Proceedings 10th MEDECOS Conference, April 25 – May 1, 2004, Rhodes, Greece, Arianoutsou & Papanastasis (eds)

The current threat to Mediterranean islands from invasive non-native plants

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Keywords: biodiversity, biogeography, exotic plant species, Mediterranean Basin

ABSTRACT: The ecology of islands is intimately associated with biological invasions. The species composition and community structure of islands is widely recognised to be a function of colonisation rates and it follows that where these have been accelerated by human activities, biological invasions will also play a significant role. Current understanding of the extent, character and consequences of the invasion of islands by non-native species is drawn largely from studies of tropical oceanic islands especially Hawaii. In contrast, what might best be called continental islands, have received far less attention yet may in themselves shed considerable light on the drivers and impacts of island invasions. This paper aims to address this imbalance by focusing on the invasion by non-native plants of islands in the Mediterranean Basin. Mediterranean climate regions are particularly susceptible to biological invasions although New World ecosystems appear more susceptible than those of the Mediterranean Basin. Nevertheless, whereas the proportion of the flora of the Mediterranean Basin composed of non-natives has been estimated at only 1%, it is substantially higher for Mediterranean islands. However, when compared to oceanic islands, Mediterranean islands have fewer non-native species and they comprise a smaller proportion of their flora. In general, oceanic islands are of more recent geological origin and are considerably more isolated (both in time and space) from the nearest continent than equivalent Mediterranean islands. These characteristics of oceanic islands are thought to lead to proportionally lower native diversity, greater disharmony in species composition arising from the absence of key plant functional groups, lower competitive ability of native species and vacant niche space than either Mediterranean islands or equivalent mainland areas. The impact of exotic plants on biodiversity remains poorly documented in the Mediterranean Basin. Several non-native plants are weeds of major economic significance, others may also be hosts of plant pathogens. Both the intensive planting of exotic species and agricultural abandonment significantly increase the risk of invasion by feral crops. Non-native plants may impact on human and animal health, and may have profound environmental consequences, exacting a significant toll on ecosystems. The problems of invasive species are often viewed as those of disturbed and anthropogenic habitats rather than intact ecosystems. However, a unique element of indigenous Mediterranean biodiversity is the anthropogenic component, a distinct subflora that evolved in the Mediterranean. These species occur in varying associations in fields, pastures and on roadsides: habitats typically invaded by non-native plant species. Many of these endemic weeds have restricted distributions and could represent the elements of the Mediterranean flora most at risk from invasions. Biological invasions can thus be seen as important drivers of change in Mediterranean ecosystems that will be facilitated by future rising CO_2 concentrations, warmer temperatures, greater nitrogen deposition and increased habitat fragmentation.

1 INTRODUCTION

Biological invasions by non-indigenous species are widely recognised as a major component of human-caused global environmental change, often resulting in a significant loss in the economic value, biological diversity and function of invaded ecosystems (Mooney and Hobbs 2000, Mack et al. 2000, Pimentel et al. 2001). Global biodiversity scenarios for 2010 (Sala et al. 2000) highlight dramatic future increases in biological invasions in Mediterranean ecosystems, proportionally more so than in any other global ecosystem. Furthermore, biological invasions are seen as one of the most important drivers of change in Mediterranean ecosystems, second only to land use change and more important than climate, nitrogen deposition or rising CO_2 concentration (Sala et al. 2000). In addition, interacting effects among drivers suggest that biological invasions will be facilitated by rising atmospheric CO_2 concentrations, warmer temperatures, greater nitrogen deposition, altered disturbance regimes and increased habitat fragmentation (Dukes and Mooney 1999). The urgency of the situation and the lack of coordinated problem solving are only just dawning on an unprepared Mediterranean Basin.

The ecology of islands is intimately associated with biological invasions (Carlquist 1974, Williamson 1981, Nunn 1994, Whitaker 1998). The species composition and community structure of islands is widely recognised to be a function of colonisation rates (Hubbell 2001) and it follows that where these have been accelerated by human activities, biological invasions will also play a significant role. Current understanding of the extent, character and consequences of the invasion of islands by non-native species is drawn largely from studies of tropical oceanic islands especially Hawaii (Vitousek 1988, Loope and Mueller-Dombois 1989, Simberloff 1995, Vitousek et al. 1995, Denslow 2003). In contrast, what might best be called continental islands, have received far less attention yet may in themselves shed considerable light on the drivers and impacts of island invasions. This paper aims to address this imbalance by focusing on the invasion by non-native plants of islands in the Mediterranean Basin.

2 THE BIOGEOGRAPHICAL CONTEXT OF MEDITERRANEAN ISLAND FLORAS

There are nearly 5000 islands in the Mediterranean Basin. Their wide ranges of sizes (from small islets to Sicily, the largest island at 25,708km^2), maximum altitudes (from sea level to 3260m for Mount Etna), substrates and morphologies, as well as human activities, have resulted in the evolution of a highly diversified flora (Greuter 1995, Delanoë et al. 1996). Surprisingly, although richer in islands than anywhere else in the world apart from the Caribbean and the archipelagoes of the Pacific Ocean, the biogeography of Mediterranean islands has received relatively little attention (Carlquist 1974, Williamson 1981, Nunn 1994, Whitaker 1998). This is surprising since the ecology of these islands present a fascinating opportunity to assess the impact of complex geological history, human impact and biogeography on the structure of ecological communities.

It is widely recognised that the key elements that shape the ecology of islands are their geological age, spatial and temporal isolation form continental landmasses and the length of time since islands were first colonised by humans (Whittaker 1998). The formation of Mediterranean islands reflects a complex geological history (Blondel and Aronson 1999). The turbulent tectonic history of the Mediterranean led to the majority of islands arising from uplift of the sea floor as it buckled between the colliding Eurasian and African plates (Blondel and Aronson 1999). However, several islands were shaped by volcanic activity during the Pleistocene (Kos, Ustica, Kos, Alicudi, Filicudi) and Holocene (Milos, Salina, Panarea) while others have been influenced by eruptions during relatively recent times (e.g. Santorini, Ischia, Stromboli, Pantelleria, Sicily). The islands have variously been connected to the mainland on several occasions. The Messinian Salinity Crisis that occurred between 5.6 and 5.3 million years ago resulted in the almost complete drying-up of the Mediterranean Sea and would undoubtedly have facilitated biotic interchange between Africa,

Asia, Europe and the former islands. Following the restitution of the sea, islands were again connected to the mainland during the Quaternary sea level minima. Sea level dropped by between 100 and 200m during several glacial periods that not only helped connect islands to the mainland but also led to the amalgamation of archipelagoes into single islands (Sfikas 2000). Thus the Mediterranean contains a complex of islands differing in age, isolation, geology and colonization history.

The native vegetation of Mediterranean islands reflects this dynamic history of island formation, connection and isolation and comprises elements with Afro-tropical, Holarctic, Irano-Turanian, Saharo-Arabian and indigenous origins (Blondel and Aronson 1999). The result is that each of the larger islands in the Mediterranean has its own distinctive set of native species. Two further biotic influences have additionally shaped Mediterranean island floras– grazers and humans. Grazing and browsing mammals, including deer, rodents, dwarf elephants and hippos, were widespread on most of the larger Mediterranean islands during the Pleistocene. Evidence of human colonization stretches as far back as 20,000 years ago in Sardinia but it is likely that most islands were colonized soon after the end of the last glaciation around 11,000 years ago. Archaeological data suggests that by 7000 years ago, Neolithic humans had begun to cut a swathe through the Pleistocene mammal fauna to the extent that all that now remains on islands are a handful of small mammal species (Blondel and Aronson 1999). Humans accidentally and deliberately introduced mammals to the islands. Commensal rodents such as the house mouse, brown and black rats colonized islands as a result of human settlement. Domesticated animals included sheep, goats and pigs whose subsequent feralisation probably gave rise to mouflon, the Cretan wild goat and the Corsican wild boar. The pressure of grazing by domesticated livestock has profoundly shaped the Mediterranean flora but is not the only human influence that characterizes the region.

As the cradle of agriculture, the Mediterranean Basin represents one of the most important centres of origin for crop plant worldwide. Current estimates approach 522 cultivated crop species in the Mediterranean Basin, including both native and non-native species first cultivated in the region (Blondel and Aronson 1999). Thus the Mediterranean possesses and extensive archaeophyte flora. Many species of cereals and pulses were introduced into Mediterranean islands in the Neolithic, where they have subsequently naturalized and on occasion hybridized with native species.

The Mediterranean was at the heart of some of the world's most ancient civilisations and the characteristics of the flora and fauna reflect this history. Many islands endured repeat invasions (by humans) and incessant wars because of their strategic position for defense, trade or natural resources. For example, Corsica has been invaded more than twenty times in the last 2500 years, first by the Phoenicians (565BC), then Etruscans (540BC), Carthaginians (270BC), Romans (259BC), Vandals (455AD), Byzantines (534AD), Goths (549AD), Sarrasins (704AD), Lombards (725AD), Pisanos (1015AD), Genoans (1195AD), Aragons (1297AD), Genoans again (1358), Milanians (1468AD) Franco-Ottomans (1553AD), French (1768AD), British (1794AD) and German-Italian Axis during the Second World War (Blondel and Aronson 1999). Similar invasion histories can be described for any other of the larger Mediterranean islands, although in each case the range of protagonists differ. With each invasion, islands suffered changes in land use and resource exploitation as well as the deliberate and accidental introduction of non-native plants and animals.

3 SPATIAL TRENDS IN THE INVASION OF MEDITERRANEAN ISLANDS

Larger islands are expected to support a greater richness of native species (Whittaker 1998) and this hypothesis could be extended to cover non-native species as well. Globally, larger islands do possess greater non-native plant richness (Lonsdale 1999). For the major islands of the Mediterranean, a weak positive relationship does exist between island area and the number of non-native plant species (Hulme 2004). The relationship appears strongest for small to medium sized islands less than 10,000km^2 and this range would encompass the vast majority of Mediterranean islands. However, the relationship disappears for larger islands suggesting that perhaps a form of species

saturation occurs. This runs contrary to the ideas that as island size increases so should the diversity of habitats and opportunities for invasive species. Examination of the distribution of non-native plants in Crete and the Balearics highlight that not all habitats are equally susceptible to invasion (Hulme 2003a). In general, non-native plants most often invade agricultural, ruderal and riparian areas. While other habitats are colonised less frequently. Hence, while habitat diversity may indeed increase with increasing island size, the diversity of habitats susceptible to invasion may be less responsive to changes in island area.

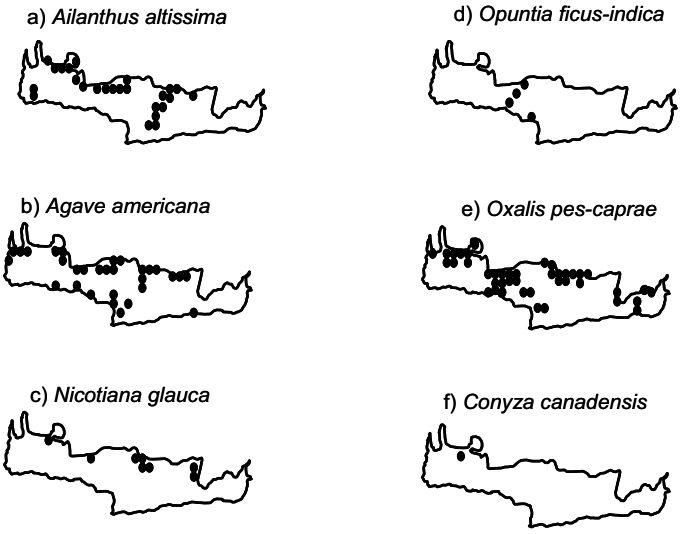

Figure 1. Distribution of six non-native plant species on the island of Crete (adapted from Turland et al. 1993*)* highlighting different spatial patterns of invasion.

Further insights into the scope for saturation arise from examination of spatial trends within islands (Figure 1). Spatial patterns highlight invasion hotspots with *Nicotiana glauca* strongly associated with the four major urban centres on Crete, *Ailanthus altissima* distribution linked to the main transport network of major roads, *Oxalis pes caprae* is widespread in lowland olive groves and orchards and both *Opuntia ficus indica* and *Agave americana* coincide in agricultural areas, probably colonizing areas of abandonment. However, most species exhibit a strong association with coastal areas (Figure 1). Although natural coastal habitats themselves are not highly invasible (Hulme 2003a), the more benign environment (lower elevation), higher degree of urbanisation and development as well as the often higher propagule influx (through ports etc.) leads to the frequent finding that a large number and higher percentage of non-native species occur along coastlines (D'Antonio and Dudley 1995). Thus perhaps a better correlate of the invasibility of islands is the extent of coastline rather than island area *per se*. If coastline is an important correlate, area based analyses may not pick up the often smaller perimeter/area ratios of larger islands that might give rise to the trend depicted in Figure 4a. This may be the simplest explanation as to why the largest Mediterranean islands have fewer non-native aliens than might be expected from species-area analyses.

4 THE IMPACT OF INVASIVE PLANTS ON MEDITERRANEAN ECOSYSTEMS

The impact of exotic plants on biodiversity remains poorly documented in the Mediterranean Basin (di Castri et al. 1990, Groves and di Castri 1991). Several non-native plants are weeds of major economic significance e.g. *Chenopodium ambrosioides*, *Paspalum distichum*, *Conyza canadensis*, *Oxalis pes-caprae*. Others may also be hosts of plant pathogens e.g. *Bromus catharticus* as host for barley yellow dwarf virus and wheat stem rust. Both the intensive planting of exotic species and agricultural abandonment significantly increase the risk of invasion by feral crops (Guillerm et al. 1990). Non-native plants are frequently planted commercially, for example, economically important crops e.g. *Eucalyptus globulus* (Blue Gum), *Helianthus tuberosus* (Jerusalem artichoke) are becoming widely naturalised in the Mediterranean basin. Non-native plants may also impact on human and animal health as in the cases of eruptive dermatitis following contact with *Agave americana*, and poisoning of humans and livestock though consumption of toxic fruit e.g. *Phytollaca americana*, *Solanum eleagnifolium*. Non-native plants may also have profound environmental consequences, exacting a significant toll on ecosystems. These range from wholesale ecosystem changes (e.g. colonisation of sand dunes by *Acacia saligna*) and extinction of indigenous species [e.g. threats to endemic coastal plants following expansion of *Carpobrotus edulis* (Garcia 1999)], to more subtle ecological changes and increased biological homogeneity. The physiognomy of exotic plants differs substantially from native Mediterranean species (Le Floc'h et al. 1990) and many of the most widespread non-native species belong to families otherwise not represented in the Mediterranean Basin e.g. Agavaceae, Cactaceae, Phytolaccaceae, Simaroubaceae. This suggests the potential ecosystem impacts could be considerable (Vitousek 1990) and is supported by studies that reveal reduced nutrient inputs due to the recalcitrant foliage of *Eucalyptus* spp. (Robles and Chapin 1995) and altered soil pH and nutrient availability following deposition of salt by *Carpobrotus edulis* (D'Antonio 1990). Finally, it is highly likely that global warming will favour non-native species currently limited by climate e.g. *Opuntia ficus-indica* (Le Floc'h et al. 1990) and *Acacia dealbata* (Quezel et al. 1990).

The problems of invasive species are often viewed as those of disturbed and anthropogenic habitats rather than intact ecosystems (Hulme 2003a). However, a unique element of indigenous Mediterranean biodiversity is the anthropogenic component, a distinct subflora of around 1500 segetal and ruderal annuals that evolved in the Mediterranean (Blondel and Aronson 1999). These species occur in varying associations in fields, pastures and on roadsides: habitats typically invaded by non-native plant species. Many of these endemic weeds have restricted distributions and could represent the elements of the Mediterranean flora most at risk from invasions.

5 THE SUSCEPTIBILITY OF MEDITERRANEAN ISLANDS TO PLANT INVASIONS

In contrast to the various monographs addressing plant invasions on oceanic islands e.g. Galapagos (Mauchamp 1997), Tiwi (Fensham and Cowie 1998), Guam (Fritts and Rodda 1998), Mauritius (Strahm 1999) there exist few detailed regional assessments of the threat from alien invasive plant species in Mediterranean islands. Mediterranean climate regions are particularly susceptible to biological invasions (Mooney 1988, Sala et al. 2000), although New World ecosystems appear more susceptible than those of the Mediterranean Basin (Fox 1990). Nevertheless, whereas the proportion of the flora of the Mediterranean Basin composed of non-natives has been estimated at only 1% (Quezel et al. 1990), it is substantially higher for Mediterranean islands (Hulme 2004). However, when compared to oceanic islands, Mediterranean islands have fewer non-native species and they comprise a smaller proportion of their flora (Hulme 2004).

The difference between tropical and Mediterranean islands may in part reflect a larger pool of potentially invasive plant species in the tropics (Cronk and Fuller 1995, Binggelli 1996). However, of possibly greater relevance is the general finding that oceanic islands are of more recent geologi-

cal origin and are considerably more isolated (both in time and space) from the nearest continent than equivalent Mediterranean islands. These characteristics of oceanic islands are thought to lead to proportionally lower native diversity (Denslow 2003), greater disharmony in species composition arising from the absence of key plant functional groups (Carlquist 1974), lower competitive ability of native species and vacant niche space (D'Antonio and Dudley 1995) than either Mediterranean islands or equivalent mainland areas. Levels of endemism may reflect the degree to which floras have become specialized and the existence of undersaturated communities. Thus, levels of endemism and extinction risk are correlated for tropical island floras (Loope and Mueller Dombois 1989). Comparison across a range of islands reveals a positive relationship between level of endemism and the proportion of non-native species in the flora (Figure 2). The trend clearly separates relatively low endemic, low invasion Mediterreanean islands from high endemic, high invasion oceanic islands. Thus, undeniably other variables correlated with these two different groups could explain the trend. However, although the data are preliminary, positive relationships between rates of endemism and invasion can be discerned in each of the two island subgroups. The finding provides tentative support to the hypothesis that the more specialized a particular flora becomes, the greater the susceptibility to invasion by non-native species.

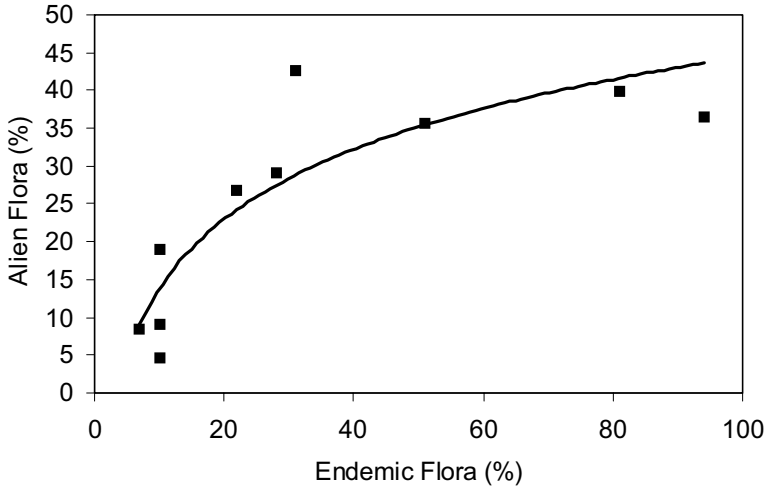

Figure 2. Positive relationship between levels of plant endemism in island floras and the proportion of the flora composed of non-native species.

In addition, the particular nature of the flora of the Mediterranean Basin may increase its resistance to biological invasions. Unlike oceanic islands, the islands of the Mediterranean Basin have suffered a high degree of human interference and disturbance, a process that dates back over ten thousand years, and this has resulted in a marked transformation of the vegetation (Heywood 1995). In contrast to California and South Africa, where large areas of relatively intact vegetation remain, much of the Mediterranean Basin has been transformed from its native state (Mooney 1988). The result is the many secondary or subseral shrubland communities (maquis, phrygana, matorral, garrigue, etc.) that form such a conspicuous part of Mediterranean landscapes. Naveh and Dan (1973) described the region as a whole as 'composed of innumerable variants of different degradation and regeneration phases'. In particular, fire, water stress, grazing and cutting contribute to the high degree of floristic and ecological diversity shown by the region (Heywood 1995). The consequences for biological invasions are that native species are likely to be good competitors under the strong selection regime imposed by humans on the Mediterranean flora and that the multi-

ple stresses of fire, drought and grazing present a formidable challenge to prospective non-native plant species. Thus it is probably not surprising that Mediterranean islands are less susceptible to invasion than oceanic islands, they also appear less susceptible than equivalent continental islands off the coast of California (Hulme 2004). It also explains why so many of the world's worst agricultural weeds have Mediterranean origins, since such species are often pre-adapted for human-altered environments (Sax and Brown 2000).

Given their close proximity to the mainland of the Mediterranean Basin, similar geological age and shared history of human disturbance, why are Mediterranean islands more susceptible to invasion than comparable mainland areas? Island floras do reveal higher levels of endemism than many comparable mainland areas of the Mediterranean (Delanoë et al. 1996, Medail and Quezel 1999). However, differences are much less dramatic than comparisons with tropical oceanic islands. An additional pressure may be human population density, which is a major correlate of invasion success (Lonsdale 1999). Frequently, islands have higher population densities than comparable mainland areas (e.g. Hawaii 71.7 *vs* USA 28.1, Canaries 228.1 and Mallorca 174.8 *vs.* Spain 77.3, Sicily 198.2 vs Italy 188 although on occasion the trend is reversed Galapagos 2.0 *vs.* Ecuador 45.3, and Corsica 86.3 *vs.* France 108, all values are persons per km^2). The Mediterranean islands have an average population density of nearly 100 persons per km^2, twice the average for the entire Mediterranean region. The individual islands themselves vary ranging from a claustrophobic 1409 persons per km^2 on Malta to as few as 4 per km^2 on the neighbouring island of Comino. Furthermore, the human population density on Mediterranean islands can more than double during the summer due to the influx of tourists. Greater population density and tourist dynamics presents plenty of scope for accidental and deliberate introductions of non-native species.

6 FUTURE OUTLOOK

To date, and in comparison with other island ecosystems, relatively little is known about the distribution and impacts of non-native species on Mediterranean islands. It is within this background that the EU funded project EPIDEMIE (Exotic Plant Invasions: Deleterious Effects on Mediterranean Island Ecosystems) was initiated (Hulme 2003b). EPIDEMIE aims to raise awareness and advance existing understanding of the vulnerability of Mediterranean ecosystems to invasion by harmful exotic plants, in order to promote sustainable management of habitats and species, in line with European Community obligations under the Biodiversity Convention. The project is the result of a collaboration among eight European partners and currently assesses, both locally and regionally, the relative importance of the environmental and socio-economic factors that determine the likelihood of exotic plant invasions in order to evaluate the sustainability of management strategies directed towards reducing these risks of invasion. In addition to drawing together data from published floras to produce MIDAS (Mediterranean Islands Database of Alien Species) detailed studies focus on the Balearics, les Iles d'Hyeres, Sardinia, Corsica, Lesvos and Crete. Research includes mapping species distributions, assessing their performance and impacts as well as determining the attitudes of stakeholders to non-native species. These studies are currently being integrated so as to predict the current and future vulnerability of ecosystems to exotic plant invasions, identify optimum management strategies and highlight appropriate planning and policy development to mitigate harmful impacts. It is hoped that project outputs will increase awareness and understanding among the general public (including tourists), stakeholders, scientists, teachers, and both local and regional policy makers of the vulnerability of semi-natural ecosystems to exotic invasion and the ecological and economic consequences of invasion in Mediterranean islands.

ACKNOWLEDGEMENTS

This study is part of EPIDEMIE (Exotic Plant Invasions: Deleterious Effects on Mediterranean Island Ecosystems) a research project supported by the European Commission under the 5th Framework, contributing to the implementation of Key Action 2.2.1 (Ecosystem Vulnerability) within the Energy, Environment and Sustainable Development thematic programme (Contract no. EVK2-CT-2000-00074).

REFERENCES

Binggeli P. 1996 A taxonomic, biogeographical and ecological overview of invasive woody plants. *Journal of Vegetation Science* 7: 121-124.

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

Carlquist, S. 1974 *Island Biology*. Columbia University Press, New York.

Cronk, Q.C.B & Fuller, J.L. 1995 *Plant Invaders. The threat to natural ecosystems.* Chapman and Hall, London.

D'Antonio C.M. 1990. *Invasion of coastal plant communities by the introduced succulent Carpobrotus edulis (Aizoaceae).* PhD dissertation, University of California, Santa Barbara. California.

D'Antonio, C.M. & Dudley, T.L. 1995 Biological invasions as agents of change on islands versus mainlands. *Ecological Studies* 115: 103-121.

Delanoë, O., de Montmollin, B. & Olivier, L. 1996 *Conservation of Mediterranean Island Plants 1. Strategy for Action*. IUCN Gland, Switzerland.

Denslow, J.S 2003. Weeds in paradise: thoughts on the invasibility of tropical islands. *Annals of the Missouri Botanical Garden* 90: 119-127.

DiCastri, F., Hansen A.J. & Debussche, M. 1990. *Biological Invasions in Europe and the Mediterranean Basin*. Kluwer Academic Publishers, Dordrecht.

Dukes, J. S. & Mooney, H. A. 1999. Does global change increases the success of biological invaders? *Trends in Ecology and Evolution* 14: 135-139.

Fensham, R.J. & Cowie, I.D. 1998. Alien plant invasions on Tiwi Islands. Extent, implication and priorities for control. *Biological Conservation*, 83: 55-68.

Fox, M.D. 1990. Mediterranean weeds: exchanges of invasive plants between the five Mediterranean regions of the world. In: Di Castri, F., Hansen, A.J. & Debussche, M. (eds). *Biological Invasions in Europe and the Mediterranean Basin.* Kluwer Academic Publishers, Dordrecht, pp. 179-200.

Fritts, T.H. & Rodda, G.H. 1998. The role of introduced species in the degradation of island ecosystems, a case study of Guam. *Annual Review of Ecology and Systematics* 29: 113-140.

García, O. 1999. *Carpobrotus edulis*, una amenaza para la flora endémica de Menorca. *Quercus* 158 : 50-51

Greuter, W. 1991 Botanical Diversity, Endemism, Rarity and Extinction in the Mediterranean Area: An Analysis. *Botanical Chronicles* 10: 63-79.

Greuter, W. 1995 Origin and peculiarities of Mediterranean island floras. *Ecologia Mediterranea* 21: 1-10.

Groves, R.H. and di Castri, F. 1991 *Biogeography of Mediterranean invasions*. Cambridge University Press, Cambridge.

Guillerm, J.L., Le Floc'h, E., Maillet, J. & Boulet, C. 1990. The invading weeds within the Western Mediterranean. In: Di Castri, F., Hansen, A.J. & Debussche, M. (eds). *Biological Invasions in Europe and the Mediterranean Basin.* Kluwer Academic Publishers, Dordrecht, pp. 61-84.

Heywood, V.H. 1995.The Mediterranean flora in the context of world biodiversity. *Ecologia Mediterranea*, 20: 11 - 18.

Hubbell, S.P. 2001. *The Unified Neutral Theory of Biodiversity and Biogeography*. Princeton Monographs in Population biology, Princeton University Press. Princeton, NJ.

Hulme, P.E. 2003. Biological Invasions: Winning the science battles but losing the conservation war? *Oryx*, 37: 178-193

Hulme, P.E. 2003. EPIDEMIE: a major new Mediterranean research initiative on invasive species. *Ecologia Mediterranea*, 29: 113-114

Hulme, P.E. 2004. Invasions, islands and impacts. In: Fernandez Palacios, J.M.(ed). *Island Ecology*. Asociación Española de Ecología Terrestre, (in press).

Le Floc'h, E., Le Houerou, H.N. & Mathez, J. 1990. History and patterns of plant invasion in Northern Africa. In: Di Castri, F., Hansen, A.J. & Debussche, M. (eds). *Biological Invasions in Europe and the Mediterranean Basin*. Kluwer Academic Publishers, Dordrecht, pp. 105-133.

Lonsdale, W. M. 1999. Global patterns of plant invasions and the concept of invasibility. *Ecology* 80: 1522-1536.

Loope, L.L. & Mueller-Dombois, D. 1989. Characteristics of invaded islands, with special reference to Hawaii. In: Drake, J.A., Di Castri, F., Groves, R.H., Kruger, F.J., Mooney, H.A., Rejmanek, M. & Williamson, M.H. (eds). *Biological Invasions: a Global Perspective.* Wiley, New York, pp. 257-280.

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. & Bazzaz, F.A. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* 10: 689-710.

Mauchamp, A. 1997. Threats from alien invasive plant species in the Galapagos Islands. *Conservation Biology* 11*:* 260-263.

Medail, F. & Quezel, P. 1999. Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. *Conservation Biology* 13: 1510-1513.

Mooney, H.A. 1988. Lessons from Mediterranean climate regions. In: Wilson, E.O. (ed). *Biodiversity.* National Academy of Sciences/Smithsonian Institution, Washington DC, pp. 157-165.

Mooney, H.A. & Hobbs, R.J. 2000. *Invasive Species in a Changing World.* Washington DC: Island Press

Naveh, Z. & Dan, J. 1973 The human degradation of Mediterranean landscapes in Israel. In: Di Castri, F. & Mooney, H.A. (eds). *Mediterranean Type Ecosystems: Origin and Structure*. Springer-Verlag, Berlin, pp. 373-390.

Nunn, P.D. 1994. *Oceanic Islands*. Blackwell Publishers, Oxford.

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, C., Wong, E., Russel, L., Zern, J., Aquino, T. &Tsomondo, T. 2001. Economic and environmental threats of alien plant, animal, and microbe invasions *Agroecosystems and Environment* 84: 1-20.

Polunin, O. & Huxley, A. 1987. *Flowers of the Mediterranean.* Chatto and Windus, London.

Quezel, P., Barbero M., Boni, G. &Loisel, R. 1990. Recent plant invasions in the Circum-Mediterranean Region. In: Di Castri, F., Hansen, A.J. & Debussche, M. (eds). *Biological Invasions in Europe and the Mediterranean Basin*. Kluwer Academic Publishers, Dordrecht, pp. 51-60.

Robles, M. & Chapin, F.S. III 1995. Comparison of the influence of two exotic species on ecosystem processes in the Berkely Hills. *Madroño* 42: 349-357.

Sala, O.E.**,** Chapin, F.S. III, Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., LeRoy Poff, N., Sykes, M.T., Walker, B.H., Walker, M., & Wall, D.H. 2000. Global Biodiversity Scenarios for the Year 2100. *Science* 287: 1770-1774.

Sax, D.F. & Brown, J.H. 2000. The paradox of invasion. *Global Ecology and Biogeography* 9: 363-371.

Sfikas, G. 2000. *Wildflowers of Crete*. Efstathiadis Group, Athens, Greece.

Simberloff, D. 1995. Why do introduced species appear to devastate islands more than mainland areas? *Pacific Science* 49: 97-97.

Strahm, W. 1999. Invasive species in Mauritius: examining the past and charting the future. In: Sandlund, O.T., Schei, P.J. & Viken, A. (eds). *Invasive Species and Management.* Kluwer Academic Publishers, Dordrecht, pp.325-348.

Turland, N.J., Chilton, L. & Press, J.R. 1993. *Flora of the Cretan Area*. The Natural History Museum, HMSO, London.

Vitousek, P.M. 1988. Diversity and biological invasions of oceanic islands. In: Wilson, E.O. (ed). *Biodiversity.* National Academy of Sciences/Smithsonian Institution, Washington DC, pp. 181-189.

Vitousek, P.M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. *Oikos* 57: 7-13.

Vitousek, P.M., Loope, L.L. & Adsersen, H. 1995. *Islands: Biological Diversity and Ecosystem Function.* Springer, Berlin.

Whittaker, R.J. 1998. *Island Biogeography. Ecology, Evolution, and Conservation*. Oxford University Press.

Williamson, M. 1981. *Island Populations*. Oxford University Press.