

A natural history of the islands' unique flora

The unique nature of Mediterranean island floras

The unusual geographical, climatic and topographical diversity and the complex historical biogeography explain the exceptionally high plant diversity and endemism of the Mediterranean Basin. The numerous islands constitute a significant component of Mediterranean plant biodiversity, notably with the presence of range-restricted plants (endemic plants) and isolated plant populations from a genetic point of view. This highly diversified insular flora is the result of the different geographical situations, of the varied paleogeography linked to important tectonic movements, and of the wide ranges of size, altitude, morphology and geology. The considerable diversity of insular landscapes is also explained by the heritage of human activities which have had profound consequences on the distribution and dynamics of plant species and ecosystems.

Main patterns of vegetation and plant biodiversity of the major islands and archipelagos

In the larger Mediterranean islands plant endemism is generally 10-12% (see map on page 32) but the overall range of flora is greater than expected, with between 1600 and 2800 taxa (species and subspecies). On insular mountain ranges, the endemism level is clearly higher since at altitudes above 1700 metres endemic plants represent about 35-40% of the vascular flora in Corsica and in Crete. Even small islands play an important role in plant biodiversity: for example, on 71 satellite islands of Sardinia, which represent only 1.1% of the total surface of the main island, 1200 plants have been identified, i.e. almost half of the total Sardinian flora.

Balearic islands The Balearic archipelago has a relatively high plant richness with about 1730 native plant taxa (including varieties) and 173 endemic and subendemic plants of which about 121 are restricted

endemics. The distribution of the flora reflects deeply the complex palaeogeography of the western Mediterranean, and these islands form two distinct units. The flora of the western islands (Formentera and Ibiza) possess strong Iberian or Ibero-Maghrebian affinities whereas those of the eastern islands (Majorca, Minorca, Cabrera) have clear Tyrrhenian affinities with the unique presence of monospecific genera (*Feminasia*, *Naufraga*, *Soleirolia*) and other palaeoendemics (*Daphne rodriguezii*, *Pimpinella bicknellii*, *Lotus tetraphyllus*...). Therefore, according to this clear biogeographical segmentation, it is not really surprising that only few endemics are common to all the Balearic islands (*Hypericum balearicum*, *Bupleu-rum barceloi*...). If tourism and land-use changes have profoundly altered and modified the habitats in Majorca and Ibiza, the islands of Menorca and Formentera are less impacted and rural landscapes are still prevalent.

The vegetation is mainly composed of typical trees and shrubs (*Quercus ilex*, *Ceratonia siliqua*, *Olea europaea*, *Pistacia lentiscus*, *Myrtus communis*...), but there are some singularities in the plant communities with the presence of the shrubs *Cneorum tricoccon* and *Buxus balearica*. Along windy and rocky coasts of the eastern islands, there is a remarkable plant community made up of spiny and cushion endemics locally named *socarrell* (*Launaea cervicornis*, *Anthyllis hystrix*, *Astragalus balearicus*, *Dorycnium pentaphyllum* subsp. *fulgurans*). Another *socarrell* community defined notably by *Teucrium subspinosum* is also present on the ridges of the upper part of the Serra de Tramuntana de Mallorca, above 1100 metres.

Corsica This mountainous island comprises 2325 indigenous plant taxa (including varieties), of which 316 are endemics or subendemics, i.e. a 13.6% rate of endemism. 146 plant taxa are strictly localised to Corsica, and the mountain alpine flora above 2100 metres is highly specific as it includes ca. 43% endemics of the 131 alpine taxa, with 34 strict Corsican endemics. Nevertheless, the most numerous group of the endemics is centered at medium altitudes, and several endemics are very common at this level

Left to right:
Cyprus cedar (*Cedrus brevifolia*),
Oleander (*Nerium oleander*) and
Stone pine (*Pinus pinea*)



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(*Thymus herba-barona*, *Stachys corsica*, *Genista corsica*...). Corsica is the most wooded Mediterranean island with almost 30% of its surface covered by forests and mature maquis. In the mountains, the dominant tree is the Corsican pine or Laricio (*Pinus nigra* subsp. *laricio*) which often forms pure and impressive stands. The upper limits of forests are roughly at 1600 metres on northern slopes and 1800 metres on southern ones, but *Abies alba* can reach 1900 metres locally. In the alpine zone, north-facing slopes are covered by *Alnus viridis* subsp. *suaveolens* scrub and grasslands, but south-facing slopes with xerophytic dwarf-shrubs (*Astragalus genargenteus*, *Berberis aetnensis*, *Genista salzmannii*) dominate the landscape. Between 1600 and 2400 metres particular vegetation (named locally pozzines) have a high conservation value with several endemics (*Bellis bernardii*, *Bellium nivale*, *Pinguicula corsica*...). Other very rich and generally still well preserved habitats, despite their location at low altitude, include temporary pools with a huge contingent of rare and restricted plants (*Isoetes*, *Pilularia*), and rocky or sandy coasts with several particular plants (*Armeria soleirolii*, *Erodium corsicum*, *Silene velutina*...).

Sardinia As in the other large Mediterranean islands, sclerophyllous species dominate the landscape notably with *Quercus suber* forests that were favoured by man. The dwarf-palm (*Chamaerops humilis*) is commonly found along the warm slopes of the coasts whereas this south-Mediterranean species is absent in neighbouring Corsica. There are some deciduous trees (*Quercus pubescens*, *Fraxinus ornus*) and more sparsely maples, together with populations of *Taxus baccata* and *Ilex aquifolium* that make up the treeline at an exceptionally low altitude of 1400-1500 metres.

The absence of trees above this limit is certainly due to ancient human deforestation and pasture and the upper part of the Gennargentu massif is characterised by the the same shrubs as in the mountains of Corsica.

Sardinia is rather rich in flora with about 2300 species and subspecies and a well-documented plant endemism (254 endemics and subendemics), with clear affinities to Corsica since 80 endemics are solely shared between these two islands. Furthermore, the existence of several closely related plants (vicarious plants: eg. *Ruta corsica* and *R. lamarmorae*) attest the strong biogeographical link between Sardinia and Corsica. Some exclusive Sardinian endemics also deserve attention, notably in two genera whose distribution is Alpine-centered, *Aquilegia* with three local endemics (*A. barbaricina*, *A. nuragica*, *A. nugorensis*) and *Ribes* (*R. sandalioticum*, *R. sardoum*).

Sicily Sicily, the largest Mediterranean island, is an area of major botanical interest, with around 2800 plant species and 321 endemics and subendemics notably located in the north-eastern part of the island. The flora of the hills of Madonie alone includes 50% of Sicily's species and 40 endemics in less than 2% of the island's area. Etna contains 21 endemic plants and shows a remarkable vertical distribution of the vegetation, from the foothills with an evergreen vegetation belt, to the presence above 1000 metres of deciduous broadleaved trees with *Quercus pubescens* and then *Fagus sylvatica* enriched by Laricio pine

woodlands, and finally a shrubby vegetation dominated by *Astragalus siculus*, an endemic thorny-cushion plant present up to 2450 metres. Sicily includes also several endemic trees, which is uncommon in the Mediterranean Basin. Two of these species are very rare and endangered: *Abies nebrodensis* with only about thirty individuals located on the Madonie mountain, and the relict *Zelkova sicula* with only one population of 250 individuals discovered ten years ago in the south-east of the island (Iblei mountains). Some endemic trees are found only on Etna: *Betula aetnensis* and *Celtis aetnensis* are strict endemics whereas *Pinus nigra* subsp. *laricio* and *Genista aetnensis* are also located on other Tyrrhenian islands. Some less disturbed areas show a trend toward a gradual replacement of evergreen forests with *Quercus ilex* by broad-leaved trees (*Quercus pubescens*, *Fraxinus ornus*, *Ostrya carpinifolia*) and *Quercus suber*.

Malta The vegetation of the Maltese archipelago has been seriously modified by man for millennia and only very reduced and isolated patches of woods with *Quercus ilex* and *Pinus halepensis* still exist. Maquis with *Ceratonia siliqua*, *Pistacia lentiscus* and *Euphorbia dendroides*, and garigues dominated by *Corydorthymus capitatus*, *Erica multiflora*, *Anthyllis hermanniae*, *Teucrium fruticans* are mostly derived formations. Of the 16 strict endemic species and sub-species, two monotypic genera (*Cremnophyton lanfrancoi* and *Palaeocyanus crassifolius*) deserve attention because they represent relict and rare species restricted to some sheer cliffs in SW Malta and Gozo. From a biogeographical point of view, the Maltese islands

are linked to other islands of the strait of Sicily (Lampedusa, Linosa, Pantelleria), but some relationships with North Africa are noticeable, such as the presence of the coniferous tree *Tetraclinis articulata*.

Nevertheless, the deep and ancient human impact is responsible for the local extinction of at least fifty indigenous plants and a severe impoverishment of the plant diversity and vegetation types.

Crete Isolated for around 5.2 million years and almost entirely spared by Quaternary glaciations, this island has a unique flora with 209 endemics out of a total of 1735 native species. The high biogeographical interest of this Cretan flora is also related to the presence of diverse elements from the Balkans, Anatolia and to a lesser extent North Africa. Calcareous cliffs and treeless mountain areas with cushion-shaped and spiny dwarf shrubs (*Berberis cretica*, *Acantholimon ulicinum*, *Astracantha cretica*...) harbour a high number of endemic plants. Indeed, if the high-mountain flora of the three main massifs (Levka Ori, Psiloritis and Dhikti) is very poor, 35% of the 217 plants censused above 1500 metres are endemic. The level, clay-based mountain habitat is very particular with a distinct vegetation and the presence of several very rare plants and endemics such as the recently described herb *Horstrissea dolinicola*, a monospecific genus.

Scrub communities dominate the Cretan landscape, with maquis or garigues including *Ceratonia siliqua*, *Cistus* spp., *Olea europaea*, *Pistacia terebinthus*,



Left to right:
European fan palm
(*Chamaerops humilis*),
Yellow asphodel (*asphodeline lutea*)
and Fig (*Ficus carica*)

Arbutus unedo, *Erica arborea* and *Quercus coccifera*, and phrygana composed of spiny, hemispherical dwarf shrubs (*Anthyllis hermanniae*, *Coridothymus capitatus*, *Euphorbia acanthothamnus*...). Woodlands are mainly composed of sclerophyllous trees at low to mid altitudes (*Ceratonia siliqua*, *Phillyrea latifolia*, *Quercus ilex*, *Quercus coccifera*) with *Pinus brutia*, whereas deciduous oaks (*Quercus brachyphylla*, *Q. ithaburensis* subsp. *macrolepis*) occur nowadays only as scattered trees. In mountain areas, *Acer sempervirens* and *Cupressus sempervirens* are the dominant trees with *Quercus coccifera*; one of the most interesting trees is *Ambelitsiá* (*Zelkova cretica*), a relict elm-like tree present sparsely in the western mountains between 850 and 1800 metres.

Cyprus Natural habitats in Cyprus are mainly composed of pine forests, with *Brutia* pine forests from sea level to 1200 m, and the Black pine (*Pinus nigra* subsp. *pallasiana*) forests which occupy a restricted area of 6000 hectares in the Troodos massif between 1200 and 1900 metres. Mainly resulting from the destruction of forests by human activities, garigues and maquis cover a large part of the island, with evergreen shrubs but also with several dwarf shrubs (*Genista sphacelata*, *Nonea mucronata*, *Sarcopoterium spinosum*, *Asperula cypria*...) in dry and eroded soils.

Cyprus comprises about 1620 plant species with 170 endemics and subendemics. The flora has clear biogeographical affinities with Anatolia, but several

plants with an African-Arabian distribution (*Prosopis farcta*, *Pteranthus dichotomus*, *Zygophyllum album*) are the testimony of arid conditions which occur in the lowlands. Some of the most remarkable endemics are *Onobrychis venosa* and *Bosea cypria*, whereas three endemic species of *Crocus* are recorded. Of about 25 endemic plants located in rocky areas, six species are included in the Stonecrop family (*Sedum*, *Rosularia*).

The most interesting sector from a botanical point of view is the Troodos massif with unique forests of the endemic trees *Cedrus brevifolia* and *Quercus alnifolia* and the existence of about 65 endemic plants mainly on serpentine soils.

Natural history and biogeography of Mediterranean island floras

Mediterranean islands constitute major refugia areas, since they represent conservatories of old (often mid-Tertiary) and relict plants with a restricted distribution, termed palaeoendemics. This pattern is well supported by the presence of several monotypic endemic plant genera, restricted to one or few of these islands (see table on page 33), and by the existence of some relict plants of the subtropical tertiary environments, eg. the genus *Zelkova*. An outstanding example of the importance of ancient palaeogeography to explain current patterns of plant distribution and biogeographical links is provided by the Tyrrhenian islands. The eastern Balearic Islands (Menorca 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 period (Oligocene-Miocene), causing notably the rotation and migration of the Corsica-Sardinia block between 23 and 16

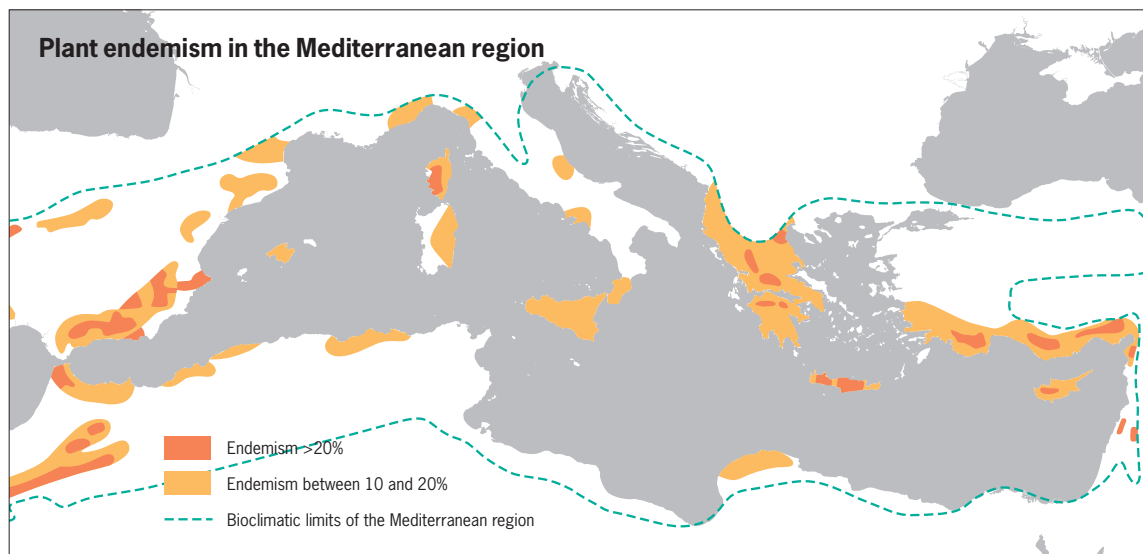
million years ago. The distribution of numerous Tyrrhenian endemic plants shared between these islands (e.g. *Arenaria balearica*, *Delphinium pictum*, *Dracunculus muscivorus*, *Teucrium marum*, *Thymus herba-barona*) reflects this crucial event (see map on page 33).

Another fascinating pattern is that offshore islands determine quite often the limits of geographical ranges of some range-restricted plants. Indeed, despite its closeness (about 10 km) from Cape Bon in Tunisia, the island of Zembra harbours the southernmost populations of plants located mainly in Italy, Sicily (*Erodium maritimum*, *Iberis semperflorens*) or in the eastern Mediterranean (*Sarcopoterium spinosum*). The Hyères archipelago, a remnant of the ancient Protoligurian massif, comprises several Tyrrhenian endemics (*Delphinium pictum*, *Ptilostemon casabonae*, *Teucrium marum*) which are totally absent along the nearby mainland of Provence, even if environmental conditions are similar.

For explaining in part these current patterns of plant distribution and endemism on the Mediterranean islands, two determinant geological periods must be invoked. First, the Messinian salinity crisis of the Late Miocene, provoked by the interruption of marine relationships between the Atlantic Ocean and the Mediterranean Sea, induced an almost complete desiccation of the Mediterranean Sea between 5.96 and 5.33 million years ago. 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,

the Balearic islands) from the mainland. Second, the severe cooling episodes beginning at the late Pliocene (ca. 1.75 million years ago) caused severe regressions of the sea level (between 100 and 150 metres below the actual), inducing numerous terrestrial migration of more competitive cool-temperate flora on offshore islands. But if Mediterranean islands have served as refugia, their role in local and more recent differentiation of plants is also important. Therefore, islands frequently harbour polymorphic species and younger endemic plants (neoendemics such as *Limonium* and *Centaurea*).

One of the most fascinating and intriguing patterns is related to the ecological uniqueness of islands. Some close islands show very different plant species composition. This is the case of the distribution of about 60 plant species (notably *Campanula*, *Dianthus*, *Erysimum*, *Helichrysum*) restricted to mostly maritime cliffs of the Aegean, with marked differences between islands even less than 10-20 km apart. Furthermore, on very small islands, it is possible to find some "islet specialists", i.e. plants that grow exclusively or are very abundant locally, but not on the mainland or on the closest larger island. Their distribution and abundance can be explained by their optimal specialisation in highly harsh and unusual environmental conditions. Islet specialists often possess a good ability for dispersal by sea drift over distances of hundreds of



kilometres since floating diaspores can stand up to a month in the sea water. Some possess a large peri-Mediterranean distribution (*Allium commutatum*, *Hymenolobus procumbens*, *Lavatera arborea*), while others constitute narrow endemics: *Atriplex recurva* and *Silene holzmannii* in the Aegean islands, or *Nanthea perpusilla* in several satellite islets around Corsica and Sardinia. Some remote islands exhibit a pattern of flora similar to those of remote oceanic islands: this is the case for Alborán island (7.1 hectares, 15 metres above sea level) isolated between Spain (85 km) and Morocco (55 km) which includes a very reduced plant richness (20 species) but with the presence of three endemic plants (*Anacyclus alboranensis*, *Diplotaxis siettiana*, *Senecio alboran-icus*) restricted only to this flat island.

Threats to Mediterranean island plants

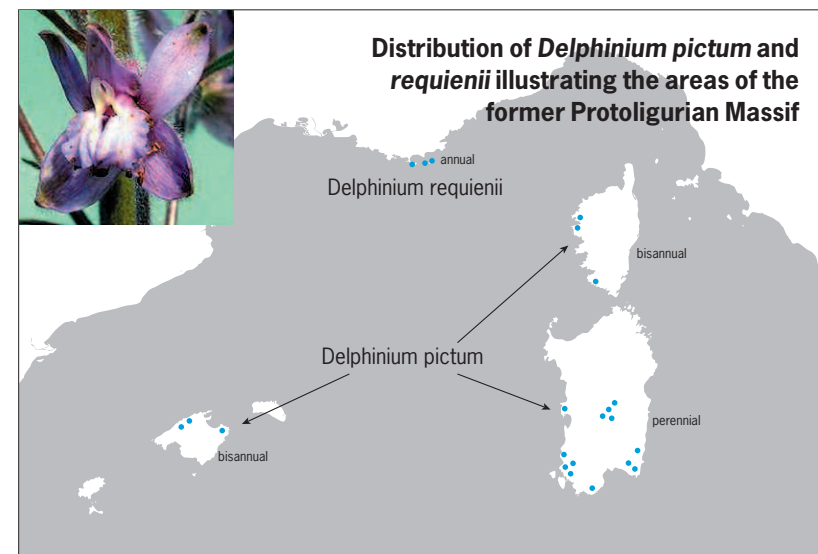
As for other Mediterranean areas, the main threats faced by island plants are mostly due to direct and indirect human impacts. These threats are manifold and they can be ranked by decreasing order of importance: urbanisation, tourism and recreation, environmental changes (land-use and global warming), biological invasions, fires, collecting pressures.

From a demographic point of view, two different situations exist. The major islands are usually characterised by an increase of human population, whereas the smaller islands (with the exception of hotspots of tourism such as Capri, Corfu and Djerba) are subject to a clear demographic decline. Since the 1960s, tourism on islands has increase extensively,

with a paroxysm on some Balearic islands (Majorca and Ibiza) where a peak was reached in 2000-2001 with 11 million tourists. 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, wetlands and to a lesser extent coastal rocky habitats. For example, on the Greek island of Skiathos tourism development since the 1970s has produced an 80% reduction of these coastal ecosystems.

Changes in agricultural and livestock farming extending inland have induced a recent collapse of the traditional Mediterranean tryptique of land-use (agriculture, pastoral, forestry) which has moulded insular landscapes during several centuries. Diverse trends in landscape dynamics cause major modifications to the structure and composition of insular ecosystems. 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 Corsican flora, even if only 6% are well established (171 naturalized taxa), 9.2% (184 taxa) of Sardinian flora, and 8.4% (124 taxa) of Balearic Islands flora.

Despite these diverse threats and the fact that a large number of endemic plant species are narrowly distributed in a single island with low populations, only a small number of plants seems to have become extinct in the Mediterranean islands. But each disappearance constitutes an irreparable loss of evolutionary history. Of about forty Mediterranean plants presumed extinct, ten species are strict insular endemics. 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 the 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*). In the eastern Mediterranean, two endemics from Thasos (*Geocaryum bornmuelleri* and *Paronychia bornmuelleri*) are presumed extinct, and one pink (*Dianthus multinervis*) from the remote islet of Jabuka in Croatia. Therefore, the unique flora of Mediterranean islands is on the whole deeply threatened, especially the endemic species which grow in coastal and low altitude habitats. On large islands, the percentage of taxa that are threatened ranges from 2% (Corsica) to 11% (Crete). In Corsica, as much as 90% of local extinct plants (74 taxa) occurred at low altitude, between sea level and 800 m, and they were mainly located in arable fields, wetlands, coastal areas and rocky grasslands.

Owing to their uniqueness and fragility, Mediterranean islands, even the smallest ones, urgently need some integrated and ambitious conservation planning for the long-term preservation of this outstanding biotic heritage.

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Indigenous plant richness and endemism, and threatened vascular plants of seven important Mediterranean island groups

islands	areas (km ²)	plant species	endemic plant species	endemism level %	endemic genera	extinct and endangered plants
Sicily	25 708	2793	321	11	Petagnaëa	87
Sardinia	24 090	2295	254	11	Castroviejoa Morisia Nananthea Soleirolia	63
Cyprus	9 250	1620	170	10		51
Corsica	8 748	2325	316	11	Castroviejoa Morisia Nananthea Naufraga? Soleirolia	47
Crete	8 729	1735	209	12	Horstrissea Petromarula	193
Balearic islands	4987	1729	173	10	(only on Menorca, Mallorca, Cabrera) Femeniasia Naufraga Soleirolia	69
Malta	316	700	16	2	Cremonophyton Palaeocyanus	16