The Endemic Vascular Flora of Supramontes (Sardinia), a Priority Plant Conservation Area

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Abstract

FENU, G., E. MATTANA, A. CONGIU & G. BACCHETTA (2010). The endemic vascular flora of Supramontes (Sardinia), a priority plant conservation area. *Candollea* 65: 347-358. In English, English and French abstracts.

The main aim of this work is to present a checklist of the endemic vascular flora of the Supramontes region (Central Eastern Sardinia) in order to classify this area in the Sardinian biogeographic subprovince and to better assess its conservation priorities. It is one of the most interesting regions of the Island and spreads for 335 km^2 from the inland limestone massif to the Orosei gulf. This work was based on bibliographic and herbarium studies, integrated by several field surveys carried out from 2004 to 2009. In this study 138 endemic taxa, belonging to 98 genera and 42 families, have been found, with 92 of which being species, 40 subspecies, 5 varieties and 1 hybrid. The analysis of biologic and chorologic data highlighted the peculiarities of this territory. Due to the relatively high number of Supramontes exclusive endemics and to the geologic and geomorphologic peculiarities, it is here proposed a biogeographic classification for these territories and the identification of an autonomous biogeographic sector divided in two distinct subsectors. According to the recent conservation policies at local level, we propose the definition of micro hotspots for this sector, which hold ca. the 40% of the endemic flora of Sardinia, and the concept of nano hotspots for three narrows areas with an exceptional concentration of endemic species, which represent less than 1% of the whole sector surface and whose in situ protection may allow conserving of more than 80% of the vascular endemic flora of this sector.

Key-words

Biogeography – Conservation – Chorology – Micro Hotspot – Nano Hotspot – Sardinia

Résumé

FENU, G., E. MATTANA, A. CONGIU & G. BACCHETTA (2010). La flore vasculaire endémique de Supramontes (Sardaigne), une aire prioritaire de conservation. *Candollea* 65: 347-358. En anglais, résumés anglais et français.

L'objectif principal de ce travail est de présenter une checklist de la flore vasculaire endémique de la région du Supramontes (Centre Est Sardaigne). Cette région est classée dans la subprovince biogéographiques sarde et son statut mieux évalué sur le plan de la conservation. C'est une des régions les plus intéressantes de l'île qui s'étend sur 335 km^2 du massif intérieur calcaire au golfe d'Orosei. Ce travail se base sur des études bibliographiques et des échantillons d'herbiers complétés lors de plusieurs sorties de terrain de 2004 à 2009. Dans cette étude, 138 taxons endémiques, appartenant à 98 genres et 42 familles, ont été trouvés, comprenant 92 espèces, 40 sous-espèces, 5 variétés et 1 hybride. L'analyse des données biologiques et chorologiques a mis en évidence les particularités de ce territoire. En raison du nombre relativement élevé d'espèces endémiques exclusives du Supramontes et des particularités géologiques et géomorphologiques, une classification biogéographique est proposée pour ces territoires ainsi que l'identification d'un secteur autonome biogéographique divisée en deux sous-secteurs. Selon les récentes décisions de politique de conservation au niveau local, nous proposons la définition de micro «hotspot» pour ce secteur qui comprend environ 40% de la flore endémique de Sardaigne, et le concept de nano «hotspot» pour définir trois petites zones qui comprennent une concentration exceptionnelle d'espèces endémiques représentant moins de 1% du total de la surface du secteur. La protection in situ de ces trois petites zones pourrait permettre la conservation de plus de 80% de la flore vasculaire endémique de ce secteur.

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Introduction

The Mediterranean basin has been recognised as one of the 25 most important biodiversity hotspots, considering its high number of endemic plant species (Myers & al., 2000). In this area Medail & Diadema (2009) individuated 52 putative refugia considering a refugium as an area whose existence implies the local long-term (one or more glacial-interglacial cycles) persistence of a species or of one or more of its component populations within a well-defined geographical area (e.g. mountain range, gorge). In the western basin, high endemism areas are related to the age of the geological platform and relict endemics prevail (Médail & Quézel, 1999). This has been supported for Sardinia, Corsica and the Balearic Islands, that were connected with continental plates for at least part of their geological history, by the findings of Mansion & al. (2008) for *Araceae.* Whereas in the eastern basin, vicariant endemism is high due to the moderate role of glaciations and the presence of ultramafic rocks (Verlaque & al., 1997). To better assess plant conservation priorities in this area 10 different hotspots were defined by Médail & Quézel (1997). More recently, Vela & Benhouhou (2007) individuated a new hotspot named 'Kabylias-Numidia-Kroumiria' and suggested to consider also the Dalmatian coast and archipelagos (Croatia), based on preliminary results on endemic plant richness (see Nikolic & al., 2008). The Balearic Islands, Corsica and Sardinia, as well as Sicily (Peloritan Massif), situated in the West Mediterranean basin, are the remnants of areas that once belonged to the Protoligurian massif (Alvarez, 1976). This Hercynian unit was fragmented in the Oligo-Miocene, causing migration of the Corso-Sardinian microplate. These islands have several floristic affinities, even if this Tertiary isolation contributed to the differentiation of neo-endemics that are specific to each area and constitute the Tyrrhenian Islands hotspot (Médail & Quézel, 1997). The Tyrrhenian islands constitute ca. the 22% (515 000 km^2) of the total Mediterranean surface and show a percentage of endemic species on their floras of 10-20% (Contandriopolous, 1990; Gamisans & Jeanmonod, 1995; Médail & Quézel, 1997; Bacchetta & Pontecorvo, 2005; Casazza & al., 2005) with 5500 species being narrow endemics (Médail & Quézel, 1999; Thompson & al., 2005). However, according to Medail & Quézel (1999), the priority-settings at finer-scales (i.e. regional, biogeographic units) seem more practical and realistic for the Mediterranean region. Conservation strategies represent a crucial issue in the Mediterranean biome because these areas (south western Australia, Cape Region of South Africa, California, Mediterranean Basin and part of Chile), which represent less than 5% of the world's surface, house 20% of the world's total floristic richness (Cowling & al., 1996). In these regions, the highest levels of protection were detected in Australia, South Africa and California (from 9-11%), whereas the lowest (<1%) in Chile and in the Mediterranean basin (Underwood & al., 2009).

Sardinia, with 24 090 km^2, is the second-largest island in the Mediterranean Sea (after Sicily); its isolation and high geological diversity have created a wide range of habitats, with high levels of endemic species, especially on its mountain massifs, where there are conditions of ecological insularity (Médail & Quézel, 1997). The Sardinian flora consists of 2408 taxa including 2295 species (Conti & al., 2005b) and 347 of these are endemics with 45.8% being exclusive endemics (Bacchetta & al., 2005b).

From a biogeographic point of view, Rivas-Martínez & al. (2002) recognized an Italo-Tyrrhenian province composed by three subprovinces: the Sardinian, the Corsican and the Tuscano-Calabrian. Manifold similarities, not only concerning floristic aspects, suggest considering Sardinia and Corsica as a province belonging to an Italo-Tyrrhenian superprovince, as formerly proposed by Ladero Alvarez & al. (1987). The Sardo-Corsican province, on its turn, can be furtherly divided into a Sardinian and a Corsican subprovinces, as stated by Bacchetta & Pontecorvo (2005). These authors, on their study on the vascular endemic flora of Iglesiente (SW-Sardinia), conferred the rank of biogeographic sector to the Sulcis-Iglesiente territory and the rank of subsector to Iglesiente. More recently Fenu & Bacchetta (2008) identified for the Sinis Peninsula (CW-Sardinia) the subsector Sinisico, included in the Campidano sector. However, the main part of the island is still unstudied from a biogeographic point of view.

The Supramontes region is one of the most interesting territories of Sardinia, and several floristic studies have been specifically focused on this area. The first floristic studies were carried out by Moris (1837-1859), Martelli (1896, 1904), Schmid (1933) and Rovinetti (1953), and, more recently, by Arrigoni & al. (1977-1991), Arrigoni (1983), Arrigoni & Tommaso (1991) and Bacchetta & al. (2007). Other authors carried out floristic studies on narrow areas of this region as Codula Sisine (Maxia & al., 2003), Capo di Monte Santo (Bocchieri & al., 2008) and, concerning only the endemic vascular flora, Codula di Luna (Bocchieri & al., 2006). Some studies were devoted recently to the description of new endemic taxa (Friedlender & Raynal-Roques, 1998; Friedlender, 1999; Giotta & al., 2002; Arrigoni, 2006a) or revisions of critical taxonomic groups (Bacchetta & al., 2003; Bacchetta & Brullo, 2006; Brullo & Giusso del Galdo, 2006; Bacchetta & al., 2008). However, floristic knowledge of this region is not yet complete and, to date, there is not an exhaustive work on the endemic component of the vascular flora of the whole Supramontes area.

The main aim of this work was to elaborate a checklist of the Supramontes endemic vascular flora in order to (1) set this area in the Sardinian biogeographic subprovince and (2) better assess the floristic richness and the conservation priorities of this territory.

Study Area

This work was carried out on the region constituted by the karstic inlands and the limestone cliffs of the Orosei gulf, named "Supramontes". This area spreads for 450 km^2 in the municipalities of Baunei, Dorgali, Oliena, Orgosolo and Urzulei (provinces of Nuoro and Ogliastra – CE Sardinia). The altitude varies from the sea level to 1463 m of the Mt. Corrasi (Oliena), with the mean altitude of the inland plateau being about 1000 m (Fig. 1).

From a geological point of view Supramontes is characterised by a Mesozoic sedimentary sequence occupying an area of approximately 335 km^2 and covering a crystalline Palaeozoic basement composed of granites and metamorphic rocks (Carmignani & al., 2001). This sequence, with a thickness of 800-850 m, starts with transitional alluvial-lacustrine conglomerates, sandstones and marls (Bajocian-Bathonian) immediately followed by greyish dolostones, fossiliferous and oolithic limestones, deposited in more or less shallow water characterised by reef and inner continental shelf environments (Bathonian-Berriasian) (Carmignani & al., 2001). Assorgia & al. (1974) detected three geolithologic formations characteristic of this region: "Dorgali", "Monte Tolui" and "Monte Bardia", with the first two being referred to the lower Malm and the later to the upper Malm. The two limestone sectors are divided by a wide lower corridor (Fig. 1) constituted by the crystalline Palaeozoic basement (Carmignani & al., 2001).

The superficial hydrography is low due to the karstic nature of the area, characterised by narrow and deep valleys. The Rio Flumineddu is the main river, which crosses the entire region and becomes a canyon gorge in Gorroppu, while numerous minor rivers (named "codule", e.g. Codula di Luna, Sisine and Fuili) lead to the sea in small creeks.

Available climatic data (Orosei, 10 m; Genna Silana, 1013 m; Nuoro, 556 m) highlight a Mediterranean pluviseasonal oceanic climate, with a continentality index "Ic" (Rivas-Martinez & Rivas-Saenz, 2009) progressively increasing from the coast (Orosei, Ic: 14.2; oceanic type, euoceanic subtype and semihyperoceanic variant), to the top of the massif (Genna Silana, Ic: 16.8; oceanic type, euoceanic subtype and euoceanic variant) and the inland areas (Nuoro, Ic: 17.2; oceanic type, semicontinental subtype) (Bacchetta & al., 2009).

In this area two Sites of Community Importance (SCI) have been designed according to the DIR. 92/43/CEE "Habitat" for the karstic inland system (ITB022212) and among the coast (ITB020014).

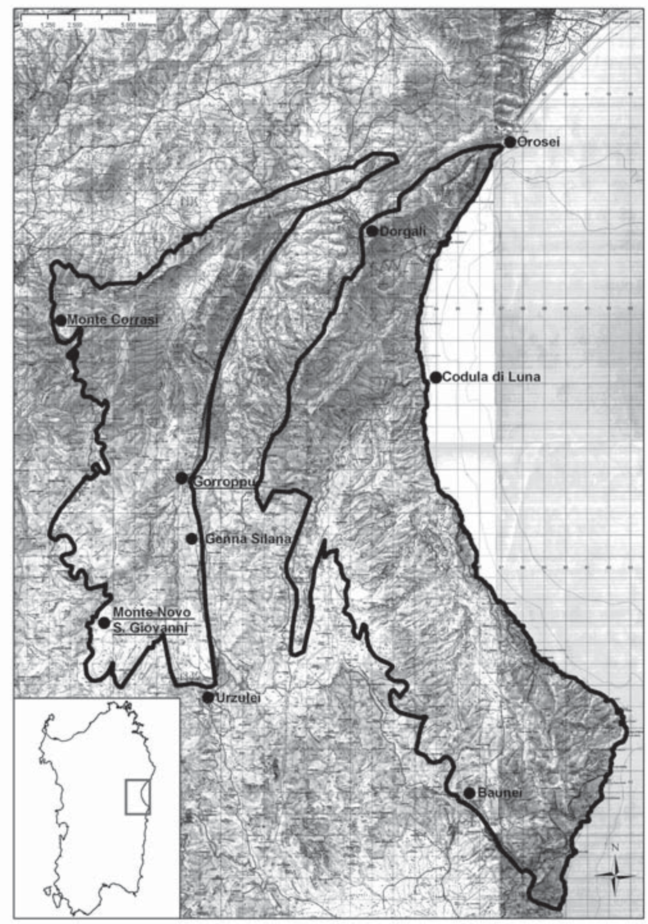

Fig. 1. – Study area.

Methods

This study was based on bibliographic and herbarium investigations, integrated by several field surveys carried out in different seasons, from 2004 to 2009. The herbarium analyses were carried out at CAG, CAT, FI, SS, SASSA, TO and VAL. All the collecting specimens were deposited at CAG. The adopted taxonomic nomenclature followed Conti & al. 2005a. To identify the collected specimens, the following works were consulted Greuter & al. (1984-2009), Tutin & al. (1964-80; 1993), Pignatti (1982), Bolòs & Vigo (1984-2001), Castroviejo & al. (1986-), Jeanmonod & Gamisans (2007) and Arrigoni & al. (1977-1991). Moreover, the classification of orchids followed Scrugli (1990) and Delforge (2005).

The biologic form of the taxa was checked in the field and expressed on the basis of the Raunkiaer's classification (Raunkiaer, 1934), according to Pignatti (1982).

In order to ascribe the surveyed taxa to the chorologic types, the ranks proposed by Arrigoni & Tommaso (1991) were adopted, as modified by Bacchetta & Pontecorvo (2005).

The biogeographic classification followed Ladero Alvarez & al. (1987), Braun-Blanquet (1951), Bolòs (1958, 1962) and Arrigoni (1974) for the characterization of the floristic territories and to Berasategui & al. (1997) and Rivas-Martínez & al. (2002) to individuate and classify the territories from a biogeographic point of view. For the endangered and/or protected taxa, the classes were quoted from Conti & al. (1992, 1997), IUCN (2009) and Habitat Directive 92/43/CEE.

The number of retrieved endemics in the Supramontes area has been co-related to the surface of the analysed territories and the obtained results compared with the values of the whole island and the other Sardinian massifs for which studies on the endemic vascular flora were available (Bacchetta & al., 2005a, 2005b; Bacchetta, 2006; Bacchetta & Pontecorvo, 2005). To compare endemic species densities in areas which are of different size the α-index sensu Hobohm (2000) was calculated following the formula in Hobohm (2003):

$$\alpha = \log E - (z \times \log A + \log c);$$

with α: vertical distance to the regression line of the species/area curve in log scale; E: number of the endemic species; A: size of area in km^2; z: slope of the log E / log A relationship; c: intercept of the slope. Positive values of α refer to areas with above average endemic species diversity, and negative values to those with below average diversity.

Results

The integration of the literature and herbarium data with the results of the field investigations allowed assessing the flora of Supramontes region to 138 endemic taxa (see Appendix 1), belonging to 98 genera and 42 families. Almost all the vascular endemics were Angiospermae, with 112 Dicotyledones, 25 Monocotyledones and only one Gymnospermae *(Juniperus nana* var. *corsicana).* Families counting the highest number of endemics were respectively: *Asteraceae* (15 taxa), *Lamiaceae* and *Orchidaceae* (11). The most represented genera were: *Ophrys* L. (8 taxa), *Genista* L. and *Euphorbia* L. (4), *Aquilegia* L., *Carex* L., *Dianthus* L., *Limonium* Mill., *Orchis* L. and *Scrophularia* L. (3). The surveyed taxa included 92 species, 40 subspecies, 5 varieties and 1 hybrid (see Appendix 1).

In addition to the taxa previously known from literature, the following ones must be added: *Thymus catharinae* (loc. Prados, Oliena-NU) and *Berberis aetnensis* (loc. Monte Corrasi, Oliena-NU), which have been reported for the first time. New populations of taxa previously signalled for Supramontes areas, were also discovered. In particular *Genista toluensis* was retrieved in Punta Cusidore (Oliena-NU), and *Rhamnus persicifolia* in Codula Orbisi (Urzulei-OG), Pischina Urtaddala (Urzulei-OG), Palumbrosa (Oliena-NU) and among the Flumineddu river (Urzulei-OG). The presence of *Aquilegia nugorensis* for Monte Corrasi, as generically reported before by Arrigoni (2006b) for "Monti di Oliena", was confirmed by characterizing three populations of this species, however the exact localities of them are omitted to avoid indiscriminate harvesting of this rare species. These populations showed morphological and ecological differences on respect of those located in the Tacchi region (Seui, OG, *locus classicus* of *A. nugorensis),* therefore further taxonomic studies have been started on them. New populations of *Aquilegia barbaricina* were also discovered, one in Orgosolo (NU) and two in Urzulei (OG) increasing significantly the distribution previously reported in literature for this rare and threatened species (Arrigoni, 2006b; IUCN, 2009). Also in this case the exact localities are omitted. *Limonium morisianum* and *Alyssum tavolarae* have been retrieved for the first time in the Monte Corrasi (Oliena – NU) at Dogones Malos and Palumbrosa respectively.

The biologic spectrum of the endemic flora of Supramontes (Fig. 2) is dominated by the hemicryptophytes (31.88%), followed by chamaephytes (30.43%), geophytes (23.19%), nanophanerophytes and phanerophytes (9.42%) and therophytes (5.07%).

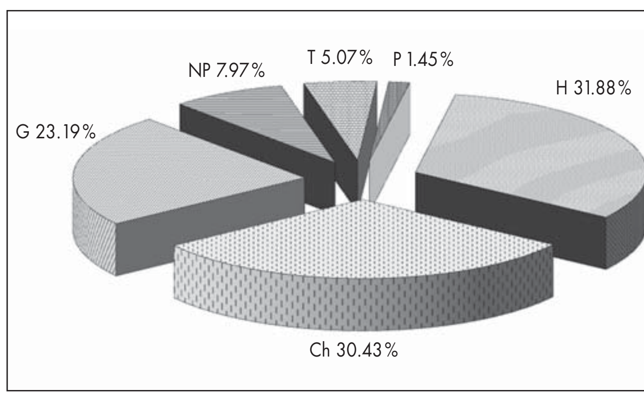

Fig. 2. – Biologic spectrum of the endemic flora of Supramontes.
[**Abbreviations:** H = hemicryptophytes; C = chamaephytes; G = geophytes; NP = nanophanerophytes; P = phanerophytes; T = therophytes].

The great majority of the taxa are exclusive endemics to Sardinia (40.88%) and, with the 30.66% of endemic to Sardinia and Corsica (Fig. 3) represent more than 70% of the total. Within the Sardinian endemics, 7 taxa (5.07%) are exclusive to these territories: *Aquilegia nuragica, Brassica tyrrhena, Centaurea filiformis* subsp. *ferulacea, Centranthus amazonum, Genista cadasonensis, Hieracium supramontanum* and *Ribes sardoum*. 13 taxa are also occurring in the Tyrrhenian islands (ETI), 9 range over the all W-Mediterranean islands (EMOI)

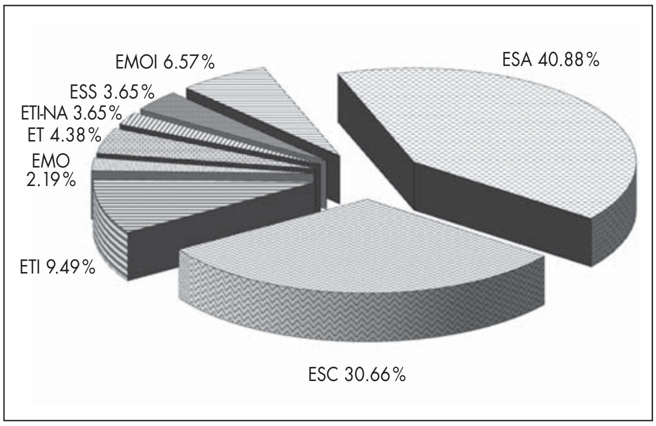

Fig. 3. – Chorologic spectrum of the endemic flora of Supramontes.

[**Abbreviations:** EMO = W-Mediterranean endemics; EMOI = W-Mediterranean insular endemics; ETI = Thyrrenian insular endemics; ET = Tyrrhenian endemics; ETI-NA = Tyrrhenian Islands and N-Africa endemics; ESS = Sardinia and Sicily endemics; ESC = Sardo-Corsican endemics; ESA = Sardinian endemics].

and further 5 stretch up to Sicily (ESS). Within the 9.4% taxa (Fig. 3) whose distribution range includes some continental territories, 3 are Tyrrhenian insular endemics stretching up to N-Africa, 7 are Tyrrhenian endemics sensu strictu and 3 are W-Mediterranean endemics (Fig. 3).

The formula for the regression of the log E / log A relationship is reported in Fig. 4. This equation forms the basis for calculating the α-index values. Supramontes region showed the highest α-index value (0.046) on respect of the other Sardinian massifs (Table 1 and Fig. 4) for which α-index values were negative, such as Iglesiente (-0.004), Sulcis (-0.067) and Sarrabus-Gerrei (-0.253).

In addition, few narrow areas, within the Supramontes region, showed a high concentration of endemic species (Table 2 and in Fig. 4). In particular the Monte Novo S. Giovanni (Orgosolo-NU), with 85 taxa (63.43% of the whole Supramontes area) and an α-index of 0.124, the Monte Corrasi (Oliena-NU), with 87 taxa (64.93%) and an α-index of 0.07 and the Gorroppu canyon (Dorgali-NU), with 64 taxa (47.76%) and an α-index of 0.001, hold together ca. the 80% of the whole region. The Codula di Luna gorge showed a negative α-index (-0.18; Table 1 and Fig. 4).

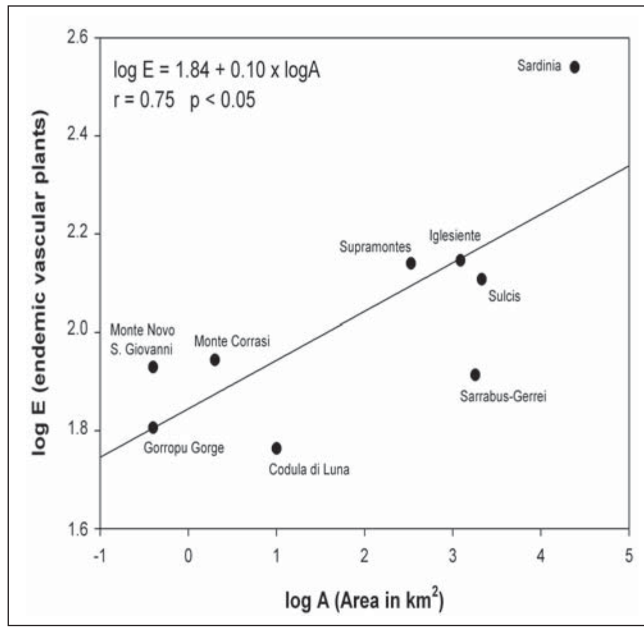

Fig. 4. – Regression curve of log E and log A relationship for the investigated areas.

Table 1. – Comparative analysis among the Supramontes sector and other massifs of Sardinia for which data on the endemic component of their flora were available.

Region	Area (km²)	Endemic species	Endemic SA	α-index	Source
Supramontes	335 (1.39%)	138 (39.77%)	55 (34.59%)	0.046	present work
Iglesiente	1225 (5.08%)	140 (40.34%)	49 (30.82%)	-0.004	Bacchetta & Pontecorvo (2005)
Sulcis	2130 (8.84%)	128 (36.89%)	42 (26.41%)	-0.067	Bacchetta (2006)
Sarrabus-Gerrei	1800 (7.47%)	82 (23.63%)	23 (14.46%)	-0.253	Bacchetta & al. (2005a)
Sardinia	24090 (100%)	347 (100%)	159 (100%)	0.262	Bacchetta & al. (2005b)

Table 2. – Floristic richness on the nano hotspots detected for the Supramontes micro hotspot. Data were calculated on the basis of the retrieved taxa.

Region	Area (km²)	Endemic species	α-index	Source
Monte Novo S. Giovanni	0.4 (0.12%)	85 (63.43%)	0.124	present work
Monte Corrasi	2.0 (0.59%)	88 (65.18%)	0.07	present work
Gorropu Gorge	0.4 (0.12%)	64 (47.76%)	0.001	present work
Codula di Luna	10 (2.98%)	54 (40%)	-0.18	Bocchieri & al., 2006
Supramontes	335 (100%)	135 (100%)	0.046	present work

Concerning the conservation measures (see Appendix 1), the present survey recorded four taxa, included in the Habitat Directive 92/43/CEE and updates, with two of them being priority species and 9 taxa included in the IUCN national and 26 in the regional Red List. According to Conti & al. (1997), 14 of them were considered at lower risk (LR), 2 vulnerable (VU), 6 endangered (EN) and 4 critically endangered (CR). More recently, *Aquilegia barbaricina, A. nuragica* and *Ribes sardoum* were included in the "TOP 50 Mediterranean Island Plants" (Montmollin & Strahm, 2005) and, with *Centranthus amazonum,* in the recent IUCN Global Red List under CR (IUCN, 2009).

Discussion

These data provide a further proof for the floristic autonomy of the Sardo-Corsican flora, more in general and of Supramontes region in particular, due to the evolution of its original elements, that descend from the Tertiary Mediterranean flora (Arrigoni, 1983). In the Mediterranean region, areas rich in conservative rupestrian habitats have an extraordinary floristic diversity, being refuge areas for many species (Domínguez Lozano & al., 1996; Médail & Verlaque, 1997). The high percentage of hemicryptophytes and chamaephytes (Fig. 2) can be co-related both to the abundance of natural rocky crevices and to the Mediterranean climatic conditions. The richness in geophytes remarks the Mediterranean-type climate, even if this datum is influenced by the *Orchidaceae,* representing the 34.37% of the total geophytes. The low percentage of nanophanerophytes and phanerophytes (Fig. 2) can be explained by the slow speciation rate of such entities, due to their long generation time (Bacchetta & Pontecorvo, 2005). The therophytes value (Fig. 2) testifies the integrity of the natural conditions of this area, considering that endemic therophytes are not tolerant to habitat disturbances and modification, as previously reported by Bacchetta (2006) for psammophylous habitats. The antiquity of the limestone mountains and the high frequency of cliffs have encouraged a long process of evolution in the flora of this region, that has given rise to many specialized chasmophytes. Many of these taxa are narrow endemics and most distinguish the endemic flora of the Sardinian mountains from that of Corsica (Arrigoni, 1983).

The highest number of taxa exclusive endemic to Sardinia (40.88%) detected for this region (Fig. 3) is co-related to the substrata. In fact, as already highlighted by previous comparative analysis between Sulcis and Iglesiente (Bacchetta & Pontecorvo, 2005), most of the Sardinian endemics are linked to limestone substrata, while the Sardo-Corsican ones to crystalline and metamorphic ones. Due to the relatively high number of exclusive endemics of Supramontes, and the geologic and geomorphologic peculiarities as its exclusive formations, it is here proposed a biogeographic classification for these territories and the identification of an autonomous sector named Supramontes. According to Ríos Ruiz & al. (2003), the floristic autonomy of this sector is highlighted not only by the presence of 7 taxa endemics to these territories, but also by several differential taxa, species with a wider distribution but that in Sardinia can be found only in this area, such as *Anthericum liliago* (Submedit.-Subatl.), *Asplenium petrarchae* (W-Medit.), *Hieracium pictum* (NW-Medit.), *Silene vulgaris* subsp. *prostrata* (Orophythic SW-European). In addition the presence of a geologic discontinuity constituted by the crystalline Paleozoic basement among the canyon of the Flumineddu river (Fig. 1) allows dividing the karstic inlands and the limestone cliffs in the "Supramontano" and "Golfo di Orosei" subsectors. *Aquilegia nuragica* and *Ribes sardoum* are exclusive of the "Supramontano" subsector, whereas *Nepeta foliosa, Colchicum actupii, Aquilegia barbaricina, A. nugorensis, Alyssum tavolarae, Erinus alpinus, Armeria morisii, Teucrium montanum, Sternbergia colchiciflora, Solidago virgaurea, Sorbus torminalis, Rhamnus alpina* subsp. *alpina, Arenaria bertolonii, Thalictrum minus, Daphne oleoides* and *Limonium morisianum* are differential taxa of this subsector.

Brassica thyrrena, Centaurea filiformis subsp. *ferulacea* and *Genista cadasonensis* are exclusive of the subsector "Golfo di Orosei", with *Hypericum annulatum, Lotus cytisoides* subsp. *conradiae, Ostrya carpinifolia, Anthericum liliago* and *Limonium hermeum* being differential of this area.

The sporadic presence in scattered individuals of species characteristic of calcifuge syntaxa (*Poetea bulbosae*, *Caricion microcarpae* and *Carici-Genistetea lobelioidis*) such as *Genista aetnensis* (loc. Genna Silana and Codula di Luna, Urzulei-OG), *Morisia monanthos* and *Cerastium palustre* (loc. Mare di Urzulei, Urzulei-OG), *Astragalus genargenteus, Euphorbia amygdaloides* and *Juniperus nana* var. *corsicana* (loc. Monte Novo S. Giovanni, Orgosolo-NU), and *Carex microcarpa* (loc. Flumineddu, Dorgali-NU) can be considered as an overlap, in particular in the Supramontano subsector, from the close siliceous Gennargentu Massif, whose biogeographic characterization is not already investigated.

Medail & Diadema (2009) classified the Mediterranean putative refugia in three main types: moist mid-altitude refugia (ca. 400-800 m), which would have allowed altitudinal shifts in response to climate changes or the in situ persistence of species (type 1); deep gorges or closed valleys with continued moisture availability owing to the protected microenvironment (type 2); and refugia of mesophilous trees located in low-altitude areas (type 3). According to this classification the karstic system of the Supramontes sector holds several areas that can be referred as type 2 of refugia, such as e.g. the deep gorge of Gorroppu or the closed valleys of Codula di Luna, Sisine, Fuili and Orbisi, where the climate stays locally wet during periods of drought.

Supramontes sector represents also a southern European refugium (sensu TZEDAKIS & al., 2002) for some temperate tree species (e.g. *Acer monspessulanum* subsp. *monspessulanum*, *Ilex aquifolium, Quercus congesta, Rhamnus alpina* subsp. *alpina, Sorbus torminalis, Taxus baccata*), therefore, an area of special value for the long-term persistence of biodiversity (TABERLET & CHEDDADI, 2002).

The high number of endemic taxa, whose only a low percentage (ca. 22%, Table 1) is actually inserted in the IUCN Red List and protected by the DIR 92/43/CEE (ca. 3%) confers to this sector a priority in the conservation policies and strategies at regional level. In fact the limited extension of these territories might allow protecting about the 40% of the endemic species of the whole island and ca. the 30% of the exclusive Sardinian endemics (Table 1).

According to MEDAIL & QUÉZEL (1999), as indicated by REID (1998) and GINSBERG (1999), the priority-settings are inadequate at a number of scales and finer-scales hotspots (i.e. regional, biogeographic units) seem more practical and realistic for the Mediterranean region. Therefore, here we propose the definition of micro hotspot for the Supramontes biogeographic sector, within the hotspot of the Tyrrhenian Islands sensu MEDAIL & QUÉZEL (1999), because biogeographic provinces (e.g. Sardinia and Corsica sensu LADERO ALVAREZ & al., 1987) or subprovinces (e.g. Sardinia sensu BACCHETTA & PONTECORVO, 2005) show a dishomogeneously distributed floristic richness (see Table 1). This statement is confirmed by the α-index obtained by this region (Fig. 4). HOBOHM (2003) reported that most of biodiversity hotpsot are characterized by high values of α-index. Supramontes' α-index was the only one positive value among all the analysed Sardinian massifs mainly characterized by siliceous substrata. In terms of practical conservation and management, the designation of micro hotspots may be integrated with local conservation measures such as the guidelines provided for the SCI, as happens for this biogeographic unit, with is covered by the two SCIs. In addition the presence of some areas with an exceptional concentration of endemic species limited in less than 3 km^2, allows defining the concept of nano hotspot for the three localities of Monte Corrasi, Monte Novo San Giovanni and Gorroppu Canyon as assessed by the α-index analysis (Table 2; Fig. 4).

Optimizing conservation resources and efforts on these three nano hotspots (all of them included in the SCI "ITB022212"), which represent less than 1% of the whole sector surface, could protect more than 80% of the vascular endemic flora and all the exclusive species of this sector, with the exception of *Genista cadasonensis* and *Centaurea filiformis* subsp. *ferulacea.* This is consistent with the findings of BROOKS & al. (2006) and WILSON & al. (2007), who stated that processes of identification of priorities at finer scales are essential to ensure the implementation of area-based conservation processes. The "microreservas" network, elaborated for the Comunidad Valenciana in Spain (LAGUNA & al., 2004), represents a good application at regional scale of this process and the implementation of these in situ protection measures may be helpful for the conservation of these nano hotspots, and consequently of the Supramontes micro hotspot.

In conclusion, the biogeographic peculiarities highlighted by the identification of an autonomous sector and two subsectors and the floristic richness of these territories, confirm the importance of this area for the conservation of the vascular plant biodiversity of Sardinia and of the West Mediterranean basin more in general.

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Appendix 1. – List of the endemics to Supramontes.

N°	Taxonomic unit	Biological type	Chorology	Biogeographic unit	IUCN (Conti & al., 1992)	IUCN (Conti & al., 1997)	Directive habitat
1	*Acinos sardous* (Asch. & Levier) Arrigoni	Ch	SA	**Sa subprov.**			
2	*Allium parciflorum* Viv.	G	SA-CO	**Sa-Co prov.**			
3	*Alyssum tavolarae* Briq.	Ch	SA	**Sa subprov.**	LR		
4	*Anthyllis hermanniae* subsp. *ichnusae* Brullo & Giusso	NP	SA	**Sa subprov.**			
5	*Aquilegia barbaricina* Arrigoni & Nardi	H	SA	**Sa subprov.**	E	CR	
6	*Aquilegia nugorensis* Arrigoni & Nardi	H	SA	**Sa subprov.**	V	EN	
7	*Aquilegia nuragica* Arrigoni & Nardi	H	SA	**Sup. sector**	CR		
8	*Arenaria balearica* L.	H	SA-CO-AT-BL	**W-Medit. subreg.**			
9	*Aristolochia rotunda* subsp. *insularis* Nardi & Arrigoni	G	SA-CO-AT	**Sa-Co prov.**			
10	*Aristolochia tyrrhena* Nardi & Arrigoni	G	SA	**Sa subprov.**			
11	*Armeria morisii* Boiss. *in* A. DC.	H	SA	**Sa subprov.**			
12	*Arum pictum* L. *fil.* subsp. *pictum*	G	SA-CO-AT	**Sa-Co prov.**			
13	*Asperula pumila* Moris	Ch	SA	**Sa subprov.**	LR		
14	*Astragalus genargenteus* Moris	Ch	SA	**Sa subprov.**	EN		
15	*Bellium bellidioides* L.	H	SA-CO-BL	**W-Medit. subreg.**			
16	*Berberis aetnensis* C. Presl	NP	SA-CO-SI-ITM	**Ital.-Tyrr. superprov.**	LR		
17	*Biscutella morisiana* Raffaelli	T	SA-CO	**Sa-Co prov.**			
18	*Bituminaria morisiana* (Pignatti & Metlesics) Greuter	Ch	SA-TN (La Galite)	**Ital.-Tyrr. superprov.**			
19	*Brassica insularis* Moris	Ch	SA-CO-SI (Pantelleria)-TN (La Galite)	**Ital.-Tyrr. superprov.**		NP	
20	*Brassica tyrrhena* Giotta, Piccitto & Arrigoni	Ch	SA	**Sup. sector**			
21	*Brimeura fastigiata* (Viv.) Chouard	G	SA-CO-BL	**W-Medit. subreg.**			
22	*Bryonia marmorata* Petit	G	SA-CO	**Sa-Co prov.**			
23	**Buglossoides minima* (Moris) Fernandes	T	SA-SI-ITM	**Ital.-Tyrr. superprov.**			
24	*Bunium corydalinum* DC. subsp. *corydalinum*	G	SA-CO	**Sa-Co prov.**			
25	*Campanula forsythii* (Arcangeli) Podlech	H	SA	**Sa subprov.**			
26	*Carduus sardous* DC.	H	SA-ITC	**Ital.-Tyrr. superprov.**			
27	*Carex caryophyllea* subsp. *insularis* (Barbey) Arrigoni	H	SA-CO	**Sa-Co prov.**			
28	*Carex microcarpa* Moris	G	SA-CO-AT	**Sa-Co prov.**			
29	**Carex panormitana* Guss.	G	SA-SI	**Ital.-Tyrr. superprov.**	V	EN	P
30	*Carlina macrocephala* Moris subsp. *macrocephala*	H	SA-CO	**Sa-Co prov.**	LR		
31	*Centaurea filiformis* subsp. *ferulacea* (Martelli) Arrigoni	Ch	SA	**Sup. sector**			
32	*Centaurea filiformis* Viv. subsp. *filiformis*	Ch	SA	**Sa subprov.**			
33	*Centranthus amazonum* Fridl. & A. Raynal	CH	SA	**Sup. sector**	LR	NP	
34	*Cephalaria mediterranea* (Viv.) Szabo	Ch	SA-BL	**W-Medit. subreg.**			
35	*Cerastium palustre* Moris	T	SA	**Sa subprov.**	R	EN	
36	*Cerastium supramontanum* Arrigoni	H	SA	**Sa subprov.**			
37	*Cistus creticus* var. *corsicus* (Loisel.) Greuter	NP	SA-CO	**Sa-Co prov.**			
38	*Clypeola jonthalaspi* subsp. *microcarpa* (Moris) Arcang.	T	SA-SI	**Ital.-Tyrr. superprov.**			
39	*Colchicum actupii* Fridl.	G	SA	**Sa subprov.**			
40	*Crocus minimus* DC.	G	SA-CO-AT	**Sa-Co prov.**			
41	*Cymbalaria aequitriloba* (Viv.) A. Chev. subsp. *aequitriloba*	Ch	SA-CO-AT-BL	**W-Medit. subreg.**			
42	*Cymbalaria muelleri* (Moris) A. Chev.	Ch	SA	**Sa subprov.**			
43	*Delphinium pictum* Willd.	H	SA-CO-BL-H	**W-Medit. subreg.**	LR		

44	*Dianthus cyathophorus* Moris	Ch	SA	**Sa subprov.**		
45	*Dianthus sardous* Bacch., Brullo, Casti & Giusso	Ch	SA	**Sa subprov.**		
46	*Dianthus siculus subsp. oliastrae* Bacch., Brullo, Casti & Giusso	Ch	SA	**Sa subprov.**		
47	*Digitalis purpurea* var. *gyspergerae* (Rouy) Fiori	H	SA-CO	**Sa-Co prov.**		
48	*Dipsacus ferox* Loisel.	H	SA-CO	**Sa-Co prov.**		
49	*Elymus corsicus* (Hackel) Kerguélen	H	SA-CO	**Sa-Co prov.**		
50	*Euphorbia gayi* Salis	G	SA-CO-BL	**W-Medit. subreg.**	EN	
51	*Euphorbia amygdaloides* subsp. *arbuscula* Meusel	Ch	SA-SI-ITM	**Ital.-Tyrr. superprov.**		
52	*Euphorbia amygdaloides* subsp. *semiperfoliata* (Viv.) Radcl.-Sm.	Ch	SA-CO	**Ital.-Tyrr. superprov.**		
53	*Euphorbia pithyusa* subsp. *cupanii* (Bertol.) Radcl.-Sm.	G	SA-CO-SI	**Sa-Co prov.**		
54	*Festuca cyrnea* (Litard. & St.-Yves) Signorini, Foggi & Nardi	H	SA-CO-ITC	**Ital.-Tyrr. superprov.**		
55	*Galium corsicum* Sprengel	H	SA-CO	**Sa-Co prov.**		
56	*Galium schmidii* Arrigoni	Ch	SA	**Sa subprov.**		
57	*Genista aetnensis* (Biv.) DC.	P	SA-SI	**Ital.-Tyrr. superprov.**		
58	*Genista cadasonensis* Vals.	NP	SA	**Sup. sector**		
59	*Genista corsica* (Loisel.) DC.	NP	SA-CO	**Sa-Co prov.**		
60	*Genista toluensis* Vals.	NP	SA	**Sa subprov.**		
61	*Glechoma sardoa* (Bég.) Bég.	H	SA	**Sa subprov.**		
62	*Helianthemum oelandicum* subsp. *allionii* (Tineo) Greuter & Burdet	Ch	SA-SI	**Ital.-Tyrr. superprov.**	LR	
63	*Helichrysum microphyllum* subsp. *tyrrhenicum* Bacch., Brullo & Giusso	Ch	SA-CO-BL	**W-Medit. subreg.**		
64	*Helichrysum saxatile* Moris subsp. *saxatile*	Ch	SA	**Sa subprov.**		
65	*Helleborus lividus* subsp. *corsicus* (Briq.) P. F. Yeo	G	SA-CO	**Sa-Co prov.**		
66	*Hieracium supramontanum* Arrigoni	H	SA	**Sup. sector**		
67	*Hypericum annulatum* Moris	H	SA	**Sa subprov.**	R	LR
68	*Hypericum hircinum* L. subsp. *hircinum*	NP	SA-CO-AT	**Sa-Co prov.**		
69	*Juniperus nana* var. *corsicana* Lebreton, Mossa & Gallet nom. nud.	NP	SA-CO	**Sa-Co prov.**		
70	*Lactuca longidentata* Moris	H	SA	**Sa subprov.**	LR	
71	*Lamium garganicum* subsp. *corsicum* (Godr. & Gren.) Arcang.	H	SA-CO	**Sa-Co prov.**		
72	*Laserpitium siler* subsp. *garganicum* (Ten.) Arcang.	Ch	SA	**Sa subprov.**		
73	*Limonium hermaeum* Pignatti	Ch	SA	**Sa subprov.**		
74	*Limonium morisianum* Arrigoni	Ch	SA	**Sa subprov.**	LR	
75	*Limonium tyrrhenicum* Arrigoni & Diana	Ch	SA	**Sa subprov.**		
76	*Lotus cytisoides* subsp. *conradiae* Gamisans	Ch	SA-CO	**Sa-Co prov.**		
77	*Mentha suaveolens* subsp. *insularis* (Req.) Greuter	H	SA-CO-AT-BL	**W-Medit. subreg.**		
78	*Mercurialis corsica* Cosson	Ch	SA-CO	**Sa-Co prov.**		
79	*Micromeria cordata* (Moris & Bertol.) Moris	Ch	SA	**Sa subprov.**		
80	*Morisia monanthos* (Viv.) Asch.	H	SA-CO	**Sa-Co prov.**		
81	**Myosotis soleirolii* Godr.	H	SA-CO	**Sa-Co prov.**		
82	*Narcissus supramontanus* Arrigoni subsp. *supramontanus*	G	SA	**Sa subprov.**		
83	*Nepeta foliosa* Moris	Ch	SA	**Sa subprov.**	R	EN
84	*Odontites corsica* (Loisel.) Don	T	SA-CO	**Sa-Co prov.**	VU	
85	*Oenanthe lisae* Moris	H	SA	**Sa subprov.**		
86	*Ophrys annae* Devillers-Terschuren	G	SA-CO	**Sa-Co prov.**		
87	*Ophrys chestermanii* (Wood) Gölz & Reinhard	G	SA	**Sa subprov.**		
88	*Ophrys conradiae* Melki & Deschâtres	G	SA-CO	**Sa-Co prov.**		
89	*Ophrys eleonorae* J. Devillers-Terschuren & P. Devillers	G	SA-CO	**Sa-Co prov.**		
90	*Ophrys funerea* Viv.	G	SA-CO	**Sa-Co prov.**		
91	*Ophrys morisii* (Martelli) Soó	G	SA-CO	**Sa-Co prov.**		
92	*Ophrys panattensis* Scrugli, Cogoni & Passei	G	SA	**Sa subprov.**		
93	*Ophrys sphegodes* subsp. *praecox* Corrias	G	SA-CO	**Sa-Co prov.**		
94	*Orchis brancifortii* Biv.	G	SA-SI	**Ital.-Tyrr. superprov.**	LR	
95	*Orchis ichnusae* Corrias	G	SA (CO-BL)	**W-Medit. subreg.**		

Appendix 1. (cont.) – List of the endemics to Supramontes.

N°	Taxonomic unit	Biological type	Chorology	Biogeographic unit	IUCN (Conti & al., 1992)	IUCN (Conti & al., 1997)	Directive Habitat
96	*Orchis* ×*penzigiana* nothosubsp. *sardoa* Scrugli & Grasso	G	SA	**Sa subprov.**			
97	*Ornithogalum corsicum* Jord. & Fourr.	G	SA-CO	**Sa-Co prov.**			
98	*Orobanche rigens* Loisel.	G	SA-CO	**Sa-Co prov.**			
99	*Paeonia corsica* Tausch	G	SA-CO	**Sa-Co prov.**			
100	*Pancratium illyricum* L.	G	SA-CO-AT	**Sa-Co prov.**			
101	*Petrorhagia saxifraga* subsp. *bicolor* (Jord. & Fourr.) Gamisans	H	SA-CO	**Sa-Co prov.**			
102	*Plantago subulata* subsp. *insularis* (Gren. & Godr.) Nyman	Ch	SA-CO	**Sa-Co prov.**			
103	*Polygala sardoa* Chodat	H	SA	**Sa subprov.**			
104	*Polygonum scoparium* Loisel.	Ch	SA-CO	**Sa-Co prov.**			
105	*Potentilla caulescens* subsp. *nebrodensis* (Zimm.) Arrigoni	Ch	SA-SI-ITM	**Ital.-Tyrr. superprov.**			
106	*Ptilostemon casabonae* (L.) Greuter	Ch	SA-CO-H-AT	**W-Medit. subreg.**			
107	*Ptychotis sardoa* Pignatti & Metlesics	H	SA	**Sa subprov.**			
108	*Pulicaria vulgaris* var. *sardoa* Fiori	H	SA	**Sa subprov.**			
109	*Ranunculus cordiger* subsp. *cordiger*	H	SA-CO	**Sa-Co prov.**	CR		
110	*Rhamnus persicifolia* Moris	P	SA	**Sa subprov.**	V	LR	
111	*Ribes multiflorum* subsp. *sandalioticum* Arrigoni	NP	SA	**Sa subprov.**	R	LR	
112	*Ribes sardoum* Martelli	NP	SA	**Sup. sector**	E	CR	P
113	*Romulea requienii* Parl.	G	SA-CO	**Sa-Co prov.**			
114	*Rumex scutatus* subsp. *glaucescens* (Guss.) Brullo, Scelsi & Spampinato	H	SA-SI-ITM	**Ital.-Tyrr. superprov.**			
115	*Rumex pulcher* subsp. *suffocatus* (Bertol.) Nyman	H	SA	**Sa subprov.**	VU		
116	**Salvia desoleana* Atzei & Picci	Ch	SA	**Sa subprov.**			
117	**Santolina corsica* Jord. & Fourr.	Ch	SA-CO	**Sa-Co prov.**			
118	*Santolina insularis* (Fiori) Arrigoni	NP	SA	**Sa subprov.**			
119	*Saxifraga cervicornis* Viv.	Ch	SA-CO	**Sa-Co prov.**			
120	*Saxifraga corsica* (Duby) Gren. & Godr.	H	SA-CO	**Sa-Co prov.**			
121	*Scorzonera callosa* Moris	H	SA	**Sa subprov.**			
122	*Scrophularia canina* subsp. *bicolor* (Sibth. & Sm.) Greuter	H	SA-CO-SI	**Ital.-Tyrr. superprov.**			
123	*Scrophularia oblongifolia* Loisel. subsp. *oblongifolia*	H	SA-CO	**Sa-Co prov.**			
124	*Scrophularia trifoliata* L.	H	SA-CO-AT	**Sa-Co prov.**			
125	*Senecio vulgaris* var. *tyrrhenus* Fiori	T	SA	**Sa subprov.**			
126	*Seseli praecox* (Gamisans) Gamisans	Ch	SA-CO	**Sa-Co prov.**			
127	*Sesleria insularis* subsp. *barbaricina* Arrigoni	H	SA	**Sa subprov.**			
128	*Silene nodulosa* Viv.	H	SA-CO	**Sa-Co prov.**			
129	*Silene velutinoides* Pomel	H	SA-AG	**W-Medit. subreg.**			
130	*Stachys corsica* Pers.	H	SA-CO-AT	**Sa-Co prov.**			
131	*Stachys glutinosa* L.	Ch	SA-CO-AT	**Sa-Co prov.**			
132	*Teucrium marum* L. subsp. *marum*	Ch	SA-CO-BL-AT-H	**W-Medit. subreg.**			
133	*Thesium italicum* A. DC.	G	SA	**Sa subprov.**			
134	*Thymus catharinae* Camarda	Ch	SA	**Sa subprov.**			
135	*Urtica atrovirens* Loisel. subsp. *atrovirens*	H	SA-CO-AT	**Sa-Co prov.**			
136	*Verbascum conocarpum* Moris subsp. *conocarpum*	H	SA-CO-AT	**Sa-Co prov.**			
137	*Veronica verna* subsp. *brevistyla* (Moris) Rouy	T	SA-CO	**Sa-Co prov.**	LR		
138	*Vinca difformis* subsp. *sardoa* Stearn	Ch	SA	**Sa subprov.**			

[**Abbreviations:** (*) Taxa not been found during field investigations; W-Mediterranean subregion = W-Medit. subreg.; Italo-Tyrrhenian superprovince = Ital-Tyrr.-superprov.; Sardo-Corsican province = Sa-Co prov.; Sardinian subprovince = Sa subprov.; Supramontes sector = Sup. sector].