ISLANDS AND PLANTS: PRESERVATION AND UNDERSTANDING OF FLORA ON MEDITERRANEAN ISLANDS

2nd Botanical Conference in Menorca
Proceedings and abstracts

Eva Cardona Pons
Irene Estaún Clarisó
Mireia Comas Casademont
Pere Fraga i Arguimbau
(editors)

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THE SECOND BOTANICAL CONFERENCE IN MENORCA

The 2nd Botanical Conference in Menorca was held in Es Mercadal from the 26th to the 30th of April 2011. Conferences sealed mainly with flora preservation on Mediterranean islands. Mediterranean basin, considered a biodiversity hot spot, shelters island systems to be highlighted for their biogeographical interest, as they constitute lands where features such as geographical isolation and special environmental conditions have fostered speciation processes and favoured the presence of many endemic taxa. In the Mediterranean scope, the islands share main threats and drawbacks related to flora preservation. Therefore, we, the organisers of the Conference, are convinced that one of the best ways to widen our knowledge and improve initiatives of preservation is the exchange and learning of experiences and outcomes obtained in other regions with similar situations.

Since 2009 the Island Council of Menorca has been developing the LIFE+ RENEIX project (http://lifereneix.cime.es), designed to recover areas on the island where flora is threatened. Given the relevance of several LIFE NATURA projects that have already devoted their efforts to the flora preservation, one of the points to be highlighted throughout this event is the networking scheduled in LIFE projects with similar goals, as well as the conception of future projects that can work together following the same line.

Conference organisation:
Island Council of Menorca (CIMe)
Menorcan Institute of Studies (IME)
University of the Balearic Islands (UIB)

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Organising and conducting a conference like this is not easy. In fact, apart from a lot of work, it needs a great deal of hopeful anticipation and disinterested devotion to a process that usually starts months or even years before the venue takes place. The driving force and spirit of the first botanical conference (2006) have been the Botanical Commission members (GOB Menorca – IME), to whom we need to pay the first acknowledgements: Cristòfol Mascaró Sintes, David Carreras Martí, Òscar Garcia Febrero, Xec Pallicer Allès, Martí Pons Gomila, Magda Seoane Barber and Miquel Truyol Olives.

In particular, we also would like to show gratitude to the members of the Scientific Committee at this conference and to all its presenters, speakers as well as the people in attendance.

Most of the conference's organisation and logistics could not have been possible without the excellent job done by the IME staff: Clemen García Cruz, Conchi Carreras Pons, Sonia Sintes Cucalón, Cristina Gomila Santa Maria and our beloved late Josep Miquel Vidal Hernández. Likewise we cannot leave out other people who generously helped in this project: Carme Garriga, Joan Juaneda, Guillem X. Pons, Ricardo Oliveira, Agnès Canals, Sònia Estradé, Maria González, Josep Guardia, Àlex Franquesa and Fina Salord. And last but not least, we also would like to thank the entities that in one way or another made all this possible: the IME (Menorcan Institute of Studies), the LIFE program of the European Commission, the UIB (University of the Balearic Islands), the Island Government of Menorca, GOB Menorca and the City Council of Es Mercadal.

This conference could not have taken place without the full collaboration and contribution of all these people, especially the publication of the book, which you are now holding in your hands.

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II Part: Abstracts

FOREWORD

Two years ago the team lead by Pere Fraga organized the very successful meeting *Islands & Plants: preservation and understanding of flora on Mediterranean islands* (April 26-30, 2011), supported by the Consell Insular de Menorca, Institut Menorquí d'Estudis and Universitat de les Illes Balears and sponsored by a number of GO (from local to European) an NGOs. The hospitality and meeting possibilities offered by the Minorcan team of botanists and institutions resulted in a number of interchanges, new projects and rich development of new ideas. But perhaps the major contribution of the *Islands & Plants* meeting has been a new and significant advance of scientific knowledge on plant diversity as well as on modern and useful management and conservation tools in a 21st-century style: putting together, face to face (or side by side), scientific researchers and managers to work in collaboration (this is not the current and expected style, at least not in the Mediterranean countries!). The result is shown in the current book as providential so as not to lose the consistent contributions presented by the participants. On the contrary, I am convinced that this book will be soon considered as a stepping stone in the study of islands' biodiversity at international level.

Among the main values of this volume, readers should note the truly wide coverage of geographic origin of authors, employed methodologies, institution profiles as well as scientific and technical points of view. Biological diversity studied from truly human diversity open to debate (far from monolithic school and self-satisfied meetings). This is also a merit of the organizing team to have obtained the participation of scientists of such excellence.

The current state of knowledge of plant diversity of Mediterranean islands is summarized by contributing authors in the chapters of this book, but it is also, in part, the result of more than two centuries of botanical exploration. I am convinced that our predecessors deserve our sincere homage. Among tens of honorable names, let me personalize Pius Font Quer (1988-1964), an outstanding Catalan botanist who began his first botanical expedition to Minorca in Spring 1911, exactly 100 years before the Minorca meeting in Es Mercadal (in Spring 2011), just now, when we commemorate the 50th anniversary of his death. Font Quer is considered the modern promoter of botanical exploration of the W. Mediterranean Islands (Menorca, Eivissa, Formentera and surrounding islets, cf. Font Quer 1916, 1918 and many other contributions). He and his collaborators are authors of noticeable chorological findings and contributed greatly to the modern concepts of Balearic Biogeography, and laid the foundation for the future progress of botanical study of Mediterranean islands. But, as demonstrated by the participants, the botanical knowledge of these islands is far from complete: new species are still being discovered each year (both after new extensive and intensive field exploration and after new experimental research), thus underlining the need to continue supporting plant research in the region. In addition to the intrinsic value of the island's biodiversity, they constitute, as a whole, a precious and irreplaceable biological laboratory, where significant new contributions to science are to be expected.

Diversity is also the physical characteristic of the territories studied, especially in size: thousands of islands, from the biggest (Sicily >25.000 km^2) to the small islets (< 5 ha), but also diversity of the deep biological sense of what happened and is still happening in wildlife in the Mediterranean islands. One of the main ideas emerging from the introductory paper by Prof. J.A. Rosselló and from many of the collected scientific contributions is the extremely complex combination of both biogeographic isolation and communication events, giving to islands and islets both the role of refuge and of passing corridor, depending on each one: particular biogeographic history, topography, geology, climate events, sea level fluctuations, long distance dispersal, locally co-evolved mutualisms, microhabitat diversity or genetic mutations occurrence. Long episodes of colonizations/extinctions, introgressions favoring local populations against wide distribution ancestors, as well as local island extinctions due to invasions of foreign genotypes. Hybridization and new ploidy levels in progressive series but also in regressive reverse lines. All this very rich and complex network of ecological and genetic interactions has led to the present day's ecological, phylogenetic, taxonomic, and genetic diversity of Mediterranean island plants, with a very high number of endemic species and subspecies which substantially contributed to the Mediterranean Hotspot of Biodiversity.

But, as exposed in the paper by Prof. F. Médail, the future of the biotic originality of Mediterranean islands is now closely dependent on human population pressures. Centuries of human occupation modelled landscapes, plant communities and populations' genetic structure and spatial distribution, mainly by traditional, slow-pace, building, agriculture and livestock pressures, resulting in balanced bio-diverse units, built and preserved at human size.

However, in the present a set of threats affecting Mediterranean islands plant diversity are repeatedly (and worryingly) reported, at increasingly fast rates. Several contributions of this book coincide with the identification of disproportionate tourism and development-derived pressures (road and building construction, overpopulation, etc.) as the main threat at present, irrespective of the political/administrative adscription of each island, whereas western, central or eastern Mediterranean, small islet or big island. Decline or loss of habitat quantity or quality is the main driver of increased fragility of our island's flora as IUCN established criteria clearly stated. New research on Conservation Biology and commitment to reinforce Protection tools (*in situ* and *ex situ*) are urgently needed.

These threats are curiously widely shared by all the Mediterranean Islands and contribute to make them as a whole, also in this field, a true unit. A set of fragile biological pearls constituting a precious and unique collar. But Mediterranean islands are, even more, an important ensemble of men and women, populations, cultures, languages, also the result of the fortunate combination of isolation and communication for centuries. In words of our poet and singer Miquel Martí i Pol and Lluís Llach, these islands (and by extension, Mediterranean countries) are united by "a bridge of blue sea" ("*un pont de mar blava*") through which both plant and human diversity have been passing during millennia. Now it's our turn to be engaged in their preservation for the next generations.

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I Proceedings

A PERSPECTIVE OF PLANT MICROEVOLUTION IN THE WESTERN MEDITERRANEAN ISLANDS AS ASSESSED BY MOLECULAR MARKERS

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Abstract

Insular systems provide a series of natural laboratories where general hypotheses on evolution, biogeography, ecology and conservation can be conceived and assessed. However, a general hypothesis exploring to what extent the different contrasts between continental and oceanic islands have left significant footprints at various levels of the molecular and genetic structure of phylogenetically related plant endemics remains to be assessed. In particular, there is a need to use model systems to undertake a comparative study of the genetic mechanisms underlying the processes that give rise to plant endemics in oceanic and continental islands. In the Mediterranean basin, the general prediction that island endemic plants often have a reduced genetic variation relative to common, widely distributed species does not seem consistent with current results. At odds with expectations, particularly the Balearic Islands (and possibly continental islands in general), apparently contain a preserve of both nuclear and organellar genetic diversity, not only in the species widely distributed in the Mediterranean but also in narrowly distributed ones. On the whole, these results might be reflecting complex evolutionary histories, in contrast to the hypotheses of insular colonization assuming demographic and genetic bottlenecks due to founder events, which are frequently suggested to explain the origin and evolution of many oceanic island plants.

Keywords: *continental islands, microevolution, genetic diversity, cpDNA, Balearic Islands*

BIOLOGICAL TYPES OF ISLANDS

Even though islands represent only ca. 5% of the earth's surface, they are considered one of the most important ecosystems of the world; indeed, they host a significant proportion of global biodiversity, amounting to between

1/6 and 1/4 of total vascular plant species known on earth (Suda *et al.,* 2003; Kreft *et al.*, 2008; Kier *et al.*, 2009). Furthermore, islands and archipelagos are outstanding biological systems because many of the species they harbour have narrow distributions and high endemicity levels (Whittaker and Fernández-Palacios, 2007). Vascular plant endemic richness has been inferred to be ca. 9.5 times higher on islands than on mainland areas (Kier *et al.*, 2009), and 20 of the 34 biodiversity hotspots defined by Myers *et al.* (2000) [and updates in http://www.biodiversityhotspots.org] are islands or have a remarkable insular component.

Far from being a by-product of only stochastic events, the special features of insular biodiversity apportionment are largely a consequence of the twofold evolutionary role undertaken by non-exclusive processes favouring that some islands have become both (i) refugia (fostering the accumulation of paleoendemics) and (ii) active speciation grounds (triggering the generation of neoendemics). As discrete, internally quantifiable, numerous, and biologically very diverse geographical units, insular systems constitute a series of natural laboratories where hypotheses of general importance in evolution, biogeography, ecology and conservation can be developed, and corroborated or falsified. All these research areas have benefited from the application of molecular markers to (i) circumscribe the origins of the ancestors of insular organisms, (ii) estimate the minimum number of colonisations required, (iii) infer both the inter-insular post-colonizing dispersal patterns, and the within-island evolution/dispersal dynamics, and (iv) identify back-colonisations of the mainland from insular propagules (for instance, among many other references, Baldwin *et al.,* 1990; Sang *et al.,* 1994; Sheely & Meagher, 1996; Kim *et al.,* 1996; Stuessy & Ono, 1998).

However, various important aspects on evolutionary biology related to patterns and processes of plant divergence and micro-speciation on islands (see below) have not been addressed previously within a comparative and conceptually unifying framework including study cases from both oceanic and continental islands. The contrasts between differentiation and evolutionary processes in both island types is of paramount importance to find out whether the evolutionary paradigms that have usually been derived from oceanic island organisms (though also applied to continental islands) have followed similar paths or, on the contrary, there are differential components contingent upon the biological type of the considered island or archipelago.

The different geological origins of islands have important biological consequences. For instance, continental islands derive from the tectonic fragmentation of continental plates; therefore, they present a subset of the flora that already existed when the separation took place, whereas the component derived from long distance dispersal is not known. By contrast, oceanic islands are the product of volcanic activity; originally devoid of life, they become populated by long-distance dispersal through oceanic barriers (Stuessy, 2007; Whittaker & Fernández-Palacios, 2007; Grant, 1998; Crawford & Stuessy, 1997). Traditionally, continental islands have been considered living museums, where the remnants of ancestral floristic elements that represent the autochthonous flora of the mainland to which they were once attached have thrived. By contrast, oceanic islands are viewed as paradigmatic centres of origin of new biodiversity, as they offer a high abundance of niches available for colonization after their emergence (Losos & Ricklefs, 2009; Mansion *et al.*, 2008; Whittaker *et al.*, 2008; Whittaker & Fernández-Palacios, 2007).

CONTINENTAL ISLANDS	OCEANIC ISLANDS
They have been attached to the continents at some past stage of their genesis. In the Western Mediterranean, most major islands have not had contact with the mainland since the end of the Messinian (5.3 Ma)	They have always been islands.
Marine transgressions and regressions have largely conditioned the geographic distribution of biodiversity.	Volcanic activity can dramatically and suddenly shift the distribution ranges of organisms, and/or provoke their extinction.
They are less rugged geographically, and therefore we might expect a higher inter-population genetic cohesion	They have rugged geographic features modelled by volcanism that may represent important barriers to gene flow.
Their biota are taxonomically harmonic	Their biota are taxonomically disharmonic
Low ratio of species per genus Adaptive radiation processes are linked to active speciation processes.	High ratio of species per genus
Adaptive radiation has not been compellingly documented as a phenomenon linked to insular speciation	Adaptive radiation processes are linked to active speciation processes.
Derived woody endemic taxa are only anecdotal	High proportion of woody endemic taxa whose closest mainland congeners are predominantly herbaceous

Table 1. Basic differential characteristics between the two fundamental types of islands.

CONTINENTAL ISLANDS IN THE WESTERN MEDITERRANEAN

The Balearic Islands, Corsica and Sardinia are the largest islands in the western Mediterranean basin, and they have been classified within the ten most biodiverse Mediterranean islands (Médail & Quézel, 1997), featuring ca. 5000 species of vascular plants that include some 360 endemics (Contandriopoulos, 1990; Mariotti, 1990; Alomar *et al.*, 1997). Especially in the Mediterranean basin, where roughly half of the native species are endemics (Médail & Quézel, 1997; Thompson, 1999), endemic plants are paramount to resolve the origins and evolution of the regional floras (Major, 1988). A high proportion of Mediterranean endemic plants occur on islands; consequently, these ecosystems play a central role on the research about spatio-temporal biodiversity dynamics in the region.

Because of their high diversity, floristic and biogeographic studies abound for the Balearic- Corsican-Sardinian flora, and they have revealed floristic links with nearby mainland areas like the Pyrenees, the Alps, Provence, Liguria, Calabria-Sicily, and North Africa (Contandriopoulos, 1962; Contandriopoulos & Cardona, 1984; Mus, 1992). Mediterranean palaeogeography reveals that the current position and extension of the Balearic, Corsican and Sardinian archipelagos has undergone dramatic changes throughout their tectonic evolution. Nevertheless, the most salient features of the geological history of these territories are well-known and, therefore, they can offer a temporal reference for framing any evolutionary study in the Western Mediterranean. Compelling evidence exists that microplates have played a fundamental role in the tectonic evolution of the Western Mediterranean, and that Corsica and Sardinia (along with other minor fragments of continental origin), shaped the core of the largest microplate in the region (Robertson & Grasso, 1995). In the late Oligocene (between 30 and 25 Mya) the Corsican-Sardinian-Minorcan microplate began to detach from the South of France and the NE of the Iberian Peninsula to drift eastwards ca. 30° counter clockwise, reaching its current position some 18-16 Mya (Speranza *et al.*, 2002). During this period, the Minorcan part of the plate came into contact with the other Balearic territories (which were at the time linked to continental landmasses of the area that currently makes up the Iberian Peninsula), detaching itself from the main Corsican-Sardinian block. In the Messinian (ca. 5.96-5.33 Mya), and throughout the subsequent glacial maximal in the Pleistocene, the Corsican-Sardinian archipelago was linked to the western part of the Italian Peninsula (Toscana), whilst the Balearic Islands were connected among them (Hsü *et al.*, 1977; Bocquet *et al*., 1978, Contandriopoulos, 1981, 1990; Contandriopoulos & Cardona, 1984; Robertson & Grasso, 1995).

MICROEVOLUTION OF WESTERN MEDITERRANEAN INSULAR ENDEMICS

The general patterns that might explain microevolutionary processes underlying plant endemization on Western Mediterranean islands have not been explored until now. Such absence of data is most surprising in an enclave where the endemicity rate on major islands far outnumbers a minimum of 10%. Only recently, a critical review about caryological evolution on the Balearic endemic component has been tackled (Rosselló & Castro, 2008), revealing that (1) the origin of the islands (continental or oceanic) is not an accurate predictor of the proportion of polyploid component in the flora, (2) there are no apparent unifying processes that explain the evolution of ploidy levels on insular endemics, and (3) the levels of autochthonous polyploidy (i.e., developed in situ) on continental islands are higher than on oceanic islands, where the percentage of polyploidy evolution on insularity conditions is comparatively low (Stuessy & Crawford, 1988). Nevertheless, other important caryotypic aspects that might be linked to the patterns and processes of insular endemization have not been analyzed as of now.

On the one hand, the examination of nuclear DNA contents (1C values) in Macaronesian endemics revealed a narrow variation range (Suda *et al*., 2003; Suda *et al*., 2005), with most sampled endemics featuring very low nuclear DNA contents (under 1.40 pg), with no endemic species found to have a high 1C value (i.e., above 14.01 pg). These results have motivated the hypothesis that genome miniaturization may carry an evolutionary advantage under the selective pressure conditions that prevail on oceanic insular systems (Suda *et al*., 2005). In fact, Suda *et al*. (2003) and Suda *et al*. (2005) propose that rapid speciation episodes linked to adaptive radiation are much more likely on angiosperms with minimal nuclear DNA contents. It is not known to what extent similar selective pressures have acted on the endemic component of continental islands, and its comparison with the Macaronesian endemic element eventually would allow us to establish unifying statements bearing on the general abundance of species with small genomes on insular systems. On the other hand, there is a glaring void of data on the eventual relationship of insular speciation and differentiation with changes in deep genomic levels (i.e., in the composition and structure of repeated DNA). Among the sequences of highly repeated DNA in the eukaryotic genome, the most important ones are (i) tandem-repeated DNA (aka satellite DNA), and (ii) dispersedly-repeated DNA, encompassing a variety of mobile genetic elements and sequences derived from retro-transposition. These two types of sequences are arranged in tandem on coincident regions with heterochromatin, especially in centromeric and sub-telomeric zones (Ugarkovic & Plohl, 2002). Satellite DNA is characterized by an unusual and non-uniform evolution, tuned by rapid evolutionary changes and concerted evolution mechanisms among closely related species that give rise to a high within-species molecular homogeneity (Pons & Gillespie, 2004). As a result, there is great intra-population homogeneity for population-specific mutations, but a considerable inter-population differentiation (on the whole, mutations occur at a rate far lower than their diffusion rate within the genome/population, thereby fostering a relatively fast replacement of variants within a given satellite DNA family in a population; Ugarkovic & Plohl, 2002). Satellite DNA studies in oceanic island animals from different phyla have revealed the utility of this technique to characterize adaptive radiation and diversification processes on oceanic islands (Pons *et al*., 2002; Pons & Gillespie, 2003; Pons & Gillespie, 2004). However, despite the fact that the evolutionary patterns of satellite DNA have been analyzed in angiosperms from complex evolutionary landscapes (but only in continents; cf. Suárez-Santiago *et al*., 2007), there is no previous study associating the genomic dynamics of this DNA with speciation and diversification phenomena on insularity conditions. Furthermore, the applications of molecular techniques to the study of the evolution of insular organisms in the Mediterranean region are relatively meagre, even though island ecosystems have a recognized importance for the general diversity contents of the area. The numerous Mediterranean islands make up one of the most important centres of plant diversity in this area, with a high proportion of endemicity and being genetically isolated (Médail & Quézel, 1997; Médail & Diadema, 2009). The proportion of endemics on the major islands (the Balearic Archipelago, Sardinia, Cyprus, Corsica, Crete, Sicily) ranges between 10-12% (Médail, 2008); consequently, these ecosystems should have a central importance in the research of the space-time dynamics of this region's biodiversity. However, molecular studies focused on plant species from Mediterranean islands are relatively scarce, though they have experienced an upward surge recently (Hurtrez-Boussès, 1996; Affre & Thompson, 1997; Affre *et al*., 1997; Sales *et al*., 2001; Widén *et al*., 2002; Bittkau & Comes, 2005; López de Heredia *et al*., 2005; Edh *et al*., 2007; Mansion *et al*., 2008; Salvo *et al*., 2008; Falchi *et al*., 2009; Rosselló *et al*., 2009).The few currently available studies suggest that plant endemics from Mediterranean islands (1) have conspicuous genetic diversity levels, which are also highly structured (Affre & Thompson, 1997; Bittkau & Comes, 2005; López de Heredia *et al*., 2005; Edh *et al*., 2007; Falchi *et al*., 2009), indicating that (2) gene flow is scarce, even within species with a high dispersal capacity, thereby highlighting a predominant role of drift on the observed diversity patterns (Widén *et al*., 2002; Bittkau & Comes, 2005; Edh *et al*., 2007).

Wolfe *et al.* (1987) contend that the variation rates in the chloroplast genome are significantly lower than those in nuclear DNA, thereby providing polymorphism levels inadequate for micro-evolutionary intra-specific studies in stenochorous taxa. However, the results so far available suggest otherwise, and highlight the scarce general applicability of that contention. Hence, in our study of the narrowly distributed Balearic endemic *Senecio rodriguezii* (Molins *et al*., 2009) we detected seven haplotypes, a similar number to that found in congeners like *S. halleri* (seven; Bettin *et al*., 2007) and *S. leucanthemifolius* var. *casablancae* (five; Coleman & Abbott, 2003) or in related species widely distributed throughout the Mediterranean basin, such as *S. gallicus*, *S. glaucus*, and *S. leucanthemifolius* (five; Comes & Abbott, 1999). Analogously, the results obtained in the Balearic-Corsican-Sardinian endemic *Thymus herba-barona* (Molins *et al*., 2011) also indicate remarkably high genetic diversity levels, either at the species or population-level. The number of cpDNA haplotypes detected (17) is similar to those found in species widely distributed in the Mediterranean, like *Cistus creticus* in Corsica and Sardinia (16 haplotypes; Falchi *et al.*, 2009). Therefore, the general prediction that island endemic plants often have a reduced genetic variation relative to common, widely distributed species (Frankham, 1997) does not seem consistent in the light of our results. In addition, similar results of cpDNA genetic diversity have been obtained in other species whose distribution is confined to the Western Balearic islands (Molins, Mayol & Rosselló, unpubl. data), and in other species from continental islands (Taiwan; Chiang and Schaal, 2006; and references therein).

At odds with expectations, particularly the Balearic Islands (and possibly continental islands in general), apparently contain a preserve of both nuclear and organellar genetic diversity, not only in the species widely distributed in the Mediterranean (*Quercus sp. pl.*; Lopez de Heredia *et al.,* 2005), but also in narrowly distributed ones (our results, and also Sales *et al.,* 2001). On the whole, these results might be reflecting complex evolutionary histories, in contrast to the hypotheses of insular colonization assuming demographic and genetic bottlenecks due to founder events, which are frequently suggested to explain the origin and evolution of many oceanic island plants.

These previous results coincide with expectations for populations of species in southern glacial refugia, where prolonged isolation in a scenario of small enclaves adequate for survival would have brought about low levels of inter-population gene flow (Hewitt, 2001; Petit *et al*., 2003; Hampe & Petit, 2005; Thompson, 2005), thereby giving rise to exceptionally high levels of genetic diversity at the regional level. Significant genetic structuring has been reported for other Mediterranean island endemics, such as *Brassica cretica* (Fst =0.628 and 1.000; nuclear and chloroplastic microsatellites, respectively; Edh *et al*., 2007), *Brassica insularis* (Gst=0.107; allozymes; Hurtrez-Boussès, 1996), *Cyclamen creticum* (Gst=0.170; allozymes; Affre & Thompson, 1997), the *Nigella arvensis* complex (Fst=0.814; cpDNA; Bittkau & Comes, 2005), or *Centaurea horrida* (Rst=0.158; nuclear microsatellites; Mameli *et al*., 2008).

Theoretical predictions suggest that significant population divergence should be expected in species with isolated populations and restricted dispersal capacity, as these features lead to reduced inter-population gene flow, thereby fostering a predominance of drift. Indeed, diverse empirical studies on insular species from the Aegean do suggest that genetic drift would be one of the main evolutionary forces to explain the high plant diversity in this area (Widén *et al*., 2002; Bittkau & Comes, 2005; Edh *et al*., 2007). Our results are consistent with this hypothesis, as the genetic differentiation values are significantly high, indicating the absence of overall genetic diversity patterns and structuring at the considered scale. Besides, many of the haplotypes found were restricted to a single population or a narrow geographical area, suggesting low (if any) gene flow levels, even at an extremely local scale. On the whole, the levels of variability and differentiation detected bolster the overlap of diverse historical events (both more and less recent) is conducive to a progressive fragmentation of the distribution areas of insular species, in some cases since the Oligocene (some 25-30 Mya). All of this evidence suggests that genetic drift may have acted as one of the main evolutionary forces conditioning the genetic variation patterns and structuring of species endemic to continental islands.

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1: General aspects

HUMANS, LANDSCAPES AND BIODIVERSITY IN THE MEDITERRANEAN REGION

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INTRODUCTION

The French historicist Fernand Braudel wrote: "What is the Mediterranean? One thousand things at a time. Not just one landscape but innumerable landscapes. Not just one sea, but a succession of seas. Not just one civilization, but many civilizations stacked on top of one another. The Mediterranean is a very old crossroads. For millennia, everything has converged upon it" (Braudel, 1985). This quotation explains why deciphering the relationships between humans and landscapes is altogether a difficult and fascinating endeavor due to the fact that the Mediterranean Basin has always been a crossroads for not only human societies, but also for wildlife, which makes it exceptionally rich and diverse (Blondel, 2006; Blondel *et al.*, 2010). The long human history in the Mediterranean resulted in a mosaic of cultural landscapes, each of which added or superimposed its biological and cultural characteristics to the effects of previous ones. These societies have impacted biota and ecosystems everywhere in the basin for so long that it has been occasionally claimed that some kind of 'coevolution' has shaped the interactions between these ecosystems and humans (di Castri, 1981). If human impact has, on average, been far from beneficial to biodiversity, at times it resulted in a significant improvement of biological diversity at various scales from populations to landscapes.

THE ESTABLISHMENT OF TRADITIONAL LAND USE SYSTEMS: WHAT EFFECTS ARE HAD ON BIODIVERSITY?

The first prerequisite for humans to establish themselves as sustainable populations is to manage a friendly living space. To do so, innumerable systems have been devised everywhere in the basin for capturing and managing resources. Some of the systems which had the most prominent effects on ecosystems include forest management (wood-cutting and coppicing, charcoal processing), controlled burning, plant and animal domestication, livestock husbandry, water management and terracing. Wood cutting and the use of fire have been among the most important forces shaping Mediterranean landscapes over the course of the last ten millennia. Fires have always been a key disturbance event in the Mediterranean (Naveh, 1974; Dubar *et al*., 1995) but rural peoples carefully attended to and controlled them so that they greatly contributed to the maintenance of a high turnover of habitats and their associated plant and animal communities and ecosystems (Vazquez *et al*., 2006).

The struggle for water has been a vital theme in the history of all Mediterranean peoples, and ingenious systems for collecting and storing rainwater went unchanged for millennia. A great many of them, some dating back to at least the Chalcolithic period 4,500 to 5,000 years ago, were designed to carry water diverted from floods to fill city and farm reservoirs and for irrigating cultivated fields. Terracing is among the most widespread and sometimes spectacular achievements of rural societies. This has always been a time-consuming and tedious but necessary activity in the mountainous areas of the Mediterranean Basin. Cultivated terraces were both a means of fighting erosion and water-saving devices for preventing run-off. Hand-built stone terraces permitted cultivation on slopes that ranged in inclination from 20–75% (Lepart & Debussche, 1992). Until the early twentieth century, terrace cultivation remained a hallmark that indelibly shaped Mediterranean landscapes, from mountainsides to valley bottoms. On these terraces, a wide range of legumes were cultivated, along with several Mediterranean trees such as olive trees and carob trees which were once planted extensively as a forage and fodder tree in association with various sylvo-pastoral systems.

The nature and intensity of landscape design by peoples of the Mediterranean Basin varied considerably from one region to the next, and from one historical period to the next, particularly with demographic and socioeconomic conditions, so that any generalization is quite difficult. Landscape management resulted in the shaping of agro-sylvo-pastoral cultural landscapes among which the two most well-known are the Sylva-saltus-ager triad and the dehesa-montado system in the Iberian peninsula and some Mediterranean islands. In the dehesa (in Spain) and montado (in Portugal) systems, as well as in similar systems called Pascolo arbolato practiced in Sardinia and other Mediterranean islands, many of the same basic advantages were provided, but the systems differed in the spatial organization of three main activities—cultivation, grazing, and harvesting of forest products. The design of the two systems resulted in a quite different distribution of habitat patches within landscapes: The Sylva-saltus-ager triad typically produced coarse-grained patchwork with clear-cut habitat patches, whereas a fine-grained patchwork was produced by the dehesa-montado system with different consequences to the distribution of various components of biological diversity (see Blondel *et al*., 2010).

Besides but in association with landscape management, the domestication of plant and animal species had many consequences on biological diversity. Domestication began about 10,000 years ago in the eastern part of the Mediterranean Basin and around two millennia later in the western part. The Mediterranean plant world linked to agricultural practices was divided by Zohary (1973) into two parts, the 'segetal' (anthropogenic) and the 'non-segetal' ("primary plants"). With many plant species that were domesticated, adaptive intraspecific variation occurred over millennia as a response to human-induced selection and with habitat changes. This process resulted in the differentiation of many local ecotypes with region-specific characters. A great variety of plant ecotypes have been selected over the centuries. Examples include hundreds of varieties of olive, almond, wheat, and grape, which have been selected intensively by humans. All these varieties have also added to the biological diversity of the Mediterranean. As argued by Diamond (2002), human influence on populations undoubtedly constituted a significant selective factor in their evolution through the process of domestication. For example, the olive tree, the most emblematic plant species across Mediterranean cultures, currently constitutes a complex of many wild forms (*Olea oleaster*), as well as weedy types and many cultivars classified as *O. europaea* var. *europaea* (Terral *et al.*, 2004). Today, more than 600 local cultivars of the olive tree occur in the basin (Breton *et al.*, 2006).

The remarkable combination of protein-rich pulses and cereals that were domesticated in Neolithic farming villages of the Fertile Crescent in the Near East, along with domesticated sheep, goats, cattle and pigs, have certainly facilitated the rapid spread of herding and farming economies (Diamond & Bellwood, 2003). Races of wild cattle have been domesticated from Pleistocene aurochs (*Bos primigenius*) since more than 6,000 years ago (Pfeffer, 1973). Other domesticated mammals of importance were horses (*Equus ferus/caballus*) and donkeys, although the domesticated animals of paramount importance for Mediterranean peoples, and which have had the most widespread impact on Mediterranean ecosystems through grazing and browsing, are sheep and goats. On the whole, a large number of gene pools have been selected in domesticated animals over millennia by traditional pastoralists, with region-specific characteristics that adapted them to local environmental conditions. The long-term human-induced selection processes have resulted in the development of more than 145 varieties of domesticated bovids and 49 varieties of sheep (Georgoudis, 1995).

HUMAN-RELATED UPS AND DOWNS IN BIODIVERSITY

It would be out of the scope of this chapter to describe in detail the historical rise and fall in biodiversity on the scale of the Mediterranean Basin (see. e.g. Blondel & Médail, 2007) but some trends are worth mentioning. Two contrasting theories, one pessimistic and the other optimistic, have been proposed to interpret the relationships between humans and ecosystems in the Mediterranean Basin. The 'Ruined Landscape' or 'Lost Eden theory,' argues that human-caused deforestation and overgrazing resulted in an endless degradation and desertification of Mediterranean landscapes and their associated wildlife. Advocates of this theory (e.g. Attenborough, 1987; McNeil, 1992; Naveh & Dan, 1973; Thirgood, 1981) argue that ten millennia or so of forest destruction and resource depletion best explain the interaction of humans and Mediterranean forests. A second school of thought challenges this view and argues that an imaginary past does not acknowledge real human contribution to the maintenance, diversity, and even the improvement of Mediterranean landscapes since the last glacial period (e.g. Grove & Rackham, 2001). There is certainly some truth in these two viewpoints, but the point of interest is trying to investigate how Mediterranean systems responded to human-induced disturbance events and what their patterns of resilience might be, understood as the amount of time required for a total recovery of the system following a disturbance event. The problem is to understand how living systems have accommodated both the intrinsic variability of Mediterranean bioclimates and the long-term influences of human activity. The continuous redesign of landscapes and habitats has had profound consequences on the distribution, dynamics, and turnover of species and communities.

Diversity losses in the distant past

Human impact has exerted sustained direct effects on Mediterranean ecosystems for a very long time, possibly as many as 50,000 years ago or so. The first significant impact of humans, well before the Neolithic revolution and the establishment of permanent settlements, was their probable role in the extinction of a number of large mammals at the end of glacial times, including on islands. Indeed, the number of large mammals that occurred in most of Western Europe dropped from 37 species to 18 between the late Pleistocene and the present (Petit-Maire & Vrielynck, 2005). Even if the overkill hypothesis suggested by Martin (1984) to explain the sudden disappearance of so many species of large mammals in the Northern Hemisphere at the end of the Pleistocene is still in debate (e.g., Owen-Smith, 1987; Brook & Bowman, 2004), there is much evidence of the direct responsibility of humans in the extinction of the 'megafauna' of Mediterranean islands (e.g. Alcover *et al.*, 1981). These insular mammal faunas, which included strange mammal assemblages with dwarf hippos and elephants the size of pigs, as well as many endemic species, were doomed to extinction in the course of the past millennia as a result of direct and indirect human impact. One well documented example is that of *Myotragus* in Menorca (Bover, & Alcover, 2003).

A true 'revolution' in the relationships between humans and biodiversity began about 10,000 years ago, when hunters in the Near and Middle East began to produce their own food supply, thus laying the foundations for the domestication of plants and animals (Vavilov, 1992; Zeder, 2008). Then human pressure became more and more severe, resulting in massive forest destruction, as demonstrated by many palaeobotanical, archaeological, and historical records. Quézel & Médail (2003) estimated that no more than 15% of the 'potential' Mediterranean forest vegetation remains today. Indeed, pollen diagrams show that large-scale Neolithic deforestation in many parts of the Mediterranean basin coincided with the steady expansion of grain culture as a result of human demographic expansion (Triat-Laval, 1979). Then, from the middle ages and until the end of the eighteenth century, the deciduous downy oak (*Quercus humilis*) and the evergreen holm oak (*Q. ilex*) were intensively used to make charcoal for glassworks and metallurgy. Since the Iron Age, charcoal has been the main source of energy in the Mediterranean area, as testified by the great abundance of ancient charcoal production sites, up to 40 sites per hectare, that are still visible in many woodlands.

Human-related variation of biodiversity in historical times

All habitats and landscapes in the Mediterranean region, except some remote mountainous and steep cliff areas, have been to various extent managed and transformed by humans. Although some of these tremendous changes have sometimes had beneficial consequences on biodiversity as already mentioned, most of them have resulted in serious threats and decline of biological diversity. Forests, wetlands, and coastal habitats together with their associated wildlife have been and continue to be most affected by human impact. Changes of anthropogenic origin have had many impacts on the distribution and abundance of populations, making a large number of them decline while some others are in fact increasing. However, for many plants, some groups of vertebrates, and most groups of invertebrates, micro-organisms and fungi, there is much uncertainty regarding their status. It is very difficult to have a precise idea of the number of plants that are threatened in the Mediterranean but some trends are quite obvious. For example, in countries of the southern shores of the sea there is still a process of ongoing degradation with as much as 25% of the flora being considered as threatened. The unique flora of Mediterranean islands is on the whole seriously threatened, especially the endemic species: on large islands, the percentage of taxa that are threatened ranges from 2% in Corsica to 11% in Crete (Delanoë *et al*., 1996). Many other examples of decline of biodiversity could be cited (see e.g., Blondel & Médail, 2009). After the mass extinction of the large mammal megafauna at the end of glacial times discussed above, the combination of habitat changes and direct persecution has doomed to extinction many other species of large mammals, especially in North Africa. Freshwater fish are perhaps the most interesting group of Mediterranean vertebrates, but also one of the less known and the most threatened with more than 500 species, 50% of them being endemic. As much as 40% of all fish species and 60% of the endemic species in the Mediterranean are vulnerable to extinction and at least eleven of them are already extinct (Smith & Darwall, 2006). Most threats stem from the degradation of water, both in quality (pollution, eutrophication), and quantity (huge amounts of freshwater are pumped for domestic use and irrigation). Reptiles and amphibians have not suffered serious extinction events in recent times but most populations of amphibians and many populations of reptiles are declining everywhere in the Mediterranean. For birds, the main problem is not so much extinction per se, but many changes in the composition and structure of bird assemblages. Many species that were formerly widespread everywhere in the basin are now limited to small, localized populations, many of them threatened, mostly as a consequence of habitat loss, pollution, and decrease of genetic diversity. For example, most large insectivorous birds such as the lesser kestrel and most species of shrikes are strongly declining as a result of food shortage resulting from intensification of agriculture and urban sprawl.

However, for many groups of Mediterranean plants and animals, the main consequences of human-induced large scale deforestation, wetland drainage and traditional landscape design and management have not been so much a decrease in overall species richness at a regional scale as in creating a tremendous proportional advantage for species adapted to open habitats, drylands and shrublands at the expense of forest dwelling species (Blondel *et al*. 2010).

The current trends of habitat changes as a result of human impact vary markedly across the regions of the basin (Mazzoleni *et al*., 2004). On the northern bank of the sea, the ongoing collapse of most traditional land-use systems and rural depopulation completely destructured traditional cultural landscapes as they were replaced by industrial-style agriculture and modern activities such as mass tourism. These changes have had many consequences on several components of biodiversity at the landscape scale (Blondel & Médail, 2007). In contrast, in North Africa and most of the eastern part of the Mediterranean, pressures on natural habitats by humans and livestock are still strongly on the increase, destroying soils and ecosystems and resulting in intense erosion. The impact of on-going woodland clearance, followed by overgrazing in these countries results in high rates of soil erosion and in an increasing clearing of arid steppe rangeland, which is a major cause of desertification in North Africa and the Near East.

On the other hand, changes in the distribution of species and local extinction events were partly compensated for by intraspecific and interspecific adaptive differentiation in response to human induced habitat changes (Zohary & Feinbrun, 1966-86).

WHY AND HOW ARE MEDITERRANEAN ECOSYSTEMS RESISTANT TO DISTURBANCE AND RESILIENT?

Variation in biodiversity in relation to human societies is not necessarily synonymous with degradation. There is some evidence, including comments by Roman writers such as Polinus and Virgilus, that landscape management has often been achieved using empirical knowledge and observation with the intent of making it more resistant and resilient to human-induced disturbance events. Wise management of fields for sustainable services was maintained through a variety of cultural institutions, as indicated by Roman authors, who repeatedly mentioned the need for regular fertilization through application of wood ash, animal manure, or green manure to fields (Dupouey *et al*., 2002). The fine balance achieved by humans among woodlots, pastoral grasslands, scrublands, and open spaces reserved for cultivation resulted in a mosaic that greatly contributed to the biological diversity of Mediterranean landscapes. Grazing, even heavy grazing, is not necessarily a monolithic threat to biodiversity in Mediterranean habitats. The high degree of resilience of Mediterranean matorral shrublands, especially in the presence of a balanced load of grazers and browsers, domesticated or wild, can result in a dynamic coexistence of living systems that are characterized by stability, diversity, and productivity (Etienne *et al*., 1989). For example, comparing two small islands off the large island of Crete, one heavily grazed by the Cretan wild goat (*Capra aegagrus cretica*) and the other ungrazed, Papageorgiou (1979) demonstrated that plant species diversity was much higher in the former than in the latter. Other experiments have shown that population densities of gazelles in Israel with ca. 15 individuals/km^2 not only allowed for optimal harvesting of animals each year but also resulted in a significant increase in plant species diversity of the grazed rangelands (Kaplan, 1992). The main conclusion of these studies is that moderate grazing intensity has the potential to maximize species diversity and optimize ecosystem productivity. Seligman and Perevolotsky (1994) obtained similar results in their review of both sheep and cattle grazing systems in the eastern Mediterranean, where pastures have been grazed by domestic ruminants continuously for more than 5,000 years.

What are the mechanisms underlying the surprisingly high resilience and resistance of Mediterranean ecosystems to long-lasting human pressure? Is it possible to demonstrate some kind of "coevolution" between humans and natural systems that could result in sustainable ecosystem function and a balance between extinction and immigration or differentiation of biota? It has been suggested that the high resistance of Mediterranean ecosystems to invaders and their resilience after disturbance could be a result of the long history of close interactions between humans and ecosystems (Blondel *et al*., 2010; di Castri, 1990; Thompson, 2005). Indeed, this situation contrasts sharply with those of most other regions in the world, including the other Mediterranean-type ecosystems of California, Chile, South Africa and Australia. One possible explanation for this property of Mediterranean ecosystems is that they have already been subjected to continuous disturbance of fluctuating regimes and intensity over many millennia. Thousands of spontaneous colonization events may have made the ecosystems of the basin progressively more resistant, with 'old invaders' preventing or slowing the entry of potential 'new invaders' (Drake *et al*., 1989). Information from archaeological and historical records, as well as observations of modern habitat responses to disturbance events such as range fires, indicate that Mediterranean ecosystems resist heavy human impacts well in the sense that they regenerate quickly after abandonment or degradation.

CONCLUSION

In the long run, one cannot dismiss the heavy and long lasting tribute paid by several components of biodiversity to the many aspects of human action everywhere in the Mediterranean basin. However, the endless redesign of Mediterranean landscapes through traditional land use systems probably benefited several components of biological diversity. Gomez-Campo (1985), Pons & Quézel (1985), and Seligman & Perevolotsky (1994), among others, have argued that the highest species diversities in the Mediterranean Basin are found in areas that have experienced frequent but moderate disturbance, giving support to the diversity-disturbance hypothesis advocated by Huston (1994). Understanding the persistence of biological diversity and sustainable ecosystem function across so many centuries, without irreparable damage, would necessitate considering the feedback mechanisms that keep ecosystems running. Positive and negative feedback cycles involving humans and operating for long periods at local or regional levels do indeed operate in the Mediterranean (see, e.g. Blondel *et al*. 2010). The highest biological diversity in Mediterranean ecosystems probably never occurred in woodlands, even in the pristine ones, but rather in the various agro-sylvopastoral systems. As human pressures on Mediterranean landscapes intensified in later periods, especially when disturbance regimes such as burning, wood-cutting, and tilling reached some threshold values, diversity declined and ecosystems followed new trajectories, leading to alternative stable states that are characterized either by highly productive industrial-style agriculture or heavily degraded ecosystems such as badlands.

After more than 10,000 years of cohabitation between humans and nature, most Mediterranean ecosystems are so inextricably linked to human interventions that the future of biological diversity cannot be disconnected from that of human affairs. The greatest challenge for the decades to come is to promote sustainable development through the development of appropriate tools for integrating environmental issues and development.

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IUCN PLANT CONSERVATION PROGRAMMES IN THE MEDITERRANEAN

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Abstract

The Mediterranean Basin is one of the world's richest places in terms of animal and plant diversity. The Mediterranean is particularly noted for the diversity of its plants – about 25,000 species are native to the region and more than half of these are endemic. This has led to the Mediterranean being recognized as one of the Global Biodiversity Hotspots (Mittermeier *et al.*, 2004).

The IUCN Species Survival Commission has identified plant conservation and red listing as a regional priority for action and has already assessed the conservation status of 200 endemic plant species and 500 freshwater plant species.

IUCN's ongoing work on plant conservation in the Mediterranean includes the following projects:

· The IUCN Mediterranean Biodiversity assessment initiative

· The Mediterranean Plant Red List: Assessing the status of steno-endemic plants

· Important plant areas of the south and east Mediterranean region

· *In situ* conservation projects

Keywords: *IUCN, Red List, plant, conservation, IPA*

IUCN – SSC

The Species Survival Commission (SSC) was established by the IUCN, International Union for Conservation of Nature, in 1949. Since that time, the SSC has grown into a global, science-based network of thousands of volunteer experts, working together towards achieving the vision of "***A just world that values and conserves nature through positive action to reduce the loss of diversity of life on earth***".

The major role of the SSC is to:

· Provide information to the IUCN and the rest of the world on the conservation of species and on the inherent value of species in terms of ecosystem health and functioning, the provision of ecosystem services and the provision of support to human livelihood.

· Promote the conservation of species, thereby leading to measurable reductions in the loss of biodiversity.

Collectively, SSC members form a highly-regarded and influential network of species experts that is able to influence conservation outcomes at all levels, particularly international, through engaging with each other and collaborating in both the IUCN's and SSC's name.

The SSC undertakes assessments of the status of species, develops species conservation action plans and strategies, prepares technical guidelines and formulates IUCN policy statements. The Commission delivers and promotes this technical knowledge, advice and policy guidance to those who can influence the implementation of conservation action around the world.

The strength behind the SSC is a worldwide network of volunteer experts who offer their time and expertise to build a scientific and practical foundation for the effective delivery of conservation. The thousands of volunteer experts are organized into Specialist Groups (SGs), Red List Authorities (RLAs) and Task Forces (TFs) arranged taxonomically, thematically and/or regionally, and convened by the SSC in response to pressing conservation issues.

The overriding goal of the Commission is:

"The species extinction crisis and massive loss of biodiversity are universally adopted as a shared responsibility and addressed by all sectors of society taking positive conservation action and avoiding negative impacts worldwide".

Main strategic objectives:

1. Assessing and monitoring biodiversity. To assess and monitor biodiversity and inform the world about the status and trends of biodiversity, especially at the species level, thus providing measures for the health of our one and only biosphere;

2. Analyzing the threats to biodiversity. To analyze and communicate the threats to biodiversity and disseminate information on appropriate global conservation actions;

3. Facilitating and undertaking conservation action. To facilitate and undertake actions for providing biodiversity-based solutions for halting biodiversity decline and catalyze measures to manage biodiversity sustainably and prevent species' extinctions both in terms of policy changes and actions on the ground;

4. Convening expertise for biodiversity conservation. To provide a forum for gathering and integrating the knowledge and experience of the world's leading experts on species science and management, and promoting the active involvement of subsequent generations of species conservationists.

The Mediterranean Islands Plant Specialist Group is one of the 25 SSC's Plant Specialist Groups. It was formed in 1995 and it currently includes some thirty members. Its objectives are:

· To evaluate and monitor changes in Mediterranean island plant diversity;

· To establish, co-ordinate and implement conservation Action Plans;

· To promote sustainable conservation of plants and their habitats among decision makers and the public.

IUCN CENTER FOR MEDITERRANEAN COOPERATION

The IUCN Center for Mediterranean Cooperation was established in Malaga in October 2001.

The objectives, which reflect the significant areas of work that the IUCN Center for Mediterranean Cooperation will fulfill in order to achieve its goal, are:

1. Making knowledge, information and experience available regarding the conservation and management of Mediterranean biodiversity and natural resources for sustainable-use and rehabilitation efforts.

2. Strengthening and supporting IUCN members and Commissions in the region to mainstream social, economic and environmental dimensions in policy-making, management, and the conservation of biodiversity and natural resources.

3. Promoting, both globally and regionally, Mediterranean policies on conservation and sustainable development, and supporting mechanisms for their implementation.

THE IUCN MEDITERRANEAN BIODIVERSITY ASSESSMENT INITIATIVE

Background

Knowledge of the Mediterranean region biodiversity is heterogeneous at a national level, sometimes restricted to species lists, occasionally also including spatial distribution. Data is dispersed, and there is no regional summary, nor internationally recognized baseline for easily assessing which plants listed as endemic or on national red lists are in fact truly threatened. Taxonomic expertise is often lacking, and there may be disagreements on nomenclature and classification, especially for the lower taxonomic groups. Protection measures for large mammals and birds tend to be adequate, but where biodiversity hotspots for flora, and other groups, have been identified there is as yet little explicit linkage to regional and national policies, beyond the limited species lists under the Habitats Directive and Barcelona Convention.

Action

The IUCN Mediterranean Biodiversity Assessment Initiative aims to produce an analysis of a wide range of species at a regional level. In addition, occurrence of threatened species is a key criterion in the identification of key biodiversity areas through combining spatial data on all vertebrate and plant species, hence moving away from "Important Bird Areas" or "Important Plant Areas" towards a more holistic approach to biodiversity conservation.

IUCN's role

IUCN has already begun the assessment of Mediterranean reptile, amphibian, shark and freshwater fish species. This has demonstrated not only the willingness of the scientific community, the vast majority of whom act in this process as volunteers, to contribute to the assessments, but the degree to which the conservation community considers a Regional Red List as an essential regional tool for guiding and assessing nature conservation priorities and progress.

The initiative seeks to mobilize existing knowledge on species status that may be dispersed or unpublished, and ensure that it is made available for conservation purposes. The key role of IUCN is to coordinate the process ensuring full participation of all appropriate experts, validate the quality of the information, ensuring results of the highest scientific quality, and free of potential individual interests of participating scientists.

Objectives

1. Assess regional species status for the major taxonomic groups
2. Support the assessment process and the production of national Red Lists to guide conservation decision-making and monitoring at a national level.

The objective is to compile the data and the species assessments that form the basis of the Mediterranean Red List for the major taxonomic groups. The IUCN will manage the work being done among the different Specialist Groups and coordinate the incoming data to ensure that assessments are completed to standard and within the timeframe. Once a preliminary assessment has been completed and compiled, a workshop will be organized to validate the results. Finally the coordinator (assisted by a consultant, appropriate Red List Authority or Commission specialist group chair) will go through each of the assessments made and the feedback from the workshop to derive a final compilation of assessments that will provide the final outputs of the assessment process and the basis for the reports and information dissemination.

Results of Phase I of the project

Thirteen taxonomic groups (amphibians, cetaceans, crabs, crayfish, dragonflies, mammals, molluscs, aquatic plants, freshwater fish, marine fish, sharks and rays, reptiles, marine vegetation), have been evaluated.

Goals of Phase II of the project

The specific outputs of Phase II are:

- Conservation status of 1,500 priority plant species assessed
- Conservation status of 400 Mediterranean butterflies assessed
- Conservation status of 450 Mediterranean saproxylic beetles assessed
- Conservation status of 70 Mediterranean dung beetles assessed
- Conservation status of ca. 200 Mediterranean anthozoan species assessed
- Important Freshwater Areas (IFWA) in the Mediterranean region identified, priorities defined and site-based pilot projects identified
- Information made available to decision-makers and stakeholders

MEDITERRANEAN PLANT RED LIST: ASSESSING THE STATUS OF STENO-ENDEMIC PLANTS

Project objectives and outputs

The Mediterranean region is home to around 25,000 plant species; approximately half of them are endemic to this biogeographic region. The endemic species are mainly – but not exclusively – concentrated on islands, peninsulas, rocky cliffs and mountains.

To date, very few plant species have been assessed using the IUCN Red List categories. A great effort has to be made to have a better idea on their vulnerability, the threats they are facing and the conservation actions that should be undertaken to protect them.

The most vulnerable endemic plants are the restricted-range endemics (steno-endemics), as their area of occupancy is small and they might be pushed to extinction by any major disturbance. In addition, when the number of individuals in a population falls below a certain threshold, the species loses genetic diversity which reduces its ability to adapt to change (for instance climate change) and therefore further increases its extinction risk. The project will therefore consider them a priority.

Even with a focus on only steno-endemics, the task is considerable. The initial list of possibly threatened Mediterranean plants to be assessed will probably contain 3,000 to 4,000 species. This preliminary list must first be established and then will need further prioritization before Red List assessments can begin.

Priority will be given to high altitude plants and to selected low altitude groups of taxa.

The main objective of this project is to assess the conservation status of about 1,500 restricted-range endemic plants, selected among the most likely to be threatened.

The production of Red Lists is not a goal *per se*, but they can be used to define conservation priorities, for example: lists of legally protected species, a basis for species recovery action plans, helping to define Important Plant Areas and protected areas. Where possible, provisions will be made within this project to encourage, support and provide training for scientists within those countries where the development of national red lists for plants is priority.

Methodology

Geographical scope of the project

The Mediterranean region and the plant species associated with it are notoriously difficult to define in an absolute fashion. For the purposes of this project, a working definition of the Mediterranean biogeographic region will be used to provide a starting point. The definition chosen is that of Médail & Quezel (1997); it includes all the strictly Mediterranean mountains that have a Mediterranean bioclimate (e.g. the Atlas and Taurus mountains) but only the Mediterranean part of the northernmost sub-Mediterranean mountains (Maritime Alps, Pyrenees, Balkan mountains, Rhodopes).

Collecting the already Red List assessed taxa

Many Mediterranean plants have already been assessed, using different methodologies. Few of them fulfill the standards of the IUCN Red List assessments and are therefore not included in the IUCN Red List database. In many cases, the assessments were made using out of date or national/local criteria, but the species already considered as "threatened" in these lists, and being steno-endemics, should be reassessed using the IUCN Red List criteria (IUCN, 2001).

The list of already assessed taxa will be established on the basis of:

· The IUCN Red List database

· Existing national or sub-national red lists (excluding non-Mediterranean taxa)

· Scientific publications

The outcome will be a list of:

• Already assessed Mediterranean taxa (corresponding to the IUCN Red List standards)

• Potentially threatened (or rare) taxa that should be reassessed using IUCN Red List standards)

Production of a Mediterranean steno-endemics list

The taxonomic information available on Mediterranean plant taxa is rather good, but dispersed in many floras and publications. It is therefore not possible to issue a list of Mediterranean steno-endemics without significant bibliographical work and without consulting experts. At a first stage, an agreed and quantitative definition of what is a steno-endemic has to be agreed upon by compiling bibliographical information and consultation of experts.

The outcome will be a list of Mediterranean steno-endemics.

Production of a list of steno-endemics to be RL assessed

The preliminary list of steno-endemics will be cross-referenced with the lists of already assessed Mediterranean taxa and potentially threatened taxa.

The outcome will be a list of steno-endemics that have to be RL assessed.

Preliminary assessment

All the listed steno-endemic taxa will be assessed using a "RapidList" procedure. This simple initial classification will allow selecting all taxa that are "possibly threatened". This preliminary assessment will be done with national and regional experts, in sub-regional workshops. The exact geography of the sub-regional workshops will depend on the species being assessed. For each taxon considered as "possibly threatened" the need for data collection in the field will be evaluated.

Outcome: A list of possibly threatened steno-endemic taxa, with indication of the ecosystems in which they grow and their altitudinal range

Full IUCN assessment

All taxa considered as possibly threatened and belonging to high-altitude or lowland selected groups will have a full IUCN assessment. The number of taxa to be assessed is estimated to be about 1,500.

The information needed for the Red List assessment could be estimated as follows:

• For 500 taxa, the information needed is sufficient to make the assessment on a desk-based procedure. In many cases, the basis will be an existing assessment, but not in English (cf Red Books for Cyprus and Greece).

· For 500 taxa, there is a need to collect additional information or to update it in the field.

· For 500 taxa, there is almost no information and therefore the need for an in-depth survey in the field.

This assessment will be made by national experts.

· Training will be provided by the IUCN. Much of the plant population data that will be used to make assessments will be held at national level.

· During training, the process of allocating the assessment of regional (multi-country) Mediterranean endemics will be discussed and completed.

· Single country endemics should be assessed at a national level, by convening national workshops or meetings.

The assessments will be validated by the scientific advisor of the sub-project and finally the Red List regional authority.

Outcomes: A full Red List assessment of 1,500 Mediterranean high altitude endemics.

Analysis and final report

The data collected during the assessments will be analyzed and will be included in a final report:

· Analysis of the main threats

· Analysis of the habitat types with threatened steno-endemics

· Analysis of the already taken conservation measures (protected areas, *ex situ* and *in situ* conservation measures)

· Mapping of sites with threatened plants

· Recommendations for conservation actions

IMPORTANT PLANT AREAS OF THE SOUTH AND EAST MEDITERRANEAN REGION

This project, involving the IUCN, Plantlife and WWF and supported by the French Development Agency was conceived to support the creation of an Ecosystem Profile for the Mediterranean region by the Critical Ecosystem Partnership Fund (CEPF). The Goal was to ensure that plant priorities were included in the Profile document which outlines biodiversity priorities in the region.

Important Plant Areas (IPA) are internationally important sites for wild plants and fungi, identified at a national level using standard criteria (Plantlife International, 2004). Initially developed to address the lack of focus on conserving plant diversity, IPAs provide a framework to assess the effectiveness of conservation activities for plants and target sites for future action. They support existing conservation programs such as protected area networks and the CBD Global Strategy for Plant Conservation.

The Mediterranean is an undisputed global biodiversity hotspot solely because of its huge plant diversity. Around 10% of the world's vascular plants (25,000) are found in the Mediterranean Basin on less than 2% of the Earth's surface and half of these species are found nowhere else on Earth. However, precise data on the distribution and status of plants are frequently insufficient, out of date or absent, particularly in the south and east of the region. This fact potentially results in the haphazard application of conservation action.

This project describes a rapid assessment of Important Plant Areas in the south and east Mediterranean; a project designed to provide the 'wild plant perspective' for the regional investment strategy of the Critical Ecosystem Partnership Fund. The project has involved botanical teams from Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Tunisia, Syria and Albania.

207 IPAs have been identified in the project countries bringing the total IPAs in the region to 888. Threatened and restricted species and habitats present on these sites have been recorded along with the threats affecting them. All Mediterranean habitats are represented: forest, maquis, garrigue, pasture, wetland, coastal and the transition to the desert zone. 40% of IPAs identified coincide with key biodiversity areas in the region; sites important for other taxa (mammals, birds, freshwater fish and amphibians).

75% of IPAs contain locally endemic species found only within one country; 60% contain very restricted species. 'Mega endemic sites' containing over 20 very restricted species can be found in Algeria, Morocco, Lebanon, Syria and Libya. Overgrazing of pastoral lands is the most significant threat to the IPAs affecting 67% of sites. Deforestation (largely due to collecting firewood), tourism development, intensification of arable farming and unsustainable collection of plants affect over one third of the analyzed IPAs.

The level of official protection for IPAs varies across the project countries from 0 to 80%. Though official protection of sites can be a helpful measure of conservation, evidence of management plans leading to biodiversity friendly land management is a better measure. Evidence of management plans for IPAs in the region is minimal.

A unique product of this project is the first preliminary list of restricted range plant species for North Africa and the Middle East, which found that

1,195 species occur within less than 5,000 km^2 and around 50% of these occur over less than 100 km^2. Understanding the level of threat to these species will help target actions against biodiversity loss. IPAs are not an optional extra and neither is their conservation. They support the livelihoods of many people and provide undervalued services such as water and flood control, carbon capture, the prevention of desertification and a reservoir of genetic species and diversity; all critically important for the Mediterranean region.

10 recommendations have been developed to help direct the conservation of wild plants in the Mediterranean:

IPA conservation

Recognize Important Plant Areas as internationally significant priority sites for conservation in local, national and regional environmental policies and plans.

Target Important Plant Areas as priority sites for conservation action in the Mediterranean region. This will ensure that direct conservation action on priority plant sites can begin now, alongside the continued efforts to improve data.

Incorporate IPAs (where appropriate) into protected area networks.

Update management plans for protected areas that contain IPAs to take account of new plant data and ensure effective implementation. To develop and implement management plans for IPAs where they do not exist (starting with top priority sites).

Ensure that Environment Impact Assessments are undertaken on development projects that affect IPAs and ensure that their recommendations are enforced and monitored.

Target IPAs for the implementation of sustainable forest management and agri-environment schemes and projects.

Encourage communities whose livelihoods depend on plant resources to participate in IPA conservation planning activities (e.g. medicinal plant collectors, promoters of nature tourism, hunters, mountain guides).

IPA data

'Ground–truth' the plant species and habitat data associated with IPAs through fieldwork (starting with priority IPAs named in this report) and ensure that IPA plant features are properly mapped.

Invest in the provision of comprehensive and updated information on plant and habitats species in the south and east Mediterranean, building on the work carried out in this project. This should include:

• A definitive list of restricted range, endemic plant taxa for the Mediterranean with accurate data on their distribution, size and importance to the local community.

• A regional IUCN Red List for the Mediterranean (begin by focusing on restricted range species that are endemic to the region).

• National IUCN Red Lists for vascular plants for all south and east Mediterranean countries.

• A list of Mediterranean habitats and threatened habitats.

Enable the data associated with IPAs to be filed electronically (such as on the IPA database) so it can be easily updated via the web.

Successful implementation of all this, in the second part of the project, will secure a sustainable future for the environment and inhabitants of this unique region; failure will result in both to a loss of natural resources and little or no resilience when faced with profound changes in climate.

IN SITU CONSERVATION PROJECTS

The Mediterranean Islands Plant Specialist Group is working on several *in situ* conservation projects related to threatened taxa listed in The Top 50 Mediterranean Island Plants (Montmollin and Strahm, 2005).

In Corsica, on *Biscutella rotgesii* Foucaud, with the Conservatoire botanique de Corse, l'Université de Corse and l'Office de l'environnement de Corse. This species is threatened by road building, invasive species, fire and overgrazing. The conservation measures taken are: legal protection, microreserves, *ex situ* conservation.

On the Balearic Islands, on *Naufraga balearica* Constance & Cannon, with the Universitat de les Illes Balears and the Jardi Botanic de Soller. This species is threatened by drought, competition with other plants and overgrazing. The conservation measures taken are: management of goat herds, microreserves and *ex situ* conservation.

Also on the Baleraric Islands, on *Apium bermejoi* l. L. Llorens, with the same partners and the Consell Insular de Menorca. This species is threatened by drought, competition with other plants and caterpillars. The conservation measures taken are: reintroduction in new sites, watering, microreserves and *ex situ* conservation.

In Sicily, on *Calendula maritima* Guss., with the Botanical Institute of Palermo, the Instituto di genetica vegetale of Palermo, the Conservatoire botanique national de Brest, with the support of the Institut Klorane. This species is threatened by development and waste disposal. The conservation measures taken are: microreserves, *ex situ* conservation and population reinforcement.

Also in Sicily, on *Pleurotus nebrodensis* (Inzenga) Quélet, with the Botanical Institute of Palermo, the Park of Mts Madonie and the Community of Mts Madonie. This species is threatened by overcollection. The conservation measures taken are: legal protection and cultivation in order to alleviate collection in the wild.

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PLANT CONSERVATION INVENTORIES, WHAT WE HAVE NOW AND WHAT WE NEED FOR THE FUTURE

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Abstract

Plant conservation inventories in Spain have experienced a paramount increase for the last three decades, not only those related to basic knowledge of endangered plants, but also on conservation tools and protection strategies. One of the key projects in this recent development is the *Atlas de Flora Amenazada* project (known by its Spanish acronym: *AFA*). Since its inception in 2000, this collaborative work among Spanish botanists has produced some important conservation tools. In the first part of this article, we present some relevant results and give some clues to explain the success of the AFA project.

As a result of AFA and several equally important regional initiatives, the amount and quality of data in relation to Spanish plant conservation is extraordinary. From our point of view, we, scientists and managers, need to step down, and rethink these inventories and try to find how we can use them to identify present and future trends in plant biodiversity. We review some monitoring variables for this purpose in the second part of the paper. We consider some of the most popular monitoring variables (area of occupancy, threat category and population size) to identify its advantages and drawbacks in the implementation of future monitoring programs. At the end of the article, we present a list of possible general recommendations derived from these analyses.

Keywords: *Atlas, hollow curve, monitoring, population viability analysis, Red Data Book, Spanish plant conservation, threat analysis.*

INTRODUCTION

The last 30 years have been the most successful period for Spanish biodiversity conservation (Morillo & Gómez-Campo, 2000). Nevertheless, during this time, threats to habitat and species populations have also been produced at an unprecedented pace and scale. In true meaning, the country can be considered a broad conservation experiment; on the one hand, inside its boundaries an important amount of European nature is maintained. Habitat diversity is at its highest in the Continent, with Spanish habitat unique to the world, and Spanish flora constitutes an original biogeographical array with high rates of endemic species, important relict species and finally, species whose Spanish populations constitute the limit of their range distribution. On the other hand, Spain has undergone a serious and rapid change in land use, economics and social awareness, all during this period. More specifically, urbanization and transport infrastructures have produced drastic changes in the landscape and altered composition and population dynamics of habitat and species.

In our point of view, this melting-pot has been fundamental to nurture some very interesting and innovative plant conservation initiatives.

To name just a few, an extensive network of local but comprehensive botanic gardens now covers all biogeographical zones of Andalusia territory (AA.VV., 2005). Pioneering work in Valencia has produced a large network of small protected areas specifically devoted to plant conservation, known as microreserves, now extended in several regions of Spain and other European countries (Laguna *et al.*, 2004). The Canary Islands and Aragon are leading regions in the development of sound and useful Recovery Plans for threatened plants in their areas (Marrero Gómez *et al.*, 2003; Alcántara *et al.*, 2007).

One example of these novelties in plant conservation action is the *Spanish Atlas of Threatened Flora* (hereinafter called "AFA project"). Since its inception, this work has represented a continuous effort to inventory and report the conservation status of the Spanish flora.

Inventories are at the core of any conservation strategy. They inform us about the species in need and also about what we need to do to protect them. Inventory activities require large investment of time and resources at the start, becoming increasingly useful and profitable with time. As more and more areas and species are covered with these inventory activities, it is required to adapt them to new situations, improve their use, and make them more cost-effective (Lughadha *et al.*, 2005; Baillie *et al.*, 2008).

The objectives of this work are twofold: firstly, we summarize here some results of the AFA project. Framing the project in the Spanish conservation context, we briefly describe its inceptions and rationale. Then, we present some of the most relevant results derived from different actions contributing to the AFA project. And finally, we give some ideas about key aspects explaining its implementation and results across Spain. In the second part of the article, we examine some of the postulates of present plant inventories and how they can be used to improve future monitoring techniques. Future monitoring programs need to rapidly and precisely report any changes in biodiversity trends, and the information and expertise derived from current inventories can be employed to save time and resources when future monitoring programs take shape.

AFA PROJECT: TEN YEARS OF RESULTS

In December 1995, a group of 20 conservation botanists came together in the Cordoba Botanic Garden to promote the new IUCN Spanish committee. Several issues were addressed; the creation of the flora commission within the IUCN Spanish committee, the launching of a plant conservation bulletin, etc. The meeting ended with a general understanding that a new list of threatened plant species was urgently needed in Spain (see Conservación Vegetal 1, 1996). The last list had been published 11 years earlier, in 1984, so there was a need to update information contained in this antiquated list. Moreover, certain results derived from several plant conservation inventory projects from different parts of Spain made this task urgent.

Eventually a Spanish flora commission within the IUCN Spanish committee was formally set up and the first meeting of the new Flora Commission was held in L'Albufera de Valencia in July 1999 under the auspices of the Government of Valencia. From this meeting a steering committee was formed with one objective: to produce the new Spanish plant Red list (see Conservación Vegetal 5, 2000).

By that time, the Biodiversity agency of the Spanish Ministry of Environment was ready to help and promote plant inventories because they were also launching a new general Spanish biodiversity inventory, involving vertebrates, invertebrates and plants. This inventory was also a requirement from the implementation of a new Spanish biodiversity conservation legal framework, and closely related to the development of some of the protocols of the Convention of Biological Diversity (CBD). Spain was part of the CBD by ratification since the end of 1993. It was not surprising that the Flora Commission of Spanish UICN committee and the Biodiversity agency of the Spanish Environmental Ministry found common grounds, and the latter organized in February 2000 another meeting in Miraflores (Madrid). The final draft of the new list was approved, and a few months later the 2000 Red List of Spanish Vascular Flora was published (AA.VV., 2000). In addition, the Spanish Ministry took the opportunity in Miraflores to present to the botanist community the need for a larger project involving field conservation inventories and the production of red data books. Rapidly, botanists and managers agreed on the advantage of the upcoming new plant red lists to develop a more ambitious project. This way, the foundations of the AFA project were laid.

During the following years an extensive survey involving many of the most threatened plants in Spain was carried out. Results came afterwards, and three years later, in 2003, the first red data book containing 478 taxa was published (Bañares *et al.*, 2003; Bañares *et al.*, 2004). Those plants were amongst the top list priorities in Spanish plant conservation, comprising mostly Critically Endangered and Endangered plants according to UICN categories. In 2007 a new volume with 35 new taxa came to light, and those taxa were studied during a two-year (2005 and 2006) campaign (Bañares *et al.*, 2007). A new volume with 53 taxa appeared in 2008, corresponding to plants studied during the previous year (Bañares *et al.*, 2008). The last one has been published recently, and it includes 57 plants surveyed in 2008 and 2009 (Bañares *et al.*, 2010).

THE AFA PROJECT AS A MODEL INVENTORY

Several conservation works came to light under the umbrella of the AFA project, most importantly, but not exclusively, red data books. The four mentioned red data books were structured following standards widely used in conservation inventories. Therefore, a red data sheet for each plant showed short depictions about current taxonomy, biology and habitats preferences, demography (including data about life span, recruitment, reproduction, etc.), reported on potential threats and finally conservation measures (active or passive). However, it was the population approach that made this work more innovative. So, for the first time in Spanish plant conservation, the unit of inventory was the population and not the species. Accordingly, populations were mapped and size recorded explicitly for the project. In addition, main threats were reported for each of them. All the information, associated with both species and population, has been recorded in an extended database.

The precise survey methods for the AFA project have been described elsewhere (see for example Moreno *et al.*, 2003). As of May 2011, AFA database contains 609 field reports covering 623 taxa, the difference consisting in extinct plants in Spain with no current location. There are 4649 areas surveyed and 3179 populations confirmed, the difference is made up of populations with more than one location and problematic locations (not found populations, misplaced references, mistaken areas, etc.). The inventory includes 32,966 referenced UTM 1x1 square km, with 5,812 of them representing a confirmed presence of a species.

Before red data books, a field handbook was elaborated for the field data gathering of AFA project (Iriondo, 2011). Thus, since the beginning of the project, a group of botanists from different disciplines (floristic, taxonomist, plant ecologist, plant conservation managers) worked together to elaborate an operation manual or basic field work protocol. This handbook set the guidelines to perform censuses and tallies, mapping, demography and threat analyses and field forms and database management. A draft was presented and approved for all AFA participants before the first field campaigns and the final document was ready to use by all regional teams at the time of field prospecting.

We may also consider red data listing as a dire product of the AFA project. We have shown already that the elaboration of the 2000 red data list was closely related to it. The 2000 red data list provided a well-accepted threatened plant ranking among the plant conservationist community, useful to provide the plant selection for work in field survey. 100 botanists coming from universities, botanic gardens, national parks, regional conservation agencies, freelance professionals, etc. produced the list in less than six months. 1,800 Spanish taxa were evaluated with the 1994 UICN criteria (Mace, 1994) and 1,414 appeared in the final approved list (Laguna & Moreno, 2000).

The next list will be published 8 years later, in 2008 (Moreno, 2008). We may think of two main reasons for the production of this new IUCN threat classification. On the one hand, not only the AFA project but several active conservation projects promoted by regional governments in Spain had produced quality data for several plants since the 2000 list. On the other hand, a new UICN cataloging system appeared in 2001. This involved not only new categories, but also changes in some thresholds in the IUCN criteria and subcriteria (IUCN, 2001). Consequently, in order to update data and classification, all plants should be reassessed following new IUCN rules. In a similar procedure to the previous 2000 red data list, 71 authors and 107 collaborators elaborated a new list: the 2008 red data list. Table 1 summarizes the main results from the two lists, and changes have been significant. For example, 197 new species were included and 40 old species were excluded in the 2008 list from the 2000 red data list. In total, there were 654 category changes from 2000 to 2008.

Finally, the AFA project produced a detailed and original survey for a group of selected plants across Spain, the so-called demographic AFA. A demographic study was set up and taxa were monitored every year for six consecutive years. In all, 37 species were selected and, 20 field teams sampled 65 populations and more than 13,000 individuals during this 6 year period. Using demographic modeling tools (Caswell, 2001), this monitoring allowed a detailed demographic analysis (Iriondo *et al.*, 2009).

Threat category	2000 RL	2008 RL
EX, EW o RE	21	25
CR	164	308
EN	244	278
VU	720	610
NT	-	172
DD	265	133
LC	-	45

Table 1. Distribution of IUCN threat categories (according to 1994 and 2001 criteria, respectively) among taxa in 2000 Red List and 2008 Red List in Spain.

AFA PROJECT: ORGANIZATION AND REASONS FOR SUCCESS

The organization of such a project was a true challenge for the Spanish botanist community. Never before had anyone tried to gather and update detailed information on such a large array of species during such a short period of time.

The whole Spanish territory was divided into five zones to be able to cope with the bulk of species and deadlines of the project: Central zone, Andalusia zone, Atlantic zone, Canaries zone and Mediterranean zone. Regions were delimited following two criteria, a region should be under a similar biogeographical settings and the number of species per region should be not very different. The only exception was the Canary Islands region, where more species than in any other territory were selected due to its insularity. Hence, the Canary regional teams supported an extra work load.

In total, 36 regional field teams were set up. A regional coordinator was established for each region or zone (see Fig. 1). These five coordinators formed the scientific steering committee of the project. In addition to them, another working group was set up to produce the above mentioned field work handbook and solve specific methodological problems during field campaigns. Finally, a management team (TRAGSA group) was also established, in charge of diverse tasks such as organization of meetings, license procedures, database design and management, data flow, image and promotion, social awareness, publication editing and coordination, etc.

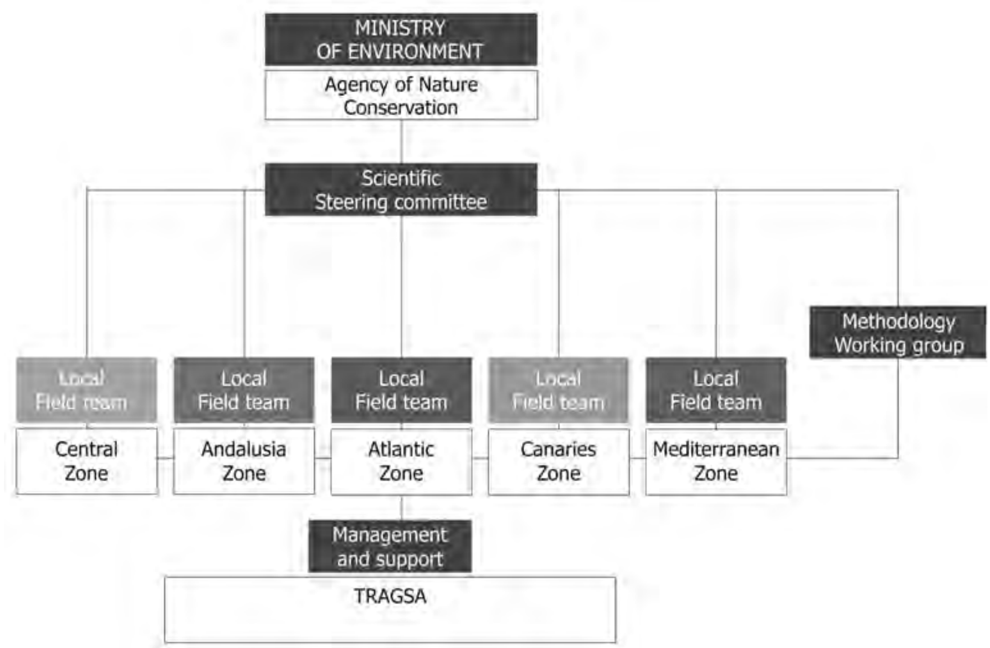

Figure 1. Flow chart of the Spanish Atlas de Flora Amenazada project.

Ten years from the start of the project may be enough, not only to describe key aspects of the organization and settings of the AFA project, but to try to shed light on some of the reasons explaining this long-running project.

From our point of view, there are two factors that have contributed to the success of this monitoring project: historical and scientific. Among the first, perhaps the most relevant is the building up of a solid Spanish plant community during previous years, probably starting in the 1960s (Domínguez Lozano *et al.*, 2001). Most of them derived from Academia, where plant taxonomy and floristic disciplines were still appreciated in the curricula and research skills at the moment of AFA inceptions and certainly more than they are today.

Another important reason is the upheaval of a small but hard working (and brave) group of plant conservation managers in Spain. Their influence areas were located in some regional conservation agencies across Spain. We should to be grateful that Spain is a member of the EU in order to explain why those plant conservation managers were so important. EU provided some legal and funding help during the 90s to start up a whole new conservation structure in Spain. As a result, a powerful network of regional conservation agencies was established, which in turn gave way to the arrival of new professionals (young botanists were among them) to the Spanish conservation arena (Moreno Saiz *et al.*, 2003).

Completing this picture was the embracing of the Spanish government of wider International conservation initiatives, the most important being the Convention of Biological Diversity. As a consequence, a sound and modern Spanish plant conservation legal framework was ready to be implemented at the start of the AFA project.

We can envisage some scientific or methodological reasons as well with regard to AFA development. Thus, one key aspect is the production of a well-accepted, easy to use field work methodology (see above). It was not an easy task if we consider the amount of plants and people involved in the AFA project.

Relevant to the work was the availability of a plethora of different kinds of floristic works produced during the previous years. In this way, local and regional floristic catalogues, databases and phytosociological efforts covering extended areas in Spain had been produced in former decades. The detailed information provided was of paramount importance for the rapid implementation of the project. Certainly without this base knowledge the compilation for AFA project would have been very different and the results never the same.

Finally, the expertise and skill provided by some basic reference taxonomic works also contributed to the success of the project. The role of *Flora Europea* first, and most importantly the continued effort of *Flora iberica* should be stressed. Several regional floras also contributed directly to provide basic taxonomic and floristic information for the project. Taxonomy work should be at the front line of the conservation strategy and from this point of view those projects produce, as with *Flora Iberica*, a comprehensive taxonomical work that with healthy tensions are translated to the conservation world.

THEORETICAL UNDERPINNINGS OF BIODIVERSITY INVENTORIES

AFA project may be considered an example of classic inventories: it gathers in a particular time frame as much information of a pool of species as possible. However, can all these efforts and resources inform us about key biodiversity aspects? As we have shown, AFA project has been operating for ten years, and usually inventories may extent for longer periods of time. So, at least theoretically, they contain information about the evolution in time of biodiversity.

But it is not clear how all this information can show us simple patterns in biodiversity. In other words, are inventories really capable of measuring biodiversity losses and gains?

Another important aspect is to know if inventories or surveys are useful to assess how effective in halting biodiversity losses present conservation strategies really are. Sooner or later, conservation measures will produce results, but it is not clear how future inventories will record them.

Finally, and particularly relevant, is to know if inventories will be sensitive enough to the several impacts and threats to plant biodiversity. Can we use present inventory techniques as early warning systems of future changes?

In order to shed light on these questions, we need to explore the quality and the quantity of data that a standard inventory usually produces. We may think of at least three main variables that most of the present biodiversity inventories usually consider:

- Overall, they record the presence of the species, most commonly measuring the area of occupancy. The way this variable is measured varies, but it usually employs a cartographic grid with a specific scale closely related to the survey effort. Atlases frequently employ a 10x10 square km grid (UTMs in Europe) on a regular basis, but more recently a reduced scale has been used: 1x1 square km grid.
- Inventories offer data related to not only the presence but the abundance of the plant. The way this information is collected is even more diverse. It usually consists of very simple information: a plant is rare, common, etc., it can use cover indexes as well, and in some particular cases, more often performed for animals, census data are also recorded.
- Finally, conservation status is an important piece of information. Inventories report threats and conservation measures for populations or species, and it is also frequent that a threat category is assigned based on this information.

AREA OF OCCUPANCY

Frequently, area of occupancy, or range size, has been one of the most and primarily recorded variable for plants. Early in the last century, Willis and Jule (1922) showed one consistent biogeography pattern related to this variable.

The frequency of rare species is always larger than the frequency of common species for a particular biota. In other words, it is easier to find rare plants than common ones in any performed inventory no matter scale or species involved.

Willis gave a name to this frequency shape curve: hollow curve (Willis, 1922). The hollow curve is similar to the normal curve but with an asymmetry towards the left side, approaching to a lognormal function. So, we say that it is skewed to the left. Skewness is then a measure of the asymmetry of a curve, or its departure for a normal towards a lognormal curve. One of its consequences is that the mean and median no longer coincide (Fig. 2).

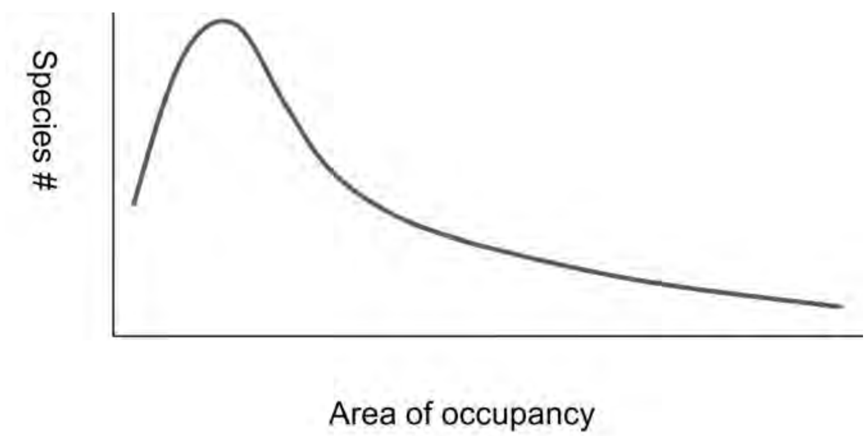

Figure 2. Hollow curve of the area frequency distribution in a model inventory. X axis represents the size of the area occupied. It is usually expressed using a grid system, for example km², UTMs or other. Y axis refers to the number of species in each area size class. In essence, the curve represents a histogram of the area size.

Therefore, it seems appropriate to explore how this curve behaves for some readily available examples of threatened plant inventories. We have been using data from three known inventories for this in a recent study (Domínguez *et al.*, 2012). These are the Protea Atlas in South Africa, the California Natural Diversity Database (CNDDB) of rare plants and the already described AFA project. Protea Atlas reports the presence of all South African taxa in the Proteaceae family as it is the result of extensive campaigns of field prospecting involving volunteering and staff capabilities. The sample unit is a 1x1 minute grid (approximately 1.5 X 1.8 km^2, Rebelo, 1991). In the case of CNDDB, rare plant data are collected by volunteers, environmental agencies and plant research facilities across California. They record population areas in different formats, but eventually a specific area polygon can be assigned to each reported population. As we have seen, AFA project records plant populations, but in this case using a 1 km^2 grid (UTM system).

Fig. 3 presents area frequency distributions (or hollow curves) for the three inventories. As expected, the curve shape is similar for all, but particular differences exist. The value of skewness is one of them for South African distribution, which indicates the most left skewed distribution of all, followed by California and then Spanish data. Another result is range, or data span, being also larger in Proteas, then Spain and finally CNDDB, which possesses the narrowest data range.

After these results, in the same study we performed a minimum sample analysis to find out how differences among the three selected inventories may effect a future monitoring program using just a portion of each biota. Results reported that, proportionally, we need less sample effort for CNDDB, then Spain and finally, for Proteas.

Range and inventory size were important parameters related to precision in the analyzed inventories. CNDDB inventory has a small range (because only rare plants are surveyed) but the size is fairly large (more than 1,100 taxa). Both characteristics make this survey the most suitable to start a monitoring program. AFA project is derived from a small range as well (only considering the most threatened plants), but, on the contrary, this survey possesses fewer total records: 250 plants, producing more variation, therefore losing some precision. Protea Atlas represent inventories difficult to monitor because of the large range covered (common and rare proteas) and again its relative small size (only Proteacae species, 422 in total).

Lessons learned

From this study we can conclude that skewness, or in other words, the shape of the relation between area of occupancy and species numbers, is related to scope and scale of the inventory (which plants and how much and where they are surveyed). But skewness *per se* does not affect the precision of the future monitoring program. Precision is associated to sources of variation. Large inventories, in terms of species numbers and time span of the survey, produce more precise outputs because some sources of variation are reduced. So, they seem better qualified to start a monitoring program able to report biodiversity changes as soon as they occur. However, we should be aware of the fact that more absolute efforts will be needed when monitoring, because large inventories involve more species or populations.

Sources of variation are several. For example they can come from the nature of the inventory itself (type of taxonomical group or scope). Thus, variation arises in wide spectrum inventories (including narrow and wide spread taxa) or inventories that consider a broad array of habitat types or include diverse locations. Finally, other sources of variation arise when inventory is poorly performed (less personnel) or not fully implemented (low surveying time per population or species).

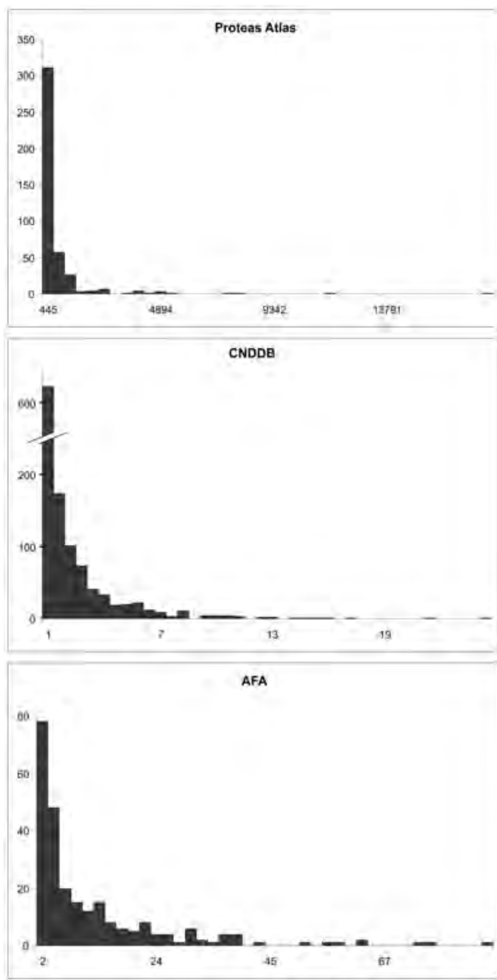

Figure 3. Area frequency distribution for (a) South Africa protea species, (b) for rare plants in California and (c) for Spanish AFA endangered plants. X axis represents an area of minute by minute cells (approx. 1.7 km²) of species range distribution for South African proteas, km² of range area for Californian plants, and UTMs squares of 1 km² for Spanish species. Figures modified from Domínguez et al. *(2012).*

MONITORING THREAT CATEGORY CHANGES

IUCN categories have been in force since the seventies (Holdgate, 1999). Several works have shown the need to use the conservation information provided by these powerful systems (Possingham *et al.*, 2002; Keith *et al.*, 2004; Rodrigues *et al.*, 2006). But in spite of this plea, and some methodological drawbacks, few examples of threat category monitoring exist (Butchart *et al.*, 2004). Plants have been targeted recently to study threat category changes in Iberian Spain and Western Australia (Domínguez *et al.*, 2013). We may focus on some examples of this study, to describe the main causes of threat category change and in which direction and at what pace those changes occur.

For example, *Tetratheca paynterae* (Tremendraceae family) has changed from EN category in 2000 to CR in 2008 in Western Australia. The reason for this upgrading is related to conservation concern because of increasing decline in their area, extent and quality of habitat due to a particular threat: mining. Another example considering a Spanish case; *Androsace halleri* (Primulaceae) has been downgrading from EN to VU during the same period of time. This downgrading has been related to increasing knowledge derived from better survey efforts that have produced new population findings and an overall better information of the population sizes and limits.

Fig. 4 shows results for both territories in relation to causes of category changes. Both charts depict similar proportions in the underlying cause of category movement. So, a threat category change along this time is not frequent in both territories. It is even more noticeable that low proportion of true conservation changes across both sets of threatened plants occurred during these 8 years. Only 12 species out of 432 in Western Australia (2.8%) and 89 out of 1,040 Spanish endangered plants (8.5%) have moved from one category of threat to another that reflects genuine changes in their conservation status.

They also maintain similar proportions in two other classes. Thus, shares of species that have experienced no change, and species with changes due to knowledge were also alike. Nevertheless, the proportion of WA taxa of 'no-change' species during this period represents up to 65% of the 432 total threatened species considered; whereas in Spain, with more species under the IUCN system, a slightly more dynamic assessment has been developed (just 43.4% species experienced no change).

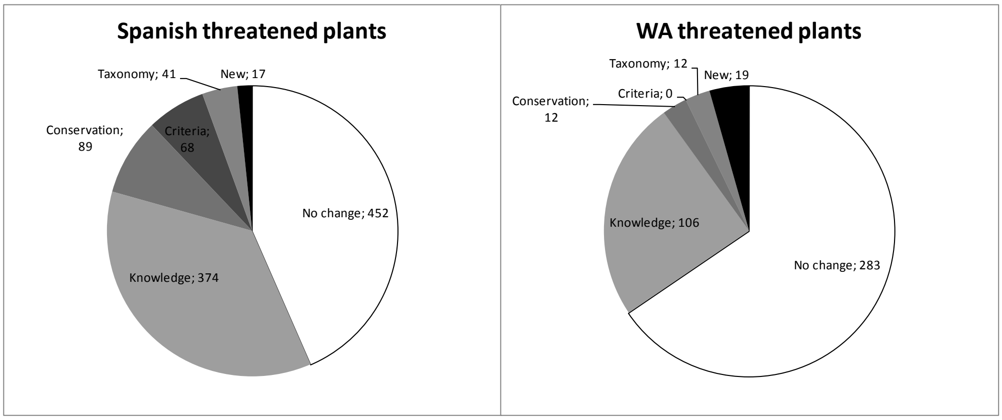

Figure 4. Spanish and Western Australia threatened plants distribution according to reasons for change in IUCN categories since 2000. Data from Domínguez et al. *(2012).*

In relation to pace of movement in categories, the same paper showed again similar trends in both regions; during this period upgrading was dominant among species that had moved through the category ranking (Table 2). Most of the reasons produce positive movement and only changes due to criteria revision in Spain and taxonomic revisions in Australia (mainly due to redetermination of herbarium specimens and new assignments to hybrids or previously thought independent species) produce negative or downgrading movements.

In Spain we are fortunate because red list comparison can move further backwards in time. This is possible because red data lists exist for 1984, 2000, and 2008. Hence, considering only mainland Spain plants (excluding Canary Islands), 1,104 plants in 1984, 953 plants in 2000, and 1,116 plants in 2008 were tracked in a previous work (see Domínguez, coord., 2008), summarizing 1,892 recorded taxa.

This example is useful to show that a part of the "no movement" section represents what we can call "recalcitrant species". Those that are unable to go further in the conservation ladder have been in the uppermost category since the beginning of the assessments and and still are due to no positive conservation effect. Thus during this time, 20 plants have been in the highest category across the whole period of assessment (1.06% of the total). It is needless to say that they are in the utmost need for conservation action. Derived from the same analysis, another important result is the proportion of flora with continuous upgrading (i.e. more sensitive to change): 34 taxa have been upgraded in the three assessments. Of the plants considered, 389 (around 20%) have been common to the three lists during those years.

	Western Australia		Spain	
Reason	Mean	Std Dev	Mean	Std Dev
Knowledge	0.5	2.6	1.3	1.6
Conservation	0.7	1.1	1.6	1
Criteria	0	0	-0.9	0.5
Taxonomy	-0.2	3.2	0.3	2.3
New	3.2	1	3.3	0.8
Total	0.9	1.3	0.6	1.4

Table 2. Average UICN movement according to reason for each territory. One unit represents a single positive movement, for example from EN to CR.

Lessons learned

Threat category is an important variable to use in a monitoring program, because it is very sensitive to change across time. Although changes are less numerous when short periods of time or only plants in the upper categories are considered, with regards to longer time spans, superior to 10 years and about plants in the lowest threat categories, movements are frequent.

Contrary to what it may seem, it is expected that most changes would not be related to true conservation reasons. However, when real conservation reasons are responsible for explaining those changes, they will usually be related to increasing conservation awareness.

Then increasing knowledge will probably be the most popular reason for changes in the status of the plants when category movements are monitored. Changes in taxonomy concepts or changes in IUCN criteria classification are also common motives to produce movements in threatened lists. Reporting and monitoring this kind of movements is also very useful from a monitoring perspective. To some extend, the "better knowledge" output is a guarantee; it shows that monitoring is working and it is able to discover new findings in the real conservation status of surveyed plants. In addition, recording higher knowledge about plants, not only will produce better conservation assessments in the near future, but a better comprehensive plant conservation strategy in the long term, assuring that the truly most endangered plants receive the best conservation measures.

Finally, the precautionary principle may explain why so few true conservation movements are produced when short comparison times are considered. Thus, in spite of active measures taken to protect plants, inertia may exist not to downgrade them until very clear signs of recovery are shown.

DEMOGRAPHIC VARIABLES

Monitoring has been closely related to counting individuals along time, in other words, producing censuses with a repeating methodology year after year (Hutchings, 1991; Schemske *et al.*, 1994). Somehow, it was a general understanding that as much meticulous and time-demanding a census was, much more accurate the monitoring would be and much more information it would contain. At this moment, structured population censuses are among the most detailed of all. They provide tools for calculating several demographic parameters, being the finite rate of increase or lambda parameter one of them (Caswell, 2001). Fig. 5 shows average lambda values and standard deviation for the above mentioned demographic AFA project. Although an overall tendency to slight negative growth may be inferred, the *intra* and *inter* year variations preclude a precise trend. So, one may conclude that there is not a clear departure for demographic stasis, and it is difficult to translate these demographic results to clear conservation recommendations. Although a short period of monitoring partially explains this lack of definition in trend lines, this is not the only cause, as some examples of structured population monitoring during more extended periods of time also appear.

Vella pseudocytisus subp. *paui* is an endemic and threatened species in Spain, forming part of the group of plants originally selected for the demographic AFA. It has been continuously monitored since then, and now ten years of continuous monitoring can be analyzed for two independent populations. Again, departure from stasis or no demographic change (lambda = 1) seems not to be significant during this time (Domínguez *et al.*, 2011a, Fig. 6). Oscillation around equilibrium is predominant and only one population, and just for some years, departs significantly from stasis. As a consequence, perturbation has to be strong in order to produce a significant departure from standard conditions and a clear negative demographic trend (see for more details Domínguez *et al.*, 2011b).

These results may contribute to explain why demographic analyses (criterion E in IUCN threat classification system) are scarcely used in IUCN assessment for plants in Spain. 10 out of 37 species with available demographic data have been qualified using the E criterion in the demographic AFA project. Considering the whole 2008 Red Data List (with more than 1,198 plants), 11 species use criterion E. In conclusion, although demographic analysis is not usually available for UICN assessments, when it is so, there is no guarantee to produce useful results for threat category assignments.

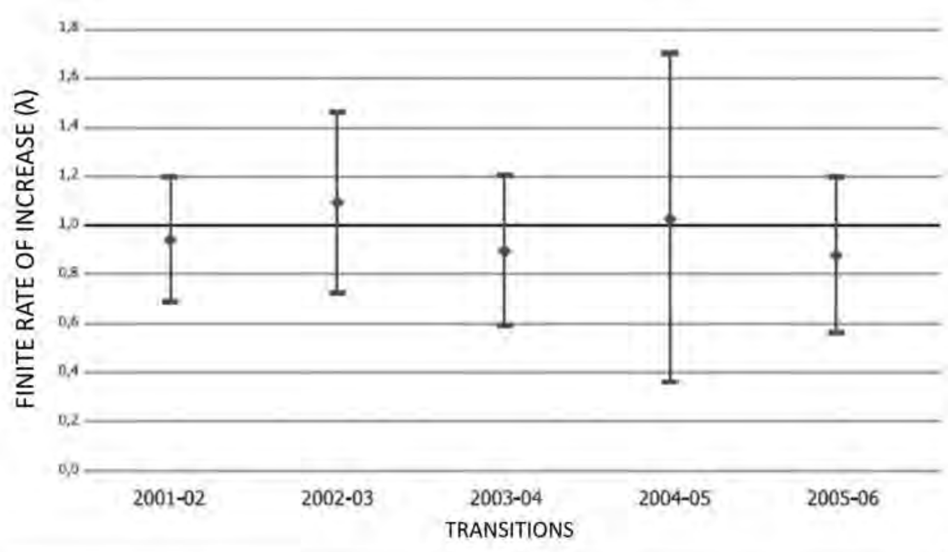

Figure 5. Average and standard deviation of finite rate of increase (lambda) values for the AFA populations per transition years. 65 populations were monitored during six consecutive years. Figure from Iriondo et al. *(2009). If lambda values are equal to one, the population is stable, if lambda values are higher than one, the population experience positive demographic growth, and if lambda values are below one, the population decreases.*

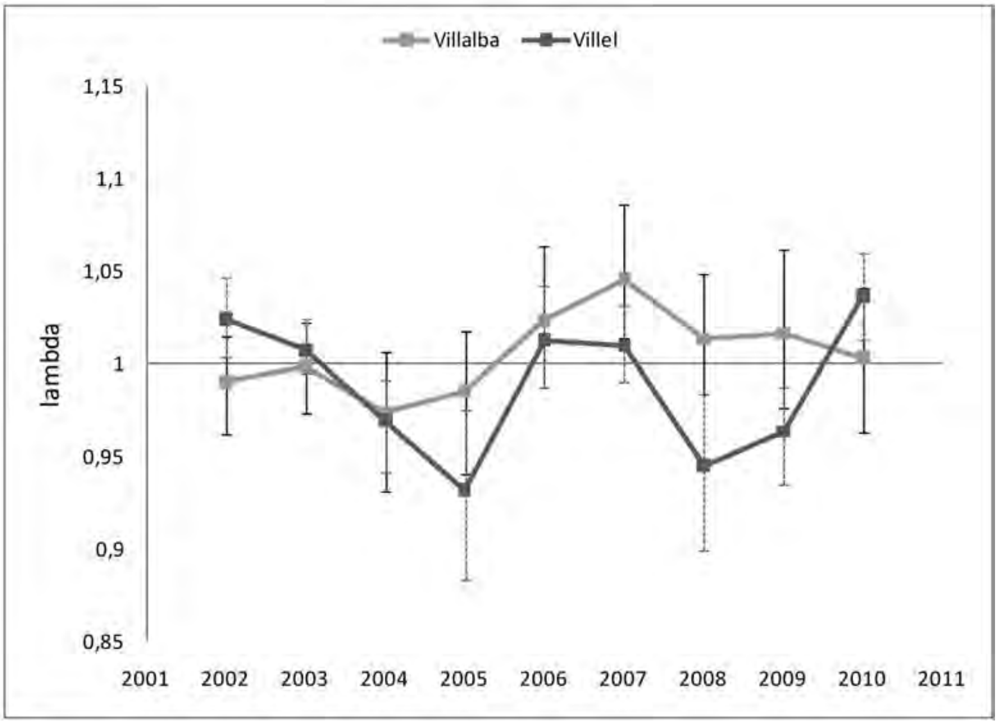

Figure 6. Finite rate of increase for two populations of Vella pseudocytisus *subsp.* paui. *Average and confidence interval values are derived from bootstrapping of the sampled individuals in both populations. Modified from Domínguez* et al. *(2011a)*

Lessons learned

Most of the demographic AFA plant populations experience stable demographic dynamics. These results may include broad variation or not, but on average, dynamics do not oscillate too much from equilibrium.

It is very difficult to detect departure from standard demographic conditions for plants with very stable population dynamics. It may be said that only strong perturbations seem to alter demographic dynamics enough to make a classic monitoring program useful.

In our opinion, there are at least two factors playing against the extended use of demographic data for conservation assessments of plants. The difficulty to obtain such information is widely accepted to be one of them (Morris & Doak, 2002). The second factor is related to definition of clear trends. As AFA monitoring and other works (Domínguez *et al.*, 2011b) seem to indicate, even when demographic data is ready to be used, there are difficulties to expose a particular conservation pattern.

So, demographic variables are not recommended for a useful monitoring program, they are difficult to monitor and as we have shown, at least for some cases, they seem not to have the ability to detect changes of conservation interest.

CONCLUSIONS: INVENTORIES FOR THE FUTURE

In spite of the fact that more resources than ever are now dedicated to monitoring and specially surveying, with the available tools that we have at hand, it is difficult to gain a clear sign in plant biodiversity trends. Explanations to this lack of monitoring patterns are complex, and often several factors add up to produce non-satisfactory patterns. We can list some of them:

Span of monitoring programs: It is almost a general claim that monitoring times are often too short to be informative. Some monitoring variables are not very sensitive for particular time spans but they become useful if monitoring time increases. For example, there might not be many threat category changes for 5-10 year period but they increase for longer periods, 20 or more years. In relation to demographic variables, it is important to bear in mind that plants may be a particularly resistant taxonomy group in relation to the usual periods of monitored times for this variable type. Longevity is a common trait, and there are also other biological properties contributing to this lack of dire response towards changes such as seed and corm dormancy, very low persistent seedling survival, negative growth or clone growth. Therefore, other time scales, different than human time scales, are required to clearly ascertain demographic trends affecting plants. In general, monitoring times are in close relation to the variables chosen, and it is highly recommended that previous to any action, we should have a strong understanding of the expected time of response of those variables.

Non-informative monitored variables: Some monitoring variables are not very informative or even redundant for plants; this may be the case of variables associated to certain demographic changes if our results are confirmed in the future. They may require more time and resources, but their results can be even less significant than those produced by other monitoring variables with less intensive prospecting. So, in addition to exploring response time, there is a need to study how methods and techniques to collect data are used when demographic variables are selected for the monitoring program. If results are not satisfactory, switching towards other more informative variables may be a more feasible alternative. A clue to effectively identify those variables is to pay attention to factors that are closely related to what is causing plant biodiversity change. Therefore, using surrogate monitoring such as those related to land use changes, over-collecting, urbanization rates, etc., often yield a better indicator of change.

Biases affecting variation: There are different sorts of biases producing unexpected sources of variation. We can identify bias in space derived from the fact that some territories are over-recorded. This bias may be explained due to proximity of research centers, expected promising lands to plant discovery (mountains, hot spots) or better accessibility, incrementing variation of the low prospecting sites. Bias in time responds to the effect of availability of resources and funding for monitoring surveys, and produces an accumulation of records in good years of monitoring and a scarcity in years when prospecting has been less intensive. Finally, a taxonomic bias should be mentioned. Some particular taxonomic groups are intensively surveyed whereas others are less prone to monitoring. For example Gimnosperm and Magnolidae (usually because they are trees or they are notorious) have more opportunities to be surveyed than, for example, Polygonaceae or Plumbaginaceae (groups that represent plants related to aquatic environments or particularly difficult taxonomic taxa).

Identifying and reducing biases should be a prior condition for monitoring programs, and present inventories contain useful information to do both. For example, they may provide targeted areas in under-recorded territories, a solution to rapidly reduce the bias related to space.

Current inventories are equally useful to detect new sources of variation. If this new variation turns out to be informative, we can always incorporate it as a new monitoring variable. For example, we may find out that low inventory effort is a new source of variation in our program. Usually, this variation is linked to some particular habitat types: managed forests, aquatic environments, habitats related to coastal locations exposed to rapid changes due to human activities: sand dunes, maritime scrublands, etc. So, we may target these habitats to gain insight of possible new changes. In short, one possible way to cope with bias and variation is focusing on a section or part of the biota: most threatened plants, bioindicators, plants associated to habitats subject to change, etc. They will provide a rapid assessment of the biodiversity status. To sum up, we have the ability to identify more informative habitats or plants using information gathered in present inventories.

Lack of baselines: We have not reached a clear baseline in knowledge yet. This is related to both taxonomy and survey efforts. The effect of taxonomy in biodiversity pattern is complex but clear (Agapow & Sluys, 2005; Knapp *et al.*, 2005; Domínguez Lozano *et al.*, 2007). It is related to species concept, taxonomists' attitudes and taxonomic effort. In addition, increasing survey effort is still effective in producing new findings about the true status of flora; this is also true for territories theoretically well explored and with long tradition of field surveys (Ertter, 2000). As results of these two factors, not only we can still expect new species and new population discoveries, but movements in boundaries and status of already known populations as well. Although this can be considered a real merit of good inventory campaigns, it comes as a drawback: there is a lack of clear baselines or past trends to compare with. One possible solution is to incorporate knowledge as another monitoring variable in our system, taking into account the effect of increasing knowledge in the general monitoring trend.

Inventory scope: The scope of classic surveying or inventory has usually been too broad (many species) and extensive (large mapping zones). They produce enormous sets of data, but they also have attached extra variation and bias loads. As a consequence, identification of trends is blurred. In general, a more focused monitoring program should be recommended. Of course this does not mean that we leave out massive inventories, but produce different levels of future monitoring according to needs (Philippi *et al.*, 2001; Marsh and Trenham, 2008). So in simple terms, more informative sites or species will carry a first level, more intensive, monitoring scheme, and successive groups of plants or sites will require less, secondary level, monitoring.

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2: Western Mediterranean

THE FLORA OF THE BALEARIC ISLANDS

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Abstract

We reviewed the data on the diversity (number of native taxa) and the number of Balearic endemics published since the last check-list. Differences may be attributed to discordant taxonomic criteria, uncertain reports, misapplication of some names, misidentifications of herbarium material and unequal floristic knowledge of the different main islands of the Archipelago. The native flora has 1,551 taxa, of which 140 are endemics. We shall discuss some aspects of biogeography and biology of the endemic flora. The number of threatened taxa in the Balearic Islands is 180 (11.6% of all native taxa). The greatest threats to the native flora are direct and indirect results of human activities followed by the overgrazing of goats. The list of protected species should be revised considering that 55.5% of the threatened species, and that almost half (46.1%) of the threatened endemic taxa, are not under legal protection.

Keywords: *Balearic Islands, native flora, endemism, Mediterranean region*

INTRODUCTION

The Balearic Islands, located at the western part of the Mediterranean Sea, consist of 5 main islands and about 100 small islets. Despite its small size (c. 5,000 km^2), the Archipelago does not present a unique flora, since the diversity of environments (salt-marshes, rock-crevices, mountain gullies, temporary ponds, woodlands, scrubs, maritime sands, small islets, etc.) and the significant differences between islands makes for a quite variable composition. This Archipelago has attracted the attention of botanists for more than 4 centuries;

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however the first serious attempts to develop floristic inventories date back from the late 19th century. Although studies on the diversity of vascular plants are numerous, at present there is not a modern and updated review of the flora of the Archipelago. The aim of our study is to update the basic information of the Balearic flora and to examine some characteristics of the endemic and the endangered taxa.

MATERIAL AND METHODS

The area under study encompasses the Balearic Islands. Following the criteria established by Pla *et al*. (1992) and Rita & Payeras (2006), we provide data for 6 islands: the Eastern Balearic Islands (Mallorca, Menorca, Cabrera and Dragonera) and the Western Balearic Islands (Eivissa and Formentera). In order to obtain a list of the Archipelago's native taxa (vascular plants) we have used as our main source the catalogue of Pla *et al*. (1992). This information has been updated with the information published in recent scientific publications. Taxa reported as present but considered doubtful, unlikely to be found on the Balearic Islands, or within a specific island of the Archipelago, have been revised where possible. In our survey, taxa of uncertain systematic value have been excluded and the doubtful reports have been considered invalid if no corroborating voucher specimen or other proof could be found. In addition, sterile hybrids, as several nothospecies of the genus *Asplenium*, *Ophrys*, etc., were not considered for purposes of calculating parameters related to the reproductive biology or conservation status. We have considered the endemic species (or subspecies) whose populations occur entirely within the limits of the Balearic Archipelago. For chorological classification, we have followed the criteria of Bolòs *et al*. (2005). The classification of the endemic taxa according to its life form, ecological preferences, pollination mode and seed-dispersal strategy were determined on the basis of published reports, or inferred from plant, flower and fruit morphology, as well as from our field observations.

RESULTS

Diversity: number of taxa

In the past two decades different amounts regarding how many taxa were comprised in the flora of the Balearic Islands have been published (Table 1). The lowest number is about 1,300 species (Bolòs, 1997) and the highest is 2,230 (Travesset, 1999). Between these two extremes, there are different approaches concerning the number of taxa constituting the Balearic flora. Our data indicate a remarkable decrease in the number of native taxa regarding the most recent studies (Table 1, 2). Differences among these studies may be attributed to various causes, but are mainly due to: 1) discordant taxonomic criteria: The different catalogues of floristic works do not employ the same nomenclature or classification system for many species (the same entity may occur in these different works as a species, a subspecies, a variety, or a synonym); 2) uncertain reports (usually outdated literature references) without voucher specimens; 3) misapplication of some names; 4) misidentification of existing herbarium material and 5) unequal floristic knowledge of the different main islands of the Archipelago.

	Taxa	% endemics
Pla *et al*. (1992)*	1,650	10.4
Rivas-Martínez *et al*. (1992)	c. 1,500	3
Bolòs (1997)	c. 1,300	3.4
Médail & Verlaque (1997)	1,500	12
Travesset (1999)	2,230	7
Rita & Payeras (2006)	1,729	10.0
Rosselló & Castro (2008)	c. 1,500	8.1
Present study**	1,551	9.0

*Table 1. Number of plant taxa and % of endemic taxa in the Balearic Islands; *sterile hybrids not included; **sterile hybrids and doubtful taxa not included.*

	Ma	Me	Ca	Dr	Ei	Fo
Pla *et al*. (1992)*	1443	979	381	106	880	534
Rita & Payeras (2006)	1445	1157	488	335	921	593
Present study*	1302	1090	418	341	876	558

*Table 2. Number of plant taxa on each specific island (Ma: Mallorca, Me: Menorca; Ca: Cabrera; Dr: Dragonera; Ei: Eivissa; Fo: Formentera); * sterile hybrids not included.*

A total of 440 native taxa (28.4%) from the Balearic Islands are located on any particular island (Table 3). Apart from these genera or groups with high endemicity, it is remarkable that virtually one third (32.4%) of the Balearic pteridophytes are found exclusively on the island of Mallorca, more specifically on the mountain ridge of Serra de Tramuntana.

	Exclusive taxa (endemic species not included)		Exclusive taxa (endemic species included)	
	Nº	%	Nº	%
Balearic Islands	--	--	440	28.4
Mallorca	189	14.5	242	18.6
Menorca	124	11.4	137	12.6
Cabrera	3	0.7	4	0.9
Dragonera	1	0.3	1	0.3
Eivissa	39	4.4	49	5.6
Formentera	10	1.8	11	2.0

Table 3. Number of taxa that occur only on a particular island of the Balearic Archipelago.

Regarding the unequal floristic knowledge of the different main islands of the Archipelago, here we provide information on the number of publications and floristic novelties for each island since the publication of the most recent check-list (Pla *et al.*, 1992). Floristic inventory with unequal intensity, at different times (Fig. 1), with different systematic criteria, determines some notable differences at floristic levels between islands.

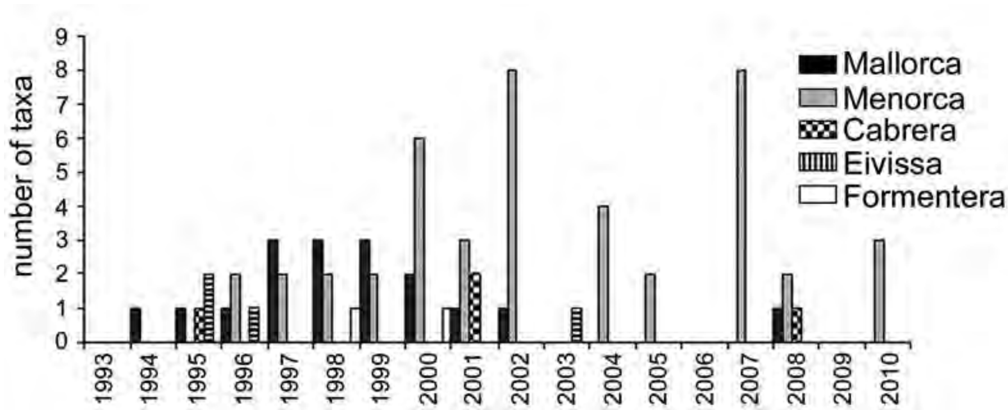

Fig. 1. New taxa for the Balearic Islands/year between 1993 and 2010. Alien, hybrids and doubtful taxa are not included. New records for a particular island that do not represent new taxa for the Archipelago are also not included.

The analysis of phytogeographical composition of the Balearic flora showed that 61.9% of the species are Mediterranean plants. The Pluriregional group is represented by 32.6% of the species, which form a diverse group in terms of their geographic origin, and the Euro-Siberian component is represented by 5.4% of the taxa. This element is mainly represented on the higher mountains of Mallorca. The percentages for these three elements are very similar to those reported by Bolòs (1997) and Rita & Payeras (2006). It is well known that the percentage of Tyrrhenian taxa is higher in the Gymnesian, whereas the taxa distributed through the Eastern Iberian Peninsula and the Balearic Islands are more frequent on the Pityusic Islands (Fig. 2).

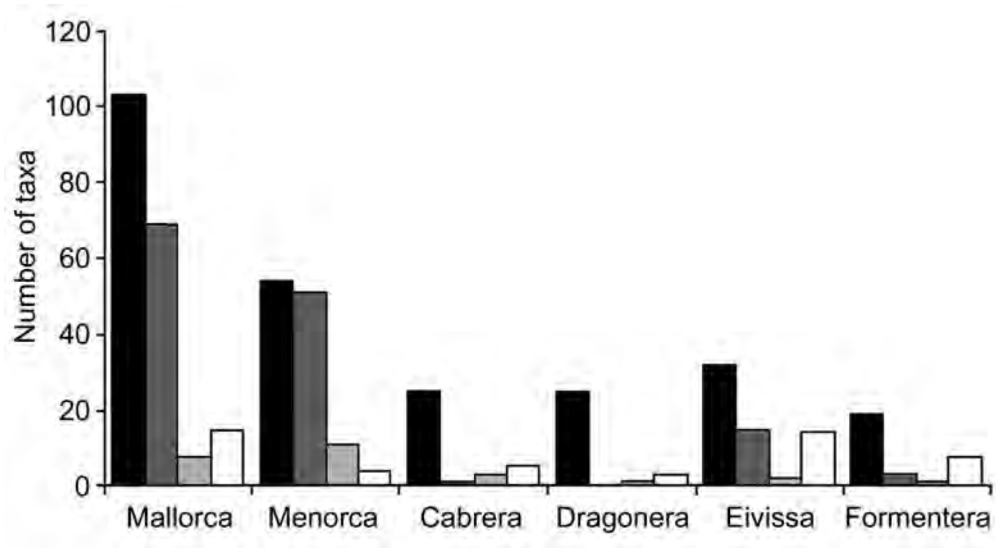

Fig. 2. Number of taxa endemic to the Balearic Islands (black); endemics restricted to each island (dark grey); Tyrrhenian taxa (light grey) and taxa distributed through the Eastern Iberian Peninsula and the Balearic Islands (white).

Endemic taxa and their characteristics

The endemic element, although subject of numerous studies and considered as relatively well known, is also subject to divergent interpretations from a quantitative point of view. Thus, it is considered that the percentage of endemic taxa ranges between 3% (Rivas-Martínez *et al.*, 1992) and 12% (Médail & Verlaque, 1997). According to our data (updated in February 2013) the endemic taxa (i.e. taxa strictly localized in the Balearic Islands) represent 9.02% of the indigenous flora of the Archipelago (Table 4). Most likely, the percentage of endemic species would increase if studies were conducted in poorly known groups; however, on the other hand, detailed systematic studies sometimes have revealed the existence of alleged endemic Balearic populations in other areas, as in the case of *Allium ebusitanum* Font Quer (Aedo, 2006).

Hybridization is a common and important evolutionary process that can create new species (Rieseberg *et al.*, 1995), among other biological consequences. Nevertheless, as noted above, we have not included the hybrid taxa (usually sterile and not apomictic) that do not constitute populations. Some hybrid taxa are easily morphologically characterized (hybrids between species of *Ophrys*, *Orchis* or *Asplenium* species, among others), and some are endemic (*Viola* x *balearica, Rhamnus* x *bermejoi*, several *Asplenium* nothotaxa, etc.), but in many cases these plants can be fertile (*Helichrysum*, *Teucrium*, *Limonium*) and it is not easy to confirm their hybrid nature and are even frequent backcrosses, which makes the inventory of these hybrids extremely complex and of doubtful utility in order to compare patterns of biodiversity or establish conservation status according to IUCN (2001) criteria.

	Pla *et al.* (1992)*		Rita & Payeras (2006)		Present study**	
	Nº	%	Nº	%	Nº	%
Balearic Islands	172	10.4	173	10.0	140	9.0
Mallorca	122	8.5	125	8.7	103	7.9
Menorca	58	5.9	60	5.2	54	4.9
Cabrera	27	7.1	30	6.1	23	5.5
Dragonera	8	7.5	29	8.7	23	6.3
Eivissa	45	5.1	44	4.8	33	3.7
Formentera	22	4.1	23	3.9	17	3.0

*Table 4. Number and % of endemic taxa on the Balearic Islands; * sterile hybrids not included; ** sterile hybrids and doubtful taxa not included.*

The differences in percentage of endemic species in recent studies (Tables 1 and 4) close in time may be due to several reasons: 1) discordant taxonomic criteria, 2) inclusion, in the number of endemic species, taxa of unconvincing taxonomic status, and 3) failure to clearly establish what is an endemic plant of the Balearic Islands: in most recent studies [with the exception of Rita & Payeras (2006)], generally not strictly endemic taxa (Tyrrhenian, taxa also present in the Iberian Peninsula and Southern France, or other territories) are included in the group of endemic species. The criteria adopted here is that an endemic species of the Balearic Islands is a taxon whose distribution area is restricted to this Archipelago. Some studies have included in the group of endemic plants several Tyrrhenian and Western Mediterranean elements that some authors recognize as sub-endemics. A critique to this addition is based on the fact that the boundary area to recognize when a plant is sub-endemic is not unequivocally established. It seems reasonable that if we wish to recognize this heterogeneous and diffuse group of sub-endemics, it is necessary to specify objective (and reviewable) criteria to identify them positively, as has been suggested in other nearby continental areas (Sáez *et al.* 2010). Until we reach a consensus on this issue, it seems that the most consistent objective and least problematic solution is to restrict the concept of endemism to those plants actually endemic to the Balearic Islands.

The five families with the largest number of endemic taxa are the same as indicated by Rita & Payeras (2006): Plumbaginaceae, Leguminosae, Compositae, Labiatae, and Umbelliferae. The endemic taxa of these families represent more than half (51.1%) of the endemic taxa. 81 endemic taxa (57.8% of all the Balearic endemics) are restricted to a single island. The number of endemic species restricted to an island could be higher (87 taxa, 63.0%), if we do not recognize the island of Sa Dragonera as independent, since it could be considered an extension of the Serra de Tramuntana in Mallorca. In fact, if Sa Dragonera is recognized as an independent island in order to establish patterns of distribution and endemism, perhaps it would also be desirable to include islands of major biogeographic singularity like Es Vedrà (off of southwestern Eivissa). Possibly the best solution is to limit this type of analysis in the future to the five major islands of the Archipelago.

In the Balearic Islands, the endemic species occur in rocky areas, cliffs and screes (35.5% --excluding maritime rock-crevices--), shrubby habitats and forest edges (28.2%), coastal ecosystems (24.0%), grasslands and open habitats (10.1%) and wet areas (2.2%). Almost half of the endemic species (44.9%) are located in mountain communities, most of which (58.1%) colonize rocky habitats.

The differences between the Eastern Balearic Islands and the Pityusic Islands regarding the composition, diversity and relationships of their endemic floras have been highlighted by different authors (Bolòs, 1997; Thompson, 2005). The Eastern Balearic Islands have a significantly more diverse endemic flora: 120 endemic taxa (105 of which are exclusive), whereas in the Pityusic Islands there are 35 endemic taxa, 20 of which are restricted to this subarchipelago. Endemic taxa shared between Eastern Balearic Islands and Pityusic Islands are scarce (15 taxa, 14.5%).

High endemism is a feature that characterizes mountain ecosystems, especially those of islands (Steinbauer *et al.* 2012). In the Balearic Islands, mountain areas have the highest rates of endemism, as indicated for other Mediterranean islands (Thompson, 2005). Within the Balearic Islands, the highest level of endemism is observed on the Serra de Tramuntana: 80 taxa (57.1% of all the Balearic endemics) occur in this area that contains more endemic taxa than any other among the islands of the Archipelago. A quarter (25.0%) of the Balearic endemics are restricted to this mountainous area. In the case of the mountain areas of Mallorca, endemic taxa with Eurasiatic or non-Mediterranean affinities are limited. Whether these mountainous areas experienced an impoverishment of flora as intense as has been suggested for other high mountains of large Mediterranean islands (Thompson, 2005) is a question that remains to be determined.

With regard to life form, almost half of the Balearic endemic taxa are chamaephytes (44.3%), which is a high percentage but similar to other areas of the Mediterranean region. The hemicryptophytes represent about a quarter of the total endemic taxa (25.7%). It is remarkable the relatively high percentage of nanophanerophytes (11.4%), by contrast, the rate of therophytes, one of the most abundant life forms in the flora of the Mediterranean basin (Quézel, 1995) is considerably low (10.7%). The geophytes represent 7.9% of the endemic taxa. These data are somewhat different from those provided by Rita & Payeras (2006), probably due to discordant taxonomic criteria regarding the endemic element (these authors admit that several taxa of doubtful taxonomic value were included), but in any case, the spectrum of life forms of the endemic flora strikingly differs from that of the whole of the Balearic flora.

The information on the reproductive biology of endemic species is still scarce, both in the Balearic Islands and the rest of Mediterranean islands (Travesset, 1999). According to this author, 90% of the endemic taxa have showy flowers, suggesting biotic pollination. Our preliminary results confirm the data provided by Traveset (1999) and indicate that biotic pollination is clearly a major feature (94.2%) in endemic taxa. However, this percentage includes taxa which have been confirmed as ambophilous and others most likely to be included in this group (such as numerous species of the genus *Limonium*).

According to Rosselló & Castro (2008), 100 of the 121 endemic taxa (82.6%) show non-apomictic reproduction (82.8%). Our results (82.9%) of the endemic taxa show non-apomictic reproduction) are very similar to those reported by these authors, who provide detailed information about the karyological evolution of the sexually-reproducing angiosperm endemic flora of the Balearic Islands.

With regard to dispersal mechanisms, 86.4% of the endemic taxa use abiotic means of dispersion, with the majority of barochorous/semachorous system. On the other hand, 13.6% of the Balearic endemics present adaptations to biotic dispersion, being endozoochory the most frequent in this group of zoochorous plants and represents 6.5% of all endemic taxa, a proportion somewhat lower than indicated by Travesset (1999). Most (55.6%) of these endozoochorous taxa correspond to nanophanerophytes.

Threatened species

Several taxa in the Balearic Islands are on the brink of extinction. Their threats have been assessed according to the criteria of the International Union for Conservation of Nature (IUCN, 2001). The number of threatened taxa (Extinct in the Wild, Regional Extinct, Critically Endangered, Endangered and Vulnerable) in the Balearic Islands is 180 (11.6 % of all native taxa). Among these endangered taxa, 32 were not included in the Red Data Book (Sáez & Rosselló, 2001). Among Balearic threatened species there are 63 taxa (35%) that are endemic to the Archipelago.

It is noteworthy that although the number of taxa assigned to the Data Deficient category has declined since 2001 (Fig. 3), as a result of improved knowledge of rare and potentially threatened species, this percentage remains relatively high (10.2% of native flora). Also noteworthy is the significant increase in the number of Critically Endangered species, as a result of: 1) the discovery of new taxa hitherto unknown in the Balearic Islands (especially in Menorca), and 2) as a result of the reassessment of the categories assigned in 2001.

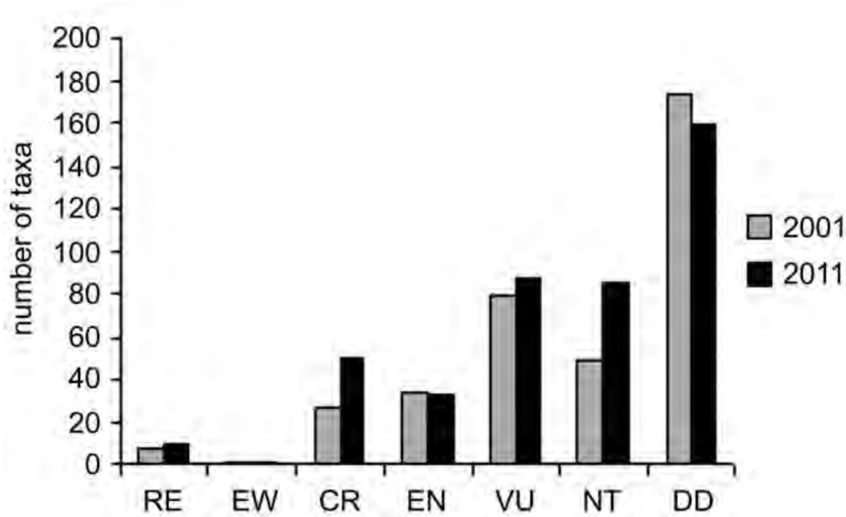

Fig. 3. Number of taxa assigned to the IUCN category (2001): Regional Extinct (RE), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near threatened (NT), Data Deficient (DD).

We quantified the threats facing all threatened species (180 taxa) (Fig. 4). Factors inherent to the species such as reproductive problems, limited dispersal, etc. have not been considered in this analysis. The greatest threats to the native flora result directly and indirectly from human activities. Urbanization [including infrastructures] is the most prevalent threat (32.6%), followed by overgrazing [mainly due to goats] (26.9%), human disturbance [pollution, degradation, trampling, collection, etc.] (16.8%), native species interactions [competition, hybridization, etc.] (15.2%), stochastic events [fire, drought, storms, etc.] (6.3%) and introduced species (2.2%).

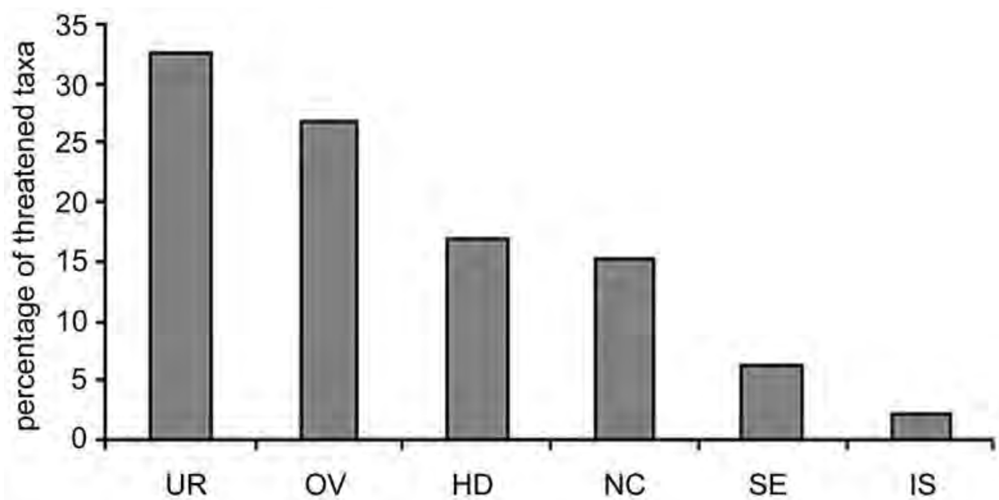

Figure 4. The percentage of threatened species by urbanization and infrastructures (UR), overgrazing (OV), human disturbance (HD), natural causes (NC), stochastic events (SE) or introduced species (IS).

Currently, 80 species of vascular plants are legally protected in the Balearic Islands. Accordingly, the list of protected species should be revised considering our results as 55.5% of the threatened species are not under legal protection. Of these 80 protected species, 56 (70%) are actually endangered according to IUCN (2001) criteria, 42 species (52.5%) are endemic and 34 (42.5%) are threatened endemic species. This means that almost half (46.1%) of the threatened endemic taxa are not protected. The most endangered Balearic endemic species must be considered as priority taxa in conservation strategies. In the Balearic Islands, unlike other Mediterranean islands, where the mountain flora is in relatively low danger (Médail & Verlaque, 1997), the most endangered Balearic endemic species are localized in a wide range of altitudes, from sea level to the highest peaks, but it is certainly on coastal areas where a high number of threatened species concentrate, mainly of the *Limonium* genus. As knowledge of the flora of the Balearic Islands imporoves, especially with regard to endangered species, it will be possible to update the Red List (or Red data book) in the future. These lists, together with specific studies to analyze population viability, will help to fill some gaps and inconsistencies in the Balearic List of Endangered Species.

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MANAGING THREATENED PLANTS ON ISLANDS: TASKS & PRIORITIES

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Abstract

The geographical isolation of the Balearic Islands has facilitated the development of a singular and endemic flora unique to the islands. Part of this flora is seriously threatened in small and very fractioned populations with few individuals. The Administration has the obligation to protect, conserve and improve both their habitat and the species themselves, which requires two basic tools: legislation and management. For five years, the Balearic Government, under the legal support of Conservation and Recovery Plans, has performed management actions to conserve species under the highest category of threat. To date, our government has approved 5 recovery plans, 2 conservation plans and 1 management plan that include the protection of a total of 23 plant species. The main conservation actions carried out are: (1) demographic monitoring of the populations, (2) exploration to discover new locations, (3) remove pressure from herbivores and provide physical protection to threatened species, (4) control of competing plant species affecting the threatened flora, (5) reinforcement / translocation of endangered plant specimens in the wild, (6) actions such as collecting seeds for botanical gardens and seed banks and (7) campaigns to raise awareness. The purpose of this paper is to present the initial results from the adoption of the first plan in mid-2007.

Keywords: *Management, conservation, endangered species, habitat restoration, reinforcement.*

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INTRODUCTION

Plants are essential for living. They are the basis of the rest of our biodiversity. The loss of plants, a substantial part of our natural heritage, must be prevented, especially when they are endemic: the disappearance of an endemic species is definitive and irreversible. Current threats to the planet's biodiversity are unprecedented, and they particularly imperil insular floras (Caujapé-Castells *et al.,* 2010). The inevitable fate of all species to extinction is particularly evident on islands. This island's vulnerability is related to the low number of populations and its small size.

The Balearic Islands (4986.7 km^2) are in the middle of the Western Mediterranean basin where about 1,730 native wild taxa make their home, 52% with Mediterranean distribution (Rita and Payeras, 2006). They are the most isolated islands in the Mediterranean, both in distance to mainland and in age of isolation. The number of taxa strictly endemic to the Balearic Islands is 173 (130 excluding the genus *Limonium* Mill.), representing 10% of the total number of taxa. The proportion of endemic flora for Balearic native flora is found at the high end of our Mediterranean environment: 5.3% Corsica, 10% Crete, 7% Cyprus, 6.3%Sardinia and 10% Sicily (Rita and Payeras, 2006).

Balearic flora is strictly protected under European, national and local laws that care for conservation and management measures. There are a total of 87 vascular species protected in different categories of protection depending on the degree of threat or socio-economic needs.

The main standards of protection are (1) *"Real Decreto 139/2011, de 4 de febrero, para el desarrollo del Listado de Especies Silvestres en Régimen de Protección Especial y del Catálogo Español de Especies Amenazadas* (*BOE* 46, 23rd February 2011), to develop some of the contents of the law, *Ley* 42/2007, 13th December, *del Patrimonio Natural y de la Biodiversidad* and (2) "*Decreto 75/2005", 8th July, por el cual se crea el Catálogo Balear de Especies Amenazadas y de Especial Protección, las Áreas Biológicas Críticas y el Consejo Asesor de Fauna y Flora de las Islas Baleares*". *BOIB* 106, 16-07-2005.

This legislation establishes conservation tools such as recovery plans or management instruments that identify threats, objectives and conservation actions to promote the stability or the increase of endangered species.

The Balearic Government has approved five recovery plans, two conservation plans and one management plan that include the protection of a total of 23 plant species. The purpose of this paper is to present the initial results from the adoption of the first plan in mid-2007.

Main goal: To ensure the long-term survival of endangered species of the natural environment reducing their vulnerability, and to ensure the maintenance of biological material genetically representative *ex situ*, in anticipation of a possible collapse in nature. For more information you can visit our website http://especies.caib.es

MANAGEMENT ACTIONS

The Balearic Government has approved eight plans of flora (Table 1). This represents 53% of the listed threatened species. Although in fact, our Species Protection Service actually works, directly or indirectly, on the conservation of 47 plants under some degree of threat.

	Plans	BOIB Num. and date *	Island
RP	5 endemic *Limonium* species.	120 (07/08/2007)	Majorca
	Limonium barceloi	65 (13/05/2008)	Majorca
	Apium bermejoi	65 (13/05/2008)	Minorca
	Vicia bifoliolata	171 (06/12/2008)	Minorca
	Euphorbia margalidiana	112 (01/08/2009)	Ibiza
CP	Endangered flora of Puig Major	171 (06/12/2008)	Majorca
	Orchis palustris	123 (22/08/2009)	Majorca
MP	*Taxus baccata*	171 (06/12/2008)	Majorca

*Table 1. Species linked with Plan. RP: Recovery Plan; CP: Conservation Plan; MP: Management Plan. *Official Gazette of the Balearic Islands.*

All these plans involve a unique species except two of them: (1) Conservation threatened species Plan of Puig Major with 31 protected or endangered species and (2) 5 endemic *Limonium* Recovery Plan of Calvià (*L. magallufianum* Llorens, *L. boirae* Llorens & Tébar, *L. ejulabilis* Rosselló, Mus & Soler, *L. inexpectans* Sáez & Rosselló and *L. carvalhoi* Rosselló, Sáez & Carvalho). These last two species have a very low number of individuals in their natural habitat. The conservation status of Puig Major species is unequal, but they suffer a series of threats that are common in many cases. The species in alarming danger of extinction on Puig Major are: *Agrostis barceloi* Sáez & Rosselló, and the "turbit" (*Ligusticum huteri* Porta). Both are catalogued under the maximum degree of protection (in danger of extinction) in the Balearic Catalogue of Threatened Species and Species of Special Interest (Decree 75/2005). The *Chaenorhinum rodriguezii* (Porta) Sáez & Vicens is classified as vulnerable in the Red Book of Vascular Flora of the Balearic Islands: all three species are endemic of Majorca. And soon, in 2013, the *Cotoneaster majoricensis* L. Sáez & Rosselló, another endemic species, will also be classified as in danger of extintion. In Puig Major, we also have the presence of species with a wider distribution in Europe and the Western Mediterranean that are endangered in the Balearic Islands. Some of these are included in the Red Book of Vascular Flora of the Balearic Islands: *Cystopteris fragilis* (L.) Bernh. subsp. *fragilis*, *Dryopteris tyrrhena* Fraser-Jenk. & Reichst., *Dryopteris filix-mas* (L.) Schott and *Hieracium amplexicaule* L., in the critically endangered category; and *Polystichum setiferum* (Forssk.) Woynar, *P. aculeatum* (L.) Roth, *Rosa squarrosa* (A. Rau) Boreau and *Colchicum lusitanum* Brot. in the endangered category. The Puig Major Conservation Plan is specially focused to this group of the 2 most endangered species and directly and indirectly benefits the other 19.

The priority to preserve endemic species and conserve species in the periphery of their range are very different, but if the measures applied are the same and have an effect on both groups of plants, the debate can be concluded.

Main conservation actions on threatened plants associated with recovery, conservation and management plans: (1) demographic monitoring of the populations, (2) exploration to discover new locations, (3) removal of pressure from herbivores and providing physical protection to threatened species, (4) control of competing plant species affecting the threatened flora, (5) reinforcement / translocation of endangered plant specimens in the wild, (6) actions such as collecting seeds for botanical gardens and seed banks and (7) campaigns to raise awareness.

MAIN THREATS TO ENDANGERED SPECIES

Destruction and loss of habitat

The limiting factor for many threatened species is habitat availability. The destruction or degradation of suitable and potential habitats is one of the main threats to the survival of many species, especially with species with rare and restricted distribution. Occupation, changes in land use and alien species introduction are the main causes of changes in nature. In the Balearic Islands the most vulnerable habitats are wetlands and coastal areas, both rich in endemic and rare species. Examples of protected plants are *Apium bermejoi* Llorens and *Euphorbia margalidiana* Kuhbier & Lewej. (both coastal plants) due to a lack of habitats, and *Vicia bifoliolata* J. J. Rofr. and endemic *Limonium* (coastal and wetland respectively) due to degraded habitats.

Climate change

The vegetation of Puig Major, the highest mountain in Majorca, is the most important biological heritage of our islands as a whole. We have a clear example of plants adapted to a special microclimate in those that live in the highest peaks of the Serra de Tramuntana range, especially in the Puig Major. Here, the unique and rare endemic vegetation finds refuge at the highest levels, on small ledges, in hollows, channels and fissures in the cliffs, where exposure to sunshine is low and therefore it is rather humid. These species have very limited distribution with few specimens, and live in isolated, highly localized areas and in very specific environmental conditions.

These mountains also shelter some relict trees as evidence of cooler and more humid ages, such as the common yew (*Taxus baccata* L.) and holly (*Ilex aquifolium* L.), or deciduous trees such as the maple, whitebeam (*Sorbus aria* L.), snowy mespilus (*Amelanchier ovalis* Medik.) and the Pyrenean honey suckle (*Lonicera pyrenaica* subsp. *majoricensis* (Gand.) Gand.), whose growth depends on herbivores. Puig Major is also an important refuge for mountain and northern bryophytes (mosses and liverworts), which are very rare on Mediterranean islands. This plant stronghold is seriously threatened by climate change, which could affect its survival and even lead to inexorable extinction.

An increase in temperatures or a decrease in precipitation would bring about an increase in the altitude of the habitats that these extraordinary plants require to live, and there are no more islands. If the climate becomes drier, they go up, and the aridity will progressively swallow up this life and will destroy this age-old refuge, without us being able to do very much to save the flora on Puig Major.

Historically, climate has not been stable, and the island has gone through periods of drought, aridity, or humidity and snow much more prolonged than today. Nevertheless these species have survived. What is currently taking place is quite noteworthy, and the Puig Major's plan includes a detailed monitoring of species in order to create a biological and demographic database that can identify the trends of the species.

Predation

Climate change is not the only problem yet. The main and most serious threat is posed by the pressure of herbivores (goats and sheep) that devour shoots, leaves, flowers, fruits and tender seedlings, destroying natural regeneration and promoting the aging of the species of highest interest.

The floristic structure and composition of the Serra de Tramuntana range is conditioned by the pressure of herbivores, which are too numerous (goat average: 0.32 individuals / hectare, with approximately, 28,000-35,000 goats living in Serra de Tramuntana). This extreme pressure, mainly exerted by goats, favors the presence and predomination of certain plant species, many of which are thorny or poisonous, and severely limits the existence of the species that serve as food. This is why the landscape would be different without this excess of herbivores and we would certainly be able to enjoy a flora not only more in consonance with the climate but also more plentiful and varied than at present. The plants that now live on inaccessible cliffs and crevices or are well protected among thorny shrubs could establish themselves and grow in any ecologically suitable habitat.

Other types of predators are also found, such as phytophagous insects (on *Apium bermejoi*, *Vicia bifoliolata* and endangered *Limonium*), rabbits and small rodents.

But we must not forget that this happens under a scenario of excessive grazing pressure. In fact, our flora has evolved under the moderating influence of certain native herbivores like *Myotragus* Bate spp., now extinct. And now these herbivores' excess is due to the progressive abandonment of farming that has led to an uncontrolled increase of goats and even feral sheep. That said, some degree of herbivores is tolerable and even necessary for our flora, or for some rare endangered species such as *Naufraga balearica* Constance & Cannon.

Intrinsic factors

This aspect is common in most threatened species. Low population densities, some significant fluctuations in the number of individuals and small distribution range are determinant of vulnerability. Also the lack of knowledge on the vectors of pollination, the viability of flowers and seeds, the capacity of germination and new specimen survival, are factors to consider in management actions.

The lack of new speciments or juveniles is also quite significant. Normally, populations of threatened species have problems with viable fruit formation or survival of seedlings is very low.

Exotic plants

According to the IUCN, alien species are the second leading cause of biodiversity loss, following habitat destruction. The entry of exotic species is due largely to habitat degradation and the opening of ecological niches. We not only have problems with the introduction of exotic species such as *Carpobrotus* N. E. Br. spp., but also with the introduction of indigenous species previously not present in the habitat of threatened species. For example *Lactuca serriola* L. and *Brachypodium sylvaticum* (Huds.) Beauv. living with *Colchicum lusitanum*, a Western Mediterranean species that in the Balearic Islands only lives on top of Puig Major. Or the enormous growth of *Primula acaulis* subsp. *balearica* (Willk.) Greuter & Burdet on *Agrostis barceloi*, endemic and endangered to the Puig Major. The proliferation of these native plants is due to the total elimination of herbivores. The debate is open…

Potential threats

Plants restricted to very small areas may be at higher risk of extinction due to natural catastrophes (Caujapé-Castells *et al.,* 2010). Devastating natural events like storms, fire, water impact, an episode of prolonged drought or other phenomena could extinguish the natural population of the species, as can changes in land use (tourism, motocross, roads and highways), and hybridization can threaten the genetic identity of the species. Coastal species like *Euphorbia margalidiana* is highly vulnerable to stochastic littoral events and the *Limonium* species to hybridization. *Pinus pinaster* Aiton is also vulnerable to fire, as could be seen in the summer of 2006, and the stoloniferous *Apium bermejoi* to prolonged drought periods. Deleterious genetic consequences related to small population size can impede population responses to sudden environmental shifts including competition from invasive alien species, the influence of population size on the genetics and reproduction of insular endemics, a major concern to conservation (Caujapé-Castells *et al.,* 2010).

MAIN RESULTS

Increasing populations and individuals

Increasing both the density and distribution of species is the main objective in threatened species management. When applying different conservation plans, we realized that this issue can be caused either by lack of initial information or by plant intrinsic characteristics or by the lack or destruction of habitat.

An example of insufficient information is the case of *Vicia bifoliolata.* Over three years of development, its Recovery Plan has made significant advances in knowledge of this species in different areas. Possibly the most notable has been those related to their chorology and determination of its effectives. An exploration effort of the natural environment has resulted in a larger area of distribution and density of individuals in previously known areas. The number of individuals has increased from hundreds to thousands. This fact suggests a new and lower conservation status classification. In fact, in the new national catalog this species was under the endangered label and has been reduced to vulnerable, a more minor category of threat. Another example of lack of information is the species *Femeniasia balearica* (Rodr.) Susanna. The first action in obtaining knowledge of this species, apart from natural seed collection, is the development of a comprehensive mapping, which recently has finished. Comparing the results of the population density conducted in 2003 and 2011, two *Femeniasia* populations have about the same adults plants number, while the population of Mongrofa-Favàritx has experienced a considerable growth going from 390 to 1.065 plants.

One of the main actions carried out to increase the number of individuals in natural areas are reinforcement and translocation (Table 2). The actions carried out with *Pinus pinaster* in Minorca are a clear example of an artificial increase of individual numbers. This widely distributed pine species presents an interesting conservation issue because in 2006 a molecular study revealed population genetic differences between the Minorcan and the Iberian populations, and its oriental affinity (Tyrrhenian islands). The original population of 12 individuals described in 2003 was completely destroyed in the summer of 2006 by a fire. Thanks to a reinforcement demographic action made the year before the fire, the original population still lives on. But the results are not as positive as we would like: currently, only 37 pines out of the 197 planted still survived after just four years in the original population. Survival values were also low in the proceedings of translocation or creation of new populations. In four years, four new populations were created, but only few specimens survived. These new populations were very recently created and we cannot ensure their viability. In total 100 specimens were planted, 15 of which are still alive (Fig.1). This high mortality rate was due to natural growth of two pathogenic fungi (*Pythiyum* sp. and *Diplodia*) that destroyed much of the original and translocated population. Excessive rainfall and high temperatures favored the development of these fungi that attacked the pines at root and shoot. However, adding the action of reinforcement and translocations, the population of *Pinus pinaster* was quintupled since its discovery (Minorcan population has grown from 12 to 54 individuals). The same happened with *Apium bermejoi,* also endemic to Minorca. Five new populations were created and the number of individuals has been nearly quadrupled. There are 32 individuals in the original population and 102 in the five newly created ones (Fig.1). These conservation efforts have also been made with the Yew *(Taxus baccata),* whose specimen count has increased by 50% with the creation of five new locations and the strengthening of two others (Table 2).

Translocation						
Species	Num. original population	Num. of individuals	Num. new populations	Nº of individuals	Total num. of populations	Total num. of individuals
Pinus pinaster	1**	37	4	15	5	52
*Apium bermejoi**	1**	32	5	102	6	134
Euphorbia margalidiana	1	700	1	131***	2	±831
Taxus baccata	10	603	5 + 2**	395	15	998
Limonium barceloi	4	7,616	1	115	5	7,731
Limonium inexpectans	1	132	0	244	1	376
Limonium carvalhoi	1	100-150	0	244	1	344-294

Table 2. Number of original and translocated populations and data for individuals. Patches, not individuals. ** Reinforcement population. *** Only 15 are reproductive plants. 2013 data.*

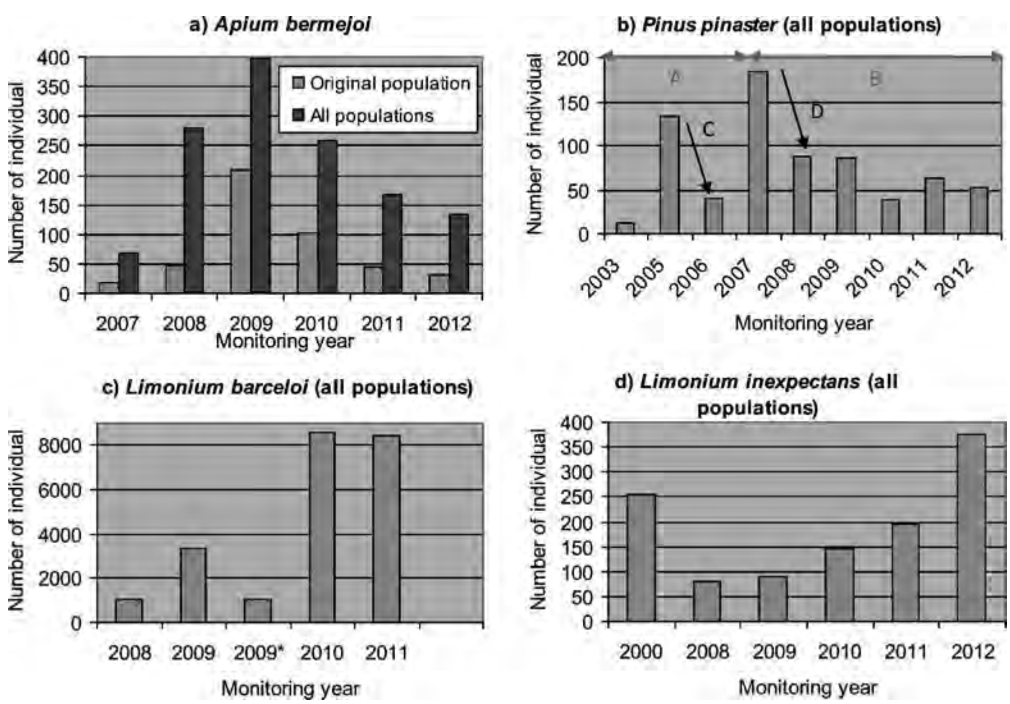

Fig. 1. Demographic trends for some species during the years of study. a) Apium bermejoi*: represents the number of patches, not individuals. b)* Pinus pinaster*: all increases are due to artificial planting. A = Reinforcement of natural population; B = Original + new populations; C = Fire that killed all natural individuals plus some reinforcement; D = Root fungus that killed part of the original population and the 77 individuals of a new one. c)* Limonium barceloi. **Number of individuals after the artificial flood episode that killed 68% of the population. d) Limonium inexpectans. Conservation actions began in 2008.*

Euphorbia margalidiana is a particular case of lack of habitat. It is an endemic plant of Ibiza where its population is restricted to only a small island of less than 2 hectares (Ses Margalides). It is theoretically highly vulnerable to stochastic events, despite its good condition with an excellent population size (± 900 individuals). In 2005 a process of creation of an artificial population of this plant on a small island named Murada commenced. Its habitat is similar to the original population in Ses Margalides and located nearby. Little by little a population on the new island, Murada, has been gaining strength. Now 15 reproductive individuals and 116 seedlings survive.

The *Conservation Plan of Puig Major Threatened Flora* is one of the most ambitious plans in terms of recovery and monitoring of both species and habitat. Among the rarest and most unusual of all the endemic species of plants in the Balearic Islands are the locally named "turbit" (*Ligusticum huteri*) and the grass *Agrostis barceloi*. They only live at the top of the highest mountain in Majorca, the Puig Major. The most important conservation action in this area is to reduce grazing pressure on the most endangered plants. Plants have been protected with exclusion fences, or individually protected with wire fencing and barbed wire. All the specimens of *Ligusticum barceloi* are protected this way, as well as about 71 natural yew trees *(Taxus baccata)*. Caves have also been protected, ledges with *Agrostis barceloi,* as have meadows of the utmost value at the foot of cliffs and even the most important ferns. From the begining of the conservation plant our Service staff carried out the reinforcement of populations (by planting vegetative specimens), in terms of number of specimens of those incurred to date. See the *Conservation Plan of Puig Major Threatened Flora* main results in Table 3.

	Specimens					
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
*Agrostis barceloi**	36	1255	996	830	1.719	383
Chaenorhinum rodriguezii	5(3)	50(20)	31(26)	93(86)	128(51)	221(56)
Colchicum lusitanum	-	100	116	152	0	19
Cystopteris fragilis subsp. *fragilis*	3	41	50(39)	67(54)	70(59)	312(211)
*Dryopteris tyrrhena***	28 plants	281	430(329)	408(289)	411(308)	391(287)
Hieracium amplexicaule	0(3)	3(2)	14(7)	14(4)	35(3)	29(10)
Ligusticum huteri	64(3)	135(2)	135(12)	209(5)	229(13)	221(2)
Cotoneaster tomentosus	34(13)	44(11)	61(14)	61(15)	74(16)	91(15)
*Polystichum aculeatum***	32(15) plants	230(93)	245(103)	290(141)	304(132)	281(122)
Orchis cazorlensis	0	0	0	0	0	11
*Polystichum setiferum***	25(12)plants	381(137)	432(201)	671(465)	694(479)	680(455)
Rosa squarrosa	24	34(10)	35(10)	45(12)	49(22)	47(15)

*Table 3. Puig Major's threatened species. * Number of flowers stems. ** Number of fronds. () Reproductive individuals. The double line indicates the beginning of the conservation actions.*

We also carried out several population reinforcement actions on tree species of conservation interest (*Acer opalus* Mill. subsp. *granatense* (Boiss.) Font Quer & Rothm., *Ilex aquifolium* and *Taxus baccata*) at the top of Puig Major. The status of the plants of these species is quite satisfactory. Hence, after rapid and remarkable growth, it is expected that in the medium term there will be an important change in the physiognomy of the vegetation of this area, currently dominated by clumps of *Ampelodesmos mauritanica* (Poiret) T. Durand et Schinz.

We also have an example of regional extinction in the environment; the male fern (*Dryopteris filix-mas*), native to northern Europe and Asia, was only found in Majorca in a shaded deep fissure on the Puig Major Mountain, but has not been seen for the last ten years. The cause of its disappearance remains unknown. Spores of a single male fern that lives in the Botanical Garden of Sóller were collected and germinated, thanks to the collaboration of the forest garden of Menut. We have obtained five plants (sporophytes) that were introduced into their natural habitat, and to date only one is alive.

The remains of two degraded wetlands with *Limonium* endemic species exist in the south of Majorca. In both habitats, we planted specimens of the more threatened *Limonium* near their natural populations (Table 2). The increase of individual population of *Limonium inexpectans* is due to the recruitment of new individuals. Most of the population consists on juveniles.

Habitat restoration

Some habitat restoration actions are essential to the survival of our threatened species.

After the fire in the original population of *Pinus pinaster*, efforts to clear burned plants were made so as not to affect smaller reinforcement plants. Some native species competing were also removed. Currently, creating a perimeter fire protection strip is being planned.

The extreme pressure of herbivores is one of the main problems for the mountain flora in Majorca. Grazing, mainly by goats, has changed the landscape increasing the heterogeneity of the environment, the degradation of the habitats and the presence of dominant species. The landscape would be different without this excess of herbivores and we would certainly be able to enjoy a flora, not only more in consonance with the climate, but also more plentiful and varied than at present. Most of the exceptional rare and endemic plants are congregated on the Puig Major Mountain. In this area, hunting of herbivores is taking place and as mentioned before, the fencing off of botanical interest areas. In 2008, 7 enclosures to protect a forest of *Acer opalus* subsp. *granatense* and promote germination and growth of juveniles were built. In 2009, 270 seedlings were germinated, but they died during the summer. Other 104 seeddings were germinated in 2010 and 141 in 2011, of which only 13 plants survive in 2012.

Important activities took place at the top of the Puig Major in 2008. The Ministry of Defence, through the company Tragsa, reduced the size of the installations, carried out a project of demolition and removal of all obsolete facilities and is now actively involved in the conservation of the enormously valuable natural heritage of the Puig Major (almost €1 million budget). These areas were subsequently restored with shrubs and herbaceous species common in the massif as well as young specimens of *Taxus baccata* provided by the Species Protection Service.

As for the Minorcan endemic *Vicia bifoliolata,* despite its population increase over recent years, the fragmentation of its habitat could be a problem for the stability of the species that depends on a specific habitat, the presence of which is currently limited to a reduced geographical area.

Limonium species are adapted to highly saline soils, and wet and poorly ventilated areas. This degraded and gradually changing habitat is sending these species towards extinction. As for the species *Limonium barceloi,* important actions to reverse this situation are being carried out, such as the elimination of competing plants, the removal of debris and irrigation with salt water. The perception is that these actions are having positive effects and we have observed a significant increase in individuals (Fig. 1). On the other hand, the exploration activities have increased the number of known individuals and populations. Soil samples have been collected to characterize the habitat and try, in future, to return to original natural state of the area. In the Marina de Magaluf, a degraded wetland with 5 different endemic species, 454 *Tamarix* L. plants from adults of the same habitat were planted. Thanks to a collaboration agreement with the city council, habitat restoration actions, such as debris and invasive species removal, have been carried out.

Population biology monitoring

This is one of the actions common to all plants related to recovery or conservation plans.

Of particular interest are the cases of each of the wild specimens of *Pinus pinaster* and *Taxus baccata*. The show data regarding the geographical location, the identification plate number, individual length and width, data on the ramifications for *P. pinaster*, flowering and state of conservation.

In the case of *Euphorbia margalidiana, Limonium magallufianum, L. boirae* and *L. ejulabilis* we established permanent monitoring plots where the number of germinations, evolution, and growth of reproductive plant and conservation status were registered.

For the remaining threatened species, data on reproduction biology such as flowering and fruiting, survival germination and in some cases data on pollination vectors are recorded annually. Botanical experts carried out all of these actions.

Deeper knowledge

The systematic exploration of the upper area of the Puig Major Mountain has resulted in the discovery of many new threatened specimens. Extreme weather conditions, steep slopes, and sometimes the small size of some plants make it difficult to find new subpopulations. Population growth in all the most endangered species of Puig Major Mountain is due, except for cases of reinforcement actions, to prospecting actions.

Orchis palustris Jacq. is an orchid in the Balearic Islands that is only present in the area of the Albufera de Mallorca (Wetland). For this reason and for the insecurity and instability of their populations a Conservation Plan was conducted in 2009. This plant is an opportunistic species that grows in open fields with high soil moisture whose ecological requirements are unknown. One of the main objectives is the understanding of the ecology of this species and its basic needs. All the actions developed to get to know this plant are just emerging but, so far, they have been performed to characterize the habitat, using population censuses, records of soil moisture and salinity, interaction with other plant species, and responses to drought and changes in flood regime. The aim is to expand the distribution of plants from population centers and consolidate them.

Ex situ

The goal, which is common to all flora conservation plans, is to make collections of plants and seed banks in three different specialization centers. This action essentially began in 2010, but since 2008 we have been collecting cuttings and seeds (and fern spores) most of which were used to grow plants, subsequently planted in natural areas.

These actions are being carried out with the help of Forest Seed Bank of the Balearic Islands (Menut), Sóller Botanic Garden, Barcelona Botanic Garden and Madrid Polytechnic University.

Keeping an updated database of all the stored material is another *ex situ* action.

Information on species' genetic diversity

Some molecular studies on species have been conducted associated with a conservation plan. We have a study on taxonomic evolutionary relationships among 11 endemic species of *Limonium*, determination of variability and genetic relationships inter and intra yews (*Taxus baccata*) populations of Majorca, phylogenetic information and the most likely origin of the population of Minorcan *Pinus pinaster,* and this year we will have results on *Orchis palustris*' diversity.

It is important to observe that many outside researchers are conducting molecular studies on endangered species of the Balearic Islands.

Disclosure and environmental education

This section focuses on *in situ* conservation actions as one of the main points of work. Each year information sessions on the status of threatened species conservation and restoration actions (detailed information on our website, brochures, congresses, *in situ* posters and training courses) take place. These actions are aimed to the general public (to raise awareness of the existence of threatened unique species) and key sectors of society that are directly or indirectly related to some endangered species and can have influence on their conservation.

Other conservation actions

Species Protection Service performs other environmental conservation activities like irrigation in dry season, protection against herbivores and elimination of competing species. For example, to benefit the *Colchicum lusitanum,* a Western Mediterranean species in the Balearic Islands which is present only in the highest part of the Puig Major, the Service has made removal actions against competing native species such as *Lactuca serriola* and *Carlina corymbosa* L. With the fern *Cystopteris fragilis* it also undertook the local removal of *Primula acaulis* subsp. *balearica*. In the case of *Limonium barceloi* Gil and Llorens, we have competition problems with the exotic *Arundo donax* L. due to the lack of adequate habitat.

CONSIDERATIONS / CONCLUSIONS

The recovery of threatened and endangered species is complicated due to the number, severity, and tractability of the threats facing each species. The most common threats are those related to resource use, exotic species, construction, and the alteration of habitat dynamics (Lawler *et al.,* 2002). Experience tells us that the limiting factors of our endangered species are mainly the lack or destruction of habitat, excessive pressure from herbivores and in some cases the lack of information.

In recent decades, human intervention (economic growth and abandonment of agricultural and traditional practices) has been exponentially affecting both quality and quantity of species habitats, changing the landscape and promoting the fragmentation of habitats. Trying to restore, as much as possible, the previous natural conditions that favored the establishment and development of endangered species, or achieving a minimum viable population to ensure their survival in the wild entirely independent of human management, means persistence and reproduction, and this is our struggle.

Small reserves should not be seen as an alternative to large protected areas but as a complement (Laguna *et.al.,* 2004) or as a start towards conservation. Small protected areas allow closer monitoring of plant diversity and tailored actions to the needs of particular species or vegetation types (Laguna *et.al.,* 2004). Our endangered species have their main threat in the lack of habitat and destruction, and our goal is to keep natural space, improve and manage the species in order to achieve stable natural populations and even increase them. Is this positive? Is so much human intervention good? Are we changing natural areas with gardens? Are we fighting against nature? Or perhaps are we repairing erroneous human activities? Whatever the answer, our crucial purpose of a recovery plan is to prescribe tasks to restore species populations to viable, self-sustaining levels so they can be removed from the endangered species list (Lawler *et al.,* 2002). The most significant actions with the best results for the targeted species are protection against herbivores, habitat restoration and reinforcement and translocation actions.

The basic biological purpose of reintroduction is establishing new or increasing existing populations in order to increase a species' survival prospect (Godefroid *et al.,* 2011). Introducing rare plants in new sites to offset effects of habitat destruction requires detailed knowledge of habitat requirements, plant demography, and management needs (Holl & Hayes, 2006). And this is how we approach our conservation work. The problem is that maintaining both existing and introduced populations of rare plants frequently requires long-term habitat management in order to maintain disturbance regimes and to minimize competition with exotic species (Holl & Hayes, 2006; Godefroid *et al.,* 2011). For many authors, recruitment is considered the highest measure of success. The species *Apium bermejoi,* endemic *Limonium* and *Euphorbia margalidiana* have new individuals, and with *Ligusticum huteri*, *Taxus baccata,* and *Pinus pinaster* as non-annual plants, it is still early to have new individuals.

The most likely common failure of plant conservation efforts is due to funding constraints. Money for the protection and recovery of threatened and endangered species is limited. Therefore, it would be prudent to set priorities clearly so that we can optimally use the funds available (Lawler *et al.,* 2002).

We have been tracking these recovery plans for few years, but every day we are learning something new. There are many questions that arise and knowledge is constantly gained, but what really matters is that endangered species have a very positive response to the right management and, hopefully, in the years to come they will continue their road to recovery.

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THE LIFE+ RENEIX PROJECT

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INTRODUCTION

The LIFE program (http://ec.europa.eu/environment/life) of the European Union is the only direct line of funding the Commission has to subsidize proposals whose goals are related to the practical management of the environment. To date, 3,950 projects with a total overall budget of €7.2 billion have been subsidized (Camarsa & Silva, 2013). The program is made up of 3 strands or areas depending on the goals of the activity or the type of proposed action: LIFE Environment (Policy and Governance), LIFE Nature (and Biodiversity), and LIFE Information and Communication. Of these three strands, it is LIFE Nature that most directly and most practically impacts conservation of biodiversity, with clear results regarding this objective (COWI, 2009).

Until the year 2006, the LIFE program funded LIFE Nature projects (COWI, 2009), the most significant investment in environmental conservation that has ever been made in Europe. This substantial sum has been most productive, as can be observed through the corresponding results. According to a statistical study, as many as 364 species have benefited from one of more of these projects and in 92% of the cases, measurable improvement in their state of conservation has been observed (COWI, 2009).

LIFE Nature projects have continually been carried out on the Island of Menorca since the year 2001 and have become some of the most important contributions to the conservation of biodiversity (table 1). The first of said projects was specifically aimed at the conservation of threatened flora: LIFE FLORA (LIFE2000NAT/E/7355; http://lifeflora.cime.es), and became the single greatest effort ever made regarding the direct management of flora on the Island of Menorca. One successful result that stands out is the development of management plans for the seven species of flora included in the Habitats Directive and other threatened species (Fraga *et al*, 2004a); a proposed network of microreserves for flora (http://lifeflora.cime.es/webeditor/pagines/file/microreservas.pdf) and especially for the control and eradication of the exotic invasive plant *Carpobrotus* (Fraga *et al*, 2005), which was a serious threat to the endemic coastal flora at that time.

Acronym, names, and code	Period	Budget	Objectives	Accomplishments
LIFE FLORA Conservation of areas with threatened species of the flora on the island of Menorca LIFE2000NAT/E/7355	2001-2004	653,662 €	Restoration of favourable conditions for the plant species included in annex I of the Habitats Directive	- Development of 8 management plans - Proposal of a plant microreserve network - Control and eradication of the alien invasive plant *Carpobrotus* - Involvement of local population in actions and objectives of the project
LIFE BASSES Management and conservation of Mediterranean temporary ponds on the island of Menorca LIFE05/NAT/ES/000058	2005-2009	1,013,549 €	Long term conservation of the priority habitat Mediterranean temporary ponds on the island of Menorca	- Cataloguing temporary ponds - Improvement of the ecology of the habitat - Specific management plan for temporary ponds - Habitat restoration - Social awareness for the conservation of temporary ponds
LIFE+ RENEIX Habitats of priority species restoration on the island of Menorca LIFE07NAT/E/000756	2009-2013	1,574,713 €	Active restoration of degraded habitats home to some communities of interest and priority species of the flora of Menorca included in the Habitats Directive	- Multidisciplinary characterisation and main threats in long term degraded areas - Development of new methodologies for habitat restoration - Landscape restoration to favour regeneration of multiple habitats and species - Consolidation of traditional techniques for habitat management - Multilevel social awareness of the importance of landscape conservation

Table 1. LIFE Nature projects developed in Menorca, their objectives and main accomplishments.

The second project, LIFE BASSES (LIFE 05/NAT/ES/000058; www.cime.es/lifebasses), broadened its objectives and directed its energy toward the conservation of an entire habitat, Mediterranean temporary ponds, considered of priority interest under the Habitats Directive of the European Union. Focus went from vegetation to a more extensive realm, not only regarding diversity of organisms, but also ecological functions and the relationship between humans and conservation of biodiversity. The proposed actions were more complex in both their techniques and execution, which were at times even considered risky. The project, its development and the results progressed from initial uncertainty to the confirmation of its objectives, in large part thanks to the direct assistance and consulting received from the Scientific Community. The initial proposal was exceeded (Fraga *et al*, 2010a) and even received recognition from the European Union (Silva *et al.*, 2011) upon receiving the Best of the Best LIFE Nature projects 2010 award.

The creation of the proposal of the LIFE+ RENEIX project (http://lifereneix.cime.es) was highly relevant to experiences and results of the two previous projects. On one hand, further work was to be carried out on threatened species of flora, considering that the most recent studies and knowledge deemed this necessary (Fraga, 2009), while at the same time it became ever more evident that effective protection of biodiversity required conservation of habitats (i. e. Groves *et al*, 2002; Franklin *et al*, 2011; Maes *et al*, 2012), considering those specific measures that are limited to the protection of individuals or the control of a certain threat to be insufficient.

Taking advantage of these two projects in the social sphere was also deemed invaluable. Special volunteer days were established within the LIFE FLORA project and were indispensable regarding increased social awareness. In the LIFE BASSES project, educational resources like the instructional pond, created by the project (Allès, 2010) or the use of traditional techniques to manage the habitat (Mascaró *et al.*, 2010), brought these projects closer to the general public.

It became necessary to convey this message to society: it is crucial and possible to restore or recover areas that appear deteriorated or excessively altered (Shapiro, 1995; Whittey, 1997; Young, 2000).

THE HABITATS DIRECTIVE IN MENORCA

The basis for the outlook and the actions of any proposal within the LIFE Nature project are those areas included in the Natura 2000 Network of the Habitats Directive. After the most recent additions, many resulting from the LIFE BASSES project (BOIB Núm. 145, 7-X-2010; http://boib.caib.es/pdf/2010145/mp15.pdf), 38.7% of the surface area of the island is now included within this territory (Fig. 1; Carreras & Truyol, 2009). Beyond this quantitative assessment, what is truly significant is how effective it is on the conservation of biodiversity, especially with that which is specific or characteristic of any given territory, as established as a European regulation (Jongman, 1995; Apostolopoulou & Pantis, 2009; Maes *et al.*, 2012). Table 2 shows a list of habitats of the Habitats Directive found on the island and their relationship with the areas of action of the LIFE+ RENEIX project, which shall be discussed in the following section.

The richness of habitats from the Habitats Directive found on the island is not a mere coincidence between this legal instrument and its characterization, nor is it an isolated case. Menorca, like other Mediterranean insular territories, is recognized as a focal point for biodiversity (Médail & Quézel, 1999; Médail & Diadema, 2009), which normally is linked to habitat diversity, and also often to their heterogeneity (Benton *et al.*, 2003). In specific groups of organisms, such as vascular flora, the updating of inventory also confirms this biological richness (Fraga *et al.*, 2004a, 2008). However, if we consider this list of species of flora included in the Habitats Directive and their level of endangerment or conservation (Table 3), according to recent field studies (Fraga *et al.*, 2010), a certain level of discrepancy may be observed. Habitats are proportionally more important, in fact, these include most taxa of vascular flora, whether endemic or not, that are found with any level of endangerment (Appendix 1).

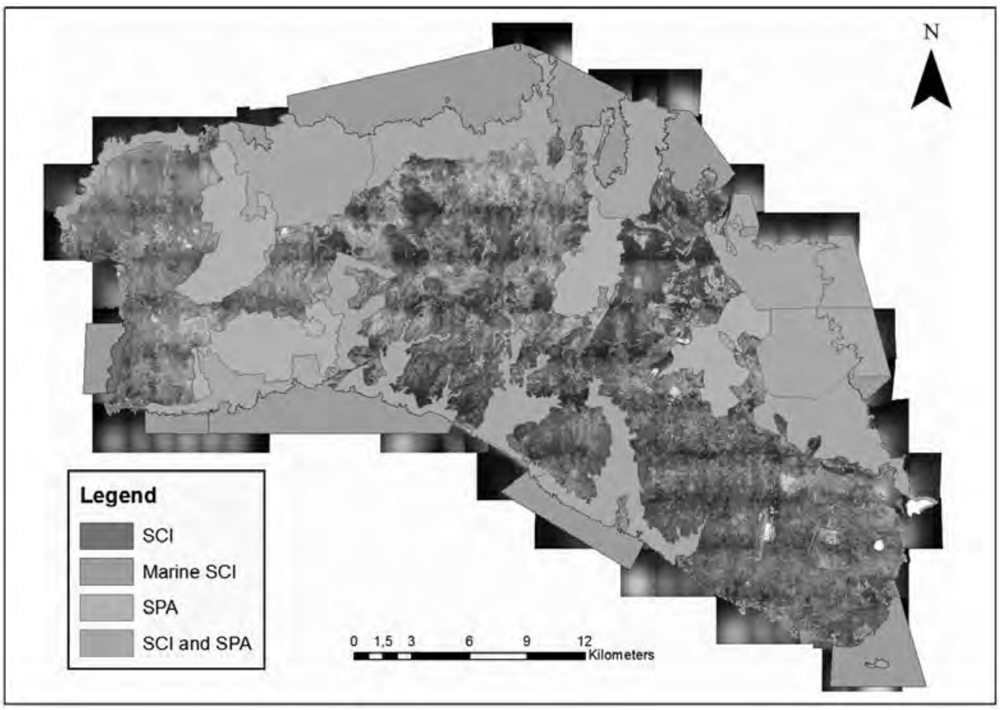

Fig 1. Current distribution of the Natura 2000 network in Menorca.

This set of data confirms just how crucial the protection of these habitats is for the conservation of biodiversity (Franklin, 1993).

The Habitats Directive determines that certain areas must be defined, based on specific criteria, which require protection and management for the conservation of biodiversity, and hence determine the Natura 2000 Network for each state or region. In the case of the Balearic Islands, such delimitation was carried out using existing figures for urban protection, called natural areas of special interest (ANEI), which originated from the need for protection of these territories from urban development destined to activities in tourism (Morillo & Gómez Campo, 2000; Carreras & Truyol, 2009). The criteria used in defining them took into account both landscape and natural values (Carreras & Truyol, 2009). In Menorca, the transposition of the ANEIs to the Natura 2000 Network was not complete as it was limited to coastal areas, excluding inland regions (Carreras & Truyol, 2009). This fact, in terms of flora, has caused the absence of certain areas of interest from within the Natura 2000 Network (Fig. 2).

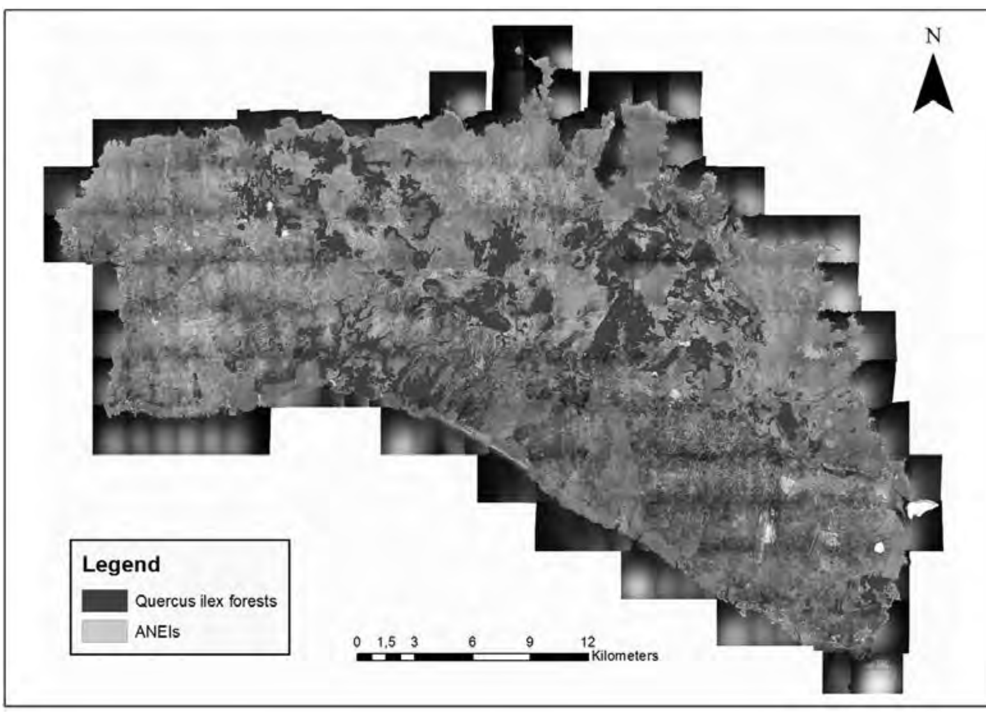

Fig 2. Protected areas in compliance with the law in Menorca 1/91 Natural Areas of conservation interest of the Balearic Islands.

Table 2. Habitats of European interest found in each action area.

Habitat [1]	Pas d'en Revull	Ets Alocs-el Pilar	Binimel·là-cala Mica	Es Murtar
1. COASTAL AND HALOPHYTIC HABITATS				
11. Open sea and tidal areas				
1120 * Posidonia beds (*Posidonion oceanicae*)		X	X	
1130 Estuaries		X	X	
1150 * Coastal lagoons		X	X	
1160 Large shallow inlets and bays		X	X	
12. Sea cliffs and shingle or stony beaches				
1210 Annual vegetation of drift lines		X	X	
1240 Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium spp*.		X	X	X
13. Atlantic and continental salt marshes and salt meadows				
1310 *Salicornia* and other annuals colonising mud and sand		X	X	
14. Mediterranean and thermo-Atlantic saltmarshes and salt meadows				
1410 Mediterranean salt meadows (*Juncetalia maritimi*)		X	X	X
15. Salt and gypsum inland steppes				
1510 * Mediterranean salt steppes (*Limonietalia*)		X	X	
2. COASTAL SAND DUNES AND INLAND DUNES				
21. Sea dunes of the Atlantic, North Sea and Baltic coasts				
2110 Embryonic shifting dunes		X	X	
2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)		X	X	
2130 *Fixed coastal dunes with herbaceous vegetation (grey dunes)		X	X	X
22. Sea dunes of the Mediterranean coast				
2210 *Crucianellion maritimae* fixed beach dunes		X	X	
2220 Dunes with *Euphorbia terracina*		X	X	
2230 *Malcolmietaliadune* grasslands		X	X	X
2240 *Brachypodietalia* dune grasslands with annuals		X	X	X
2250 * Coastal dunes with *Juniperus spp*.		X	X	X
2260 *Cisto-Lavenduletalia* dune sclerophyllous scrubs		X	X	X
2270 * Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*		X		X
3. FRESHWATER HABITATS				
31. Standing water				
3120 Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean with *Isoetes spp*.		X		X
3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoeto-Nanojuncetea*		X		
3140 Aguas oligomesotróficas calcáreas con vegetación béntica de *Chara spp*.			X	
3170 * Mediterranean temporary ponds		X		X

** Denotes priority habitat*

Habitat [(1)]	Pas d'en Revull	Ets Alocs-el Pilar	Binimel·là-cala Mica	Es Murtar
32. Running water				
3290 Intermittently flowing Mediterranean rivers of the *Paspalo-Agrostidion*		X	X	
5. SCLEROPHYLLOUS SCRUB (MATORRAL)				
52. Mediterranean arborescent matorral				
5210 Arborescent matorral with *Juniperus spp.*		X	X	X
5230 * Arborescent matorral with *Laurus nobilis*	X			
53. Thermo-Mediterranean and pre-steppe brush				
5320 Low formations of *Euphorbia* close to cliffs		X	X	X
5330 Thermo-Mediterranean and pre-desert scrub	X	X	X	X
54. Phrygana				
5430 Endemic phryganas of the *Euphorbio-Verbascion*		X	X	X
6. NATURAL AND SEMI-NATURAL GRASSLAND FORMATIONS				
62. Semi-natural dry grasslands and scrubland facies				
6220 * Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	X	X	X	X
64. Semi-natural tall-herb humid meadows				
6420 Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*		X	X	
7. RAISED BOGS AND MIRES AND FENS				
72. Calcareous fens				
7220 * Petrifying springs with tufa formation (*Cratoneurion*)			X	
8. ROCKY HABITATS AND CAVES				
82. Rocky slopes with chasmophytic vegetation				
8210 Calcareous rocky slopes with chasmophytic vegetation	X	X		
8220 Siliceous rocky slopes with chasmophytic vegetation		X	X	X
83. Other rocky habitats				
8310 Caves not open to the public	X			
9. FORESTS				
92. Mediterranean deciduous forests				
92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)		X	X	X
93. Mediterranean sclerophyllous forests				
9320 *Olea* and *Ceratonia* forests	X		X	X
9340 *Quercus ilex* and *Quercus rotundifolia* forests	X	X		
95. Mediterranean and Macaronesian mountainous coniferous forests				
9540 Mediterranean pine forests with endemic Mesogean pines		X		X

(1) Habitat denomination and classification follows criteria established in the latest version of the Interpretation Manual of European Union Habitats (EUR 28, April 2013).

Taxa	Conservation status	Source	Observations
Anthyllis hystrix (Willk. ex Barc.) Cardona, Contandr. et Sierra	NT	Moreno (2008)	
Carduncellus (*Femeniasia*) *balearicus* (J.J. Rodr.) G. López	VU	Moreno (2008)	
Daphne rodriguezii Teixidor	VU	Moreno (2008)	
Helosciadium (*Apium*) *bermejoi* (L. Llorens) Popper et M.F. Watson	CR	Moreno (2008)	
Marsilea strigosa Willd.	VU	Sáez and Rosselló (2001)	Not included in Moreno (2008)
Paeonia cambessedesii (Willk.) Willk.	LC	Sáez and Rosselló (2001)	Not included in Moreno (2008)
Vicia bifoliolata J.J. Rodr.	VU	Catàleg d'espècies amenaçades de les Illes Balears	Classified as CR in Moreno (2008), updated to VU from field studies (Fraga, 2010)

Table 3. Plant species of the flora of Menorca included in the Habitats Directive (annex I) and their conservation status

THE PROJECT'S AREAS OF ACTION

The achievement of the proposal's goals required the definition of specific areas of action moreso than simply carrying out wide-spread activities throughout the whole of the area included in the Natura 2000 Network. Hence, the very actions and their results would be more visible, as well as more easily evaluated. The selection of possible areas in which to act was based on the substantial work carried out within the LIFE FLORA project. Not only due to the management plans it developed, with its subsequent revision of sites, but also due to the vital land exploration, so as to identify new populations of threatened species or to detect the presence of the invasive *Carpobrotus* plant. All this, along with the experience and knowledge of the technical team regarding the island's flora, made the development of an island map with areas of concentration of biodiversity (Fig. 3) possible, with the Sites of Community Importance (SCI) superimposed. A list that included a series of criteria that affected the viability of the proposal was then applied regarding: accessibility, concentration of threats, land ownership, property's potential to carry out interventions, availability of social participation, possible innovative or demonstrative nature of actions to be performed, etc. Most of these criteria are already included as selected recommendations within several projects for planning habitat restoration (Collinge, 1996; Margules & Pressey, 2000; Sutherland *et al.*, 2004; Miller & Hobbs, 2007).

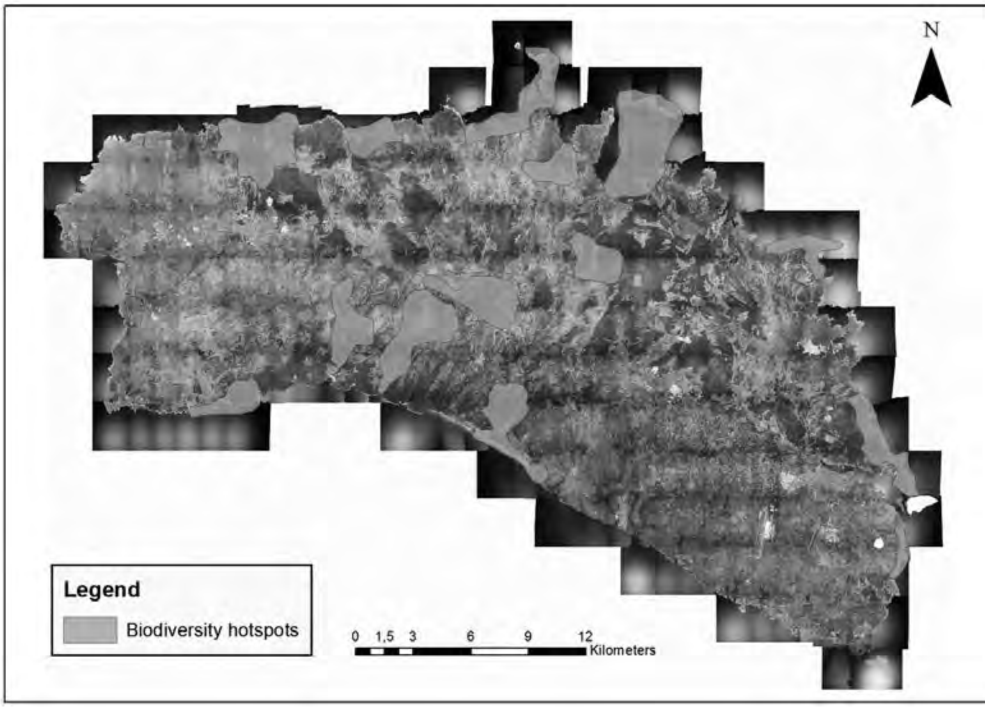

Fig 3. Plan biodiversity hotspots in Menorca, as a result of preparatory actions whitin the LIFE+ RENEIX Project.

This process resulted in four areas (see figure 3) that can be characterized according to the aforementioned criteria in table 4. In addition to the required criteria of being located within the Natura 2000 Network, we also see how all four areas coincide with zones of concentration of floristic diversity (Fig. 3; Table 5). In two cases (Binimel·là-Cala Mica, Es Alocs-El pilar) the level of threat of deterioration stemmed from efforts of urbanization (Fig. 4) that were of notable social debate and resulted in an overall consensus for environmental rehabilitation. The other two developed from different situations. In Es Murtar the state of degradation was more restricted, although elevated, and the repercussions on biodiversity were relatively high, for both habitats and species that were affected as well as for any and all social repercussions it could have. At El Pas d'en Revull, social and communication factors played a significant role. It is a key access point to one of the most popular wilderness settings on the island, the Algendar ravine, with considerable ethnological heritage and as part of the route of the historic "Royal Road", which volunteers have been rehabilitating over recent years. Although the threat level was relatively low, certain circumstances coexisted that led to the restoration and protection of the habitats combined with social awareness using educational tools and the fostering of public participation. In this manner, the goal of putting into practice one of the premises considered fundamental to the ecology of restoration was set (Miles *et al.*, 1998; Ryan *et al.*, 2001; Aronson *et al.*, 2010).

Area of action	Threat
Pas d'en Revull	- Lack of information - Excessive visitation - Lack of social awareness - Changes in vegetation
Es Alocs – El Pilar	- Lack of information - Vehicle accesses - Excessive visitation - Lack of social awareness - Stages of erosion - Changes in vegetation
Binimel·là – Cala Mica	- Lack of information - Abandoned roads - Vehicle accesses - Excessive visitation - Lack of social awareness - Stages of erosion - Changes in vegetation
Es Murtar	- Lack of information - Vehicle accesses rodats - Excessive visitation - Lack of social awareness - Stages of erosion

Table 4. Areas of action and their corresponding threats

Table 5. Taxa of the vascular flora of Menorca with conservation interest found in each area of action of the LIFE+ RENEIX project.

Taxon	Es Murtar	Binimel·là Cala Mica	El Pilar Es Alocs	Pas d'en Revull
Anacamptis morio subsp. *longicornu* (Poir.) H. Kretzschmar, Eccarius et H. Dietr.			•	
Anthyllis hystrix (Willk. ex Barc.) Cardona, Contandr. et Sierra		•	•	
Aristolochia clematitis L.			•	
Aristolochia paucinervis Pomel			•	
Arum pictum L. f.	•	•	•	•
Asplenium balearicum Shivas	•	•	•	
Asplenium trichomanes subsp. *inexpectans* Lovis				•
Astragalus balearicus Chater	•		•	
Avena barbata subsp. *castellana* Romero Zarco			•	
Bellium bellidioides L.	•	•	•	•
Brimeura fastigiata (Viv.) Chouard	•	•	•	
Calicotome villosa (Poir.) Link	•			
Carduncellus balearicus (J.J. Rodr.) G. López		•		
Carex rorulenta Porta		•	•	•
Carlina corymbosa subsp. *major* (Lange) López Martínez et Devesa		•	•	
Chelidonium majus L.				•
Cneorum tricoccon L.	•			
Coronilla glauca L.				•
Coronilla montserratii P. Fraga et Rosselló			•	
Crepis triasii (Camb.) Nyman				•
Cressa cretica L.			•	
Crocus cambessedesii Gay	•	•	•	•
Cyclamen balearicum Willk.	•	•	•	•
Cymbalaria aequitriloba (Viv.) A. Cheval.		•	•	
Cymbalaria fragilis J.J. Rodr.				•
Digitalis minor L.	•	•	•	•
Echinophora spinosa L.			•	
Elatine macropoda Guss.	•			•
Epipactis microphylla (Ehrh.) Swartz				•
Equisetum telmateia Ehrh.				•
Euphorbia maresii subsp. *maresii* Knoche	•	•	•	
Exaculum pusillum (Lam.) Caruel	•			
Helicodiceros muscivorus (L. f.) Engl.	•	•	•	
Hippocrepis balearica Jacq.				•
Hypericum balearicum L.				•
Launaea cervicornis (Boiss.) Font Quer et Rothm.	•	•	•	
Leucojum aestivum subsp. *pulchellum* (Salisb.) Briq.	•	•	•	•

Taxon	Es Murtar	Binimel·là Cala Mica	El Pilar Es Alocs	Pas d'en Revull
Limonium companyonis (Gren. et Billot) Kuntze	•	•	•	
Limonium minoricense Erben	•	•	•	
Limonium minutum (L.) Chaz.	•	•	•	
Limonium saxicola Erben		•		
Limonium tamarindanum Erben	•	•	•	
Lomelosia cretica (L.) Greuter et Burdet				•
Lotus tetraphyllus L.	•	•	•	•
Lysimachia minoricensis J.J. Rodr.[1]				•
Matthiola tricuspidata (L.) R. Br.		•		
Melissa officinalis L.				•
Micromeria cordata (Moris ex Bertol.) Moris		•	•	•
Micromeria filiformis (Aiton) Benth.	•	•	•	•
Micromeria rodriguezii Freyn et Janka	•	•	•	•
Ononis crispa L.	•			•
Ophrys balearica Delforge				•
Orobanche cernua L.		•		
Orobanche foetida Poir.	•			
Orobanche rumseiana Pujadas et P. Fraga		•		
Orobanche santolinae Loscos et J. Pardo		•		
Paeonia cambessedesii (Willk.) Willk.				•
Paronychia capitata (L.) Lam.		•		
Pastinaca lucida L.		•		•
Phlomis italica L.		•		
Polycarpon colomense Porta	•	•	•	
Polycarpon dunense P. Fraga et Rosselló			•	
Romulea assumptionis Garcias Font	•	•	•	•
Santolina chamaecyparissus subsp. *magonica* O. Bolòs, Molin. et P. Monts.		•		
Scrophularia auriculata subsp. *pseudoauriculata* (Sennen) O. Bolòs et Vigo				•
Scrophularia ramosissima Loisel.	•	•	•	
Senecio rodriguezii Willk. ex J.J. Rodr.	•	•	•	
Serapias nurrica Corrias			•	
Sibthorpia africana L.				•
Silene mollissima (L.) Pers.				•
Sonchus montanus (Willk.) Rosselló	•	•		•
Spergularia heldreichii Fouc.			•	
Teucrium asiaticum L.				•
Teucrium capitatum subsp. *majoricum* (Rouy) T. Navarro et Rosúa	•	•	•	•
Teucrium subspinosum Pourr. ex Willd.	•	•	•	•

(1). Extinct in the wild. Plants in Pas d'en Revull originated from reintroductions.

Taxon	Es Murtar	Binimel·là Cala Mica	El Pilar Es Alocs	Pas d'en Revull
Thapsia gymnesica Rosselló et A. Pujadas		•	•	
Thymelaea velutina (Pourr. ex Cambess.) Endl.			•	
Vicia bifoliolata J.J. Rodr.	•			
Vincetoxicum hirundinaria var. *balearicum* O. Bolòs et J. Vigo		•	•	•
Viola stolonifera J.J. Rodr.				•

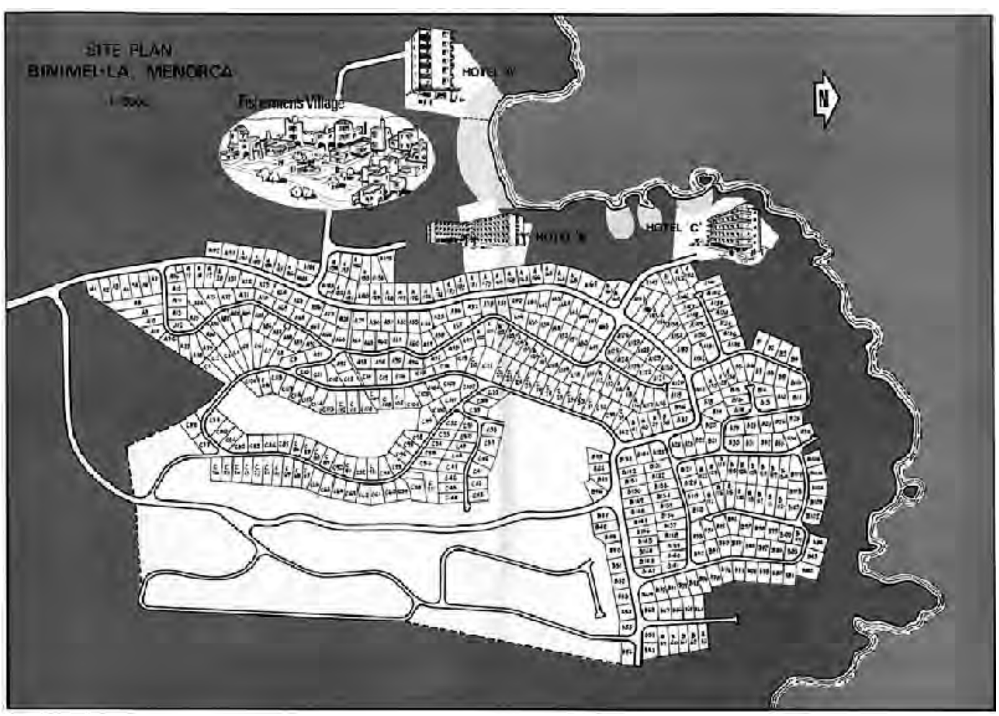

Fig 4. Programmed urbanistic development in the actuation area of Binimel·là, ca.1971.

PLANNING OF ACTIONS: PREPARATORY ACTIONS AND IMPROVING KNOWLEDGE OF THE ENVIRONMENT

The regulations of the LIFE projects declare that proposals must be developed from a starting point of previously consolidated knowledge regarding the situation of threat or the need for conservation that justify the means that shall be set forth (Brouwer *et al.*, 2005; Kettunen *et al.*, 2011). Still, the planning and the execution of proposed actions on the natural environment or those of communication, often require further knowledge or perhaps further organization so as to be truly useful, both for achieving the established goals, and for the efficient execution of the entire project. The fact is, the restoration of habitats, with positive results in the middle to long term, and designed to endure, may fail if proper use is not made of the available information beforehand (White & Walker, 1997; Miller & Hobbs, 2007).

In the original proposal of the project there were six preparatory actions that could be divided into three groups according to their function or expected result:

- Facilitate the development of the project and the creation of interaction and cooperation with social sectors (actions A1 and A6).
- Compilation and treatment of information regarding elements of interest for the project to facilitate the development of direct management actions for the natural medium (actions A2, A3, and A4).
- Develop work methods and restoration techniques (actions A4 and A5).

As seen above, some may have multiple orientations, and as for preparatory phases, execution often continues beyond the initial stages, in reconsideration of the project. One example can be found in action A6, technical consulting from NGOs and owners in developing management actions for the environment, which in certain areas, like the Pas d'en Revull, has been active throughout the entire project.

Another positive aspect of these preparatory actions is the information they generate and their usefulness in other projects or initiatives. The detailed cartography of species from project A2, or that of accesses and roads including detailed characteristics (A3) or the selection of species for revegetation (A4), have already been used by other actions of environmental conservation.

Throughout the project, during the redesigning of actions or efforts to guarantee proper execution, other actions may be developed in the form of studies or fieldwork, which could actually be considered additional preparatory actions. Some examples of this dynamic are the geomorphological studies carried out in the Binimel·là region that have resulted in the creation of a both innovative and fundamental paper (Rodríguez *et al.*, 2013) or the survey on social perception regarding the project and its objectives set forth by members of the Scientific Committee.

ACTIONS OF RESTORATION: WHICH ONES AND WHY?

The second group of actions, those of direct activity upon the natural medium, includes those performed *in situ* regarding project goals. In the initial proposal there is a predefined list of actions and techniques for investigation, but the truth is that most of them actually arise together or sequentially. One example is the construction of dry stone walls (C1), which is often associated with the installation of other accessories such as gates and openings (C5), and normally serve to control or eliminate access points or roads (C2), and when these two actions are carried out, revegetation quite often results (C3). Similarly, the primary objective of the construction of two bridges (C4) is the elimination of access points (C2) in the case of Es Alocs, and the control of vehicle access (C2) in Binimel·là. Table 6 shows the functions and objectives of each action within the areas of action and figure 4 shows an illustrative document that summarizes the importance of joint planning.

In accordance with the established planning process for LIFE Nature proposals, these actions must be fixed on guaranteeing habitat and species conservation object of the proposal, with emphasis on the control of any identified threats. Hence, selection and configuration will have previously been contemplated during the process of development of a proposal.

Dry stone wall constructions (action C1) are a typical ethnological element in many regions of the Mediterranean (Grove & Rackham, 2001; Pinto-Correia & Vos, 2004) and have been valued for many years, not only for their landscape value, but also for their ecological function and for proper administration of land usage (Naveh, 1994). Within the LIFE BASSES project, their useful nature in both habitat protection as well as their positive assessment on behalf of society were observed (Mascaró *et al.*, 2010; Allés, 2010). In this project, their function as a management tool or for habitat recovery is widened using them directly as closures for access points and roads or in control of processes of erosion. In Menorca, these constructions often go beyond simple separation or road blocks, as they commonly serve to define and lay out areas or systems of tracks. This multi-functionality includes the related accessories or associated constructions that show a typology found on the island. In this way, yet another action (C5) is destined not only to the construction and installation of these complements to dry stone walls.

The closure of accesses and roads (action C2) makes inherent reference to a threat that repeatedly appeared in all the LIFE projects developed on the island and is equally present in other regions around the world (p. ex. Wilshire *et al.*, 1978; Rickard *et al.*, 1994; Kutiel *et al.*, 2000; Pickering & Hill, 2007) This action should seemingly be included within the previous one, however due to environmental and habitat diversity at the location of the project, it is not always possible to use dry stone walls as enclosing elements. Where sandy unstable soils are found (dune systems, sandy areas) these constructions could have an undesirable effect on the dynamic of morphological formation. In other situations, the closure of an access point or a road may be done using different techniques like decompaction of soil or the recovery of the original water supply system.

The return of a habitat's original vegetation, as it had been prior to alteration, may be a relatively slow process, as it is not always possible for it to occur more suddenly (Le Houreou, 2000; Vallejo *et al.*, 2006). Optimal results are obtained when the succession of plant communities takes place with focus on stable vegetation (Niering, 1987). During this process, pioneer plants play a crucial role as those that are best suited to lead to more permanent plant communities (Padilla & Pugnaire, 2006). The focal point of preparatory action A4 was precisely plant species with this type of behavior, and action C3, revegetation of eroded areas, applies it in specific points or areas of action where vegetation had virtually disappeared. This action in unison with other actions becomes even more evident. The presence of vegetation may reduce the amount of human traffic in an area, and also serves to control access points (C2). Sowing or planting may require the prior decompaction of soil, yet another action that may help eliminate roads or access points (C2), or perhaps the need for construction of dry stone walls will arise (C1), resulting in stabilized soil.

The construction of bridges (action C4) is an action that more clearly affects two specific points. At Es Alocs, its purpose is the conservation of a relatively vast area that was being harmed due mainly to an access point to a cove, and separated a wet area in the process of rehabilitation into two parts. The construction of the bridge and the elimination of roads allow a series of habitats and species with a high level of conservation interest to be further protected from detected threats. One goal of the Habitats Directive is hence achieved, increased connectivity between habitats with reduced fragmentation. The Binimel·là bridge shares this goal of connectivity, although in a less direct fashion.

Table 6. Objectives and interventions carried out in areas of action

Area	Objective	LIFE+RENEIX intervention
Pas d'en Revull	Improve the state of conservation of key species. Restore elements of ethnological heritage. Expand knowledge and interpretation of habitats and species present, through the creation of an interpretative botanic route.	GIS cartography of unique species (2010 and 2013), GIS of vehicle accesses and map of habitats of interest.* Modification and restoration of ethnological elements. Construction and restoration of sections of dry stone walls and pavements. Planting of woody species typical of the ravine and follow up care. Installation of a botanic route and habitat signage. Four organized volunteer workdays. Guided tours for school-aged children since 2010 (30 groups).
Es Alocs	Minimize effects stemming from excessive human presence. Eliminate stages of erosion and reduce the banality of the landscape. Organize vehicle access and channel pedestrian traffic to the cove. Recover the end of the torrent and the associated wetland and the habitats of interest. Recover sensitive species.	Construction of dry stone wall to reorganize vehicle access. Construction of a bridge to divert access to the beach around the right side of the torrent and hence aid in the recovery of the coastal wetland. Elimination of housing development roads, via decompaction and revegetation. First volunteer workday. Installation of informative signage.
El Pilar	Minimize effects stemming from excess of human presence. Control erosion. Recover dune systems with redevelopment, as well as associated species and communities. Create a botanic route as a tool for visitor awareness. Modify the path to access the cove using traditional techniques.	Redirection of part of the Camí de Cavalls track that crossed the dune system, via an alternative existing path of less environmental impact. Installation of systems of sand retention using dry branches on the dune system to foster revegetation. Signage of a botanic route and guided tours for school children.
Binimel·là	Geomorphological and landscape recovery of the area. Control of free vehicle access and erosion. Recovery of habitats of community interest and populations of priority species. Minimize the effects of the presence of all-terrain vehicles. Expand knowledge and interpretation of habitats, key species, and the geological heritage of the area.	Creation of a method for cultivation of the *Femeniasia balearica*. Geomorphological study of the massif of Binimel·là. Survey on social perception of the project. Recovery of acequia watercourses and restoration of the original drainage network. Construction of barriers with dry stone walls to stop processes of erosion. Construction of a bridge over the torrent to recover the ecological connectivity and restore the habitats of the torrent. Elimination of uncontrolled accesses to areas where *Femeniasia balearica* is found. Elimination of roads, decompaction, and revegetation with indigenous plants. Placement of informative signage.
Pregondó	Minimize effects stemming from excess of human presence. Control erosion in dune systems. Recover dune systems with redevelopment, as well as associated species and communities. Redirect human visitation of the area via the Camí de Cavalls track to reduce effects on sensitive communities and species.	Redirection of the Camí de Cavalls track over the dune system and placement of systems of sand retention using dry branches. Restoration of dry stone walls and placement of fences to deter visitation to the areas with the presence of *Femeniasia balearica.*
Es Murtar	Habitat recovery (temporary ponds, fossil dune systems, coastal maquis shrublands) and associated priority species. Eliminate invasive species. Control free vehicle access.	Elimination of uncontrolled roads via the restoration of dry stone walls and placement of metallic and wooden security fences to mark out roads. Decompaction and extraction of the layers of foreign materials around the football pitch for the recovery of the original layer of paleozoic material. Re-sow and plant indigenous species to encourage the natural regeneration of the habitats. Elimination of invasive species (*Carpobrotus*). Placement of informative signage.

** This activity has been carried out in all areas of the project.*

Two other actions from this group initially had a more concrete objective. One of them, the recovery of the Es Murtar area (C6) was intended to eliminate an area used as a sports field that became a focus for the generation and expansion of threats. In addition to this specific intervention, others have been carried out that correspond to other actions: the construction of dry stone walls (C1) to close off access points (C2), decompaction of access points (C2) for their elimination so as to benefit the regeneration of vegetation or for sowing and planting for revegetation (C3). All these are further examples of complementary actions of these interventions.

The goal of delimiting the wetland and the dune system of Binimel·là (C7) was similar as it was intended to act upon a series of habitats that make up one landscape and ecological unit, although some of the expected activities had already been performed during the process of evaluation of the proposal. Finally, this action has been redesigned so as to restore a specific area where threats like excessive visitation or the proliferation of access points around sensitive habitats was causing substantial erosion to the environment.

BRINGING THE PROJECT TO SOCIETY

Communication and social awareness should be basic goals of the LIFE Natura projects' proposals, and in fact most often they are essential in achieving initiatives of habitat recovery or conservation of species for positive and constant results for an extended period of time.

In areas physically divided, such as islands, it may occur that communication and social involvement are easier, but this proximity may also compel us to consider the message intended for society and the channel through which such message may arrive (Apostolopoulos & Gayle, 2002).

Communicating is quite simple, and currently more so thanks to new technologies in communication and spreading of information. The LIFE Natura project proposals must include some actions with this focus: creating a web site, installation of informative panels, publishing of printed educational material and spreading of scientific results. Other non-compulsory actions could include: the creation of a project image, the use of social networks and local newspapers so as to provide information regarding the project's activities, etc. Nevertheless, such actions are still exclusively about communication. In limiting ourselves to these channels it is very likely that society will remain a passive subject that receives information without truly feeling involved or identified with the project's goals. Hence, it is highly recommended to design actions that allow for the direct participation of society, at least for those groups who are more sensitive to the conservation of the natural environment (Pretty & Smith, 2003).

This is why the LIFE+ RENEIX project communication and awareness-raising actions are so vital with regard to the diversity of actions and desired results. Apart from those above mentioned, common to virtually any proposal, other actions allowing for the involvement of society have been designed within this communication and increasing awareness package. This participation and union must come from both the most actively involved groups related to conservation of our natural environment, as well as from those who may create or increase the threats or those who in the future will be responsible for the continuity of our successes.

Volunteer work and social participation sessions (action D6) have been successful in the LIFE FLORA project; focused here on the eradication of the invasive plant *Carpobrotus* (Fraga *et al.*, 2005). This current project sought to be included in further actions such as the recovery of traditional tracks and roads, supportive measures for threatened flora or recovery of vegetation.

The creation of botanical tours (action D7), although simply an activity of communication or dissemination, brings the characteristic habitats and species of Menorca's flora to the general public. If we enhance them and make them more visible, it will be easier for various sectors of the community to get a better understanding of the project's goals as well as the reasons behind them. The on-line publishing of information about the biodiversity and endemic flora concentration focuses (action D9) has a similar goal, which ventures beyond this initial idea and is extended so as to make it suitable for new communication technologies (Cots *et al.*, 2013).

The increased awareness towards groups or social sectors most directly related to some of the menaces has been achieved through specific actions. In the case of visitors to the project's areas of action, primarily tourists, action D4 hopes to provide information by means of informative panels *in situ*, about the primary natural values of the most crowded areas. For those who frequently drive motor vehicles through sensitive areas, action D5 intends to develop several interventions, although, at the beginning of this project, both the implementation and how to get to the group in an effective way caused several doubts, partly due to previous experience of a similar action in a LIFE FLORA project, and also to the information on results from other initiatives (Priskin, 2003). Finally these have been implemented in an awareness enhancement campaign directed at drivers of motor vehicles and other groups that practice outdoor activities in the natural environment.

RESULTS

The structuring of the project in areas of action, where actions often develop in a sequential or simultaneous way, make results much easier to evaluate in each of these areas rather than for each particular action. Table 7 shows a summary of results for each area depending on the project actions, habitats or species involved.

Pas d'en Revull. The first interventions were carried out here. A new *in situ* reconsideration with town hall representatives and volunteer work groups promoting the recovery of the *Camí Reial* (Royal Road) and its maintenance served to directly involve these groups in the project. A day of field work open to the public kicked off the activities: cleaning and preparing to rebuild dry stone walls, road surface and track reconditioning of the *Camí Reial* and protection measures for threatened plant species. Recovery of the *Camí Reial* track, its boundaries through the restoration of dry stone walls, improvement of the track surface, placement of sign-posts along the botanical tour and, especially, direct and constant contact with the volunteer work groups, have had two clear overall results:

- Increased visitation in order to discover more about this area and walk along the botanical tour
- Improvement of the habitats and populations of several species of conservational interest.

The former directly links to the objectives of increased awareness and communication, although it also involves an obvious risk of excessive visitation. However, this risk has been reduced thanks to suitable sign-posting along the track and positive assessment of the groups of volunteers in charge of track maintenance. Nevertheless, some conflictive situations may occur due to vehicles parked outside of the designated areas.

Es Alocs – El Pilar. Essentially, this area consists of two different focal points. On the eastern side, around Es Alocs cove, fencing and decompaction tasks along the roads of the failed housing development have been carried out, as well as the construction of a bridge, and the boundaries of the final stretch of the access road to the cove were set, and finally plants were sowed to regenerate vegetation. Four main results can be highlighted:

- Significant decrease in the alteration level due to uncontrolled traffic of all terrain vehicles.
- Recovery of the native vegetation, currently herb plant pioneer communities.
- Recovery of wetlands.
- General improvement of the landscape value since alterations have been limited to specific areas marked out by traditional constructions.

On the western side, the area of influence of El Pilar beach, the protection of the sandy soil habitats has been a primary focus, hence the access ways to the shore along less sensitive points have been marked out, old tracks with limited environmental impact have been recovered, in addition to other interventions mostly designed to favour the recovery of modified habitats while also serving as a deterrent to potential excessive human presence. Also in this area volunteer work groups, mainly young people, have had certain prominence. These are the most remarkable project results:

- Effectiveness of some innovating techniques of low visual impact so as to benefit plant regeneration in dune systems.
- Obvious improvement to sandy areas and dune system habitats.
- Positive reaction of visitors to the regulation and marking of access points.

As a negative point, an increase in visitation is causing the degradation of habitats on sandy soils in areas where no actions were envisaged. This new situation should lead to additional actions.

Es Murtar. From early on, this was the area of action that seemed to require greater social consensus to develop the foreseen actions. However, there were no guarantees regarding the characteristics of the subsoil in the area covered by the sports field. After several discussions and proposed interventions, work was carried out rather quickly. Decompaction and excavation of the sports area confirmed the previous existence of an old dune system or sandy area. This took place along with decompaction and closing of roads and a subsequent action of plant regeneration. The primary results are:

- Confirmation of the recovery process of the sandy area's vegetation.
- Improvement of the conservation status of habitats and species of conservational interest. The priority species *Vicia bifoliolata* J.J. Rodr. is noteworthy, having undergone a remarkable population increase at decompacted access points.
- Viability of the use of aggressive techniques (such as heavy machinery, modification focused on regeneration) in order to achieve landscape recovery.

Binimel·là – Cala Mica. This is the largest area of action, also one that has required major organisational efforts and consensus among different institutions and entities, both public and private. A rethinking of some project actions also differentiated two separate focal points.

On the western side, the marking of accesses and the regeneration of sandy soil environments have been carried out at the access to Pregonda beaches, similar to the El Pilar area. The results observed are very similar to those observed in this area, hence confirming the effectiveness of some innovative techniques used during the project.

On the eastern side, the entire area where the construction of a housing development had been planned, actions have been rather complex and diversified. Apart from the initial project plans, the specifications for action were based on preparatory actions: cartography and characterisation of accesses, cartography of species of interest, especially the recommendations of a geomorphological study. Actions developed have also followed a sequential process according to an accurate previous plan; recovery of the original water supply system, removal of tracks and access points via the very recovery of temporary water courses (excavation) or through the construction of dry stone walls, stabilisation of man-made slopes, decompaction in order to enhance plant regeneration, control of erosion, and sowing and planting of vegetation. As a further action, in accordance with the drafting team of the revision of the Special Plan for the *Camí de Cavalls* horse track, a modification of this hiking track has been made so as to increase accessibility and distance it from sensitive and dangerous areas. Some achieved results are:

- The use of accurate planning and detailed knowledge of the area of action.
- Traditional techniques such as construction of dry stone walls, versatile in their function and use.
- Recovery of the water network, including the man-made one, as a key aspect in landscape restoration.

Apart from these results for each area and those further elaborated in Table 7, an overall conclusion can be made from the LIFE+ RENEIX project, which is its main goal: the recovery or restoration of environmentally deteriorated areas is possible, both for habitats and species. This achievement often means carrying out interventions on landscapes while developing more universal and general actions, and not those of a solely specific or restrictive nature.

Table 7. Some of the main results of the LIFE+ RENEIX project and their relationship with actions, habitats and species of common interest

Results	Area	Actions	Habitats	Species
Increase of the distribution scope	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	A2. Detailed cartography of the affected species distribution C2. Removal of tracks and uncontrolled accesses C3. Planting of native species to regenerate the vegetation C4. Construction of bridges on temporary Mediterranean torrents D6. Organisation of informative and civic participation sessions	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	*Anthyllis hystrix*, *Aristolochia clematitis*, *Asplenium trichomanes* subsp. *inexpectans*, *Astragalus balearicus*, *Bellium bellidioides*, *Calicotome villosa, Carduncellus balearicus*, *Carlina corymbosa* subsp. *major, Chelidonium majus*, *Cneorum tricoccon*, *Coronilla montserratii*, *Crocus cambessedesii*, *Cyclamen balearicum*, *Euphorbia maresii* subsp. *maresii*, *Launaea cervicornis*, *Leucojum aestivum* subsp. *pulchellum, Limonium companyonis*, *Limonium minoricense*, *Limonium minutum*, *Limonium saxicola*, *Limonium tamarindanum*, *Lotus tetraphyllus*, *Lysimachia minoricensisMicromeria cordata*, *Micromeria filiformis*, *Micromeria rodriguezii*, *Ononis crispa*, *Orobanche cernua*, *Orobanche foetida*, *Orobanche rumseiana*, *Orobanche santolinae*, *Paeonia cambessedesii*, *Polycarpon colomense*, *Polycarpon dunense*, *Romulea assumptionis*, *Santolina chamaecyparissus* subsp. *magonica*, *Scrophularia ramosissima, Senecio rodriguezii*, *Sonchus montanus*, *Teucrium asiaticum*, *Teucrium capitatum* subsp. *majoricum*, *Teucrium subspinosum*, *Thymelaea velutina*, *Vicia bifoliolata*, *Viola stolonifera*
Removal of tracks and uncontrolled accesses	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	A3. Identification and cartography of the accesses and tracks in the affected areas C2. Removal of tracks and uncontrolled accesses C.3 Planting of native species to regenerate the vegetation C4. Construction of bridges on temporary Mediterranean torrents D6. Organisation of informative and civic participation sessions	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	*Anthyllis hystrix*, *Aristolochia clematitis*, *Arum pictum*, *Astragalus balearicus*, *Bellium bellidioides*, *Calicotome villosa, Carduncellus balearicus*, *Carlina corymbosa* subsp. *major, Chelidonium majus*, *Cneorum tricoccon*, *Coronilla montserratii*, *Crocus cambessedesii*, *Cyclamen balearicum*, *Helicodiceros muscivorus*, *Launaea cervicornis*, *Leucojum aestivum* subsp. *pulchellum, Limonium companyonis*, *Limonium minoricense*, *Limonium minutum*, *Limonium saxicola*, *Limonium tamarindanum*, *Lotus tetraphyllus*, *Matthiola tricuspidata*, *Micromeria filiformis*, *Micromeria rodriguezii*, *Ononis crispa*, *Orobanche cernua*, *Orobanche foetida*, *Orobanche rumseiana*, *Orobanche santolinae*, *Polycarpon colomense*, *Polycarpon dunense*, *Romulea assumptionis*, *Santolina chamaecyparissus* subsp. *magonica*, *Scrophularia ramosissima*, *Senecio rodriguezii*, *Sonchus montanus*, *Spergularia heldreichii, Teucrium capitatum* subsp. *majoricum*, *Teucrium subspinosum*, *Thymelaea velutina*, *Vicia bifoliolata*
Habitat recovery	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	A4. Selection of species for vegetation recovery C2. Removal of tracks and uncontrolled accesses C.3 Planting of native species to regenerate the vegetation C4. Construction of bridges on temporary Mediterranean torrents D6. Organisation of informative and civic participation sessions	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	*Anthyllis hystrix*, *Aristolochia clematitis*, *Aristolochia paucinervis*, *Arum pictum*, *Asplenium balearicum*, *Asplenium trichomanes* subsp. *inexpectans*, *Astragalus balearicus*, *Avena barbata* subsp. *castellana*, *Bellium bellidioides*, *Calicotome villosa, Carduncellus balearicus*, *Carlina corymbosa* subsp. *major, Chelidonium majus*, *Cneorum tricoccon*, *Coronilla montserratii*, *Crocus cambessedesii*, *Cyclamen balearicum*, *Digitalis minor*, *Echinophora spinosa*, *Epipactis microphylla*, *Euphorbia maresii* subsp. *maresii*, Helicodiceros muscivorus, *Launaea cervicornis*, *Leucojum aestivum* subsp. *pulchellum, Limonium companyonis*, *Limonium minoricense*, *Limonium minutum*, *Limonium saxicola*, *Limonium tamarindanum*, *Lotus tetraphyllus*, *Micromeria filiformis*, *Micromeria rodriguezii*, *Ononis crispa*, *Orobanche cernua*, *Orobanche foetida*, *Orobanche rumseiana*, *Orobanche santolinae*, *Paeonia cambessedesii*, *Pastinaca lucida*, *Polycarpon colomense*, *Polycarpon dunense*, *Romulea assumptionis*, *Santolina chamaecyparissus* subsp. *magonica*, *Scrophularia ramosissima, Senecio rodriguezii*, *Sonchus montanus*, *Spergularia heldreichii, Teucrium asiaticum*, *Teucrium capitatum* subsp. *majoricum*, *Teucrium subspinosum*, *Thymelaea velutina*, *Vicia bifoliolata*, *Viola stolonifera*
Specification of the cultivation methodology	Binimel·là – Cala Mica	A5. Explanation of the cultivation method for *Femeniasia balearica*	5430	*Carduncellus balearicus*
Collaboration with local entities and associations	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	A6. Technical consultation with NGOs and owners for assistance with environmental management D6. Organisation of informative and civic participation sessions	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	*Aristolochia clematitis*, *Aristolochia paucinervis*, *Asplenium trichomanes* subsp. *inexpectans*, *Astragalus balearicus*, *Bellium bellidioides*, *Calicotome villosa, Carduncellus balearicus*, *Carlina corymbosa* subsp. *major, Chelidonium majus*, *Cneorum tricoccon*, *Coronilla montserratii*, *Crocus cambessedesii*, *Cyclamen balearicum*, *Cymbalaria fragilis*, *Digitalis minor, Helicodiceros muscivorus*, *Launaea cervicornis*, *Leucojum aestivum* subsp. *pulchellum, Limonium companyonis*, *Limonium minoricense*, *Limonium minutumLimonium tamarindanum*, *Lotus tetraphyllus*, *Lysimachia minoricensis*, *Micromeria filiformis*, *Micromeria rodriguezii*, *Ononis crispa*, *Orobanche cernua*, *Orobanche foetida*, *Orobanche rumseiana*, *Orobanche santolinae*, *Paeonia cambessedesii*, *Polycarpon colomense*, *Polycarpon dunense*, *Romulea assumptionis*, *Santolina chamaecyparissus* subsp. *magonica*, *Scrophularia auriculata* subsp. *pseudoauriculata*, *Scrophularia ramosissima, Senecio rodriguezii*, *Sibthorpia africana*, *Silene mollissima*, *Sonchus montanus*, *Spergularia heldreichii, Teucrium asiaticum*, *Teucrium capitatum* subsp. *majoricum*, *Teucrium subspinosum*, *Thymelaea velutina*, *Vicia bifoliolata*, *Viola stolonifera*
Restoration of dry stone walls	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	C1. Construction of dry stone walls using traditional techniques C2. Removal of tracks and uncontrolled accesses C.3 Planting of native species to regenerate the vegetation	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	*Anthyllis hystrix*, *Arum pictum*, *Asplenium balearicum*, *Asplenium trichomanes* subsp. *inexpectans*, *Astragalus balearicus*, *Bellium bellidioides*, *Carduncellus balearicus*, *Carex rorulenta*, *Carlina corymbosa* subsp. *major, Chelidonium majus*, *Crepis triasii*, *Cressa Crocus cambessedesii*, *Cyclamen balearicum*, *Cymbalaria fragilis*, *Digitalis minor, Epipactis microphylla*, *Euphorbia maresii* subsp. *maresii*, *Helicodiceros muscivorus*, *Launaea cervicornis*, *Leucojum aestivum* subsp. *pulchellum, Limonium companyonis*, *Limonium minoricense*, *Limonium minutum*, *Limonium saxicola*, *Limonium tamarindanum*, *Lotus tetraphyllus*, *Lysimachia minoricensis*, *Micromeria cordata*, *Micromeria filiformis*, *Micromeria rodriguezii*, *Paeonia cambessedesii*, *Pastinaca lucida*, *Polycarpon colomense*, *Polycarpon dunense*, *Romulea assumptionis*, *Santolina chamaecyparissus* subsp. *magonica*, *Scrophularia ramosissima, Senecio rodriguezii*, *Sibthorpia africana*, *Silene mollissima*, *Sonchus montanus*, *Teucrium asiaticum*, *Teucrium capitatum* subsp. *majoricum*, *Teucrium subspinosum*, *Thymelaea velutina*, *Viola stolonifera*
Construction of new dry stone walls	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	C1. Construction of dry stone walls using traditional techniques C2. Removal of tracks and uncontrolled accesses C3. Planting of native species to regenerate the vegetation	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	*Anthyllis hystrix*, *Aristolochia clematitis*, *Aristolochia paucinervis*, *Arum pictum*, *Asplenium balearicum*, *Astragalus balearicus*, *Bellium bellidioides*, *Calicotome villosa, Carduncellus balearicus*, *Carex rorulenta*, *Carlina corymbosa* subsp. *major, Cneorum tricoccon*, *Cyclamen balearicum*, *Digitalis minor, Epipactis microphylla*, *Helicodiceros muscivorus*, *Launaea cervicornis*, *Leucojum aestivum* subsp. *pulchellum, Limonium companyonis*, *Limonium minoricense*, *Limonium minutum*, *Limonium saxicola*, *Limonium tamarindanum*, *Lomelosia cretica*, *Lotus tetraphyllus*, *Lysimachia minoricensisMicromeria cordata*, *Micromeria filiformis*, *Micromeria rodriguezii*, *Ononis crispa*, *Orobanche foetida*, *Orobanche rumseiana*, *Orobanche santolinae*, *Romulea assumptionis*, *Santolina chamaecyparissus* subsp. *magonica*, *Scrophularia ramosissima, Senecio rodriguezii*, *Sonchus montanus*, *Teucrium capitatum* subsp. *majoricum*, *Teucrium subspinosum*, *Vicia bifoliolata*, *Vincetoxicum hirundinaria* var. *balearicum*, *Viola stolonifera*

Results	Area	Actions	Habitats	Species
Construction or installation of ethnological elements	Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	C1. Construction of dry stone walls using traditional techniques C4. Construction of bridges over temporary Mediterranean torrents C5. Construction and installation of traditional gates and barriers	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	Asplenium trichomanes subsp. inexpectans, Bellium bellidioides, Carduncellus balearicus, Carlina corymbosa subsp. major, Chelidonium majus, Cyclamen balearicum, Leucojum aestivum subsp. pulchellum, Limonium companyonis, Limonium minoricense, Limonium minutum, Limonium saxicola, Limonium tamarindanum, Lotus tetraphyllus, Lysimachia minoricensis, Paeonia cambessedesii, Pastinaca lucidaSantolina chamaecyparissus subsp. magonica, Scrophularia ramosissima, Senecio rodriguezii, Teucrium asiaticum, Teucrium capitatum subsp. majoricum, Teucrium subspinosum, Viola stolonifera
List of most suitable plants for recovery of vegetation	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	A4. Selection of species for the recovery of vegetation C3. Planting of native species to regenerate the vegetation	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	Anacamptis morio subsp. longicornu, Anthyllis hystrix, Aristolochia clematitis, Aristolochia paucinervis, Arum pictum, Asplenium balearicum, Asplenium trichomanes subsp. inexpectans, Astragalus balearicus, Avena barbata subsp. castellana, Bellium bellidioides, Brimeura fastigiata, Calicotome villosa, Carduncellus balearicus, Carex rorulenta, Carlina corymbosa subsp. major, Chelidonium majus, Cneorum tricoccon, Coronilla glauca, Coronilla montserratii, Crepis triasii,Cressa cretica, Crocus cambessedesii, Cyclamen balearicum,Cymbalaria aequitriloba,Cymbalaria fragilis,Digitalis minor, Echinophora spinosa, Elatine macropoda, Epipactis microphylla, Equisetum telmateia, Euphorbia maresii subsp. maresii, Exaculum pusillum, Helicodiceros muscivorus, Hippocrepis balearica,Hypericum balearicum, Launaea cervicornis, Leucojum aestivum subsp. pulchellum, Limonium companyonis, Limonium minoricense, Limonium minutum, Limonium saxicola, Limonium tamarindanum, Lomelosia cretica, Lotus tetraphyllus, Lysimachia minoricensis, Matthiola tricuspidata, Melissa officinalis, Micromeria cordata, Micromeria filiformis, Micromeria rodriguezii, Ononis crispa, Ophrys balearica, Orobanche cernua, Orobanche foetida, Orobanche rumseiana, Orobanche santolinae, Paeonia cambessedesii, Paronychia capitata, Pastinaca lucida, Phlomis italica, Polycarpon colomense, Polycarpon dunense, Romulea assumptionis, Santolina chamaecyparissus subsp. magonica, Scrophularia auriculata subsp. pseudoauriculata, Scrophularia ramosissima, Senecio rodriguezii, Serapias nurrica, Sibthorpia africana, Silene mollissima, Sonchus montanus, Spergularia heldreichii, Teucrium asiaticum, Teucrium capitatum subsp. majoricum, Teucrium subspinosum, Thapsia gymnesica, Thymelaea velutina, Vicia bifoliolata, Vincetoxicum hirundinaria var. balearicum, Viola stolonifera
Development of methodologies and techniques to regenerate dune habitats	Binimel·là – Cala Mica Es Alocs – El Pilar	A2. Detailed cartography of the affected species distribution A4. Selection of species for the recovery of vegetation C2. Removal of tracks and uncontrolled accesses C3. Planting of native species to regenerate the vegetation	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	Coronilla montserratii, Echinophora spinosa, Matthiola tricuspidata, Ononis crispa, Orobanche foetida, Polycarpon colomense, Polycarpon dunense, Scrophularia ramosissima, Senecio rodriguezii, Thymelaea velutina
Reclamation	Es Murtar	A2. Detailed cartography of the affected species distribution C2. Removal of tracks and uncontrolled accesses C3. Planting of native species to regenerate the vegetation D6. Organisation of informative and civic participation sessions C6. Landscape recovering in the area of Es Murtar and regeneration of the fossil dune system E3. Establishment of the project's Monitoring Board	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	Arum pictum, Astragalus balearicus, Bellium bellidioides, Calicotome villosa, Cneorum tricoccon, Crocus cambessedesii, Exaculum pusillum, Launaea cervicornis, Leucojum aestivum subsp. pulchellum, Limonium companyonis, Lotus tetraphyllus, Micromeria filiformis, Micromeria rodriguezii, Ononis crispa, Orobanche foetida, Polycarpon colomense, Romulea assumptionis, Scrophularia ramosissima, Senecio rodriguezii, Sonchus montanus, Teucrium capitatum subsp. majoricum, Teucrium subspinosum, Vicia bifoliolata
Local population involvement	Es Murtar Es Alocs – El Pilar Pas d'en Revull	D6. Organisation of informative and civic participation sessions C3. Planting of native species to regenerate the vegetation E8. Communication and coordination with the land owners and affected social sectors D5. Deterrent campaign for drivers of motor vehicles in the natural environment	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	Anthyllis hystrix, Aristolochia clematitis, Aristolochia paucinervis, Arum pictum, Asplenium balearicum, Asplenium trichomanes subsp. inexpectans, Astragalus balearicus, Bellium bellidioides, Calicotome villosa, Carduncellus balearicus, Carex rorulenta, Carlina corymbosa subsp. major, Chelidonium majus, Cneorum tricoccon, Coronilla montserratii, Crepis triasii, Crocus cambessedesii, Cyclamen balearicum, Digitalis minor, Echinophora spinosa, Epipactis microphylla, Euphorbia maresii subsp. maresii, Exaculum pusillum, Helicodiceros muscivorus, Hippocrepis balearica, Launaea cervicornis, Leucojum aestivum subsp. pulchellum, Limonium companyonis, Limonium minoricense, Limonium minutum, Limonium saxicola, Limonium tamarindanum, Lomelosia cretica, Lotus tetraphyllus, Lysimachia minoricensis, Matthiola tricuspidata, Micromeria cordata, Micromeria filiformis, Micromeria rodriguezii, Ononis crispa, Orobanche cernua, Orobanche foetida, Orobanche rumseiana, Orobanche santolinae, Paeonia cambessedesii, Pastinaca lucida, Phlomis italica, Polycarpon colomense, Polycarpon dunense, Romulea assumptionis, Santolina chamaecyparissus subsp. magonica, Scrophularia ramosissima, Senecio rodriguezii, Sibthorpia africana, Silene mollissima, Sonchus montanus, Spergularia heldreichii, Teucrium asiaticum, Teucrium capitatum subsp. majoricum, Teucrium subspinosum, Thapsia gymnesica, Thymelaea velutina, Vicia bifoliolata, Vincetoxicum hirundinaria var. balearicum, Viola stolonifera
Visual identification of project	-	D1. Creation of the project's image	-	-
Pproject's information spreading	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	D2. Developing of the project's website E3. Establishment of the project's Monitoring Board	-	-

Results	Area	Actions	Habitats	Species
Dissemination of the flora and habitats importance	-	D3. Publishing of material focused on the increase of awareness on biodiversity and Natura 2000 network designed to younger audiences D8. Production of a DVD on LIFE project D9. On-line publishing about the biodiversity and endemic flora concentration focuses on the Island D10. Information and constant raising of awareness of society through both local and regional mass media D13. Installation of information panels about the LIFE project E3. Establishment of the project's Monitoring Board	-	-
Landscape restoration	-	A2. Detailed cartography of the affected species distribution C2. Removal of tracks and uncontrolled accesses C3. Planting of native species to regenerate the vegetation C4. Construction of bridges over temporary Mediterranean torrents D6. Organisation of informative and civic participation sessions	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	Anacamptis morio subsp. longicornu, Anthyllis hystrix, Aristolochia clematitis, Aristolochia paucinervis, Arum pictum, Asplenium balearicum, Asplenium trichomanes subsp. inexpectans, Astragalus balearicus, Avena barbata subsp. castellana, Bellium bellidioides, Brimeura fastigiata, Calicotome villosa, Carduncellus balearicus, Carex rorulenta,Carlina corymbosa subsp. major, Chelidonium majus, Cneorum tricoccon, Coronilla glauca, Coronilla montserratii, Crepis triasii,Cressa cretica, Crocus cambessedesii, Cyclamen balearicum,Cymbalaria aequitriloba,Cymbalaria fragilis,Digitalis minor, Echinophora spinosa, Elatine macropoda, Epipactis microphylla, Equisetum telmateia, Euphorbia maresii subsp. maresii, Exaculum pusillum, Helicodiceros muscivorus, Hippocrepis balearica,Hypericum balearicum, Launaea cervicornis, Leucojum aestivum subsp. pulchellum, Limonium companyonis, Limonium minoricense, Limonium minutum, Limonium saxicola, Limonium tamarindanum, Lomelosia cretica, Lotus tetraphyllus, Lysimachia minoricensis, Matthiola tricuspidata, Melissa officinalis, Micromeria cordata, Micromeria filiformis, Micromeria rodriguezii, Ononis crispa, Ophrys balearica, Orobanche cernua, Orobanche foetida, Orobanche rumseiana, Orobanche santolinae, Paeonia cambessedesii, Paronychia capitata, Pastinaca lucida, Phlomis italica, Polycarpon colomense, Polycarpon dunense, Romulea assumptionis, Santolina chamaecyparissus subsp. magonica, Scrophularia auriculata subsp. pseudoauriculata, Scrophularia ramosissima, Senecio rodriguezii, Serapias nurrica, Sibthorpia africana, Silene mollissima, Sonchus montanus, Spergularia heldreichii, Teucrium asiaticum, Teucrium capitatum subsp. majoricum, Teucrium subspinosum, Thapsia gymnesica, Thymelaea velutina, Vicia bifoliolata, Vincetoxicum hirundinaria var. balearicum, Viola stolonifera
Inclusion of geological values	Binimel·là – Cala Mica	D5. Deterrent campaign for drivers of motor vehicles in the natural environment E2. Establishment of the project's Scientific Board	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 3140 , 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 8210, 8220, 92D0 , 9320	Anthyllis hystrix, Arum pictum, Asplenium balearicum, Bellium bellidioides, Brimeura fastigiata, Carduncellus balearicus, Carex rorulenta, Carlina corymbosa subsp. major, Crocus cambessedesii, Cyclamen balearicum, Cymbalaria aequitriloba, Digitalis minor, Euphorbia maresii subsp. maresii, Helicodiceros muscivorus, Launaea cervicornis, Leucojum aestivum subsp. pulchellum, Limonium companyonis, Limonium minoricense, Limonium minutum, Limonium tamarindanum, Lotus tetraphyllus, Micromeria cordata, Micromeria filiformis, Micromeria rodriguezii, Orobanche rumseiana, Orobanche santolinae, Paronychia capitata, Pastinaca lucida, Phlomis italica, Polycarpon colomense, Romulea assumptionis, Santolina chamaecyparissus subsp. magonica, Scrophularia ramosissima, Senecio rodriguezii, Sonchus montanus, Teucrium capitatum subsp. majoricum, Teucrium subspinosum, Vicia bifoliolata, Vincetoxicum hirundinaria var. balearicum
Improvement on floristic knowledge	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	A4. Selection of species for the recovery of vegetation A2. Detailed cartography of the affected species distribution	1240 , 1410 , 1510 *, 2120, 2210, 2220 , 2230 , 2240, 2250 *, 2260, 2270 *, 3140 , 3170 *, 3290, 5210, 5320 , 5330 , 5430 , 6220 * , 6420, 8210, 8220, 92D0 , 9320 , 9340, 9540	Anacamptis morio subsp. longicornu, Anthyllis hystrix, Aristolochia clematitis, Aristolochia paucinervis, Arum pictum, Asplenium balearicum, Asplenium trichomanes subsp. inexpectans, Astragalus balearicus, Avena barbata subsp. castellana, Bellium bellidioides, Brimeura fastigiata, Calicotome villosa, Carduncellus balearicus, Carex rorulenta, Carlina corymbosa subsp. major, Chelidonium majus, Cneorum tricoccon, Coronilla glauca, Coronilla montserratii, Crepis triasii,Cressa cretica, Crocus cambessedesii, Cyclamen balearicum,Cymbalaria aequitriloba,Cymbalaria fragilis,Digitalis minor, Echinophora spinosa, Elatine macropoda, Epipactis microphylla, Equisetum telmateia, Euphorbia maresii subsp. maresii, Exaculum pusillum, Helicodiceros muscivorus, Hippocrepis balearica,Hypericum balearicum, Launaea cervicornis, Leucojum aestivum subsp. pulchellum, Limonium companyonis, Limonium minoricense, Limonium minutum, Limonium saxicola, Limonium tamarindanum, Lomelosia cretica, Lotus tetraphyllus, Lysimachia minoricensis, Matthiola tricuspidata, Melissa officinalis, Micromeria cordata, Micromeria filiformis, Micromeria rodriguezii, Ononis crispa, Ophrys balearica, Orobanche cernua, Orobanche foetida, Orobanche rumseiana, Orobanche santolinae, Paeonia cambessedesii, Paronychia capitata, Pastinaca lucida, Phlomis italica, Polycarpon colomense, Polycarpon dunense, Romulea assumptionis, Santolina chamaecyparissus subsp. magonica, Scrophularia auriculata subsp. pseudoauriculata, Scrophularia ramosissima, Senecio rodriguezii, Serapias nurrica, Sibthorpia africana, Silene mollissima, Sonchus montanus, Spergularia heldreichii, Teucrium asiaticum, Teucrium capitatum subsp. majoricum, Teucrium subspinosum, Thapsia gymnesica, Thymelaea velutina, Vicia bifoliolata, Vincetoxicum hirundinaria var. balearicum, Viola stolonifera
Exchange of experiences and results	Es Murtar Binimel·là – Cala Mica Es Alocs – El Pilar Pas d'en Revull	D7. Planning of botanical routes within the flora microreserve in Pas d'en Revull and El Pilar area D11. Dissemination of scientific results E6. Networking with other LIFE projects E2. Establishment of the project's Scientific Board E3. Establishment of the project's Monitoring Board	-	-

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Appendix 1. Habitats included in the Habitats Directive of the EU and taxa of conservation interest of the vascular flora they hold

Habitat	Taxa	Conservation interest[(1)]
1130 Estuaries	*Zostera noltii* Hornem.	Less than five populations
1150 * Coastal lagoons	*Althenia orientalis* (Tzvelev) García Murillo et Talavera	Less than five populations
	Tripolium pannonicum (Jacq.) Dobrocz.	Less than five populations
1160 Large shallow inlets and bays	*Althenia orientalis* (Tzvelev) García Murillo et Talavera	Scattered populations within the whole distribution area
1210 Annual vegetation of drift lines	*Salicornia emerici* Duval-Jouve	Less than five populations
	Atriplex tornabenei Tineo ex Guss.	Less than five populations
1240 Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium spp.*	*Anthemis secundiramea* Biv.	Single population within the Iberian flora
	Arum pictum L. f.	Endemic
	Limonium artruchium Erben	Endemic
	Limonium biflorum (Pignatti) Pignatti	Endemic
	Limonium fontqueri (Pau) L. Llorens	Endemic
	Limonium minoricense Erben	Endemic
	Limonium minutum (L.) Chaz.	Endemic
	Limonium saxicola Erben	Endemic
	Limonium tamarindanum Erben	Endemic
	Orobanche iammonensis Pujadas et P. Fraga	Endemic
	Polycarpon colomense Porta	Endemic
	Senecio rodriguezii Willk. ex J.J. Rodr.	Endemic
1310 *Salicornia* and other annuals colonising mud and sand	*Tripolium pannonicum* (Jacq.) Dobrocz.	Less than five populations
1410 Mediterranean salt meadows (*Juncetalia maritimi*)	*Allium coppoleri* Tineo	Less than five populations
	Tripolium pannonicum (Jacq.) Dobrocz.	Less than five populations
1510 * Mediterranean salt steppes (*Limonietalia*)	*Cressa cretica* L.	Less than five populations
2120 Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)	*Echinophora spinosa* L.	Less than five populations
2210 *Crucianellion maritimae* fixed beach dunes	*Echinophora spinosa* L.	Less than five populations
2220 Dunes with *Euphorbia terracina*	*Cyperus capitatus* Vand.	Single population
	Otanthus maritimus (L.) Hoffmanns.	Single population
	Scrophularia ramosissima Loisel.	Endemic
2230 *Malcolmietalia dune* grasslands	*Coronilla montserratii* P. Fraga et Rosselló	Endemic
	Polycarpon dunense P. Fraga et Rosselló	Endemic
	Matthiola tricuspidara (L.) R. Br.	Endemic
2230 *Malcolmietalia dune* grasslands	*Senecio rodriguezii* Willk. ex J.J. Rodr.	Endemic
2240 *Brachypodietalia* dune grasslands with annuals	*Coronilla montserratii* P. Fraga et Rosselló	Endemic
2250 * Coastal dunes with *Juniperus spp.*	*Coronilla montserratii* P. Fraga et Rosselló	Endemic
	Catapodium hemipoa Delile ex Spreng.	Less than five populations
2260 *Cisto-Lavenduletalia* dune sclerophyllous scrubs	*Cneorum tricoccon* L.	Single population
	Coronilla montserratii P. Fraga et Rosselló	Endemic
	Catapodium hemipoa Delile ex Spreng.	Less than five populations
	Echium arenarium Guss.	Single population
	Euphorbia nurae P. Fraga et Rosselló	Endemic
	Ononis crispa L.	Endemic
	Orobanche foetida Poir.	Less than five populations
	Scrophularia ramosissima Loisel.	Endemic
	Thymelaea velutina (Pourr. ex Cambess.) Endl.	Endemic
2270 * Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*	*Coronilla montserratii* P. Fraga et Rosselló	Endemic
3120 Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean with *Isoetes spp.*	*Isoetes histrix* Bory	Less than five populations
	Acis autumnalis (L.) Sweet	Narrow distribution
3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or *Isoeto-Nanojuncetea*	*Isoetes histrix* Bory	Less than five populations
3140.Oligotrophic standing waters with benthos vegetation of Chara *spp.*	*Potamogeton crispus* L.	Less than five populations
	Potamogeton pusillus L.	Less than five populations
	Ranunculus tricophyllus Chaix	Less than five populations
3170 * Mediterranean temporary ponds	*Bupleurum tenuissimum* L.	Less than five populations
	Callitriche obtusangula Le Gall	Less than five populations
	Centunculus minimus L.	Less than five populations
	Corrigiola littoralis L.	Less than five populations
	Damasonium bourgaei Coss.	Small and scattered populations
	Elatina macropoda Guss.	Small and scattered populations
	Eleocharis acicularis Roem. et Schult.	Single population
	Exaculum pusillum (Lam.) Caruel	Small and scattered populations
	Galium debile Desv.	Small and scattered populations
	Isoetes velata A. Braun	Small and scattered populations
	Lythrum tribracteatum Spreng.	Small and scattered populations
	Marsilea strigosa Willd.	Less than five populations
	Myriophyllum alterniflorum DC.	Single population
	Pilularia minuta Durieu ex A. Braun	Less than five populations
	Polygonum romanum subsp. *balearicum* Raffaelli et L. Villar	Endemic
	Pulicaria vulgaris Gaertn.	Less than five populations
	Ranunculus tricophyllus Chaix	Less than five populations
	Teucrium scordium L.	Less than five populations
	Thymelaea gussonei Boreau	Less than five populations
	Trifolium micranthum VIv.	Less than five populations
	Trifolium ornithopodioides L.	Less than five populations
	Verbena supina L.	Small and scattered populations
	Zannichellia obtusifolia Talavera, Garcia Murillo et Smit	Small and scattered populations
3290 Intermittently flowing Mediterranean rivers of the *Paspalo-Agrostidion*	*Calystegia sylvatica* (Kit.) Griseb.	Single population
	Equisetum telmateia Ehrh.	Less than five populations
	Zannichellia obtusifolia Talavera, Garcia Murillo et Smit	Small and scattered population
	Zannichellia peltata Bertol.	Less than five populations
	Allium subvillosum Salzm. Ex Schult et Schult f.	Small and scattered populations

Habitat	Taxa	Conservation interest[1]
	Arum pictum L. f.	Endemic
	Bellium artrutxensis P. Fraga et Rosselló	Endemic
	Bellium bellidioides L.	Endemic
	Crocus cambessedesii Gay	Endemic
	Helicodiceros muscivorus (L. f.) Engl.	Endemic
5210 Arborescent matorral with *Juniperus spp.*	*Micromeria filiformis* (Aiton) Benth.	Endemic
	Micromeria rodriguezii Freyn. et Janka	Endemic
	Polycarpon colomense Porta	Endemic
	Romulea assumptionis Garcias Font	Endemic
	Teucrium capitatum subsp. *majoricum* (Rouy) T. Navarro et Rosúa	Endemic
	Teucrium subspinosum (Pourr.) Willd.	Endemic
	Aristolochia bianori Sennen et Pau	Endemic
	Crocus cambessedesii Gay	Endemic
	Helicodiceros muscivorus (L. f.) Engl.	Endemic
5320 Low formations of *Euphorbia* close to cliffs	*Polycarpon colomense* Porta	Endemic
	Malva minoricensis Cambess.	Endemic
5320 Low formations of *Euphorbia* close to cliffs	*Micromeria filiformis* (Aiton) Benth.	Endemic
	Micromeria rodriguezii Freyn. et Janka	Endemic
	Teucrium capitatum subsp. *majoricum* (Rouy) T. Navarro et Rosúa	Endemic
	Teucrium subspinosum (Pourr.) Willd.	Endemic
	Thapsia gymnesica Rosselló et A. Pujadas	Endemic
	Allium subvillosum Salzm. Ex Schult et Schult f.	Small and scattered populations
	Bellium artrutxensis P. Fraga et Rosselló	Endemic
	Bellium bellidioides L.	Endemic
	Crocus cambessedesii Gay	Endemic
	Cyclamen balearicum Willk.	Endemic
	Daphne rodriguezii Teixidor	Endemic
	Helicodiceros muscivorus (L. f.) Engl.	Endemic
	Euphorbia nurae P. Fraga et Rosselló	Endemic
	Fumana juniperina (Lag. ex Dunal) Pau	Single population
	Leuzea conifera (L.) DC.	Single population
	Lotus tetraphyllus L.	Endemic
	Malva minoricensis Cambess.	Endemic
	Micromeria filiformis (Aiton) Benth.	Endemic
	Micromeria rodriguezii Freyn. et Janka	Endemic
5330 Thermo-Mediterranean and pre-desert scrub	*Ononis crispa* L.	Endemic
	Ophrys balearica Delforge	Endemic
	Orobanche rumseiana Pujadas et P. Fraga	Endemic
	Phlomis italica L.	Endemic
	Rhamnus ludovici-salvatoris Chodat	Endemic
	Romulea assumptionis Garcias Font	Endemic
	Santolina chamaecyparissus subsp. *magonica* O. Bolòs, Molin. et P. Monts.	Endemic
	Serapias nurrica Corrias	Endemic
	Teline monspessulana (L.) K. Koch	Single population
	Teucrium balearicum (Pau) Castrov. et Bayón	Endemic
	Teucrium capitatum subsp. *majoricum* (Rouy) T. Navarro et Rosúa	Endemic
	Teucrium subspinosum (Pourr.) Willd.	Endemic
5330 Thermo-Mediterranean and pre-desert scrub	*Thapsia gymnesica* Rosselló et A. Pujadas	Endemic
	Thymelaea velutina (Pourr. ex Cambess.) Endl.	Endemic
	Valantia hispida L.	Less than five populations
	Vicia bifoliolata J.J. Rodr.	Endemic
	Viola arborescens L.	Less than five populations
	Anthyllis hystrix (Willk. ex Barc.) Cardona, Contandr. et Sierra	Endemic
	Astragalus balearicus Chater	Endemic
	Bellium bellidioides L.	Endemic
	Crocus cambessedesii Gay	Endemic
	Lotus fulgurans (Porta) Sokolov	Endemic
	Helicodiceros muscivorus (L. f.) Engl.	Endemic
	Euphorbia maresii Knoche	Endemic
	Carduncellus balearicus (J.J. Rodr.) G. López	Endemic
	Malva minoricensis Cambess.	Endemic
	Launaea cervicornis (Boiss.) Font Quer et Rothm.	Endemic
	Lotus tetraphyllus L.	Endemic
5430 Endemic phryganas of the *Euphorbio-Verbascion*	*Micromeria filiformis* (Aiton) Benth.	Endemic
	Micromeria cordata (Moris ex Bertol.) Moris	Endemic
	Micromeria rodriguezii Freyn. et Janka	Endemic
	Orobanche santolinae Loscos et J. Pardo	Less than five population
	Polycarpon colomense Porta	Endemic
	Romulea assumptionis Garcias Font	Endemic
	Santolina chamaecyparissus subsp. *magonica* O. Bolòs, Molin. et P. Monts.	Endemic
	Senecio rodriguezii Willk. ex J.J. Rodr.	Endemic
	Teucrium balearicum (Pau) Castrov. et Bayón	Endemic
	Teucrium capitatum subsp. *majoricum* (Rouy) T. Navarro et Rosúa	Endemic
	Teucrium subspinosum (Pourr.) Willd.	Endemic
	Thapsia gymnesica Rosselló et A. Pujadas	Endemic
	Thymelaea velutina (Pourr. ex Cambess.) Endl.	Endemic
6220 * Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	*Aegilops neglecta* Req. ex Bertol.	Small and scattered populations
	Allium nigrum L.	Single population
	Rostraria pubescens (Lam.) Trin.	Single population

Habitat	Taxa	Conservation interest[1]
	Crocus cambessedesii Gay	Endemic
	Leucojum aestivum subsp. *pulchellum* (Salisb.) Briq.	Endemic
	Neatostema apulum (L.) I.M. Johnst.	Less than five populations
	Ononis alopecuroides L.	Single population
6420 Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*	*Althaea officinalis* L.	Small and scattered populations
	Lotus gracile Salisb.	Single population
	Elytrigia atherica (Link) Kerguélen	Single population
	Leucojum aestivum subsp. *pulchellum* (Salisb.) Briq.	Endemic
	Oenanthe lachenalii C.C. Gmel.	Less than five populations
	Ranunculus repens L.	Less than five populations
	Sonchus aquatilis Pourr.	Single population
8210 Calcareous rocky slopes with chasmophytic vegetation	*Allium antonii-bolosii* Palau	Endemic
	Asplenium petrarchae (Guérin) DC.	Less than five populations
	Bellium bellidioides L.	Endemic
	Carex rorulenta Porta	Endemic
	Brimeura fastigiata (Viv.) Chouard	Endemic
	Chelianthes acrostica (Balbis) Tod.	Single population
	Coronilla glauca L.	Single population
	Crepis triasii (Camb.) Nyman	Endemic
	Cyclamen balearicum Willk.	Endemic
	Cymbalaria aequitriloba (Viv.) A. Cheval	Endemic
	Cymbalaria fragilis J.J. Rodr.	Endemic
	Digitalis minor L.	Endemic
	Erodium reichardii (Murray) DC.	Endemic
	Euphorbia maresii Knoche	Endemic
	Helichrysum ambiguum (L.) C. Presl	Endemic
	Hippocrepis balearica Jacq.	Endemic
	Hypericum balearicum L.	Endemic
	Lavatera olbia L.	Single population
	Magydaris pastinacea subsp. *femeniesii* O. Bolòs et Vigo	Endemic
	Matthiola tricuspidara (L.) R. Br.	Less than five populations
	Micromeria filiformis (Aiton) Benth.	Endemic
	Micromeria cordata (Moris ex Bertol.) Moris	Endemic
	Paeonia cambessedesii (Willk.) Willk.	Endemic
	Pastinaca lucida L.	Endemic
	Romulea assumptionis Garcias Font	Endemic
	Lomelosia cretica (L.) Greuter et Burdet	Endemic
8210 Calcareous rocky slopes with chasmophytic vegetation	*Scilla obtusifolia* (Guss.) Bég	Single population
	Sibthorpia africana L.	Endemic
	Silene mollissima (L.) Pers.	Endemic
	Teucrium asiaticum L.	Endemic
	Teucrium capitatum subsp. *majoricum* (Rouy) T. Navarro et Rosúa	Endemic
8220 Siliceous rocky slopes with chasmophytic vegetation	*Asplenium balearicum* Shivas	Endemic
	Bellium bellidioides L.	Endemic
	Brimeura fastigiata (Viv.) Chouard	Endemic
	Cosentinia vellaea (Aiton) Tod.	Single population
	Cymbalaria aequitriloba (Viv.) A. Cheval	Endemic
	Digitalis minor L.	Endemic
	Micromeria cordata (Moris ex Bertol.) Moris	Endemic
	Pastinaca lucida L.	Endemic
	Romulea assumptionis Garcias Font	Endemic
	Romulea revelieri Jordan et Fourr.	Endemic
	Silene mollissima (L.) Pers.	Endemic
	Teucrium capitatum subsp. *majoricum* (Rouy) T. Navarro et Rosúa	Endemic
	Trigonella monspeliaca L.	Single population
92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)	*Aristolochia clematitis* L.	Single population
	Leucojum aestivum subsp. *pulchellum* (Salisb.) Briq.	Endemic
	Tamarix boveana Bunge	Single population
	Urtica atrovirens Loisel.	Endemic
	Viola stolonifera J.J. Rodr.	Endemic
	Vitex agnus-castus L.	Small and scattered populations
9320 *Olea* and *Ceratonia* forests	*Sonchus montanus* (Willk.) Rosselló	Endemic
	Anemone coronaria L.	Small and scattered populations
	Cyclamen balearicum Willk.	Endemic
	Lotus tetraphyllus L.	Endemic
9340 *Quercus ilex* and *Quercus rotundifolia* forests	*Asplenium trichomanes* subsp. *Quadrivalens* D.E. Meyer	Less than five localities known
	Cephalanthera damasonium (Mill.) Druce	Single population
	Cyclamen balearicum Willk.	Endemic
	Leucojum aestivum subsp. *pulchellum* (Salisb.) Briq.	Endemic
	Paeonia cambessedesii (Willk.) Willk.	Endemic
	Quercus suber L.	Small and scattered populations
	Viburnum tinus L.	Single population
	Viola alba Bess.	Single population
	Viola stolonifera J.J. Rodr.	Endemic
9540 Mediterranean pine forests with endemic Mesogean pines	*Juniperus oxycedrus* subsp. *oxycedrus* L.	Single population
	Pinus pinaster Aiton	Relict population in the Balearic Islands

TUSCAN ARCHIPELAGO FLORA: FROM GENESIS TO CONSERVATION

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Abstract

The Tuscan Archipelago consists of seven islands and about twenty islets and is one of the most interesting areas in the Tyrrhenian Sea from a naturalistic and anthropological point of view. The Archipelago is geologically related to the evolution of the northern Apennine and the Cyrno-Sardinian block. Currently, the flora of the entire Tuscan Archipelago is made up of 1,300 *taxa*, 80% of which are herbaceous, reflecting the Mediterranean setting of the area and the prevalence of secondary vegetation forms; 1.2% of *taxa* are endemic, most of which are related to Cyrno-Sardinian elements, suggesting that the Tuscan Archipelago represents a bridge between the floristic Cyrno-Sardinian territories and the Italian peninsula. Human influence on the natural environment has been massive since Roman times (5th century B.C.), and more recently changes in land use and the development of tourism have increased the level of threat upon the flora. Following the constitution of the National Park of the Tuscan Archipelago, several activities, e.g. LIFE Natura Projects, were launched to contrast the loss of biodiversity due to (1) habitat damage, (2) invasion of foreign plants and animals, and (3) change in ecological patterns. *In situ* conservation measures are backed by *ex situ* programmes in an integrated fashion, both as a safety tool and as source of material for reintroduction projects. Through this study we try to suggest further opportunities for new strategies of conservation.

Keywords: *Tuscan Archipelago, endemic flora, National Park,* in situ *conservation, ex situ conservation, seed banks.*

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"*Islands are an enormous source of information and unparalleled testing sites for several scientific theories. But this great relevance places an obligation on us. Their biota is vulnerable and precious. We must protect it. We have an obligation to hand over this singular fauna and flora with a minimum of loss from generation to generation. What is once lost is lost forever because a large extension of the island biota is unique. The Island's fauna offers us a great deal of information both scientifically and aesthetically. Let us do our share to live up to our obligations for their permanent preservation*". E. Mayr, 1967: 374

INTRODUCTION

The Tuscan Archipelago is made up of seven islands: Elba, Giglio, Capraia, Montecristo, Pianosa, Giannutri and Gorgona; furthermore there are several islets, less than 10 ha in size (Fig. 1). All islands have been explored several times over the last centuries. Between the 19th and 20th centuries Stèphen Sommier published the first comprehensive study on the Tuscan Archipelago flora (Sommier, 1902, 1903). His work is considered one of the first studies devoted to a group of small islands (Greuter, 1995).

Starting from the mid-1900s, several reviews followed, like the completion of the floristic list of Montecristo (Paoli & Romagnoli, 1976) and Elba Island (Fossi Innamorati, 1983, 1989, 1991, 1994, 1997), the contributions by Baldini (1998, 2000, 2001) for Giglio, Pianosa and Giannutri respectively, by Foggi *et al*. (2001a) for Capraia. The islets' flora was also studied (Baldini, 1990, 1991 and Foggi *et al*., 2009). Based on this data and on numerous floristic (Mannocci, 2004; Frangini *et al*., 2005, 2007; Borzatti & Mannocci, 2008; Carta *et al*., 2008a; Peruzzi *et al*., 2008) and taxonomic acquisitions (Signorini & Foggi, 1998; Peruzzi & Carta, 2011; Peruzzi & Carta, 2013), a review of the flora on these islands -currently under construction- was undertaken.

Over recent decades the biota of the Tuscan Archipelago has undergone severe changes mostly due to socio-economic transformations, shared by all the Mediterranean islands (Delanoë *et al*., 1996), that increased the threat level over the flora. Since the initiation of the Tuscan Archipelago National Park (1996), several initiatives for the conservation of flora and related habitats have begun. Their goals are (1) to describe main patterns of plant diversity in the Archipelago, (2) to discuss major threats affecting plant diversity and the most important actions undertaken to contrast them and (3) to suggest further opportunities for new strategies of conservation.

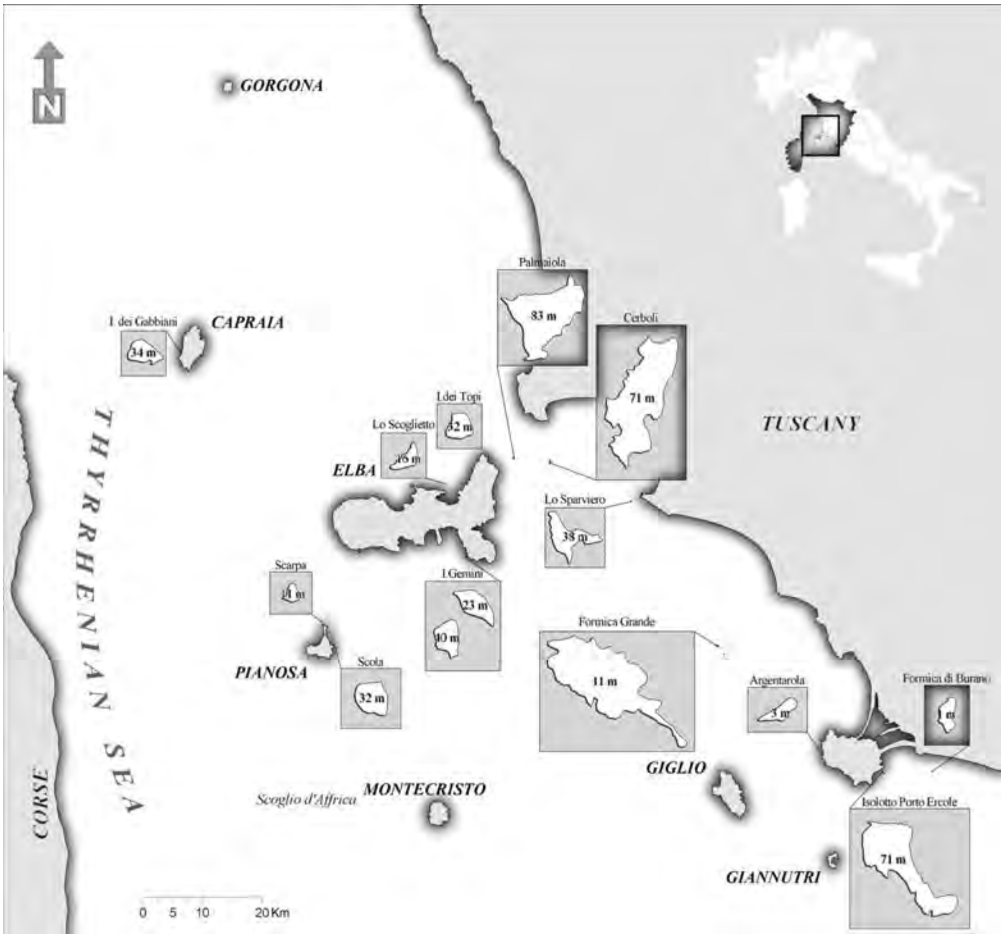

Fig. 1. The Tuscan Archipelago. The islets are highlighted in the boxes.

GENESIS OF THE ARCHIPELAGO AND ORIGIN OF THE FLORA

The geological history of the Tuscan Archipelago begins in the Upper Oligocene, in connection with the evolution of northern Apennine and the Cyrno-Sardinian block (Carmignani *et al*., 1995; Bortolotti *et al*., 2001). The influences of terrestrial connections among the Cyrno-Sardinian-block and the Ligurian-Provenzal areas are demonstrated by the current presence of both Cyrno-Sardinian and Thyrrenian endemic qualities in the Tuscan Archipelago (Table 1) (Arrigoni, 1975; Bertacchi *et al*., 2005). During the last ice-age, some of the islands (Elba, Pianosa, Giglio, Giannutri) were an integral part of the peninsula: these links allowed the migration of southern Mediterranean species (*Ranunculus bullatus* L.) or boreal species (*Ostrya carpinifolia* Scop.), which are now present only on Elba island thanks to its mesophilous climate belt, non-existent on other islands.

Endemic species belonging to the Corso-Sardinian territories	GOR	CAP	ELB	GIA	GIG	PIA	MON
Arum pictum L. fil.							•
Borago pygmaea (DC.) Chater et W. Greuter		•					
Carduus fasciculiflorus Viv.							•
Carex microcarpa Bertol. ex Moris		•	•		•		
Festuca arundinacea Schreber subsp. *corsica* (Hack.) Kerguélen		•					
Galium caprarium Natali	•	•					
Hypericum hircinum L.			•				?
Limonium contortirameum (Mabille) Erben		•					
Mentha suaveolens Ehrh. subsp. *insularis* (Req.) Greuter		•					
Pancratium illyricum L.		•	•				
Scrophularia trifoliata L.	•						•
Soleirolia soleirolii (Req.) Dandy		•					
Stachys glutinosa L.		•					
Stachys salisii Jord. & Fourr.		•	•				
Trisetaria burnoufii (Req. ex Parl.) Banfi et Soldano		•					
Verbascum conocarpum Moris							•
Urtica atrovirens Req. ex Loisel.	•	•	•		•	•	
Endemic species belonging to the Thyrrhenian territories							
Helichrysum litoreum Guss.	•	•	•	•	•	•	•
Ophrys exaltata Ten. subsp. *tyrrhena* (Gölz et Reinh.) Del Prete		•					
Silene badaroi Breistr.	•	•	•				

Table 1. Endemic species belonging to the Corso-Sardinian and the Thyrrhenian territories.

Although it is difficult to reconstruct the geological events that could help us to recognize past links between islands and mainland, it is possible to find some major patterns in the composition of the flora: (1) the Tuscan Archipelago flora is largely (70%) constituted by Mediterranean and Tethydic species present since late Tertiary (Arrigoni, 1975), (2) while some islands (Gorgona, Capraia and Montecristo) show floristic affinities with the Cyrno-Sardinian territories; others (Pianosa, Giglio, Giannutri) are clearly linked to the Tyrrhenian lands (Arrigoni *et al*., 2003), and (3) Elba island appears to be divided into two sectors: the west, with obvious affinities with the Cyrno-Sardinian territories, and the east, similar to the Ligurian-Thyrrhenic territories (Foggi *et al*., 2006).

Moreover, insularity set the stage for the differentiation or conservation of species exclusive to the Archipelago, which eventually became endemic (Garbari, 1990). The percentage of endemic plants on the Tuscan Archipelago (about 1.2%), is very low compared with other Mediterranean islands, even more so on account of the high density of species (Greuter, 1995). The highest number of endemisms occurs on Elba and Capraia islands (Table 2).

Endemic species exclusive to the Tuscan Archipelago	GOR	CAP	ELB	GIA	GIG	PIA	MON	FOR
Biscutella pichiana Raffaelli subsp. *ilvensis* Raffaelli			•					
Centaurea aethaliae (Sommier) Bég.			•					
Centaurea gymnocarpa Moris et De Not.		•						
Centaurea ilvensis (Sommier) Arrigoni			•					
Crocus ilvensis Peruzzi et Carta			•					
Festuca gamisansii Kerguélen subsp. *aethaliae* Signorini et Foggi			•					
Limonium doriae (Somm.) Pign.								•
Limonium gorgonae Pign.	•							
Limonium ilvae Pign.			•					
Limonium planesiae Pign.						•		
Limonium sommierianum (Fiori) Arrigoni				•	•		•	
Linaria capraria Moris et De Not.	•	•	•		•	•	•	
Mentha requienii Benth. subsp. *bistaminata* Mannocci et Falconcini		•					•	
Romulea insularis Sommier		•	•					
Silene capraria Sommier		•						
Viola corsica Nyman subsp. ilvensis (W.Becker) Merxm.			•					

Table 2. Endemic species exclusive to the Tuscan Archipelago.

Many of them (e.g *Viola corsica* subsp. *ilvensis*) are related to Cyrno-Sardinian *taxa*, and only a few (e.g. *Crocus ilvensis*) to peninsular *taxa*. Very interesting evidence obtained from genetic analysis is the presence of *L. capraria*, the only endemic species found in almost all the Archipelago islands: contrary to what was suggested on the basis of morphological data, *L. capraria* seems to be closer to *L. cossoni* and *L. purpurea* rather than *L. arcusangeli* (Coppi *et al*., 2013).

In addition to endemic species, there are species with an interesting disjunctive distribution scope, especially with a western or southern Mediterranean distribution that in the Tuscan Archipelago reach their eastern or northernmost locations as peripheral isolated plant populations. This is the result both of palaeobiogeographical influences and the presence of considerable environmental diversity that supports rich diversity of ecological niches: such as, *Cymbalaria aequitriloba* (Viv.) Cheval. grows in shaded and wet rock communities; *Gennaria diphylla* (Link) Parl. in lowland therophytic grasslands; *Gagea bohemica* (Zauschn.) Schult. & Schult. f. in supramediterranean therophytic grasslands; *Cneorum tricoccon* L. in thermomediterranean maquis; *Brassica procumbens* (Poir.) O.E. Schultz in abandoned cultivations. The Tuscan Archipelago is also one of the richest areas of pteridophytic diversity in Tuscany, with significant populations of micropteridophytes of ephemeral wetlands (Carta *et al*., 2008a and b) and the presence of species of phytogeographical interest like *Cosentinia vellea* (Aiton) Tod. (Atzori, 2007), *Asplenium balearicum* Shivas (Foggi *et al*., 2001), *Asplenium septentrionale* (L.) Hoffm. (Foggi *et al*., 2006), and *Phyllitis sagittata* (DC.) Guinea & Heywood (Baldini, 2000).

DIVERSITY FACTORS AND FLORAL COMPOSITION OF THE ISLANDS

Environmental and vegetation diversity determine floristic richness (Arrigoni *et al.*, 2003). The flora around the entire Tuscan Archipelago consists of 1,300 *taxa*, scattered around the different islands as shown in Table 3. The influence of land surface area on floristic diversity of the islands shows a logical increase in floristic diversity (Arrigoni *et al.*, 2003).

Island	Area (Ha)	Max. alt. (m)	Min. dist. from Corsica (Km)	Min. dist. from Tuscany (Km)	Min. dist. from Elba (Km)	Substrate	Number of *taxa*
Elba	22409	1018	50	9	-	Several	1043
Giglio	2154	498	108	15	52	Granite/Limestone	708
Capraia	1931	447	27	52	33	Trachyte	669
Montecristo	1043	645	60	66	40	Granite	465
Pianosa	1028	27	42	57	13	Limestone	532
Giannutri	239	93	127	11	75	Limestone	337
Gorgona	225	255	59	34	72	Granite	528

Table 3. Physiographical and floristic characters of the Tuscan Archipelago islands.

Capraia and Giglio, of approximately the same size and with similar topographical-edaphic characters, show roughly the same floristic diversity. However, their floristic affinity (Fig. 2) is not significant, due to different geographical settings and the origin of their respective flora. The affinity indices for Elba are only partially indicative because its size, and consequently its flora, differ widely from the rest of the islands (Peruzzi *et al.*, 2012). In fact, Elba can boast about having 80.23% of the entire Archipelago flora.

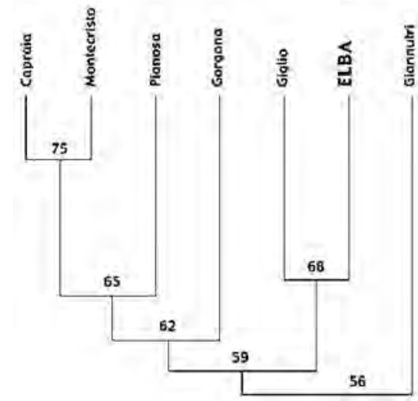

Figure 2. Floristic similarity calculated using the Sorensen index (presence-absence data).

Only 132 species are present on all the islands. These are mostly annual herbs and grasses, with Mediterranean, Euro-Mediterranean and Euro-Tethydic distribution; they mostly belong to marginal habitats and more or less xerophytic meadows (Arrigoni *et al*., 2003). The islets show a strong floristic autonomy to one another. No species is present on all the islets, while 90 species (i.e. about 50% of the total islet flora) are found on only one islet (Foggi *et al*., 2009b).

From a chorological point of view (Table 4), there is a prevalence of Mediterranean and Tethydic elements. Nevertheless, the abundant presence of Euro-Mediterranean and Euro-Tethydic species reveals a rather northern Mediterranean floristic combination.

Chorological groups	**%**
Endemic species of the Archipelago	1.2
Endemic qualities of the Cyrno-Sardian lands	1.3
Endemic qualities of the Thyrrhenian lands	0.3
Mediterranean	26.8
Mediterranean and Tethydic	9.7
European-Mediterranean and European-Tethydi	32.3
European	4.0
Eurosiberian. Olartic and Boreal	14.4
Subcosmopolite and Cosmopolite	5.7
Adventitious	3.9

Table 4. Percentage of major chorological groups in the Tuscan Archipelago flora.

The distribution of the growth forms, the phenologic cycle and the ecological spectrum of the flora in the Archipelago (Table 5) reflect the Mediterranean setting of the area and the prevalence of anthropogenic, secondary forms of vegetation. The prevalent growth form is shown by herbs with late-winter vegetative development that forms especially in open, sunny areas derived from the degradation of woodlands. Human influence has been massive since Roman times (5^{th} century b.c.), while over recent decades, after the decrease of mining and agricultural activity, the vegetation has evolved towards more structured communities.

Growth forms	%	Ecological elements	%
Hydrophytes (HY)	1.0	Halophytic	3.2
Pteridophytes (PT)	2.6	Casmophytic	6.2
Parasitic (Ø) (herbaceous)	1.3	Commensal	1.2
Woody	13.0	Helophytic	0.9
Trees (W)	2.1	Hydrophytic	0.3
Saplings (WA)	0.9	Hygrophytic	7.1
Shrubs (WB)	2.0	Lithophytic	3.5
Lianas (WL)	0.5	Ruderal	8.6
Frutexes (WF)	2.3	Marginal	37.1
Suffrutexes (WS)	5.1	Nemorose	7.8
Herbs	81.9	Orophytic	0.08
Annual (HA)	41.3	Meadowy	14.1
Biennial and perennial (HB. HP)	40.6	Psammophytic	1.2
		Ubiquitous	0.8
		Xerophytic	7.4

Table 5. Percentage of growth forms and ecological elements in the Archipelago flora.

MAIN THREATS AFFECTING PLANT DIVERSITY IN THE TUSCAN ARCHIPELAGO

The Tuscan Archipelago economy has experienced a spectacular increase during the last thirty years, with deleterious impacts on landscape and indigenous flora and vegetation (Arrigoni *et al*., 2003; Foggi *et al*., 2006). All threats are directly or indirectly related to human activities, in particular following the abandonment of agriculture and the subsequent increase of tourism and trade: (1) housing developments are a common feature near the coast, related to tourism and recreational development, affecting the residual sand dune systems, the stability of sea cliffs and the hygrophilous coenoses on floodplains; (2) the reduction of cultivated surfaces led to change in landscape patterns, paving the way for the evolution of Mediterranean series of vegetation in a progressive direction, towards the re-establishment of *Quercus ilex* woods, while reducing open habitats where high biodiversity coenoses are typical (Foggi *et al*., 2008); (3) reforestation is a highly disturbing factor; conifer reforestation, in particular, drastically alters the ecology of the sites; pine plantations (*Pinus halepensis* Mill. and *Pinus pinaster* Aiton) negatively affect the preservation of habitats of great value like e.g. *Juniperus turbinata* Guss. brushwood on Pianosa Island (Foggi *et al*., 2009a) and *Quercus ilex-Ostrya carpinifolia* woods on Elba

(Foggi *et al*., 2006); (4) an excessive number of wild introduced herbivores, especially ungulates like goats, mouflon and boar (*Capra hircus*, *Ovis musimom*, *Sus scrofa*). These species, foreign to the Tuscan Archipelago's fauna, threaten the renewal of woodland species and decimate a large part of the herbaceous plants they find palatable (Giannini and Montauti, 2010); (5) the massive increase of the seagull population (*Larus michahellis*) (Baccetti *et al*., 2008) has especially affected the biota of small islets, where a direct anthropic effect is lacking. The impact of these colonies on the plant communities of small islets is shown by the extinction of 89 local species (about 1/3 of the whole islet flora) in the last 100 years (Foggi *et al*., 2009), paralleled by a functional shift (Grime, 2001) in plant communities gradually from stress-tolerant to ruderal strategies (Foggi *et al*., 2001).

With regard to 16 endemic species of the Tuscan Archipelago, the IUCN procedures labeled 13 of them as being under risk (Guidi, 2010, Foggi *et al*., submitted) (Table 6). *Romulea insularis* and *Silene capraria* are under threat due to a variation in land management: these species live in *Isoëto-Nanojunceta* coenoses or in therophitic grasslands. They are threatened by the abandonment of the agro-pastoral management of the area that limited the development of forbs and woody species. A new land management system is needed for them (Foggi *et al*., 2008). All other endemic species are suffrutices, living in casmophytic or lithophytic habitats. In many cases they are threatened by invasive alien species, excessively trampled, or by weed management at roadside. Furthermore, although not threatened by change in land use, the current genetic variation pattern of *Linaria capraria* populations in Capraia Island mismatches their geographic distribution and could be explained on the basis of former connections provided by populations established on the stone walls of agricultural terracing. The abandonment of agriculture and the subsequent loss of stone walls aggravated the connections, causing the current pattern of isolated populations (Coppi *et al*., 2013).

Exclusive endemic species of the Tuscan Archipelago	Principal treaths	Category
Biscutella pichiana subsp. *ilvensis*	1.1 1.3 2.3	**EN**
Centaurea aetaliae	1.3 2.3 4.1 5.2.1 8.1.2	**EN**
Centaurea gymnocarpa	5.2.1 8.1.2	**EN**
Centaurea ilvensis	2.3 4.1 5.2.1 7.3 8.2.1	**VU**
Crocus ilvensis	1.1 2.3 4.1 5.2.1 7.3 8.1.2 8.2.1	**EN**
Festuca gamisansii subsp. *aethaliae*	2.3 7.3 8.2.1	**VU**
Limonium doriae	8.1.2 8.2.1	**CR**
Limonium gorgonae	8.1.2	**EN**
Limonium ilvae	1.1 1.3 8.1.2 8.2.1	**NT**
Limonium planesiae	8.1.2	**EN**
Limonium sommierianum	1.1 1.3 8.1.2	**NT**
Linaria capraria	1.1 1.3 2.3 4.1 5.2.1 8.1.2 10.3	**NT**
Mentha requienii subsp. *bistaminata*	8.1.2	**EN**
Romulea insularis	7.3 8.2.1	**CR**
Silene capraria	7.3 8.2.1	**CR**
Viola corsica subsp. *ilvensis*	1.3 2.3 5.2.1 7.3 8.2.1	**EN**

Table 6. Endemic species exclusive to the Tuscan Archipelago and threat level.

CONSERVATION ACTIVITIES

In view of the high naturalistic value of the Tuscan Archipelago, several actions have been undertaken to warrant the conservation of its floristic and ecologic diversity (Tab. 7). The most important steps made in this sense are: (1) the constitution of the National Park (1996), (2) the launching of research projects providing baseline data to plan the protection of species and habitats, and (3) the implementation of the Habitats Directive and the establishment of Natura 2000 Sites, which enabled conservation actions to be funded by EU-supported LIFE projects.

Globally, about 80% of the territory is included in protected areas. Wild plant species and natural and semi-natural habitats are protected by the Habitat Directive and by Regional Law (56/2000), including in its annexes 87 species and 25 habitats present in the Tuscan Archipelago; furthermore this law appoints the Botanical Gardens as the Center for the *ex situ* conservation of the native flora (CESFL).

Activities	Started in	Institutions	Status
Containment of ungulate populations	1997	National Park	In progress
Monitoring of flora and vegetation on islets	1998	Florence University	Completed - Monitoring
Restoration of the Stagnone pond on Capraia Island	2001	National Park - Florence University	In progress
Experimental introduction of *Quercus ilex* on Capraia and Montecristo	2001	National Park - Florence University	In progress
Felling of cultivated Aleppo pine on Pianosa island	2004	National Park - Florence University	In progress
Increasing extension and biodiversity richness of terophitic grassland and temporary wetlands on Capraia and Montecristo islands	2004	National Park - Florence University	Monitoring - in progress
Ex situ conservation of *Pianosa germplasm*	2004	Livorno Seed bank	Needs integration
Studies on threatened flora	2005	Florence University. Pisa University	Needs integration
Ex situ conservation of endemic germplasm	2007	Pisa Botanical Garden Seed bank	Needs integration
Ex situ conservation of local endangered *taxa*	2009	Pisa Botanical Garden Seed bank	Needs integration
Eradication of foreign plants on Capraia, Pianosa and Montecristo	2009	National Park - Florence University	In progress
Lacona dunes conservation and recovery	2009	« Amici dune di Lacona » Association. National Park	In progress

Table 7. Most important conservation activities in the Tuscan Archipelago.

The National Park of the Tuscan Archipelago received EU funds for LIFE Projects aiming at the removal/control of major threat factors. Important goals were achieved and further actions are scheduled: (1) to increase in extension and in biodiversity richness the ephemeral wetland vegetation and xerophile therophytic communities on Capraia Island, following a shrub clearing treatment (Foggi *et al.*, 2008, Carta *et al.*, 2013); (2) experimental implant of *Quercus ilex* on Capraia (Foggi *et al.*, 2001) and Montecristo, where soil erosion and predation (by goats and black rats, particularly on Montecristo) prevent the species from constituting not only woods but also well structured maquis; (3) eradication of the invasive alien plants from Capraia, Pianosa and Montecristo islands; (3) elimination of rats from Giannutri and Montecristo islands (Sposimo *et al.*, 2007); (4) felling of cultivated Aleppo pine (*Pinus halepensis*) on Pianosa island with a consequent expansion of *Juniperus turbinata* brushwood (Giunti & Sposimo, 2007); (5) to plan and start the recovery of the Stagnone pond on Capraia Island, which is undergoing a rapid process of silting due to the spread of tall helophytes introduced to the island in 1991 (Lastrucci *et al.*, 2009). Furthermore, on a regular basis, the National Park enforces the containment of ungulate populations on Elba, Capraia and Giglio islands (Giannini & Montauti, 2010).

Compared to *in situ* actions, *ex situ* conservation initiatives started more recently (Tab. 7). They were developed as a complement to *in situ* programmes, as recommended by the CBD (art. 9). Since 2008, endemic or threatened *taxa* have been kept *ex situ* in the seed bank of the Botanic Garden of Pisa (Bedini & Carta, 2011), as a contribution towards the EU-funded ENSCONET project (ENSCONET, 2009) and the national project "Conservazione *ex situ* e caratterizzazione tassonomica, ecofisiologica e genetica di specie minacciate della flora spontanea italiana" (PRIN, 2007). Seed collections stored in the seed bank are being used to study the germination ecology of threatened *taxa*, both to support their *in situ* management and to produce healthy living specimens in the Botanic Garden for further ecological, demographic, and genetic research.

The comparison of genetic diversity between *in situ* populations and *ex situ* individuals is a current research goal (Minuto *et al*., 2010), in the light of the future reinforcement of depauperated populations and reintroduction into natural habitats of local ones that had become extinct (Carta *et al*., 2012). In this respect, utmost care is given to the traceability of genetic materials from their access into the seed bank through every step of the treatment process, as a measure to avoid genetic pollution (Godefroid *et al*., 2011).

Besides their use for research and as a possible source for reinforcement/reintroduction into natural habitats, *ex situ* living collections are valuable tools for raising public awareness of the conservation of biodiversity. An *ex situ* collection of *Ranunculus baudotii* Godron from Capraia was included in a video showing the commitment of the Botanic Garden of Pisa to conservation (http://www.youtube.com/watch?gl=IT&v=s92GOGC9FEE), while some endemic species (*Centaurea gymnocarpa, C. aethaliae, C. ilvensis*) are featured in a series of didactic cards downloadable from the web site of CCB (Biodiversity Conservation Centre of Cagliari) (http://lnx.ondeweb.net/ccb2/index.php?catID=16&artID=911).

Local associations have established a small "dune garden" at Lacona, Elba Island, to raise public awareness of the conservation of the psammophile communities. Interestingly, they have adopted a "flagship" species (*Pancratium maritimum* L.) to help get their message across (Zanichelli *et al*., 2010).

FURTHER PERSPECTIVES TOWARDS THE CONSERVATION OF THE TUSCAN ARCHIPELAGO FLORA

The flora and vegetation of the Tuscan Archipelago, as on all Mediterranean islands, are obviously undergoing significant transformations. In areas with scarce human impact like the islets, whether the change is caused mainly by external forces or by the effect of the natural dynamics on small islands is still debatable (Foggi *et al.*, 2009). At present, a monitoring program that would enable recording these variations and addressing appropriate conservation measures is still lacking. However, although from a general point of view the current patterns of floristic diversity have been identified; specific research is needed on two levels. First, on a species level, it is necessary to encourage ecological and genetic studies supporting *in situ* conservation measures and to suggest sampling strategies of populations to maximise the genetic diversity of *taxa* in the seed bank collections. In views of an effective, integrated *in situ* and *ex situ* strategy, all stakeholders (scientific research centres, seed banks, botanic gardens, local administrative bodies, protected areas, and local associations) should join together in a network with the aim to exchange available information, coordinate the request for funds, and set common priorities for the conservation, management and monitoring of *taxa*. In this respect, recovery plans should be drafted based on demographic structure and genetic diversity, such as proposed for *Linaria capraria* (Coppi *et al.*, 2013), which was integrated thanks to *ex situ* conservation measures. Many things are still to be done to assess the conservation status of all flora, and in particular of those non endemic *taxa* exhibiting a particular phytogeographical significance or an ecosystem value to maintain the functionality of highly fragmented habitats (e.g. sand dunes).

The impact of invasive alien species, documented for a handful of species (Genovesi & Shine, 2004), needs to be assessed at a closer scale. In fact they affect native communities not only at species level, by competing with native species for resources, but also at landscape level, by disrupting vegetation series over vast tracts of territory. In this case, conservation projects based on the eradication of long-established plants need to be carefully explained to the general public. The role of local associations is pivotal to develop consent about such interventions, and should be planned from the start. In any case, an adequate awareness raising policy is essential for successful conservation initiatives.

Secondly, on a landscape level, it is necessary to define a management of vegetation series at landscape unit scale, necessary to maintain the simultaneous presence of different vegetation dynamic stages. Management of vegetation dynamics is needed on all the islands as reported by Foggi *et al.* (2008; 2011) for Capraia and Giannutri, respectively. However, Elba Island stands out due to the presence of different land units expressed by a number of forest vegetation series and due to the more pronounced change in land use with comparison to the other islands. For these reasons, land use planning should focus especially on sustainable development, as proposed by the Tuscan Archipelago National Park and by specific projects (Morelli, 2001; Carta, 2011).

Many studies have pointed out the interesting plant diversity patterns in the Tuscan Archipelago and several actions have been put into place to preserve them; other goals may be set considering that "*islands are not simply miniature continents*" (Nunn, 2004). Challenges remain at the policy level; for example, the need to factor in the value of natural resources, the decision making process, and the opportunity to better define the role of public sector science (Smith *et al.*, 2010).

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CONSIDERATIONS ON THE ENDEMIC FLORA OF SICILY

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Abstract

A survey on the endemic flora exclusive of Sicily has been carried out. Based on the taxonomical, ecological, karyological, chorological, phytosociological, phenological and conservation data concerning each endemic taxon, their role within the Sicilian territory has been examined. In particular, we provide detailed information on the numerical consistency of the Sicilian endemics in respect to the type of endemism, family, phenology, life form, chorology, environment, ecology, phytosociology, and vulnerability.

A total of 322 taxa have been recognized as narrow Sicilian endemics, roughly corresponding to 10% of the whole Sicilian flora. The noteworthy relevance of the Sicilian endemic flora is due to the occurrence of several paleo-endemics, usually with a punctiform distribution and chiefly localized on rocky habitats. The thermo-xerophilous and orophilous species are also well represented, mostly linked to highly preserved environments. Furthermore, the occurrence of several halophilous and nitrophilous endemics is quite relevant, testimony to the historic geographical isolation of Sicily from the neighbouring mainland territories.

Keywords: *Sicily, endemism, flora, phytogeography.*

INTRODUCTION

The endemic flora of a given territory provides useful information on its paleo-geographical history and climatic changes that affect the area at hand. This is the main reason why any information concerning the taxonomical position and current geographical distribution of the endemic taxa is extremely important, especially when they are compared to the most related species. In particular, detailed information on their life cycle, morphology, karyology,

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ecology, chorology, phytosociology, nomenclature, systematic position and, if possible, even on its genome are essential not only to have a complete picture of the endemic component characterizing the flora of the surveyed area, but also to define the role played by each endemism.

Aiming at increasing our knowledge of the most relevant species growing in Sicily, an in-depth analysis focused on the endemic species living on the largest Mediterranean island has been carried out. In particular, the survey is focused on those taxa that are exclusive to this territory, neighbouring islets included. Therefore, those taxa whose distribution range also include the Maltese Archipelago are excluded, even if this area phytogeographically belongs to the Sicilian territory.

In order to have an updated list, as comprehensive as possible, several Sicilian floras were examined, together with a selection of the most popular and relevant Italian, European or Mediterranean floras. In particular, several floras and floristic papers published during the 18th and 19th centuries (e.g. Presl, 1826; Gussone, 1843-1845; Parlatore, 1839, Cesati *et al.*, 1868-1889; Strobl, 1878-1887, 1880-1885; Tornabene, 1889-1892), as well as those published in the 20th and 21st centuries, such as Lojacono-Pojero (1888-1909), Fiori (1923-1929), Tutin *et al.* (1964-1980, 1993), Pignatti (1982), Greuter *et al.* (1984-1989), Giardina *et al.* (2007), Greuter (2008), Raimondo & Spadaro (2009) have been examined. In addition to this literature, many local floristic checklists, taxonomical revisions of genera, critical groups or species, as well as several karyological, phytogeographical, phytosociological and conservation papers have also been considered.

Based on current knowledge, the Sicilian flora consists of about 3,250 taxa at infra-generic level, also including naturalized and adventitious plants. With regard to the narrow Sicilian endemics, namely those exclusively growing in Sicily and neighbouring islets, 322 taxa have been counted, roughly corresponding to 10% of the total.

For each surveyed endemic species, detailed information concerning its nomenclature, phenology, life cycle, karyology, ecology, chorology, phytosociological role, type of endemism, and conservation status is provided.

List of the Sicilian endemics

Abies nebrodensis (Lojac.) Mattei

Acer obtusatum Willd. subsp. *aetnense* (Tineo ex Strobl.) C. Brullo & Brullo

Acinos alpinus (L.) Moench subsp. *nebrodensis* (Kerner & Strobl) C. Brullo & Brullo

Adenocarpus bivonii (C. Presl) C. Presl
Adenocarpus commutatus Guss.
Adenostyles hybrida Guss.
Allium agrigentinum Brullo & Pavone
Allium castellanense (Garbari, Miceli & Raimondo) Brullo *et al.*
Allium cupanii Rafin.
Allium franciniae Brullo & Pavone
Allium hemisphaericum (Sommier) Brullo
Allium lehmannii Lojac.
Allium lopadusanum Bartolo, Brullo & Pavone
Allium nebrodense Guss.
Allium obtusiflorum DC.
Allium panormitanum Brullo, Pavone & Salmeri
Allium pelagicum Brullo, Pavone & Salmeri
Allium vernale Tineo
Alyssum nebrodense Tineo subsp. *nebrodense*
Anthemis aetnensis Schouw
Anthemis cossyrensis (Guss.) Guss.
Anthemis cupaniana Tod. ex Nyman
Anthemis intermedia Guss.
Anthemis ismelia Lojac.
Anthemis lopadusana Lojac.
Anthemis messanensis Brullo
Anthemis muricata (DC.) Guss.
Anthemis pseudoabrotanifolia Brullo C., Brullo, Giusso & Pavone
Anthyllis hermanniae L. subsp. *sicula* Brullo & Giusso
Anthyllis vulneraria L. subsp. *busambarensis* (Lojac.) Pignatti
Arabis madonia C. Presl
Aristolochia sicula Tineo
Armeria gussonei Boiss.
Armeria nebrodensis (Guss.) Boiss.
Arrhenatherum nebrodense Brullo, Minissale & Spampinato
Asperula gussonei Boiss.
Asperula peloritana Brullo C., Brullo, Giusso & Scuderi
Asperula rupestris Tineo
Astragalus huetii Bunge
Astragalus nebrodensis (Guss.) Strobl

Astragalus raphaelis Ferro
Astragalus siculus Biv.
Aubrieta deltoidea (L.) DC. subsp. *sicula* (Strobl) Phitos
Bellardiochloa aetnensis (C. Presl) Brullo & Siracusa
Bellardiochloa nebrodensis (Asch. & Graebn.) C. Brullo, Brullo & Giusso comb. et stat. nov.
[Bas.: *Poa violacea* Bell. var. *nebrodensis* Asch. & Graebn., Syn. Mitteleur. Fl. 2:435, 1900]
Bellevalia dubia (Guss.) Reichemb.
Bellevalia pelagica C. Brullo, Brullo & Pasta
Betula aetnensis Rafin.
Bothriochloa panormitana (Parl.) Pilg.
Brassica bivoniana Mazzola & Raimondo
Brassica drepanensis (Caruel) Damanti
Brassica macrocarpa Guss.
Brassica rupestris Rafin subsp. *hispida* Raimondo & Mazzola
Brassica tinei Lojac.
Brassica villosa Biv. subsp. *brevisiliqua* (Raimondo & Mazzola) Raimondo & Geraci
Brassica villosa Biv. subsp. *villosa*
Buglossoides splitgerberi (Guss.) Brullo
Bupleurum dianthifolium Guss.
Bupleurum elatum Guss.
Calendula maritima Guss.
Calendula suffruticosa Vahl. subsp. *gussonei* Lanza
Campanula marcenoi Brullo
Carduus nutans L. subsp. *siculus* (Franco) Greuter
Celtis aetnensis (Tornab.) Strobl
Celtis asperrima Lojac.
Centaurea aeolica Guss. ex. Lojac.
Centaurea busambarensis Guss.
Centaurea erycina Raimondo & Bancheva
Centaurea giardinae Raimondo & Spadaro
Centaurea gussonei Raimondo & Spadaro
Centaurea macroacantha Guss.
Centaurea parlatoris Heldr.
Centaurea saccensis Raimondo, Bancheva & Ilardi
Centaurea seguenzae (Lacaita) Brullo, Marcenò & Siracusa

Centaurea sicana Raimondo & Spadaro
Centaurea todaroi Lacaita
Centaurea panormitana Lojac.
Centaurea tyrrhena C. Brullo, Brullo & Giusso
Chiliadenus lopadusanus Brullo
Colymbada tauromenitana (Guss.) Holub
Crepis bivonana (Reichenb.) Soldano & F. Conti
Crepis hyemalis (Biv.) Cesati, Pass. & Gibelli
Crepis gussonei Greuter
Crocus pygmaeus Lojac.
Crocus siculus Tineo ex Guss.
Cymbalaria pubescens (J & C. Presl) Cuf.
Cynoglossum nebrodense Guss.
Cytisus aeolicus Guss.
Daucus lopadusanus Tineo
Daucus nebrodensis Strobl
Daucus rupestris Guss.
Delphinium emarginatum C. Presl
Desmazeria pignattii Brullo & Pavone
Dianthus busambrae Soldano & Conti
Dianthus gasparrinii Guss.
Dianthus graminifolius C. Presl
Dianthus rupicola Biv. subsp. *aeolicus* (Lojac.) Brullo & Minissale
Dianthus rupicola Biv. subsp. *lopadusanus* Brullo & Minissale
Dianthus siculus C. Presl subsp. *siculus*
Diplotaxis crassifolia (Rafin.) DC.
Diplotaxis scaposa DC.
Draba olympicoides Strobl
Echinaria todaroana (Ces.) Ciferri & Giacom.
Echium italicum L. subsp. *siculum* (Lacaita) Greuter & Burdet
Elatine gussonei (Sommier) Brullo, Lanfranco, Pavone & Ronsisvalle
Eleocharis nebrodensis Parl.
Erica sicula Guss. subsp. *sicula*
Erodium neuradifolium Delile var. *linosae* (Sommier) Brullo
Eryngium bocconei Lam.
Eryngium crinitum C. Presl
Erysimum bonannianum C. Presl
Erysimum brulloi Ferro

Erysimum etnense Jordan
Erysimum metlesicsii Polatschek
Euphorbia bivonae Steudel
Euphorbia gasparrinii Boiss.
Euphorbia papillaris (Boiss.) Raffaelli et Ricceri
Euphorbia pycnophylla (K. U. Kramer & Westra) C. Brullo & Brullo
Evacidium discolor (DC.) Maire
Festuca humifusa Brullo & Guarino
Festuca morisiana Parl. subsp. *sicula* Cristaudo, Foggi, Galesi & Maugeri
Festuca pignattiorum Markgr.-Dannenb.
Filago cossyrensis Lojac.
Fraxinus excelsior L. subsp. *siciliensis* Ilardi & Raimondo
Gagea busambarensis (Tineo ex Guss.) Parl.
Gagea chrysantha Schult. & Schult f.
Gagea lacaitae A. Terracc.
Gagea nebrodensis (Tod. ex Guss.) Nyman
Galium litorale Guss.
Galium pallidum C. Presl
Genista aristata C. Presl
Genista cupanii Guss.
Genista demarcoi Brullo, Scelsi & Siracusa
Genista gasparrinii (Guss.) C. Presl
Genista madoniensis Raimondo
Genista tyrrhena Vals. subsp. *tyrrhena*
Helianthemum nebrodense Heldr.
Helianthemum sicanorum Brullo, Giusso & Sciandrello
Helichrysum archimedeum Brullo C, Brullo & Giusso
Helichrysum errerae Tineo
Helichrysum hyblaeum Brullo
Helichrysum italicum (Roth) G. Don fil. subsp. *siculum* (Jordan & Fourr.) Galbany *et al.*
Helichrysum nebrodense Heldr.
Helichrysum panormitanum Tineo ex Guss. subsp. *cophanense* Brullo C, Brullo & Giusso
Helichrysum panormitanum Tineo ex Guss. subsp. *messeriae* (Pignatti) Brullo *et al.*
Helichrysum panormitanum Tineo ex Guss. subsp. *panormitanum*

Helichrysum panormitanum Tineo ex Guss. subsp. *stramineum* (Guss.) Brullo *et al.*
Helichrysum pendulum (C. Presl) C. Presl
Helichrysum preslianum C. Brullo & Brullo
Herniaria fontanesii Gay subsp. *empedocleana* (Lojac.) Brullo
Hesperis cupaniana Guss.
Hieracium cophanense Lojac.
Hieracium lucidum Guss.
Hieracium madoniense Raimondo & Di Gristina
Hieracium pallidum Biv.
Hieracium pignattianum Raimondo & Di Gristina
Hieracium symphytifolium Froelich
Hornungia revelierei (Jord.) Soldano *et al.* subsp. *sommieri* (Pamp.) Brullo *et al.*
Iris sicula Tod.
Jacobaea ambigua (Biv.) Pelser & Veldkamp
Jacobaea candida (C. Presl) B. Nord. & Greuter
Jurinea bocconei (Guss.) Guss.
Koeleria splendens C. Presl subsp. *splendens*
Laserpitium siculum Sprengel
Lavatera agrigentina Tineo
Leontodon siculus (Guss.) Nyman
Leopoldia gussonei Parl.
Limonium aegusae Brullo
Limonium albidum (Guss.) Pignatti
Limonium algusae (Brullo) Greuter
Limonium bocconei (Lojac.) Litard.
Limonium calcarae (Todaro ex Janka) Pignatti
Limonium catanense (Tineo ex Lojac.) Brullo
Limonium catanzaroi Brullo
Limonium cosyrense (Guss.) O. Kuntze
Limonium densiflorum (Guss.) O. Kuntze
Limonium flagellare (Lojac.) Brullo
Limonium furnarii Brullo
Limonium halophilum Pignatti
Limonium hyblaeum Brullo
Limonium intermedium (Guss.) Brullo
Limonium ionicum Brullo
Limonium lilybaeum Brullo

Limonium lojaconoi Brullo
Limonium lopadusanum Brullo
Limonium mazarae Pignatti
Limonium melancholicum Brullo, Marcenò & Romano
Limonium minutiflorum (Guss.) O. Kuntze
Limonium optimae Raimondo
Limonium opulentum (Lojac.) Brullo
Limonium pachynense Brullo
Limonium panormitanum (Todaro) Pignatti
Limonium parvifolium (Tineo) Pignatti
Limonium pavonianum Brullo
Limonium ponzoi (Fiori & Bèguinot) Brullo
Limonium secundirameum (Lojac.) Brullo
Limonium selinuntinum Brullo
Limonium sibthorpianum (Guss.) O. Kuntze
Limonium syracusanum Brullo
Limonium tauromenitanum Brullo
Limonium tenuiculum (Tineo ex Guss.) Pignatti
Limonium todaroanum Raimondo & Pignatti
Linaria multicaulis (L.) Miller subsp. *humilis* (Guss.) De Leonardis, Giardina & Zizza
Linaria multicaulis (L.) Miller subsp. *aetnensis* (Giardina & Zizza) Brullo *et al*.
Linaria multicaulis (L.) Miller subsp. *multicaulis*
Linaria multicaulis (L.) Miller subsp. *panormitana* (Giardina & Zizza) Brullo *et al*.
Linaria pseudolaxiflora Lojac.
Linum punctatum C. Presl
Logfia lojaconoi (Brullo) C. Brullo & Brullo
Lotus versicolor Tineo
Malus crescimannoi Raimondo
Matthiola incana (L.) R. Br. subsp. *pulchella* (P. Conti) Greuter & Burdet
Megathyrsus bivonianus (Brullo, Minissale, Scelsi & Spamp.) Verloove
Micromeria fruticulosa (Bertol.) Šilić
Muscari lafarinae (Tineo ex Lojac.) C. Brullo & Brullo
Myosotis tinei C. Brullo & Brullo
Odontites bocconei (Guss.) Walp. subsp. *angustifolia* (Lojac.) Giardina & Raimondo

Odontites bocconei (Guss.) Walp. subsp. *bocconei*
Odontites rigidifolius (Biv.) Bentham
Odontites vulgaris Moench subsp. *siculus* (Guss.) Bolliger
Oncostema cerulea (Rafin.) Speta
Oncostema dimartinoi (Brullo & Pavone) Conti & Soldano
Oncostema hughii (Tineo ex Guss.) Speta
Oncostema sicula (Tineo ex Guss.) Speta
Onosma canescens C. Presl
Ophrys archimedea Delforge & M. Walravens
Ophrys biancae (Tod.) Macchiati
Ophrys calliantha Bartolo & Pulvirenti
Ophrys flammeola Delforge
Ophrys laurensis Melki & Geniez
Ophrys lunulata Parl.
Ophrys mirabilis Geniez & Melki
Ophrys obaesa Lojac.
Ophrys pallida Rafin.
Ophrys panormitana (Tod.) Soò
Orobanche chironii Lojac.
Pancratium linosae Soldano & F. Conti
Petagnaea gussonei (Spreng.) Rauschert
Peucedanum nebrodense (Guss.) Nyman
Phagnalon metlesicsii Pignatti
Pimpinella tragium Vill. subsp. *glauca* (C. Presl) C. Brullo & Brullo
Plantago afra L. subsp. *zwierleinii* (Nicotra) Brullo
Plantago peloritana Lojac.
Poa bivonae Parl. ex Guss.
Prospero hierae Brullo C., Brullo, Giusso, Pavone & Salmeri
Prunus cupanianus Guss. ex Nyman
Pseudoscabiosa limonifolia (Vahl) Devesa
Puccinellia gussonei Parl.
Pyrus castribonensis Raimondo, Schicchi & Mazzola
Pyrus sicanorum Raimondo, Schicchi & Marino
Pyrus vallis-demonis Raimondo & Schicchi
Quercus fontanesii Guss.
Quercus gussonei (Borzì) Brullo
Quercus leptobalanos Guss.

Ranunculus rupestris Guss.
Retama raetam (Forrskal) Webb subsp. *gussonei* (Webb) Greuter
Rhamnus lojaconoi Raimondo
Romulea linaresii Parl.
Romulea melitensis Bég.
Rosa strobliana Burnat & Gremli
Rubus aetneus Tornab.
Rumex aetnensis C. Presl
Salix gussonei Brullo & Spampinato
Salsola agrigentina Guss.
Scabiosa parviflora Desf.
Scleranthus annuus L. subsp. *aetnensis* (Strobl) Pignatti
Scleranthus vulcanicus Strobl
Scutellaria rubicunda Hornem.
Senecio aegadensis C. Brullo & Brullo
Senecio aethnensis Jan ex DC.
Senecio glaber Ucria
Senecio glaucus L. subsp. *hyblaeus* Brullo
Senecio leucanthemifolius Poir. subsp. *cossyrensis* (Lojac.) C. Brullo & Brullo
Senecio leucanthemifolius Poir. subsp. *pectinatus* (Guss.) C. Brullo & Brullo
Senecio pygmaeus DC.
Senecio siculus All.
Senecio squalidus L.
Serapias cossyrensis B. & H. Baumann
Serapias orientalis (Greuter) H. Baumann & Kunkele subsp. *siciliensis* Bartolo & Pulvirenti
Seseli bocconi Guss.
Sesleria nitida Ten. subsp. *sicula* Brullo & Giusso
Sideritis sicula Ucria
Silene hicesiae Brullo & Signorello
Silene saxifraga L. subsp. *rupicola* (Huet ex Nyman) C. Brullo & Brullo
Silene vulgaris (Moench) Garcke subsp. *aetnensis* (Strobl) Pignatti
Spergularia madoniaca Lojac.
Stachys germanica L. subsp. *dasyanthes* (Rafin.) Arcangeli
Sternbergia aetnensis (Rafin.) Guss.
Sternbergia exscapa Tineo ex Guss.
Stipa gussonei Moraldo

Stipa sicula Moraldo, Caputo, La Valva & Ricciardi
Suaeda kocheri Guss. ex C. Brullo, Brullo & Giusso
Suaeda pelagica Bartolo, Brullo & Pavone
Symphytum gussonei Schultz
Tanacetum siculum (Guss.) Strobl
Taraxacum garbarianum Peruzzi, Aquaro, Caparelli & Raimondo
Thapsia garganica L. subsp. *messanensis* (Guss.) Brullo *et al.*
Thapsia pelagica Brullo *et al.*
Thymus nitidus Guss.
Tillaea basaltica (Brullo & Siracusa) Brullo, Giusso & Siracusa
Tolpis gussonei (Fiori) Brullo *et al.*
Tolpis quadriaristata Biv.
Tolpis sexaristata Biv.
Torilis nemoralis (Brullo) Brullo & Giusso
Trachelium lanceolatum Guss.
Trifolium bivonae Guss.
Trifolium congestum Guss.
Trifolium macropodum (C. Presl) Guss.
Trifolium mutabile Portenschl. subsp. *gussoneanum* (Gibelli & Belli) Brullo *et al.*
Trifolium nigrescens Viv. var. *dolychodon* Sommier
Trifolium savianum Guss.
Tripolium sorrentinoi (Tod.) Raimondo & Greuter
Tuberaria villosissima (Pomel) Grosser subsp. *sicula* (Grosser) Bartolo, Pulvirenti & Salmeri
Urtica rupestris Guss.
Valantia calva Brullo
Valantia deltoidea Brullo
Verbascum siculum Tod. ex Lojac.
Viola aethnensis (DC.) Strobl
Viola nebrodensis C. Presl
Viola tineorum Erben & Raimondo
Viola ucriana Erben & Raimondo
Zelkova sicula Di Pasquale, Garfì & Quézel

RESULTS

Based on our investigations on the Sicilian endemic flora, we highlight the relationships existing between plants and their environment, as well as the role that abiotic factors, like soil, climate, orography, and paleo-geographical vicissitudes play and played in shaping their current distribution area. Depending on the taxonomical, morphological, karyological, ecological, chorological, phytosociological, and phenological features of the endemic species, the outcome of our analyses is here presented.

1. Type of endemism

The Sicilian flora, with about 3,250 taxa at an infrageneric level, is the richest among the five larger Mediterranean islands. The narrow Sicilian endemic taxa are 322, and they can be referred to different categories of endemism, chiefly depending on their taxonomic and phylogenetic relationships, as well as on their karyology, chorology, ecology, and ontogenetic cycle.

In particular, in order to provide an updated arrangement of the different types of endemism occurring in Sicily, it is here proposed a threefold classification based on the following criteria (Favager & Contandriopoulos, 1961; Contandriopoulos, 1962;): origin (paleo-endemics and neo-endemics), taxonomical isolation (macro-endemics and micro-endemics), geographical isolation, and chromosome complement (paleo-polyploids, neo-polyploids, apomictics, patro-endemics, apo-endemics, and schizo-endemics).

According to this classification, it was possible to recognize a noteworthy occurrence of schizo-endemic taxa (27.6%), whose origin is strictly linked to the geographical isolation of the Sicilian populations from those occurring in neighbouring territories. Such endemism is usually represented by taxa with the same chromosome complement. The most relevant schizo-endemics occurring in Sicily are: *Adenostyles hybrida*, *Anthemis messanensis*, *Armeria nebrodensis*, *Bellevalia pelagica*, *Campanula marcenoi*, *Helianthemum sicanorum*, *Hesperis cupaniana*, *Lavatera agrigentina*, *Leopoldia gussonei*, *Salsola agrigentina* and *Trifolium savianum*. Similarly, the micro-endemics are represented by a fairly substantial number of taxa (22%), to which are referred microspecies and taxa treated at a subspecific level, both commonly arisen from more widely spread taxa. For instance, *Anthemis cossyrensis*, *A. intermedia*, and *A. lopadusana*, all belonging to the cycle of *A. secudiramea* Biv., *Brassica bivoniana*, *B. drepanensis*, *B. rupestris* subsp. *hispida*, *B. tinei*, *B. villosa* subsp. *brevisiliqua*, *B. villosa* subsp. *villosa*, belonging to the *B. pubescens* (L.) Ardoino group, as well as *Centaurea gussonei*, *C. parlatoris*, *C. sicana*, and *C. giardinae,* all closely related to *C. dissecta*

Ten. On the contrary, only one macro-endemic species has been recognized in Sicily. It is *Petagnaea gussonei*, monospecific genus of the *Apiaceae,* which is taxonomically extremely isolated. Paleoendemics are numerically rather substantial (19.6%), whose ancient origin makes these species minimally, if at all, related to other congeneric taxa (*Abies nebrodensis*, *Asperula gussonei*, *Astragalus nebrodensis*, *Bupleurum elatum*, *Genista cupanii*, *Hieracium lucidum*, *Limonium calcarae*, *Megathyrsus bivonianus*, *Pseudoscabiosa limonifolia*, *Trachelium lanceolatum*, *Urtica rupestris,* etc.). Whereas neoendemic species, even if taxonomically well differentiated, are numerically less consistent (11.2%), possibly because they are linked to substrates geologically more recent (e.g. Quaternary), such as *Betula aetnensis*, *Centaurea macroacantha*, *Erysimum brulloi*, *Helichrysum errerae*, *Senecio aethnensis*, *Serapias cossyrensis*, *Tanacetum siculum*, *Tillaea basaltica*, *Valantia calva,* etc.

Rather low is the number of polyploid taxa. Within the polyploids, two typologies are here recognized: paleo-polyploids (5.3%), characterized by weak phylogenetic relationships with other congeneric species (*Allium franciniae*, *Bupleurum dianthifolium*, *Cytisus aeolicus*, *Genista aristata*, *Zelkova sicula* and *Viola tineorum*), and neo-polyploids (5.0%), showing instead close relations with diploid species widely occurring in other territories (*Anthemis aetnensis*, *Astragalus siculus*, *Hieracium pallidum*, *Limonium pachynense*, *Limonium ponzoi*, *Limonium tauromenitanum*, *Symphytum gussonei*, *Viola aethnensis*). Another relevant group of endemics is represented by the apomictic species (6.8%), whose chromosome complement is always odd (x=3n, 5n). Such species are characterized by asexual reproduction, and, therefore, each population appears rather homogeneous and morphologically well differentiated from the allied species. Many endemic taxa fall into this category, such as several species of the genus *Limonium* (*L. cosyrense*, *L. flagellare*, *L.intermedium*, *L. minutiflorum*, *L. optimae* and *L. todaroanum*), and *Hieracium* (*H. madoniense*, *H. pignattianum*). Finally, based on the current karyological knowledge, only a few apo-endemics (1.9%), like *Allium vernale*, *Calendula maritima*, *Diplotaxis crassifolia*, and *Valantia deltoidea*, and one patro-endemic (*Crepis hyemalis*) occur in Sicily.

2. Family

As one might expect, families with the highest degree of endemism are those whose speciation processes were, and in many cases still are, particularly intense and active. Thus, there is a positive correlation among plant diversity and differentiation, evolutionary trends and degree of endemism.

In Sicily, *Asteraceae* is the most endemic-rich family, with 72 endemics (22.4%) mainly belonging to the genera *Anthemis*, *Centaurea*, *Helichrysum,* and *Senecio.* Also quite rich in endemics is the family of the *Plumbaginaceae* with 37 taxa (11.5%), and with almost all its endemic taxa belonging to the genus *Limonium*. Also well represented are the *Fabaceae* (23 endemics corresponding to 7.1% of the total flora), while *Brassicaceae*, *Poaceae*, *Orchidaceae*, *Caryophyllaceae*, *Alliaceae, Apiaceae*, and *Scrophulariaceae* range from 20 (6.2%) to 11 (3.4%) endemic taxa. Finally, the remaining families make up a number of endemics never exceeding 7 (2.2%).

3. Phenology

In order to have a classification of the endemic species based on their flowering time, the blooming highest peak (acme) was considered. In particular, the winter-blooming species blossom between January and March, sometimes extending their flowering time until April, while the optimal conditions for the spring-blooming plants begin in April and last until June, occasionally they may blossom as early as March. The flowering time of the summer-blooming plants lasts from June to September, while the autumnal blooming taxa are typically characterized by a late flowering time, which usually starts in September and lasts until December.

Like most Mediterranean plants, Sicilian endemics are also characterized by a clear dominance of the spring-blooming plants, whose flower production reaches its highest peak right before the dry season. In fact, 183 endemic taxa (corresponding to 56.8%) are spring-blooming, followed by summer-blooming (94 taxa corresponding to 29.2%), which are chiefly represented by orophytes and halophytes. Lower numbers are recorded both for the autumnal endemics (19 taxa, 5.9% of the total) and for the late-flowering ones, with only 16 taxa (5%). Lastly, the behaviour of 10 endemics is rather unusual from a phenological point of view, since they produce flowers almost continuously, sometimes for the whole year, thus they may not be included in any of the above-mentioned categories.

4. Life form

One of the most common features of the Mediterranean plants is having reduced vegetative parts, thus reducing transpiration during the remarkable summer drought, which undoubtedly represents a severe constraint for plant development. Also for this reason, dwarf species are strongly favoured by such climatic conditions, thus becoming prevailing chamaephytes or plants which form perennial buds close to the ground (hemicryptophytes) or even under the ground (geophytes).

The endemic flora of Sicily is clearly dominated by chamaephytes (37.6%), mostly found in ecologically selective habitats, such as high-mountain stands, cliffs or coastal environments. In particular, chasmophytic species are able to vegetate even in summer, thanks to their high capacity to retain atmospheric moisture or to use the residual water content, while halophytes exploit the marine spray. High-mountain endemic taxa (orophytes), thanks to their physiology and structural organization, are ecologically very well adapted, being able to get water directly from the atmospheric moisture during the night and the early morning.

A fairly good number of hemicryptophytes (16.1%) and geophytes (15.8%) have been recorded within the Sicilian endemic flora. They are mainly found in open environments characterized by herbaceous vegetation (e.g. dry grasslands or meadows) or by shrubby plant communities, such as garigues, maquis, and so on. Such habitats are usually characterized by relatively deep soils, which favours the survival of underground reserve organs.

Annual endemic species are about 13% of the total, and are chiefly localized within ephemeral plant communities or disturbed habitats, such as abandoned fields, ruderal sites, roadsides, cultivated lands, etc. Endemic trees and shrubs are 55, and they are represented both by nanophanerophytes (11.5%) and phanerophytes (5.6%). The noteworthy importance of such plants is mainly linked to their ancient origin, which is due to the geographical isolation of the Sicilian populations. In most cases these species represent the dominant element of peculiar and ecologically specialized woodlands or shrubby communities. Finally, only one endemic hydrophyte has been found in Sicily. It grous in temporary ponds, which are rather uncommon in Sicily.

5. Chorology

The distribution of the Sicilian endemic species has been investigated in order to verify the occurrence of each taxon within the phytogeographical districts recognized by Brullo *et al.* (1995). Actually, they distinguish two biogeographical sectors: Eusicilian and Pelagian. The former includes Sicily, Ustica, Aeolian and Egadi Islands, while the latter groups Pantelleria, Lampedusa, Linosa, and Maltese Archipelago. Based on their floristic, geological and bioclimatic peculiarities, many different subsectors and districts have been recognized within the above-mentioned sectors (Fig.1).

The highest number of endemics is found in the Eusicilian sector (22.4%), followed by the Drepano-Panormitano (15.2%) and Madonita (11.5%) districts. The high degree of endemism characterizing the latter districts is likely due to the occurrence of many mountains whose ancient origin and geographical isolation favoured the establishment of several narrow endemics. Another district particularly rich in neo-endemics is the Etnean (6.5%), whose wide altitudinal range (the highest peak reaches about 3,400 m a.s.l.) favoured the establishment of many ecologically specialized species, especially in the oro- and crio-oromediterranean bioclimatic belts. Also the Agrigentino district is rather rich in endemics (5.3%). This is probably due to the occurrence of many thermo-xeric habitats, whose environmental conditions are suitable for many North-African species which are usually linked to halomorphic substrates. The last two districts, in terms of endemic richness, are Camarino-Pachinense and Hyblaean, with 3.1% and 2.8% of endemics respectively. The Peloritano (3.4%) and Nebrodense (1.9%) districts, even if they chiefly include mountain areas, are rather poor in endemics, probably because they are geologically homogeneous, mostly consisting of siliceous substrata.

As for the circum-Sicilian islets, the highest degree on endemism has been recorded for Lampedusa (4.8%), whereas the Egadense and Aeolian districts are characterized by lower values, 3.1% and 1.6% respectively. Geologically speaking, the volcanic nature and recent origin of the latter archipelago seems to be the main reason for this low number of endemics, but very important from the phytogeographical and taxonomical point of view (*Cytisus aeolicus, Silene hicaesiae, Genista thyrrena* subsp. *thyrrena, Centaurea eolica, Erysimum brulloi,* etc.)

6. Ecology

Endemic species, depending on their ecological requirements, seem to prefer some particular soil types or environments that are characterized by peculiar edaphic or microclimatic conditions.

In Sicily, we can observe that carbonatic substrates (limestones, dolomites, and marls) are definitely richer in endemic species. Actually, 50.3% of endemics are strictly calcicolous, thus founding their optimal conditions on carbonatic rocks, while about 25.5% are those growing on siliceous substrates, likely because low-pH soils are ecologically less limiting and probably even less suitable for hosting endemic species. The endemics not linked to any particular substrate are well represented too (24.2%).

Considering the soil texture, it has been possible to recognize other types of endemism. In particular, the highest degree of endemism is represented by taxa growing on mature soils, particularly rich in humus, which are here indicated as terricolous (63.0%); whereas psammophytes, linked to sandy soils, make up 5%, ceramophilous endemics, exclusive of clayey soils, make up 4.7%, glareicolous, growing on pebbly riverbeds or screes, make up 3.4%, and the comophilous, exclusively localized on rocky ledges, make up 1.6%. Finally, a rather interesting group of endemic taxa is represented by the chasmophytes. Such species are quite abundant (22.4%), and represent an ecologically extremely specialized component of the Sicilian endemic flora. These relic species are circumscribed to the rocky crevices, and their current narrow distribution clearly denotes their regressive status of surviving remnants of Tertiary flora.

Quite relevant is the occurrence of a fairly good number of endemic halophytes (14.0%), linked to rocky coastal habitats or salt marshes. The nitrophilous endemic species are less represented but still very relevant (6.8%), and are linked to synanthropic stands, characterized by soils particularly rich in nitrates.

Another limiting factor is water availability, in turn related to the soil granulometry, which allows for recognition of xerophilous endemics (56.5%), mesophilous (39.4%), quite common on the mountain belt, hygrophilous (3.7%), and hydrophilous (0.3%); the latter typically growing on periodically submerged pools. Depending on the bioclimatic features of the explored sites, four main types of endemics have been distinguished: thermophilous (57.8%), located within the infra- and thermo-Mediterranean belts; mesophilous (17.7%), widely spread in the submontane or mountain stands, chiefly falling within the meso-Mediterranean bioclimatic belt, or partially in the supra-Mediterranean one; orophilous (22%), exclusively found in high-mountain stands with supra- or oro-Mediterranean belts. Lastly, a low number of endemics (2.5%) are not linked to any particular bioclimatic conditions, since they are found in many bioclimatic belts.

Finally, open habitats characterized by long lasting solar radiation are richer in heliophilous endemics (60%) than those where the shade of the canopy or created by rocky outcrops enables the establishment of nemoral (4%) or, in any case, sciaphilous (3.1%) species. Very abundant are the endemics indifferent to solar radiation (32.6%).

7. Environment

Our investigations on the Sicilian endemic flora led us to highlight the fact that several different habitats behave as suitable refuge for many endemic species. Woodlands, pulvinate scrubs, maquis, garigues, dry grasslands, as well as many other environments (like rivers, lagoons, salt-marshes, screes, badlands, dunes, cliffs, rocky coasts, volcanic substrates, etc.) are rich in endemics. Even some synathropic habitats, such as abandoned fields, roadsides, pastures, host endemic taxa whose ecology and, therefore differentiation, is likely favoured by soils enriched with nitrogen and phosphates.

As one might expect, the most endemic-rich habitats are those more specialized and ecologically selective, such as rocky walls (68), rocky coasts (43), orophilous pulvinate scrubs (38), cliffs (22), and badlands (15). All these habitats are characterized by severe environmental conditions that usually hamper the establishment of widespread and common species, and therefore they are colonized by few, extremely specialized, and genetically differentiated species.

Both woods and garigues host 23 endemic taxa, followed by dry grasslands (22), and ephemeral plant communities (28). These natural or semi-natural formations are usually represented by primary or secondary communities, being characteristic elements of the Sicilian landscape since a long time ago. Furthermore, they seem to be particularly suitable for hosting endemic plants that locally may become quite frequent. As for wet environments, the degree of endemism is low, with only a few species circumscribed to salt-marshes (6) and temporary ponds (4). On the contrary, several endemics are found in synanthropic habitats, such as pastures (21), abandoned fields (14) and roadsides (12). This is probably due to the long-lasting occurrence of abundant livestock (sheep, goats, cows, etc.) that likely acted as selective pressure for the differentiation of pabular plants.

8. Phytosociology

The analysis of the plant communities floristically characterized by Sicilian endemics allows highlighting the role played by each of them within the landscape of the island. They are usually key-species of one or, exceptionally, more associations, but even of higher syntaxa. In order to provide complete and detailed information on the habitats where they usually grow, the phytosociological classes including associations characterized by Sicilian endemics have been examined.

The highest degree of endemics has been recorded for the *Asplenietea trichomanis* (Br.-Bl. in Meier & Br.-Bl., 1934) Oberd. 1977 (19.8%), a class notoriously rich in rare or narrowly distributed species. In particular, these endemics are represented by chasmophytes whose origin may be dated back to the Tertiary, and that usually find refuge on cliffs or rocky walls, mainly carbonatic, where their pioneering character facilitate their own establishment.

Several endemics also occur within the plant communities of the *Rumici-Astragaletea siculi* Pignatti & Nimis in Pignatti *et al.*, 1980 (11.7%), class grouping orophilous shrubby phytocoenoses colonizing the high-mountain ridges and the highest peaks of Sicily. Many of these species belong to the Tertiary flora, especially those found on the Mesozoic mountains where they can be considered as relic elements, while the endemic species growing on the top of Mt. Etna have a recent origin, since they are exclusively found on this Quaternary volcano.

The perennial dry grasslands of the *Lygeo-Stipetea* Rivas-Martínez 1978 class, host a considerable number of endemics (11.7%), mostly being very well adapted to the extremely thermo-xeric ecological conditions of the explored sites. The distribution of these endemics was originally restricted to primary stands, much more circumscribed than they are currently. Later, human impact strongly favoured the degradation processes involving most of the natural woods, thus leading to the spreading of these grasslands, and consequently the widening of the distribution range of their characteristic endemic species.

Rocky coasts are suitable habitats for the halophilous communities of the *Crithmo-Limonietea* Br.-Bl. in Br- Bl. *et al.* 1952, in which several endemic species are localized (8.3%). These sites are colonized by ecologically very specialized species, chiefly belonging to the genus *Limonium*, which are here represented by amphimictic diploid or polyploid populations (often with ancestral origins), or by apomictic ones, chiefly triploids or aneuploids.

Also, the basophilous ephemeral plant communities of the *Stipo-Trachinetea distachyae* Brullo in Brullo *et al.* 2001, host a fairly good number of endemics (7.4%), mostly represented by geophytes and therophytes. In particular, they are found on the islets where they grow along the rocky coast and small hollows whose geographical isolation and ecological peculiarity favoured the speciation processes. The shrubby communities of the *Cisto-Micromerietea* Oberd. 1954, represented by thermophilous garigues, host a fair number of endemic species (6.9%), having a chamaephytic, geophytic, or hemicryptophytic habitat. These habitats represent secondary stands, whose current wide distribution in Sicily is strictly correlated with the degradation of the original woody vegetation, which took place during the last millennia. Actually, these garigues were previously localized on rocky habitats, where they played the role of edapho-xerophilous communities. The endemic flora characterizing this vegetation has undergone intense speciation processes, which were, and in some case still are, particularly active on the *Orchidaceae*, as well as on taxonomically isolated shrubby plants.

Another habitat rich in endemic species is represented by the mountain mesophilous meadows, whose typical plant communities fall in the *Molinio-Arrhenatheretea* R.Tx.1937 class (4.6%). Most of the endemic species found in these habitats are hemicryptophytes and geophytes, whose evolution has been influenced by the selective pressure caused by grazing animals. In Sicily, these meadows are floristically characterized by the occurrence of many rare taxa coming from North-Africa and the eastern Mediterranean area. Within the thermophilous and mesophilous woods, ascribed to the *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 and to the *Querco-Fagetea* Br.-Bl. & Vlieger in Vlieger 1937 class respectively, it is possible to find some endemic species. As for the former class, they amount to 4.6% of the total flora, while the mesophilous plant communities of the *Querco-Fagetea* host 3.2% of endemic species. In both cases these insular phytocoenoses are geographically isolated from those found on mainland Italy.

The remaining phytosociological classes are characterized by a lower number of endemics (less than 10). Such taxa, although few in number, have a remarkable taxonomical, phytogeographical, or landscape value. In particular, it is important to note that also in classes grouping nitrophilous plant communities, such as *Stellarietea mediae* von Rochow 1951, *Onopordetea acanthi* Br.-Bl.1964, *Artemisietea vulgaris* von Rochow 1951 or *Pegano-Salsoletea* Br.-Bl. & O. Bolòs 1958, some endemic species whose origin is likely quite recent were found.

9. Vulnerability

The role played by endemic species is extremely relevant both in terms of plant diversity and naturalistic value of a given territory. This means that mankind should pay particular attention to take great care of the preservation of the endemic plants. In other words, any action should take into consideration the priority necessity of safeguarding and protecting narrow endemics as a unique natural heritage, which must be passed on to forthcoming generations.

The International Union for Conservation of Nature (IUCN) proposed specific criteria for assessing the vulnerability of plants and animals. The application of such criteria needs in-depth field surveys in order to better evaluate the real delimitation and consistency of the natural populations. A fundamental pre-requisite for the conservation of any species is the protection of the natural or semi-natural habitats where they live.

With regard to Italian territory, some red books have been published by Conti *et al*. (1992, 1997), Pignatti *et al*. (2001), and Marconi (2007). In addition to these books, other red lists including Italian taxa are available; they are

Montmollin & Strahm (2005), Baillie *et al*. (2004), and a red list edited by EU Commission (DG Environment, 2007).

As for the Sicilian endemic flora, about 31.1% of the species is vulnerable (VU). Fairly abundant are species falling into the Critically Endangered (CR) category (27.3%), followed by the Low Risk species (LR), with 25.5% of the total. Far fewer are those species falling into the Less Concern (LC) category (8.4%) or endangered (EN) category (5%), while only very few taxa are labelled as Near Threatened (NT), Extinct (EX), or Extinct in the Wild (EW).

Based on the outcome of our survey, it is clear that more research is needed in order to have detailed information on the real conservation status of many endemic species of Sicily. In fact, many endemics are still not included in any of the current red lists, since only 196 taxa are quoted in these lists, 144 of which occur in only one red list (Conti *et al*., 1997). Most of the species not included in any red list are rare and extremely localized, with only few populations still surviving. This means that great efforts must be made urgently in order to preserve the natural environments suitable for the conservation of these plants.

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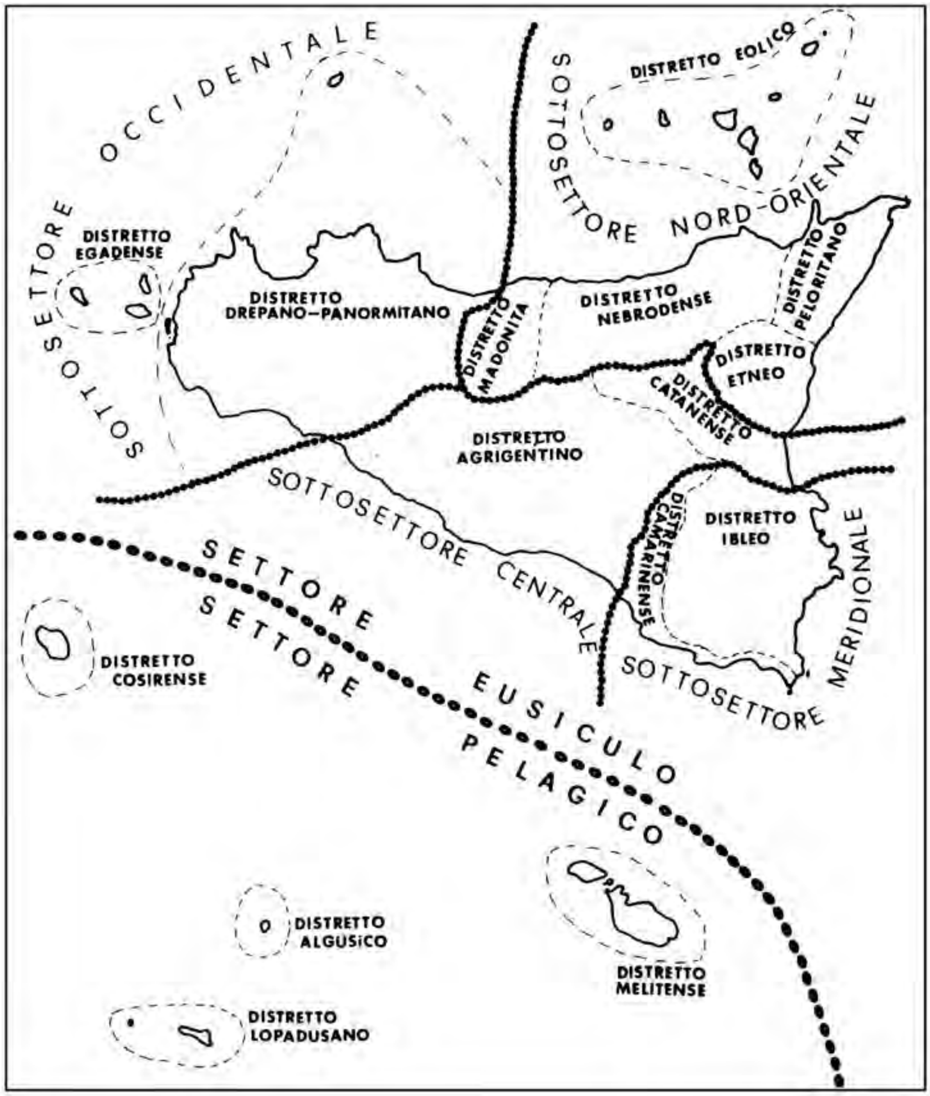

Fig. 1 Phytogeographical subdivision of Sicily (after Brullo et al., 1995).

SPECIES RICHNESS, BIOGEOGRAPHIC AND CONSERVATION INTEREST OF THE VASCULAR FLORA OF THE SATELLITE ISLANDS OF SICILY: PATTERNS, DRIVING FORCES AND THREATS

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Abstract

The vascular flora has been investigated on about 60 of the approximately 100 islands and islets of the Sicilian archipelago. This paper provides detailed information on the number of exclusive, rare, or threatened vascular plants living on these islands and islets. Focusing on the 18 most-investigated islets, we evaluate the extent to which species richness, rate of endemism, number of alien plants, and number of terrestrial habitats have been influenced by 1) geographical setting, 2) geological history, 3) geo-pedological variability, 4) bioclimate, 5) number and patchiness of local plant communities, and 6) natural and human disturbance history and regime. Special attention is directed to the rarefaction and extinction of many interesting species that live or have lived only on these islands. Rarefaction and extinction are mostly linked to the increase in anthropogenic disturbance, which have caused the destruction, degradation, and/or fragmentation of many plant communities and especially those associated with rocky or sandy shores and temporary ponds. Interestingly, in some cases extinction has resulted from a reduction in certain human activities. For example, many noteworthy species are disappearing with the abandonment of traditional land uses that created low-impact agro-ecosystems, new microhabitats (e.g., stone walls), and open semi-natural habitats (including vineyards, cereal crops, olive groves, and fallows subject to extensive grazing).

Finally, we emphasize the need for current information about species turnover, invasion processes, and demographic patterns of the vascular flora of those islands and islets that support the most fragile communities and/or species.

Keywords: *species richness, rate of endemism, 92/43 EU Directive, conservation policies, island biogeography*

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INTRODUCTION

The so-called "Tyrrhenian area" is among the most important hot spots of plant diversity in the world (Médail and Quézel, 1997; Myers *et al.*, 2000). According to the most recent checklist of the Sicilian vascular flora (Raimondo *et al.*, 2010), about 3,000 native plants live on the island, and 13% of them are endemic (Table 1). Circum-Sicilian satellite islands and islets also have high species richness. In fact, although they represent just 1% (ca. 250 Km^2) of the whole regional territory, they host some 44% of its total flora (Pasta, 1997). In addition, the number of endemic plants hosted by them is high if compared with the main island and its two floristically richest mountainous areas, i.e., Madonie Mts. and Mt. Etna (Table 1).

Territory	Number of endemic plant taxa
Sicily (main island)	395
Madonie Mts.	34
Etna Mt.	16
all circum-Sicilian islands	44
Pelagie Archipelago	21
Egadi Archipelago	9
Pantelleria	6
Eolie Archipelago	6
Ustica	1
Linosa + Pantelleria	1

Table 1. Endemic species richness in Sicily: a rough comparison between mountain ranges and satellite islands.

The Sicilian vascular flora is one of the best studied in Europe. This is also true for the satellite islands of Sicily: over 2,300 years ago, Theophrastos (372-286 B.C.) wrote about plants growing on the Aeolian Islands, while Boccone, Cupani, and Ray, who were among the most renowned European botanists of the 17th century, began to explore the plants growing on circum-Sicilian islets. One century later, the monk Ucria (1789) followed the Linnaean classification system in creating the first checklist of the autochthonous and cultivated plants growing in Sicily. In the first half of the 19th century, many Italian botanists (e.g., Gussone, 1832-1834), collected and described many new species on the islets.

The circum-Sicilian satellite islands and islets number more than 100, but botanical knowledge is greater for some than for others. Over the last 60 years, the vascular flora of 61 islands has been explored at least once and that of 18 has been monitored two or more times. The main steps in the development of the current state of knowledge concerning the circum-Sicilian flora are detailed in Table 2.

Plant lists with a comprehensive revision after 2000 (39 islands)
Pelagie Arch. (Lampione, Lampedusa, Linosa and Isola dei Conigli: Pasta, 2001, 2002; La Mantia *et al.*, 2009; Lo Cascio and Pasta, 2012); Egadi Arch. (Favignana, Levanzo and Marettimo: Romano *et al.*, 2006; Gianguzzi *et al.*, 2006 + 5 satellite islets: Pasta and Scuderi, 2008; Pasta *et al.*, submitted); Ustica (Pasta *et al.*, 2007b); Isola delle Femmine (Caldarella *et al.*, 2010); Eolie Arch. (23 satellite islets: Lo Cascio and Pasta, 2008); Stagnone Arch. (Santa Maria and Scuola: Scuderi *et al.*, 2007)
Plant lists with a comprehensive revision after 1990 (5 islands)
Stagnone Arch. (Mozia: Catanzaro, 1992); Scogli dei Ciclopi (3 islets: Siracusa, 1996); Rocca di San Nicola (Pasta, pers. obs.)
Plant lists written after 1970 and then partially updated (3 islands)
Pantelleria (Brullo *et al.*, 1977); Eolie Arch. (Alicudi and Filicudi: Di Benedetto, 1973; Longhitano, 1983; Pasta, 1997; Pasta and Lo Cascio, 2002)
Plant lists written after 1960 and then partially updated (3 islands)
Stagnone Arch. (Isola Lunga: Di Martino & Perrone, 1970; Pasta, 2004); Eolie Arch. (Vulcano and Stromboli: Ferro & Furnari, 1968, 1970)
Plant lists written after 1910 and subject to few or no improvements (5 islands)
SE Sicily (Marzamemi grande, Marzamemi piccola, Vendicari, Capo Passero, Isola delle Correnti: Albo, 1919, 1959; Pirola, 1960; etc.)
19th century plant lists that have been partially updated (3 islands)
Eolie Arch. (Lipari, Salina and Panarea: Lojacono, 1878; Ferro, 1984, 2005; Pasta *et al.*, 1999; Pasta & Lo Cascio, 2002; etc.)
19th century plant lists subject to few or no improvements (3 islands)
Egadi Arch. (Maraone and Formica: Gussone, 1832-1834); Eolie Arch. (Dattilo: Gussone, 1832-1834)

Table 2. Current overview on the published plant lists for the circum-Sicilian islands and islets (from Pasta, 1997, updated). Arch = archipelago.

This paper provides an overview on the number of exclusive, rare, or threatened vascular plants living on the circum-Sicilian islands and islets, and focuses on the 18 most-investigated islets. We evaluate the extent to which species richness, rate of endemism, number of alien plants, and number of terrestrial habitats have been influenced by a number of abiotic and biotic factors. We pay special attention to those species whose numbers have been decreasing and that are threatened with extinction.

WHICH FACTORS ARE RESPONSIBLE FOR THE FLORISTIC DIVERSITY OF THE CIRCUM-SICILIAN SATELLITE ISLANDS AND ISLETS?

Many papers have emphasized the high phytogeographic importance of Sicilian plant heritage (Di Martino & Raimondo, 1979; Nimis, 1985; Brullo *et al.*, 1995; Brullo *et al.*, 2013) but only a few have focused on the major role played by the satellite islands (Pasta, 1997; Mazzola *et al.*, 2002; Raimondo, 2004; Bocchieri & Iiriti, 2011; Troìa *et al.*, 2012; Troìa, 2012). The recorded high values of both species-richness and endemism depend on six main factors: 1) geographical setting; 2) geological (and geological disturbance) history; 3) geo-pedological variability; 4) bioclimatic belts; 5) number and patchiness of local plant communities; and 6) natural and human disturbance history and regime. Basic data on some of these factors are provided in Table 3, while additional information on their effects is provided in the following paragraphs.

Geographical setting

The circum-Sicilian islands (Figure 1) have a wide latitudinal range and extend from Lampedusa in the Pelagie Archipelago (at 35°30' N) to the south and Strombolicchio in the Aeolian Archipelago (at 38°50' N) to the north. The Strait of Messina (which is 3 km wide) currently separates Sicily from Eurasia, while the nearest part of Africa (Tunisia) is about 70 km from the island of Pantelleria. These separations may have been less significant or non-existent at some times in the geologic past. Plio-Pleistocenic climate change, for example, may have favoured direct plant migration between Sicily and both Eurasia and Africa. In fact, during the Last Glacial Maximum (hereinafter LGM, about 18-12 Kya), the sea level was some 80–120 m lower than today (Lambeck *et al.*, 2010), so that the Egadi Islands, Sicily, and the Maltese Archipelago were united; Lampedusa and Lampione were part of Africa; and Pantelleria was less than 10 km from Sicily. Hence, the complex history of past connection and proximity between Sicily and nearby territories may have greatly affected the present composition and the species richness of the region's vascular flora. For example, because it is part of the African continental shelf, Lampedusa hosts a remarkable number of south, southwest, and southeast Mediterranean and Mediterranean-Irano-Turanian species (e.g., *Suaeda pelagica*, *Caralluma europaea* subsp. *europaea*, and *Echinops spinosus* subsp. *spinosissimus*). Similarly, because of their repeated past connections with the main island, the Egadi islands host a high number of Sicilian endemics (Table 3).

Island	No. taxa	No. hab	No. end isl	No. end arc	No. end sic	No. excl isl	surf (ha)	rou	cli	dis	Dist LGM
Lpe	437	15	12	2	1	15	2,020	c	t	205	140
Lpi	18	2	2	0	0	2	4	c	t	215	142
Lin	303	10	3	2	2	8	520	v	t	161	30
Pte	645	11	7	0	2	15	8,301	v	t-m	70	15
Ilu	444	9	0	0	6	0	286	c	t	0.5	0
Fav	593	13	1	1	17	0	1,948	c	t	8	0
Mar	489	9	7	1	9	4	1,230	c	t-m	24.5	2
Lev	480	12	0	0	14	0	565	c	t	12.5	0
Ust	498	7	1	0	2	0	865	v	t	55	50
Ali	398	5	1	3	2	1	520	v	t-m	53	50.5
Fil	405	7	0	1	3	0	950	v	t-m	41.5	31
Vul	356	13	0	3	0	1	2,100	v	t-m	19.5	17.5
Lip	658	10	0	2	3	2	3,760	v	t-m	20.5	17.5
Sal	506	11	0	2	3	0	2,524	v	t-m-s	24	17.5
Pan	379	8	0	3	2	1	336	v	t	35	29.5
Lbi	45	2	1	1	1	0	3.8	v	t	53	41.5
Str	288	8	0	3	0	0	1,260	v	t-m	53	41.5
Stc	20	3	0	0	0	2	0.1	v	t	56.5	51

Table 3. Statistical data concerning the 18 best-studied circum-Sicilian islets (from Pasta, 1997, updated): Lpe = Lampedusa, Lpi = Lampione, Lin = linosa, Pte = Pantelleria, Ilu = Isola Lunga, Fav = Favignana, Mar = Marettimo, Lev = Levanzo, Ust = Ustica, Ali = Alicudi, Fil = Filicudi, Vul = Vulcano, Lip = Lipari, Sal = Salina, Pan = Panarea, LBi = Lisca Bianca, Str = Stromboli, and Stc = Strombolicchio. No. taxa = number of terrestrial

vascular plants; No. hab = number of terrestrial habitats; No. end isl = number of endemics exclusive to the given island; No. end arch = number of endemics on the archipelago; No. end sic = number of endemics of the whole Sicilian region; No. excl arch = number of taxa exclusive to the given island; surf refers to the surface area measured in hectares.; rou = main rock outcrop (c = prev. calcareous, v = prev. volcanic); cli = bioclimate following Rivas-Martínez (2008): i = infra-, t = thermo- and m = meso-mediterranean; dis = distance from the nearest mainland (measured in Km). N.B.: the sharpest differences between present and past distances are underlined; the nearest mainland is Calabria for Stromboli, Panarea for Lbi, Str for Stc, and Africa for Lampedusa, Linosa, and Pantelleria. During the LGM, the nearest mainland for Linosa and Pantelleria was Sicily.

Geological (and geological disturbance) history

If we go back millions rather than thousands of years in geological history, the picture becomes even more complex. Although many palaeontologists (e.g., Rook *et al.*, 2006) share the opinion that most of Sicily rose out of the sea only during the Miocene (i.e., 23–5.3 Mya), many others argue that repeated emersion events may have occurred earlier, i.e., during the Mid Cretaceous (120–90 Mya: Zarcone *et al.*, 2010) or at least since the Oligocene (34–23 Mya: Rosenbaum *et al.*, 2002). These fragments of land may have acted as 'stepping stones' for plant migration between Eurasia and Africa even before the Mediterranean Sea acquired its present size and shape. Within this context, only the island of Marettimo may have experienced partial emersion as long as 230–200 Mya (Martini *et al.*, 2007), while all the other islands have a more recent and discontinuous history of connection with the main island. For example, only a few volcanic islands emerged ca. 1.5 Mya, while most of them (e.g., the Aeolian Archipelago) appeared more recently (Calanchi *et al.*, 2007). The ancient and long-lasting isolation of Marettimo probably accounts for much of its floristic originality. In fact, the western-most island of the Egadi Archipelago hosts the only known Sicilian population of four species of high phytogeographic interest, while the only extant relatives of several local endemics currently occur very far away. For example, *Thymus nitidus* is related to *T. richardii* subsp. *ebusitanus* of Ibiza as well with *T. richardii* subsp. *richardii* of Majorca and the former Yugoslavia (Morales, 1997); *Bupleurum dianthifolium* is related to *B. barceloi* of Majorca; and *Pseudoscabiosa limonifolia* is closely related to *P. saxatilis* of southern Spain.

As a consequence of the tectonic uplift of southern Spain and NW Africa, at the end of the Miocene (5.96–5.33 Mya), the Mediterranean Sea was separated from the Atlantic Ocean, and its waters gradually dried and disappeared.

Hence, many drought and salt-tolerant African species could colonize Europe via the Strait of Sicily. If this event, known as the Messinian crisis, ended with a tremendous tsunami, as suggested by García-Castellanos *et al.* (2009), then the lowland life of most of the Mediterranean Basin probably had to re-start from bare rock.

The geological history of Sicily provides many examples of catastrophic volcanic activity that erased the existing flora: Vulcano (De Astis *et al.*, 1997) and Stromboli (Rosi *et al.*, 2000) erupted explosively and nearly continuously during the Plio-Pleistocene, while Pantelleria (Civetta *et al.*, 1988), Lipari (Crisci *et al.*, 1990), Salina (Gertisser & Keller, 2000), and Panarea (Lucchi *et al.*, 2007) have been active during human history.

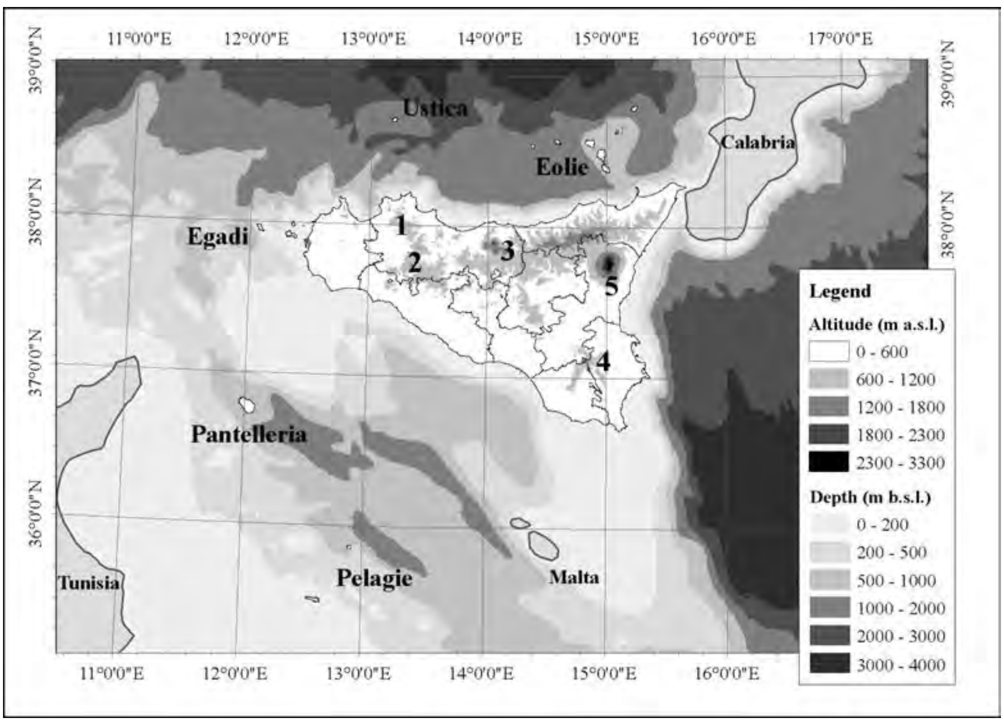

Fig. 1. Map of the major satellite islands and archipelagoes and some of the main mountainous areas of Sicily (1: Palermo Mts.; 2: Sicani Mts.; 3: Madonie Mts.; 4: Iblei Mts.; 5: Mt. Etna).

Geo-pedological variability

Another important consequence of the rather complex geological history of Sicily is the diversity of rock outcrops, which in turn involve a high variety of soil types. On the circum-Sicilian islands, the most common geological substrata are: 1) sandy or compact limestones/dolomites (which cover most of Lampedusa, Lampione, Egadi islands, and Stagnone islands and also all the minor W, NW, and SE islets); 2) base-rich or acid vulcanites (which cover Linosa, Pantelleria, Ustica, the Aeolian Islands and islets, Scogli dei Ciclopi, and part of Capo Passero islet); and 3) marls (which cover part of Lampedusa). Calcareous islands share the same pedological pattern: uneven soil depth, scattered distribution of soil and rock outcrops, and a high variety of soil assemblages. The co-occurrence of the latter three factors seems to enhance species richness (Pasta, 1997) by multiplying the niches available to root systems (Figure 2). The low plant species richness recorded on some volcanic islands (e.g., Linosa, Vulcano, and Stromboli) may be due to their rather recent emersion and/or to the frequent disruptive events, so that they are not yet saturated in terms of species richness, which is consistent with the basic principles of island biogeography (MacArthur & Wilson, 1963).

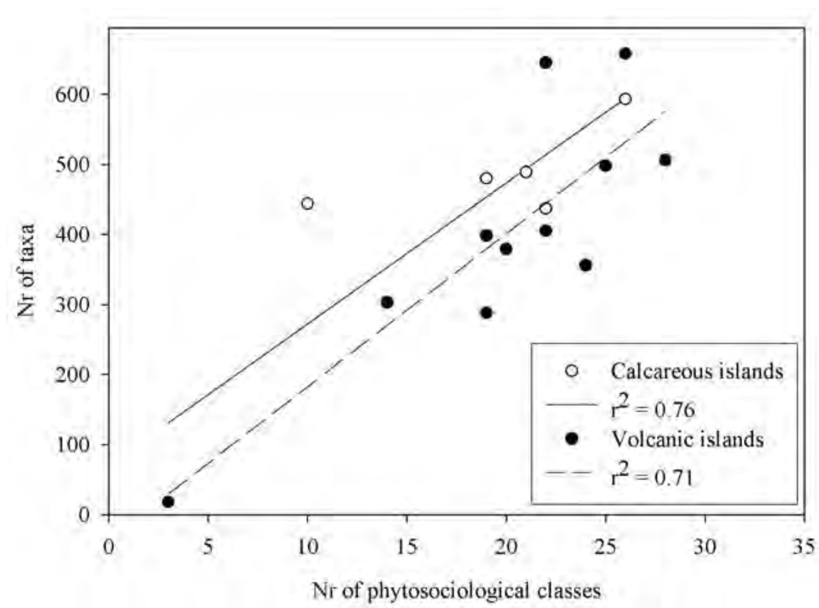

Fig. 2. The pattern of correlation between α- (i.e., species-richness) and β-diversity (i.e., number of suitable ecosystems) appears to be rather regular and distinct for volcanic and calcareous islands.

Bioclimatic belts

Although circum-Sicilian islets host very few weather stations, the models provided by Drago (2002) indicate that they harbour three bioclimatic thermotypes (*sensu* Rivas-Martínez, 2008) whose distribution (Figure 1) mostly depends on latitude and altitude. The harshest thermotype, infra-mediterranean, occurs on the islets in the Strait of Sicily (the whole Pelagian Archipelago and the lowest part of the Egadi islands and Pantelleria). The thermo-mediterranean thermotype is widespread up to 450 m a.s.l. on all the satellite islands. The tops of the major islands (i.e., Pantelleria, Marettimo, Alicudi, Filicudi, Lipari, Salina, and Stromboli) that exceed 600 m a.s.l. experience the meso-mediterranean thermotype. Moreover, a very humid microclimate occurs on the top (> 800 m a.s.l.) of Pantelleria, Salina, and Stromboli.

In the absence of anthropogenic disturbance, those circum-Sicilian islets that are subject to the infra or thermo-mediterranean climate should be covered by a discontinuous maquis dominated by evergreen or summer-deciduous shrubs (e.g., *Anagyris foetida*, *Euphorbia dendroides*, *Lycium intricatum*, *Periploca angustifolia*, *Rhus pentaphylla*) and a few conifers like *Pinus halepensis* and *Juniperus turbinata*, while the meso-mediterranean belt should be dominated by thermophilous oak woods containing *Quercus ilex*, *Q. suber*, and *Q. virgiliana* (and *Pinus pinaster* subsp. *hamiltonii* at Pantelleria).

According to many recent studies of the Pleistocene (Agnesi *et al.*, 2000; Incarbona *et al.*, 2010), glacial maxima probably coincided with very arid conditions in the central Mediterranean, so that the most widespread Sicilian natural landscape was a savannah with very scattered tree cover (Noti *et al.*, 2009; Tinner *et al.*, 2009). On the other hand, several works focusing on the genetic diversity of woody trees have highlighted the special role played by the main island; the canyons and the mountain ranges facing the northern coast acted as refugia because of their humid meso and microclimate (Dumolin-Lapègue *et al.*, 1997; Hewitt, 1999; Fineschi *et al.*, 2005; ecc.). The same role could have been played by satellite islands, which still host some exceptionally isolated species such as *Pseudoscabiosa limonifolia* (Devesa, 1984), *Bupleurum dianthifolium* (Neves & Watson, 2004), *Cytisus aeolicus* (Cristofolini & Troìa, 2006), and *Eokochia saxicola* (Kadereit & Freitag, 2011).

Number and patchiness of local plant communities

Table 4 outlines the high heterogeneity of the natural landscape of 18 circum-Sicilian islets. In fact, these islets host 29 different habitats of community interest according to the 92/43 EU Directive. The large number of niches and the unevenness of their distribution and cover probably account for much of the floristic richness and diversity between archipelagoes and among islets of the same archipelago.

	Habitat status on 18 circum-Sicilian islets																	
Habitat	**Lpe**	**Lpi**	**Lin**	**Pte**	**ILu**	**Fav**	**Lev**	**Mar**	**Ust**	**Ali**	**Fil**	**Vul**	**Lip**	**Sal**	**Pan**	**LBi**	**Str**	**Stc**
1210	P		L	EX	P	P		P	T	L	L	P	L	L	P		P	
1240	P	L	T	P	P	P	P	P	P		P		EX	P	L	P	P	P
1310					P	L	L							P				
1410					P	T						T	T					
1420	L	P			P	L	L	L				P	L	L		P		
1430	P													EX				
1510*					P													
2110	T		P			L						T					EX	
2210*	T																	
2230	T		L									T			T			
3140	T																	
3150	T					T												
3170*	T			T	L	T	T	T	T			EX	EX					
5210	EX		EX	P														
5320	P		T					T			P	P	P	P	P		P	P
5330	P		P	P	P	P	P	P	P	P	P	P	P	P	P		P	P
5430	P		P	P		P	P	P										
6220*	P		P	P	P	P	P	P	P	P	P	P	P	P			P	
6310												L						
8130								P		P	P	P		P	P		P	
8210						P	P	P		P	P	P	P	P	P		P	
8220			P	P					P			P		P				
8310						P	P											
8320			P	P					P			P	P		P		P	
91AA*										EX	EX	EX	EX	EX	EX			
9260											EX		T	T				
9320	T			P		EX			EX									
9340				P			EX	T		EX	EX	EX	T	EX	EX		EX	
9540	EX			P				T										
P	15	2	10	11	9	13	9	12	7	5	7	13	10	11	8	2	8	3
T	7	0	2	1	0	3	1	4	2	0	0	3	3	1	1	0	0	0
L	1	1	2	0	1	3	2	1	0	1	1	1	2	2	1	0	0	0
EX	2	0	1	1	0	1	1	0	1	2	3	3	3	3	2	0	2	0

Table 4. The status of the terrestrial habitats (according to the 92/43 EU Directive) on 18 circum-Sicilian islets. P = present; T = threatened by direct human pressure; L = localised; EX = extinct in historic times. Island abbreviations are provided in Table 3.

The history of natural and human disturbance

Besides earthquakes, tsunamis, and volcanoes, two other disturbance factors have greatly affected the Sicilian landscape: herbivores and humans. Herbivores could have affected the floristic assemblages of chersogenous islands (Greuter, 1991) like Favignana, Levanzo, and Lampedusa at least since the beginning of the Pleistocene (Capasso Barbato *et al.*, 1988; Bonfiglio *et al.*, 2002), while humans first occasionally and permanently colonized Sicily c. 35 and c. 20 Ky BP, respectively (Tusa, 1994; Mussi, 2001). Human activities have influenced the natural landscapes of the main circum-Sicilian islands since the Mesolithic (e.g., Levanzo) and during the Neolithic (e.g., Lampedusa, Pantelleria, Favignana, Ustica, and the Aeolian Archipelago). Burning, clearing, cutting, farming, ploughing, etc. not only fostered the success of many allochthonous pioneer and helio-xerophilous plants now referred to as "archaeophytes" but also gave rise to a complicated mosaic of prevalently open habitats dominated by sub-shrubs and grasses (Guarino *et al.*, 2005; Guarino, 2006). Forest communities were nearly erased, so that many woody species such as *Acer campestre* or *Quercus* cfr. *virgiliana* disappeared during pre-historic (Poggiali *et al.*, 2012) or historic (Calò *et al.*, *2013*) times or are now threatened with extinction (La Mantia & Pasta, 2005).

In recent times, and especially during the last 20–40 years, nearly all Mediterranean islands experienced a strong decline in agro-pastoral activities. Nonetheless, the frequency and intensity of past human disturbance still affects the current plant communities, including the speed and the path of succession (Quézel & Médail, 2003; Blondel, 2007).

Over recent decades, the major threats to natural conservation involve the destruction and fragmentation of native ecosystems, mostly due to seasonal mass tourism and its by-products (e.g., garbage dumping and alien introduction: Briasoulis, 2003; Vogiatzakis *et al.*, 2008; Affre *et al.*, 2010) and to improper afforestation activities.

A DEEPER INSIGHT INTO THE EFFECTS OF HUMAN PRESSURE

In the following paragraphs, we analyse the complex interaction between botanical heritage, past and present human pressure, and conservation priorities.

Agriculture

Human activities can increase floristic diversity: in fact, the traditional low-impact agricultural practices typical of the circum-Sicilian islands (including horticulture; cereal crop culture; olive, caper, and wine culture on terraces surrounded by stone walls; etc.) gave rise to complex agro-ecosystems formed by cultivated areas and fallows that hosted, and still host, many interesting species and plant communities that are rapidly disappearing with land abandonment. This is the fate of many companion species of the last cereal crops and fallows at Lampedusa (Pasta, 2001; La Mantia *et al.*, 2011), Marettimo (Gianguzzi *et al.*, 2006), Ustica (Pasta *et al.*, 2007b), Pantelleria, and the Aeolian Islands (Rühl & Pasta, 2008). At present, some of these plants, like *Volutaria lippii* and *Marrubium alysson*, live only in the fallows of Linosa and Lampedusa, and nowhere else in Sicily.

Fig.3. One of the last terraced areas of Lampedusa (Pelagie Archipelago) devoted to cereal crop cultures (photo T. La Mantia).

Fig.4. The progressive succession after abandonment of Pantelleria's cultivated terraces leads to a very fast recovery of shrubland and maquis communities (photo J. Rühl).

Grazing

Grazing and cattle management are important for nature conservation in the circum-Sicilian islands, as exemplified by the vascular flora of Lampedusa. The island hosts the only Italian populations of several "grazing-dependent" plants like *Colymbada acaulis* and *Echinops spinosissimus* subsp. *spinosus*. According to recent reports (La Mantia *et al.*, 2009), the spread and survival of the former species depends on grazing disturbance, while the rapid decrease of the latter species correlates with the cessation of pastoral practices. Moreover, *Caralluma europaea* subsp. *europaea*, *Ophrys picta*, and *Oncostema dimartinoi* are "grazing-tolerant" in that they prefer open areas with more light and space but suffer from overgrazing and mechanical damage caused by trampling. Finally, overgrazing leads to the increasing extension of grasslands dominated by poisonous geophytes like *Charybdis maritima* and *Asphodelus ramosus* and the local endemic *Thapsia pelagica* (Brullo *et al.*, 2009b); the latter species may be indirectly favoured by high grazing pressure because of its low palatability.

Seasonal tourism

Mass summer tourism provides rapid, short-term economic benefits but causes long-lasting ecological and economic damage. Summer tourism heavily impacts coastal ecosystems, especially sandy beaches (on Lampedusa, Linosa, Favignana, Vulcano, Panarea, and Stromboli), whose plant communities are greatly altered or even destroyed. Moreover, the continuous increase of off-road vehicles and parking areas near the coasts not only threatens the survival of many noteworthy species by increasing the fragmentation of their communities but also reduces their reproductive success because the dust generated by cars outcompetes pollen. This seems to be the sad fate of many endemic *Limonium* species such as *L. aegusae* at Favignana.

Some species, like rupicolous ones, seem to be safe from this form of disturbance because they colonize sites that are difficult to reach and/or are far from the most crowded areas. In contrast, species like *Juncellus laevigatus* subsp. *laevigatus*, *Limonium secundirameum*, and *Schoenoplectus lacustris* subsp. *thermalis* live along the borders of "Lago di Venere" at Pantelleria and are subject to high anthropogenic pressure; because of their extreme localization, they seem somehow "self-condemned" as they become rarer and rarer due to high human pressure near the hot springs during summer.

Fig. 5. The Aeolian Islands have experienced deep land use changes over recent decades. Here we see the touristic centre of Vulcano (photo T. La Mantia).

Mass tourism causes other collateral damage. For example, the entire life cycle of some endemic (e.g., *Elatine gussonei*) and protected species (e.g., *Matricaria aurea*) on Lampedusa is linked to small rock pools and temporary ponds, which have been and are continuing to be destroyed by unmanaged and illegal urbanization associated to tourism.

Waste increase

Insufficient or incorrect management of public and private waste dumps has supported a rapid increase in numbers of the yellow-legged seagull (*Larus michahellis*) throughout the whole Mediterranean basin (Médail & Vidal, 1998; Vidal *et al.*, 2000). The consequences have been large and negative. Lampione, for example, currently hosts only 20 of the 36 plant species that it hosted 50 years ago, when no seagulls lived there; today, 300 pairs of seagulls breed and exploit the rubbish mounds on Lampedusa (some 20 Km from the islet). The local impact of seagull colonies has been particularly large on endemic plant species: *Daucus rupestris*, a rare Sicilian endemic, has already become extinct, while *Limonium albidum* and *Bellevalia pelagica*, which are strictly endemic on this tiny islet, are currently represented by only ca. 50 individuals (Brullo *et al.*, 2009) and are threatened by direct disturbance (trampling, nesting activities) and indirect disturbance (nutrient increase and soil quality disruption) caused by seagulls (Pasta, 2002a; Lo Cascio & Pasta, 2012). Large seagull colonies have greatly influenced other Sicilian microinsular plant assemblages; seagull colonies, for example, have caused an intense species turnover and a significant increase of xenophytes at Isola delle Femmine near Palermo (Caldarella *et al.*, 2010).

Fig. 6. The natural landscape of Lampione and many others islets is strongly affected by a huge colony of yellow-footed seagulls (photo S. Pasta).

Fig. 7. Many circum-Sicilian islands, like Linosa, are characterised by a patchy landscape due to gradual land abandonment (photo S. Pasta)

Alien introduction

The data reported in Table 5 suggest that volcanic islands are more vulnerable than other kinds of islands to xenophytes. The data also confirm a pattern previously observed on many other Mediterranean and Canarian islands, which is that the vulnerability to alien invasion is positively correlated with the endemism rate. Many xenophytes are already established on the circum-Sicilian islands. They were mostly introduced for ornamental purposes (Mazzola & Domina, 2008) and began to become naturalised during the 19th century (Pasta, 2003). Some currently act as dangerous invaders and are menacing not only to pre-forest and forest communities (e.g., *Acacia* spp., *Ailanthus altissima*, and *Paraserianthes lophantha*: Villari & Zaccone, 1999; Badalamenti *et al.*, 2012; Pasta *et al.*, 2012b) and coastal communities (e.g. *Carpobrotus* spp., *Pennisetum setaceum*: Vilà *et al.*, 2006; Pasta *et al.*, 2010), but also to islet endemics (Troìa *et al.*, 2005; Pasta & La Mantia, 2008). Global warming may have played an important role in the steep increase of casual, naturalized, and even invasive aliens on Sicilian satellite islands during recent decades, and the ecological consequences of this trend could be even more severe in the future (Gritti *et al.*, 2006; Heywood, 2011).

	Number of noteworthy and alien taxa on 18 circum-Sicilian islets																	
Taxon type	**Lpe**	**Lpi**	**Lin**	**Pte**	**ILu**	**Fav**	**Lev**	**Mar**	**Ust**	**Ali**	**Fil**	**Vul**	**Lip**	**Sal**	**Pan**	**LBi**	**Str**	**Stc**
Noteworthy extant	74	5	38	75	53	80	61	70	26	37	39	31	57	50	41	4	25	6
Noteworthy extinct	25	1	12	8	0	5	2	15	17	2	5	1	8	2	3	0	3	0
Alien	43	3	26	42	26	42	32	41	21	21	28	19	38	26	26	2	14	1

Table 5. A rough comparison between the conservation value and the invasion rate of the vascular flora of 18 circum-Sicilian islets. Island abbreviations are provided in Table 3.

Afforestation

Since the 1960s, some parts of Lampedusa, Linosa, Marettimo, Levanzo, Ustica, Salina, Vulcano and Favignana have been used for the development of artificial plantations. Unfortunately, these plantations have greatly reduced local plant diversity and harmed ecosystem functioning, especially in plantations where the final canopy cover is too dense, where needle litter is not managed, and where soil erosion is excessive because of incorrect pre-planting practices (Pasta *et al.*, 2012a). In particular, the use of non-native *Pinus halepensis* germplasm has substantially reduced the survival of the small remnant nuclei of indigenous pines once present on Lampedusa and Marettimo and has favoured the establishment of several allochthonous trees and shrubs.

CONCLUDING REMARKS

A precious but endangered treasure

More than 300 vascular plants (i.e., about 20% of the total flora of the circum-Sicilian islands) should be considered ‘noteworthy’ because of their biogeographic interest, e.g. 129 regional or local endemics or taxa situated at the latitudinal or longitudinal limit of their distribution area (Pasta, 1997). Moreover, 49 out of 135 Sicilian plants included in the annexes and appendices of the Bern and/or Washington (CITES) Conventions and/or the 92/43 EU Directive (Table 6) live also or only on circum-Sicilian islands. When considering the two available regional red lists following IUCN risk categories, 182 of 660 and 118 of 1,057 extinct or threatened species reported by Conti *et al.* (1997) and Raimondo *et al.* (2011), respectively, live on the considered islands and islets.

Although Greuter (1991) emphasized the very high stability of Mediterranean flora, over the last two centuries extinction has occurred much more frequently than previously thought on many circum-Sicilian islands and islets. In fact, two-thirds of those species that are extinct or extinct-in-the-wild are microinsular endemics (Table 7), and many species that are protected and/or included in Sicilian red lists have experienced local extinction or strong rarefaction over recent decades. These include *Allium subvillosum*, *Ambrosia maritima*, *Arbutus unedo*, *Asphodelus tenuifolius*, *Asplenium balearicum*, *Brassica macrocarpa*, *Calendula maritima*, *Cistus parviflorus*, *Cynomorium coccineum*, *Daucus rupestris*, *Erica sicula* subsp. *sicula*, *Erucastrum virgatum*, *Euphorbia papillaris*, *Glaucium corniculatum*, *Globularia alypum*, *Limonium avei*, *Loeflingia hispanica*, *Ophrys lunulata*, *Orchis provincialis*, *Osmunda regalis*, *Phyllitis sagittata*, *Pinus halepensis*, *Silene bellidifolia*, *Silene turbinata*, *Suaeda vermiculata*, among others.

In most cases, plant disappearance has been caused, or at least enhanced, by human activities. This has undoubtedly been the case for Lampedusa and Linosa, whose natural landscapes were rapidly disrupted during the second half of the 19th century (Pasta & La Mantia, 2004). Many local extinctions involved plants that were linked to the most fragile ecosystems, such as sandy shores, dunes, brackish lagoons, temporary ponds, and forests; these habitats have been strongly disturbed or completely destroyed by human activities and are still severely threatened by them (Table 4). Moreover, psammophilous plant communities (and their habitats, i.e., 1210, 2110, 2210*, and 2230) often occur in small areas and can be easily destroyed by human disturbance.

Other species may have disappeared (or are severely threatened) because of their extremely narrow ecological requirements and/or distribution range. An example is *Eokochia saxicola* (Santangelo *et al.*, 2012).

Taxon	**Bern**	**CITES**			**92/43 EU Directive**		
	Ann. 1	**App. 2**	**Ann. A**	**Ann. B**	**Ann. 2**	**Ann. 4**	**Ann. 5**
Brassica insularis Moris	X				X	X	
Brassica macrocarpa Guss.	X				X	X	
Bupleurum dianthifolium Guss.	X				X	X	
Cephalanthera rubra (L.) L.C.M. Richard		X		X			
Cyclamen hederifolium Aiton		X		X			
Cyclamen repandum Sm.		X		X			
Cytisus aeolicus Guss.	X			X	X	X	
Dianthus rupicola Biv.[1]	X			X	X	X	
Elatine gussonei (Sommier) Brullo					X	X	
Eokochia saxicola (Guss.) Freitag & G. Kadereit	X				X	X	
Epipactis cfr. *microphylla* (Ehrh.) Sw.[2]		X		X			
Euphorbia dendroides L.		X		X			
Himanthoglossum robertianum (Loisel.) P. Delforge		X		X			
Limodorum abortivum (L.) Sw.		X		X			
Limodorum trabutianum Batt.		X		X			
Linaria pseudolaxiflora Lojac.	X			X	X		
Ophrys apifera Huds.		X		X			
Ophrys apulica (O. & E. Danesch) O. & E. Danesch		X		X			
Ophrys bertolonii Moretti		X		X			
Ophrys bombyliflora Link		X		X			
Ophrys explanata Lojac.		X		X			
Ophrys flammeola Delforge		X		X			
Ophrys grandiflora Ten.		X		X			
Ophrys incubacea Tod.		X		X			
Ophrys lunulata Parl.	X	X	X		X	X	

Ophrys lutea Cav.		X		X			
Ophrys picta Link		X		X			
Ophrys scolopax Cav.		X		X			
Ophrys sicula Tineo		X		X			
Ophrys speculum Link		X		X			
Ophrys sphegifera Willd.		X		X			
Orchis anthropophora (L.) All.	X	X		X			
Orchis collina A. Russel		X		X			
Orchis commutata Tod.		X		X			
Orchis intacta Link		X		X			
Orchis italica Poir.		X		X			
Orchis lactea Poir.		X		X			
Orchis longicornu Poir.		X		X			
Orchis papilionacea L.		X		X			
Ruscus aculeatus L.							X
Serapias bergonii E.G. Camus		X		X			
Serapias cordigera L.		X		X			
Serapias cossyrensis B. & H. Baumann		X		X			
Serapias lingua L.		X		X			
Serapias nurrica Corrias		X		X			
Serapias parviflora Parl.		X		X			
Serapias vomeracea (Burm. fil.) Briq.		X		X			
Silene hicesiae Brullo & Signorello					X	X	
Spiranthes spiralis (L.) Chevall.		X		X			

Table 6. Plants of the circum-Sicilian islands protected by the Bern and CITES international conventions and the 92/43 EU Directive (data from Mercurio et al.*, 2012, modified). Ann. = Annex; App. = Appendix; [1]the populations of Lampedusa are ascribed to subsp.* lopadusanus*, while those of The Aeolian Islands are ascribed to subsp.* aeolicus*; [2]the population of* Epipactis *on Pantelleria is designated cfr.* microphylla *pending the results of ongoing investigations.*

Endemic plants of the circum-Sicilian islands that have become extinct *Echium spurium* Lojac. and *Limonium parvifolium* (Tineo) Pignatti (Pantelleria); *Limonium catanense* (Lojac.) Brullo (sea cliffs near the harbour of Catania)
Endemic plants of the circum-Sicilian islands that only survive in farming *Limonium intermedium* (Guss.) Brullo and *Cistus* × *skanbergi* Lojac. (Lampedusa)
Regional extinction of plants once present only on circum-Sicilian islands Lampedusa: *Carthamus lanatus* L. subsp. *baeticus* (Boiss. & Reuter) Nyman, *Launaea nudicaulis* (L.) Hook. f., *Teucrium creticum* L. Linosa: *Medicago secundiflora* Durieu, *Patellifolia patellaris* (Moq.) A.J. Scott, R.V. Ford-Lloyd & J.T. Williams, *Silene muscipula* L., *Spergula fallax* (Lowe) E.H.L. Krause Egadi: *Astragalus thermensis* Valsecchi Eolie: *Lamium purpureum* L.
Exclusive endemic plants of the circum-Sicilian islands Pelagie: *Limonium lopadusanum* Brullo; Lampedusa: *Allium hemisphaericum* (Sommier) Brullo, *Allium lopadusanum* Bartolo, Brullo & Pavone, *Allium pelagicum* Brullo, Pavone & Salmeri, *Anthemis lopadusana* Lojac., *Chiliadenus lopadusanus* Brullo, *Daucus lopadusanus* Tineo, *Dianthus rupicola* Biv. subsp. *lopadusanus* Brullo & Minissale, *Diplotaxis scaposa* DC., *Oncostema dimartinoi* (Brullo & Pavone) F. Conti & Soldano, *Suaeda pelagica* Bartolo, Brullo & Pavone and *Thapsia pelagica* Brullo, Guglielmo, Pasta, Pavone & Salmeri; Linosa: *Erodium neuradifolium* Delile var. *linosae* (Sommier) Brullo, *Limonium algusae* (Brullo) Greuter, *Pancratium linosae* Soldano & F. Conti and *Valantia calva* Brullo; Lampione: *Bellevalia pelagica* C. Brullo, Brullo & Pasta, *Limonium albidum* (Guss.) Pignatti↓ and *Pancratium* sp. Pantelleria + Linosa: *Filago lojaconoi* (Brullo) Greuter Pantelleria: *Anthemis cossyrensis* (Guss.) Guss., *Helichrysum errerae* Tin. var. *errerae*, *Limonium cosyrense* (Guss.) O. Kuntze, *Limonium secundirameum* (Lojac.) Greuter↓, *Matthiola incana* (L.) R. Br. subsp. *pulchella* (P. Conti) Greuter & Burdet and *Serapias cossyrensis* B. & H. Baumann Egadi: *Brassica macrocarpa* Guss.↓; Marettimo: *Allium franciniae* Brullo & Pavone, *Bupleurum dianthifolium* Guss., *Helichrysum errerae* Tin. var. *messerii* (Pignatti) Raimondo, *Limonium tenuiculum* (Guss.) Pignatti, *Oncostema hughii* (Guss.) Speta, *Prospero hierae* Brullo, C. Brullo, Giusso, Pavone & Salmeri and *Thymus nitidus* Guss.; Favignana: *Limonium aegusae* Brullo↓ Ustica: *Limonium usticanum* Giardina & Raimondo Eolie: ?*Anthemis aeolica* Lojac.↓, *Centaurea aeolica* Lojac. subsp. *aeolica*, *Cytisus aeolicus* Guss.↓, *Genista thyrrena* Valsecchi subsp. *thyrrena* and *Silene hicesiae* Brullo & Signorello; Alicudi: *Erysimum brulloi* Ferro

Plants that only occur on circum-Sicilian islands within the regional territory

Lampedusa: *Caralluma europaea* (Guss.) N.E. Br. subsp. *europaea*, *Cistus parviflorus* Lam.↓, *Colymbada acaulis* (L.) Holub, *Echinops spinosissimus* Turra subsp. *spinosus* Greuter, *Elatine gussonei* (Sommier) Brullo, *Eruca sativa* Mill. subsp. *longirostris* (Uechtr.) Jahand. & Maire, *Hypericum aegypticum* L. subsp. *webbii* (Spach) N.K.B. Robson, *Linaria reflexa* (L.) Desf. subsp. *lubbockii* (Batt.) Brullo, *Marrubium alysson* L., *Ophrys picta* Link and *Paronychia arabica* (L.) DC. subsp. *longiseta* Batt., Linosa: *Astragalus peregrinus* Vahl subsp. *warionis* (Gand.) Maire, *Linaria pseudolaxiflora* Lojac., *Lotus halophilus* Boiss. & Spruner, *Silene apetala* Willd.↓, *Silene behen* L.↓ and *Volutaria lippii* (L.) Maire

Pantelleria + Linosa: *Bellium minutum* L.

Pantelleria: *Allosorus guanchicus* (Bolle) Christenh., *Antirrhinum tortuosum* Bosc., *Calicotome spinosa* (L.) Link, *Carex illegitima* Cesati, *Genista aspalathoides* Lam., *Juncellus laevigatus* (L.) C.B. Clarke subsp. *laevigatus*, *Limodorum trabutianum* Batt., *Ophrys sphegifera* Willd., *Pinus pinaster* Solander subsp. *hamiltonii* (Ten.) Huguet del Villar, *Schoenoplectus litoralis* (Schrader) Palla subsp. *thermalis* (Trabut) Hooper and *Scrophularia frutescens* L.

Egadi: *Aristolochia navicularis* Nardi; Favignana: *Ophrys scolopax* Cav.; Marettimo: *Erodium maritimum* (L.) L'Hérit., *Daphne sericea* Vahl and *Thymelaea tartonraira* (L.) All.

Eolie: *Clematis vitalba* L., ?*Daucus foliosus* Guss., *Eokochia saxicola* (Guss.) Freitag & G. Kadereit, *Vicia articulata* Hornem., *Wahlenbergia lobelioides* (L. f.) Link subsp. *nutabunda* (Guss.) Murbeck

Isole del Canale di Sicilia: *Filago gussonei* Lojac., *Hornungia revelierei* (Jordan) Soldano, F. Conti, Banfi & Galasso subsp. *sommieri* (Pamp.) Soldano, F. Conti, Banfi & Galasso, *Periploca angustifolia* Labill. and *Reichardia tingitana* (L.) Roth

Table 7. Biogeographical "highlights" of the vascular flora of Sicilian satellite islands. ↓ = subject to recent demographic decrease. ? = taxa whose taxonomic status is uncertain.

Fig. 8. Filago lojaconoi *is a dwarf annual plant endemic of Linosa and Pantelleria (photo S. Pasta).*

Fig. 9. Oncostema dimartinoi *is endemic to Lampedusa Island (photo G. Nicolini).*

Fig. 10. Matthiola pulchella *colonizes the rocky habitats of Pantelleria (photo L. Scuderi).*

Fig. 11. Silene hicesiae *is one of the most interesting plants that live only on Aeolian Islands (photo P. Lo Cascio).*

Fig. 12. Limonium lojaconoi *is a plant endemic of Egadi Islands and western Sicily (photo L. Scuderi).*

Natural processes and conservation policies

How to cope with land-use change?

The high level of species and habitat-richness of the circum-Sicilian islands and islets cannot be maintained by a strategy of non-intervention. Recent field investigations of succession on the circum-Sicilian islands have demonstrated that in the absence of low and regular disturbance regimes (e.g., monitored agricultural and pastoral activities), the patchy vegetation of some islands (especially the volcanic ones) will change into monotonous and rather species-poor pre-forest and forest communities within a few decades (Rühl *et al.*, 2006; Pasta *et al.*, 2007a; La Mantia *et al.*, 2008; Rühl & Pasta, 2008). As a consequence, many cultural landscapes will vanish along with many noteworthy plant species, like the dwarf annual species that thrive in the ephemeral prairies or in the fallows. On the other hand, the intervention required for promoting forest recovery and for maintaining local species-richness must be carefully planned.

To prevent the irreversible loss of many island ecosystems, we emphasize the urgent need to apply the land-use measures already described in the Management Plans of the Natura 2000 Sites concerning Sicilian satellite islands (http://www.artasicilia.eu/web/natura2000/index.html).

Re-think afforestation, now or never

Six of eleven of the terrestrial habitats that have disappeared on at least one of the circum-Sicilian islands correspond to woody plant communities, and these are 5210 (arborescent matorral with *Juniperus* spp.), 91AA* (Eastern white oak woods), 9260 (*Castanea sativa* woods), 9320 (*Olea* and *Ceratonia* forests), 9340 (*Quercus ilex* and *Quercus rotundifolia* forests), and 9540 (Mediterranean pine forests with endemic Mesogean pines) (Table 4). Moreover, the above-mentioned studies on succession outlined that the speed and the path of secondary succession mostly depend on 1) the structure of landscape patchwork (i.e., the average distance between patches requiring propagules and mature patches where those propagules are produced), 2) the disturbance regime (i.e., frequency and intensity), and 3) climate and microclimate. Because of different combinations of these three parameters, succession at Lampedusa will require more than one century in order to reach a mature woody community, while a total recovery of the evergreen maquis at Pantelleria will occur within 50 years.

Thus, afforestation practices could be recommended not only where pre-forest and forest ecosystems are critically endangered or have already disappeared but also to facilitate the natural progressive succession processes under severe bioclimatic stress. For this purpose, old-fashioned practices like subsoiling and planting pure, dense, and monospecific stands should not be used because they have been proven to be ineffective in re-activating local ecosystem functioning. Such practices should be replaced by more sustainable and low-impact ones, like the regular sowing of a mixture of seeds of native shrubs that are able to enhance or restore local facilitation mechanisms (Pasta *et al.*, 2012a).

As already emphasized by Pasta and La Mantia (2009), Sicilian forest ecosystems play an important role in protecting many endemic, rare, or endangered plants. This is true also in the case of satellite islands, where semi-natural woodlands also deserve special attention. For example, the remnant *Castanea sativa* orchards at Pantelleria and in the Aeolian Archipelago are not only a living monument of past agro-forestry activities but also continue to be the unique habitat for the rare, threatened, and/or protected plant species listed in Tables 6–7. As a consequence, any future project aimed at managing or even restoring Sicilian microinsular pre-forest and forest ecosystems must be planned carefully to avoid abrupt changes of abiotic factors (e.g., light and humidity) or biotic factors (e.g., herb-layer coverage) that could menace those plants that require protection.

First efforts to conserve the botanical heritage of Sicilian satellite islands

The Aeolian Islands provide a paradigmatic example of the sharp differences between conservation legal measures and their present application. Although most of them are included within regional nature reserves, and although they belong to the Natura 2000 network and are included in UNESCO's World Heritage List (http://whc.unesco.org/en/list/), illegal practices leading to environmental damage are still very common and usually go unpunished.

On the other hand, after decades of mere species listing, researchers and politicians are demonstrating an increasing interest in the conservation of Mediterranean island plants (Delanoë *et al.*, 1996; Montmollin & Strahm, 2005). At the local scale, the first field inventories for conservation purposes have been conducted (e.g., rare and threatened woody species of Lampedusa: La Mela Veca *et al.*, 2003) and trials have been made in order to assess the best multidisciplinary criteria for determining the natural values of some territories (e.g. Aeolian Archipelago: Lo Cascio & Pasta, 2004). Meanwhile, some LIFE Projects have already aimed at conserving the vascular flora and the plant communities of Sicilian satellite islands. The first project, NAT/IT/006217 (named "Eolife99"), focused on *in situ* and *ex situ* conservation of four species on The Aeolian Islands of priority interest according to the 92/43 UE Directive (Troìa *et al.*, 2005; http://web.tiscali.it/ecogestioni/eolife). Subsequently, some locally threatened species have been propagated within the Project NAT/IT/000163 "Riduzione impatto attività umane su *Caretta* e *Tursiope* e loro conservazione in Sicilia" at Lampedusa (La Mantia *et al.*, 2012), while invasive alien plant eradication is one of the objectives of Project NAT/IT/000093 ("Pelagic Birds"; http://www.pelagicbirds.eu/).

It is important that e*x situ* conservation actions (through seed banks: Gómez Campo, 1979; Khoury *et al.*, 2010) and *in situ* conservation actions (Olivier & Hernández-Bermejo, 1995) carefully consider the genetic variability of the threatened species at the population level (Conte *et al.*, 1998; Troìa & Burgarella, 2004; Palla *et al.*, 2007; Scialabba *et al.*, 2008). Moreover, a very wide knowledge gap on the reproductive biology of nearly all Sicilian insular endemics still needs to be filled (Iriondo *et al.*, 1994).

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APPENDIX A - COMPLETE EPITHETS OF THE PLANTS QUOTED IN THE TEXT (see also tables 6-7)

Acer campestre L.
Ailanthus altissima (Mill.) Swingle
Allium subvillosum Schult. & Schult. f.
Ambrosia maritima L.
Anagyris foetida L.
Arbutus unedo L.
Asphodelus ramosus L.
Asphodelus tenuifolius Lam.
Asplenium balearicum Shivas
Bupleurum barceloi Willk.
Charybdis maritima (L.) Speta
Colymbada acaulis (L.) Holub
Cynomorium coccineum L.
Daucus rupestris Guss.
Erica sicula Guss. subsp. *sicula*
Erucastrum virgatum (C. Presl) C. Presl
Euphorbia dendroides L.
Euphorbia papillaris (Boiss.) Raffaelli & Ricceri
Glaucium corniculatum (L.) J.H. Rudolph
Globularia alypum L.
Juniperus turbinata Guss.
Limonium avei (De Not.) Brullo & Erben
Loeflingia hispanica L.
Lycium intricatum Boiss.
Matricaria aurea (Loefl.) Sch.-Bip.
Osmunda regalis L.
Paraserianthes lophantha (Willd.) I.C. Nielsen
Pennisetum setaceum (Forssk.) Chiov.
Phyllitis sagittata (DC.) Guinea & Heywood
Pinus halepensis Mill.
Pseudoscabiosa saxatilis (Cav.) Devesa
Quercus ilex L.
Quercus suber L.
Quercus virgiliana (Ten.) Ten.

Rhus pentaphylla (Jacq.) Desf.
Silene bellidifolia Jacq.
Silene turbinata Guss.
Suaeda vermiculata J.F. Gmel.
Thymus richardii Pers. subsp. *ebusitanus* (Font-Quer) Jalas
Thymus richardii Pers. subsp. *richardii*

3: Eastern Mediterranean

FLORA AND PHYTOGEOGRAPHY OF THE IONIAN ISLANDS (GREECE)

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Abstract

The Ionian Islands are located in the Ionian Sea in western Greece. The major Ionian Islands are Corfu (Kerkira), Lefkada, Ithaci, Cephalonia and Zacynthos, but there are also many smaller islands and islets. The size of each island ranges from 1.5 ha to 78,100 ha, while the maximum elevation ranges from 12 m to 1,628 m. In the phytogeographic region of the Ionian area, there is a National Park (Mount Aenos, Cephalonia), a National Marine Park (Zacynthos) and all, or in two cases part of, the twenty-one SCI and/or SPA Natura 2000 Sites covered by more than 20 different habitat types from Annex I. With regard to the Ionian Islands floristic composition, a database has been created using all available literature and the authors' unpublished data, with a total number of about 2,500 plant species and subspecies, 3.2% of which are Greek endemics and 0.9% of which are endemic to the area or a single island. This low rate of endemism is possibly due to the palaeogeography of the Ionian area, which is quite simple, with most islands becoming isolated from the mainland during the Pleistocene or even more recently. The relationship between biogeographical factors and plant diversity is examined and discussed as well as b-diversity between islands and islets. We also focus on the presence of invasive species in the floristic composition of the islands and the conservation status, measures and strategies for the protected areas and the critical species.

Keywords: *Biodiversity, island flora, endangered species, single island endemics, island biogeography, alien species.*

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INTRODUCTION

Among the main characteristics of the Greek area, focal points are: the rich plant species diversity, the high rates of endemism and rarity as well as the huge number of islands and islets surrounding mainland and dispersed in the Aegean, the Cretan and the Ionian seas. Greek islands occupy 19% of the land area of Greece and they are mainly of continental origin (Strid & Tan, 1997). The geotectonic evolution of the Greek Islands has had a major contribution in shaping the biogeographic patterns of all recent taxa of these areas (Triantis & Mylonas, 2009).

The Ionian Islands (IoI) are located in the Ionian Sea in western Greece (Fig. 1). The major Ionian Islands are Cephalonia, Corfu (Kerkyra), Lefkas, Zacynthos and Ithaci (Table 1). The island of Cephalonia is the largest and has a greatest elevation (1628 m) (Table 1). There are also groups of small islands and islets like the Paxoi and Antipaxoi group (both islands surrounded by many islets), Diapontia islands group, Echinades islets group (more than 20 islets), Strofades group (the 2 small islands of Stamphani and Arpuia), (Table 1).

In the phytogeographic region of the Ionian Islands, there is a National Park (GR2220002: Mount Aenos, Cephalonia), a National Marine Park (GR 2210002: Zacynthos), and all, or in two cases part of, the twenty-one SCI and/or SPA Natura 2000 Sites covered by more than 20 different habitat types from Annex I (Table 2). It should also be mentioned that most of the Echinades islets are part of two overlapping Natura 2000 sites (GR 2310001, GR2310015), which are also included in the Ramsar Convention protected sites and have recently been defined as a National Park.

Many floristic studies have been carried out on the Ionian Islands (Table 3). Tzanoudakis and Panitsa (1995) also refer to floristic information concerning Ionian Islands and islets. Tan & Iatrou (2001) mention a total number of 1,886 plant taxa while Georghiou & Delipetrou (2010) are providing quantitative data for the Greek endemic plant taxa of the Ionian phytogeographical area. The Red Data Book of Rare and Threatened Plants of Greece (Phitos *et al.*, 1995, 2009) also includes critical taxa of the Ionian Islands flora.

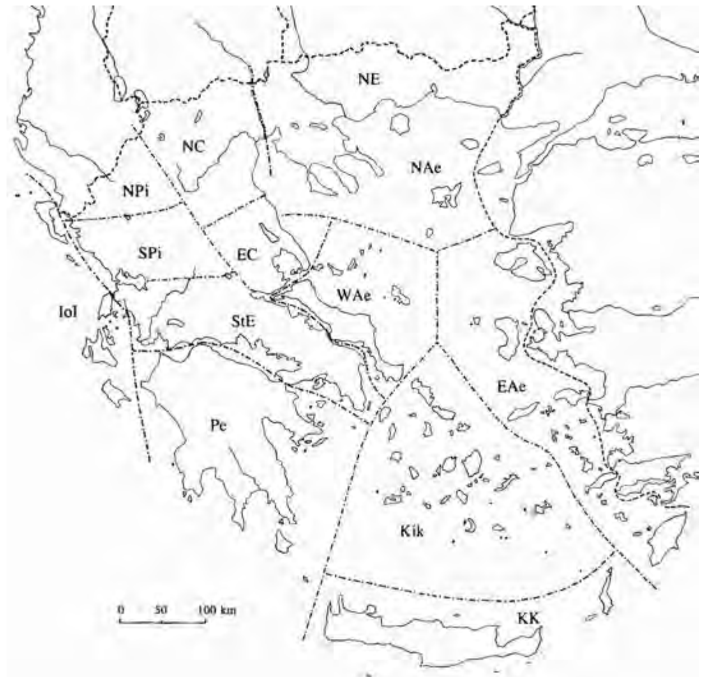

Fig. 1. The phytogeographical regions of Greece (Strid & Tan, 1997).

FLORISTIC ANALYSIS

Species richness

In the framework of our studies concerning plant species diversity and biogeography of the small islands and islets of the Ionian area (IoI), a database has been created using all available literature for 13 islands and the authors' unpublished data for more than 20 islets of the Echinades islets group. Over 2,540 plant species and subspecies have been registered belonging to 132 families. Table 1 presents floristic data concerning islands and island groups.

For this vascular flora, angiosperms predominate (97% of the total flora) and among them more than 30% belong to three dominant families, Leguminosae, Compositae and Gramineae. Nearly 50% of the plant taxa in the database present very low incidence and has been registered on one or two of the islands or islets while none have been found on all and only 3% of the total flora is found on more than half of the islands and islets. The most common species are: *Pistacia lentiscus* L., *Euphorbia dendroides* L., *Lotus cytisoides* L., *Asparagus acutifolius* L., *Brachypodium retusum* (Pers.) Beauv., *Parapholis incurva* (L.) C.E. Hubbard, *Urginea maritima* (L.) Baker, *Smilax aspera* L. and *Valantia muralis* L.

Island group	Island/Islet	S	A	E
	Cephalonia (Kf)	1597	78100	1628
	Kerkyra (Kr)	1866	59200	914
	Zacynthos (Za)	937	40600	758
	Leukada (Le)	369	32500	1158
	Ithaki (It)	609	9600	806
	Kalamos (Ka)	223	2500	724
	Vidos (Vi)	175	53.8	33
Paxoi - Antipaxoi		553	3410	230
	Paxoi (Px)		3000	230
	Antipaxoi (APx)		410	103
Diapontia Islets		558	1770	393
	Othonoi (Ot)	269	1010	393
	Erikousa (Er)	90	450	137
Strofades		364	134.3	22
	Stamfani (St)	336	118	22
	Arpuia (Ar)	60	16.3	12
Echinades (Ec)	Oxeia (Ox)		426	421
	Makropoula		9.3	20
	Makri (Ma)		95.3	126
	Vromonas		95	130
	Modi		26.5	66
	Apasa		2.8	17
	Swros		3.5	31
	Gravaris		1.5	24
	Kalogeros		25.1	34
	Tsakalonisi		10	25
	Filippos		4.5	30
	Bistros		11.4	41
	Pontikos		73.2	62
	Labrino		35.3	61
	Sofia		15	43
	Provati		120.3	75
	Prasso		1.3	12
	Karlonisi		75	77
	Petalas		525	238
	Drakonera		240	121
	Total	377	1796	

Table 1. Floristic richness and values of the predictive variables used for each of the evaluated Ionian Islands. Abbreviations: S = all native plant richness (species and subsp.), A = area (ha), E = elevation (m).

Islands	Sitecode	Category	Area (ha)	Habitat type codes
Za, Ar, St	GR2210001	SCI-SPA	21419,24	1110, 1120*, 1170, 119A, 119B, 1240, 1410, 2110, 5210, 5330, 5420, 5430, 7210*, 72A0, 9320, 9540
	GR2210002	SCI	6957,7	
	GR2210003	SCI	523,13	
	GR2210004	SPA	136,01	
Kf - It	GR2220001	SCI	2566,19	1110, 1120*, 1170, 119A, 5420, 5330, 934A, 8140,8216, 951B
	GR2220002	SCI	2779,43	
	GR2220003	SCI	88333,27	
	GR2220004	SCI	3736,16	
	GR2220005	SCI	18742,55	
	GR2220006	SPA	20715,15	
Kr, Px, APx, Ot, Er	GR2230001	SCI-SPA	187,95	1120, 1150*, 1170, 119A, 119B, 1210, 1240, 1310, 1410, 1420, 2110, 2210, 2250, 5210, 5330, 5420, 6420, 7210, 72A0, 9290, 92A0, 92D0, 9320, 934A, 9540
	GR2230002	SCI	2292,38	
	GR2230003	SCI-SPA	242,97	
	GR2230004	SCI	5649,66	
	GR2230005	SCI	888	
	GR2230007	SPA	1050,98	
	GR2230008	SPA	10146,26	
Le	GR2240001	SCI-SPA	2143,4	1150, 1240, 1310, 1410, 1420, 2110, 6420, 72A0, 8210, 9320, 934A0, 9540,
	GR2240002	SCI	1255,59	
Ec (part of Ramsar site)	GR2310001	SCI	35509,89	1210, 1240, 1420, 5330, 5420
	GR2310015	SPA	44185,62	

Table 2. Site codes, category, area covered and habitat type codes (Annex 1, Dir. 92/43/EU) of the Natura 2000 sites of the Ionian phytogeographical area. Abbreviations as in Table 1.

Island/Islet	Literature
Ionian Islands	Greuter and Raus (2000, 2002, 2005, 2006), Artelari (1984), Artelari and Kamari (1986), Kamari (1991), Boratynski and Browicz (1996, 1997), Damboldt and Phitos (1970), Gutermann (1995), Kamari and Phitos (2006), Bareka *et al*. (2006), Spanou *et al*. (2006), Karakitsos (2006), Iliadou and Panitsa (unpublished data), Ostermeyer (1887), Spreitzenhofer (1877), Theodoridis *et al*. (2006), Samuel *et al*. (2006)
Cephalonia	De Bolos *et al*. (1996), Phitos *et al*. (2003), Brullo and Tzanoudakis (1994), Phitos and Artelari (1981), Phitos and Damboldt (1985), Snogerup and Snogerup (2001)
Kerkyra	Georghiou (1988), Biondi (1989), Hansen (1982), Raus (1999), Borkowsky (1994), Ronniger (1941)
Zacynthos	Braüchler *et al*. (2008), Zieliński (1991), Gutermann and Ehrendorfer (2000),
Leukada	Brullo and Tzanoudakis (1994), Phitos and Strid (1994), Snogerup and Snogerup (2001), Strasser (2001), Trigou (2006), Hofmann (1968), Willing and Willing (1983)
Ithaki	Phitos *et al*. (2003), Brullo and Tzanoudakis (1994), Markantonatou *et al*. (2002)
Kalamos	Baliousis and Yannitsaros (2010)
Vidos	Hansen (1982)
Paxoi - Antipaxoi	Georgiadis (1986), Mamasis and Panitsa (unpublished data)
Othonoi	Georgiadis (1983)
Erikousa	Georgiadis (1985)
Strofades	Yannitsaros *et al*. (1995), Panitsa *et al*.(unpublished data)
Oxeia	Christodoulakis *et al*. (1988), Iliadou and Panitsa (unpublished data)
Echinades islets group (20 islets)	Iliadou (2008), Iliadou and Panitsa (unpublished data)

Table 3. Plant species diversity contributions to Ionian Islands and islets (1981-2011).

Endemism

Endemicity of plants was estimated at different levels, as described below. Single island endemics (ES) are species whose distribution range is limited to a single island. The category of Ionian endemics (IoE) includes endemics restricted to the Ionian phytogeographical region while Greek endemics include endemics of more than one phytogeographical region, as defined by Strid and Tan (1997), (Fig. 1). Following these levels of endemicity, 81 plant taxa of the Ionian Islands flora are Greek endemics (GrE), 13 are Ionian endemics (IoE) found on more than one of the Ionian Islands and 12 are single island endemics (ES). The island of Cephalonia shelters 5 single island endemic taxa, Zacynthos has 4 and each one of the islands of Kerkyra and Lefkada hosts 1 single island endemic species. *Ajuga orientalis* L. subsp. *aenesia* (Heldr.) Phitos & Damboldt, *Limonium cephalonicum* Artelari, *Saponaria aenesia* Heldr. *Viola cephalonica* Bornm. and *Poa cephalonica* Scholtz. are endemics to Cephalonia island. *Asperula naufraga* Ehrend. & W. Gutermann, *Limonium zacynthium* Artelari, *L. phitosianum* Artelari and *Micromeria browiczii* Ziel. & Kit Tan are endemics to Zacynthos island. *Narcissus corcyrensis* (Herbert) Nyman is endemic to the island of Kerkyra and *Arenaria leucadia* to Leukada. *Limonium antipaxorum* Artelari has a restricted geographical distribution only to Paxoi and Antipaxoi islands like *Centaurea paxorum* Phitos & Georgiadis, which is also distributed mainly to Paxoi and Antipaxoi islands. *Silene cephallenia* Heldr. subsp. *cephallenia*, a rare chasmophyte, *Limonium ithacense* Artelari, a chasmophyte endemic of Cephalonia and Ithaci and other critical plant taxa of the Ionian Islands included in the Red Data Book of Rare and Threatened Plants of Greece (Phitos *et al.*, 2009) are presented in Table 4.

In addition, Krigas *et al*. (2010) mentioned that up to 7% of the 1,853 Natura 2000 Important Plant Species (IPS) recorded from Greece can be found in the Ionian Islands. The wild habitats of the IPS of the Ionian Islands may range from maritime limestone rocks to fir forests and subalpine rocky outcrops.

Family	Taxon	Status	Distribution in the Ionian area
Caryophyllaceae	*Silene cephallenia* Heldr. subsp. *cephallenia*	Critically Endangered (CR)	Kf
Violaceae	*Viola cephalonica* Bornm.	Critically Endangered (CR)	Kf
Caryophyllaceae	*Arenaria leucadia* Phitos & Strid	Endangered (EN)	Le
Caryophyllaceae	*Asperula naufraga* Ehrend. & Guterm.	Endangered (EN)	Za
Caryophyllaceae	*Saponaria aenesia* Heldr.	Endangered (EN)	Kf
Labiatae	*Scutellaria rupestris* Boiss. & Heldr. subsp. *cephalonica* (Bornm.) Greuter & Burdet	Endangered (EN)	Kf
Campanulaceae	*Campanula garcanica* Ten. subsp. *cephallenica* (Feer) Hayek	Vulnerable (VU)	Za, Kf, It, Le
Compositae	*Centaurea paxorum* Phitos & T. Georgiadis	Vulnerable (VU)	Px, APx
Compositae	*Centaurea pumilio L.*	Vulnerable (VU)	Kf
Ranunculaceae	*Consolida brevicornis* (Vis.) Soó	Vulnerable (VU)	Kf, It, Le, Ks
Coriariaceae	*Coriaria myrtifolia* L.	Vulnerable (VU)	Kr
Leguminosae	*Medicago muricoleptis* Tineo	Vulnerable (VU)	Kr, Le, Za
Labiatae	*Moluccella spinosa* L.	Vulnerable (VU)	Le, It
Liliaceae	*Lilium candidum L.*	Near Threatened (NT)	Kr, Px, APx, LE, Kf
Paeoniaceae	*Paeonia mascula* (L.) Mill. subsp. *russi* (Biv.) Cullen & Heywood	Near Threatened (NT)	Le, Kf, Za

Table 4. Ionian Islands endemics and plant taxa with wider distribution included in the Red Data Book of rare and threatened plants of Greece (Phitos et al.*, 2009). Abbreviations as in Table 1.*

Phytogeographical correlations

Using as criterion the number of common endemic plant taxa between the phytogeographical area of the Ionian Islands (IoI) and the other phytogeographical areas (Fig. 1), it is concluded that IoI is closest to the other two phytogeographical regions with west-facing coastal areas, Peloponnisos (Pe) and Sterea Ellas (StE) as well as South Pindos (SPi), (Georghiou &

Delipetrou, 2010). According to these authors the IoI has 53 Greek endemic plant taxa in common with StE, 52 with Pe and 30 with SPi, while it has less than 17 Greek endemic plant taxa in common with the other phytogeographical areas of Greece. In addition, there are eight Greek endemic plant taxa with a geographical distribution restricted to IoI and Pe, 6 restricted to IoI and StE and 1 to IoI and SPi. The Preston's dissimilarity coefficient between pairs of IoI with the other Greek floristic regions has its lower values when values for IoI are compared with StE (0.72), with Pe (0.74) and with SPi (0.77) and these values also confirm the closest phytogeographical correlations of the Ionian phytogeographical area (IoI) with its neighbouring ones StE, Pe and SPi (Fig. 1).

The rather simple, compared to the complex palaeogeography and geological history of the Aegean area, geological evolution of the islands of the Ionian, with most islands becoming isolated from the mainland during the Pleistocene or even more recently (Triantis & Mylonas, 2009; Perissoratis & Conispoliatis, 2003), has played an important role in the evolution of floral richness on the islands and could be an explanation of the low rate of endemism in the area.

Alien plant species

It should be pointed out that 82 of the 150 most widespread alien plant species in Europe (Lambdton *et al.*, 2008) are among the alien taxa registered. 66 of them are found on the island of Kerkyra, 55 on Cephalonia, 36 on Lefkada, 24 on Zakynthos, 16 on Ithaki and Paxoi, 12 on Kalamos and 6 on Vidos, while on the small islands and islets there are no more than 3 of these alien taxa. On the other hand, 189 out of the 340 alien plant taxa of Greece (Arianoutsou *et al.*, 2010) have been found, 146 of them on the island of Kerkyra, 112 on Cephalonia, 65 on Lefkada, 64 on Zakynthos, 33 on Ithaki and on Paxoi, and 20 on Kalamos, while on the small islands and islets there are no more than 11 of these alien taxa. The most common alien species found on the Ionian Islands used in this study are present on half of the islands included in this study and belong to the families of Malvaceae, Asteraceae, Brassicaceae, Fabaceae and Valerianaceae and are: *Malva sylvestris* L., *Conyza bonariensis* (L.) Cronquist, *Hirschfeldia incana* (L.) Lagrze-Fossat, *Chrysanthemum segetum L., Vicia villosa* Roth, *Rapistrum rugosum* (L.) All. and *Centranthus ruber* (L.) DC.

The number of native species is always a crucial point in island biogeography studies. There will always be uncertainties for islands with a long period of human habitation regarding whether species occurring have been introduced by man, and whether the activities of humans have led to the extinction of native species (Willerslev *et al.*, 2002).

Predictors of species richness

Independent variables examined as potential predictors of species diversity in the Ionian Islands were: island area (A, ha), maximum elevation (E, m), shortest distance from the nearest possible source and habitat diversity (H). Distance from the nearest source is the shortest distance from the nearest inhabited island (Di, km) or distance from the nearest mainland (Dm, km). As a measure of habitat diversity we used the number of different Corine land cover units recorded on the islands. Standard linear regressions, carried out with Statistica 6 (StatSoft, Inc., 2001), were used for exploring the relationships of plant species richness (S) with A, E, Di, Dm and H.

The best model is the log-log for overall native species richness and results of the simple linear regressions are given in Table 5. Species richness variance in the Ionian Islands is highly related to A ($R^2 = 0.847$), H ($R^2 = 0.796$) and E ($R^2 = 0.706$). Distance from the nearest mainland (Dm) is not significantly related with species richness and Di is only slightly related. Kallimanis *et al.* (2010) also found for the Aegean area that distance from the mainland or other inhabited islands displayed limited predictive value.

As Panitsa *et al.* (2010) remarked for the East Aegean area, where most of the islands have been recently isolated from the neighbouring mainland as is the case of the Ionian Islands, results for the Ionian area stress an important role of habitat diversity, of which elevation is another dimension, in shaping floral diversity patterns. Choros model (Triantis *et al.*, 2003) that considers the combined effect of area (A) and habitat diversity (H) as a predictor of species richness (K) described slightly better species richness patterns ($R^2 = 0.877$) than area alone and has had a higher predictive power than habitat diversity alone. Increased habitat diversity due to greater topographic and geological heterogeneity is promoting species richness, particularly when the species involved tend to be habitat specialists (Whittaker & Fernández-Palacios, 2007; Sfenthourakis & Triantis, 2009).

$\log S = 1.529 + 0.302 \log A$	$R^2=0.847$*
$\log S = 0.989 + 0.600 \log E$	$R^2=0.706$*
$\log S = 2.778 - 0.539 \log Di$	$R^2=0.329$**
$\log S = 2.024 + 0.205 \log Dm$	$R^2=0.067$ ns
$\log S = 1.908 + 0.842 \log H$	$R^2=0.796$*
$\log S = 1.521 + 0.230 \log K$	$R^2=0.877$*

Table 5. Results of simple regressions (the best fit) for the dependent variable S with A, H, E, Di and Dm as independent variables. Area (A) and habitat diversity (H) as independent variables are also given so as to evaluate the performance of the Choros (K) model. E = elevation, Dm and Di = distances from the nearest mainland and island (km), respectively. (= P<0.0001, ** = P < 0.001, ns=non significant).*

Floral similarities among Ionian Islands

Analysis of the distributional pattern of the native plant species and of the relationship between the composition of the islands' floras, based on their common plant taxa, was made by cluster analysis (Fig. 2). The preliminary analysis resulted in three distinct groups of islands / islets for the species data sets. According to analysis, the first unit (1, in Fig. 2) includes the two largest islands, Cephalonia and Kerkyra, which also have a high elevation and present islands low similarity measures between themselves and other smaller islands and islets. The third unit (3, in Fig. 2) includes the islets of Echinades islet group, which show rather high similarity values in comparison with the other units, with the exception of Oxeia (Ox) and Makri (Ma) which are larger and are included in the second unit (2, in Fig. 2).

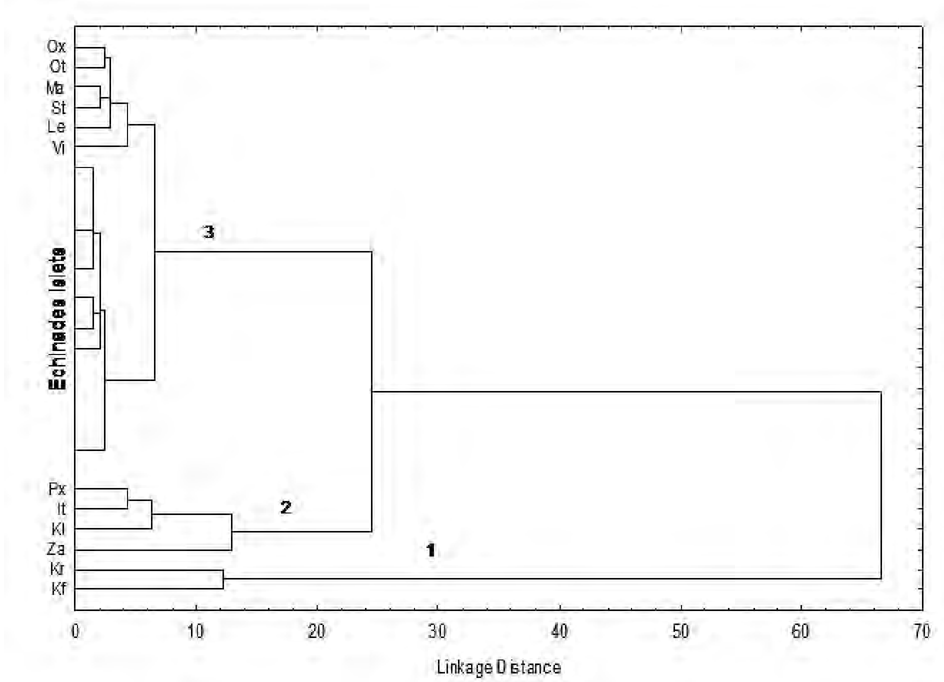

Fig. 2. Dendrogram of the cluster analysis of the distribution of plant taxa in the Ionian Islands. Abbreviations as in Table 1.

Island similarities concerning all native species show a significant geographical component, reflecting the spatial autocorrelation of floras before the fragmentation of the mainland or the effects of intensive post-fragmentation dispersal. The Ionian Islands are land-bridge islands and still behave as parts of a continuous land-mass, and for this reason the reduction of area has not yet led to a significant loss of species (Triantis *et al.*, 2008). The high species turnover rates documented by Panitsa *et al.* (2008) for small islets in the same geographical region indicate a role for dispersal in shaping the geographically congruent pattern of native species.

Concluding remarks

The biota of the Ionian Islands is very similar to those of the adjacent mainland, although few endemic taxa can still be found, most of which live on the larger and more heterogeneous islands (such as Cephalonia). Additionally, the fauna and flora of the Ionian Islands are far more "harmonic," without profound gaps in their taxonomic composition (Triantis & Mylonas, 2009). Tzanoudakis and Panitsa (1995) mentioned the enormous amount of new and basic biological information to be gathered especially in the topics where ecology and taxonomy come together.

It is well known that insular ecosystems are sensitive to human interference and any measures for their development should be taken after the ecological and socio-economic parameters in the area are considered. In the Ionian area, there is very rich plant diversity (almost 40% of the plant taxa of the Greek flora are also found in the area) although not rich in endemic plant species. The ecological importance of the Ionian area is more pronounced if we consider the existence of a large number of areas under a protection status, the presence of 11 single island endemic taxa, and according to the IUCN criteria, of 2 critically endangered, 4 endangered and 7 vulnerable plant taxa (Tables 1 and 4), as well as more than 20 habitat types, which are included in Annex I of the Directive 92/43/EU, and this should be taken into consideration in any management plan related to area development.

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THE VASCULAR FLORA OF THE MALTESE ISLANDS

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Abstract

The flora of the Maltese Islands comprises approximately 1,100 indigenous, archaeophytic and naturalised alien species and approximately 700 casual alien species. The most represented families are the Poaceae, Asteraceae and the Fabaceae. Life forms are predominantly therophytes or hemicryptophytes whilst most indigenous perennials are characterised by adaptations characteristic of xerophytes.

The proportion of endemics is relatively low (2%), compared to that of other Mediterranean islands, and this may be a consequence of the high human population density (>1,500 persons km^{-2}). Most endemics have only been subject to taxonomic and distributional studies and knowledge of their ecology is lacking. Ongoing work suggests that one of the endemics, *Helichrysum melitense*, has very low rates of reproductive success.

Keywords: *Maltese Islands, flora, endemism*

INTRODUCTION

Location, population and land cover

The Maltese Archipelago consists of a group of small, low-lying islands located in the central Mediterranean, approximately 96 km south of Sicily and 320 km north of North Africa. The Archipelago extends for 45 km in a NW-SE direction and covers a total land area of 315.6 km^2. The largest islands are Malta (length 27 km; area 245.7 km^2) and Gozo (14.5 km; 67.1 km^2). The other islands of the Archipelago are much smaller and comprise Comino (area 2.8 km^2), St Paul's Islands (10.1 ha), Cominotto (9.9 ha), Filfla (2.0 ha) and General's Rock (0.7 ha). The population of the Maltese Islands as of 2010 was approximately 418,000 persons (NSO, 2011), 92% of which lived in Malta and 8% in Gozo,

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giving a population density of more than 1,500 persons km^{-2} on the main island. Much of the land surface on these highly populated islands is consequently either agricultural (51%) or urban (22%) and patches characterised by 'natural vegetation' are limited to 18% of the total islands area (MEPA, 2010).

Climate

The climate of the Maltese Islands is markedly biseasonal and alternates a dry season and a wet season, a characteristic pattern of the southern and central Mediterranean. The wet season, during which approximately 86% of total annual precipitation is recorded, lasts from October to March, whilst the dry season extends from April to September. The average annual rainfall is approximately 553.12 ± 156.99mm (Galdies, 2012). December is the wettest month (average *c*.102.48mm) and July the driest (average *c*.0.49mm). Much variation occurs from year to year, with some years being excessively wet and others excessively dry.

Temperatures are generally stable from year to year (average 18.62 ± 0.40°C) (Galdies, 2012). August is the hottest month (average 26.3°C) and February the coldest (average 12.4°C). Continuous cloudy skies are very rare and extended periods of sunshine in winter tend to raise soil and air temperatures. Wind speeds greater than 1.8 km hr^{-1} are recorded on 92.3% of days in an average year.

Geology and geomorphology

The rocks of the Maltese Islands are all sedimentary and consist of a simple layer-cake series of marine sediments of Oligo-Miocene age overlain by sparse and sporadic terrestrial, fluvial and lacustrine deposits of Quaternary age. Weathering, erosion and tectonic activity have caused a variety of geomorphological features including sheer coastal cliffs, inland scarps, isolated plateaux, dry valleys, karst terrain and sandy beaches. With the exception of the *terra rossa* soils of karstic plateaux, the soils derived from these parent rocks are largely young and poorly-developed.

VASCULAR FLORA

The current flora of the Maltese Islands is a product of concurrent processes of immigration, establishment, isolation and local extinction. Processes contributing to immigration include long-range dispersal of propagules by wind and animal vectors across water, shorter-range dispersal across land bridges during glacial periods, and direct introduction by humans over the past

6,000-7,000 years.

Although currently isolated from surrounding land-masses, the Maltese Islands have been intermittently connected with southeastern Sicily through the Malta Plateau, a submerged feature that was exposed during the periods of lower sea levels that were characteristic of the past 1 million years (Micallef *et al*., 2012). No similar land bridge between the Maltese Islands and North Africa has been postulated. As such, over the past 1 million years, the Maltese Islands have been alternately connected to, and isolated from, the European mainland. It is assumed that rates of immigration of propagules increased during periods of lower sea level ('connection'), and then decreased during period of higher sea level ('isolation'). Influx of European fauna, including megafauna, to the Maltese Islands is known to have occurred during marine regressions (Reyment, 1983) and such episodes may also have been accompanied by migration of plants over the land bridges that were exposed at the time.

Subsequent isolation of the Maltese Islands during periods of marine transgression would have reduced genetic input from mainland populations, promoting differentiation of immigrant mainland species into distinct local forms through genetic drift, hybridisation and adaptation to local conditions.

Species, families and lifeforms

The vascular flora of the Maltese Islands, which may be considered an appendage to that of the Hyblean region of Sicily, comprises approximately 1,100 species from 151 families, with ten families accounting for half the species recorded. The families with highest species representation are the Poaceae (12% of species), Asteraceae (10%) and Fabaceae (9%). Approximately 77% of the species are indigenous or archaeophytic whilst 23% are naturalised aliens. A further *c*.700 species that may be categorized as casual aliens have also been recorded. In terms of life-form representation (*sensu* Raunkiaer, 1934), approximately two-thirds of the species are therophytes or hemicryptophytes (44% and 22%, respectively) whilst 15% of species are phanerophytes. The relative predominance of therophytes and hemicryptophytes is a consequence of the constraints represented by the dry season in which an 'avoidance' strategy would be characterised by high fitness. The principal floral communities of the Maltese Islands are generally considered as seral stages of a sclerophyll series characterised by steppe, shrub formations, maquis and scattered woodland. Complex communities dominated by ruderal species and characterised by considerable seasonal and inter-annual change are also widespread. Other plant communities are restricted to specific habitats including temporary ponds, watercourses, saltmarshes, coastal dunes and cliffs.

Vegetation patterns during the earliest stages of human colonisation have been investigated in studies based on sedimentological and palynological evidence. The results of these studies suggest the presence of Pinus-Cupressaceae woodland that was subject to deforestation in the early Neolithic (Carrol *et al.*, 2012) while work by Djamali *et al.* (2012) suggests the replacement of open steppe by dense *Pistacia lentiscus* scrub approximately 7000BP, an event that has also been recorded in sediments from Gela, in Southern Sicily (Di Rita & Magri, 2012).

Endemic species

Forty-three taxa are endemic to the Maltese Islands. Of these, 23 species are strictly endemic whilst a further twenty are sub-endemic and restricted to the Maltese Islands and circum-Italian islands. The Asteraceae contribute 26% of the endemic taxa (11 species) whilst the remaining 32 species represent 16 families including the Orchidaceae (5 species), Iridaceae (4 species) and Brassicaceae (3 species). Endemic taxa include palaeoendemics such as *Cheirolophus crassifolius* (Bertol.) Susanna, *Cremnophyton lanfrancoi* Brullo & Pavone and *Darniella melitensis* (Botsch.) Brullo and neoendemics such as *Limonium melitense* Brullo, *L. zeraphae* Brullo, *Anthemis urvilleana* (D.C.) Sommier & Carauana-Gatto, *Helichrysum melitense* (Pignatti) Brullo *et al.* and *Matthiola incana* subsp. *melitensis* Brullo, Lanfranco, Pavone & Ronsisvalle. Two hydrophytes, *Elatine gussonei* (Sommier) Brullo *et al.* and *Zannichellia melitensis* Brullo, Giusso del Galdo & Lanfranco, are also endemic or sub-endemic to the islands. The number of endemic species, representing approximately 2% of indigenous/archaeophytic species, is relatively low compared to other Mediterranean islands and may be attributable to early and intense habitat degradation through anthropogenic influence. It should also be emphasized that most Maltese endemic plants are colonists of relatively inaccessible rupestrian habitats, areas that are generally insulated from much of the effect of anthropogenic disturbance.

Most studies on the endemic flora have been either distributional or taxonomic, with very few ecological studies, which are essential for the design of effective conservation strategies. Ongoing work on *Helichrysum melitense*, a critically-endangered endemic plant (Montmollin & Strahm, 2005) restricted to the western coast of Gozo (Sciberras & Sciberras, 2009) indicates that levels of reproductive success are very low (Xiberras & Lanfranco, in prep.), with obvious implications for conservation and restoration strategies involving this species. Similar studies are planned for other endemic species.

Chorological characteristics of some endemic species

The biogeographic relationships of the flora on the Maltese Islands are varied and complex. Principal contributors to this complexity may include differential survival of species in refugia during glacial periods, post-glacial dispersal from these glacial refugia and dispersal of propagules by wind and by animal vectors. The chorological characteristics of a number of endemic species may be used to infer the biogeographic complexity of the flora of the Maltese Islands.

Cremnophyton lanfrancoi: A palaeoendemic species that seems to be most closely related to *Atriplex cana* C.A. von Meyer, native to the semi-deserts of central Asia (Kadereit *et al.,* 2010).

Palaeocyanus crassifolius (Bertol.) Dostal: A palaeoendemic species most closely related to the genus *Cheirolophus* of the western Mediterranean area and Macaronesia (Susanna, 1999), in which it is now often included.

Darniella melitensis: A palaeoendemic species. The genus *Darniella* (often included in *Salsola*) is distributed throughout much of North Africa as well as Israel. The Maltese Islands are the only European station (Brullo, 1984).

Jasonia bocconei (Brullo) Pardo & Morales: A species that is probably schizoendemic. The genus *Jasonia* (including *Chiliadenus*) is distributed discontinuously throughout North Africa, the Middle East (Israel, Sinai), the western Mediterranean coasts (Spain, southern France) as well as the Maltese Islands and the Pelagian Islands (Brullo, 1979).

Allium lojaconoi Brullo, Lanfranco & Pavone: A schizoendemic species. One of a group of schizoendemics and an apoendemic species occurring in the Maltese, Aegadian and Pelagian Islands in the central Mediterranean (Brullo & Pavone, 1983).

Hyoseris frutescens Brullo & Pavone: A species that is probably palaeoendemic. The genus *Hyoseris*, as narrowly defined, occurs throughout the Mediterranean area, including the Maltese Islands. Two species, *Hyoseris radiata* L. and *H. scabra* L. are widespread throughout the Mediterranean. Two other species, *H. taurina* (Pamp.) Martinoli and *H. lucida* L., have a more circumscribed distribution, the former being endemic to southern Sardinia and northern Sicily, while the latter is native to eastern North Africa (Brullo & Pavone, 1988). *H. frutescens* is endemic to the Maltese Islands, being quite frequent in rupestrian and coastal habitats in Gozo but very rare on the island of Malta. It is probably most closely related to *H. taurina* which, apart from its geographical proximity is the only other species of *Hyoseris* to show a tendency towards a shrubby form, though not to the extent of *H. frutescens.*

Limonium zeraphae and *L. melitense*: These species are schizoendemic. The genus *Limonium* is widespread with numerous species occurring in coastal habitats throughout the Mediterranean area. Many of these are microspecies that are found only in very restricted geographical areas. The two Maltese endemic species are most probably derived from *L. virgatum* Maire & Petitm., which seems to be widespread throughout the Mediterranean area. Probable hybrids between *L. virgatum* and *L. zeraphae* have been observed where these species coexist (Lanfranco, 1989).

Helichrysum melitense: This species is schizoendemic and closely related to *H. rupestre*, an Italian species (Pignatti, 1980; Lanfranco, 1989).

Euphorbia melitensis Parl.: This species is schizoendemic and closely related to *E. bivonae* Steudel of northwest Sicily and *E. papillaris* (Boissier) Raffaelli & Ricceri. These three species are somewhat related to *E. spinosa* L., which is found in peninsular Italy (Raffaelli & Ricceri, 1988; Lanfranco, 1989).

Anacamptis urvilleana Sommier & Caruana-Gatto: A species that is probably schizoendemic, perhaps palaeoendemic. Clearly closely related to *A. pyramidalis* (L.) Richards, which is widespread throughout the Mediterranean region including Malta. Although closely related, *A. pyramidalis* and *A. urvilleana* in Malta are reproductively isolated such that no hybridisation occurs. Moreover, whilst *A. urvilleana* is diploid (like most of the continental populations of *A. pyramidalis*) with 2n = 36, the Maltese population of *A. pyramidalis* is tetraploid with 2n = 72 (Del Prete *et al.*, 1984, 1991; Lanfranco, 1989) and may merit taxonomic recognition as suggested by Sommier & Caruana Gatto (1915).

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4. Islets

FLORA OF HABIBAS ISLANDS (N-W ALGERIA): RICHNESS, PERSISTENCE AND TAXONOMY

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Abstract

Within the Alboran Sea, along the NW-Algerian coasts, the Habibas Archipelago belongs to the Betico-Rifean hotspot and was probably a good refuge during glacial ages and subsequently during the Holocene period. Since Maire, Wilczek and Faure in 1934, floristic investigations have been very poor. More than 100 vascular plant taxa are known on the main island, from which 5 species (*Spergularia pycnorrhiza*, *Brassica spinescens*, *Anthemis chrysantha*, *Rostraria balansae*, *Fumaria munbyi*) are endemic from Algerian, Moroccan-Algerian or Spanish-Algerian coasts, and 2 varieties (*Sonchus tenerrimus* var. *amicus*, *Asteriscus maritimus* var. *sericeus*) were described from the archipelago as narrow endemic. Since 2006, several expeditions organized by "PIM Initiative" (initiative for the Small Islands of the Mediterranean) allowed us to confirm the presence of the main taxa and particularly the endemic ones. About 80% of the initial flora is still observed 72 years later, and the new taxa are essentially belonging to spontaneous Mediterranean flora. Nevertheless, 3 potentially invasive xenophytes on the islands are listed and need to be surveyed in the future. A succinct biogeographical analysis is made in comparison with other north-western African archipelagos. The recent classification as Protected Marine Area should allow good conservation of natural habitats and their endemic and spontaneous flora (in a good conservation status) although field surveys and deeper taxonomic investigations would be very useful.

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INTRODUCTION

The Habibas archipelago is a small archipelago located at 10 km NW from the Algerian coast (Cap Blanc) between the cities of Oran and Beni-Saf (*wilaya* of Ain-Temouchent). It is circumscribed by the Alboran Sea, which represents the south-western part of the Mediterranean Sea. This marine area was expanded during the late Oligocene and early Miocene (Gueguen *et al.* 1998) while Rifean and Betican micro-plates were driving towards the west until they collapsed respectively into the African and Iberian plates causing an elevation of mountain chains or collision (Rif and Sierra Nevada). During the Miocene microplate migration, magmatic activity associated to back-arc basin formation consequently to rollback subduction (Rosenbaum & Lister 2004) kept us until today magmatic outcrops (e.g. Cabo de Gata, Alboran, Habibas, Rechgoun, etc.). Thus, more than 90% of the outcrops of the archipelago consist of volcanic rocks (Maire & Wilczek, 1936). During Quaternary glaciations, low bathymetry (< 100 m) makes us think that the archipelago was at times connected to the African continent.

The Habibas Archipelago, recently classified as an "important plant area" (Yahi *et al.*, 2012), belongs to the Betico-Rifean hotspot (Médail & Quézel, 1997), as they can be included in the Oran coastal hills sector "O1" (Quézel & Santa, 1962). While larger islands and the peninsula are known as glacial refugia in the Mediterranean basin (Médail & Diadéma, 2009), small islands, "which contain relict populations not involved in post-glacial migrations" (Médail & Diadéma, 2009) are often micro-refugia favourable to long-term persistence phenomenon. Until the present day, some of them, due to their inaccessibility and inhospitality during Holocene and Historical times, are naturally protected against strong human impact relatively to the continental coasts.

Habibas Islands were seldom visited by botanists until the 1990's. In 1875, Pomel described precisely *Brassica spinescens* from Habibas islands, without saying if he had visited the place or if he did it from reported specimens. He does not mention the *Brassica scopulorum* Coss. & Dur., a *nomen nudum* first mentioned by Balansa [Pl. Alg. n° 657 (1852)] from Cap Falcon, but validly described only in 1882 by Cosson himself [Illustr. FI. Atlant. p. 28, tab. 20 (1882)] and also considered as taxonomical synonym of *B. spinescens*. After Pomel had given his herbarium to Battandier, Foucaud named it unofficially *Spergularia pycnorrhiza* another plant from Oran, but it is Battandier (1910) who first published the name. This plant remained unknown in the field until the historical expedition of Maire, Wilczek and Faure in 1934 (cf. Maire & Wilckzek, 1936) when they discovered the same plant in abundance on Habibas islands.

It was then that Maire, Wilczek and Faure first visited the island on the 4th and 5th of May 1934 with the aim of carrying out a strong botanical exploration. They published "Florule des Îles Habibas (Maire & Wilczek, 1936), where they listed 103 vascular plant species (+ 18 cultivated by inhabitants) and several non vascular cryptogamous taxa (5 fungi, 7 lichens, 29 marine algae and 1 bryophyte new to science *Tortula muralis* subsp. *mairei* Meylan). With regard to vascular flora, they have seen five narrow endemic species previously known on the continent (*Anthemis chrysantha* J. Gay, *Brassica spinescens* Pomel, *Fumaria munbyi* Boiss. & Reut., *Rostraria balansae* (Cosson & Durieu) J. Holub, *Spergularia pycnorrhiza* Foucaud ex Batt.), and have described three new endemic varieties from the Habibas island (*Asteriscus maritimus* var. *sericeus* Maire & Wilczek; *Sagina ciliata* var. *obtusisepala* Faure, Maire & Wilczeck; *Sonchus tenerrimus* var. *amicus* Faure, Maire & Wilczek) without regarding several minor forms, subvarieties or varieties only based on flower coloration (Maire, 1935).

During the 1990's, Algerian ornithologists have discovered *Asplenium marinum* L., a rare fern in Algeria, new to the archipelago's flora (Boukhalfa 1993).

Established in 2000, the Algerian ministry of Planning and of Environment (*Ministère de l'Aménagement du Territoire et de l'Environnement*, MATE) started cooperation with the French conservatory of coastal areas and lake shores (*Conservatoire de l'Espace Littoral et des Rivages Lacustres*, CELRL). The PIM initiative (*initiative pour les Petites Iles de la Méditerranée*, initiative for the small islands of the Mediterranean) was initiated by CELRL in 2006 and one of its goals is to encourage prospection with the aim of knowing better the rare and peculiar flora of these small and neglected territories. The objectives of this first expedition were: 1) to compare current flora with flora at Maire's period, 2) to highlight taxonomical position of endemic and/or neglected taxa, 3) to analyse biogeographical affinities of the Archipelago.

MATERIAL AND METHODS

With approximately 40 hectares of emerged land area, the archipelago is the largest in Algeria and consists of two main islands, a large south-western one (around 30 ha, 105 m high) and a small north-eastern one (around 10 ha, 24 m high), with a remarkable islet in an intermediate position (around 1 ha, 30m high!) and many other insignificant islets in peripheral position. The intermediate islet is inaccessible but offers little vegetation, while other islets consist essentially of maritime rocks.

The team working with Maire *et al.* (1936) in spring 1934 consists of three botanists studying also non vascular terrestrial and maritime plants during two consecutive half-days (4th May afternoon and 5th May morning) only on the larger island. The PIM team in 2006 consists of one botanist (E.V.) studying only terrestrial plants (including lichens) during one day and a half (1st May afternoon and 2nd May all day (long) only on the larger island. Complementary data, including the smaller island, were collected by two botanists (E.V., A.S.) in October 2007 during another expedition financed by Algerian MATE, via a private contract. Another expedition made by J. Delauge, during spring 2007, was essentially focused on mapping vegetation and several specific taxa (cf. Delauge & Véla, 2007).

The two data sets are compiled in one table with the old (Maire, 1952-1987) and the modern (Dobignard & Chatelain, 2010-2013) taxonomical referential, and critical point of view will be developed on several endemic and/or neglected taxa. Relative species changes (expressed in % yr−1) between the two data sets have been calculated using Morrison's formula (1997, 1998): $Sr=[(I+E)/t(S1+S2)]x100$. E and I are the number of species extinctions and species colonisations, respectively, occurring between two surveys separated by t years. S1 and S2 are the number of species on each island in the first and second census (cf. Vidal et al., 2000). In our case, only the larger islands are considered with t=72 years.

So we can provide a quick overview of the biogeographical links with other archipelagos and with coastal areas from the south-western Mediterranean. The invasion potential by xenophytes on the archipelago will be introduced.

RESULTS

Persistence of flora

We have compiled the two species lists using the synonymic referent of "African Plant Database" for North Africa (Dobignard & Chatelain, 2010-2013), which can be searched online at <http://www.ville-ge.ch/musinfo/bd/cjb/africa/index.php>.

The number of spontaneous taxa found in 1934 (Maire & Wilczek, 1936) were 103 species or subspecies. In addition, 18 species were cultivated by inhabitants, mainly for food uses.

The number of spontaneous taxa found in 2006-2007 (present work) is 97 species or subspecies, of which 81 are in common with the previous inventory, and 16 new ones for the island. In addition, 3 taxa are cultivated and more or less naturalised. Two of them were originally introduced before 1934, and one is recently cultivated for ornamental uses.

During the main phase of inventory (May 2006), only 83 spontaneous taxa have been found: 71 are in common with the first date set from 1934 and 12 are new. Two additional cultivated / naturalised taxa, previously known in 1934, have been found.

During the complementary inventory (October 2007), 10 previously known species have been rediscovered and 4 additional new taxa have been found. Furthermore, one new cultivated taxon has been found.

The calculation of the turnover is made with only spontaneous taxa from the two data sets, separated by a period of 72 years:

Sr = [(16+22)/72(103+97)]x100 = 0,264 % yr $^{-1}$

Endemism and biogeography

With regard to the previously known 9 endemic taxa of the Alboran area in 1934, all of them have been easily seen in 2006 and in 2007 (Table 1). It seems to be a tenth taxon, temporarily named "*Lobularia maritima* subsp. *columbretensis*?". Half of them are chamephytic perennial sub-shrubs with stress-tolerant (S) demographical strategy and another half are therophytic annual herbs with mixed stress-tolerant and ruderal (SR) demographical strategy.

Table 1. List of the endemic taxa from Alboran area found on Habibas Archipelago (spring 2006 / autumn 2007) and Rechgoun island (spring 2006: Véla, unpubl. data) and their biological type and demographical strategy.

Taxa endemic from Alboran Sea:	Biological form*	Grime**	Habibas	Rechgoun
Anthemis chrysantha J. Gay	Th/Ch (annual/biennial)	SR	CC	R
Brassica spinescens Pomel	Ch	S	AC	∅
Fumaria munbyi Boiss. & Reut.	Th	R	R	R
Rostraria balansae (Cosson & Durieu) J. Holub	Th	SR	AC	∅
Spergularia pycnorrhiza Foucaud ex Batt.	Ch	S	AC	∅
Arenaria cerastioides Poir. var. *oranensis* (Batt.) Maire	Th	SR	R	∅
Asteriscus maritimus (L.) Less. var. *sericeus* Maire & Wilczek	Ch	S	AC	∅
Silene pseudoatocion Desf. var. *oranensis* Batt.	Th	SR	R	∅
Sonchus tenerrimus L. var. *amicus* Faure, Maire & Wilczek	Th/Ch (biennial)	S	AC	R
Additional possible endemic taxa:				
Lobularia maritima (L.) Desv. subsp. *columbretensis* R. Fern. ?	Ch	S	R	? (to be confirmed)

** cf. Raunkiaer 1934. ** cf. Grime 1977, sensu Véla 2002.*

Between the two data sets (1934-2006), 22 taxa could be considered locally extinct (Table 2). Most of the extinct taxa are Mediterranean therophytic annuals with ruderal strategy or mixed stress-tolerant + ruderal strategy.

Table 2. List of the 22 extinct taxa on the Habibas Archipelago between 1934 and 2006 and their biogeography, biological type and demographical strategy.

Taxa extinct on Habibas Archipelago	Biogeography*	Raunkiaer**	Grime***
Anisantha madritensis (L.) Nevski, subsp. *madritensis*	Med.(steno-)	Th	SR
Beta vulgaris L. subsp. *maritima* (L.) Arcang.	Med.-Tour.	Ch	S
Bupleurum lancifolium Hornem	Med.(eury-)	Th	SR
Convolvulus althaeoides L.	Med.(steno-)	Ge	CS
Cuscuta epithymum Murr. subsp. *epithymum*, (var. *alba*…)	Med.(eury-)	Th	R ?
Cynomorium coccineum L.	Subtrop.	Ge	CS
Euphorbia peplus L., [s.l.]	Med.(eury-)	Th	R / SR
Filago fuscescens Pomel	Med.S.(stepp-)	Th	SR
Hirschfeldia incana (L.) Lagrèze-Fossat subsp. *incana*	Med.(eury-)	Th / He ?	SR
Lamium mauritanicum Batt.	Med.S.(steno-)	Th	R ?
Lolium rigidum Gaudin, cf. subsp. *rigidum* ?	Subtrop.	Th	SR
Lotus edulis L.	Med.(steno-)	Th	SR
Malva parviflora L. subsp. *parviflora*	Med.(steno-)	Th	R
Muscari comosum (L.) Mill.	Med.(eury-)	Ge	CS
Neslia apiculata Fischer, C.A. Meyer & Avé.-Llall.	Med.(steno-)	Th	SR
Papaver pinnatifidum Moris	Med.(steno-)	Th	SR
Plantago afra L.	Med.(steno-)	Th	SR
Plantago coronopus L., sensu lato ?	?	Th / He ?	SR
Rapistrum rugosum (L.) All. subsp. *linnaeanum* (Cosson) Rouy & Fouc.	Med.(steno-)	Th	SR
Sinapis alba L. subsp. *alba*	Med.-Tour.	Th	R
Sonchus oleraceus L.	Paleotemp.	Th	R
Trifolium spumosum L.	Med.(eury-)	Th	SR

Following Carazo & Fernandez 2006, Fennane & Ibn Tattou 2005, modif. ** cf. Raunkiaer 1934. * cf. Grime 1977, sensu Véla 2002.*

Between the two data sets (1934-2006), 16 taxa could be considered recently established (Table 3). More than a half are still Mediterranean s.l., but several paleotemperate or subcosmopolite synanthropic taxa and two xenophytes can be found.

Table 3. List of the 16 recently established taxa on the Habibas Archipelago between 1934 and 2006 and their biogeography, biological type and demographical strategy.

Recently established taxa on Habibas Archipelago	Biogeography*	Raunkiaer**	Grime***
Arthrocnemum macrostachyum (Moric.) K. Koch	Subtrop.	Ch / Ph	S
Asplenium marinum L.	Med.-Atl.	He	CS
Bromus lanceolatus Roth subsp. *lanceolatus*	Paleotemp.	Th	SR
Cakile maritima Scop. subsp. *maritima*	Med.-Atl.	Th	SR
Carduus tenuiflorus Curtis	Med.-Atl.	Th	SR
Centaurium sp. (cf. *pulchellum* ?)	?	Th	SR
Hedypnois rhagadioloides (L.) F. W. Schmidt, [subsp. rhagadioloides]	Med.(-steno)	Th	SR
Heliotropium europaeum L.	Med.-Tour.	Th	R
Juncus acutus L., s.l.	Subcsom.	He	CS
Mesembryanthemum crystallinum L.	Med.-S.Afr.	Th	SR
Oxalis pes-caprae L.	Xenoph. S.Afr.	Ge	CS
Parietaria judaica L.	Med.(eury-)	Ch	S
Phoenix sp.	Xenoph. Macar.	Ph	CS
Reichardia tingitana (L.) Roth, s.l. (…)	Med.-Sahar.	Th / He	SR
Sagina maritima G. Don fil.	Med.-Atl.	Th	R
Silybum marianum (L.) Gaertner	Med.-Tour.	Th	SR

Following Carazo & Fernandez 2006, Fennane & Ibn Tattou 2005, modif. ** cf. Raunkiaer 1934. * cf. Grime 1977, sensu Véla 2002.*

With regard to the 18 originally cultivated species (mainly for traditional food uses), 16 have completely disappeared and only 2 (*Carpobrotus cf. acinaciformis*, *Ficus carica*) still exist today as more or less naturalised xenophytes. Only one new cultivated species (*Opuntia microdasys* (Lehm.) Pfeiff. var. *microdasys*), with risk of naturalisation, has been identified.

DISCUSSION

Species turn-over and persistence

The relative species change that is measured here (turn-over < 0.3 %) is very low compared to those observed in the French archipelago near Marseille, where gull overpopulation and other synanthropic perturbations have induced a turn-over between 0.47 and 1.19 (Vidal *et al.*, 2000). Turn-over value decreases around the land areas of the island, and we can notice that in the same area (around 30 ha), Maire island has got species turn-over > 0.8 %.

A very low species turn-over confirms the global consideration about a good conservation status of natural habitats seen on the island during the 2006-2007 expeditions. More than 80% of native species seen in 1934 are still present 72 year later, which demonstrates very good persistence capacities of indigenous communities, where even seabirds' populations have been increasing for several years. If the extinct taxa are mainly Mediterranean annuals from dry ooligotrophic grasslands (SR therophytes), this natural phenomenon is partially compensated by several colonisations from the same functional group. Nevertheless, some of the newly established taxa are subcosmopolitan and/or xenophytic perennials, indicating a beginning of pattern change. Species such as *Oxalis pes-caprae* which has recently colonised the archipelago must be surveyed and some ornamental species such as *Carpobrotus cf. acinaciformis* and *Opuntia microdasys* (Lehm.) Pfeiff. var. *microdasys* should be eradicated before their definitive establishment on the island.

Endemism and taxonomical controversies

We have highlighted 10 poorly known endemic taxa. None of them are previously known as endemic around the southern Alboran area (Algerian-Moroccan coasts), five at species level and four at variety level:

Spergularia pycnorrhiza is a narrow endemic species from Habibas and Ain Franin in Algeria (Oran). Its affinities are not known, but it shows morphological convergences with *S. macrorrhiza* (Loisel.) Heynh., a corso-sardinian endemism. *S. pycnorrhiza* differs by its large oval pink petals and obtuse sepals, but share with *S. macrorrhiza* a very peculiar woody root, fat leaves and fruits with large not winged seeds.

Brassica spinescens is a narrow endemic species from Habibas, Cap Falcon and Djebel Santon in Algeria (Oran). It seems to be a paleoendemism with possible affinities with *B. balearica* Pers. from Mallorca (Spain). Its small habitus (15-20 cm high), with highly branched woody stems and very fat and small leaves give it a very different appearance from other spontaneous *Brassica* taxa from *B. fruticulosa* agregate or *B. oleracea* agregate.

Rostraria balansae is an endemic species from the southern Alboran Sea in north-western Algeria (Kristel, Canastel, Cap Falcon and Habibas) while old mentions from Melilla could be confused with *R. festucoides* (= *Avellinia michelii*) following Romero Zarco (2002). It shows some morphological and ecological affinities with the Mediterranean *R. littorea* aggregate (= *Koeleria pubescens* aggr.), but its phylogenetical affinities are not known.

Fumaria munbyi is a species found around a fragmented area, mainly from the southern Alboran Sea (Habibas, Rechgoun and Oran coast) and from the Columbretes islands in eastern-Spain. Old mentions from NE Morocco are not confirmed. It shows morphological and ecological affinities with other south-western Mediterranean species such as *F. mellilaica* from NE Morroco and SE Spain, but its phylogeny is not known.

Anthemis chrysantha is an endemic species from both the Alboran coast in SE Spain and NW Algeria (Sánchez Gómez *et al.*, 2004). Spanish populations were described as subsp. *jimenezii* (Pau) Sánchez Gómez, M. A. Carrión & A. Hernández, while the Algerian ones correspond to subsp. *chrysantha*. It belongs to the section *Anthemis*, but seems to be a paleoendemic without direct affinities.

Asteriscus maritimus* var. *sericeus is known as endemic taxa from Habibas Archipelago and again Cap Falcon (but not seen here since its description). It remains strongly misunderstood and shows affinities and/or convergence forms with some populations from Santa Cruz's cliffs near Oran and coastal forms from Rechgoun Island (NW Algeria) or from Cap de Garde, near Annaba (NE Algeria), but none of them are identical (Fig. 1). We think that a subspecies rank will be a good taxonomical hypothesis to reconsider this very peculiar plant from the Habibas Archipelago:

***Asteriscus maritimus* (L.) Less. subsp. *sericeus* (Maire & Wilczek) Véla, comb. et stat. nov.**

<u>Basionym</u>: *Asteriscus maritimus* (L.) Less. var. *sericeus* Maire & Wilczek in Maire, Bull. Soc. Hist. Nat. Afr. Nord 26: 211 (1935).

"*A var. mauritanico Jord. differt foliis dense et longe sericeovillosis plus minusve* *incanis; florum radii tubo parcissime pilosulo, glabrescente. Hab. in rupibus maritimis ad occidentem urbis Oran (Cap Falcon ; Iles Habibas), aprili et maio florens.*» (Maire, 1935)

Sonchus tenerrimus* var. *amicus is known as endemic taxa from the Habibas Archipelago but it grows on Rechgoun island too (E. Véla, obs. pers.). It is strongly different from other forms of *S. tenerrimus* s.s. from coastal areas along Oran and hills, but shows morphological convergences with the *S. pustulatus / masgindalii* agregate from N-Morocco (Fig. 2). It probably corresponds to *S. briquetianus* Gand. (in Bull. Soc. Bot. France 55: 657 [1909]) from Chafarinas Archipelago and could be considered as subspecies rank like the halophytic taxa *S. asper* subsp. *glaucescens* (Jord.) Boulos, for example:

***Sonchus tenerrimus* L. subsp. *amicus* (Faure, Maire & Wilczek) Véla, comb. et stat. nov.**

Basionym: *Sonchus tenerrimus* L. var. *amicus* Faure, Maire & Wilczek in Maire, Bull. Soc. Hist. Nat. Afr. Nord 26: 217 (1935).

"*Foliis crassiusculis eximie pectinatis, lacinia terminali aliis minore et habitu ad ssp. pustulatum (Willk.) Batt. vergit, sed ab ilio radice annua l. vix bienni (nec perenni suffrutescente) discedit. Rami inflorescentiae parce glandulosi ; anthodium glabrum ; pedunculi sub anthodio lanati. Hab. in rupibus vulcanicis insulae Habiba majoris, aprili et maio florens.*" (Maire, 1935)

Silene pseudoatocion* var. *oranensis is described from Oran and grows along southern Alboran coasts from Oran to Beni-Snassen in NE Morocco. Following Maire (1963), it differs morphologically and ecologically from var. *pseudoatocion* ("var. *genuina*"), but the criteria announced are partially unstable on the field. Furthermore, Iberian and Balearic populations described in "Flora iberica" (Talavera 1990) and their relationships with var. *oranensis* are poorly known and remain unclear.

Arenaria cerastioides* var. *oranensis, recombined after its original description as *A. spathulata* var. *oranensis* Batt., B. Soc. Bot. France, 45, p. 238 (1898) is considered as an endemic species on the Oran coastal area, but like other species varieties, it remains currently poorly known and its morphological, ecological and biogeographical properties should be studied.

The taxon number ten must be highlighted here. Population of ***Lobularia maritima*** from the Habibas Archipelago (only on the main island) offers strong morphological and ecological affinities with **subsp. *columbretensis* R. Fern**, in Anales Jard. Bot. Madrid 49: 314 (1992) recently described in the Columbretes Archipelago in E Spain and previously known as strictly narrow endemic species. Its woody erect stem, bigger leaves and bigger flowers than from subsp. *maritima* (Fig. 3), shows strong similarities with the description of subsp. *columbretensis* on the Columbetes Islands around 500 km far away: "*Planta claramente sufruticosa, con tallo robusto, erecto, muy ramificado; ramas ± gruesas, muy foliosas; hojas mayores, de hasta 60 × 8 mm; pétalos 3,5-4,5 × 3 mm; semillas c. 2 mm. (...) Suelo volcánico, muy nitrificado. IV-X.*" (Fernandes, 1993)

Biogeographical affinities

As we can see considering endemic taxa detailed above, biogeographical links are strong between Moroccan and Spanish coastal areas of the Alboran Sea, as well as the Chafarinas Islands. But biogeographical links are particularly pronounced among the small islands of the Columbretes Archipelago, around 500 km north-east, which share the same volcanic soils, semi-arid climate and high populations of seabirds. South-western and western Mediterranean taxa on fragmented coastal areas are abundant, like *Succowia balearica* (L.) Medik or the "small islands specialist" *Stachys brachyclada* De Noé.

This biogeography strongly differs from the other main northern African archipelagos located in Tunisia. La Galite Archipelago in NW Tunisia shows strong affinities with Corso-Sardinian and other peri-Tyrrhenian shared taxa like *Brassica insularis* Moris or *Limonium intricatum* Brullo & Erben from the *L. articulatum* agregate (Pavon & Véla, 2011). Zembra Archipelago in NE Tunisia shows strong affinities with Sicilian and other Central Mediterranean shared taxa like *Dianthus rupicola* Biv subsp. *hermaeensis* (Coss.) O. Bolos & Vigo or *Iberis semperflorens* L. (cf. Labbe, 1954).

CONCLUSION

With ten endemic taxa, and half of them at specific level, the Habibas Archipelago is one of the best key biodiversity areas of plants in northern Algeria (cf. Yahi *et al.*, 2012) in such a small territory. Its recent classification as Protected Marine Area should allow conservation of natural habitats and their endemic and spontaneous flora in good conditions. Scientific surveys and assessments will be needed to reach this goal. Furthermore, obviously it is necessary to contract field investigations and moreover to deeply re-initiate taxonomical investigations on north-African flora and its close relationships with the flora on the European side of the Mediterranean.

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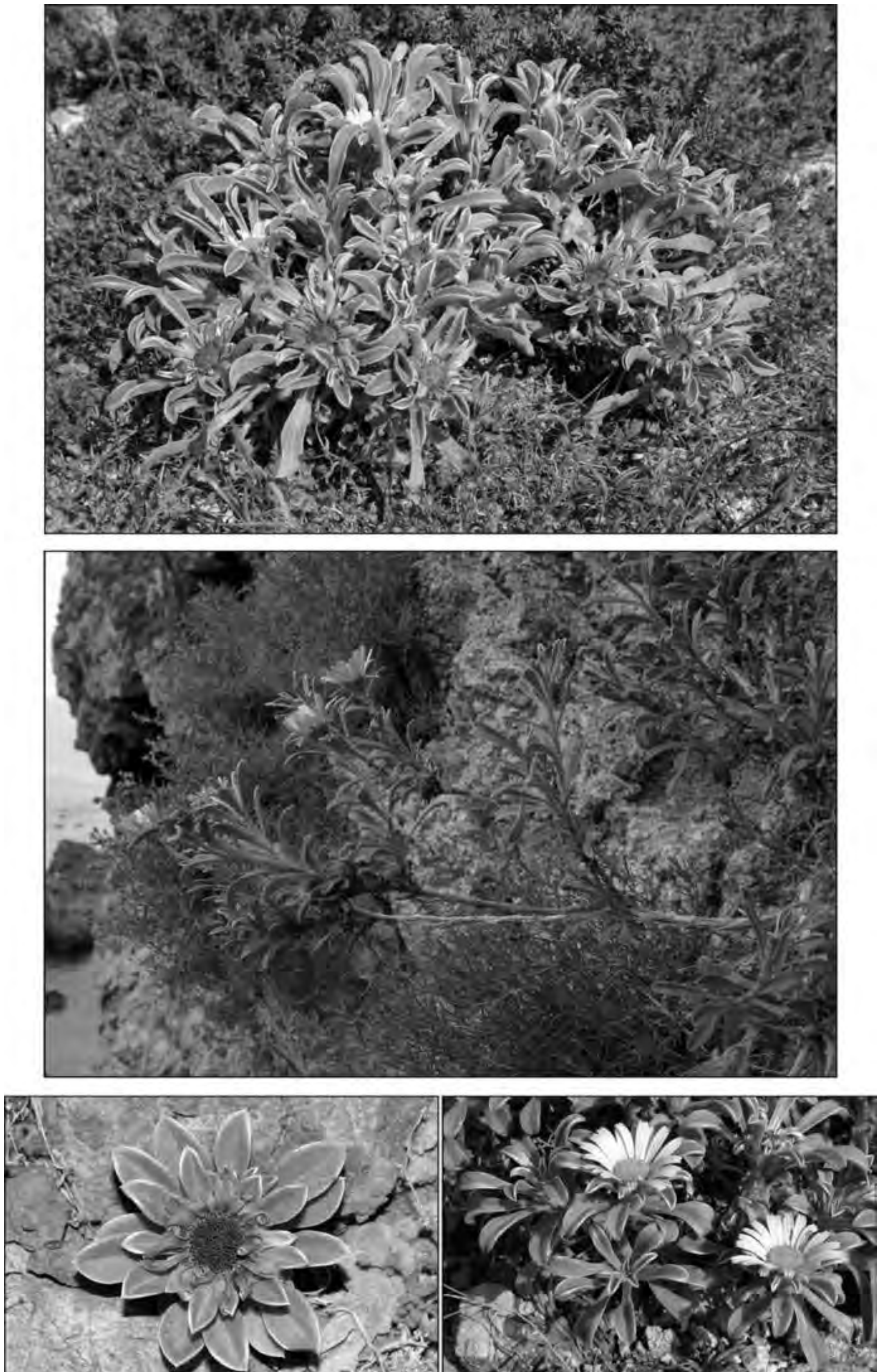

Fig. 1. Asteriscus maritimus *subsp.* sericeus *(Habibas island, E. Véla, 1&2.V.2006)*

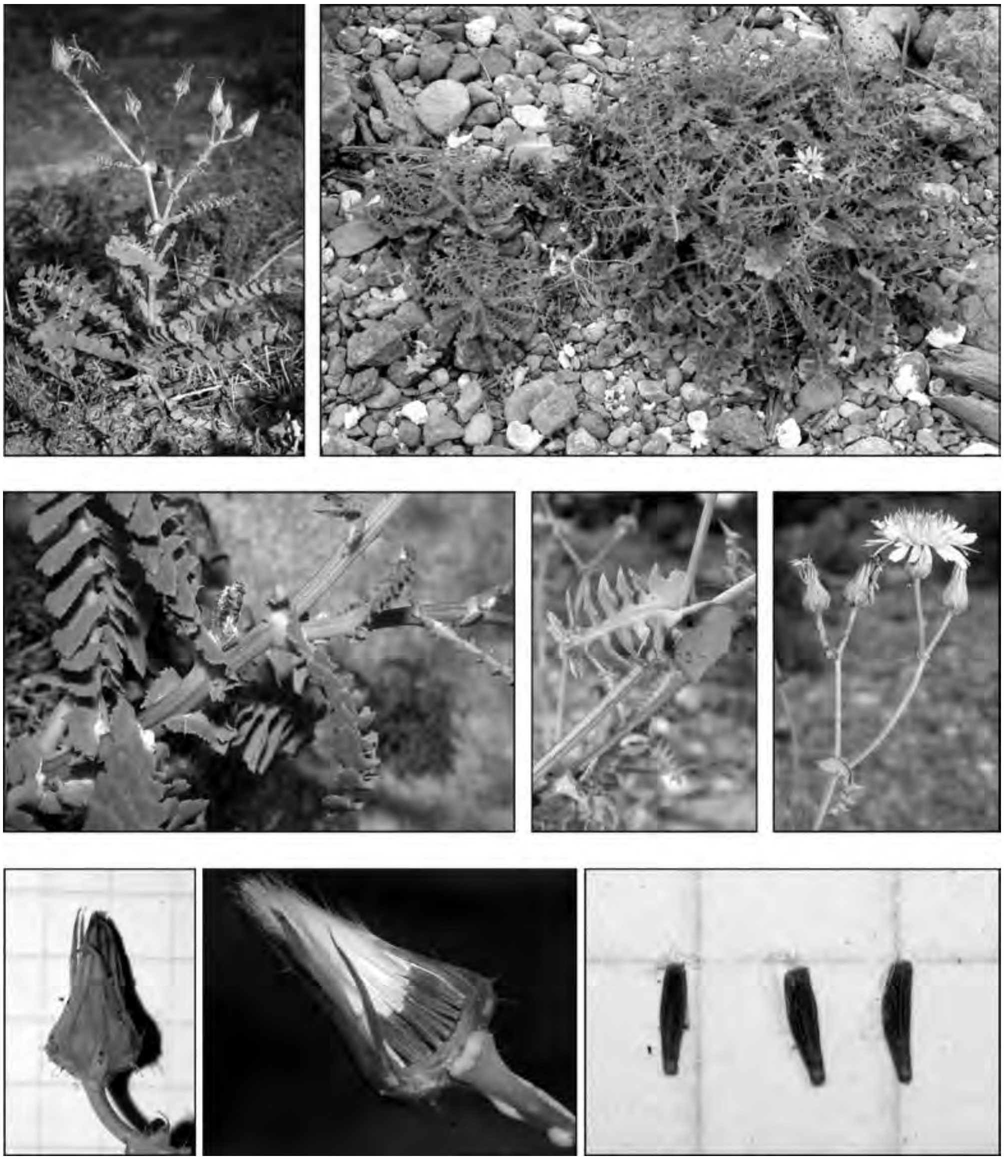

Fig. 2. Sonchus tenerrimus *subsp.* amicus *(Habibas island, E. Véla, 1&2.V.2006)*

Fig. 3. Lobularia maritima *subsp.* columbretensis *(Habibas island, E. Véla, 21.X.2007)*

FLORA OF THE HYÈRES ISLANDS HIGHLIGHTS: ORIGINALITY AND THREATS

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Abstract
The Hyères Islands, located in south-eastern France, consist of 3 small islands, the largest of 1,254 ha. Since the Middle Ages, medicinal herbs from the Archipelago have been largely used. From the 19th century up to now, the knowledge of the flora steadily increased. Today, 1,068 taxa are known on the whole Archipelago. The most remarkable species are Tyrrhenian elements, insular plants and species in northern limit of their range, all of them absent or exceptional on the nearby mainland. This flora is mainly threatened by excessive frequentation, natural maturation of the ecosystems and invasive plants.

Keywords: *Tyrrhenian flora, insular plants, excessive frequentation, invasive plants.*

INTRODUCTION TO THE HYÈRES ISLANDS
The Hyères Islands are located in the south-east of France. They constitute the old Stoechades Archipelago which consists of three main islands and some rocky islets, namely, from West to East, Porquerolles, Port-Cros and Le Levant (Fig. 1). Some physical characteristics of the islands are shown in Table 1. The geologic substratum is made up of gneisses, phyllites and mica schists. Porquerolles and Port-Cros are crossed by the forty third parallel of northern latitude. The climate is mild and less rainy than on the mainland. For example, in Porquerolles, the annual rainfall average is 575 mm reaching its peak in autumn; the annual temperature average is 15.3°C, the monthly average peaks in the hottest month (M) is 26.8°C and the average of the monthly lowest temperature of the coldest month (m) is 6.1°C. With regard to Hyères, the values are 651 mm, 14,7°C, 27,3°C and 3,8°C (Aboucaya, 1989), respectively.

The Port-Cros Island has been a National Park since 1963. Its coverage also extends to the neighbouring island of Porquerolles, managing 1,000 ha of natural habitats, placed under its responsibility by the Ministry of Environment. Le Levant Island is mainly (80%) under military rule.

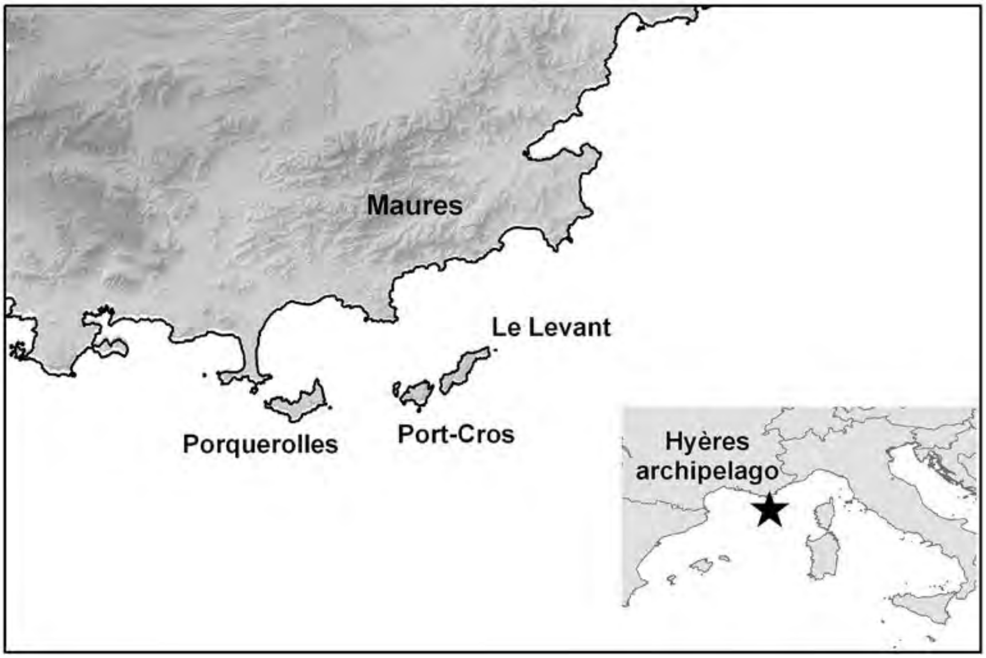


Fig. 1. Location of the Hyères islands

	Distance to the continent	Area	Altitude
Porquerolles	2.6 km	1254 ha	144 m
Port-Cros	8.3	640 ha	199 m
Le Levant	9.2	996 ha	131 m

Table 1. Somme physical characteristics of the Hyères islands

KNOWLEDGE EVOLUTION ON FLORA

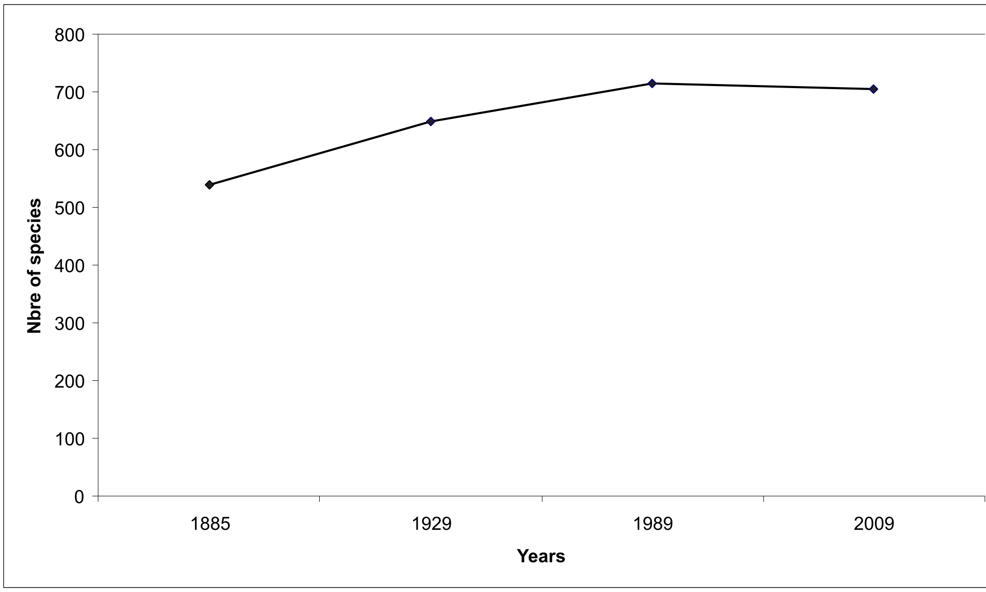
The knowledge about the Hyères Islands flora started in the Middle Ages when medicinal herbs from the Archipelago enjoyed a large reputation. Apothecaries from Montpellier used to come to stock up there (Jahandiez, 1929). During the 17th century, the first Floras of Provence (Garidel, 1715; Gérard, 1761) quote some of the rare species from the Hyères Islands, for example Gérard indicates *Teucrium massiliense* L. as *rarissima planta in Insulis Stoechadum* (Jahandiez, 1913). At the beginning of the next century, 48 species were mentioned by Lauvergne (1829) and Robert (1838), 9 of them being part of the remarkable species of the Archipelago (*Alkanna lutea* Moris, *Asplenium marinum* L., *Crepis leontodontoides* All., *Delphinium pictum* Willd., *Genista linifolia* L., *Ptilostemon casabonae* (L.) Greuter, *Teucrium marum* L., *T. massiliense, Thymelaea tartonraira* (L.) All.). The first synthesis was made by Ollivier, who published in 1885 the first comprehensive catalogue about flora on Porquerolles Island, where 538 species were listed in a synthesis after 50 years of plants collection. 45 years later, thanks to the researches by Jahandiez (1929), the first lists with a common purpose for the three islands were published. In 1989, Aboucaya made a new synthesis on the flora's knowledge on the Archipelago based mainly on the work of Jahandiez, and completed with the data of the most recent literature. In order to illustrate these changes, Fig. 2 highlights the situation for Porquerolles. The most recent publication was issued two years ago (Crouzet, 2009). Through a well documented bibliographic analysis backed up by a comprehensive field survey, this work provides a more accurate statement on the Archipelago's flora. The deep modification driven by ecological, agricultural, and economical changes which occurred during the last century is taken into account in this paper. Crouzet considers that in 2009, 704 taxa are currently present; 237 ones that are mentioned in the literature are not confirmed recently, 36 are doubtful and 52, extinct. The same work has not been done for the other islands and only the total amount of taxa observed for each island is known (Port-Cros, 594; Levant, 642; the entire archipelago, 1,068; data from http://flore.silene.eu). In the last decade notable findings were made on the three islands, especially regarding plant groups poorly sampled because of their special phenology or taxonomic status. Examples of such discoveries are *Asplenium balearicum* Shivas, *Romulea florentii* Moret, *R. assumptionis* Garcias Font, *Verbena supina* L., *Fumaria bicolor* Sommier ex Nicotra, *F. flabellata* Gasp. or *Silene badaroi* Breistr. (Médail, 1998 ; Moret *et al.*, 2000; Médail & Loisel, 2001; d'Onofrio *et al.*, 2003; Crouzet *et al.*, 2005). Although some species have disappeared since the first known inventories were made, none of the most original species of the flora of the Archipelago (Table 2): Tyrrhenian elements (*e.g. Delphinium pictum*), insular plants (*e.g. Fumaria bicolor*, *Orobanche sanguinea* C. Presl), and plants around the northern limit of their range (*e.g. Spergularia diandra* (Guss.) Boiss., *Genista linifolia*), have been impacted. It should be noticed that the two endemic species described on the Hyères Islands have a controversial status. *Delphinium requieni* DC. is now considered to be simply a minor variant of *D. pictum* (Léotard, 2002), and *Romulea florentii* is very close to *R. requienii* Parl. particularly of its var. *parviflora* Bég.

Table 2. Distribution of patrimonial plants through the Hyères Islands.

	Porquerolles	Port-Cros	Levant	
Alkana lutea	X		x	
Asplenium balearicum	X			Ins.
Asplenium marinum			X	
Crepis leontodontoides	X	X	X	Tyrrh.
Delphinium pictum	X	X	X	Tyrrh.
Fumaria bicolor		X	X	Ins.
Fumaria flabellata	X		X	
Galium minutulum Jord.	X	X	X	
Genista linifolia	X	X	X	
Hypericum perfoliatum L.	X	X	X	
Leucojum pulchellum	X		X	Tyrrh.
Myosotis congesta Shuttlew. ex Albert & Reynier	X	X		
Orobanche fuliginosa Reut. ex Jord.	X	X	X	
Orobanche sanguinea		X		Ins.
Phelipanche olbiensis (Cosson) L. Carlón et al.	X			
Polypogon maritimus Willd. subsp. subspathaceus (Req.) K. Richter	X	X	X	
Ptilostemon casabonae			X	Tyrrh.
Romulea assumptionis			X	Tyrrh.
Romulea florentii		X	X	Tyrrh.
Romulea rollii Parl.	X	X	X	
Silene badaroi	X			Tyrrh.
Spergularia diandra			X	
Tecucrium marum		X	X	Tyrrh.
Teucrium massiliense			X	Ins.
Thymelaea tartonraira			X	
Verbena supina			X	
Vicia elegantissima Shuttlew. ex Rouy	X	X	X	

Tyrrh.: Tyrrhenian element, Ins.: insular plants

Fig. 2. Evolution of the total number of species on the Porquerolles Island according to main inventories.



MAIN THREATS AND CONSERVATION ACTIONS PERFORMED NOWADAYS

The tourist success of the Hyères Island entails an excess of human pressure during the tourist periods: 1 million visitors each year to Porquerolles, 220,000 to Port-Cros (http://www.portcrosparcnational.fr). The main impact is suffered on coastal ecosystems and the National Park is involved in a constant recovering of these habitats by fencing and replanting local plants, and by limiting the number of tracks and paths in order to control people's crossing. In contrast, a low level of disturbance on other areas of the Islands induces the development of preforest and forest units where *Quercus ilex* predominates. Médail *et al.* (1995) and Médail & Loisel (1999) have proposed a model for a spatial-temporal dynamic management of heliophylous or mesosciaphylous species based on a metapopulation concept. Local disturbances by clearing patches favour the proliferation of plants like *Delphinium pictum* or *Genista linifolia*; hence plant communities could develop naturally reconstituting the organic matter and the soil seed bank. This kind of dynamic management also limits the parasite populations. For very local plants (*e.g. Leucojum pulchellum* Salisb.) new populations have been created.

Invasion by exotic plants represents also a threat to the local flora. On the coastline, *Carpobrotus edulis* (L.) N.E. Br. and *C. affine acinaciformis* (L.) L. Bol. are very present and dynamic, producing fertile fruits (Suehs et al. 2003 ; 2004). The first mention of their presence (in Porquerolles) is made by Hanry (1886). The National Park has eradicated the *Carpobrotus* spp. on an islet (Îlot du Petit Langoustier) by an action over 14 years with an annual follow-up. Another invasive plant is *Cortaderia selloana* (Schult. & Schult. F.) Asch. & Graebn., particularly on Le Levant Island where the plant is dynamic in temporary streams. Each year, an eradication day is organised, and some local volunteers on the Island take part. Locally, *Acacias spp.* (mainly *A. dealbata* Link and *A. retinodes* Schltr.) are invasive; the proliferation control of the *Acacias* is difficult because these plants are highly popular in gardens. *Opuntia* spp. are also dynamic on rocky coastal slopes. There, preliminary identification has been done (Crouzet, 2009) and the most dynamic and problematic species is *Opuntia stricta* (Haworth) Haworth which spreads through seedlings and cuttings.

AN APPROACH TO THE FUTURE

Even if the flora seems to be well known today on the Archipelago, the efforts to follow up and improve this knowledge of the flora have to be maintained. New groups of rare or endangered plants may be still discovered, and due to human activity, new exotic species will certainly settle in the future. The management of the whole Archipelago is planned for the future in the management plan performed for the Natura 2000 site "*La côte d'Hyères et son archipel*", which integrates the presence of remarkable species of the Islands as well as their main threats.

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FROM FIRE TO NATURE: EVOLUTION, RESTORATION AND CONSERVATION OF THE COLUMBRETES ISLANDS FLORA

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Abstract

This paper deals with plant richness and singularity of the Columbretes Islands (Valencian Community, E Spain), a small volcanic archipelago 56 km off the southeast coast of Spain. These islands are home to the entire wild population of the exclusive endemic plant *Lobularia maritima* subsp. *columbretensis*, as well as the Iberian-balearic endemic moon trefoil *Medicago citrina*. They also hold the unique Spanish populations of *Reseda hookeri* and *Fumaria munbyi*, and a majority of *Lavatera mauritanica*. Since 1987, the Wildlife Service of the Generalitat Valenciana has been developing actions to restore the ancient vegetation, saving from extinction several climacic and preclimacic taxa (*Withania frutescens*, *Lycium intricatum*, etc.). The successful re-introduction of *M. citrina* on the main island –Illa Grossa– was achieved, and several conservation actions for the main threatened taxa are being carried out.

Keywords: *Columbretes Islands, Mediterranean flora, endemics, plant micro-reserve, plant conservation, re-introduction.*

A BRIEF APPROACH TO THE COLUMBRETES ARCHIPELAGO

The Columbretes Islands, a volcanic archipelago 56 km off the coast of Castellón, in southeastern Spain, with a surface of nearly 19 Ha, consists of 30 small islands and rock formations distributed in four groups. The largest islets are known as Illa Grossa (13.33 Ha, 67 m, Fig. 1), Ferrera (1.53 Ha, 43 m), Foradada (1.63 Ha, 55 m) and Carallot. Only the first three islets are large enough to harbour vascular plant species.

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The Columbretes Islands originated from volcanic materials (basalts, trachyandesites) with pH ranging from 6.6 to 7.7, as a basic characteristic. Due to sea influence and the presence of numerous seabirds, most of the soils are more or less saline and rich in soluble nitrogenated substances. The climate can be described in general terms as warm Mediterranean with mild winters and severe aridity, especially in summer (Bolòs, 1992). The average annual temperature ranges between 16.4 and 16.8 ºC. Rainfall data gives an average annual precipitation of 265 mm, spread over 23 days per year (Gisbert, 1987).

The archipelago is noteworthy for the uniqueness of some species of its flora and for some of its vegetation types. Moreover, it is an important site for seabirds and also a significant recreational resource. Activities such as spearfishing and scuba diving are strictly regulated. Guided visits to the largest island are also allowed, although the number of visits per day is limited. Moreover, the Illa Grossa bay is used by several recreational yachts for mooring.

The name of the archipelago comes from early sailors, Greek and Latin, which included it in their charts with the name of Ophiusa or Colubraria, amazed by the abundance of snakes they found. Many fishermen, smugglers and pirates visited the islands until the late nineteenth century. The colonization of the archipelago occurred in the mid-nineteenth century following the lighthouse construction on Illa Grossa between 1856 and 1860. The arrival of the lighthouse-keepers represented a dramatic change in an extremely wild environment. The vegetation of the main island was burnt to eliminate the presence of snakes. Domestic animals (such as rabbits, pigs or goats) were introduced and most of the shrubs were removed to obtain firewood. Subsequent soil erosion by rainfall following deforestation, completed a process of severe degradation of vegetation cover in the archipelago, especially noticeable on Illa Grossa, whose present development clearly differs from the historic original references published by Smyth (1831).

Lighthouse-keepers inhabited the island continuously for more than a century, in precarious conditions, as evidenced by the intensive use of all resources offered by the poor terrestrial environment and extraordinarily rich marine resources. The small colony of settlers left the island in 1975, when the lighthouse was automated. Since then, the islands had been uninhabited until the Natural Park was declared and the first surveillance service was created. The Columbretes Islands –emerged portion– were declared Natural Park in 1988. The marine environment of the Columbretes archipelago was declared Marine Reserve in order to preserve its outstanding richness in 1991. Currently, a team of four wardens remains on the main island carrying out surveillance, maintenance and conservation tasks.

Fig.1. Illa Grossa, the main island of Columbretes archipelago (Photo: C. Fabregat)

COLUMBRETES FLORA AND VEGETATION

Historical approach

The first references to the flora of Columbretes correspond with the impression of an English sailor (Smyth, 1831) who visited the islands before the lighthouse construction. He described the vegetation of the ridges that rise up on both ends of Illa Grossa stating: "These hills are covered with an exuberance of dwarf olives, geraniums, prickly pears, myrtles and brushwood". Years later, Archduke Ludwig von Salvator of Austria arrived at the island and his vision clearly reflected the great change that had occurred since human colonization: "The Columbretes (...) do not even have trees and shrubs. (...) Only *Suaeda fruticosa* covers the main island as a green scrub" (Salvator, 1895).

The first modern study on the flora of the archipelago was conducted by Manuel Calduch. He explored the islands between 1947 and 1965, obtaining a list of 107 species. Unfortunately, his observations were not published until many years later, after Calduch's death. Boira and Carretero (1987) published the first flora of Columbretes, which comprised a catalogue of 100 species. They also published the first vegetation study where 9 communities were described (Carretero & Boira, 1987). Subsequently, Bolòs (1989) completed the study of vegetation, extending the typology to 12 communities, and updated and published the Calduch's list (Bolòs, 1992), increasing the flora of the islands to 114 species. Subsequent studies (Laguna & Jiménez, 1995; Fabregat & López-Udias, 1997; Juan & Crespo, 1999, 2001) have completed and clarified the floristic catalogue and vegetation typology in the archipelago.

Current status and main features

In 2005, the Environmental Department of the Generalitat Valenciana -GV, regional government of the Valencian Community- started a project to monitor the flora and vegetation of the archipelago in order to ascertain its evolution and current status in the Columbretes Islands Nature Reserve. During the project development, existing references of the flora of Columbretes were reviewed, some new taxa were found and a floristic catalogue of 120 native or naturalized taxa was established. After five years of monitoring, only 87 species from the previous list have been confirmed (Fabregat *et al.*, 2009). The main reason is that first studies of the flora were made when the main island was still inhabited by lighthouse-keepers, who established and maintained crops for food, and the archipelago did not enjoy protection. Crop loss, and progressive decline of human activity since the islands were protected could be the cause of the disappearance of several weeds or ruderal species such as *Papaver rhoeas* L., *Asperula arvensis* L., *Galium verrucosum* Hudson among others. In other cases, heavy storms which sprayed sea water over the islets have been responsible for the disappearance of other species such as *Smilax aspera* L.

The phytogeographic spectrum of the Columbretes' flora (Fig. 2) is dominated by Mediterranean taxa (65%) followed by pluriregional taxa (28%), with a minor percentage (7%) of exotic taxa introduced by man (Mestre *et al.*, 2008). The high proportion of Austromediterranean elements stands out from the Mediterranean taxa, some of which represent outstanding disjunctions (e.g. *Fumaria munbyi* Boiss. & Reuter, *Lavatera mauritanica* Durieu). Characteristic plants of xeric climates of the arid Iberian SE such as *Withania frutescens* (L.) Pauquy, *Lycium intricatum* Boiss. or *Triplachne nitens* (Guss.) Lam. are also noteworthy. Life forms spectrum (Bolòs, 1989) is shown in Fig. 3, and is characterized by the dominance of therophytes and the absence of geophytes. The most common species are *Suaeda vera* Forsskal ex J.F. Gmelin, *Lobularia maritima* (L.) Desv. subsp. *columbretensis* R. Fern., *Lavatera mauritanica*, *L.*

arborea L., *Chenopodium murale* L., *Erodium chium* (L.) Willd., *Brachypodium distachyon* (L.) Beauv., *Sonchus tenerrimus* L., *Medicago littoralis* Rohde ex Loisel. and *Mesembryanthemum nodiflorum* L.

The vegetation of the archipelago is dominated by halo-nitrophilous communities, being the shrubby seablite scrub (*Lavatero mauritanicae-Suaedetum verae* O. Bolòs, Folch *et* Vigo in O. Bolòs 1989) the most widespread formation. In addition, some other associations are noteworthy for their singularity, such as *Medicagini citrinae-Lavateretum arboreae* O. Bolòs, Folch *et* Vigo in O. Bolòs *et* Vigo 1984 (ornithocoprophilous tall shrub dominated by tree mallows in addition to the arborescent moon trefoil) and *Euphorbio terracinae-Lobularietum columbretensis* Carretero *et* Boira 1987 corr. Carretero *et* Aguilella 1995 (prairies with tall grasses interspersed with *Lobularia maritima* subsp. *columbretensis*). Woody vegetation was almost completely destroyed, although some scarce palmettos (*Chamaerops humilis* L.) and lentiscs (*Pistacia lentiscus* L.) still remain on Ferrera islet, as a relict of the coastal maquis [*Querco cocciferae-Pistacietum lentisci* (Br.-Bl. *et al.* 1935) A. *et* O. Bolòs 1950] that could have covered the better soils on the islands. A complete list of plant communities of the Columbretes archipelago can be found in Table 1.

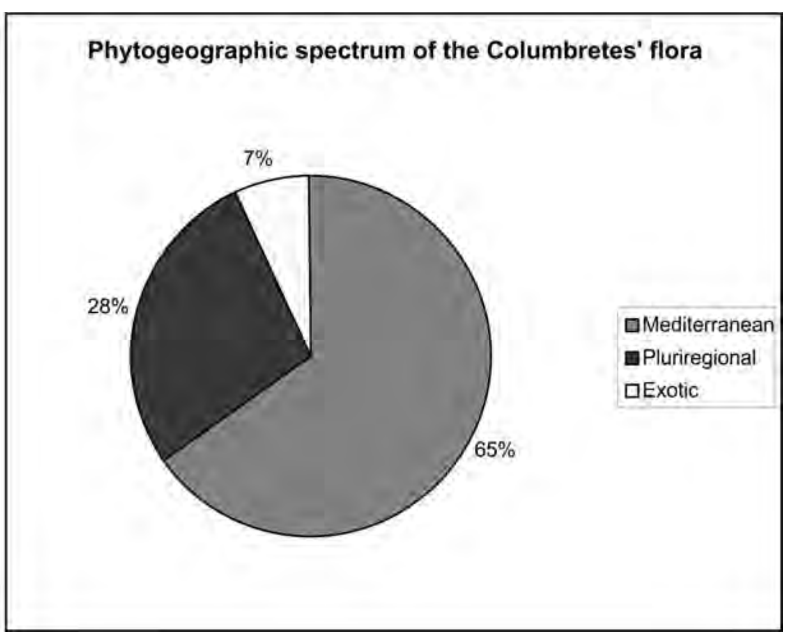

Fig. 2. Phytogeographic spectrum of the Columbretes' flora

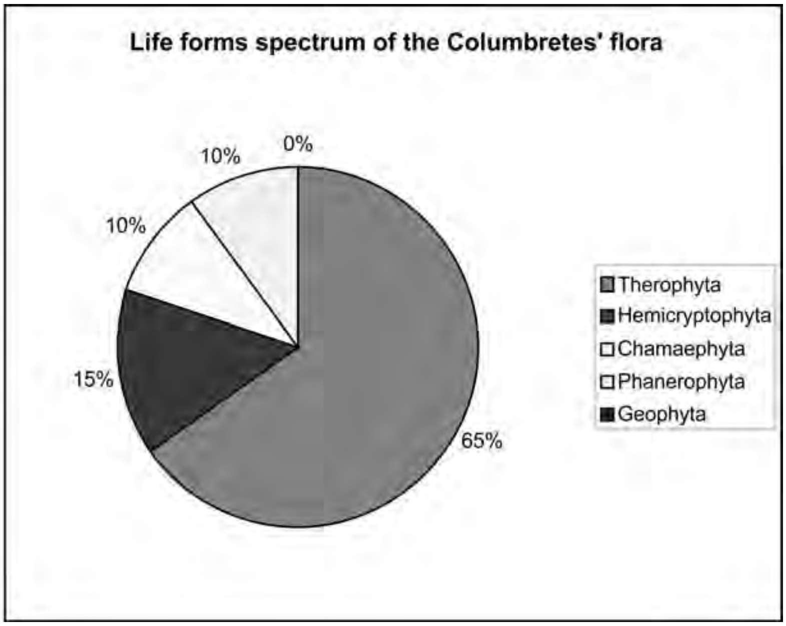

Fig. 3. Life forms spectrum of the Columbretes' flora

Endemic, rare or threatened plant species

The most important vascular plant species are *Lobularia maritima* subsp. *columbretensis*, an endemic restricted to the archipelago, and *Medicago citrina* (Font Quer) Greuter (Fig. 4), endemic to the archipelago and some islets surrounding the island of Ibiza and the NE Alicante coast (Serra *et al*., 2001). Moreover, interesting plants such as the rare *Fumaria munbyi*, *Reseda hookeri* Guss. –both are the unique Spanish populations– and *Lavatera mauritanica* can also be found, as previously stated. These five plants are protected by the Valencian Community laws.

RESTORATION AND CONSERVATION OF THE COLUMBRETES ISLANDS FLORA

The emerged land of Columbretes belong to the city of Castellón de la Plana, and are fully managed by the GV. In 1987, the Spanish Parliament empowered the Valencian Community to protect and manage the emerged part of the archipelago. In January 1988, the GV protected the islands as a Natural Park. They were reclassified as Nature Reserve in 1994. In addition to its plant treasures, Columbretes holds the best Valencian colonies of endangered seabirds, as well as a dozen endemic species of invertebrates and an endemic lizard. In 1991, the Spanish Ministry of Agriculture protected 4400 Ha of offshore waters and seabeds surrounding the archipelago. Furthermore, Ferrera and Foradada islets were the first two protected Plant Micro-Reserve (PMR) islands legally designated by the Valencian administration in 1998, according to the model explained by Laguna (2001). Both PMRs are devoted to ensure monitoring and active conservation projects of the main rare, endangered or endemic plant species, particularly *Reseda hookeri* and *Medicago citrina*.

*Fig. 4. The endemic moon trefoil (*Medicago citrina*) on the Foradada islet. Ferrera islet can be seen in the background (Photo: C. Fabregat).*

The main actions to conserve the flora and to restore the vegetation of Columbretes Islands have been described by Laguna and Jiménez (1995), and updated by Jiménez (1998). The first main activity, carried out during summer 1987, was the eradication of rabbits (*Oryctolagus cunniculus*, introduced in the late 19th century) on main island -Illa Grossa- avoiding the use of firearms, in order to prevent damages to the outstanding colonies of protected seabirds. Traps and bow and arrow were used to hunt 213 rabbits. Quick vegetation recovery was noticed, and several rare species (e.g. *Lobularia maritima* subsp.

columbretensis, Lavatera arborea, L. mauritanica) became dominant in the landscape of Illa Grossa within 1-2 years.

All the individuals of the climacic shrubs *Withania frutescens* and *Lycium intricatum* -only 4 old plants for each species- remained scattered in inaccessible sites on the sea cliffs of Illa Grossa in 1987, without opportunities to produce seeds due to the lack of local long-distance pollinators. Between 1989 and 1990, a common number of cuttings coming from each individual were cultivated on Illa Grossa, obtaining new seeds and starting a plant production line (Suárez, 1992). The progressive reinforcement started on Illa Grossa in 1992-1993, within the plant community dominated by *Suaeda vera*. In those initial years, all individuals of the invading prickly pear *Opuntia maxima* Mill. were eradicated, except for the case of the oldest monumental individuals –trees up to 4 m tall-, mainly maintained to secure food sources for migrant birds. The green stems of *Opuntia* were composted and used subsequently as mulch to fertilize the holes where new native species produced in the archipelago were planted. The main conservation project was the re-introduction of *Medicago citrina* on Illa Grossa, which had not been present since the 1960s (Klemmer, 1961), using both cuttings and seeds from Ferrera and Foradada islets. More than 400 plants were planted between 1990 and 1998. The population of *M. citrina* on Illa Grossa currently is made up of more than 300 adult individuals and new seedlings are regularly included, so the effective re-introduction task has been achieved. In order to restore the vegetation, a long-term programme was simultaneously proposed (Laguna & Jiménez, 1995), combining civil work –e.g. stonework micro-walls on surface run-off to stop the effects of soil erosion– with vegetation improvement, such as sowing annual species and planting perennial species which were fully produced in a small nursery built on Illa Grossa. However, the recovery of the last step –climacic vegetation- is still uncertain due to the lack of seed production of the remainder of individuals of *Pistacia lentiscus* and *Chamaerops humilis*.

As a main management action, the Nature Reserve carries out the biological control of the woodlouse *Iceria purchasi*, a serious pest for the cellebrated *Citrus* crops of the Valencian area, which entered the Columbretes archipelago in April 1997, destroying in just a few weeks more than 2/3 of *Medicago citrina* population. By 1995 and 1996, the Valencian *Citrus* crops suffered the attack of a new pest (the leafminer *Phyllocnistis citrella*), which was quickly but ineffectively combated using strong doses of pesticides. As a collateral effect, the biocides destroyed most of the population of the main predator of *I. purchasi*, the beetle *Rhodolia cardinalis*. The biocides generated the imbalance on biological control of *Iceria*, favouring a sudden increase in their populations on the coastal agricultural lands and city gardens of the Valencian Community. Woodlouses were inadvertently carried in the feathers of migrant birds coming from the continent and stopping in Columbretes. Since 1997, hundreds of individuals of *Rhodolia* were regularly released in key sites of the archipelago and the population of *M. citrina* has been actively self-recovered. Apparently, the population explosion of *Iceria* killed the oldest specimens of *Medicago*, and most of the new individuals seem to be resistant to the pest, ensuring the survival of this species, listed in the 'Top 50 Mediterranean Island Plants' (Montmollin & Strahm, 2005).

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Table 1. Syntaxonomical scheme of the Columbretes Islands plant communities to subassociation level [according with Rivas-Martínez & al., Syntaxonomical checklist of vascular plant communities of Spain and Portugal to association level. Itinera Geobotanica, *14: 5-341 (2001), with minor modifications]*

THE FLORA OF THE ISLETS OF THE BALEARIC ISLANDS

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Abstract

A description of the flora and vegetation of the islets of the Balearic Islands shall be presented here. We have found 654 species on 91 islets of the Balearic Islands. 30% of these species were found on only one island, and only 82 species have been found on more than 20% of the islets, which shows the great variability of the flora from one islet to another. We will also present a summary of the major plant communities, which include the nitro-halophytic shrub communities, as well as those that colonize the cliffs that are very rich in endemic species.

The islands of less than 5 ha poorly fit into the general model that relates the number of species and island area. The number of habitats is shown as a better descriptor of the number of species than the surface area for these small islands. Significant differences were observed between the rates of life forms, especially chamaephytes and therophytes, between the islands of less than 5 ha and more than 5 ha. Finally, we mention some of the main environmental disturbances affecting the islets, with special reference to the introduction of goats and rabbits, and the presence of seagull colonies.

Keywords: *Insularity, endemism, species-area relationship, life form, Cabrera, biogeography*

INTRODUCTION AND BACKGROUND

The Balearic Islands are located in the centre of the Western Mediterranean basin, at a minimum distance of 87 Km from the Iberian Peninsula, and about 230 km from North Africa. They consist of five inhabited islands: Mallorca, Menorca, Eivissa, Formentera and Cabrera, plus more than a hundred small islands, islets and rocky outcrops (from 0.05 to 270 ha), as satellites of the major islands.

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The vegetation of these islands is composed almost exclusively of Mediterranean elements, being particularly abundant southern Mediterranean species. Some taxa have their northern distribution limit here.

The study of these habitats is interesting because they are places where there are very specific ecological conditions, with high environmental stress and a relative isolation from the larger islands. Some species live exclusively in these habitats due to their protective effect or because they are true specialists of small islands (Höner & Greuter, 1988).

There have been several contributions to the flora and vegetation of the Balearic islets, but usually in a context of broader work. For example, catalogues and floras of the Balearic Islands made during the nineteenth and twentieth century, such as Barceló (1879-1881), Knoche (1921-1923), Duvigneaud (1979), Pla *et al.* (1992) provide some interesting data.

The archipelago of Cabrera, with the works of Marcos (1936), Palau, (1976), Bolòs *et al.* (1976), Bibiloni *et al.* (1993), Rita & Bibiloni (1993), Bibiloni & Rita (1995 and 2000), has been quite well explored. A comprehensive floristic checklist of the islets that surround the island of Mallorca is yet to be published, with the exception of the island of Dragonera with the works of Alomar (1981) and Alomar *et al.* (1998). In Menorca the situation is similar, as most floristic citations refer to the Illa d'en Colom (Rodríguez, 1904, Bolòs *et al.* 1970) but again, there is not a checklist of the flora of their islets. On the other hand, regarding the Pitiüses, we find the contributions of Kuhbier & Finschow (1977) and Kuhbier (1978a and b). Previously, the main islets of the Pitiüses attracted the attention of other authors such as Font i Quer (1920, 1926, 1933, etc.) and Tebar *et al.* (1989).

The following pages include some results of the floristic exploration of more than 90 of these small islands. We present the main characteristics of their flora as well as some information about plant communities and some comments about the relationship between the surface of the islets and the number of species included in their floras.

CHARACTERISTICS OF THE BALEARIC ISLETS

A floristic checklist of 91 islands of less than 300 ha of the Balearic Islands has been made (see Figure 1). Each islet was visited at least three times in different seasons over the three years of fieldwork.

This sample of islands represents, in fact, most of the Balearic islets that have been colonized by vascular plants. In Mallorca we have studied 23 islets, 28 in Eivissa, 9 in Formentera, 15 and Menorca, and 15 in the Archipelago of Cabrera, (we have excluded Cabrera Gran, the main island, because it has a significantly larger surface than the other islands).

Table 1 shows the size classes of the islets studied. The islets smaller than 0.5 ha represent more than a quarter of all islets studied, those smaller than 5 ha are more than three quarters of the sample. Only four islands cover an area larger than 100 ha.

85% of the islets studied are less than 50 m in height. Only five islands are over 100 m in height, and only two (Es Vedrà in Eivissa and Dragonera in Mallorca) are higher than 300 m.

Approximately 60% of the islets are less than 500 m from the coast, and only two groups of islands, the archipelago of Cabrera and Bledes, are found more than 4 km from Mallorca and Eivissa, respectively.

All Balearic Islands are associated with the continental shelf, and all of them are composed of carbonate substrates, except the Illa d'en Colom on the northern coast of Menorca.

Fig. 1. Map showing the location of the islets studied (Es Faralló d'Albarca (8) and Cabrera (26) were not included).

Islet surface area	Num. Islets	%	Average num. sp.	± std. error	Max.	Min.
<0,5 ha	24	26,4	23	5,3	122	1
0,5-1 ha	19	20,9	20	5,1	80	1
1-2 ha	13	14,3	22	4,7	58	1
2-5 ha	14	15,4	82	14,1	139	13
5-10 ha	7	7,7	46	9,9	80	16
10-20 ha	5	5,5	124	11,7	159	98
20-100 ha	5	5,5	175	30,0	268	90
100-300 ha	4	4,4	201	44,6	300	113

Table 1. Major values of size and plant diversity of the Balearic Islands.

THE FLORA OF THE ISLETS

We have found 654 species of vascular plants on the 91 islets studied. The variability from one islet to another is huge, even between the islands of similar size and geographic location. About 30% of these species (190) are found on a single island, and about 60% of species were found only in 4 islands or less. Surely many of them are occasional species that are part of the natural turnover of these islands (Snogerup & Snogerup, 2004; Panitsa *et al*., 2008). By contrast, only nine species have been found on more than 50% of the islands. The most frequent plant is *Asparagus horridus* (found on 69% of the islets), followed by *Crithmum maritimum* (62% of the islets), and *Desmazeria marina, Parapholis incurva, Suaeda vera, Mesembryanthemum nodiflorum, Sonchus oleraceus* and *Medicago littoralis*. Three of these nine species have halophytic characteristics or belong to the coastal plant communities, and two of them are more typical of ruderal areas. 82 species (12.6%) have been found on more than 20% of the islands. These species probably are those that best characterize the islets' habitats; however, over 35% of these species are ruderal or associated with perturbed environments.

Despite the great variability of the floristic composition of the islets, that is the result of different idiosyncrasies of each islet (Lomolino & Weiser, 2001, Panitsa *et al*., 2001), it is possible to recognize floristic affinities and differences between the islets from the eastern Balearic Islands (Mallorca, Menorca and Cabrera), and those of the Pitiüses (Eivissa and Formentera).

We have found 85 endemic and narrowly distributed species. Some of these are true islet specialists (Höner & Greuter, 1988), for example *Euphorbia margalidiana*, which lives on a single islet (Ses Margalides in the north of Eivissa), or *Medicago* *citrina* and *Beta vulgaris* subsp. *marcosii*, which live on a few small islands of the archipelago of Cabrera and Eivissa (see below) but not on the main islands (*Medicago citrina* can be also found on the smallest islands of the Columbretes Archipelago). *Rubia angustifolia* subsp. *caespitosa*, endemic of Cabrera Gran, and *Silene cambessedesii,* endemic of a few islets, could also be included in this group, but they can also be found on some beaches of Eivissa and Formentera and in a area of the mainland. Other cases are *Withania frutescens* and *Parietaria mauritanica*, living in the Balearic Islands mainly on islets. *Daphne rodriguezii*, cited as an islets' specialist (Höner & Greuter, 1988), is a very interesting case. There is a large healthy population on the Illa d'en Colom (north of Menorca) of this species, which lives together with its natural disperser, the endemic lizard *Lacerta lilfordii* (Traveset, 2002). There are other senescent populations of this plant on the Island of Menorca, but there, on the main island, *Lacerta lilfordii* was extinguished and this mutual relationship was disrupted, currently the plant has significant difficulties to maintain these populations outside the islet (Traveset, 2002).

Some islands, like Cabrera Gran, Es Vedrà, Vedranell and Espartar, have endemic or narrowly distributed plants linked with cliffs and fissures of rocks, such as *Hippocrepis balearica, Asperula paui*, and the threatened *Silene hifacensis*.

PLANT COMMUNITIES OF THE ISLETS

The islets vegetation is clearly under the influence of a marine environment. On the smallest islets only halophytic species are able to survive. However, on the medium to large sized islets it is possible to recognize a zoning of shrub communities from the coastline to the inland (see for example Fig. 2).

The plant landscape of these islands is made up primarily of three major vegetation types: coastal and nitro-halophytic communities, inland shrub communities, and herbaceous communities, generally with a ruderal character. There is wide variation in these communities, with notable floristic differences between the islands of Eivissa and Formentera and the islands of Mallorca and Menorca. The Cabrera Archipelago has some characteristics in common with both groups of islands, but in general it has a closer relationship with the eastern Balearic Islands.

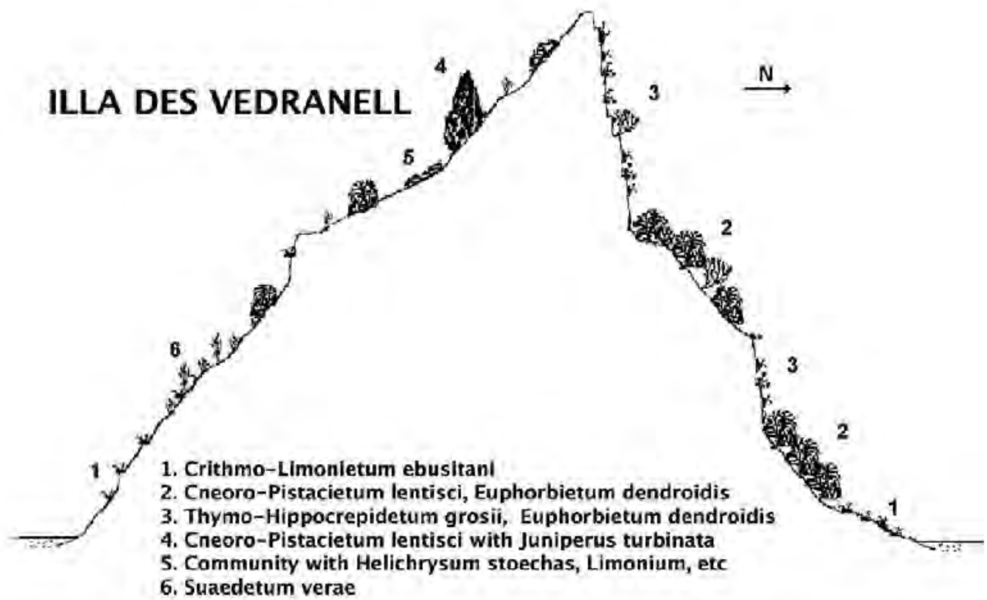

Fig. 2. Diagram of the main plant communities of Es Vedranell (Eivissa).

Coastal communities

Pulvinate chamaephytes communities: Communities with *Limonium* spp. (Al. *Crithmo-Limonion*) colonize areas particularly vulnerable to penetration of salts of marine origin, mainly those closest to coastal zones. Different species of mostly endemic *Limonium* (*L. ebusitanum, L. dragonericum, L. caprariense*, etc.) may be the only colonizers of these areas, along with *Crithmum maritimum*. On the islands of Menorca and Mallorca As. *Launaeetum cervicornis* can also appear.

Annual communities of saline soils (Al. *Frankenion pulverulentae*): it appears in places with sediment with high concentration of salt, sometimes it is replaced by *Mesembryanthemum nodiflorum*.

Salt and nitro-halophytic shrub communities: In areas with greater influence of the sea with limited amounts of soil, it is common to find shrubs with *Sarcocornia fruticosa* and *Arthrocnemum macrostachyum*. In a more inland position there is a richer community with *Suaeda vera*, accompanied by other species such as *Daucus carota* subsp. *commutatus*, *Dactylis glomerata* subsp. *hispanica*, *Silene secundiflora*, *Asparagus horridus, Allium commutatum*, etc. On some islands, in this zone *Lavatera arborea* can also be found, which even become dominant (As.

Lavatero-Suadetum verae). On a few small islets there are *Medicago arborea* and *Beta vulgaris* subsp. *marcosii* communities (As. *Medicagini citrinae-Lavateretum arborae*), probably these endemic species are very sensitive to the actions of herbivores (goat and rabbits) and hence are found on small islets without these animals or in inaccessible places. Its distribution is limited to the islets of Ses Bledes, S'Estell des Coll y S'Estell de Fora in Cabrera, Els Malvins, S'Espartar, Illes Bledes in the Pitiüses.

Nitrophilous shrub communities: On many islands of the Cabrera Archipelago, and some from the Pitiüses and Mallorca, there is a shrubland with *Whitania frutescens* (As. *Ephedro-Whitanietum frutescentis*), its ecological area is in the transit zone between coastal communities and the inland sclerophyllous maquis of the Al. *Oleo-Ceratonion*. It has a thermophile and nitrophilous character and is probably linked to seabird colonies.

Maquis and non-coastal scrub

Woody communities are behind nitro-halophytic vegetation; they have a high plasticity of forms and structures depending on weather, geomorphological and soil conditions of each island. In windy areas the sclerophilous shrubland acquires a coastal character, where *Pistacia lentiscus, Euphorbia dendroides,* and *Ephedra fragilis* can be dominant, as well as *Phillyrea media* in some islets of Cabrera Arch. and I. Colom in Menorca. On the other hand, *Juniperus phoenicea* subsp. *turbinata* is common on many islets, especially in the Pitiüses. Calcareous thickets of Al. *Rosmarino Ericion* are only important in Cabrera and Dragonera, sometimes they have a tree layer of Aleppo pine (*Pinus halepensis*).

Ruderal herbaceous communities

On many islands herbaceous communities dominated by nitrophilous species appear: *Urtica* spp., *Chenopodium* spp., *Lavatera* spp., *Beta* spp., *Parietaria* spp., etc. In islets of the Pitiüses the presence of *Diplotaxis ibicensis* in these environments is also common. In most cases these communities are associated with seabird colonies, or the presence of goats or rabbits.

Communities of cliffs and rock fissures

A case in point for the richness of endemic species is the casmophytic vegetation that colonizes the shady side of rocks and limestone cliffs of some islets. The As. *Hippocrepidetum balearicae* with *Hippocrepis balearica, Crepis triasii, Helichrysum ambiguum* is mostly found on Cabrera Gran and Dragonera. While on some islands of the Pitiüses like Es Vedrà, Vedranell and Espartar, we find the As. *Hippocrepidetum-Thymo ebusitani grossi*, with *Asperula paui, Silene hifacensis, Lamottea dianae, Scabiosa cretica, Saxifraga corsica* subsp. *cossoniana*, *Teucrium cossonii* subsp. *punicum*, etc.

Other types of communities

On the larger islets there are other plant communities, usually linked to particular environments such as dune systems, humid zones, therophyte communities, etc., which are rare or do not exist on the smaller islets.

ISLANDS AREA AND NUMBER OF SPECIES

The classic relationship between species and island area (SAR) was discussed for the Balearic Islands by Fraga *et al*. (2004), Rita & Palleras (2006), and for the archipelago of Cabrera by Bibiloni *et al*., (1993). For the Balearic islets (not including the five main islands) a significant positive correlation between the logarithms of number of species and area has also been found, but the coefficient R^2 offers a much lower value (0.426) than has been published for others for the bigger islands (Bibiloni *et. al*., 1993; Rita & Palleras, 2006). The correlation between the logarithms of the number of species and island area for the islands of less than 5 ha is significant despite being offered a coefficient of $R^2 = 0.157$, so that data fit very poorly to the regression line obtained (Fig. 4). By contrast, the islets of more than 5 ha presented a much smaller variance, and a $R^2 = 0.597$, so the regression line fairly describes more accurately the relationship between species number and island area.

This anomaly of species-area relationship (SAR) on small islands has been described previously and called the Small Island Effect (SIE) (Whitehead & Jones, 1969; Lomolino & Weiser, 2001; Panitsa *et al*., 2006). It occurs because for these small islets many environmental factors (stochasticity of environmental factors, such as strong storms, and the idiosyncrasy of each island: localisation more or less exposed to prevailing winds, distance from shore, history, etc.) may be more relevant to define the number of species than the surface area of the island itself.

However, the relationship between the number of species and number of habitats (defined on the basis of plant communities present) shows a strong positive significant correlation ($R^2 > 0.8$) (Fig. 5), both for the two ranges of island sizes as for the whole sample. This shows that, in this case, environmental heterogeneity is the ecological factor that best describes the floristic richness in terms of number of species over other simpler geographical variables, like the surface area that does not summarize the complexity of ecological factors that act on these islets.

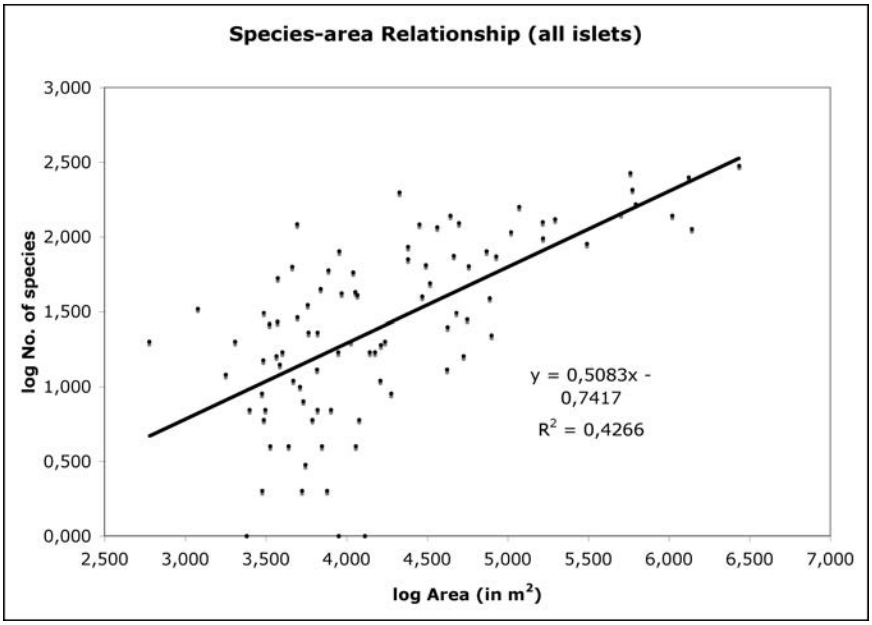

Fig 3. Species-area relationship for all Balearic islets studied.

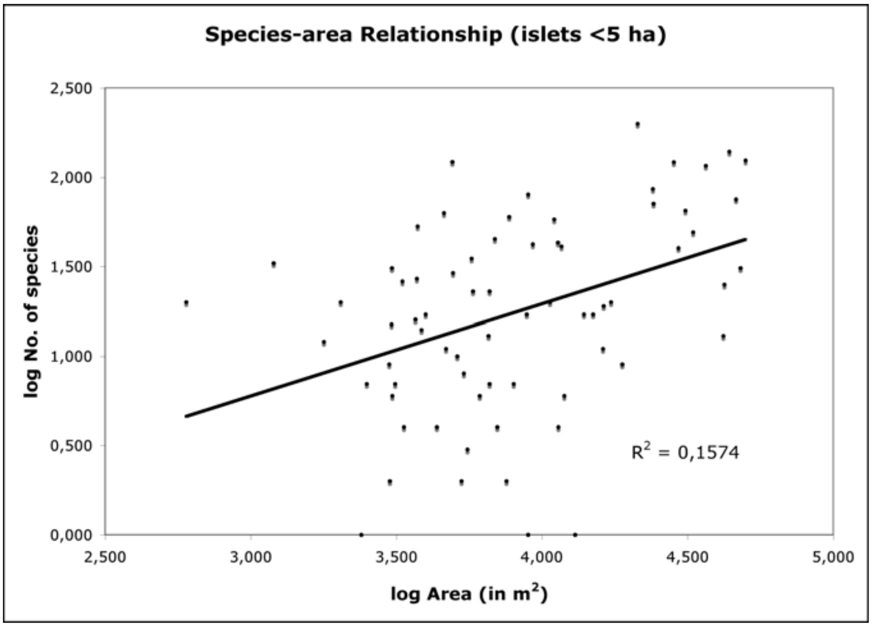

Fig 4. Species-area relationship for Balearic islets covering less than 5 ha.

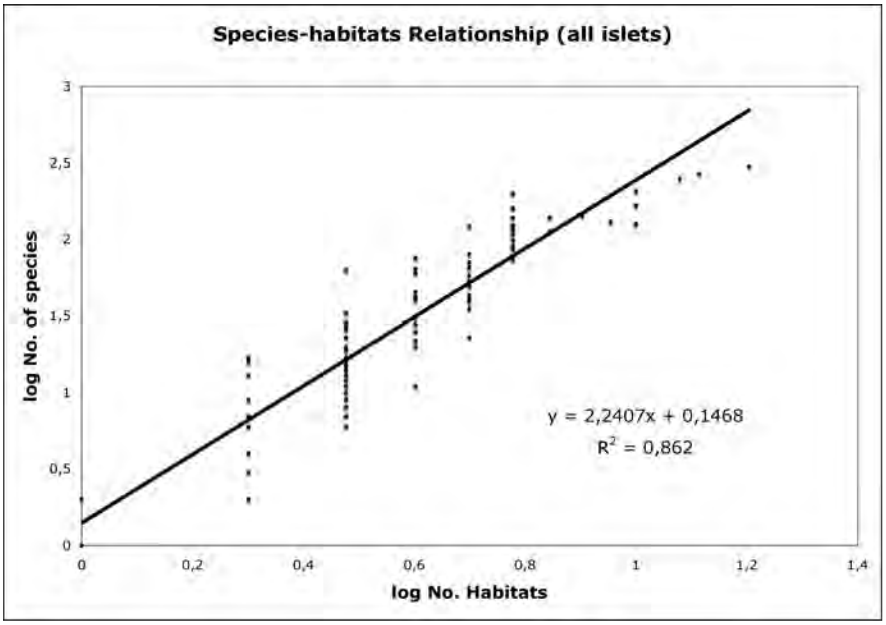

Fig 5. Species-habitat relationship for all Balearic islets studied.

ISLET SIZE AND STRUCTURE OF LIFE FORMS

The life forms structure of the floras of the islets deviates significantly from the model showed by the major islands. Its Mediterranean character is recognized in the rate of therophytes, it is the largest species group with values even higher than those given on the main islands (Fig. 6). However, the second largest group is the chamaephytes, ahead of hemicryptophytes. Phanerophytes also had higher levels than in the five largest islands in the Archipelago. This pattern is more substantial on the islands of less than 5 ha. In this sense, significant differences were found between the average ratios of therophytes, chamaephytes and phanerophytes of islands of more or less than 5 ha (Fig. 6.). On the islands of less than 5 ha, the chamaephytes rate, which average around 30%, is more than double that in Mediterranean environments of the mainland. As for the ratio of therophytes on the islets of less than 5 ha, it is significantly lower, close to 40% versus 60% on the islets of more than 5 ha, which are similar values to those published by Panitsa *et al*. (2001). These differences can arise due to the lack of suitable environments for non-halophilous annual plant communities on the smallest islands.

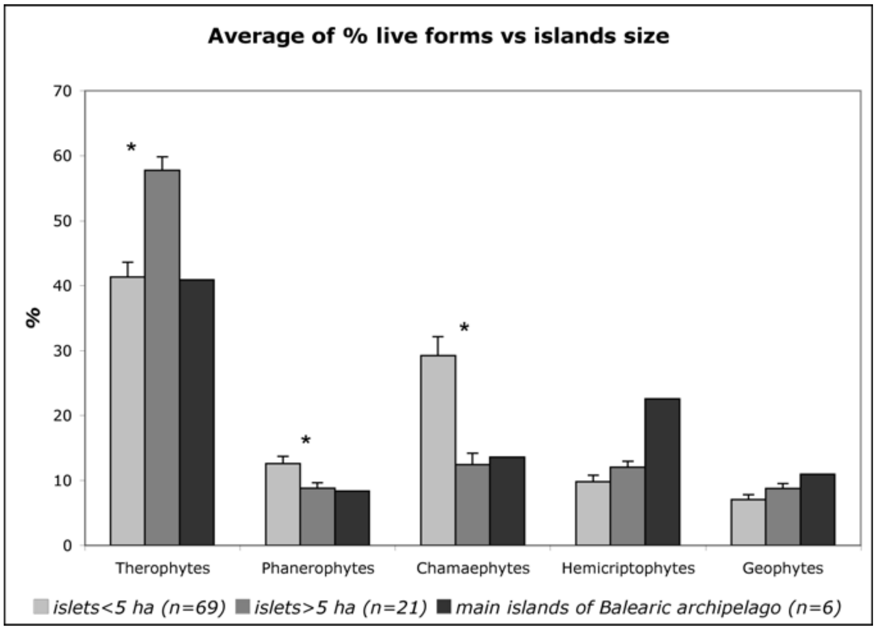

Fig. 6. Average of % of life forms for islets with less than 5 ha versus islets larger than 5 ha with asterisks where differences are significant. The average of the six main islands of the archipelago are included to comparison (source Rita & Palleras, 2006).

ENVIRONMENTAL PERTURBATIONS OF THE ISLETS

Archaeological remains exist on some islands of the Balearic Islands showing an occupation dating to the fourth century BC. Since then, these environments have been widely used by humans to a greater or lesser degree. Too often we have introduced goats, sheep or pigs. On the islets that are large enough, mankind has cultivated and there has been a more or less regular human presence. Some islands have had very specific uses like pesthouse, hospital, jail for prisoners of war, target shooting for the army or navy, etc. Naturally these uses, especially agriculture and the introduction of livestock, have changed the vegetation of the islands and have facilitated the introduction of many plant species. Even now, islets as interesting as Es Vedrà (Eivissa) have a population of goats that destroys the natural vegetation. Mankind has also introduced other animals such as rats and, especially, rabbits, causing a major impact on vegetation (very evident on the Illa de l'Aire in Menorca and Espartar in Eivissa). On Es Vedrà an old forest of *Juniperus turbinata* was cut down to obtain timber.

Seabird colonies occupy many islands, in some cases their presence is so massive that they significantly affect the vegetation, usually with an increase in ruderal species (Table 2), as has been documented on other Mediterranean islands (Vidal *et al*., 1998 and 2000).

	Es Pantaleu	Sa Torre	Na Guardis	Es Malgrats	Illeta de Sóller	Imperial
% no ruderal Therophytes	**68,5**	**66,6**	**56,8**	35	36,6	24
% ruderal Therophytes	31,5	33,4	43,2	**65**	**63,4**	**76**

Table 2. Proportion of non-ruderal vs ruderal therophytes on six islets. The first three with low pressure from seabirds, the last three with large colonies of sea gulls.

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THE UNIQUE NATURE OF MEDITERRANEAN ISLAND FLORAS AND THE FUTURE OF PLANT CONSERVATION

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Abstract

The biotic originality of Mediterranean islands can be explained by complex interactions between a highly heterogeneous historical biogeography and unique ecological processes linked to various insular conditions. But most of the ups and downs of this unique biodiversity are now closely linked with human population pressures, which have changed many times through the long history of insular systems. These impacts will probably be exacerbated on islands because of no (or highly limited) adjacent areas of expansion. Therefore, conservation and ecological monitoring of small islands and islets must be reinforced, since they constitute major refuge areas with the presence of endemic relict plants, often threatened on the continent.

This global overview presents some key issues for future research devoted to future conservation and monitoring of the Mediterranean islands' plants and habitats.

Keywords: *conservation biogeography, human impact, insular biogeography, islets, Mediterranean islands, mutual interactions, threats.*

THE UNIQUE NATURE OF MEDITERRANEAN ISLAND FLORAS

The unusual geographical, climatic and topographical diversities and the reticulate historical biogeography of the Mediterranean Basin explain the exceptional high plant diversity and endemism of this area, one of the 34 biodiversity hotspots identified around the world (Médail & Myers, 2004). With about 10,000 islands and islets, of which 244 are inhabited by humans (Arnold, 2008), the Mediterranean Sea encompasses one of the largest "archipelagos" in the world. Some Mediterranean countries such as Greece and Croatia, with *ca*. 1150 islands and islets according to Nikolic (2013), encompass a significant number of these islands. Insular areas harbour a significant component of the Mediterranean plant biodiversity, with the presence of narrow endemic plants or range-restricted ones, and the occurrence of genetically isolated populations. Factors explaining the biological unicity of these insular floras are manifold: (i) varied paleogeography and geology, (ii) different geographical situations, (iii) wide ranges of morphology, size (from the biggest island of Sicily with 25,700 km^2 to small islets of a few dozen square meters), or altitude (from 3342 m at Mt. Etna to flat islets of less of one meter).

If the unique richness of Mediterranean insular floras is mainly due to strong environmental heterogeneities between islands, another key factor is the long-lasting influence of man who acts as a major disperser of plants and as a huge «designer» of Mediterranean insular landscapes through burning, cutting, grazing and ploughing. Indeed, the considerable beta and gamma diversities of insular ecosystems are also the heritage of various human activities that have had profound consequences on the distribution and dynamics of species, ecosystems, and landscapes (Blondel, 2008; Vogiatzakis *et al.*, 2008).

For historical and geographical reasons, but also due to the particular biotic interactions between species, insular conditions determine a specific nature of plant assemblages and biodiversity. The percentage of endemism often reaches high levels while there is rather limited plant richness (eg. Whittaker & Fernández-Palacios, 2007). This general insular pattern is also found on the larger Mediterranean islands. Here, plant endemism is generally comprised of between 10-12% whereas the overall range of flora is greater than expected, including between 1,600 and 2,800 taxa (species and subspecies) (Médail, 2008). On insular mountain ranges, endemism level is clearly higher since at altitudes above 1,700 m a.s.l. endemics represent about 35-40% of the vascular flora in Corsica and in Crete.

If the global patterns of taxonomic diversity are now well estimated, at least for large Mediterranean islands (Greuter, 1995, 2001; Quézel, 1995), several gaps of knowledge exist in ecological research and conservation planning. This synthesis proposes some key issues for future ecological and evolutionary research on Mediterranean island plants in order to better assign conservation priorities and biodiversity monitoring.

BIOGEOGRAPHY AND EVOLUTION OF MEDITERRANEAN ISLAND FLORAS

Mediterranean islands represent major refuge areas and conservatories of old, often mid-Tertiary floras with numerous relict plants characterized by a prolonged evolutionary standstill (Médail & Diadema, 2009). The relict nature of Mediterranean island plants is well supported by the presence of palaeoendemics restricted to one or few of these islands, and by the existence of some relicts of the subtropical Tertiary environments. This is the case, for example, for the few populations of the fern *Woodwardia radicans* in Corsica and Crete, and for two small trees of the Elm family, *Zelkova sicula* in Sicily and *Z. abelicea* in Crete.

An outstanding example of the importance of ancient palaeogeography to explain current patterns of plant distribution and biogeographical links concerns the Tyrrhenian islands. The eastern Balearic Islands (Minorca and Majorca), Corsica, Sardinia, and part of Sicily are some of the remnant areas that once belonged to the Protoligurian massif, a west-Mediterranean Hercynian formation that was fragmented in the mid-Tertiary (Oligocene-Miocene), causing notably the rotation and migration of the Corsica-Sardinia block between 23 Ma and 16 Ma. The distribution of numerous Tyrrhenian endemic plants shared among these islands (eg. *Arenaria balearica, Delphinium pictum, Dracunculus muscivorus, Teucrium marum*) reflects this crucial palaeogeographical event. Nevertheless, more recent evolutionary history related to the climatic aridification since the Pliocene (ca. 3.2 Ma) and the onset of the Mediterranean climate influence also the phylogeography of species as suggested by *Thymus herba-barona* (Molins *et al.*, 2011).

In order to explain current patterns of plant distribution and endemism on the Mediterranean islands, two other major geological events must be invoked: the Messinian salinity crisis of the Late Miocene, and the severe cooling episodes along the late Pliocene and the Early-Middle Pleistocene (Tzedakis, 2009). The Messinian salinity crisis was provoked by the interruption of marine relationships between the Atlantic Ocean and the Mediterranean Sea. This has induced an almost complete desiccation of the Mediterranean Sea between 5.96 Myr and 5.33 Myr, with two evaporitic steps. During these two episodes, there were some opportunities for the migration and establishment of drought-resistant plant species as even the major islands were completely joined to the continent. Five million years ago, the beginning of the Pliocene was marked by the return of the sea and this resulted in the final separation of some major islands (Crete and Karpathos, Corsica, Sardinia, Balearic Islands) from the mainland. The second determinant episode is related to several drastic marine regressions that have occurred during the recurrent ice ages at the end of the Pliocene and until the Last Glacial Maximum (*ca.* 18,000 ± 2000 yr BP). Marine regressions consist in more or less severe decreases in sea level, between 100 and 150 m below the current level, inducing the possible terrestrial migration of a more competitive cool-temperate flora on some offshore islands. This is the case of most of the Aegean islands, except Rhodes, the Cyclades and the Crete-

Karpathos island group which remained insular throughout the Pleistocene. On the whole, the contribution of these land-bridge connections is important to explain biogeographical affinities between currently distant and isolated floras. Nevertheless, long-distance dispersal of seeds by birds or marine currents is also relevant to island colonisation but well-documented evidence is still rare except for common halophilous plants (Westberg & Kadereit, 2009). Nevertheless, an eastwards long-distance dispersal is invoked to explain the geographical disjunction of *Armeria pungens,* a disjoint western Mediterranean coastal sand-dune plant, and recent genetic analysis suggests that Corso-Sardinian populations originated from the southwest Portuguese ones (Piñeiro *et al.,* 2007).

If Mediterranean islands have served as important Tertiary and glacial refuges, their role in the local and more recent differentiation of plants is probably equally important. These islands possess highly polymorphic species and vicariant endemic plants stemming from more or less recent speciation events (eg. *Limonium, Centaurea*) (Rosselló, 2013). Isolation and environmental heterogeneity have favoured here diverse evolutionary processes of gradual speciation of plants, such as genetic drift or adaptive radiation. Several well-studied examples are found in the Aegean islands (*Eysimum* sect. *Cheiranthus, Nigella arvensis* complex), where the history of isolation of these multiple islands determine pronounced random plant differentiation following fragmentation of a former contiguous distribution area. Detailed molecular studies in *Nigella* of the Aegean archipelago demonstrate that the main diversification process occurs during Late Pleistocene (Bittkau & Comes, 2009). Therefore, if Mediterranean island floras are in part relict, their evolutionary dynamics are probably underestimated, in particular on small islands subject to harsh and stochastic environmental conditions.

INSULAR BIOGEOGRAPHY AS DETERMINANT OF CURRENT PLANT DIVERSITY

According to the seminal theory of insular biogeography developed by Robert H. MacArthur and Edward O. Wilson in the 1960s, there is a global dynamic equilibrium determining the number of species found on an island. This equilibrium theory of species richness is based upon the balance between species immigration to an island, and extinction from it of local populations, under the influence of island isolation and island area, respectively. Another classic rule is the strong and recurrent relationship between species number and area, but this pattern is not as simple as it may seem since the analysis of the species-area relationships (SARs) reveal a high level of uncertainty across biomes or taxa (Guilhaumon *et al.,* 2008). A study of the species composition of 48 small islands of the Provence archipelago (S.E. France) demonstrates the combined effects of physiographic variables (area, isolation, elevation and substrate) and habitat diversity on plant species richness and composition (Médail & Vidal, 1998). The cornerstone of this relationship is habitat diversity, which increases on larger islands, which have stronger topographical diversity and elevation, favouring the settlement and persistence of plant species and ecosystems not strictly linked to the presence of salt. For the Provence islands, there is a greater random variation in the number of plant species present and in presence/absence of plants on smaller islands (area less than 3.5 hectares) than on larger islands. Small islands are submitted to harsh environmental conditions (continuous sea-sprays and strong winds) but also often suffer greater disturbances (storms, nesting sea gulls), which explains why an important set of plant species cannot survive on islands below a critical size. This «small island effect» is perceptible for islands below 1-3 ha, and for some Aegean islets, a significant increase in plant richness is only detected when the land surface is greater than 500 m in length and has an altitude of at least 50 m a.s.l. (Höner & Greuter, 1988).

Due to the generally small distances of islands from each other and from the continent, the effect of isolation is not always so obvious and it is in general poorly correlated with plant richness. Nevertheless, there are often some striking differences in floristic composition between offshore islets and the roughly similar ecosystems located on the opposite coast, in spite of the reduced physical barrier, the short time of separation and their apparently similar environmental conditions. Furthermore, some remote islands exhibit a floristic pattern quite similar to those of the remote oceanic islands: this is the case of Alborán island (7.1 ha, 15 m a.s.l.) isolated between Spain (85 km) and Morocco (55 km) which includes very limited plant richness (20 species) but with the presence of three endemic plants (*Anacyclus alboranensis, Diplotaxis siettiana, Senecio alboranicus*) only restricted to this flat island (Mota *et al.,* 2006).

One of the most fascinating and intriguing patterns is related to the botanical unicity of each island. Some close islands show very different plant species composition, suggesting the existence of selective plant dispersal through some narrow stretches of sea, as well as random colonisation and extinction processes. For example, the distribution of *ca.* 60 plants species (notably *Campanula, Dianthus, Erysimum, Helichrysum*) restricted to mostly maritime cliffs (chasmophyte plants) of the Aegean show marked differences between islands, even on those less than 10-20 km apart. Recent investigations on Ionian Islands demonstrate indeed the high beta-diversity, i.e. floristic independence, for the Echinades islets group (Panitsa & Eleni, 2013). Despite repeated land-connections linked to sea-level changes during geological times, small distances have played here an effective barrier to plant dispersal, allowing plant population isolation and speciation processes.

INSULARITY, A FACTOR PROMOTING ORIGINAL PLANT DYNAMICS AND BIOTIC INTERACTIONS

Since islands constitute more simplified systems in terms of species richness -notably redundant ones- and ecosystem function, they represent robust "natural mesocosms" to test hypotheses related to the complex links between biodiversity, ecosystem structure and function.

Compared to the continent, island communities and ecosystems are more sensitive to exogenous disturbances and to environmental stochasticity, which promotes often rapid and contrasted dynamics. This is particularly the case of small islands and islets which often house large sea-bird colonies as they benefit from the tranquillity necessary to accomplish their nesting cycle. These colonial seabirds exert high pressure on ecosystems by modifying patterns and dynamics of plant communities. The impact of seabirds on the vegetation is severe, with physical (trampling, pulling-up, soil erosion, burrowing) or chemical (soil manuring induced by guano rich in phosphorous and nitrogenous compounds, salt deposition) disturbances (Vidal *et al.,* 1998, 2000; García *et al.,* 2002). These strong ecological pressures favour the most resistant (ruderal) plants at the expense of oligotrophic stress-tolerant species. Seagulls' influence may lead to severe imbalances for insular communities since (i) they often induce changes in the leaf nutrient status of the dominant plants, (ii) they alter the cover, composition or turnover of the plants, and (iii) they modify interactive processes between species. Besides wind, birds act also as important natural vectors for the dispersal of seeds from mainland or other islands. Thus, passive introductions of new islet plants are indeed frequently observed near nesting colonies of seagulls. The effects of an increasingly large yellow-legged gull *Larus cachinnans* colony on the flora of the Marseilles archipelago were studied through the analysis of floristic changes (*species turnover*) that have occurred in the past 40 years (Vidal *et al.,* 1998). Plant turnover appears to be positively linked to gull nesting density and it is inversely correlated to island area since small islets appear to be more affected than larger islands. Plants with the highest turnover rate were primarily ruderal, annual, wind-dispersed species, with a wide geographic distribution (Vidal *et al.,* 2000). Disturbance by seabirds favours the massive establishment of non-native species which has led to the extinction of some endangered plants on islets characterized by important species turnover.

Because of the intrinsic characteristics of island ecosystems, there exist particular types of plant-animal interactions. One of the most striking examples is the plant-lizard mutualism deeply studied in the Balearic archipelago. Here, endemic lizards (*Podarcis lilfordi* and *P. pityusensis*) acted as probably the only seed dispersers of a native shrub species *Cneorum tricoccon* (Riera *et al.,* 2002) and of an endangered endemic Minorcan shrub *Daphne rodriguezii* (Traveset & Riera, 2005). But introduction of carnivorous mammals in the Balearic Islands has caused a dramatic mutualism disruption, between *Daphne rodriguezii* and *Podarcis lilfordi*. Seed dispersal by lizards is the critical stage that limits population expansion and seedling recruitment, drastically reducing *Daphne* populations, except on the Colom islet where lizards still persist (Rodriguez-Pérez & Traveset 2010). Disperser loss also has a negative impact on the genetic diversity of this *Daphne,* which possesses higher relatedness among individuals for Minorcan populations (Calviño-Cancela *et al.,* 2012). Lizards can also pollinate some coastal Mediterranean plants (*Crithmum maritimum, Euphorbia dendroides*), notably on islets where they occur with a high density and are not threatened by the introduction of exotic carnivores.

Studies of reproductive ecology of plants on small islands appear also relevant to better understand the pollination syndrome occurring in isolated populations when insects are occasional (Pérez-Bañón *et al.,* 2007), or even absent as for the bee-pollinated endemic *Medicago citrina* in the Columbretes archipelago (Pérez-Bañón *et al.,* 2003).

Structuration / continent	Functioning
Plant communities with original floristic composition	Specific functional processes (flux, biotic interactions)
Poor communities with few redundant species	Impacts exacerbated by exogenous disturbances
Higher abundance of rare, endemic and relict species, often in range limit	Inflation density: relaxation of competition processes / expansion of ecological niches
Isolated populations, with few individuals	Processes of genetic differentiation (genetic drift, founding effects) and local adaptation
Communities subject to drastic ecological stress, with important stochasticity	Huge spatio-temporal fluctuations of plant richness and composition

Table 1. Main patterns determining the ecological and functional importance of small islands

THREATS TO MEDITERRANEAN ISLAND PLANTS

If the coupled natural and human influences contribute to the extreme heterogeneity and the biotic originality of Mediterranean islands (Vogiatzakis *et al.,* 2008), the current main threats faced by the island biodiversity are mostly due to direct and indirect human impacts.

Evidence of early insular colonisation by man are still debated in the Mediterranean, but a lower Palaeolithic occupation dated to at least 130,000 years ago in southern Crete (Plakias region) suggests that the early "inhabitants" reached this island using sea craft (Strasser *et al.,* 2010): this finding could push the history of seafaring in the Mediterranean back by more than 100,000 years! But the first proofs of long human presence on an island seem to occur on Cyprus -where the settlement of Mesolithic hunter-gatherers dates back at least 10,000 years b.C. and the development of agriculture occurs between 8700-8000 years b.C. (Guilaine *et al.,* 2011). Nevertheless, it is still highly difficult to assess the magnitude of plant extinction induced by man during Holocene history. The local disappearance of the Dwarf-Palm (*Chamaerops humilis* L.) in Crete during the Antiquity, because of over-exploitation, constitutes a rare well-documented case, already mentioned by Theophrastus (Amigues, 1991).

Current human-induced threats are manifold in the Mediterranean region and they can be ranked by decreasing order of global importance: urbanization, tourism and recreation, environmental changes (land-use and global warming), biological invasions, fires, collecting pressures.

The major islands are usually characterized by an increase in human population, whereas smaller islands (except some hotspots of tourism such as Capri, Corfou, Djerba) are subject to a clear demographic decline. Since the 1960s, tourism on islands has increased extensively, with a height on some Balearic Islands (Majorca and Ibiza) where a peak was reached in 2000-2001 with 11 million tourists. Therefore, on the Balearic Islands (López *et al.*, 2013), it is estimated that urbanization and infrastructure explain one third of the current threats concerning the 180 threatened plant taxa. This huge human pressure induces a strong urban development, which is concentrated along the coasts, destroying or threatening several fragile ecosystems such as sand-dunes and wetlands, and to a lesser extent, coastal rocky habitats. For example, on the Greek island of Skiathos (N. Sporades), tourism development since the 1970s has produced an 80% reduction of these coastal ecosystems.

Changes in agricultural and livestock farming extending inland have caused a recent collapse of the traditional Mediterranean triptyque of land-use (agriculture, grazing, forestry), which has moulded insular landscapes over several centuries (Rackham & Moody 1996; Blondel, 2008). Diverse trends in landscape dynamics cause major modifications to the structure and composition of ecosystems. In the western part of Crete, human immigration from arid mountains has lead to the decline of agricultural land surfaces by 39% between 1945 and 1990, and favoured expansion and the densification of forest ecosystems dominated by *Cupressus sempervirens* and *Pinus brutia*. On the contrary, high shrublands and natural forests of eastern Sardinia have diminished by 35% between 1955 and 1996, whereas grazing, burned low shrublands and deforestation are progressing. On this island, and on other smaller islands of the Aegean, uncontrolled grazing by sheep and goats can lead to overgrazing and even to desertification, i.e. land degradation under arid and semi-arid climates. Landscape dynamics are more contrasted in Corsica, because if land-abandonment determines a global increase of shrublands and forested areas, frequent fires linked to illegal pastoral practices can counterbalance this trend.

Islands of the world have proven to be especially sensitive to biological invasions in both frequency and the degree of impact when compared to the continent (Whittaker & Fernández-Palacios, 2007). Invasions often modify population dynamics, community structure, the composition and functioning of ecosystems and may accelerate the extinction of indigenous plants. Mediterranean islands and islets are also in places seriously threatened by aggressive alien plants, notably along coasts, in lowlands and along rivers. Exotic plant species represent 17% (473 taxa) of the Corsican flora but only

6% of which are well established (171 naturalized taxa), 9.2% (184 taxa) of the Sardinian flora, and 8.4% (124 taxa) of the Balearic Islands' flora. Small islands are probably the most threatened by plant invasions (Pretto *et al.,* 2012). Some these most invasive plants are *Acacia* spp., *Ailanthus altissima, Carpobrotus* spp., *Cortaderia selloana, Opuntia* ssp., *Oxalis pes-caprae* and *Senecio angulatus.* Comparative studies conducted on several large Mediterranean islands demonstrate that impact depended on the identity of the invasive plant and the invaded island, suggesting that impact of invaders is context-specific (Traveset *et al.,* 2008).

Climatic changes represent a new threat for the persistence of several insular plant populations and communities, notably those linked to temporary wet habitats. This is the case of *Apium bermejoi*, a narrow endemic of Minorca located in a single area of 50m^2 where the *ca.* 100 individuals occupy only one square meter; this critically endangered plant (CR *sensu* IUCN) is highly vulnerable to prolonged drought period and its present decline is probably related to a series of dry summers (Moragues & Mayol, 2013). Regarding Cyprus, several populations of narrow endemics (*Sideritis cypria*, *Onosma caespitosa*, *Salvia veneris*) are also threatened by the strong reduction of annual rainfall (less than 20 to 40%) and the significant increase in temperatures (Kadis, 2013). Climate change will strongly affect orophilous plant diversity, species turnover and local endemics of the mountain zones, notably the spatially-restricted sub-alpine and alpine areas, as in the Lefka Ori massif of Crete (Kazakis *et al.,* 2007).

But despite these diverse threats and the fact that a large number of endemic plant species are narrowly distributed on a single island with few populations, only a reduced number of endemics seem to have still become extinct on the Mediterranean islands. Of the about forty Mediterranean plants presumed extinct, ten species are strictly insular endemics (Blondel & Médail, 2009). Two of these species are only extinct in the wild, *Lysimachia minoricensis* from Minorca and *Diplotaxis siettiana* from the Alborán islet, but in this latter case plant reintroduction was successful. Sicily seems to be the most impacted island with the extinction of four endemics (*Allium permixtum, Anthemis abrotanifolia, Carduus rugulosus, Limonium catanense*) and one from Lampedusa (*Limonium intermedium*). Over the course of history, Sicily has been at the crossroad of important trading routes and human presence has impacted ecosystems over an earlier and more constant period than on the Italian peninsula. Human activities caused a huge retraction of woodlands that occupy at present only about 10% of Sicily, mostly on Mount Etna and in the northern mountains (Madonie, Nebrodi, and Peloritani). In the eastern Mediterranean, two endemic species from the Thasos island (N. Aegean) (*Geocaryum bornmuelleri* and *Paronychia bornmuelleri*) are presumed extinct, and one endemic pink (*Dianthus multinervis*) from the remote islet of Jabuka in Croatia.

On large islands, the percentage of taxa that are threatened ranges from 2% (Corsica) to 11% (Crete). In Corsica, as much as 90% of the local extinct plants (74 taxa) occurred in low altitude, between 0 and 800 m a.s.l., and they were mainly located in arable fields, wetlands, coastal areas and rocky grasslands (Verlaque *et al.,* 2001). Therefore, the flora of Mediterranean islands is on the whole deeply threatened, especially the endemic species that grow in low altitude habitats and in wet habitats.

IMPORTANCE OF SMALL ISLANDS AND ISLETS FOR PLANT CONSERVATION

Most of the ecological studies carried out were devoted to large Mediterranean islands, but even the smallest ones should be better investigated since several studies point out their high biotic originality and their often high taxonomic diversity considering their reduced size: this is the case of the satellite islands of Sicily (Pasta and La Mantia, 2013) or the Balearic Islands (Rita and Bibiloni, 2013).

From the taxonomic diversity point of view, several comparative inventories demonstrate that small islands (i.e. size < ca. 1000 ha) play a disproportionate role for the magnitude of plant richness. On 71 satellite islands of Sardinia -which represent only 1.1% of the total surface of the main island- 1,200 plants were censused on the whole, i.e. almost half of the total Sardinian flora. In Corsica, 39 properly censused islets harbour 534 plant taxa, i.e. 21.6% of the whole Corsican flora on only 0.025% of the total surface of the main island (Serrano, 2008). The same pattern is found for the flora of the satellite islets of the Balearic Islands: 654 species occur on 91 islets, i.e. 40% of the flora of this archipelago, whereas 30% of these micro-insular plants are present on a single islet (Rita & Bibiloni, 2013).

Within these highly spatially-reduced territories occur rapid micro-speciation processes, and the combination with particular biotic assemblages and interactions between species favour the presence of some «islet specialists» (Höner & Greuter, 1988). These plants grow exclusively or are very abundant on these islets, but not on the mainland or on the closest larger island. They are often adapted to some disturbance or stress (ruderal and stress-tolerant strategies *sensu* Grime) and are salt-tolerant, but not strictly halophilous. Some possess a large pan-Mediterranean distribution (*Allium commutatum, Hymenolobus* *procumbens, Lavatera arborea*), others constitute narrow endemics (e.g. *Atriplex recurva* and *Silene holzmannii* in the Aegean islands, *Nananthea perpusilla* and *Silene velutina* on some satellite islets around Sardinia or Corsica, *Euphorbia margalidiana* on a unique Balearic islet). Their distribution and abundance can be explained by their optimal specialisation to the highly harsh and unusual environmental conditions of these islets. Islet specialists often possess a good ability for dispersal by sea drift over distances of hundreds of kilometres since floating diasporas can stand up to a month in the sea water.

Another interesting pattern is that small offshore islands can determine extreme limits of geographical ranges for some range-restricted plants. This is the case for the island of Zembra, which harbours the southernmost populations of some plants located mainly in Italy-Sicily (*Erodium maritimum, Iberis semperflorens*) or in the eastern Mediterranean (*Sarcopoterium spinosum*) and that are absent from the close (ca. 10 km) Tunisian continental coast. This pattern is also found on the Hyères archipelago, a remnant of the ancient Protoligurian massif, sheltering several Tyrrhenian endemics (*Delphinium pictum, Ptilostemon casabonae, Teucrium marum*), which are totally absent along the close mainland of the siliceous Provence, even though environmental conditions are similar.

Because of their significant number (more than 1,500 for the western Mediterranean), small islands and islets encompass a large range of environmental and biogeographical situations, forming suitable "experimental laboratories" to test evolutionary and functional hypothesis which are useful for a better implementation of conservation efforts. Small islands also represent current refuges of very scattered or highly threatened plants with regards to the disproportionate human impacts destroying the coasts of the mainland, and they need therefore to be included in international conservation networks. This task represents the main objective of the "Small islands initiative" ("PIM: Petites îles de Méditerranée") launched by the French Conservatoire du Littoral in 2006 (Renou, 2012).

WHAT IS NEEDED FOR THE FUTURE OF MEDITERRANEAN ISLAND FLORA CONSERVATION?

The complicated historical biogeography of the Mediterranean islands has induced the persistence of original and relict floras, but it has also favoured repeated local extinctions and re-colonisations of specialized plants. Therefore, the future of their conservation planning should be included within a conservation biogeography schedule (Ladle & Whittaker, 2011) in order to furnish the prerequisite tools for the identification of the most threatened plants and the crucial conservation areas in today's context of global change. Here, I propose some key issues for future research, in order to improve conservation and management of ecosystems and plant diversities on the Mediterranean islands and islets.

Prioritising scientific knowledge in order to increase conservation planning efficiency

i) Understanding evolutionary and biogeographical processes

Phylogenetical and phylogeographical studies have demonstrated the complex and reticulate historical biogeography of the Mediterranean region and the importance of large islands as reservoirs of unique genetic lineages, notably for most endemics and narrowly distributed plants (Médail & Diadema, 2009). Nevertheless, the time frame and evolutionary consequences of biogeographical events linked to repeated cycles of island connections and isolation, in relation to marine regressions-transgressions, remain largely unknown (Mansion *et al.*, 2008). This is particularly worrying because these aspects are essential for an optimal evolutionary conservation of these heterogeneous insular floras.

There is increasing evidence that primary speciation induced by geographical isolation (mainly by vicariance events), followed by inter-specific gene flow is deeply involved in the diversification and cryptic speciation in several insular plant groups of the Mediterranean (Rosselló, 2013). The few studies examining intra-island phylogeographies of endemic plants demonstrate the frequent split of populations into several isolated and genetically divergent lineages, and their persistence in some particular areas, an "island beneath island syndrome" (Bauzà-Ribot *et al.,* 2011). The narrow Balearic endemic *Senecio rodriguezii* exhibits a high number of haplotypes restricted to some small areas, probably shaped by the repeated cycles of sea-level changes during the Quaternary (Molins *et al.,* 2009), whereas for the Corso-Sardinian endemic *Mercurialis corsica*, AFLP markers allow to detect a clear geographical isolation of the Cap Corse genotypes in N. Corsica (Migliore *et al.,* 2011). This kind of genetic study also appears useful to perform the distinction between different Evolutionary Significant Units (ESUs) and for evolutionary conservation planning.

Despite a long tradition of studies concerning rare insular plants and endemics, a focus on the evolutionary process of this distinct component is still necessary (Rosselló, 2013). Phylogenetic studies have to be used to better assess endemic species' categories -and not only the classical categories based upon chromosome numbers and polyploidy level (Favarger & Contandriopoulos, 1961)- and to evaluate the spatial restriction of phylogenetic diversity, termed *phylogenetic endemism* by Rosauer *et al.* (2009). Some recent studies concerning continental regions point out that there is a non-random relationship between evolutionary distinctiveness and geographical rarity of species: rare species possess high levels of evolutionary distinctiveness (Tucker *et al.,* 2012; Taberlet *et al.,* 2012), and this pattern should be tested for insular Mediterranean floras of various sizes.

On short time-scales, mitigation of biodiversity loss requires estimation of populations and community responses to rapid environmental changes. This concern relies on the emerging concept of evolutionary rescue, "*the idea that evolution might occur quickly enough to arrest population decline and allow population recovery before extinction ensues*" (Gonzalez *et al.,* 2013).

Therefore, many more studies are needed: (a) to better define insular refuges at the scale of an archipelago or a larger biogeographic area; (b) to predict hotspots of evolutionary distinctiveness (evolutionary hotspots), based notably on endemic and rare plants; (c) to develop fine and local phylogeographies for conservation planning on the island scale; (d) to distinguish cryptic diversity linked to independently evolving lineages; and (e) to estimate short term evolutionary rescue of plants or communities.

ii) Reconstructing palaeoenvironments and estimating the magnitude of ancient human impacts

Due to their confined environment and their contrasted histories of human impacts, Mediterranean islands form suitable systems to better evaluate the influence of man on the structure and function of ecosystems and landscapes, but also to understand the dynamics of current biodiversity. Palaeoecological studies must indeed be developed (i) to obtain a better knowledge of past environments between and within islands, (ii) to infer vegetation dynamics in relation to human impact *versus* climatic forcing (eg. Djamali *et al.,* 2013), (iii) to identify tipping points of ecological collapse, and (iv) to propose suitable trajectories for ecological restoration. These results could also furnish new insights for the long-lasting debate about the nature of Mediterranean environments: the "lost Eden paradigm" *versus* the "cultural landscape paradigm" (Blondel, 2013). If palaeoecological data exists for some large islands (Corsica, Sicily, Malta, Balearic Islands), almost no data is available for medium and small islands, and this precludes a good estimate of vegetation dynamics and ecosystem naturalness.

iii) Identifying key biological interactions and ecosystem functions

Since functional diversity is often correlated with island area, isolation index, elevation and island age, it appears desirable to confront these aspects with a various range of insular conditions. Processes of interactions among organisms are related to ecosystem services that plants provide. But there are too few studies linking biodiversity of a community to ecological function and the delivery of ecosystem services for Mediterranean islands. Most of the works concern the biology of plants on large oceanic islands (eg. Bramwell & Caujapé-Castells, 2011), and there is indeed a serious need to identify the main functional drivers of biodiversity loss for continental and small Mediterranean islands because the magnitude of processes will be highly different among islands. The diversity of Mediterranean island situations should facilitate their integration as laboratories of testing grounds of extinction in relation to global change and human pressures. A worrying case is related to the disproportionate and detrimental effects of biological invasions on small islands. Despite several research projects, it appears still necessary to better evaluate the links between native species diversity and invasion by alien species and their consequences on ecosystem functions.

Insular systems have probably suffered from several dramatic losses of community function incurred by species extinction, especially on trophic-oversimplified small islands that exhibit particularly low resilience. But very few studies have taken into account the magnitude of biological interactions for rare or threatened taxa, whereas this represents proactive research to mitigate mutual disruptions or species extinction. Therefore, future research should identify key processes of biological interactions, quantify the loss of functional diversity and estimate the biogeography of functional diversity loss.

iv) Considering the spatial congruence between biodiversity levels and protected areas

The global taxonomic diversity of insular plants is now quite well-known for the largest Mediterranean islands, but serious gaps in knowledge persist for smaller islands; precise and current plant inventories (performed according a consistent taxonomic reference) are still scarce on some archipelagos, even for medium islands. These approaches are useful but they are not sufficient.

To date, most past and current conservation strategies in the world have focused on taxonomic diversity (TD) in order to protect threatened, endemic or total species. But the most widely used TD indicator, i.e. species richness, is uninformative about functional and phylogenetic differences among species, whereas phylogenetic diversity (PD) and functional diversity (FD) are both recognized as important components of biodiversity, respectively for ensuring ecosystem functioning and for assessing an evolutionary history of conservation interest (Diaz *et al.*, 2007). Phylogenetic diversity (PD) represents the accumulation of evolutionary adaptations in a group of species and may be related to evolutionary potential of those species. It is also often positively correlated with ecosystem function such as primary productivity (Cadotte *et al.*, 2009). Measuring PD in species assemblages appears to be a way to explain the role of species interactions and biogeographic history in community structures and composition. This refers to the fast-growing field of ecophylogenetics (Mouquet *et al.,* 2012). Functional diversity (FD) reflects the diversity of morphological, physiological and ecological traits within communities and is a way to explain ecosystem functioning. Plant traits determine where a species can live, how species interact with one another and the contributions of species to ecosystem functioning.

Therefore, recent results highlight the need for effective conservation planning measures that rely not only on the maintenance of species, but also on functional and evolutionary processes at different scales, and that incorporate multiple and complementary conservation indicators (Pio *et al.,* 2011). Gap analyses are also necessary to evaluate the proportion of each biodiversity component included and excluded from existing protected area networks. Areas of mismatch and congruence between biodiversity and protected areas will allow for the evaluation of short-term efficiency of current conservation policies and should include the deep uncertainties linked to global change on insular systems.

Some proposals for the future monitoring and conservation of Mediterranean islands' plants and habitats

i) Developing long-term monitoring in relation to global change

Because of an increase in key threats across the Mediterranean region (Underwood *et al.,* 2009) and the detrimental consequences of climate change here (Klausmeyer & Shaw, 2009), it appears increasing necessary to observe, monitor, and analyse vegetation and plant biodiversity changes through ecological and biogeographical gradients. Networking long term research sites and observation plots should become an integral part of biodiversity management and this monitoring must be coupled with functional-demographic studies, such as the analysis of consequences induced by extreme climatic events on the recruitment of keystone tree species (Matías *et al.*, 2011), or relict and threatened plants (eg. Hampe & Arroyo, 2002).

Mediterranean islands, notably the small ones, form favourable sites for these long-term biodiversity observations and monitoring at various spatial scales. Since the ecological consequences of global changes are highly complex, "natural insular microcosms" constitute indeed relevant systems to study adaptation to climate change of taxa or communities. As proposed by the Small Mediterranean Islands Initiative (PIM), a network of "Sentinel islands" where environmental and biological parameters would be censused using common methodologies, could allow a better understanding of the rate of environmental change, in order to mitigate biodiversity loss (Renou, 2012).

ii) Needs for a global insular ecology framework and to develop / reinforce cooperative networks

In the context of the biome crisis of the Mediterranean basin (Hoekstra *et al.,* 2005), islands constitute key biological systems to ensure both the preservation of plant biodiversity and the sustainable development of human activities. Because the most important changes in flora, vegetation and insular landscapes are, and will be, induced by human practices, the only sustainable solution depends on a systemic and interdisciplinary approach of biodiversity conservation considering the diverse socio-economic trajectories of each island. Therefore, it is necessary to develop ambitious integrated programmes taking into account biodiversity and ecosystem preservation, human well-being, and socio-economic trajectories as stated in the Millenium Ecosystem Assessment (Wong *et al.,* 2005). To perform integrated island systems management, a global ecology perspective is needed in order to prioritise actions in relation to the unicity and vulnerability of insular biodiversity but also according to the high economic vulnerability of Mediterranean islands (structural handicaps, low diversification of production, and high exposure to international and local fluctuations). It would be relevant to combine reactive approaches on the most threatened (often largest) islands, and proactive approaches on relatively less threatened islands (notably small islands and islets). From a biological and socio-economical point of view, it is necessary to launch international programmes to go beyond strict administrative frontiers. Ecologists and land-managers have to better consider the biogeographic dimension of insular biodiversity by developing trans-national actions of conservation biogeography defined as the *« Application of biogeographical principles, theories, and analyses, being those concerned with the distributional dynamics of taxa individually and collectively,* *to problems concerning the conservation of biodiversity* » (Whittaker *et al.,* 2005).

Cooperative networks between insular stakeholders should be implemented, notably between the European conservationists and those from the southern and eastern part of the Mediterranean. These tasks could be performed on a global biogeographical scale and on the island scale (Table 2). The Small Islands Initiative (PIM) of the French Coastal Protection Agency ("Conservatoire du Littoral") is a good example of this kind of international network between scientists and site managers of these insular microcosms (Renoud, 2012). There was also an IUCN plant specialist group devoted to Mediterranean island plants (Montmollin & Strahm, 2005). Unfortunately, this group is going to be included within a larger one devoted to the whole Mediterranean region, but it would be important to maintain in the future some "insular specificity" for this IUCN/SSC group. Otherwise, as for species, IUCN launched a few years ago a global process to establish a Red List criteria for threatened ecosystems (Rodríguez *et al.,* 2011), and this risk assessment system should be implemented between Mediterranean islands of the same biogeographical unit. For Mediterranean Europe, European projects, notably LIFE projects devoted to habitat and plant conservation, should be implemented like those successfully established in Crete (Thanos & Fournaraki, 2013) or in Minorca (Cardona *et al.,* 2013).

On the island scale, several interesting tools exist on some islands, and they could be beneficial in other insular conditions: (i) the concept of plant micro-reserves (PMRs) proposed by the Generalitat Valenciana in 1993 is a relevant implementation to protect taxa with a limited distribution, notably narrow endemics. This was already performed in Western Crete (7 PMRs) and on several Croatian islands, and this approach is ongoing in Minorca (24 PMRs are selected according to Fraga *et al.,* 2013) and in Cyprus (5 PMRs); (ii) the French coastline conservation authority "Conservatoire du Littoral", created in 1975, is an efficient structure to purchase coveted coastal sites that become inalienable. In Corsica, 68 sites have already been acquired, representing more than 18,000 hectares and 295 km of coasts, i.e. 20% of the coastline of the whole island; (iii) under the French environment ministry, the network of the National Botanical Conservatories ("Conservatoires botaniques nationaux") constitutes an efficient organisation devoted to the knowledge and the conservation (both *in-situ* and *ex-situ*) of local flora. In Corsica, the "Conservatoire botanique national de Corse" created in 2008, has undertaken several important actions in particular to increase the botanical knowledge of this highly heterogeneous island and to preserve the native flora.

If insular systems still represent fascinating ecological systems, they also form key entities to disentangling the role of environmental *versus* human pressures for the long-term maintenance and conservation of these biodiversity hotspots. Therefore, due to their unicity and fragility, Mediterranean islands, even the smallest ones, urgently need comprehensive and ambitious conservation planning for the long-term preservation of this outstanding biotic heritage. If we consider with Ricklefs & Cox (1978) that «*Each island population is an evolutionary unit with ecological changes occurring independently on each*», conserving the unique flora of the Mediterranean islands constitutes a disproportionate and highly complex task, but of major priority.

Insular biogeographical scale	Island scale
To perform an inter-island analysis of conservation priorities (with common databases), including comparative perspectives of territorial dynamics between islands	To include some medium-sized islands within the MAB Biosphere Reserve network (eg. the Gozo case in Malta)
To establish a IUCN Red List evaluation of threatened insular ecosystems at the relevant biogeographical scale	To develop integrative conservation frameworks between scientists and stakeholders
To develop the PIM initiative together with an Important Plant Areas (IPAs) programme devoted specifically to the Mediterranean islands	To establish networks of insular Plant Micro-Reserves (PMRs)
To develop European (LIFE) or trans-Mediterranean projects for biogeographical conservation of insular plants and habitats between islands	To extend some efficient national initiatives: - Protected coastal areas of the Conservatoire du Littoral in France - National botanical conservatories

Table 2. Some topics to develop cooperative networks of plant and habitat conservation, between and within Mediterranean islands

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II Abstracts

TECTONIC EVOLUTION OF THE MEDITERRANEAN DURING THE CENOZOIC

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The Mediterranean palaeogeography during Cenozoic times is exposed through the description of the tectonic features of the Aegean domain (Hellenic arc-trench system and Anatolian peninsula escape and extension of the Aegean-West-Anatolian region), the Central Mediterranean domain (Calabrian arc, Apennines and the Sicily Channel) and the Iberian domain (The Iberian microcontinent and the Betic-Balearic orogen). Deserving special attention is the reconstruction of the Western Mediterranean Subduction (WMSZ) and its relation to large displacements of the Balearic Islands, Corsica and Sardinia islands during the Tertiary. The type and characteristics of active stresses around the Mediterranean region, and their relationship with the seismic level of the area are then described. A further highlight is the opening and closing of marine gateways (Gibraltar, Marmara) that have played an important role in the Neogene and Quaternary history of the Mediterranean.

***Keywords**: geology, marine gateways, Aegean, Central Mediterranean, Western Mediterranean, Iberian*

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THE EXCLUSIVE VASCULAR FLORA OF SARDINIA: UPDATE AND CONSERVATION ACTIONS

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Sardinia is the second-largest island in the Mediterranean Sea and its isolation and high geological diversity have created a wide range of habitats with high levels of endemism, especially on its mountain massifs, where there are conditions of ecological insularity. In this study the exclusive endemic flora of Sardinia has been updated and it consists of 167 taxa, 139 of which are species, 23 subspecies, 4 varieties and 1 hybrid, belonging to 37 families and 72 genera. Despite this rich biodiversity and the threats to these species, few biological conservation studies have been carried out. Therefore the "Regione Autonoma della Sardegna" funded in 2007 a conservation project for the most threatened exclusive endemic species of Sardinia. To categorize these species to be conserved, a priority list was created by applying 11 parameters based on rarity, threats and protection status. This work allowed the most threatened species of the Sardinian endemic flora to be identified.

Keywords: *Endemics, IUCN, Mediterranean island, population monitoring, seed-banking, threatened vascular flora.*

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CONSERVATION AND MANAGEMENT OF THE FLORA AND VEGETATION OF CRETE

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Crete, the fifth largest island of the Mediterranean, is a well known hotspot of plant diversity as a result of both its longstanding isolation from the Greek and Anatolian mainlands and its great variety of habitats and climates. It hosts 1,742 vascular plant species (ca. 2000 taxa) and shows a considerably high degree of single island endemism (159 species, 9.1%). On the other hand, the Greek flora is among the richest in Europe and the Mediterranean basin and comprises (according to a recently compiled checklist) 6,041 species (or 6,912 taxa); Greek endemics amount to 1,224-1,442 taxa, with an overall endemism at the country level in the range 17.7-20.9% (or 15.1-17.6% at species level). The contribution of the Cretan flora to the Greek one amounts to 28.8% while, among the 13 floristic regions of Greece, Crete and Karpathos is second (next to Peloponnese) in absolute number of Greek endemics and first in local endemics.

Furthermore, out of the 26 plant taxa growing in Greece (all of them angiosperms) that have been included as priority species in Annex II of the Directive 92/43/EEC, 8 plants are Cretan endemics, representing 5% of the total number of 158 embryophytes (among which 110 in the Mediterranean biogeographical region) of European priority on a continental level (while 17 taxa of Crete in total are among the 63 Greek plants included in the various annexes of the Habitats Directive).

In the two Red Data Books of Greek flora (1995, 2009), Crete is represented by a significant number of threatened taxa (110 – of which 68 are Cretan endemics – out of a total of 476, or 23.1%); however, it is believed that this number will be at least doubled (on both island and country level) when the conservation status assessment is completed for the entire flora.

Habitat diversity is also extremely rich in Crete, as illustrated by the long list of European habitat types (mapped by the Project LIFE94/NAT/GR/001201); 44 habitat types (among which 6 priority ones out of a total of 72 priority habitats for the entire European Union) are found within the boundaries of the 28 SCIs of Crete, which along with the 26 SPAs comprise 30-35% of the total

land surface of the Island. Despite the legal proclamation of 54 protected areas for the Natura 2000 network in Crete, it is very unfortunate that a Management Authority has only been established in a single area, GR4340008 – Lefka Ori, the largest mountainous wilderness of Crete, which also includes the Samaria Biosphere Reserve (Samaria Gorge) currently efficiently managed by the Forest Directorate of Chania.

Several national and a few European projects have been implemented for the *in situ* plant and habitat conservation in Crete: LIFE95/NAT/GR/001143 (5 sites in western Crete), LIFE98/NAT/GR/005264 (Vai Palm Forest), LIFE99/NAT/GR/006497 (Rouvas Forest), LIFE04/NAT/GR/000105 (*3170 Mediterranean temporary ponds), LIFE04/NAT/GR/000104 (6 priority plants and *9370 Palm groves of *Phoenix*) and LIFE07NAT/GR/000296 (*2250 Dune juniper thickets [*Juniperus* spp.]). In addition, through several national and European projects (e.g. ENSCONET, GENMEDOC, SEMCLIMED), *ex situ* conservation of ca. 200 Cretan plants has been achieved by safeguarding seed collections in the Seed Banks of MAICh and NKUA (accompanied by the elaboration of detailed germination protocols).

Keywords: *floristics, endemics, priority species, habitat diversity, LIFE projects*

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THE FLORA OF CYPRUS: DIVERSITY, THREATS AND CONSERVATION

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Cyprus hosts a great variety of habitat types. This is due to the varied environmental conditions, which can meet the specific needs of a large number of plant species. So far, 1,978 taxa have been identified, out of which 145 are endemic to Cyprus. The most important floristic areas of Cyprus are the Troodos mountain range and the Pendadaktylos range, which host 94 and 60 endemic plants of Cyprus, respectively.

Many of the plant species of Cyprus are considered rare since they form few and small populations. The survival of many of these species is under immediate threat due to external anthropogenic pressures, such as urbanization, development (golf courses, tourism, etc.), military activities within natural areas, changes in agriculture, expansion of the mountainous road network, introduction of invasive species, climate change, etc. According to the *Red Data Book of the Flora of Cyprus*, which evaluates the conservation status of the Cyprus flora based on the criteria set by the IUCN, 23 taxa are characterized as Regionally Extinct, 46 as Critically Endangered, 64 as Endangered, 128 as Vulnerable, 45 as Data Deficient and 15 as Near Threatened. Moreover, 18 taxa are included in Annex II of the EU Habitats Directive, and require the establishment of protected areas for their conservation, and 26 taxa are included in Appendix I of the Bern Convention and are characterized as Strictly Protected. Over the last 20 years, several initiatives have been developed focusing on the conservation of the flora of Cyprus. These include the ratification of relevant legislation (e.g. the adoption of the EU Habitats Directive), the preparation and implementation of management plans for the Natura 2000 sites of Cyprus and the implementation of a series of projects focusing on the *in situ* and *ex situ* conservation of endemic, rare and threatened plants of Cyprus.

***Keywords**: Cyprus flora, endemic species, plant conservation*

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FLORA OF THE ADRIATIC ISLANDS

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The eastern Adriatic coast, besides the Greek coast, is one of the most diverse in the Mediterranean area. There are 1,151 islands, islets and reefs, and 80 additional reefs periodically appear above the sea level, depending on tides. During the Pleistocene the Adriatic basin was strongly influenced by the Ice Ages. The recession and elevation of the sea level significantly influenced the coastlines, causing various levels of island isolation and different encirclement for endemism development. For approximately 250 islands the flora is well known, but for the rest, the data is mostly incomplete or the flora is barely known. SAR extrapolation (Species-Area Relationships) shows that for the whole area of all Croatian islands (approximately 3300 km^2), up to 2,600 species were estimated. The same models show that for the whole Mediterranean area along the east Adriatic coast (approximately 17,250 km^2) the number of species comes to more than 4,000 taxa. From this total number of endemic taxa from within the Croatian Mediterranean area, there are 244 endemic taxa (66%), and the proportion of these endemics per island varies from 0% up to 28.6%. To define the areas of particular botanical value, the Important Plant Area (IPA) concept is used. Using IPA criteria the total of 94 IPAs were identified in Croatia with a total area of 9,543 km^2, i.e., 17% of the country's territory. The smallest land area covers only 0.022 km^2 (island of Jabuka), and the largest as many as 2,013 km^2 (Velebit mountain), while 75% of IPAs cover an area up to 100 km^2. 66% of IPAs in Croatia are located in the Mediterranean area defined in a wider sense (i.e. including mountain chains in very close vicinity). In the majority of IPAs (60%) biodiversity threats and negative trends can be observed. Direct appliance of the National Ecological Network and Natura 2000 network in preparation, together with regular application of related legislation could favor the possibility of preservation.

Keywords: *diversity, flora, Adriatic islands, endemism, important plant area*

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AEGEAN ISLAND FLORA AND ENDEMISMS

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The Aegean Sea is a continental archipelago with c. 1300 islands and islets ranging from 100 m^2 to 8,260 km^2. Regarding phytogeography, it includes 5 main insular floristic regions (North, West and East Aegean, and the Cardaegean area of the Kyklades and Kriti) and several islands, which belong to 2 mainland floristic regions (Peloponnisos and Sterea Ellada). Isolation time varies among the islands, from 9–10 mya to 1.8 mya, but some islands were isolated as recently as 10,000 years ago whilst others are oceanic (never connected to land). The extant flora and endemisms are the result of these complex paleogeographical circumstances, the rugged geomorphology and geographic position surrounded by 3 continents as well as the extensive human presence on the islands. The Aegean is one of the most studied areas in Greece and plant collectors and botanists have been compiling surveys since the 18th century, with a key study being the Flora Aegaea by K.H. Rechinger published in 1943. However, there are still some gaps in the floristic knowledge of the islands: there are complete floras for 41 out of the 145 larger islands (≥100 Km^2) and for 185 out of more than 1000 islets. The insular floristic regions host 1600 – 2400 plants species each and endemism levels range from 1% (N Aegean) to 8% (Cretan Area). In total, the Aegean is home to c. 600 species (800 taxa) which are endemic to Greece, of which c. 380 species (580 taxa) are endemic to the Aegean only. On a regional floristic scale, simple area adequately explains total species numbers but not endemic species numbers, while species area curves indicate higher endemism in insular than in mainland regions in Greece. On an insular scale, both total and endemic species richness are significantly correlated to island area, but are driven by different biogeographical factors. There is adequate data for the conservation status of c. 800 of the Aegean plants (620 of them Greek endemics). According to such data, in the Aegean there are 242 threatened and 340 rare or near threatened plants. For most, the threat is mainly related to their highly restricted distribution. Tourism development and grazing and its management are identified as the main causes of the decline of plant populations. Legal protection is quite adequate, including international conventions and national law. Moreover, the National List of Natura 2000 sites in Greece includes a total of 73 SCIs in the Aegean (25 of them on the

largest islands of Evvoia and Kriti). However, the examples of actual *in situ* management for conservation and of application of the legal provisions are few.

***Keywords**: Natura 2000, endemism, threats, conservation status, floristics*

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BALEARIC AND TYRRHENIAN FLORA AT THE BOTANICAL GARDEN OF BARCELONA

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Introduction and objectives

The Botanical Garden of Barcelona possesses Mediterranean plant collections from around the world. Its main objectives include the preservation and documentation of Catalonia's natural heritage and that of other surrounding territories. We take care of the plant collections in the garden and/or the seed bank and we try to study their growing patterns.

The plants are grouped according to the five Mediterranean regions of the world, and within these areas, the plants are separated by their ecological affinity, i.e., they represent the natural landscapes.

One of these areas is the Mediterranean Basin, the lands that surround the Mediterranean Sea. And one of the landscapes that we try to represent is called "Balearic Island and Tyrrhenian flora rock crevice community."

Balearic and Tyrrhenian rock crevice community flora

A calcareous rock formation contains a representation of the most frequently found plants and endemic species from the coast, scrublands, oak forests and high mountains of the Balearic Islands. The predominant species in coastal areas are *Astragalus balearicus* and *Launaea cervicornis*, while holm oak predominates in the scrub and low woody species from the Lamiaceae and Leguminosae families, as well as many geophytes. In our landscape we have many Balearic and Tyrrhenian endemisms like: *Dracunculus muscivorus, Erodium reichardii, Paeonia cambessedesii, Digitalis minor, Femeniasia balearica* and *Lysimachia minoricensis*, among others.

Germination tests

In the seed bank of the Botanical Garden we have been testing if there are germination differences between different species of hypericum growing on the Iberian Peninsula and the endemic hypericum of the Balearic Islands.

Keywords: *Balearic-Tyrrhenian flora, botanical garden, endemism, germination, hypericum*

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ENVIRONMENTAL RESTORATION ACTIVITIES IN THE SCIS OF BINIMEL·LÀ AND ES ALOCS WITHIN THE LIFE + RENEIX PROJECT

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The main goal of the LIFE+ RENEIX project is to recover four deteriorated areas that hold some communities of interest and priority species of the Menorcan flora included in the Habitats Directive. All of them are found within the Natura 2000 Network area on the island. Two of those areas, Es Alocs and Binimel·là, on the north coast, are threatened by severe degradation processes. Both areas underwent substantial change when projects to develop these areas began in the 1970s. Fortunately, these projects were not carried out, and the construction of more than 4,000 apartments was interrupted. Four decades later, the degradation persists in both areas, now caused also by motor vehicles off the established roads, the practice of motocross and pressure from tourism.

This is the framework of the LIFE+ RENEIX project, which includes the recovery of both areas. Hence, some of the scheduled activities are the restitution of original geomorphology, the recovering of ancient dry stone structures to mark out paths using traditional techniques, and the recovery of original plant communities.

Beyond the island of Menorca, the results and experiences of this project may have an added value for other Mediterranean regions. The combination of landscape and habitat restoration with threatened plant species management and a wide social implication in activity can give to this project an innovative scope.

Keywords: *LIFE Nature, Menorca, habitat restoration, priority species,*

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THE LIFE + RENEIX PROJECT AND SOCIAL AWARENESS ABOUT THE PRESERVATION OF BIODIVERSITY IN MENORCA

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LIFE+ RENEIX project, Island Council of Menorca

One of LIFE Nature projects' main goals is to raise social awareness on major issues and preservation objectives on which they operate.

The LIFE+ RENEIX project aims to provide the basis for ecological restoration of natural sites on the island that have been diminished due to several attempts for development, road opening, excessive human pressure and proliferation of motor vehicle access. Therefore, in order to achieve increased awareness among the general population, we have focused on two major aspects: firstly, to prevent the misuse of the natural environment (i.e. motor vehicles off the established roads, the practice of motocross, excessive pedestrian pressure, etc..), and secondly, to promote increased awareness among the general population regarding the value of the biodiversity and ecosystem services it provides, and the need to recover, maintain and protect unique natural areas on the island which have undergone significant pressure since the 1970s.

Some of the scheduled activities are the dissemination of project objectives and results through a website and the publishing of educational materials, creating educational botanical routes, developing specific campaigns to raise motorcyclists' awareness and involving the general population in the habitat restoration taking part in volunteer activities.

Keywords: *LIFE Nature, Menorca, habitat recovery, social awareness, involvement*

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THE RECOVERY OF THE PAS D'EN REVULL UNDER THE LIFE+ RENEIX PROJECT

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One of the areas covered by the LIFE+ RENEIX project is the Pas d'en Revull, which is a stretch of the Camí Reial, an ancient route that once connected the two main villages of the island until the eighteenth century, which runs through the Algendar gorge. This is one of the most famous scenic spots on the island, originated following significant karstic activity. It holds a high diversity of habitats and species in a confined space, in addition to human influence since ancient times.

The recovering of the Pas d'en Revull has been carried out to restore the ancient dry stone wall structures that delimit and protect this area, using the traditional techniques of dry stone wall construction, and posting signage along the route in order to raise awareness on the ecological and botanical values of the area and fulfill the important role of social awareness that can be developed in this area. Different social groups and volunteers from the municipality of Ferreries, who are concerned about the conservation of this unique trail, have taken an active role in the process of clearing and recovery.

Keywords: *LIFE Nature, Menorca, habitat restoration, dry stone wall, social awareness, involvement*

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LEAF SHAPE VARIATION IN TWO SYMPATRIC RUPICOLOUS SPECIES OF *HELICHRYSUM* (ASTERACEAE) FROM THE BALEARIC ISLANDS, ASSESSED BY GEOMETRIC MORPHOMETRY

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The selection of useful morphological traits to discern closely related species has not always succeeded, especially when qualitative characters are scarce, like with the western Mediterranean *Helichrysum* sect. *Stoechadina*. The Balearic endemic *H. crassifolium* (L.) D. Don, is a rather variable species in terms of leaf size and shape, and it is frequently differentiated from the remaining taxa of this section based on ambiguous qualitative traits and on leaf width measurements. Thus, the goals of this study are (i) to characterize leaf morphological variation between the two rupicolous species of *Helichrysum* in the Balearic Islands: the endemic *H. crassifolium* and the sympatric and widespread Mediterranean *H. pendulum* (C. Presl) C. Presl, to ascertain to what extent leaf shape is a good taxonomic feature to discriminate between these rupicolous species; and (ii) to outline the underlying causes in the observed leaf variation.

A geometric morphometric approach was used to characterize leaf size and shape of both species, using Relative Warp Analysis. Both species were sampled in the entire distribution area in the Gymnesic islands, and linear and geometric morphometric measurements were correlated between species. Also, morphology was correlated towards several climatic variables from each sampled locality using two-block partial least squares analysis.

Results show that there is a continuous range of leaf variation between *H. crassifolium* and *H. pendulum*, besides both species can be discriminated depending on leaf traits. Variation between populations of either or both species do not respond to abiotic factors. Recurrent natural hybridization events do however seem to better explain this situation. Also data suggest that other *Helichrysum* species are involved in such hybridization events. Therefore, the preservation of the endemic *H. crassifolium* must be linked to the preservation of the whole genus species of the Archipelago.

Keywords: *Balearic Islands, geometric morphometrics,* Helichrysum crassifolium, Helichrysum pendulum*, leaf variation, natural hybridization.*

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THE CONTRIBUTION OF THE E+M / PESI PROJECTS TO THE VASCULAR FLORA OF THE MEDITERRANEAN ISLANDS

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The Euro+Med PlantBase (http://www.emplantbase.org) has provided an updated and critically evaluated on-line database and information system for the vascular plants of Europe and the Mediterranean region. The first stage of this project was funded by the European Union under Framework V, for three years (2000-2003). The first result was a rough taxa list with detailed distribution including the major strictly Mediterranean islands, the Canary islands, the Azores and Madeira, but never completely checked above all for extra European territories. This list has been critically reviewed in part by editors and appointed experts by certain countries or groups. One of the first tangible results of this project was the publishing of Med-Checklist vol. 2, which includes the treatment of the *Compositae* for all Mediterranean countries. Under the Euro+Med PlantBase project, 62 families have been confirmed. The review of the remaining families is currently being done with the support of the PESI.

PESI (http://www.eu-nomen.eu) is a three-year project, started in May 2008, funded by the European Union within Framework VII. Led by the University of Amsterdam, PESI comprises 40 partner organizations from 26 countries in the fields of botany, zoology, mycology and phycology. PESI is intended to facilitate access to taxonomic information using standardized records of names and synonyms for the benefit of experts responsible for the management of biodiversity in Europe.

PESI coordinates the integration of various taxonomic and nomenclatural systems in use in Europe and involves the establishment of a common interface to allow users to get the information they need.

A key element of this initiative is the critical evaluation of the database. A mechanism for interregional cooperation enables the gradual review of the taxonomy of families, genera, species and subspecies described in the Euro-Mediterranean region.

Currently, 140 families make up only around the 85% of the whole flora.

Keywords: *Checklist, databasing, nomenclature.*

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ENDANGERED TAXA OF THE SICILIAN FLORA AND CONSERVATION PERSPECTIVES

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Sicily is one of the phytodiversity hotspots in the Mediterranean area. Its flora includes 322 strictly endemic species and 180 taxa shared with some nearby territories (9.91% and 5.54% of the entire flora, respectively). This without considering several taxa for which Sicily represents their southern or western distribution boundary. Several of them occur in few or a single populations often limited to a restricted area.

Some species have already been the subject of specific studies (*Abies nebrodensis*, *Betula aetnensis*, *Brassica* sp. pl., *Calendula maritima*, *Cytisus aeolicus*, *Petagnaea gussonei*, *Silene hicesiae*, *Zelkova sicula*). Others, recently discovered or taxonomically re-evaluated, are still deficient in an accurate monitoring. Examples are: *Acinos minae*, *Adenostyles alpina* subsp. *nebrodensis*, *Anthyllis hermanniae* subsp. *sicula*, *Centaurea erycina*, *C. saccensis*, *Erica sicula* subsp. *sicula*, *Hieracium* sp. pl., *Isoetes todaroana*, *Ptilostemon greuteri*, *Rhamnus lojaconoi*; a majority being data deficient regarding population size and trends necessary to define the IUCN categories.

The occurrence of protected areas (Natural parks and reserves) plays an important role in *in situ* conservation of these taxa. But this action is often only indirect since local managers are unaware of the rarities to be protected. So these taxa need specific conservation projects starting from a careful population study. Taking into account the low number of individuals, in several cases *ex situ* conservation interventions are needed including micropropagation techniques starting from cell cultures. Particular attention must be paid to popular sciences to inform public opinion about plant diversity richness in their area and its fragility. The Department of Environmental Science and Biodiversity (formerly Botanical Sciences) of the University of Palermo has been working for several years in this direction organizing round tables and meetings also in peripheral structures (the Laboratory Sistema Madonie and the Nebrodi Seedbank).

Keywords: *Sicily, micropropagation, popular science.*

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GERMINATION BEHAVIOUR OF FIVE THREATENED ENDEMIC PLANT SPECIES FROM WESTERN MEDITERRANEAN ISLANDS AND COASTAL CLIFFS

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The CIEF's Germplasm Bank of Valencian Wild Flora evaluates the germination rates (G) of five steno-Mediterranean (SM) or Iberian-Balearic (IB) endemic plant species living on islands, and strictly protected (PR) by the Valencian Community (Spain) laws: *Diplotaxis ibicensis* (IB, PR), *Lavatera mauritanica* (SM, unprotected), *Medicago citrina* (IB, PR), *Reseda hookeri* (SM, PR) and *Silene hifacensis* (IB, PR). Seeds were collected on the Columbretes Islands and along the complex of plant microreserves placed on small islands and coastal cliffs of north-eastern Alicante. Germination protocols have followed the current ISTA rules. Seeds were sown in a sterile environment provided by a laminar flux chamber, using Petri dishes (9 cm in diameter), and two Albet filter papers, damped with distilled water up to saturation level. Each lot held 4 replication plates holding 25 seeds per dish. The germination tests where made using an incubator chamber programmed to hold several culture conditions: 10/20ºC, 20ºC, 15ºC y 10ºC, with balanced photoperiod (12/12h light/shade). Only *Reseda hookeri* shows low germination values, maximum G=3% at 15 and 10ºC (T_{50}=39±22,63 and 41.6±0.70 days for n=7 different tests). *Diplotaxis ibicensis* reached G=96±3,23% at 10/20ºC , T_{50}= 8,23±0,38 (n=3). Both for *M. citrina* and *L. mauritanica*, the maximum values are obtained at 20ºC: G=90±8,3% (T_{50}=3,1±0,95; n= 3) in *Medicago* and G=83±13,22% (T_{50}=4,67±0,53; n=3) in *Lavatera*. In the case of *S. hifacensis* (n=32), germination rate was from G=58±12,4 to 100%, except for 2 accessions only yielding G=5% -apparently caused by immature seeds. On the germination speed the extreme values obtained ranged between T_{50}=2,58±0,53 (at 20ºC; G=98±2,3%) and 16,25±1,7 (at 10/20ºC; G=79±8,8%); the average value for the whole treatment was 5,74±0,54 days (n=32). Except for the Critically Endangered *Reseda hookeri*, the results show that the insular threatened species usually have good and quick germination response under controlled conditions.

Keywords: *Germination, Endemic species, Endangered Species, Mediterranean islands, Valencian Community.*

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EXPERIENCIES AND RESULTS OF THE CONSERVATION OF PLANT SPECIES THROUGH LIFE NATURE PROJECTS IN MENORCA

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LIFE Nature projects focus on the conservation of habitats and species within the Nature 2000 network. These projects should be understood not only as proposals developed within a limited period of time , but also as a starting point of conservation and management that should persist beyond the project itself. Required follow-ups, such as the Post-LIFE action plan, are clearly related to the longer-term duration of the project's objectives. In the particular case of Menorca, a retrospective examination of the results achieved by three consecutive LIFE Nature projects, more or less related to plant conservation, can be seen as an example of continuity of objectives and goals after the formal completion of each one.

LIFE2000NAT/E/7355 (http://lifeflora.cime.es) was devoted to long-term management of those plant species on Menorca included in the Habitats Directive. Different actions were carried out including the elaboration of individual management and investigation plans into the threats and conservation needs of these species. Noteworthy intervention within this project was the eradication of the invasive alien species *Carpobrotus*, which has become a demonstrative case study of alien plant control within a whole territory.

LIFE05/NAT/ES/000058 (www.cime.es/lifebasses) had as its main objective the conservation and management of Mediterranean temporary ponds, a priority habitat that stands out for the high diversity of plants it supports, most of them restricted to this type of habitat and rare within their distribution range. Some outstanding features of this project were the use of traditional techniques to restore and preserve such habitats and the cooperation of landowners and stakeholders. Some actions of the project are still ongoing and positive results have been clearly achieved with preservation of local populations and habitats.

LIFE07NAT/E/000756 (http://lifereneix.cime.es) is currently being developed and is focused on the restoration of complex areas that hold a high diversity of habitats and species. Some results, mainly regarding social participation, are already visible.

Keywords: *LIFE Nature, invasive species, habitat conservation, biodiversity, long-term management*

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Fig. 1. Binimel·là, on the north coast of Menorca, is one of the areas of environmental restoration of the LIFE07NAT/E/000756 project.

CARTOGRAPHY OF RIPARIAN VEGETATION AND ASSESSMENT OF ITS ECOLOGICAL STATUS IN MENORCA (WESTERN MEDITERRANEAN, SPAIN).

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The riparian vegetation has an important function in the maintenance of a good ecological status of rivers and streams: stabilization of river banks, maintenance of water quality and water flow, habitats for aquatic species, and maintenance of biological diversity are some of its main functions.

The mapped area corresponds to a buffer of 100 meters along 19 primary streams in Menorca using phytosociological classification. The cartography of the vegetation communities shows that the streams and the associated vegetation have been modified and altered. The largest area covered in the riparian zone contained in a buffer of 30 meters is farmland. The riversides are occupied by farming and pastures in 45% of the total buffer surface, 29% are forest climax communities: *Prasio-oleetum* (wild olive maquis), *Cyclamini-Quercetum ilicis* (holm oak forest) or mixed forest, and 8% is *Rubo-Crataegetum brevispinae* (bramble patch). The buffers of 10 meters are still mainly occupied (28%) by farmland and pastures, another 28% are forest climax communities and *Rubo-Crataegetum brevispinae* increases its percentage, in this case 17%. The riparian climax communities are less abundant but of high value. *Tamaricetum* represents 3,4% of the buffers of 10 meters. Priority habitats of European interest, *Scirpetum maritimo-litoralis* and *Thypho-Schoenoplecteteum tabernaemontani* represent 3.2% and 1.8% respectively. In 2.3% of the surface of those buffers we find *Arundo donax*, a community with strong invasive power. The presence of European interest and protection, threatened and high interest species like *Vitex agnus-castus, Alisma plantago-aquatica, Eleocharis palustris, Iris pseudacorus* and *Aristolochia rotunda* among others is remarkable.

Thus most of the stream banks are extremely humanized. In many cases, farming to the edge of the riverbed and mechanical clearing have almost completely removed the vegetation. The canalization and excavation of the riverbeds, along with the ephemeral conditions of the streams, make the

settlement of vegetation with higher water demand difficult. The abundance of bramble highlights that the riparian vegetation is deteriorated, and the vegetal cover is dominated by secondary communities with an important presence of invasive species. Particularly alarming is the presence of *Arundo donax*.

Keywords: *riparian vegetation, priority habitats of European interest, invasive species.*

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THE HERBARIUM GENERALE MINORICAE

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After the historic Rodríguez Femenías Herbarium, now preserved in the Institut Menorquí d'Estudis, the Herbarium Generale Minoricae (HGM) is the second most important botanical collection of vascular plants that is carried out on the Balearic island of Menorca. This herbarium was founded in 1999 by the initiative of the Commission of Botany, belonging to the Balearic Ornithological Group (GOB) in Menorca, and the Institut Menorquí d'Estudis, in response to the need for a basic tool for further study and knowledge of the island's flora.

From its inception, it has seen steady growth with some peaks of activity that have taken the HGM to house currently 1,031 records that include 577 different taxa distributed in 309 genera and 83 families of vascular plants, mostly native to Menorca. All these records are fully computerized using the new 3.7 version of HERBAR, an application software designed by Francisco Pando of the Royal Botanical Garden of Madrid, which has been adopted as standard by the AHIM (Association of Ibero-Macaronesian Herbariums) and which is recommended and supported by the Spanish Node of GBIF (Global Biodiversity Information Facility). This fact perfectly matches with one of the main future goals of the HGM: to introduce this collection of vascular plants in the large database of the GBIF network with the aim of providing adequate dissemination and international relevance.

Beyond the digitization of the collection, currently the management and conservation tasks of the HGM also includes a labeling process of the different documents that contain the specimens recorded. Once labeled, these documents will be stored in boxes already arranged alphabetically by families and genera. Meanwhile the HGM collection continues to grow thanks to the research and collecting work of the Commission of Botany's scientists.

Keywords: *Herbarium, Menorca, HERBAR, computerization, GBIF*

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MANAGEMENT OF ENDANGERED PLANT SPECIES WITHIN THE LIFE+ RENEIX PROJECT

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The long-term management of habitats and plant species is a main objective of the Habitats Directive of the European Union. Menorca, like other Mediterranean islands, has a significant endemic flora with plant species of narrow distribution that likely require legal protection to assure successful conservation. Moreover, it is well known that in most cases the conservation of a single species cannot be implemented with positive results without taking into account the whole habitat where it grows. Under this premise, some years ago a LIFE Natura proposal (LIFE 2000NAT/E/7355) was developed in order to manage Menorca's endangered plant species. Unlike other projects, LIFE+ RENEIX (LIFE07 NAT/E/000756) proposes to proceed with conservation from a comprehensive approach - that is, considering the whole context where targeted plant species are growing. Thus, in the island's particular case, this means not only developing actions designed to work on individuals (i.e. reinforcing populations, increasing knowledge about ecology, control of specific threats), but also working in a multidisciplinary fashion: preceding situation, habitat restoration, social awareness, etc. In order to clarify actions and results, four areas of the island have been selected that have the following common features: a high concentration of habitats and plant species of conservation interest, the presence of active threats that urgently need restoration actions and can be easily recognized by locals and tourists.

With this approach it is expected that the project will develop with evident positive results, not only on plant species included in the Habitats Directive, but also on many others that are of interest for conservation due to their narrow distribution (endemic) or to their significance for locals. Taken together, these experiences and results may be exportable to other regions with similar problems of habitat and species conservation.

Keywords: *LIFE+ RENEIX, Habitats Directive, Menorca, endemic flora, habitat restoration, species conservation*

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NEW PLANT SPECIES RECENTLY DESCRIBED IN THE FLORA OF MENORCA: THE IMPORTANCE OF NEGLECTED HABITATS

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The islands of the Mediterranean area are usually considered to be among the richest points of conservation interest, as they hold a high concentration of unique and restricted biodiversity among their autochthonous flora. Endemicity on insular territories can be related, besides insularity itself, to other factors favoring plant differentiation like mountain ranges, geological diversity and soil singularities or harsh environmental conditions. In the particular case of Menorca, despite the absence of tall mountains (the maximum altitude is 350 m a.s.l.), some particularities like extreme environmental conditions caused mainly by persistent, strong north winds and a diversified geology seem to be the major forces driving local speciation processes. Recently, a group of up to four new species have been described from habitats sharing several common environmental features, viz *Bellium artrutxensis, Coronilla montserratii, Euphorbia nurae* and *Polycarpon dunense*. They grow on sandy calcareous soils derived from coastal sand dune systems, but with a different degree of consolidation. Thus, they range from small patches of mobile sands of inland progressing dune systems (e.g., *P. dunense*) to thin sandy soils originated by erosion of fossilized limestone dunes (e.g., *B. artrutxensis* and *E. nurae*). Soil characteristics of these habitats favor a vegetation of small annual plants with a high degree of species diversity, showing some physiognomic similarities with *Isoetes* communities of sandy siliceous soils. What is shown after years of studying these miniature grasslands is that even habitats apparently are not favourable for speciation they can hold different plant communities. Some of them can be linked to very local environmental conditions that are singular and thus favor plant diversification and ultimately speciation.

Keywords: *sandy soils, speciation, Bellium, Coronilla, Euphorbia, Polycarpon*

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FOREST HABITAT MAP OF MENORCA 2007. A TOOL FOR FOREST MANAGEMENT AND BIODIVERSITY PRESERVATION

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LIFE+ BOSCOS (LIFE+07ENV/E/000824) is a project developed by the Menorcan government (CIMe) with the co-funding of the European Union's LIFE+ program, which aims to develop tools and sustainable management strategies to deal with climate change effects on Mediterranean forests. A new forest habitat map of Menorca (the second largest island of the Balearic Islands) has been developed at the Institut Menorquí d'Estudis (IME), as an analysis and management tool to define forest management guidelines for the adaptation to climate change, as well as to simplify and facilitate forest planning on both local and regional levels.

This Forest Habitat Map of Menorca is currently the most detailed habitat map (scale 1:25000) ever made in Menorca and one of the first in the Iberian Peninsula. The map focuses exclusively on forest habitats and covers 51% of island's surface (358 km^2). The map uses two of the most widely used habitat classifications: (1) the *Habitat types of Community Interest* developed by Council directive 92/43/CEE and listed under *Interpretation Manual of European Union Habitats* (version EUR27), as well as (2) the *Corine biotopes* developed by EU CORINE program's *CORINE Biotopes project.*

The map has been digitalized using Geographic Information System's techniques and has also been extensively validated by field campaigns (over 40% of its surface has been visited). The resulting cartography includes 30 different forest habitats (according to *CORINE Biotopes project* classification) distributed in nine *Habitat types of Community Interest*. The map contains almost 4,000 landscape units, each of which holds a maximum of three different habitats. Thanks to its detail and thoroughness, the forest habitat map will be a helpful tool when drafting the guidelines for forest management of Menorca and, at the same time, will allow drawing forest management plans of the properties of the island.

Keywords: *Mapping, forest habitat, Habitat types of Community Interest, HIC, CORINE Biotopes Project, Menorca, LIFE+*

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ENDANGERED PLANT SPECIES OF MARETTIMO ISLAND (SICILY, ITALY)

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Marettimo Island (Egadian Archipelago, NW Sicily), unlike the surrounding areas of Levanzo and Favignana, and also of Sicily itself, has not been affected by the Quaternary glaciations (Francini & Messeri, 1956), hence the vegetation physiognomy is quite different; we could just think of e.g. the *Rosmarinus officinalis* and *Erica multiflora* macchia-garrigue, very common here, but residual elsewhere and located within restricted geographical areas. The peculiarity of flora, represented by 612 infrageneric taxa (Gianguzzi et al., 2006), is the result of the vicissitudes that have affected phytogeographic flows in this sector of the Mediterranean Sea. There are different endemic species, some of which paleoendemic, or entities of phytogeographic significance, with small populations and therefore "at risk".

The study investigates these entities, highlighting the problems related to their conservation. Among the exclusive endemic species to the Island, there are *Allium franciniae*, *Helichrysum errerae* var. *messerii*, *Limonium tenuiculum*, *Bupleurum dianthifolium*, *Oncostema hughii*, *Thymus richardii* subsp. *nitidus* and *Anthemis secundiramea* var. *cosyrensis*; a species endemic to the Egadian Archipelago (*Brassica macrocarpa*). Moreover, many other taxa are to be mentioned: some of them are endemic to Sicily, i.e. *Asperula rupestris*, *Bellevalia dubia*, *Euphorbia papillaris*, *Plantago afra* subsp. *zwierleinii*, *Pseudoscabiosa limonifolia* and *Ranunculus spicatus* subsp. *rupestris*, or to the Central Mediterranean area, such as *Crocus longiflorus*, *Dianthus rupicola* subsp. *rupicola*, *Iberis semperflorens*, *Pimpinella anisoides*, etc. Many other plants are absent or very rare/threatened at a regional level, such as *Aristolochia navicularis*, *Daphne sericea*, *Erodium maritimum*, *Lagurus ovatus* subsp. *vestitus*, *Periploca laevigata* subsp. *angustifolia*, *Reichardia tingitana*, *Simethis mattiazzi*, *Thymelaea tartonraira*, etc.

Other entities, rather frequent on the nearby Sicilian coast, retain only one or few relict stations in Marettimo, e.g. *Hedera helix*, *Teucrium fruticans*, *Chamaerops humilis*, *Phillyrea latifolia*, *Cyclamen hederifolium*, *Ephedra fragilis*, locally represented by very few individuals, for which therefore protection actions would be necessary.

Keywords: *Vascular flora, conservation of species, Marettimo Island (Channel of Sicily), phytogeography.*

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INVESTIGATIONS INTO THE DISTRIBUTION OF FLORISTIC EMERGENCIES OF PANTELLERIA ISLAND (CHANNEL OF SICILY, ITALY)

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Pantelleria Island is the emerged part of an imposing volcano that rises along the "contact rift" between Africa and Europe. It's dominated by Montagna Grande summit (836 m), followed by Monte Gibele (700 m) and other inactive volcanic cones. According to the most recent contributions, the vascular flora is composed of approximately 600 infrageneric entities (Brullo *et al.*, 1977; Gianguzzi, 1999a, 1999b), a rather small number compared to the territory surface area, being due to its young geological age and to geographic isolation in the Channel of Sicily.

This study focuses on the floristic emergencies of the island, which include several endemic species, all neogenic, among which are exclusive: *Limonium cosyrense*, *Matthiola incana* subsp. *pulchella*, *Medicago truncatula* var. *cossyrensis*, *Trifolium nigrescens* subsp. *nigrescens* var. *dolychodon* and *Serapias cossyrensis*. Among other endemic species, which are present in nearby areas, are the *Anthemis secundiramea* var. *cosyrensis*, *Filago lojaconoi* and *Senecio leucanthemifolius* subsp. *crassifolius*. There are, furthermore, several elements of certain phytogeographical significance, almost all from the South, like *Pinus pinaster* subsp. *hamiltonii*, *Periploca laevigata* subsp. *angustifolia*, *Genista aspalathoides*, *Carex illegitima*, *Andryala rothia* subsp. *cossyrensis*, *Limodorum trabutianum*, *Ophrys sphegifera*, *Brassica insularis*, *Tillaea alata*, etc.

Among the most vulnerable biotopes, for their peculiarity and limited distribution, are fumaroles and "Specchio di Venere" lake. In the fumarolic series it is possible to find rare species, such as *Radiola linoides*, *Kickxia cirrhosa*, *Isoetes duriei* and *Ranunculus parviflorus*.

Along the sides of "Specchio di Venere", located within a calderic depression, there is *Schoenoplectus litoralis* s.l., whose insular population is considered critical, in addition to the very rare *Limonium secundirameum*, considered seriously threatened. On this basis, therefore, the factors of the human pressure on the biotope are not to be neglected, especially pronounced during the summer, becoming one of the most significant threats.

Keywords: *Vascular flora, conservation of species, Pantelleria Island (Channel of Sicily), phytogeography.*

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PHYLOGEOGRAPHY OF *QUERCUS COCCIFERA* S.L. IN THE MEDITERRANEAN BASIN

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In the context of compared phylogeography of Mediterranean species, *Quercus coccifera* L. is studied through cpSSR markers. Plant material was collected in 66 natural populations from around the Mediterranean Basin, including the most relevant archipelagos. Five out of the six universal primers tested were variable with a total of 18 different alleles, giving 34 haplotypes. A map of haplotypes in the sampled populations is presented. The analysis using Permut software shows high levels of genetic variability and structure (Rst = 0.982 > Gst = 0.87, p = 0.000). Two AMOVA analyses were performed based on geographical and bayesian distribution. In the first, most of the variability (65.5%) was among groups, being lower among populations within groups (33.4%), while in the second analysis both of them were similar (50.6% and 45.6%, respectively). Bayesian analysis with BAPS software distributed the populations into 3 groups, one of them (37 populations, 11 haplotypes), found mainly in the west of the Mediterranean Basin, and the Cyrenaic region, the second one in the Middle East, Turkey and Cyprus (13 populations, 11 haplotypes) and the third (16 populations, 13 haplotypes) present in most of the main islands (except Cyprus), Southern France, Balkans and Northern Africa (Argelia and Tunisia). All these results, together to the haplotypes network constructed with TCS software, suggest 2 different migration routes from the Iberian Peninsula where the basal haplotype is located, one through the Siculo-Tuniasian Strait and the other one through Northern Africa to the Middle East and Turkey.

Keywords: Quercus coccifera*, Kermes oak, cpSSR markers, phylogeography, migration routes*

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IN SITU CONSERVATION STRATEGIES OF A THREATENED SPECIES: THE CASE OF *CAREX PANORMITANA* GUSS. IN SICILY

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Carex panormitana Guss. (Cyperaceae) is a species distributed in Sicily and Sardinia, which, according to Arrigoni (1984), represents a neoendemic vicariant of *Carex acuta* Good. In Sicily it can only be found in one place in the north-west, near Palermo. This rhizomatous geophyte, sciaphilous-hygrophilous, typical of river banks, is a species of community interest listed in the Habitats Directive 92/43/EEC under annex II as priority species and under annex IV; it is also found on a national red list (Conti *et al.*, 1997), indicated as vulnerable (VU), unlike the Sicilian subpopulation considered threatened (Raimondo *et al.*, 1994).

Carex panormitana is actually located in the downstream section of the Ponte delle Grazie in the Oreto river, whose station is also the *locus classicus* of the species. According to the investigation carried out, the subpopulation, rather fragmentary, is particularly threatened with extinction. The main causes of this threat are three:

1 - Extreme simplification of the original river morphology with straightening of the river channel and deletion of bends, meanders, river beds, etc.

2 - Significant reduction of radiation under the canopy, since the ripisilva often tends to occupy the entire floodplain area; this leads to a change in the habitus of the species, from heliophilous to sub-sciaphilous.

3 - Eutrophication of water body, as result of the urbane sewage from the upstream areas.

In order to elaborate a specific plan for the *in situ* conservation of the considered subpopulation, preventing its further regression, which could also lead to the extinction in the medium term, we suggest the following actions:

1 - restoration of the typical riverine morphology of the terminal stretch of the river;

2 - periodic cleaning interventions of the riverbanks, aimed at the restoration of the typical environmental balance of *Carex panormitana*;

3 - reduction of organic load.

Keywords: *Oreto River (Palermo), Habitats Directive 92/43/EEC, Conservation of species, Phytogeography.*

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ESTABLISHMENT OF A PLANT MICRO-RESERVE NETWORK IN CYPRUS FOR THE CONSERVATION OF PRIORITY SPECIES AND HABITATS

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The project titled 'Establishment of a Plant Micro-reserve Network in Cyprus for the Conservation of Priority Species and Habitats' (PLANT-NET CY) is implemented under the EU LIFE+ programme. Its main objective is to improve the conservation status of four priority plant species and two priority habitat types of the EU Habitats' Directive that are found exclusively in Cyprus, through the establishment, monitoring and management of a network of five Plant Micro-Reserves (PMRs). The PMRs approach was initially developed about 15 years ago in Valencia (Spain) and since then it has been successfully implemented in several other parts of Europe. This concept is now widely accepted as one of the most effective practices towards the conservation of plant diversity in small land areas that are of peak value in terms of plant richness, endemism or rarity. The project introduces an integrated approach for the conservation of the targeted species and habitats through monitoring of all environmental parameters affecting the targeted species and their habitats, implementing specific *in situ* conservation actions, implementing complementary *ex situ* conservation actions and promoting public awareness and controlled public involvement in the conservation activities. The project is expected to secure the protection and sound management of the targeted species and habitats and increase the participation of local people/stakeholders in the design and implementation of conservation initiatives. Moreover, PLANT-NET CY brings together scientists who have been involved in the PMRs approach over the last 15 years to facilitate networking and exchange of scientific information and best practices.

Keywords: *Plant Micro-Reserves, priority species, priority habitats, plant conservation, Cyprus.*

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ENDEMIC TAXA OF *ASPERULA* L. SECT. *CYNANCHICAE* (DC.) BOISS. ON THE MEDITERRANEAN ISLANDS

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Recent research on molecular phylogeny (based on cpDNA) of the family *Rubiaceae* confirmed that the genus *Asperula* is not monophyletic (Soza & Olmstead, 2010). *Asperula* L. sect. *Cynanchicae* (DC.) Boiss consists of approximately 60 taxa with a hotspot of diversity in the Adriatic and Aegean Basin. Around the Adriatic Basin several endemic taxa of the *Asperula* sect. *Cynanchicae* ser. *Paleomediterraneae* have been recorded based on morphological, caryological ecological and geographical differences. The most interesting taxa are those that belong to the *Asperula staliana* complex (Korica, 1979, 1981, 1986, 1992) such as *A. staliana*, *A. woloszczakii*, *A. visianii*, *A. borbasiana*, *A. staliana* ssp. *arenaria*, *A. staliana* ssp. *issaea, A. staliana* ssp. *diomedea*. Morphologically closely related taxa are *A. garganica*, *A. calabra*, *A. crassifolia* from the Apennine peninsula, *A. deficiens* from Sardinia, *A. pauii* from Balearic Islands (Peruzzi *et al.* 2004), *A. gussoneii* and *A. peloritana* from Sicily (Brullo et. al 2009), *A. naufraga* and *A. samia* from Greek islands (Ehrendorfer & Guterman, 2000, Christodoulakis & Georgiadis, 1983), *A. suberosa* from Northern Greece and *A. idea* from Crete (Schönbeck-Temesy & Ehrendorfer 1991). Geographical vicinity and punctiform distribution of these taxa in the Mediterranean makes the story of their diversification especially interesting.

The main goal of this research is to solve taxonomic incongruences among endemic taxa, discover species-area biogeographic relationships between islands and main lands (Italian and Balkan peninsula), and assess their genetic diversity as well as phylogenetic relationships.

Phylogenetic relationships were inferred from plastid DNA sequences (*trnH-psbA* and *matK*) and nuclear sequences (ITS). Tested populations were sampled on some Croatian islands and in Italy. Preliminary results indicate the existence of great variability among the investigated taxa. We found interesting patterns of inter-/intra-specific polymorphism which will be further assessed in future research involving taxa from Greece and other Mediterranean islands.

Keywords: *Asperula sect. Cynanchicae, phylogeny, endemism, trnH-psbA, matK, ITS*

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WILD PHOENIX IN THE MEDITERRANEAN: PALEONTOLOGICAL AND ARCHAEOBOTANICAL EVIDENCE

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The number of wild palm species in the Mediterranean is restricted to *Chamaerops humilis* L. in numerous floras and monographs. However in the second half of the 20th century, the discovery of *Phoenix theophrastii* in several areas on the island of Crete (Greece), which was later found in the Aegean coasts of Turkey, and the description of *Phoenix iberica* from SE Spain raised the question on the origins of these palm trees and the possibility of wild palm species in the Mediterranean other than *Chamaerops humilis*. In addition, several *Phoenix* microspecies were described since the 18th century but usually considered as varieties of *P. dactylifera* (e.g. *P. excelsior* from Eastern Spain). Are these merely subspontaneous date palms escaped from cultivation which reverted to the wild phenotypes, or remnants of ancient *Phoenix* populations which persisted during the Holocene in refuge zones, including some Mediterranean islands? If the latter option was true, how could they participate in the domestication processes of *Phoenix dactylifera* along the Southern Mediterranean side? Is the similarity of the external macrocharacters and appearance amongst all these taxa the expression of local phenotypes of *P. dactylifera* or a possible evidence of the introgression and genetic displacement caused by this Afro-Asian species on a rich group of Mediterranean taxa currently in extinction? Here we comment on the morphology of fossilized and non-fossilized remains from different sites and periods in the Mediterranean, Europe and North Africa, which can be compared with the extant Mediterranean *Phoenix*. The results here obtained advises to describe and characterize in a close future all the Mediterranean microspecies, in order to better discriminate between native and current *Phoenix* and their remnant morphological influence in the *P. dactylifera* complex.

Keywords: *Phoenix theophrastii, Phoenix iberica, Phoenix dactylifera, Mediterranean palms, Paleobotany, Archaeobotany*

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PSAMMOPHYTE VEGETATION ON THE DUNE FRONT OF ES COMÚ DE MURO (MALLORCA, BALEARIC ISLANDS). FROM CONSERVATION STATUS TO THE NEED FOR MANAGEMENT

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The beach-dune ecosystems' situation in the Balearic Islands is characterized by its high fragmentation, mainly due to anthropogenic pressure and the coastal management policies made by the local administration. Economic interests have prevailed over ecological ones, generating serious environmental impacts. Fragmentation signs are clear in both geomorphic and ecological features, mainly along the first line of dune systems. Although there are many variables to consider, the ecological status should be considered as an important feature to take into account.

The existing relationship among geomorphic, ecological and management conditions is vital to understand the current situation of Es Comú. In this way, it is important to observe the role that vegetation plays here. In fact, the disappearance of the herbaceous vegetation on the front line has implied a high loss of sediment, increasing the erosion rate.

Hence, we propose contributing to the knowledge of the dune beach-system of Es Comú de Muro (Mallorca, Balearic Islands) by carrying out an exhaustive characterization of its ecological conditions present along its dune front, with the purpose of establishing a representative explanation of its fragmented situation through the blowout erosive shapes and fore-dune status. For this, 58 floristic inventories corresponding to each analyzed blowout have been sampled taking into account ecological variables in order to establish and propose new management tools.

A Cluster analysis has been made through Bray Curtis similarity index to show the field work results, taking into account the 19 main herbaceous species detected along the dune front. Ecological conditions are taken out from both herbaceous and bush vegetation. In fact, the geomorphologic front dune degradation has been analyzed as well, starting with the roots of *Juniperus oxycedrus* subsp. *macrocarpa* outcrops, showing a strong correlation with the system fragmentation.

Thus, the main species of each type have been identified to determine their presence/absence index, distribution, and conservation state, in order to get a clear perspective about the current situation of this area, and the potential management tools suitable to apply.

Keywords: *beach-dune ecosystems, conservation, management, Mallorca, Balearic Islands.*

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ECOLOGICAL QUALITY OF RIPARIAN HABITAT ASSESSMENT BY MEANS OF QBR INDEX (MUNNÉ *ET AL.*, 2003) IN EPHEMERAL STREAMS OF MENORCA (WESTERN MEDITERRANEAN, SPAIN).

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In response to the increasing ecological impacts related to human activities and the greater social environmental concerns, policy-makers of developed countries are implementing initiatives aimed at reducing those impacts in aquatic ecosystems to restore water quality levels found in pristine ecological status. Thus, the General Directorate of Freshwater Resources of the Balearic Islands Government, in order to implement the European Water Framework Directive (WFD; 2000/60/EC) requested that OBSAM carry out a vegetation communities cartography and a riparian habitat assessment. Riparian vegetation is contained in landscapes where terrestrial and aquatic ecosystems meet, such as streams, river banks and river floodplains, wetlands and areas surrounding lakes. Native riparian vegetation plays an important role in providing ecosystem services. These services include stabilization of river banks, maintenance of water quality and water flows, habitat for aquatic species, and maintenance of biological diversity in remnant habitats.

To assess the ecological quality of riparian areas, a visual index (QBR, Munné *et al.*, 2003; ACA, 2006) was used. This methodology developed for Mediterranean stream catchments is based on 4 categories of riparian habitats (vegetation cover, cover structure, cover quality and channel alterations). Scores for each category range from 0 to 100, with the value 100 assigned as the highest quality and founding 5 groups. For this purpose, 19 major streams within 12 drainage basins were chosen. The streams were divided into 4 uniform geomorphological-depending categories (reaches) and each reach was divided into stretches according to fertile lowland floodplains land use. None of the streams obtained very good ecological quality; 2, good ecological quality; 6, moderate ecological quality; 8, poor ecological quality; and 1 obtained bad ecological quality. The main threats detected were riparian vegetation clearance and its replacement with pastures, animal waste, sewage input and the introduction of non-native species.

Keywords: *European Water Framework Directive, QBR, riparian vegetation, ephemeral streams.*

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DETAILED MAPPING OF THE DISTRIBUTION OF THE PLANT SPECIES OF INTEREST TO THE PROJECT LIFE+RENEIX IN MENORCA (PHASE I)

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We present the methodology and results of the first phase of the detailed mapping of plant species considered of interest for the project LIFE+RENEIX (LIFE+07/NAT/E/000756). The species studied are: *Anthyllis histrix*, *Astragalus balearicus*, *Cneorum tricoccon*, *Cymbalaria aequitriloba*, *Cymbalaria fragilis*, *Echinophora spinosa*, *Femeniasia balearica*, *Orobanche foetida* (*Ononis crispa* parasite), *Paeonia cambessedesii*, *Pastinaca lucida*, *Teucrium asiaticum*, *Teucrium marum*, *Thymelaea velutina* and *Viola stolonifera*. The areas of study are: Alocs-El Pilar, Binimel·là, Sa Mesquida-Es Murtar, Pas d'en Revull (Barranc d'Algendar). The data from the first field survey (conducted during the autumn of 2010) are structured in a geographic information system, in polygons and point maps. Where the populations exceed 400 m^2 they have been digitized as polygons (in some cases, when it has been considered of interest and possible, a smaller minimum area has been used). The fieldwork was carried out over recent printed orthoimages in scales between 1:2,500 and 1:4,500 and the final GIS demarcation of the polygons has been done in more detailed scales. For smaller populations or isolated individuals the mapping information is a point layer (from captures in the field with the GPS). The database associated with the mapping contains the following information: number of individuals (adults, young, seedlings and dead), number of populations (individuals or groups of individuals), surface, conservation status (good, medium, bad) and observations. The poster describes the species found in each of the studied areas and its population data, as well as some conservation problems detected during the fieldwork. In the second phase (scheduled for 2013) the data from this first session will be updated and the mapping of species that have not been properly studied due to their phenology (*Orobanche foetida* and *Serapias nurrica*) will be carried out.

Keywords: *LIFE+ RENEIX, flora of interest, GIS, detailed mapping*

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SYSTEMATICS OF THE NARROW ENDEMIC SPECIES *BRIMEURA DUVIGNEAUDII* (HYACINTHACEAE)

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Brimeura is an endemic genus of the western Mediterranean region which includes three species: *B. amethystina* (L.) Salisb., endemic to the north-eastern Iberian Peninsula (mountains bordering the Ebro basin), *B. fastigiata* (Viv.) Chouard, endemic to Western Mediterranean islands (Corsica, Sardinia, Majorca and Menorca), and the Majorcan endemic *Brimeura duvigneaudii* (L. Llorens) Rosselló, Mus & Mayol. *Brimeura duvigneaudii* was described on the basis of specimens collected in Penyal Fumat, Formentor (northern Majorca). Intraspecific morphological variation in *B. duvigneaudii* has been noted, and two groups of populations that correspond to separate areas in which plants show morphological differences (scape and flower length) could be defined. These differences were attributed to phenotypic adaptations to a humid and shady microhabitat in Coma Freda karst gorge. Indeed, variation in flower features in this species has been observed by us during the last decade, which seems to be clearly related to the geographic origin of the plants. To clarify these relationships, we carried out a morphological study of *Brimeura duvigneaudii* (Hyacinthaceae). Morphological analyses showed noticeable variability which is correlated with geographic distribution and some ecological factors. These data led us to propose a new subspecies of *Brimeura duvigneaudii*, which is endemic to a single locality from the middle range of Serra de Tramuntana. The new taxon, which has been recently described (*Brimeura duvigneaudii* subsp. *occultata*), differs from *B. duvigneaudii* subsp. *duvigneaudii* in several vegetative (leaf anatomy and leaf width) and flower features (corolla size, corolla lobe length and shape, scape length). Data on the local distribution and ecology of the new taxon have been reported. The new subspecies is restricted to a karst gorge and is in danger of extinction, due to its small population size.

Keywords: *Brimeura, Majorca, morphometric analysis, subspecies*

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THE *THYMELAEA TARTONRAIRA* (L.) ALL. VARIATION IN SARDINIA (ITALY)

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The *Thymelaea tartonraira* L. All. (Thymelaeaceae) is a very interesting species group and can be a good model to study morphological population variation. *T. tartonraira* is a Mediterranean species with a complex nature of variation difficult to define, as already observed by Aymonin (1971, 1974). A quite varying intra specific taxonomy was carried out by different authors, among them Tan (1980) and Galicia Herbada, (1995, 2006). All the Italian populations (among them Capri, Marettimo and Sardinia) are named *T. tartonraira* subsp. *tartonraira*, the main taxon of the W Mediterranean. *T. tartonraira* in Sardinia is a quite common species present in different coastal and mountain sites on sand dunes (e.g.: Porto Ferro), on consolidated sands of fossil dunes (e.g.: Porto Palmas) on rocks/cliffs (e.g.: Porticciolo) and on Mesozoic calcareous lime-stones (all the mountain sites in this project). The variety of habitats and the presence of this taxon in a great number of sites, make Sardinia a good study site to test and, possibly, to quantify the morphological variation in *T. tartonraira* subsp. *tartonraira*. The objective of this study is to evaluate the intra and inter population morphological variation of nine Sardinian sites and to test the possible discontinuities among this variation. Preliminary data from morphological analysis of vegetative and reproductive structures of *T. tartonraira* (e.g.: leaves, flowers, fruits and seeds) are taken into account, elaborated and discussed.

Keywords: *Thymelaeaceae, Thymelaea tartonraira subsp. tartonraira, morphology, systematics.*

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ESSENTIAL OIL COMPOSITION OF SOME *CENTAUREA* SP. (ASTERACEAE), FROM DIFFERENT ITALIAN ISLANDS

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Introduction

The genus *Centaurea* (Cardueae tribe, Asteraceae) contains a very large number of species (400-700) predominantly distributed in the Old World (Greuter, 2008). Several papers on secondary metabolites of *Centaurea* species are available in the literature (Baykan-Erel *et al*., 2010), a few on volatile constituents (Rosselli *et al.*,2009; Tava *et al*., 2010; Viegi *et al*., 2010).

Objectives

Taxonomically this genus is complex and warrants further study by new cytological and chemical techniques. Extending our study of *Centaurea* species in Italy, the aim of this research was to look into the essential oil composition of some species from different Italian islands.

Methodology

The aerial parts (fresh and dry flower heads and leaves) of *Centaurea veneris* (Sommier) Bég. from Palmaria island, in the Ligurian Sea, *C. gymnocarpa* Moris & De Not. from Capraia island, *C. ilvensis* (Sommier) Arrigoni and *C. aetaliae* (Somm.) Bég. from Elba island in the north Tyrrhenian Sea, were collected during their flowering period (April-July) in 2006 and 2007 [nomenclature follows Greuter (2006-09)]. Voucher specimens of these plants were deposited in PI (Herbarium Horti Pisani, Pisa University). For each population, a sample of 20 individuals was collected. The volatile components of all samples were obtained by hydrodistillation and identified by GC and GC/MS. The essential oil from these four species has never previously been researched.

Results and conclusion

The volatile oils of the four *Centaurea* species contained several compounds, the most abundant of which were sesquiterpenes (34.4-61.7% of the total), followed by aldehydes (6.5-10.3%), alcohols (0.6-7.9%), monoterpenes (0.6-2.2%), hydrocarbons (1.7-14.7%), ketones (0.3-2.4%), acids (0.8-4.0%) and esters (0.1-4.7%). Several unidentified compounds were also detected as in other *Centaurea* sp. (Tava *et al*., 2010; Viegi *et al*., 2010). The results are discussed on the basis of the taxonomical implications of these species.

Keywords: Centaurea veneris, Centaurea gymnocarpa, Centaurea ilvensis, Centaurea aetaliae*, Asteraceae, essential oils*

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