940. Other plant communities—such as those of temporary ponds, watercourses, and rocky cliffs—are extremely localized. In the small flat areas where a thin soil layer persists, communities such as *Menthetum requienii* Filipello et Sartori 1981 can develop. *Quercus ilex* is rare but represents the only relatively consistent native tree species on the island (Crudele et al. 2005) and includes some of the oldest known extratropical broadleaved trees worldwide (Filibeck et al. 2023). *Juniperus phoenicea* subsp. *turbinata* occurs sporadically below 200 m a.s.l. (Landi et al. 2007), while other woody species are extremely scarce. Vegetation in Cala Maestra is mainly anthropogenic, with *Pinus pinea* and *Pinus halepensis* putatively not native to the island, along with exotic species introduced by George Watson Taylor (owner of the island from 1852 to 1869). The remaining parts of the island are predominantly rocky, with sparse coverage of cliff-face vegetation, which remains poorly studied. A preliminary analysis of the cliff-faces vegetation of Montecristo Island was recently provided by Landi et al. (2023).

Data collection and analysis

Despite the exploration being very difficult due to the island's geomorphology and the almost total lack of paths, 40 relevés were made and distributed across large parts of the island. A preferential sampling approach was adopted, as it allows the detection and sampling of rare vegetation types (Roleček et al. 2007), such as cliff and rock-face communities. Accordingly, during the exploration of the island along its elevational gradient, all sites hosting rock-face vegetation that were encountered were investigated through relevés. The size of the relevés was variable but consistently very small (always < 2 m²; detailed relevé sizes are reported in Suppl. material 1: table S1), reflecting the limited spatial extent of plant communities associated with cliff. The minimal sample area follows area according to Ellenberg and Mueller-Dombois (1974). The sampling criterion consisted of recording, for each relevé, the area occupied by vegetation on the rock surface, excluding areas of bare rock. As noted by Tomaselli et al. (2019) and confirmed by our observations, increasing the relevé size does not necessarily lead to a corresponding increase in species richness in rock-face communities, since larger areas may include surfaces completely devoid of vegetation. Given the steep slopes, which greatly limit the number of rock-face communities that can be reached and surveyed, approximately 3–4 relevés were carried out per day. The relevés were carried out in April–May 2023 and in May 2024, using the Braun-Blanquet method to assess physiognomic–station homogeneity. Plant species, including bryophytes and lichens, were recorded. Species cover was visually estimated using the following scale: 0.1%, 0.5%, 1% to 10% at 1% intervals and 10% to 100% at 5% intervals. Species were identified using Pignatti et al. (2017–2019) and their nomenclature followed the Portal

to the Flora of Italy (2025), that of lichens follows Nimis (2025), and that of bryophytes follows Aleffi et al. (2023). The nomenclature of syntaxa, above the alliance level, is according to Mucina et al. (2016).

Environmental parameters acquired during the field campaign were both continuous and categorical. Continuous variables are elevation above sea level, orientation, northness, mean slope, and moss cover. Northness is a topographic variable related to aspect and slope of relevés, calculated following Amatulli et al. (2018). In the Northern Hemisphere, a value of 1 indicates a strong affinity for a north-facing vertical slope, which receives very little direct solar radiation. Categorical variables are the position of the relevé on the cliff face or into rock cavities, and the degree of humidity, depending on whether the rock or moss substrate is wet. The environmental parameters, recorded for each relevé, are available in Suppl. material 1: table S1.

The original floristic relevés (abundance data) were submitted to classification by agglomerative cluster analysis via PAST software (Hammer et al. 2001), using the Bray-Curtis dissimilarity coefficient with Unweighted Pair Means Average linkage (UPGMA) (Kent 2012). The diagnostic species among the groups superimposed were statistically defined by the phi coefficient of association (Chytrý et al. 2002). The significance of the fidelity coefficient was calculated according to Fisher's exact test. We considered a species as diagnostic of each group if $\phi > 0.20$, with $p < 0.05$ (Douda et al. 2016). Moreover, a Non-metric Multidimensional Scaling analysis (NMDS) based on the Bray-Curtis distances was performed to identify distinct plant communities and to assess their relationship with environmental factors. The significance of the correlations between environmental parameters and the NMDS axes was assessed a posteriori using the “envfit” function from the R package “vegan” (Oksanen et al. 2025).

Finally, we gather in a synoptic table all the associations described for the cliff vegetation in the Tuscan Archipelago: Capraia (Foggi and Grigioni 1999), Elba (Foggi et al. 2006), Giglio (Foggi and Pancioli 2008), and Montecristo (Filipello and Sartori 1981), in addition to our own observations. In this comparative table, roman numerals represent the frequency of a species within a group: I = < 20%; II = 21–40%; III = 41–60%; IV = 61–80%; V = >80%. Unfortunately, statistical analyses could not be conducted because bryophyte species data from the other islands were unavailable. Since bryophyte species are crucial for classification within the class *Polypodietea*, only qualitative comparisons involving vascular plant species can be carried out.

Results

The cluster analysis of the relevés from the rock-face vegetation of Montecristo Island provided an overview of the chasmophytic–chomophytic composition and their levels of similarity (Figure 2a). The dendrogram shows an initial separation between relevés 1–18 (Group

A), which include the chomophytic vegetation occurring on north-facing vertical walls or protruding rocky outcrops at higher elevations, and the remaining relevés 19–40 (Group B), which comprise chasmophytic communities established in rock crevices and cavities. A subsequent bifurcation within Group B further distinguishes relevés 32–40 (Group B1), characterized by thermo-xerophilous vegetation at lower elevations, from relevés 19–31 (Group B2), representing sciaphilous and hygrophilous communities occurring at medium and high elevations.

The diagnostic species, along with their frequencies, of these three groups, defined by the phi coefficient of association (Chytrý et al. 2002), are reported in Table 1. They allow us to highlight that: Group A is dominated by *Polypodium cambricum*, *Saxifraga montis-christi*, and from the bryophyte *Nagopterium gracile*; Group B1 is characterized by *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum*, and from the exclusive presence of *Festuca bromoides*; Group B2 is dominated by *Arenaria balearica* and *Cymbalaria aequitriloba*.

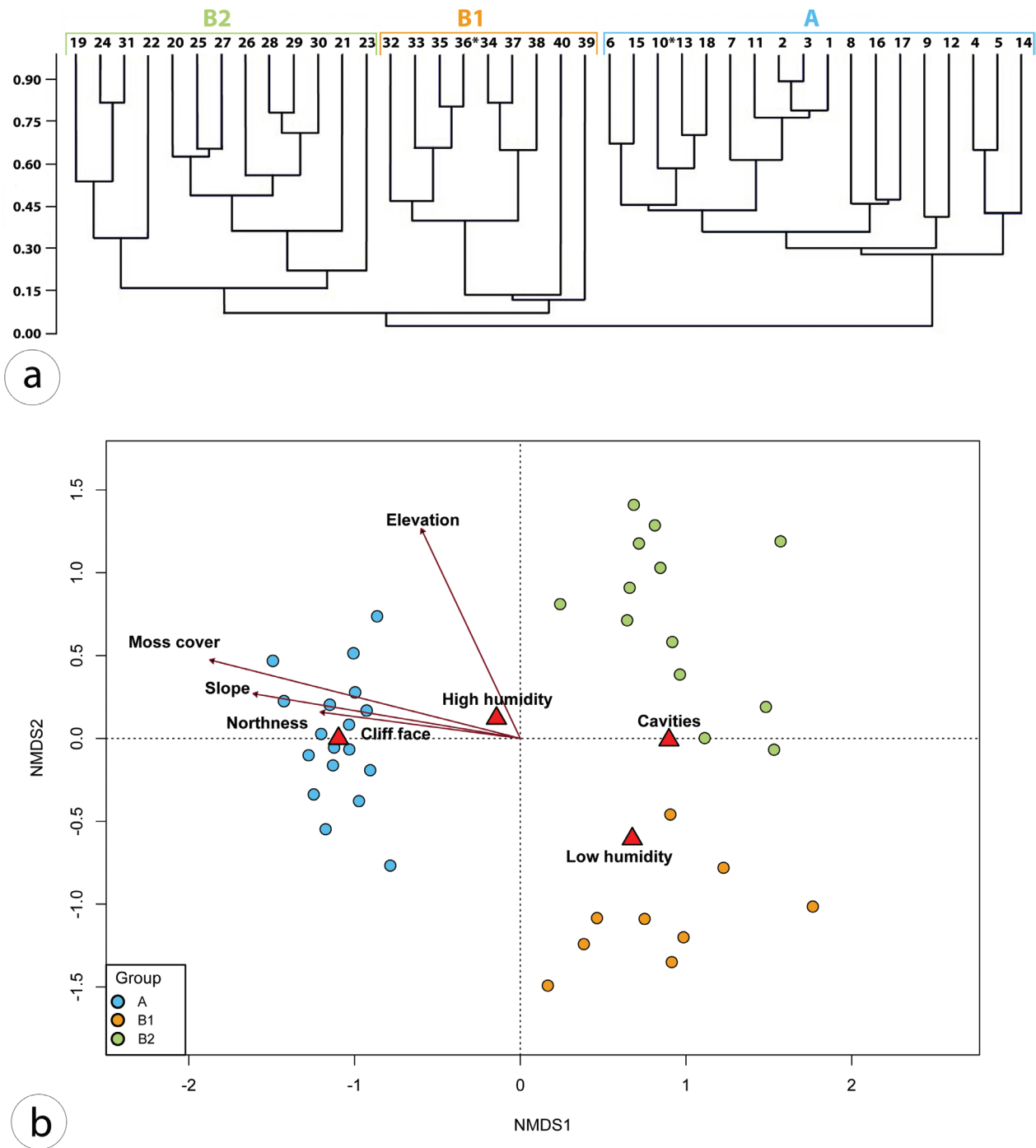


Figure 2. Multivariate analyses of original relevés: (a) UPGMA dendrogram using the Bray-Curtis coefficient based on 40 vegetation relevés; (b) NMDS ordination.

The NMDS ordination, with a stress value of 0.16, is shown in Figure 2b. This analysis further confirms the clear ecological separation among the three groups. The blue dots represent the chomophytic relevés of Group A, positioned on the negative side of the x-axis. Plant communities that pertain to this group are distributed along north-facing cliff faces in the upper areas of the island, which are correlated with high degrees of slope and moss cover. By contrast, the chasmophytic relevés of Group B are located on the positive side of the x-axis. These plant communities grow in cavities that appear on the cliff. Within Group B, the relevés are further separated along the y-axis according to their elevation and degree of hygrophily: plant communities of group B1, represented by orange dots in the lower right quadrant, are found in lower elevation localities than those of group A and B2, showing also a more pronounced correlation with low levels of humidity. In comparison, communities of group B2, which are represented by green dots in the upper right quadrant, are found in higher locations with slightly higher moss cover and humidity.

Rupicolous communities of Montecristo Island

Our analysis showed three clearly separated vegetation groups that can be interpreted at the association or community level. Figure 3 presents a schematic representation of the plant species that most clearly characterize these three groups and the photos of the communities sampled.

Group A represents chomophytic vegetation of cliff faces from higher elevation sites. For this we propose a new association named *Saxifraga montis-christi*-*Polypodium cambricum* ass. nov.

***Saxifraga montis-christi*-*Polypodium cambricum* Foggi, Landi et Angiolini ass. nov.** (typus relevé no. 10, Suppl. material 2: table S2).

Holotypus: *Isoetecium myosuroides* (30%), *Saxifraga montis-christi* (30%), *Trichostomum littorale* (30%), *Polypodium cambricum* (20%), *Nogopterium gracile* (10%), *Aira elegans* subsp. *elegans* (2%), *Crepis leontodontoides* (2%), *Umbilicus rupestris* (2%); *Cynosurus effusus* (1%), *Festuca lachenalii* (1%), *Rumex bucephalophorus* (1%). Locality: Montecristo Island, on a rock face between “Cima dei Lecci” and “Cala Scirocco” (latitude: 42,326203; longitude: 10,31081); Area 0.25 m²; Aspect North, Slope 75%; Elevation 485 m a.s.l.

Diagnostic species: *Nogopterium gracile*, *Polypodium cambricum*, *Saxifraga montis-christi*.

Description: The association is found at elevations above 200 m, in vertical walls or protruding granite rocks. It is generally found in northern exposures, and it is rich in bryophytes, including *Nogopterium gracile* and *Homalothecium sericeum*, which, according to Bardat and Huegel (2002), are characteristic of the *Anogramma*

leptophyllae-*Polypodieta serrati* class (referred to as *Polypodieta* by Mucina et al. 2016). The development of the community begins with a bryophyte layer, as these species are the first to colonize the bare rock. On this substrate, epiphytic pteridophytes, most commonly *Polypodium cambricum*, become established. Through their rhizomes, they likely increase the compactness of the bryophyte mat, enhancing its resistance to tearing and detachment by gravity. The most stable and mature communities are subsequently enriched by the establishment of vascular plants. Two local endemic species live in it: *Saxifraga montis-christi* and *Hieracium racemosum* subsp. *amideii*.

This new association differs from the other communities of the Tuscan Archipelago assigned to the *Polypodium* alliance in being characterized by a well-developed layer of fern-mosses dominated by the endemic *Saxifraga montis-christi* (see Table 2). The most similar relevés to the *Saxifraga montis-christi*-*Polypodium cambricum* appear to be those referred to as the “*Saxifraga capraiae* community” by Foggi and Grigioni (1999). However, that community was not formally described at the rank of association, bryophytes were not surveyed, and it is further differentiated by the presence of the endemic *Saxifraga capraiae*.

Group B1 represents chasmophytic vegetation of the crevices found at lower elevations. We propose the name ***Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum* community** (Suppl. material 3: table S3).

Community species: *Anogramma leptophylla*, *Asplenium obovatum* subsp. *obovatum*, *Festuca bromoides*.

Description: This community occurs between 4 and 240 m a.s.l. in small granite rock crevices and is consistently characterized by the thermo-xerophytic ferns *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum*, the latter replaced at higher elevations by *A. obovatum* subsp. *billotii*. It is floristically poor in both vascular plants and bryophytes.

The community cannot be assigned to *Anogramma leptophyllae*-*Cheilanthes tinai* (Foggi et al. 2006), described from thermo-xerophilous diabase and radiolarite outcrops on Elba (Foggi et al. 2006), due to the absence of *Polypodium cambricum* and the generally low representation of the *Polypodium* alliance. It shows closer affinity to *Selaginello denticulatae*-*Anogrammetum leptophyllae* Molinier 1937 (e.g. relevé no. 40 in Suppl. material 3: table S3), widespread in the Thermomediterranean and Mesomediterranean belts of the western Mediterranean, but differs in the dominance of *Asplenium obovatum* subsp. *obovatum* and in the presence of diagnostic species of *Arenario balearicae*-*Cymbalariaetum aequitrilobae*, including *Anogramma leptophylla* and *Cymbalaria aequitriloba* as well as other species such as *Arisarum vulgare* and *Sagina hawaiiensis*.

We therefore interpret this vegetation as a basal, thermophilous expression of *Arenario balearicae*-*Cymbalariaetum aequitrilobae*, confined to granite crevices lacking a developed terricolous substrate and prevented by warmer conditions from evolving into the full association.

Group B2 represents the rock vegetation of the cavi- ties. It is dominated by *Arenaria balearica* and *Cymbalaria aequitriloba*, two Tyrrhenian endemic species, and has been classified within the *Arenario balearicae-Cymbalari- etum aequitrilobae* Filipello et Sartori 1981.

***Arenario balearicae-Cymbalarietum aequitrilobae* Fili- pello et Sartori 1981** (Suppl. material 4: table S4).

Type relevé: relevé no. 2 of Table 11 (Filipello and Sartori 1981).

Diagnostic species: *Arenaria balearica*, *Anogramma leptophylla*, *Asplenium obovatum* subsp. *billotii* (we be- lieve that the *A. forisiense* reported by the authors and yet not found in this study nor in the recent flora by Siccardi et al. (2025) refers to this species), *Cymbalaria aequitrilo- ba*, *Rocella fuciformis*, *Phaeoceros laevis*, *Ptychostomum capillare* (reported by the authors under its synonym *Bryum capillare*).

Description: According to Filipello and Sartori (1981), it is an association of rocky crevices, with a mesophilic microclimate, hygrophilous and shaly, rich in mosses. It appears as a small carpet in which the herbaceous layer and the moss layer have a similar and continuous cover- ing. The association occurs between 100 and 515 m of el- evation and North-West aspect.

Consistently, we find this association in cavities or large crevices of granite rocks, between 150 and 600 m a.s.l. We therefore observe a shift to higher elevations, compared to what was detected by Filipello and Sartori (1981), which could have been caused by the aridification of the island. It is generally found in the shade, sometimes with a slow flow of water. Among the accompanying species, we also recorded the hygrophytic bryophyte *Brachythe- cium rutabulum* and *Reboulia hemisphaerica* (Dierssen 2001). Similar plant communities have been described in Capraia Island (Foggi and Grigioni 1999), under the new association *Cymbalario aequitrilobae-Samoletum valeran- dii* Foggi et Grigioni 1999, and on Elba Island (Foggi et al. 2006), referred to as *Cymbalarietum aequitrilobae* Gamis- ans et Paradis 1992, both differentiated by the absence of *Arenaria balearica*.

In Table 2, the Montecristo communities were only visually compared with data in literature from other ar- eas of the Tuscan Archipelago (the complete table is in Suppl. material 5: table S5). The communities of Mon- tecristo appear considerably richer in chomophytes, such as bryophytes (mosses and liverworts) and with higher cover of some pteridophytes (*Polypodium cam- bricum* and *Selaginella denticulata*) (see Foggi and Gri- gioni 1999; Foggi and Pancioli 2008; Foggi et al. 2006). Moreover, these communities are clearly distinguished from those of *Linarion caprariae* alliance by their low content in characteristic species of *Linarion caprariae* and of *Asteraceae* family plants, largely present in the rock-faces of the other islands of the Tuscan Archipel- ago (of the genera *Centaurea*, *Helichrysum*, *Robertia*, and *Reichardia*).

Table 1. Shortened synthetic table of diagnostic and constant spe- cies of the three rupicolous communities of Montecristo Island. Cluster A: *Saxifraga montis-christi*-*Polypodium cambrici*; Clus- ter B1: *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum* community; Cluster B2: *Arenario balearicae-Cymbalar- ietum aequitrilobae*. Only species with a significant phi coefficient (p value < 0.05) are shown in grey shading (species are sorted by decreasing phi coefficient), but only the percentage frequen- cy is shown. Only species with a frequency greater than 10% are shown. Mosses and lichens are indicated by the symbol “*”.

Species	Cluster A	Cluster B1	Cluster B2
	(n = 18)	(n = 9)	(n = 13)
<i>Polypodium cambricum</i>	100	•	•
<i>Nogopterium gracile*</i>	83	•	8
<i>Saxifraga montis-christi</i>	89	•	•
<i>Isoetecium myosuroides*</i>	22	•	•
<i>Frullania tamarisci*</i>	22	•	•
<i>Asplenium obovatum</i> subsp. <i>obovatum</i>	•	89	8
<i>Anogramma leptophylla</i>	6	67	46
<i>Arisarum vulgare</i>	•	56	23
<i>Sagina hawaiiensis</i>	•	33	15
<i>Festuca bromoides</i>	•	67	•
<i>Arenaria balearica</i>	33	•	77
<i>Cymbalaria aequitriloba</i> subsp. <i>aequitribolba</i>	•	33	77
<i>Brachythecium rutabulum</i> var. <i>rutabulum*</i>	•	•	38
<i>Reboulia hemisphaerica*</i>	•	•	46
<i>Sedum dasyphyllum</i> subsp. <i>glanduliferum</i>	•	•	38
<i>Parietaria judaica</i>	•	•	31
<i>Umbilicus rupestris</i>	78	89	92
<i>Selaginella denticulata</i>	28	22	15
<i>Trichostomum littorale*</i>	28	11	15
<i>Asplenium obovatum</i> subsp. <i>billotii</i>	6	11	31
<i>Cladonia rangiformis*</i>	28	11	•
<i>Rumex bucephalophorus</i>	39	•	23
<i>Sedum andegavense</i>	39	•	23
<i>Homalothecium sericeum*</i>	17	•	8
<i>Ptychostomum torquescens*</i>	17	•	8
<i>Asplenium trichomanes</i>	11	•	8
<i>Hypnum cupressiforme</i> var. <i>cupressiforme*</i>	11	•	23
<i>Corsinia coriandrina*</i>	•	11	8
<i>Mentha requienii</i> subsp. <i>bistaminata</i>	•	11	8
<i>Cynosurus effusus</i>	22	•	•
<i>Aira elegans</i>	17	•	•
<i>Bartramia aprica*</i>	17	•	•
<i>Crepis leontodontoides</i>	17	•	•
<i>Festuca lachenalii</i>	17	•	•
<i>Hieracium racemosum</i> subsp. <i>amideii</i>	17	•	•
<i>Parmotrema perlatum*</i>	17	•	•
<i>Cladonia pyxidata</i> f. <i>pyxidata*</i>	11	•	•
<i>Hypnum jutlandicum*</i>	11	•	•
<i>Linaria capraria</i>	11	•	•
<i>Silene neglecta</i>	11	•	•
<i>Gastridium ventricosum</i>	•	11	•
<i>Stellaria media</i>	•	11	•
<i>Theligonum cynocrambe</i>	•	11	•
<i>Tortella flavovirens</i> var. <i>flavovirens*</i>	•	11	•
<i>Cerastium ligusticum</i>	•	•	23
<i>Galium parisiense</i>	•	•	23
<i>Ranunculus parviflorus</i>	•	•	23
<i>Radula lindenbergiana*</i>	•	•	15

[illegible]

Class	Polypodietea								Asplenietea		
	Polypodion				Arenarion				Linarion		
	SP	AT	P	Sc	AC	AA	CS	C	CL	LU	RC
Alliance	M	E	G	C	M	M	C	E	E	C	E
Association											
Island											
N° relevés	18	3	2	2	18	10	8	2	6	6	10
<i>Phagnalon saxatile</i>	.	.	.	.	.	.	.	.	I	.	.
<i>Teucrium flavum</i>	.	.	.	.	.	.	.	.	I	.	.
<i>Antirrhinum latifolium</i>	.	.	.	.	.	.	.	.	.	.	I
<i>Asplenium septentrionale</i>	.	.	.	.	.	.	.	.	.	.	I
<i>Coincya monensis</i> subsp. <i>cheiranthos</i>	.	.	.	.	.	.	.	.	.	.	I

Discussion

Regarding the *Saxifraga montis-christi*-*Polypodietum cambrici* association, the presence of several bryophyte species led us to classify it as belonging to the class *Polypodietea* and to the order *Anomodonto-Polypodietalia serrati*, which includes two Thermomediterranean alliances (Biondi and Blasi 2015; Mucina et al. 2016; Chytrý et al. 2024): *Polypodion serrati* – circum-mediterranean moss and fern-rich epilithic communities of shaded rock faces and crevices and epiphytic on branches of old trees, and *Arenarion balearicae* – chomophytic and chasmophytic herb-rich vegetation of shaded rock faces and crevices of the Tyrrhenian Sea archipelagos. The rock face plant communities of Montecristo Island are acidophilic and among the characteristic species listed for both the order and the alliances, the following were found: *Anogramma leptophylla*, *Homalothecium sericeum*, *Reboulia hemisphaerica*, and *Selaginella denticulata*. *Saxifraga montis-christi*-*Polypodietum cambrici* is an association dominated by *Polypodium cambricum*, a fern that grows epilithically (on rocks) as well as epiphytically (on mosses), and where *Selaginella denticulata* and some mosses as *Homalothecium sericeum* are recurrent. Thus, this new association can be referred to the alliance *Polypodion serrati* (that includes the acidophilous alliance *Bertramio-Polypodion serrati* O. de Bolòs et Vives in O. de Bolòs 1957, syntax. synonym in Mucina et al. 2016) and that, according to Carmona et al. (1997) and Deil et al. (2008), includes *Umbilicus rupestris* as characteristic species. The relevés from Elba and Capraia Islands do not report the bryophytic contingent, and unfortunately, this made statistical comparison with our relevés unreliable. However, personal observations suggest that bryophytes are absent or only sparsely represented in most plant communities on Elba and Capraia Islands, with the exception of a few sites in the rock crevices on the north faces of the higher elevations of Capraia, where *Saxifraga granulata* var. *brevicaulis* now *Saxifraga capraiae* (Mannocci et al. 2016) has been recorded. Considering the chomophytic behavior of the related species *Saxifraga montis-christi* and species of the “granulata group”, the *Saxifraga capraiae* community could be regarded as belonging to the alliance *Polypodion serrati*. On the steepest cliffs of Monte della Fortezza, which are impossible to survey using conventional methods, *Leontodon montecristensis* was observed growing in rock crevices using high-resolution drone imagery, mostly as isolated individuals. Where some soil accumulation occurs, the species also occurs sporadically within this association (together with *Hieracium racemosum* subsp. *amideii*, *Polypodium cambricum*, *Saxifraga montis-chris-*

ti, and mosses) or in proximity to small shrubs of *Teucrium marum* and *Erica* spp.

The *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum*, is assigned to the alliance *Arenarion balearicae*, as also *Arenario balearicae*-*Cymbalarietum aequitrilobae*. Filipello and Sartori (1981) assigned the *Arenario balearicae*-*Cymbalarietum aequitrilobae* to the order *Androsacetalia vandellii* Br.-Bl. in Meier et Br.-Bl. 1934 (*Asplenietea trichomanis*), while acknowledging its strong affinity with the alliance *Arenarion balearicae* and expressing reservations about the appropriateness of their original placement. Moreover, given that *Androsacetalia vandellii* is restricted to mountain environments of the nemoral, boreal, and arctic zones of Europe (Biondi and Blasi 2015; Mucina et al. 2016; Chytrý et al. 2024), the attribution of *Arenario balearicae*-*Cymbalarietum aequitrilobae* to the *Arenarion balearicae* alliance appears the most plausible. In Biondi and Blasi (2015), *Arenarion balearicae* is an alliance of Sardinian-Corsican-Balearic communities that grow on granitic rocks in shaded and damp sites. Along with the consistent ecological characteristics of our two associations, we find two diagnostic species (*Arenaria balearicae* and *Cymbalaria aequitrilobae*) and the frequency of *Mentha requienii* subsp. *bistaminata*, which allow inclusion in this alliance. Consistently, in the past the *Arenarion balearicae* alliance has been reported for the eastern Tyrrhenian islands by Wikus-Pignatti and Pignatti (1974), Arrigoni (1986), and Biondi and Bagella (2005) for various localities in Sardinia. However, apart from these species, no additional diagnostic taxa have been reported from either Corsica or Italy. The alliance *Arenarion balearicae* was originally described for Mallorca, yet more recent studies (Reymann et al. 2016; Lafon 2024) conclude that it is not present in France, including Corsica. For this reason, we suggest that future analyses should explore the establishment of a new alliance of shaded, humid rock crevices on siliceous substrates in the eastern Tyrrhenian islands, replacing *Arenarion balearicae* in this context. Indeed, when describing the association *Cymbalarietum aequitrilobae*-*Samoletum valerandii* for Capraia Island, Foggi and Grigioni (1999) already noted that the use of *Arenarion balearicae* in its typical form was problematic. They therefore proposed the suballiance *Cymbalarienion aequitrilobae* Foggi in Foggi and Grigioni (1999), which includes *Cymbalaria aequitriloba*, *Sagina hawaiiensis*, *Selaginella denticulata*, *Asplenium trichomanes*, *A. billotii*, and *A. obovatum* as characteristic species. Considering these reflections, elevating the Capraia suballiance to the rank of alliance appears plausible, a hypothesis that could be further assessed through statistical analyses based on relevés from Mediterranean islands.

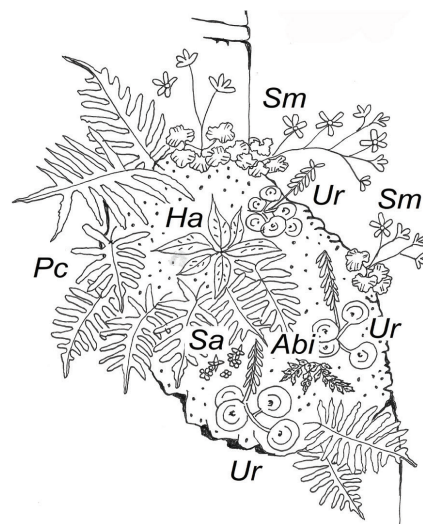
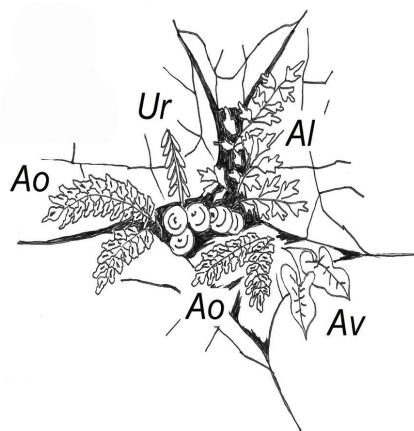
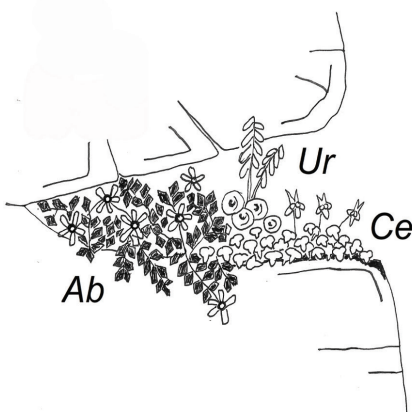
**Group A*****Saxifraga montis-christi* – *Polypodium cambricum*****Group B1*****Anogramma leptophylla* and *Asplenium obovatum* community****Group B2*****Arenaria balearicae*-*Cymbalaria aequitrilobae***

Figure 3. Scheme and photos of the three Montecristo rupicolous plants communities. The abbreviations are as follows: Ab = *Arenaria balearica*; Abi = *Asplenium obovatum* subsp. *billotii*; Al = *Anogramma leptophylla*; Ao = *Asplenium obovatum* subsp. *obovatum*; Av = *Arisarum vulgare*; Ur = *Umbilicus rupestris*; Ce = *Cymbalaria aequitriloba*; Ha = *Hieracium racemosum* subsp. *amideii*; Pc = *Polypodium cambricum*; Sa = *Sedum andegavense*; Sm = *Saxifraga montis-christi*. Image credits: M. Landi.

Linarion caprariae alliance is defined as including chasmophytic vegetation of the siliceous rocks more or less acidic. It was described by Foggi et al. (2006) for the chasmophytic vegetation of Elba Island and was subsequently

also applied to the chasmophytic vegetation of Capraia Island, previously assigned to the *Asplenio billotii*-*Umbilicion rupestris* alliance by Foggi and Grigioni (1999). This alliance was attributed to the order *Asplenietalia lanceolato-obovati*

(*Asplenietea trichomanis* class), as defined in Mucina and Theurillat (2015) and Mucina et al. (2016). As can be seen from the floristic compositions of our relevés, according to the diagnostic species of *Linarion caprariae* alliance and frequent species as *Centaurea aetaliae*, *C. ilvensis*, and *Robertia taraxoides*, the associations described for Elba and Capraia islands attributed to *Linarion caprariae* (*Centaureo aetaliae-Linarietum caprariae*, *Linario caprariae-Umbilicetum rupestris*, *Robertio taraxacoidis-Centaureetum ilvensis*) remain floristically distinct from those of *Polypodietea* class.

Conclusions

This study clearly shows that phytosociological relevés of cliff vegetation should systematically incorporate the cryptogamic component, long overlooked in Mediterranean studies, as its omission may substantially affect vegetation classification. On Montecristo Island, bryophytes played a key role in the floristic and ecological differentiation of rock-face communities, with several taxa displaying diagnostic value comparable to that of vascular plants. In crevice vegetation, the inclusion of non-vascular species is particularly crucial, since in the class *Polypodietea* bryophytes are considered diagnostic at both class and subordinate syntaxonomic levels (Mucina et al. 2016). This pattern aligns with evidence from other Mediterranean vegetation types, including temporary ponds and dry grasslands, where bryophytes have traditionally been overlooked (Puglisi et al. 2015; Guarino et al. 2025).

From a conservation perspective, the communities identified in this study can be directly assigned to habitat 8220 “Siliceous rock walls with chasmophytic vegetation” under the European Directive 92/43/EEC (Habitats Directive), including the association *Arenario balearicae-Cymbalarietum aequitrilobae* (Bensettiti et al. 2004).

Overall, the present study not only advances knowledge of cliff vegetation on Montecristo but also provides a valuable contribution to the clarification and updating of the syntaxonomy of rock-face vegetation across the Tyrrhenian basin, thereby strengthening the ecological and phytosociological framework at both local and regional scales.

Syntaxonomic scheme

Class *Polypodietea* Jurko et Peciar ex Boscaiu, Gergely et Codoreanu in Ratiu et al. 1966

Order *Anomodonto-Polypodietalia* Serrati O. De Bolòs et Vives in O. De Bolòs 1957

Alliance *Polypodion serrati* Br.-Bl. in Br.-Bl. et al. 1952

Association *Saxifraga montis-christi* – *Polypodietum cambrici* Foggi, Landi et Angiolini ass. nov.

Association *Anogramma leptophyllae-Cheilanthes tinai* Foggi et al. 2006

Association *Polypodietum serrati* Br.-Bl. in Br.-Bl., Roussine et Nègre 1952

Saxifraga caprariae community
Alliance *Arenarion balearicae* O. Bolòs et Moliner 1969

Suballiance *Cymbalarienion aequitrilobae*
Foggi 1999

Association *Arenario balearicae-Cymbalarietum aequitrilobae* Filipello et Sartori 1981

Association *Cymbalarion aequitrilobae-Samoletum valerandii* Foggi 1999

Association *Cymbalarietum aequitrilobae*
Gamisans et Paradis 1992

Association *Asplenio obovati-Cymbalarietum aequitrilobae* E Pignatti et S Pignatti 1974

Anogramma leptophylla and *Asplenium obovatum* subsp. *obovatum* community

Class *Asplenietea trichomanis* (Br.-Bl. in Meier and Br.-Bl. 1934) Oberd. 1977

Order *Asplenietalia lanceolato-obovati* (Loisel 1970)
Theurillat et Mucina in Mucina et Theurillat 2015

Alliance *Linarion caprariae* Foggi et al. 2006

Association *Centaureo aetaliae-Linarietum caprariae* Foggi et al. 2006

Association *Linario caprariae-Umbilicetum rupestris* Foggi 1999

Association *Robertio taraxacoidis-Centaureetum ilvensis* Foggi et al. 2006

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Artificial Intelligence (AI) Use

Artificial intelligence tools were used solely to improve the clarity and grammar of the English language; no text, ideas, or scientific content were generated by AI.

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Author contributions

Relevés were collected by Marco Landi and Antonio Zoccola. Species were identified by Bruno Foggi, Giulio Pandeli, Marco Landi, and Tiberio Fiaschi.

Bruno Foggi: Conceptualization, Methodology, Investigation, Data Curation, Visualization, Writing – Original Draft, Project administration. Marco Landi: Conceptualization, Methodology, Investigation, Data Curation, Visualization, Writing – Original Draft. Antonio Zoccola: Methodology, Investigation, Data Curation, Writing – Original Draft. Giulio Pandeli: Investigation, Data Curation, Writing – Original Draft. Giovanni Quilghini: Investigation, Data Curation, Writing – Original Draft, Project administration. Alessio Brogi: Investigation, Data Curation, Writing – Original Draft. Leopoldo de Simone: Investigation, Data Curation, Visualization, Formal analysis, Writing – Original Draft. Tiberio Fiaschi: Investigation, Data Curation, Writing – Review & Editing. Matilde Gennai: Writing – Review & Editing, Validation. Paola Ciampelli, Writing – Review & Editing, Validation. Eugenia Siccardi: Writing – Review & Editing, Validation. Claudia Angiolini: Conceptualization, Methodology, Validation, Writing – Original Draft, Project administration.

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Data availability

The vegetation plot data are available in the CircumMed database (GIVD: EU-00-026 – CircumMed <https://www.givd.info/ID/EU-00-026>) and in VegItaly (GIVD: EU-IT-001 – VegItaly <https://www.givd.info/ID/EU-IT-001>).

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Supplementary material 1

Supplementary table S1

Authors: Bruno Foggi, Marco Landi, Matilde Gennai, Antonio Zoccola, Giulio Pandeli, Giovanni Quilghini, Alessio Brogi, Leopoldo de Simone, Tiberio Fiaschi, Paola Ciampelli, Eugenia Siccardi, Claudia Angiolini

Data type: xlsx

Explanation note: Relevés site data (the coordinate accuracy is approximately ± 5 m).

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Link: <https://doi.org/10.3897/ved.182774.suppl1>

Supplementary material 2

Supplementary table S2

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Data type: xlsx

Explanation note: Group A: *Saxifraga montis-christi*-*Polypodium cambrici* ass. nov.

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Link: <https://doi.org/10.3897/ved.182774.suppl2>

Supplementary material 3

Supplementary table S3

Authors: Bruno Foggi, Marco Landi, Matilde Gennai, Antonio Zoccola, Giulio Pandeli, Giovanni Quilghini, Alessio Brogi, Leopoldo de Simone, Tiberio Fiaschi, Paola Ciampelli, Eugenia Siccardi, Claudia Angiolini

Data type: xlsx

Explanation note: Group B1: *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum* community.

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Link: <https://doi.org/10.3897/ved.182774.suppl3>

Supplementary material 4

Supplementary table S4

Authors: Bruno Foggi, Marco Landi, Matilde Gennai, Antonio Zoccola, Giulio Pandeli, Giovanni Quilghini, Alessio Brogi, Leopoldo de Simone, Tiberio Fiaschi, Paola Ciampelli, Eugenia Siccardi, Claudia Angiolini

Data type: xlsx

Explanation note: Group B2: *Arenario balearicae*-*Cymbalariae aquitrilobae* Filipello et Sartori 1981.

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Link: <https://doi.org/10.3897/ved.182774.suppl4>

Supplementary material 5

Supplementary table S5

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Data type: xlsx

Explanation note: Complete synoptic table with the relative frequency of species within a community indicated by roman numbers: SP = *Saxifraga montis-christi*-*Polypodium cambrici*; AT = *Anogramma leptophyllae*-*Cheilanthes tinaei*; P = *Polypodium serrati*; Sc = *Saxifraga caprariae* community; AC = *Arenario balearicae*-*Cymbalariae aquitrilobae*; AA = *Anogramma leptophylla* and *Asplenium obovatum* subsp. *obovatum* community; CS = *Cymbalariae aquitrilobae*-*Samoletum valerandii*; C = *Cymbalariae aquitrilobae*; CL = *Centaureo aetaliae*-*Linaria caprariae*; LU = *Linaria caprariae*-*Umbilicetum rupestris*; RC = *Robertio taraxacoidis*-*Centaureetum ilvensis*. The abbreviations referred to the islands are: E = Elba; C = Capraia; G = Giglio; M = Montecristo. Mosses and lichen are indicated by the symbol “*”.

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Link: <https://doi.org/10.3897/ved.182774.suppl5>