Chapter 1
The Balearic Islands

Lleonard Llorens and Lorenzo Gil

Abstract The Balearic archipelago is located in the western Mediterranean Sea, just off the east coast of the Iberian Peninsula. The archipelago comprises four principal islands and some minor islands and islets, 10 of which are larger than 25 ha. These islands have a Mediterranean climate, mainly thermo-Mediterranean, although we can find meso- and supra-Mediterranean climates in the mountains of Majorca. Ombroclimates are present from humid to semi-arid, although sub-humid and dry are the most common. The lack of connections with the European continent since the Pliocene-Pleistocene periods and the inter-island isolation has resulted in the separation of two biotic sub-archipelagos: the Gymnesics (Majorca, Minorca and Cabrera) and the Pityusics (Ibiza and Formentera). The predominant forest vegetation consists of the evergreen forests, woodlands and sclerophyllous shrublands dominated by *Quercus ilex*, *Pinus halepensis*, *Olea europaea*, *Pistacia lentiscus* and *Juniperus turbinata*. In Majorca, broadleaved forests of *Acer granatense* and shrublands of Balearic boxwood (*Buxus balearica*) are also present. In the Gymnesics, some riverside forests exist (principally of *Fraxinus angustifolia*), and in the coastal areas, *Tamarix* forests are common. Scrub and grasslands constitute the most important substitution vegetation. Among the former, endemic Gymnesic cushion-like formations (xeroacanthic thickets) are common as well as the thermophilous garrigue (especially remarkable in the Pityusics). Grasslands are more diverse; the most important ones are dry perennial grasslands (of *Brachypodium retusum* and of *Allium chamaemoly*), pseudo-steppic grasslands of *Ampelodesmos mauritanica* (related to wildfires) and *Hyparrhenia*, annual grasslands on carbonate-containing substrata, annual grasslands on non-calcareous soils with *Xolantha guttata* (in parts of the North of Minorca), annual grasslands on skeletal soils rich in succulents, and annual grasslands on sandy soils and dunes. Endemic grasslands related to trampled soils of old cattle paths are unique and very scarce. The length and diversity of the archipelago's coast and the importance of sea wind, especially in Minorca and some parts of Majorca, determine the importance of salt-marsh vegetation, dunes and coastal cliffs, which are also very unique. The existence of pronounced relief, especially steep in Majorca, favors the diffusion of different types of rupicolous

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J. Loidi (ed.), *The Vegetation of the Iberian Peninsula*, Plant and Vegetation 13,
DOI 10.1007/978-3-319-54867-8_1

vegetation in which numerous endemic species can be found. On the other hand, long, intense human pressure (agriculture, touristic and urban) has emphasized the importance of synanthropic vegetation.

1.1 Introduction

Location, Geology and Relief The Balearic archipelago is located in the western Mediterranean Sea, off the eastern coast of the Iberian Peninsula (90 km) and at comparable distances away from the southern coast of France, the north coast of Africa and the island of Sardinia. The Balearic archipelago is composed of four main and populated islands: Majorca (3610 km^2), Minorca (701 km^2), Eivissa (Ibiza) (541 km^2) and Formentera (82 km^2); as well as more than 146 minor islands, among which the Cabrera sub-archipelago, south of Majorca. This last group of islands has a surface of 5,014 km^2 and is bound by 1240 km of coast.

The Balearic archipelago includes the Gymnesic Islands (Majorca, Minorca and Cabrera) and the Pityusic Islands (Ibiza and Formentera). The current biogeographic pattern of Balearic taxa is derived from different palaeogeographic and climatic events that took place during the Tertiary and Quaternary periods. The theory of plate tectonics allows a reconstruction of the geological history of the archipelago. According to most tectonic reconstructions (Álvarez 1972; Rosenbaum et al. 2002) of the Upper Miocene geological period, the Balearic Islands, Corsica, Sardinia and Kabylies were once linked to the continent and formed the northeastern part of the mountain ridge of the southern Iberian Peninsula. The Balearic-Kabylies block separated from the Corsica-Sardinia-Calabria block in the Late Oligocene (ca. 25 Ma). Subsequent events due to the drift of microplates in the western Mediterranean have linked and divided the different areas recursively through marine transgressions (De Jong 1998) and the promotion of isolation (Fig. 1.1).

During the Messinian Salinity Crisis (5.59–5.33 Mya) (Krijgsman et al. 1999), land bridges between the islands and mainland probably acted as corridors, allowing exchanges of taxa between the mainland and the islands, at least between the nearest places (Schule 1993; Bocquet et al. 1978; Hsü et al. 1977). In the early Pliocene, Ibiza-Formentera (Pityusic Islands) became separated from the Gymnesics (Majorca and Minorca) by a marine transgression (Colom 1978). Majorca, Minorca and Cabrera formed a single entity (the Great Balearics) during some stages of the Pliocene and Pleistocene. Since then, no connections between the Balearic Islands and the mainland are known. Moreover, the final separation of Majorca and Minorca happened after the Pleistocene climatic oscillations (c. 13,000 ya) (Colom 1978; Contandriopoulos and Cardona 1984), although eustatic sea level fluctuation during glacial-interglacial phases could have connected these islands several times during the Pleistocene (Kaiser 1969). As a result, from a biogeographical perspective, the Balearics contain two groups of islands: the Gymnesics and the Pityusics. The eastern and larger group forms the Gymnesics, which includes as principal islands Majorca and Minorca as well as the small island of Cabrera. The western group

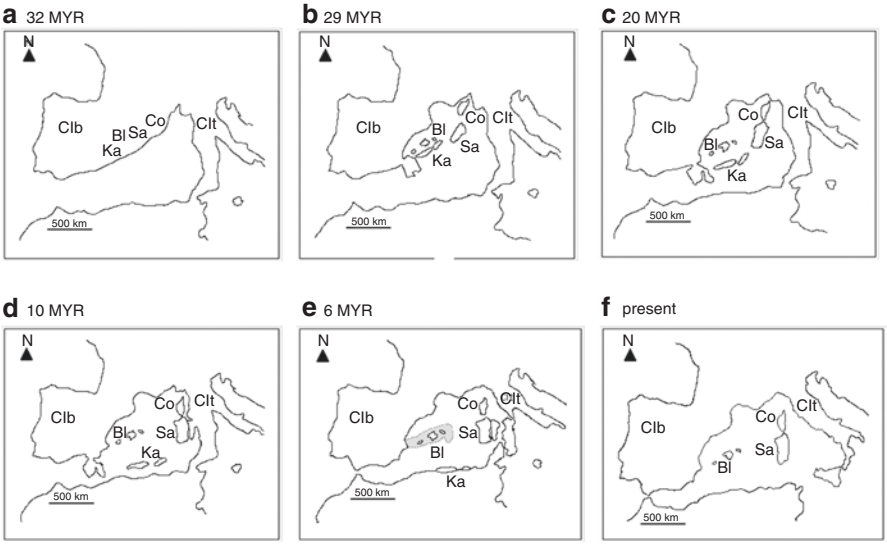

Fig. 1.1 Geological evolution of the peri-Tyrrhenian area. Panels (**a**) to (**f**) show reconstructions of the split of the Western microplates from the Iberian Peninsula. (*Ib* Iberian Peninsula, *Bl* Balearic Islands, *Sa* Sardinia, *Co* Corsica, *CIt* Continental Italy, *MYR* million years), *Grey* posible connections during Messinian Salinity Crisis (Adapted from Meulenkamp and Sissingh 2003)

(Pityusics) includes the island of Ibiza, as well as Formentera and numerous small islets.

The largest island, Majorca, as well as Ibiza and Formentera, are formed mainly of calcareous soils; in contrast, Minorca has in its northern part a considerable extent of land without calcium carbonate. The relief of Majorca is the most varied among all of the islands. It comprises a central plain (which has only six little isolated mountains each with an altitude of less than 550 m), bordered on the northwest by the Serra de Tramuntana and on the southeast by the mountains of Llevant. The Serra de Tramuntana is a continuous, mainly karstic mountain range with numerous peaks over 1000 m and with a maximum elevation in the Puig Major of 1445 m in the central area. The Serres de Llevant are of a lower altitude (maximum 509 m high). Minorca lacks high high mountains. The highest points are located in the centre of the island (El Toro 358 m, S'Enclusa 276 m). In the north of Minorca there are several low hills, separated from one another by short and narrow valleys, which allow the formation of marshes along the coast. The south of Minorca consists of a flat calcareous area, crossed by deep cliffs that end up forming coves. The relief of Ibiza is quite hilly. Towards the northwest is where the most mountainous area is located, Es Amunts, which form a coast lined with strong cliffs. The highest point of the island, S'Atalaia de Sant Josep, is 476 m high. Many coves can be found all around the island. The southeast of Ibiza is the lowest and flattest area, where salt marshes and dunes can be found. Formentera and Cabrera are small limestone islands, the former with a significant proportion of materials of dune origin.

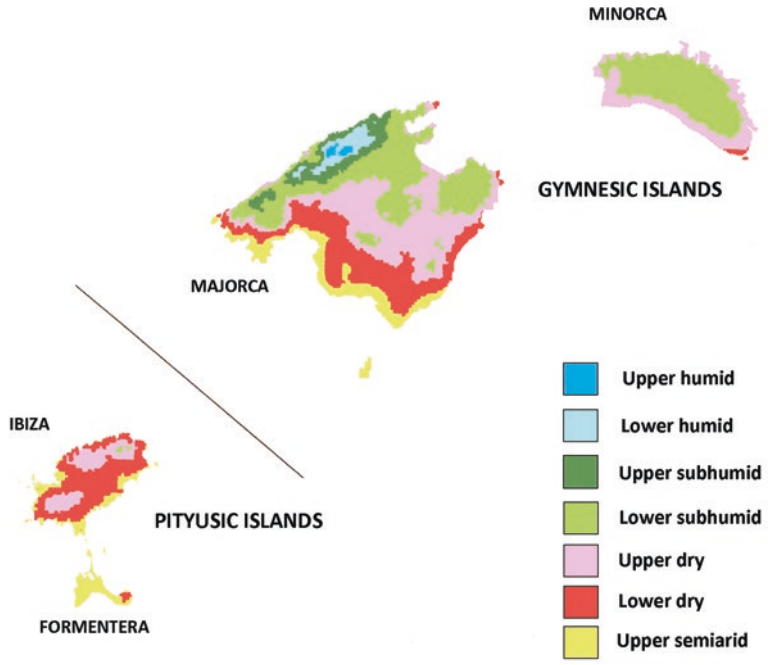

Fig. 1.2 Ombroclimatic map of the Balearic Islands

Climatic Features The Balearic Islands are completely enveloped in the Mediterranean climatic area of southern Europe, with a dry summer. More precisely, supra-, meso- and thermo-Mediterranean thermotypes and ombrotypes between humid and semi-arid can be found (Fig. 1.2). Rainfall increases from W to E, from S to N and with higher altitude. Thus, annual rainfall is approximately 350 mm in the southern areas and may reach 1500 mm in the highest mountain areas of the Serra de Tramuntana. Nevertheless, in most parts of the territory, the rainfall is between 450 and 650 mm. Generally, rainfall is greatest in autumn, followed by spring, then by winter, then by summer. Approximately 40% of the total rain falls during autumn, from September to November, and 25% in spring, from March to May. Furthermore, the proximity to the sea, favours high humidity percentages, which reach annual averages of 80% in coastal areas.

Wind is another important feature of the islands' climate and has an especially strong influence in Minorca, Formentera and the Serra de Tramuntana in Majorca. The most important winds are the ones from the North (Tramuntana) in Minorca and the Northeast wind (Mestral) in the northern part of Majorca. These winds come from the pressure distribution that emerges around the Pyrenees due to orographic interaction, which creates an acceleration and, afterwards, a displacement due to inertia in the flow towards the gulf of Leon, where it gradually loses strength due to the influence of the sea (Campins 1998). Additionally, sea breeze is an important feature of the summer in Majorca. The origin of this breeze is the daily heating of

the land with respect to the sea. When the air gets hotter, it ascends and attracts the cooler maritime breeze towards the centre of the island. Thus, in coastal areas, daily temperatures during summer are moderate and humidity is high.

Floristic Affinity The Balearic Islands have a closer floristic affinity with the Iberian Peninsula than with the Tyrrhenian Islands (Corsica and Sardinia). However, this second relation is especially noticeable in the Gymnesics, and it is reflected in the number of common or related endemic species (Tyrrhenian element), including various palaeoendemics. On the other hand, genetic drift is an important driving force of the evolutionary diversification of the plants of the Balearic Islands, while processes of long-distance migration have played a minor role in structuring diversity patterns.

Human Influence As in other territories of the Mediterranean region, human influence has been a major biotic factor. The terrestrial mammal fauna of the Balearics had enjoyed great stability for more than five million years prior to human contact. The arrival of humans, probably between 2350 and 2150 B.C. (it seems that the Balearic Islands were the last ones to be colonized), provoked drastic changes. Several autochthonous species suffered extinction, and some new species were introduced. Among the first species to go extinct was a most remarkable, endemic, even-toed ungulate (goat) of Pleistocene origin, *Myotragus balearicus,* which until the humans' arrival had a great impact on the development of certain types of vegetation. With the arrival of Romans, other ecological changes took place. Thereafter, the current Balearic landscapes have been strongly influenced by the impact of the many people who have inhabited the islands during the past centuries. Fourteen cultural landscapes can be recognized, and all but three are related to traditional agriculture and farming; they range from dry farming types to irrigated farming. At present, the Balearic landscape is a mix of natural and ancient cultural relict landscapes, as well as many modern urban-tourist landscapes, mainly in the coastal areas.

1.2 Forests, Woodlands and Sclerophyllous Shrublands

The Balearic Islands have abundant forest vegetation (de Bolòs 1996; Rivas-Martínez et al. 1992a, b). Forests and woodlands (*maquia*), which represent the mature stage of vegetation development, occupy large surfaces of the various islands and are an important feature of the general landscape. Nevertheless, the absence of rivers and the limited extent of supramediterranean bioclimate (which is only present in the high mountainous areas of Majorca) lead to a scarce and concentrated distribution of hardwoods and marcescent vegetation (Querco-Fagetea sylvaticae). On the other hand, human settlement and the development of agriculture have led to the management of the best areas for the development of forest vegetation as croplands or for the production of timber or fuel (firewood). This history explains why most of the primeval forests have been substituted by other, less mature formations,

which often prefer more xeric environments. It is also important to consider that the development of different types of vegetation are determined by the quality and intensity of human activity, as for instance in the case of the holm oak forests, *Quercus ilex,* which have been appropriately cared for and not only used as a forest resource but also as a source of fruit for feeding pigs. As a consequence of all of these historical factors forests with original characteristics are rare, and areas occupied by secondary forest prevail, often pinewoods or woodlands (such as wild olives or *Arbutus* formations).

1.2.1 Deciduous and Riparian Forests (Querco-Fagetea sylvaticae and Salici-Populetea)

Current climatic conditions determine that areas suitable for the development of these forests are scarce. Only few suitable sites can be found in the area of Serra de Tramuntana in Majorca, with a supramediterranean climate and sub-humid or humid ombroclimate, in which the average temperature in January is between −1 and 4 °C, or with hydrological compensation during the warm seasons; these habitats often have hydromorphous soils (banks of streams). These conditions are rare in Majorca and Minorca and very rare in Ibiza. Insularity has also been a constraining factor for the arrival of new deciduous species to substitute extinct ones during adverse climatic periods, and this contributed to their current low diversity, particularly in the riparian forests. Moreover, the autochthonous character of many species from these forests is certainly doubtful.

The main mountain formations have been reduced to broadleaved forests of *Acer granatense* (Primulo balearicae-Aceretum granatensis) and *Corylus avellana* wood vestiges. Currently, the former can only be found in the upper, shaded areas of the main mountain peaks (mainly Puig Major and Massanella). Isolated fragments of the community, composed of bushes, within the rugged terrain on the north-facing slopes of the highest mountains, are easier to find. However, in this rupicolous situation, it is not possible to recognize any type of vegetation structure. The lack of deciduous *Quercus* (which are basically only present in small groups or isolated in riparian formations) favours the development of communities dominated by other species, such as *Acer granatense, Sorbus aria*, *Amelanchier ovalis*, *Lonicera pyrenaica* subsp. *majoricensis*, *Helleborus foetidus* var. *balearicus*, *Primula acaulis* subsp. *balearica, Hedera helix*, *Tamus communis* and, more occasionally, *Ilex aquifolium*, *Taxus baccata* or *Buxus balearica*.

Poplar woods (Vinco difformis-Populetum albae) and field elm–narrow-leaved ash (Vinco difformis-Fraxinetum angustifoliae) forests are the only riverbank forests that, at present, occupy noteworthy surfaces, although they do not cover large areas and, in fact, are often fragmented. Thus, only in the proximity of upwelling water can populations of field elms (*Ulmus minor*) or alvar poplar (*Populus alba*) be found, often under the dominance of plane trees (*Platanus* × *hispanica*). At the

stream banks, abundant ash forests (Vinco difformis-Fraxinetum angustifoliae) can be found, in which the most predominant species is *Fraxinus angustifolia*, which can be accompanied by other species of allochthonous or doubtful autochthonous character, such as *Platanus* × *hispanica* or *Quercus* × *cerrioides*. The semicaducifolious spiny bush (Prunetalia spinosae) which accompanies this type of vegetation appears more regularly in Minorca and the humid areas of Majorca, while being more scattered in Ibiza. Typical species of these formations include *Coriaria myrtifolia*, *Crataegus monogyna, Osyris alba*, *Prunus spinosa, Rosa sempervirens*, *Rubus ulmifolius, Arum italicum, Brachypodium sylvaticum, Ranunculus ficaria,* etc.

1.2.2 Evergreen Forests, Woodlands and Sclerophyllous Shrublands

Some of the most relevant features of Majorca's sclerophyllous forests and shrublands, which define the aesthetics of its landscape, are the small physiognomic modifications that the landscape suffers from one season to another. In the Balearic Islands, this vegetation is composed of holm oak forests, pine tree forests and closed woodlands, which represent climatophilous vegetation. Two types of such vegetation are present: oak forests (Quercetalia ilicis) or pine forests and sclerophyllous woodlands (Pistacio lentisci-Rhamnetalia alaterni). There are two types of holm oak forests belonging to the former category: the ones from the mountains (Cyclamini balearicae-Quercetum ilicis) and the thermophilous ones (Clematido cirrhosae-Quercetum rotundifoliae). Pine forests and sclerophyllous shrublands are more complex, among which are included olive tree and mastic woodlands and secondary pine forests (Cneoro tricocci-Ceratonietum siliquae, Prasio majoris-Oleetum sylvestris, Aro picti-Phillyreetum rodriguezii), primary pine forest and juniper woodlands (Cneoro tricocci-Pistacietum lentisci, Junipero turbinatae- Pinetum halepensis, Rhamno-ludovici-salvatoris-Juniperetum turbinatae), *Arbutus* shrublands (Ampelodesmo mauritanici-Arbutetum unedonis), Balearic boxwood communities (Genisto majorici-Buxetum balearici), myrtle formations (Clematido flammulae-Myrtetum communis), communities dominated by mediterranean Smilax (Smilaco balearicae-Ampelodesmetum mauritanicae), formations of tree spurge (Euphorbietum dendroidis), spiny buckthorn dwarf-shrub (Cneoro tricocci-Rhamnetum bourgeani) and the juniper shrublands from coastal dunes (Clematido cirrhosae-Juniperetum turbinatae and Rubio longifoliae-Juniperetum macrocarpae) (Figs. 1.3 and 1.4).

Holm-oak Forests The typical holm oak forest (alzinars) of the Balearic Islands (*Quercus ilex* subsp. *ilex*) is widely present at mesic sites, such as hillsides and humid valleys of the Serra de Tramuntana in Majorca between 500 and 800 m (on mesomediterranean soils of a humid ombroclimate), and in Minorca. In contrast, plants with characters of *Quercus rotundifolia* (syn. *Q. ilex* subsp. *ballota*) grow at

Fig. 1.3 The sclerophyllous shrubs of *Juniperus oxycedrus* subsp. *macrocarpa* (cadequers) on dune sands represent one of the most particular woodland formations of the island of Majorca. They are located only in the bay of Alcudia, where human pressure has limited their survival to some protected zones around the beach of Muro

Fig. 1.4 The sclerophyllous shrubs of *Juniperus phoenicea* subsp. *turbinata* are a clear example of the strength of this species. In the dunes, the continuous movement of sand and the influence of wind, favor the development of ancient specimens with unique morphologies

more xeric places (in mesomediterranean dry or thermomediterranean dry-subhumid bioclimates). Therefore, the fundamental niche of *Quercus roundifolia* potentially covers all of Ibiza and the lower areas of Majorca. Nevertheless, most holm oak populations have intermediate features between both taxa. The heterogeneous character of the populations, developed in such a confined space as an island, could be a consequence of the manifestation of major or minor parental characters. This fact could be related to the features of the habitat in which each population has developed and to the historical treatment of each forest. In this respect, it is important to remember that *Quercus ilex* and *Pinus halepensis* have been, until some decades ago, the main and almost only resource of fuel (firewood) and wood on the islands.

In terms of diversity, the Balearic holm oak forest stands out for the poverty of species in its undergrowth. Thus, the Clematido cirrhosae-Quercetum rotundifoliae contains *Quercus*, often accompanied by *Pinus halepensis,* and a mix of bushes and lianas, such as *Arbutus unedo, Pistacia lentiscus, Olea europaea, Phillyrea latifolia, Osyris alba, Teucrium chamaedrys* subsp. *pinnatifidum, Rubia peregrina* subsp. *longifolia, Clematis flammula, Asparagus acutifolius, Smilax aspera*, etc. The mesic holm-oak forests, the Cyclamini balearicae-Quercetum ilicis, on the contrary, are rich in herbaceous species, such as *Carex distachya, Cephalanthera longifolia, Cyclamen balearicum, Epipactis helleborine, Monotropa hypopitys, Neottia nidus-avis* and *Viola alba* subsp. *dehnhardtii,* and with bushes, among which the most common ones are *Daphne gnidium, Erica arborea, Euphorbia characias, Phillyrea latifolia, Rhamnus ludovici-salvatoris, Ruscus aculeatus* and *Viburnum tinus.*

Pine Tree and Sclerophyllous Shrublands These associations are common and varied. This fact is related to the ability of these associations to act as potential, permanent or seral vegetation. Pinewoods (*Pinus halepensis*) are located on all the islands and, as a whole, they form the largest associations. Wild olive woodlands and mastic tree (ullastrar) woodlands are unique and abundant in the Gymnesics (Cneoro tricocci-Ceratonietum siliquae, Prasio majoris-Oleetum sylvestris). Among these, wild olive woodlands stand out in the southern areas of Majorca and Minorca, which may be considered one of the original refuges of this species in Europe. They mainly grow on red clayey soils developed on limestone rocks from the Miocene or Pliocene periods. In these communities are also commonly found *Pistacia lentiscus, Phillyrea* spp., *Cneorum tricoccon, Rhamnus alaternus, R. lycioides, Asparagus albus, Asparagus horridus, Ephedra fragilis, Prasium majus, Smilax aspera, Clematis cirrhosa* and *Rubia peregrina*. In the more xeric areas of Majorca, generally more affected by fires, with less developed wild olive, the presence of the Mediterranean fan palm (garballó, *Chamaerops humilis*) is common.

Formations dominated by *Smilax aspera* and *Ampelodesmos mauritanica* are relevant in the subhumid or humid areas of Majorca and also in areas subject to fires and soil erosion. On the other hand, *Myrtus communis* woodlands are sometimes present on hydromorphic soils. The *Euphorbia dendroides* formations present remarkable morphological similarities with the *tabaibales* from the Canary Islands, due to the conspicuous traits of the dominant species, *Euphorbia dendroides*. These are its intricate branching (dichotomous or trichotomous at the apex), succulence, seasonal foliar changes, epicuticular wax coverings and thickening of the epidermis.

Fig. 1.5 Balearic boxwood (*Buxus balearica*) communities have a dolomiticulous and thermophilous character. Currently, they are relicts and only occur in Majorca and Cabrera. They preferentially occupy enclaves of eroded slopes of the Serra de Tramuntana mountains

These formations behave as a thermo- and edaphoxerophilous community and grow on clayey lithosols of warm areas, often on slopes facing south or east. Often, only few species are part of this community; among them are *Asparagus albus* and *Ephedra fragilis.*

Also remarkable, for their singularity and quality, are the formations of *Buxus balearica* and the *Juniperus turbinata* (savina) woodlands. The former are practically exclusive to the Serra de Tramuntana in Majorca (Fig. 1.5), and despite their rarity, they are the best developed and extensive woodlands in Europe. They preferably grow on dolomitic limestones, on slopes and rocky mountain peaks/tops and on crags and cliffs with a meso- and thermomediterranean bioclimate, and they can even go down until just some dozens of meters above the sea (as at Sant Vicenç in Pollença or on the islands of Cabrera). From the beginning of the last expansion of the Mediterranean climatic area c. 10,000 years ago, until a period that coincides with the intensification of summer droughts and the first important stage of human influence in the Gymnesics, light woodlands of *Buxus balearica* have been one of the most extensive types of vegetation on the islands. The increase of human influence and the intensification of dry summer seasons have resulted in the areal decline of these forests, which has led to the current situation of fragmentation. Furthermore, juniper woodlands are characteristic of the Pityusics (Cneoro tricocci-Pistacietum

lentisci) and southern coastal areas of Majorca and rare localities in Minorca (Junipero turbinatae-Pinetum halepensis). Ibiza and Formentera, for their xeric character, have optimal conditions for the development of juniper woodlands; consequently, these juniper woodlands, together with pinewoods, are the most extensive vegetation formations. The richness of pines and junipers (*J. turbinata* and *J. oxycedrus*) is one of the most significant features of the forest profiles from these islands. The dune juniper woodlands and pinewoods (Clematido cirrhosae-Juniperetum turbinatae and Rubio longifoliae-Juniperetum macrocarpae) constitute unique vegetation associations of the Balearic Islands (Figs. 1.3 and 1.4). They can be found on all the islands, and the ones in Majorca and the Pityusics are the most extensive and the most relevant from a landscaping point of view. These facts together with their actual conservation status determine their high quality among Mediterranean habitats.

1.3 Scrub

In the Balearic Islands, Mediterranean scrub formations present conspicuous inter-island variability apart from differences due to edaphic variation (those of the Balearic Islands grow, almost exclusively, on calcareous substrates). In general, these scrub formations share their main features with other Mediterranean formations, such as the predominance of chamaephytes and nanophanerophytes (from 0.2 to 1.5 m high), superficial roots with small or non-existing leaves that often fall in summer, the abundance of protective hairs and glands, many of which are aromatic (often used as an allelopathic mechanism), entomophilous flowers and dry diaspores. As in other Mediterranean formations, the most abundant species belong to the families *Lamiaceae*, *Fabaceae* and *Cistaceae*. Nevertheless, noticeable differences exist in the way the scrub develops/grows in the two sub-archipelagos (Gymnesics and Pityusics), and this is related to different isolation patterns that the islands have followed. However, most of these formations are not very diverse and to a greater or lesser extent share a Western Mediterranean floristic background, integrated by species such as *Anacamptis pyramidalis*, *Anthyllis cytisoides, Argyrolobium zanonii, Cistus* spp., *Coris monspeliensis, Coronilla juncea, Dorycnium pentaphyllum, Erica multiflora, Fumana* spp., *Globularia alypum, Helichrysum stoechas, Leuzea conifera, Ononis minutissima, Ophrys* spp., *Orchis* spp., *Phagnalon rupestre, Rosmarinus officinalis, Teucrium capitatum* (s.l.), *Thymbra capitata* and *Viola arborescens*; the formations also all lack or very rarely contain representatives of recently evolved genera, such as *Thymus* or *Sideritis*. In the Pityusics, these formations (Rosmarinion officinalis) are very widespread and occupy vast areas. On the other hand, despite the limited presence of endemic taxa, (*Genista dorycnifolia*, *Teucrium capitatum* subsp. *majoricum*), they harbour a remarkable proportion of unique species, some with a southeastern Mediterranean distribution, that are often predominant or common elements of the vegetation (Teucrio majorici-Corydothymetum capitati). Some examples are *Cytisus*

fontanesii, Cistus clusii subsp. *multiflorus* and several *Micromeria* (*Micromeria filiformis, Micromeria inodora, Micromeria microphylla, Micromeria nervosa*).

In the Gymnesic Islands, similar communities can be found, although they are poorer from a floristic point of view (Anthyllido-Teucrietum majorici and Loto tetraphylli-Ericetum multiflorae). The most remarkable plant is *Cistus monspeliensis* (a species that is often considered as typical of acidophilous thickets), which grows on slightly basophilous, red-clayey soils over limestone (Cabrera, Marina de Llucmajor and Llevant in Majorca or Migjorn in Minorca). Dune systems constitute favourable habitats for the development of these thickets. Those that grow on Majorca's dunes are characterized by the presence of thermophilous species, such as *Cistus clusii* subsp. *multiflorus*, *Helianthemum caput-felis, Teucrium murcicum* or *Anthyllis cytisoides,* together with other sabuliculous species*,* such as *Teucrium dunense*, *Halimium halimifolium* or the Gymnesic endemic *Thymelaea velutina*.

In contrast, cushion-like formations (xeroacanthic thickets) from Majorca and Minorca are the most unique ones. These communities belong to the Hypericion balearici, which is characteristic of the mountains and of some coastal regions. These environments, which at first seem so different, in fact share the effects of intense wind exposure (with saline deposition in coastal areas) and shallow soils subjected to strong wind erosion. These environmental characteristics, apart from pasturage, strong insolation and scarce pedogenic potential (typical of the karstic regions on the islands that are often characterized by erosion) have determined the most significant features of the plants of these communities: a rounded shape, a small size and the development of specific structures for protection against droughts and excess insolation, such as reduction of foliar surface area (leptophyllous leaves), thorny structures or hair covers. Additionally, many species have developed or promoted specific mechanisms against herbivory, such as the production of spines, or the synthesis of deterrent chemical substances. As a result, the thicket is short, not very dense, aerodynamic and aromatic (often with intense and unpleasant odours). In fact, this vegetation has a physiognomy very similar to that of the Xeracantho-Erinacion from the Baetic and Valencian mountains, which share similar environmental and edaphic affinities. However, the floristic similarities are limited: with the exception of sharing a common base in species such as those characteristic of the Rosmarinetea officinalis and a few other taxa (*Santolina chamaecyparissus* subsp. *magonica, Helianthemum appeninum*)*,* these associations do not share any other species. On the contrary, associations of the Hypericion balearici show common affinities with Tyrrhenian syntaxa or with species from the eastern Mediterranean (*Teucrium marum* subsp. *occidentale*, *Teucrium marum* subsp. *marum*, *Teucrium asiaticum*, *Helichrysum massanellanum*, *Genista valdes-bermejoi*, *Euphorbia fonqueriana*), or they contain more or less differentiated endemics (*Hypericum balearicum*, *Astragalus balearicus*, *Scutellaria balearica*, *Pastinaca lucida*, *Paeonia cambessedesii*, *Thymelaea velutina*). The early isolation of the Gymnesic Islands explains the phytogeographic profile of this type of vegetation. Thus, the lack of terrestrial connections with other territories prevented other species with dry diaspores from reassembling with the existing flora and simultaneously determined the evolution of different species, which enabled the adaptation to the conditions

Fig. 1.6 The cushion-like communities of Majorca constitute an important element of the landscape of the mountain tops (in the image, Es Teix in the Serra de Tramuntana). Here the thorny cushions of *Astragalus balearicus* confer a very characteristic landscape

derived from climatic changes. The differentiation between communities among this type of vegetation is complex, although some specific types can be recognized: Pastinacetum lucidae (scree tendency), Teucrietum subspinosi (from the mountains of Majorca), Arenario bolosii-Euphorbietum maresii (unstable, gravelly slopes), Genisto fasciculatae-Thymelaeetum velutinae (very permeable soils) and Astragalo balearici-Teucrietum marii and Santolino magonicae-Astragaletum balearici (coastal areas of Minorca and northern Majorca, respectively, Fig. 1.6).

1.4 Grasslands

Currently, much of the surface of the Balearic Islands is occupied by grasslands and wastelands rich in herbaceous plants (hemicryptophytes, geophytes and therophytes). Without the intervention of humans, this extent would probably be much smaller. In its natural state, grasslands would only grow on the driest, shallow and poorest soils, which means that they would be more abundant in the southern islands

rather than in the northern ones. All of the species of these grasslands are heliophilous and xerophilous. Within those constraints, the ecological amplitude is reflected in both the extent and the great diversity of these communities, not only in terms of number of communities but also in terms of their floristic richness.

Mesophilous Grasslands These are dense grasslands in which vigorous plants prevail (hemicryptophytes and chamaephytes). They grow on base-rich substrates with relatively deep soils and a good capacity for water storage. These formations (Hyperico perfoliati-Brachypodietum phoenicoidis and Brachypodietum phoenicoidis) are only found at places with hydrological compensation, such as at stream borders (rills), coastal slopes, etc. Common species of these grasslands are *Brachypodium phoenicoides, Allium ampeloprasum, Allium roseum, Centaurea aspera, Foeniculum vulgare, Scabiosa atropurpurea, Psoralea bituminosa, Hypericum perforatum, Kundmannia sicula, Crepis vesicaria, Convolvulus althaeoides, Urospermum dalechampii, Carlina corymbosa* subsp. *corymbosa, Reichardia picroides, Asteriscus spinosus, Cichorium intybus, Asphodelus aestivus* and *Centaurium erythraea*. Uniquely, coastal communities thrive on maritime slopes, hydrologically compensated by marine fog. Within these communities the predominance of the gramineous species *Avenula bromoides, Brachypodium phoenicoides, Dactylis glomerata* and *Festuca arundinacea*, as well as the presence of *Thapsia gymnesica* (endemic of Majorca and Minorca) is notable.

Dry Perennial Grasslands These grasslands are widespread in all potential areas of climatophilous vegetation on all the islands. The main associations in these areas are the Hypochoerido achyrophorae-Brachypodietum retusi and Allietum chamaemolyos. The first one is a graminoid formation (fenassar) in which *Brachypodium retusum* dominates, accompanied by a varied group of species, mostly hemicryptophytes and geophytes (such as *Allium antonii-bolosii, Allium sphaerocephalon, Allium subvillosum, Allium subhirsutum, Convolvulus althaeoides, Gladiolus illyricus, Linum narbonense, Narcissus elegans, Ononis minutissima, Orchis olbiensis, Leuzea conifera, Ononis pusilla, Ophrys lutea, Ophrys tenthredinifera, Ophrys balearica, Ophrys speculum, Ophrys fusca, Ornithogalum narbonense, Serapias parviflora, Serapias lingua, Asphodelus aestivus, Hypochoeris achyrophorus, Aetheorhiza bulbosa* subsp. *willkommii*, etc.). Generally, these formations grow on clayey soils with a high exchange capacity, but they are never hydromorphic. Their development is favoured by abundant dew. The Allietum chamaemolyos is a community rich in geophytes present in the south and in areas not far from the coast; Ibiza is the island where it is most abundant. This community develops early and has a strongly seasonally-variable character. Its flowering starts at the end of summer-autumn (with *Urginea fugax, Scilla numidica, Merendera filifolia, Scilla autumnalis, Scilla obtusifolia, Allium chamaemoly,* etc.) and lasts until spring (*Dipcadi serotinum, Ophrys* spp., *Ornithogalum*, etc.).

Pseudo-Steppic Grasslands These are perennial grasslands dominated by tall grasses, i.e., *Ampelodesmos*, *Dichantium, Heteropogon* and *Hyparrhenia*. *Ampelodesmos mauritanica* (càrritx) grasslands are very relevant in the northern

and mountainous areas of Majorca and Minorca (rare and fragmentary in Ibiza) and are characterized by their exposure to wildfire. These communities are tall secondary grasslands (up to two meters in height), particularly poor in species, and they replace thickets or holm oak forests. Their development is complex, but essentially depends on wildfires, the intensity of the erosion of the substrate, and the utilization intensity and type of pasturage. In general, they commonly evolve towards cushion-like formations, open thickets with little therophytic coverage or, more rarely, are substituted by other forms of grassland.

In the southern, warmer parts of Majorca and Ibiza, often on red, fine-textured soils, shorter formations dominated by *Hyparrhenia hirta* (Andropogonetum hirto-pubescentis) develop. In these formations other species are also common, namely A*sphodelus aestivus, Convolvulus althaeoides, Euphorbia serrata, Lathyrus clymenum, Micromeria graeca, Phagnalon saxatile, Psoralea bituminosa* and *Scorpiurus muricatus*, and less frequently, *Dichanthium ischaemum*, *Heteropogon contortus,* etc.

Annual Grasslands Due to the almost complete prevalence of calcareous rocks throughout the islands, only a minor portion of Minorca and very limited areas of Majorca contain a carbonate-free substratum. Thus, calcifugous grasslands are poorly represented. One such community, the Linario cirrhosae-Helianthemetum guttati, is typical and is dominated by therophytes, such as *Aira cupaniana, Briza maxima, Centaurium maritimum, Filago gallica, Galium divaricatum, Linaria cirrhosa, Linum trigynum, Plantago bellardi, Rumex bucephalophorus, Silene gallica, Tolpis barbata, Vulpia bromoides, Xolantha guttata* and *Xolantha praecox*. The annual grasslands that develop on carbonate-containing substrates, however, are very abundant and diverse. The most abundant ones are the Irido sisyrinchii-Stipetum retortae (mostly in Majorca and Ibiza) and the Airo cupanianae-Chaenorhinetum formenterae (on sandy soils in the Pityusic Islands). As in other communities in Mediterranean areas, these annual grasslands are very rich, and the list of species occurring therein is extensive: *Aira cupaniana, Althaea hirsuta, Anagallis arvensis, Arenaria leptoclados, Arenaria serpyllifolia, Asterolinon linum-stellatum, Asteriscus aquaticus, Atractylis cancellata, Avellinia michelii, Avena barbata, Bellis annua, Blackstonia perfoliata, Bombycilaena discolor, Brachypodium dystachyon, Bupleurum baldense, Bupleurum semicompositum, Campanula erinus, Cardamine hirsuta, Centranthus calcitrapae, Cerastium semidecandrum, Chaenorhinum formenterae, Chaenorhinum rubrifolium, Clypeola jonthlaspi, Crucianella angustifolia, Cynosurus elegans, Desmazeria rigida, Erophila verna, Euphorbia exigua, Euphorbia falcata, Euphorbia peplus, Euphorbia sulcata, Evax pygmaea, Filago pyramidata, Galium murale, Gagea iberica, Gastridium ventricosum, Gynandriris sisyrinchium, Hedypnois cretica, Helianthemum salicifolium, Hippocrepis multisiliquosa, Hymenolobus procumbens, Lamarckia aurea, Leontodon longirostris, Linum strictum, Medicago littoralis, Medicago minima, Medicago orbicularis, Misopates orontium, Neatostema apulum, Ononis reclinata, Parentucellia latifolia, Paronychia argentea, Paronychia capitata, Plantago afra, Polygala monspeliaca, Reichardia picroides, Reichardia tingitana, Senecio gallicus,*

Sherardia arvensis, Sideritis romana, Silene sclerocarpa, Silene secundiflora, Stipa offneri, Trifolium angustifolium, Trifolium campestre, Trifolium scabrum, Trifolium stellatum, Trigonella monspeliaca, Valantia muralis, Valerianella eriocarpa, Vicia amphicarpa, Vulpia ciliata, Vulpia myuros, Xeranthemum inapertum, etc.

The other main formations are strongly related to specific edaphic conditions. These are:

1. Sandy soils and dunes (Chaenorhino formenterae-Silenetum cambessedesii, Laguro ovati-Silenetum balearicae, Malcolmio ramosissimae-Vulpietum membranaceae, Vulpiello tenuis-Cutandietum maritimae). See the section on coastal vegetation.
2. Skeletal soils (Saxifrago tridactylitae-Sedetum stellati, Crassuletum tillaeae).
3. Trampled soils, often on paths used by cattle or men (Crepido pusilli-Filaginetum petro-ianii, Solivetum stoloniferae, Euphorbietum chamaecyso-prostratae)
4. Saginetea maritimae. Communities dominated by *Limonium echioides*, which grow as a lawn that does not exceed 20 cm. At the end of spring it has a glowing appearance due to its reddish coloured pattern. It grows on dry, lightly compacted, sandy soils. (See coastal vegetation).

Grasslands Related to Skeletal Soils Shallow skeletal soils (1 to 4 cm deep) only allow the development of communities formed by species with the capacity to complete very short life cycles (like *Hornungia petraea, Minuartia mediterranea* or *Sagina apetala* and several bryophytes). Often, they contain specialized structures to store water from either rain or dew. Most of these belong to two families: *Crassulaceae* (*Crassula tillaea, Sedum caespitosum, Sedum rubens, Sedum stellatum*) and *Saxifragaceae* (*Saxifraga tridactylites*). The most relevant communities are included in the Saxifrago tridactylitae-Sedetum stellati and the Crassuletum tillaeae. Also belonging to this group are the rupicolous calcareous grasslands, the Alysso-Sedion albi. These are open xerothermophilic pioneer communities on superficial calcareous soils, dominated by succulents such as *Sedum album* subsp. *micranthum*, *Sedum dasyphyllum* subsp. *glanduliferum* and *Sedum sediforme.*

Grasslands Related to Overgrazed or Trampled Soils Some trampling areas, such as old cattle paths (sometimes related to the old transhumance system), are covered by special grasslands dominated by low-lying vegetation (microphanerophytes). In urban areas, communities such as the Euphorbietum chamaecyso-prostratae thrive. These are dominated by tropical neophytes (like *Soliva (Gymnostyles) stolonifera*) or by different *Chamaesyce* species. However, the more special ones are those living on soils trampled by cattle, the most remarkable being the Crepido pusilli-Filaginetum petro-ianii, which grows on southern plateaus of the Marina de Llucmajor, in Majorca. These grasslands have a winter-spring cycle and are floristically unique because of the presence of very rare species such as *Crepis pusilla, Filago congesta* or the Majorcan endemic *Filago petro-ianii* (Fig. 1.7).

Fig. 1.7 The endemic *Filago petro-ianii* grassland (Crepido pusilli-Filaginetum petro-ianii) occurs on overgrazed or trampled clayey soils, often in paths used by cattle or men. It is a microtherophytic community of ephemeral winter-spring species

There are two additional communities related to overgrazing: the Poo bulbosae-Phlomidetum italici and the Salvio verbenacae-Plantaginetum albicantis. The first, which is exclusive to Majorca and Minorca, is highlighted by the presence of the endemic plant *Phlomis italica* which is often accompanied by the non-palatable species *Carlina corymbosa, Asphodelus aestivus*, and by a limited number of smaller herbaceous plants, *i.e.*, *Poa bulbosa, Cynosurus elegans, Dactylis glomerata, Tripodion tetraphyllum*. The second association is rather xerophilous and thermophilic and is dominated by *Salvia verbenaca* and *Plantago albicans*. This species can form almost monospecific stands favoured by the allelopathic strength of its secreted products.

1.5 Hygrophilous Vegetation

In the Balearic Islands, owing to the predominance of a dry ombroclimate, hygrophilous vegetation occupies limited areas, most often associated with valleys, torrents, creeks, wetlands, springs, temporary ponds, etc. Despite their paucity, hygophilous communities are of high biotic and landscape value because they are composed of vegetation that is markedly different from the surrounding areas, favouring landscape heterogeneity, and creating the biggest contrast in such arid climates.

Their distribution in the islands is associated with the ombroclimate, and accordingly they are more diverse in Minorca, while in the Pityusic Islands they occupy residual, although not less interesting, areas.

The habitats found in these hygrophilous environments are:

- Reedbeds and subnitrophilous meadows on wet soils, rarely flooded: Molinio-Arrhenatheretea
- Helophytic vegetation: Phragmito-Magnocaricetea
- Amphibious vegetation associated with temporary ponds or seasonal flooding: Isoeto-Nanojuncetea
- Submerged herbaceous vegetation: Potametea, Ceratophylletea, Ruppietea maritimae and Charetea fragilis
- Floating vegetation: Lemnetea minoris

Among the Molinio-Arrhenatheretea communities, the most prominent and unique association is the Hypericetum cambessedesii. It grows only in the northern half of the Serra de Tramuntana at creek beds or rocky margins and more humid areas next to springs. The endemic *Hypericum hircinum* subsp. *cambessedesii* characterizes this community, which often contains other smaller herbaceous species.

As regards helophytic vegetation, we can observe extensive reeds in wetlands and some creeks. More interesting is, however, the association Helosciadietum nodiflori, which is formed by basophilic communities constituted of hardened broadleaved helophytes such as *Helosciadium nodiflorum*, *Rorippa nasturtium-aquaticum* or *Veronica anagallis-aquatica*. They thrive in creek beds, wells and ditches with permanent and nutrient-rich waters. They became severely reduced in many creeks, especially in the driest areas, due to canalization and the agricultural use of springs. During the last decades they have partially recovered due to the spill of post-purification waters that provides an almost permanent source of nitrogenous water in the torrents. Among all of the helophyte communities, the most special belong to the Isoeto-Nanojuncetea**.** This vegetation develops in humid areas and typically occupies limited areas, on soils with a low permeability. This low permeability is responsible for the accumulation of water during autumn and winter, when the vegetation develops, while the soil becomes completely dry with the onset of spring. These formations occur mostly in the south of Majorca, Minorca and Formentera. When these temporary ponds occur over a silicic, non-calcareous substratum, formations of low reeds and ferns from the genus *Isoetes* dominate, as in Minorca and occasionally in Majorca. In the Balearic Islands we can observe several associations, including the Isoetetum duriei, Bellio bellidioidis-Menthetum pulegi or Damasonio bourgaei-Crassuletum vaillantii.

Another special community is the Apietum bermejoi. This association is found exclusively in eastern Minorca where it occupies temporarily flooded areas over non-carbonated substrates. The most prominent species, almost unique, is the Minorcan endemic *Apium bermejoi.* This species is extremely scarce, being found in only two locations. It has been recently translocated to up to five new locations, some of them with high success, in order to increase its range.

Both floating and submerged herbaceous vegetation formations are, as mentioned above, in clear decline in the archipelago because of the overuse and canalization of water springs. In the latter case, only the communities in brackish environments are able to persist.

1.6 Marine Vegetation

The maritime phanerophytic vegetation deserves special mention. These are represented by the meadows of *Cymodocea nodosa* (Halodulo-Thalassietea), *Zostera* (Zosteretea) and most remarkably *Posidonia oceanica* (Posidonietea). These latter ones represent one of the most typical habitats of the archipelago. They develop in water that varies in depth from shallow to 30 to 40 m (and exceptionally 50 m) in depth. The formations in which the leaves float on the surface are of particular interest. They are found occasionally on all the islands in calm water, normally in very narrow or almost closed coves.

All of these maritime habitats are currently endangered in the Balearic Islands. The main causes of their current delicate situation are eutrophication and other chemical changes in the water associated with spills, the construction of marinas, trawling, the anchoring of boats and yachts, and competition with invading species.

1.7 Rupicolous Vegetation

Like other Mediterranean territories, the Balearic Islands have an important mountainous topography, as a result of major geological activity. This fact determines a peculiar sea-mountain relationship in the islands, in which the steep slopes and rocky surfaces are one of the most important features of the landscape. Besides, the widespread limestone rocks favor the proliferation of karst phenomena that generate a vast number of microenvironments. In situations where there is a lack of soil and where high slopes are dominant, the conditions become unfavorable for the development of higher plants. It is impossible to establish rooted plants on bare rock, and only some vegetables, like lichens, can colonize them. However, after long periods of time, sometimes centuries, through the decomposition of the rock, the contribution of plant debris and other particles, usually aided by wind and water, an incipient soil is formed. This soil allows the establishment of other vegetables such as mosses and ferns, or even later annual and perennial vascular plants, often succulent. They, progressively accelerate the process of soil formation (pedogenesis), allowing the maintenance and stabilization of a groundcover. In addition, irregularities in the rock, such as puckers, and especially cracks, facilitate the development of these incipient soils. In order to live in strictly ‘rupicolous’ environments, plants must be particularly adapted to such inhospitable conditions and so they usually have a

"special" character. Rupicolous plants use to be small-sized, reaching at most the size of a small shrub. Of these, those that manage to establish, must be able to withstand adverse conditions on the spot for long periods of time. This fact, coupled with the limited level of competition, makes the image of a rupicolous landscape seem to remain unchanged over the course of time. In parallel, it is not uncommon to find species of relict character in these areas, testimony of extinct vegetation types by climate change or indicators of the potential of certain areas. Also, along with these, it is common to find other peculiar species, such as local endemics and other species of limited distribution.

The Balearic Islands have a wide representation of limestone crags with singular chasmophytic and comophytic vegetation, particularly rich in endemic species and relict vegetation of Tertiary origin. Calcareous tuffs are likewise abundant. However, scree vegetation has not reached a similar level of singularity and existing examples are fragmentary.

Rupicolous environment is not at all homogeneous. Conversely, various types of habitat can be distinguished within it, each of them having its own, non-interchangeable, set of species. Broadly, these habitat types can be recognized as follows: (a) that of cracks, or *chasmophytic*, which allows the establishment of plants whose roots develop deep inside the rock crevices (Asplenietea trichomanis); (b) that of slightly inclined rocks and small flat areas, or *comophytic*, with plants generally small, sometimes partially succulent, of variable duration (annual or perennial), with fine roots growing inside the sparse and insecure substrate being formed on the rock (Anomodonto-Polypodietea); (c) the *mobile screes*, which entail communities of plants that often have long roots or flexible stems that allow them to stay on these superficially unstable substrates which are highly permeable and with abundant air-filled spaces; and, (d) the places where there is dripping of calcium carbonate-rich water, that precipitates forming calcareous tuffs (Adiantetea). In addition to these, it should be considered that some rupicolous environments can be enriched in organic matter or nitrogenous substances, allowing the establishment of peculiar *chasmo-nitrophilous* communities (*Parietarietea judaicae*).

Among these types, the first two are of greater biological interest, as 25% of the islands' endemic species are found within them. Most of these species find shelter from herbivores in vertical walls. This has induced an evolutionary adaptation to the particularly stressing conditions within this environment. Because these species are already embedded within an insular environment, these adaptations often give rise to the development of new species, often by vicariance from species found in the surrounding territories.

The chasmophytic vegetation in the archipelago, grouped in the associations of the Brassico balearicae-Helichrysion rupestris alliance (especially the Hippocrepidetum balearici in Majorca and Minorca and the Thymo ebusitani-Hippocrepidetum grosii in Ibiza), are represented by communities with a spectacular appearance, particularly during the flowering season. This spectacular appearance is due to a combination of their exposed location on vertical walls together with the dominance of chamaephytic and nanophanerophytic species with intense and bountiful blooms. Such blooming shows one of the most striking adaptations to life in

those environments, where pollinators are scarce and where there is a limited production of seeds due to allogamy. Most of these species also possess other adaptations, such as medium-high percentages of allogamy, small diaspores capable of anemochory or baro-anemochory, as well as extensive root systems with great penetration capacity into the fissures and cracks of the rock. In the Balearic Islands, the most remarkable examples of these formations are found in Majorca (in particular in the Serra de Tramuntana and Serres de Llevant) and in the Pityusic Islands (Amunts de Eivissa and La Mola in Formentera). In Minorca, due to its flat topography, these habitats are only found in El Toro and a few ravines. In all of them, important populations of endemic species, such as *Crepis triasii*, *Hippocrepis balearica*, *Hippocrepis grosii*, *Helichrysum crassifolium* or *Galium crespianum* are found.

Comophytic vegetation includes communities that develop on other plants or that live on skeletal lithosols in shady locations. These habitats are formed on the landings of walls and rocky slopes, especially those facing north. Bryophytes, ferns, chamaephytes and hemicryptophytes, often crawling or decumbent, dominate these communities. The most prominent comophytic vegetation of the archipelago is included in the association Arenarion balearici. These communities are found in all the islands, but are especially abundant in Majorca and Minorca. They are located in cool areas such as those exposed to coastal fog. Some authors (e.g., de Bolòs and Molinier 1958) believe that these communities, rich in endemic species, have a relic character, associated with fresher and wet periods during the late Tertiary. The endemic character of this type of vegetation is particularly relevant, reaching 40% endemicity, including species such as *Carex rorulenta*, *Sibthorpia africana*, *Naufraga balearica*, *Oxalis ferae* or *Brimeura duvigneaudii*. Another group of species, which reinforce the hypothesis of a relic origin, include *Cymbalaria muralis*, *Arenaria balearica*, *Soleirolia soleirolii* and *Bellium bellidioides*. Another defining feature of this vegetation is its variability. The Sibthorpio africanae-Arenarietum balearici is most prominent because of its extent and heterogeneity, and can be found on all the islands, although in Ibiza and Formentera its occurrence is very limited. Another example is the Solenopsio balearicae-Naufragetum balearicae association, which is found in the coastal areas of the northeast of Majorca.

Some human interventions have additionally modified the original rupicolous conditions further creating the so called chasmo-nitrophilous environments, such as walls in the vicinity of human habitations, terraces, etc. On the islands these contributions are very important, and that decisively influences on both the biological richness they possess, as well as on their rural landscape. Noteworthy examples are the shady terraces of the middle- and lowlands of the Serra de Tramuntana where these elements, in addition to defining the landscape, are conducive to the development of some peculiar subnitrophylous communities, in which thrive new species of hybrid origin in the genus *Asplenium*.

1.8 Coastal Vegetation

The coastal vegetation of the Balearic Islands can be partitioned into four distinct categories: dune systems, salt marshes, rocky cliffs and ornithocoprophilous vegetation.

Dunes The dune systems of the archipelago, unlike those of most of the Western Mediterranean, receive little input of sand. Only the north of Majorca and Minorca receive significant deposits of sand. This fact structures the vegetation of the moving dunes and their geomorphology (Rita and Tébar 1990). Thus, the dune systems of southern Majorca, Minorca and the south of Ibiza and Formentera have dune formations oriented parallel to the sea. The communities of grasses typical of these systems correspond to the Cypero mucronati-Agropyretum juncei with *Elymus farctus* as the most representative species. In these dune systems the Medicagini marinae-Ammophiletum australis is also found. In contrast, in the north of the two main islands, the important influence of northerly winds causes the dunes to be oriented perpendicular to the sea. There, communities of the Ammophilion australis dominate the landscape.

A noteworthy element is the vegetation of beaches that are protected from wind and currents. In these environments, the supply of sand is even smaller, and grasses, which are virtually absent, are replaced by a guild including *Pancratium maritimum* and *Eryngium maritimum* as its main species (Fig. 1.8). *Posidonia oceanica* remains contribute substantially to most of the beaches of the islands. During the storms of autumn and winter, large amounts of plant remains are deposited. These deposits have great influence on the dynamics of the dune system. First, they reduce the impact of these storms; second, they constitute one of the few sources of organic matter and substrate to the dune. Current human practices that involve the removal of these residues significantly alter the dune dynamics. One major consequence is the impoverishment of *Cakile maritima* communities. Thus, the populations of species as *Chamaesyce peplis* have diminished in the islands. Others, such as *Cakile maritima* or *Glaucium flavum*, have been displaced from their original habitat to depressions or post-dune plains where the remains of *Posidonia* are stored.

In grey dunes, the communities of the Loto cretici-Crucianelletum maritimae, dominated by chamaephytes (*Crucianella maritima, Lotus cytisoides, Teucrium dunense* or *Helichrysum stoechas*), are well represented, especially in the large dune systems of all islands.

The grasslands of the Malcolmietalia (Chaenorhino formenterae-Silenetum cambessedesii, Laguro ovati-Silenetum balearicae, Malcolmio ramosissimae-Vulpietum membranaceae, Vulpiello tenuis-Cutandietum maritimae) are interesting, especially the first two, which are typical of southern Majorca and the southern Balearic Islands. They contain some locally occurring endemic species, such as *Silene sericea* var. *balearica, Chaenorhinum formenterae, Linaria pedunculata* or *Lotus halophilus*.

Fig. 1.8 At protected beaches, like Capifort (NE of Minorca), low mobile sand and seasonal deposits of *Posidonia* debris favour types of Ammophiletea vegetation characterized by the absence of grass and the dominance of *Eryngium maritimum* and *Pancratium maritimum*

Coastal Cliffs The rocky cliffs of the Balearic Islands represent one of the most unique habitats, especially in Majorca and Minorca. Factors such as salinity (both in the substrate and air) and the scarcity of nutrients, soil and water strongly condition these habitats. Therefore, a unique flora that is distinct from any of the other insular environments forms the cliff vegetation. Remarkably, the percentage of endemicity in these habitats is over 40%.

Generally, salinity decreases with increasing distance from the waterfront. The limits of this vegetation type are determined by the action of the salt spray blown inland by the wind. The amount depends on factors such as coastal geomorphology and exposure to prevailing winds and wind strength. In low and flat coastal areas that are heavily exposed to winds, these communities occupy large areas and are distinct from other types of vegetation. All of these communities are included in the

Fig. 1.9 Gymnesic communities of the Crithmo-Limonion contain a significant number of endemic species. The image (SW of Majorca) shows dominance of *Daucus carota* subsp. *majoricus* and *Limonium ebusitanum*

Crithmo-Limonietea class. In the areas closest to the sea, communities of the Crithmo-Limonion (Fig. 1.9) are located. They are particularly poor communities, dominated by chamaephytes and hemicryptophytes, and in which endemic species of *Limonium* are particularly relevant. The Balearic Islands contain a remarkable richness of this genus, which is explained by the combination of two phenomena: its peculiar reproduction, in particular the ease of forming hybrids and the presence of apomixis; and the existence of multiple microecological conditions at the Balearic coast (Gil and Llorens 1995). The species that occupy these habitats base their success on the combination of a high tolerance to salt and drought. In addition, some species of the genus *Limonium* play an important edaphogenetic role, *i.e.*, as generators of soil.

Somewhat further from the coastline, the habitats of the Launaeion cervicornis are found. These associations are exclusively present in Majorca and Minorca and are dominated by pulvinate chamaephytes, most of them spiny. The most common associations are the Launaeetum cervicornis and, in Minorca, the Euphorbio pithyusae-Anthemidetum maritimae. The abundance of endemic species present in both Majorca and Minorca (e.g., *Launaea cervicornis* and *Dorycnium fulgurans*) or only in Minorca (e.g., *Anthyllis hystrix* and *Femeniasia balearica*) is the main distinguishing feature of these habitats, which are mostly concentrated in the north of the two main islands.

Fig. 1.10 In the salt marshes Limonion confusi communities have a high number of species of the genus *Limonium*. Primarily they occupy non-flooded saline soils. Secondarily, they also develop on gypsum wastes coming from the exploitation of the salt mines

Salt Marshes Salt marshes are unique habitats in which different types of vegetation thrive characterized by their high level of specialisation. Thus, in the Balearic archipelago, extensive fruticose and annual communities dominated by succulent species (i.e., Salicornietea fruticosae and Thero-Suaedetea), *Tamarix* forests (Nerio-Tamaricetea), perennial halophilic grasses (Juncetea maritimae) and annual grasslands (Saginetea maritimae) are found. In addition, in low-salt areas, helophytic Phragmito-Magnocaricetea vegetation can develop.

The highlight of the Balearic salt marshes is found in the communities of the Limonion confusi (Llorens 1986; Gil et al. 1998, Fig. 1.10). This vegetation is characterized by the predominance of hemicryptophytes, with various species of *Limonium* as the most important and plentiful. These species, even if they exhibit a remarkable tolerance to salinity, have no ability to withstand periods of flooding. They colonize clay or sandy soils, usually with abundant carbonates and sulphates. As a result of their remarkable ability to initially colonize soils, favoured by the partially nitrophilous nature of many species, it is not uncommon to find them as part of secondary communities on mobile saline substrates, on roadsides or on deposits relatively rich in gypsum products that are obtained from the salt mines. In the archipelago, these habitats are mainly located in the salt marshes of the Pityusic Islands and in the south of Majorca. The high percentage of endemicity is once more one of the main features of these habitats, with more than 20 endemic species described in the genus *Limonium* occurring within these habitats.

The **ornithocoprophilous vegetation** in the Balearic Islands is dominated by nanophanerophytes and chamaephytes. This vegetation is characteric of soils with a certain degree of salinity and where organic matter derived from seabird guano is abundant. Their optimal location in the islands is in the semiarid thermo-Mediterranean or inferior dry bioclimates. The best examples of these habitats are located on the islets and at some coastal slopes of southern Majorca and Ibiza and Formentera. As with most unique elements, we can distinguish two types of ornithocoprophilous vegetation.

The first type corresponds to the Salsolo vermiculatae-Lycietum intricate**.** This is a low-density vegetation present on coastal slopes exposed to sun and salinity and linked to colonies of nesting seabirds. The species of this association show fleshy leaves and xeromorphy. Some prominent species with a southwestern Mediterranean distribution are *Lycium intricatum*, *Withania frutescens* and *Salsola oppositifolia*. Alongside these species, *Euphorbia dracunculoides*, a species with very scarce distribution on the Iberian mainland, can be found in the Marina de Llucmajor.

The second type corresponds to communities of the Medicagini citrinae-Lavaterion arboreae. These communities are morphologically and floristically diverse. Along with the widespread *Lavatera arborea*, some of the most singular species of the islands can be found in this vegetation. This is the case of *Medicago citrina*, a nanophanerophyte distributed only in the islets of Cabrera, Ibiza, Columbrets and one next to Alicante, in which rabbits are completely or almost completely absent. Another endemic example would be the Pityusic *Euphorbia margalidiana*, a species with a very particular ecology that occurs naturally only on the islet of Ses Margalides, Ibiza (Fig. 1.11); very recently another population has been artificially established at Illa Murada (Ibiza).

In areas with an upper dry to subhumid ombroclimate, this vegetation is replaced by Suaedion verae communities. These often correspond to monospecific populations of *Suaeda vera*.

Fig. 1.11 The pityusic Margalides islet is the single locality where the endemic *Euphorbia margalidiana* grows. It colonizes rocky crevices and sills under ornithocoprophilic conditions

1.9 Synanthropic Vegetation

The current vegetation of the islands has been intensely altered by the action of man and man-bred animals. We can say, with no doubt, that human activities carried on for thousands of years represent the most important factor structuring the current state of the vegetation of the Balearic Islands. This influence has had many degrees of intensity. The most obvious are those related to agriculture, industry and urban development. Most of the surface of the islands, especially the lower areas, has seen its original vegetation replaced by other new groups formed by plants better adapted to the new circumstances. These types of vegetation grow on substrates rich in nitrogen-containing compounds or soluble phosphates. In turn, the pace of human intervention prevents the renewal of natural vegetation, providing very particular conditions of nutrients availability and cycles. Nevertheless, some types of nitrophilous vegetation have a more original character. Before the arrival of humans, ruderal vegetation in areas where organic matter accumulated must have already existed.

In today's rural landscapes on the islands, one cannot ignore the importance of some weed communities such as the Resedo albae-Chrysanthemetum coronarii, Galactito tomentosae-Vulpietum membranaceae, Reichardio gracilis-Stipetum capensis or Diplotaxietum erucoidis. In winter and spring, these landscapes change their colour following the flowering of different species such as *Asphodelus fistulosus*, *Calendula arvensis*, *Chrysanthemum coronarium*, *Diplotaxis erucoides* or *Lavatera cretica*. On landscapes closer to populated areas, other communities are dominant, such as the widespread Oryzopsio miliaceae-Daucetum maximae (Artemisietea vulgaris).

The most unique nitrophilous communities in the Islands are integrated into the Galio-Urticetea class. Among them, the Urtico membranaceae-Smyrnietum olusatri is prominent, a thermophilic community with a lower seasonal moisture demand than others of the same class. Species such as *Smyrnium olusatrum* or *Conium maculatum* occur in it. Moreover, one of the most singular communities of the archipelago is located within a few square kilometres of the Serra de Tramuntana in Majorca. It corresponds to the original ruderal vegetation, probably linked to populations of *Myotragus balearicus*. This is the Pimpinelletum balearici formed by various endemic species of highly localized distribution such as *Urtica atrovirens* subsp. *bianorii* or *Pimpinella bicknellii* (Fig. 1.12).

1.10 Vegetation Series and Geoseries

In the absence of disturbance, the natural tendency of the Balearic plant communities is to undergo succession towards the Potential Natural Vegetation. The dynamism determines a succession of communities that has been studied by many authors (i.e, de Bolòs 1996; Gil et al. 1995; Rivas-Martínez 1987; Rivas-Martínez et al. 2001, 2002, 2011). According to this literature, the concept of Vegetation Series

Fig. 1.12 The influence of herbivores in prehuman periods is manifested in some types of vegetation. In areas close to animal resting areas, such as the cave in the picture, there are some grasslands such as the Poo bulbosae-Phlomidetum italici, or several rare types of endemic vegetation, such as communities of *Soleirolia soleirolii* or the association Pimpinelletum balearici

has been developed. In the Balearic Islands, the main units of Vegetation Series are climatophilous series or sigmeta, as well as geoseries or geosigmeta, i.e., complexes of communities conditioned by factors that prevail over climate (salinity, sea wind, sand dunes, etc.), and which are positioned along an environmental gradient.

The main units are:

1. Majorcan supramediterranean humid series of *Acer granatense* and *Primula balearica* with *Amelanchier comafredensis* and *Paeonia cambessedesii*: Primulo balearicae-Aceri granatensis sigmetum
2. Majorcan meso-thermomediterranean subhumid-humid series of *Quercus ilex* and *Cyclamen balearicum* with *Rhamnus ludovici-salvatoris* and *Clematis flammula*: Cyclamini balearici-Querco ilicis sigmetum
3. Minorcan thermomediterranean subhumid series of *Quercus ilex* and *Carex bracteosa* with *Myrtus communis* and *Pulicaria odora*: Carici bracteosae-Quercetum ilicis sigmetum
4. Majorcan thermomediterranean dry-subhumid series of *Quercus rotundifolia* and *Clematis cirrhosa* with *Olea sylvestris* and *Arisarum vulgare*: Clematido cirrhosae-Querco rotundifoliae sigmetum (=Quercetum ilicis galloprovinciale ampelodesmo-cneoretosum)

5. Minorcan thermomediterranean dry-subhumid climatophilous and edaphoxerophilous series of *Olea sylvestris* and *Prasium majus* with *Pinus ceciliae* and *Phillyrea rodriguezii*: Prasio majoris-Oleo sylvestris sigmetum
6. Majorcan thermomediterranean dry-semiarid series of *Ceratonia siliqua* and *Cneorum tricoccon* with *Olea sylvestris* and *Rhamnus angustifolius*: Cneoro tricocci-Ceratonio siliquae sigmetum
7. Pityusic thermomediterranean dry-semiarid series of *Juniperus turbinata* and *Pinus halepensis* with *Pistacia lentiscus* and *Cneorum tricoccon*: Cneoro tricocci-Pistacio lentisci sigmetum
8. Cabreric thermomediterranean semiarid-dry series of *Juniperus turbinata* and *Pinus halepensis* with *Rhamnus ludovici-salvatoris* and *Pistacia lentiscus*: Rhamno ludovicisalvatoris-Junipero turbinatae sigmetum
9. Gymnesic thermomediterranean subhumid-dry coastal edaphoxerophilous and anemogenous series of *Phillyrea rodriguezii* and *Arum sagittifolium* with *Pistacia lentiscus* and *Juniperus turbinata*: Aro sagittifolii-Phillyreo rodriguezii sigmetum
10. Majorcan thermo-mesomediterranean subhumid-dry edaphoxerophilous series of *Buxus balearica* and *Genista majorica* with *Hypericum balearicum* and *Ampelodesmos mauritanica*: Genisto majoricae-Buxo balearicae sigmetum
11. Gymnesic thermomediterranean semiarid-dry coastal edaphoxerophilous and anemogenous series of *Pinus halepensis* and *Juniperus turbinata* with *Pistacia lentiscus* and *Euphorbia dendroides*: Junipero turbinatae-Pino halepensis sigmetum
12. Gymnesic thermo-mesomediterranean riparian series and geoseries of *Populus alba* and *Vinca difformis* with *Platanus hispanica* and *Brachypodium sylvaticum*: Vinco difformis-Populo albae sigmetum
13. Majorcan thermo-mesomediterranean riparian series and geoseries of *Fraxinus angustifolia* and *Vinca difformis*, with *Ulmus minor* and *Arum italicum*: Vinco difformis-Fraxino angustifoliae sigmetum
14. Balearic-Mediterranean thermomediterranean dry-subhumid edaphoxerophilous dune series of *Juniperus turbinata* and *Clematis balearica* with *Phillyrea rodriguezii* and *Teucrium dunense*: Clematido balearicae-Junipero turbinatae sigmetum
15. Majorcan thermomediterranean subhumid edaphoxerophilous dune series of *Juniperus macrocarpa* and *Rubia longifolia* with *Thymelaea velutina* and *Lotus cytisoides*: Rubio longifoliae-Junipero macrocarpae sigmetum
16. Gymnesic thermomediterranean subhumid riparian series and geoseries of *Vitex agnus-castus* and *Rubus ulmifolius* with *Tamarix africana* and *Leucojum pulchellum*: Leucojo pulchelli-Viticeto agni-casti sigmetum
17. Pityusic and Western-Mediterranean thermomediterranean dry-semiarid riparian series and geoseries of *Nerium oleander* and *Rubus ulmifolius* with *Coriaria myrtifolia* and *Scirpus holoschoenus.* Rubo ulmifolii-Nerio oleandri sigmetum

In addition to these series, a set of relevant communities, series and vegetation complexes, with dynamics different from the general, exist. In the Balearic Islands the main ones are:

1. Halophilous and subhalophilous geosigmetum of salty and brackish marshes. Enteromorpho intestinalidis-Ruppietum maritimae, Typho angustifoliae-Schoenoplecteto glauci, Leucojo pulchelli-Viticetum agni-casti, Tamaricetum gallicae, Schoeno-Plantaginetum crassifoliae, Juncetum maritimi, Salicornietum emerici, Statico bellidifoliae-Salicornietum fruticosae, Sarcocornietum alpini, Sphenopo divaricati-Arthrocnemetum macrostachyi, Limonion confusi communities
2. Psammophilous geosigmetum of coastal dunes. Medicagini marinae-Ammophiletum australis, Eryngio maritimi-Pancratietum maritimae, Cypero mucronati-Agropyretum juncei, Sporoboletum arenarii, Loto cretici-Crucianelletum maritimae, Crucianellion maritimae, Ononido crispae-Scrophularietum minoricensis, Hypochoerido radicatae-Glaucietum flavi, Salsolo kali-Cakiletum aegyptiacae, Chaenorhino formenterae-Silenetum cambessedesii, Laguro ovati-Silenetum balearicae, Malcolmio ramosissimae-Vulpietum membranaceae, Vulpiello tenuis-Cutandietum maritimae
3. Rupicolous and haloanemogenous coastal geosigmetum. Crithmo maritimi-Limonion communities (general) and Launaeion cerviconis communities of the Gymnesics (Dactylido hispanicae-Anthemidetum maritimae, Helichryso microphylli-Dorycnietum fulgurantis, Launaeetum cervicornis, Santolino magonicae-Anthyllidetum hystricis)
4. Rupicolous and nitrohalophilous coastal geosigmetum. Suaedetum fruticosae, Soncho tenerrimi-Salsoletum vermiculatae, Salsolo vermiculatae-Lycietum intricati, Suaedo fruticosae-Salsoletum oppositifoliae, Medicagini citrinae-Lavateretum arboreae
5. Rupicolous (or chasmo-comophytic communities) Balearic inland geosigmetum. Polypodietum serrati, Bellio bellidioidis-Crocetum cambessedesii, Micromerio filiformis-Allietum antonii-bolosii, Sibthorpio africanae-Arenarietum balearicae, Solenopsio balearicae-Naufragetum balearicae, Saturejo filiformis-Asplenietum petrarchae, Hippocrepidetum balearici, Thymo ebusitani-Hippocrepidetum grosii

To these, we can add some more complexes, such as various hydrophilic formations (Lemnetum gibbae, Charetum vulgaris, Zannichellio palustris-Potametum colorati, Ranunculetum aquatilis), seasonal ponds with amphibian habitats (Bellio bellidioidis-Menthetum pulegii, Damasonio bourgaei-Crassuletum vaillantii, Isoetetum durieui), petrifying springs with tufa formation (Eucladio verticillati-Adiantetum capilli-veneris), or marine waters (Posidonietum oceanicae, Zosteretum marinae, Zosteretum noltii, Cymodoceetum nodosae).

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