Chapter 4
Island Biogeography and Landscape Ecology

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Two Cretan plant endemics a) *Ebenus cretica* b) *Origanum dictamus* and the Cretan ibex *Capra aegagrus* (Photos: Th. Arampatzis)

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4.1 Introduction

Islands have always been a source of fascination and inspiration for biogeographers. Ecological processes on islands were the focus of early work by Darwin (1859) and Wallace (1892) and later inspired a critical theory in biogeography, the theory of island biogeography (MacArthur and Wilson 1967). True islands have high rates of colonisation and extinction, unusually high proportions of endemic and relict species, and good dispersers and favour the evolution of 'peculiarities': dwarf, giant and flightless forms (Huggett 1998). The majority of comparative studies on island biogeography deal with islands in the Pacific, Indian and Atlantic oceans (Grant 1998; Whittaker 1998; Stuessy and Ono 1998). This can be partly attributed to the pioneer work in the field by Wallace and Darwin but also to the fact that these islands host diverse and sometimes peculiar species. Despite the ecological significance of the Mediterranean Islands and the pioneer work of Rechinger (1943) followed by the exceptional contribution of Greuter (1991, 1994, 1995, 2001), there have to date been only limited attempts to compare the biogeography of Mediterranean Islands (Médail and Quézel 1997; Delanoë et al. 1996; Mayer 1995; Kuhbier et al. 1984). This mainly reflects the complexity of issues related to Mediterranean Island biogeography and presents a challenge for the future, as suggested by Greuter (2001): *In the Mediterranean the choice is yours: there are about 5000 of them ……. Just define your problem and choose the island or islet tailored to your needs. And remember you may need a boat to get there*.

MacArthur and Wilson's theory (1967) set out to identify and measure the variables involved in the colonisation of islands by biota and their subsequent evolution or extinction. The key biogeographical variables identified by their theory were island size and distance from the mainland. They suggested that an island's biodiversity is proportionate to the island's size (i.e. the larger the island the higher the species number) and inversely proportionate to its distance from the mainland (i.e. more remote islands tend to support less species). Equally significantly they argued that the number of species on an island is in a state of *dynamic* equilibrium – diversity eventually stabilises but turnover remains high as species continually colonise and go extinct. Dynamism is a defining concept when attempting to understand the biogeography of islands and, in the Mediterranean in particular, the impact of human activity over millennia has resulted in very high levels of dynamism with profound consequences for the biota.

This chapter examines this dynamism in relation to some of the generalisations emerging from island biogeography (Table 4.1) and sets them in a Mediterranean context. In particular, the dynamism of Mediterranean Island biota and habitats is discussed including an analysis of the impact of recent, rapid changes in land use and the prospects for the protection of biodiversity and ecological restoration.

Table 4.1 Generalisations emerging from the Theory of Island Biogeography (MacArthur and Wilson 1967)

1. No island has nearly the number of species it would have if it were part of the mainland
2. A large island is likely to have a greater variety of habitats than a small island and therefore contain a greater diversity of species
3. Adaptation to the new environment of the island may be difficult for an immigrant (species) which is usually adapted to mainland conditions
4. The precariousness of some of the ecosystems based on low diversities of flora and fauna makes them susceptible to rapid and sometimes catastrophic change
5. Adaptations to islands take a number of well-known forms such as speciation, adaptive radiation, preservation of 'peculiar' forms of life (giants, flightless birds) due to lack of competition

4.2 Types of Islands

In biogeographical terms two broad types of islands can be distinguished: *continental* and *oceanic*. The former are located over the continental shelf and in the past were connected to the mainland. The latter are found over the oceanic plate and have never been connected to continental land masses (Whittaker 1998). Continental islands are commonly further subdivided into ancient and recent. A third island type commonly referred to in biogeography is *mainland islands*: 'islands' of habitat in a 'sea' or matrix of surrounding often hostile land use. The theory of island biogeography became one of the foundations of landscape ecology (Forman and Godron 1986).

A number of classification schemes for the origin of the Mediterranean Islands have been proposed. The majority are based on a distinction between islands of continental versus oceanic origin (e.g. Greuter 1972; Alcover et al. 1998; Schüle 1993). Islands may have even changed class type in the course of geological time (Marra 2005). This reflects the importance of geology and insularity and there is a time dimension for both. The majority of islands in the Mediterranean are of the continental type since they have been connected to the mainland on several occasions in the geological past (see Chapters 2 and 3). Many Mediterranean Islands are volcanic in origin, most famously and recently Santorini together with Stromboli, the Eolian and the Liparian islands (Schüle 1993). Other volcanic islands are older in origin, shaped by volcanic activity during the Pleistocene (Kos, Ustica, Alicudi, Filicudi) and Holocene (Melos, Salina, Panarea) (Hulme 2004). Continental type islands such as those found in the Mediterranean may shed considerable light on ecological processes (Hulme 2004).

4.3 Mediterranean Island Environments

Throughout the geological history of the Mediterranean Basin islands have changed size, appeared or disappeared altogether, split and reformed as a result of tectonic activity (as described in Chapter 2 and the individual island chapters in this book). The

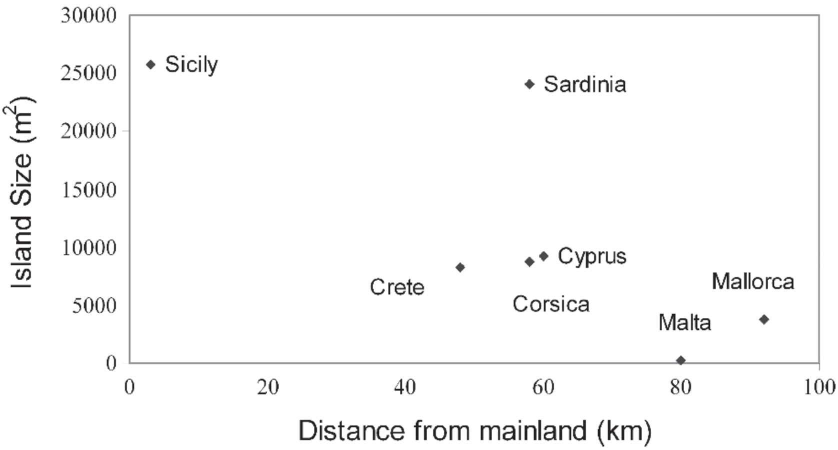

Fig. 4.1 Distribution of the Mediterranean Islands in terms of size and distance from the nearest mainland (After Patton 1996)

Mediterranean contains a complex of islands differing in shape, size, spatial arrangement and distance from the mainland (Fig. 4.1). Examples include large relatively isolated islands such as Cyprus and islands so close to the mainland, such as Sicily, to render insularity almost meaningless. There are large islands with many satellite islets around them (e.g. Sardinia and Crete) and islands in groups of various arrangements: elongated such as the Dodecanese and Ionian islands and the Kornati archipelago in the Adriatic or circular such as the Cyclades and Sporades in the Aegean Sea.

In addition these islands differ in age, isolation, geology and human colonisation history. The 5,000 or so islands present in the Mediterranean Basin display a wide range of sizes from a fraction of 1 km^2 (various islets in the Aegean Archipelagos and Dalmatian coast) to Sicily (25,708 km^2). A range of altitudes is also present from sea level to 3,323 m at Mt. Etna, Sicily. A clear climatic divide exists between the Central-West and East Mediterranean Islands. Summer drought is shorter in the West (Corsica-Sardinia) than the Eastern Mediterranean Islands (e.g. Crete and Cyprus). The Spanish islands of Alboran and Columbretes are among the driest places in Europe compared to islands near the Balkan coast such as Corfu. On islands with steep elevation gradient (e.g. Crete and Sicily) and islands close to high mountains on the mainland (e.g. islands of the Dalmatian coast) the climate is diverse. Due to their complex tectonic history the Mediterranean Islands are equally diverse geologically. Metamorphic substrates are dominant in Corsica and Sardinia, but also present in Sicily and Crete. Calcareous substrates dominate in Crete, Malta and the Balearics.

Palaeoecological and archaeological records indicate a variable pattern in the colonisation of Mediterranean Islands by humans (Chapters 2, 3, 5). At present the inhabited islands vary considerably in terms of average population density. At nearly 100 persons per km^2 island population densities are, on average, twice the

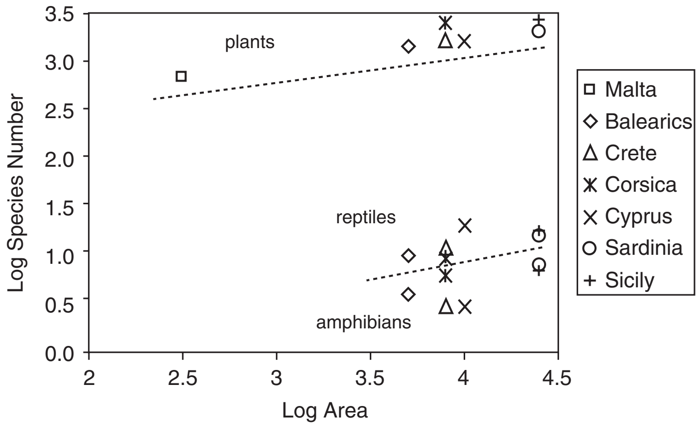

Fig. 4.2 Reptiles, amphibians and plants of the large Mediterranean Islands

average for the entire Mediterranean region. Malta is the extreme with 1,461 persons per km^2 (Chapter 13). There are many other islands that are uninhabited or have been abandoned in the last century. Some are seasonally inhabited during the summer months, e.g. Gaidouronisi near Crete, and others are visited mainly by tourists, e.g. the islands of Palea and Nea Kameni off the island of Santorini. These islands, usually of a small size, outnumber those which are inhabited.

4.4 Mediterranean Island Biogeography

It is widely recognised that the biota present on an island is a function of the island's geological age, spatial and temporal isolation from continental land masses and the length of time since islands were first colonised by humans (Whittaker 1998; Spellerberg and Sawyer 1999). For certain taxa or groups of biota smaller islands generally have fewer species than larger islands (Fig. 4.2). Although many studies have demonstrated the relationship between richness in certain taxonomic groups and area, it is widely accepted that area per se does not determine species richness (Spellerberg and Sawyer 1999). Snogerup and Snogerup (1987) suggest that the number of species in the Aegean increases significantly on islands with a length greater than 500 m and altitude higher than 50 m. The larger islands in the Mediterranean have higher alpha (i.e. numbers of species) and beta (i.e. number of habitats) diversity than islets and therefore host particular communities such as wetlands. Most importantly they are not functionally equivalent in ecological terms to an assemblage of smaller islands totalling the same area (Médail and Vidal 1998). Single islands, island chains and groups of islands may act as barriers or stepping stones for biota facilitating or inhibiting their dispersal. As demonstrated by a study on the island of Hyères in France, for islands close to the mainland the distance/isolation effect seems to influence species composition and relative abundance more than it influences richness while distance between islands played a negligible role in explaining the islands' floristic composition (Médail and Vidal 1998). In theory islands close together should have a more similar flora compared to islands that are distant from each other; this is not always the case due to dispersion difficulties. For example, in the central Aegean distances between islands never exceed 40 km (in some cases less than 10 km) but even this has had an isolating effect acting as a barrier to migration even for light, wind dispersed species (Runemark 1971). Genetic studies indicated that insular populations are genetically less diverse than the populations of their native sources (Blondel and Aronson 1999). Nevertheless Mediterranean Islands have always been a source of genetic variation (López-de-Heredia et al. 2005) and ecological differentiation (Greuter 1995, 2001).

With each human invasion of the islands (see Chapter 3) deliberate and accidental introduction of non-native plants and animals occurred. Some of these species have persisted until today. Examples include the rat (*Rattus rattus)*, house mouse (*Mus musculus)*, and rabbit (*Oryctolagus cuniculus*) while plant species such as *Agave americana, Ailanthus altissima, Carpobrotus edulis, Opuntia ficus-indica, Oxalis pes-caprae* and various *Eucalyptus* species are now part of the Mediterranean landscape.

4.4.1 Vegetation

In general islands share the vegetation types found in the Mediterranean region (Table 4.2) such as forests, open woodlands, maquis, garrigue, phrygana and steppe. Most of these categories occur, often as a mosaic of communities on

Table 4.2 The main vegetation types in the Mediterranean Islands

Term	Definition
Forest	Tree-covered land but can also include other habitats in a matrix of trees
Maquis	A dense mostly evergreen shrub community 1–3 m high characteristic of the Mediterranean region
Garrigue	A community of low scattered often spiny and aromatic shrubs of the Mediterranean region
Phrygana	Low shrub developed over dry stony soil in the Mediterranean region. In general it is an equivalent term to garrigue which is used in the West Mediterranean.
Steppe	Composed of grasses, bulbous and other herbaceous plants
Savanna	A term that denotes big trees widely spaced with an understorey of phrygana or steppe (Grove and Rackham 2001)

Table 4.3 Altitudinal zonation of the Mediterranean vegetation (After Quézel 1981; Thompson 2005)

European region	Mediterranean region	Vegetation formation
	Thermo-Mediterranean zone	Maquis or garrigue
Plains zone	Eu-Mediterranean zone	Maquis or garrigue
Hill zone	Supra-Mediterranean zone	Deciduous oak forests
Montane zone	Montane-Mediterranean zone	Upland coniferous forests
Sub-alpine zone	Lower Oro-Mediterranean zone	Thorny xerophytes
Alpine zone	Upper Oro- or Alti-Mediterranean zone	Dwarf chamaephytes

the larger islands. However, there are many variations between islands with some islands characterised by unique assemblages. Examples include the carob forests in Cyprus, the cork oak forests in Sardinia, valonia oak (*Quercus macrolepis)* forests in Crete, chestnut forests in Corsica and upland hazel groves in Sicily and Sardinia (Barbero et al. 1995). The most widely used altitudinal zonation for Mediterranean vegetation (Table 4.3) proposed by Quézel (1981) is based on latitude, and corresponds to climatic variations, especially temperature. However, it is not applicable to all the Mediterranean Islands since many of them (e.g. Malta) do not have a steep elevation gradient which affects vegetation distribution.

4.4.2 Flora

Mediterranean Island floras are different to the mainland floras, a reflection of their unique natural and cultural characteristics. The flora of the Mediterranean Islands can be classified into three broad categories according to their origin (Greuter 1979): (1) a relict element: ancestors of pre-isolation phase, (2) a telechorous element: resulting from natural long-range dispersal and (3) an anthropic element: human induced. The larger islands in the Mediterranean had significant floristic elements at the time of isolation from the mainland which, until today, have not undergone significant evolutionary change (Greuter 1995). In some cases this flora dates back to the post-Messinian transgression during the Pliocene, that is, some 5–6 million years ago (e.g. Crete, Cyprus). The Messinian Salinity Crisis (see Chapter 2) would have facilitated the interchange of biota between Africa, Asia, Europe and the former (and present) islands. Therefore, and despite the fact that the autochthonous Mediterranean element dominates, floristic elements from all three continents are represented in the islands' flora (Fig. 4.3). In many cases islands represent the southern limits of Circumboreal and northern European elements (Chapter 7) or northern boundaries of many African elements (Chapter 11); while the mountains of east Mediterranean Islands such as Crete support a significant Irano-Turanian element (Vogiatzakis et al. 2003; Kazakis et al. 2007). The floristic affinities between islands reflect their geographical position in the Basin with two

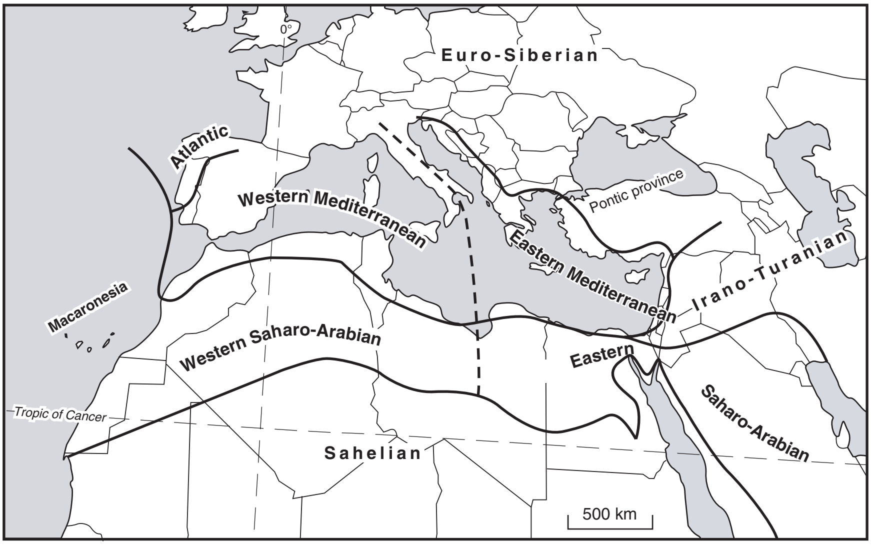

Fig. 4.3 Biogeographical realms in the Mediterranean area (Vogiatzakis et al. 2006)

distinct groups, a western (Tyrrhenian and the Balearics) and an eastern (Aegean, Crete, Cyprus).

Most of the islands in the Mediterranean are biodiversity 'hot spots' (locations of unusually high species diversity according to Médail and Quézel 1997) which have provided refuge for many endemic plant species and contributed to evolutionary differentiation (Greuter 1972, 1979; Snogerup 1985). Many plants have had to adapt to the moisture stress caused by water deficiency across many Mediterranean Islands. The flora of Mediterranean Islands includes several wild relatives of agricultural crops (Heywood 1995). All of the islands examined within this book have been subject to detailed floristic and taxonomical research (Greuter et al. 1984, 1986, 1989) but the continued discoveries of new species (Tzanoudakis and Kypriotakis 1993; Greuter and Strid 1981) and even genera (Egli et al. 1990) suggest that a complete inventory has not yet been achieved.

Most of the large Mediterranean Islands are surrounded by smaller satellite-islets of varying sizes that have been linked to the history and life of the largest islands (Table 4.4). These small islands have generally received less attention than their large counterparts. The islands of the Maltese archipelago are such examples, possibly due to their proximity to Sicily and the Italian mainland and their relative low habitat diversity. On the other hand the Aegean islands are among the best known floristically in the Mediterranean, thanks to the early work of Rechinger followed by Greuter, Runemark and Snogerup. There have always been and still are peculiarities about the floristic composition of the smaller islets and islands. For example, Rechinger and Rechinger-Moser (1951) were the first to recognise that

Table 4.4 Major Mediterranean Islands and their satellite islets

Main island or Archipelagos	Satellite islets
Sicily	Egadi islands, Aeolian Islands, Pelagie Islands*
Sardinia	Asinara, Maddalena, Caprera, Santo Stefano, Spargi, Budelli, Santa Maria, Razzoli San Pietro, San Antioco, Isola dei cavolli
Cyprus	Kila, Glaros, Lefkonisos, Skaloudia, Galounia, Dalmonaris, Kordylia,* Kleides*
Corsica	Iles Sanguinaires,* Iles Lavezzi,* Iles Cerbicale,* Cavallo
Crete	Ghavdos, Dia, Theodorou, Elafonisi, Chrisi, Dionysades,* Koufonisi, Paximadia*
Maltese Archipelago*	Malta, Gozo, Comino
Balearics*	Mallorca, Minorca, Ibiza, Formentera

*Group of islands.

Table 4.5 Globally and locally threatened taxa in the larger Mediterranean Islands (After Delanoë et al. 1996)

	Extinct		Endangered		Vulnerable		Rare		Uncertain		Total		% of island flora	
	Glob	Loc	Glob	Loc	Glob	Loc	Glob	Loc	Glob	Loc	Glob	Loc	Glob	Loc
Sicily	1	1	11	21	26	72	45	76	4	12	87	182	3	6
Sardinia	0	2	11	33	30	64	21	60	1	3	63	162	3	8
Cyprus	0	–	9	11	14	14	22	29	6	7	51	61	3	4
Corsica	1	3	8	146	27	115	10	40	1	1	47	305	2	12
Crete	0	–	11	14	61	73	118	146	3	5	193	238	11	13
Balearics	1	8	10	20	14	34	43	110	1	3	69	175	5	12
Malta	1	84	0	54	1	22	10	108	4	9	16	277	2	28

plant species occurring on small islets in the Aegean Sea were not found in similar habitats in larger islands. Islets often provided a refuge for species that have gone extinct on the larger islands close to them (Blondel and Aronson 1999). Some chasmophytes (not obligate) confined to cliffs on large islands were found colonising different habitats on small islands (Höner and Greuter 1988). This is attributed to the abiotic and biotic similarities of the two environments (e.g. low level interspecific competition, absence of a well developed soil layer, severe drought and extreme daily temperature ranges). Even more peculiar are the reported similarities in the distribution of species between islets off Corsica and large Aegean islands (Blondel and Aronson 1999). Low floristic and biogeographic similarity between neighbouring islets also occurrs, as demonstrated by a comparison of the islet groups of Arki and Lipsi in Dodecanese East Aegean area, Greece (Panitsa and Tzanoudakis 2001).

Despite the long history of botanical recording in the Mediterranean, there is a lack of species distribution and abundance maps which hinders effective conservation and management of flora. The latest assessment of the Mediterranean Islands' Flora (Delanoë et al. 1996) suggests that a significant proportion of the islands' flora is under threat (Table 4.5) from new development, especially coastal tourism, agricultural intensification and climate change. According to Table 4.5 Crete, followed by the Balearics, has the highest percentage (11%) of plants threatened at a global level. The Maltese flora has the highest percentage (28%) of plants threatened at the local level (Table 4.5) reflecting the pressure on the island's habitats (Chapter 13). A recent report from IUCN (De Montmollin and Strahm 2005) identified 50 island plants facing extinction due to their population size and distribution that render them more susceptible than others to disturbance.

4.4.2.1 Endemic Flora

Endemism is present at all taxonomic levels and it owes its origin to a variety of factors such as genetics, ecology, history and their interactions over time (Huston 1994). Endemic species may, therefore, provide insights into biogeographical processes (Myers and Giller 1988). There are two kinds of endemics: palaeo-endemics, ancient vestiges of taxa that were once widespread, and neo-endemics, that is, newly evolved (Kruckenberg and Rabinowitz, 1985). The term sub-endemic is also used for taxa shared between adjacent regions that have been connected in past geological times and therefore exhibit phytogeographic similarities. These may include island connections such as, for example, Sardinia and Corsica (Gamisans 1991), Malta and Sicily (Chapter 13), Crete and Karpathos (Turland et al. 1993) but also island and mainland connections, e.g. Sicily and Calabria, Dodecanese islands and the west coast of Turkey (Davis 1965–1980). These have given rise to distinct phytogeographical regions such as the Balearic-Cyrno-Sardinian (Chapter 10) or the Cardaegean (Greuter 1972). In the Mediterranean small islets have served as natural laboratories of plant evolution while large islands have contributed to the conservation of mid-Tertiary flora with a high degree of endemism (Greuter 1995).

The levels of endemism vary greatly among islands (Table 4.6) with the Balearics having the highest percentage endemism (12.4%) and Malta the lowest (4.6%). Insularity and mountain terrain are considered to be significant causes of high endemism. The best example of their combined influence is the island of Crete with a high relative number of endemics (Table 4.6), many of which are confined

Table 4.6 Islands' size and plant diversity (Delanoë et al. 1996)

Island	Area (km^2)	Species no.	Endemics no.	% Endemism
Sicily	25,708	2700	310	11.5
Sardinia	24,090	2054	200	9.7
Cyprus	9,250	1620	170	10.5
Corsica	8,748	2354	270	11.5
Crete	8,700	1706	200	11.7
Balearics	5,014	1450	180	12.4
Malta	316	700	32	4.6

to the high mountain zones and gorges (Bergmeier 2002; Vogiatzakis et al. 2003). In Corsica it is the middle altitudinal zones that support most of the endemic plant species and this appears to be unrelated to the island's geology (Médail and Verlaque 1997). The presence of endemic trees is also remarkable, particularly on larger islands, and includes fir species *Abies nebrodensis* and *Abies cephalonica* in Sicily and Cephalonia respectively, *Zelkova sicula* in Sicily and *Zelkova cretica* in Crete, *Quercus alnifolia* and *Cedrus brevifolia* in Cyprus (Barbero et al. 1995).

4.4.3 Fauna

The fauna of insular environments is thought to be recruited from the available pool of species on the basis of abundance on the mainland and adaptability of their habitat requirements (Sará and Morand 2002). Schüle (1993) argues that colonisation in Mediterranean Islands by mammals was due to their ability to swim rather than past land connections. Apart from relict species and endemics the biology of island biota often has special features. As discussed in Chapter 2 there are certain faunistic similarities between islands such as dwarf elephants and hippos but also the absence of the elephant–deer assemblage in the case of Corsica-Sardinia complex (Blondel and Aronson 1999). Vera's hypothesis (2000) suggested that large herbivores maintained an open landscape in the primeval landscape of lowland northern Europe. Although this view is now contested by Mitchell (2005), Grove and Rackham (2001) propose that the 'savanna' model might have been the case in Mediterranean Islands since forest reaches its climatic limit.

Although the present day fauna of the Mediterranean Islands is mostly derived from mainland Europe there are elements, particularly in the reptile and amphibian fauna, that indicate affinities with other continents and biogeographical regions. For example, *Chamaeleo chamaeleo* in Sicily, Crete and Cyprus is a tropical relict. Compared to mainland areas in the Mediterranean of similar size, species impoverishment in the islands is 43% and 60% in reptiles and amphibians respectively (Blondel and Aronson 1999). There are more amphibians in western Mediterranean Islands than eastern ones while the reptile fauna includes snakes, lizards and tortoises. Some notable elements include European leaf-toed gecko (*Phyllodactylus europaeus)* in Corsica and Sardinia and the loggerhead turtle (*Caretta caretta)* in Crete, Cyprus, the Ionian islands, but also Sicily and the Balearics.

Large herbivores present currently on larger islands include the mouflon, ibex and deer although most of them were probably introduced (see Chapters 7–13). The presence of marten, weasel, wild pig, fox and wild cat is also common in most of the larger islands. Island insect fauna demonstrate a diverse pattern of species richness reflecting the influence of island area and isolation. Corsica for example has a rich entomofauna often dependent on endemic flora (Médail and Verlaque 1997). Most of the islands are located along principal migratory routes and therefore have a rich bird fauna, especially during the winter. The presence of particular features in some islands contributes further to this richness. For example, the lagoons of

Sardinia host species such as the pink flamingos but also crane, spoonbill, avocet and others. Many islands exhibit a remarkable presence of birds of prey including vultures, eagles, buzzards and falcons. Birds of prey richness patterns in the Mediterranean Islands reflect a distinction between eastern and western islands and corroborate the theory of island biogeography for the importance of island area and accessibility from the continent (Donázar et al. 2005).

4.4.3.1 Endemic Fauna

The Mediterranean Islands are inhabited by several endemic reptile genera such as *Podarcis*, *Lacerta* and *Algyroides* (Gasc et al. 1997) and endemic species such as the Melos viper *Macrovipera schweizeri* (Nilson et al. 1999). Endemic mammals include the spiny mouse *Acomys minous* in Crete and shrew species such as *Crocidura sicula* in Sicily and *Crocidura zimmermani* in Crete. Endemism is generally high in beetles, stoneflies and butterflies in larger islands and may account for 15–20% of the insect fauna (Table 4.7; Blondel and Aronson 1999). Within the bird group and despite their diversity there are few species endemic to Mediterranean Islands. According to Blondel and Aronson (1999) this is because most of the islands are too close to the mainland for differentiation to have had a chance to occur between two colonisation events. Historical factors are the determinants to inter-island differences in endemic fauna as a study in the Balearics by Palmer et al. (1999) revealed.

4.5 Island Landscape Ecology

The Theory of Island Biogeography has also had a profound influence upon theories and models concerning ecological processes in terrestrial environments (Forman and Godron 1986). An 'island' can be defined simply as a habitat that is 'ecologically' isolated often by an inhospitable matrix of intensive agriculture, but

Table 4.7 Endemic reptiles and amphibians in the Mediterranean Islands (After Blondel and Aronson 1999)

	Reptiles		Amphibians	
Island	Total	Endemics	Total	Endemics
Sicily	18	1	7	0
Sardinia	16	3	8	5
Cyprus	21	1	3	0
Corsica	11	3	7	2
Crete	12	0	3	0
Balearics	10	2	4	1

not always. Isolating factors are many and various. Islands, as already pointed out, can be isolated simply as a function of their distance from a 'source' of new colonists; the effective distance will vary between species, with some vagile species able to travel long distances to colonise new sites. In terrestrial environments isolating factors are more complex: habitats and species are more or less isolated depending upon distance, climatic, geological, geomorphological and altitudinal factors. In the Mediterranean context, cliff faces, scree slopes, gorges, mountain summits can all be effectively isolated for large numbers of plants, especially, and animals. A good example are the mountain summits of the Lefka Ori in Crete; here there are high levels of endemism in this Oro-Mediterranean zone since the high mountain peaks remained isolated even during the Miocene when subsidence caused the break up and resubmergence of most of the Aegean landmass. Equally important however, is the isolating impact of human activity; areas of phrygana, for example, becoming functionally isolated (beyond the dispersal capacity of many species) with the encroachment of olive production or other forms of modern, intensive agriculture.

By contrast, the degree of isolation of habitats on Mediterranean Islands may be ameliorated by 'connections' many of which are an integral part of the farmed landscapes. Typical examples in a Mediterranean context include field boundaries, particularly stone walls, terraces, many now abandoned and returning to garrigue and irrigation channels (Kizos and Koulouri 2006). In Malta *widien* are water run-off channels formed by either stream erosion during a former wetter regime or by tectonic movements. Where *widien* are fed by perennial springs the vegetated water course forms a natural connection for plants and animals between otherwise 'isolated' fragments of garrigue scrub in an otherwise dry and water stressed landscape. Artificial (human-made) corridors in the landscape also have a role to play in species distribution as exemplified by the case of the invasive tree *Ailanthus altissima* in Crete which is associated with the main transport network of major roads (Hulme 2004).

Recent work in landscape ecology (Wiens and Moss 2005) has formalised the spatial pattern of habitat islands and their connections within a frequently inhospitable matrix into: habitat, conduit, filter, source and sink. In the human dominated landscapes of the majority of Mediterranean Islands, virtually all natural habitats are destined to resemble islands in that they will eventually become isolated fragments of formerly much larger continuous natural habitat. Whilst Grove and Rackham (2001) among others have cast doubt on the orthodoxy of 'ruined landscape theory' (the theory that suggests almost catastrophic and wholesale denudation of Mediterranean forests), there is no doubt that the human impacts of development, most recently as a result of rapid urban expansion and tourism pressure, and intensive agriculture, have served to fragment former much larger areas of habitat into small, remnant patches. In landscape ecological terms such patches can serve as conduits for the movement of species, as filters inhibiting the movement of some species and facilitating that of others, as sources of species for the colonisation of other patches and as 'sinks'. The ecology of corridors remains contentious with some suggestions that a corridor simply serves to increase the total area of 'habitat' in the landscape whilst others counterclaim that linear connections between patches operate as conduits, linking otherwise isolated patches in a functioning ecological network allowing for the dispersal of plants and animals (Bennett 2003). There are many examples of ecological corridors in a Mediterranean context at a wide range of scales from the micro-scale already discussed (terraces, stone walls) to the macro, whole island scale of 'greenways' (Jongman and Pungetti 2004).

Landscapes are increasingly regarded in an integrative and holistic way as … *total space/time defined concrete ecological, geographical and cultural systems* (Naveh 1990). Therefore Naveh (1994, 2000) advanced the idea for a holistic approach to the conservation of both the natural and cultural assets of a region's landscape (Farina and Naveh 1993; Green and Vos 2001). According to these studies the following cultural landscapes are threatened in the Mediterranean Basin:

- Relict natural landscapes which consist of remnants of relatively undisturbed ecosystems where agriculture is limited due to physiography/topography (Vos 2001)
- Vanishing traditional landscapes which were originally oriented towards subsistence agriculture as for example, the wooded pastures (*montados* and *dehesas*) in Portugal and Spain (Pinto-Correia 2000) also abundant in Sardinia.
- Stressed landscapes comprise large-scale agricultural landscapes with an increasingly intensive land use as in Western Crete (Rackham and Moody 1996)

In many situations where agriculture has been important for long periods the ecological interest is richest in the cultural elements in the landscape which include terraces, stone walls and other field boundaries. Land abandonment however, is having a profound impact on the ecological characteristics of the agricultural landscape with terraces and walls falling into disuse and fields reverting to early succession Mediterranean scrub (Grove and Rackham 2001).

Habitat patches operating as sources versus sinks of species is a complex topic and it remains difficult to quantify the ecological function of a patch in this context. The Theory of Island Biogeography is unhelpful in this respect since it does not provide all the answers. For example, how large does a patch have to be to act as a source? For which species is this true and surrounded by what type of land use matrix? Despite a long history of management for cork production the extensive cork oak (*Quercus suber*) forests of Sardinia are large enough to act as reservoirs for a wide range of species capable of dispersing into the surrounding landscape. In other parts of the Mediterranean the combined impact of grazing, fire and development has effectively isolated fragments of scrub such that they become ecologically isolated and no longer operate as part of a functioning ecological network.

This type of analysis has important implications for the selection of sites for nature protection, management and restoration of existing sites and for the recreation of lost habitats. Important in this respect is the Habitats Directive (Council of Europe 1992) and the establishment of the pan European network of protected sites

(Natura 2000). The Directive establishes a European ecological network known as 'Natura 2000' comprising 'Special Areas of Conservation' and 'Special Protection Areas' (for the conservation of wild birds) designated by Member States in accordance with the provisions of the Directive. Effective protection is likely to be best achieved from a network of large, well-connected habitats. However, the danger of such an approach is that small sites are overlooked resulting in risks to the future of isolated populations of important endemic species. Techniques are required for the ecological evaluation of sites. Recent work (Boteva et al. 2004) has demonstrated the implementation of the Ratcliff (1977) criteria within a GIS environment for evaluating the ecological quality of a Natura 2000 site on Crete. The assessment identified and scored the most valuable communities within the protected area using the most frequently used criteria for nature conservation. The final conservation score for each community was derived using Multiple Criteria Evaluation within a GIS. The results demonstrated that the method is an effective tool for evaluating and comparing conservation significance and could be applied to other sites across the Mediterranean.

Very little work has been undertaken on habitat restoration and recreation, either in a theoretical or practical sense, in Mediterranean landscapes (Naveh 1988, 1994, 1998). GIS modelling techniques are now well developed and can be used to identify potential sites for habitat re-creation based upon landscape ecological principles. Such techniques rely upon reliable and up to date maps of the type and extent of habitats and knowledge about the dispersal strategies and distances of a range of species, information that is often lacking.

4.6 Conservation on Islands

The combination of endemism and high species richness has resulted in the majority of Mediterranean Islands being recognised as global biodiversity hotspots (Davis et al. 1994; Médail and Quézel 1997). An island is a constrained system which imposes restrictions on biotope area. Island flora is therefore fragile and vulnerable compared to mainland flora (Snogerup 1985; Heywood 1995). Rackham and Moody (1996) contest this in the context of Crete since the island has retained its indigenous plants and the soil is not irreversibly degraded. The designation of Natural Protected Areas in the Mediterranean Islands (Chapter 6) has contributed to conservation efforts, sometimes contradictory and conflicting (see Chapter 11). Indeed, there is much variation between Mediterranean Islands in terms of the level and extent of protected area reflecting the uneven approach to conservation that characterises Mediterranean countries.

The approach taken so far towards nature/landscape conservation has followed established and widely adopted methods. The ecosystem-based approach has been advocated in the Mediterranean because it ensures the protection of species' genetic diversity and the ecological processes essential for species survival (Greuter 1974; Blondel and Aronson 1999). This is of utmost importance particularly for endemic species due to their high ecological specialisation and the lack of competitiveness (Médail and Verlaque 1997). However, it is widely recognised that biodiversity conservation cannot be achieved by concentrating efforts solely on habitats and species within protected areas. This is because many processes affecting species survival operate at a scale beyond the protected areas boundaries (i.e. the landscape).

Although there are examples of islands with a large proportion of their total surface area under protection such as Corsica (Chapter 10) and the Balearics (Chapter 12), the Kornati archipelago in the Adriatic is the most extensive National Park in the Mediterranean that encompasses a high number of islands (89 islands, islets and reefs along 238 km of coastline) in a total area of c.220 km^2. Special protection measures are advocated particularly for the islets in the Mediterranean since their flora is at significant risk (Greuter 1995).

During the course of evolution extinction has been a common and natural phenomenon. However, the 20th century has witnessed the most far-reaching ecological change in the history of humanity. The Mediterranean flora has to a degree adapted to the destructive actions of humans. The present extinction rate of Mediterranean higher plants is 0.1% (i.e. 37 species presumed to be extinct), while 4,251 taxa are considered to be under threat (Greuter 1994). This leads to the conclusion that although the present loss appears to be tolerable, future extinction might be on a substantial scale. A recent assessment on global imminent extinctions includes two Mediterranean Islands (Ricketts et al. 2005). The most important factor that will determine the future of island flora is human activity. Although these activities are similar to those observed in the mainland Mediterranean region they are usually amplified because of insularity. Despite the range of conservation efforts their efficiency for the long term management and protection of Mediterranean biodiversity in the light of future climatic changes is questioned (Allen 2003). The risk for endemic species in particular is expected to be higher as altitude increases since important habitats will be rendered unsuitable at these zones for some species. In Crete, for example, preliminary results suggest that certain species might be in risk of extinction in the high mountain zones (Kazakis et al. 2007) while similar cases are reported from Cyprus (Section 9.3). However, Médail and Verlaque (1997) suggest that the mountain flora in Corsica is in less danger since both endemics and pressures are concentrated at mid altitudes (800–1,700 m).

Mediterranean Islands have always been very vulnerable to invasion by exotic species. Whereas the proportion of the flora of the Mediterranean Basin composed of exotics is only 1% it is substantially higher for Mediterranean Islands (>10%) (Hulme 2004). The devastation of island ecosystems worldwide has raised awareness about the global threat that human-driven species dispersal is posing for biological diversity. With every human invasion of the islands (see Chapter 3) deliberate and accidental introduction of non-native plants and animals occurred (Azzaroli 1981; Grove and Di Castri 1991). The introduction of alien predators has, in the past, led to adverse effects on various trophic levels of island ecosystems and eventually species extinction (Palmer and Pons 1996; Riela et al. 2002). It is highly likely that future global warming will favour non-native species, e.g. *Opuntia ficus-indica* and *Acacia dealbata* (Hulme 2004; Gritti et al. 2006). There remains a strong interest in predicting potential impacts of rapid, anthropogenic climate change on the biota of Mediterranean Islands.

4.7 Conclusion

The complex geological evolution of Mediterranean Islands combined with the more recent impact of human activity, has resulted in the biogeographical patterns that we see today. Many of these patterns conform to theory with islands displaying, for example, high levels of endemism and the effects of isolation. The profound impact of human activity over millennia however, tends to obscure and confound many of the underlying patterns and this has enriched the biota on some islands and impoverished it on others.

An understanding of the underlying causes of species distribution across Mediterranean Islands is critically important if we are to maintain and enhance ecologically important habitats and protect species. Biogeography has an important role to play in this respect but much more knowledge of the habitat preferences of species and their response to habitat fragmentation resulting from increasing development pressures and climate change is required. In particular, very little is known about the dispersal capability of species, both plants and animals, and this will be of vital importance if strategies to combat the potentially adverse effects of climate change are to be accommodated. Landscape ecology will play an increasingly important role in this respect, providing the spatial context within which to select ecologically important sites for protection, for monitoring change and for identifying sites for habitat restoration and re-creation.

References

Alcover, J.A., Sans, A. and Palmer, M. (1998) The extent of extinction of mammals on islands. Journal of Biogeography 25: 913–918.

Allen, H.D. (2003) Response of past and present Mediterranean ecosystems to environmental change. Progress in Physical Geography 27: 359–377.

Azzaroli, A. (1981) Cainozoic mammals and the biogeography of the Island of Sardinia, western Mediterranean Palaeogeography, Palaeoclimatology, Palaeoecology 36: 107–111.

Barbero, M., Loisel, R. and Quézel, P. (1995) Les essences arbores des îles mediterranennes: leur role écologique et paysager. Ecologia Mediterranea 21: 53–69.

Bennett, A.F. (2003) Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN.

Bergmeier, E. (2002) The vegetation of the high mountains of Crete: a revision and multivariate analysis. Phytocoenologia 32(2): 205–249.

Blondel, J. and Aronson, J. (1999) Biology and Wildlife of the Mediterranean Region. Oxford University Press.

Boteva, D., Griffiths, G.H. and Dimopoulos, P. (2004) A method for the evaluation and mapping of the nature conservation significance of habitats using GIS: an example from Crete, Greece. Journal for Nature Conservation 12: 237–250.

Council of Europe (1992) Council Directive 92/43 EEC of 21 May 1992 on the Conservation of Natural Habitats and Wild Fauna and Flora. O.J. Eur. Comm. No. L206/7: 7–50.

Darwin, C. (1859) On the Origins of Species By Means of Natural Selection. J. Murray: London.

Davis, P.H. (ed.) (1965–1980) Flora of Turkey and the East Aegean Islands, Vols. I–X. Edinburgh University Press.

Davis, S.D., Heywood, V.H. and Hamilton, A.C. (eds.) (1994) Centres of Plant Diversity. WWF/IUCN: Cambridge.

Delanoë, O., De Montmollin, B. and Olivier, L. (1996) Conservation of the Mediterranean Island plants. 1. Strategy for Action. IUCN: Cambridge.

De Montmollin, B. and Strahm, W. (eds.) (2005) The Top 50 Mediterranean Island Plants. IUCN/SSC Mediterranean Islands Plant Specialist Group.

Donázar, J.A., Gangoso, L., Forero, M.G. and Juste, J. (2005) Presence, richness and extinction of birds of prey in the Mediterranean and Macaronesian islands. Journal of Biogeography 32: 1701–1713.

Egli, B., Gerstberger, P., Greuter, W. and Risse, H. (1990) *Horstrissea dolinicola*, a new genus and species of umbels (*Umbelliferae, Apiaceae*). Wildenowia 19: 389–399.

Farina, A. and Naveh, Z. (eds.) (1993) Landscape Approach to regional planning: The future of the Mediterranean Landscapes. Special Volume. Landscape and Urban Planning 24.

Forman, R.T.T. and Godron M. (1986) Landscape Ecology. Wiley: New York.

Gamisans, J. (1991) La Végétation de la Corse. Conservatoire et Jardin botaniques de la ville de Genève.

Gasc, J.P., Cabela, A., Crnobrnja-Isailovic, J., Dolmen, D., Grossenbacher, K., Haffner, P., Lescure, J., Martens, H., Martvnez Rica, J.P., Maurin, H., Oliveira, M.E., Sofianidou, T.S., Veith, M. and Zuiderwijk, A. (eds.) (1997) Atlas of amphibians and reptiles in Europe. Collection Patrimoines Naturels 29, Societas Europaea Herpetologica, Muséum National d'Histoire Naturelle & Service du Patrimoine Naturel, Paris, 496 pp.

Grant, P.R. (1998) Evolution on Islands. Oxford University Press.

Green, B. and Vos, W. (2001) Threatened Landscapes: Conserving Cultural Environments. Spon Press: London.

Greuter, W. (1972) The relict element of the flora of Crete and its evolutionary significance. In V.H. Valentine (ed.) Taxonomy, Phytogeography and Evolution. Academic Press: London, pp. 161–177.

Greuter, W. (1974) Floristic report on the Cretan area. Memorias da Sociedade Broteriana 24: 131–171.

Greuter, W. (1979) The origins and evolution of island floras as exemplified by the Aegean Archipelago. In D. Bramwell (ed.) Plants and Islands. Academic Press: London, pp. 87–106.

Greuter, W. (1991) Botanical diversity, endemism, rarity and extinction in the Mediterranean area: an analysis based on the published volumes of Med – Checklist. Botanika Chronika 10: 63–79.

Greuter, W. (1994) Extinctions in the Mediterranean areas. Philosophical Transactions of the Royal Society London B 344: 41–46.

Greuter, W. (1995) Origin and peculiarities of Mediterranean Island floras. Ecologia Mediterranea 21: 1–10.

Greuter, W. (2001) Diversity of Mediterranean Island floras. Bocconea 13: 55–64.

Greuter, W. and Strid, A. (1981) Notes on Cardaegean plants. 2. A new species of *Ranunculus* sect. *Ranunculus* from the mountains of Kriti. Wildenowia 11: 267–269.

Greuter, W., Burdet, H. and Long, G. (eds.) (1984, 1986, 1989) Med – checklist. A Critical Inventory of Vascular Plants of the Circum – Mediterranean Countries. Conservatoire et Jardin Botaniques de la Ville de Genève, Genève.

Gritti, E.S., Smith, B. and Sykes, M.T. (2006) Vulnerability of Mediterranean Basin ecosystems to climate change and invasion by exotic plant species. Journal of Biogeography 33: 145–157.

Grove, R.H. and Di Castri, F. (1991) Biogeography of Mediterranean invasions. Cambridge University Press: Cambridge.

Grove, A.T. and Rackham, O. (2001) The Nature of the Mediterranean Europe. Yale University Press: New Haven, CT.
Heywood, V.H. (1995) The Mediterranean flora in the context of world biodiversity. Ecologia Mediterranea 21(1/2): 11–18.
Höner, D. and Greuter, W. (1988) Plant population dynamics and species turnover on small islands near Karpathos (South Aegean, Greece). Vegetatio 77: 129–137.
Huggett, R.J. (1998) Fundamentals of Biogeography. Routledge: London.
Hulme, P.E. (2004) Islands, invasions and impacts: a Mediterranean perspective. In J.M. Fernández-Palacios and C. Morici (eds.) Ecología Insular/Island Ecology. Asociación Española De Ecología Terrestre, pp. 359–383.
Huston, M.A. (1994) Biological Diversity: The Co-existence of Species in Changing Landscapes. Cambridge University Press: Cambridge.
Jongman, R.H.G. and Pungetti, G. (2004) Ecological Networks and Greenways: Concept, Design, Implementation. Cambridge University Press.
Kazakis, G., Ghosn, D., Vogiatzakis, I.N. and Papanastasis, V.P. (2007) Vascular plant diversity and climate change in the alpine zone of the Lefka Ori, Crete. Biodiversity and Conservation. 16: 1603–1615.
Kizos, Th. and Koulouri, M. (2006) Agricultural landscape dynamics in the Mediterranean: Lesvos (Greece) case study using evidence from the last three centuries. Environmental Science and Policy 9: 330–342.
Kruckenberg, A.R. and Rabinowitz, D. (1985) Biological aspects of endemism in higher plants. Annual Review of Ecology and Systematics 16: 447–479.
Kuhbier, H., Alcover, J.A. and D'Arellano, G. (eds.) (1984) Biogeography and Ecology of the Pityusic Islands. Dr. W. Junk Publishers: The Hague.
López-de-Heredia, U., Jiménez, P., Díaz-Fernández, P. and Gil, L. (2005) The Balearic Islands: a reservoir of cpDNA genetic variation for evergreen oaks. Journal of Biogeography 32: 939–949.
MacArthur, R.H. and Wilson, E.O. (1967) The Theory of Island Biogeography. Princeton University Press: Princeton, NJ.
Marra, A.C. (2005) Pleistocene mammals of Mediterranean Islands. Quaternary International 129: 5–14.
Mayer, A. (1995) Comparative Study of the Coastal Vegetation of Sardinia (Italy) and Crete (Greece) with Respect to the Effects of Human Influence. IHW-Verlag: Eching bei München.
Médail, F. and Quézel, P. (1997) Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Annals of the Missouri Botanical Gardens 84: 112–127.
Médail, F. and Verlaque, R. (1997) Ecological characteristics and rarity of endemic plants from southeastern France and Corsica: Implications for biodiversity conservation. Biological Conservation 80: 269–281.
Médail, F. and Vidal, E. (1998) Organisation de la richesse et de la composition floristiques d'îles de la Méditerranée occidentale (sud-est de la France). Canadian Journal of Botany 76(2): 321–331.
Mitchell, F.J.G. (2005) How open were European primeval forests? Hypothesis testing using palaeoecological data. Journal of Ecology 93: 168–177.
Myers, A.A. and Giller, P.S. (eds.) (1988) Analytical Biogeography: An Integrated Approach to the Study of Animal and Plant Distributions. Chapman & Hall: London.
Naveh, Z. (1988) Multifactorial reconstruction of semi-arid Mediterranean landscapes for multipurpose land uses. In E. Allen (ed.) The Reconstruction of Disturbed Arid Lands: An Ecological Approach. Westview Press: Boulder Col., pp. 234–256.
Naveh, Z. (1990) Ancient man's impact on the Mediterranean landscape in Israel – ecological and evolutionary perspectives. In S. Bottema, G. Entjes-Nieborg and W. Van Zeist (eds.) Man's Roles in the Shaping of the Eastern Mediterranean Landscape, pp. 43–50.
Naveh, Z. (1994) From biodiversity to ecodiversity – a landscape ecological approach to conservation and restoration. Restoration Ecology 2: 180–189.

Naveh. Z. (1998) Ecological and cultural landscape restoration and the cultural evolution towards a post-industrial symbiosis between human society and nature. Restoration Ecology 6: 135–143.
Naveh, Z. (2000) What is holistic landscape ecology? A conceptual introduction. Landscape and Urban Planning 50: 7–26.
Nilson, G., Andrén, C., Ioannidis, Y. and Dimaki, M. (1999) Ecology and conservation of the Milos viper, *Macrovipera schweizeri* (Werner, 1935) Amphibia Reptilia 20, 355–375.
Palmer, M. and Pons, G.X. (1996) Diversity in West Mediterranean islet: effect of rat presence on a beetle guild. Acta Oecologica 17: 297–305.
Palmer, M., Pons, G.X., Cambefort, I. and Alcover, J.A. (1999) Historical processes and environmental factors as determinants of inter-island differences in endemic faunas: the case of the Balearic Islands. Journal of Biogeography 26: 813–823.
Panitsa, M. and Tzanoudakis, D. (2001) A floristic investigation of the islet groups Arki and Lipsi (East Aegean Area, Greece). Folia Geobotanica 36: 265–279.
Pinto-Correia, T. (2000) Future development in Portuguese rural areas: how to manage agricultural support for landscape conservation? Landscape & Urban Planning 50, 95–106.
Quézel, P. (1981) The study of groupings in the countries surrounding the Mediterranean: some methodological aspects. In F. Di Castri, D.W. Goodall and R.L. Sprecht (eds.) Mediterranean-type Shrublands. Elsevier: Amsterdam, pp. 87–93.
Rackham, O. and Moody, J.A. (1996) The Making of the Cretan Landscape. Manchester University Press: Manchester.
Ratcliff, D. (ed.) (1977). A Nature Conservation Review: The Selection of Sites of National Importance to Nature Conservation in Britain. Cambridge University Press, 401 p.
Rechinger, K.H. (1943) Flora Aegea. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Denkschr. 105(1).
Rechinger, K.H. and Rechinger-Moser, F. (1951) Phytogeographia Aegaea. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Denkschr. 105(2): 1–208.
Ricketts, T.H. et al. (2005) Pinpointing and preventing imminent extinctions. PNAS 102(51): 18497–18501.
Riela, N., Traveset, A. and Garcia, O. (2002) Breakage of mutualisms by exotic species: the case of *Cneorum tricoccon* L. in the Balearic Islands (Western Mediterranean Sea). Journal of Biogeography 29: 713–719.
Runemark, H. (1971) Distributional patterns in the Aegean. In P.H. Davis, P.C. Harper and J.C. Hedge (eds.) Plant Life of S.W. Asia. Botanical Society of Edinburgh, pp. 3–12.
Sará, M. and Morand, S. (2002) Island incidence and mainland population density: mammals from Mediterranean Islands. Diversity and Distributions 8: 1–9.
Schüle, W. (1993) Mammals, vegetation and the initial human settlement of the Mediterranean Islands: a palaeoecological approach. Journal of Biogeography 20: 399–411.
Snogerup, S. (1985) The Mediterranean Islands. In C. Gomez-Campo (ed.) Plant Conservation in the Mediterranean Area. Dordrecht, pp. 159–173.
Snogerup, S. and Snogerup, B. (1987) Repeated floristical observations on islets in the Aegean. Plant Systematics and Evolution 155:143–164.
Spellerberg, I.F. and Sawyer, J.W.D. (1999) An introduction to applied biogeography. Cambridge University Press: New York.
Stuessy, T.F. and Ono, M. (eds) (1998) Evolution and Speciation of Island Plants. Cambridge University Press: New York.
Thompson, J.D. (2005) Plant Evolution in the Mediterranean. Oxford University Press, p. 293.
Turland, N.J., Chilton, L. and Press, J.R. (1993) Flora of the Cretan area. Annotated Checklist and Atlas. HMSO: London.
Tzanoudakis, D. and Kypriotakis, Z. (1993) *Allium platakisii*, a new species of the Greek insular flora. Flora Mediterranea 3, 309–314.
Vera, F.W.M. (2000) Grazing Ecology and Forest History. CABI: Wallingford, CT.
Vogiatzakis, I.N., Griffiths, G.H. and Mannion, A.M. (2003) Environmental factors and vegetation composition Lefka Ori massif, Crete, S. Aegean. Global Ecology and Biogeography 12: 131–146.

Vos, W. (2001) The Solano Basin, Italy. In B. Green and W. Vos (eds.) Threatened Landscapes: Conserving Cultural Environments. Spon Press: London, pp. 91–99.

Wallace, A.R. (1892) Island Life: Or the Phenomena and Causes of Insular Faunas and Floras Including a Revision and Attempted Solution of the Problem of Geological Climates. Macmillan: London.

Whittaker, R.J. (1998) Island Biogeography. Oxford University Press: Oxford.

Wiens, J.A. and Moss, M.R. (eds.) (2005) Issues and Perspectives in Landscape Ecology. Cambridge University Press.